COMBINED AQUATICS WORKING GROUP

CAWG 14-FISH PASSAGE

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EXECUTIVE SUMMARY

The CAWG 14 Fish Passage study identifies physical and flow barriers to fish movement and potential influences of Big Creek Project facilities on fish passage within Project study streams. The study area includes the South Fork San Joaquin River drainage, the San Joaquin River drainage from slightly upstream of Mammoth Pool Reservoir to Big Creek Powerhouse 3 upstream of Redinger Lake, the Big Creek drainage and the Stevenson Creek drainage (Map CAWG 14-ES-1). Information collected for other Big Creek ALP studies, especially CAWG 1 *Characterize Stream and Reservoir Habitats* (SCE 2003a), CAWG 3 *Determine Flow-Related Physical Habitat in Bypass Reaches* (SCE 2003b), and CAWG 7 *Characterize Fish Populations* (SCE 2003c) was used to characterize fish habitat and barriers, flow-related passage, fish populations and age structure for this report. The information from the various CAWG technical reports was used to describe habitat fragmentation due to natural or Project-related passage barriers and to identify indicators of the viability of target fish populations, which may be affected by passage, among other factors.

Literature describing conditions affecting fish passage was reviewed and appropriate criteria were identified and applied to the various study streams. Field observations of facilities and potential natural barriers were made using these criteria to identify potential barriers to fish passage and potential fish passage as related to flow conditions. Fish population and barrier identification data were evaluated to identify potential barrier effects on the ability of fish populations to rear and reproduce upstream and downstream of barriers.

Project dams and diversion structures act as barriers to upstream passage. Many of the study streams also had numerous natural barriers and limitations to passage at low flows. Seasonal runoff conditions affect passage of migrating fish, particularly prior to or during spawning periods. Brown and brook trout spawning migrations occur in the fall (September through December) when unaltered flows are generally low. Rainbow trout spawning migrations may occur in April through June during the spring runoff period, and therefore are less likely to be affected by flow-related passage issues. The barriers that were complete at all flows block all upstream spawning migrations, and therefore cumulatively have a greater effect on fish populations. Downstream passage past diversions and many of the natural barriers, especially smaller ones, may occur during periods of high flow and spill (for diversions).

Longitudinal trends in relative abundance, such as observed in the South Fork San Joaquin River (SFSJR), and in species composition, such as that observed in the San Joaquin River are gradual. More abrupt changes in abundance and species composition would be expected if the cause for the differences were migration barriers. Such differences were primarily associated with small streams and related to passage barriers, both natural and Project diversions, as well as differences in habitat conditions related to channel geomorphology.

1.0 INTRODUCTION

A primary goal of the CAWG 14 study plan (SCE 2001a) is to identify the potential influences of the Project on fish passage within study streams upstream of Redinger Lake (Dam 7). To meet this goal, this report addresses the objectives of the CAWG 14 Study Plan (SCE 2001a). These objectives are to: identify fish passage migration barriers in study streams and reservoir tributaries; evaluate the effects of Project facilities and operations on fish passage in areas where passage may be impeded by conditions in the stream channel; determine if habitat fragmentation for native fish species has likely occurred and, if so, the extent of any adverse biological impacts to those species; and determine the actual biological needs for fish passage. Results of a literature review are presented to identify fish passage criteria for fish passage of the various fish species and lifestages in the study area. Analysis of potential effects of existing fish passage constraints on the viability of target fish populations is provided. However, analysis of Project impacts is not part of this report.

Fish passage barriers are the result of man-made or naturally occurring conditions in the stream channel, which impede the migration of fish. Diversions, natural stream structures such as waterfalls or bedrock sheets, and the effect of stream flows (high or low) are among the commonly seen conditions that may be responsible for creating barrier conditions. In the Big Creek Project Area, barriers related to Project operations and facilities may occur in streams downstream of Project diversions, streams crossed by roads, and streams tributary to Project reservoirs and diversion pools.

2.0 STUDY IMPLEMENTATION

2.1. STUDY OBJECTIVES

The CAWG 14 Fish Passage Study Plan (SCE 2001a) identifies a series of study objectives. These are:

1. Identify fish passage migration barriers in Project stream reaches and reservoir tributaries.

2. Evaluate the effects of Project facilities and operations on fish passage in areas where passage may be impeded by conditions in the stream channel. Anadromous fish do not occur in the Project area.

3. Determine if habitat fragmentation for native fish species has occurred and, if so, the extent of any adverse biological impacts to those species.

4. Determine the actual biological need for fish passage (within context of FPA, Section 18, 10j).

2.2. STUDY ELEMENT STATUS

Implementation of the CAWG 14 Study Plan was designed to take place through a general approach that contained the following elements:

Study Element to be Implemented	Implementation
1. Scientific literature addressing fish passage will be reviewed to determine fish passage criteria for fish species and lifestages found in the Project Area. The passage criteria will be presented in a brief report and presented to the CAWG.	This report presents the results of literature review of fish passage criteria developed by various agencies that have expertise in the fish passage discipline and have jurisdictional authority concerning fish passage issues within Project study streams.

Study Element to be Implemented	Implementation
2. Information developed in studies CAWG 1 (Characterize Stream and Reservoir Habitats) and CAWG 3 (Determine Flow-Related Physical Habitat in Bypass Reaches) will be used to identify potential fish passage barriers in the Project bypass reaches and in tributaries to Project impoundments. These locations will be evaluated based on current Project operations to evaluate potential impediments to fish movement in the stream reaches and from Project impoundments.	Potential fish passage barriers are identified and described. Non-flow related barriers, are characterized as to their potential impediment to fish movement within those stream reaches and impoundment tributaries affected by Project operation. Flow-related passage conditions also are described for study streams where fish passage flow studies have been completed.
3. Technical drawings and plans for Project diversions will be reviewed to determine if they impede fish passage. Other structures occurring in study area reaches will be evaluated if they are shown to impede fish passage due to Project operations. Mechanisms currently providing fish passage will be evaluated.	Project and non-project structures are described and characterized in this report relative to fish passage capabilities in study streams.
4. Information resulting from CAWG 1 (Characterize Stream and Reservoir Habitats) and CAWG 7 (Characterize Fish Populations) will be used to evaluate if, under the current levels of passage, habitat fragmentation for target fish species has occurred. The viability of the target fish populations in Project waters will be evaluated, as well as the extent of adverse biological impacts to those species.	Fish population information from CAWG Study Plan 7 is considered relative to the effect of barriers and related fish passage conditions on partitioning or fragmenting fish populations within the study area. The results are provided in this report. However, conclusions are left for the impact evaluation phase of the CAWG process.

3.0 METHODS

3.1. GENERAL APPROACH

Scientific literature and agency reports addressing fish passage were reviewed to determine fish passage criteria for fish species and lifestages found in study streams. These criteria are presented here. Potential fish passage barriers were identified from information developed from the CAWG 1 *Characterize Stream and Reservoir Habitats* Technical Study Report (SCE 2003a) and CAWG 3 *Determine Flow-related Physical Habitat in Bypass Reaches* 2002 and 2003 Technical Study Reports (SCE 2003b, SCE 2004).

Technical drawings and plans for Project diversions were reviewed to determine if they were likely to impede fish passage. Non-Project structures associated with Project bypass reaches were evaluated to see if they were likely to impede fish passage due to Project operations. Information from CAWG 1 and 7 Technical Study Reports (SCE 2003a and 2003c) was used to evaluate if under the current levels of passage, including the presence of natural barriers, fragmentation of habitat for target fish species has likely occurred. The viability of the target fish populations in Project waters was evaluated, but impacts are not evaluated in this report.

Detailed study methods for CAWG 1, CAWG 3, and CAWG 7 Technical Study Reports are presented in those respective reports. Study methods relevant to passage issues are summarized in Appendix A of this report.

3.2. DETAILED METHODOLOGY

3.2.1. LITERATURE REVIEW

Scientific literature and agency reports addressing fish passage were reviewed to identify appropriate passage criteria for study streams, as needed to supplement those already selected for use in the CAWG 1 and CAWG 3 studies. The review included fish passage criteria, as they apply to the lifestages of target fish species found in study streams and impoundments. Target salmonid species include rainbow trout, brown trout, and kokanee. Native non-salmonid species evaluated include hardhead, Sacramento pikeminnow, and Sacramento sucker. Passage criteria were identified based on available information. Passage criteria were used to evaluate potential movement upstream and downstream of potential passage barriers. Criteria include information on passable width, velocity and depth. Species specific information was used, as available. However, where such information is not available, information from similar or closely related species of similar size was used, if available.

3.2.2. Fish Passage Mechanisms at Project Diversions

Technical drawings and plans for large (i.e., reservoirs) and small (i.e., stream) Project diversions were evaluated for fish passage. Based on the details of the drawings and plans for each structure, fish passage was assessed using criteria developed from the literature review. If other non-Project structures (e.g., culverts) in study streams impede fish passage, the conditions creating the barrier were characterized from ground surveys. Data from USGS 7.5-minute topographic maps and habitat mapping surveys (CAWG 1) were used to indicate areas where non-Project structures exist, which may be potential passage barriers.

The passage of fish at each of the diversions was characterized for each of the major study streams and their tributaries including South Fork San Joaquin River (SFSJR), Mammoth and Stevenson Reaches of the San Joaquin River (SJR), and Big Creek. Table CAWG 14-1 presents a list of the Project reservoirs and forebays associated with Project diversions and dams. Facilities at large diversions (i.e., reservoirs), such as spillways and diversion intakes, were reviewed to characterize potential for fish passage.

Diversions at reservoir intakes may entrain and pass fish to areas below reservoirs (see CAWG 9 Entrainment Final Technical Study Plan [SCE 2001a]). Fish entrained by a diversion intake may be diverted to a reservoir, powerhouse, or other stream in the Project Area. Diversions at Huntington Lake, for example, may divert fish to Balsam Meadow Forebay, North Fork Stevenson Creek or Big Creek Powerhouse No. 1.

Small stream diversion structures were evaluated for fish passage based on details from the technical drawings and plans, and from information collected during the habitat mapping surveys (CAWG 1). Many of the small diversions are “turned-out” and all streamflow is allowed to pass downstream for much of the year, after the main run-off period. Depending upon the timing and mechanism by which this is accomplished, some potential for upstream passage may be available. Fish passage criteria were used to determine if the diversion structure is likely to be an impediment to fish movement.

3.2.3. Fish Passage Assessment

3.2.3.1. Ground Surveys

Fish passage barriers on streams were visually assessed and characterized by experienced fish biologists during the habitat mapping surveys (SCE 2003a). These included culverts, road crossings, debris jams, cascades, bedrock sheets, shallow riffles, and dewatered areas (see CAWG 1 Section 2.2.3 for barrier assessment methodology). Photographs were taken and spatial coordinates were collected using a GPS for each of the barriers identified during the ground surveys.

Table CAWG 14-1. Big Creek Project Reservoirs and Forebays Associated with Project Diversions.

DIVERSION	ELEVATION (FT)
Lake Thomas A. Edison	7651
Florence Lake	7329
Huntington Lake	6954
Shaver Lake	5371
Mammoth Pool Reservoir	3361
Redinger Lake	1414
Balsam Forebay	6675
Big Creek PH 3 Forebay	2250
Portal Forebay	7185
Big Creek PH 2 Forebay	4805
Big Creek PH 8 Forebay	2950
Mono Creek Diversion Forebay	7350
Hooper Creek Diversion Forebay	7350
Tombstone Creek Diversion	7673
South Slide Creek Diversion	7560
North Slide Creek Diversion	7520
Crater Creek Diversion	8762
Bear Creek Diversion Forebay	7350
Chinquapin Creek Diversion	7273
Camp 62 Creek Diversion	7257
Bolsillo Creek Diversion	7535
Warm Creek Diversion	8004
Rock Creek Diversion	3336
Ross Creek Diversion	3359
Pitman Creek Diversion	6998
Balsam Creek Diversion	4881
Ely Creek Diversion	4845

3.2.3.2. Hydraulic Modeling Passage Analysis – CAWG 3

SCE used channel geometry and a stage-discharge model to evaluate the flows needed for fish passage. The passage flows were determined using Thompson's (1972) criteria for the passage of adult trout. These criteria call for a minimum depth of 0.4 foot occurring over a minimum of 25 percent of the channel width. At least a contiguous 10 percent of the channel width must meet the depth criterion, for a transect to be considered passable. Thompson's criteria also requires that maximum water velocity be less than four feet per second (fps) to be passable. This analysis was completed for each transect in the wetted perimeter study, and then, as described in Thompson's method, the average of the resulting flows was calculated to determine the recommended flow for that sub-reach of the stream. For PHABSIM transects, a similar approach was used, however since the PHABSIM transects were located in larger streams, the 10 percent contiguous width of channel criterion was dropped, after discussion with and agreement of the CAWG. It was found that this criterion did not affect the flow at which passage criteria were met in the larger streams.

The purpose of the passage flow analysis was to estimate the flows necessary for passage in the stream through the shallower habitats present, typically riffles, in the absence of other structural passage barriers (i.e., drops, dams, weirs, or substantial debris jams).

3.2.3.3. Fish Passage from Diversion Reservoirs and Forebays

Upstream passage for spring and fall spawning migrations to tributaries from Project reservoirs and impoundments was evaluated from visual surveys at different reservoir elevations that typified the operating range of the reservoir. The ranges of typical operating elevations of the reservoirs during spring and fall spawning migrations were evaluated to determine whether passage conditions are acceptable.

3.3. Study Area

The study area included the South Fork San Joaquin River drainage from upstream of Florence Lake to the confluence with the San Joaquin River; the mainstem San Joaquin River and project tributaries from upstream of Mammoth Pool to Redinger Lake; and the Big Creek and Stevenson Creek drainages, including project tributaries and reservoirs. Project facilities that are included in this study plan are listed in Table CAWG 14-1 (Maps CAWG 14-1 through 14-3).

3.4. Analysis Approach

In order to determine the potential effect of passage barriers on the fish populations in the study area, data collected during the fish population and habitat mapping surveys (CAWG 7 and CAWG 1, respectively) were compared to stream reaches upstream and downstream of the potential passage barrier. Comparisons of the fish populations and available aquatic habitat could help to determine if a fish passage barrier is likely to affect the viability of the fish populations. An assessment of the fish population structure (age classes present) and available habitat in the river reaches above and below the diversion was made to determine if the available habitat conditions can sustain life history stages of the target and native species. Population structure was evaluated to determine if recruitment is likely being affected.

Since physical mesohabitat, flow-related habitat, spawning substrate, and water quality, especially temperature may affect fish populations (among other parameters), the focus of this analysis is on observed physical habitat characteristics. In particular, the amount and distribution of spawning gravels between barriers is presented to help evaluate the effect of habitat fragmentation on access to spawning habitat. Other habitat and water temperature characteristics may change seasonally with flow and are addressed extensively in other CAWG reports.

The assessment was based on the amount and types of habitat available and the extent to which passage barriers affect their use. The emphasis was placed on spawning habitat, as indicated by the presence of gravels, which are generally in limited supply. This was evaluated both within tributaries and for access from mainstem streams to tributaries. Data on population structure and fish condition also were presented to evaluate the presence of potential population-level effects.

3.5. LITERATURE REVIEW

Literature on fish passage requirements primarily deals with salmonids. Numerous sources report passage requirements for salmon, steelhead and trout adults and juveniles relative to manmade and natural impediments to migration. Sources reviewed include Lauman 1976, Powers and Orsborn 1985, Reiser and Peacock 1985, Katopodis 1989, Bjornn and Reiser 1991, Bates 1992, Mallen-Cooper 1994, Robinson 1997, Olsen et al. 1998, and Gallagher 1999. Salmonid passage requirements have been summarized into a standard set of conditions that procedurally define fish passage (Flosi et al. 1998).

Per Flosi et al. (1998), a structure is considered a barrier to adult upstream salmonid migration if its height is greater than two feet, its slope greater than three percent and upstream or receiving water depth is less than 0.5 feet. Vertical heights up to six feet may be jumped if the base pool depth is at least 1.25 times the height of the drop. However, an incline or chute can form a hydraulic jump further downstream, encouraging fish to jump too far from the crest of the drop. It should be noted that these criteria were developed for anadromous salmonids. Resident stream trout, which are smaller, may have greater difficulty navigating barriers. Flosi et al. (1998) also list minimum depth criteria at stream crossings, which are 0.5 feet for resident trout greater than six inches in length and 0.3 feet for juvenile trout less than six inches. Flosi et al. (1998) suggest that over prolonged periods swimming speeds that may be sustained by resident trout are four ft/s and 1.5 ft/s for adults and juveniles, respectively. Short-term burst speeds are identified as five and three ft/s for five sec for adults and juveniles, respectively.

Minimum passage flows for upstream migration were determined using Thompson's (1972) criteria for passage of adult trout. These criteria call for a minimum depth of 0.4

feet occurring over a minimum of 25 percent of the channel width. For smaller streams (those analyzed using the wetted perimeter approach), the portion of the criteria that states *at least a contiguous 10 percent of the channel (transect) width must meet the depth criterion* to be considered passable also was used. This criterion was not used in wider streams analyzed using PHABSIM. Thompson's criteria also require that maximum water velocity be less than four feet per second (fps) to be considered passable. The average of the resulting passage flows of all transects in a stream reach is calculated to determine the recommended passage flow for that reach of the stream. The recommended passage flow is intended to estimate the instream flow necessary for passage through the shallower habitats present, in the absence of other structural barriers to passage.

Upstream fish passage at some of the smaller diversions may be available when the diversions are turned out. In addition to the structural components that affect passage as described by Flosi et al. (1998), water velocities through pipes or culverts and the distances fish have to travel affect upstream passage. Fish are capable of swimming at high speeds for short bursts (Beamish 1978). In general, analysis of passage at small diversions focussed on the structural features of the diversion.

Fish populations are considered self-sustaining if there is evidence of successful reproduction and recruitment to the population. Moyle et al. (1998) defined good condition for a species at the population level; "…good condition means that each population must have (1) multiple age classes (evidence of reproduction), (2) a viable population size, and (3) healthy individuals." These attributes were used as general guidance in helping the reader to identify whether there was a potential effect on a fish population due to habitat fragmentation or some other cause. Data collected for the CAWG 7 technical report addressed these characteristics. CAWG 14 Appendix C summarizes the status of fish populations in study streams from the CAWG 7 data with respect to potential barrier effects.

4.0 RESULTS

4.1. INTRODUCTION

Fish passage issues and the relevant information on the status of populations of target fish species are summarized by stream for each of the main study area drainages (Maps CAWG 14-1 through 14-3, CAWG 14 Appendix C).

4.2. SOUTH FORK SAN JOAQUIN RIVER DRAINAGE

The SFSJR study area encompasses Florence Lake and its tributary streams and about 28 miles of the SFSJR from Florence Dam downstream to the confluence with the San Joaquin River (Map CAWG 14-1). The study area also includes streams tributary to the SFSJR that contain Project diversions.

4.2.1. FLORENCE LAKE

Florence Dam (SFSJR RM 27.9) forms Florence Lake (Map CAWG 14-1). The lake is fed by unregulated flows from the SFSJR and Boulder Creek and flows diverted from Crater Creek, Tombstone Creek (not currently in operation), North Slide Creek (not currently in operation), South Slide Creek (not currently in operation), and Hooper Creek diversions. Water level in the reservoir varies considerably throughout the year (See CAWG 1 for the Florence Lake winter and summer average lake elevation, volume, and surface area by water year in Table CAWG 1-243 [SCE 2003a]). The reservoir is normally operated to store runoff for use downstream. Winter reservoir elevations are maintained at a minimum level.

Fish Populations - Only brown trout were collected in Florence Lake in August 2002 (CAWG 14 Table Appendix B-1). Rainbow trout were observed during a subsequent visit. The persistence of brown trout, despite the lack of stocking since 1969, indicates that the population is self-sustaining. The sampled population included age classes from 0+ to 6+, with the majority of fish of ages 4+ to 6+. Brown trout were observed moving upstream from Florence Lake to the SFSJR during their fall spawning migration. The average condition factor[1] for brown trout was calculated to be 1.47.

4.2.1.1. UPSTREAM PASSAGE FROM FLORENCE LAKE

Passage for potential upstream migration from Florence Lake to the SFSJR is maintained at the full range of operational lake elevations. However, a 10-ft high waterfall, with a plunge pool approximately 20 feet deep, located a short distance

[1] Condition factors (weight/length ratios, Carlander 1969) are used to describe growth and health of fish. Average condition factors for sampled fish populations in the study area are presented in greater detail in CAWG 7 Characterize Fish Populations (SCE 2003c).

upstream of Florence Lake in the SFSJR (SFSJR RM 30.6) forms a partial barrier to upstream fish migration. Field observations indicate that trout may be able to pass over the waterfall, but that it would require significant effort. Portions of the SFSJR that are normally inundated by Florence Lake during the summer months are used by brown trout for spawning in the fall, when the lake level is lower. Brown trout were observed to spawn in such areas during the fall of 2002.

