3.2.1 Geology and Soils

3.2.1.1 Overview

In addition to this introductory information, this section is divided into eight subsections. Sections 3.2.1.2 through 3.2.1.7 provide general information regarding geologic features, tectonic history, mineral resources, physiography, geomorphology, and soils in the Project Region. Section 3.2.1.8 describes existing, relevant, and reasonably available information regarding geology and soils upstream of the Project, within the Project Area, and the lower Bear River. Section 3.2.1.9 describes known or potential Project effects on geology and soils.

SSWD prepared this section based on its collection of existing, relevant and reasonably available information on geology and soils. Specifically, SSWD found 35 source documents regarding geology and soil conditions. These are listed below and cited throughout this section:

- Seventeen papers and literature on the general geology, mining, and faults of the Sierra Nevada and Bear River Drainage.
- Eight papers and literature on the effects of hydraulic mining on the Bear River.
- Forest Service 2002.
- Waring 1919.
- TNF 1975-2001.
- Placer County Planning Department 2004
- Placer County Planning Services Division 2012 and 2015
- Placer County 2004
- ECORP 2014
- STATSGO USDA NRCS Soils Data Base : soil data published in 2001
- Mines from USGS (Reston, VA), publication date is 2005 (http://mrdata.usgs.gov/mineplant/)
- Geology maps: data for the 30'x60' 1:100k maps accessed 6/30/15 from the CA Geologic Survey site (http://www.conservation.ca.gov/cgs/rghm/rgm/Pages/preliminary_geologic_maps.aspx)

3.2.1.2 Geologic Features

The Project Region is located within the Sierra Nevada physiographic and geologic province. The geology within the Project Region has evolved through many complex interactions within and beneath the earth's crust. These processes include plate tectonics, where continents are created by various mechanisms and are transformed by other mechanisms. 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 the period from the mid-Paleozoic, approximately 300-400 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 terrains 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 as 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 (Forest Service 2002).

The middle Tertiary was a time of volcanic eruptions that deposited lava, mudflows, pyroclastic flows, and ash throughout the Yuba and upper Bear River basin. These deposits filled many pre-existing drainages such as the ancestral Bear 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 pre-existing early Mesozoic rocks. From 14 to 4 mya, these tuffs were in turn buried by andesites, andesitic mudflows, and associated volcanic sedimentary rocks (PG&E, Piedmont 2003).

Subsequent to this latest orogeny of eruptions and mudflows, three late Quaternary glacial stages, each with multiple stages, occurred in the northwestern Sierra Nevada (James 2003, James et al. 2002). Glacial till and associated moraines extend west into the upper Bear River near Drum Forebay at Alta (PG&E, Piedmont 2003).

Uplift along the eastern margin of the Sierra produced erosion through the beginning of the Tertiary Period (65 mya), exposing the gold veins that had been created during the Mesozoic. These gold veins were eroded and the gold-laden sediments re-deposited throughout the ancestral Yuba River drainage, which ran approximately north to south. The “Tertiary River Gravels” are the source for much of the gold mined during the 19th century in the Yuba River drainage (Forest Service 2002), which also includes the Bear River. The ancestral headwaters of the Bear River was captured by the Yuba River (James 1995), but was once a part of the Yuba. Because of the gold-laden gravels deposited, uplifted and subsequently exposed, the Bear River was one of the most heavily mined and modified drainages in the Sierra (James 2004).

Specifically within the Project Vicinity, downstream of the Camp Far West Reservoir, valley sediments are dominated by Quaternary alluvium (Figure 3.2.1-1), which comprises 64.9 percent of the Project Vicinity (Table 3.2.1-1). Bedrock geology near the Reservoir is composed of Jurassic volcanic rocks, quartz diorite, and massive diabase of the Smartville Complex, and is the second-most common material at 22.4 percent. The Bear River arm of the Camp Far West Reservoir has an intrusive mafic dyke that strikes northwest across both Bear River and Wolf Creek (Alpers et al. 2008).

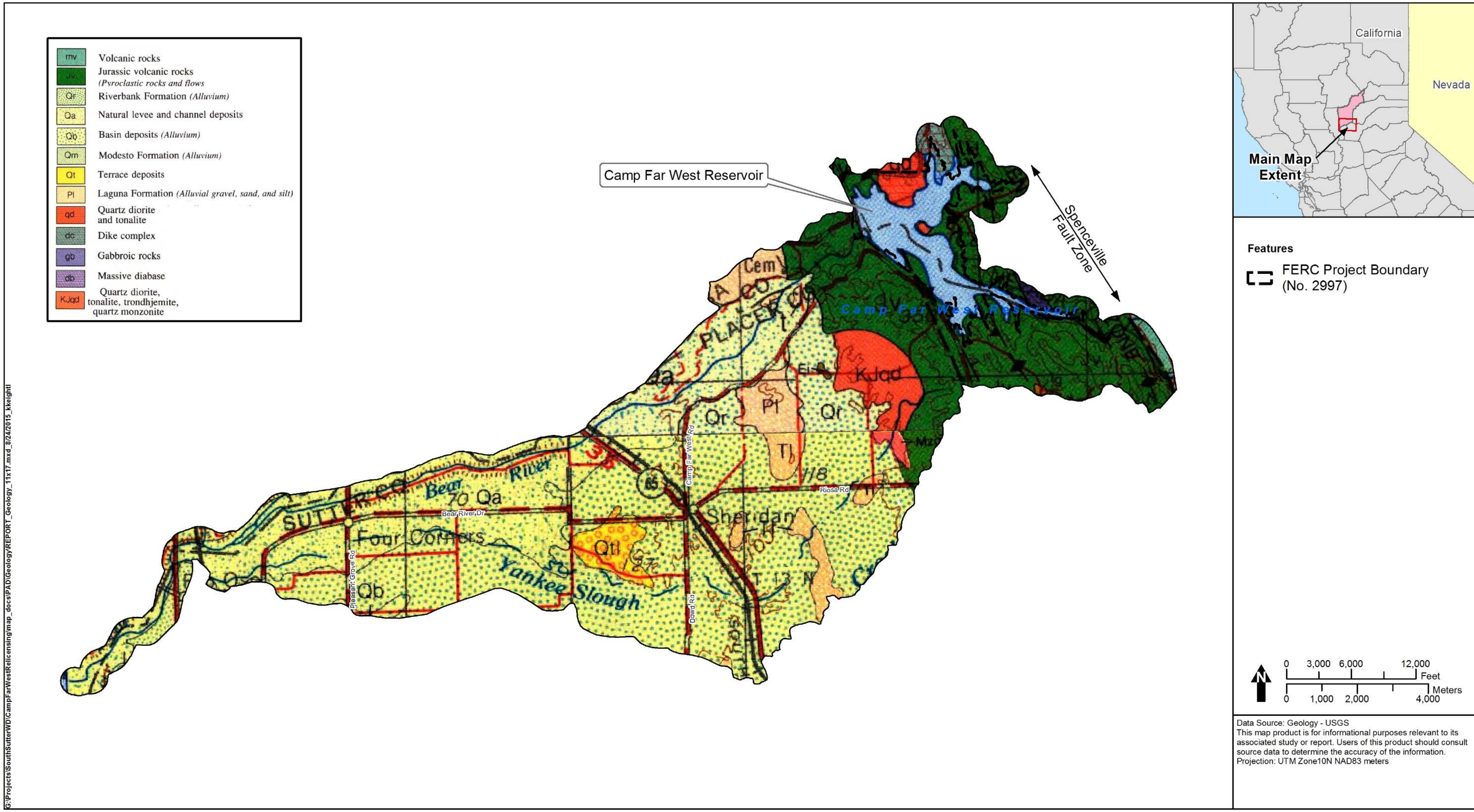

Figure 3.2.1-1. Geology map of Project Vicinity.

