4.3 GEOLOGIC PROBLEMS

4.3.1 REGIONAL SETTING

The three Bay Area power plants (Potrero, Contra Costa, and Pittsburg) are located on the western coast of California in the Coast Range Geomorphic Province, which is an area of moderate-to-high seismic activity. Major northwest-trending fault zones, including the San Andreas Fault Zone (the dominant fault zone in California), parallel the coast. All of the fossil-fueled power plants to be divested as part of the project are located within 46 miles of at least one major fault zone and are subject to moderate-to-high seismic activity (see Table 4.3-1 and Figure 4.3-1).

The San Andreas fault and many other faults in the Coast Range and offshore areas have produced earthquakes during historic times and have a very high probability of generating future earthquakes. For example, the 1989 Loma Prieta earthquake was centered on the Santa Cruz Mountains segment of the San Andreas fault and resulted in casualties and massive damage to structures in Santa Cruz, San Francisco, and Oakland and in the San Francisco Bay and Monterey Bay regions (ESA, 1997).

The San Andreas fault is considered one of the most hazardous active fault systems in California. The Santa Cruz Mountains segment had earthquakes with estimated magnitudes over 6.5 in 1838, 1865, 1890, 1906, and 1989; this segment of the fault is considered capable of generating a maximum credible earthquake (MCE) of 8.2 Richter Magnitude. The probability of an MCE occurring on the southern segment of the Santa Cruz Mountains segment of the fault before the year 2020 is considered low, primarily due to the release of strain that accompanied the 1989 Loma Prieta earthquake, which had a magnitude of 7.1. That probability was based on the assumption that the 1989 Loma Prieta earthquake was a recurrence of movement on the fault that moved in the 1906 event (San Francisco earthquake, with an 8.3 magnitude). However, both MCE and occurrence probabilities increase for segments of the San Andreas fault in the northern Santa Cruz Mountains, San Francisco Peninsula, and the area north of San Francisco Bay. For example, the mid-Peninsula segment of the fault has an estimated 23 percent probability of a 7.0 magnitude earthquake in the next 30 years (ESA, 1997). Major earthquakes also may be generated on the San Andreas fault in segments to the southeast of Santa Cruz.

Both the Hayward and Calaveras faults may be linked to each other and to the San Andreas fault. Both faults are considered active and have relatively high probabilities of generating major earthquakes. The northerly extension of the Hayward fault is the Rogers Creek fault. The Hayward fault has an MCE of 7.5, with a 23 percent probability of occurrence in the next 30 years. The Calaveras fault has an MCE of 7.0 and also a 23 percent probability of occurrence in the next 30 years. The region may have entered a period of renewed earthquake activity following a lull after the 1906 San Francisco earthquake. There is some evidence of a northerly migration of moderate-sized earthquakes along the Calaveras fault to the southern end of the Hayward fault (ESA, 1997).

TABLE 4.3-1
ACTIVE AND POTENTIALLY ACTIVE EARTHQUAKE FAULTS NEAR PG&E'S FOSSIL-FUELED POWER PLANTS

Generating Station	Fault	Trend	Closest Segment	Last Movement	Slip Rate[a]	MPE[b]	MHE[c]
Potrero	San Andreas, SF Peninsula segment	NNW	8 miles SW	Historic (1906)	19 mm/year	7.0	7.1
	Northern Hayward	NNW	9 miles NE	Historic (1836)	9-15 mm/year	6.5-7.5	7.1
	San Gregorio (Seal Cove)	NNW	17 miles SW	Historic	NA	7.1	6.4
	Calaveras	NNW	22 miles E	Historic	13-17 mm/year	6.0	6.9
	Rodgers Creek	NNW	26 miles NE	Holocene	6-10 mm/year	5.7	7.1
Pittsburgh	Greenville	NNW	5 miles SW	Historic	NA	7.1	5.9
	Concord-Green Valley	NNW	8 miles W	Holocene	4 mm/year	7.1	2-3
	Antioch	NNW	9 miles E	Historic	NA	6.5	6.0
	Calaveras	NNW	20 miles SE	Historic	13-17 mm/year	6.0	6.9
	Northern Hayward	NNW	23 miles SW	Historic (1836)	9-15 mm/year	6.5-7.5	7.1
	Rodgers Creek	NNW	29 miles N	Holocene	6-10 mm/year	5.7	7.1
	San Andreas, SF Peninsula segment	NNW	40 miles NE	Historic (1906)	19 mm/year	7.0	7.1
Contra Costa	Antioch	NNW	1 miles E	Historic	NA	6.5	6.0
	Greenville	NNW	9 miles W	Historic	NA	7.1	5.9
	Concord-Green Valley	NNW	16 miles SW	Holocene	4 mm/year	7.1	2-3
	Calaveras	NNW	20 miles SW	Historic	13-17 mm/year	6.0	6.9
	Northern Hayward	NNW	24 miles SW	Historic (1836)	9-15 mm/year	6.5-7.5	7.1
	Rodgers Creek	NNW	35 miles NW	Holocene	6-10 mm/year	5.7	7.1
	San Andreas, SF Peninsula segment	NNW	46 miles SE	Historic (1906)	19 mm/year	7.0	7.1

a Slip Rate = data indicating the amount of surface displacement in millimeters along the fault over a unit period; the higher the slip rate, the shorter the expected time to the next earthquake.

