4.7 GEOLOGY / SOILS

4.7 GEOLOGY / SOILS

Geology / Soils – Environmental Setting [1]

This section presents the geologic and seismic hazards as well as the soil, mineral, and geothermal resources found in Sonoma County. The topics discussed in this section overlap with other sections of this EIR, including the Hydrology and Water Resources, Agricultural Resources, Land Use, and Visual Resources sections. Geology impacts are most closely related to the *Land Use*, *Open Space and Resource Conservation* and the *Public Safety* elements of the *Draft GP 2020.*

REGIONAL GEOLOGY

The topography in Sonoma County is varied, including several mountain ranges, distinctive valleys, and coastal terraces. The geology is quite complex and is continually evolving because of its location at an active plate margin. The county is bounded on the south by the San Pablo Bay and associated wetlands. The Cotati and Petaluma Valleys create the wide basin stretching from Santa Rosa to the Bay. Rolling hills and grasslands predominate here, as well as in Marin County to the south. The rugged Mayacamas and Sonoma Mountains geographically form the eastern boundary and physically separate Sonoma County from Lake and Napa Counties. The Sonoma Valley runs north-south between the Sonoma Mountains on the west and the taller Mayacamas Mountains to the east. The Geysers geothermal field, located in the northeastern section of the county, extends into both Sonoma and Lake Counties. The Mendocino Highlands form a common geographic unit with Mendocino County to the north. The Alexander Valley runs from northwest to southeast, bounded on the east by the Mayacamas Mountains and on the west by the Coast Range. The Pacific Ocean forms the western county boundary, including an interesting assemblage of steep hills, marine terraces, beaches, and off-shore sea stacks.

The geology of Sonoma County is a result of the past tectonic, volcanic, erosion, and sedimentation processes of the California Coast Range geomorphic province. Ongoing tectonic forces resulting from the collision of the North American Plate with the Pacific Plate, combined with more geologically recent volcanic activity, have resulted in mountain building and down warping of parallel valleys. The margin of the two tectonic plates is defined by the San Andreas Fault system: a broad zone of active, dormant, and inactive faults dominated by the San Andreas Fault which trends along the western margin of the county. This fault system results in the northwestern structural alignment that controls the overall orientation of the county's ridges and valleys. The land has been modified by more recent volcanic activity, evidenced by Mount St. Helena that dominates the northeastern part of the county. Erosion, sedimentation, and active faulting occurring in recent times have further modified Sonoma County's landscape to its current form.

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1 The information in this section has been updated from basic geologic setting information previously developed for the *1978 General Plan* and the *1989 General Plan*. These basic information sources are listed in ***Appendix 7.8 Hydrology and Geology Source Information***.

SEISMICITY

Earthquakes are most common along geologic faults that are planes of weakness or fractures along which rocks have been displaced. Faults located within Sonoma County are part of the San Andreas Fault system which extends along most of the length of California and represents the boundary between the Pacific and North American plates of the earth's crust. The faults mapped by the California Division of Mines and Geology are those that show significant surface evidence of lateral or vertical movement in the past two million years (i.e., the Quaternary geologic period) and are defined as active or are considered to be potentially active in the future. [2] Sudden movement or displacement along faults generally causes earthquakes. However, earthquakes are also caused by volcanic activity. Although there are no known active volcanic sources in Sonoma County, the Geysers’ Known Geothermal Resource Area (KGRA) is a source of similar seismic events related to movement within deep seated hot or semi molten rock. This area is the source of numerous small seismic events that cluster around the KGRA. These small earthquakes typically range up to Magnitude 3.5 with occasionally larger events. There has been some concern expressed about this the seismic activity since the steam resource has been developed for electrical production. These concerns have been increasingly expressed recently as the schedule for injection of treated wastewater into the deep hot rock source area for enhanced steam production approaches.

Historic Fault Activity

Faults are geologic hazards because of both surface fault displacement and seismic ground shaking that are distinct but related properties. Surface fault displacement results when the fault plane ruptures and that rupture surface extends to, or intersects, the ground surface. Surface fault rupture can be very destructive to structures constructed across active faults. However, the zone of damage is limited to a relatively narrow area along either side of the fault as opposed to seismic ground shaking damage that can be quite widespread.

The only fault in Sonoma County with known surface displacement in historic times is the San Andreas Fault. During the magnitude 8.3 earthquake of 1906, horizontal displacements along this fault averaged 15 feet and surface rupture was mapped along the fault’s extent through Sonoma County from the Gualala area to the Bodega Bay area. Lateral displacement was reported to be as much as 12 feet near Fort Ross, and in the Bodega Bay area lateral displacements of up to eight feet with 18 inches of vertical displacement were reported. [3] In addition to the San Andreas Fault, the Healdsburg, Rodgers Creek, and Mayacamas faults all show evidence of surface displacement during the past 11,000 years (i.e., Holocene epoch) but not during the last 200 years. These faults are considered active faults for planning purposes. [4] The Healdsburg fault, which is a northern extension

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2 *Geologic Map of the Santa Rosa Quadrangle, California,* D. L. Wagner, and E. J. Bortungno (compilers), Regional Geologic Map Series, Map 2A, Sheet 1 of 5, scale 1:250,000, California Division of Mines and Geology, 1982

3 The California Earthquake of April 18, 1906, Report of the State Earthquake Investigation Commission, A. C. Lawson, the Carnegie Institution of Washington, 1908, reprinted 1969.

4 *Geologic Map of the Santa Rosa Quadrangle, California,* D. L. Wagner, and E. J. Bortugno, (compilers), Regional Geologic Map Series, Map 2A, Sheet 1 of 5, scale 1:250,000, California Division of Mines and Geology, 1982.

of the Rogers Creek fault, has recently been removed by the State of California from the Alquist-Priolo earthquake fault zoning maps. [5] [6]

Since 1855, more than 140 earthquakes have resulted in property damage in Sonoma County. The 1906 earthquake on the San Andreas Fault had an estimated Richter-scale magnitude of 8.3, the largest seismic event in California in historic times. Effects in Sonoma County included 61 deaths, destruction of most downtown buildings in Santa Rosa, and major damage in Sebastopol, Healdsburg and other communities. [7]

The strongest earthquake since 1906 occurred in 1969 on the Healdsburg fault near Santa Rosa. The *Santa Rosa Earthquakes*, occurring on October 1, 1969, were moderate earthquakes with magnitudes of 5.6 and 5.7 on the southern end of the Healdsburg fault, north of Santa Rosa. These shocks are of special interest for planning in Sonoma County because of the unexpected damage to earthquake-resistant buildings and the concentration of dwelling damage in a relatively small area. The earthquakes were not strong enough to cause building collapse, however, one major brick wall partially fell, other brick walls were cracked or partially failed, hundreds of brick chimneys toppled, and a number of older wood-frame dwellings fell off their foundations or were otherwise seriously damaged. [8] No deaths occurred, but about 15 people were treated in hospitals. Most injuries were lacerations from broken glass. Losses to commercial and public buildings were estimated at two million dollars and losses to dwellings at four million dollars. [9]

Principal damage to non-dwelling construction was primarily in the downtown in older commercial structures. Most damaged structures were brick bearing-wall buildings with sand-lime mortar; none of the damaged brickwork was reinforced. A few older buildings with reinforced concrete walls and wood floors also were damaged. There was significant structural damage to three modern earthquake resistant buildings: the Sonoma County Social Service Building, the Sonoma County Fairground grandstand, and the Crocker-Citizens Bank Building.

Widespread breaks occurred in the eastern part of Santa Rosa in water system pipes, sidewalks, curbs, and street pavements. None of these breaks appears to have resulted from surface fault displacement. Apparently permanent deformation of the underlying alluvium in the form of lurching, or collapse of unconsolidated fill, was responsible. However, the fact that these effects were largely confined to a north-northwest-trending zone two miles long and more or less in line with the fault plane determined for the earthquake suggests that ground motion was especially strong directly over the fault. The most recent significant earthquake in the San Francisco Bay area was the October 1989 Loma Prieta

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5 *Alquist-Priolo Earthquake Fault Zoning Act*, California Civil Code Chapter 7.5, Sections 2621 – 2630, October 25, 2002.

6 *Index to Official Maps of Earthquake Fault Zones*, California Geological Survey, 2002, www.consrv.ca.gov/CGS/rghm/ap/Map_index/index.htm , edited on October 25, 2002.

7 *The California Earthquake of April 18, 1906*, Report of the State Earthquake Investigation Commission, A. C. Lawson, the Carnegie Institution of Washington, 1908, reprinted 1969.

8 *The Santa Rosa, California Earthquakes of October 1, 1969*: *Environmental Science Services Administration and Coast and Geodetic Survey*, K. V. Steinbrugge, et al, 1970.

9 *Geology for Planning in Sonoma County,* Special Report 120, M. E. Huffman, and C. F. Armstrong, California Division of Mines and Geology, 1980.

earthquake of Richter Magnitude 7.1 (Modified Mercalli Intensity VII) centered on a branch of the San Andreas fault zone in the Santa Cruz Mountains over 100 miles southeast of Sonoma County. [10] This earthquake caused substantial damage (i.e., 67 lives lost and approximately seven billion dollars in damage) primarily in the Santa Cruz, San Francisco, and Oakland areas. Most losses were due to seismic ground shaking and associated foundation failures. Although that earthquake caused little or no significant damage in Sonoma County, it was widely felt.

Earthquake Probability

Recent planning studies by the State of California indicate that a similar magnitude earthquake on the Rogers Creek fault in Sonoma County could cause Modified Mercalli Intensity VII damage in this area. [11] The U.S. Geological Survey presents a summary of historic major earthquake activity in the San Francisco Bay area and expected magnitude and probability. [12]

The USGS has conducted extensive research of earthquake probabilities in the San Francisco Bay region. The major causative faults in the region were divided into segments with similar strain characteristics. The strain accumulation rates and the earthquake history on each of the fault segments were then evaluated to estimate the probabilities of future Richter Magnitude 7.0 or larger seismic events during the next 30 years. USGS conclusions about earthquake probabilities for major Bay Area faults are summarized in **Exhibit 4.7-1** and represent a consensus of several leading professionals. [13]

The two most important faults for purposes of planning for seismic impacts in Sonoma County are the San Andreas and Rodgers Creek faults. As shown in **Exhibit 4.7-1**, the present analysis of seismic data indicates that the highest magnitude earthquakes to be expected for the northern San Andreas Fault and the Rodgers Creek faults are 8.0 and 7.5, respectively, on the Richter scale. It has been accepted for many years that earthquakes of magnitude 8.0 or more somewhere on the San Andreas Fault can be expected to reoccur every 50 to 200 years. [14] Recent studies indicate that in Sonoma County an earthquake of approximately 7.0 on the Richter scale on the Rogers Creek fault is estimated to have a 30 year probability of 22 percent. [15] A seismic event equivalent to the strongest ground-shaking in Santa Rosa from the 1969 earthquake can be expected somewhere in Sonoma County once

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[10] The Modified Mercalli Intensity Scale ranges from intensity I to intensity XII and describes effects of earthquakes as opposed to the Richter Scale which measures energy. The effects of a MMI VII earthquake include: All people frightened and run out doors, some people find it difficult to walk, waves on ponds, lakes, etc., caving of sand and gravestream banks, negligible damage to well designed and constructed buildings but poorly built buildings badly damaged, falling plaster and some stucco, numerous broken windows, over turned and damaged heavy furniture.