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Table 3.2.1-1. Description of generalized geologic rock types in the Project Vicinity.

Rock Type[1]	Area (acres)	Percent (%)	Description	Age
Quaternary Alluvium (Qr, Qb, Qa, Qt, Pl)	27,102	64.9%	Poorly consolidated gravels, sands and clays along river courses, levees, river banks, terraces adjacent to and within Dry Creek and Bear River downstream of the Project Area.	Quaternary – Pleistocene and Holocene
Laguna Formation	1,935	4.6%	Consolidated Alluvium – gravel sand and silt	Pliocene
Tailings	68	0.2%	Hydraulic and placer mining tailings	Recent, historical
Smartville Complex (Jv, qd, dc, gb)	9,352	22.4%	Pyroclastic rocks and flows, quartz diorite and tonalite, dike complex and gabbro that surround Camp Far West Reservoir.	Jurassic
Volcanic Rocks (mv)	1,432	3.4%	Undifferentiated rocks of the Smartville complex upstream of Camp Far West and dominate Wolf and Bear Creek drainages to Lake Combie.	Jurassic
Ultramafic and metasedimentary rocks	98	0.2%	Folded and faulted rocks near the Wolf Creek fault zone at the upper end of Wolf and Little Wolf Creeks.	Triassic
Water	1,775	4.3%	--	--
Total	**41,762**	**100%**	--	--

[1] Refer to Figure 3.2.1-1 for a description of each rock type.

3.2.1.3 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.

Most faults resulted from late Paleozoic and Mesozoic tectonic collisions. Faults that were re-activated in the late-Cenozoic are predominantly high-angle, northwest-trending, east-dipping, normal faults resulting from extensional stresses (Schwartz et al. 1977). Deformation is pronounced in bands of weak, ultramafic rock (Bennett 1983), as with the formations associated with the Wolf Creek Fault at the upper end of Wolf and Little Wolf Creeks.

The Spenceville Fault Zone trends northwest-southeast and occurs just to the east of Camp Far West Reservoir. The Wolf Creek Fault Zone bisects Wolf and Little Wolf creeks, and the Bear River downstream of Lake Combie, and several mi upstream of the Camp Far West Reservoir. The Wolf Creek Fault in the Bear River Basin is also known as the Highway 49 Lineament (Bennett 1983) and recognized as a southern extension of the Big Bend Fault (Rogers and Williams 1974).

3.2.1.4 Mineral Resources

Five mines were found in the Project Vicinity, most of which were gold and copper mines (Figure 3.2.1-2, Table 3.2.1-2).

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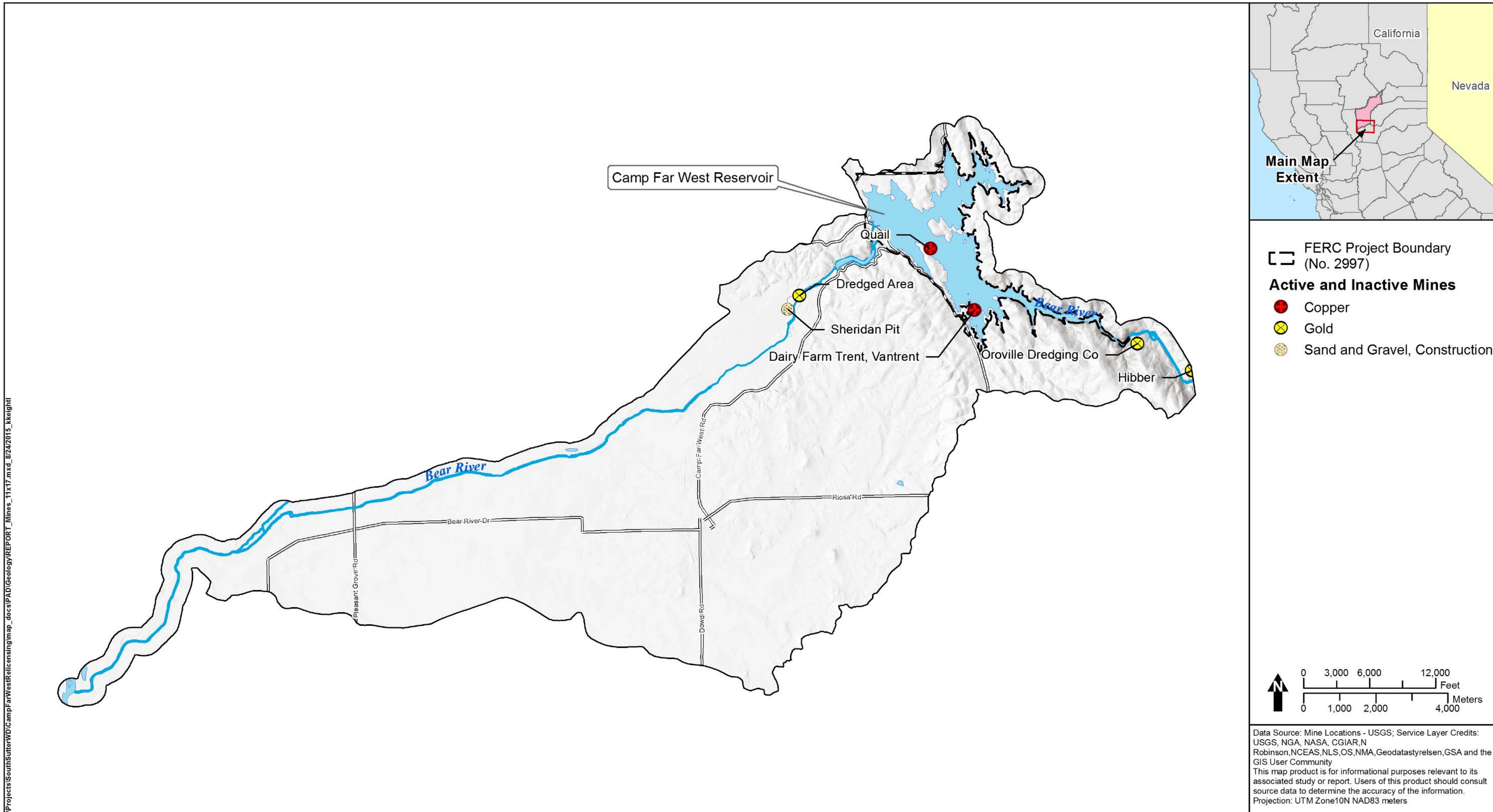

Figure 3.2.1-2. Active and inactive mines in the Project Vicinity.

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Table 3.2.1-2. Mines in the Project Vicinity.