b MPE = Maximum Probable Credible Earthquake Magnitude, an estimate of the largest earthquake that is judged by geologic studies to be capable of occurring on a fault or segment of a fault for a design period. The MPE is equated here with the design earthquake scenario used by the Association of Bay Area Governments in its planning document and maps *On Shaky Ground*, 1995.

c MHE = Maximum Historic Earthquake Richter Magnitude, based on measurements or inferred from geologic and observed evidence of earthquake effects.

SOURCES: Working Group on California Earthquake Probabilities, 1990, *Probabilities of Large Earthquakes in the San Francisco Bay Region, California*.
California Division of Mines and Geology, 1992, Anderson, J.G., 1984, *Synthesis of Seismicity and Geologic Data in California*, U.S. Geologic Survey Open File Report 84-424.
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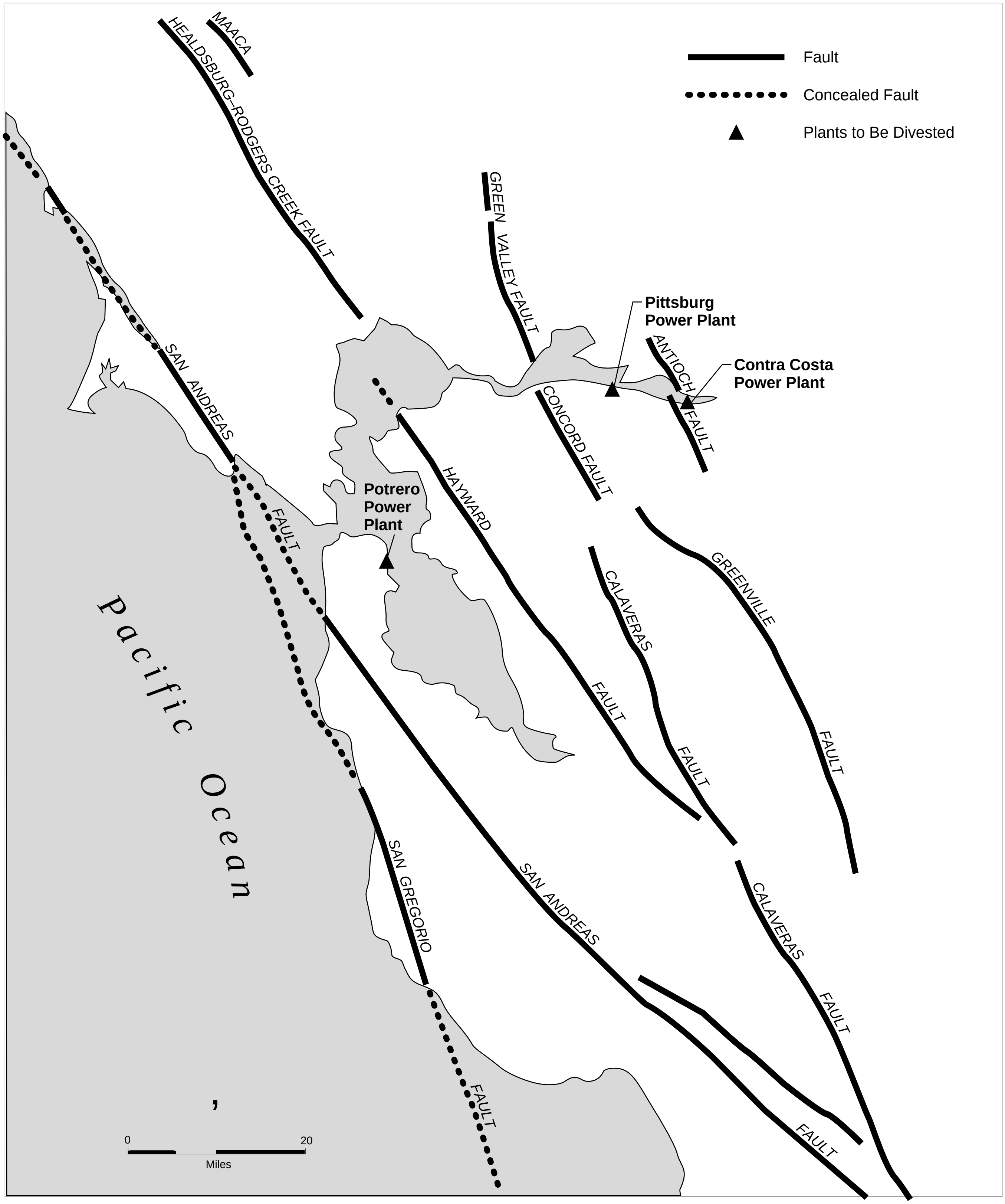
Association of Bay Area Governments, 1995, *On Shaky Ground*. Greensfelder, R.W., 1974. *Maximum Credible Rock Accelerations from Earthquakes in California.*
California Division of Mines and Geology, Map Sheet 23.
Jennings, C.W., 1994, *Fault Activity Map of California and Adjacent Areas with Locations and Ages of Recent Volcanic Eruptions*.
California Division of Mines and Geology, Geologic Data Map No. 6.



