

4.3 GEOLOGY, SOILS, AND SEISMICITY

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4.3 GEOLOGY, SOILS, AND SEISMICITY

This chapter provides information regarding potential impacts related to geological hazards, soils, and seismicity for alternative sites being considered for the Seasonal Storage Project (SSP). To provide a basis for this evaluation, the Setting Section describes the basic geological setting in the SSP study area, which includes the Cotati Valley – Santa Rosa Plain area of Sonoma County, and for each of the alternative seasonal storage sites. A discussion of the regulatory framework is also provided.

IMPACTS EVALUATED IN OTHER SECTIONS

The following subjects are related to the Geology, Soils, and Seismicity Section, but are evaluated in other sections of this document:

- Topographic Alterations. Potential visual impacts that would result from topographic alterations are discussed in Section 4.13, Visual Resources.
- Flooding Due to Embankment Failure. Potential impacts from embankment failure and inundation are discussed in Section 4.7, Public Health and Safety.
- Soil Erosion. Sedimentation of waterways is discussed in Section 4.6, Surface Water Quality. Streambank erosion is discussed in Section 4.4, Surface Water Hydrology. Construction-related erosion is discussed in this Geology Section.

SETTING

As the primary basis for the evaluation of hazards related to geology, soils, and seismicity, this section presents and discusses the geologic setting, faults, seismicity, soil characteristics, geotechnical hazards, and applicable laws and regulations previously presented in the Environmental Impact Report (EIR), but modified to focus on specific areas of the SSP. Geotechnical hazards that may affect SSP construction or operation are discussed; these include exposure to ground shaking, fault rupture, induced seismicity, landslides and slope instability, seismically induced slope instability and ground cracking, liquefaction and lateral spreading, expansive or corrosive soils, and similar potential geologic hazards that may affect SSP construction or operation.

Geology

The SSP sites are located within the California Coast Ranges physiographic province, which is situated along the complex boundary margin between two tectonic plates: the North American Plate and the Pacific Plate. Geologic conditions in the region have been and continue to be primarily controlled by the interaction of these two massive blocks of the earth's crust. Under the current tectonic regime, the Pacific Plate moves northwestward relative to the North American Plate at a rate of about 4 centimeters per year (WGCEP 2003). Most of this movement is accommodated by major faults associated with the San Andreas fault system. Relative motion between the two plates is predominantly lateral (strike-slip). An increase in convergent motion along the plate boundary within the past few

million years has resulted in the formation of mountain ranges and structural valleys of the Coast Ranges province.

The Cotati Valley – Santa Rosa Plain, where the SSP sites are located, forms an elongate, northwest-trending basin that is in part bounded by northwest-trending faults associated with the San Andreas fault system. Low hills composed of Late Miocene to Pliocene-age (approximately 12 to 1.6 million years old) sedimentary rocks form the arcuate (curved) western rim of the valley. The relatively linear east side of the valley is bordered by the higher ranges of the Sonoma Mountains, which are composed of Late Miocene to Pliocene-age volcanic and sedimentary rocks. Figure 4.3-1 presents a geologic map of the region.

Core or basement rocks underlying the region are composed of variably altered and highly deformed (folded, fractured, and faulted) sedimentary and volcanic rocks belonging to the Jurassic/Cretaceous-age (approximately 206 to 65 million years old) Franciscan Complex. In the vicinity of the Cotati Valley – Santa Rosa Plain, rocks of the Franciscan Complex are overlain by much younger rocks, including Late Miocene to Pliocene-age sedimentary rocks of the Wilson Grove and Petaluma formations and volcanic rocks belonging to a geologic unit known as the Sonoma Volcanics. The Wilson Grove formation, mapped within the low coastal hills west of the Cotati Valley and southern Santa Rosa Plain, was formed in a shallow marine environment and consists primarily of sandstone with lesser amounts of siltstone, claystone, gravelly conglomerate, and tuff (Wagner and Bortugno 1982). The Petaluma formation, comprised primarily of non-marine claystone, siltstone, and mudstone, is mapped on the lower central and western slopes of the Sonoma Mountains and around the margins of the Cotati Valley.

A Late Miocene to Pliocene episode of volcanic activity within the region resulted in formation of the Sonoma Volcanics, which are composed primarily of mafic (basaltic to andesitic) flow and pyroclastic deposits. Since their formation, rocks of the Sonoma Volcanics have been folded and intensely faulted as a result of regional tectonic stresses. Within the project area, the Sonoma Volcanics are mapped primarily within the Sonoma Mountains.

The northern end of the Cotati Valley and much of the Santa Rosa Plain are underlain by the Pleistocene-age (approximately 1.6 million to 11,000 years old) Glen Ellen and Huichica formations. These formations, mapped together in most areas, include fluvial (river- or stream-borne) deposits of gravel, sand, silt, and clay with mudstone and minor interbedded volcanic tuffs (Wagner and Bortugno 1982; Huffman et al. 1980). Holocene-age (less than 11,000 years old) alluvial deposits, consisting of unconsolidated gravel, sand, silt, and clay are also mapped within valley bottoms and the Santa Rosa Plain, particularly adjacent to rivers, creeks, streams, and other waterways.

Faults

At the latitude of Sonoma County, the San Andreas fault system is comprised of several major faults, including the San Andreas, Rodgers Creek, Maacama-Garberville, and Concord-Green Valley faults. In addition to these, many other named and unnamed faults within the region accommodate relative motion between major faults and relieve compressional stresses that also act along the plate boundary. Figure 4.3-2 shows mapped faults within the region.

Fault Classification and Zoning

Faults within the study area are classified as Historic, Holocene, Late Quaternary, Quaternary, and Pre-Quaternary according to the age of most recent movement (Jennings, 1994). These classifications are described as follows:

- Historic: faults on which surface displacement has occurred within the past 200 years;
- Holocene: shows evidence of fault displacement within the past 11,000 years, but without historic record;
- Late Quaternary: shows evidence of fault displacement within the past 700,000 years, but may be younger due to a lack of overlying deposits that enable more accurate age estimates;
- Quaternary: shows evidence of displacement sometime during the past 1.6 million years; and
- Pre-Quaternary: without recognized displacement during the past 1.6 million years.

The California Geological Survey (CGS) describes faults of Quaternary age using one of two activity classes, “active” and “potentially active” (CGS, 1992). “Active” describes Historic and Holocene faults that have had surface displacement within about the last 11,000 years. “Potentially active” describes faults showing evidence of surface displacement during pre-Holocene Quaternary time (between about 1.6 million and 11,000 years ago). Pre-Quaternary faults are classified as “inactive.” This classification is not meant to imply that inactive fault traces will not rupture; only that they have not been shown to have ruptured within the past 1.6 million years and that the probability of fault rupture is low.

Because of the relatively long design life and critical nature of most dams and other impoundment structures, the California Division of Safety of Dams (DSOD) has established stricter standards for characterizing fault activity than those set by the CGS (Fraser, 2001). Faults that have ruptured within the last 35,000 years are considered “active” by the DSOD and must be accounted for in dam analysis and design. In accordance with DSOD guidelines, fault inactivity is demonstrated by a confidently located fault trace that is consistently overlain by unbroken geologic materials older than 35,000 years. Faults known to be Quaternary active, and for

which displacement history is not known well enough to determine activity or inactivity, are classified by the DSOD as “conditionally active.”

The Alquist-Priolo Special Studies Zones Act, passed in 1972, requires the establishment of “earthquake fault zones” (EFZs, formerly known as “special studies zones”) along known active faults in California (CGS 1992). Strict regulations on development within these zones are enforced to reduce the potential for damage due to fault displacement. In order to qualify for EFZ status, faults must be “sufficiently active” and “well-defined.” As a result, only faults or portions of faults with a relatively high potential for ground rupture are zoned, while other faults, which may meet only one of the “sufficiently active” and “well-defined” criteria, are not zoned. The potential for fault rupture, therefore, is not limited solely to faults or portions of faults delineated as EFZs.

In the vicinity of the five SSP alternatives, the Rodgers Creek fault has an Alquist-Priolo EFZs associated with it (CGS 1983, 1993). However, none of the SSP alternatives is located closer than approximately 5 miles from an EFZ.

Regional Faults – General

Active and potentially-active faults within the region have been mapped and documented by a number of government agencies. The U.S. Geological Survey (USGS) and CGS have published numerous maps and reports on faults of various types, ages, and levels of activity. General agreement between sources was found for the location and activity of faults listed in Table 4.3-1, which presents information on major active and potentially active faults located within approximately 30 miles of the SSP alternatives.