Site Name	Major	Minor	Operation	Status	Previous Name
Dairy Farm (Trent, Vantrent)	Copper, Gold	Silver	Unknown	Past Producer	--
Hibber	Gold	Copper	Unknown	Past Producer	--
Dredged Area	Gold	--	Placer	Unknown	--
Oroville Dredging Company	Gold	--	Placer	Unknown	--
Quail	Copper	Silver (trace)[1]	Unknown	Occurrence	--
Sheridan Pit	Sand and gravel	--	Surface	Producer	Sheridan Plant

[1] Not specifically defined in the database, but is assume to be less than a "minor" component.

One of the main mines near Camp Far West Reservoir is the inactive Dairy Farm Mine (Trent Mine and Vantrent Mine). The deposit from which copper, zinc, and gold were derived is part of the Foothill Copper-Zinc Belt, which extends along the western slope of the Sierra Nevada in eastern California (Heyl 1948). Open pit and underground mining began during the 1860s and continued in the early 1900s and 1930s. The pit created during the 1920s and 1930s extends more than 150 ft below the surface, which is inundated by the Camp Far West Reservoir during high levels, but is hydraulically isolated at low elevation (Alpers et al. 2008). Underground mining followed the massive-sulfide deposit to a total depth of at least 500 ft; the deposit was 10 to 60 ft thick and more than 600 ft long. In 1915, 350 tons of ore per day were mined (Waring 1919). A cyanide plant with a capacity of 100 tons per day was active on the site prior to 1915. In the 1930s, gold was recovered from the oxidized portion of the deposit (Clark 1963).

The auriferous gravels of the Bear River were mined extensively by hydraulic mining methods in the mid to late 1800s. In addition, there was underground mining of lode gold-quartz vein deposits in the Grass Valley mining district, which drains into Wolf Creek (Alpers et al. 2008). Much of the fluvial deposits of hydraulic mine waste in the Bear River watershed remain to this day (James 1991, 1993, 1999).

The dredging industry was an important aspect of placer mining in the early 1900s. A small district was worked for some time near Camp Far West on the Bear River above Wheatland, but the gravels were too low grade and operations were suspended (Lindgren 1911).

There is one active quarry site along the Bear River in both Placer and Yuba counties. Cemex Construction is expanding the existing Patterson Sand and Gravel Mine operation over a 38-year span (Placer County 2015). Currently, the company is permitted through 2028 to operate the mining operation on 326 ac at 8705 Camp Far West Road. The 448-ac proposed expansion is immediately south and west of the existing operation on the Bear River floodplain (Foster 2005).

3.2.1.5 Physiography and Geomorphology

The current Bear River basin drains the northwestern Sierra Nevada via a series of deep canyons cut by mountain channels, separated by high, steep sided ridges and a parallel drainage network. In the upper section of the Bear River above Lake Combie, downcutting, through the relatively soft Paleozoic metamorphic rock (Shoo Fly Complex) has created a deep, v-shaped canyon where short, steep-sided tributary drainages are typical (Geomatrix 1997). However, in the lower Bear River downstream of Camp Far West Dam, the river flows through alluvial material and constructed levees. According to Sacramento River Watershed Program's report on the Bear

River, a high volume of mining sediment and the levees restricting lateral movement have caused the lower Bear River to become incised (SRWP 2010); Foothills Water Network (FWN) (2015a) also cites this condition but neither have provided data nor sources. During habitat mapping of the lower Bear River in 2015, SSWD found numerous locations where the channel is bounded by near vertical slopes between levees, though there are also inset floodplains and terraces where gravel bars form between the levee and hillslopes.

3.2.1.6 Erosion and Sedimentation

There are no known excessive sources of erosion that would lead to sedimentation within the Project Area. In 2008, a bathymetry study was done on Camp Far West Reservoir and compared against 1968 bathymetry. The 1968 storage volume was estimated at 104,000 ac-ft and in 2008 at 93,740 ac-ft, a loss of 10,530 ac-ft[1] (Mead and Hunt 2012). Based on an average specific weight of 70 pounds/cubic feet (cu ft), as estimated by Dendy and Champion (1978) for Lake Combie, this volume of sediment deposition in the reservoir indicates 16 million tons of sediment have been deposited, or 321,000 tons/year (yr.), which translates to 2,188 tons/mi^2/yr. Accumulation rates for other reservoirs in the area are shown on Table 3.2.1-3.

Table 3.2.1-3. Accumulation rates in nearby reservoirs.

Stream	Reservoir (River Mile (RM) at Dam)	Rate of Deposition (ac-ft/mi/yr)
Bear River	Rollins Reservoir (RM 50.4)	2.1
	Lake Combie (RM 37.2)	0.75[1]
	Camp Far West (RM 18.2)	1.4
Yuba River	Englebright Reservoir (RM 24.3)	0.6

[1] Estimated by Dendy and Champion (1978).

Though sediment supply is high in the lower Bear River due to continued movement and availability of hydraulic mining debris, downstream of some dams, the channel can respond either with coarsening of the bed, or there may be no change if the downstream channel was originally transport-dominated (e.g., bedrock control with little storage of sediment). Construction of Camp Far West Dam and Lake Combie Dam (aka Van Geisen Dam) in 1928 halted downstream transport of most mining sediment (James 1988). Downstream channel responses to Van Geisen Dam were negligible in the middle Bear River because channels are dominated by bedrock. There was significant accumulation of sediment in the early 1900s at the Van Trent Gage, which was inundated by the Camp Far West Reservoir, which was attributed to historic mining sediment (James 1999).

Slopes are generally less than 25 percent downstream of Camp Far West Dam. The Bear River arm of the Camp Far West Reservoir is in the 25-50 percent range (Figure 3.2.1-3). A small number of areas have a slope greater than 50 percent, and are located on the Bear River where it narrows upstream of the main reservoir body. However, it appears that these steepest slopes are dominated by bedrock, judging from aerial photographs, and are likely resistant to erosion. The spillway just below the dam is also in the 25-50 percent range, but the spillway runs over bedrock.

[1] Calculated volume: 10,530 ac-ft*43,560 ft^2= 458,686,800 ft^3. 70lbs/ft^3 = 3.2x10^{10} lbs = 16 meter (m) tons/50 year = 321,000 tons/year. Camp Far West Dam drains an area of 146.7 mi^2.