NOTE: Figure 4.3-2 shows the location of the Geysers Power Plant relative to regional faults.

SOURCE: Environmental Science Associates

Figure 4.3-1
Bay Area Regional Faults

The Geysers plant is located within the Mayacamas Mountains, over 60 miles north of the Bay Area plants. The Franciscan Formation is the predominant rock type within the area and consists of an assemblage of volcanic and sedimentary rocks that were deposited in a subsiding marine trough.

A northwest/southeast-trending fault zone is located in the vicinity of Big Sulfur Creek. This fault zone generally coincides with zones of intensive hydrothermal alteration of the Franciscan rocks and steam-generating conditions. Steeply tilted alluvial sediments adjacent to one of these faults suggest Quaternary or possibly Holocene activity (within the last 10,000 years) (CDM, 1997a).

The Geysers geothermal steam field is located in a seismically active region. However, relatively few earthquakes greater than Richter Magnitude 4.0 have occurred in this area. Instead, the majority of the earthquakes are classified as microearthquakes which, as discussed below, have been attributed to steam withdrawal and to fluid reinjection from the geothermal energy development activities (CDM, 1997a).

Unconsolidated Quaternary deposits within the region are primarily the extensive landslide deposits that are typical of the Coast Range. Landslide activity, including some deep-seated rotational slides involving blocks of bedrock, is exacerbated in the Geysers area as a result of rock degradation through hydrothermal alteration and faulting (CDM, 1997a).

4.3.2 LOCAL SETTING

POTRERO POWER PLANT

The plant is underlain by older non-marine and marine sedimentary rocks that lie on serpentine bedrock. The regional bedrock, consisting of Late Jurassic to Late Cretaceous Franciscan Formation, has been folded and faulted as a result of major uplift of the area. Located on the eastern edge of the Potrero Hill serpentinite rock mass, Potrero Point is within a major northwest-trending shear zone, which approximately parallels the San Andreas fault. The plant is partially located on artificial fill. The Bay has been filled with imported soil, demolition debris, and hydraulic fill to form the ground under a portion of the plant and in the plant vicinity (CDM, 1997c).

The bedrock/Bay Mud contact extends north-south through the site, just east of Tank 3-3 and Maryland Street, and parallels the historic Bay margin. Bedrock outcrops are evident in a small area north of Station A, extending to the north on the west side of Tank 3-4. Artificial fill covers the site and thickens to the east, from 1 to 30 feet. All the plant structures lie in areas of artificial fill; however, foundations for these structures may rest on bedrock (CDM, 1997c).

The area is subject to high seismic activity. There are several major fault zones in the Bay Area that have experienced historic and Holocene activity (Figure 4.3-1). These fault zones, which trend northwestward of the site, include the San Andreas (about 8 miles southwest) and the Hayward (about 10 miles northeast). Other active or potentially active faults in the vicinity include the Calaveras, City College, Concord, Green Valley, Greenville/Clayton/Marsh Creek, Hillside, Rodgers Creek, San Bruno, San Gregorio, and Seal Cove faults (PG&E, 1998).

PITTSBURG POWER PLANT

The site is located on the northern flank of the Mount Diablo foothills at the edge of Suisun Bay. The site is comprised of flat-lying, tidal marshland with subsurface materials consisting of Holocene-aged sediments. These sediments include unconsolidated, interbedded alluvium and Bay Mud. The alluvium consists of interbedded coarse- to fine-grained sediments. Bay Mud is a carbonaceous silty clay with layers of peat and organic clay. The eastern portion of the plant is underlain by approximately 7 to 10 feet of fill from an unknown source (CDM, 1997d).

The plant site is immediately underlain by recent superficial flood plain and river basin deposits consisting of silt, sand, gravel, and clay. Beneath the recent sediments is the Montezuma Formation, a sequence of semi-consolidated older river and terrace deposits. Details of the bedrock structure beneath the site are not well known, but data from oil and gas wells in the site area indicate that the site is underlain at depth by north- to northeast-dipping Tertiary and Cretaceous rocks (PG&E, 1998).

