6.6 GEOLOGY, SOILS, AND SEISMICITY

INTRODUCTION

This section of the EIR describes the existing geology, soils, and seismic conditions in the vicinity of the Regional University Specific Plan (RUSP) Area (the study area), including the project site and adjacent infrastructure corridors to the east and southeast (see Figure 2-4 in Chapter 2, Project Description). This section analyzes the potential physical environmental effects related to seismic hazards and erosion and evaluates geotechnical problems that could affect development in the study area. Regional soils, geology, and seismicity characteristics were examined to provide a context to evaluate project-related conditions. Faulting, groundshaking, erosion, slope and soil instability, and mineral resources are addressed specifically this section of the EIR. Water quality issues relating to erosion are addressed in Section 6.8, Hydrology and Water Quality, of this EIR. Paleontological resources are addressed in Section 6.5, Cultural Resources, of this EIR.

Data used in preparation of this section of the EIR were obtained from various sources, including the Consolidated Preliminary Geotechnical Engineering Report (Wallace-Kuhl & Associates No. 6546.07, dated November 27, 2006). Other sources include the Placer County General Plan, the City of Roseville General Plan, published information from the United States Geological Survey (USGS) and the California Geological Survey ([CGS], formerly California Division of Mines and Geology), and previously prepared environmental documentation for projects and investigations in the vicinity the study area. Full bibliographic entries for all referenced materials are provided in the footnotes of this section of the EIR.

No comments regarding geology, soils, or geological hazards were received in response to the NOP for this project.

ENVIRONMENTAL SETTING

Regional Geology

The study area is in the Sacramento Valley of the Great Valley geomorphic province. The Sacramento Valley is formed by the Great Valley geosyncline, which is a large, elongated, northwest-trending asymmetric structural trough. It is bordered by the Coast Ranges to the west, the Klamath Mountains and Cascade Range to the north, and the Sierra Nevada range to the east. The geologic formations of the Great Valley on the east side of the Sacramento Valley are thick sequences of alluvial (river-deposited) sediments derived from erosion of the granitic rocks of the Sierra Nevada.

Regional Faults and Seismicity

The seismicity of the Sacramento Valley is dominated by the San Andreas fault system in the Coast Ranges to the west. This fault system separates two of the major tectonic plates that comprise the earth's crust. The Pacific Plate, which lies west of the fault system, is moving in a northwesterly direction relative to the North American Plate, which lies east of the fault system. This ongoing movement produces the earthquakes common to northern California and seismic groundshaking as far east as Placer County.

There are hundreds of faults throughout northern California that have been categorized by the CGS as active, potentially active, or inactive. A fault is considered active by the state if it has caused surface displacement (movement) during the Holocene epoch (during the last 11,000 years) or if it is included in an Alquist-Priolo Earthquake Fault Zone (as established by the CGS). Faults that do not show evidence of Holocene movement are not necessarily inactive. If a fault has experienced displacement activity during the Quaternary period (the last 1.6 million years), it could be considered a source for future earthquakes.[1] Such a fault is considered potentially active by the CGS.

Faults that have not moved in the last 1.6 million years are considered inactive by the CGS and are not considered sources for future earthquakes.[2]

The study area is between the seismically active San Andreas fault system, about 50 miles southwest in the Coast Ranges, and the historically seismic Foothills fault zone, about 21 miles northeast in the Sierra Nevada. There are a number of other mapped faults within 62 miles (100 kilometers) of the study area currently zoned as active by the CGS, under the Alquist-Priolo Earthquake Fault Zoning Act. These include the Cleveland Hill fault (approximately 44 miles north-northeast of the study area), the Green Valley fault (60 miles southwest), the Antioch fault (60 miles south-southwest), and the Hunting Creek fault (60 miles west).

Project Site and Off-Site Improvement Areas

Topography

The study area is in the "Dissected Alluvial Plains" geomorphic unit, which is characterized by gently rolling plains and rounded knolls and ridges that are separated by intermittent streams. The entire region slopes gently west toward the Sacramento River. Several streams, with narrow floodplains entrenched 10 to 15 feet below the surrounding topography, drain the region from east to west. The elevation of the study area ranges from approximately 50 feet above mean sea level (msl) at the western boundary to approximately 90 feet msl at the eastern boundary.

Local Geology

The geology in the vicinity of the study area is transitional between the alluvial deposits of the Valley and the granitic materials characteristic of the Sierra Nevada. According to the *Geologic Map of Late Cenozoic Deposits of the Sacramento Valley and Northern Sierran Foothills, California*, the project site and off-site areas are entirely underlain by the Riverbank Formation. The creek channels through the study area contain Quaternary alluvium.[3]

The Riverbank Formation consists of moderately weathered reddish sandy sediment containing unconsolidated to semi-consolidated gravel, sand, and silt. These sediments formed dissected alluvial terraces and fans along the east margin of the Sacramento Valley between 150,000 and

1 Hart, E.W., and Bryant, W.A., *Fault-Rupture Hazard Zones in California, Alquist-Priolo Earthquake Fault Zoning Act with index to Earthquake Fault Zones Maps*, California Geological Survey, Special Publication 42, revised 1997, Supplements 1 and 2, 1999, Supplement 3, 2003.

2 Hart, E.W., and Bryant, W.A., *Fault-Rupture Hazard Zones in California, Alquist-Priolo Earthquake Fault Zoning Act with index to Earthquake Fault Zones Maps*, California Geological Survey, Special Publication 42, revised 1997, Supplements 1 and 2, 1999, Supplement 3, 2003.

3 Helley, E.J., and D.S. Harwood. 1985. *Geologic map of late Cenozoic deposits of the Sacramento Valley and northern Sierran foothills, California, showing major late Cenozoic structural features and depth to basement*. USGS Miscellaneous Field Studies Map MF-1790. scale 1:62,540.

450,000 years ago. Soils associated with this formation typically are well drained and underlain at varying depths by impervious clay hardpan.

Quaternary alluvium consists of deposits of cobbles, gravel, silt, sand, and clay. These unconsolidated terrace deposits and recent stream deposits occur along the creek channels in the study area. Soils originating from alluvial deposits typically are well drained, and vary in depth to an impervious layer of clay hardpan.

