3.2.1 Geology and Soils

The section discusses geology and soils resources potentially affected by the Project. Geology is discussed in Section 3.2.1.1.1 and soils are discussed in Section 3.2.1.1.2.

3.2.1.1 Affected Environment

3.2.1.1.1 Geology

Geologic Setting

The Project is located within the Sierra Nevada physiographic and geologic province. The geology of this province has evolved through many complex interactions within and beneath the earth's crust (e.g., plate tectonics). Other smaller-scale local processes, such as mass wasting, weathering, erosion, and sedimentation also constantly change the landscape.

The geologic history of the Project region spans from the mid-Paleozoic (i.e., approximately 300 to 400 million years ago [mya]) to the present day. The deepest basement rocks were emplaced about 225 mya, but are actually younger than many of the overlying metamorphic, volcanic, and sedimentary rocks exposed in the Project region. The basement rock and overlying rocks began to move westward with the formation of a subduction boundary on what was then the western margin of the North American land mass (Schweickert et al. 1984), located east of the present-day Sierra Nevada. Paleozoic and Mesozoic terranes were both accreted upon and subducted beneath the continent. Accretion occurred along the continental margin in long, linear strips, striking roughly parallel to the present-day Sierra crest. The subduction zone supplied the mantle with new rock to a depth great enough for the subducting plate to melt. The resulting magma eventually rose as both surface volcanic rock and subsurface granitic plutons. The granitic plutons compose much of the core of the current Sierra Nevada. Concurrent with the development of the plutons, the hot magma intruded into the folded sedimentary rocks, resulting in metamorphism and the creation of the famous Sierra Nevada gold deposits in the fractures (Bateman 1992).

Uplift along the eastern margin of the Sierra produced erosion through the beginning of the Tertiary Period (65 mya), exposing gold veins created during the Mesozoic. These gold veins eroded and the gold-laden sediments re-deposited throughout the ancestral Yuba River drainage, which ran approximately north to south across the peneplain that existed at the time. Tertiary river gravels are the source for much of the gold mined during the nineteenth century in the Yuba River drainage (Yeend 1974). The middle Tertiary was a time of volcanic eruptions that deposited lava, mudflows, pyroclastic flows, and ash throughout the Yuba River basin. These deposits filled many pre-existing drainages such as the ancestral Yuba River, as well as emplacing a cap of volcanic rock and volcanic debris on both the plutonic rocks and the eroded and intruded remnants of the preexisting early Mesozoic rocks.

Uplift along the eastern Sierra Nevada margin resulted in the predominantly east-to-west trends of incised drainages evident today. Subsequent to the middle Tertiary volcanic eruptions and mudflows, three late Quaternary glacial stages, each with multiple sub-stages, occurred in the

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northwestern Sierra Nevada (James 2003; James et al. 2002). The bedrock geology in the Project region is composed of Paleozoic metasediments and metavolcanics (undifferentiated), Paleozoic and Mesozoic granitics (i.e., Valley Pluton, Cascade Pluton [Day et al. 1985], Yuba Rivers Pluton [Day et al. 1985; Day and Bickford 2004]), and a Mesozoic ophiolite complex (i.e., Smartsville Complex; Beard and Day 1987; Day et al. 1985; Day and Bickford 2004). Tertiary auriferous (gold-bearing) sediments, including auriferous river gravels deposited by the ancestral Yuba River, are present in the eastern portions of the Project region.

The Narrows Penstock Geologic and Geotechnical Evaluation (Geomatrix 2000), includes a description of the area's geologic setting. An excerpt from the report is included here:

> The Project is in the northeastern portion of the western Sierra Nevada metamorphic belt. Bedrock at the site and surrounding region consists of variably metamorphosed Triassic-Jurassic intrusive and extrusive igneous rocks of the Smartsville Complex (Saucedo and Wagner 1992). The Smartsville Complex is the westernmost of four fault-bounded lithotectonic belts in the northern Sierra Nevada that record the transition from continental crust in the east to accreted oceanic crust on the west. The Smartsville Complex represents a rifted volcanic arc, consisting of igneous basement, volcanic flow deposits and fragments of post-volcanic sedimentary cover.
>
> In the site vicinity the Smartsville Complex consists of a Jurassic ophiolitic dike complex composed largely of metavolcanic rocks (tuffs, breccias and flow basalts) intruded by crosscutting igneous dikes. The composition of the dikes range from basaltic to silicic and in general, they are north-northeast trending, dip steeply to the east, and have an average thickness of about 1 to 2 meters.
>
> The area is structurally complex due to ductile shearing, folding, and faulting related to regional accretionary processes and deformation during Jurassic collision between the island arc and continental North America. The Smartsville Complex is bounded on the east by the Big Bend - Wolf Creek fault zone, and on the west by the Swain Ravine fault zone, both of which are members of the Foothills Fault System.