CONTRA COSTA POWER PLANT

The plant is underlain by three different types of material. The uppermost material is an approximately 6-foot-thick artificial fill comprised of silty sand derived from sources on or near the plant. The second layer consists of an approximately 125- to 140-foot-thick aquifer comprised of fine- to coarse-grained sand (Delphi sands) interfingered with lenses of clay, silt, and peat which are from 1 to 15 feet in thickness. The third layer beneath the plant consists of an approximately 1,200-foot-thick clay, sand, and gravel mixture named the Montezuma Formation (CDM, 1997e).

There is no evidence of seismic activity within 3,000 feet of the plant. However, two local faults that have recorded Holocene displacement, the Vaca and the Antioch, are located between 1 and 25 miles from the plant (CDM, 1997e).

GEYSERS POWER PLANT

The Geysers plant is located within the Mayacmas Mountains, over 60 miles north of the Bay Area plants. The plant is in the northeastern-most portion of Sonoma County and a smaller adjoining portion of Lake and Mendocino Counties. This highland area is made up of a series of rugged northwest-trending ridges and valleys. The central ridge of the northwest-trending Mayacmas Mountains forms the boundary between Lake County on the east and Sonoma County on the west and extends into Mendocino County. Topography at the Geysers is steep and rugged. Elevations range from just over 1,000 feet in the base of Big Sulfur Creek to a maximum of about 3,600 feet along the ridge near the Lake County line (Parsons, 1996).

The main ridge of the northwest-trending Mayacmas Mountains is a prominent drainage divide. Creeks on the west side of the ridge flow toward the northwest, joining the Russian River near Cloverdale. Creeks on the east side flow both northeastward toward Clear Lake and southeastward into Lake Berryessa (Parsons, 1996).

The bedrock within the Geysers area consists of two basic groups: the Quaternary and Tertiary age volcanic rocks of the Clear Lake Volcanic Series and the Franciscan Formation of Jurassic-Cretaceous geologic age. The Clear Lake Volcanic Series rocks are of basaltic to rhyolitic composition and overlie the Franciscan rocks in the Clear Lake area north of the plant. The closest outcrop of these volcanic rocks to the plant is on Cobb Mountain. The Franciscan Formation is the predominant rock type within the area and consists of an assemblage of volcanic and sedimentary rocks that were deposited in a subsiding marine trough. Major rock types of the Franciscan Formation include graywacke, shale, and basaltic volcanics. These deeply imbedded rocks were subjected to regional metamorphism and intrusion by ultramafic rocks and are intensely fractured and degraded by hydrothermal (hot water) alteration due to infusion with hot, mineral-rich water. A thin veneer of valley alluvium sediments can be found in the local drainage channels, with thicker sequences found in the valleys to the east and west of the Geysers area (CDM, 1997a).

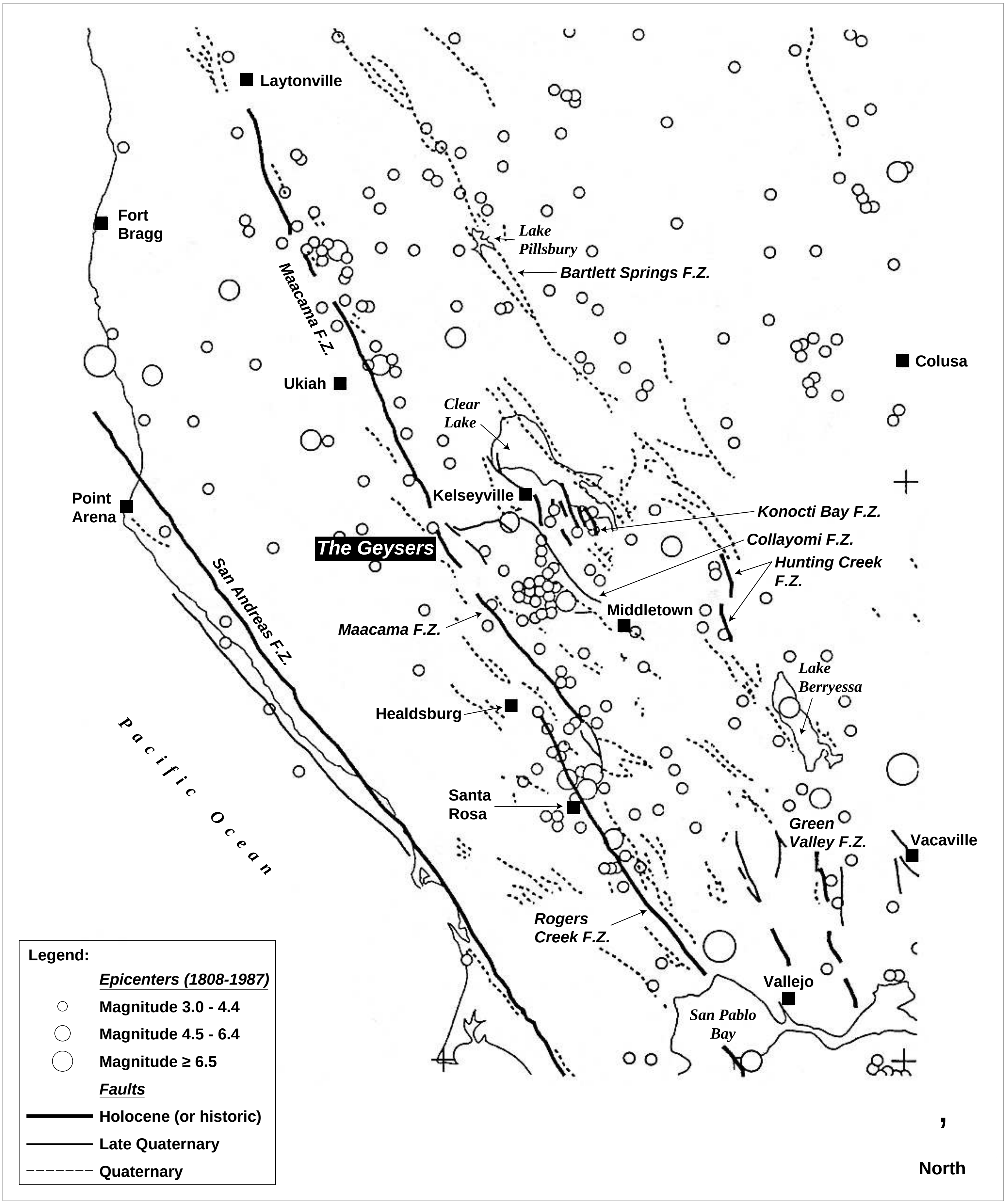
Soil cover is generally thin, and bedrock lies at or near the surface. Bedrock of other formations is scarce within the Geysers area. Pyroclastic (erupted volcanic material) and flow rocks of the Pleistocene Clear Lake Volcanics occur east of the project area at Cobb Mountain, Boggs Mountain, and Mount Hannah. Deep magma chambers such as those responsible for the Clear Lake Volcanics are presumed to contribute the heat that generates steam at the Geysers (Parsons, 1996).