Local Faults and Seismicity

Local Faults

Although faults have been identified in the Sacramento area, no active faults are known to exist in Placer County, and the study area is not in an Alquist-Priolo Earthquake Fault Zone. The southern part of Placer County is classified by the CGS as a low-severity earthquake zone.[4]

There is some potential for inactive faults to reactivate or experience displacement along a segment sometime in the future. The Foothills fault zone is approximately 21 miles east and northeast of the study area. This zone includes the potentially active Spenceville, Swain Ravine, Maidu, Dewitt, Bear Mountains and Melones faults. The potentially active Dunnigan Hills fault is approximately 21 miles west of the study area.

The Foothills fault zone was considered inactive until evidence of an earthquake (approximately 1.6 million years ago) was found near Spenceville, California, causing the fault zone to be considered potentially active. Then, in 1975, an earthquake occurred on another segment in the zone near the City of Oroville on the Cleveland Hills fault. Because of the potential for fault movement, even though the likelihood of the occurrence is low, the following discussion about inactive and potentially active faults is included in this section.

There are no mapped active faults in Placer County; however, three inactive faults have been identified within 10 miles of the study area. These include the Volcano Hill fault, the Linda Creek fault, and an unnamed fault segment extending east/west between Folsom Lake and the City of Rocklin. The Volcano Hill fault extends northwesterly from Volcano Hill for a distance of approximately one mile, terminating near Eureka Road. There has been no recorded activity along the fault; therefore, it is considered inactive. In 1973, the CGS identified the Linda Creek fault, along Linda Creek. The extent of this inferred fault is limited to a segment of the creek in the City of Roseville and Sacramento County, east of the study area.[5] The unnamed fault extends east to west between Folsom Lake and the City of Rocklin. Segments of this fault are concealed and, consequently, unmapped; however, the east/west alignment suggests that the fault could connect to the Bear Mountain fault, branches of which are beneath Folsom Lake. The Bear Mountain fault is identified as one of the faults that could be undergoing reactivation as a result of continental tectonic activity.

4 *City of Roseville General Plan*, November 18, 1992.

5 *City of Roseville General Plan*, November 18, 1992, *Safety Element.*

Groundshaking

The study area is in a part of Placer County that is classified by the CGS as a low-severity earthquake zone.[6] The maximum seismic groundshaking intensity that can be anticipated during the next 30 years at the project site would be MMI V from a Moment Magnitude (M_W) 7.9 earthquake, rupturing all four segments of the San Andreas fault in the San Francisco Bay Area. There is about a 5 percent probability (P=0.05) of such an event occurring in this timeframe.[7] The most likely large-earthquake scenario in this 30-year timeframe (P=0.15) would be a M_W 7.0 event on the Hayward-Rodgers Creek fault, which would produce groundshaking intensities of MMI IV to V at the project site.[8]

The last seismic activity recorded in the study area with a Richter Magnitude of at least 4 occurred in 1908. The epicenter of this event was on a north-south line between Folsom and Auburn and on an east-west line between Placerville and Roseville, about 20 miles east of the study area. There have been several less severe events since 1908, but no major activity has been recorded in the vicinity of the study area.[9]

Secondary Seismic Hazards

Results of a site-specific preliminary geotechnical investigation prepared for the study area indicate that the underlying soils are not likely to be susceptible to liquefaction, ground lurching, differential settlement, or lateral spreading.[10]

<u>Soils</u>

Soil Characteristics

Soils of the Central Valley are erosional deposits from the Sierra Nevada to the east. Soil limitations can include slow or very slow permeability, limited ability to support a load, high shrink-swell potential (expansive soil), moderate depth to hardpan, shallow depth to rock, and frequent flooding. The U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) has identified and mapped soils in Placer County. Each identified soil has characteristics that affect soil behavior. Characteristics of relevance to the study area include the following:

- <u>Permeability:</u> The ability of a soil to transmit water or air. Permeability is considered in the design and construction of soil drainage systems, where the rate of water movement under saturated conditions affects the behavior of water movement through the soil.
- <u>Shrink-Swell (Expansion) Potential:</u> The potential for volume change in a soil with a loss or gain in moisture. If the shrink-swell potential is rated moderate to high, damage to buildings, roads, and other structures can occur.

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6 *City of Roseville General Plan*, November 18, 1992.

7 USGS Working Group on California Earthquake Probabilities, *Earthquake Probabilities in the San Francisco Bay Region: 2002–2031* Open-File Report 03-214, 2003, pages 7.3 – 7.7 and figure 7.1a.

8 USGS Working Group on California Earthquake Probabilities, *Earthquake Probabilities in the San Francisco Bay Region: 2002–2031* Open-File Report 03-214, 2003, pages 7.3 – 7.7 and figure 7.2a.

9 City of Roseville, *North Central Roseville Specific Plan, Annotated Draft Environmental Impact Report*, SCH # 88053010, 1990, page 4.3-9.

10 Wallace-Kuhl & Associates, *Consolidated Preliminary Geotechnical Engineering Report Regional University Specific Plan, November 27, 2006*, page 13.

- Runoff: The volume of rainwater leaving an area as surface drainage, as opposed to the volume that seeps into the area to become groundwater.
- Erosion: The susceptibility of a soil to water (rainfall) or wind transport.

Near-surface soils in the study area consist primarily of Alamo-Fiddyment complex, Cometa Sandy Loam, Cometa-Fiddyment complex, Cometa Ramona sandy loams, Fiddyment Loam, Fiddyment-Kaseberg loams, San Joaquin-Cometa sandy loams Xerofluvents, Occasionally Flooded, Xerofluvents, Frequently Flooded, and Xerofluvents-hardpan substratum. Soil types for the project site and areas designated for off-site improvements are shown on Figure 6.2-2 in section 6.2, Agricultural Resources. Characteristics of site soils are summarized in Table 6.6-1.

Soil Constraints

Expansive Soils

Expansive soils (i.e., clay or silt) are those that increase in volume when they absorb water (swell) and shrink when they dry out. These types of soils may be found in areas with a fluvial depositional history. Expansion can cause damage to building foundations, concrete slabs, hardscape, pavement, and other surface or near-surface improvements. Soils having moderate to high expansion potential are found throughout the study area.[11]

Erosion, Runoff, and Drainage

Erosion potential of the soils at the project site ranges from low to moderately high because of their fine texture and low slopes. Soils exposed during cultivation or excavation activities would be more erosion prone than in their natural states because of loosening of the soil particles.

The soils at the project site have relatively low percolation rates, but tend to drain quickly during moderate rainfall. These soils transmit water and/or air slowly and can cause ponding and soil drainage problems during heavy rainfall, particularly in the Alamo-Fiddyment complex and the Xerofluvents along the creek channels. Detailed explanation of site drainage and runoff features (including hydrologic soil types) appears in Section 6.8, Hydrology and Water Quality of this EIR.

