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5.2.3 Geomorphology

5.2.3.1 Environmental Setting and Expected Environmental Impacts

The geomorphic resources in the environmental setting of the four Big Creek ALP Projects are described within this section, as well as any potential geomorphic-related resource impacts (Potential Resource Issues). These potential resource issues reflect conditions under current Project operations (No Action Alternative). Each section concludes with a discussion of the identified environmental impacts resulting from the implementation of new environmental measures recommended in the Proposed Action for each of the four Big Creek ALP Projects.

Methods

The methods utilized to assess geomorphic resources were based on a review of relevant information, qualitative and quantitative studies, and extensive agency and stakeholder consultation. The geomorphology along bypass and flow-augmented streams in the vicinity of the four Big Creek ALP Projects and selected comparison streams was evaluated between 2002 and 2006 in order to determine the effects of Project operations on the geomorphology. The geomorphology of a stream, among other watershed attributes, directly influences the types of aquatic and riparian habitats that may exist within a particular stream segment, and the degree of responsiveness of the stream segment to changes in stream flow and/or sediment regime caused by Project operations and maintenance.

Geomorphology studies included:

- Qualitative reconnaissance level assessments were first completed from historical and recent aerial photography, and low-elevation helicopter and ground surveys along all the bypass streams to describe the present-day stream channel and sediment transport characteristics of the Project area (refer to CAWG 2, Geomorphology, 2002 Final Technical Study Report (FTSR) (SCE 2003; Volume 4, SD-C (Books 7 and 21)).

- Studies completed in 2003 were primarily quantitative assessments and were focused on selected areas of the streams that were expected to be more responsive to changes in flow and/or sediment regime. The assessments included stream type, streambed particle size composition, overbanking thresholds, gravel transport, flood-frequency analyses under pre- and post-Project conditions, fine sediment deposition in pools (V* Analysis) and in spawning gravels (bulk sediment analysis), and historical aerial photo interpretation (refer to CAWG 2, Geomorphology, 2003 FTSR (SCE 2004; Volume 4, SD-D (Books 11 and 23)).

- Qualitative and quantitative studies were completed in 2003 on several unregulated streams within the regional watershed area as comparisons with the geomorphology along the bypass streams. The specific approaches, methods, data collected, and results are described in CAWG 2, Geomorphology, 2003 FTSR (SCE 2004; Volume 4, SD-D (Books 11 and 23)).

- Focused studies on three streams, North Fork Stevenson Creek, South Fork San Joaquin River – Jackass Meadow complex, and Mono Creek, were completed in 2005 to refine the overbanking thresholds (South Fork San Joaquin River) and sediment transport flow thresholds (North Fork Stevenson Creek and Mono Creek) (SCE 2005; Volume 4, SD-E (Books 19 and 24)).

- Additional studies were conducted on Mono Creek in 2006 in order to determine the effect of wet year spill flows on fine sediment accumulation and transport through pools (V* measurements before and after spill) (SCE 2007a; Volume 4, SD-E (Books 19 and 24)).

- Summaries of agency and other stakeholder consultation are provided in Section 4.0, Consultation.

5.2.3.2 Affected Environment

This section summarizes the existing geomorphic environment in the vicinity of each of the four Big Creek ALP Projects. This includes a general description of the stream geomorphology in the Project vicinity and importance to other resources including aquatics and riparian, followed by a description of the existing geomorphic resources for each stream, focusing on stream morphology (channel form and bed particle size), sediment sources (fines and gravels), and sediment transport characteristics, organized by Project.

Adjustments in stream morphology in response to flow and sediment regime changes due to Project operations and maintenance activities tend to be relatively small in the Project area. This is due to the geology of the watersheds, the coarseness of the channel substrate, (bedrock and boulder); and to the predominantly steep-gradient, confined, and well-entrenched channels that are controlled by bedrock valley walls often found in high elevation mountain terrain. These mountain streams are typically supply-limited, that is the natural flow regime and transport capacity is much greater than the sediment load delivered to the channel. Sixty-one percent (55 miles) of the streams associated with the four Big Creek ALP Projects are not considered to be particularly responsive to changes in the flow or sediment regime. These streams are in high-gradient, deeply entrenched bedrock and bedrock/boulder channels and exhibit little tendency to adjust their configuration (Montgomery and Buffington, 1997). In comparison, channels bedded with relatively higher percentages of cobble, gravel, and fine-grained clay are, in general adjustable channel types (i.e., moderately to highly responsive to alterations of the flow or sediment regime). Unconfined and poorly entrenched channels are also more responsive to alterations in the flow and sediment regime than confined well-entrenched channels.

Some channel morphological alterations may occur in non-adjustable reaches when the flow or sediment regime is altered, but the type and extent of changes tend to be limited. Coarsening or fining of bed particle sizes at the habitat-scale (as opposed to the larger geomorphic scale) is one of the more likely responses of non-adjustable channel types. The scale and variety of responses for adjustable channel types is much greater, and may include changes in channel dimensions, planform, gradient, and particle size. For example, channels that have a higher sediment supply than transport capacity (i.e., are transport-limited), have a potential to accumulate fine sediments, if the magnitude of high flows is reduced. Lastly, in adjustable stream segments, with cobble or smaller dominant grain sizes, large woody debris (LWD) may strongly influence channel configuration by forming scour pools and separation bars or promoting bank scour and erosion. Large woody debris has much less influence on channel morphology when the bed particle size is dominated by bedrock or boulders, the gradient is very steep, and the channel is highly entrenched. General resource data for each stream, including reach length, stream classification based on Rosgen (1996) and Montgomery and Buffington (1997) classification systems, reach gradient, local water surface slope, bank erodibility, presence of floodplain, fine sediment accumulation, and relative presence of large woody debris are summarized in Table 5.2.3-1, Geomorphology Resource Information Matrix.

A total of 35 miles of streams associated with the four Big Creek ALP Projects (39%) are potentially responsive to Project operations (based on Montgomery-Buffington Classification). The majority of the stream miles classified as responsive are on the San Joaquin River from Mammoth Pool to Redinger Lake and the South Fork San Joaquin River between Florence Lake and Rattlesnake Crossing. Almost all of the San Joaquin River, however, is highly confined by steep valley topography with mostly non-erodible valley walls that limit the ability of the channel planform pattern to respond to changes in flow regime. In these types of channels, the most likely response to changes in flow and/or sediment load is a change in particle size or sediment storage.

Sediment in streams associated with the four Big Creek ALP Projects is primarily derived from weathering products of granitic rock and some glacial deposits. Much of the granitic rock weathers directly to decomposed sands. Gravels are primarily derived from areas with glacial till and Mesozoic granitic lithology. Boulder size material is derived from rock-falls originating within the steep valley walls of the inner gorges of the San Joaquin River and the South Fork San Joaquin River. Much of these boulders are rarely, if ever mobilized by streamflow. Even though 23% of stream miles in the Project vicinity are classified as having erodible streambanks, comparatively little sediment is derived from actual streambank erosion (CAWG 2, Geomorphology, 2003 FTSR (SCE 2004; Volume 4, SD-D (Books 11 and 23)).

The influence of Project facilities and operations on sediment transport and deposition varies considerably throughout the bypass stream reaches, depending on the magnitude and direction of the hydrologic and sediment regime changes, as well as the channel morphology and watershed geology. The large reservoirs capture and permanently store nearly all of the bedload sediment that is transported to them, reducing the amount of sand and gravel that would have naturally been available for recruitment to downstream reaches. The extent to which capture and storage of bedload influences downstream morphology depends upon several factors, including the amount of sediment naturally delivered to the reservoir reach, the availability of sediment sources below the reservoir, the extent of changes to the high-flow regime below the reservoir, and the downstream channel morphology. The timing and method of sediment maintenance practices can also affect sediment supply and transport. Below several of the small and mid-size diversions and impoundments, particularly those that have a diminished high flow bypass regime, sediment maintenance practices have the largest Project influence on stream channel sedimentation.

The conditions of aquatic resources are, in part, influenced by the sediment and flow regimes. Gravels are important for fish habitat in the bypass reaches, but are not naturally present to any great extent and are not found as a dominant particle size within any of the Project watersheds, or comparison streams, except in short channel segments (i.e., limited to hundreds of feet of channel length). Most of the Project streams do not have the appropriate, unconfined, low-to-moderate gradient, pool-riffle geomorphology to support suitable sites for gravel deposition and/or well-sorted gravel deposits for spawning. With few exceptions, gravels are almost exclusively found deposited in the small "pockets," found in the lee and stoss of boulders or bedrock outcrops where a velocity shadow is created. Excess fine sediment can accumulate in gravels or pools in the absence of flushing flow, degrading fish and aquatic habitat. The criteria for assessing the suitability of gravels for fish spawning are based on the relative proportion of gravel substrate that is comprised of fine sediments. Gravel suitability criteria is based on Kondolf (2000), which is described in CAWG 2, Geomorphology, 2003 FTSR (SCE 2004; Volume 4, SD-D (Books 11 and 23)). Criteria for evaluating the effect of sediment deposition in pools has not been well-established in either the fisheries or geomorphology literature, however pool sediment guidelines are established for the relicensing studies in CAWG 2, Geomorphology, 2003 FTSR (SCE 2004; Volume 4, SD-D (Books 11 and 23)).