TABLE 4.3-1
Active and Potentially Active Faults in the SSP Vicinity

Fault	Approximate Distance^a (miles)	Age of Most Recent Displacement^b	Slip Type^c	Slip Rate^{c, d} (mm/year)	Maximum Moment Magnitude^{c, e}
Rodgers Creek	6	Holocene	Strike Slip	9 ± 2	7.0
Healdsburg	12	Quaternary	Strike Slip	n/a ^f	n/a ^f
Maacama-Garberville	13	Holocene	Strike Slip	9 ± 2	7.5
San Andreas	14	Historic	Strike Slip	24 ± 3	7.9
West Napa	22	Holocene	Strike Slip	1 ± 1	6.5
Point Reyes	24	Quaternary	Reverse	0.3 ± 0.2	7.0

TABLE 4.3-1
Active and Potentially Active Faults in the SSP Vicinity

Fault	Approximate Distance^a (miles)	Age of Most Recent Displacement^b	Slip Type^c	Slip Rate^{c,d} (mm/year)	Maximum Moment Magnitude^{c,e}
Collayomi	26	Late Quaternary	Strike Slip	0.6 ± 0.3	6.5
Hayward	28	Historic	Strike Slip	9 ± 2	6.9
Hunting Creek-Berryessa	30	Holocene	Strike Slip	6 ± 3	7.1

Notes:

- a. Measured horizontally from mapped fault traces to the nearest SSP site alternative.
- b. From Jennings, 1994.
- c. From CGS 2003 and WGCEP 2003.
- d. The average, long-term rate of movement along the fault.
- e. The maximum moment magnitude event is based on empirical relationships between rupture area and earthquake magnitude. It is considered a rational and believable event that can be supported by the geologic evidence of past movement and the recorded seismic history of the region.
- f. n/a: not available

In addition to the major active and potentially active faults shown in Table 4.3-1, a number of named, lesser faults are also mapped within the region. These include the Quaternary-age Tolay, Americano Creek, Bloomfield, and Dunham Faults. Located within the Petaluma Valley and in the hills west of the Cotati Valley, the Tolay, Americano Creek, Bloomfield, and Dunham Faults are mapped approximately 4 to 7 miles southwest of the Kelly Farm, Brown Farm, and Alpha Farm sites. These faults are relatively small, exhibit little or no evidence of geologically recent activity, and are mapped at least several miles from the SSP alternative sites. As a result, potential seismic hazards associated with these minor faults are considered negligible in comparison with those associated with the major faults shown in Table 4.3-1.

Regional Faults for Primary Consideration

Due to their size, proximity, and/or apparent level of activity, regional faults with the greatest potential to affect SSP facilities include the Rodgers Creek, Healdsburg, Maacama, and San Andreas faults. These fault structures are further described in the following sections.

Rodgers Creek Fault

Located in the foothills along the eastern margins of the Petaluma Valley, Cotati Valley, and Santa Rosa Plain, the Rodgers Creek fault zone is the most significant geologic feature in the project area. Designated as the northernmost segment of the active Hayward-Rodgers Creek fault system, the northwest-trending Rodgers Creek fault extends approximately 39 miles from San Pablo Bay to an area just south of

Healdsburg (WGCEP 2003). Movement along the fault is primarily right-lateral strike slip. Regional geologic and seismic evidence suggests that movement along the Rodgers Creek fault is transferred to the Maacama fault north of Santa Rosa in an approximately 4-mile wide “stepover” region between the two faults.

Although the Rodgers Creek fault has not produced a major, surface-rupturing earthquake during historical time, the most recent large event on the fault is believed to have occurred sometime between 1670 and 1776. Based on available paleoseismic data, major surface-rupturing events on the Rodgers Creek fault are believed to have recurrence intervals in the range of approximately 200 to 300 years (WGCEP 2003). The fault is believed to be capable of generating earthquakes of approximately Magnitude 7.

Healdsburg Fault

The Healdsburg fault zone begins at the northern end of the Rodgers Creek fault and continues along a similar trend for approximately 10 to 15 miles through the City of Healdsburg and along the western margin of the Alexander Valley. Generally considered to be a northwestern splay of the Rodgers Creek fault, the Healdsburg fault is often described along with the Rodgers Creek fault as part of the Rodgers Creek – Healdsburg fault zone. However, evidence of recent fault activity is less pronounced along the Healdsburg portion of the Rodgers Creek – Healdsburg fault zone.

At present, no traces of the Healdsburg fault are considered active by the CGS. Traces of the Healdsburg fault mapped by Jennings (1994) are shown as potentially active Quaternary faults. However, trenching investigations for subdivisions performed within the past decade and a half by various consultants have exposed traces of the Healdsburg fault that display features that are interpreted to indicate Holocene activity (Geomatrix 2001). However, due to the less-pronounced evidence of recent activity and the apparent transfer of movement across the “stepover” region between the Rodgers Creek and Maacama faults, the potential for large displacements along the Healdsburg fault appears to be significantly less than for portions of the Rodgers Creek fault farther to the south.

Maacama Fault

The Maacama fault zone extends in a northwesterly direction from the southern end of the Mayacamas Mountains and has been interpreted as the northern continuation of the Hayward-Rodgers Creek fault system. From its southern end east of Healdsburg, the Maacama fault extends approximately 115 miles to the steep coastal mountains south of Garberville. As with the Hayward-Rodgers Creek fault system, movement along the Maacama fault is primarily right-lateral strike-slip.

Due to the presence of youthful geomorphic features, elevated rates of relatively low magnitude seismicity and contemporary creep, the Maacama fault is considered active by the CGS. The Maacama fault has not produced a major, surface-rupturing

earthquake during historical time; however, recent paleoseismic studies of fault traces near the City of Ukiah indicate the most recent large event on the fault occurred sometime between 1520 and 1660 (Sickler et al. 2005). Rupture of the entire length of the Maacama fault zone in a single event may produce an earthquake as large as approximately Magnitude 7.5 (CGS 2003).

San Andreas Fault

The San Andreas fault is the largest and most active fault within the broader San Andreas fault system. Extending for approximately 600 miles from Mexico to the north coast of California, the fault accommodates predominantly right-lateral movement between the Pacific and North American crustal plates. In northern California, the San Andreas fault is divided into four segments (WGCEP 2003) with a total length of approximately 300 miles. The segment nearest the study area is the North Coast segment, which extends approximately 120 miles from an area offshore of the Golden Gate to Point Arena, approximately 70 miles northwest of Santa Rosa. The San Andreas fault has produced numerous large, historical earthquakes, including the 1906 San Francisco earthquake, which ruptured all four-fault segments in a single Magnitude 7.9 event. Paleoseismic studies indicate return intervals of several hundred years (ranging from approximately 180 to 370 years) for major earthquakes on the North Coast segment of the fault. Evidence from other segments of the fault suggests that ruptures along the North Coast segment may occur as part of multi-segment, “1906-type” earthquakes (WGCEP 2003). Individual segments of the San Andreas fault are also considered capable of producing large earthquakes of Magnitude 6.7 or greater during the intervening periods between major, multi-segment events.

Local Faults

In addition to the regional faults identified above, numerous unnamed and relatively minor potentially active or inactive faults have been mapped throughout the region. These faults are shown on Figure 4.3-2. Compared with the seismic risk associated with major faults identified in Table 4.3-1, the regional seismic risk associated with these unnamed minor faults is relatively low. However, seismic risks associated with minor faults may be locally significant, particularly in situations where faults are located within or immediately adjacent to SSP alternatives. Descriptions of minor faults that could affect the SSP sites are included below in the section titled “Geologic Soils, and Seismic Conditions at the SSP Sites.”

Seismicity

Historical Seismicity

The five SSP alternatives are located in one of the most seismically active areas in the U.S. Since 1800, numerous moderate to large earthquakes have occurred in the region, the largest being the Magnitude 7.9, 1906 San Francisco Earthquake.

Significant historical earthquakes affecting the project area are summarized in Table 4.3-2.