Agricultural Soils

Soils are categorized by their potential use as agricultural land. "Prime Farmland" is defined by the State Department of Conservation as land that has the best combination of physical and chemical characteristics for the production of crops. These lands generally consist of Class I and II soils. As shown in Table 6.6-1, most of the soils in the study area are Class III and IV, which have severe limitations for agricultural production, as defined by the USDA-NRCS. There is no Prime Farmland on the project site or off-site improvement areas. See Section 6.2, Agricultural Resources for additional information regarding conversion of agricultural land.

11 Wallace-Kuhl & Associates, *Consolidated Preliminary Geotechnical Engineering Report Regional University Specific Plan*, November 27, 2006, page 14.

TABLE 6.6-1

SOIL CHARACTERISTICS OF THE PROJECT SITE

Soil Type[1]	Unit Number	Soil Texture	Percent Slopes	Percolation Rate[2]	Expansion Potential[3]	Erosion Hazard[3]	Liquefaction Potential[3]	Soil Strength[4]	Agricultural Capability Class[5]
Alamo – Fiddyment	104	complex	0 to 5	S-VS	H	L-MH	L	P	IV
Cometa	140	sandy loam	1 to 5						
Cometa – Fiddyment	141	complex	1 to 5	M-VS	H-L	L-MH	L	P	IV
Cometa – Ramona	142	sandy loam	1 to 5	M-VS	L-H	L-M	L	P	III
Fiddyment	146	loam	1 to 8	M-VS	L-H	ML-MH	L	P	IV
Fiddyment – Kaseberg	147	loam	2 to 9	M-VS	L-H	ML-MH	L	P	IV
San Joaquin – Cometa	182	sandy loam	1 to 5	M-VS	L	L-M	L	P	IV
Xerofluvents	193	occasionally flooded							
Xerofluvents	194	frequently flooded							
Xerofluvents	195	hardpan substrate	---	---	---	---	---	---	III
Off-Site Areas Fiddyment	146	loam	1 to 8	M-VS	L-H	ML-MH	L	P	IV
Off-Site Areas Cometa – Ramona	142	sandy loam	1 to 5	M-VS	L-H	L-M	L	P	III

Notes:

1. See Figure 2 of Wallace-Kuhl & Associates, November 27, 2006, for distribution of soil units on the project site

2. VR = Very Rapid
   R = Rapid
   MR = Moderately Rapid
   M = Moderate
   MS = Moderately Slow
   S = Slow
   VS = Very Slow

3. VH = Very High
   H = High
   M = Moderate
   L = Low
   VL = Very Low

4. G = Good
   F = Fair
   P = Poor

5. I = Few Limitations
   II = Moderate Limitations
   III = Severe Limitations
   IV = Very Severe Limitations
   V = Impractical to Cultivate
   VI = Severe Limitations; Generally Unsuitable for Cultivation
   VII = Very Severe Limitations: Unsuitable for Cultivation
   VIII = Precluded from Use for Commercial Planting

Source: USDA — NRCS, 1980.

Topsoil

The topsoil in the study area is characterized by the NRCS as "poor" to "fair." Soil units with these classifications are not considered good sources of topsoil because they form relatively thin layers and contain appreciable amounts of gravel, stones, or soluble salts, or are poorly drained.[12]

Other Geotechnical Considerations

Slope Instability

Landslides and slope stability are not a constraint in the study area because of the lack of steep slopes.

Subsidence

Subsidence is the sinking of the ground surface, usually caused by the withdrawal of groundwater or other subsurface fluids. It can accompany underground mining extraction or the natural or induced collapse of subsurface materials. The study area is not subsidence prone and is not expected to experience substantial subsidence or subsequent constraints to development resulting from subsidence.[13]

Groundwater

The highest recorded groundwater level in the study area is 10 feet below existing grade. Perched groundwater was observed at approximately 4.5 feet below grade in a few test pits excavated in April 2005 as part of the preliminary geotechnical investigation for the proposed project. A permanent high groundwater table has not been identified as a site constraint.

During the rainy season, infiltrating surface water would tend to create a saturated surface condition due to the relatively impermeable nature of the near-surface soils, sands, clays, and underlying cemented soils. Perched water could be present within utility excavations, especially if construction occurs in the winter or early spring months.[14]

Mineral Resources

Placer County is rich in mineral resources. Its gold production since 1849 is estimated at more than $75,000,000. Several large drift mines are in operation in the county. Large bodies of gold, copper, and iron ore occur in the Sierra Foothills and in the Sierra Nevada ranges. Valuable deposits of asbestos, lime, and clay occur in the Sacramento Valley and the Sierra Foothills. In the vicinity of Lincoln (northeast of the study area) are deposits of clay, used for the manufacture of pottery, a

12 USDA Natural Resources Conservation Service, *Soil Survey Placer County, California, Western Part*, 1980, Table 9 and page 83.

13 City of Roseville, *West Roseville Specific Plan and SOI Amendment Area EIR* (SCH #2002082057), September 2003, page 4.6-5.

14 Wallace-Kuhl & Associates, *Consolidated Preliminary Geotechnical Engineering Report Regional University Specific Plan*, November 27, 2006, page 18.

major industry in the County. In Rocklin (east of the study area), there are quarries that produce high quality granite building material.[15]

CGS is responsible under the California Surface Mining and Reclamation Act of 1975 (SMARA) for the classification and designation of areas that contain (or could contain) significant mineral resources. The purpose of the identification of these areas is to provide a context for land use decisions by local governments in which mineral resource availability is one of the pertinent factors being balanced along with other considerations. Mineral aggregate resources are classified as one of six mineral resource zone categories (MRZ-1, -2a, -2b, -3, -3a, or -4).[16] These classifications are based on the relative knowledge about the resource's presence and the quality of the material.

The CGS has mapped mineral and mineral aggregate resources in Placer County. Of the classifications listed, only MRZ-4 occurs in the study area. The MRZ-4 designation is defined as "areas of no known mineral occurrences where geologic information does not rule out either the presence or absence of significant mineral resources."[17] No mineral extraction operations exist in the study area.

REGULATORY SETTING

Regulations and standards related to geology, soils, and seismicity, as well as mineral resources in Placer County are included in State regulations, county ordinances, and plans adopted to protect public safety and to conserve open space. The following is a brief summary of the regulatory context under which geology and soils and hazards are managed. Agencies with responsibility for protecting people and property in the study area from damage associated with soil conditions and geologic hazards are described below.