Boulder Creek (SFSJR RM 30.3) is a tributary to the SFSJR with its confluence just downstream of the waterfall in the SFSJR. Fish from Florence Lake can access Boulder Creek via a short reach of the SFSJR. A nine-ft high, 20-ft long, debris jam was located in Boulder Creek about 250 feet upstream of the SFSJR in 2001. The debris jam formed a partial to potentially complete barrier to fish migration. However, this barrier is not considered to be permanent.

The Crater Creek Diversion Channel only operates during the primary run-off period when Florence Lake is at near capacity. There are no fish migration barriers into the channel when the reservoir is at maximum capacity and when there is water in the channel. When operation of the diversion ceases, channel flow declines and migration is precluded between the lake and the channel. Passage barriers in this channel are discussed with Crater Creek. While there is flow in this channel during the runoff period when rainbow trout spawn, there are apparently relatively few rainbow trout in Florence Lake. There is little flow in this channel during the fall, when brown trout spawn.

4.2.1.2. Florence Lake Dam

Florence Lake Dam is a complete barrier to upstream migration from the SFSJR. Rainbow and brown trout both occur downstream of the dam (CAWG 14 Table Appendix B-1). Spill may occur over the dam spillway, which is controlled by hydraulic gates (7,315.5 ft MSL). Spills may result in downstream transport of fish. The Ward Tunnel intake, located on the bottom of the lake at the dam outlet works 2,000 feet from the left abutment on the western shore of Florence Lake, form the entrance to Ward Tunnel. A hydroacoustic survey conducted on August 15, 2002 showed there were very few fish near the bottom of the lake at the dam (SCE 2003c). Approach velocities at the intake are low and the potential for entrainment and downstream movement of fish from this mechanism is likely low.

4.2.2. Mainstem of SFSJR

Overview

The mainstem SFSJR study reach extends 28 miles from Florence Lake Dam (SFSJR RM 27.9) to its confluence with the San Joaquin River (SFSJR RM 0.0) (Map CAWG 14-1).

Historically, the SFSJR was isolated from anadromous fish, including steelhead trout (Yoshiyama et al. 1998). Yoshiyama et al. (1998) reports that upstream access to anadromous salmonids was limited to the Mammoth Pool Dam area (SJR RM 26) of the San Joaquin River located 13 miles downstream of the confluence of the SFSJR. Since the late 19th century, individuals, groups, and the CDFG have stocked brown, rainbow, golden and brook trout in the drainage. Currently, the SFSJR is stocked primarily with rainbow trout from the San Joaquin Hatchery (SCE 2003c). Brown trout and brook trout are not currently stocked.

CAWG 7 study results from 2002 (SCE 2003c) show the mainstem fish communities were primarily comprised of brown trout and rainbow trout (CAWG 14 Table Appendix B-1). Both species were relatively abundant, with higher densities of brown trout occurring further upstream. The SFSJR upstream of Florence Lake, downstream of Florence Lake Dam to near Bear Creek (SFSJR RM 22.3), and a Rosgen type G channel site in the reach between Bear Creek and Mono Crossing, were dominated by brown trout. Rainbow trout dominated reaches downstream. Multiple age classes, including age 0+ fish, were present for both species. This indicates that both rainbow and brown trout successfully reproduce and rear in the SFSJR and/or its tributaries. The largest numbers of age 0+ brown trout were collected in the reach between Florence Lake and Bear Creek, while the largest numbers of age 0+ rainbow trout were collected downstream of Mono Crossing. Most of the rainbow trout collected (and all of the age 0+ fish) were presumed to be wild fish based on their appearance. There was no significant statistical difference between condition factors between sites for either brown trout (range of 1.24 to 1.45, p=0.17) or rainbow trout (range of 1.31 to 1.84, p=0.16).

The most prominent barrier within the surveyed reach is a 36-ft high waterfall located about 0.5 miles upstream of Hoffman Creek (SFSJR RM 6.9). This waterfall is a complete barrier to upstream migration under all flow conditions and is a natural barrier that isolates the SFSJR watershed from the lower basin. Five other natural barriers to fish upstream migration, only one of which was a complete barrier at all flows, were identified on the mainstem downstream of Mono Crossing, as described below (Map CAWG 14-1). In the area not surveyed on the ground, downstream of Hoffman Creek to the confluence with the San Joaquin River, several barriers were apparent from aerial photography and overflights. Since these were not surveyed on the ground, details of whether they are complete barriers or not are unclear, and they are not discussed further.

4.2.2.1. SFSJR – FLORENCE DAM TO BEAR CREEK

The South Fork San Joaquin River between Florence Dam (SFSJR RM 27.9) and Bear Creek (SFSJR RM 22.3) (Map CAWG 14-1) is a low to moderate gradient stream comprised primarily of Rosgen type B channel, with short reaches of Rosgen type C and G channels. This reach contained many pools and runs, as well as a complex mix of cover types. Little spawning gravel was observed in the Rosgen type B and G channel areas, more was located in the Rosgen type C channel areas. Most of the spawning gravel was characterized as poor or fair in quality, and a small amount (800 square feet) was characterized as good.

Fish Populations - A brown trout population consisting of multiple age classes dominated this reach (CAWG 14 Table Appendix B-1). The presence of multiple age classes, including age 0+ trout indicates that brown trout successfully recruit and rear within this reach. The largest numbers of age 0+ brown trout were collected here, as compared with the other reaches of the SFSJR. Estimates for densities of numbers (303 to 522 fish/km) and biomass (11.1 to 35.1 kg/ha) for brown trout were relatively high. The average fish condition factor for brown trout ranged from 1.37 to 1.45 and for rainbow trout ranged from 1.31 to 1.84 in sites sampled.

Fish Barriers - No physical barriers to fish passage within the mainstem were identified within this reach. Tributary access is described with each of the tributaries.

Flow-related Fish Passage - PHABSIM Fish passage study sites were established immediately downstream of Florence Dam (SFSJR RM 27.5 to 27.7), and between Slide and Hooper creeks (SFSJR RM 25.2 to 25.3 and RM 24.9 to 25.0), and are used to represent passage as a function of flow in Rosgen type B channels in this reach. The flow needed to meet the Thompson passage criteria at all study transects was 8.28 cfs with an average value of 8.28 cfs.

4.2.2.2. SFSJR - Bear Creek to Mono Crossing

The SFSJR from Bear Creek (SFSJR RM 22.3) to Mono Crossing (SFSJR RM 18.0), located immediately upstream of Camp 61 Creek (Map CAWG 14-1), is a low gradient stream. It was comprised primarily of Rosgen type B channel and short sections of Rosgen type C and G channels. This reach had a complex mixture of habitat types, including deep pools. Little spawning gravel was observed (1,068 square feet), most of it of fair to poor quality.

Fish Populations - Rainbow trout were slightly more abundant than brown trout (CAWG 14 Table Appendix B-1). The presence of multiple age classes of both rainbow and brown trout suggests that both species successfully recruit and rear within this reach. Estimates for densities of numbers and biomass for rainbow (32 to 700 fish/km and 0.4 to 23.9 kg/ha, respectively) and brown trout (220 to 306 fish/km and 8.3 to 9.3 kg/ha, respectively) were relatively high, but varied among sampling sites located in different Rosgen channel types. The average fish condition factor for rainbow trout ranged from 1.31 to 1.44 and for brown trout ranged from 1.32 to 1.38.

Fish Barriers - No physical barriers to fish migration were identified.

Flow-related Fish Passage - PHABSIM study sites were located adjacent to the mouth of Camp 62 Creek (SFSJR RM 20.1 to 20.3) and between Bolsillo Creek and Camp 61 Creek (Mono Crossing) (SFSJR RMs 18.8 to 19.1, 18.6, 18.4, and 17.9), and are used to represent passage as a function of flow in Rosgen type B, C and G channels in this reach. The range of flows needed to meet the Thompson passage criteria in the Rosgen type B channel sites was 10.0 to 30.0 cfs with an average value of 20 cfs. The flow needed to meet the Thompson passage criteria was 10 cfs in all of the Rosgen type C and G channel transects, with an average value of 10 cfs. The average flow needed over all transects in the Rosgen type B, C and G channel types was 12.9 cfs.

4.2.2.3. SFSJR - Mono Crossing to Downstream of Rattlesnake Creek

This segment of the South Fork San Joaquin River between Mono Crossing (SFSJR RM 18.0) and Rattlesnake Creek (SFSJR RM 14.5) is a low gradient stream dominated by Rosgen type B channel, with a smaller component of Rosgen type G channel. This reach had mostly pool and riffle habitats, but also included a complex mixture of habitat types. Spawning gravel was relatively abundant (5,105 square feet) in the Rosgen type B channel, although smaller amounts also were found in the Rosgen type G channel upstream of the first low-flow barrier.

Fish Populations - Both rainbow and brown trout were observed in this reach (CAWG 14 Table Appendix B-1). The density of rainbow trout was much higher than brown trout. The majority of rainbow trout were age 0+. No age 0+ brown trout was observed. The reach clearly supports rainbow trout spawning and rearing. Brown trout spawning may occur in this reach, or in tributaries. However, the presence of age 1+ brown trout suggests that recruitment is occurring. Estimates for densities of numbers and biomass for rainbow (984 fish/km and 5.8 kg/ha, respectively) and brown trout (350 fish/km and 4.7 kg/ha, respectively) were relatively high. The average fish condition factor for rainbow trout was 1.38) and for brown trout was 1.24.

Fish Barriers - Two physical barriers to upstream fish migration were identified in the Rosgen type G channel.

- SFSJR RM 15.5 - A five-ft high cascade waterfall located 5,423 feet upstream of the confluence with Rattlesnake Creek forms a partial barrier at low flows, and
- SFSJR RM 16.6 - A five-ft high waterfall in a cascade located 10,953 feet upstream of Rattlesnake Creek represents a complete barrier at low flows.

These natural barriers would likely not be barriers to rainbow trout that spawn in the spring during runoff, but may be barriers to brown trout upstream spawning migrations in the fall. However, spawning gravel was available both downstream and upstream of the complete, low-flow barrier.

Flow-related Fish Passage - PHABSIM data were collected in Rosgen type B and G channel sites between Florence Dam and Mono Crossing, which were used to represent passage as a function of flow in the Mono Crossing to Rattlesnake Creek reach. The range of flows needed to meet the Thompson passage criteria in the Rosgen type B channel sites was 8.28 cfs to 30 cfs, with an average value of 14.1 cfs. The flow needed in the Rosgen type G channel transects was 10 cfs. Over both Rosgen channel types, the range of flows needed to meet the Thompson passage criteria was 8.28 to 30.0 cfs with an average value of 12.76 cfs.

4.2.2.4. SFSJR – Rattlesnake Creek to San Joaquin River/South Fork Confluence

This segment of the SFSJR is a low gradient, Rosgen type G channel. This reach had pools, riffles and flatwater habitats. Spawning gravel was less abundant (650 square feet between Rattlesnake and Hoffman creeks) than upstream. The lower-most portion of this reach, from upstream of Hoffman Creek (SFSJR RM 6.9) to the confluence with the San Joaquin River was not ground surveyed, as discussed in CAWG 1 Technical Study Report (SCE 2003a), due to extremely difficult access. Mapping from aerial photography and video indicated that pools and flatwater habitats were dominant.

Fish Populations - Rainbow and brown trout were both observed within this reach (CAWG 14 Table Appendix B-1). Age 0+ fish dominated the rainbow trout population. No age 0+ brown trout was observed. This indicates rainbow trout spawning and rearing is successful in the reach. Brown trout spawning may occur in this reach, or in tributaries. The presence of age 1+ brown trout indicates that recruitment is occurring. Rainbow trout dominated this reach. Estimates for densities of numbers and biomass for rainbow (837 fish/km and 9.3 kg/ha, respectively) and brown trout (385 fish/km and 10.2 kg/ha, respectively) were relatively high. The average fish condition factor was of 1.43 and 1.27 for rainbow and brown trout, respectively.

Fish Barriers - Three waterfalls form physical barriers to upstream fish migration, one of which forms a complete barrier at all flows.

- SFSJR RM 6.9 - A 36-ft high waterfall in a long cascade, located 2,839 feet upstream of the confluence with Hoffman Creek, forms a complete barrier to migration at all flows,
- SFSJR RM 7.0 - An eight-ft high waterfall, located 3,140 feet upstream of the confluence with Hoffman Creek, forms a complete barrier to migration at low flows, and
- SFSJR RM 7.2 - A 12-ft high waterfall in a cascade, located 4,332 feet upstream of the confluence with Hoffman Creek, forms a complete barrier to migration at low flows. Most of the river flowed under a bedrock slab.

The low-flow barriers would likely not be natural barriers to rainbow trout that spawn in the spring during runoff, but may be barriers to brown trout upstream spawning migrations in the fall. The waterfall at SFSJR RM 6.9 would block upstream migration for both species. Small amounts of fair to good quality spawning gravel were available between and upstream of the low-flow barriers, but spawning gravel was not found downstream of RM 7.0 to Hoffman Creek at the time of the surveys.

Flow-related Fish Passage - PHABSIM data were collected in Rosgen type G channel sites between Bear Creek and Mono Crossing, which are used to represent passage as a function of flow in this reach. The flow needed to meet the Thompson passage criteria at all sites was 10.0 cfs.

4.2.3. TRIBUTARIES TO THE SOUTH FORK SAN JOAQUIN RIVER

The study streams tributary to the SFSJR that are subject to diversion or augmentation by the Project were evaluated, including (from upstream to downstream): Tombstone, South Slide, North Slide, Hooper, and Crater creeks, Crater Creek Diversion Channel, and Bear, Chinquapin, Camp 62, Bolsillo and Mono creeks (Map CAWG 14-1). Fish sampling was conducted at representative sites above and below diversions. Diversions on Tombstone, North and South Slide creeks were not and are not currently in operation.

4.2.3.1. TOMBSTONE CREEK

Tombstone Creek enters the SFSJR at RM 27.4 (Map CAWG 14-1). The lower reach of Tombstone Creek included a low gradient Rosgen type C/E channel through Jackass Meadow that was dry during the fall 2002 habitat survey and during fish surveys. This reach also had Rosgen type Aa+ channel with run, cascade and pool habitat. Tombstone Creek, upstream of the diversion, is a Rosgen type Aa+ channel with predominantly cascade, step run and bedrock sheet habitat, which may limit the habitat value for trout. Small amounts of fair to poor quality spawning gravel were observed above (50 square feet) and below (842 square feet) the diversion, mostly in step run, run and low gradient riffle habitats. The diversion is not currently in operation. Formerly, diverted water was conveyed through a combination of 14-inch-diameter steel pipe and natural channel, 3,300 feet long, to Florence Lake.

Fish Populations - No fish was found upstream of the diversion, despite historical stocking of golden trout. The Rosgen type Aa+ channel downstream of the diversion contained only brown trout (CAWG 14 Table Appendix B-1), although other species have been reported previously. Brown trout from multiple age classes, including age 0+ through age 4+ and older fish, were collected, indicating reproduction and recruitment occurred. Estimates for densities of numbers (416 fish per km) and biomass 188.4 kg/ha) were relatively high. The average fish condition factor was 1.37.

Fish Barriers - The only physical barrier within Tombstone Creek is the Tombstone Diversion (Tombstone Creek RM 1.0), which forms a complete barrier to upstream migration. The diversion is a five-ft high, masonry structure and has no gates or pipes that could provide fish passage from the reach below the diversion.

Flow-related Fish Passage - Three wetted perimeter study sites were located upstream of the diversion and three were located downstream (SCE 2003b). To meet the Thompson (1972) criteria for adult trout upstream passage within the creek, flows of 0.5 to 3.5 cfs, with an average of 1.7 cfs, are necessary below the diversion. This would likely be met during the spring runoff period when rainbow trout spawn, but not during the fall when brown and brook trout spawn. Above the diversion, passage flows range from 0.3 to 1.5 cfs, with an average of 0.9 cfs.

Fish passage from the SFSJR - There are no physical barriers downstream of the diversion. Natural flow at some sites in Tombstone Creek above and below the diversion may be insufficient to meet the Thompson criteria for adult trout upstream passage during brown trout spawning runs in the fall. Minimum passage flows are likely to be met during the spring runoff period when rainbow trout spawn.

4.2.3.2. South Slide Creek

South Slide Creek (SFSJR RM 25.8), both upstream and downstream of the South Slide Creek Diversion (South Slide Creek RM 0.3) consists of Rosgen type Aa+ channel. Downstream of the diversion is a steep, bedrock/boulder stream with cascades and bedrock sheets. No significant pools were observed. A small amount (60 square feet) of poor-quality spawning gravel was found downstream of the diversion, 50 square feet located in cascades and the rest in step runs.

The diversion is not currently in operation. Formerly, diverted water was conveyed through eight-inch-diameter steel pipes between the diversion to a wye branch, and thence, through 12-inch-diameter steel pipe, 1,028 feet to a point where it was discharged into the Hooper Creek Conduit and flowed to Florence Lake.

Fish Populations - No fish was observed in South Slide Creek.

Fish Barriers - The only physical barrier in South Slide Creek is the South Slide Creek Diversion structure located 0.3 mile upstream of the confluence with the SFSJR. The diversion is a five-ft high masonry structure with no gates or pipes that could provide fish passage from the reach below the diversion. The diversion forms a total barrier to upstream migration.

Flow-related Fish Passage - Three flow evaluation study sites were established on South Slide Creek downstream of the diversion. To meet the Thompson (1972) criteria for adult trout upstream passage, flows of 0.9 to 7.5 cfs, with an average of 3.6 cfs, are necessary below the diversion during the spawning season. The 7.5 cfs value at transect C was considerably higher than that of the other two transects and also is higher than that found in some of the other, larger streams, such as Hooper and Tombstone creeks. The unusually high 7.5 cfs value at this transect was caused by a wide bar on the left side of the channel that was inundated at all flows. An examination of the channel cross section indicates that width and depth are sufficient for trout migration at locations on the transect at flows of 0.5 cfs. When using 0.5 cfs for this transect, the recommended passage flow would be 1.2 cfs. This would likely be met during the spring runoff period when rainbow trout spawn, but would not be met during the fall when brown and brook trout spawn.

Fish passage from the SFSJR - There are no physical barriers downstream of the diversion. Natural flow at some sites in South Slide Creek below the diversion may be insufficient to meet the Thompson criteria for adult trout upstream passage during time of brown trout spawning runs in the fall, but minimum passage flows are likely to be met during the spring runoff period when rainbow trout spawn.

4.2.3.3. North Slide Creek

North Slide Creek (SFSJR RM 25.8) below the diversion (North Slide Creek RM 0.3) is a very steep, bedrock/boulder stream with a Rosgen type Aa+ channel. Cascades and bedrock sheets predominate. No pools or spawning gravels were found. The diversion is not currently in operation. Formerly, diverted water was conveyed through an eight-inch-diameter steel pipe between the diversion to a wye branch, and thence, through 12-inch-diameter steel pipe, 1,028 feet to a point where it was discharged into the Hooper Creek Conduit and flowed to Florence Lake.

Fish Populations - No fish was observed in North Slide Creek.

Fish Barriers - The North Slide Creek Diversion is a five-ft high, masonry structure with no gates or pipes that could provide fish passage from the reach below the diversion. Therefore the diversion forms a total barrier to upstream migration. Four barriers to upstream fish migration were identified downstream of the diversion.

- North Slide Creek RM 0.0 - A 15-ft high waterfall in a cascade 17 feet upstream of the river forms a total barrier at all flows,
- North Slide Creek RM 0.04 - A road crossing forms a total barrier at all flows,
- North Slide Creek RM 0.2 - A 20-ft high waterfall in a cascade forms a total barrier at all flows,
- North Slide Creek RM 0.23 - Dry stream channel forms a complete barrier at low flows, and
- North Slide Creek RM 0.3 - The five-ft high North Slide Creek Diversion forms a total barrier at all flows.

Flow-related Fish Passage - Three wetted perimeter study sites were established in runs and riffles in North Slide Creek downstream of the diversion. To meet the Thompson (1972) criteria for adult trout upstream passage within the creek, flows of 0.4 to 0.5 cfs, with an average of 0.5 cfs, are necessary. This would likely be met during the spring runoff period when rainbow trout spawn, but not during the fall, when brown and brook trout spawn.

Fish passage from the SFSJR - As identified above, a 15-ft high waterfall in a cascade located 17 feet upstream of the confluence with the SFSJR forms a total barrier at all flows. This precludes the use of most of this creek by fish resident in the SFSJR. No spawning gravel was found in North Slide Creek.

4.2.3.4. Hooper Creek

Hooper Creek (SFSJR RM 24.6) (Map CAWG 14-1) is a very steep, bedrock channel stream with a Rosgen type Aa+ channel and is dominated by cascade and bedrock sheet habitats. Fair to good quality spawning gravels were located in the reach below the diversion (183 square feet) primarily in cascades and dammed pools, with only small amounts in high and low gradient riffles. Small amounts (18 square feet) also were located in the short reach above the diversion, mostly in low gradient riffles. Flow is diverted through a 34-inch diameter steel pipe (Hooper Conduit) to Florence Lake, which could provide passage to Florence Lake for fish originating upstream of the diversion.