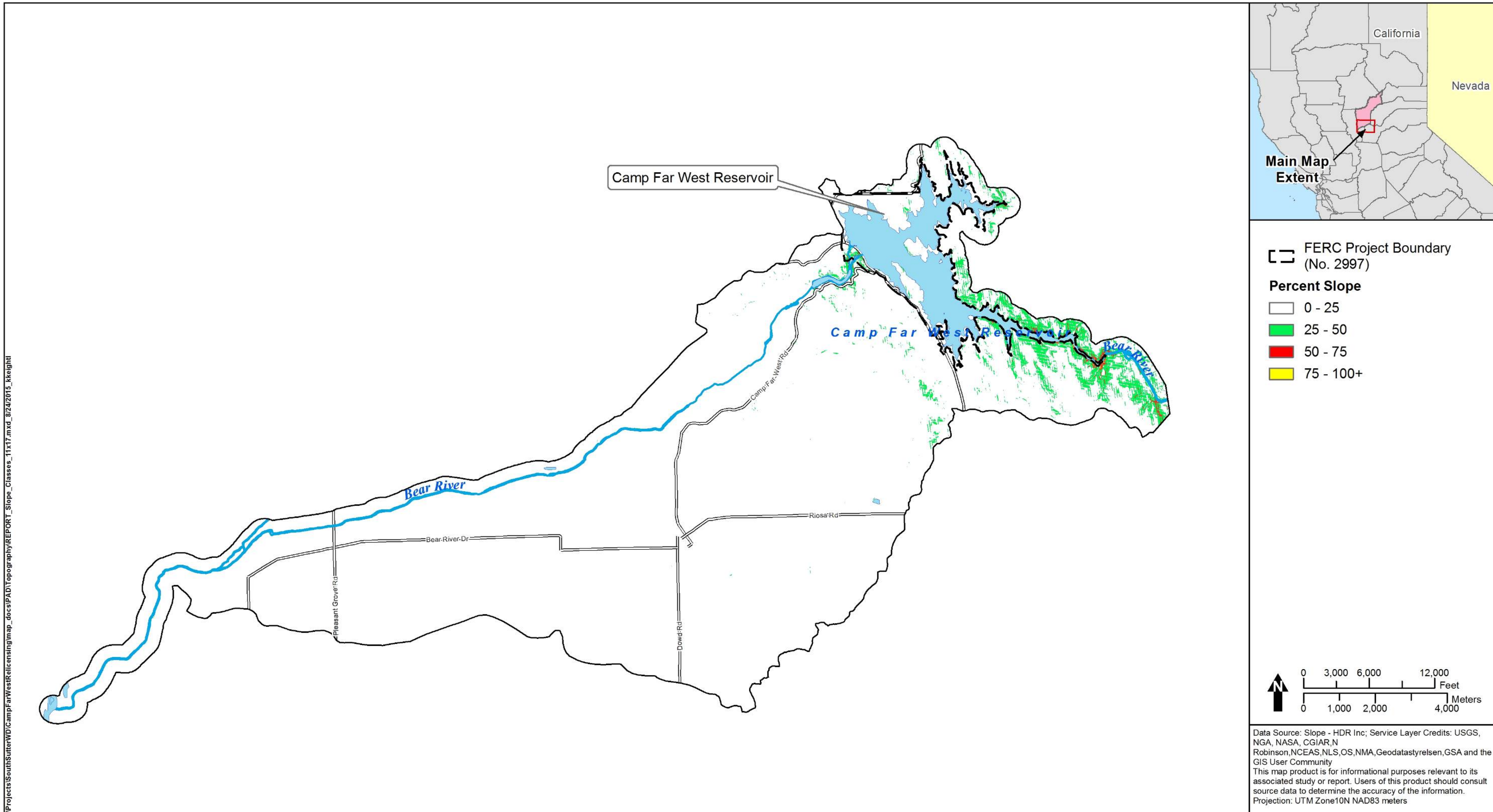

Figure 3.2.1-3. Slopes in the Project Vicinity.

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In June 2015, SSWD mapped 6.4 mi of the Bear River below Camp Far West Dam for habitat features and channel characteristics. Out of the 6.4 mi, only about 3,500 ft (i.e., 5%) were noted to be actively eroding. There are significant quantities of gravel in the Bear River, much of which may be derived from hydraulically mined sediments. During habitat mapping, about 32,000 square feet (sq ft) of trout and salmon spawning-size material was estimated in the 6.4 mi. It is estimated that 160 million cubic yards (cu yd) of mining sediment are stored in the lower Bear River (FWN 2015a). The high volume of mining sediment, in combination with restricting levees, has caused the lower Bear River to change from wide and shallow to deeply incised, according to the FWN, but no data have been collected.

3.2.1.7 Soils

Soil associations in the Project Vicinity are shown in Table 3.2.1-4 and Figure 3.2.1-4.

Table 3.2.1-4. Soil associations in the Project Vicinity.

Soil No.	Soil Association	Acres	% of Total
s855	Sycamore-Shanghai-Nueva-Columbia	11,552	28%
s840	Sobrante-Rock outcrop-Auburn	9,088	22%
s870	Tisdale-Kilaga-Conejo	13	<1%
s825	San Joaquin	6,799	16%
s8369	Water	2,071	5%
s821	Redding-Corning	8,533	20%
s839	Xerofluvents-Ramona-Kilaga-Cometa	1,912	5%
s817	Sierra-Caperton-Andregg)	1,794	4%
Total	**8**	**41,762**	**100%**

Source: USDA/NRCS STASGO soil data published in 2001.

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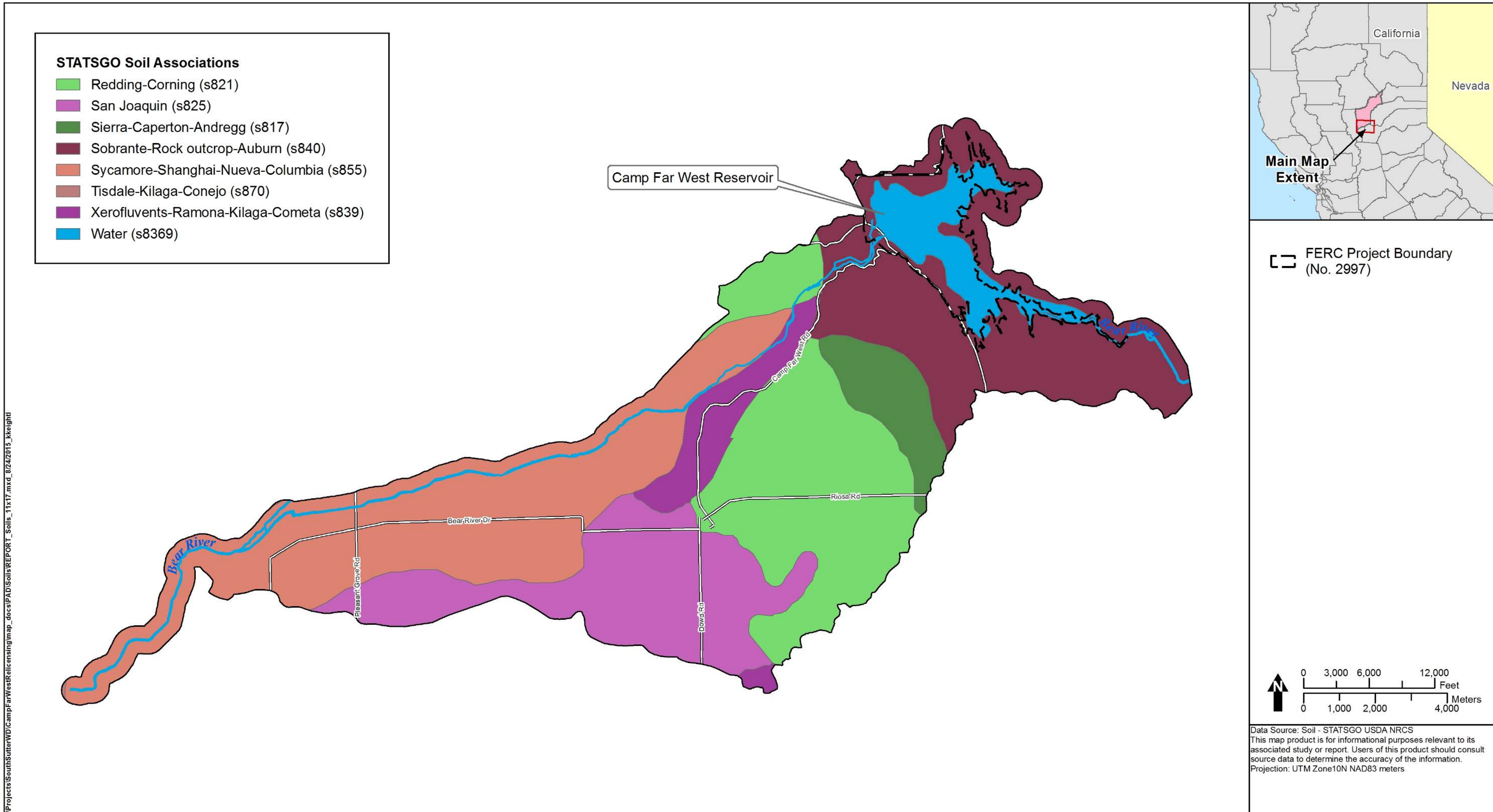

Figure 3.2.1-4. Soil associations in the Project Vicinity.