Federal Regulations

There are no federal regulations applicable to geologic resources.

State Regulations

Seismicity and Soils

The State of California provides minimum standards for structural design and site development through the California Building Standards Code (California Code of Regulations (CCR), Title 24). The California Building Code (CBC) is based on the Uniform Building Code, which is used widely throughout United States (generally adopted on a state-by-state or district-by-district basis) and has been modified for California conditions with numerous more detailed and/or more stringent regulations.

Chapter 16 of the CBC is intended to reduce impacts associated with exposure of people and structures to seismic hazards, and ensure development of structures on expansive soils remain less

15 Perazzo, P. B. and G.P. Perazzo, 2005, *Stone Quarries and Beyond: Quarries – Quarries, Stone Cutters & Stone Carvers, Historical Dealers of Stone & The Finished Products*, www.cagenweb.com/quarries/states/ca/quarry_photo/ca-placer_indus.html#min_res_intro_c1915, accessed November 28, 2005.

16 CDMG, Mineral Land Classification of Placer County, California. DMG, Open File Report 95-10, Plate 5 (Areas Classified MRZ-2a and MRZ-2b for all minerals), 1995.

17 *Open File Report 95-10, Mineral Land Classifications of Placer County, California*, California Department of Conservation, Division of Mines and Geology, 1995, page 18.

than significant by requiring that any development meet specific minimum seismic safety and structural design requirements. Chapter 18 is intended to reduce such impacts by requiring that any development adhere to requirements for excavation of foundations and retaining walls. Appendix Chapter 33 is intended to reduce such impacts by requiring that any development adhere to regulations pertaining to grading activities, including drainage and erosion control, and construction on expansive soils. The State Earthquake Protection Law (California Health and Safety Code 19100 et seq.) requires that structures be designed to resist stresses produced by lateral forces caused by wind and earthquakes. Specific minimum seismic safety and structural design requirements are set forth in Chapter 16 of the CBC. The CBC requires a site-specific geotechnical study to address seismic issues and identifies seismic factors that must be considered in structural design.

Because the study area is not in an Alquist-Priolo Earthquake Fault Zone, no associated provisions of the Alquist-Priolo Earthquake Fault Zoning Act related to fault rupture would be required for project development related to fault rupture.

Installation of underground utility lines must comply with industry standards specific to the type of utility (e.g., National Clay Pipe Institute for sewers and American Water Works Association for water lines). These standards contain specifications for installation and design to reflect site-specific geologic and soils conditions.

The State of California has also established construction standards and design criteria for roadways to safeguard life and property. Construction standards and seismic design criteria are contained in such regulatory codes as Caltrans' *Seismic Design Criteria Version 1.2* (December 2001), Highway Design Manual, Sections 110.6, *Earthquake Consideration* (November 2001), and 113, *Geotechnical Design Report* (November 2001), or similar codes adopted by the county for roadway corridor protection. These criteria deal with pavement and subsurface utility design (flexible joints and couplings, overpass construction, etc.), slope stability (especially slumping, settling, and liquefaction in fills), and alignment modification to reduce exposure to fault rupture, intense groundshaking, and ground failures such as liquefaction. Prior to construction, geotechnical studies would be undertaken and recommended seismic-protection measures accommodated in the project design. The recommendations would provide at least the minimum required protection from the anticipated effects of seismic groundshaking. Adherence to these standards of protection would reduce the risk of injury or death from earthquakes to the maximum extent technically practicable.

Other State regulations pertaining to the management of erosion/sedimentation as they relate to water quality are described in Section 6.8, Hydrology and Water Quality, of this EIR. Such regulations include, but are not limited to, the National Pollutant Discharge Elimination System (NPDES) program for management of construction and municipal stormwater runoff, which is part of the federal Clean Water Act and is implemented at the State and local level through issuance of permits and preparation of site-specific pollution protection plans. The primary purpose of these regulations and standards is the protection of surface water resources from the effects of land development. Among other measures included in such regulations and standards are the requirements to reduce the potential for sedimentation caused by erosion.

Streambed Alteration

Sections 1600 through 1607 of the California Department of Fish and Game Code regulate activities that would alter stream characteristics, including erosion. Under Sections 1600-1607, the California Department of Fish and Game (CDFG) regulates activities that would alter the flow, bed, channel, or bank of streams and lakes. The limits of CDFG jurisdiction are defined in the code as the "bed, channel or bank of any river, stream, or lake designated by the department in which there is at any time an existing fish or wildlife resource or from which these resources derive benefit..." A Streambed Alteration Agreement would identify the specific controls that would be implemented.

Local Regulations

The Placer County Building Department and the Community Development Resource Agency (CDRA) regulate construction at the local level. The Placer County General Plan contains policies regarding seismic and geological issues as they relate to public health and safety and natural resources. Relevant County General Plan goals and policies include the following:

Placer County General Plan

Goal **To minimize the loss of life, injury, and property damage caused by seismic and geological hazards.**

Policies

8.A.1. The County shall require the preparation of a soils engineering and geologic-seismic analysis prior to permitting development in areas prone to geological or seismic hazards (i.e., groundshaking, landslides, liquefaction, critically expansive soils and avalanche).

8.A.2. The County shall require submission of a preliminary soils report, prepared by a registered civil engineer and based upon adequate test borings, for every major subdivision and for each individual lot where critically expansive soils have been identified or are expected to exist.

8.A.3. The County shall prohibit the placement of habitable structures or individual sewage disposal systems on or in critically expansive soils unless suitable mitigation measures are incorporated to prevent the potential risk or these conditions.

8.A.8. The County shall continue to support scientific geologic investigations which refine, enlarge, and improve the body of knowledge on active faults zones, unstable areas, severe ground shaking, avalanche potential, and other hazardous conditions in Placer County.

8.A.9. The County shall require that the location and/or design of any new buildings, facilities, or other development in areas subject to earthquake activity minimize exposure to danger from fault rupture or creep.

8.A.10. The County shall require that new structures permitted in areas of high liquefaction potential be sited, designed and constructed to minimize the dangers from damage due to earthquake-induced liquefaction.

Implementation Programs

8.1 The County shall continue to enforce provisions of the Uniform Building Code which address seismic concerns, including masonry building design requirements.

8.2 The County shall assess the need for an ordinance requiring evaluation of un-reinforced masonry structures and the repair or replacement of identified hazardous structures.