Fluvial geomorphic processes and channel morphology are also important determinants of riparian habitat. These physical processes, which vary with valley geology and morphology, control the creation, development, and evolution of geomorphic landforms, such as bars, along a stream, which are potential locations for riparian establishment and can also strongly influence hydroperiod (magnitude, duration, frequency, and timing of inundation). As a result, characteristics of riparian resources are strongly related to the occurrences of these landforms. Riparian habitat complexity and species diversity are driven by the flux and exchange of energy, nutrients, sediment, propagules, and biota, and are influenced by the sediment and flow regimes. Aquatic and Riparian resources are described in Sections 5.2.4 and 5.2.6, respectively.

A summary discussion of the channel morphology, sediment sources, and sediment transport and deposition in bypass streams associated with each Project are discussed in the following sections. The geographic location of the streams discussed can be found on Figures CAWG 2-1a through 2-1d in CAWG 2, Geomorphology, 2002 FTSR (SCE 2003; Volume 4, SD-C (Book 21)).

Mammoth Pool Project (FERC Project No. 2085)

The Mammoth Pool Project includes Mammoth Pool Reservoir and three bypass stream reaches, San Joaquin River, Mammoth Pool Dam to Dam 6, Rock Creek, Diversion to San Joaquin River, and Ross Creek, Diversion to San Joaquin River.

Mammoth Pool Reservoir: Most gravels recruited to the San Joaquin River originate from sources upstream of Mammoth Pool Dam. These gravels are now trapped by Mammoth Pool Reservoir, thereby reducing gravel recruitment to the downstream reach. However, gravel supply is not identified as a limiting aquatic habitat factor.

San Joaquin River, Mammoth Pool Dam to Dam 6 (8 mi): The San Joaquin River between Mammoth Pool Dam and Dam 6 is a moderate gradient, highly entrenched channel, with mostly a high width-depth ratio (bankfull widths range from 125 to 200 ft). Some sections have a more moderate width-depth ratio. The channel bedform is forced pool-riffle to plane-bed, and is considered to be adjustable, predominantly susceptible to changes in bed particle size. The channel, however, is highly confined by the bedrock walls of the San Joaquin River Canyon, so that any lateral adjustment in planform is restricted. The canyon walls are a source of very coarse material (boulders) from rock-falls, and supply virtually no fines (sands) or medium size material (gravel or cobble) to the channel, except from smaller tributary contributions such as Shakeflat Creek.

The dominant river bed material is boulder or cobble, although the reach near the Mammoth Powerhouse has nearly equal proportions of boulder-cobble-gravel. Gravels are deposited in either poorly sorted mixtures with larger particle sizes on bars, or in small, relatively well-sorted “pockets” mixed with sand in the lee of boulders that provide a velocity shadow during high flows. Fewer gravels were found in this reach, compared to unregulated comparison stream segments on the San Joaquin River at Miller’s Crossing. Sand is not found as a dominant particle size. Most sand deposits are either along the channel margins, or mixed with poorly-sorted material on bars. One of three bulk samples of pocket gravels just exceeded spawning gravel sand content criteria for successful reproduction of trout (CAWG 2, Geomorphology, 2003 FTSR (SCE 2004; Volume 4, SD-D (Books 11 and 23)).

Spills at Mammoth Pool Dam generally occur about every other year (in Wet and Above Normal water year types), with flows equaling or exceeding 6,000 cfs. These flows regularly mobilize and transport much of the fine (sand) to medium size (gravel and cobble) particles present in the channel bed. Based on V* measurement, little sand was found to be stored in pools, indicating that the existing flow regime is adequate to flush sands and maintain pool volumes.

Rock Creek, Diversion to San Joaquin River (0.39 mi) and Ross Creek, Diversion to San Joaquin River (0.85 mi): These two tributary streams to the San Joaquin River are very steep gradient, non-adjustable bedrock channels with non-erodible banks. No fine sediment accumulations were identified for either channel, indicating that sediment transport capacity is greater than the sediment supply. There are very limited suitable depositional sites, or upstream sources for spawning gravels in these two bypass reaches.

Big Creek Nos. 1 and 2 Project (FERC Project No. 2175)

The Big Creek Nos. 1 and 2 Project includes: Huntington Lake; Big Creek between Huntington Lake to Dam 4; Big Creek between Dam 4 to Dam 5; and four tributary stream reaches – Ely Creek from the Diversion to Big Creek, Balsam Creek from the forebay to Balsam Creek Diversion, Balsam Creek, from the Diversion to Big Creek and Rancheria Creek below Portal Powerhouse.

Huntington Lake: Huntington Lake captures all sediments from the upstream Big Creek watershed. Under current operations the lake does not spill, interrupting the transport of gravels through Big Creek and the downstream system. Gravels from Rancheria Creek are also trapped in Huntington Lake. Historically, the area where Huntington Lake is currently located was a large, low-gradient meadow. Most bed load sediments, including gravel transport during high flows more than likely would have been deposited and stored in this low-gradient channel area, rather than transported downstream of the current lake basin.

Big Creek, Huntington Lake to Dam 4 (3.5 mi) and Dam 4 to Dam 5 (4.3 mi): Except for a 2-mile reach immediately downstream of Huntington Lake, Big Creek is a non-adjustable, predominantly steep-gradient, highly to moderately entrenched, bedrock and boulder channel. The 2-mile low-gradient section is an adjustable moderately entrenched channel, with erodible banks, and co-dominated by sand and boulders, with poorly sorted gravels. Sandy hillslopes immediately below Huntington Lake are a source of fines that are delivered to the channel during local run-off events.

Flows in Big Creek for approximately 4 miles below the dam are limited to a few cfs, with very limited tributary flow accretion until the confluence with Pitman Creek. In effect, the drainage area and flows immediately below the dam reflect conditions associated with a first order headwater channel, in place of the natural third order stream channel.

Existing flows in the first 2-mile segment of the Big Creek channel are insufficient to maintain sediment transport, such as flushing fines from pools or spawning gravels. As a result, channel cross sectional area has been reduced due to sediment deposition, and dense riparian vegetation encroachment into the channel. Sediment storage is high in pools, and spawning gravels have a high fine sediment content, exceeding the criteria for successful reproduction of trout. Spawning gravels in Big Creek upstream from Huntington Lake, however, were also found to have a high fine sediment content that exceeded the criteria (refer to CAWG 2, Geomorphology, 2003 FTSR (SCE 2004; Volume 4, SD-D (Books 11 and 23)) for study details).

From approximately 2 miles downstream of Huntington Lake to Dam 4 and then to Dam 5 (approximately 4.3 miles), Big Creek is predominantly a very steep gradient, highly-entrenched, bedrock channel with occasional boulders present. The streambanks are non-erodible, and the channel is non-adjustable. Channel morphology is not suitable to support well-sorted gravel deposits. Sediment is delivered from unregulated tributary inputs, and coarse materials (boulders) are recruited from rock-falls. Bar deposits are rarely observed. Periodic de-watering of Dam 4 for tunnel inspections may cause the release of sediments of sufficient volume to temporarily cause sedimentation of pools and aggradations of the channel bed. Fine sediment deposits were not observed in Big Creek, except at the confluence with Balsam Creek. High flows during wetter years appear to flush any accumulated fine sediments downstream.

Balsam Creek, Diversion to Big Creek (0.74 mi): From the diversion to the confluence with Big Creek, the channel reach is very steep gradient, bedrock and boulder dominated, with a bedrock-cascade bedform. The banks are non-erodible, and the channel is non-adjustable.

Ely Creek, Diversion to Big Creek (1.0 mi): Ely Creek is a very steep gradient, boulder and bedrock dominated channel. The channel is non-adjustable and the banks are predominantly non-erodible. The diversion is small with virtually no storage capacity. No fine sediment accumulations were identified on Ely Creek.

Rancheria Creek downstream of Portal Powerhouse (1.9 mi): Below the powerhouse, the 500-foot artificially constructed channel has been widened to approximately 100 feet. The stream channel alignment, gradient, cross-section and streambed particle size of Rancheria Creek were replaced by an excavated waterway between the Ward Tunnel outlet and Huntington Lake. Augmented powerhouse flows have produced a widened and incised channel and coarsened the bed particle size. The dominant bed particle size is boulder. Sediment transport is maintained by flow from the Ward Tunnel, which potentially may increase the transport of gravels in the reach.

<u>Big Creek Nos. 2A, 8 and Eastwood Project (FERC Project No. 67)</u>

The Big Creek Nos. 2A, 8 and Eastwood Project includes: Florence Lake; the South Fork San Joaquin River from Florence Lake to its confluence with the mainstem of the San Joaquin River and eventual confluence with Mammoth Pool Reservoir; Bear Diversion Pool; Bear Creek from the diversion to South Fork San Joaquin River; Mono Diversion Pool; Mono Creek from the diversion to South Fork San Joaquin River; Bolsillo Creek from the diversion to South Fork San Joaquin River; Camp 62 Creek from the diversion to South Fork San Joaquin River; Chinquapin Creek from the diversion to South Fork San Joaquin River; Crater Creek from the diversion to South Fork San Joaquin River; North Slide Creek from the diversion to South Fork San Joaquin River; South Slide Creek from the diversion to the confluence with North Slide Creek; Tombstone Creek, from the diversion to South Fork San Joaquin River; Hooper Creek from the diversion to South Fork San Joaquin River; Balsam Creek from the forebay to Balsam Creek Diversion; Big Creek from Dam 5 to San Joaquin River, and North Fork Stevenson Creek from the Tunnel 7 Outlet to Shaver Lake (see Figures CAWG 1d through 2-1a in CAWG 2, Geomorphology, 2002 FTSR (SCE 2003; Volume 4, SD-C (Books 7 and 21)).