Fish Populations - Golden x rainbow trout hybrids were collected both upstream and downstream of the Hooper Creek Diversion (CAWG 14 Table Appendix B-1). Trout from multiple age classes, including age 0+, were collected below the diversion, indicating reproduction and recruitment occurred. No age 0+ trout were found above the diversion. However, the presence of this species despite the lack of stocking in recent years indicates spawning and recruitment occurs. Above and below the diversion, estimated densities (663 and 962 fish/km, respectively) and biomass (71.3 and 124.9 kg/ha, respectively) were high. There was no statistically significant difference in condition factors for fish above and below the diversion. Populations of golden x rainbow trout in Hooper Creek appear to be self-sustaining.

Fish Barriers - Hooper Creek Diversion is a 30-ft-high concrete diversion. The overpour-type spillway located on the left side of the diversion may provide downstream fish passage when water spills. The diversion has a 24-inch sluice pipe located near the bottom of the dam and a gate valve is used to turn out the diversion. However, a one- to two-ft drop onto bedrock from the pipe likely makes the diversion a complete barrier to upstream migration.

There were five barriers to upstream fish migration below the diversion, all in cascade habitats, which formed barriers only at low flows under current operations. A waterfall 1,025 feet upstream of the diversion formed a complete barrier at all flows (Map CAWG 14-1).

- Hooper Creek RM 0.0 - A cascade with insufficient depth at the confluence with the river forms a complete barrier at low flows,

- Hooper Creek RM 0.11 - A cascade with insufficient depth (during the summer-fall baseflow period) forms a complete barrier at low flows,

- Hooper Creek RM 0.32 - A five-ft high waterfall in a cascade forms a complete barrier at low flows,

- Hooper Creek RM 0.41 - A cascade with insufficient depth forms a complete barrier at low flow,

- Hooper Creek RM 0.54 - A five-ft high waterfall in a cascade forms a complete barrier at low flow,

- Hooper Creek RM 0.6 - The 30-ft high Hooper Creek Diversion is a total barrier to upstream fish migration.

- Hooper Creek RM 0.8 - A 25-ft high waterfall forms a complete barrier at all flows.

Flow-related Fish Passage - Five wetted perimeter study sites were located on Hooper Creek, two sites upstream of the diversion and three downstream (Hooper Creek RMs 0.05 and 0.1). To meet the Thompson (1972) criteria for adult trout upstream passage at these locations, flows of 0.5 to 3.5 cfs, with an average of 2.5 cfs, are necessary below the diversion during the spawning season. Above the diversion, passage flows are estimated to range from 0.1 and 0.3 cfs, for an average of 0.2 cfs. Depths and velocities suitable for fish passage were provided at the upstream transects at the lowest measured flows (two to six cfs). Water velocities were high even at the lower flows, however fish passage criteria were met at flows up to 32 cfs. Fish passage criteria were not met at the lowest measured flows at the downstream transects (one cfs), but were met when measured at a flow of 5.8 cfs.

Fish passage from the SFSJR - As stated above, there are multiple physical barriers that limit access to this creek from the SFSJR. The cascades at the confluence of the SFSJR and Hooper Creek RM 0.11 would be barriers to brown trout (which dominate this reach of the SFSJR) and brook trout during the low flows that occur in the fall spawning season under current operations. These would likely not be barriers to rainbow trout or their hybrids that spawn in the spring during runoff, depending upon flow available below the diversion. The diversion forms a complete barrier at all flows at RM 0.60, which would block upstream passage for all fish species. Upstream of this barrier, spawning gravels were found in locations between the natural barriers to migration.

4.2.3.5. CRATER CREEK

Crater Creek (SFSJR RM 23.5) (Map CAWG 14-1) is a steep, bedrock stream that is comprised mainly of Rosgen type Aa+ channel above and below the diversion. A short segment of Rosgen type C/E channel exists just below the diversion (Crater Creek RM 2.9) and near the confluence with the SFSJR. Habitat is primarily cascade and step run throughout the stream. In the reach above the diversion, 50 square feet of good quality spawning gravel were located entirely in step runs. Large amounts of spawning gravels were observed in the longer reach below the diversion, primarily in step runs, with fair amounts in runs and pools (including tailouts) and smaller amounts in other habitats. In the Rosgen type C/E channel, good to excellent gravels were prevalent.

Crater Creek Diversion Channel extends 7,260 feet from Crater Creek Diversion to Florence Lake. The diversion channel is a combination of ditch and natural channel and was classified as a Rosgen type Aa+ channel. Much of the habitat is either cascade or bedrock sheet, but small components of complex habitat types were observed. Poor to fair quality spawning gravel was distributed over many habitat types. All diverted flow is routed to Florence Lake.

Fish Populations - Brook trout was the only species collected upstream and downstream of Crater Creek Diversion and in the diversion channel (CAWG 14 Table Appendix B-1). Multiple age classes, including age 0+, were collected, indicating reproduction and recruitment occurred. Estimated trout densities and biomass were much higher in the diversion channel than in Crater Creek. Densities above the Crater Creek Diversion were greater than downstream. The condition factors above the diversion (average of 1.46), Crater Creek below the diversion (average of 1.05) and the Crater Creek diversion channel (average of 1.33) were statistically different among sites (p=0.05).

Fish Barriers - The Crater Creek Diversion is a three-ft-high, concrete diversion. There is a stoplog near the top of the diversion wall, with no valve, and the diversion is turned out with diversion boards. The ditch to the natural channel below the diversion has a rubble wall on one side (with fill behind it), which makes the upper edge of the channel wall and diversion two inches higher in elevation than the streambed upstream of the diversion pool and creates a large drop from the top of the diversion to the channel below. Therefore, the diversion blocks upstream fish passage, even when turned out. Seven barriers to fish migration were identified in the Rosgen type Aa+ channel downstream of the diversion.

- Crater Creek RM 0.4 - A 12-ft high waterfall forms a complete barrier to upstream migration at low flows,
- Crater Creek RM 0.5 - Insufficient depth in a pool formed a complete barrier at low flows,
- Crater Creek RM 1.1 - Insufficient depth in a pool formed a complete barrier at low flows,
- Crater Creek RM 1.3 - A 10-ft high waterfall in a cascade forms a complete barrier to upstream migration at all flows,
- Crater Creek RM 1.5 - A 25-ft high waterfall in bedrock sheet habitat forms a complete barrier to upstream migration at all flows,
- Crater Creek RM 1.7 - A cascade reach with insufficient depth forms a complete barrier at low flows,
- Crater Creek RM 2.3 - A 20-ft high waterfall in a cascade forms a total barrier to upstream migration at all flows, and
- Crater Creek RM 2.9 - The three-ft high Crater Creek Diversion is a total barrier to upstream migration.

Spawning gravel was found between all barriers except the natural barriers at Crater Creek RMs 1.3 and 1.5.

Crater Creek Diversion Channel only operates during the primary run-off period when Florence Lake is filling. Two barriers to migration were identified in the Crater Creek Diversion Channel.

- A 4.2-ft high waterfall in a cascade located 1,245 feet upstream of Florence Lake forms a partial barrier at all flows, and

- A road crossing located 445 feet upstream of Florence Lake forms a partial barrier at low flows.

Flow-Related Fish Passage in Crater Creek Diversion - Fish passage from Florence Lake is available when the reservoir is at maximum capacity and when there is water in the channel, but not when operation of the diversion ceases. During runoff, flow may permit rainbow trout to ascend this channel. However, there are apparently relatively few rainbow trout in Florence Lake. There are small amounts of poor to fair spawning gravels downstream of both partial barriers. There is little flow in this channel during the fall, when brown trout spawn.

Flow-Related Fish Passage in Crater Creek - Six wetted perimeter study sites were located on Crater Creek. Three were located upstream (Crater Creek RMs 3.05 to 3.1) and three downstream (RMs 1.6, 1.75 and 1.85) of the diversion (Map CAWG 14-1). To meet the Thompson (1972) criteria for adult trout upstream passage, flows of 0.3 to 1.5 cfs, with an average of 0.7 cfs, are necessary below the diversion during the spawning season. Above the diversion, passage flows range from 0.3 to 0.9 cfs, with an average of 0.6 cfs. The downstream transects clearly provided upstream migration at the lowest measured flow (2.1 cfs). However, all the downstream transects went dry during summer, with low flow conditions during the period that the diversion is turned out and all flow routed through the natural stream channel.

Fish passage from the SFSJR - As stated above, at Crater Creek RM 0.4, a 12-ft high waterfall forms a complete barrier at low flows, limiting access to Crater Creek to the lower 0.4 miles during the fall brown and brook trout spawning season. This is probably not a barrier to rainbow trout that spawn in the spring during runoff, depending upon flow below the diversion. The barrier at RM 1.3 would block upstream passage for all fish species at that point. Low flows likely limit passage within this length after the spring runoff period, under current operations. Spawning gravel scattered throughout the 0.4 mile downstream of the first barrier at low flows was accessible to fish resident in the SFSJR. Additional spawning gravel was located between the low flow barriers downstream of the first complete barrier at all flows (Crater Creek RM 1.3).

4.2.3.6. Bear Creek

Bear Creek (SFSJR RM 22.3) (Map CAWG 14-1) is a bedrock/boulder stream. The reach upstream of Bear Creek Diversion (Bear Creek RM 1.6) is a Rosgen type B channel with abundant riffle, run and pool habitats. The downstream reach is primarily Rosgen type A channel consisting largely of pool and high gradient riffle habitats. A small amount (30 square feet) of spawning gravel was found in low gradient riffle and run habitat above the diversion. A fair amount (410 square feet) of fair to good quality spawning gravels was observed scattered throughout the reach below the diversion, mostly (260 square feet) located in step pools tailouts, with smaller amounts in high gradient riffles, lateral scour pools tailouts and step run. Flow is diverted via the Ward

Tunnel to Huntington Lake. This may move fish from above the diversion to Huntington Lake at times.

Fish Populations - Brown trout were found upstream and downstream of Bear Creek Diversion (CAWG 14 Table Appendix B-1), although other species have been reported. Multiple age classes of brown trout, including age 0+ fish, were collected, indicating recruitment occurred. Densities of numbers and biomass were substantially higher (more than three-fold greater) in the reach downstream of the diversion (CAWG 14 Table Appendix B-1) (SCE 2003c). There was no significant statistical difference between condition factors above and below the diversion.

Fish Barriers - The Bear Creek Diversion is a 55-ft high, concrete diversion. It has an ungated, overpour spillway with an effective length of 232 feet. The diversion is turned out with a gate valve. It has two 24-inch sluice pipes located 25 feet above the bottom of the diversion, and a 10 to 12-inch pipe extending downstream. The pipes are too high to provide upstream passage past the diversion. Four waterfalls in step pool habitats formed barriers to upstream fish migration in the reach below the Bear Creek Diversion, in addition to the diversion.

- Bear Creek RM 0.27 - A 15-ft high waterfall river forms a complete barrier at low flows,
- Bear Creek RM 0.5 - A six-ft high waterfall forms a complete barrier to upstream migration at low flows,
- Bear Creek RM 0.74 - A 12-ft high waterfall forms a complete barrier to upstream migration at all flows,
- Bear Creek RM 0.75 - A six-ft high waterfall forms a partial barrier to upstream migration at low flows, and
- Bear Creek RM 1.6 - The 55-ft high Bear Creek Diversion forms a complete barrier to upstream migration.

Flow-Related Fish Passage – Three PHABSIM study sites situated downstream of the Bear Creek Diversion (Map CAWG 14-1) were used to identify fish passage flow requirements. The flow needed to meet the Thompson passage criteria at each of the three study transects was 1.12 cfs.

Fish passage from the SFSJR - As stated above, at RM 0.27 a 15-ft high waterfall river forms a complete barrier at low flows under current operations, which would block access to fall-spawning brown and brook trout originating in the SFSJR to areas upstream. At RM 0.74, a 12-ft high waterfall, which forms a complete barrier at all flows, would block upstream migration of rainbow trout in the spring. Spawning gravel was scattered throughout the reach below the diversion and was found between all barriers. In the 0.27 mile downstream of the first barrier at low flows, 25 square feet of fair quality spawning gravel was accessible to species resident in the SFSJR. In the

0.74 mile downstream of the first barrier at all flows, 215 square feet (55 square feet in non-pool habitat) of fair quality spawning gravel was accessible.

4.2.3.7. BEAR CREEK DIVERSION FOREBAY

Bear Creek Diversion Dam creates a medium-sized Project impoundment located approximately 1.6 miles upstream of the confluence with the SFSJR (Map CAWG 14-1). Flow is diverted to the Ward Tunnel via the Mono-Bear Siphon and then to Huntington Lake.

Fish Populations - Fish surveys conducted in summer 2002 collected only brown (93 percent) and rainbow trout (seven percent) (CAWG 14 Table Appendix B-1). Multiple age classes of brown trout, including age 0+, were collected, indicating reproduction occurred upstream, which resulted in recruitment to the fish in the forebay. Rearing occurred in the forebay. Wild rainbow trout of two age classes were collected, including age 0+. The presence of young-of-the-year brown and rainbow trout indicates that successful spawning occurs in the area upstream of the forebay, despite the absence of stocking since 1948. The average condition factors for brown and rainbow trout were 1.38 and 0.85, respectively.

Upstream Fish Passage to Bear Creek - Upstream migration into Bear Creek from the forebay is blocked by a steep, bedrock sheet located immediately upstream of the forebay. This suggests that recruitment to the forebay may occur through downstream movement of fish from upstream areas, or that some upstream passage may be available during high spring flows.

4.2.3.8. CAMP 62 CREEK

Camp 62 Creek (SFSJR RM 20.2) is a steep, bedrock/boulder-controlled stream with Rosgen type Aa+ channel both upstream and downstream of Camp 62 Creek Diversion. There were fair amounts of complex habitat types. Spawning gravel (90 square feet) was of fair to good quality upstream of the diversion and was located mostly in cascades and step pool tailouts, with a small amount in step runs. Relatively large amounts (2,028 square feet) of good to excellent quality spawning gravels were scattered throughout the reach below the diversion. Flow is diverted via the Ward Tunnel to Huntington Lake, which may result in transport of trout to Huntington Lake.

Fish Populations - Brook trout were collected upstream and downstream of the diversion (CAWG 14 Table Appendix B-1). Multiple age classes, including age 0+ fish, were collected, indicating reproduction and recruitment occurred. Trout densities and biomass were relatively high above (945 fish/km and 152.3 kg/ha, respectively) and below (1,162 fish per km and 124.4 kg/ha, respectively) the diversion. There was no statistically significant difference between condition factors above and below the diversion (average of 1.21 in each reach).

Fish Barriers - Camp 62 Diversion is located about 1.4 miles upstream of the SFSJR. The seven-ft high diversion has a 24-inch-diameter sluice pipe at the bottom of the diversion and an eight-inch release pipe that descends from the pool behind the diversion dam to the streambed. The drain pipe outlet has a large drop off to the streambed and the release pipe has a steep vertical bend, so fish passage is not available even when the diversion is turned out. However, at high flow, fish passage may be possible through the drain pipe. Upstream of the diversion pool, upstream passage is blocked by a steep, bedrock wall with shallow sheet flow characteristics. At low flows, it is not possible for fish to pass above the diversion pool. Downstream migration may occur during spills. No physical barriers were identified upstream of the diversion, beyond the walls of the diversion itself. Five barriers were identified downstream of the diversion.

- Camp 62 Creek RM 0.07 - A 45-ft high waterfall in a cascade forms a complete barrier to upstream migration at all flows,
- Camp 62 Creek RM 0.46 - A 12-ft high waterfall forms a complete barrier to upstream migration at all flows,
- Camp 62 Creek RM 0.5 - A dry stream section forms a complete barrier to movement at low flows,
- Camp 62 Creek RM 0.6 - A six-ft high waterfall in a cascade forms a complete barrier to upstream migration at low flows,
- Camp 62 Creek RM 1.0 - A seven-ft high waterfall forms a complete barrier to upstream migration at low flows, and
- Camp 62 Creek RM 1.4 - The diversion forms a barrier to upstream migration. At high flows, fish passage may be possible through the drain pipe.

Flow-Related Fish Passage - Two wetted perimeter study sites were established downstream of Camp 62 Creek Diversion and one upstream of the diversion (Map CAWG 14-1). To meet the Thompson (1972) criteria for adult trout upstream passage, flows of 0.1 to 4.5 cfs, with an average of 1.9 cfs, are necessary below the diversion. Above the diversion, passage flows were 0.1 and 1.5 cfs, for an average of 0.8 cfs.

Fish passage from the SFSJR - As stated above, at RM 0.07 (413 feet upstream of the confluence) a 45-ft high waterfall in a cascade forms a complete barrier at all flows. This limits access to this creek from the SFSJR to the lower 0.0.7 mile. In this 0.07-mile stream segment, 80 square feet of fair to good quality spawning gravel was accessible to fish. The waterfall blocks access to relatively large amounts of good to excellent quality spawning gravel located upstream of the barrier and downstream of the diversion.

4.2.3.9. CHINQUAPIN CREEK

Chinquapin Creek enters Camp 62 Creek about 1.05 miles upstream of the SFSJR (Map CAWG 14-1). The stream is a steep, bedrock/boulder, Rosgen type Aa+ channel. Most of the stream habitats were step pool, step run or cascade. Fair amounts (630 square feet) of fair to good quality spawning gravel were observed below the diversion, mostly in step runs and step pool tailouts, with smaller amounts in other habitat types. No spawning gravel was found above the diversion. Flow is diverted through a vertical intake shaft drilled directly into the Ward Tunnel to Huntington Lake. Diversion of flow through the Ward tunnel may result in transport of trout to Huntington Lake.

Fish Populations - Brook trout were collected both upstream and downstream of the Chinquapin Creek Diversion (Chinquapin Creek RM 1.0) (CAWG 14 Table Appendix B-1). Multiple age classes, including age 0+ through age 4+ fish, were collected both upstream and downstream of the diversion, indicating reproduction and recruitment occurred. Trout density was high and was nearly three-fold greater (2,034 fish/km) in the reach below the diversion. Condition factors in Rosgen type Aa+ channel above the diversion were different (average of 1.35) at a statistically significant level ($p<0.05$) from those below the diversion (average of 1.01).

Fish Barriers - Chinquapin Creek Diversion is an eight-ft high concrete structure with two 12-inch sluice gates at the bottom of the diversion, an eight-inch release pipe that descends from the bottom of the diversion pool to the streambed and a six-inch drainpipe that drains from the fill material below the diversion pool. The diversion is turned out with a gate valve. However, the release pipe has a drop-off of several feet to the streambed. The diversion forms a complete barrier to upstream migration at all flows. Fish can pass downstream during spills.

One migration barrier was found upstream of the diversion and four barriers between the diversion and Camp 62 Creek (Map CAWG 14-1). A waterfall located only 785 feet upstream of the confluence with Camp 62 Creek is likely to block upstream migration to most of Chinquapin Creek from the Camp 62 Creek watershed.

- Chinquapin Creek RM 0.18 - An eight-ft high waterfall in a step run forms a complete barrier to upstream migration at low flows,

- Chinquapin Creek RM 0.2 - A six-ft high waterfall in a step pool forms a complete barrier to upstream migration at low flows,

- Chinquapin Creek RM 0.27 - A four-ft high waterfall forms a complete barrier to upstream migration at all flows,

- Chinquapin Creek RM 0.6 - A man-made weir in a step pool forms a complete barrier to upstream migration at low flows,

- Chinquapin Creek RM 1.0 - The eight-ft high Chinquapin Creek Diversion forms a barrier to upstream migration, and

- Chinquapin Creek RM 1.0 - A 15-ft high waterfall in a step pool located 472 feet above the diversion forms a complete barrier to upstream migration at all flows.

Spawning gravels were found between all of the barriers to upstream migration in the reach below the diversion.

Flow-Related Fish Passage - Three wetted perimeter study sites were located on Chinquapin Creek downstream of the diversion (Chinquapin Creek RM 0.2, 0.11 and 0.6). To meet the Thompson (1972) criteria for adult trout upstream passage, flows of 0.9 to 1.8 cfs, with an average of 1.3 cfs, are necessary below the diversion. Fish passage criteria were met at all three sites at a measured flow of 2.64 cfs, but none met the criteria at the lowest measured flow (0.15 cfs). Since brook trout are a fall-spawning species, flow-related passage would be limited by the seasonal low flows in the creek (i.e., 0.15 cfs), even after the diversion has been turned out.

Fish passage from the SFSJR - Chinquapin Creek is a tributary of Camp 62 Creek. As identified above, at Camp 62 Creek RM 0.07 a 45-ft high waterfall in a cascade forms a complete barrier at all flows. This limits access from the SFSJR to well downstream of the confluence of Chinquapin Creek with Camp 62 Creek (Camp 62 Creek RM 1.05).