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The Project Vicinity soil distribution coincides with the underlying bedrock and geomorphic location. Table 3.2.1-5 provides a summary of the soil series characteristics including parent material, geomorphic position, slope, elevation range, average precipitation, mean annual temperature, and drainage. Soil descriptions have been summarized from https://soilseries.sc.egov.usda.gov/OSD_Docs for each of the series.

Table 3.2.1-5. Soil series and order summary description in the Project Vicinity.

Series	Parent Material	Geomorphic Position	Slope (%)	Elevation (ft)	Avg. Annual Precipitation (in.)	Mean Annual Temperature (°F)	Drainage
Andregg	Weathered granitic	Undulating to steep slopes on foothills	2-75	200-1,500	27	60°	Well-drained
Auburn	Amphibolite schist	Foothills	2-75	125-3,000	24	60°	Shallow to moderately deep, well drained
Caperton	Weathered granitic	Uplands	2-50	200-1,500	27	60°	Shallow, somewhat excessively drained
Columbia	Alluvium	Flood plains and natural levees	0-8	10-155	12-25	61°	Very deep, mod well drained
Cometa	Granitic	Gently sloping, slightly dissected older stream terraces	0-15	200-600	16	62°	Moderately well or well-drained
Conejo	Alluvium from basic igneous or sedimentary rocks	Alluvial fans/stream terraces	0-9	30-2,000	20	62°	Very deep, well drained
Corning	Gravelly alluvium	High terraces with mound, intermound relief	0-30	75-1,300	23	62°	Very deep, well or moderately well drained
Kilaga	Alluvium from mixed sources	Terraces	0-9	50-200	20	62°	Deep and very deep, well drained
Nueva	Alluvium from mixed sources	Floodplains	0-2	20-80	16	62°	Very deep, somewhat poorly drained
Ramona	Alluvium from granitic rocks	Terraces and fans	Nearly level to mod steep	25-3,500	15	63°	Well-drained
Redding	Alluvium	High terraces	0-30	40-2,000	22	61°	Moderately deep to duripan, well or mod well drained
San Joaquin	Alluvium from predom. Granitic source	Undulating low terraces	0-9	20-500	15	61°	Mod deep to duripan, well and mod well drained
Shanghai	Alluvium from mixed sources	Floodplains	0-2	20-150	18	62°	Very deep, somewhat poorly drained
Sierra	Acid igneous	Foothills	Gently sloping to steep	200-3,500	20-38	59° - 62°	Deep, well drained
Sobrante	Basic igneous and metamorphic	Foothills	2-75	125-3,500	32	60°	Mod deep well drained
Sycamore	Mixed sedimentary alluvium	Floodplains	Nearly level	10-100	15-20	60° - 62°	Poorly drained
Tisdale	Alluvium from mixed sources	Low terraces	0-2	20-80	18	62°	Mod deep, well drained

Table 3.2.1-5. (continued)

Series	Parent Material	Geomorphic Position	Slope (%)	Elevation (ft)	Avg. Annual Precipitation (in.)	Mean Annual Temperature (°F)	Drainage
Xerofluvents	Young soils not differentiated enough to separate from soil suborder. Shallow, developed in Mediterranean climate, slopes of less than 25% and mean annual soil temperature above freezing and Holocene-age carbon; associated with low-gradient alluvial material adjacent to the lower Bear River corridor.						
Total	**18 Soil Types**						

Erosion hazard within a soil series is often strongly dependent upon slope. In general, the steeper the slope, the more erosive the soil, although erosion potential on steeper slopes may be moderated by coarse, well drained soils, such as those derived from granitic parent material.

3.2.1.8 Existing Information

3.2.1.8.1 Upstream of the Project

Material flowing into Lake Combie is included as some of the mercury and sediment may transfer downstream, and the character of the Lake Combie sediments may be similar to those accumulating in Camp Far West Reservoir.

The Bear River between Lake Combie and Camp Far West Reservoir is considered a "steep gorge" (James 1999). In reviewing the aerial view (Google EarthPro 2015®), the channel flows through bedrock and boulder and there are substantial sections of bedrock gorge. There are few accumulations of sediment that are noticeable at this level. James (1999) reports that there has been little sediment production and storage between Lake Combie and Camp Far West Reservoir due to the steep gorge, and there are no major obstacles to sediment transport. A rough estimate of average gradient, based on change in elevation of 1,200 ft over 13.8 mi, is 1.6 percent.

NID owns and operates the Combie Project. Dredging to maintain water storage capacity has occurred over the past 40 years, but was halted in 2002 due to high mercury levels. The reservoir fills with each storm event. A sediment and mercury removal project was approved to extract mercury from dredged sediments, estimated to be initially about 150,000 to 200,000 tons while monitoring and studying the effect on water quality and biota. The project is estimated to take 3-5 years to complete, with on-going maintenance to remove the annual estimated 50,000 tons/year (NID 2010). Initially, 804 milligrams of elemental mercury was removed from 944 kilograms of material from Lake Combie.

At the request of NID, reach assessments were conducted within an approximately 5.5 mi section of the Bear River from Lake Combie to Wolf Creek (ECORP 2014). One response reach within the Bear River was selected for an instream flow and sediment study. Three potential study sites were identified and an 844 ft section of the Bear River, known as the Laursen Reach, was selected by interested parties and found to be representative of habitat types and composition. Generally, the river is controlled by bedrock and large boulders with little vegetative cover. The complete results are found in the ECORP documentation but general findings were:

- Average width was 35.5 ft for the Bear River location, and 34 ft within the study area, and widths within the study area ranged from 12 to 69 ft, and depth from 1 to 23 ft.
- Mid-channel pools composed over 50 percent of the habitat type, with riffles next (25%) and then run/glide habitat (22%).
- Cover provided by vegetation is less than 10 percent; cover from undercut banks is about 1 percent; large boulders provide 15 percent; surface turbulence and depth provided an average of 15 percent.
- Trout spawning habitat is less than 1 percent. Sediment typically ideal for trout spawning are scare or armored below larger imbricated cobbles.
- Large woody debris (LWD) is largely absent in the entire 5.5 mi section.
- Bear River is largely bedrock-controlled. Specifically within the Laursen Reach substrate ranged from coarse sand to bedrock, but is 20-60 percent boulders and 10-65 percent bedrock.
- Very little sediment and what little there was on point bars, behind boulders, and underneath or behind LWD. In the Laursen Reach, if sediments did exist it was mostly gravels and to a lesser extent cobbles. Little sediment available for sampling.
- Bankfull discharge is estimated to be about 60-80 cfs.
- Roughly half of the sediments between 20-43 millimeters (mm) in diameter would be entrained at flows up to 15 cfs within most of the habitat units.
- Minimum annual peak flow from 2001 to 2011 was 823 cfs.
- Flows capable of mobilizing and transporting large sediments likely occur every year. Bear River appears to be highly competent to transport 15 to 35 percent of the gravel materials at flows under 10 cfs, which makes this river unsuitable for gravel augmentation.