Florence Lake: The upstream watershed is primarily exposed granitic bedrock, which produces minimal gravel size material. Overall, there is little sediment deposition in Florence Lake based on field studies identifying tree-stumps that define the original valley bottom prior to inundation by closure of Florence Dam. Most of the deposits in Florence Lake are sand-sized, with very few gravels (CAWG 2, Geomorphology, 2003 FTSR (SCE 2004; Volume 4, SD-D (Books 11 and 23)). A large amount of gravels are deposited and stored in a low gradient area (Blayney Meadows) several miles upstream from Florence Lake, but very few gravels are deposited between Blayney Meadows and Florence Lake.

South Fork San Joaquin River, Florence to Mammoth Pool (27.7 mi): The South Fork San Joaquin River consists of two distinct geomorphic reaches. The first is the relatively short Jackass Meadow reach (1.6 miles) just below Florence Lake. The second is the much longer reach from Jackass Meadow to the confluence with the main stem of the San Joaquin River (26.1 miles) and eventual confluence with Mammoth Pool Reservoir.

Florence Lake to Jackass Meadow Reach (1.6 mi.)

The Jackass Meadow reach is a low-gradient, moderately to poorly entrenched, adjustable channel type with erodible banks. The bedform is plane-bed to pool-riffle, with sediments stored in bars and sorted gravel deposits that provide spawning habitat. Gravel is the dominant particle size, with the largest amount of gravel inventoried on any bypass stream associated with the four Big Creek ALP Projects. LWD is present in this reach, providing aquatic habitat cover, and influencing pool scour.

Spills at Florence Lake occur during Wet and some Above Normal water years. Spill flows are adequate to initiate sediment transport starting at approximately 750 cfs (based on a spillway rating curve discharge estimated during the 2003 tracer gravel study). This is a revision from the 1,460 cfs discharge recorded at the U.S. Geological Survey (USGS) Gaging Station 11230215, on the South Fork San Joaquin River near the Hooper Creek confluence, as reported in the CAWG 2, Geomorphology, 2003 FTSR (SCE 2004; Volume 4, SD-D (Books 11 and 23)). The moderate-to-poorly entrenched low-gradient channel in this meadow reach is bordered by a floodplain. This channel morphology limits velocities during high flows (due to over-banking and spreading of floodwaters) resulting in lower sediment transport rates than higher gradient and more highly entrenched channel segments of the South Fork San Joaquin River. Sediment storage in pools, though, was found to be relatively low (based on V* analysis), and very similar to an unregulated reach upstream from Florence Lake in Blayney Meadows. The suitability of sampled spawning gravels for trout reproduction was inconclusive, with one sample exceeding and one meeting the criteria. However, one of two samples also exceeded the criteria in the upstream comparison reach at Blayney Meadow.

Jackass Meadow floodplain is not inundated as frequently under existing project operations as under unimpaired flow conditions. Overbanking along the entire channel length within Jackass Meadow need not occur to inundate large portions of the floodplain. Flooding can occur from flows entering the meadow at various low points along the banks, which was observed at 1,270 cfs (Jackass Meadow Inundation Study (SCE 2005; Volume 4, SD-E (Books 19 and 24)).

Lateral channel position adjustments are evident in the historical aerial photographs. These types of changes likely develop over a time scale of centuries, and are likely linked to relatively infrequent high flow events, which continue to occur with spill events.

Jackass Meadow to San Joaquin River Reach (26.1 mi.)

This reach has a predominantly moderate gradient channel with moderate to high entrenchment. The segment is an adjustable channel type. Dominant bed particle size is small boulder to cobble. Gravels are present only in pockets where larger bed elements provide a velocity shadow. LWD has little influence on this type of channel morphology. There is a short part of this reach at Mono Hot Springs, which is a poorly entrenched channel type.

Stream flows downstream from Jackass Meadow are sufficient to maintain pools and to provide mobilization of gravels. Gravels are entrained beginning at approximately 750 cfs, although transport is not uniform across the bed due to the “hiding factors” that can shelter gravels in association with the larger bed elements that are present. Samples of spawning gravels found that fine sediment content did not exceed criteria for successful trout reproduction.

Bear Diversion Pool: The Bear Diversion Pool captures most sediments that are transported into the pool. The outlet gates of the pool, to the downstream channel are about mid-level in the dam, and there is no low-level outlet or sluice gate structure through which material can be passed. Woody debris is periodically removed from the diversion, but sediment removal is not performed, except small incidental amounts associated with the woody debris removal. Large-woody debris removed from the diversion is not available for recruitment downstream under current operations.

Bear Creek, Diversion to South Fork San Joaquin River (1.6 mi): Bear Creek is predominantly a steep-gradient, highly entrenched, non-adjustable channel with non-erodible banks. There are short segments that are more moderately entrenched. The dominant bed material is small boulder, and is suitable to support pocket gravels. The watershed contains gravel-bearing lithologies. Gravel supply is not identified as a limiting aquatic habitat factor. Spills regularly occur, with nine events in the past 23 years exceeding 450 cfs, which is sufficient to transport the fine and coarse sediment load downstream.

Mono Diversion Pool: Excavation of sediments periodically occurs around the diversion intake only, which may increase the risk of inadvertent sediment release downstream during the sediment removal activities. Excavated sediments are mostly sand, with about 20% of the excavated material comprised of gravels. Excavated sediments are transported away from the channel by dump truck, so that they are permanently removed as a source to the downstream reach.

Mono Creek, Diversion to South Fork San Joaquin River (5.8 mi): Mono Creek is predominantly a moderate-gradient, moderately entrenched, non-adjustable boulder-dominated channel, except for two short lengths of adjustable channel with a combined length of 0.7 miles. The bedform is step-pool to plane-bed, with some steeper cascade sections, suitable to support pocket gravel deposits. The adjustable channel sections are low-gradient, gravel dominated, pool-riffle bedform, with LWD influencing gravel deposition, scour pool development, and bank erosion.

There are infrequent spill flows from Mono Creek Diversion, which restricts the frequency and extent of sediment-transporting and overbanking events. In the adjustable reaches, excess fine sediment was found in a portion, but not all of the sampled spawning gravels. Excess fine sediment was also found in some of the sampled spawning gravels from the comparison reach upstream of Thomas A. Edison Lake (Edison Lake). Sediment storage in pools is moderate, compared to other streams associated with the four Big Creek ALP Projects, based on V* studies conducted in the adjustable channel segments in 2003.

Sediment transport studies conducted in 2005 (Mono Creek Sediment Transport and Floodplain Connectivity Study (SCE 2005; Volume 4, SD-E (Books 19 and 24)) found that flows as low as 425 cfs will mobilize sand and gravels, including the median bed particle diameter (D50), 12mm (small gravels) and up to 45mm size gravels in the adjustable channel reaches. Spawning gravels in typical redd locations (i.e., pool tail-out/top of riffle) would remain stable during flows of 400 cfs to 700 cfs (the upper limit of the study flows, and maximum capacity of the Vermilion Dam Howell Bunger valve). In the non-adjustable reach, it was determined that flows of 425 cfs will mobilize pocket gravels, and can disrupt these gravel pockets to an extent that trout reproductive success could be impaired. Larger magnitude flows, up to the study limit of 700 cfs, will have an even greater capacity to mobilize pocket gravels and there is a greater risk of impairing reproduction, compared with a flow magnitude of 425 cfs.

Additional studies measuring fine sediment storage in pools (V*) were conducted in 2006 (Mono Creek Sediment Studies (SCE 2007a; Volume 4, SD-E (Books 19 and 24)). The 2006 V* study measured fine sediment storage in the non-adjustable reach before and after spill at the Mono Diversion to determine if the spill flow would reduce fine sediment loading in pools. The 2006 study also measured pool sediment storage, after spill in the adjustable reach for comparison to the 2003 data. Pools in the non-adjustable reach were determined to have a low amount of fine sediments based on the pre-spill V* study data. Pools in the non-adjustable reach had about one-third less sediment than pools measured in the adjustable reach in 2003. The magnitude of the 2006 spill flows, exceeding 1,000 cfs for over 13-days, well exceeded the 425 cfs flow identified as capable of transporting sand and gravels (based on sediment transport studies conducted in 2005, see below). The 2006 spill flow also exceeded both the magnitude and duration of the channel riparian maintenance flow (CRMF) to be implemented under the Settlement Agreement. However, the post-spill results indicate that only a small amount of fine sediment was flushed from pools in either the adjustable or non-adjustable reaches. This suggests that recruitment of new fine sediments was keeping pace with the removal of existing fine sediments within both reaches during the 2006 spill event.