Placer County Community Development Resource Agency Engineering and Surveying Department

The Placer County Community Development Resource Agency Engineering and Surveying Department (CDRA-ESD) maintains policies and guidelines regarding grading, erosion control, storm water design, inspection, and permitting. The Placer County Environmental Health Department has permitting authority for well installation/destruction. Permits related to earthwork and well installation/destruction that may be required within the study area include:

- Grading permits
- Improvement Plans
- Well drilling/destruction permits
- U.S. Army Corps of Engineers Nationwide Permit 12, for utility line backfill and bedding
- California Department of Fish and Game Streambed Alteration Agreement
- California State Water Resources Control Board general Construction Activity Discharge of Stormwater Permits (NPDES)

Site-Specific Geotechnical Investigation

Prior to the commencement of any earthwork in the study area, a full-scale geotechnical investigation would be completed. The geotechnical investigation must include soil borings to collect samples and laboratory testing to determine the appropriate design parameters for use in determination of the structural fill, roadbed fill, and landscaping fill requirements, along with the fill placement requirements. The various soils may be tested for corrosivity to allow for proper infrastructure and foundation design.

The geotechnical evaluation must provide grading and design recommendations to address potential slope and foundation instability, stream bank protection and slope evaluation, expansive soils, and differential settlement. The report must evaluate the soil types to test for shrink-swell potential to determine load-bearing and strength concerns. The geotechnical evaluation would be provided to the County as part of the County's Improvement Plan process. The County would review the geotechnical report along with project design to confirm that the recommendations in the geotechnical report are reflected in project design.

The County requires design of engineered fills to be addressed in the geotechnical investigation by assessing the structural properties of each of the different soils types throughout the study area. Such investigations would address specific portions of the study area to be developed. The designs would be required to account for the various structures and roadways proposed. In addition to evaluation for engineered fills, specific geotechnical evaluation of engineered slopes (for foundation drainage, landscaping, channel walls, etc.) must be included in the geotechnical evaluation. All proposed cut and/or fill slopes must be evaluated for proper design to reduce the hazard of over-steepening and/or removal of their lateral support, both of which could lead to slope instability, soil creep, and/or structural failure. If necessary, slopes must be designed with additional lateral support, such as buttressing, and fill slopes must be keyed properly into competent formational materials. Slopes (banks) along the creek channels must be designed with proper slope protection to prevent soil erosion and channel-bank undercutting. Grading and fill placement must be monitored and compaction testing should be performed to ensure proper placement of all fill types (structural, non-structural, and roadbed). Soils must be tested for their shrink-swell potential. Soils with low strength and/or high shrink-swell potential must be controlled using such techniques as over-excavation and replacement, or by covering with a sufficient amount of granular soils (as determined by the geotechnical investigation), or wet compaction. Potentially expansive soils may be used for structural fill upon approval of the geotechnical consultant.

IMPACTS AND MITIGATION MEASURES

Methods of Analysis

Potential impacts were assessed by comparing the proposed project to information from numerous sources, including the *Regional University Specific Plan;* the *Placer County General Plan;* the Wallace-Kuhl & Associates, Inc. Consolidated Preliminary Geotechnical Engineering Report of November 27, 2006; geology, seismicity, and mineral resource publications of the California Geological Survey and the United States Geological Survey; the United States Department of Agriculture *Soil Survey of Placer County, Western Part;* the California Department of Conservation Farmland Mapping and Monitoring Program; and the Geographic Information Systems (GIS) data for the project site. Project-specific geologic information and liquefaction potential were obtained from the Wallace-Kuhl & Associates, Inc. report. Estimated earthquake magnitudes resulting from potential seismic activity on various active faults in the region were obtained from previous documentation prepared for the Specific Plan area and from the USGS Working Group on California Earthquake Probabilities. Additional information was gathered during a site visit conducted by PBS&J staff on August 18, 2005.

Where potential geological hazards are identified, such hazards would be expected to affect any proposed development in the study area. Adherence to design and construction standards, as required by State and local regulations, would ensure maximum practicable protection for users of the buildings and associated infrastructure.

Geologic and soils conditions do not vary substantially between the project site and off-site improvement areas. Therefore, each impact analysis considers these project components as a single “study area” and the conclusions for each impact apply equally to the project site and off-site improvement areas.

Standards of Significance

Under criteria based on the State CEQA Guidelines, for the purposes of this EIR, an impact would be considered significant if the proposed project would:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
  - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault;
  - Strong seismic groundshaking;
  - Seismic-related ground failure, including liquefaction; or
  - Landslides.

- Result in substantial soil erosion or the loss of topsoil.
- Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse.
- Be located on expansive soil, as defined in Table 18-1-A of the California Building Code (2001), creating substantial risks to life or property.
- Result in the loss of, or loss of access to, mineral resources identified in a Mineral Resource Zone by the California Geological Survey.

The impact analysis assumes that the design-controllable aspects of building foundation support, protection from seismic ground motion, and slope instability are governed by existing regulations of the State of California and Placer County. Compliance with these regulations is required, not optional, and compliance must be demonstrated by the project sponsor to have been incorporated in the project's design before permits for project construction would be issued.

Adverse impacts in any of the above categories would be considered unavoidable significant effects of the project, if they could not be (a) reduced to an acceptable level of risk, (b) eliminated, or (c) avoided through compliance with adopted regulations and implementation of design and construction methods generally recognized by geotechnical consultants in California to be applicable and feasible for geologic conditions in the region.

Project-Specific Impacts and Mitigation Measures

6.6-1 The proposed project could expose people or structures to fault rupture.

The study area is more than 40 miles from the nearest zoned fault (the Cleveland Hill fault); therefore, fault-line surface rupture would not be a hazard at the project site. Thus, the proposed project would have ***no impact***.

Mitigation Measure

None required.

6.6-2 The proposed project could expose people or structures to strong seismic groundshaking.

From a review of regional and local geo-seismic conditions, there is a possibility that the study area would be subject to at least one major earthquake during the useful life of the project. The most likely large-earthquake scenario in the 30-year timeframe projected by the USGS would be a M_W 7.0 event on the Hayward-Rodgers Creek fault, which would produce groundshaking intensities of MMI IV to V at the project site.[18] The resulting vibration could cause damage to some buildings, roads and infrastructure (primary effects). However, as reported in the Preliminary Geotechnical Engineering Report, the potential for liquefaction and seismic deformation beneath the site is not probable. In addition, the potential for ground lurching, differential settlement, or lateral spreading during or following seismic events is considered low, provided proper geotechnical engineering and design recommendations are followed.