4.2.3.10. BOLSILLO CREEK

Bolsillo Creek (SFSJR RM 19.6) (Map CAWG 14-1) is a steep, bedrock/boulder-dominated stream. It has a Rosgen type Aa+ channel upstream of Bolsillo Creek Diversion (Bolsillo Creek RM 1.6) and nearly equal reaches of Rosgen type Aa+ and B channels downstream of the diversion. It has mostly step pool, step run, and cascade habitats. A small amount (80 square feet) of good quality spawning gravel was observed upstream of the diversion in step pools tailouts and step runs. A fair amount (440 square feet) of fair to good quality gravel was found scattered throughout the reach below the diversion, primarily located in step pool tailouts and step runs, with smaller amounts in runs and cascades. Flow is diverted via the Ward Tunnel to Huntington Lake. Trout may be transported to Huntington Lake with the diverted flows.

Fish Populations - Brook trout were collected above and below the diversion (CAWG 14 Table Appendix B-1). Multiple age classes, including age 0+ fish, were collected above the diversion, indicating reproduction and recruitment occurred. No age 0+ brook trout was found below the diversion. High trout densities and biomass were measured upstream of Bolsillo Creek Diversion (2,187 fish/km and 431.9 kg/ha, respectively) and in the Rosgen type B channel downstream of the diversion (1,509 fish/km and 216.5 kg/ha, respectively). Condition factors at the Rosgen type B channel site below the diversion (average of 1.24) were different at a statistically significant level ($p<0.05$) from those in the Rosgen type Aa+ channel site above the diversion (average of 1.11). However, there was no significant statistical difference between condition factors between the Rosgen type Aa+ channel sites above and below the diversion, or between sites below the diversion in Bolsillo Creek. The presence of large numbers of brook trout above and below the diversion, despite the lack of recent stocking, suggests that the populations are self-sustaining.

Fish Barriers - Bolsillo Creek Diversion is a six-ft high rock and earth structure and is turned out with a gate valve. It has a 24-inch sluice pipe three inches off the bottom of the diversion and a three- to two-inch pipe extending downstream. The diversion forms a complete barrier to upstream migration because the drop from the culvert to the downstream bed is too large and water depth below the culvert is insufficient for fish passage. One physical barrier was identified above the diversion and nine below the diversion.

Downstream of Bolsillo Creek Diversion

- Bolsillo Creek RM 0.02 - A 90-ft high waterfall in a cascade formed a complete barrier to upstream migration at all flows,
- Bolsillo Creek RM 0.03 - A seven-ft high waterfall in a cascade formed a complete barrier to upstream migration at low flows,
- Bolsillo Creek RM 0.24 - A six-ft high bedrock sheet formed a complete barrier to upstream migration at all flows,
- Bolsillo Creek RM 0.9 - A 17-ft high waterfall in a cascade formed a complete barrier to upstream migration at all flows,
- Bolsillo Creek RM 1.0 - An eight-ft high waterfall in a step pool formed a complete barrier to upstream migration at low flows,
- Bolsillo Creek RM 1.1 - A 20-ft high waterfall in a cascade formed a complete barrier to upstream migration at all flows,
- Bolsillo Creek RM 1.2 - A 12-ft high waterfall formed a complete barrier to upstream migration at low flows,
- Bolsillo Creek RM 1.36 - Downstream of a cascade, the stream flows under the substrate (boulders, bedrock, debris and sand), then reappears, forming a complete barrier to fish movement at low flows,
- Bolsillo Creek RM 1.5 - A dry stream reach forms a complete barrier to fish movement during low flows,
- Bolsillo Creek RM 1.6 - The six-ft high Bolsillo Creek Diversion forms a barrier to upstream migration, and
- Bolsillo Creek RM 1.8 - A 16-ft high cascade waterfall located 1,116 feet upstream of the diversion formed a complete barrier to upstream migration at low flows.

Most of the spawning gravel was scattered throughout the first mile of Bolsillo Creek upstream of the confluence with the SFSJR. Thirty square feet of good quality gravels also were located in a step run between RM 1.5 and the diversion.

Flow-Related Fish Passage - Eight wetted perimeter study sites were located on Bolsillo Creek, all sited in pools. Five were located upstream of the diversion and three downstream (Map CAWG 14-1). To meet the Thompson (1972) criteria for adult trout upstream passage, flows of 0.1 to 0.18 cfs, with an average of 0.12 cfs, are necessary below the diversion during the spawning season. Above the diversion, passage flows were 0.1 cfs at all three sites.

Fish passage from the SFSJR - A large waterfall located 130 feet upstream of the confluence with the San Joaquin River prevents upstream passage into Bolsillo Creek from the SFSJR at all flows. This limits access to this creek from the SFSJR to the lower 0.2 mile. No spawning gravel was located in this 130-ft reach.

4.2.3.11. Camp 61 Creek and Portal Forebay

Fish passage in Camp 61 Creek and Portal Forebay was evaluated as part of the traditional relicensing process for the Portal Power Plant Project (Southern California Edison Company, Portal Hydroelectric Power Project Application For New License, Exhibit E, Section 2.4, Table 2.4-9 and page E-2.4-38 [SCE 2003d]).

Fish Passage from the SFSJR - A bedrock sheet with insufficient depth located 194 feet upstream of the confluence with the SFSJR forms a complete barrier to upstream passage at all flows. This precludes access to most of Camp 61 Creek for resident fish species in the SFSJR.

4.2.3.12. Mono Creek

Fish passage is addressed in this report from Mono Creek and its confluence with the SFSJR to the Mono Diversion Forebay. Passage from Mono Diversion Forebay to Mono Creek downstream of Vermilion Valley Dam also is addressed. The remainder of Mono Creek is addressed in the traditional relicensing of the Vermilion Valley Hydroelectric Project (Southern California Edison Company, Vermilion Valley Hydroelectric Project (FERC Project No. 2086) Final Application for New License for Minor Project – Existing Dam, Exhibit E, Volume 2, Section 2.4 [SCE 2001b]).

Mono Creek enters the SFSJR at SFSJR RM 16.55 (Map CAWG 14-1). Mono Creek Diversion (Mono Creek RM 5.9) is a 64-ft high concrete structure located across Mono Creek about 1.5 miles downstream of the Lake Thomas A. Edison (Map CAWG 14-3). Vermilion Valley Dam (Mono Creek RM 7.4) impounds Lake Thomas A. Edison on Mono Creek.

Mono Diversion Forebay

The Mono Diversion Forebay receives flow released from Lake Thomas A. Edison at Vermilion Valley Dam through the reach of Mono Creek upstream of the diversion. Mono Diversion captures the majority of these flows into the Mono-Bear Siphon and diverts them to the Ward Tunnel, which empties into Huntington Lake. Fish present in the Mono Diversion Forebay may be transported along with the diverted flow.

Fish Populations - Stocked rainbow trout and wild brown trout were collected in the forebay and upstream (SCE 2001b, Vermilion Exhibit E). Multiple age classes of brown trout, including numerous age 0+ fish, indicates spawning takes place upstream of Mono Diversion Dam. It is likely that there is no recruitment of rainbow trout downstream of Vermilion Valley Dam. The average condition factors for brown and rainbow trout were 1.41 and 2.19, respectively. The high value observed for rainbow trout is likely to be the result of their hatchery origin.

Fish Passage from Mono Diversion Forebay - There are no upstream migration barriers to Mono Creek from Mono Diversion Forebay.

Mono Creek downstream of Mono Diversion

Mono Creek downstream of the Mono Creek Diversion is a steep, boulder/bedrock stream in a Rosgen type B channel. It was primarily composed of pool, step run, and cascade habitats, but complex habitats such as pocket water and riffles were present, as well as some deeper pools. A low-gradient reach flows through Mono Meadow. Large amounts (13,976 square feet) of spawning gravels were observed, generally of fair to good quality and primarily in pool tailouts and flatwater habitats.

Fish Populations - Brown and rainbow trout were collected in Mono Creek downstream of the Mono Diversion (CAWG 14 Table Appendix B-1). This was the only SFSJR tributary study stream with rainbow trout (not including golden x rainbow hybrids) collected in the stream (rather than a forebay). Multiple age classes, including age 0+ trout, were collected, indicating reproduction and recruitment occurred. Relatively small densities of brown trout (65 fish/km) and rainbow trout (11 fish/km) were found, less than densities found between Vermilion Valley Dam and Mono Diversion Forebay (SCE 2001b). Condition factors for brown and rainbow trout were 1.1 and 0.91 respectively.

Fish Barriers - The 64-ft high Mono Creek Diversion has two 24-inch sluice pipes at the bottom of the diversion, an eight-inch release pipe that descends from near the bottom of the diversion pool to the streambed and a six-inch drainpipe at the bottom of the diversion. The outlet of the release pipe is located too high above the streambed to provide passage for upstream migration. The ungated, overpour spillway has an effective length of 106 feet and may provide downstream fish passage when water spills. Two barriers to upstream fish migration were identified below the diversion.

- Mono Creek RM 2.0 - An 11-ft high waterfall formed a complete barrier to upstream migration at low flows,
- Mono Creek RM 4.9 - An eight-ft high waterfall in a cascade formed a partial barrier to upstream migration at all flows, and
- Mono Creek RM 6.2 - The 64-ft high Mono Creek Diversion forms a barrier to upstream migration.

Fish Passage - Three PHABSIM study sites are located in Mono Creek downstream of the diversion (Mono Creek RM 3.7, 4.3 and 4.5). The range of flows needed to meet the Thompson passage criteria was 3.52 to 10.0 cfs with an average value of 5.5 cfs.

Fish passage from the SFSJR - As stated above, at Mono Creek RM 2.0 an 11-ft high waterfall forms a natural barrier to upstream migration during the fall when brown or brook trout spawning migrations occur under current operations. At Mono Creek RM 4.9, a waterfall blocks upstream passage for all species at all flows. Spawning gravel was found above and below all natural barriers.

4.2.3.13. WARM CREEK

Warm Creek enters the SFSJR near RM 15.9 (Map CAWG 14-1). Warm Creek Diversion is located about 4.4 miles upstream of the SFSJR, where flows are seasonally diverted through Boggy Meadow Creek to Lake Thomas A. Edison. Fish habitat and populations in Warm Creek were evaluated as part of the traditional relicensing process for the Vermilion Valley Hydroelectric Project (Southern California Edison Company, Vermilion Valley Hydroelectric Project (FERC Project No. 2086) Final Application for New License for Minor Project – Existing Dam, Exhibit E, Volume 2, Section 2.4 [SCE 2001b]).

Fish passage from the SFSJR - An 80-ft high waterfall and a cascade located at the confluence with the SFSJR form a complete barrier to fish upstream migration at all flows. The waterfall hits bedrock at its base. Additional sections of cascades and falls occur above the confluence as well. Upstream migration is precluded for fish originating in the SFSJR.

4.3. SAN JOAQUIN RIVER DRAINAGE

Overview - The study reach of the San Joaquin River (SJR) extends from the upstream extent of Mammoth Pool Reservoir (SJR RM 35.6) downstream to Big Creek Powerhouse 3 tailrace (SJR RM 11.2) located upstream of Redinger Lake (Map CAWG 14-2). The Mammoth Reach of the San Joaquin River extends from Mammoth Pool Dam (SJR RM 25.55) to Mammoth Pool Powerhouse (SJR RM 18.3), which is located at the head of the Dam 6 Forebay. The Stevenson Reach extends from Big Creek Dam 6 (SJR RM 17.1) to Big Creek Powerhouse 3 (SJR RM 11.2).

4.3.1. MAMMOTH POOL

Mammoth Pool Dam (SJR RM 25.6) impounds water in Mammoth Pool Reservoir upstream to approximately SJR RM 35.6 (Map CAWG 14-2). Water is diverted from Mammoth Pool through Mammoth Pool Power Tunnel to the Mammoth Pool Powerhouse (SJR RM 18.2). There is some potential that fish may be entrained with flow and transported downstream (See Section Mammoth Pool Dam, below).

Fish Populations - Fish surveys conducted in the fall of 2002 collected both brown (71 percent) and rainbow (29 percent) trout within the reservoir (CAWG 14 Table Appendix B-1). No trout of either species under age 3+ was collected, which suggests young brown trout may not rear in the reservoir or that they are subject to predation. Rainbow trout are currently stocked and the rainbow trout collected were likely to have been primarily of hatchery origin. The presence of brown trout despite the lack of recent stocking suggests the population is self-sustaining. Tributaries are available for spawning and juvenile rearing for adult trout originating within the reservoir. Brown trout had an average condition factor as high as 1.10 and rainbow trout condition factors averaged 1.33.

4.3.1.1. Upstream Passage from Mammoth Pool

Passage for potential upstream migration from Mammoth Pool to the San Joaquin River and Jackass Creek is maintained at the full range of operational lake elevations (Map CAWG 14-2). Steep, bedrock sheets that become exposed as the lake elevation drops below maximum water surface elevation form migration barriers to Mill and Kaiser creeks (see CAWG 1 for Mammoth Pool Reservoir winter and summer average lake elevation, volume, and surface area by water year in Table CAWG 1-255 [SCE 2003a]). Chiquito Creek and Daulton Creek are inaccessible at all reservoir elevations. Steep, bedrock sheet falls and large boulders at the mouths of both creeks form barriers even when the reservoir is at maximum water surface elevation.

4.3.1.2. Mammoth Pool Dam

Mammoth Pool Dam is a complete barrier to upstream migration from the San Joaquin River. Sacramento sucker, rainbow trout and brown trout occur downstream of the dam (CAWG 14 Table Appendix B-1). Spill may occur over the ungated, chute-type spillway (3,361 feet MSL). Spills may result in downstream transport of fish. The base of the intake to the Mammoth Pool Power Tunnel is located at the bottom of the lake. The water conduit, consisting of the Mammoth Pool Power Tunnel and a penstock, connects Mammoth Pool Reservoir to Mammoth Pool Powerhouse. A hydroacoustic survey indicated that the fish density at the dam area of the lake was relatively low (in comparison to the other two regions of the lake surveyed) (SCE 2003b). Fish were detected in nearly all of the depth strata, but fish densities were low near the intake. Approach velocities at the intake are low (less than one ft/s) to medium (one to three ft/s) and the potential for entrainment and downstream movement of fish from this mechanism is likely low to medium.

4.3.2. Mainstem San Joaquin River

Fish passage in the mainstem of the San Joaquin River was evaluated from Mammoth Pool Dam to Big Creek Powerhouse 3 upstream of where the river enters Redinger Lake (Map CAWG 14-2). Two principal reaches of the mainstem were evaluated, the Mammoth Reach and the Stevenson Reach. Study stream tributaries that drain into the Mammoth Reach of the San Joaquin River include Rock and Ross creeks.

Yoshiyama et al. (1998) reports that upstream access to anadromous salmonids was limited to the Mammoth Pool Dam area (SJR RM 26) of the San Joaquin River. CAWG 7 study results from 2002 (SCE 2003c) show the mainstem fish communities of the Mammoth Reach were dominated by Sacramento sucker, with substantially smaller numbers of rainbow and brown trout. The Stevenson Reach included the native transition zone fish community, which included Sacramento pikeminnow, hardhead (a

USFS sensitive species and a California species of special concern), and a smaller component of Sacramento sucker (CAWG 14 Table Appendix B-1).

4.3.2.1. San Joaquin River: Mammoth Reach

The Mammoth Reach of the San Joaquin River extends from Mammoth Pool Dam (SJR RM 25.55) to Mammoth Pool Powerhouse (SJR RM 18.3) (Map CAWG 14-2). The Mammoth reach of the San Joaquin River is a moderately low gradient, boulder/bedrock stream. The reach is comprised of Rosgen type B and G channels. It contains complex habitat types, including deep pools. A few larger deposits of fair to excellent quality spawning gravel were observed (2,005 square feet total). Gravel was generally scarce in the lower half of the Mammoth Reach, most of it was located in the upper half. More spawning gravel was found in the Rosgen type G channel than in the Rosgen type B channel, and most of the gravel was found in step pool tailouts, with smaller amounts in runs, other pool tailouts, and high gradient riffles.

Fish Populations - Sacramento sucker dominated the Mammoth Reach, representing over 70 percent of the surveyed fish (CAWG 14 Table Appendix B-1). Rainbow and brown trout were present, but substantially less abundant. Multiple age classes were present for all three species, which suggests recruitment and rearing occurs in this portion of the San Joaquin River. Brown trout densities were highest in the upper site sampled (125 fish/km) and rainbow trout densities were highest in the lower site (384 fish/km). There was no significant statistical difference between condition factors between the two sites for either species.

Fish Barriers - Four waterfalls, in addition to Mammoth Dam, formed barriers to upstream fish migration in this reach. The only complete barrier at all flows was a waterfall in the upstream end of the reach near Mammoth Pool Dam. The barriers included:

- SJR RM 18.5 - An eight-ft high waterfall in a cascade over boulder substrate forms a complete barrier to upstream migration at low flow,
- SJR RM 23.0 - A 15-ft high waterfall in a cascade forms a complete barrier to upstream migration at low flows,
- SJR RM 25.8 - A 10-ft high waterfall in a step pool forms a complete barrier to upstream migration at low flows,
- SJR RM 26.4 - A waterfall in a 30-ft long cascade/bedrock sheet near the Mammoth Pool Dam forms a complete barrier to upstream migration at all flows, and
- SJR RM 26.7 - Mammoth Pool Dam is a complete barrier to upstream fish migration.

Flow-related Fish Passage - PHABSIM data were collected in Rosgen type B and G channel sites between Mammoth Dam and Mammoth Pool Powerhouse, which are used to represent passage as a function of flow in this reach. The flow needed to meet the Thompson passage criteria was 10.0 cfs in both the Rosgen type B and G channels, with an average value of 10.0 cfs over all three sites.

No spawning gravel was found between Mammoth Pool Powerhouse and the first low-flow barrier, and only two deposits (530 square feet total) were found below the low-flow barrier at SJR RM 23.0. The remainder of the spawning gravel was found upstream. This suggests that primary spawning habitat would likely be found in the upper half of the Mammoth Reach or in tributaries to the Mammoth Reach. Waterfalls located 0.3, 4.2, seven, and 7.6 miles upstream of the Mammoth Pool Powerhouse form barriers at low flows that may impede brown trout upstream migration in the fall under current operations, but may not affect rainbow trout migrations during the spring runoff period (depending upon conditions). Sacramento sucker, which is native to the San Joaquin River basin, also spawns in the spring and early summer during spring runoff. The presence of multiple age classes of Sacramento sucker at the upper site suggest that successful spawning and recruitment occurs in this portion of the San Joaquin River.

4.3.2.2. ROCK CREEK

Rock Creek (SJR RM 22.55) (Map CAWG 14-2) is a steep, bedrock/boulder stream in a Rosgen type Aa+ channel. It has mostly step pool, cascade and bedrock sheet habitats, and several pools were deep. No spawning gravel was observed. Flow is diverted into the Mammoth Pool Power Tunnel.

Fish Populations - Brown and rainbow trout were collected upstream and downstream of Rock Creek Diversion (Rock Creek RM 0.4) (CAWG 14 Table Appendix B-1). Multiple age classes of brown and rainbow trout, including age 0+ fish, were collected, indicating reproduction and recruitment occurred. The presence of rainbow trout smaller than the catchable-sized hatchery fish planted suggests rainbow trout reproduction occurs in Rock Creek or its tributaries. Trout densities (241 to 930 fish/km) and biomass (29.0 to 91.5 kg/ha) were relatively high. There was no significant statistical difference between brown trout condition factors between sites above and below the diversion. Rainbow trout condition factors were statistically significantly different ($p<0.05$) between sites above (average of 1.19) and below (average of 1.46) the diversion.

Fish Barriers - The nine-ft high, concrete diversion has a 24-inch sluice pipe at the bottom of the diversion. The diversion is turned out with a gate valve. Upstream passage is available when the gate valve is open, but the diversion is rarely turned out. Therefore, the diversion is usually a barrier to upstream migration. Three waterfalls, one upstream and two downstream of Rock Creek Diversion, form complete barriers to fish migration at all flows. Two of the waterfalls are located only several hundred feet upstream of the confluence with the river.

- Rock Creek RM 0.07 - A 20-ft high waterfall in a step pool forms a complete barrier to upstream migration at all flows,

- Rock Creek RM 0.12 - A 14-ft high bedrock waterfall in a step pool forms a complete barrier to upstream migration at all flows,

- Rock Creek RM 0.4 - The nine-ft high Rock Creek Diversion usually forms a barrier to upstream migration because it is rarely turned out, and

- Rock Creek RM 0.6 - A 50-ft high bedrock waterfall 1,151 feet upstream of the diversion forms a complete barrier to upstream migration at all flows.

Flow-related Fish Passage - Three wetted perimeter study sites are located on Rock Creek, one downstream and two upstream of the diversion. To meet the Thompson (1972) criteria for adult trout upstream passage, flows of 0.1 cfs are necessary below the diversion. This would be met during the spring runoff period when rainbow trout spawn. Above the diversion, passage flows also are 0.1 cfs.