Upper Basin Tributaries

Bolsillo Creek (1.6 mi), Camp 62 Creek (1.37 mi), Chinquapin Creek (0.81 mi), and Crater Creek (3.0 mi), Diversions to South Fork San Joaquin River: Bolsillo, Camp 62, Chinquapin, and Crater creeks are very steep gradient, highly to moderately entrenched channels, with the exception of 0.5-mile reach of lower Crater Creek at its confluence with the San Joaquin River (Hellhole Meadow). All streams have watersheds that contain gravel-bearing lithologies. Most of the streams are boulder and bedrock dominated, with non-adjustable beds, but erodible banks. Chinquapin Creek is dominated by gravel particle sizes, although boulders are also present. Lower Crater Creek is a sand-dominated, low-gradient, poorly-entrenched channel with erodible banks and adjacent floodplain. Except during extremely wet years, it is unlikely that high flows are routed to the channel below the diversion. As a result, inundation frequency of the floodplain in the lower gradient section has been reduced. Chinquapin Creek crosses a large alluvial fan where the stream channel is subject to avulsion during infrequent debris flows, which recruits sediment to the channel. Bolsillo Creek has a relatively high amount of fine sediment storage in pools compared with other streams associated with the four Big Creek ALP Projects, but pool sediment storage is similar to the amount measured in several pools upstream of the diversion.

North Slide Creek from diversion to South Fork San Joaquin River (0.24 mi), South Slide Creek from diversion to Confluence with North Slide Creek (0.30 mi), Tombstone Creek from diversion to South Fork San Joaquin River (1.1 mi), and Hooper Creek from diversion to South Fork San Joaquin River (0.73 mi): North Slide, South Slide, Tombstone and Hooper creeks are very steep gradient, highly to moderately entrenched channels, with the exception of a 0.6 mile reach of lower Tombstone Creek through Jackass Meadow. The watersheds of each of these streams contain gravel-bearing lithologies. Most of the streams are boulder and bedrock dominated, with non-adjustable beds, but erodible banks. Cobble and gravel are co-dominant bed material over boulders in Hooper Creek. The stream morphology is suitable to support pocket gravels and sand occupies a relatively high proportion of pool volumes. Lower Tombstone Creek is a low-gradient, poorly-entrenched channel with erodible banks and adjacent floodplain, dominated by a sand bed. North Slide Creek, South Slide Creek, Tombstone Creek (except the lower meadow reach), and Hooper Creek cross large alluvial fans where the stream channel is naturally subject to avulsions (i.e., episodic realignment of channel position) during infrequent debris flows. The debris flows, avulsions, and bank erosion along the alluvial fans are sources of sediment to the channel.

Gravels are trapped behind Hooper Diversion. Sediments, typically an estimated 40 yds^3, comprised of mostly sand with about 35% gravel, are periodically excavated from behind the diversion. The sediment maintenance is necessary to ensure that the diversion intake is functional. Although gravels are trapped in Hooper Diversion, the amount and quality of gravel are not aquatic resource issues. There is more spawning gravel present in Hooper Creek below the diversion than there is in the unregulated comparison stream, Sallie Keyes Creek (unregulated tributary to South Fork San Joaquin River in Blayney Meadow).

The Tombstone Creek, North Slide Creek and South Slide Creek diversions have been out of service for at least the past 20 years. The geomorphic conditions observed downstream of the diversions are representative of natural free flowing streams.

Lower Basin Tributaries

Balsam Creek, Forebay to Balsam Creek Diversion (2.05 mi): This segment includes three stream channels. First is the natural Balsam Creek channel that flows near, but not into Balsam Forebay. Balsam Forebay discharges into two separate channels, a spillway/drainage channel and a separate outlet valve/channel (for release of instream fish flows); both channels join the natural channel about ½ mile downstream from the Forebay.

The natural Balsam Creek channel is predominantly very steep-gradient bedrock and boulder with non-erodible banks with minimal channel changes in response to the high flows. The spillway channel upstream from its confluence with the natural channel shows past evidence of bank erosion. There is considerable storage of fine sediments in pools in the spillway channel, which is a result of past spill events. Gravels are dominant in the spillway channel.

Mitigation actions to stabilize the spillway channel were taken following an accidental release of approximately 700 cfs in 1999. Mitigation measures developed by SCE and agencies as part of the Habitat Area Planning (HAP) team included streambank stabilization, re-shaping the channel, planting willow cuttings, installing a step-pool channel, and installation of a sediment detention basin. The HAP team concluded that the erosion control measures were successful, and the mitigation is complete.

Big Creek, Dam 5 to San Joaquin River (1.7 mi): Big Creek below Dam 5 is a steep-gradient, bedrock and boulder dominated, non-adjustable channel, with non-erodible banks. Boulders provide velocity shadows suitable for pocket gravels. Periodic de-watering of Dam 5 for FERC mandated tunnel inspections or sediment removal activities may cause the release of sediments of sufficient volume to temporarily cause sedimentation of pools and aggradations of the channel bed, until they are mobilized by sufficient subsequent flows.

North Fork Stevenson Creek, Tunnel 7 Outlet to Shaver Lake (2.6 mi): North Fork Stevenson Creek is augmented by releases from Tunnel No. 7. Most of the channel is steep-gradient, highly entrenched, bedrock and boulder dominated, and therefore a largely non-adjustable reach. These non-adjustable channel sections have not been altered by flow augmentation.

Immediately below the Tunnel No. 7 discharge, a 0.1-0.2 mile long channel section has been widened, incised, and the bed material coarsened from the augmentation flows. Also, in response to the augmented flows, there are two adjustable reaches between

RM 2.4-1.8 and 1.2-1.3 where the channel is widened, aggraded, and bed material has probably become smaller in size due to deposition of gravels and cobbles. Gravels are likely recruited during high flows from tunnel spoils at Tunnel No. 7 outlet, and from channel incision and widening that eroded the former channel bed materials.

In the two adjustable channel sections, the gravel bed material in spawning locations are stable to at least 500 cfs, but are subject to mobilization and sub-surface scour at 790 cfs (North Fork Stevenson Creek Gravel Mobility Study (SCE 2005; Volume 4, SD-E (Books 19 and 24)). Fine sediment in sampled gravels did not exceed criteria for successful trout reproduction.

Pitman Creek, Diversion to Big Creek (1.5 mi): Pitman Creek is a very steep gradient, bedrock, non-adjustable channel type. The bedrock banks are non-erodible. Stream morphology is not suitable for pocket gravels or well-sorted gravel deposits. Pitman Creek is a supply-limited stream type. No sediment accumulations were observed in the channel. Flows capable of transporting fine sediment have occurred in at least four out of the last 20 years. The Pitman Diversion was re-built with a 12-inch drain gate that has about a 14 cfs capacity, used to flush a sediment collection box that holds a maximum capacity of approximately 3 yds^3 of material. This material is flushed from the diversion on an as-needed basis, as soon as spring run-off is low enough to allow access to the drain gate.

Shaver Lake: Trapping of gravels in Shaver Lake was not visually assessed during the studies due to insufficient drawdown of the reservoir. A minimal amount of gravel is likely trapped in the reservoir, based on the upstream geology.

Stevenson Creek, Shaver Lake Dam to San Joaquin River (4.3 mi): Stevenson Creek is predominantly a steep-gradient, bedrock, non-adjustable channel type, with the exception of two short adjustable reaches. The first, immediately below Shaver Lake Dam (0.1 mi.) is low gradient, with a cobble and sand bed. The other reach (0.6 mi), which is downstream of Railroad Grade Road, is moderate gradient, and cobble dominated. No fine sediment deposits were found in the channel, except the short reach immediately below the dam, which has a relatively high pool sediment storage compared to other streams associated with the four Big Creek ALP Projects. A Highway 168 culvert may be restricting high flows, causing backwater that could result in sediment deposition within this reach. Additionally, sandy slopes adjacent to the channel immediately below the dam appear to be a fine sediment source to this reach. Both adjustable reaches are suitable for sorted gravel deposits. Periodically, high flow releases from Shaver Lake occur when SCE moves water out of Shaver Dam during spring run-off of wet years. Six events have occurred in the past 12 years, equaling or exceeding 300 cfs - the unimpaired Q1.5. These have been sufficient to transport sediment through the majority of the reach (excluding the reach immediately downstream of Shaver Dam).

Big Creek No. 3 Project (FERC Project No. 120)

Dam 6 Forebay: This Forebay has a history of sedimentation. Although estimates have not been made regarding the amount of sediment periodically flushed into the San Joaquin River from this impoundment, photographs of the downstream channel taken two years before and then after a flushing operation in the 1960's show considerable sedimentation. Because of the small size of the impoundment behind Dam 6 and the need to keep the Big Creek No. 3 intake screens clear, the impoundment is periodically flushed of sediment.

San Joaquin River, Dam 6 to Redinger Lake (5.7 mi): The San Joaquin River from Dam 6 to Redinger Lake has a lower width-depth ratio and fewer bars in comparison to the upstream reach. The channel bedform is forced pool-riffle with a moderate gradient, is deeply entrenched, and is highly confined by non-erodible bedrock canyon walls that supply only boulder size material from rock-falls. The dominant bed material is boulder with some bedrock outcrops. Gravels that are present are either poorly sorted mixtures with coarser bed material, or well-sorted pocket gravels mixed with sand in the lee of boulders.