TABLE 4.3-2
Significant Historical Earthquakes Affecting the Project Area

Date	Locality (Causative Fault, if known)	Estimated Magnitude^a	Approximate Distance to Nearest SSP Site^b (miles)
09/03/2000	Yountville	5.2	20
10/17/1989	Loma Prieta (San Andreas ^c)	6.9	95
10/01/1969	Santa Rosa (Rodgers Creek)	5.6	7
10/01/1969	Santa Rosa (Rodgers Creek)	5.7	7
04/18/1906	San Francisco (San Andreas)	7.9	14
10/12/1899	Santa Rosa	4.0 – 5.0	< 10
04/15/1898	Mendocino (San Andreas?)	6.8	75
03/30/1898	Mare Island	6.2	25
08/09/1893	Santa Rosa	5.1	< 10
04/21/1892	Winters	6.2	40
04/19/1892	Vacaville	6.4	40
10/11/1891	Napa – Sonoma	5.5	25
02/29/1888	Petaluma	4.0 – 5.0	10
10/21/1868	East San Francisco Bay (Hayward)	6.8	50
10/08/1865	Santa Cruz Mountains	6.5	95
03/08/1865	Santa Rosa	4.0 – 5.0	< 10
06/--/1838	San Francisco Peninsula	6.8	50

Notes:

- a. Magnitude is moment magnitude (MW) for earthquakes after 1911. For earthquakes before 1911, magnitude is estimated from observed shaking intensity.
- b. For earthquakes after 1911, distances are estimated between nearest SSP alternative site and reported extent of fault rupture or epicenter. For earthquakes before 1911, distances are estimated from location of causative fault. If causative fault is unknown, distance is estimated from area of highest reported shaking intensity. Because the SSP alternatives sites are so close to one another and are underlain by similar geologic materials, all of the SSP alternatives were likely affected to a similar degree by each of these earthquakes.
- c. The Loma Prieta earthquake is believed to have occurred on a previously unknown fault located adjacent and roughly parallel to the San Andreas Fault.
- d. Information compiled from Cloud, et al. 1970, Ellsworth 1990 and WGCEP 2003

In the latter half of the 1800's, eight moderate to large earthquakes caused significant damage to buildings and other structures within the Santa Rosa Area. Three of these earthquakes, in 1868, 1891, and 1898 caused widespread structural and architectural damage, particularly to unreinforced masonry structures in the City of Santa Rosa (City). Earthquakes in 1865, 1892, 1893, and 1899 caused localized minor damage

including broken chimneys and cracked plaster within the City (Cloud et al. 1970; Parsons 2003).

Structures and other facilities within the City and surrounding communities suffered widespread, severe damage during the 1906 San Francisco Earthquake. Due to underlying bedrock conditions and the presence of deep alluvial sediments, ground shaking during the earthquake was more severe within the Cotati Valley – Santa Rosa Plain than in surrounding upland areas. As a result, on a per capita basis, loss of life and earthquake damage in Santa Rosa was greater than or equal to that within the City of San Francisco.

Two earthquakes generated by the Rodgers Creek fault on October 1, 1969, caused several million dollars of damage in Santa Rosa and surrounding communities. Numerous water system pipeline breaks occurred in the eastern part of the City. More recently, the 1989 Loma Prieta earthquake was widely felt within the study area, but caused very little damage due to the distance of the study area from the earthquake source.

Numerous instances of liquefaction-related phenomena and other forms of ground failure in the region were reported following the 1906 and 1969 earthquakes. In 1906, ground failures occurred predominantly in low-lying marshy areas adjacent to the Laguna de Santa Rosa and within the Russian River floodplain. In 1969, ground cracking was common along the banks of Matanzas and Santa Rosa Creeks and near traces of the Rodgers Creek fault within and near the City (Youd and Hoose 1978).

Seismic Potential

A 2003 estimate made by the WGCEP gave a 62 percent probability for one or more Magnitude 6.7 or larger earthquakes to occur within the San Francisco Bay Area in the 30-year period between 2002 and 2031. The potential for one or more smaller (Magnitude 6.0 to 6.7) earthquakes to occur within the region over the same time period was estimated by the WGCEP to be greater than 80 percent. Based on these estimates and historical levels of seismicity, it is likely that proposed Project facilities will experience periodic minor to moderate earthquakes and potentially a major earthquake (Magnitude 7.0 or greater) during their service lives.

The greatest potential sources of strong seismic ground shaking within the region are the Rodgers Creek - Healdsburg fault, the Maacama fault, and the North Coast segment of the San Andreas fault. The WGCEP's 2003 estimate included a 17 percent probability for one or more Magnitude 6.7 or larger earthquakes to occur along the Rodgers Creek fault and an 11 percent probability for one or more Magnitude 6.7 or larger earthquakes to occur along the North Coast segment of the San Andreas fault during the 30-year period between 2002 and 2031. The Maacama fault was outside the WGCEP study area. Large earthquakes on any of these faults would cause very strong to violent ground shaking and high ground accelerations within the project area. Large earthquakes on other nearby active and potentially

active faults listed in Table 4.3-1 may also cause significant ground shaking within the project area.

Strong seismic ground shaking takes the form of complex vibratory motion in both the horizontal and vertical directions. The amplitude, duration, and frequency content of ground shaking experienced at a particular site during an individual earthquake are highly dependent on several factors, including:

- Distance between the area fault rupture and the site;
- Magnitude of the earthquake;
- Characteristics of the fault rupture;
- Topographic features;
- Subsurface soil and bedrock structures; and
- Types, distributions, and dynamic properties of soils beneath the site.

Because seismic waves weaken with distance from their source, sites located close to the zone of fault rupture typically experience stronger motions than similar sites located farther away. Similarly, because large magnitude earthquakes release a greater amount of seismic energy, they typically produce stronger ground shaking than small-magnitude events at comparable distances. As observed within the Cotati Valley – Santa Rosa Plain during the 1906 San Francisco earthquake, topographic features and/or subsurface bedrock structures may also affect ground motions. Basin and ridgeline features may focus seismic energy within a particular area, resulting in locally stronger ground motions. Site soils also have the capability to amplify or dampen ground motions within particular frequency ranges. In general, soft and/or deep soils tend to amplify lower frequency (longer period) motions, while stiff shallow soils tend to amplify higher frequency (shorter period) motions.

Soils

Soil surveys of the region have been prepared and maintained by the U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service). The NRCS soil survey for Sonoma County (Miller 1972), identifies two major soil groups within Sonoma County. The first group includes “lowland” soils primarily developed on unconsolidated geologic deposits in basins and on tidal flats, floodplains, terraces, and alluvial fans. The second group includes “upland” soils primarily developed on bedrock or on bedrock thinly overlain by unconsolidated material on high terraces and in foothill and mountainous areas.

Soil Associations

Within Sonoma County, soils belonging to the “lowland” group have been further divided into five soil associations and soils belonging to the “upland” group have been further divided into 10 soil associations. Soil associations are described by the NRCS as landscapes that have distinctive proportional patterns of soils. Of the 15

soil associations mapped within Sonoma County, two are mapped in the vicinity of the SSP alternatives sites. Table 4.3-3 summarizes the general characteristics of these associations and identifies areas where they are primarily located.

TABLE 4.3-3
Soil Associations Within the Project Vicinity^a

Association	Group	Locality	Description
Clear Lake-Reyes	Lowland	West side of Petaluma Valley, south end of Cotati Valley, and western edge of Santa Rosa plain, adjacent to the Laguna de Santa Rosa	Poorly drained, nearly level to gently sloping clays to clay loams, in basins and on tidal flats. Used mainly for irrigated pasture.
Huichica-Wright-Zamora	Lowland	Northern end of Cotati Valley and Santa Rosa Plain	Somewhat poorly drained to well drained, nearly level to strongly sloping loams to silty clay loams, on low bench terraces and alluvial fans. Used mainly for pasture and hay.

Soil Types

Each of the soil associations described above includes a variety of individual soil types or series. Soil series are further subdivided into mapping units based on the slope of the ground surface, depth of the soil profile, subsurface drainage, and the presence of seasonal surface water. Based on information collected from the NRCS soil survey for Sonoma County (Miller 1972) and online national soils database (USDA 2006), two soil types are mapped within or in the vicinity of the five alternative storage sites. Table 4.3-4 summarizes typical, engineering-related properties of the soils.

TABLE 4.3-4
Soil Types Mapped in the Vicinity of SSP Alternatives

Soil Type	Mapped within or near Site(s)	Permeability	Shrink-Swell Potential	Corrosion Potential ^a
Clear Lake Series	Kelly Farm, Brown Farm, Alpha Farm	Slow	Moderate to High	High
Wright Series	Kelly Farm, Brown Farm, Alpha Farm	Very Slow	Low to High	High

Sources: Miller 1972 and USDA 2006

Notes: ^a Corrosivity to uncoated steel

Geotechnical Hazards

Landsliding and Slope Instability

Landslides occur when stresses within a slope exceed the available strength of soil materials underlying the slope. In general, degree of slope is the most important factor contributing to landslide hazard, with steep slopes being more susceptible to failure than shallow slopes. Zones of weakness and the presence and movement of water can also influence slope stability.