Tectonic History

Uplift of the Sierra Nevada began approximately 3 to 5 mya (Unruh 1991; Wakabayashi and Sawyer 2001; Henry and Perkins 2001), which is approximately synchronous with the uplift of the Carson Range, bordering the Tahoe basin on the east, at 3 mya (Surpless et al. 2000). The uplift was accompanied by westward tilting of the range, stream incision, and downwarping of the Central Valley.

The Project is in a region dominated by extensional tectonics of the Sierra Nevada; most modern faults in the region were reactivated in the late-Cenozoic as predominantly high-angle, northwest-trending, east-dipping, normal faults (Schwartz et al. 1977). Deformation is pronounced in bands of weak, ultramafic rock (Bennett 1983). The Swain Ravine Fault Zone is

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located approximately 4 miles west of the Project, parallel to the Big Bend Wolf Creek Fault Zone. The Cleveland Hill Fault is the northern extension of this zone near Lake Oroville, approximately 15 miles northwest of the Project. The 1975 Oroville earthquake occurred on the Cleveland Hill fault and also developed racks over the northern portions of the Swain Ravine fault (Page and Sawyer 2004)

One historically active[1] and two potentially active, late Quaternary faults are located within 15 miles of the FERC Project Boundary (CDC 2010), discussed below in order of increasing distance from the Project. The next closest potentially active faults include the late Quaternary active Dunnigan Hills fault located 45 miles to the southeast and the Holocene active Mohawk Valley fault located approximately 52 miles to the east. The first potentially active fault is the Swain Ravine fault, located 3.6 miles west of the FERC Project Boundary. The Swain Ravine fault is a northwest-striking fault in the western Sierra Nevada foothills that extends approximately 15 miles from Honcut Creek on the north to the area between the Yuba River and Beale Air Force Base on the south. The Swain Ravine fault was originally recognized and mapped as a series of topographic, tonal, and vegetation lineaments. It is generally interpreted to be part of a Mesozoic fault system that includes both the Swain Ravine fault and the Cleveland Hill fault to the north. Paleoseismic studies have documented evidence for post-Pliocene and late-Quaternary rupture on the Swain Ravine fault.

The second potentially active fault is the Paynes Peak fault, which is located 10 miles north-northwest of the FERC Project Boundary. Only the Swain Ravine and Cleveland Hill faults have previously been considered active or potentially active, but recent studies for the South Feather Water and Power Agency's seismic and geologic investigations of the Little Grass Valley and Miners Ranch Dams concluded that the Paynes Peak fault is potentially active and capable of a magnitude 6.5 earthquake, similar to the Cleveland Hill fault.

The historically active Cleveland Hill fault is an approximately 8-mile-long fault, located 15 miles northwest of the Project FERC Boundary. The central portion of the Cleveland Hill fault ruptured on August 1, 1975 during the local magnitude 5.7 Oroville earthquake. This earthquake produced about 3 to 4 centimeters of right-lateral surface displacement and about 4 to 5 centimeters of vertical surface displacement, suggesting an oblique sense motion on the fault. The hypocenter locations of over three hundred aftershocks during August 1975 define a fault plane that strikes N03 degrees east and dips about 60 degrees to the west.

Mineral Resources

Gold mining is the dominant mineral resource activity in the region and there are many abandoned and active mines scattered throughout the Yuba River Basin. However, no mines or mine tailings occur within the Project Boundary or in the vicinity of the Project along the 2 miles of the Yuba River immediately downstream of the Project (Loyd and Clinkenbeard 1990).
USACE's Englebright Dam was constructed in 1941 by the California Debris Commission to capture sediment from upstream sources. Although no hydraulic mining has occurred in the

[1] "Historically active" is defined as a fault along which displacement has occurred during the last 200 years (CDC 2010).

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upper Yuba River watershed since construction of Englebright Dam, the historical mine sites continue to contribute sediment to the river.