Fish Passage from the San Joaquin River - As stated above, a 20-ft high waterfall located 344 feet upstream of the San Joaquin River forms a complete barrier at all flows. This limits access to this creek from the San Joaquin River to the lower 0.07 mile. No spawning gravel was observed.

4.3.2.3. ROSS CREEK

Ross Creek (SJR RM 18.7) (Map CAWG 14-1) is a very steep, bedrock/boulder stream in a Rosgen type Aa+ channel. Habitat types were mostly step pool with substantial components of cascade and bedrock sheet. Pools were shallow. The stream is intermittent even in wet years. At the time of the first habitat survey, the upstream reach and about a third of the downstream reach were dry. No spawning gravel was observed. Flow is diverted into the Mammoth Pool Power Tunnel, when available.

Fish Populations - Ross Creek was not sampled because the reach upstream of the diversion and a large segment below the diversion go dry in the summer and were dry during the summer of 2002.

Fish Barriers - Ross Creek Diversion is a seven-ft high, concrete diversion with a 24-inch sluice pipe at the bottom of the diversion. However, the drop off at the outlet is too high to provide upstream fish passage. Several waterfalls, one upstream and five downstream of Ross Creek Diversion, formed complete barriers to upstream migration at all flows. As identified above, lack of flow results in dry areas that form barriers to fish movement. The physical barriers include the following.

- Ross Creek RM 0.0 - A 35-ft high waterfall in a cascade 75 feet upstream of the river forms a complete barrier to upstream migration at all flows,

- Ross Creek RM 0.08 - A 20-ft high waterfall in bedrock sheet habitat forms a complete barrier to upstream migration at all flows,

- Ross Creek RM 0.12 - A 20-ft high waterfall in bedrock sheet habitat forms a complete barrier to upstream migration at all flows,

- Ross Creek RM 0.14 - A 150-ft high waterfall in bedrock sheet habitat forms a complete barriers to upstream migration at all flows,

- Ross Creek RM 0.36 - A 15-ft high waterfall in a step pool forms a complete barrier to upstream migration at all flows,

- Ross Creek RM 0.89 - The seven-ft high Ross Creek Diversion forms a barrier to upstream migration, and

- Ross Creek RM 1.1 - A 60-ft high waterfall in a step pool 931 feet upstream of the diversion forms a complete barrier to upstream migration at all flows.

Flow-related Fish Passage - The CAWG decided that it was not necessary to conduct wetted perimeter studies in Ross Creek, as the stream is intermittent even in wet years. Therefore, no data are available on this topic.

Fish Passage from the San Joaquin River - As stated above, a 35-ft high waterfall located in Ross Creek 75 feet upstream of the confluence with the San Joaquin River forms a complete barrier at all flows. This precludes access to this creek by fish species resident in the San Joaquin River.

4.3.2.4. SAN JOAQUIN RIVER: BIG CREEK POWER HOUSE 3 FOREBAY / DAM 6

The impoundment behind Dam 6 (SJR RM 17.0) serves as the forebay for Big Creek Powerhouse 3, which is located 5.8 miles downstream (Map CAWG 14-1). Dam 6 receives the discharge from both the Mammoth Pool Powerhouse and Big Creek Powerhouse No. 8. The forebay also receives flow from both the San Joaquin River and Big Creek. The elevation of the forebay rarely varies significantly over the year. Winter and summer average forebay water surface elevation, volume, and surface areas by water year are presented in the CAWG 1 Report, Table CAWG 1-282 (SCE 2003a).

Fish Populations - Fish surveys conducted in the summer of 2002 collected Sacramento sucker (79 percent), brown trout (15 percent) and rainbow trout (six percent) (CAWG 14 Table Appendix B-1). The fish community in the forebay resembled that of the San Joaquin River upstream and downstream. Multiple age classes for all fish species were represented, which indicates ongoing recruitment. However, no juvenile brown or rainbow trout under age 2+ were collected, which suggests that either young fish do not move downstream to rear in the forebay until they are larger than age 0+ or that age 0+ fish are subject to predation. The average condition factors for brown and rainbow trout were 1.11 and 1.36, respectively.

Upstream Passage to the San Joaquin River

There are no barriers to fish upstream migration from the Dam 6 forebay to the San Joaquin River or to Big Creek upstream.

Dam 6

Dam 6 is a complete barrier to upstream fish migration. Sacramento sucker, brown trout and rainbow trout occur downstream of the dam, as well as prickly sculpin and Sacramento pikeminnow (CAWG 14 Table Appendix B-1). Hardhead only occur in the lower portion of the Stevenson reach. Water is diverted through Tunnel 3 to Big Creek Powerhouse 3. The tunnel has an invert at the bottom of the impoundment. Approach velocities at the intake are low (less than one fps), so the potential for entrainment and downstream movement of fish from this mechanism is likely low.

4.3.2.5. SAN JOAQUIN RIVER: STEVENSON REACH

The Stevenson Reach of the San Joaquin River extends from Dam 6 (SJR RM 17.0) to Big Creek Powerhouse 3 (SJR RM 11.2) located upstream of Redinger Lake (Map CAWG 14-1). The reach is a moderate gradient, boulder/bedrock stream in a Rosgen type G channel. It has primarily deep pool and complex pocket water habitats, with small components of riffles. A modest amount (560 square feet) of fair to good quality, widely distributed spawning gravels were observed, mostly in pool tailouts and pocket waters, with smaller amounts in step runs.

Fish Populations - Fish surveys were conducted at SJR RM 15.4, 1.6 miles downstream of Dam 6, and at SJR RM 11.9, 0.7 miles upstream of Redinger Lake (CAWG 14 Table Appendix B-1). The sampled fish community at the upstream site was composed of Sacramento sucker (76 percent), prickly sculpin (11 percent) rainbow trout (nine percent), brown trout (two percent), and Sacramento pikeminnow (two percent). Multiple age classes for Sacramento sucker and prickly sculpin were collected. The presence of age 0+ and 1+ rainbow trout suggests that this species may spawn in the vicinity of this site. In comparison, pikeminnow (56 percent) and hardhead (40 percent) (a US Forest Service sensitive species and a California Species of Special Concern) dominated the downstream site (CAWG 14 Table Appendix B-1). Brown trout also was present. In addition, large numbers of small, unidentified cyprinids (likely pikeminnow and/or hardhead) were found in the margins of the pool habitat snorkeled. Multiple age classes of Sacramento pikeminnow and hardhead, including age 0+ fish, suggest these species are successfully spawning and rearing in the vicinity of this site. Condition factors for rainbow trout at the upper site ranged from 0.98 to 1.61. Brown trout condition factors for the upper and lower site, each represented by a single specimen, were 1.22 and 1.16, respectively. Hardhead condition factors ranged from 0.69 to 1.51.

Fish Barriers - One barrier, which was a complete barrier only at low flows, to upstream fish migration was identified within the Stevenson Reach in addition to Dam 6.

- SJR RM 11.9 - A five-ft high waterfall in pocket water habitat forms a complete barrier to migration at low flows, and

- SJR RM 17.05 - Dam 6 is a barrier to upstream migration at all flows.

Spawning gravel was found above and below the low-flow barrier at SJR RM 11.9.

Flow-related Fish Passage - Two PHABSIM study sites situated in the San Joaquin River Stevenson Reach (Map CAWG 14-1) are used to identify fish passage flow requirements. The sites are located at SJR RM 15.5 and 15.6. The flow needed to meet the Thompson passage criteria was 6.0 cfs at all study transects with an average value of 6.0 cfs.

4.4. BIG CREEK DRAINAGE

The Big Creek Drainage area included in this study extends from Big Creek Dam 1 at Huntington Lake (Big Creek RM 9.9) to Big Creek Powerhouse 8 (Big Creek RM 0.0) and includes both Big Creek and its tributaries downstream of Huntington Lake (Map CAWG 14-3). Three study reaches were defined in Big Creek based on location of project features:

- Downstream of Dam 1 at Huntington Lake (BIG Creek RM 9.9) to upstream of Big Creek Powerhouse 1 (Big Creek RM 6.3),
- Dam 4 (Powerhouse 1 tailrace) (Big Creek RM 6.2) to upstream of Big Creek Powerhouse 2 (Big Creek RM 1.9), and
- Dam 5 (Powerhouse 2 and 2A tailraces) to upstream of Big Creek Powerhouse 8 (Big Creek RM 0.0).

Study streams tributary to Big Creek downstream of Dam 1 include Pitman (Confluence at Big Creek RM 6.3), Balsam (Confluence at Big Creek RM 4.8), Ely (Confluence at Big Creek RM 3.3), and Adit No. 8 creeks (Confluence at Big Creek RM 2.6) (Map CAWG 14-3).

Fish Population Surveys conducted within the three reaches indicate brown trout dominated the fish community in the upper portion of Big Creek and rainbow trout dominated the lower portion (CAWG 14 Table Appendix B-1). Multiple age classes of brown and rainbow trout and prickly sculpin were collected indicating that reproduction and recruitment of all three species occurs in this drainage. Rainbow trout spawning or survival appears to be most successful in the reach between Dam 5 and Big Creek Powerhouse 8[2].

4.4.1. HUNTINGTON LAKE

Huntington Lake is located upstream of Dam 1 (Big Creek RM 9.9) on Big Creek. Dams 2, 3, and 3A, located in other areas of the lake, also impound the lake. Ward Tunnel discharges water from the upper portion of the watershed through Portal Powerhouse and/or a Howell-Bunger Valve into Rancheria Creek, a tributary of Huntington Lake.

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[2] Conditions factors were calculated for the Dam 1 to Big Creek Powerhouse 1 reach, but due to equipment failure in the field, could not be calculated for the other reaches.

Water from Huntington Lake may be diverted to Big Creek Powerhouse 1 or to the Huntington-Pitman siphon (HPS, or Tunnel 7). The HPS flows primarily to Balsam Meadow Forebay and then to Shaver Lake through the Eastwood Power Station, but also flows through Gate 2 to provide augmented flow to North Fork Stevenson Creek.

Fish Populations - Historically, many fish species have been introduced into Huntington Lake, but only rainbow trout and kokanee are currently stocked. CDFG believes that reproduction of kokanee in lake tributaries is undesirable and could contribute to lowered growth rates (Wickwire pers. comm.).

Fish species collected included brown trout (11 percent), rainbow trout (five percent), Sacramento sucker (39 percent), prickly sculpin (40 percent), and kokanee (five percent) (CAWG 14 Table Appendix B-1). Multiple age classes for all fish species were collected indicating that they are rearing in Huntington Lake. The presence of young-of-the-year rainbow trout and Sacramento sucker indicates these species are likely to reproduce in streams tributary to Huntington Lake. However, most rainbow trout collected were catchable-sized fish, which originated from the CDFG San Joaquin fish Hatchery. Brown trout, rainbow trout and kokanee had average condition factors of 2.28, 1.97, and 2.94, respectively.

4.4.1.1. Upstream Passage from Huntington Lake

Passage for potential upstream migration from Huntington Lake to its major tributaries, including Rancheria Creek, Big Creek, Line Creek, Coon Creek, and Home Camp Creek, is maintained at the full range of operational lake elevations. However, during the time when the reservoir is drawn down, stream flow in Line, Coon, and Home Camp creeks and in Big Creek upstream of Huntington Lake (which are not affected by project operations) are potentially insufficient for upstream fish migration.

4.4.1.2. Dam 1, Tunnel 1 and Tunnel 7 Intakes

Dam 1 is a complete barrier to upstream fish migration. Rarely, spills may occur over the dam spillway. Spills may result in downstream transport of fish. Releases from Huntington Lake to Big Creek downstream and to Big Creek Powerhouse 1 are made from near the bottom of the dam. During hydroacoustic surveys near the Tunnel 1 and Tunnel 7 intakes no fish were detected near the bottom. Approach velocities at the intake are low. Therefore, the potential for entrainment and downstream movement of fish from this mechanism is likely low, as well.

4.4.1.3. Rancheria Creek

The upper segment of Rancheria Creek (upstream of the Portal Powerhouse tailrace) is a low to moderate gradient stream composed of Rosgen type B and A channels. Huntington Lake receives a large portion of its inflow from Ward Tunnel via Portal Powerhouse and an adjacent Howell-Bunger valve. The upper segment of Rancheria Creek includes reaches upstream and downstream of an energy dissipater. The lower segment of Rancheria Creek is the 432-ft long Portal Power Tailrace from the powerhouse to Huntington Lake. This short reach has a low to moderate gradient, Rosgen type C channel. Small amounts of spawning gravel were observed above (20 square feet) and below (100 square feet) the energy dissipater. Some gravel also was present in the tailrace.

Fish Populations - The fish populations included rainbow, brook and brown trout, as well as Sacramento sucker. Fish data were collected as part of the traditional Portal Hydroelectric Power Project Relicensing (SCE 2003d). Kokanee have been observed to spawn within the Portal tailrace.

Fish Barriers - No physical barriers to fish migration were identified.

Flow-related Fish Passage - Nine wetted perimeter study sites are located on Rancheria Creek, three downstream and six upstream of the energy dissipater. To meet the Thompson (1972) criteria for adult trout upstream passage in the upstream reach, flows of 0.7 to 5 cfs, with an average of 2.7 cfs, are necessary during the spawning season. This would likely be met during the spring runoff period when rainbow trout spawn, but may not be met in the fall when brown and brook trout spawn. To meet the Thompson (1972) criteria for adult trout upstream passage in the lower reach, flows of 0.3 to 3.75 cfs, with an average of 1.7 cfs, are necessary during the spawning season.

Upstream Passage from Huntington Lake - There is no passage barrier from Huntington Lake to Rancheria Creek.

4.4.2. Big Creek: Dam 1 to Powerhouse 1

This segment of Big Creek extends 3.6 miles from Powerhouse 1 (RM 6.3) upstream to Dam 1 (Huntington Lake Dam at Big Creek RM 9.9) (Map CAWG 14-3). The reach is a sandy, bedrock/boulder stream composed mostly of Rosgen type Aa+ channel with Rosgen type B, A, and G channel segments also present. It had a mixture of habitat types, including some that are fairly complex. Small amounts of fair to good quality spawning gravels were found scattered throughout the surveyed reaches.

Fish Populations - Brown trout and prickly sculpin were the only species collected in this reach (CAWG 14 Table Appendix B-1). The presence of multiple age classes of brown trout, which is no longer stocked, indicates the presence of self-sustaining populations in the vicinity of this reach. Estimated brown trout densities ranged from 320 to 1,214 fish/km and biomass estimates ranged from 16.0 to 117.6 kg/ha. Condition factors for brown trout in the Rosgen type Aa+ channel site (average of 1.42) was statistically greater than in the Rosgen type B channel (average of 0.92).

Fish Barriers - Twelve physical barriers to fish migration were identified. All of the waterfalls located within the approximately 7,438 feet of Rosgen type Aa+ channel upstream of Big Creek Powerhouse 1 form complete barriers to upstream migration at all flows. A steep section of this reach was assessed with aerial surveys, due to difficulty in scaling natural barriers on the ground (e.g., cascades, and waterfalls). Growth of riparian vegetation into the channel may also affect fish passage in some locations. In many sections there was considerable encroachment of riparian vegetation in the stream channel. This encroachment occurred within the approximately two miles of Rosgen type B, A, and G channels below Huntington Lake. The large amount of riparian vegetation within the stream channel can affect the ability of fish to migrate within this segment of Big Creek. The barriers present include the following:

- Big Creek RM 6.38 - An eight-ft high waterfall, 242 feet upstream of Powerhouse 1, forms a complete barrier to upstream migration at all flows,
- Big Creek RM 6.45 - A 17-ft high waterfall forms a complete barrier to migration at all flows,
- Big Creek RM 6.51 - A 10-ft high waterfall in a cascade forms a complete barrier to upstream migration at all flows,
- Big Creek RM 6.64 - From the aerial survey, a waterfall forms a complete barrier to upstream migration at all flows,
- Big Creek RM 6.82 - From the aerial survey, a waterfall forms a complete barrier to upstream migration at all flows,
- Big Creek RM 6.84 - From the aerial survey, a waterfall forms a complete barrier to upstream migration at all flows,
- Big Creek RM 6.91 - From the aerial survey, a waterfall forms a complete barrier to upstream migration at all flows,
- Big Creek RM 6.93 - From the aerial survey, a waterfall forms a complete barrier to upstream migration at all flows,
- Big Creek RM 6.94 - From the aerial survey, a waterfall forms a complete barrier to upstream migration at all flows,
- Big Creek RM 7.03 - From the aerial survey, a waterfall forms a complete barrier to upstream migration at all flows,
- Big Creek RM 7.75 - A 15-ft high vertical waterfall in a step pool forms a complete barrier to upstream migration at all flows,
- Big Creek RM 7.76 - A 20-ft high vertical waterfall in a cascade forms a complete barrier to upstream migration at all flows, and
- Big Creek RM 9.9 - Dam 1 (Huntington Lake Dam) forms a complete barrier to upstream migration at all flows.

Flow-Related Fish Passage - No passage study sites are located within this reach.

4.4.2.1. BIG CREEK: DAM 4/ POWERHOUSE 2 FOREBAY

The medium-sized impoundment behind Dam 4 (Big Creek RM 6.2) serves as the Powerhouse 2 Forebay. Inflow comes from the Big Creek Powerhouse 1 tailrace, Big Creek upstream of Powerhouse 1, and Pitman Creek. Water entering the forebay is diverted through Tunnel 2 to Big Creek Powerhouse 2 (Big Creek RM 1.65)

Stocking no longer occurs in the forebay, although rainbow trout occasionally escape from the nearby SCE hatchery (SCE 2003c) and are present upstream of the forebay. Multiple age classes of rainbow trout, brown trout, and prickly sculpin were collected, which indicates that these species are reproducing in the areas upstream of the forebay and rearing in the forebay. Condition factors for brown trout and rainbow trout were 1.24 and 1.47, respectively.

Upstream Passage to Big Creek

There are no physical barriers to upstream fish migration from the forebay to Big Creek and its tributary stream Pitman Creek. Migration is unimpeded even during periods of reservoir drawdown. However, a weir in Pitman Creek near the confluence with Big Creek blocks upstream fish migration into the creek. As discussed above, at Big Creek RM 6.38 an eight-ft high waterfall, 242 feet upstream of Powerhouse 1, forms a complete barrier to upstream migration at all flows

Dam 4

Dam 4 is a 75-ft high concrete dam that forms a barrier to upstream fish migration. Brown and rainbow trout occur downstream of the dam. Water from Dam 4 forebay flows into an intake for Big Creek Powerhouse 2. During typical operations of Big Creek Powerhouse 1, the volume of water in the forebay is replaced many times in a single day. Approach velocities at the Tunnel 2 intake are low to medium and the potential for entrainment and downstream movement of fish from this mechanism is low. Fish may be transported to the reach of Big Creek downstream during spills at Dam 4.

4.4.2.2. PITMAN CREEK

Pitman Creek (Big Creek RM 6.3) (Map CAWG 14-3) is a bedrock/boulder stream comprised of moderate-gradient Rosgen type B channel upstream of the diversion and very steep Rosgen type Aa+ and B channels downstream of the diversion. The reach above the diversion has mostly step pool and flatwater habitats, but had small components of complex habitats such as pocket water and riffle. The reach below the diversion was almost completely step pool, cascade, and bedrock sheet, and there were many deep pools. Only small amounts of good quality spawning gravels (70 square feet) were observed above the diversion, mostly in runs. No spawning gravel was found below the diversion. Flow is diverted through Tunnel No. 7 (HSB), which transports water from Huntington Lake to Balsam Meadow Forebay and North Fork Stevenson Creek.

Fish Populations - Rainbow trout (73 percent) dominated the sampled fish community upstream of Pitman Creek Diversion. Rainbow trout also made up about 94 percent of the fish surveyed downstream of the diversion, and smaller components of brown and brook trout were collected (CAWG 14 Table Appendix B-1). Multiple age classes, including age 0+ trout, were collected upstream of the diversion, indicating reproduction and recruitment occurred. The populations appear to be self-sustaining. Multiple age classes of rainbow trout also were collected downstream of the diversion. Low densities of brown and brook trout suggest populations below the diversion may be seeded from upstream habitat or in competition with the more numerous rainbow trout. Estimated densities of brown trout ranged from 22 to 338 fish/km, of rainbow trout ranged from 613 to 1,647 fish/km, and of brook trout ranged from 22 to 82 fish/km. Average condition factors for rainbow trout in the Rosgen type B channel site above the diversion (1.20) were statistically significantly lower ($p<0.05$) than the Rosgen type B channel site below the diversion (1.71). There was no statistically significant difference in brown and brook trout condition factors above (1.12 and 1.00, respectively) and below (1.23 and 1.06 respectively) the diversion.