Peak flows of 6,850 cfs or more generally occur at Dam 6 every two out of three years (Q1.5 recurrence interval). Much of the fine to medium size particles comprising the channel bed are regularly mobilized and transported by the existing flow regime. In some years, such as during the high flows of 1997, a substantial amount of fine sediment can be transported through the San Joaquin River. Gravel mobility studies show that the majority of pocket gravels were mobilized and scoured by flows of about 6,000 cfs, and probably by somewhat lower magnitude flows (CAWG 2, Geomorphology, 2003 FTSR (SCE 2004; Volume 4, SD-D (Books 11 and 23)). Pools were found to store very low amounts of sand, indicating that the existing flow regime flushes sands and maintains pool volume. Spawning gravels were sampled and found to be of adequate quality to support successful reproduction of trout (CAWG 2, Geomorphology, 2003 FTSR (SCE 2004; Volume 4, SD-D (Books 11 and 23)).

5.2.3.3 Impacts of Proposed Action

This section discusses potential impacts on geomorphic resources of continued operations and maintenance of the four Big Creek ALP Projects under the Proposed Action. First, the potential geomorphic resource issues are generally described (Potential Resource Issues). These potential resource issues reflect conditions under current Project operations (No Action Alternative). A discussion of environmental impacts resulting from implementation of new environmental measures recommended in the Proposed Action for each of the four Big Creek ALP Projects follows.

Potential Resource Issues

Project operations and maintenance have the potential to affect the stream geomorphology primarily through changes in the flow and sediment regime. These changes can affect gravel recruitment, dominant bed particle size, and the extent of fine sediment storage, as summarized below.

- Limiting Sediment Transport - Dams and diversions typically reduce the magnitude and/or frequency of sediment transporting flows. Sediments, including fines, if available, may accumulate downstream in pools and spawning gravels without these transporting flows, potentially degrading aquatic and riparian habitat. Accumulation of sediment may also cause a change in channel morphology, for example smaller channel cross-sectional area and aggradations, particularly if vegetation encroachment also occurs.

- Limiting Sediment Supply – Dams and diversions can interrupt the typical downstream recruitment of sediment, including gravels. In some streams, relatively little change in gravel deposits would be expected to occur as a result of Project operations: 1) where gravel recruitment is minimal; 2) sediment transport was very high; or 3) where the channel morphology does not provide suitable opportunities for deposition of stable, sorted gravels (for example high-gradient bedrock channels). If high flows continue to occur while sediment supply is limited, then cobbles, gravels, and sand, may be exported from the system. This can cause a net loss of gravels within the channel, reducing the availability of spawning habitat. In this situation, the amount of gravel downstream of the dams and diversions may be less than would be present under unimpaired conditions. However, this does not necessarily mean that the loss of gravels has been reduced to the extent that spawning is a limiting factor for fish populations. A small, but sufficient amount of gravels may still be available in a given stream reach or its tributaries, to provide enough spawning to support a self-reproducing population.

Reductions in sediment supply may also cause sediment mining and scouring of the channel bed downstream of the diversion, if high flows capable of transporting sediments are occurring, resulting in an overall loss of finer sediments and coarsening of the streambed. This may not be a substantial change (i.e., the change may be at site-specific locales at the habitat-unit scale) if the channel was already dominated by coarse bed material, for example boulders.

- Transport of Large Woody Debris (LWD) – In adjustable stream reaches with cobble or smaller grain sizes, and moderate to low entrenchment and gradient, LWD may be an important factor that influences channel morphology. LWD can form scour pools, bar separation, moderation of sediment transport, or promote bank scour and erosion. LWD is a natural component of the stream system and increases aquatic habitat diversity and complexity in the adjustable channel types. Lowered recruitment of LWD, due to a reduction in stream flows, can cause changes in channel morphology and aquatic habitat. In higher gradient bedrock or boulder channel types, LWD has been found to have very little influence on the channel morphology of Sierra Nevada streams.

These changes in fluvial geomorphic processes and concomitant adjustments in channel morphology and sediment characteristics can potentially adversely impact aquatic and riparian resources. These issues are discussed in Sections 5.2.4, Aquatic Resources, and 5.2.6, Riparian Resources, respectively.

Project Impacts

Under the Proposed Action, various environmental measures are recommended to modify the existing flow regime to enhance geomorphic resources, and aquatic and riparian habitats in select streams where Project-related resource issues have been identified (Table 5.2.3-2). The proposed recommendations include increasing the frequency and magnitude of sediment transporting flows by establishing CRMF, providing high flows through scheduled flow releases, establishing time periods when diversions may not be operated, or by decommissioning diversion facilities. The Proposed Action includes the implementation of Sediment Management Prescriptions (SMPs), which include sediment pass through, physical removal of sediment, and monitoring at various diversion facilities. These SMPs are described in detail in Table 3.1.7-3, and also in Sediment Issues and Proposed Sediment Management Prescriptions for the Four Big Creek ALP Projects; Settlement Agreement, Appendix J (SCE 2007b; Volume 4, SD-H (Book 20)).

The Proposed Action also includes measures for LWD at Bear Creek diversion to ensure that LWD will remain in the stream system.

Implementation of the Proposed Action would restore some of the natural high flow regime to bypass streams with small diversions in the vicinity of the four Big Creek ALP Projects, particularly during spring run-off of wetter years, and would improve sediment transport and sediment conditions. As a result, the environmental measures of the Proposed Action will enhance and benefit geomorphic resources, as well as aquatic and riparian resources in the Upper San Joaquin River Basin by reducing the risk of channel sedimentation and providing continuity of sediment load transport through the small diversions.

Mammoth Pool Project (FERC Project No. 2085)

Mammoth Pool Reservoir: Under the Proposed Action, Mammoth Pool Dam and Reservoir would trap gravels and a portion of the finer sediments from the upstream watershed.

San Joaquin River, Mammoth Pool to Dam 6: The volume of gravel deposits has decreased within this reach, with an associated coarsening of the bed material, compared to pre-Project conditions. Although recruitment of gravel within this reach has always been low, most recruitment occurred from bedload transport originating upstream. The entrapment of spawning sized gravel by Mammoth Pool Dam is unavoidable; and aquatic studies indicate that there is a low abundance of spawning gravels in the reach, although the gravel supply is not limiting trout populations (see Section 5.2.4, Aquatic Resources). The amount of gravel present is sufficient to support the expected trout population for a stream at this elevation at the current minimum instream flows (No Action Alternative). Gravel transport through the reservoir (even at drawdown), is not practical, due to the size and length of Mammoth Pool and the absence of low level sluice gates in Mammoth Dam.

Under the Proposed Action proposal, the volume of gravel deposits in the reach will remain the same, which is not expected to adversely impact downstream aquatic or riparian resources.

Rock Creek from diversion to San Joaquin River and Ross Creek from diversion to San Joaquin River: Under the Proposed Action the frequency and magnitude of flows are sufficient to maintain channel morphology and sediment transport. Under the Proposed Action, sediment SMPs will be conducted as described in the SMP.

As no resource issues were identified within these reaches, including aquatic and riparian, no adverse impacts are expected from the Proposed Action.

Big Creek Nos. 1 and 2 Project (FERC Project No. 2175)

Huntington Lake: Huntington Lake traps upstream sediments, but limitations of the existing infrastructure and concerns for downstream effects limits the flows that can be released at the low-level outlets. The loss of transport flows, riparian encroachment, and gravel recruitment have adversely impacted geomorphic and riparian resources, which are discussed below.

Under the Proposed Action, the adverse impacts to the geomorphic and riparian resources will continue, as it is neither feasible nor practical to provide flows to Big Creek below Huntington Lake.

Big Creek, Huntington Lake to Dam 4: For 2 miles downstream of Huntington Lake, Big Creek has a smaller cross section, and increased sediment deposition of finer bed particle sizes as a result of Project operations and maintenance. These changes are, to a large degree, unavoidable. Dams 1, 2, and 3 were constructed almost 100 years ago to impound Huntington Lake. For more than 60 years, operations have ensured that Huntington Lake does not spill and threaten downstream infrastructure, including the Domestic Water Intake Structure and bridge serving the community of Big Creek and the flooding of Powerhouse No. 8. Since construction, sediment (derived from hillslope erosion) and increased riparian vegetation within the channel have reduced the cross sectional area of Big Creek (downstream of Huntington Lake) to a fraction of its former size. This reach of Big Creek will continue to function as a first order, headwater channel, rather than a third order channel.

Under existing operations, the channel morphology and sediment transport capability in the upper 2-mile section of the reach is much different from the transport reach than it was historically, and it will continue to function in the same manner under SCE's Proposed Action. Due to infrastructure constraints, and to protect the integrity of downstream infrastructure, the adverse impacts to geomorphic and riparian resources from the Proposed Action are unavoidable. The Proposed Action acknowledges this constraint.