[11] *Planning Scenario for a Major Earthquake in the Rogers Creek Fault in the Northern San Francisco Bay Area*, Special Publication 112, T. R. Toppozada, et al, California Division of Mines and Geology, 1994.

[12] *Probability of Large Earthquakes in the San Francisco Bay Region, California,* USGS Circular 1053, Working Group on California Earthquake Probabilities, U.S. Geological Survey, 1990.

[13] *Probability of Large Earthquakes in the San Francisco Bay Region, California*, USGS Circular 1053, Working Group on California Earthquake Probabilities, U.S. Geological Survey, 1990.

[14] *Sonoma County General Plan Draft EIR,* 1986.

[15] *Planning Scenario for a Major Earthquake in the Rogers Creek Fault in the Northern San Francisco Bay Area*, Special Publication 112, T. R. Toppozada, et al, California Division of Mines and Geology, 1994.

every 20 to 30 years. This estimate is rough and subject to change as research continues to provide new information. The main point is that the potential impact from damaging earthquakes, especially from ground shaking and secondary effects, needs to be anticipated while planning, locating, and designing new development in Sonoma County.

Exhibit 4.7-1
Summary of Major Earthquake Activity, San Francisco Bay Area Region

Fault	*Historic Magnitude* [a]	*Year of Event*	*Fault Distance / Direction* [b]	*Maximum Credible Earthquake* [c]	*30-Year Probability* [d]
San Andreas	8.2	1906	14.5 SW	8.0	North Coast Segment P = 0.02 M = 8
	7.1	1889			
	7.0	1838			
	6.2	1885			
Hayward	6.8	1868	14 SE	7.0	Northern Segment P = 0.28 M = 7
	6.8	1836			
	6.3	1865			
Rogers Creek	6.7	1898	6 NE	7.5	P = 0.22 M = 7
	5.7 & 5.6	1969			
Green Valley	6.4 & 6.2	1892	23 E	7.0	NE
Concord	5.4	1955	26 SE	7.0	NE
Calaveras	6.6	1911	40 SE	7.0	NE
	6.2	1984 & 1897			
		1979			

a Richter Magnitude.

b From Santa Rosa in miles.

c Moment Magnitude, estimated.

d P = probability in 30 years; M = estimated Richter magnitude of probable 30 year event; NE = not estimated.

Source: *Probability of Large Earthquakes in the San Francisco Bay Region, California,* Circular 1053, Working Group on California Earthquake Probabilities, U.S. Geological Survey, 1990.

Ground Shaking and Liquefaction

Seismic ground-shaking can result in damaging impacts to both close to and at great distances from the source of the earthquake. As evidenced by the numerous structural failures in the Marina District of San Francisco due to the 1989 Loma Prieta earthquake, liquefaction can cause wide spread damage. Seismic ground shaking causes liquefaction by increasing pore water pressure between the sand or silt grains, which temporarily transforms certain water saturated soils to a semi-liquid state. This results in loss of shear strength, thereby removing support from foundations and causing differential settlement, subsidence or total collapse of buildings, bridges, roadways or other structures. The most susceptible areas are the silty "Bay muds" south of Petaluma and Sonoma and near Bodega Bay.

Deposits that are also susceptible to liquefaction are areas underlain by saturated unconsolidated alluvium that has fairly uniform grain size. Thus in alluvial basins within Sonoma County, the potential for liquefaction failures will tend to increase in the winter and spring when the ground water table is higher. These areas include the largest population centers and most intensely developed areas of Sonoma County, as shown on maps prepared by the California Division of Mines and Geology. [16]

Tsunamis and Seiches

Ocean waves generated by certain undersea earthquakes, volcanic eruptions, or landslides are called tsunamis or seismic sea waves. The height and shoreline run up distance of a tsunami are determined by water depth, underwater topography, and shape and orientation of the coastline relative to the tsunami source. The tsunami level expected once in 200 years could affect areas along Sonoma County's Pacific coast up to 20 feet above sea level, with lesser expected run up along the county's San Pablo Bay shoreline. [17] The areas of Sonoma County where tsunami impacts have been predicted in a general and simplified way are shown on the tsunami and seiche maps prepared by the California Division of Mines and Geology. [18] Seismic waves on inland water bodies such as lakes, reservoirs, as well as coastal bays are called seiches. Shoreline areas along Bodega Harbor, Lake Sonoma, and similar enclosed bodies of water in Sonoma County are subject to impacts from seiches.

Earthquake-Induced Landslides

Beyond the immediate area of surface fault rupture, ground deformation can distort the surface, secondary ground cracks can open, and both can damage structures. These kinds of ground failures are caused by the torsion effects on the ground adjacent to the fault trace as blocks of the earth move past each other. Seismic lurching is the movement of a soil or rock mass toward an unsupported free face such as a sea cliff, road cut, or steep natural hillside. These kinds of ground failures are caused by seismic accelerations and are transitional to seismically triggered landslides.

Structural Hazards Due to Earthquakes

The susceptibility of a structure to damage from ground shaking, in addition to being related to structural design and construction quality, is also related to the underlying foundation material. [19] A foundation of rock or very firm material can intensify short-period motions, which affect low-rise buildings more than tall, flexible ones. Such materials transmit a broad range of seismic frequencies. A deep layer of water saturated soft alluvium, which transmits lower frequencies, can cushion low-rise buildings, but it can also accentuate the motion in tall buildings. A building's height and flexibility relate to its natural frequency of vibration, or harmonic. Where this frequency is similar to that of the

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[16] *Planning Scenario for a Major Earthquake in the Rogers Creek Fault in the Northern San Francisco Bay Area*, Special Publication 112, T. R. Toppozada, et al, California Division of Mines and Geology, 1994.

[17] *Geology for Planning in Sonoma County,* Special Report 120, M. E. Huffman and C. F. Armstrong, California Division of Mines and Geology, 1980.

[18] *Geology for Planning in Sonoma County,* Special Report 120, M. E. Huffman and C. F. Armstrong, California Division of Mines and Geology, 1980. Plates 1A and 1B.

[19] *Earthquake Planning Scenario for a Magnitude 8.3 Earthquake on the San Andreas Fault in the San Francisco Bay Area*, Special Publication 61, J. F. Davis, et al., California Division of Mines and Geology, 1981.

seismic shaking transmitted to the structure through the earth / bedrock foundation materials the building will be more susceptible to earthquake damage. The amplified motion resulting from softer alluvial soils can also severely damage older masonry buildings.

Other potentially dangerous conditions include, but are not limited to: architectural building features that are not firmly anchored, such as parapets and cornices; roadways, including column and pile bents and abutments for bridges and over-crossings; and aboveground storage tanks and their mounting devices. Such features could be damaged or destroyed during strong or sustained ground shaking. Modern, well-constructed buildings, one or two stories high and of wood-frame construction, are considered to be the most structurally resistant to earthquake damage if constructed after earthquake resistance provisions were included in the building codes in the 1960s. Older masonry buildings without seismic reinforcement (i.e., unreinforced masonry) are the most susceptible to the type of structural failure that causes injury or death. The area over which structural damage can occur is substantial, as evidenced by the major damage in Oakland from the 1989 Loma Prieta earthquake with an epicenter in the Santa Cruz Mountains 27 miles to the south, and the extensive damage in Santa Rosa from the 1906 San Francisco earthquake caused by rupture of the San Andreas fault 23 miles to the west. The structural design, quality of construction, foundation design and construction, soil ground water characteristics, as well as the energy and duration of seismic shaking all contribute to the degree of structural hazard. The California Division of Mines and Geology describes various kinds of structures based on age and their potential for resultant earthquake damage. [20] The kinds of structures and the risk from earthquake damage they pose are described below.

Unreinforced Masonry Buildings

These buildings have the highest risk of damage or collapse in a major earthquake. The seismic strengthening of unreinforced masonry (URM) buildings is a useful risk reduction measure. Buildings retrofitted with reinforcing structural elements have significantly improved resistance to collapse of walls and parapets. However, even with seismic retrofitting the earthquake resistance of such structures is less than that of new construction built to the latest seismic codes. After a major earthquake in Sonoma County it is likely that some retrofitted URMs will collapse and many will be so damaged that it will not be economical or feasible to repair them.

Pre-1940 Wood Frame Houses

Wood frame dwellings built before 1940 or even those built as recently as 1950 have often shifted or fallen from their foundations in earthquakes. This is due to the lack of foundation anchorage or to weak cripple walls connecting the first floor to the foundation. Even some newer wood frame houses have been dislodged from their foundations by seismic shaking due to poor quality construction. In general, this mode of structural failure is typical of houses built prior to 1940.

Pre-1973 Tilt-up Concrete Buildings

These kinds of buildings are common throughout industrial and some commercially zoned areas of Sonoma County. The most common cause of severe damage to pre-1973 tilt-up concrete panel buildings is separation between the concrete tilt-up wall panels and the roof structure. This is caused by inadequate structural connection between the roof and the wall panels. As a result, the wall panels

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20 *Earthquake Planning Scenario for a Major Earthquake on the Rogers Creek Fault in the San Francisco Bay Area,* Special Publication 112, Toppozada., et al., California Division of Mines and Geology, 1994.

fall outward, leading to collapse of the roof and floors. These buildings are common as warehouses or office buildings in industrial parks and in some commercial developments.