18 USGS Working Group on California Earthquake Probabilities, *Earthquake Probabilities in the San Francisco Bay Region: 2002–2031* Open-File Report 03-214, 2003, pages 7.3 – 7.7 and figure 7.2a.

To reduce the primary and secondary risks associated with seismically induced groundshaking, it is necessary to take the location and type of subsurface materials into consideration when designing foundations and structures at the project site. In Placer County, educational, residential, and commercial buildings and all associated infrastructure are required to reduce the exposure to potentially damaging seismic vibrations through seismic-resistant design, in conformance with Chapter 16, Structural Design Requirements, Division IV, Earthquake Design, of the *California Building Code*.

Adherence to the Building Code, as required by state and County law, would ensure maximum practicable protection available for users of the building and associated infrastructure. Adherence would include:

- the use of CBC Seismic Zone 3 Standards, as the minimum seismic-resistant design for all proposed facilities;
- seismic-resistant earthwork and construction design criteria, as needed, based on the site-specific recommendations of a California Certified Engineering Geologist in cooperation with the project's California-registered geotechnical and structural engineers;
- an engineering analyses that demonstrates satisfactory performance of alluvium or fill where either forms part or all of the support, especially where the possible occurrence of liquefiable soils exists; and,
- an analysis of soil expansion potential and appropriate remediation (compaction, removal/replacement, etc.) prior to using any expansive soils for foundation support.

Based on an existing regulatory framework that addresses earthquake safety issues and adherence to the requirements of the Building Code, seismically induced groundshaking would not be a substantial hazard at the project site. In view of the above, the proposed project would have a ***less-than-significant*** impact regarding exposing people or structures to seismic groundshaking.

Mitigation Measure

None required.

6.6-3 The proposed project could expose people or structures to landslides.

The study area contains low slopes and gently undulating terrain. The Preliminary Geotechnical Report prepared for the proposed project did not identify landslide hazards at the site. Therefore, landslides would not be a hazard in the study area. There would be ***no impact***.

Mitigation Measure

None required.

6.6-4 Construction activities resulting in ground disturbance have the potential to result in soil erosion or the loss of topsoil as well as topographic alterations.

Natural forces, both chemical and physical, are continually at work breaking down soils. Erosion poses two hazards: (1) it removes soils, thereby undermining roads and buildings and producing unstable slopes, and (2) it deposits eroded soil in waterways through stormwater runoff. Human activities, such as site preparation for construction and alteration of topographical features, frequently accelerate natural erosion. The following analysis focuses on the potential geotechnical effects of erosion related to project development. For a discussion of potential effects on water quality due to erosion and sedimentation caused by construction activities or urban runoff, please see Section 6.8, Hydrology and Water Quality.

Future development within the Plan Area would require some grading and leveling of the site to accommodate new suburban uses. The alteration of topographic features can lead to increased erosion by creating unstable rock or soil surfaces, by changing the permeability or runoff characteristics of the soil, or by modifying or creating new pathways for drainage.

As noted in the Setting, the project site is not considered a good source of topsoil.

Upon completion of the project, structures, roadways, and landscaping or revegetated areas would eventually cover any soils exposed during construction; thus, no long term new erodible soils would be created as a result of the proposed project.

Therefore, because erosion is anticipated to occur in disturbed soil areas, these impacts are considered *potentially significant*.

Mitigation Measures

Implementation of the following mitigation measures would reduce erosion impacts to ***less than significant***.

6.6-4 a) *The applicant shall prepare and submit Improvement Plans, specifications, and cost estimates (per the requirements of Section II of the Land Development Manual [LDM] that are in effect at the time of submittal) to the ESD for review and approval of each new development project. The plans shall show all conditions for the project as well as pertinent topographical features both on- and off-site. All existing and proposed utilities and easements, on-site and adjacent to the project, which may be affected by planned construction, shall be shown on the plans. All landscaping and irrigation facilities within the public right-of-way (or public easements), or landscaping within sight distance areas at intersections, shall be included in the Improvement Plans. The applicant shall pay plan check and inspection fees. (Prior to plan approval, all applicable recording and reproduction costs shall be paid). The cost of the above-noted landscape and irrigation facilities shall be included in the estimates used to determine these fees. It is the applicant's responsibility to obtain all required agency signatures on the plans and to secure department approvals. If the Design/Site Review process and/or DRC review is required as a condition of approval for the project, said review process shall be completed prior to submittal of Improvement Plans. Record drawings shall be prepared and signed by a California Registered Civil Engineer at the applicant's expense and shall be submitted to the ESD prior to acceptance by the County of site improvements.*

b) *All proposed grading, drainage improvements, vegetation and tree removal shall be shown on the Improvement Plans and all work shall conform to provisions of the County Grading Ordinance (Ref. Article 15.48, Placer County Code) that are in effect at the time of submittal. No grading, clearing, or tree disturbance shall occur until the Improvement Plans are approved and all temporary construction fencing has been installed and inspected by a member of the DRC. All cut/fill slopes shall be at 2:1* *(horizontal:vertical) unless a soils report supports a steeper slope and the ESD concurs with said recommendation.*

The applicant shall revegetate all disturbed areas. Revegetation undertaken from April 1 to October 1 shall include regular watering to ensure adequate growth. A winterization plan shall be provided with project Improvement Plans. It is the applicant's responsibility to assure proper installation and maintenance of erosion control/winterization during project construction. Where soil stockpiling or borrow areas are to remain for more than one construction season, proper erosion control measures shall be applied as specified in the Improvement Plans/Grading Plans. The applicant shall also provide for erosion control, implementing similar erosion control measures, where roadside drainage is off the pavement, to the satisfaction of the ESD.

The applicant shall submit to the ESD a letter of credit or cash deposit in the amount of 110% of an approved engineer's estimate for winterization and permanent erosion control work prior to Improvement Plan approval to guarantee protection against erosion and improper grading practices. Upon the County's acceptance of improvements, and satisfactory completion of a one-year maintenance period, unused portions of said deposit shall be refunded to the project applicant or authorized agent.