Allan James is a professor of geomorphology in the Department of Geography at the University of South Carolina. He has published and co-written numerous articles on the Bear River geology and geomorphology. Some of his research is presented, but a complete list of extensive published material regarding the Sierra Nevada geomorphology and mining history and effects can be found in his curriculum vitae (James 2014).

Channel reaches within the Bear River mining districts remain dominated by mining tailings after more than 100 years (James 1991). Much of the sediment produced by incision into mining tailing deposits was deposited near the aggrading confluences of Steephollow and Greenhorn creeks with the Bear River and currently forms deltas in Rollins Reservoir (James 2004). Detention of down-valley sediment deliveries by dams created a sediment-starved environment dominated by channel erosion in the lower valley below Rollins, Van Gleisen, and Camp Far West dams. Channel incision below these dams reflects lowered sediment loads and effects of altered flow regime have exacerbated incision (James 1988). Anthropogenic changes due to mining changed the Bear River from a supply-limited system to a transport-limited system, and a change in geomorphic processes away from long-term drainage evolution dominated by ingrown meanders.

3.2.1.8.2 Within the Project

Camp Far West Reservoir receives acidic, metal-rich drainage seasonally from the inactive Dairy Farm Mine. This mine is discussed in Section 3.2.1.4. Removal of pyrite-bearing waste rock and mill tailings in the 1980s reduced some of the acidic runoff and poor soil quality, but the pit remains a likely source of trace metals, sulfate, and acidity to Camp Far West Reservoir and the lower Bear River. High concentrations of total mercury in the water of Camp Far West Reservoir and in biological taxa over a range of trophic levels were observed in fall and winter from October 2001 through August 2003 (Alpers et al. 2008). Mercury bioaccumulation factors are high compared to other reservoirs in northern California, which indicates relatively efficient biomagnification (Alpers et al. 2008).

The Bear River had a waterfall that barred upstream salmon movement in the vicinity of the Camp Far West Reservoir. The waterfall was submerged or built upon during construction of the dam (Wildland Resources Center 1996).

On the section of the Bear River now inundated by the Camp Far West Reservoir was the Van Trent stream flow gage that operated from 1905 to 1928. It was reported by Keyes (1878) that there was 3 meters (m) of aggradation that occurred in the 1870s. Channel instability and rating-curve changes were noted between 1907 and 1927. Large volumes of sediment were produced in the Bear Basin from 1913-1914 and from 1918-1921; hydraulic mining provided sediment to the channel and high flows transported and redistributed the material. These sediment volumes correspond to high flows recorded at the Van Trent gage (James 1991). Rating curve changes were noted in most years from 1914 to 1927, and in 1909 were specifically attributed to the movement of “mining debris” (James 1999).

Section 3.2.1.6 discusses the accumulation rate of sediment in the Camp Far West Reservoir. This is based on bathymetry comparison between 1968 and 2008. The 1968 storage volume was estimated at 104,000 ac-ft and in 2008 at 93,740 ac-ft, a loss of 10,530 ac-ft (Mead and Hunt 2012). The accumulated sediment is likely related to input from historic mining tailings. There is little storage of mining sediment in the Bear between Lake Combie and Camp Far West Reservoir; the sediment would have been added prior blockage of sediment by Van Giesen and Rollins dams, and from evacuation of sediment below Van Giesen Dam.

There are no Project roads as part of the FERC-licensed Project facilities. However, judging from an aerial view (Google EarthPro® 2015), there are unsealed roads on the western side of the reservoir that may be contributing fine sediment. Slopes are fairly flat (i.e., less than 25%) on this side of the reservoir and there do not appear to be landslides or deep-seated failures. Slopes are steepest in the Bear River arm of the reservoir, but there are few roads close to the water and the river appears to be bounded by resistant parent rock (i.e., there is no evidence of channel or hillslope instability that adds coarse or fine sediment).

Patterson Sand and Gravel is planning an expansion of the mining of aggregate in the Bear River floodplain on the Camp Far West Road (Placer County 2012). The main haul route is from Riosa Road through Sheridan to Highway 65. As a condition of the expansion, Cemex is contributing to roadway pavement reconstruction along the truck route between Highway (HWY) 65 and the mine. Drainage ditches will be enclosed, curbs and gutters will be constructed. These activities should keep surface sediment additions due to heavier road use at a minimum.

The non-Project Diversion Dam 1.3 mi downstream of Camp Far West Dam creates a backwater that extends from the diversion dam to the outflow of the spillway. It has strong backwater influence from the diversion dam and was not characterized for habitat by SSWD in 2014 (i.e., physical properties are dominated by standing water [lentic] and not flowing water [lotic]). The stream width ranges from about 180 ft near Camp Far West Dam to 550 ft just upstream of the diversion dam. The area is about 0.06 mi. Depth is unknown, though the bottom can be seen near Camp Far West Dam.

The downstream channel below Camp Far West Dam spillway terminates in a chute excavated in solid rock. This underlined channel then joins the Bear River approximately 1,200 ft below the main embankment. There is a fan of material eroded from the spillway at the junction with the Bear River that is about 450 ft by 300 ft. The fan is composed of fairly coarse, stable material (Figure 3.2.1-5). The distal end of the fan restricts the mainstem about 700 ft downstream of the dam face from 70 ft to 23 ft, then the channel increases to over 200 ft downstream of the fan. All the material added would be stored within the backwater area of the diversion dam. There are no obvious additional failures or excessive sediment sources on the slopes within the backwater below the reservoir.