Non-ductile Concrete Frame Buildings

These structures are lightly reinforced concrete framed buildings typically constructed before 1971. This kind of construction was used in industrial, commercial, office and warehouse buildings, as well as for some parking garages. Problems conducive to structural failure during earthquakes in this kind of construction include inadequate reinforcement in the columns, beams, and connection joints. Failure modes include shear and flexural failure of columns and the displacement of joints resulting in the collapse of beams supporting floor and roof structures.

Mobile Homes

Mobile homes that are installed without seismic foundation restraints are very susceptible to earthquake damage. Like pre 1940 wood frame houses seismic accelerations typically knock such mobile homes from their foundations. A survey of damage to mobile homes in San Benito, Santa Clara, and Santa Cruz counties after the 1989 Loma Prieta earthquake found that in 27 mobile home parks, 24 percent (592 out of 2,334) of the mobile homes were dislodged from their foundations and suffered damage.

SLOPE STABILITY AND LANDSLIDING

The most frequent and widespread type of ground failure in Sonoma County is landsliding. In the broadest sense, a landslide is a downward and outward movement of slope forming materials composed of rock, soils, artificial fills, or a combination of these. Because of the highly fractured rock formations, steep topography, long coastline, and the area's seismicity, extensive land areas of the county are subject to this destructive hazard. Virtually all parts of the county except the flat lying alluvial valleys are subject to damaging landslides of various kinds. Landslides vary in size, speed of movement, and mechanism. Many landslides occur as smaller slumps or flows within older larger slide masses, however there have been landslides in the County that were as long as two miles, including the Mill Stream landslide two miles northwest of Mount St. Helena.

The areas most susceptible to landsliding are shown on maps prepared by the California Division of Mines and Geology. [21] Areas prone to landsliding include locations of past landslides in the County and hillsides where clay and silt-rich soils absorb water and loose strength and where rock strata are parallel to surface slopes. [22] In addition, landslides occur where faults have fractured rock and along the base of slopes or cliffs where supporting material has been removed by stream or wave erosion, or human activities. Heavy rainfall, human actions, or earthquakes can trigger landslides. They may take the form of a slow continuous movement such as a slump or may move very rapidly as a semi-liquid mass such as a debris flow or avalanche. During very high rainfall years in the San Francisco Bay

[21] *Geology for Planning in Sonoma County,* Special Report 120, M. E. Huffman and C. F. Armstrong, California Division of Mines and Geology, 1980.

[22] An example is the Blucher Valley landslide, which reactivated on March 9, 1998. This slide, which is located on very gentle (10 to 20 degrees) dip slopes of the Wilson Grove Formation, originally moved in 1983.

area, such as the winters of 1968-69, 1972-73, 1981-82, 1985-86, and 1997-98 large numbers of damaging landslides were common in Sonoma County.

Some slides move relatively fast: the Rio Nido slide of February 7, 1998 was a large complex landslide that failed along the Russian River at Canyon Three near Sweetwater Springs Road. The slide started as a rotational failure near the ridge top that split down slope into debris flows affecting houses at the base of two canyons and put approximately 200 people at risk. Like many other slides, this landslide was triggered by the storm of February 1998 and the preceding saturation of the ground. The California Geological Survey has reported nine damaging landslides occurring in Sonoma County in February and March 1998 as a result of that winter's storms. Many of these landslides were the reactivation of pre-existing landslides.

SOIL HAZARDS

Soil characteristics can greatly influence land-use activities. Important soil characteristics include the properties related to agricultural and natural habitat resources, as well as those properties related to land development projects. Site-specific soil properties vary widely throughout Sonoma County and require site-specific investigation to develop a project or implement a land use that will perform properly. Within Sonoma County there are soils with characteristics that include: seasonal shrink and swell (i.e., expansive soils), weak or collapsing soils that compress under a load or when wet, soils that are corrosive to certain materials, soils that may liquefy during seismic shaking, and soils that are susceptible to erosion.

Subsidence and Differential Settlement

Most subsidence is caused by the withdrawal of fluids (e.g., ground water or oil) from subsurface reservoirs or from the collapse of surface and near surface soils and rocks over subterranean voids such as mines and caves. The aerial extent over which subsidence occurs can be very localized, or it can impact large areas such as in California's Central Valley where in the Los Banos / Kettleman City area over 5,000 square kilometers have subsided more than 0.3 meters on the average, with localized areas of up to 8.5 meters of subsidence.[23] The cause of this subsidence was the pumping of ground water from a deep confined aquifer. As the water is removed, fluid pressure is reduced and the pore spaces between the grains in the aquifer collapse. Managing groundwater pumping from basins and recharging the aquifers has proven to be effective in mitigating, and in some cases reversing subsidence due to this cause.

Settlement is a more localized phenomenon and is related to the loading of soils and their subsequent compression as a result of construction activities. Differential settlement results when settlement across an area settles at different rates or in different amounts. Settlement can result if the native soils are porous or weak such that the weight to a building or other structure causes the soil to compress. This can occur in native soils or in manmade fills. The amount of settlement depends on the thickness of the weak compressible soils or fill, the load imposed by the construction, as well as the original density of the soils. Non-uniform or differential settlement can occur if the compressible soil section beneath the structure is variable, if the soil is heterogeneous, or if there are variable loads imposed across the footprint of the structure. If a structure is constructed such that it spans native soil and bedrock or native soil and a section of fill, differential settlements can be expected. In pavement

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23 *Environmental Geology, 3rd Edition,* E. A. Keller, p.123, Charles, E. Miller Publishing, Co., 1981.

sections differential settlement is common when utility trench backfill is improperly compacted. This can happen when the fill is placed by saturation with water (i.e., *jetting*), if the soil is too moist or to dry, or if the lifts are too thick. The kinds of damage cause by settlement and differential settlement are similar to that caused by expansive soil (e.g., tilted and cracked floor slabs, uneven floors in buildings, cracked pavements, etc.).

Expansive and Creeping Soil

Expansive soils, which are found in various parts of Sonoma County, greatly increase in volume when they absorb water and shrink when they dry out. Expansion is most often caused by clay minerals, primarily montmorillonite and illite although some rocks are also expansive including claystones or altered volcanic tuffs that contain large proportions of montmorillonite. Expansive soils are classified as CL or CH soils using the Unified Soil Classification System (USCS), with CH soils being the most highly expansive. Expansion of the soil or rock is due to the attraction and absorption of water into the expansible crystal lattices of the clay minerals. The water may be derived from moisture in the air, or ground water beneath the foundations of buildings. When buildings are placed on expansive soils, foundations may rise each wet season and fall each dry season. Roadways, pavements, and other flat construction are highly susceptible to damage from expansive soils. Movements may vary under different parts of a building with the result that foundations crack, various structural portions of the building are distorted, and doors and windows are warped so that they do not function properly. Where expansive soils are located on hill slopes which are common in parts of Sonoma County, they undergo a process of seasonal down slope movement called “soil creep”. Soil creep forces can be substantial and need to be evaluated to determine their effects on foundation elements, retaining walls and other structures.

Erosion

Erosion is the removal of soil by wind or water under the force of gravity. This process results in sheet and gully erosion of land surfaces, the wind-blown denudation of lands, the erosion of stream courses and banks, and the erosion of coastal cliffs, sand dunes and beach areas. All of these erosion processes occur or can occur in Sonoma County. Erosion is a naturally occurring process but can be exacerbated by man’s activities such as vegetation removal, improper farming practices, and grading for roadways and construction. Extreme cases of erosion can lead to landsliding. Erosion results in the loss of topsoil that may reduce yield of crops or forage and cause sedimentation problems downstream. Sediment can fill reservoirs and stream channels, reducing water quality and storage capacity, as well as damaging wildlife habitats, including fisheries. Erosion is a major contributor to water quality impairment (see ***Section 4.5 Hydrology and Water Resources***).

Erosion hazard is rated from slight to very high, based on the runoff characteristics of the soil and land management practices. The vulnerability of natural soil types to erosion (i.e., erodibility) has been mapped by the U .S. Soil Conservation Service and other soils surveys. The generalized distribution of erosion potential in Sonoma County can be estimated by evaluating the soil characteristics described in the Sonoma County Soils Report.[24] In most landscapes undergoing development, however, the natural erodibility of the soil is far less important in determining the severity of future erosion than is the slope, type and degree of land-modification proposed.

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[24] *Soil Survey, Sonoma County, California,* V. C. Miller, United States Department of Agriculture in cooperation with the University of California Agricultural Experiment Station, first issued May 1972, reviewed and reprinted August 1990.

Areas of particular concern are the Petaluma Valley where soil losses can be as high as 20 tons/acre/year; steep hillsides that are cultivated for wine grapes; and rangelands where overgrazing may occur. Within Sonoma County, the Dry Creek, Gualala River, Russian River, Sulphur Creek, Salmon Creek, and Blucher Creek have accelerated stream bank erosion that directly impacts fish spawning areas through sedimentation. For example, the Gualala River watershed, which is in both Sonoma and Mendocino counties, is an impaired water body due to sedimentation. Sedimentation, as well as an increase in water temperature, has resulted in the decline of the coho salmon and steelhead trout fisheries; elevated water temperatures can result from the loss of streamside vegetation and well as reduced stream flows. The watershed's rugged terrain has relatively erodible soils and the area experiences heavy rainfall. Unstable slopes are present throughout the watershed and timber harvesting activities on these slopes affects slope stability. As noted in the Gualala River Watershed Management Initiative, hillside vineyard development is becoming an increasing threat to water quality as more and more steep land is converted to vineyards. [25]

GEOLOGIC RESOURCES

Some of Sonoma County's geologic formations are suitable for managed development or protection because of their uniqueness or visibility (see ***Section 4.11 Visual Resources***). One geologic resource in Sonoma County is the Geysers' Known Geothermal Resource Area (KGRA). It has been a source of significant electric power production since the 1960's as a result of not only the size of the resource but because the steam is relatively dry and has a low chemical reactivity. The mineral resources of the Russian River are also an important geologic resource that has been developed over the years.

MINERAL RESOURCES

Mineral resources are extremely valuable because of their limited supply and their usefulness in modern construction and industrial processes. Sonoma County has many mineral resources that have been valuable enough to justify commercial extraction and processing. Historic activities, including mercury, chromite, and copper mining, have had long-term impacts on down stream soils and water quality.

Sand, gravel, crushed rock, and building stone are considered the most valuable mineral resources in the county with 3.9 million tons of such materials mined in 2003. Over 97 percent of the production was used for construction projects within the county. [26] Removal of bedrock for building blocks, road base, and fill materials has taken place in many different areas and geologic settings of the county but usually in highland areas with steep terrain. Most of the Russian River and parts of other major streams in the county have been mined for sand and gravel to use in concrete and high-quality base and fill. Recent operations have been located along the middle and upper reaches of the Russian River, either within the channel or on adjacent alluvial terraces, along with operations along the Gualala River and Austin Creek.

