COUNTY GUIDELINES FOR ENGINEERING GEOLOGY REPORTS

January 2005

(Updated October, 2013)

PLANNING & BUILDING DEPARTMENT • COUNTY OF SAN LUIS OBISPO

976 OSOS STREET • ROOM 200 • SAN LUIS OBISPO • CALIFORNIA 93408 • (805) 781-5600

SAN LUIS OBISPO COUNTY GUIDELINES FOR ENGINEERING GEOLOGY REPORTS

Originally prepared by Lewis I. Rosenberg, CEG 1777 (Former County Geologist for SLO County Department of Planning & Building) Revised by Brian E. Papurello, CEG 2226

Introduction

These guidelines are to provide geologic consultants with an understanding of the kinds of information necessary for approval of reports submitted to the County. These guidelines do not include comprehensive discussion of methodologies or topics, nor should all methods described be used or all topics listed be dealt with in every project. These guidelines will be periodically updated to reflect future code changes, new seismology methods, and current geologic publications.

The SLO County guidelines are adapted mainly from the California Geological Survey's (CGS) Note 48, with the main change being a shift in focus from schools and hospitals to residential and commercial construction. Sections on fault rupture are modified from Salt Lake County (2000), sections on sewage disposal are from the Central Coast Regional Water Quality Control Board, and sections on coastal hazards are from the California Coastal Commission BEAR study.

These guidelines may be amended from time to time, including the following requirements incorporated by reference herein as though set forth in full. Where State guidelines are more restrictive, the State Guidelines shall supersede any inconsistent provisions of these County Guidelines.

When are geologic reports required?

Geologic reports are required for projects requiring a permit within a County-designated Geologic Study Area (GSA). As defined in sections 22.14.070 of the San Luis Obispo County Land Use Ordinance (LUO) and 23.07.080 of the San Luis Obispo County Coastal Zone Land Use Ordinance (CZLUO), GSAs include these hazards:

- <u>Seismic hazard</u>: Areas of fault rupture as defined by the State of California under the Alquist-Priolo Earthquake Fault Zone Act (sections 2621 et seq. of the Public Resources Code).
- <u>Landslide hazard</u>: Areas within urban and village reserve lines, identified by the San Luis Obispo County Safety Element as being subject to moderately high to high landslide risk; and rural areas subject to high landslide risk.
- Liquefaction hazard: Areas identified by the San Luis Obispo County Safety Element as being subject to liquefaction.
- Erosion and stability hazard: Areas along the coast with bluffs and cliffs greater than 10 feet in vertical relief and that are identified in the "Assessment and atlas of shoreline erosion" (Habel and Armstrong, 1977) as being critical to future or present development.

The LUO and CZLUO (sections 22.14.070C and 23.07.082, respectively) provide exceptions for the following cases:

- One single-family residence, not exceeding two stories, when not constructed in conjunction with two or more residences by a single contractor or owner on a single parcel or abutting parcels, unless the site is located in an area subject to liquefaction or landslide.
- Any agricultural use not involving a building, and any agricultural accessory structure.
- Alterations or additions to any structure, the value of which does not exceed 50 percent of the assessed value of the structure, except where the site is adjacent to a coastal bluff.

Engineered grading (quantities over 5,000 cubic yards, slope 20 percent or greater, or within a GSA or flood hazard area) require engineering geology and geotechnical reports as required by sections 22.05.030 of the LUO and 23.05.030 of the CZLUO. For more details, see the LUO and CZLUO at

http://www.slocounty.ca.gov/getattachment/6d93f812-df15-4203-b033-7d802c5c9cf0/Inland-Land-Use-Ordinance-(Title-22).aspx

(CEG) must prepare all engineering geology reports submitted to the county. The Planning Department maintains a list of CEGs at

http://www.slocounty.ca.gov/Departments/Planning-Building/Planning-(Current-and-Environmental)/Services/Environmental-Review/Qualified-Environmental-Consultants.aspx

However, any California-licensed CEG may submit reports to the County. To check the status of the geologist's license, see the California Board of Geologists and Geophysicists website at http://www.dca.ca.gov/geology .

The County of San Luis Obispo also requires geotechnical (soil) reports for many projects. Geotechnical reports are typically prepared by California-licensed Registered Geotechnical Engineers (RGE). Although these guidelines do not specifically address geotechnical report guidelines or content, the RGE preparing the soil report should coordinate with the CEG to ensure necessary issues such as slope stability analysis or liquefaction are adequately addressed.

Geologic review process

Engineering geology reports conducted in San Luis Obispo County may be reviewed by the County Geologist. The County Geologist will review the engineering geology report to evaluate the adequacy of presented data and evaluations to support conclusions regarding geologic and seismic constraints and hazards. These geologic reviews aid Planning and Building Department staff, Planning Commissioners, and Board of Supervisors in their evaluation of proposed projects. These guidelines thus serve as the basis for the review and approval of engineering geology reports and the associated land-use permits.

Reports will be reviewed using the attached checklist as a guideline. Consultants should use the checklist to verify that their reports are complete before submitting them to the County.

Before beginning work, consultants are encouraged to contact the County Geologist (Brian Papurello) by email at bpapurello@landseteng.com ; telephone at (831) 444-4212; or by U.S. Mail at 976 Osos Street, Room 200, San Luis Obispo, CA 93408.

Field review

Field review by the County Geologist is required during exploratory excavations such as trenching of faults or downhole logging of landslides. The CEG must provide a minimum of one-week notice to schedule the field review with the County Geologist. The trench/borehole should be open and a preliminary log should be completed at the time of the review.

The field review allows the County Geologist to discuss the subsurface data (i.e., age and type of sediments; presence or absence of faulting/landsliding) with the consultant.

Change of CEG There can be only one CEG in responsible charge of the engineering geology work on any one project during any one time. If a new CEG is taking over the professional work of another, then the previous licensed person and the County Geologist must be informed in writing within two weeks of the change. Documentation such as cut-off and start dates, signature, and license numbers, should be included in a change of CEG letter. If there is a change of the CEG during grading or foundation operations, then earthwork must be suspended until the new CEG provides the County Geologist with the change of-CEG letter.

Number of copies to duplicate for your client

The Planning and Building Department needs two copies for review purposes. Engineering geology reports should be bound or stapled together in a secure manner. Map pockets should be used for any CD-ROMs and oversized geologic maps or cross-sections. Consultants are encouraged to submit digital copies of reports saved as Portable Document Format (PDF) files. This will facilitate distributing and archiving reports.

Geology and seismology references cited

Only appropriate and current geology and seismology references should be cited at the back of the consulting report. For references cited in the text of the consulting report, indicate the page number or figure number in the reference. Do not include citations that are not actually used in the text. Follow the citation formats used by the U.S. Geological Survey.

Geotechnical design criteria and recommendations for development

Although geotechnical design criteria and recommendations do not necessarily need to be included in the engineering geology report, these should be provided by a RGE working in conjunction with the CEG. This work should be performed before plans are prepared. The County Geologist does not review geotechnical reports. However, in some cases, geotechnical reports may be submitted for third-party peer review.

Explanations Keyed to Numbered Items within SLO County Guidelines

Project Description, Zoning, and Location

1. Project description
In order to identify pertinent geologic review standards, there needs to be a detailed project description. Describe the following features as applicable: approximate total acreage, building size, type of construction, number of stories (including basements), intended foundation system, grading concept, heights of cut slopes, depths of embankment fills, retaining wall heights, maximum topographic relief, description of existing drainage (natural and improved), typical slope angle(s) within the building pad and property, and existing vegetation cover.