If, at any time during construction, a field review by County personnel indicates a significant deviation of from the proposed grading shown on the Improvement Plans, specifically with regard to slope heights, slope ratios, erosion control, winterization, tree disturbance, and/or pad elevations and configurations, the plans shall be reviewed by the DRC/ESD for a determination of substantial conformance to the project approvals prior to any further work proceeding. Failure of the DRC/ESD to make a determination of substantial conformance may serve as grounds for the revocation/modification of the project approval by the appropriate hearing body.

c) *Stockpiling and/or vehicle staging areas shall be identified on the Improvement Plans and located as far as practical from existing dwellings and protected resources in the area.*

d) *Developers of projects within the Plan Area, including off-site improvements, with ground disturbance exceeding one-acre that are subject to construction stormwater quality permit requirements of the National Pollutant Discharge Elimination System (NPDES) program shall obtain such permit from the State Regional Water Quality Control Board, and shall provide to the ESD evidence of a State-issued WDID number or filing of a Notice of Intent and fees prior to start of construction.*

6.6-5 Construction of the proposed project on expansive soils could result in potential impacts to foundations, structures, roadways, and other near surface improvements.

The Consolidated Preliminary Geotechnical Engineering Report noted that laboratory test results of near-surface soils indicate the native sandy and silty clays on-site exhibit moderate to high expansion (shrink-swell) potential. Such soils are capable of exerting substantial expansion pressures on structural foundations, interior floor slabs, and exterior flatwork. Soils with moderate to high expansion potential can also cause damage to hardscape, pavement, and other surface or near-surface improvements. Therefore, construction on expansive soils is considered a *potentially significant impact*.

Mitigation Measures

Implementation of the following mitigation measures would reduce the impacts of expansive soils to ***less than significant***.

6.6-5 a) *The developer of any new project within the Plan Area, including off-site improvements, shall submit to the Engineering and Surveying Department (ESD), for review and approval, a geotechnical engineering report produced by a California Registered Civil Engineer or Geotechnical Engineer. The report shall address and make recommendations on the following:*

1) Road, pavement, and parking area design;

2) Structural foundations, including retaining wall design (if applicable);

3) Grading practices;

4) Erosion/winterization;

5) Special problems discovered on-site, (i.e., groundwater, expansive/unstable soils, etc.); and

6) Slope stability.

Once approved by the ESD, the project developer shall provide two copies of the final report to the ESD and one copy to the Building Department for their use. If the soils report indicates the presence of critically expansive or other soils problems which, if not corrected, could lead to structural defects, a certification of completion of the requirements of the soils report will be required for subdivisions and other entitlements, prior to issuance of Building Permits. This certification may be completed on a Lot by Lot basis or on a Tract basis, or other defined project basis. This shall be noted in the CC&Rs and on the Informational Sheet filed with the Final Map(s). It is the responsibility of the developer to provide for engineering inspection and certification that earthwork has been performed in conformity with recommendations contained in the report.

b) *For non-pad graded lots, prior to Improvement Plan approval, the applicant shall submit to the ESD for review and approval, a soil investigation of each lot in the subdivision produced by a California Registered Civil or Geotechnical Engineer (Section 17953-17955 California Health and Safety Code). For pad graded lots, prior to Final Acceptance of project improvements or consideration of early Building Permits and after the completion of the pad grading for all lots, the applicant shall submit to the ESD for review and approval, a soil investigation of each lot produced by a California Registered Civil or Geotechnical Engineer (Section 17953-17955 California Health and Safety Code).*

6.6-6 New development on the project site could be exposed to unstable soil conditions.

The project site is underlain by soils with physical characteristics that vary, which could affect the performance of foundations and excavations, concrete slabs, roadways, and the structural integrity of buildings and structures. Such characteristics include, but are not limited to, the sizes and relative proportions of fine- and coarse-grained soil particles (texture), the degree of cementation, plasticity index, liquid limit, and permeability. If these characteristics are not identified prior to design and construction and planned site features not engineered properly, foundations, buildings, roadways, and other project components could be subject to damage from underlying soil types. Because development of the proposed project may increase the potential for buildings, roadways, and structures to be exposed to unstable soil conditions, this would be a *potentially significant impact.*

Mitigation Measure

Implementation of the following mitigation measures would reduce these impacts to a ***less than significant level***.

6.6-6 *Implement Mitigation Measures 6.6-5(a) and (b).*

6.6-7 The proposed project could result in the loss of, or loss of access to, mineral resources identified in a Mineral Resource Zone by the California Geological Survey.

The study area contains no mineral extraction operations or known mineral resources. The loss of, or loss of access to, identified mineral resources would not be an anticipated effect of the proposed project. Therefore, there would be ***no impact***.

Mitigation Measure

None required.

Cumulative Impacts

The geographic context for the analysis of impacts resulting from geologic hazards generally is site-specific, rather than cumulative in nature, because each project site has a different set of geologic considerations that would be subject to uniform site development and construction standards. As such, the potential for cumulative impacts to occur is limited.

There would be no project impacts related to fault rupture, landslide hazards, or loss of mineral resources. Therefore, there would be no cumulative impacts, and these issues are not further evaluated.

6.6-8 Cumulative development in Placer County, including the proposed project, could expose people and structures to hazards associated with seismic groundshaking.

Cumulative development in Placer County, including the proposed project, would increase the number of people and structures that could be exposed to hazards associated with seismic activity. As described in Impact 6.6-2, groundshaking intensities of MMI IV to V can be anticipated, and the resulting vibration could cause damage to some buildings, roads and infrastructure.

Impacts associated with potential geologic hazards related to soil or other conditions occur at individual building sites. Buildings and facilities in the County must be sited and designed in accordance with appropriate geotechnical and seismic guidelines and recommendations consistent with the requirements of the County Building Code. Adherence to all relevant plans, codes, and regulations with respect to project design and construction would provide adequate levels of safety, and the cumulative impact would be less than significant. Such adherence would ensure that the proposed project would not result in a cumulatively considerable contribution to cumulative impacts regarding seismic groundshaking and ground failure, and, therefore, the cumulative impact would be ***less than significant***.

Mitigation Measure

None required.

6.6-9 Cumulative development in Placer County, including the proposed project, could result in erosion and topsoil loss.

Impacts from erosion and loss of topsoil from site development and operation can be cumulative in effect within a watershed. Development throughout Placer County is subject to State and local runoff, erosion, and sedimentation prevention requirements, including the applicable provisions of the general construction permit, BMPs, and Phases I and II of the NPDES permit process, as well as implementation of fugitive dust control measures in accordance with Air Quality Management District Rule 403 (see Section 6.3, Air Quality, of this EIR). These requirements would be implemented as conditions of approval of project development and subject to continuing enforcement.