Big Creek, Dam 4 to Dam 5: Under existing operations Big Creek below Dam 4 is periodically impacted by sediment pulses when the impoundment is drained for tunnel inspection. Under the Proposed Action, sediment pass-through activities will be implemented as identified in the SMP's. Implementation of the SMP will reduce the risk of a large amount of sediment accumulating and being released when the Dam 4 impoundment is drained. The SMP will also help to ensure that any sediment released is also efficiently transported through the bypass reach below. As a result, geomorphic and aquatic resources will be enhanced.

Balsam Creek, Diversion to Big Creek: Under the Proposed Action the frequency and magnitude of flows are sufficient to maintain channel morphology and sediment transport. Under the Proposed Action, SMP's will be conducted to address the accumulation of sediment behind the diversion and in the bypass reach below.

As no resource issues were identified within these reaches, including aquatic and riparian habitat, no adverse impacts are expected from the Proposed Action.

Ely Creek, Diversion to Big Creek: Under the Proposed Action the frequency and magnitude of flows are sufficient to maintain channel morphology and sediment transport. Under the Proposed Action, the SMP will also address the accumulation of sediment behind the diversion.

As no resource issues were identified within these reaches, including aquatic and riparian habitat, no adverse impacts are expected from the Proposed Action.

Rancheria Creek downstream of Portal Powerhouse: Under existing conditions, the local gradient and channel cross section downstream of the Ward Tunnel outlet have been modified and augmented high flows may transport gravels more frequently through the stream segment than would occur under natural conditions. However, the stream segment is composed largely of boulder and cobble bed elements and does not experience much delivery of gravel, as most of the flow in this reach comes from a fourteen-mile long tunnel with very little elevation change over its length.

These adverse impacts will continue to occur under the Proposed Action.

Big Creek Nos. 2A, 8 and Eastwood Project (FERC Project No. 67)

Florence Lake: The total sediment volume accumulated in Florence Lake since its construction is very small, and the proportion of the total captured sediment load that is gravel is a very small amount. There has been no fine sediment accumulation in the South Fork San Joaquin River, and spill flows are of adequate magnitude and frequency to provide sediment transport. The Jackass Meadow reach is already dominated by gravel sizes. Therefore, no prescriptions for managing sediment at Florence Lake are necessary.

South Fork San Joaquin River, Florence to Mammoth Pool: No geomorphic resource issues were identified on the South Fork San Joaquin River. However, a CRMF release is proposed to address riparian resource issues associated with floodplain inundation (see Section 5.2.6, Riparian Resources). As no geomorphic resource issues were identified within this reach, no adverse impacts are expected from the implementation of the CRMF release.

Bear Diversion Pool: SCE proposes to place LWD removed from the diversion downstream, immediately below the USGS gaging weir along the channel margins to enable downstream transport during high flows. The specific actions for removing and placing LWD in Bear Creek are described in the Large Wood Debris Management License Article (SCE 2007c; Volume 4, SD-G (Book 19)).

As no resource issues were identified within the diversion pool, no adverse impacts are expected from the implementation of the Large Wood Debris Management License Article.

Bear Creek, Diversion to South Fork San Joaquin River: Under existing operations, LWD is captured in the diversion and removed from the stream system. Sediment transporting flows occur in association with spills during most wet years. The frequency and magnitude of flows are sufficient to maintain channel morphology and sediment transport.

Under the Proposed Actions, the Large Woody Debris Management License Article will enhance geomorphic resources and aquatic habitat and are not expected to adversely affect riparian resources. Most of the LWD is likely to remain within the Bear Creek system, decaying or otherwise breaking down into smaller wood pieces before reaching the South Fork San Joaquin River and, therefore, will have no effect on resources on the South Fork San Joaquin River.

Also, under the Proposed Action, Bear Creek Diversion will be turned out during Wet and Above Normal water years while Florence Lake is spilling for more than two consecutive days, such that natural peaks will remain in the channel. Increased frequency and magnitude of spring run-off flows in Bear Creek will propagate downstream to increase flows in the South Fork San Joaquin River, but this is not expected to alter geomorphic resources.

Mono Forebay: Under existing operations, releases of fine sediment can occur during maintenance activities. Sediment maintenance is required to ensure that the intake structure remains operational. The forebay traps sediment, including gravels, a portion of which is subsequently removed from the system by SCE sediment maintenance activities. Limited gravel, however, was not found to be a factor limiting aquatic resources in the downstream channel.

Under the Proposed Action, SCE proposes to inspect the forebay once every 5 years, and if necessary excavate sediments near the intake to reduce accumulation as described in the SMP. Implementation of the SMP will reduce the risk that a large amounts of sediment will accumulate or be released when the forebay impoundment is drained. As a result, geomorphic and aquatic resources will be enhanced.

Mono Creek from diversion to South Fork San Joaquin River: There are infrequent spill flows from Mono Creek Diversion, which reduces the frequency and extent of sediment-transporting flows and overbanking events. In the adjustable reaches (which represent 0.7 mile or about 15% of Mono Creek below the forebay), excess fine sediment was found in a portion, but not all, of the sampled spawning gravels. Sediment storage in pools is moderately high in the adjustable reach, and low in the non-adjustable reaches, based on 2006 V* studies conducted to measure the amount of fine sediment in pools (Mono Creek Sediment Studies (SCE 2007a; Volume 4, SD-E (Books 19 and 24))). The frequency and magnitude of high flows under existing operations have also adversely affected riparian resources, as described in Section 5.2.6, Riparian Resources.

Under the Proposed Action, SCE proposes a CRMF regime that will enhance the geomorphic resources to improve aquatic and riparian habitats. The geomorphic purpose of the CRMF regime is to limit accumulations of fine sediment in pools and gravels. The Mono Creek Channel Riparian Maintenance Flow Plan, Appendix D in the Settlement Agreement, uses monitoring of fine sediment for determining which of two Wet water year CRMF schedules will be released (SCE 2007d; Volume 4, SD-H (Book 20)). There is also a CRMF proposed for Above Normal water years. The criteria used as the basis for deciding which Wet water year CRMF schedule will be released is the weighted mean value of the proportion of fine sediments to residual pool volume (V^*_w) in a representative set of pools. If V*w values are less than 0.20, then a CRMF of lower magnitude and duration will be used in wet years, and if the V*w is greater than 0.20, then a CRMF of higher magnitude and duration will be used in wet years.

All of the proposed CRMF schedules have the capacity to mobilize fine sediment and gravels and to inundate large portions of the bars and floodplain present in the bypass reach. The CRMF schedule is expected to maintain a low amount of fine sediment accumulations in pools, in both adjustable and non-adjustable reaches, which is an overall benefit to aquatic habitat. In the non-adjustable reaches, flows of 425 cfs will mobilize pocket gravels, and may disrupt gravel pockets to an extent that trout reproductive success could be impaired. The CRMF schedule requiring a maximum flow of 800 cfs for three days has a potential to scour pocket gravels in the non-adjustable reaches, and thereby adversely affect trout reproductive success. Sandy banks downstream of the diversion will potentially be a continual source of fine sediment recruitment to the channel.

The rate of recruitment of new sediment to the channel will likely increase under any of the CRMF schedules implemented. However, this will not increase the amount of fine sediment actually deposited in pools or spawning gravels, and will not impair aquatic habitat conditions because any newly recruited sediments will be adequately monitored and flushed from Mono Creek by the CRMF schedule. All sediments transported through the Mono Creek channel will be routed through the South Fork San Joaquin River and will eventually be captured at Mammoth Pool Reservoir.

Upper Basin Tributaries

Crater Creek from diversion to South Fork San Joaquin River: High flows rarely occur along Crater Creek, which have adversely affected riparian and meadow resources within Hellhole Meadow downstream.

Under the Proposed Action, the Crater Creek Diversion will be decommissioned, restoring natural flow to Crater Creek. Peak high flows will remain in the channel, which will mobilize and periodically flush sediment accumulations in the channel. The decommissioning of the Crater Creek Diversion will benefit and enhance geomorphic, aquatic and riparian resources in Crater Creek and Hellhole Meadow.

Bolsillo Creek, Camp 62 Creek, Chinquapin Creek: Geomorphic resource issues and fine sediment accumulations, were identified along Bolsillo Creek. No geomorphic resource issues were identified in Camp 62 and Chinquapin creeks.

Under the Proposed Action, the diversions on these creeks will be turned out until July 1 or when Florence Lake stops spilling (whichever is earlier) during wet years. Therefore, peak high flows will remain in the channel, mobilizing and flushing any sediment accumulations in the channels. These high flows will maintain and may enhance geomorphic and aquatic resources in these creeks.

North Slide Creek from diversion to South Fork San Joaquin River, South Slide Creek from diversion to Confluence with North Slide Creek, and Tombstone Creek from diversion to South Fork San Joaquin River: Under the Proposed Action, SCE proposes to decommission the diversions at North Slide, South Slide, and Tombstone creeks. As these diversions have been out-of-service for approximately 20 years, the conditions of the resources are not expected to be adversely impacted.