Digital images or tiled photographs are encouraged for panoramic views of the existing site from several vantage points.

2. San Luis Obispo County Geologic Study Areas
The San Luis Obispo County Safety Element shows relative fault rupture, liquefaction, and landslide hazards on a series of maps. The LUO and CZLUO contain a Geologic Study Area (GSA) combining designation, which identifies potentially hazardous areas of fault rupture, liquefaction, and landslides.

If the site is within a GSA, plot the site on a page-size figure showing the relation of the site to the GSA. This establishes that the CEG is aware that the site is within an official Geologic Study Area and notifies the owner of that zoning designation.

Paper copies of the Safety Element and GSA maps are available from the San Luis Obispo County Planning Department at (805) 781–5600. Digital maps are available 1) on the County's website www.sloplanning.org
or as images (jpg format) and GIS files (ESRI shapefile format) at no cost from http://discover.lib.calpoly.edu/gis.

3. Site location
To clearly identify the project location, plot the site and property boundaries on a 7.5-minute USGS topographic quadrangle map. If your regional geological map is also plotted on a 7.5-minute topographic base map, then use of the geologic map for location is sufficient, provided the site boundaries are shown. Include the Assessor's parcel number and street address (if known).

Provide the latitude and longitude of the site to three decimal places (example: 35.160°N, 120.534°W) for review of strong-motion computations by the County. This is a necessary and essential step for probabilistic seismic hazard analysis (PSHA).

Many engineering geologists and seismologists use websites such as www.topozone.com to quickly determine the latitude and longitude. Global Positioning Satellite methods may also be used to directly measure latitude and longitude in the field. If there is a cluster of new buildings on the site, select the largest principal building for site coordinates.

Engineering Geology

4. Regional geologic map
Provide a regional geologic map using an appropriate scale map such as 1:24,000 or 1:62,500. Many geologic maps of the County can be downloaded from http://ngmdb.usgs.gov . Include an explanation of map units and symbols.

5. Original site engineering geologic map
Because regional geologic maps are not detailed enough for site-specific work, provide an engineering geologic map based on original work by the project CEG. The site engineering geologic map should be on a large-scale base-map, preferably the same base as the site grading map, or at least 1:6,000 scale (1 inch = 500 feet). The degree of geologic detail shown on the engineering geologic map should be appropriate for the geologic complexity, type of building structure, and intended foundation system (e.g., spread footings, or caissons and grade-beams).

Show the building locations and grading areas on the site geologic map. If major grading is anticipated, delineate areas of existing and planned cuts and fills by use of distinct lines on the site grading plans. For hillside sites, include upslope and downslope adjacent properties. Relatively flat alluvial sites still need a geologic map with the appropriate Quaternary geologic units shown.

The engineering geologic map explanation should include descriptions of lithology (bedrock, surficial deposits and artificial fill) and geologic structure. Use the format outlined in the U.S. Bureau of Reclamation (USBR) Engineering Geology Field Manual for lithologic descriptions. The USBR Manual can be downloaded at no cost from: http://www.usbr.gov/pmts/geology/geoman.html . Use the Munsell Color Chart name and number to describe soil and rock colors, rather than subjective terms such as “light brown.”

6. Aerial photograph interpretation

For projects involving landslides, faults, or coastal bluffs, aerial photograph interpretation provides a valuable perspective. Engineering geologic reports for these types of projects that do not include aerial photograph interpretation will be considered incomplete. Provide original scale color copies of aerial photographs used in the report. Include the photo numbers, flight lines, date, and scale of stereoscopic aerial photographs in an appendix.

7. Subsurface site geology

Boreholes and trenches should be of appropriate depth and spacing to obtain meaningful subsurface data (see NAVFAC Design Manual 7.01, 1986: tables 6 and 7). For hillside sites with shallow bedrock or outcrops, one geologic trench may count as the equivalent of one borehole. Boreholes and trenches from previous studies can be used, but only if the former boreholes are geologically pertinent to the new construction and if the original locations can be accurately plotted on the current base map. If borings or trenches from previous reports are used, then provide complete and legible copies of these in an appendix. Each consulting geotechnical report must stand independently, based on complete documentation.

A useful technique during the early planning stages of the drilling phase is to draw several detailed geologic cross-sections through the building site. Include sloping ground surfaces, basements, retaining walls, and foundations of existing structures. The amount of blank space on the geologic cross section (data gaps) will provide insight into where the boreholes should be located, how the deep the boreholes should be drilled, and how frequently sampling should be performed.

Accurately locate the boreholes, trenches and test pits must on the site engineering geologic map. Show total depth of the borehole (e.g., B-7 TD = 53 ft.) and depth of groundwater or perched water next to each borehole number (e.g., $\underline{\nabla}$ 13 ft.). Boreholes are typically on the order of 30 feet deep, but much depends on the subsurface geologic conditions and the type of drill rig and access conditions. For large structures, the boreholes should be appropriately deeper.

Trench and test pit logs should be equal vertical and horizontal scale, and show an accurate and detailed representation of the subsurface geotechnical conditions.

Generalized or idealized representations do not fulfill the above requirements. Test pit and trench logs plotted on boring logs are unacceptable because they are one-dimensional representations and omit valuable detail.

Sampling frequently in the upper 20 feet is recommended because the structural foundations are most affected by the shallow subsurface. In contrast, sampling by rote methods at “every five feet” is not recommended because important stratigraphic layers can be missed. Instead, sample at lithologic changes based on stratigraphy. In addition, delineate any existing fill areas on the site and evaluate whether they are engineered fills suitable for foundations, or unsuitable fills that were poorly compacted.

Classify sediments using the Unified Soil Classification System. Use a standardized gradation scale for size descriptions. Other items to be included in the log are rock type, bedding attitude, discontinuities (joints, faults), lithologic changes, color changes, pebble orientation, and other characteristic useful for structural or stratigraphic interpretation. Additionally, appropriate physical and engineering properties relative to foundation and slope stability should be presented.

Engineering geophysics may be used in conjunction with boreholes and backhoe trenches for a wide variety of purposes such as evaluation of the subsurface geology of the site, planning optimum locations of fault trenches, evaluation of rippability of bedrock in grading operations, evaluation of groundwater conditions, and determination of the average shearwave velocity of the geologic subgrade for purposes of selecting the appropriate earthquake attenuation formula.

8. Geologic cross sections

Geotechnical engineers can reliably evaluate complex subsurface conditions when the CEG provides detailed geologic cross sections at the same scale as the building foundations and grading plans. Draw large-scale (detailed) geologic cross sections through the building area and perpendicular to contour lines on hillside lots, representing the entire slope width, height, and length. If applicable, show foundations of existing adjacent structures and adjacent buildings on hillside sites. Detailed geologic cross sections are required for alluvial sites with the potential for liquefaction because the stratigraphic and groundwater conditions need to be graphically characterized.

Draw the geologic cross section at the same scale as the site engineering geology map. Show the location and azimuth of the cross section on the base map. In general, the geologic cross sections should be drawn through existing boreholes at true scale (vertical = horizontal). If groundwater surfaces (including perched water) or thin beds are present, then the cross section can be drawn at exaggerated vertical scale. Prepare supplemental geologic cross sections at enlarged scale (as appropriate) if they help explain the geologic field conditions.