Fish Barriers - Pitman Diversion is a 10-ft high concrete structure with a 12-inch-diameter, 25-ft-long pipe at the bottom of the diversion. A two-ft drop off from the pipe on the downstream side of the diversion blocks upstream migration. No physical barriers to fish migration were identified in the reach above the diversion. Four complete barriers to upstream migration at all flows were identified in the Rosgen type Aa+ channel below the diversion:

- Pitman Creek RM 0.16 - A nine-ft high weir impounds a dammed pool near the confluence with Big Creek and formed a complete barrier to fish migration at all flows,
- Pitman Creek RM 0.2 - A 20-ft high, bedrock sheet waterfall formed a complete barrier to fish migration at all flows,
- Pitman Creek RM 0.3 - A 28-ft high waterfall formed a complete barrier to fish migration at all flows,
- Pitman Creek RM 0.4 - A six-ft high waterfall in a cascade formed a complete barrier to fish migration at all flows, and
- Pitman Creek RM 1.5 - The 10-ft high Pitman Diversion is a complete barrier to upstream migration.

Flow-related Fish Passage - Four wetted-perimeter study sites are located in Pitman Creek near the diversion (Map CAWG 14). To meet the Thompson (1972) criteria for adult trout upstream passage, flows of 0.2 to 7.1 cfs, with an average of 2.5 cfs, are necessary below the diversion during the spawning season. This would likely be met during the runoff period when rainbow trout spawn, but may not be met in the fall when brown trout spawn. Above the diversion, minimum upstream passage flows are 1.2 to 6.6 cfs, for an average of 3.6 cfs.

Fish Passage from Big Creek - A weir in Pitman Creek near the confluence with Big Creek forms a complete barrier to upstream fish migration at all flows. This blocks access to Pitman Creek from Big Creek. No spawning gravel was found below the diversion.

4.4.3. BIG CREEK: DAM 4 TO POWERHOUSE 2

Big Creek from Dam 4 (Big Creek RM 6.2) to Powerhouse 2 (Big Creek RM 1.9) is a moderately steep, bedrock/boulder stream in a Rosgen type A channel, with a small inclusion of Rosgen type B channel. It has primarily step pool and cascade habitats, with substantial amounts of pool, riffle and flatwater. A fair amount of spawning gravel (864 square feet) was observed in pool tailouts.

Fish Populations - Brown and rainbow trout were collected in this reach (CAWG 14 Table Appendix B-1). The presence of brown trout, which are no longer stocked, indicates the populations are self-sustaining. Brown and rainbow trout densities were equal and relatively high (363 fish/km each).

Fish Barriers - Five waterfalls form complete barriers to upstream fish migration at all flows in this segment of Big Creek. These natural barriers are likely to fragment habitat within this reach.

- Big Creek RM 4.13 - A 10-ft high waterfall in a cascade forms a complete barrier to upstream migration at all flows,
- Big Creek RM 4.63 - A 60-ft high bedrock waterfall in a step pool forms a complete barrier to upstream migration at all flows,
- Big Creek RM 4.66 - A nine-ft high bedrock waterfall forms a complete barrier to upstream migration at all flows,
- Big Creek RM 4.73 - A four-ft high waterfall that falls onto granite (no pool at its base) in a cascade forms a complete barrier to upstream migration at all flows,
- Big Creek RM 4.95 - An eight-ft high waterfall in a cascade forms a complete barrier to upstream migration at all flows, and
- Big Creek RM 6.2 - The 75-ft high Dam 4 forms a complete barrier to upstream migration at all flows.

Flow-Related Fish Passage - Four PHABSIM study sites are located in Rosgen type A and B channels in this reach of Big Creek (RM 2.1 to 2.3, RM 5.28, 5.3 and 5.35). The ranges of flows needed to meet the Thompson passage criteria were 0.29 to 1.75 cfs with an average value of 0.85 cfs in the Rosgen type A channel, and 0.29 to 1.0 cfs with an average value of 0.65 cfs in the Rosgen type B channel. The average flow needed over all channel types was 0.77 cfs.

4.4.3.1. BIG CREEK: DAM 5/ POWERHOUSE 8 FOREBAY

The medium-sized impoundment behind Dam 5 (Big Creek RM 1.65) forms the Big Creek Powerhouse 8 Forebay (Map CAWG 14-3). Dam 5 impounds water from Big Creek and the discharge from Powerhouse 2 and Powerhouse 2A. Water from Dam 5 forebay is released into Big Creek below Dam 5 and diverted into an intake for Big Creek Powerhouse 8.

Fish Populations - Brown trout was the dominant species collected in the forebay, but rainbow trout and prickly sculpin also were collected (CAWG 14 Table Appendix B-1). Multiple age class brown trout were present, but the lack of age 0+ and age 1+ trout suggests that young-of-the-year fish do not move downstream to rear in the forebay until they are larger, or that they are subjected to predation or entrainment in the forebay. There were low numbers of rainbow trout present.

Upstream Passage from the Forebay

There are no physical barriers to upstream migration from the forebay to Big Creek.

Dam 5

Dam 5 is a 60-ft high, concrete dam. Dam 5 forms a barrier to upstream fish migration. Brown and rainbow trout occur downstream of the dam. Water from the forebay is diverted into an intake for Big Creek Powerhouse 8. Approach velocities at the intake are low to medium, and the potential for entrainment and downstream movement of trout from this mechanism is likely low.

4.4.4. BIG CREEK: DAM 5 TO POWERHOUSE 8

Big Creek from Big Creek Powerhouse 8 (RM 0.0) to Dam 5 (RM 1.7) is a moderately steep, bedrock/boulder stream in a Rosgen type A channel, with a smaller component of Rosgen type Aa+ channel at its downstream end. It has mostly step pool and other pool habitats with only small amounts of riffle and flatwater habitats. Small amounts (241 square feet) of spawning gravel were observed in pools.

Fish Populations - Multiple age classes of rainbow and brown trout were observed within this reach (CAWG14 Table Appendix B-1), which suggests reproduction and recruitment occurs in this reach. Many age 0+ rainbow trout were collected. Estimated trout densities were high (160 to 602 brown trout/km and 769 to 930 rainbow trout/km).

Fish Barriers - Two waterfalls near Big Creek Powerhouse 8 from complete barriers to upstream fish migration at all flows.

- Big Creek RM 0.09 - An 18-ft high, vertical waterfall in a cascade, six feet upstream of Big Creek Powerhouse 8, forms a complete barrier to upstream migration at all flows,

- Big Creek RM 0.19 - A 25-ft high waterfall in a cascade forms a complete barrier to upstream migration at all flows, and
- Big Creek RM 1.7 - The 60-ft high Dam 5 forms a complete barrier to upstream fish migration.

All of the spawning gravel was observed upstream of the natural barrier at Big Creek RM 0.19. The natural barrier at Big Creek RM 0.09 restricts fish upstream migration to Big Creek from the San Joaquin River.

Flow-related Fish Passage - Three PHABSIM study sites are located within this reach at RM 0.25, 0.3 and 1.4 to 1.7. The range of flows needed to meet the Thompson passage criteria was 1.51 to 3.5 cfs with an average value of 2.0 cfs.

4.4.5. Big Creek Tributaries

4.4.5.1. Balsam Creek

Balsam Creek (Big Creek RM 4.9) (Map CAWG 14-3) is a small, steep, bedrock stream with a mix of Rosgen type Aa+ and B channels above the diversion and Rosgen type Aa+ channel below the diversion. An instream flow release from Balsam Meadow Forebay is made to the creek at Balsam Dam at Balsam Creek RM 2.75. Balsam Creek has its confluence with Big Creek in the Dam 4 to Powerhouse 2 reach at Big Creek RM 4.9. Flow is diverted to Tunnel No. 2 where it flows to Powerhouse 2.

Habitats present included shallow pools, riffle, cascades and flatwater. Spawning gravel (1,806 square feet) was observed above the diversion in high gradient riffles and runs, and small amounts (84 square feet) were observed below the diversion in high gradient riffle, step pool tailouts and step run habitats. Quality of spawning gravel was varied, but mostly poor to fair above the diversion and fair below the diversion.

Fish Populations - Multiple age classes of rainbow trout, including age 0+, were collected upstream of the diversion, indicating reproduction and recruitment occurred (CAWG 14 Table Appendix B-1). Only one rainbow trout (age 2+) was collected downstream of the diversion. Fish density (1,335 fish/km) and biomass (171.6 kg/ha) were high above the diversion but low below the diversion (12 fish/km and 2.3 kg/ha, respectively). The population above the diversion appears to be self-sustained, but the limited number of trout downstream of the diversion suggests the population may be seeded from upstream locations. There was no statistically significant difference between rainbow trout condition factors above and below the diversion.

Fish Barriers - Balsam Creek Diversion is a nine-ft high, concrete diversion. It has a 24-inch sluice pipe and a six-inch drain pipe six inches above the bottom. The drop off at the end of the pipe is too high to provide upstream fish passage. Balsam Creek has numerous waterfalls, most of which form complete barriers to migration at all flows. Twenty-one barriers to upstream migration were found in the reach upstream of the diversion. Ten barriers were identified downstream of the diversion. The barriers downstream of the diversion included the following:

- Balsam Creek RM 0.02 - A 27-ft high, bedrock sheet waterfall forms a complete barrier to upstream fish migration at all flows,
- Balsam Creek RM 0.07 - A three-ft high waterfall in a plunge pool with a depth of 1.9 feet forms a partial barrier to upstream fish migration at low flows,
- Balsam Creek RM 0.10 - A nine-ft high bedrock sheet waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 0.22 - A 60-ft high bedrock waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 0.27 - A 69-ft high bedrock sheet waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 0.3 - A 13-ft high bedrock waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 0.38 - A 21-ft high bedrock sheet waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 0.39 - A 12-ft high bedrock waterfall with a slope of about 45 percent forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 0.6 - A nine-ft high waterfall in a step pool forms a complete upstream barrier to migration at all flows,
- Balsam Creek RM 0.65 - A 30-ft high bedrock sheet waterfall forms a complete upstream barrier at all flows, and
- Balsam Creek RM 0.70 - The nine-ft high Balsam Creek Diversion forms a complete barrier to upstream migration at all flows.

Upstream of Balsam Diversion the following barriers were present.

- Balsam Creek RM 0.80 - A five-ft high waterfall, 483 feet upstream of the diversion, forms a complete barrier to upstream migration at low flows,
- Balsam Creek RM 0.95 - A 30-ft high waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 0.99 - An 18-ft high waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 1.0 - A five-ft high waterfall forms a complete barrier to upstream migration at all flows,

- Balsam Creek RM 1.07 - A five-ft high waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 1.12 - A five-ft high waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 1.14 - An eight-ft high debris jam forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 1.2 - A 20-ft high waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 1.33 - A 10-ft high waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 1.36 - An eight-ft high waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 1.4 - A five-ft high debris jam forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 1.42 - A five-ft high debris jam forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 1.5 - A 75-ft high waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 1.7 - A 10-ft high waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 1.87 - A five-ft high debris jam forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 1.93 - A 20-ft waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 2.1 - A 200-ft waterfall located in a 1,000-ft long cascade forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 2.2 - A 10-ft high waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 2.3 - A 40-ft high waterfall forms a complete barrier to upstream migration at all flows,
- Balsam Creek RM 2.7 - A 40-ft high waterfall forms a complete barrier to upstream migration at all flows.

- Balsam Creek RM 2.75 - The 123-ft tall Balsam Meadow Dam, which forms Balsam Meadow Forebay is a complete barrier to upstream migration.

Numerous natural barriers throughout Balsam Creek are likely to fragment habitat in Balsam Creek. This, combined with a low amount of spawning gravel below the diversion, may limit reproduction downstream of the diversion.

Flow-related Fish Passage - Six wetted perimeter study sites are located in Balsam Creek; two riffles upstream (RM 0.75 and 0.80) and four downstream (RM 0.05, 0.12, 0.43, and 0.67) of the diversion. To meet the Thompson (1972) criteria for adult trout upstream passage, flows of 1.2 to 3.75 cfs, with an average of 2.4 cfs, are necessary below the diversion during the spawning season. This would likely be met during the runoff period when rainbow trout spawn, but may not be met in the fall when brown trout spawn. Above the diversion, passage flows are 0.9 and 1.4 cfs, for an average of 1.2 cfs.

Fish Passage from Big Creek - A 27-ft high bedrock sheet waterfall located 105 feet upstream of the confluence with Big Creek forms a natural barrier to fish upstream migration at all flows. This blocks access to Balsam Creek for fish species in Big Creek. No spawning gravel was found in this 105-ft reach.

4.4.5.2. BALSAM MEADOW FOREBAY

Balsam Meadow Forebay is located on Balsam Creek, approximately 2.75 miles upstream of the confluence with Big Creek. Water moves from Huntington Lake and Pitman Creek to Balsam Meadow Forebay and from there to Shaver Lake through Eastwood Powerhouse. Water also is pumped from Shaver Lake to Balsam Meadow Forebay for pump-storage operation.

Fish collected in Balsam Meadow Forebay included brown trout (two percent), rainbow trout (seven percent), Sacramento sucker (19 percent), and prickly sculpin (41 percent) kokanee (28 percent) and smallmouth bass (three percent) (CAWG 14 Table Appendix B-1). Most of these species likely originated from Huntington Lake or from Shaver Lake through pumpback and historically did not occur in Balsam Creek.

Multiple age classes, including young fish (CAWG 14 Table Appendix B-1), were represented in the sampled fish except brown trout, which suggests that for most species, rearing may occur in the forebay or that multiple age classes originate from Shaver or Huntington Lakes. Only age 6+ and older brown trout were collected in this location and could have passed from Shaver or Huntington lakes. Rainbow trout could be stocked fish.

Upstream Passage from Balsam Meadow Forebay - No perennial stream flows into Balsam Meadow Forebay.

4.4.5.3. ELY CREEK

Ely Creek (Map CAWG 14-3) is a very steep, bedrock/boulder stream comprised of Rosgen type Aa+ channel, which has its confluence with Big Creek (Big Creek RM 3.32) within the Dam 4 to Powerhouse 2 reach. The reach above the diversion primarily consisted of cascade and bedrock sheet habitat. Much of the reach downstream of the diversion was dry during summer 2002, but the wetted reaches were composed primarily of step run, step pool and high gradient riffle. No spawning gravel was observed above the diversion and small amounts (72 square feet) of fair to good quality gravels were observed below the diversion.

Only rainbow trout aged 3+ and older were collected from Ely Creek upstream of the diversion, which may be due to the limited availability of suitable spawning and rearing habitat. Multiple age classes of rainbow and golden x rainbow trout hybrids were collected downstream of the diversion, indicating reproduction and recruitment occurred (CAWG 14 Table Appendix B-1). Rainbow trout density and biomass were 190 fish/km and 133.9 kg/ha, respectively, above the diversion and 266 fish/km and 76.7 kg/ha, respectively, below the diversion. There was no statistically significant difference between average condition factors above (1.25) and below (1.38) the diversion ($p=0.15$). Density (102 fish/km) and biomass (31.4 kg/ha) were lower for golden x rainbow trout, and the average condition factor for golden x rainbow trout was 1.40.

Fish Barriers - The Ely Creek Diversion is located approximately 1.1 miles upstream of the confluence with Big Creek. The diversion has an 18-inch sluice pipe six inches above the bottom of the diversion and a six-inch drainpipe. The drop-off at the outlet is too high to provide upstream fish passage. Two waterfalls formed complete barriers to upstream fish migration at all flows downstream the Ely Creek Diversion.

- Ely Creek RM 0.3 - A six-ft high waterfall, part of a cascade forms a complete barrier to upstream migration at all flows,
- Ely Creek RM 0.5 - A 24-ft high trench chute with a 12 percent grade forms a complete barrier to upstream migration at all flows, and
- Ely Creek RM 1.1 - Ely Creek Diversion is a seven-ft high concrete structure that forms a complete barrier to upstream migration at all flows.

Small pockets of spawning gravel were found above and below barriers to migration downstream of the diversion.

Flow-related Fish Passage - Five wetted perimeter study sites were located on Ely Creek, three downstream of the diversion (RM 0.45, 0.55, and 0.57) and two upstream (RM 1.16 and 1.24). To meet the Thompson (1972) criteria for adult trout upstream passage, flows of 1.2 to 3.75 cfs, with an average of 2.4 cfs, are necessary below the diversion during the spawning season. This would likely be met during the runoff period during spawning periods of rainbow trout and their hybrids, but may not be met in the fall when brown trout spawn. Above the diversion, passage flows range from 0.9 and 1.4 cfs, for an average of 1.2 cfs.

Fish Passage from Big Creek - At Ely Creek RM 0.35, a waterfall forms a natural barrier to fish upstream migration at all flows. This limits passage to Ely Creek to the lower 0.35 mile. Minimum passage flow criteria may be met in this reach during the spring runoff period when rainbow trout and their hybrids spawn, but may not be met in the fall when brown trout spawn. Only 10 square feet of fair quality spawning gravel was found in a run located in this 0.35 mile reach.

4.4.5.4. ADIT NO. 8 CREEK

Adit No. 8 Creek has its confluence with Big Creek at Big Creek RM 2.6 (Map CAWG 14-3). It is a very steep, boulder-dominated stream in a Rosgen type Aa+ channel. Adit No. 8 was evaluated downstream of the diversion. Much of the creek was dry and a substantial component was cascade, which may limit habitat value for fish. A fair amount of spawning gravel was observed, primarily in flatwater and high gradient riffles. Although currently not in use, the Adit No. 8 Diversion can be used to divert Tunnel 5 water (from Shaver Lake) into Tunnel 2 (to Powerhouse 2). The diversion has not been operated in many years.

Fish Populations - No fish was collected from Adit No. 8 Creek below the diversion. Sampling could not be conducted above the diversion because the stream could not be safely accessed.

Fish Barriers - The Adit No. 8 Diversion, which is no longer in service, forms a complete barrier to fish upstream migration. Nine waterfalls, most of which form complete barriers to fish upstream migration, were identified in Adit No. 8 Creek below the diversion. These include the following:

Adit 8 Creek RM 0.35 - A 13-ft high waterfall in a cascade forms a complete barrier to upstream migration at all flows, and streamflow went underground at the bottom of the falls,

Adit 8 Creek RM 0.36 - A six-ft high waterfall forms a complete barrier to upstream migration at all flows,

Adit 8 Creek RM 0.37 - A 5.5-ft high waterfall in a run forms a complete upstream barrier to migration at all flows,

Adit 8 Creek RM 0.4 - An eight-ft high waterfall in a step run forms a complete barrier to upstream migration at all flows,

Adit 8 Creek RM 0.4 - A seven-ft high waterfall in a step pool forms a complete barrier to upstream migration at all flows,

Adit 8 Creek RM 0.44 - A three-ft high waterfall in a run forms a complete barrier to upstream migration at low flows,

Adit 8 Creek RM 0.62 - A 15-ft high bedrock sheet waterfall in a run habitat forms a complete barrier to upstream migration at all flows, Adit 8 Creek RM 0.64 - A 15-ft high waterfall in a cascade forms a complete barrier to upstream migration at low flows,

Adit 8 Creek RM 0.7 - A 20-ft high, bedrock sheet waterfall in a high gradient riffle forms a complete barrier to upstream migration at all flows, and

Adit 8 Creek RM 0.95 - Adit 8 Diversion is a 30-ft high concrete structure that forms a complete barrier to upstream fish migration at all flows.

Some creek reaches naturally go dry during the summer/fall period and act as barriers to both upstream and downstream fish migration. Above the diversion, the stream is dry most of the year. Below the diversion, Adit No. 8 Creek flow results from leakage from Tunnel 2.

Flow-related Fish Passage - Three wetted perimeter study sites were located in Adit No. 8 Creek below the diversion at RM 0.35, 0.55 and 0.6. Because the stream above the diversion is dry most of the year, no reference transects were placed there. To meet the Thompson (1972) criteria for adult trout upstream passage, flows of 0.6 to 2.4 cfs, for an average of 1.6 cfs, are necessary during the spawning season. Since the creek originates from tunnel leakage, relatively little additional flow would contribute to passage, even during what would be the runoff season in other creeks.

Fish Passage from Big Creek - At Adit No. 8 Creek RM 0.34, a waterfall forms a natural barrier to fish upstream migration at all flows. This limits passage to the creek to the lower 0.35 mile. Within this accessible reach, minimum adult trout upstream passage flows may be met during the spring runoff period when rainbow trout spawn, but may not be met in the fall when brown trout spawn. No useable spawning gravel was located in the 0.35 miles downstream of this impassable waterfall.

4.4.6. Stevenson Creek Drainage

The study area within the Stevenson Creek drainage extends from upstream of Shaver Lake to the confluence of Stevenson Creek with the San Joaquin River (SJR RM 13.6) (Map CAWG 14-3). Stevenson and North Fork Stevenson creeks are included in the study area. Project facilities within the study area include Shaver Lake Dam on Stevenson Creek (Stevenson Creek RM 4.25) and Tunnel 7 outlet (Gate 2) on North Fork Stevenson Creek (North Fork Stevenson Creek RM 3.55).