Because of generally flat to gently rolling terrain within the Cotati Valley – Santa Rosa Plain, landslides, earthflows, and debris flows are not mapped within or in the vicinity of the alternative storage sites. However, localized areas of steep terrain, including incised stream banks and man-made cut and fill slopes, may be subject to relatively minor landsliding and slope instability hazards. The ground surface at the SSP alternative sites is generally flat to gently sloping and existing landslides or unstable slopes have not been identified at any of the sites. Overall, the potential for landsliding and slope instability hazards at the three City farms is considered very low.

Fault Surface Rupture

A fault is a fracture or zone of fractures in rock along which displacement has occurred on one side relative to the other. Fault displacement, or rupture, occurs in response to stresses in the earth's crust. Fault rupture may occur suddenly and rapidly, releasing strain energy in the form of earthquake-producing seismic waves. Fault rupture may also occur slowly over time, without producing seismic waves, through a phenomenon known as fault creep.

The potential for fault surface rupture exists where an active or potentially active fault is exposed at or near the surface of the earth. However, none of the SSP alternatives is located within an "Alquist Priolo" earthquake fault zone or overlying any mapped fault traces. As a result, the potential for fault surface rupture at the City farms is considered very low.

Strong Seismic Ground Shaking

Based on the activity of major regional seismic sources, it is likely that all of the SSP alternative sites would be exposed to strong seismic ground shaking as a result of a large earthquake during the lifetime of the Project. As a result, the potential for strong seismic ground shaking at the five alternative sites is considered high. The most significant sources of potential strong seismic ground shaking within the study area are the Rodgers Creek – Healdsburg, San Andreas, and Maacama faults. Each of these faults is active and capable of generating earthquakes on the order of Magnitude 7.0 or larger.

Probabilistic seismic hazard models are used to estimate potential ground motions in terms of the probability that a particular level of ground motion, such as peak

horizontal ground acceleration (PHGA), will be exceeded over a given time period. Probabilistic estimates of seismic ground motion are based on the activity, structural characteristics, and relative location of potential seismic sources that may produce strong ground shaking at a given site. Based on probabilistic seismic hazard models published by the USGS (2003), PHGAs are commonly estimated based on 10 percent and 2 percent probabilities of being exceeded in a 50-year period. Recurrence intervals associated with these two levels of probability are 475 years and 2,475 years, respectively. Typically, PHGA is represented in terms of g, where 1g is equal to the acceleration due to the force of gravity.

Estimated planning-level PHGAs for the SSP alternative sites are 0.42g and 0.65g for 10 percent and 2 percent in 50-year probabilities of exceedence, respectively. Planning-level PHGA values are the same for all the sites because of their proximity to one another and similar distances from nearby seismic sources. Planning-level PHGA values are based on published attenuation relationships for “firm rock” sites, which assume a shear wave velocity of about 2,500 feet per second in soil/rock materials underlying the site. Design-level ground motions may be higher or lower depending on seismic design criteria, site response characteristics and other factors, as discussed above.

Liquefaction and Lateral Spreading

Liquefaction can occur when relatively loose, saturated, cohesionless soil is subjected to undrained, cyclic loading, such as that generated by earthquakes. Excess pore pressures developed during cyclic loading cause a decrease in the effective stresses between individual soil particles and a corresponding decrease in the internal shear strength of the soil. As effective stresses approach zero, the soil-water mixture begins to behave as a fluid. Soils particularly susceptible to liquefaction generally include very loose to medium dense sand, silty sand, and clayey sand. Gravels and low plasticity silt materials may also be susceptible to liquefaction.

Potential consequences of liquefaction include loss of soil strength and bearing capacity, post-liquefaction settlement, sand boils, and lateral spreading. Lateral spreading may occur where a relatively continuous deposit of liquefied soil underlies sloping ground or is located adjacent to a free face, such as a riverbank or shoreline slope. Under such conditions, liquefied materials tend to flow downslope (or towards the free face), carrying overlying soil and structures with them.

A map showing areas susceptible to liquefaction within the SSP project area is presented on Figure 4.3-3. Based on large-scale mapping of geologic materials and groundwater conditions, the map shows the Kelly Farm and Alpha Farm sites to be located in areas with very low susceptibility to liquefaction. The map shows the northern portion of the Brown Farm site to be located in an area with moderate liquefaction susceptibility and the southern portion of the Brown Farm site to be located in an area with very low liquefaction susceptibility.

Results of preliminary, site-specific subsurface investigations and liquefaction analyses indicate low to very low potential for widespread liquefaction at the SSP alternatives sites. Isolated layers and lenses of potentially liquefiable soil appear to underlie portions of the sites. However, where encountered, these layers are typically less than 5 feet thick, confined by overlying deposits of non-liquefiable soil, and appear to be relatively discontinuous. As a result, the potential for liquefaction-related loss of bearing capacity, sand boils, and lateral spreading within these areas is generally considered to be very low.

Although regional mapping suggests that the Brown Farm site is generally more susceptible to liquefaction than the Kelly Farm and Alpha Farm sites, the results of preliminary, site-specific studies indicate liquefaction and liquefaction-related hazards exist to a similar degree at all three sites. Upland areas at the sites generally appear to have very low susceptibility to liquefaction, while existing drainage swales and stream channels appear to have low to moderate susceptibility to liquefaction. Overall, the potential for liquefaction and liquefaction-related hazards at the three sites are considered low. Although some potential for localized lateral spreading may exist along the banks of stream channels that traverse the sites, the overall potential for lateral spreading at the three sites is considered low.

Seismically-Induced Slope Instability and Ground Cracking

Strong earthquakes often cause landslides, particularly in areas already susceptible to landslides due to the presence of steep slopes and/or existing landslide deposits. Failure of steep slopes, collapse of natural-stream banks, and reactivation of existing landslides may occur widely during a major earthquake. Ground cracking is a secondary effect of seismic ground shaking and appears as fissures or cracks in the ground that open in response to strong shaking. Ground cracking typically occurs along the crests of relatively steep ridges. The exact mechanism that causes earthquake-induced ground cracks is not clear; however, these fissures could severely damage overlying structures during an earthquake.

Localized areas of steep terrain, including incised stream banks and man-made cut and fill slopes may be subject to instability during a major earthquake. However, the overall potential for seismically-induced slope instability and ground cracking at the alternative sites is considered very low.

Soft, Loose, and/or Compressible Soils

Soft, loose and/or compressible soils are typically found in active or recently (in geologic terms) active depositional environments and areas that have been disturbed by human activity. Due to their physical and/or engineering characteristics, these soils present unique challenges for design and construction of SSP facilities. Soft, loose, and/or compressible soils typically present adverse conditions for earthwork and other construction activities and development of support for overlying structures. The presence of such materials may also affect the potential for other geologic hazards such as landsliding, slope instability, and liquefaction.

Results of preliminary, site-specific subsurface investigations indicate the presence of soft, loose, and/or compressible soils at all of the SSP alternatives sites. Although most clayey soils encountered at the sites are firm to stiff in consistency, occasional zones of soft clay were encountered in some borings. Near-surface clayey soils encountered at all the sites also become soft to very soft when saturated, particularly where they have been disturbed by agricultural activities. As a result, the overall potential for soft, loose, and/or compressible soils is considered moderate.

Expansive and Corrosive Soils

Shrink-swell or expansive soil behavior is a condition in which clayey soil reacts to changes in moisture content by expanding or contracting. Swelling occurs when water infiltrates between and within clay particles, causing them to separate. Shrinkage occurs as water leaves the soil, allowing the clay particles to come more closely together. Soil that has a high expansion potential exhibits relatively large volume changes, while soil that has a low expansion potential exhibits relatively small volume changes in response to variations in moisture content. Corrosive soils can corrode and degrade structural integrity of metals unless measures are taken to protect facilities from corrosion.

Results of preliminary, site-specific subsurface investigations indicate the presence of expansive and corrosive soils at all of the alternative storage sites. Near-surface soils encountered at the sites generally have high clay contents and most have moderate to high expansion potential and pose a high corrosion hazard for unprotected steel facilities. As a result, the overall potential for expansive soils at the sites is considered moderate, and the potential for corrosive soils is considered high.

Groundwater Movement through Soil and Rock

Groundwater travels both horizontally and vertically through pore spaces in saturated and unsaturated soils and through fractures in bedrock formations. The rate of groundwater movement through a soil or bedrock formation is governed by the pressure differential, or gradient under which the flow is driven and the permeability of soil or rock materials within the formation.