9. Active faulting and coseismic deformation across site

For sites within an Alquist-Priolo Earthquake Fault Zone or faults that may cause coseismic deformation, evaluate the potential for surface faulting. Recommended guidelines are California Geological Survey Special Publication 42 (Hart and Bryant, 1997), CGS Note 49, and the California State Board for Geologists and Geophysicist's "Geologic guidelines for earthquake and/or fault hazard reports." CGS SP-42 and Note 49 are posted on the website of the California Geological Survey at www.consrv.ca.gov/cgs . The Board for Geologists and Geophysicists guidelines are at http://www.dca.ca.gov/geology . Copies of Alquist-Priolo fault zone maps are available from the County or from the California Geological Survey.

Structures for human occupancy, such as houses or offices, within an Alquist-Priolo Earthquake Fault Zone or across "potentially active" (Pleistocene age) faults in San Luis Obispo County require appropriate setbacks. The County of San Luis Obispo uses the methodology developed by Salt Lake County, Utah to evaluate fault setbacks (Salt Lake County, 2002).

The focus of fault investigations is to accurately locate existing faults, evaluate the recency of their activity, and estimate amounts of past displacement to derive recommended fault setbacks. The most direct method of locating existing faults and evaluating the history of fault activity is to excavate exploratory trenches using a backhoe or excavator. Existing faults can also be identified and mapped in the field by direct observation of young, fault-related geomorphic features, or by examination of aerial photographs.

The exploratory trench should be oriented perpendicular to the fault trace, and of adequate length to explore the proposed building site. Additionally, the trench must extend beyond the building footprint at least the minimum setback distance for the building type (see table 1). The trench should be located outside the proposed building footprint, because the trench is generally backfilled without compaction, which could lead to settlement beneath the footings. Additional trenches may be necessary to accurately determine the trend of the fault as it crosses the property. In order to locate building setbacks accurately, trenches and fault locations be surveyed by a licensed land surveyor.

The CEG should clean debris and backhoe smear off one or both of the trench walls, and carefully log the trench at a minimum scale of 1 inch = 5 feet (1:60) following accepted fault trench investigation practices (McCalpin, 1996). Some form of vertical and horizontal logging control must be used and shown on the log. The log must accurately depict stratigraphic and structural features exposed in the trench.

The trench must be deep enough to extend below Holocene deposits—generally in the 8 to 12-foot range, but sometimes deeper. The CEG should interpret the ages of sediments exposed in the trench, or, when necessary, obtain radiocarbon or other age determinations, to constrain the age of most recent fault movement to determine whether Holocene displacement has occurred. In cases where Holocene active faults may be present, but pre-Holocene deposits are below the practical limit of excavation, the trenches must extend at least through sediments inferred to be older than several fault recurrence intervals. The practical limitations of the trenching must be acknowledged in the report and recommendations must reflect resulting uncertainties.

To address wide discrepancies in fault setback recommendations, San Luis Obispo County uses a slightly modified version of the fault setback calculation developed by the Salt Lake County, Utah (Batatian and Nelson, 1999). The fault study report should use this method to establish the recommended fault setback for critical facilities and structures designed for human occupancy. If another fault setback method is used, the CEG must provide justification in the report for the method used. Faults and fault setbacks must be clearly identified on full-size site plans and maps. Minimum setbacks are based on the type of proposed structure listed below:

Setbacks should be calculated using the formulas presented below, and then compared to the minimum setback established above. The greater of the two is the setback. Minimum setbacks apply to both the hanging wall and footwall blocks.

Upthrown fault block

The fault setback for the downthrown block is calculated using the following formula:

S= U (2D + F/tanθ) where:

S = Setback within which structures for human occupancy are not permitted;
U = Criticality Factor, based on the proposed occupancy of the structure (see Table 1)
D = Expected fault displacement per event (assumed to be equal to the net vertical displacement measured for each past event). Note: displacements for the San Andreas and Los Osos faults can be found in the geologic literature. For other faults, use displacements observed in site-specific trenching or the methodology outlined by Wells and Coppersmith (1994)
F = Maximum depth of footing or subgrade portion of the building
θ= Dip of the fault (degrees)

Downthrown fault block

The dip of the fault and foundation depth of the structure are irrelevant in calculating the setback on the downthrown fault block. Therefore, the setback for the downthrown side of the fault is calculated as:

S= U x 2D

The setback is measured from the portion of the building closest to the fault, whether it is below or above grade. Minimum setbacks apply as discussed above.

Table 1. Setback recommendations and criticality factors (U)

2013 CBCClass	Occupancy group	U	Minimum setback (ft)
A	Assembly	2.0	25
B	Business	2.0	20
E	Educational	3.0	50
F	Factory/Industrial	3.0	20
H	Hazardous	3.0	50
I	Institutional	3.0	50
M	Mercantile	2.0	20
R	Residential (R-1: Hotels and apartment houses)	2.0	20
R	R-3 Residential (Dwellings and lodging houses. Includes single family homes)	1.5	15
S	Storage	1.0	0

For a vertical strike slip fault, the equation for the downthrown fault would probably be appropriate, but if the fault has a dip, use the equation appropriate for the site geometry—the goal is to maintain the setback even in the subsurface. Note also that the guidelines require minimum setbacks for different types of structures.

10. Landslides
Evaluate the potential for landslides, including immediately adjacent property, for both bedrock landslides and debris flows. Recommended guidelines for landslide investigations are: CGS Special Publication 117A (chapter 5, p. 19–33), Blake and others (2002), and the National Research Council report by Turner and Schuster (1996).

Specifically, the investigation of a landslide should: (1) consider the proposed development; (2) geomorphic analysis using aerial photography or other remote sensing techniques— include full-size copies of stereo pair aerial photographs used in the study; (3) original engineering geologic mapping; (4) subsurface data derived from exploratory boring and trenching, and if appropriate, engineering geophysics; (5) determine geometry and mechanics of movement, including discussing how the critical failure surface was determined and what assumptions were applied to make that determination; (6) evaluate hydrogeologic conditions past and present, and estimate effects from changes in land use, including wastewater disposal and landscape irrigation; and (7) provide appropriate remediation measures, including recommendations for construction and maintenance of features such as drains or dewatering wells.

Slope stability analyses (SSA) and earth material testing are usually completed by a geotechnical engineer utilizing geologic information and cross sections developed by an engineering geologist. The SSA is typically included in a geotechnical engineering investigation and report. The SSA must show formulas and methods used for slope stability analysis, including computer printouts, if applicable. In additions, the SSA should include parameters used in equations and how they were derived and state all assumptions. Enough information should be provided to allow the reviewer to repeat the calculations. The minimum factors of safety for landslide analyses are: static SF≥1.5 and dynamic SF≥1.1.

11. Flooding, severe erosion, and deposition
Evaluate the potential for flooding, severe erosion and deposition, dam inundation, or breached levees. If within or near the "100-year" flood zone, plot the site on the official FEMA flood-zone maps, and include as a page-size figure. In rapidly urbanizing areas, these 100-year flood-zone maps may be out-of-date, so the CEG should consider the present and future impact of human activities on floodplain zoning. Remediation options include elevated floor slabs, landscaping berms that can double as dikes, and flood walls.

12. On-site septic systems
The septic system is commonly one of the last features designed for a residential development project. However, due to the physical constraints and State/County regulations, the septic system should be laid out first, followed by access roads, and finally the building area.

Using engineering geologic mapping, evaluate one or more geologically suitable locations for the septic leach-field system. Consider future expansion plans, so that the septic leach-field will not interfere with possible future foundations and grading. Hillside leach fields should not be sited directly downslope of the structure for slope instability reasons. For hillside projects, evaluate the potential for hydrologic changes from the new leach-field to induce landsliding. Show the proposed location of the septic system on the site engineering geologic map.