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[25] *Gualala River Watershed, Watershed Management Initiative*, North Coast Regional Water Quality Control Board.

[26] *Mineral Land Classification of Aggregate Materials in Sonoma County*, California, California Department of Conservation, Geologic Survey, 2005.

Because of the differences in original materials and the processes involved, each geologic formation provides different types of useful minerals. Maps on file with the Sonoma County Permit & Resource Management Department shows the location and extent of the mineral resources considered significant by recent studies. [27] All of the existing and potential hard rock, terrace, and in stream source areas are designated in the Aggregate Resources Management Plan. [28] The source areas are indicated on the map as well as all the lands classified as regionally significant by the California Division of Mines and Geology. [29]

Geothermal Resources

Geothermal resources in Sonoma County consist of hot water, steam, and heat found at or below the earth's surface. The Geyser’s Known Geothermal Resource Area (KGRA), located in northeastern Sonoma County in the Mayacamas Mountains, is the largest steam-powered geothermal development in the world with a peak of 1,800 megawatts of electricity being generated in 1986. Within the KGRA, designated by the California Energy Commission, generation of electricity is permitted only within the central primary area; the surrounding secondary area is restricted to exploration. The electrical generating capacity is estimated at 2,000-3,000 megawatts but the total extent and productive life of this resource is not yet known. Since the late 1980's steam production has decreased and recent efforts have been made to extend the productive life of the steam fields by deep injection of water into the hot rock heat source.

Geothermal steam power occurs when water deep below the earth's surface is heated by exposure to hot porous rock, and the resulting dry steam is tapped at depth by geothermal wells that pipe the steam directly into steam turbine generators to create electricity. Wells, some greater than two miles deep, have been drilled to tap this natural steam. The geothermal power at the KGRA provides an alternative energy source. Hot water geothermal resources also exist in the Dry Creek Valley, Alexander Valley, and Sonoma Valley, but exploration and use of these resources have been very limited. The Regional Wastewater Project operated by the City of Santa Rosa has recently completed a wastewater disposal system which injects treated water into the steamfield in order to recharge the steamfield and boost energy production.

SOILS

Soil is defined by soil scientists as earth surface material that has been so modified or acted upon by physical, chemical or biological agents that it supports plant life. Engineers and geologists define soil as an earth material that is soft enough that it can be removed without blasting. Characteristics such as depth, compressive strength, density, expansion potential, corrosivity, permeability, ability to hold water, and fertility vary widely from place to place. Soils analysis for planning is performed to determine the suitability of soils for agriculture or other resource uses and to characterize engineering

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[27] Nichols • Berman communication with David Schlitgen, County of Sonoma, Permit and Resource Management Department, January 2003.

[28] *Sonoma County Aggregate Resources Management Plan and Environmental Impact Report*, E.I.P. & Associates, November 1994.

[29] *Special Report 146*, California Division of Mines and Geology, 1983.

properties as they relate to the soils' constraints on development. For planning purposes in Sonoma County, both agricultural resource and engineering properties are discussed.

There are 259 soil types mapped within Sonoma County.[30] To facilitate evaluation of these soils, they are classified into 15 major soil associations, with each soil association typically correlated to a particular geographic area. There are five soil associations found in basins, tidal flats, flood plains, terraces and alluvial fans. The remaining ten soil associations are characteristic of high terraces, foothills, uplands and mountains. ***Appendix 7.9 Soils Association Characteristics*** is a comparison of soil association characteristics. Soils associations are divided into broad groups based upon color and texture. These groups illustrate the general pattern of soil occurrence in Sonoma County; the first group includes soils found primarily in basins, flood plains, terraces and alluvial fans while the second group includes soils found primarily in high terrace, foothill, upland, and mountain areas. The associations provide information for general planning and resource management, but do not provide specific technical data on a particular soil. The Sonoma County Soils Survey contains detailed information on individual soil series. For project planning within the county, site-specific geotechnical or agricultural soil investigations may be required prior to environmental review and design of the project.

Prime Agricultural Soils

The Soil Conservation Service's land capability classification system rates soils by capability classes designated by Roman numerals I to VIII, with Class I soils having the fewest limitations for farming.

Class I and II soils, the best suited for agricultural use, are the most fertile with the best drainage and soil depth. Texture is optimum for root penetration and moisture availability. The Ph factor is medium acid to neutral; slopes range from 0 to 15 percent. These soils are located on alluvial fans, terraces, and edges of basins, and are suitable for all crops including row crops, field, truck and specialty crops, fruit trees, nut trees and vineyards. Shrink-swell and erosion potential are minimal, and they have good septic suitability and good water availability. As a result, there is direct competition between agricultural uses and development interests for land containing these soils particularly in the flat areas near cities and transportation routes.

Class III soils are mostly on low hills and terraces, old flood plains, and valley plains. Fertility is most1y moderate with some low and some high fertility for certain soils. These soils produce forage and field crops, row and truck crops, vineyards, orchards, and specialty crops such as strawberries and cut flowers. Class IV soils have severe limitations that reduce the choice of plants and require careful management if cultivated. There are small patches of these soils throughout the county, mainly interspersed with Class II and III soils. They are found on low foothills, terraces, broad ridge tops, flood plains, rounded hills, and moderately steep hillsides. These soils are good for pasture, grazing, forage, hay, alfalfa, oats, small grains, vineyards, and some types of timber production.

There are no Class V soils in Sonoma County.

Class VI, VII, and VIII soils are mostly on steep slopes, except for the soils that comprise dunes, stream channels, and tidal marshes. These soils are used for pasture and range and support grasses, forbes, shrubs and various trees (e.g., Douglas-fir, tan oak, live oak, madrone, and redwood). Areas in

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[30] *Soil Survey, Sonoma County, California*, V. C. Miller, United States Department of Agriculture in cooperation with the University of California Agricultural Experiment Station, first issued May 1972, reviewed and reprinted August 1990.

Sonoma County with steep slopes typically support substantial growths of trees and shrubs that are important for wildlife habitat. These are also areas of high runoff into their watersheds, so maintenance of vegetation is important for protecting the soils of this terrain. Many recreational uses (e.g., parks, trails, nature preserves, etc.) are located in these soil areas because of their attractive natural attributes.

Soils Suitability Types

Another way to classify soils is by their predominant suitability. There are four general classifications of suitabi1ity: prime agricultural soils, timber soils, range soils, and woodland/wildlife habitat soils. ***Appendix 7.9 Soils Association Characteristics*** shows major uses by soil suitability.

Agricultural Soils

These soils are suitable for cultivation and the production of food and fiber. They possess physical properties that allow the production of high crop yields. Typically these are deep, fertile soils with suitable moisture supply, permeability, drainage, PH, and soil temperature. Generally, prime agricultural soils are those under soil capability classes I and II. However, many other soil classes have proven suitable for agricultural use in Sonoma County.

Timber Soils

More than half of Sonoma County, or about 553,000 acres, are in woodland, with commercial timberlands totaling approximately 292,000 acres.[31] The Sonoma County Soils Report states that in 1952 about 64 percent of the woodland acreage was commercial. However, over the past 50 years the percentage of commercial woodland has steadily declined. This trend is expected to continue. Present zoning shows there are 93,875 acres zoned as timberland in Sonoma County.[32] This comprises about 17 percent of the county's total woodland area. Timber soils are assigned to woodland suitability groups that range in depth from 20 to 60 inches. These soils are subject to high erosion hazards have rapid water runoff, and are easily destroyed unless careful logging practices are enforced. Clear cutting tends to destroy slope stability and increase the potential for landslides, stream bank erosion, and sedimentation of streambeds.

Range Soils

A range is an open region over which livestock may roam and feed. The soils used for grazing in Sonoma County have been grouped into twelve range sites comprising a total of 211,500 acres. Each range site is distinguished from the others by its ability to produce significantly different kinds and amounts of vegetation as well as the management needed to keep the site in good condition. Of the twelve sites, nine exhibit erosion potential and two are subject to land slippage.

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[31] *Soil Survey, Sonoma County, California,* V. C. Miller, United States Department of Agriculture in cooperation with the University of California Agricultural Experiment Station, first issued May 1972, reviewed and reprinted August 1990.

[32] Nichols • Berman communication with Julie Milankowski, County of Sonoma, PRMD, GIS Services, January, 2003.

Woodland / Wildlife Habitat Soils

These soils are characterized by chaparral and rocky land. They are valuable as wildlife habitat and watershed lands but are not as valuable for resource production. Suitability of the soils for various kinds of wildlife varies according to the depth of the soil, its slope and texture, the stones and rocks present, drainage characteristics, and the water absorption capacity. The eight wildlife soil groups delineate the relative soil suitability for growing plants important for wildlife habitat.

Septic Suitability

These soil limitation categories are designated as low, moderate, or severe. The determinants for this rating are based on slope, soil depth, permeability, depth to seasonal high water table, and whether or not the soil is subject to inundation or ponding. Generally soils such as those with United States Soil Classifications GW, GP, and GM have high transmisivity, while those soils classified as CH have very low transmisivity. Soils with either extreme range of transmisivity are problematic for septic leach fields and special designs or mitigation is needed in such areas. Areas with soils suitable for septic systems are shown the Soil Survey of Sonoma County. [33]

Geology / Soils – Regulatory Setting

COUNTY REGULATIONS

Aggregate Resources Management Plan

The Sonoma County *Aggregate Resources Management Plan* (ARM Plan) currently serves as the regulatory document providing guidelines for sound management of aggregate mining in the county. This plan was first adopted by the County in 1980 and later updated in 1994. A program EIR was certified by the County at that time for addressing potential impacts from mining in the areas subject to the plan. In addition to compliance with the ARM Plan, proposed new gravel operations require County approval of a Mining and Reclamation Plan, and a use permit pursuant to County Zoning Ordinance Article 72.

Sonoma County Zoning Code

Article 72 of the County's Zoning Code, the MR or Mineral Resource Combining District, regulates mining and reclamation of mined lands within the county, consistent with the ARM Plan. Combined with several bases zones, various uses are permitted as a right or subject to a use permit. Incompatible uses and residential uses are restricted. Provisions of this article require the approval by the County of a surface mining use permit and approval of a reclamation plan.