The permeability of a soil or rock formation is dependent on the size and continuity of its pore spaces and fractures. In general, sandy and gravelly soils and highly fractured bedrock formations are far more permeable than silty and clayey soils and unfractured bedrock formations. Typical permeabilities of natural soils, ranging from coarse gravel to high plasticity clay, may vary by seven or more orders of magnitude. As a result, localized seepage through a relatively small seam of sand or gravel may far exceed the amount of seepage through a large deposit of clay. Similarly, in bedrock materials, seepage through fractures and discontinuities may greatly exceed seepage through surrounding materials.

Based on the results of preliminary, site-specific subsurface investigations, near-surface soils at the Kelly Farm, Brown Farm, and Alpha Farm sites consist primarily

of relatively low permeability clay. However, occasional zones of clayey sand and gravel were encountered in some borings. Where encountered, these zones of more permeable material appear to be isolated and generally discontinuous. As a result, the overall potential for permeable soil or rock at the three sites is considered low.

Regulatory Framework

This section identifies State and local laws and regulations related to geology, soils, or seismicity in the SSP study area.

Federal Clean Water Act

The federal Clean Water Act (Federal Water Pollution Control Act 1948) regulates the discharge of stormwater from construction sites. Construction activities include clearing, grading, or excavation that results in soil disturbance of at least one acres of total land area disturbance. Construction activities that result in soil disturbance of more than one acre require a permit. Therefore, the owner of the land where construction would occur is responsible for obtaining coverage under a California state-wide General Permit (99-08-DWQ) and is required to file a Notice of Intent for each construction activity prior to commencement of construction.

The General Permit requires development and implementation of a Storm Water Pollution Prevention Plan and identification of a monitoring program and reporting requirements. Sediment control measures that shall be included in the General Permit (from State Water Resources Control Board Fact Sheet) are as follows:

1. Soil stabilization practices. These practices shall be designed to preserve existing vegetation where feasible and to revegetate open areas as soon as feasible after grading or construction. In developing these practices, the discharger shall consider temporary seeding, permanent seeding, mulching, sod stabilization, vegetation buffer strips, protection of trees, or other soil stabilization practices. At a minimum, the operator must implement these practices on all disturbed areas during the rainy season.
2. Control practices which, to the extent feasible, will prevent a net increase of sediment load in stormwater discharge. In developing control practices, the discharger shall consider a full range of erosion and sediment controls such as detention basins, straw bale dikes, silt fences, earth dikes, brush barriers, velocity dissipation devices, drainage swales, check dams, subsurface drain, pipe slope drain, level spreaders, storm drain inlet protection, rock outlet protection, sediment traps, temporary sediment basins, or other controls. At a minimum, sandbag dikes, silt fences, straw bale dikes, or equivalent practices are required for all significant sideslope and downslope boundaries of the construction area. The discharger must consider site-specific and seasonal conditions when designing the control practices.
3. Control practices to reduce the tracking of sediment onto public or private roads. These public and private roads shall be inspected and cleaned as necessary.

4. Control practices to reduce wind erosion.

California Division of Safety of Dams

Since 1929, the State of California has supervised the construction and operation of dams to prevent failure to safeguard life and protect property. The State Water Code (Division 3) stipulates that the supervision of non-federal dams in California is generally under the jurisdiction of the DSOD. However, an exception exists in the Water Code for certain water impoundments that are part of wastewater control facilities. Specifically, a wastewater impoundment that is less than 1,500 acre-feet in volume, and with a maximum depth less than 15 feet, may qualify as non-jurisdictional. For purposes of determining jurisdictional authority the maximum depth is defined as the vertical distance between the maximum possible water surface and the lowest elevation of the outboard toe of the embankment. For the SSP, the impoundments are expected to have depths greater than 15 feet, so they would not fall under the exemption and would be subject to DSOD jurisdiction.

When reviewing permit applications, the DSOD evaluates the safety of dams and reservoirs by assessing the potential for seepage, earth movement, and other conditions that may occur in the vicinity of a dam or reservoir. The DSOD requires that data concerning subsoil, foundation conditions, availability of construction materials, and geologic hazards be gathered to review the design, construction, and operation of dams and reservoirs. Investigations usually include exploratory pits, trenches, drilling, coring, geophysical surveys, tests to determine leakage rates, and physical tests to measure properties of foundation materials. Staff at the DSOD performs an independent evaluation of the dam engineer's design to ensure that the design meets or exceeds required standards. Special conditions may be attached to the DSOD permit approval, and design and construction plans may be modified by the DSOD at any time after approval to insure safety.

During the construction or repair of any dam or reservoir, the DSOD is required to make continuous and periodic inspections to verify that construction is proceeding in accordance with approved plans. No foundations or abutments may be covered until the Division's field engineer has inspected and approved them. The DSOD permit approval may be revoked whenever the dam or reservoir constitutes a danger to life and property.

Building Permits

SSP structures would be constructed in City jurisdiction. The City has adopted building codes, typically based on the Uniform Building Code, that specify design and construction standards and require that an approved building permit be obtained prior to construction. They also require that a building inspector review plans and inspect the construction site and grant final approval upon completion of construction. Building permits would be required for pump stations.

Grading Ordinance

Construction or installation of SSP facilities would require grading of land located in City jurisdiction. The City has adopted grading ordinances to regulate grading and to minimize environmental impacts associated with construction grading. Grading ordinances typically require setbacks from property lines, erosion and sediment control, soil stockpile management methods, and inspection procedures. A grading permit may be required, depending on local jurisdiction ordinance specifications, for pipeline installation, road construction, transmission line construction, or other earth works.

Mineral and Aggregate Resource Areas

California Surface Mining and Reclamation Act

Under the California Surface Mining and Reclamation Act of 1975, the State Geologist classifies land in the State for its mineral resource potential according to various Mineral Resource Zone (MRZ) categories that reflect varying degrees of mineral potential. Within the SSP study area, there are mineral resources identified in the Resource Conservation Element of the Sonoma County General Plan as Mineral Resource Deposits subject to resource conservation policy requirements under the MRZ-2 classification. The MRZ-2 classification includes areas where geologic data indicate significant measured, indicated, or inferred resources. The largest areas of such designations within the SSP study area consist of aggregate deposits along the Russian River in the Alexander Valley and south of Healdsburg. There are no MRZ-2 designations within the SSP alternatives sites.

Sonoma County Aggregate Resources Management Plan

The Sonoma County Aggregate Resources Management (ARM) Plan establishes policies and standards for the management of the County's aggregate resources (County of Sonoma, 1994). One of the objectives of the ARM Plan is to increase quarry production to provide a full range of products and replace river terrace sources as the primary source of supply for future construction aggregate. The ARM Plan designates seven new quarry sites in Sonoma County as well as expansion areas for most existing quarries. There are no designated quarries within the five SSP alternative sites.

The ARM Plan indicates that all designated new quarry sites and potential expansion areas shall be protected from incompatible uses by being considered in the review of all nearby development proposals; and that uses which would be incompatible with future quarry development on designated sites shall not be permitted unless the public benefits of the proposed use outweigh the public benefits of potential quarry development. The ARM Plan also identifies Potential Quarry Resource Areas. These Potential Quarry Resource Areas are for informational purposes only and do not restrict other uses allowed by zoning. The development review process need not consider potential quarry resources in these undesignated areas.

Geologic, Soils, and, Seismic Conditions at SSP Sites

The Kelly Farm, Brown Farm, and Alpha Farm sites are situated in the Cotati Valley – Santa Rosa Plain, with similar geologic conditions.

Geology & Soils

As shown on Figure 4.3-1, published geological mapping indicates the Kelly Farm, Brown Farm, and Alpha Farm sites are underlain predominantly by older Quaternary alluvial deposits associated with the Glen Ellen and Huichica formations. As discussed above, these formations typically include fluvial deposits of gravel, sand, silt, and clay with mudstone and minor interbedded volcanic tuffs. Relatively small fingers of Holocene-age alluvium are mapped within existing stream channels and drainage swales that traverse the SSP sites and within the Laguna de Santa Rosa floodplain, which is located to the west of the sites.

To supplement soil information from NRCS soil maps that was discussed above, subsurface investigations, including soil borings and laboratory testing, were performed at the SSP alternatives sites to evaluate site geotechnical conditions. Borings and tests at the Kelly Farm, Brown Farm, and Alpha Farm sites show the sites to be underlain predominantly by firm to stiff clay and silt, with lesser amounts of medium dense silty to clayey sands and gravels. The *TM 2, Geotechnical Evaluation Technical Memorandum*, provided in Volume 4 of this EIR, presents a more complete discussion of site soil conditions at the Kelly Farm, Brown Farm, and Alpha Farm sites. Boring logs and laboratory test results are presented in Attachments 5 and 7, respectively, of *TM 2*.