Septic system design in San Luis Obispo County is regulated under section VII.D.3.a of the Central Coast Regional Water Quality Control Board Basin Plan (1994), which requires the following items: (some of which may be included in a geotechnical engineering report):

a. At least one soil boring or excavation per on-site system should be performed to determine soil suitability, depth to groundwater, and depth to bedrock or impervious layer. Soil borings are particularly important to seepage pits. Impervious material is defined as having a percolation rate slower than 120 minutes per inch or having a clay content 60 percent or greater. The soil boring or excavation should extend at least 10 feet below the drainfield (refers to either a leachfield or seepage pit) bottom at each location.

b. An excavation should be made to detect mottling or presence of underground channels, fissures, or cracks. Soils should be excavated to a depth of 4 to 5 feet below drainfield bottom.

c. For leachfields, at least three percolation test locations should be used to determine system acceptability. Tests should be performed at proposed subsurface disposal system sites and depths.

d. If no restrictive layers intersect, and geologic conditions permit surfacing, the setback distance from a cut, embankment, or steep slope (greater than 30 percent) should be determined by projecting a line 20 percent downgradient from the sidewall at the highest perforation of the discharge pipe. The leachfields should be setback far enough to prevent this projected line from intersecting the cut within 100 feet, measured horizontally, of the sidewall. If restrictive layers intersect cuts, embankments, or steep slopes, and geologic conditions permit surfacing, the setback should be at least 100 feet measured from the top of the cut.

e. Natural slope of the disposal area should not exceed 20 percent.

f. For new land divisions, lot sizes less than one acre should not be permitted.

For specific County design requirements, see the San Luis Obispo County Planning Department's "Private Sewage Disposal System" guidelines:

http://www.slocounty.ca.gov/Departments/Planning-Building/Building/Onsite-Wastewater-Treatment-Systems.aspx

In areas where fanglomerate and alluvium have high void ratios, evaluate the geologic potential for hydrocollapse or hydroconsolidation of soils under structural load. Consider sustained use of landscape irrigation and septic systems at the site, or from adjacent golf courses or housing tracts. The CEG should make reasoned analysis of potential water levels and how they may fluctuate.

Seismology and Calculation of Earthquake Ground Motion

14. Evaluation of historical seismicity and regional faults

Prepare a page-size seismicity map at intermediate scale (1:250,000 to 1:750,000) that is centered on the property. It is typically a concise extract from published maps or a plot from a digital catalog. Show significant past earthquakes (typically ≥M5) within approximately 60 miles of the site. A convenient and useful map is CGS Map Sheet 49; Epicenters of and areas damaged by ≥M 5 California earthquakes, 1800–1999. Also show the faults contributing the most significant ground-motion hazard to the site.

Epicenter data can be obtained from software programs such as EQSEARCH, the Northern California Earthquake Data Center (http://quake.geo.berkeley.edu/) or the Southern California Earthquake Center website (www.scec.org).

In the text, tabulate fault distances in kilometers and report by increasing distance from the site. Use the moment magnitude scale (symbol Mw) for the Maximum Magnitude (Mmax) of each fault. Avoid using the local magnitude scale, ML, commonly known as the Richter scale, because it is known to saturate at higher magnitudes, and it does not correlate well with other fault parameters (fault length and slip rate)..

15. Characterize and classify the geologic subgrade

Characterize and classify the upper 30 meters of the geologic site class in accordance with the2013 CBC §1613.3.2. Although the 2013 CBC requires that the geologic subgrade be evaluated to 30 meters (100 feet), it does no mean that a borehole must be drilled to a depth of precisely 30 meters. For most deep alluvial basins, boreholes on the order of 50 feet are usually sufficiently deep. Exceptions include large structures with multi-level basements that will rely on deep foundations.

Use either the average shear-wave velocity (Vs) or the Standard Penetration Test N-blow counts for the classification of the geologic subgrade. Some consultants believe that Vs may deliver a more accurate classification than the SPT. If the average shear-wave velocity is not reliably measured or evaluated based on comparison to velocities measured for similar subsurface geologic conditions, then §1613.3.2 requires that the site be classified as Site Class D "stiff soil" by default. There are several papers and comprehensive tables of shearwave velocities for California geologic units (Wills and Silva, 1998; Wills and others, 2000).

16. Probabilistic evaluation of earthquake ground motion

The 2013 CBC requires a probabilistic seismic hazard analysis (PSHA) to be computed in accordance with §1613 of the 2013 CBC. Seismology software such as EZ-FRISK may also be used for this step. State in the report that you are using PSHA methods and name the software used. In an appendix, include a printout of the output from the software program. Ground motion should not be estimated or extrapolated from regional ground-motion maps such as CGS Map Sheet 48.

Deterministic ground motion will not be reviewed or approved for residential or commercial buildings: it is not in conformance with code requirements for these types of structures. However, deterministic ground motion is appropriate for certain types of structures such as bridges and dams.

Avoid using obsolete seismology terms (e.g., "maximum credible earthquake" or "repeatable high ground acceleration"). Older 1970s seismology concepts, terms, and formulas have been replaced and updated by knowledge gained from more recent earthquakes; these modern developments should be used.

17. Peak ground acceleration for MCE_R levels of ground motion and site coefficients Fa & Fv

State in the engineering geology report that the Risk Targeted Maximum Considered Earthquake (MCE_R) ground motion is defined to have a 10 percent chance of exceedance in 50 years, with a statistical return period ≅ 475 years for the parameters S_s and S_1. (Reference: 2013 CBC §1613.3 (definition), and 1613.3.1 (ground motion maps).

Compute the mapped spectral response acceleration for the short period F_a^a (0.2 second) and long period F_v^{a} (1.0 second) in accordance with Tables 1613.3.3(1) & 1613.3.3(2) respectively. Round the ground-motion values to three significant figures.

For large sites where some of the buildings are founded on soft rock and other buildings are founded on alluvium or engineered fill, then report different levels of ground motion corresponding to the different site conditions. If you are performing advanced geotechnical modeling with SHAKE-91 software by Idriss and Sun (1992), then provide all parameters used in an appendix (thickness and properties of each stratigraphic layer and input ground-motion).

The 2003 San Simeon earthquake revealed that parts of San Luis Obispo County experience enhanced shaking due to basin effects (Oceano) or ridgetop amplification (Santa Lucia Range). For example, in Oceano, the estimated PGA was nearly double from what distance-attenuation relationships predicted (Holzer and others, 2004). For areas subject to site amplification, the PGA needs to be appropriately adjusted to take into account the enhanced shaking levels.

Commonly, the MCE ground motion will be used by the RGE for liquefaction analysis. If so, then it is advisable for the to deaggregate the data to find the optimum seismogenic source to be used as the Magnitude Scaling Factor, MSF. For example, a nearby active fault with a low Mmax and low slip-rate should be set aside and not used for liquefaction analysis if there are more active faults slightly further away from the site. The appropriate seismogenic source for MSF might be an intermediate-distance fault with a large Mmax and a high slip-rate . The only way to determine this is to disaggregate the seismic hazard. Suggested references are Bazzurro and Cornell (1999) and Harmsen (2001).

An interactive seismic-hazard deaggregation menu item has been added to the USGS probabilistic seismic-hazard analysis website (http://geohazards.cr.usgs.gov/eq) that allows visitors to compute mean and modal distance, magnitude, and ε corresponding to ground motions having mean return times from 250 to 5,000 years for any site in the United States.