The Zoning Regulations were amended in 1993 to include the Geologic Hazard Area Combining District (G District), the purpose of which is to reduce unnecessary exposure of people and property to risks of damage or injury from earthquakes, landslides, and other geologic hazards.

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33 *Soil Survey, Sonoma County, California*, V. C. Miller, United States Department of Agriculture in cooperation with the University of California Agricultural Experiment Station, first issued May 1972, reviewed and reprinted August 1990.

The G District has been applied to properties which are located within the Alquist-Priolo Earthquake Fault Zone (maps showing this zone are available at PRMD). All uses permitted within the zoning districts with which the G District is combined are permitted, except that no structure intended for human occupancy or otherwise defined as a project in the Alquist-Priolo Earthquake Fault Zoning Act is permitted to be placed across the trace of an active fault or within 50 feet of the surface trace of any fault. A geologic report is required for development of property within the G District. The report must describe the geologic hazards that exist on or affect the property and include mitigation measures to reduce the exposure of people and property to risks of damage, or injury from these hazards, to acceptable levels.

Unreinforced Masonry Buildings

SB547, approved in 1986, mandates that local jurisdictions identify and mitigate seismic hazards in *unreinforced masonry buildings* (UMBs). Referred to as *potentially hazardous buildings* in the State legislation, UMBs are those buildings constructed prior to the adoption of local building codes requiring earthquake resistant design of buildings and constructed of unreinforced masonry wall construction.

In December 1989, the Sonoma County Building Inspection Department (now a Division of the Permit and Resource Management Department) completed a list of properties in Sonoma County that contained UMBs. The Board of Supervisors adopted Resolution #89-2390 that acknowledged this list of UMBs and the Department notified property owners.

The State Seismic Safety Commission has strongly encouraged proactive mitigation programs beyond the minimum notification mandated by SB547, acknowledging that such programs could have the benefits of preservation of human life; reduced disaster response demand and expense; preservation of the tax base; preservation of building contents, often more valuable than the building; and reduced likelihood of the release of hazardous substances.

The cities of Santa Rosa, Sebastopol, Sonoma, and Petaluma have adopted a seismic hazard mitigation ordinance that requires the strengthening and reinforcing of UMBs. To date, Sonoma County has not adopted an ordinance requiring the seismic retrofit of UMBs.

Sonoma County Building Code

ABAG and the U.S. Geological Survey (USGS) have updated information on the importance of groundshaking intensity as a measure of the effect of an earthquake at a specific location. The regional ABAG report *On Shaky Ground* indicates that the intensity of groundshaking is a more important indicator of earthquake hazard and potential damage than is proximity to a fault or location within an Alquist-Priolo Earthquake Fault Zone. There are two separate but related kinds of earthquake hazard. One is surface fault rupture damage which is localized within relatively close proximity to the active fault. The other is groundshaking, which is significant over a much larger area. [34]

Design engineers for new projects determine the required seismic design standards required under the current California Building Code by calculating the *seismic base shear* for structural components and

[34] The ABAG report is on file with the PRMD and available online at *www.abag.org*.

the *lateral seismic force* for non-structural components and equipment. PRMD Plan Checking staff review these calculations.

Sonoma County is in Seismic Zone 4, the most seismically active of the four seismic zones in the United States. Type A and B faults occur throughout the county. These conditions in the county increase the seismic coefficient and near-source zones and factors, which increase the seismic base shear and lateral seismic force, which in turn increase the seismic design standards. In addition, for essential service buildings, the *importance factor* is greater than 1.0, which results in a 25 percent increase in the seismic base shear and a 50 percent increase in the lateral seismic force, which in turn increase the seismic design standards for such buildings.

The Sonoma County Building Code (periodically updated to conform to revisions in the California Building code) addresses groundshaking intensity issues as part of the review of structures for seismic safety. The California Building Code is another name for the body of regulations known as the California Code of Regulations (CCR), Title 24, Part 2, which is a portion of the California Building Standards Code (CBSC).[35] Title 24 is assigned to the California Building Standards Commission, which, by law, is responsible for coordinating all building standards. Published by the International Conference of Building Officials, the Uniform Building Code is a widely adopted model building code in the United States. The CBSC incorporates by reference the Uniform Building Code (UBC), with necessary California amendments. About one-third of the text within the California Building Code has been tailored for California earthquake conditions.

Subdivision Ordinance

The Sonoma County Subdivision Ordinance lists standards for approval of subdivision applications. These standards include the requirement for preparation of a geological report where further geological investigation is warranted. The geological report must summarize and illustrate areas where standard foundation and other conventional construction techniques are satisfactory; areas where geologic hazards may exist but which the geologist believes can be mitigated, such as through foundation design; and areas where geologic suitability is uncertain without additional geotechnical and/or subsurface investigation. The Ordinance also outlines requirements for a soil condition report to accompany the tentative map, a preliminary soil report based on test borings or excavations to accompany the final subdivision map, and a soil investigation of each lot in the subdivision. The soil investigation report is to be prepared by a registered civil engineer and to include recommended corrective actions which are likely to prevent structural damage on sites with unstable geologic conditions.

Vineyard Erosion and Sediment Control Ordinance

See discussion of ordinance in ***Section 4.8 Agricultural and Timber Resources***.

STATE AND FEDERAL REGULATIONS

Geothermal

Refer to ***Section 4.12 Energy***, for geothermal regulations.

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[35] California Building Standards Code, 1995.

Surface Mining and Reclamation Act

All mining operations in the county and throughout the state are subject to the California Surface Mining and Reclamation Act (SMARA). The purpose of SMARA is to identify and protect areas containing significant mineral resources. In doing so, SMARA: a) regulates surface mining operations to assure that adverse environmental effects are prevented or minimized, b) requires reclamation of mined lands to a usable condition that is readily adaptable to alternative land uses, c) produces and conserves minerals, and considers values relating to recreation, watershed, wildlife, range and forage, and aesthetic enjoyment, and d) eliminates residual hazards to the public health and safety. Mining must comply with SMARA through all phases of a project, including the reclamation process. Refer to *Aggregate Resources Management Plan* under *County Regulations,* above. [36]

Alquist-Priolo Earthquake Fault Zoning Act

The Alquist-Priolo Earthquake Fault Zoning Act (formerly the Alquist-Priolo Special Studies Zone Act), signed into law December 1972, requires the delineation of zones along active faults in California. The purpose of the Alquist-Priolo Act is to regulate development on or near active fault traces to reduce the hazard of fault rupture and to prohibit the location of most structures for human occupancy across these traces. [37] Cities and counties must regulate certain development projects within the zones. Such regulation includes withholding permits until geologic investigations demonstrate that development sites are not threatened by future surface displacement. The Rogers Creek Fault Zone and the San Andreas Fault Zone are the two major fault zones in Sonoma County designated by the Alquist-Priolo Earthquake Fault Zoning Act. Sonoma County implements this requirement through the Geologic Hazard Zoning District provisions as part of the County Zoning Code.

Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act was developed to protect the public from the effects of strong ground shaking, liquefaction, landslides, or other ground failure, and from other hazards caused by earthquakes. This act requires the State Geologist to delineate various seismic hazard zones and requires cities, counties, and other local permitting agencies to regulate certain development projects within these zones. Before a development permit is granted for a site within a seismic hazard zone, a geotechnical investigation of the site must be conducted and appropriate mitigation measures incorporated into the project design. The California Geological Survey (formerly the California Division of Mines and Geology) has not completed preparation of a Preliminary Seismic Hazards Map for Sonoma County and the Santa Rosa Area. The hazards maps will depict areas susceptible to land sliding and liquefaction and be accompanied by a report describing the basis for the maps. The State is developing the seismic hazards maps first in areas with the highest growth. The estimated date for completing seismic hazard zone maps for Sonoma County is approximately 2006. [38]

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[36] *General Plan Background Report - Agricultural and Mineral Resources*, City of Healdsburg November 7, 2002.

[37] The Alquist Priolo Act defines a “structure for human occupancy” as any structure used or intended for supporting or sheltering any use that has an occupancy rate of more than 2,000 man hours per year.

[38] Environmental Geology Services conversation with Chuck Real, Director of Geologic Hazards Mapping Program, California Geological Survey, 2003.

Geology / Soils - Significance Criteria

The geologic analysis uses criteria from the *State CEQA Guidelines.* According to these criteria, the project would have a significant geologic impact if it 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 ground shaking;
    - Seismic-related ground failure, including liquefaction; or
    - Landslides.
- 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;
- Result in substantial soil erosion or the loss of topsoil;
- Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), [39] creating substantial risks to life or property;
- Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater;
- Result in the loss of availability of a known mineral resource that would be of value to the region and residents of the state; or
- Result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan.

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[39] Table 18-1-B of the Uniform Building Code (Classification of Expansive Soil) simply states the potential expansion as a function of the expansion index of the soil (an Expansion Index of 1-20 has a Very Low potential expansion, 21-50 has Low, 51-90 has Medium, 91-130 has High, and above 130 has Very High potential expansion). The expansion index normally is not determined until site-specific geological investigations are conducted.

Geology / Soils - Impacts and Mitigation Measures

GEOLOGIC HAZARDS

Impact 4.7-1 Seismic Ground Shaking

*Land uses and development consistent with the Draft GP 2020 would expose people or structures to substantial adverse seismic effects, including the risk of loss, injury, or death involving strong seismic groundshaking. This would be a significant impact. (**S**)*

The county has a 70 percent probability of experiencing ground shaking from at least one major earthquake (i.e., Moment Magnitude 6.7 or greater) by 2030.[40] Ground shaking can result in structural failure and collapse or cause nonstructural building elements to fall, presenting a hazard to occupants and damage to contents. Older, unreinforced masonry (URM) buildings and other buildings within the county constructed before 1930 that have not been seismically retrofitted are most subject to structural failure or collapse. URM buildings with seismic structural upgrades should be more resistant to seismic shaking damage. However, even these structurally upgraded URMs, as well as newer buildings, could still experience damage that could present a hazard.