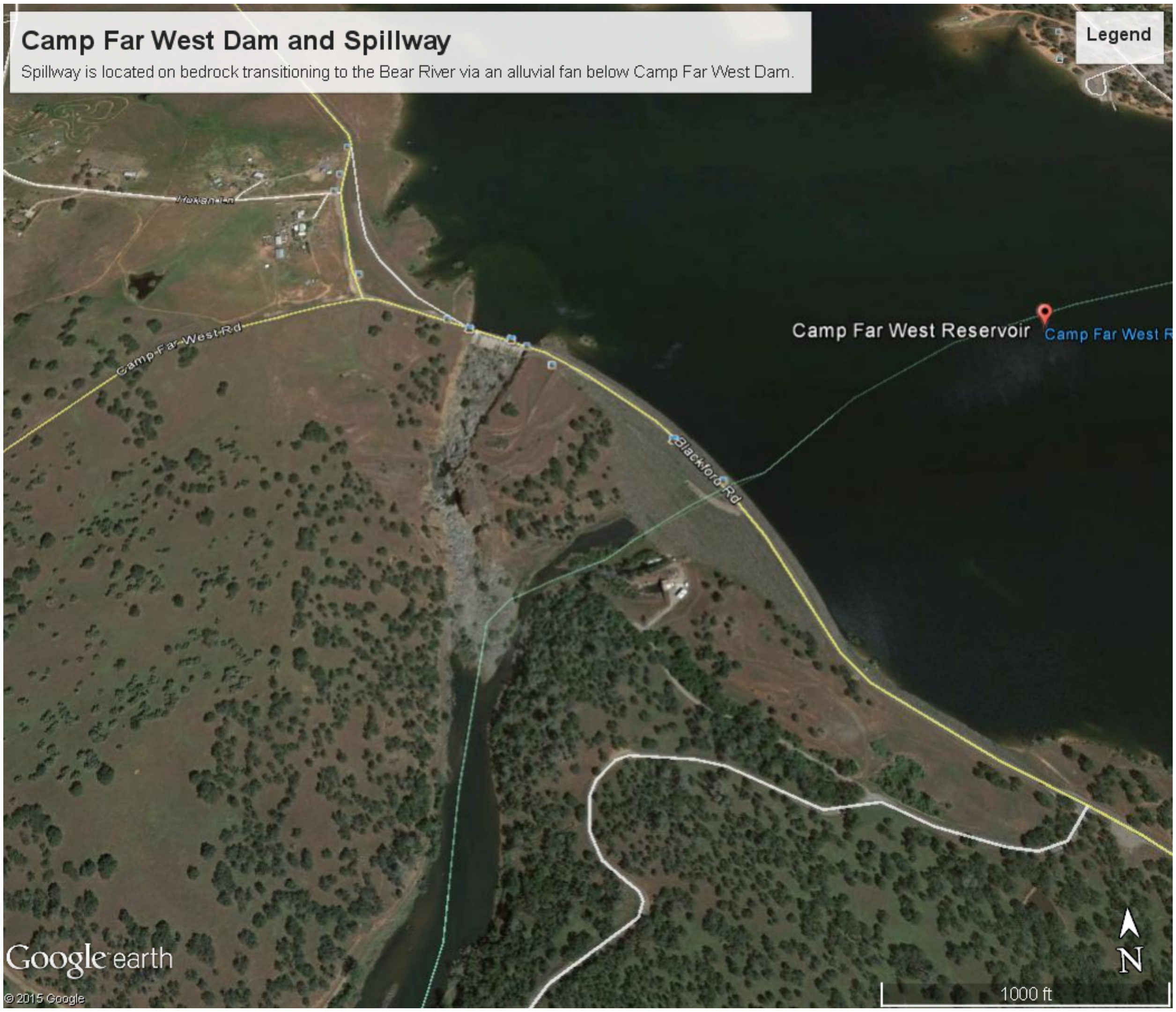

Figure 3.2.1-5. Camp Far West Dam and Spillway on the Bear River at RM 16.9.

In most years, SSWD collects no large woody material (LWM) from the surface of Camp Far West Reservoir. Little LWM enters the reservoir from upstream and the reservoir shoreline has very little LWM.

SSWD is unaware of any reservoir shoreline stability issues. In general, the shoreline is gently sloping and stable.

SSWD is unaware of any Project road or recreation road issues.

3.2.1.8.3 Lower Bear River

Allan James, FWN, the Sacramento Watershed Program, and SSWD have material related to the lower Bear River.

The lower Bear River was an anastomosing channel with a series of sloughs and with two terrace sets described by early settlers, the lowest terrace remains inundated by mining sediment (James 1988). James estimated 164 million cu yd stored in the lower Bear River during maximum aggradation. In the lower Bear River, incision dominated from 1905 to 1928. Between 1930 and 1955, the channel was relatively stable as pre-mining alluvial gravel armored the bed. The channel began to incise in 1955 after a large flood penetrated the coarse gravel layer. Incision was unaffected by construction and enlargement of Camp Far West Dam, which suggests that changes in flow regime and sediment loads caused by the dam were much less important than penetration of the channel armor layer (James 1988).

In 2004, the Environmental Defense Fund, FWN and their partners reported in *Assessing Flow Improvement Needs and Opportunities in Northern California's Bear River Problemshed* various flow needs and flow-related challenges in the lower Bear River. Particularly, they noted that downstream gravel recruitment had been limited for many years and would need to be supplemented to improve habitat. The USFWS was to develop competitive Request for Proposals for studies to evaluate baseline conditions as well as fishery restoration needs and opportunities on the lower Bear River below Camp Far West Reservoir (Yardas and Eberhart 2005). As of 2013, no projects have been conducted, nor is there information for the watershed (USFWS 2013a). FWN (2015a) claims that a high volume of mining sediment in combination with restricting levees has caused incision and channel simplification, though FWN presents no data to support this claim.

Between 2005 and 2009, the Bear River Setback levee was designed and constructed by the Three Rivers Levee Improvement Authority to replace an existing levee. The improved levee was approximately 9,600 ft long and replaced levee portions at the junction of the Feather and Bear rivers. The setback levee was designed to provide a 200-year flood protection level. In addition, 1 million shrubs and trees were planted in the setback area to prevent erosion and to benefit threatened and endangered species in the expanded floodway (SRWP 2015).

SSWD conducted habitat mapping and channel characterization in the lower Bear River in June 2015 because development of aquatic study plans depends on an understanding by SSWD of the general physical and biological character of the Bear River that may be affected by the Project. The purpose of the habitat mapping effort was to develop specific, comprehensive, and detailed information on aquatic habitat and channel morphology characteristics of the Bear River downstream of the Project to the junction with the Feather River. Additional discussion can be found in Section 3.2.3.

The lower Bear River is generally confined between levees, though the confinement caused by the levees varies. There is little urban development along the corridor, though agriculture uses and levees influence floodplain development, water distribution, and riparian environments. At times, the slopes adjacent to the channel are vertical (Figure 3.2.1-6) and the channel is narrowly confined, which is about 61 percent of the mapped area, though only 35 percent of the lower Bear River was mapped. At other sites along the lower Bear River, there are bars and terraces with which the river interacts with a frequency of every 1.5 years. The 1.5-yr. frequency height was estimated using instantaneous peak flows recorded at USGS Gage Station 11424000 on the Bear River near Wheatland (RM 11.5) Provisional Data 1964 to present using the gage height/discharge relationship. The less confined sections of the river occur in about 38 percent of the mapped area (Figure 3.2.1-7). In the section of the Bear River downstream of Pleasant Grove Road, the low flow active channel and the 1.5-yr-return-frequency (i.e., floodflow; the channel is inundated levee toe to levee toe) ratio was measured to indicate extent of floodplain development. The ratios ranged from 1 (i.e., active low flow channel and floodflow approximately equal and there is no functional floodplain; 61 percent) to as much as 4 (i.e., a wide floodplain; 38 percent). The average low flow active channel width was 60 ft and the 1.5-yr. width was 112 ft. The "low-flow active channel" was defined as the area where vegetation was still hydrologically connected when flow was at a minimum instream flow release (about 25 cfs). The return interval of 1.5-yr. is generally associated with bankfull discharge in unregulated systems. However, in a regulated system, the "low flow active channel" is important hydrologically because the releases from the diversion dam control flow timing and volume.