However, do not report ground motion downloaded from the USGS/NEHRP website without careful consideration because: (1) these are soft rock data and many sites are on alluvium, resulting in incorrect rock site ground-motion for alluvial sites; (2) the grid spacing may be too coarse for use in coastal hills of California, resulting in an incorrect latitude and longitude; and (3) the disclaimer on the USGS website states that it is not to be used for site-specific work.

18. Adjusted Maximum Considered Earthquake Parameters

Calculate and report the site modified spectral response acceleration parameters S_{MS} & S_{M1} in accordance with the 2013 CBC §1613.3.3 using equations 16-37 and 16-38. Calculate and report the design spectral response acceleration parameters S_{DS} and S_{D1} in accordance with 2013 CBC §1613.3.4 using equations 16-39 and 16-40. coefficients should be reported to three decimal places.

Liquefaction Analysis

19. Geologic setting, stratigraphy, and geologic cross sections for liquefaction analysis

Evaluate the potential for seismically induced liquefaction based on subsurface conditions and historical evidence. Include the potential for lateral spreading (when near a free face, such as a river bank, canal, or cut slope). Refer to California Geological Survey SP-117A for pertinent geologic site conditions: shallow groundwater surface or perched water conditions, <15 meters or <50 feet, unconsolidated sandy alluvium..

For liquefaction analysis, attempt to sample every sandy bed, and obtain Standard Penetration Test (SPT) N-blow counts, fines corrections from grain-size analysis, and unit weight/moisture content. Report SPT blow counts as both measured in the field and converted to standardized $N1_{60}$ blow counts.

The Cone Penetration Test (CPT) may be used for liquefaction analysis, if there is reasonable correlation with adequate samples by SPT for fines corrections. Complete CPT logs should be furnished, along with conversion tables to SPT *N*-blowcounts.

Incorporate the SPT and CPT data into geologic crosssections across the building footprint, including adjacent buildings, and features such as stream banks, beaches, and lagoons. The cross sections should show detailed Quaternary stratigraphy and emphasize sandy layers. Show phreatic surfaces, including any perched water surfaces, the present groundwater surface from borehole data, the historic high water surface, and water levels inferred from color change from brown to gray soils.

Consider the potential for human-induced changes in the regional or local water levels. These changes might include the following: landscape irrigation, golf courses, man-made lakes, agricultural fields, orchards and vineyards, aquatic fish farming, environmental restoration of wetlands, spreading grounds for treated wastewater, leaking reservoirs, impounding floodwaters behind levees, and groundwater injection wells. Any of these hypothetical situations might result in changes in the groundwater surface.

20. Liquefaction methodology

For liquefaction analysis, utilize current geotechnical publications. Recommended guidelines for liquefaction investigations are: CGS Special Publication 117A (chapter 6, p. 35–45), Martin & Lew and others (1999),Cite authors, methodology, and formulas used in spreadsheets and calculations. Present geotechnical data so that it can be reviewed and checked. Use and cite current publications on liquefaction analysis, such as Youd and others (2001). Liquefaction analyses must include the following items, some of which may be included in a geotechnical report:

a. The geotechnical report must include at least one boring extending to a minimum 50 feet depth.

b. Drilling logs must include field and normalized blow counts. Field blow counts should be normalized to (N1)60 values.

c. A geologic cross section depicting the proposed building location, borings, stratigraphy, groundwater levels (observed and historical high), and proposed foundation depths.

d. Factor of Safety analysis for liquefaction (minimum factor of safety for liquefaction analysis is SF≥1.3.

e. Specific detailed recommendations for mitigating liquefaction, such as deep foundations/caissons extending below the zone of liquefaction

Coastal Hazards

21. Bluff erosion

To prevent the loss of property or life, new development should be sited far enough from the bluff edge, or top of bluff, that it will not require a seawall, revetment or any other bluff alteration for the full life of the development. This is a two-step effort—determining a safe distance from the bluff edge for development, and determining the location and configuration of the bluff edge at some time in the future, often taken to be the life of the development. While the Coastal Act does not define the economic lifetime of a structure, the California Coastal Commission's ReCAP effort has shown that most structures last at least 75 years. Furthermore, the Coastal Commission has indicated that an economic lifetime of structures of 100 years is preferable (Ewing and others, 1999, p. 124).

The report should address the entire site with special attention to the area of demonstration, i.e., that area which lies 50 feet inland from the edge of the bluff or that area which lies between the top of the bluff and the point at which a line from the toe of the bluff inclined 20 degrees above horizontal intersects the surface, whichever is greater.

The geologic report must include a predicted long-term average erosion rate and a setback that will ensure the development will not require shoreline protection during its economic life, based on either a or b below:

a. Develop a long-term annual average erosion rate, multiply this by the economic life of the structure and either multiply that by a buffer factor or add a buffer factor as a set distance. For example, if the rate of erosion is determined to be 3 inches per year, the economic life of the structure is 100 years, and the buffer factor is 1.2, then the minimum setback is 30 feet (3 in. x 100 yrs. = 300 in., 300 in. = 25 feet, 25 feet x 1.2 = 30 feet). If the buffer factor were a set distance of, say, 10 feet, and the rate of erosion and economic life of the structure were the same as in the preceding example, then the setback would be 35 feet. The buffer factor may vary regionally, based on the quality of the shoreline change data and the size or magnitude of extreme erosion events.

Based on the above criteria, all development, including second story and cantilevered portions of a structure shall be set back a minimum of 25 feet or the long-term annual average erosion rate multiplied by the economic life of the structure and by a buffer factor of 1.2 from the top edge of the bluff, whichever is greater.

An additional setback beyond what this erosion formula may yield is required to meet a 1.5 factor of safety for gross or surficial landsliding. If the bluff exhibits a factor of safety of less than 1.5 for either gross or surficial landsliding, then the location on the bluff top at which a 1.5 factor of safety exists shall be determined. Development shall be set back a minimum distance equal to the distance from the bluff edge to the 1.5 factor-of-safety line, plus the distance that the bluff might reasonably be expected to erode over 100 years (determined by the formula in this section). These determinations, to be made by a state-licensed Certified Engineer Geologist, Registered Civil Engineer, or Geotechnical Engineer, shall be based on a site-specific evaluation of the long-term bluff retreat rate at this site and shall include an allowance for possible acceleration of historic bluff retreat rates due to sea level rise.

If the bluff exhibits both a gross and surficial factor of safety against landsliding of greater than 1.5, then development shall be set back a minimum distance equal to the distance that the bluff might reasonably be expected to erode over 100 years plus a buffer to ensure that foundation elements are not actually undermined at the end of this period (determined by the formula in this section). The determination of the distance that the bluff might be expected to erode over 100 years is to be made by a state-licensed Certified Engineer Geologist, Registered Civil Engineer or Geotechnical Engineer, and shall be based on a site-specific evaluation of the long-term bluff retreat rate at the site and shall include an allowance for possible acceleration of historic bluff retreat rates due to sea level rise.

b. Provide 100-year setback lines and give the methodology for determining the setback. Define the bluff edge as the upper termination of a bluff, cliff, or sea cliff. In cases where the top edge of the cliff is rounded away from the face of the cliff, the bluff line or edge is that point nearest the cliff beyond which the downward gradient of the surface increases more or less continuously until it reaches the general gradient of the cliff. In a case where there is a step-like feature at the top of the cliff face, the landward edge of the uppermost riser is taken to be the cliff edge.

In either case a or b, the report should include the features used for calculating the retreat amounts and present them in a table showing the following: measured point, measured retreat distances (from year x to year y), and calculated retreat rate. Include original-size copies of aerial photographs used in the bluff retreat analysis so the County can review these measurements.