Faults in the Geysers area are generally northwest oriented. The bedrock in the Geysers area is intensely faulted and fractured. Older, apparently inactive faults are abundant and are cross-cut by younger faults.

Seismicity

The northern portion of the Geysers area (Unocal lease area) is extremely active seismically with earthquakes of relatively small magnitude (Figure 4.3-2). Earthquakes occur at apparently random intervals rather than in related groups or swarms and generally have epicenters less than 20,000 feet deep. Seismic monitoring has demonstrated that the rate of earthquake occurrence increased as steam development increased from the 1960s to 1970s. Studies have revealed a correspondence between production wells, episodes of water injection, and earthquakes. Both steam production and injection of water to restore production may induce seismic activity (Parsons, 1996).

Baseline seismicity at the Geysers, before geothermal development began, is not well documented. It appears that the currently high rate of seismicity in the vicinity of the Geysers Geothermal Area began in the early 1960s, shortly after initiation of commercial steam power



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SOURCE: Harland Bartholomew & Associates, Inc.
Parsons Engineering Science, Inc.

Figure 4.3-2
Geysers Regional Faults and Seismicity

generation. Studies of induced seismicity in the Geysers area began in 1971, and by 1972 regional seismographic monitoring capabilities were established. At this time, numerous small earthquakes with epicenters in the Geysers area began to be routinely reported. Since 1975, more than 20,000 earthquakes with magnitudes ranging from 0.7 to 3.0 (Richter magnitude) and about 300 larger earthquakes (magnitudes ranging from 3.0 to 4.6) have been reported to originate at the Geysers. In the period from 1975 to 1985, 21 were reportedly felt in Cobb. Felt earthquakes reported from Cobb during this 10-year period ranged in intensity from II to V on the Modified Mercalli Scale (see Table 4.3-2), with 3 of the 21 reported events classified as Modified Mercalli V (earthquakes in May 1982, June 1983, and September 1984) (Parsons, 1996).

Based on the documented parallel increase of seismicity rates and geothermal development, including steam production and water/steam condensate injection, it has been established that these activities cause small earthquakes (microseismic events of 3.0 or less on the Richter scale). It is generally accepted that injection can generate earthquakes in the vicinity of wells by increasing water pressure on pre-existing fracture planes in the reservoir rock. This pressure reduces resistance to shearing and permits the release of natural tectonic stress and strain. However, the detailed mechanism of the release of natural elastic energy is not completely understood (Parsons, 1996).

Static-stress modeling calculations indicate that the small earthquakes induced at the Geysers do not contribute to the risk of larger earthquakes on nearby faults (Parsons, 1996).

Geysers Faults

The Maacama fault is a recognized Holocene fault that is located about four miles southwest of the Geysers Geothermal Area. The Green Valley fault, also Holocene, extends from Suisun Bay 55 miles northeast along the west side of Lake Berryessa and has recently been determined to extend north to connect with the Hunting Creek fault (Figure 4.3-2) (Parsons, 1996).