Physiography and Geomorphology

The Sierra Nevada crest forms the eastern limit of the Yuba River watershed and trends north-northwest with steep, eastward-dipping escarpments to the Tahoe Basin. Downfaulting of the eastern Sierra face has affected drainage evolution by beheading channels (James and Davis 1994). Uplifting and tilting of the Sierra Block reorganized drainage networks and initiated a period of sustained channel incision (Curtis et al. 2005a, 2005b), and many of the modern channels have elevations below the Tertiary channels. The ancestral (Tertiary) Yuba River has cut about 985 feet below a surface defined by the San Juan, Washington, and Harmony ridges (James 2003). These ancestral deep channels drained north-northwest across the strike of the modern drainages (James 1991). The channels were filled first by very coarse, bouldery material rich in gold, followed by finer gravel and sand filling also rich in gold (James and Davis 1994). These Tertiary gravel deposits are the source of the gold that was heavily mined in the late 1800s starting a little over 2 miles downstream of the FERC Project Boundary and in other places in the Yuba River watershed. Due to the proximity of the Project to USACE's Englebright Dam, there are no known upland sources of sediment to the Yuba River between Englebright Dam and the FERC Project Boundary.

History of Fluvial Geomorphic Perturbations in the Lower Yuba River

The Yuba River is one of the most severely disturbed rivers in the U.S. Between 1852 and 1906, an estimated 366,500,000 cubic yards of hydraulic mining debris moved downstream from the upland mining areas of the greater Yuba River watershed and were deposited in the Yuba River downstream of Englebright Dam causing aggradation on the order of 26 to 85 ft (Adler 1980). This massive sedimentation in the channel and floodplains transformed the river into a braided, unstable stream system, though Mendell (1881) stated that most of the sediment was not exported from near-mine locations until the floods of 1861. Even prior to mining, the river had already been highly altered by sedimentation, agriculture, and engineering projects (James 2013). Pre-European, the riparian zone near Marysville had been described as covered by tall trees, brush and vines, with a low floodplain in places with a dark soil developing; an older terrace rose above the floodplain further from the channel that was capped with a soil that supported fewer trees. Adler (1980) states that by 1906, the supply of hydraulic mining debris from upland areas was mostly depleted and degradation became the dominant process along the Yuba River. Based upon historical channel cross-section data collected along the Yuba River during the late 1800s and early 1900s and updated in 1979, Adler concluded that the river channel had attained equilibrium by 1940 to a channel morphology similar to its pre-1849 channel configuration (i.e., single stable channel, similar channel elevation), except the stream channel is now bordered by large cobble training walls that constrain the channel width in many sections (Adler 1980). The study further concluded that since 1940, almost 90 percent of the hydraulic mining debris deposited in the Yuba River downstream of Englebright Dam remains today as quasi-permanent deposits in the floodplains. The cobble training walls, along with the massive deposit of hydraulic mining debris behind the training walls, are now a stable, generally immobile part of the lower Yuba River system.

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The effects of hydraulic mining are particularly significant where the Feather and Yuba rivers converge near Marysville (EDAW 2006). At the mouth of the Yuba River at the south edge of Marysville, 70 ft or more of sediment eventually filled the river channel. Upstream of Marysville, entire communities were buried under more than 40 ft of silt and gravel (Hoover et al. 1990). Sacramento River Flood Control Project levees were constructed along the Feather and Yuba rivers and their tributaries to prevent flooding of valley communities. The levees prevented communities from becoming buried under the sediments that were washed down from the mountains. The levees were built even higher and designed to confine the floodwaters to a relatively narrow channel that would maintain sufficiently high velocities to efficiently convey sediment through the system, reducing the amount of dredging necessary to maintain navigation. As a result of the levees, Marysville, Olivehurst, and Linda are now many feet below the floodwater levels of the Feather and Yuba rivers. James (2013) has constructed a more detailed history of the Yuba River downstream of Englebright Dam.

More recently, studies by the Three Rivers Levee Improvement Authority broadly state that as hydraulic mining sediment supplies decline, the rivers again will adjust to a new equilibrium. Ultimately, hundreds to thousands of years in the future, it is likely that the river channels will cut down to their pre-mining elevations and begin migrating laterally (TRLIA 2006).