4.4.6.1. Shaver Lake

Shaver Lake Dam (Stevenson Creek RM 4.25) impounds Shaver Lake on Stevenson Creek (Map CAWG 14-3). Water from Shaver Lake that is not released to Stevenson Creek is diverted through Tunnel 5 to Big Creek Powerhouse 2A. Stream inflow to Shaver Lake is primarily from Stevenson and North Fork Stevenson creeks upstream of the lake. The flow in North Fork Stevenson Creek is natural flow augmented by Project releases from Tunnel 7 (HPS). Shaver Lake receives most of its volume of water through the Huntington-Pitman-Shaver conduit from Huntington Lake through Balsam Forebay and the Eastwood Power Station. Average reservoir storage and corresponding elevation and surface area for winter and summer operations periods are presented in the CAWG 1 Technical Study Report (SCE 2003a, Table CAWG 1-297).

Fish Populations - Rainbow trout and kokanee are the only species currently stocked in Shaver Lake (CAWG 14 Table Appendix B-1). The sampled fish community in Shaver Lake included rainbow trout (37 percent), Sacramento sucker (three percent), kokanee (19 percent), smallmouth bass (27 percent), bluegill (six percent), and crappie (four percent) (CAWG 14 Table Appendix B-1). The presence of multiple age classes indicates that rearing of most fish species occurs in the Shaver Lake drainage. The absence of small rainbow trout and kokanee and the results of scale analyses of both species suggest that these fish are likely of hatchery origin.

Upstream Passage from Shaver Lake

Passage for potential upstream migration from Shaver Lake to Stevenson Creek upstream, is maintained at the full range of operational lake elevations. North Fork Stevenson Creek is only accessible when the reservoir is at maximum elevation. A complete barrier to fish migration also exists in North Fork Stevenson Creek 457 feet upstream from the lake. All other Shaver Lake tributaries, which do not have Project features, generally have insufficient flow for upstream migration.

Shaver Lake Dam

The 185-ft high Shaver Lake Dam forms a barrier to upstream migration. Rainbow trout were collected downstream of the dam. Spill is rare, but may occur over the 250-ft long overpour spillway located in the center of the dam (5,370 feet above MSL). Spills may result in downstream transport of fish. Releases to Stevenson Creek are made from near the bottom of the dam. The Tunnel 5 intake also is located near the bottom of the lake. During hydroacoustic surveys near the Tunnel 5 intake, most fish were detected in the upper section of the water column and there were fewer fish near the bottom. Approach velocities at the Tunnel 5 intake were low. Therefore the potential for entrainment and downstream movement of fish from this mechanism is also likely low.

4.4.6.2. North Fork Stevenson Creek

North Fork Stevenson Creek is a moderate to steep gradient, bedrock/boulder stream with Rosgen type Aa+, A, B, C, and G channels. An augmented instream flow release is made to the creek at the Tunnel 7 outlet (North Fork Stevenson Creek RM 3.55). A very small amount (13 square feet) of spawning gravel was observed above the Tunnel 7 outlet in pools, of which 10 square feet was of fair quality and three square feet was poor. A fair amount (1,225 square feet) of widely distributed, fair (330 square feet) and good to excellent quality (895 square feet) gravel was found downstream of the outlet.

Fish Populations - No fish was found in the Rosgen type Aa+ channel site upstream of the Tunnel 7 outlet. The fish community sampled in 2002 downstream of the Tunnel 7 outlet was predominantly brown trout, rainbow trout and golden x rainbow trout hybrids, with a small number of age 4+ and older Sacramento suckers. Riffle sculpin were collected in 2000 and 2001, but not in 2002. The absence of young Sacramento suckers suggests reproduction may not have been successful in recent years. Multiple age classes of trout species were found, including age 0+ trout in the downstream-most reach, indicating that successful reproduction and recruitment continues to occur in North Fork Stevenson Creek. Downstream of the Tunnel 7 outlet, estimated density and biomass of rainbow trout ranged from 210 to 314 fish/km and 13.5 to 29.8 kg/ha respectively, and of brown trout ranged from 305 to 430 fish/km and 33.2 to 43.7 kg/ha, respectively between sampled sites. Average condition factor was 1.27 for rainbow trout and 1.23 to 1.39 for brown trout. Estimated density and biomass of golden x rainbow trout ranged from 11 to 583 fish/km and 1.3 to 9.0 kg/ha. Average condition factors were 0.98 to 1.35. Estimated density and biomass of Sacramento sucker ranged from 11 to 42 fish/km and 13.5 to 65.9 kg/ha, respectively (Table CAWG 14 Appendix B-1).

Fish Barriers - One barrier to upstream fish migration was identified above the Tunnel 7 outlet. Seventeen barriers were identified downstream of the outlet, all of which form complete barriers at all flows.

- NF Stevenson Creek RM 1.07 - A 30-ft high waterfall, 457 feet upstream of Shaver Lake forms a complete barrier to upstream fish migration at all flows,
- NF Stevenson Creek RM 1.14 - A 25-ft high waterfall forms a complete barrier to upstream migration at all flows
- NF Stevenson Creek RM 1.18 - A 15-ft high waterfall forms a complete barrier to upstream migration at all flows,
- NF Stevenson Creek RM 1.36 - A 15-ft high waterfall forms a complete barrier to upstream migration at all flows
- NF Stevenson Creek RM 1.6 - A 30-ft high waterfall forms a complete barrier to upstream migration at all flows,
- NF Stevenson Creek RM 2.33 - A 23-ft high waterfall forms a complete barrier to upstream migration at all flows,
- NF Stevenson Creek RM 2.5 - An 18-ft high waterfall forms a complete barrier to upstream migration at all flows,
- NF Stevenson Creek RM 2.7 - A 40-ft high waterfall in a step pool forms a complete barrier to upstream migration at all flows,
- NF Stevenson Creek RM 2.9 - A 20-ft high bedrock waterfall in a step pool forms a complete barrier to upstream migration at all flows,
- NF Stevenson Creek RM 3.0 - A 35-ft high bedrock waterfall in a cascade forms a complete barrier to upstream migration at all flows,

- NF Stevenson Creek RM 3.14 - A 20-ft high bedrock/cascade waterfall forms a complete barrier to upstream migration at all flows,
- NF Stevenson Creek RM 3.2 - A 20-ft high bedrock waterfall in a cascade forms a complete barrier to upstream migration at all flows,
- NF Stevenson Creek RM 3.4 - A 13-ft high waterfall in a high gradient riffle forms a complete barrier to upstream migration at all flows,
- NF Stevenson Creek RM 3.45 - A 22-ft high bedrock waterfall at the bottom of a bedrock cascade (entire unit is a barrier) forms a complete barrier to upstream migration at all flows,
- NF Stevenson Creek RM 3.5 - A five-ft high boulder waterfall in a step pool forms a complete barrier to upstream migration at all flows,
- NF Stevenson Creek RM 3.51 - A 10-ft high vertical waterfall forms a complete barrier to upstream migration at all flows,
- NF Stevenson Creek RM 3.53 - A 20-ft high bedrock sheet/cascade waterfall with a 70-ft long, 45 percent grade forms a complete barrier to upstream migration at all flows, and
- NF Stevenson Creek RM 3.8 - A 15-ft high bedrock waterfall in a cascade located 1,232 feet upstream of the Tunnel 7 outlet forms a complete barrier to upstream migration at all flows.

Fish Passage from Shaver Lake - A natural barrier located 457 feet upstream of the Shaver Lake blocks upstream fish migration to North Fork Stevenson Creek at all flows. No spawning gravel was found in this 457-ft reach in run habitat.

4.4.6.3. STEVENSON CREEK

Half of Stevenson Creek downstream of the Shaver Lake Dam (Stevenson Creek RM 4.25) is Rosgen type Aa+ channel and the rest is composed of Rosgen type A and B channels and a small section of Rosgen type G type channel. The dominant habitat types were cascade and pool. Small amounts (130 square feet fair quality and five square feet good quality) of spawning gravel were observed primarily in pools, with 20 square feet in step run habitat.

Fish Populations - Rainbow trout was the only species found at representative sites in the Rosgen type B, Aa+, and A channels (CAWG 14 Table Appendix B-1). Multiple age classes, including age 0+ rainbow trout, were collected indicating reproduction and recruitment occurred in Stevenson Creek. Fish densities ranged from 128 to 966 fish/km and biomass ranged from 52.3 to 74.9 kg/ha. Average condition factors were 1.04 to 1.34.

Fish Barriers - Thirteen barriers to upstream fish migration were identified in Stevenson Creek downstream of Shaver Lake Dam, most of which are complete barriers at all flows. Shaver Lake Dam is a complete barrier to upstream fish migration. The largest barrier to upstream fish migration is a series of waterfalls in the first 0.5 mile upstream of the confluence with the San Joaquin River including the several hundred-ft high Stevenson Creek Falls.

- Stevenson Creek RM 0.55 - Stevenson Creek Falls and a series of waterfalls within the first half mile of the creek upstream of the SJR, form complete barriers to upstream migration at all flows,
- Stevenson Creek RM 1.0 - A 16-ft high waterfall in a cascade forms a complete barrier to upstream migration at all flows,
- Stevenson Creek RM 1.9 - An 18-ft high waterfall in a cascade forms a complete barrier to upstream migration at all flows,
- Stevenson Creek RM 2.2 - A 13-ft high waterfall in a cascade forms a complete barrier to upstream migration at all flows,
- Stevenson Creek RM 2.35 - A nine-ft high waterfall in a cascade forms a complete barrier to upstream migration at all flows,
- Stevenson Creek RM 2.4 - A 15-ft high waterfall in a cascade forms a complete barrier to upstream migration at all flows,
- Stevenson Creek RM 2.5 - A ten-ft high waterfall in a cascade forms a complete barrier to upstream migration at low flows,
- Stevenson Creek RM 2.6 - A six-ft high waterfall in a cascade forms a complete barrier to upstream migration at all flows,
- Stevenson Creek RM 2.7 - A three-ft high waterfall in a cascade forms a complete barrier to upstream migration at low flows,
- Stevenson Creek RM 2.9 - A 2.5-ft high weir with 0.4-ft depth at the base forms a complete barrier to upstream migration at all flows,
- Stevenson Creek RM 2.9 - A 30-ft high waterfall in a high gradient riffle forms a complete barrier to upstream migration at all flows,
- Stevenson Creek RM 3.5 - A 15-ft high waterfall in a plunge pool forms a complete barrier to upstream migration at all flows,
- Stevenson Creek RM 3.6 - A 100-ft high waterfall in a cascade, forms a complete barrier to upstream migration at all flows, and

- Stevenson Creek RM 4.26 - Shaver Lake Dam forms a complete barrier to upstream migration at all flows.

No spawning gravel was found below the first waterfalls upstream of the confluence with the San Joaquin River. Small patches of spawning gravel were found above the waterfalls, between Stevenson Creek RM 1.0 and 1.9, RM 1.9 and 2.2, above RM 2.5, and above RM 2.9.

Flow Passage - A PHABSIM study site is located at Stevenson Creek RM 3.15. The range of flows needed to meet the Thompson passage criteria was 3.5 to 6.0 cfs with an average of 4.8 cfs in the Rosgen B type channel, and 3.25 cfs in the Rosgen A type channel. Over all transects, the range of flows needed was 3.25 to 6.0 cfs with an average value of 4.25 cfs.

Fish Passage from the San Joaquin River - Stevens Creek Falls and a series of waterfalls within the first half-mile of the creek upstream of the San Joaquin River form natural barriers to upstream migration at all flows. This limits upstream migration to the first half mile of Stevenson Creek. No spawning gravels were found in this half-mile reach.

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Personal Communications

R. Wickwire, Fishery Biologist, CA Department of Fish and Game, Region 4, Fresno, California.

MAPS

Figure CAWG 14-ES-1. Fish Passage Evaluation Sites (Overall Map of Study Area)

Figure CAWG 14-1. Fish Passage Evaluation Sites (Detail Map 1 of 3)

Figure CAWG 14-2. Fish Passage Evaluation Sites (Detail Map 2 of 3)

Figure CAWG 14-3. Fish Passage Evaluation Sites (Detail Map 3 of 3)

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Appendix A

Detailed Study Methods

APPENDIX A
DETAILED STUDY METHODS

Portions of study methods from CAWG 1, CAWG 3 and CAWG 7 technical Study Reports (SCE 2003a, 2003b, and 2003c) are presented as they relate to the information used in this report. These are listed by study.

1.1 CAWG 1 CHARACTERIZE STREAM AND RESERVOIR HABITATS

1.1.1 Stream Habitat Methods

The major elements used to describe habitat included:

- Rosgen channel typing - Level I was applied to Project streams. Channel types were evaluated using criteria developed by Rosgen (1996).
- Mesohabitat typing (Hawkins et al. 1993 and McCain et al. 1990) was performed. Mesohabitat is the stream channel structure aquatic organisms might use for shelter, feeding, spawning, rearing or other activity.
- Dominant substrates, including the presence of fines and spawning substrate, pool depth, riparian vegetation, and woody debris was characterized and recorded. Potential passage barriers were identified and located in the field.
- Riparian vegetation communities along bypass reaches were characterized primarily as components of habitat for aquatic organisms. The information was supplemented by a combination of aerial photography and partial ground-truthing.
- Spatial referencing of data collections was performed using GPS (where feasible) and hip chain distances between measured coordinates on each stream reach.

1.1.2 Stream Habitat and Channel Typing

Project streams were evaluated using the Rosgen Level I (Rosgen 1996) stream classification system with supplemental data collection. Rosgen Level I classifications were made based on a combination of topographic information and field verification. In general, the Rosgen Level I classifications were based upon the information provided in the CAWG 2 "SCE Big Creek ALP Level I Geomorphic Classification Information August 2002" CD-ROM. Information missing from the "SCE Big Creek ALP Level I Geomorphic Classification Information August 2002" was supplemented when the geomorphology ground-truthing was completed. More detailed classifications were made during activities conducted in support of the CAWG 2 Geomorphology Report (2003d), but these exceeded the level of detail needed to conduct this work.

Habitat inventories were made for all Project area streams during the summer and fall of 2000 and 2001. These were supplemented for inaccessible areas by typing based on aerial photography and visual observations.

A habitat inventory was used to characterize the aquatic habitat types (mesohabitats) of Project area streams. Mesohabitats represent the commonly identified local conditions, which aquatic organisms use for shelter, feeding, spawning, rearing or other activities. These include such types as pools, runs, and riffles at a general level of characterization. The inventory helps describe places available for aquatic organisms to live and proportions of mesohabitats, which may influence the composition of aquatic communities present. Aquatic habitat types were identified using the most commonly accepted classification approaches for the Sierra Nevada. The composition and distribution of instream habitats were determined by on-the-ground surveys. Trained field biologists walked the entire length of the stream segments and identified habitat types based on two classification levels.

The first level assigns channel habitat to the following four broad categories: turbulent, non-turbulent, scour pool and dammed pool habitat (Table CAWG 1-2) (Hawkins et al., 1993). Riffle and run habitats fall into the turbulent and non-turbulent categories described by Hawkins et al. Pool habitats are described by their position and cause of their formation; they are either dammed pool habitats or scour pool habitats. This level of assessment provides a general view of the habitat based on geomorphic and hydraulic characteristics.

The second level of classification reflects a higher level of resolution and is based on the USFS Region 5 habitat types (Table CAWG 1-3) (McCain et al., 1990). USFS Region 5 methodology outlines procedures to inventory fish habitat (McCain et al., 1990). Riffle, run, and pool habitats describe the three major categories found in stream channels (Table CAWG 1-3). Each category is further subdivided to reflect the diverse habitat types found in natural channels. Riffle habitat is classified as either being high gradient or low gradient. Pool habitat is classified by the location of the pool in the stream channel (whether it is in the main channel, secondary channel, backwater, or lateral) and the occurrence and cause of the scour that forms the pool (obstruction, blockage, constriction, or merging flows). Run habitat is typically low gradient and is classified by the velocity and depth of the habitat. In general, a mesohabitat must be at least one-channel width in length to be identified as an individual habitat unit.

Some stretches of stream reaches within the Big Creek Basin were inaccessible and posed surveying safety concerns. Mapping of these stream segments was completed from aerial photographs and orthorectified digital imagery (where available) and relatively low-level overflights. This was carried out by experienced field biologists familiar with the Big Creek area, after verifying identifications of mesohabitats identified from this method against areas identified on the ground in reaches containing similar features. Lengths were based on information derived from GIS from orthorectified imagery. The study stream reaches and the lengths of those reaches that were completed from aerial photographs overflights were: the South Fork San Joaquin River (SFSJR) downstream of Hoffman Creek to the San Joaquin River/SFSJR confluence

(6.4 river miles); a portion of Rock Creek below the Rock Creek diversion (1000 feet); a steep Rosgen type Aa+ channel section of Big Creek between Dam 1 and Powerhouse 1 (6,610 feet) containing many water falls; and Stevenson Creek near the confluence with the SJR (3326 feet), a steep section consisting primarily of a waterfall. In general, the identification of mesohabitats obtained from this method was at a lower level of resolution than from ground-based identifications. The level of classification presented reflects this.

Describing the mesohabitats of the Project area waters with the Hawkins and USFS Region 5 habitat classification methodologies provided both a general and a detailed assessment of available aquatic habitats. This assessment, when combined with the collection of associated information on habitat characteristics such as pool depth, dominant substrate, cover, and spawning gravels (described below), described the presence and condition of aquatic habitats in the Project area waters, and served as a framework for analyzing habitat, and selection of sampling locations to understand potential Project effects on aquatic life.

Habitat lengths and widths were measured to the nearest foot using a hip-chain for length and a stadia rod or tape for widths. Where aerial photographs or aerial typing was used habitat lengths were determined from digital orthorectified imaging. The mean and maximum depth of each habitat type was measured to the nearest 0.1 feet with a stadia rod for depth of less than 20 feet. For depths in excess of 20 feet, a hand held depth finder was used.

Streambed substrates provide microhabitat conditions required for aquatic organisms and provides information about local influences on stream habitat quality. During the habitat mapping surveys, the two most abundant class sizes of surficial substrate were visually estimated to the nearest ten percent. Substrate data were visually classified following the categories described by Rosgen (1996):

- fines (silt/clay), <0.062 mm
- sands, 0.062 - <2 mm
- gravels, 2 - <64 mm
- cobbles, 64 - <256 mm
- boulders, 256 - <4,096 mm
- bedrock, ≥4,096 mm

Substrate smaller than gravel was compared to a sand gage, so that sands could be distinguished from fines. Gravel-sized and larger substrates were determined based on diameter. Substrate was compared to common items for easy evaluation. Stream bank vegetation was measured as the percentage of stream bank covered by vegetation in the following groups: zero, one-25, 26-50, 51-75, and 76-100 percent.

Spawning gravel was measured as the estimated amount (square feet) of spawning-sized gravel (0.64-7.6 mm diameter, adapted from Bjornn and Reiser (1991)) occurring in each habitat. In addition, habitat areas with spawning gravel were assigned a "Spawning Quality" score of "Poor, Fair, Good, or Excellent." The score was based primarily on substrate composition, since much of the mapping was conducted during the summer and fall months when streamflow was lowest. The quality of spawning gravel was characterized based on the angularity of the gravels and embeddedness. Gravels of higher suitability for use by spawning trout are highly rounded. Gravel that is more angular is considered of lower quality for spawning. Generally, a "Good" or "Excellent" score was assigned to rounded spawning gravels with little sand and fines present and low embeddedness. Spawning gravels with high embeddedness and high proportion of sand received a "Fair" or "Poor" score, regardless of angularity.

Riparian vegetation was described by the dominant vegetation covering the stream banks. Vegetative groups included no vegetation, grasses, shrubs, deciduous trees, coniferous trees, and mixed trees. Stream bank vegetation was characterized by the percentage category of stream bank covered by vegetation. The categories recorded were zero, one-25, 25-50, 50-75, and 75-100 percent. Canopy was measured to the nearest 10 percent using a spherical densiometer. Canopy cover was recorded as hardwood or softwood.

Cover (instream shelter) provides refuge habitat for fish from predators and high water velocities. Cover elements, including undercut banks, woody debris, root wad, terrestrial vegetation, aquatic vegetation, surface turbulence, boulder/cobble, and bedrock, were evaluated for their percent contribution to the total available cover for the habitat unit to the nearest quartile.

Large woody debris (LWD) was counted by stream habitat unit. The total number of pieces of wood in or intersecting the active stream channel with a diameter of six inches or greater was recorded. Wood was counted if approximately 33 percent or greater of the total length of the wood was situated within the stream channel. In the case of debris jams or other accumulations of wood, all pieces of wood meeting the criteria were counted. Woody debris counts were added to the data collection after data for some reaches had been collected without these counts. In those cases, the text indicates that no wood counts were made. Stakeholders indicated that the primary concern with LWD was related to SCE's handling of LWD at diversions, and whether this handling results in a change in LWD transport and abundance.