To help the owner and contractor maintain the intended setbacks, plot the bluff retreat setback zones on the site geologic map and on the official building plans. Bluff retreat setbacks should be also be flagged in the field before construction so it is clear where the limits of the development are.

22. Tsunami and seiche
If the site is near to the coastline or adjacent to the shoreline of a large body of water (lake or reservoir), then evaluate the potential for tsunamis or seiches. Tsunamis are described in CGS Bulletin 198, p. 41–43. Tsunami run-up zones are shown recent NOAA documents on Pacific Coast tsunamis: www.noaa.gov . Show inundation area on site map.

Review the Governor's Office of Emergency Services website: www.oes.ca.gov for tsunami inundation information of the California coastline. Other hyperlinks include www.tsunamiresearchcenter.com/ and the West Coast and Alaska Tsunami Warning Center: http://wcatwc.arh.noaa.gov .

Hazards from Geologic Materials

23. Expansive soils
The CEG should valuate expansive soils at site from a geologic perspective. This term includes both expansive fills derived from on-site grading and expansive bedrock-cut pads. The CEG should briefly summarize the potential for expansive soils based on field observations and review of published resources such as the "table of physical and chemical properties of soils" contained in the USDA-NRCS Soil Surveys for San Luis Obispo County (Lindsey, 1983; Ernstrom, 1984). Detailed evaluation of soil expansion is typically performed by geotechnical engineers based on laboratory testing of soil and rock samples and is not required in the engineering geology report.

24. Naturally Occurring Asbestos
Serpentine is a common rock type in San Luis Obispo County. It was identified by the California Air Resources Board (CARB) as having the potential to contain naturally occurring asbestos (NOA) and is considered by the CARB as a toxic air contaminant. The San Luis Obispo County Air Pollution Control District (APCD) serves as the local enforcement agency on asbestos-dust problems for development in areas of serpentine terrain. The APCD is responsible for enforcing two Air Toxics Control Measures (ATCM) for NOA recently developed and implemented by the CARB:

- Asbestos ATCM for construction, grading, quarrying, and surface mining regulations, California Code of Regulations, Title 17, Section 93105.
- Asbestos ATCM for surfacing applications, California Code of Regulations, Title 17, Section 93106. "Surfacing" means applications such as aggregates for unpaved roads, parking lots, driveways, and walkways.

These two ATCMs regulate the disturbance of NOA-containing areas during construction and grading activities and NOA-containing material for surfacing applications (aggregate). The full text of these ATCMs is on the CARB website at www.arb.ca.gov/toxics/asbestos/reginfo.htm .

Prior to any grading activities, geologic evaluation following the guidelines in CGS Special Publication 124 (Clinkenbeard and others, 2002) will be necessary to determine if NOA serpentine rock is present. If NOA is found, an Asbestos Health and Safety Program and an Asbestos Dust Mitigation Plan is required to be approved by the APCD before construction begins. Alternatively, it may be more cost effective to not test for NOA, and instead use the Asbestos Health and Safety Program and an Asbestos Dust Mitigation Plan measures.

25. Radon and other hazardous gases

Only for appropriate areas in the County, evaluate the potential for radon gas (222Rn). A reasonable approach is to consider available indoor data for particular geologic units in the area of the site. If a significant amount of the data exceed the U.S. EPA recommended action level of 4 pCi/l (pico-curies per liter), then radon mitigation methods should be considered in the design of buildings at the site. Five geologic factors for consideration in evaluating a site for indoor radon potential are:

- What is the likelihood that the rock and soil units at the site will have higher than crustal average uranium or radium contents? If this is likely, then the odds of excessive indoor radon are increased. Geologic formations of particular interest (but are not limited to) the following: organic-rich marine shale, diatomaceous shale, phosphate-rich marine sedimentary units, certain granitic rocks (especially two-mica granites, and felsic volcanic rocks.
- Is the soil a moderate to low permeability, high shrink-swell soil? If yes, then the odds of excessive indoor radon are increased.
- If the buildings overlie faults or shear zones, then the odds of excessive indoor radon are increased.
- If buildings overlie areas with uranium mineralization, shallow geothermal reservoirs, or shallow oil and gas reservoirs, then the odds of excessive indoor radon are increased.
- The radon content of soil gas is several hundred pCi/l, but such levels are not commonly associated with indoor radon hazards. The higher the soil gas radon level, the greater the odds for indoor air radon problems. However, a universally applicable soil gas radon threshold does not exist for predicting whether or not a building will have indoor radon hazards.

The California Geological Survey has produced a special report SP-208 with maps (Churchill, 2008) that addresses radon potential in San Luis Obispo, County. This publication and maps must be reviewed when addressing radon potential for sites in San Luis Obispo County. This report may be downloaded from the CGS website at

http://conservation.ca.gov/cgs/minerals/hazardous_minerals/radon/Documents/SR208_SLO_RadonReport.pdf

As applicable, evaluate the potential for methane gas, hydrogen sulfide gas, or similar hazardous gases from petroleum fields or former dairy sites. Evaluate potential hazards from oil seeps and tar seeps from both natural and developed sites.

The California. Division of Oil, Gas, and Geothermal Resources (CDOGGR) publishes oil and gas field maps: Many of these maps can be downloaded from their website at http://www.conservation.ca.gov/DOG/ Provide CDOGGR specifications for your client regarding legal requirements for petroleum pipelines and oil well abandonment/destruction.

In addition, the California Department of Water Resources and the San Luis Obispo County Environmental Health Department have their own standards for abandoning and destroying wells. Contact these agencies for more information on their requirements.

Site Grading Plans, Grading Plan Review, and Foundation Plan Review

26. Geologic constraints anticipated during grading operations

Discuss the potential for rippability of rock, production of over-sized rock (cobbles and boulders), and how these are to be either windrowed, stockpiled for erosion control (rip-rap), used for ornamental landscaping, or exported offsite.

Only as appropriate and applicable: for mass grading of hillside sites, plot locations of canyon subdrains, gallery drains, and back-drains. For basement excavations with shallow groundwater or perched water, evaluate dewatering. Some basements may need permanent dewatering systems (drains and sump pumps) and waterproofing.

Assess the possibilities of uncovering unknown sewage systems, leach fields, water wells, or cisterns. If improperly abandoned or unknown oil or gas wells are uncovered, then indicate that these must be properly abandoned according to state and local rules (CDOGGR, County of San Luis Obispo).

Significant vertebrate or invertebrate fossils, or human artifacts may be unexpectedly uncovered during initial stripping of soil and overburden. If these are found, then the owner or contractor must immediately contact the project planner at the San Luis Obispo County Planning and Building Department. Indicate in the grading-plan review that grading operations would halt temporarily while these sites are evaluated and salvaged by professional paleontologists and archeologists.

27. Areas of cut and fill, preparation of the ground, depths of removals and recompaction

Delineate areas on the grading plans where the geologic subgrade is to be over-excavated and specify depths of removals. Removal and recompaction depths should be substantiated by an adequate number of shallow consolidation tests, dry density tests, and relative compaction tests performed by the RGE.

For former orchard or vineyard sites, evaluate the depths of tree stumps or vines to be ripped out with deep over-excavation. Delineate extent and depth of organic soils to be stripped, stockpiled, and reused for future lawns and landscape areas. Evaluate suitability of alluvium and soils to be used in structural fills. If there is evidence of krotovina (holes from gophers, moles, or other burrowing rodents), then provide appropriate recommendations for over-excavation and recompaction.