While no specific sites were identified, Yuba County (2008) identified eastern Yuba County soils on steep topography as being prone to erosion when disturbed. In general, the highest erosion hazards are located along the Yuba River between Smartsville and the northeast boundary of the county. Additionally, the erosion hazard rating of “Very Severe” also applied to soils downstream of the Merle Collins Reservoir for about 4 mi along Dry Creek.

A continuing source of sediment to the Yuba River is artificial gravel injection to enhance Chinook spawning habitat. University of California, Davis, USFWS and USACE collaborated on a pilot gravel injection project downstream of Englebright Dam in November 2007 (Pasternack 2009). They added to the Yuba River an estimated 361 cubic yards (5,000 short tons) of material. Since 2007, USACE has continued adding gravel to the Yuba River, injecting the gravel immediately downstream of the Narrows 1 Powerhouse. Through 2020, USACE has injected approximately 15,500 short tons of gravel.

Due to these historical perturbations, today the 24.3 miles-long section of the Yuba River downstream of Englebright Dam to the Feather River confluence is a single-thread channel, the morphology and functional processes of which are in accordance with similar alluvial channels (i.e., C3 Rosgen channel types). The river corridor is confined in a bedrock canyon in the uppermost 2 miles where the Project is located, then transitions to a wider bedrock valley and finally, to a wide alluvial valley to the Feather River. The lower Yuba River has an average channel gradient of 0.16 percent and a mean substrate size of 97 mm (i.e., cobble-size material). Historical hydraulic mining, which is discussed above, is the source for the vast majority of the modern alluvium, and the tailings were used to create training berms for much of the lower river corridor. The channel and floodplain are highly connected - floods spill regularly onto the floodplain. The valley corridor is wide enough to allow for potential meandering and, in fact, meandering is cutting into artificial training berms presenting the potential of eventual re-incorporation of the Yuba Goldfields. Avulsion is a key geomorphic mechanism that keeps

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distal floodplain regions geomorphically active even in the absence of high sinuosity. Bars and floodplains are hydraulically connected, and the floodplain up to the level of the floodway/valley is inundated about every 2.5 years under recent historic conditions. Overall, there is a slight deficit of sediment; namely, scour processes (i.e., mostly within-channel scour processes) exceed depositional fill processes from all other processes, including in-channel bar processes, which is one reason why USACE is injecting sediment into the river, as described above. Sediment is both eroded and deposited throughout the river valley in a complex spatial pattern, with a relatively small net outflux, though outflux is still quite large compared to other rivers in the region. The river is continuing to adjust back to the pre-mining base level through dynamic processes.

3.2.1.1.2 Soils

Soil Types

Soil types are strongly influenced by underlying bedrock. The Project is located on steep, stable slopes with two types of major soil series that occur within the FERC Project Boundary: 1) the Rock Land series; and 2) the Auburn-Rock outcrop complex series (USDA-SCS and USFS 1993) (Table 3.2.1-1).

Table 3.2.1-1. Soil types within the FERC Project Boundary.

Unit name	Kind	Dominant Order	Dominant Suborder	Drainage Class
Rock Land, 2 to 75 percent slopes	--	--	--	Well Drained
Auburn-Rock outcrop complex, 2 to 30 percent slopes	Complex	Inceptisols	Xerepts	Well Drained

Source: USDA-SCS and USFS 1993

The Rock Land series occurs throughout approximately 95 percent of the FERC Project Boundary, including all areas except around the tram house. It is predominantly composed of rock outcrop with little to no soil cover, consisting of extremely rocky or stony basic, metabasic, metamorphosed, ultrabasic and sedimentary rock material. The Rock Land series is found on undulating to very steep with slopes ranging from two to 75 percent, and commonly adjacent to major drainage channels (USDA-SCS and USFS 1993).

The Auburn-Rock series occurs in about 5 percent of the FERC Project Boundary, found only in the area surrounding the tram house, and consists of well-drained soils underlain by weathered diabase and metabasic rock. These soils are found on undulating to steep slopes and are on mountainous uplands of the middle and lower parts of foothills. Slopes range broadly from 2 to 30 percent. Runoff is slow to medium. Typical depth to bedrock ranges from approximately 14 to 27 inches. In a representative profile the surface layer is about 9 inches of brown and reddish-brown loam and heavy loam. The subsoil is about 7 inches of yellowish-red light clay loam. Approximately 10 to 25 percent of the Auburn-Rock series exists as rock outcrop with no soil layer.

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