Because of the regional effects of large earthquakes, future land uses and development that occur anywhere within the unincorporated area would be subject to ground shaking during such events. Locations where shaking is expected to be more intense are valley and Bay margin areas. Figures PS-1a through PS-1i in the Public Safety Element of the *Draft GP 2020* illustrate the areas in each of the nine planning areas that are subject to seismic hazards. Examples of areas in each of the nine planning areas where the potential for adverse impacts from seismic ground shaking is expected are those areas depicted on Figures PS-1a through PS-1h in the Public Safety Element as Strong Shaking Severity, Very Strong Shaking Severity, Violent Shaking Severity, and Very Violent Shaking Severity. As can be seen on these maps, the areas with the greatest concentration of development with buildings are the generally flat lying basins and valleys which are underlain by thick, poorly consolidated alluvium, with high ground water in some areas. These are areas of deep, unconsolidated deposits, (e.g., alluvium and bay mud), and thus are subject to higher amplitude, longer duration shaking motions that, among other factors, contribute to structural damage.

However, this greater shaking potential is recognized in the Uniform Building Code (UBC), which provides for more stringent earthquake resistant design parameters for such areas. Thus, while these shaking impacts are potentially more damaging, they also will tend to be reduced in their structural effects due to UBC criteria. Older and poorly constructed buildings in these areas would still be prone to seismic damage.

The *Draft GP 2020* contains many policies and standards in the Public Safety Element, which, if adopted and implemented, would reduce the potential impacts associated with strong seismic ground shaking by encouraging or requiring the use of current seismic data in building location, design, and construction, as described below. These policies are presented below along with a discussion of each policy and how the policy could reduce impacts associated with seismic ground shaking.

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[40] Working Group on California Earthquake Probability, 1999.

Policy **PS-1a** would result in the ongoing use of available information on geologic hazards and related risks in the county. Using existing and new geologic hazards information geologic hazards from Sonoma County, the California Geological Survey, the US Geological Survey and other sources would allow identification of known geologic hazards, their geographic extent and probabilities for occurrence. When applied to decision-making for siting of critical or sensitive structures and for building design this policy would help keep the Public Safety Element up-to-date and lessen these geologic hazards.

Policy **PS-1b** would result in the use of studies of geologic hazards prepared during the development process. Ongoing studies of geologic hazards developed in Sonoma County by the California Geological Survey, the US Geological Survey, universities and other sources, such as investigations for specific development projects would provide up-to-date information about geologic hazards impacting the county and allow County planners to incorporate the data into decision making for the siting of critical or sensitive structures. This policy would also reduce this impact by informing County planners of the need for updating building codes, structural design, and inspection requirements. Keeping abreast of the latest knowledge regarding geologic hazards in the Sonoma County, and applying it to the planning process would reduce the impact of seismic ground shaking by alerting developers and County officials of problematic conditions and providing for siting and design mitigations. As with Policy **PS-1a**, this policy would help keep the Public Safety Element up-to-date with regard to new information about the locations and magnitudes of geologic hazards in the county.

Policy **PS-1c** would provide for amendments of the Public Safety Element so that new data that significantly change the hazard assessment of the Public Safety Element can be incorporated. As new information about the geologic hazards impacting Sonoma County are developed though research, public agency investigation, geologic events, and project specific experience, this information would be evaluated by the PRMD relative to the existing policies to determine if policies should be amended. If the new information can significantly change the hazard assessment of seismic ground shaking, then the information would be used as a basis for amending the affected policy or policies. As with the preceding policies, this policy would help keep the Public Safety Element up-to-date with regard to recognition of kinds and locations and magnitudes of geologic hazards.

Policy **PS-1d** would encourage research on geologic hazards, their probabilities and their effects within Sonoma County and thereby help to further assure that the Public Safety Element would remain up-to-date. Encouragement of new research on geologic hazards can be accomplished through a variety of means, including working with public agencies such as the California Geological Survey, the US Geological Survey, and State universities to facilitate investigations and research in Sonoma County. This policy would help reduce the impacts of seismic ground shaking and other geologic hazards by helping to provide the latest geologic information to the County planning officials. In addition this policy would help in public awareness and avoidance of geologic hazards.

Policy **PS-1e** would allow for continued implementation of the “Geologic Hazard Area” combining district. These special districts establish regulations for permissible types of uses and their intensities and appropriate development standards within areas that have known adverse geologic conditions. The use of the “Geologic Hazard Area” combining district would be one of the more effective policies to mitigate the damaging effects of geologic hazards. The establishment of such geologic hazard areas is based on the existing maps of the nine planning areas in Sonoma County that delineate areas subject to seismic hazards (specifically Figures PS-1a through PS-1i in the *Draft GP 2020*). This policy would effectively reduce geologic and soils impacts by providing a mechanism for control of development of properties in areas with potentially high to moderate seismic ground shaking impacts.

Policy **PS-1f** consists of three parts. The first part would require review of geologic reports prior to decisions on projects that would subject property or persons to significant risks. The general areas where these risks are expected are shown on Figures PS-1a through PS-1i of the *Draft GP 2020* and related file maps and source documents. This part of the policy would significantly decrease geologic hazards. A geologic evaluation of a site proposed for development, combined with a site and project specific geotechnical engineering investigation that describes the hazards and includes mitigation measures to reduce risks to acceptable levels would result in project plans and designs that would significantly reduce risk from geologic or soils impacts because site specific conditions would be identified and incorporated into the projects. The policy of reviewing these reports adds a level of quality control to the process that would help further reduce seismic ground shaking impacts.

Secondly, for new projects this policy would require geologic reports to describe the hazards and include measures to reduce risks to acceptable levels. In addition the policy would require, where appropriate, that the project engineer or geologist certify that risks have been reduced to an acceptable level. This would lessen the impact of geologic hazards by requiring the project planners and designers to more clearly identify the level of risk after mitigation and allow permitting agencies to approve or deny the project design based on the regulatory acceptance of that level of mitigation.

Policy **PS-1g** specifies a 50 foot building setback from any fault. Because there are numerous faults in Sonoma County that are inactive and extremely unlikely to reactivate, this policy would limit or prevent development of many properties that would not be expected to experience significant geologic or soils impacts that could not be mitigated to the normal acceptable level through the use of the UBC. To the extent that this policy would limit building in the vicinity of known active faults, it would reduce geologic and soils impacts related to an earthquake on those faults.

Policy **PS-1h** would continue to require the County to adopt revisions to the UBC that would increase resistance of structures to ground shaking and other geologic hazards after approval of those revisions by the International Congress of Building Officials (ICBO) and the State of California. This policy would serve to significantly reduce geologic hazards by using the latest UBC requirements for site investigations, design, and construction.

Policy **PS-1i** would apply to structures that have irregular shape or other factors that prevent adequate determination of seismic load distribution by static analysis. This policy would serve to significantly reduce geologic hazards by requiring a dynamic analysis of structural response to earthquake forces prior to County approval of building permits. This would result in structural design that would best mitigate expected strong seismic shaking forces for projects that include structures with irregular shape or otherwise cannot be adequately designed using static analysis.

Policy **PS-1j** would encourage strong enforcement of State seismic safety requirements for the design and construction of projects subject to State and federal standards. As a result, this policy would help assure that these projects (i.e., bridges, dams, power plants, hospitals and schools) are designed and built to the best legally required standard and thus reduce damage from geologic hazards.

Policy **PS-1k** would apply to roads, public facilities, and other County projects. This policy would help to reduce identified geologic hazards by requiring consideration of those geologic conditions at the planning and design stages of the project.

Policy **PS-1l** would result in the siting of essential service buildings and facilities, and high public occupancy buildings outside those areas subject to Very Violent, Violent or Very Strong ground shaking, where possible. But in cases where it is not feasible to so locate those kinds of projects, the policy would result in their being designed and constructed to the highest feasible safety standard.

Through appropriate siting and design this policy would reduce adverse impacts to essential and high occupancy public buildings.

Policy **PS-1m** would make all maps identifying geologic hazards in Sonoma County readily available to property owners and the public thus reducing the potential for further geologic and soils impacts by providing information during project planning phase for determining the kinds of geologic impacts that would need to be addressed.

PS-1n would require a Strategic Plan for damage assessment and recovery of essential service buildings and facilities, (i.e., especially high public occupancy facilities and facilities where ground shaking would be strongest). This policy would enhance the County's emergency response planning and thus reduce geologic and soils impacts. However, because there is no schedule for development of the Strategic Plan in the policy, it cannot be relied upon to reduce impacts associated with seismic activity in the near future.

Policy **PS-1o** would result in an ordinance requiring the strengthening of unreinforced masonry (URM) buildings, except residential structures, thus reducing property damage and reducing the possibility of injuries and loss of life. Residential structures, however, could be damaged resulting in property damage and possible lost of life.

Although these policies would reduce some of the impacts associated with strong seismic groundshaking, the potential for damage or loss during an earthquake and prior to mitigation would be a significant impact.

Mitigation Measure 4.7-1 Revise Policy **PS-1o** to specifically include all multiple family residential URM structures.

> **Policy PS-1o**: Adopt an ordinance requiring strengthening and / or reinforcement of Unreinforced Masonry Buildings, <u>including multi-family</u>, but not single family residential structures.

Significance After Mitigation Although implementation of Mitigation Measure 4.7-1 would further reduce the impact of seismic ground shaking, it would not be possible to fully mitigate the impact for the more severe seismic events that may occur. For small and moderate seismic events the impact of strong seismic shaking would be generally reduced to less-than-significant levels. However in the case of more severe seismic events such as the maximum credible earthquake, the potential for property damage and bodily injury would remain. Therefore this would be a significant unavoidable impact. (**SU**)

Responsibility for Monitoring The Board of Supervisors would be responsible for adopting the policy proposed in Mitigation Measure 4.7-1 as part of *GP 2020*. PRMD would be responsible for enforcement of UBC requirements and assuring the latest UBC requirements are adopted by the County, keeping abreast of current geologic and seismic research and investigations in the area, reviewing geotechnical and geologic reports and project structural designs, and in general assuring all policies are enforced.

Impact 4.7-2 Seismic Related Ground Failure

Land uses and development consistent with the Draft GP 2020 would expose people or structures to potential substantial adverse seismic effects, including the risk of loss, injury, or death from seismic-related ground failures such as surface fault rupture, lateral spreading, lurching, differential settlement, and flow failures. While the policies included in the Draft GP 2020 would reduce most impacts to an acceptable level, seismic related ground failure impacts related to roads, public facilities, and other County projects would remain significant. ***(S)***

Seismic related ground failures include liquefaction, lateral spreading, ground cracking, lurching, and seismically triggered land sliding. Surface fault rupture is a special kind of seismic related ground failure that is generally localized along the earthquake-producing fault. As noted in *Impact 4.7-1 Seismic Ground Shaking* the county has a 70 percent probability of experiencing at least one major earthquake (i.e., Moment Magnitude 6.7 or greater) by 2030.[41] Major earthquakes can result in various kinds of seismic related ground failures. The type of seismic related ground failure that results depends on numerous factors such as the kind of soil, ground water depth, soil saturation, slope steepness and topography, duration and amplitude of seismic energy at the site, and other factors. Injection of water into the Geysers Steamfield is being considered as a possible factor which may increase the potential for seismic activity.