The CEG and RGE should specify times and circumstances of mandatory “called inspections” when the grading contractor needs to call the CEG to approve a canyon clean-out, subdrain placement, buttress keyway, or retaining wall footing. These in-grading inspections should not be performed by a soils technician who normally performs only compaction tests, but by experienced licensed CEGs and RGEs.

28. Subdrainage plans for groundwater

During grading-plan review, plot all seepage areas and planned subdrains on the project grading plans. Show dimensions and layout of the subdrains on the grading plans. Include subdrain cleanouts, if necessary.

29. Final grading report and as-built map

At the completion of the rough grading, the CEG will be required to submit a final grading report and an as-built (as-graded) map. The purpose of this report is to obtain the consultant's specific approval of the rough grading. The as-graded map must be based on the original scale project grading plans and include contour lines which show the pre- and post-site grading and all geotechnical corrective measures as actually constructed. These data will become a permanent record and can be used to assess any further grading modification or geotechnical problem that may develop in the future.

The final grading report is to contain a compilation of all testing done on the site, the accurate location, both vertically and horizontally, of all tests referenced to a permanent datum/ fixed point, maximum laboratory density curves with back-up data, etc. The as-graded map must include, but is not limited to, the following (some items will apply to RGE):

a. The geology as exposed by the grading in sufficient detail to justify the consultant's conclusions.

b. The cut-fill-natural ground daylight line, legible, clearly drawn, and labeled.

c. The location of geologic cross sections, subdrains, shear keys, buttresses, special replacement fills, restricted use areas, foundation setback lines, landslides not removed by grading, the geology of the adjoining natural terrain affecting or affected by planned development, exploratory excavations not removed by grading, areas of over-excavations, and sufficient geologic symbols to clearly depict the geologic structure and lithologies.

d. Compaction tests accurately located.

e. Tract and lot numbers and their boundaries that correspond with the latest available final map.

If the County determines that the final grading report or the as-built map is not sufficient in detail, or departs from independent observations of the as-graded conditions, approval of the grading will be withheld until the report and/or map is revised to a satisfactory condition.

Engineering Geology Report Documentation

30. Summary sheet

Each geological report must contain a summary of the report contents. This is a condensation of the data in the body of the report, with conclusions and recommendations derived from the data. The purpose of the summary is to facilitate review by the County. The summary sheet must be at the beginning of the report and contain the following elements with page reference to the appropriate text within the report:

a. Statement of the potential hazards to the development site.

b. Itemized conclusions.

c. Itemized recommendations. Recommendations typically are incorporated in the conditions of project approval. Therefore, these recommendations must be as specific as possible commensurate with the quantity and reliability of the data presented. (Example: In a engineering geology report which is submitted for the review of a grading plan, the CEG shall indicate by lot number which cut-slopes must be retained, rather than indicating that "all north-facing cut slopes" must be retained). The recommended corrective measures shall be clearly depicted on all geologic maps.

31. Age of report

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

32. Engineering geology report signed by CEG

In accordance with the Business and Professions Code §7835, the engineering geology report must be prepared and legally signed or stamped with the professional seal by a Certified Engineering Geologist, and the CEG license number must be legibly provided. Original signatures of the licensee are required. Copies will not be accepted.

Acknowledgements

Robert Sydnor (CGS Senior Engineering Geologist) graciously shared unpublished draft copies of CGS Note 48, allowing me to liberally borrow from it. Darlene Batatian (Salt Lake County Geologist) provided information on fault rupture setbacks. Peer review by William Cole (Cotton, Shires and Associates), and Dennis Burke (consulting engineering geologist),

References Cited

Batatian, L.D., and Nelson, C.V., 1999, Fault setback requirements to reduce rupture faulting hazards in Salt Lake County [abs.]: Association of Engineering Geologists, Program with abstracts, 42nd Annual Meeting, Salt Lake City, Utah, p. 59.

Bazzurro, P., and Cornell, C.A., 1999, Disaggregation of seismic hazard: Bulletin of the Seismological Society of America, vol. 89, no. 2, p 501–520.

Blake, T.F., Hollingsworth, R.A. and Stewart, J.P., 2002, Recommended procedures for implementation of DMG Special Publication 117 guidelines for analyzing and mitigating landslide hazards in California: Southern California Earthquake Center report, 108 p., 1 appendix.

Bonilla, M.G., 1982, Evaluation of potential surface faulting and other tectonic deformation: U.S. Geological Survey Open- File Report 82-732, 58 p.

California Division of Mines and Geology, 1973, Urban Geology Master Plan for California, 112 p.

California Geological Survey 2008, Guidelines for evaluating and mitigating seismic hazards in California: California Division of Mines and Geology Special Publication 117A, 92p.

_____1998, Guidelines for evaluating the hazard of surface fault rupture, 4 p.

California Division of Mines and Geology/ International Conference of Building Officials, 1998, Maps of known active fault near-source zones in California and adjacent portions of Nevada: Whittier, Calif., International Conference of Building Officials, 215 p

Central Coast Regional Water Quality Control Board, 1994, Central Coast Regional Water Quality Control Board Basin Plan: unpublished document adopted September 8, 1994.

Churchill, R.K., 2008, Radon potential in San Luis Obispo County, California: California Geolocal Survey Special Report 208, 72 p. 2 Plates

Clinkenbeard, J.P., Churchill, R.K., and Lee, Kiyoung, eds., 2002, Guidelines for geologic investigations of naturally occurring asbestos in California: California Geological Survey Special Publication 124, 70 p.

Ernstrom, D.J., 1984, Soil survey of San Luis Obispo County California, coastal part: U.S. Department of Agriculture, Soil Conservation Service, 265 p.

Ewing, Leslie; Fuchs, Liz; Klien, Adrienne; Locklin, Linda; Roach, Amy; Auyong, John; Roth, Rebecca; Capelli, Mark; Guiney, Steve; Loomis, Dave; Merrill, Bob; Willis, Cope; and Coyne, Melanie, 1999, Beach erosion and response (BEAR) guidance document: California Coastal Commission unpublished report, 177 p.

Habel, J.S., and Armstrong, G.A., 1977, Assessment and atlas of shoreline erosion along the California coast: California Department of Navigation and Ocean Development, 355 p., scale 1:48,000.

Harmsen, S.C., 2001, Mean and modal ε in the deaggregation of probabilistic ground motion: Bulletin of the Seismological Society of America, v. 91, no. 6, p. 1537–1552.

Hart, E.W., and Bryant, W.A., 1999, Fault-rupture hazard zones in California: California Division of Mines and Geology Special Publication 42, 38 p.

Hatheway, A.W., and Leighton, F.B., 1979, Trenching as an exploratory tool in Hatheway, A.W., and McClure, C.R., Jr., editors, Geology in the siting of nuclear power plants: Geologic Society of America, Reviews in Engineering Geology, vol. IV, p. 169–195.

Holzer, T.L., Noce, T.E., Bennett, M.J., Di Alessandro, Carola, Boatwright, John, Tinsley, J.C. III, Sell, R.W., and Rosenberg, L.I., 2004, Liquefaction-induced lateral spreading in Oceano, California, during the 2003 San Simeon earthquake: U.S. Geological Survey Open-File Report 2004-1269, 51 p.

Idriss, I.M. and Sun, J.I., 1992, SHAKE91, Equivalent linear seismic response analysis of horizontally layered soil deposits: National Information Service for Earthquake Engineering, University of California, Berkeley.

International Conference of Building Officials, 1997, Uniform Building Code: Whittier, Calif., International Conference of Building Officials, 3 volumes, variously paginated.

Ishihara, K., 1985, Stability of natural deposits during earthquakes: Proceedings, 11th International Conference on Soil Mechanics and Foundation Engineering, San Francisco, v. 1, p. 321–376.