Faults

As shown on Figure 4.3-2 above, the Rodgers Creek Fault Zone runs along the eastern edge of the Santa Rosa Plain near the City of Santa Rosa, and is situated approximately 6 miles northeast of the Kelly Farm, Brown Farm, and Alpha Farm sites. Several unnamed buried fault traces are shown on the floor of the Santa Rosa plain within a mile of the sites; however, based on their concealed nature beneath younger and older Quaternary alluvial deposits, these fault traces are presumed inactive.

Potential Geologic and Geotechnical Hazards

Based on site geotechnical evaluations discussed in the *TM 2, Geotechnical Evaluation* provided in Volume 4 of this EIR, potential geologic and geotechnical hazards at the Kelly Farm, Brown Farm, and Alpha Farm sites are summarized below in Table 4.3-5.

TABLE 4.3-5
Summary of Potential Geologic and Geotechnical Hazards at the SSP Sites

Hazard	Hazard Potential by SSP Site		
	Kelly Farm	Brown Farm	Alpha Farm
Landsliding and Slope Instability	VL	VL	VL
Fault Surface Rupture	VL	VL	VL
Strong Seismic Ground Shaking	H	H	H
Liquefaction	L	L	L
Lateral Spreading	L	L	L
Seismically-Induced Slope Instability	VL	VL	VL
Seismically-Induced Ground Cracking	VL	VL	VL
Soft, Loose, and/or Compressible Soils	M	M	M
Expansive Soils	M	M	M
Groundwater Movement through Soil and Rock	L	L	L

Notes:

- a. VL = Very Low, L = Low, M = Moderate, H= High

GOALS, OBJECTIVES, AND POLICIES

Table 4.3-6 identifies goals, objectives, and policies for geology, soils, and seismicity that relate to the SSP. The table also indicates which evaluation criteria in the Geology, Soils, and Seismicity Section are responsive to each set of policies.

TABLE 4.3-6
Goals, Objectives, and Policies – Geology, Soils, and Seismicity

Adopted Plan Document	Document Section	Document Numeric Reference	Policy	Relevant Evaluation Criteria
Santa Rosa General Plan	Noise and Safety Element	Goal NS-C Objective NS-C-1	Minimize potential earthquake impacts and assure provisions of the Alquist-Priolo Special Studies Zone Act are met	2, 3, 4, 5
		Objective NS-C-2 Objective NS-C-3 Objective NS-C-4 Objective NS-C-7 Objective NS-C-8	Identify and mitigate geologic and soils hazards, restrict development, especially of critical facilities like wastewater treatment facilities, where appropriate, and require inspection of water storage and conveyance systems after a major seismic event	1-8
	Safety Element	Goal 1 Policy 1 Program 1.1 Program 1.2 Program 1.3 Program 1.4	Reduce risks from seismic hazards, require geotechnical reports for development proposals, comply with Alquist-Priolo Act, mitigate potential hazards, require professional inspection during construction	2, 5, 7
		Goal 2 Policy 3 Program 3.1 Goal 3 Program 10	Minimize risk resulting from slope instability, liquefaction potential, and expansive soils. Enforce measures to minimize runoff related soil erosion	1, 3, 6, 7

Source: Santa Rosa 2002

Note: 1. Evaluation criteria are identified in Table 4.3-7

EVALUATION CRITERIA WITH SIGNIFICANCE THRESHOLDS

The evaluation criteria for Geology, Soils, and Seismicity are presented in Table 4.3-7. These criteria are drawn from CEQA and regulatory requirements. According to the CEQA Guidelines, exposure of people or structures to major geologic hazards is considered a significant impact. Potential geologic hazards within the SSP project area include slope instability, strong ground shaking, ground rupture, liquefaction, soils with a high potential for shrinking/swelling, corrosive soils, and induced seismic activity.

TABLE 4.3-7
Evaluation Criteria with Significance Thresholds – Geology, Soils, and Seismicity

Evaluation Criteria	As Measured by	Significance Thresholds	Sources of Criteria
1. Will the SSP be located within an area of unstable slope conditions?	Geotechnical assessment of landslide risk potential	Location of facilities in area mapped as Mostly Landslide or Many Landslides	The rating takes into consideration the prevalence of mapped landslides in the area. Landslides and other slope failure could occur in areas where landslides are common. Areas with Few Landslides or Flat Land are expected to have stable slope conditions. CEQA Guidelines Appendix G, Checklist Item VI (c).
2. Will the SSP facilities be subject to ground rupture due to location near a surface trace of an active fault?	Location of facilities within an Alquist-Priolo Earthquake Fault Zone or location of key structures on a fault that has ruptured in the last 35,000 years	Any portion of facilities within an Alquist-Priolo zone or key structures on a fault that has ruptured in the last 35,000 years	Earthquake fault zones are established under the Alquist-Priolo Earthquake Fault Zoning Act by the California Division of Mines and Geology (CDMG), now the CGS, to regulate development near active faults to mitigate the hazard of surface rupture. The Act applies only to structures for human occupancy but the zones accurately delineate areas at greatest risk for surface fault rupture. CEQA Guidelines Appendix G, Checklist Item VI (a)(i). The DSOD has established guidelines to assess earthquake fault activity to prevent dam failure, safeguard life, and to protect property.

TABLE 4.3-7
Evaluation Criteria with Significance Thresholds – Geology, Soils, and Seismicity

Evaluation Criteria	As Measured by	Significance Thresholds	Sources of Criteria
3. Will the SSP be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?	Geotechnical assessment of potential for liquefaction	A rating of High for liquefaction for project facilities	Certain soil types, especially fine sandy soils, underlain by shallow groundwater, are prone to liquefaction. The CDMG has identified areas where soil properties are highly susceptible to liquefaction (CDMG 1997, Special Publication 117.) SSP facilities in these areas would be vulnerable to damage from liquefaction. CEQA Guidelines Appendix G, Checklist Item VI (c).
4. Will the SSP induce seismicity?	SSP induced ground shaking intensity	Ground shaking effects of Modified Mercalli intensity V or greater increasing in frequency by 20% or more	Earthquakes that produce ground shaking intensity of Modified Mercalli IV (generally corresponds to a Magnitude 3 earthquake within an epicentral distance of several miles) are not generally associated with damage to people or property. CEQA defines damage to people or property as a significant effect.
5. Will earthquake-induced strong ground shaking damage the SSP facilities?	Structural and geotechnical design and construction not in conformance with requirements of regulatory agencies and applicable building codes	Construction not in conformance with requirements of the DSOD or applicable building codes	Uniform Building Code (UBC 1997) as amended locally and DSOD regulations. CEQA Guidelines Appendix G, Checklist Item VI (a)(ii and iii).
6. Will construction of the SSP facilities cause off-site water-related erosion?	Construction activities not in compliance with requirements of the program National Pollutant Discharge Elimination System Permit (NPDES), DSOD regulations, or building and grading codes.	Construction not in compliance with NPDES, DSOD, or building and grading codes.	Clean Water Act regulations, DSOD regulations, and local building or grading ordinances.
7. Will the SSP facilities be exposed to damage due to expansive soils?	Shrink-swell potential as rated in Sonoma County Soil Survey (Soil	Any construction inconsistent with standard	The USDA Soil Conservation Service (SCS) indicates that: "If the shrink-swell potential is rated moderate to very high, shrinking,

TABLE 4.3-7
Evaluation Criteria with Significance Thresholds – Geology, Soils, and Seismicity

Evaluation Criteria	As Measured by	Significance Thresholds	Sources of Criteria
	Conservation Service 1972)	engineering practices	and swelling can damage buildings, roads, and other structures”. CEQA Guidelines Appendix G, Checklist Item VI (d).
8. Will the SSP facilities be exposed to damage due to construction on corrosive soils?	Corrosion potential as rated in Sonoma County Soil Survey (SCS 1972)	Any construction inconsistent with standard engineering practices	The NRCS (formerly SCS) indicates that soils with High corrosion can damage uncoated steel and concrete by chemical actions that dissolve and weaken the material.
9. Will the SSP be an incompatible land use type in the MRZ-2 classification, designated quarry area, or in the Geysers?	a. Acres of MRZ-2 land developed in incompatible uses	Greater than 0 acres of land	CEQA Guidelines Appendix G, Checklist Item X (a).
	b. Acres of quarry site designated by the ARM plan developed in incompatible uses	Greater than 0 acres of land	CEQA Guidelines Appendix G, Checklist Item X (a).
	c. Acres of Geysers developed in incompatible uses	Greater than 0 acres of land	Lake County Geothermal Element Bureau of Land Management (BLM) [30 United States Code 1001-1025; 43 CFR Part 3200]
10. Will the SSP cause a substantial adverse change to a hot spring or other unique geologic feature?	Alternation of a unique geologic feature	Any alteration	CEQA Guidelines Appendix G, Checklist Item V(c).