Hooper Creek, Diversion to South Fork San Joaquin River: Hooper Creek between the diversion and the South Fork San Joaquin River is more stable and retains more gravel in the downstream channel under current operations than prior to diversion, due to reduced peak flows. Some delivery of gravel has been reduced, due to sediment excavation of the impoundment for maintenance. However, Hooper Creek below the diversion has more gravel than similar comparison streams, and is not spawning limited. Implementation of the SMP has the potential to decrease the release and deposition of fine sediments downstream. Fine sediment deposits in pools are likely now increased, due to current sediment maintenance procedures and reduction of peak flows by diversion.

Under the Proposed Action, the SMP will be conducted as described above to address the accumulation of sediment behind the diversion. The implementation of the SMP's will reduce the amount of sediment accumulated and released downstream. As a result, geomorphic and aquatic resources will be enhanced.

Lower Basin Tributaries

Balsam Creek from Forebay to Balsam Creek Diversion: Balsam Creek contains high concentrations of fine sediment in the spillway channel as a result of bed and bank erosion along the spillway channel due to past spills at Balsam Forebay.

Under the Proposed Action (No Action Alternative) to continue existing operations, flows are sufficient to maintain channel morphology and sediment transport. Since there is no means for regulating flows through the spillway channel to flush sediments, and an erosion mitigation plan was implemented and successfully completed for the spillway channel, no additional actions are proposed. In addition, SCE has improved the reliability of the forebay monitoring system so that future uncontrolled spills are less likely. Therefore, no adverse impacts are expected under the Proposed Action.

Big Creek from Dam 5 to San Joaquin River: Big Creek below Dam 5 may be periodically affected by Project operations releasing sediment into the creek. Periodic de-watering of Dam 5 for FERC mandated tunnel inspections every five to eight years, is the reason for these periodic operations. This release of sediments may temporarily cause sedimentation of pools and aggradations of the channel bed, until they are mobilized by sufficient subsequent flows. Under the Proposed Action, long-term sediment deposition will be reduced in Dam 5 Forebay, and the potential for sedimentation downstream of Dam 5 will be minimized, based on the implementation of the SMP. The implementation of the SMPs will reduce the risk that a large amount of sediment will have accumulated and could be released when the Dam 5 impoundment is drained for tunnel inspections. As a result, geomorphic and aquatic resources will be enhanced.

North Fork Stevenson Creek from Tunnel Outlet to Shaver Lake: The channel alignment, gradient, and cross section, and streambed particle size of North Fork Stevenson Creek have been altered in various specific locations between the Tunnel 7 outlet and Shaver Lake as a result of large historic releases from Tunnel 7. Most of the channel is non-adjustable bedrock, and these sections have not been altered by the augmented flow regime.

Under the Proposed Action, SCE is recommending flows that will maintain the current channel morphology, including the altered channel sections and protect riparian resources. The need for occasional necessary higher flows, when Eastwood Power Station is out-of-service and water must be moved from Huntington Lake to Shaver Lake, can cause unavoidable and adverse impacts to the downstream resources.

Pitman Creek, Diversion to Big Creek: A relatively small proportion of the annual sediment load carried by Pitman Creek upstream of the diversion may be released from the sediment trap at the diversion. The sediment trap is a feature of the recently re-built diversion, which does not have a long history of use from which to judge its performance. Under the Proposed Action to continue existing operations at Pitman Creek, flows are sufficient to maintain the bedrock channel morphology and sediment transport.

Since the maximum amount of sediment that can be collected and flushed from the sediment trap at any one time is small, about 3 yds^3, it is most likely that sedimentation will be localized immediately below the diversion and not over an extensive length of the channel. Any released sediments would not be transported and deposited any further downstream than the gaging weir, about 700 ft below the diversion, where they would be captured until there was an adequate high flow to transport them over the weir and safely disperse the sediments downstream. Sedimentation is not likely to occur in years when the sandbox is not flushed.

Under the Proposed Action, that the SMP will be implemented to address the accumulation of sediment behind the diversion. The implementation of the SMP will benefit geomorphic and aquatic resources by reducing the potential for localized downstream sedimentation associated with releases from the sediment trap.

Shaver Lake: Sediment releases have not been observed from the HB valve at Shaver Lake Dam. This is likely due to the fact that tributary inflows from North Fork Stevenson and Stevenson Creek that supply sediment to the lake are relatively small and located at a considerable distance from the dam and HB valve, so that sediment does not reach and deposit near this part of the dam. Therefore, no prescriptions for managing sediment at the Shaver Lake HB valve are necessary.

Stevenson Creek from Shaver Lake Dam to San Joaquin River: Fine sediment accumulations occur in the very short reach between Shaver Dam and Highway 168. These accumulations are not likely Project-induced, but likely related to the limited capacity of the culvert crossing at Highway 168 during high flows, which would cause backwater conditions upstream of the culvert, and could induce sediment deposition. Currently, high flows (up to approximately 600 cfs) are periodically provided, which have not mobilized and transported fine sediment from this stream segment. These accumulations are not adversely affecting aquatic resources (see Section 5.2.4, Aquatic Resources).

Under the Proposed Action, SCE will continue with existing operations. No new environmental measures are provided under the Proposed Action for geomorphic resources. SCE will continue to periodically, release high flows from Shaver Lake to intentionally move water during spring run-off of wet years. These flows have been sufficient to transport sediment through the majority of the reach (excluding the reach immediately downstream of Shaver Dam). Therefore, no adverse impacts are expected under the Proposed Action, with the exception of sediment accumulations between Shaver Lake and Highway 168, which are unavoidable and will likely continue due to the limited hydraulic capacity of the culvert at Highway 168.

Big Creek No. 3 Project (FERC Project No. 120)

Dam 6: Fine sediment can be released from Dam 6 during maintenance activities.

Under the Proposed Action, the implementation of the SMP will reduce the risk that a large amount of sediment will have accumulated and could be released when the Dam

6 impoundment is drained. As a result, geomorphic and aquatic resources will be enhanced.

San Joaquin River from Dam 6 to Redinger Lake: Gravels in the stream channel are either poorly sorted mixtures with coarser bed material, or more well-sorted pocket gravels mixed with sand in the lee of boulders. The proportion of gravels, however, is less than that found in comparison reaches. Pools, currently store very low amounts of sand, indicating that the existing flow regime flushes sands and maintains pool volume.

Under the Proposed Action, SCE proposes to maintain the existing operations, as Dam 6 spills every Wet and Above Normal water year. Although, the entrapment of spawning sized gravel by Dam 6 and Mammoth Pool is unavoidable, aquatic studies indicate that the spawning habitat is not limiting. Under the Proposed Action proposal, the long-term volume of gravel deposits in the reach will remain at least the same, and will likely increase slightly under the sediment pass-through program. There are no expected adverse impacts to resources.

No unavoidable and adverse impacts to geomorphic resources have been identified under the Proposed Action.

TABLES

Table 5.2.3-1. Geomorphology Resource Information Matrix.

Bypass and Flow Augmented Stream Reaches	Reach Length (miles)	Rosgen Classification	Montgomery-Buffington Classification	Reach Slope (%)	Local Water Surface Slope (%)	Bankfull Width (ft)	Bank Erodibility	Adjustable / Non-Adjustable	Floodplain (Historic/Present-day)	Spawning Gravel Inventory (ft/ 1,000ft channel)	Fine Sediment (V*w)	Fine Sediment Bulk Sample (% < 6.4mm/ % < 0.8mm)	LWD Influence on Channel Morphology
Bypass Stream Reaches (Small Tributaries)													
Tombstone Creek													
Tombstone Creek, RM 0.6 to Diversion (RM 1.1)	0.5	A1a+/A2a+	Co-Ca	2.8		-	E	NA	-	17	-	-	Low
Tombstone Creek, campground meadow reach, South Fork San Joaquin (RM 0.0) to RM 0.6	0.6	C5c/E5	PB-PR SP-PB	0.1		7.6, 10.4	E	A	Y/Y	-	-	-	High
North Slide Creek, Diversion to South Fork San Joaquin River	0.24	A2a+	SP	23.3		4	E	NA	-	-	-	-	Low
South Slide Creek, Diversion to Confluence with North Slide Creek	0.33	A2a+	Ca B	21.3		7	E	NA	-	-	-	-	Low
Crater Creek													
Crater Creek, Diversion (RM 3.0) to RM 0.5 (upstream from adjustable reach)	2.5	A1a+/A2a+ (w/B2 inclusions), B5a	Ca Ca-SP	10.4		11	NE	NA	-	-	0.2	-	Med
Crater Creek, adjustable meadow reach (RM 0.0-0.5)	0.5	E5, C5	PB-PR, PR	< 0.1		11.2, 13.8	E	A	Y/I	-	-	-	High
Chinquapin Creek, Diversion to South Fork San Joaquin River	0.81	A4a+, B4	Ca-SP, PB	14.6		9.8, 11.51	E	NA	-	-	-	-	Low
Camp 62 Creek, Diversion to South Fork San Joaquin River	1.37	B2/B3, A2a+	Ca-SP, Ca	10.8		12	E	NA	-	-	-	-	Low
Bolsillo Creek, Diversion to South Fork San Joaquin River	1.6	A1a+/A2a+, B2/B5	B-Ca, PB	11.9		-	E	NA	-	19	0.26	-	Med
Rock Creek, Diversion to San Joaquin River	0.39	A1a+	B	29.2		-	NE	NA	-	-	-	-	Low
Ross Creek, Diversion to San Joaquin River	0.85	A1a+	B	24.1		-	NE	NA	-	-	-	-	Low
Ely Creek, Diversion to Big Creek	0.98	A1a+/A2a+ B2/B3	B, B-Ca	26.3		-	NE	NA	-	-	-	-	Low
Balsam Creek, Diversion to Big Creek	0.74	A1a+/A2a+	B-Ca	19.6		-	NE	NA	-	-	0.45	-	Low
Bypass Stream Reaches (Moderate Tributaries)													
Bear Creek, Diversion to South Fork San Joaquin River	1.6	A2 (w/B inclusions), A1	SP, B	7.8		-	NE	NA	-	-	-	-	Low
Mono Creek													
Mono Creek, Diversion to South Fork San Joaquin River (excluding two adjustable reaches)	5.1	B2, A2	SP-PB, Ca-SP	3.4		-	NE	NA	-	-	-	-	Low
Mono Creek, adjustable reaches (RM 2.3-2.8 and 3.5-3.7)	0.7	B4c	PR-PB	0.8	0.3, 0.5	23.7, 32.7	E	A	I/N	-	0.29	34.8/ 10.8, 14.1/ 2.7	
Hooper Creek, Diversion to South Fork San Joaquin River	0.73	A1a+/A2a+ B3a/B4a	Ca-SP, PB	12.8	11.3	7.8, 17.1	NE	A	-	129	0.45	-	Med
Pitman Creek, Diversion to Big Creek	1.53	A1a+, B1	B	27.2		-	NE	NA	-	-	-	-	Low
Big Creek													
Big Creek, Huntington Lake (RM 9.9) to RM 7.9	2	B2/B5c, A1/A2	PB, SP	10.4	0.5	25	E	A	N/N)	4	-	70.1/ 11.1	High
Big Creek, RM 7.9 to Dam 4 (RM 6.4)	1.5	A1a+	B	10.4		-	NE	NA	-	-	-	-	Low
Big Creek, Dam 4 to Dam 5	4.3	A1, B2	B, PB	7.9		-	NE	NA	-	-	-	-	Low