The Bartlett Springs fault, located 20 miles east of the Maacama fault, has displaced Holocene alluvium in several segments, and alignments of seismicity suggest that the fault is active. The largest earthquake magnitudes associated with this Bartlett Springs fault have been about magnitude 5 (Parsons, 1996).

The Konocti fault is a Holocene fault that may be responsible for three historic earthquakes. In 1954, a magnitude 4.4 earthquake caused slight damage at Lakeport. Two other earthquakes occurred near Kelseyville in 1955 and had magnitudes of 3.6 and 4.6 to 5.0. The first of these broke chimneys and windows at Lower Lake, and the second had similar effects and was felt over a 1,700-square-mile area (Parsons, 1996).

The Collayomi fault is located about 10 miles northwest of the Maacama fault and is mapped as late Quaternary. The Big Valley fault, located just northeast of the Geysers Geothermal Area, is considered to be a prominent splay of the Collayomi fault (Parsons, 1996).

TABLE 4.3-2
MODIFIED MERCALLI INTENSITY SCALE

I.	Not felt except by a very few under especially favorable circumstances.
II.	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended object may swing.
III.	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated.
IV.	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably.
V.	Felt by nearly everyone, many awakened. Some dishes, windows, and so on broken; cracked plaster in a few places; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.
VI.	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage slight.
VII.	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving cars.
VIII.	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving cars disturbed.
IX.	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
X.	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from riverbanks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks.
XI.	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII.	Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into the air.

[1] Abridged Modified Mercalli Intensity Scale (1956 version)

The Geyser Peak and Cobb Mountain faults have been mapped in the vicinity of the Geysers. These faults are classed as early Quaternary (700,000 years to 2 million years old) and are considered to be inactive. Numerous other pre-Quaternary faults are present in the vicinity of the Geysers. These older faults generally are related to the coastal thrust belt or the Coast Range thrust fault. They were active tens of millions of years ago, but have not shown evidence of activity during the last 2 million years (Parsons, 1996).

4.3.3 SIGNIFICANCE CRITERIA

A geologic impact would be considered significant if the project would result in any of the following, adapted from CEQA Guidelines, Appendix G (Governor's Office, 1997):

- Substantial flooding, erosion, or siltation.
- Exposure of people or structures to geologic hazards, soils, and/or seismic conditions so unfavorable that such conditions could not be overcome by special design using reasonable construction and/or maintenance practices.
- Construction on substrate that consists of material subject to liquefaction in the event of groundshaking.
- Earthwork with substantial or sustained import or export of soils through off-site areas.
- Construction on excessively steep slopes that could result in slope failure or landslides.
- Deformed foundations from exposure to expansive soils (those characterized by shrink-swell potential).

4.3.4 IMPACTS AND MITIGATION MEASURES

Impact 4.3-1: Minor construction activities resulting from the project (e.g., fences and site remediation) could cause soil disturbance. (Less than Significant)

The construction activities expected at the plants would be minor, such as building fences to separate properties being sold from PG&E's remaining properties and the remediation of contaminated soils. Construction contractors would be required to follow appropriate design criteria for seismic loading and other geologic hazards, as provided in the seismic elements of city and county general plans, which typically incorporate the design standards of the Uniform Building Code. Such minor construction activities would not result in any change in the public exposure to geologic hazards.

The project would not involve any physical changes that would contribute to land subsidence. No unique geologic or physical features or mineral resources have been identified that would be affected by the project.

If new owners wish to modify the plants, development entitlements and associated environmental review would be required. Assuming that appropriate engineering, design, and construction practices would be adhered to, as would be expected, impacts from expansive soil conditions would be less than significant.

The Potrero, Pittsburg, and Contra Costa Power Plant sites are almost flat. The minor construction activities that may be associated with the project would not change topography and would have little risk of causing erosion. Such minor construction activities at the Geysers may involve earthmoving activities on hillsides; however, the quantities of soils that would be disturbed are anticipated to be small. The construction activities associated with the project (e.g., fences) could disrupt soils and increase the potential for minor soil erosion. Soil remediation activities that may be a part of the ownership transition could cause stockpiled contaminated soil to contact rainfall runoff and wind. As described in Section 4.9, Hazards, soil remediation activities are subject to oversight by the pertinent local agency and/or the California Department of Toxic Substances Control. Worker safety related to remediation activities is promoted by federal and state OSHA regulations. Permits would need to be obtained prior to remediation work, and a remediation plan is usually prepared before such work begins. Remediation plans, and sometimes permits themselves, require that specified precautions be taken during remediation in order to protect human health and environment. This oversight typically includes means to control erosion of stockpiled materials.