METHODOLOGY

The EIR impacts analysis is based on a review of relevant geologic literature and data and information in the *TM 2, Geotechnical Evaluation Technical Memorandum* provided in Volume 4 of this EIR.

IMPACTS AND RECOMMENDED MITIGATION MEASURES

TABLE 4.3-8
Geology, Soils, and Seismicity Impacts

Evaluation Criteria	Significance Threshold	Impact	Type of Impact ¹	Level of Significance ²
3.1. Will the SSP facilities be located within an area of unstable slope conditions?	Location of facilities in area mapped as <i>Mostly Landslide</i> or <i>Many Landslides</i>	Level ground	P	○
3.2. Will SSP facilities be subject to ground rupture due to location near a surface trace of an active fault?	Any portion of facilities within an Alquist-Priolo Earthquake Fault Zone	None	P	==
3.3. Will SSP facilities be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?	A rating of High or Very High for liquefaction for storage facilities, except pipelines	Low to moderate liquefaction hazard	P	○
3.4. Will the SSP induce seismicity?	Ground shaking effects of Modified Mercalli intensity V or greater increasing in frequency by 20% or more	None	P	==
3.5. Will earthquake-induced strong ground shaking damage the SSP facilities?	Construction not in conformance with requirements of the DSOD or applicable building codes	Conform with building requirements	P	○
3.6. Will construction of the SSP facilities cause off-site water-related erosion?	Construction not in compliance with NPDES, DSOD, or building and grading codes.	Comply with appropriate codes	C	○
3.7. Will the SSP facilities be exposed to damage due to expansive soils?	Any construction inconsistent with standard engineering practices	Some expansive soils	P	○

**TABLE 4.3-8
 Geology, Soils, and Seismicity Impacts**

Evaluation Criteria	Significance Threshold	Impact	Type of Impact ¹	Level of Significance ²
3.8. Will the SSP facilities be exposed to damage due to construction on corrosive soils?	Any construction inconsistent with standard engineering practices	Some corrosive soils	P	○
3.9. Will the SSP be an incompatible land use type in the MRZ-2 classification, in a designated quarry area or in the Geysers?	a. Greater than 0 acres of MRZ-2 land	Not within MRZ-2 zones	P	==
	b. Greater than 0 acres of quarry site designated by the ARM plan	Not within a quarry site	P	==
	c. Acres of Geysers developed in incompatible uses	Not within the Geysers area	P	==
3.10. Will the SSP cause a substantial adverse change to a hot spring or other unique geologic feature?	Any alteration of a unique geologic feature	No unique geologic features	P	==

Notes: 1. Type of Impact:
 C Construction
 O&M: Operation and Maintenance
 P: Permanent

2. Level of Significance:
 ● Significant impact before and after mitigation
 ⊙ Significant impact before mitigation; less than significant impact after mitigation
 ○ Less than significant impact; no mitigation proposed
 == No impact

Impact: 3.1. Will the SSP be located within an area of unstable slope conditions?

Analysis: *Storage component - Less than Significant: KF1, KF2, BF1, BF2, and AF*

Each of the sites is on flat to gently sloping land with little or no potential for unstable slope conditions. Storage facilities would not be exposed to significant landslide or slope instability hazards, and impacts are considered less than significant.

Pump Station component - Less than Significant: KF1, KF2, BF1, BF2, and AF

The pump stations would be located on the top of the pond embankments, or at-grade if Mitigation Measure 3.3.18 is implemented, both of which are on level ground. The embankments are constructed in such a manner to have little or no potential for unstable slope conditions. Connecting electrical distribution lines would be constructed within areas that are flat to gently sloping land with little or no potential for unstable slope conditions. Pump stations would not be subject to significant landslide or slope instability hazards, and impacts are found to be less than significant.

Mitigation: No mitigation is needed.

Impact: 3.2. Will the SSP facilities be subject to ground rupture due to location near a surface trace of an active fault?

Analysis: *Storage component - No Impact: KF1, KF2, BF1, BF2, and AF*

The Storage component at the KF1, KF2, BF1, BF2, and AF sites would not be subject to ground rupture due to location near a surface trace of an active fault. The Rodgers Creek Fault Zone is situated approximately 6 miles northeast of the sites. Several unnamed buried fault traces are shown within one mile of the sites; however, based on their concealed nature beneath younger and older Quaternary alluvial deposits, these fault traces are presumed inactive. No impact relative to ground rupture has been identified.

Pump Station component - No Impact: KF1, KF2, BF1, BF2, and AF

None of the pump stations or electrical distribution lines would be subject to ground rupture due to location near a surface trace of an active fault, as no active faults are closer than 6 miles. No impact relative to ground rupture has been identified.

Mitigation: No mitigation is needed.

Impact: 3.3. Will the SSP be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?

Analysis: *Storage component - Less than Significant: KF1, KF2, BF1, BF2, and AF*

The storage facilities at each of the sites would not be located in areas with soils or groundwater conditions that are highly susceptible to liquefaction; however, there may be localized areas with low to moderate susceptibility to liquefaction. Subsurface exploration and testing at the sites show predominantly clayey soils without significant zones of loose silty sands that might liquefy under expected earthquake loading and lead to lateral spreading or stability failures of the overlying storage pond embankment. This confirms the low hazard categorization of the sites in published liquefaction susceptibility maps. In accordance with DSOD requirements, if isolated zones of potentially liquefiable soils are encountered in localized areas during design investigations, foundation ground improvement methods such as vibrocompaction would be undertaken. Impacts are found to be less than significant.

Pump Station component - Less than Significant: KF1, KF2, BF1, BF2, and AF

The storage pond embankment that supports the pump station would not be constructed of soils that are susceptible to liquefaction. Pump station construction at grade due to implementation of Mitigation Measure 3.3.18 and connecting electrical distribution lines would be constructed in areas that do

not have soils or groundwater conditions that are highly susceptible to liquefaction. Impacts are found to be less than significant.

Mitigation: No mitigation is needed.

Impact: 3.4. Will the SSP induce seismicity?

Analysis: *Storage component - No Impact: KF1, KF2, BF1, BF2, and AF*

Storage reservoir-induced seismicity research, including studies of thousands of case histories, indicates that a few, very large, reservoirs have induced large earthquakes (greater than Magnitude 5) due to the weight of the stored water. However, a reservoir water depth of at least 260 feet is required to induce seismicity. Induced earthquakes large enough to be damaging have never been documented to occur in reservoirs with lesser water depths (Allen 1982). The storage ponds would be of limited horizontal extent and only have a maximum depth of from 15 to 23 feet, which is much less than the depths associated with induced seismicity. No impact relative to induced seismicity has been identified.

Pump Station component - No Impact: KF1, KF2, BF1, BF2, and AF

Pump stations and electrical distribution lines do not have the potential to induce seismicity.

Mitigation: No mitigation is needed.

Impact: 3.5. Will earthquake-induced strong ground shaking damage the SSP facilities?

Analysis: *Storage component - Less than Significant: KF1, KF2, BF1, BF2, and AF*

Based on PHGA estimates and historical levels of seismicity, it is likely that Storage component facilities at each of the sites would experience periodic minor to moderate earthquakes and potentially a major earthquake (Magnitude 7.0 or greater) during the facilities' service life. Strong seismic ground shaking associated with these earthquakes has the potential to damage Storage component facilities.

DSOD requires stringent analysis, design, and construction practices to assure embankment safety under seismic loading events that are more extreme than those in public building codes. Analysis, design detailing, and construction Quality Assurance/Quality Control (QA/QC) would conform to DSOD requirements. With implementation of these design measures, reservoirs could withstand strong ground shaking from forecast earthquakes. Impacts are considered less than significant.

Pump Station component - Less than Significant: KF1, KF2, BF1, BF2, and AF

Because of location of each of the sites in a seismically active area, strong levels of seismic ground shaking are expected over the life of the Pump

Station component. Strong seismic ground shaking associated with these earthquakes has the potential to damage Pump Station component facilities.