_____1996, Soil behavior in earthquake geotechnics: Oxford Engineering Science Series, No 46, Oxford University Press, 360 p.

Lindsey, W.C., 1983, Soil survey of San Luis Obispo County, California, Paso Robles area: U.S. Department of Agriculture, Soil Conservation Service, 236 p.

Martin, G.R., and Lew, M., eds., 1999, Recommended procedures for implementation of DMG Special Publication 117, Guidelines for analyzing and mitigating liquefaction hazards in California: Southern California Earthquake Center, 63 p.

McCalpin, J.P., 1987, Recommended setbacks from active normal faults, in McCalpin, James, ed., Proceedings of the 23rd Annual Symposium on Engineering Geology and Soils Engineering: Logan, Utah State University, April 6–8, 1987, p. 35–56.

_____1996, Paleoseismology: San Diego, Calif., Academic Press, International Geophysics Series, v. 62, 588 p.

Munsell Color, 1990, Munsell Soil Color Charts: Baltimore, Maryland, Macbeth Division of Kollmorgen Instruments Corporation, 18 p.

Naval Facilities Engineering Command, 1986, Design manual 7.01, Soil mechanics: U.S. Navy Publication SN 0525-LP- 300-7056, 143 p.

Rogers, J.D., 1992, Long-term behavior of urban fill embankments, in Seed, R.B., and Boulanger, R.W., eds., Stability and performance of slopes and embankments – II: American Society of Civil Engineers, Geotechnical Special Publication no. 31, v. 2, p. 1258–1273.

Salt Lake County, 2002, Salt Lake County Code of Ordinances, Chapter 19.75, Geologic Hazards Ordinance, Appendix A—Minimum standards for surface fault rupture studies.

San Luis Obispo County Planning & Building Department, 2003, San Luis Obispo County Land Use Ordinance (Title 22 of the San Luis Obispo County Code), San Luis Obispo County General Plan: San Luis Obispo County Planning & Building Department open-file report.

_____2001, San Luis Obispo County Coastal Zone Land Use Ordinance (Title 23 of the San Luis Obispo County Code), San Luis Obispo County General Plan: San Luis Obispo County Planning & Building Department open-file report.

Sherard, J.L., Cluff, L.S., and Allen, C.R., 1974, Potentially active faults in dam foundations: Geotechnique, Institute of Civil Engineers, London, v. 24, no. 3, p. 367–428.

Slemmons, D.B., 1977, State-of-the-art for assessing earthquake hazards in the United States: Report 6, faults and earthquake magnitude: U.S. Army Engineer Waterways Experiment Station Miscellaneous Paper S-73-1, 129 p.

Slemmons, D.B., and dePolo, C.M., 1992, Evaluation of active faulting and associated hazards: in Studies in Geophysics- Active Tectonics: National Research Council, p. 45–62.

Stewart, J.P., Bray, J.D., McMahon, D.J., Smith, P.M., and Kropp, A.L., 2001, Seismic performance of hillside fills: ASCE Journal of Geotechnical and Geoenvironmental Engineering, v.127, no. 11, p. 905–919.

Taylor, C.L., and Cluff, L.S., 1973, Fault activity and its significance assessed by exploratory excavation in Proceedings of the Conference on Tectonic Problems of the San Andreas Fault System; Stanford University Publication, Geological Sciences, v. XIII, September 1973, p. 239–247.

Turner, A.K., and Schuster, R.L., eds., Landslides: Investigation and mitigation: Transportation Research Board Special Report 247, 673 p.

U.S. Bureau of Reclamation, 1988, Engineering geology field manual: Denver, Colo., U.S. Department of the Interior, 599 p.

Wallace, R.E., 1977, Profiles and ages of young fault scarps, north-central Nevada: Geological Society of America Bulletin, v. 88, p. 1267–1281.

Wells, D.L., and Coppersmith, K.J., 1994, New empirical relationships among magnitude, rupture length, rupture width, and surface displacement: Bulletin of the Seismological Society of America, v. 84, no. 4, p. 974– 1002.

Wills, C.J., Petersen, M.D., Bryant, W.A., Reichle, M.S., Saucedo, G.J., Tan, S.S, Taylor, G.C, and Treiman, J.A., 2000, A site conditions map for California based on geology and shear wave velocity: Bulletin of the Seismological Society of America, v. 90, no. 6b, p S187–S208.

Wills, C.J., and Silva, Walter, 1998, Shear-wave velocity characteristics of geologic units in California: Earthquake Spectra, v. 14, no. 3, p. 533–556.

Youd, T.L., and Garris, C.T., 1995, Liquefaction-induced ground-surface disruption: ASCE Journal of Geotechnical Engineering, v. 121, no. 11, p. 805–809.

Youd, T.L., Hansen, C.M., and Bartlett, S.F., 1999, Revised MLR equations for predicting lateral spread displacement, in Proceedings of the 7th U.S.-Japan Workshop on earthquake resistant design of lifeline facilities and countermeasures against soil liquefaction: Multidisciplinary Center for Earthquake Engineering Research: MCEER Report 99-0019, p. 99–114.

Youd, T.L., Idriss, I.M., co-chairmen, and Andrus, R.D. Arango, I., Castro, G., Christian, J.T., Dobry, R., Liam Finn, W.D.L., Harder, L.F., Jr., Hynes, M.E., Ishihara, K., Koester, J.P., Liao, S.S.C., Marcuson, W.F., III, Martin, G.R., Mitchell, J.K., Moriwaki, Y., Power, M.S., Robertson, P.K., Seed, R.B., Stokoe, K.H., II, 2001, Liquefaction resistance of soils: Summary report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils, ASCE, Journal of Geotechnical and Geoenvironmental Engineering, v. 127, No. 10, p 817–833.

SAN LUIS OBISPO COUNTY ENGINEERING GEOLOGY & GEOTECHNICAL REPORT REVIEW FORM

The San Luis Obispo County Planning and Building Department uses the following checklist as part of reviewing engineering geology and/or geotechnical reports for sites located in high potential zones for seismically induced liquefaction and/or landsliding. Explanatory notes are appended and keyed to each numbered item.

Checklist item within consulting report	Adequately described: satisfactory	Additional data needed: unsatisfactory
1. Project Description		
2. SLO County Geological Study Area Map		
3. Site Location		
4. Regional Geologic Map		
5. Original engineering geologic map of site		
6. Aerial photograph interpretation		
7. Subsurface site geology		
8. Geologic cross sections		
9. Active faulting and coseismic deformation across the site		
10. Landslides		
11. Flooding, severe erosion, deposition		
12. On-site septic systems		
13. Hydrocollapse of alluvial fan soils		
14. Evaluation of historical seismicity and regional faults		
15. Characterize and classify geologic site class		
16. Probabilistic evaluation of earthquake ground motion		
17. Peak ground acceleration for MCE levels of ground motion & site coefficients		
18. Spectral accelerations S_{MS}, S_{M1} S_{DS} & S_{D1}		
19. Geologic setting for liquefaction analysis		
20. Liquefaction methodology		
21. Bluff erosion		
22. Tsunami or seiche potential		
23. Expansive soil		
24. Naturally occurring asbestos		
25. Radon and other hazardous gasses		
26. Geologic constraints anticipated during grading operations		
27. Areas of cut and fill, preparation of the ground, and depth of removals		
28. Subdrainage plans for groundwater		
29. Final grading report and as-built map		
30. Summary sheet		
31. Age of reports		
32. Reports signed by CEG		