Examples of procedural and operational controls that typically are implemented during remediation activities include covering soil stockpiles to prevent erosion and reduce infiltration; installing a leachate-control system to capture any leachate generated; constructing a containment cell to prevent runoff; installing treatment systems for treating groundwater, surface water, or air containing hazardous substances; collecting and analyzing test samples; watering disturbed areas to reduce dust generation; and wearing proper protective equipment to prevent worker contact with contaminated soil or groundwater. Many of these controls are contained in permit requirements that are issued by the regulatory agencies that oversee remediation activities. The entities that own these plants—whether PG&E or a future purchaser—would be subject to the same environmental and worker safety laws, rules, and regulations. The plants, under whatever ownership, would be expected to conform to all pertinent environmental and safety requirements.

If minor construction activities would disturb over five acres of land, an NPDES Stormwater Pollution Prevention Plan, which includes erosion control measures, would be required by the appropriate RWQCB. However, the project is not expected to disturb more than five acres at any of the plants and therefore expected disturbances would not be significant.

Mitigation Measures Proposed as Part of Project

None.

Mitigation Measures Identified in This Report

None required.

Impact 4.3-2: Potential operational changes due to the transfer in ownership of the Potrero, Pittsburg, and Contra Costa Power Plants would not create geologic problems. (Less than Significant)

Geologic problems, such as fault rupture, seismic groundshaking and failure, landslides, etc. would not be anticipated at these plants from any potential changes in operation of the plants, including increased electrical generation.

Mitigation Measures Proposed as Part of Project

None.

Mitigation Measures Identified in This Report

None required.

Impact 4.3-3: The change in ownership of the Geysers should not affect the potential for the facility to induce microseismicity in the project area and vicinity. (Less than Significant)

Previous studies have concluded that steam production and water injection of geothermal fluid at the Geysers have resulted in increased microearthquakes in the area (ESA, 1994; Parsons, 1996). Microearthquakes are those with a Richter magnitude of 3.0 or less and generally are rarely felt by the public.

The generating facilities operate only within specific ranges of steam pressure. As the pressure in a well decreases below the minimum, the well is shut down to allow water to flow back to the area and increase the pressure. The generation of steam is limited by the availability of water. Steam production at the Geysers has been declining since 1987 (Parsons, 1996). The apparent cause of the decline is the reduction in steam reservoir pressure. Sufficient injection water to adequately replace the amount of steam produced is not available. The steam field reservoir is rapidly declining. Many of the plants are not able to operate at full capacity due to the lack of sufficient water supply for producing steam (Winsor, 1998).

Supplementing the natural deep groundwater with condensate from the power plants, stormwater runoff, and with imported water has allowed for increased production. A project to import treated domestic wastewater and water from Clear Lake via a pipeline and inject this water into the steam field has been operating since September 1997 and has provided additional steam and electricity production. The project is designed to deliver an annual average of 5,400 gallons per minute (gpm) of injection water to the Southeast Geysers. The injection water is treated effluent from the Lake County Sanitation District's Southeast Regional Wastewater Treatment Plant and the Middletown Wastewater Treatment Plant. Water to supplement these flows is purchased from Yolo County and diverted from Clear Lake. As flows increase from the wastewater treatment plants due to population growth in the service areas, the need for Clear Lake water to supplement those flows for injection water is expected to decline. The Environmental Impact Report/Environmental Impact Statement (EIR/EIS) for the wastewater injection pipeline analyzed the potential of additional injection and production to increase seismic activity in the area. The study found that injection and steam production trigger large numbers of microearthquakes in the area by changing the natural stress regime and/or rock strength. Steam production appears to be a significant cause of shallow seismic events (above a depth of around 1.2 kilometers), whereas injection appears to be the main trigger for deeper events. These activities, however, correlate only to the occurrence of microseismicity. It was concluded that the enhanced injection from the project would be likely to increase microseismicity, which does not pose a public safety hazard or contribute significantly to property damage (ESA, 1994).

The Lake County Board of Supervisors created a Southeast Geysers Monitoring Advisory Committee to examine and report on seismic monitoring activity in the effluent injection area. The committee consists of representatives of homeowners, steam suppliers, the U.S. Geological Survey (USGS), the California Division of Oil, Gas and Geothermal Resources (DOGGR), the U.S. Bureau of Land Management (BLM), and the Lake County Sanitation District. The committee exchanges data on seismic activity and effluent injection and examines these data to estimate what effect, if any, effluent injection has on seismic activity in the area (Lake County, 1997).