If the pump stations are placed within the storage pond embankment or at grade, DSOD requires stringent analysis, design, and construction practices to assure embankment safety under seismic loading events that are more extreme than those in public building codes. Analysis, design detailing, and construction of the embankments would conform to DSOD requirements. Connecting electrical distribution lines would also be subject to strong ground shaking, but facilities would be constructed according to the stringent local building code standards. This would reduce the potential for damage to pump station facilities to a less-than-significant level.

Mitigation: No mitigation is needed.

Impact: 3.6. Will construction of the SSP facilities cause off-site water-related erosion?

Analysis: *Storage component - Less than Significant: KF1, KF2, BF1, BF2, and AF*

Grading and other earthwork-related construction activities would disturb substantial areas of each of the sites, exposing soil that could be eroded by rainfall or flowing water, as well as temporarily increasing site runoff during storm events. To prevent a temporary increase in stormwater runoff and soil erosion from exposed soils surfaces, the Project would incorporate temporary runoff and sediment control measures until the site is revegetated as outlined in Project Measure 3.2.2. Measures would be defined in and implemented in conformance with the NPDES permit and governed by a Stormwater Pollution Prevention Plan (SWPPP) (Project Measure 3.2.3) as well as local grading and erosion control ordinances. These measures, adopted as part of the Project, would reduce erosion to less than significant levels.

Pump Station component - Less than Significant: KF1, KF2, BF1, BF2, and AF

The pump station and electrical distribution lines at each the sites would be constructed within the storage pond embankment and in adjacent soils. Therefore, minimal ground-disturbance would be required, beyond the areas disturbed by storage pond facilities construction. The measures identified in the SWPPP (Project Measure 3.2.3) and in Project Measure 3.2.2, Revegetate Temporarily Disturbed Sites, would be implemented for pump station and pipeline work. Impacts would be less than significant.

Mitigation: No mitigation is needed.

Impact: 3.7. Will the SSP facilities be exposed to damage due to expansive soils?

Analysis: *Storage component - Less than Significant: KF1, KF2, BF1, BF2, and AF*

Expansive soils are common throughout the region, and preliminary investigations indicate that soils at each of the sites are expected to pose a

moderate expansion hazard for constructed facilities. The Project would incorporate Standard Engineering Methods for Expansive Soils (Project Measure 3.2.6) to protect against heave or shrinkage cracking of soils that might cause excessive movement or cracking of overlying structures. Project Measure 3.2.6 includes options such as compaction with careful moisture/density control to reduce expansion potential, removal/ replacement with less expansive soils, stabilization of soils, use of specialized foundation designs to isolate structures from movement, and inclusion of flexible connections to accommodate movement. Appropriate methods would be selected during design based on facility and site specific conditions. With implementation of measures adopted as part of the Project, impacts would be less than significant.

Pump Station component - Less than Significant: KF1, KF2, BF1, BF2, and AF

If the pump stations are constructed within the pond embankment, they would not be affected by local soil conditions. If the pump stations are built at grade, their construction, and that of the electrical distribution lines, would incorporate Standard Engineering Methods for Expansive Soils (Project Measure 3.2.6) to protect against heave or shrinkage cracking of soils that might cause excessive movement or cracking of the pipeline. With implementation of measures adopted as part of the Project, impacts would be less than significant.

Mitigation: No mitigation is needed.

Impact: 3.8. Will the SSP facilities be exposed to damage due to construction on corrosive soils?

Analysis: *Storage component - Less than Significant: KF1, KF2, BF1, BF2, and AF*

Corrosive soils are common throughout the region, and preliminary evaluations indicate that soils at each of the pond sites are expected to pose a high corrosion hazard for unprotected steel facilities. The Project would incorporate Standard Engineering Methods for Corrosive Soils (Project Measure 3.2.5) to protect facilities from corrosion. Project Measure 3.2.5 includes options such as use of non-corrodible materials such as PVC piping, or a cathodic protection system; the appropriate method would be selected during design based on facility and site-specific conditions. With implementation of measures adopted as part of the Project, impacts would be less than significant.

Pump Station component - Less than Significant: KF1, KF2, BF1, BF2, and AF

If the pump stations are constructed within the pond embankment, they would not be affected by local soil conditions. If the pump stations are constructed at grade, their construction, and that of the electrical distribution line, would incorporate Standard Engineering Methods for Corrosive Soils (Project

Measure 3.2.5) to protect facilities from corrosion. Project Measure 3.2.5 includes options such as use of non-corrodible materials such as PVC piping, or a cathodic protection system; the appropriate method would be selected during design based on facility and site specific conditions. With implementation of measures adopted as part of the Project, impacts would be less than significant.

Mitigation: No mitigation is needed.

Impact: 3.9. Will the SSP be an incompatible land use type in the MRZ-2 classification, in a designated quarry area or in the Geysers?

Analysis: *Storage component - No Impact: KF1, KF2, BF1, BF2, and AF*

None of the sites are located in areas that are classified as MRZ-2, are designated quarry areas, or are in the Geysers.

Pump Station component - No Impact: KF1, KF2, BF1, BF2, and AF

None of the sites are located in areas that are classified as MRZ-2, are designated quarry areas, or are in the Geysers.

Mitigation: No mitigation is needed.

Impact: 3.10. Will the SSP cause a substantial adverse change to a hot spring or other unique geologic feature?

Analysis: *Storage component - No Impact: KF1, KF2, BF1, BF2, and AF*

No unique geological features occur at the KF1, KF2, BF1, BF2, or AF sites.

Pump Station component - No Impact: KF1, KF2, BF1, BF2, and AF

No unique geological features occur at any of the sites.

Mitigation: No mitigation is needed.

No Project

Impact: 4.1 through 4.10. Will the No Project Alternative cause geology, soils, or seismicity impacts based on evaluation criteria 1 through 10?

Analysis: *No Impact*

Under the No Project alternative no facilities would be constructed. Therefore, the No Project alternative would not present hazards associated with constructing facilities in areas susceptible to unstable slope conditions, ground rupture, liquefaction, earthquake-induced strong ground shaking damage, or expansive or corrosive soils. The No Project alternative would not induce seismicity or erosion, and would not be an incompatible land use or change a unique geologic feature.

Mitigation: No mitigation is needed.

CUMULATIVE IMPACTS

Impact: 3.1C, 3.3C, 3.5C, 3.7C, and 3.8C. Will the SSP plus cumulative projects cause geology, soils, and seismicity impacts based on evaluation criteria 1, 3, 5, 7, or 8?

Analysis: *Less than Significant*

Appropriate design measures and engineering standards, which are part of the Project, would reduce, or eliminate potential impacts related to geology and soils. The impacts would be site-specific to the SSP sites, and would not contribute to or exacerbate any geology or soils impacts that might be caused by other projects within the region. No significant cumulative impacts would occur.

Mitigation: No mitigation is needed.

Impact: 3.2C, 3.4C, 3.9C, and 3.10C. Will the SSP plus cumulative projects cause geology, soil, or seismicity impacts based on evaluation criteria 2, 4, 9, or 10?

Analysis: *No Impact*

The SSP alternatives sites are not subject to ground rupture due to location near a surface trace of an active fault and would not induce seismicity. They are not located in designated quarry areas or areas classified as MRZ-2, or in the Geysers, and do not contain unique geological features. Therefore, the SSP would not contribute to any cumulative impacts related to ground surface rupture, induced seismicity, or placement of facilities within important or unique geologic areas.

Mitigation: No mitigation is needed.

Impact: 3.6C. Will construction of the SSP plus cumulative projects cause off-site water-related erosion?

Analysis: *Less than Significant*

Grading and other earthwork-related construction activities would disturb substantial areas of the SSP sites, exposing soil that can be eroded by rainfall or flowing water, as well as temporarily increasing site runoff during storm events. Similar circumstances could occur from other grading and agricultural activities in the area. To prevent a temporary increase in stormwater runoff and soil erosion from exposed soils surfaces, the Project would incorporate temporary runoff and sediment control measures until the site is revegetated as outlined in Project Measure 3.2.2. Both the SSP and other grading of one acre or more must adopt runoff sediment control measures in conformance with the NPDES permit and governed by a SWPPP (Project Measure 3.2.3) as well as local grading and erosion control ordinances. Therefore, cumulative

erosion would tend to remain less than significant, and the SSP would not make a considerable contribution to any water-related erosion that might be caused by other projects in the region.

Mitigation: No mitigation is needed.

SUMMARY OF SIGNIFICANT IMPACTS AND MITIGATION MEASURES

No significant Geology, Soils, and Seismicity impacts have been identified for the SSP.

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