Figure 3.2.1-6. Example of slopes and floodplain development downstream of Pleasant Grove Road.

Figure 3.2.1-7. Example of active floodplain just downstream of non-Project diversion dam.

There is very little LWM in the lower Bear River channel. The highest concentration was in the section in the long pools between vertical slopes (about RM 10). LWM averages about 11 pieces/mi within bankfull.

Since the slope of the lower Bear River is generally less than 0.5 percent, there are no falls, cascades, chutes, rapids, step runs, pocket water, or sheet flow habitat types, which are generally associated with steeper gradients and coarser substrate (Figure 3.2.1-8). The substrate of the mapped units is dominated by gravel with mostly cobble sub-dominant (Table 3.2.1-6). Sand is a minor component though is often subdominant. Increasing amounts of exposed bedrock and cobble substrates occur in the upstream direction to just downstream of the diversion dam. The coarsening of material in the upstream direction is likely due to a both a change in parent material (i.e., alluvium to volcanics) and a decrease in available sediment due to storage in Camp Far West Reservoir. Additional mudstone bedrock is exposed in the channel above HWY 65 at about RM 12.4 and upstream of Pleasant Grove Road at RM 6.7. Very little silt occurs in the active channel, though the banks are often composed of this finer material. There was not much cover and most of it was due to the introduced giant cane (*Arundo donax*) concentrations that line and often extend across the channel (Figure 3.2.1-9). The giant cane is pervious to flow, however, and serves to scour pools and develop some spawning gravel concentrations of spawning gravel (i.e., 2 mm to 64 mm) but occasionally up to 128 mm nearer the diversion dam. It provides cover and habitat heterogeneity.

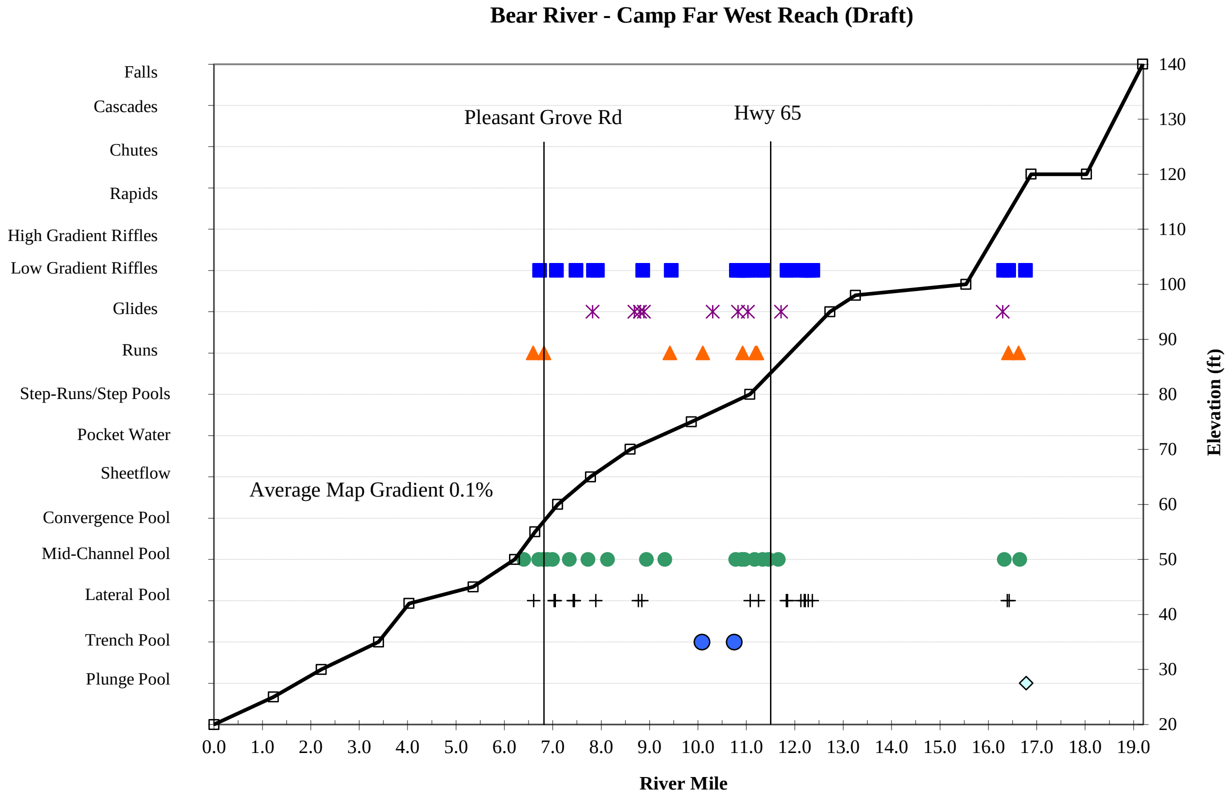

Figure 3.2.1-8. Longitudinal profile and habitat types mapped in the lower Bear River.

Table 3.2.1-6. Dominant, subdominant and bank substrate in mapped sections of the lower Bear River.

Substrate Type	Dominant Substrate		Subdominant Substrate		Bank Substrate	
	Total Length (ft)	Length Rel Frequency	Total Length (ft)	Length Rel Frequency	Total Length (ft)	Length Rel Frequency
Bedrock	696	3.9%	603	3.8%	872	7.0%
Boulder	538	3.0%	0	--	538	4.3%
Cobble	4,893	27.1%	4,577	29.0%	1,257	10.1%
Gravel	10,179	56.4%	5,496	34.8%	3,269	26.3%
Sand	1,753	9.7%	3,849	24.3%	2,996	24.1%
Silt	0	--	1,282	8.1%	3,478	28.0%
Total	**18,059**	**100.0%**	**15,807**	**100.0%**	**12,410**	**100.0%**

Figure 3.2.1-9. Effects of introduced giant cane in enhancing cover, channel complexity, and sorting of spawning-size gravels (2-64 mm).

3.2.1.9 Known or Potential Project Effects

Provided below is a list of known or potential Project effects on geology and soils. The list was developed based on responses to SSWD's PAD Information Questionnaire and SSWD's current understanding of the issues.

- From Responses to SSWD's PAD Information Questionnaire:
  - Effects of Project O&M on channel morphology in the Bear River below Camp Far West Dam (e.g. channel stability, erosion/sedimentation, substrate composition, and floodplain/channel connectivity) (identified by Cal Fish and Wildlife, NMFS, Placer County).
- From SSWD:
  - Effects of Project O&M on sediment and sediment movement in the Bear River downstream of the Project, especially related to the trapping of sediment in Camp Far West Reservoir and Project flows.

- Effects of Project O&M on soil erosion, slope failures and slope stability at the Camp Far West Reservoir shoreline and in the Bear River downstream of the Project.
- Effects of Project O&M on runoff from Project roads and other hard surface runoff on erosion and sediment transport and Project flow-related movement of sediment.
- Effects of Project O&M on soil erosion and bank stability due to use of the Camp Far West Dam spillways and outlet facilities.
- Effects of Project O&M on LWM distribution and recruitment into the Bear River downstream of the Project.
- Effects of Project-related recreation on soil compaction and erosion.

3.2.1.10 List of Attachments

There are no attachments to this section.