These kinds of ground failures, like seismic ground shaking in general, can cause damage to infrastructure, damage or collapse of buildings, or cause nonstructural building elements to fall, presenting a hazard to occupants and damage to contents. Because of the regional effects of large earthquakes, future developments that occur in many parts of the unincorporated area would be subject to seismic related ground failure during a major earthquake. Locations where seismic related ground failure is expected to be more intense are valley and Bay margin areas, along costal bluffs and steep stream or riverbanks, in hilly terrain with existing landslides (i.e., active through dormant), and areas underlain by sandy soils with a high water table. Figures PS-1a through PS-1i in the Public Safety Element of the *Draft GP 2020* illustrate that each of the nine planning areas has some areas that are susceptible to seismic related ground failure.

As noted above, seismic related ground failure is a common hazard that cannot be eliminated in seismically active regions such as Sonoma County where there is diverse topography, areas of shallow ground water, and large active faults exist that are capable of producing very strong to violent ground shaking. However, over time engineers and geologists have learned more about the behavior of soils and earth materials during earthquakes in the region. By applying the lessons from past seismic events to the practices of building location and design, practices have improved greatly so that by using the best and most current standards, seismic damage from seismic related ground failure can be reduced to levels that are generally considered acceptable.

The *Draft GP 2020* contains policies in the Public Safety Element that would reduce the potential impacts associated with seismic related ground failure. See *Impact 4.7-1 Seismic Ground Shaking* above for a discussion of Policies **PS-1a** through **PS-1g**, **PS-1k**, and **PS-1m**. As with *Impact 4.7-1 Seismic Ground Shaking*, implementation of these policies would not eliminate the impact for the more severe seismic events that may occur. For small and moderate seismic events the impact of seismic related ground failure would be generally reduced to a less-than-significant level for new development through implementation of the *Draft GP 2020* policies (including enforcement of the

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[41] Working Group on California Earthquake Probability, 1999.

current UBC), but in the case of more severe seismic events such as the maximum credible earthquake, this would be a significant impact.

Mitigation Measure 4.7-2 No mitigation available beyond the *Draft GP 2020* policies discussed in the impact analysis above.

Significance After Mitigation This would be a significant unavoidable impact. (**SU**)

Impact 4.7-3 Landsliding

*Land uses and development consistent with the Draft GP 2020 would expose people and structures to substantial damaging effects of landsliding, including the risk of loss, injury, or death from down slope earth movement that may be slow or rapidly occurring. This kind of geologic hazard can be caused by earthquake, seasonal saturation of the soils and rock materials, erosion, or grading activities. This would be a significant impact. (**S**)*

The most frequent and widespread type of ground failure in Sonoma County is landsliding. Because of the highly fractured rock formations, steep topography, long coastline, and the area's seismicity and rainfall, extensive land areas of the county are subject to landsliding. Virtually all parts of the county except the flat lying alluvial valleys are subject to damaging landslides of various kinds. Landslides vary in size, speed of movement, and mechanism; some are small slumps or flows within older larger slide masses, while some landslides in the county have been as long as two miles. Areas prone to landsliding include locations of past landslides, hillsides where clay and silt-rich soils absorb water and loose strength, and areas where rock strata are parallel to surface slopes. In addition, landslides occur where faults have fractured rock and along the base of slopes or cliffs where supporting material has been removed by stream or wave erosion, flowing water, or human activities. Heavy rainfall, human actions, or earthquakes can trigger landslides. Locations where landslide failure is expected to be more common are along costal bluffs and steep stream or riverbanks, and in hilly terrain with existing landslides (i.e., active through dormant).

Figures PS-1a through PS-1i in the Public Safety Element of the *Draft GP 2020* show the areas within each of the nine planning areas that are susceptible to landslide failure. Examples of areas in each of the nine planning areas where the potential for adverse impacts from landsliding is expected are those areas on Figures PS-1a through PS-1i designated as high to very high landslide susceptibility.

Landsliding is a widespread impact that cannot be eliminated completely in a geologically complex region such as Sonoma County where there is diverse topography, highly variable seasonal rainfall, and large active faults that can produce very strong to violent ground shaking that can trigger slope failures. However, over time engineers and geologist have learned ever more about the behavior of soils and earth materials under extreme groundwater and rainfall conditions and during earthquakes in the region. In addition, maps of existing landslides and landslide prone regions in the county have been developed. By applying knowledge about the locations of existing landslides and areas with poor slope stability the practices of building location and slope stabilization have improved greatly. By using the best and most current standards, landslide damage can be minimized.

The *Draft GP 2020* contains many policies and standards in the Public Safety Element that, if adopted and implemented, would reduce the potential impacts associated with landsliding. See *Impact 4.7-1 Seismic Ground Shaking*, above for a discussion of Policies **PS-1a** through **PS-1f**, **PS-1k**, and **PS-1m**. For small and moderate seismic events and lower rainfall events the impact of landslide failure would be generally reduced to a less-than-significant level for new development through implementation of the *Draft GP 2020* policies (including enforcement of the current UBC). As with *Impact 4.7-1*

Seismic Ground Shaking, implementation of these policies would not completely eliminate the impact of landsliding events that may occur during maximum rainfall or seismic activity occurrences. In the case of severe seismic events or unusually high rain fall over a short duration, it would not be possible to eliminate the potential impact in some locations. As a result, this would be a significant impact.

Mitigation Measure 4.7-3 No mitigation available beyond the *Draft GP 2020* policies discussed in impact analysis above.

Significance After Mitigation This would be a significant unavoidable impact (**SU**).

Impact 4.7-4 Subsidence and Settlement

Land uses and development consistent with the Draft GP 2020 could expose property and structures to the damaging effects of ground subsidence hazards. This kind of geologic hazard can be seismically triggered (e.g., liquefaction), caused by seasonal saturation of the soils and rock materials, or caused by grading activities. This would be a significant impact. ***(S)***

Subsidence and settlement are localized and site and project specific kinds of geologic hazards. Most subsidence is caused by the withdrawal of fluids (e.g., ground water or oil) from subsurface reservoirs or from the collapse of surface and near surface soils and rocks over subterranean voids such as mines and caves. This type of subsidence has thus far not been reported in Sonoma County. Settlement, a kind of subsidence, is a more localized phenomenon and is related to the loading of soils and their subsequent compression as a result of construction activities. Settlement can result if the native soils are porous or weak such that the weight to a building or other structure causes the soil to compress. This can occur in native soils or in manmade fills. Non-uniform or differential settlement can occur if the compressible soil section beneath the structure is of variable thickness, if the soil is heterogeneous, or if there are variable loads imposed across the footprint of the structure. In pavement sections differential settlement is common when utility trench backfill is improperly compacted. The kinds of damage caused by settlement and differential settlement are similar to that caused by expansive soil (e.g., tilted and cracked floor slabs, uneven floors in buildings, cracked pavements, etc.). As with expansive soils, standard geotechnical engineering procedures and soil testing, proper design and testing, and quality control can identify compressible soil during construction. A special category of settlement is liquefaction. This category of subsidence is triggered by seismic shaking and impacts areas underlain by granular soils that are saturated by groundwater. This impact is related to both seismic shaking (i.e., the triggering mechanism), as well as soil and groundwater conditions. Liquefaction is the transformation of water saturated granular soils from a solid state to a liquid state as a result of an increase in the inter-granular (or pore) water pressure caused by intense ground shaking. The kinds of damage caused by liquefaction include sudden collapse or overturning of structures, collapse of pavements, and in some cases lateral spreading. As with settlements resulting from compressible soils and expansive soils, standard geotechnical engineering procedures and soil testing, proper design and testing, and quality control can identify liquefiable soils during site exploration. By applying knowledge about the kinds of soils, their strengths, the groundwater conditions and properly designing and constructing fills and foundations modern soil engineering practices have improved greatly so that by using the best and most current standards, subsidence and settlement damage can be reduced to levels that are generally considered acceptable. By applying such standards to future projects in the county, the impact of subsidence and settlement failure can be essentially eliminated.

The *Draft GP 2020* contains policies and standards in the Public Safety Element that, if adopted and implemented, would reduce the potential impacts associated with subsidence and settlement. See *Impact 4.7-1 Seismic Ground Shaking*, above for a discussion of Policies **PS-1f**, **PS-1k**, and **PS-1m**.

For small and moderate seismic and rainfall events the impact of settlement would be generally reduced to a less-than-significant level for new development through implementation of the *Draft GP 2020* policies (including enforcement of the current UBC). As with *Impact 4.7-1 Seismic Ground Shaking*, implementation of these policies would not completely eliminate the impact of subsidence settlement that could be expected during maximum rainfall or seismic activity events. In the case of severe seismic events or unusually high rain fall over a short duration the impact would be significant in some locations. These locations are those areas on Figures PS-1a through PS-1I designated as high to very high liquefaction susceptibility.

Mitigation Measure 4.7-4 No mitigation available beyond the *Draft GP 2020* policies discussed in impact analysis above.

Significance After Mitigation This would be a significant unavoidable impact (**SU**).

Impact 4.7-5 Tsunamis and Seiches

Land uses and development consistent with the Draft GP 2020 could expose people and structures in limited areas of the county to potential, substantial adverse seismically caused flooding and strong tidal effects, including the risk of loss, injury, or death. While the policies included in the Draft GP 2020 would reduce impacts to an acceptable level, tsunami and seiche impacts related to roads, public facilities, and other County projects would be significant. ***(S)***

Ocean waves generated by certain undersea earthquakes, volcanic eruptions, or landslides are called tsunamis or seismic sea waves. The height and shoreline run up distance of a tsunami are determined by water depth, underwater topography, and shape and orientation of the coastline relative to the tsunami source. The tsunami level expected once in 200 years could affect areas along Sonoma County's Pacific coast up to 20 feet above sea level, with lesser run up expected along the county’s San Pablo Bay shoreline. The areas of Sonoma County subject to tsunamis are identified on published maps by the California Geological Survey (formerly California Division of Mines and Geology) available at the County PRMD offices. These maps are included in the report Geology for Planning, Sonoma County, California. [42] In addition the planning areas where tsunami hazards are expected are along the San Pablo Bay margin and along the Pacific Coast. These areas are coastal areas depicted on Figures PS-1a (Sonoma Coast and Gualala Basin) and the southernmost part of the Sonoma Valley in the Bay wetland area of PS-1h (Petaluma and Environs). Seismic waves on inland water bodies such as lakes, reservoirs, as well as coastal bays are called seiches and can result tin damage to structures along the edges of these water bodies. Shoreline areas along Bodega Harbor, Lake Sonoma, and similar enclosed bodies of water in Sonoma County are subject to impacts from seiches. Tsunamis and seiches impact limited areas of Sonoma County. Their impact can be minimized in Sonoma County by applying the lessons from past seismic events, and by implementing the practices of careful building location, setback, and design.