Implementation of the proposed project would modify soil and topographic conditions at the site to accommodate development and to provide a stable and safe physical environment. This modification during the construction phase could expose areas of soil to erosion by wind or water. Development of other cumulative projects in the vicinity of the study area could expose soil surfaces, and further alter soil conditions, subjecting soils to erosional processes during construction. To reduce the potential for cumulative impacts that could cause erosion, the proposed project in the study area and cumulative projects in the adjacent area are required to be developed in conformance with the provisions of applicable federal, State and County laws and ordinances. The implementation of Mitigation Measures 6.6-4(a) through (d) and 6.6-5 would ensure that the proposed project's contribution to cumulative impacts on the watershed caused by runoff and erosion from cumulative development activity would be ***less than significant***. No further mitigation is required.

Mitigation Measure

None required.

6.6-10 Cumulative development in Placer County, including the proposed project, could be constructed on expansive soils or soils that could become unstable.

The geographic context for analysis of impacts on development from expansive soil or soils exhibiting characteristics that could make them unstable (e.g., re-use of soils for engineered fill) or depth to groundwater is generally is site-specific. Prior to construction of any development requiring a soils/geotechnical report, the County would require that soils characteristics at a specific site are identified and that design and construction incorporate the recommendations suggested in the report. With adherence to these requirements and the implementation of Mitigation Measures 6.6-4 and 6.6-5, the cumulative impact would be considered ***less than significant***. No further mitigation is required.

Mitigation Measure

None required.

GLOSSARY

Alquist-Priolo Earthquake Fault Zone — In 1972 the State of California began delineating special studies zones (called Earthquake Fault Zones since January 1994) around active and potentially active faults in the state. The zones are revised periodically, and extend 200 to 500 feet on either side of identified fault traces. No structures for human occupancy may be built across an identified active fault trace. An area of 50 feet on either side of an active fault trace is assumed to be underlain by the fault, unless proven otherwise. Proposed construction within the Earthquake Fault Zone is permitted only following the completion of a fault location report prepared by a California Registered Geologist.

Characteristic Earthquake — Characteristic earthquakes are repeat earthquakes that have the same faulting mechanism, magnitude, rupture length, location, and, in some cases, the same epicenter and direction of rupture propagation as earlier shocks. As used in this report, the moment magnitude (M_W) of the "characteristic earthquake" indicates the scale of the seismic event considered representative of a particular fault segment, based on seismologic observations and statistical analysis of the probability that a larger earthquake would not be generated during a given time frame (often 50 or 100 years). In the Los Angeles Basin Area, a characteristic earthquake for the Newport-Inglewood fault would have a moment magnitude (M_W) between 6.0 and 7.4. M_W for the San Jacinto fault characteristic earthquake would be between 6.5 and 7.5. M_W for the San Andreas Fault would be between 6.8 and 8.0. The term "characteristic earthquake" replaces the term "maximum credible earthquake" as a more reliable descriptor of future fault activity.

Horizontal Ground Acceleration — The speed at which soil or rock materials are displaced by seismic waves. It is measured as a percentage of the acceleration of gravity (0.5 g = 50 percent of 32 feet per second squared, expressed as an horizontal force). Peak horizontal ground acceleration is the maximum acceleration expected from the characteristic earthquake predicted to affect a given area. Repeatable acceleration refers to the acceleration resulting from multiple seismic shocks. Sustained acceleration refers to the acceleration produced by continuous seismic shaking from a single, long duration event.

Maximum Credible Earthquake (MCE) — The largest Richter magnitude (M) seismic event that appears to be reasonably capable of occurring under the conditions of the presently known geological framework. This term has been replaced by "characteristic earthquake," which is considered a better indicator of probable seismic activity on a given fault segment within a specific time frame.

Modified Mercalli Intensity (MMI) Scale — A 12-point scale of earthquake intensity based on local effects experienced by people, structures, and earth materials. Each succeeding step on the scale describes a progressively greater amount of damage at a given point of observation. Effects range from those that are detectable only by seismicity recording instruments (I) to total destruction (XII). Most people will feel Intensity IV ground motion indoors and Intensity V outside. Intensity VII frightens most people, and Intensity IX causes alarm approaching panic. The scale was developed in 1902 by Giuseppi Mercalli for European conditions, adapted in 1931 by American seismologists Harry Wood and Frank Neumann for conditions in North America, and modified in 1958 by Dr. Charles F. Richter to accommodate modern structural design features.

Moment Magnitude (M_W) — A logarithmic scale introduced by Hiroo Kanamori in 1977 that is used by modern seismologists to measure the total amount of energy released by an earthquake. For the purposes of describing this energy release (i.e., the "size" of an earthquake on a particular fault segment for which seismic-resistant construction must be designed) the moment magnitude (M_W) of the characteristic earthquake for that segment has replaced the concept of a maximum credible earthquake of a particular Richter magnitude. This has become necessary because the Richter scale "saturates" at the higher magnitudes; that is, the Richter scale has difficulty differentiating among the sizes of earthquakes above M 7.5. To correct for this effect, the formula used for the M_W scale incorporates parameters associated with the rock types at the seismic source and the area of the fault surface involved in the earthquake. Thus, the moment magnitude is related to the length and width of the fault rupture. It reflects the amount of "work" (in the sense of classical physics) done by the earthquake. The relationship between Richter and moment magnitudes is not linear (i.e., moment magnitude is not a set percentage of Richter magnitude): the two values are derived using different formulae. The four well-know earthquakes listed below exemplify this relationship.

Location	Date	Richter Magnitude	Moment Magnitude
New Madrid MO	1812	8.7	8.1
San Francisco CA	1906	8.3	7.7
Anchorage AK	1964	8.4	9.2
Northridge CA	1994	6.4	6.7

Although some of the values shown on the M_W scale appear lower than those of the traditional Richter magnitudes, they convey more precise (and more useable) information to geologic and structural engineers.

Richter Magnitude Scale — A logarithmic scale developed in 1935 and 1936 by Dr. Charles F. Richter and Dr. Beno Gutenberg to measure earthquake magnitude (M) by the amount of energy released, as opposed to earthquake intensity as determined by local effects on people, structures, and earth materials (for which, see Modified Mercalli Intensity Scale, above). Each whole number on the Richter scale represents a 10-fold increase in amplitude of the waves recorded on a seismogram and about a 32-fold increase in the amount of energy released by the earthquake. Because the Richter scale tends to saturate above about M 7.5, it is being replaced in modern seismologic investigations by the moment magnitude (M_W) scale (see above).