Table 5.2.3-1. Geomorphology Resource Information Matrix.

Bypass and Flow Augmented Stream Reaches	Reach Length (miles)	Rosgen Classification	Montgomery-Buffington Classification	Reach Slope (%)	Local Water Surface Slope (%)	Bankfull Width (ft)	Bank Erodibility	Adjustable / Non-Adjustable	Floodplain (Historic/Present-day)	Spawning Gravel Inventory (ft/ 1,000ft channel)	Fine Sediment (V*w)	Fine Sediment Bulk Sample (% < 6.4mm/ % < 0.8mm)	LWD Influence on Channel Morphology
Big Creek, Dam 5 to San Joaquin River	1.7	A1, A2	B, B-PB	8.0		-	NE	NA	-	-	-	-	Low
Bypass Stream Reaches (Moderate Tributaries) (continued)													
Stevenson Creek													
Stevenson Creek, Shaver Lake Dam (RM 4.3) to RM 4.1	0.2	B3c/B5c	PB, B	16.3	0	28	E	A	-	-	-	-	Med
Stevenson Creek, RM 4.1 to RM 3.3	0.8	A1a+, B1	B	16.3		-	NE	NA	-	-	-	-	Low
Stevenson Creek, RM 3.3 to RM 2.75	0.55	B3	PB-PR, B	16.3	1.5	24	E	A	I/N	-	-	-	Med
Stevenson Creek, RM 2.75 to San Joaquin River	2.75	A1a+, A1	B, Ca-SP	16.3		-	NE	NA	-	-	-	-	Med
Bypass Stream Reaches (San Joaquin River)													
South Fork San Joaquin River													
South Fork San Joaquin River, Jackass Meadow (RM 27.7 to 26.1)	1.6	B4c/C4c	PB-PR	1.9	0.1	109	E	A	Y/N	2279	0.13	36.8/ 7.3, 27.9/ 3.5	
South Fork San Joaquin River Jackass Mdw to SJR (RM 26.1 to RM 0.0)	26.1	G2, B2/B3, F3/B3c	SP-PB, PB	3	1.5, 0.7, 0.6	76.3, 102.8	E	A	N/N	22	-	27.1/ 4.5, 6.5/ 0.3	
San Joaquin River, Mammoth Pool Dam to Dam 6 (RM 26.2 to 18.2)	8	Bc/F-2,3,4	PR-PB	2.2	0.7, 1.0	123.4, 196.3	NE	A(12)	-	-	-	31.0/ 5.9, 29.7/ 4.3	
San Joaquin River, Dam 6 to Redinger (RM 17 to 11.3)	5.7	G2c	PR	2.6		-	NE	A(12)	-	687	0.09	24.5/ 7.1	Med
Flow Augmented Streams													
Rancheria Creek below Portal Powerhouse	1.9			4.2			E	-					
Balsam Creek, Forebay to Balsam Creek Diversion	2.05	A1a+/A2a+, B4	-	17.6		-	NE	NA	-	-	-	-	-
North Fork Stevenson Creek													
North Fork Stevenson Creek, tunnel outlet (RM 3.3) to RM 3.5	0.2	A1a+/A2a+	B, SP	9.7		-	E	NA	-	-	-	-	Low
North Fork Stevenson Creek, RM 3.3 to RM 2.4	0.9	A1a+ B1/B2	B, SP	9.7		-	NE	NA	-	-	-	-	Low
North Fork Stevenson Creek, adjustable reaches RM 2.4 to RM 1.8 and RM 1.2-1.3	0.7	C3, F4	PB-PR, PR	4.4	1.2	132.7	E	A	N/N	-	0.11	28.4/ 8.2, 22.4/ 5.3, 25.6/ 7.4	
North Fork Stevenson Creek, RM 1.8 to Shaver Lake (RM 1.0)	0.8	G1, A1/A1a+	B	9.7		-	NE	NA	-	-	-	-	Med

Table 5.2.3-2. Geomorphic Resources Issues and Environmental Measures On Streams in the Four Big Creek ALP Projects[1].

Bypass and Flow Augmented Stream Reaches	Geomorphic Resource Issues					Environmental Measures		
	Channel Dimensions	Bed Particle Size	Sedimentation	Gravel Recruitment	LWD Recruitment	CRMF	Natural Flow[2]	Sediment Management Prescriptions(SMP)[3]
San Joaquin River, Mammoth Pool Dam to Dam 6				X				X
Rock Creek, Diversion to San Joaquin River								X
Ross Creek, Diversion to San Joaquin River								X
Big Creek, Huntington Lake to Dam 4	X	X	X	X				
Big Creek, Dam 4 to Dam 5								X
Balsam Creek, Diversion to Big Creek								X
Ely Creek, Diversion to Big Creek								X
Rancheria Creek below Portal Powerhouse	X	X		X				
South Fork San Joaquin River, Florence to Mammoth Pool								
Bear Creek, Diversion to South Fork San Joaquin River					X	X		
Mono Creek, Diversion to South Fork San Joaquin River						X		X
Bolsillo Creek, Diversion to South Fork San Joaquin River								X
Camp 62 Creek, Diversion to South Fork San Joaquin River								X
Chinquapin Creek, Diversion to South Fork San Joaquin River								X
Crater Creek, Diversion to South Fork San Joaquin River							X	
North Slide Creek, Diversion to South Fork San Joaquin River[4]							X	
South Slide Creek, Diversion to Confluence with North Slide Creek[4]							X	
Tombstone Creek, Diversion to San Joaquin River[4]							X	
Hooper Creek, Diversion to South Fork San Joaquin River				X				X
Balsam Creek, Forebay to Balsam Creek Diversion		X(a)	X(a)					

Table 5.2.3-2. Geomorphic Resources Issues and Environmental Measures On Streams in the Four Big Creek ALP Projects[1].

Bypass and Flow Augmented Stream Reaches	Geomorphic Resource Issues					Environmental Measures		
	Channel Dimensions	Bed Particle Size	Sedimentation	Gravel Recruitment	LWD Recruitment	CRMF	Natural Flow[2]	Sediment Management Prescriptions(SMP)[3]
Big Creek, Dam 5 to San Joaquin River			X					X
North Fork Stevenson Creek, Tunnel Outlet to Shaver Lake	X	X						
Pitman Creek, Diversion to Big Creek								X
Stevenson Creek, Shaver Lake Dam to San Joaquin River			X(b)					
San Joaquin River, Dam 6 to Redinger			X	X				X

[1]"X" indicates an identified geomorphic resource issue. The proposed environmental measure(s) under the Proposed Action to enhance and benefit geomorphic resources are similarly shaded in the appropriate box.

[2]Natural Flow includes only decommissioning diversions.

[3]Table includes only the medium and large diversion Sediment Management Prescriptions (SMP) actions and does not include actions identified for all small diversions (i.e., sediment and flow pass-through during spring run-off of wet years, and capture/removal of sediment in channel below diversion during maintenance activities).

[4]These diversions have been out-of-service for approximately 20 years.

(a) refers only to Balsam spillway channel, not the natural channel.

(b) sedimentation is not related to project operations, but to a highway culvert.