The committee met on August 25, 1997 and on February 2, 1998. In the minutes of the February meeting, the seismic monitoring data collected by the Lawrence Berkeley National Laboratory (LBNL) were presented. The LBNL's representative interpreted the data and concluded that seismic rates are similar to those in 1994 and 1995, and that rates of seismicity and the magnitudes of events have not changed. Seismicity data from the Unocal/Calpine seismic monitoring network were also presented. The representative from Calpine stated that while previous data had suggested a correlation between steam production and number of seismic events, data since 1996 have not shown any correlation. A review of USGS seismic data was presented. The following was entered into the meeting minutes:

> Listed below are the results of a review of USGS reported seismic events of magnitude 0.9 and greater located in the Geysers Area during the period of May 1, 1997 through January 31, 1998, in light of production and injection operations in the SE Geysers area.
>
> 1. The SE Geysers Effluent Pipeline Project began delivery of water on September 25, 1997. The period of time reviewed for seismic events was selected to be the 4 months to date that have followed the start of injection of pipeline water, and the approximately equal period of 4 to 5 months prior to that startup event.
>
> 2. A total of 1,254 seismic events (of magnitude 0.9 and greater) were located by the USGS within all of the Geysers area during those 9 months, and of that total 158 events were recorded from within the SE Geysers.
>
> 3. The maximum-magnitude event recorded was 4.3, occurring October near Unit 14 in the Central Geysers. Five other events of 3.0 to 3.2 magnitude were recorded; the only one located in the SE Geysers Area was in July 1997.
>
> 4. The number of events per month recorded in the SE Geysers has varied between 9 and 28 during the past 9 months. The number of events per month neither correlates directly with the amount of steam production from the area, nor the amount of injection within the area.
>
> 5. However, it is apparent that more events have occurred in the Geysers area starting in December, and in the SE Geysers starting in January. This is perhaps in response to an overall increase of injection throughout all of the Geysers, due to the seasonal increase in the availability of plant condensate, due to increased rain water collection and extraction of water from streams, and, within the SE Geysers area, due to the

delivery of pipeline water. The recent increase in weekly events may also have been in part a response to the recent increase in the amount of seismic activity that had occurred throughout the North Coast and Bay region.

6. The average magnitude of the seismic events reported by the USGS has remained the same throughout the past 9 months, however. The median size event (of those of magnitude 0.9 or greater) was a magnitude of 1.6 during both periods, that period of about 5 months before the startup of pipeline operations, and during the 4-month period that has occurred to date following the startup.

7. In summary, the seismic events that have been reported by the USGS throughout the past 9 months would seem to indicate that the operations of the SE Geysers pipeline and the resulting injection activities have not caused any damage to the geothermal facilities or resources, not to any neighboring structure or condition. As in the past, the seismic activity of the SE Geysers area can be reasonably characterized as being of a microseismic nature, with few events of sufficient magnitude to be felt or noticed (Seismic Committee, 1998).

Only a few months of monitoring data have been collected since the introduction of injection of effluent from the Lake County project. Should the data indicate that the injection may be causing problematic seismic events, several remedies could occur. The BLM and DOGGR would work with the operators to move injection water to other wells to reduce the frequency of seismic events. Both agencies have the authority to shut down the operators or require adjustments in the injection of water or production of steam. The advisory committee could request that the Lake County Board of Supervisors, which is the same board that oversees Lake County Sanitation District, prepare a technical study (Dellinger, 1998).

Two other water importation projects are in planning stages. One would involve the conveyance and injection of treated wastewater from the City of Santa Rosa to the Geysers, and the other would increase the amount of treated wastewater from Lake County being injected at the Geysers. These potential projects are addressed in the cumulative impacts analysis in Chapter 5 of this EIR.

The generation of power at the Geysers cannot be substantially increased from existing levels without additional water supplies. Divestiture would not affect the ability to provide additional water and increase production and, therefore, would not alter microseismicity effects. Even with additional water supplies, which is not a part of divestiture, the studies referenced above have found that increased injection and production from the additional water supply would induce microseismicity, but the level of seismic activity would be minimal and considered less than significant.

Mitigation Measures Proposed as Part of the Project

None.

Mitigation Measures Identified in this Report

None required.

Impact 4.3-4: The transfer in ownership of the Geysers should not increase the frequency and magnitude of major earthquakes. (Less than Significant)

None of the above-mentioned studies (ESA, 1994; Parsons, 1996) have determined a relationship between steam production or water injection and an increase in frequency or magnitude of major earthquakes. Estimates from both a deterministic analysis and a probabilistic analysis in the Lake County EIR/EIS (ESA, 1996) indicated that the induced seismicity from production and injection at the Geysers would be an insignificant contribution to major seismic activity in the area. The Santa Rosa document (Parsons, 1996) states that, based on a statistical analysis, the wastewater importation project would not affect the maximum magnitude of earthquakes in the region.

Studies of the water importation projects, which are not a part of the divestiture project, have concluded that these projects would have insignificant effects on major seismicity in the area. This suggests that any operational changes as a result of the transfer of ownership, which does not include additional water supplies, would also not have a significant impact.

In summary, divestiture and the identity of the power plant owners should not affect the frequency and magnitude of major earthquakes at the Geysers. No mitigation is required.

Mitigation Measures Proposed as Part of Project

None.

Mitigation Measures Identified in This Report

None required.

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