The locations of the line delineating tsunami run up is presented on the planning maps for the Sonoma Coast / Gualala Basin (Figure PS-1a) and Sonoma Valley (Figure PS-1i) planning areas. For the Sonoma Coast / Gualala Basin area this line basically parallels the coast, but in the vicinity of Jenner it extends up the Russian River approximately one mile, almost to the community of Duncan’s Mills.

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42 *Geology for Planning For Planning, Sonoma County, California,* California Division of Mines & Geology Special, Report 120 CDMG, 1980.

For the Sonoma Valley planning area the tsunami run up line extends along the margin of the Bay mud flats within approximately one mile of Sears Point. [43]

The *Draft GP 2020* contains policies in the Public Safety Element that, if adopted and implemented, would reduce the potential impacts associated with tsunamis and seiches. See *Impact 4.7-1 Seismic Ground Shaking*, above for a discussion of Policies **PS-1a** through **PS-1f**, **PS-1k**, and **PS-1m**. As with *Impact 4.7-1 Seismic Ground Shaking,* implementation of these policies would not eliminate the impact for the more severe seismic events that are to be expected. For small and moderate seismic events the impact of tsunamis and seiches would be generally reduced to a less-than-significant level for new development through implementation of the *Draft GP 2020* policies (including enforcement of the current UBC), but in the case of more severe seismic events such as the maximum credible earthquake, the impact would be significant.

Mitigation Measure 4.7-5 No mitigation available beyond the *Draft GP 2020* policies discussed in the impact analysis above.

Significance After Mitigation This would be a significant unavoidable impact. (**SU**)

Impact 4.7-6 Soil Erosion

Erosion can result in the loss of agricultural soil resources, as well as expose improvements to erosion-related damage such as undermining and settlement, and in severe cases can progress to landsliding. This would be a significant impact. ***(S)***

Soil erosion through sheet flow and channeled runoff causes the wearing down of land surfaces, development of gullies, the erosion of stream courses and banks, and the erosion of coastal cliffs, sand dunes, and beach areas. Wind erosion is another mechanism for denudation of lands. Causes include vegetation removal, improper farming practices, and grading for roadways and construction, improper diversion and discharge of water. Extreme cases of erosion can lead to landsliding. Erosion results in the loss of topsoil that may reduce yield of crops or forage and cause sedimentation problems downstream.

Erosion is a wide spread impact that cannot be eliminated in areas of moderate to steep topography in the San Francisco Bay Area and Sonoma County where development takes place. However, over time engineers and geologists have developed practical and effective approaches to control and minimize soil erosion in the region due to both agricultural and non-agricultural development. By applying modern erosion control practices to building location and design, and to agricultural development management of soil erosion losses have improved greatly so that they can be reduced to levels that are generally considered acceptable.

The *Draft GP 2020* contains policies and standards in the Public Safety Element that, if adopted and implemented, would reduce the potential impacts associated with erosion. See *Impact 4.7-1 Seismic Ground Shaking*, above for a discussion of Policies **PS-1a** through **PS-1c**, **PS-1e**, **PS-1f**, and **PS-1k**. For lower rainfall rates the impact of erosion would be generally reduced to a less-than-significant level for new development through the implementation of the *Draft GP 2020* policies (including enforcement of the current UBC). As with *Impact 4.7-1 Seismic Ground Shaking* though,

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[43] These areas of tsunami run up are more easily viewed on the source maps, California Division of Mines & Geology, Special Report 120, *Geology for Planning in Sonoma County*, 1980, available at PRMD offices in Santa Rosa.

implementation of these policies could not completely eliminate the impact of erosion during the more severe maximum rainfall events. In the case of unusually high rain fall over a short duration the impact would remain in some locations. Therefore, this would be a significant impact.

Mitigation Measure 4.7-6 No mitigation available beyond the *Draft GP 2020* policies discussed in the impact analysis above.

Significance After Mitigation This would be a significant unavoidable impact. (**SU**)

Impact 4.7-7 Expansive Soils

*Land uses and development consistent with the Draft GP 2020 could expose property improvements to potential adverse effects from expansive soils. Expansive soils can cause damage to improvements, especially structures such as residential buildings, small commercial buildings and pavements. This would be a less-than-significant impact. (**LTS**)*

Expansive soils contain clay minerals that greatly increase in volume when they absorb water and shrink when they dry. When light buildings such as houses and light commercial buildings are placed on expansive soils, foundations may rise each wet season and fall each dry season. Roadways, pavements, and other flat construction are also highly susceptible to damage from expansive soils. Movements may cause foundations to crack, various structural portions of the building to be distorted, and doors and windows to warp so that they do not function properly.

The adverse effects of expansive soils can be avoided through proper subsoil preparation, drainage, and foundation design. In order to design an adequate foundation, however, the condition must be recognized through appropriate soil sampling and laboratory soils testing. Expansive soils are identified through expansion tests of samples of soil or rock, or by means of the interpretation of Atterberg limit tests, a standard soils testing procedure. Procedures employed in expansive soils testing are found in many codes and regulations; Chapter 70 of the Uniform Building Code requires such soils testing.

The *Draft GP 2020* contains policies and standards in the Public Safety Element that, if adopted and implemented, would reduce the potential impacts associated with expansive soils. See *Impact 4.7-1 Seismic Ground Shaking*, above for a discussion of Policies **PS-1a** through **PS-1c**, **PS-1e**, **PS-1f**, and **PS-1k**. For new development the impact of expansive soils would be reduced to less-than-significant levels through the implementation of the *Draft GP 2020* policies (including enforcement of the current UBC).

Mitigation Measure 4.7-7 None required.

Impact 4.7-8 Septic Suitability of Soils

*The construction of septic tanks or alternative wastewater disposal systems on soils incapable of adequately supporting such systems can cause damage to improvements and can adversely impact surface and ground water resources. Policies and programs contained in the Draft GP 2020 would reduce such impacts to a less-than-significant level. (**LTS**)*

Soils with limitation on their suitability for septic systems are described by categories designated as low, moderate, or severe. The determinants for this rating are based on slope, soil depth, permeability, depth to seasonal high water table, and whether or not the soil is subject to inundation or ponding. Generally soils such as those with USCS Classifications GW, GP, and GM have high transmisivity and those soils classified as CH have very low transmisivity. Soils with either extreme range of transmisivity are problematic for septic leach fields and special designs or mitigation is needed in such areas.

The adverse effects of the impacts associated with septic suitability of soils can be avoided through proper in-situ soil percolation testing and septic system design, careful construction monitoring, as well as post construction system monitoring and maintenance. In order to design an adequate septic system, however, the site conditions must be recognized through appropriate field-testing during specified times of the year, as required by the PRMD. Procedures employed in soils testing and percolation testing are found in the present County regulations. By applying appropriate field testing and using current practices for septic system location and design, construction monitoring and post construction monitoring and maintenance, adverse impacts due to septic suitability of soils can be reduced to levels that are acceptable.

The *Draft GP 2020* contains many policies and standards in the Public Safety Element that would reduce the potential impacts associated with the septic suitability of soils. See *Impact 4.7-1 Seismic Ground Shaking*, above for a discussion of Policies **PS-1a** through **PS-1c**, and **PS-1m**. For new development the impact of the septic suitability of soils would generally be reduced to less-than-significant levels through the implementation of the *Draft GP 2020* policies (including enforcement of the current UBC).

For the purposes of this analysis, the impact is considered to be reduced to a less-than-significant level if all currently available geotechnical engineering and construction practices are implemented. By applying such standards to future projects in the county, the impact of septic suitability of soils can be essentially eliminated. Because the policies discussed above would considerably reduce potential septic suitability of soils impacts, this would be a less-than-significant impact.

Mitigation Measure 4.7-8 None required.

MINERAL RESOURCES

Impact 4.7-9 Mineral Resources

Land uses and development consistent with the Draft GP 2020 could result in the loss of the availability of a known mineral resource. This would be a less-than-significant impact. ***(LTS)***

A policy that results in the loss of availability of a known mineral resource that would be of value to the region and residents of the state, or that results in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan would be considered to be a policy with a significant impact according to the significance criteria.

In Sonoma County sand, gravel, crushed rock, and building stone are considered the most valuable mineral resources, which are actively mined in a number of areas of the county. Mining of these materials has taken place in many different geologic settings of the County including highland areas with steep terrain, the Russian River, and parts of other major streams. Recent aggregate mining has been located along the middle and upper reaches of the Russian River, within the channel and on adjacent alluvial terraces. Presently approximately 50 percent of the high quality alluvial aggregates are being quarried from terrace deposits. Terrace mining of aggregates is currently being phased out, while at the same time, in-stream operations are limited by regulations of the depth of skimming and by recent listings of endangered species.

Mining activities would continue with the *Draft GP 2020*. Mineral resources are discussed in the Open Space and Resource Conservation Element of the *Draft GP 2020*. This element builds on the County's *Aggregate Resources Management Plan* (ARM Plan).[44] Policy **OSRC-13a** is to consider land designated in the ARM Plan as priority sites for aggregate production and mineral extraction and to review requests for additional designations for conformity with the *GP 2020* and the ARM Plan. Policy **OSRC-13b** directs the County when approving mining permits to review the individual projects for environmental impacts and land use conflicts. In order to avoid incompatible land uses adjacent to potential mineral resource exaction areas Policy **OSRC-13c** requires the review of projects which are on or near sites designated Mineral Resources in the ARM Plan for compatibility with future mineral extraction.

Implementation of the *Draft GP 2020* policies would avoid significant impacts from the loss of availability of potentially valuable mineral resources.

Mitigation Measure 4.7-9 None required.

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[44] *Sonoma County Aggregate Resources Management Plan and Environmental Impact report*, EIP & Associates, November 1994.