Fish passage barriers were visually assessed and characterized by experienced fish biologists. These included culverts, road crossings, debris jams, cascades, bedrock sheets, shallow riffles, and dewatered areas, among others. Photographs were taken and spatial coordinates collected using GPS for each of the barriers identified during the ground surveys.

Crews also identified the location of prominent features, such as tributaries, gaging stations, diversions, recreational facilities and other facilities with GPS coordinates.

The data collected from the habitat mapping surveys and channel typing were stored in an electronic format and used to produce a tabular summary of existing habitats by stream reach. The database output will provide detailed information on the aquatic habitat in Project streams. The analyzed data will also prioritize areas for protection, mitigation, enhancement, or further evaluation.

1.1.3 Stream Data Analysis

Data were entered into an electronic database. Standard reports were designed to provide tabular and graphic summaries of habitat types, channel types, dominant substrates, woody debris counts, vegetation conditions, and pool depths by stream. Habitat data for surveyed stream reaches were summarized by Rosgen Level I channel types and by the presence of a diversion (i.e. above diversion [AD] versus below diversion [BD]). Pie charts were generated summarizing mesohabitat data. Data were analyzed to characterize average pool depths, counts of large woody debris, cover, canopy, and substrate.

1.1.4 Reservoir Habitat

Reservoir habitat data were collected to characterize conditions for fish and other aquatic organisms in Project reservoirs. Reservoir habitat data were collected in the summer and fall of 2002. Project reservoirs included in the study were: Florence Lake, Bear Diversion Forebay, Mono Diversion Forebay, Mammoth Pool, Dam 6 Forebay, Huntington Lake, Dam 4 Forebay, Dam 5 Forebay, Balsam Meadow Forebay, and Shaver Lake. Non-ALP reservoirs within the Big Creek Hydroelectric System were reported in license applications for Big Creek No. 4, Vermilion Valley, and Portal. The main elements of reservoir habitat collection are identified below.

- Reservoir morphometry, and shoreline development were analyzed using SCE plans and drawings.

- Reservoir substrate was characterized at low lake elevations by observation. If necessary, substrates in deeper areas were characterized using an underwater camera (Atlantis Underwater Black and White Camera), or by sampling. Reservoir surficial substrate was evaluated by visually estimated percentage by category using the same size categories as used in stream habitat mapping. The percentages of near shore substrate types were recorded, along with the presence or absence of aquatic vegetation, and the types of cover available for fish.

- Available habitats in Project reservoirs were evaluated based on the following information:

  - SCE's stage-capacity tables, which are more detailed versions of those published by USGS (2002);

  - Reservoir water storage data obtained from USGS published records for the period 1980-2001;

  - Reservoir morphometry from SCE Project drawings; and

  - Arithmetic calculation of surface area by depth interval based on stage-capacity tables for each reservoir.

- Spawning access for fish into reservoir tributaries were evaluated by observation, reservoir morphometry, and area-capacity curves.

- Limnological conditions including the physical properties of the reservoir waters were evaluated in conjunction with the water temperature (CAWG 5) study.

Available habitat in Project reservoirs was evaluated based on area-capacity curves and reservoir morphometry. The reservoir morphometry was determined from SCE plans and drawings of the reservoir. Available area and volume were calculated for each reservoir for three-foot elevation intervals. Where necessary, values were interpolated between points. In addition using this information, potential habitat areas for the following depth intervals were calculated:

- three feet
- six feet
- nine feet
- 12 feet

These intervals represent areas for potential habitat for shallow water or near-shore species.

Elevation and storage data for the forebays (Balsam Meadow Forebay, Bear Diversion Forebay, Mono Diversion Forebay, Dam 4 Forebay, Dam 5 Forebay, and Dam 6 Forebay) were obtained from SCE, they are not reported by United States Geological Survey (USGS). Forebay elevations fluctuate frequently and information was summarized on a daily basis for information available during the past three years.

Each reservoir was characterized by the shoreline steepness, near shore substrate, the presence of aquatic vegetation, and the presence of potential habitat structure. Shoreline steepness was measured from SCE drawings and reservoir morphometry. Near shore substrate, the presence of aquatic vegetation, and the presence of potential habitat structure were measured from reservoir surveys.

The effects of water levels on passage from Project reservoirs to tributary streams were assessed based on data collected during field reconnaissance, operational data, and reservoir morphometry (primarily to be discussed in the report resulting from the CAWG 14 Fish Passage Study Plan). Tributaries used, or with the potential to be used, by stream spawning fish were identified in each reservoir. The reservoir elevation(s) that provide access to the stream were determined from field surveys and reservoir morphometry during low reservoir elevations. In addition, each tributary stream was visited to determine the reservoir elevation at which passage into the stream is likely limited. As the reservoir water levels dropped, fish passage from the reservoirs into the tributaries was visually evaluated. Field biologists evaluated potential fish passage barriers such as limited stream flow, passage obstacles, and height barriers that occurred without adequately deep pools. Reservoir morphometry, or specifically, the shape and the gradient of the slope around the reservoir, along with fluctuations in the reservoir elevation also were taken into account.

Limnological conditions including physical properties and water quality also define the habitat of reservoirs (Busch and Sly 1992). Thermal stratification of lakes affects the quality of habitat for fish. The presence of stratification can facilitate the coexistence of both warm and cold water fish species by thermal partitioning of the lake environment. Temperature stratification also affects productivity and dissolved oxygen concentration. Temperature profiles of the Project reservoirs were collected in conjunction with the water temperature study (CAWG 5) as were profiles of other parameters including specific conductance. Transparency of waters also affects productivity and habitat. Transparency also was measured in conjunction with these programs. Transparency was measured using a Secchi disc, which is a standard limnological instrument and provides an index of the passage of light through water. The information in this report derives specifically from the data collected for the CAWG 5 study.

1.2 CAWG 3 Flow-Related Physical Habitat in Bypass Reaches

The methods used followed those agreed to in the Big Creek ALP process CAWG 3 Study Plan (SCE 2001). As part of the CAWG 3 study plan, it was agreed that the wetted perimeter approach would be used to assess habitat for the small streams in the Upper Basin including: Camp 62 Creek, Chinquapin Creek, Crater Creek, Hooper Creek, North Slide Creek, South Slide Creek, and Tombstone Creek in 2002. PHABSIM was applied in other locations. Information on methods is provided where it may be relevant to that information used in the analysis of fish passage.

1.2.1 Study Site and Transect Selection

As outlined in the CAWG 3 Study Plan (SCE 2001), the preliminary Rosgen Level I evaluation (August 2001) and mesohabitat typing conducted in 1999-2001 was used as the basis for selecting the channel segments and habitat units to be represented in the Wetted Perimeter studies.

Transects were placed above and below the Project diversions across similar habitat types and in representative habitats. Riffles (and runs where riffles are not present) are the main focus of the wetted perimeter analysis. While transects were placed through pools, these transects are not appropriate for use in wetted perimeter analysis, and are used primarily to assess the amount of flow needed to fill the channel bottom and the habitat value of pool depths under different flow regimes.

Prior to field visits by the CAWG Transect Selection Team (CTST), preliminary habitat units were randomly selected within each of the preliminary Rosgen Level I channel types. Five or six habitat units were randomly selected based upon the results of habitat inventory studies (SCE 2002). Riffles are the preferred habitat type for wetted perimeter transect placement because they are very responsive to changes in flow. In some reaches, however, riffles were (a) absent, (b) represented a very small proportion of the total reach length, or (c) were present but contained hydraulic features which could not be accurately modeled. Runs were used in place of riffles, where necessary, because these habitat types are also very responsive to changes in flow and are commonly thought of as “flooded riffles”. The candidate study sites were inspected by an experienced instream flow specialist to screen out any non-representative sites or areas that could not be modeled. The remaining sites were retained for inspection and final transect selection by the CTST.

Adit 8 creek is created from leakage from Tunnel 2 and hence it was not possible to place reference transects upstream of this diversion. This diversion also allows SCE to move water from Tunnel 5, which conveys water from Shaver Lake to Powerhouse 2A, to Tunnel 2, which conveys water from Dam 4 to Powerhouse 2. This diversion has not been operated in many years, either as a diversion or to transfer water between the tunnels. Above the diversion, the stream is dry most time of year; while the water below diversion comes from tunnel leakage. Three transects were selected below the diversion and the CTST agreed that the necessity of a Wetted Perimeter study in those circumstances was questionable.

In Balsam Creek, three transects were selected above the diversion. The most downstream of these three transects was placed below another small diversion for Camp Sierra, which caused some flow variation between transects during the study. Another three transects were selected below the diversion; two near the confluence with Big Creek, one half a mile upstream, near the Camp Sierra swimming hole.

Three transects were selected below Ely Diversion, near Canyon Road. The most downstream transect, located below the road, had different flows than the other two transects at the high calibration flow due to a side channel which became active at high flow. Only two transects were placed above the diversion because other suitable locations could not be found for transect placement.

In Pitman Creek, three transects were placed upstream and three transects were placed downstream of the diversion. The area above the diversion was dissimilar to the area below the diversion. While the stream is wide and open upstream of the diversion, with a gravel and cobble dominant substrate, the area downstream of the diversion is a succession of bedrock cascades, bedrock chutes, and step pools. The CTST acknowledged the difference but elected to pursue this approach at the time. The three transects upstream of the diversion were placed within close proximity and in a classic riffle habitat. Below the diversion, in the absence of other more appropriate habitat types, two pocket water and bedrock sheet habitat were selected for transect placement. Two of these transects were placed upstream of the Huntington Lake road. The third transect was placed just downstream of the diversion, almost one mile upstream of the lower two transects. A side channel became active at high flow at the most downstream transect, which resulted in a difference in calibration flows between this transect and the adjacent one.

Rancheria Creek does not have a diversion, but SCE has the potential to occasionally affect stream flow through an energy dissipater operated when Portal Powerhouse goes offline in an emergency. This results in higher flows downstream of the structure. Three transects were placed upstream of the Energy Dissipater, and six downstream. Three transects were place downstream of the Energy Dissipater in each Rosgen Level 1 channel type present, A and B. Three transects above the Energy Dissipater were placed in B channel.

Rock Creek is a very steep bedrock stream which presents very little riffle and run habitat. Given the lack of suitable habitat on Rock Creek for conducting wetted perimeter studies, the CTST elected to place transects to apply the food transport approach as an alternative methodology for assessing instream flows. Few suitable locations were available due to large plunge pools and difficult access below the diversion, and only one transect was placed just upstream of the confluence with the San Joaquin River. Only two suitable locations were found above the diversion. This included one transect with very jumbled hydraulics.

The CTST decided that it was not necessary to conduct wetted perimeter studies in Ross Creek as the stream is intermittent even in wet years.

1.2.2 Transect Installation and Data Collection

The wetted perimeter method evaluates how wetted perimeter changes with stream flow. Wetted perimeter is the distance along the stream bottom from one water edge to the other along a transect established perpendicular to the flow. Usually this is evaluated in riffles (Lohr 1993). To accomplish this analysis it is necessary to know the bed profile and the location of the left and right water edges at a series of flow levels. To facilitate this analysis, SCE elected to use portions of the PHABSIM programs developed by USFWS to model water surface elevations at different simulated flow levels. Therefore, the field measurement procedures used for the wetted perimeter data collection follow those described for use in PHABSIM studies (Trihey and Wegner 1981).

Each transect selected by the CTST was marked with permanent headpins and a staff gage was placed at each transect to facilitate stage measurement at different flow levels. The headpins, staff gage, and bed profile were surveyed in using standard surveying techniques at a level of detail sufficient to describe the shape of the channel (Trihey and Wegner 1981). Elevations were established relative to a temporary benchmark installed for this purpose. Stage measurements were made at three flow levels. In addition, mean column velocities and depths were measured at several points along each transect. The first set of measurements were taken during spring 2003.

In the performance of this study, several conventions were adopted to facilitate the collection of quality data and timely reduction of those data. These included:

1. All survey loops were closed in the field (± 0.02 ft).

2. All headpins and water surface elevations were referenced to benchmarks allowing relocation of headpins, etc.

3. More than two water surface elevations were surveyed for transects with rapidly varying flow conditions.

4. Water surface elevations were checked before and after transect measurements to identify any change in discharge during the data collection.

5. Discharges were computed in the field prior to leaving the site.

6. The distance of right headpin was established for each transect and matched in subsequent tape placements to facilitate the collection of point velocity measurements at different calibration flows.

After head pin elevations had been established, transects were surveyed to provide bed profiles for input into the IFG-4a stage-discharge model. While surveying the bed profile, the water surface elevation, water surface slope, and stage of zero flow were also surveyed. The stage of zero flow is defined as "the water surface elevation at a cross section when the flow reaches zero. This is either the lowest point of the bed or the pool water surface when no flow occurs" (Hardy 2002).

Measurements were taken at various times during the natural runoff period with the objective of collecting measurements over a range of flows wider than could be obtained through operation of Project facilities alone. The flow measurements taken were used to develop stage-discharge models. Project operations were modified, as necessary, during the study to provide the flows needed to develop reliable stage-discharge relationship.

Discharge was measured within each study site at each of three calibration flows. Flow measurements were taken within each study site, where transects were closely clustered, or near each transect where the transects were more distant from each other. Flow measurements were collected at locations with the best characteristics for a good flow measurement. These were typically not located on the wetted perimeter analysis transects selected by the CAWG. Locations with uniform depth and velocity profiles, preferably runs or pool tails, were selected for calibration discharge measurements. Three stage-discharge measurements were collected for the entire flow-related habitat transects.

For each discharge measurement, standard USGS protocols were followed: depths were measured to the nearest 0.05 ft and velocity to the nearest 0.01-foot per second (fps). The velocity correction angle also was noted at each vertical. The spacing and number of verticals per transect depended on the cross-section profile and complexity of the velocity distribution along each of the transects. An attempt was made to collect measurements at a minimum of 15 to 20 verticals for each measurement, but because of the small size of the channels, this was not always possible. In these cases, we placed as many verticals as possible at 0.2-foot spacing.

1.2.3 Modeling and Analysis

The data collected at the study transects were used to develop stage-discharge models which were used for the wetted perimeter and fish passage analyses. Stage-discharge predictions were developed using either the IFG4a regression of the PHABSIM program. This model regresses the logarithm of discharge against the logarithm of water surface elevation minus the stage at zero flow. The MANSQ model was not used for any of the transects surveyed in 2003.

The stage-discharge models were used to predict water surface elevations at a series of unmeasured discharges. On rare occasions, in order to complete the analyses, it was necessary to model discharges either higher or lower than the range of calibration flows that were measured in the field.

1.2.3.1 Wetted Perimeter Analysis

The wetted perimeter inflection point method is usually based on stream riffles (Lohr 1993), which are affected more by flow changes than other areas of streams. Riffles are important sites for production of invertebrate fish-food organisms (Hynes 1970). Leathe and Nelson (1986) found that the carrying capacity of the stream for fish is proportional to fish-food producing areas and that riffle wetted-perimeter is a reliable index of food producing areas. Because the physical characteristics of riffles are more sensitive to changes in flow than most other habitat types, maintenance of acceptable flows in riffles preserves other stream habitats for fish and macroinvertebrates, as well.

From zero flow, wetted perimeter increases rapidly with small increases in flow until water reaches the sides of the channel. At the point where the instantaneous rate of change in wetted perimeter with increasing discharge decreases, an inflection point occurs on a plot of wetted perimeter versus discharge. A typical wetted perimeter versus discharge curve has either one or two prominent inflection points. Flow recommendations are made at stream discharges equal to or greater than the discharge at the inflection point since flows are judged sufficient to maintain existing aquatic invertebrate communities. When two inflection points occur in the wetted perimeter curve, the upper inflection point is assumed to represent flows providing optimal stream conditions (Nelson 1989). Ultimate selection of a flow recommendation is based on professional judgment relative to the biological potential of the specific stream.

The stage-discharge model for each transect was used in conjunction with the bed profile to develop a wetted perimeter versus flow relationship for each transect. This relationship was plotted, along with the instantaneous rate of change in the wetted perimeter vs. flow relationship to assist in determining the inflection points. In this analysis, emphasis was placed on the instantaneous rate of change curve, as the inflection point of the curve is more clearly identified. The flows at which these inflection points occur serve as the basis for identifying the recommended flow levels in this analysis.

The wetted perimeter analysis for the study streams covers a broad range of flows. Wetted perimeter was simulated for flows approaching and sometimes exceeding bank-full flow. By doing this, the inflection points associated with the channel in non-flood conditions were captured. The wetted perimeter method is intended to assess the flow levels that provide adequate habitat conditions under baseflow conditions. It is not intended to assess habitat conditions under flood conditions. Inflection points in the range of flood flows are not appropriate flow levels for maintaining habitat during the summer months.

1.2.3.2 Fish Passage Analysis

SCE used the channel geometry and the stage-discharge model to evaluate the flows needed for fish passage. The passage flows were determined using Thompson's (1972) criteria for the passage of adult trout. These criteria call for a minimum depth of 0.4 ft occurring over a minimum of 25 percent of the channel width. At least a contiguous 10 percent of the channel width must meet the depth criterion for a transect to be considered passable. However, the 10 percent passable width criterion only was applied in the case of wetted perimeter transects used in smaller streams. It has been our experience that this criterion is almost always met in larger streams where there passage conditions are suitable in at least 25 percent of the transect width. The 25 percent passage width criteria was therefore used without the 10 percent contiguous width criterion in the larger streams analyzed with PHABSIM. Thompson's criteria also requires that maximum water velocity be less than four feet per second (fps) to be passable. This analysis was completed for each transect, and then, as described in Thompson's method, the average of the resulting passage flows of all the transects in that stream reach was calculated to determine the recommended passage flow for that sub-reach of the stream. The recommended passage flow is intended to estimate the instream flow required for passage through the shallower habitats present, in the absence of other structural barriers to passage (i.e., drops, dams, weirs, or substantial debris jams).

1.3 CAWG 7 CHARACTERIZE FISH POPULATIONS

The CAWG 7 Study Report characterized the abundance, distribution, and age structure of target fish populations in Project-affected waters. It also characterized the growth of target fish species.

1.3.1 Review Existing Data

Prior to initiating field data collection, available information was reviewed and summarized by stream. The summary for each stream for which information was available includes the year the sampling was conducted, sampling locations, site characteristics, the species present and their estimated abundance and biomass. Information on fish stocking was reviewed and records of historic introductions were compiled.

1.3.2 Stream Site Selection

Sampling sites were selected in major Rosgen Level I channel types within river and stream reaches associated with study streams. Within each major channel type, potential 100 meter-long candidate fish population sampling sites were identified based on the presence of representative habitats. In the case of small and medium-sized diversions, sites were selected in the reach above the diversion in addition to sites within the bypass reach. Prior to sampling, the candidate sample sites were discussed with the CAWG. Sampling for each site was conducted after CAWG approval was obtained.

1.3.3 Electrofishing Sampling

Electrofishing was conducted using Smith-Root Type 12B backpack electrofishing units. This sampling technique was used in habitats sufficiently shallow (under normal Project operating conditions) to allow adequate sampling. The upstream and downstream ends of the site were blocked using 0.25-inch mesh block nets. Sampling was conducted using multiple pass depletion, in which fish are stunned and removed from the site in multiple sequential passes. In this case, population estimates were based on the maximum likelihood technique of Zippin (1958).

Sampling was performed in an upstream direction beginning at the downstream block net and finishing at the upstream block net. A typical electrofishing team consisted of one backpack electrofisher, one or two net persons, and one net/livecar person for streams smaller than 20 feet wide. Additional backpack electrofishers and net persons were necessary for streams greater than 20 feet wide. Electrofishing was generally conducted as described by Reynolds (1996).

1.3.4 Snorkel Survey Sampling

Snorkel surveys were conducted in habitat units (*i.e.,* pool habitats) that were too deep to be effectively sampled using electrofishing. The snorkeled habitat units were divided into one or more swimming lanes parallel to the direction of stream flow. Methods were generally similar to those presented in Griffith (1972), Platts et al. (1983), Hicks and Watson (1985), Hankin and Reeves (1988), and Hillman et al. (1992). Divers identified and counted fish species in their lane while moving slowly upstream at a uniform, even, pace with no abrupt movements. A bank-side observer monitored and verbally directed diver distribution and sampling rate. Fish lengths were estimated by comparison with a fish length calibration cord. Hankin and Reeves (1988) recommended that visual fish counts should be calibrated using electrofishing techniques.

1.3.5 Fish Measurement and Handling

All captured fish were identified to species, measured for length to the nearest millimeter total length or fork length, and weighed to the nearest 0.1 g for fish up to two kg, or to the nearest one g for fish over two kg. If very large numbers (>100) of a species were captured, the measurements were collected from 10 fish within each 25-

mm size range. Scale samples were collected from trout and hardhead for age and growth determinations.

1.3.6 Physical Condition Measurements

Routine observations were made of habitat and physical conditions in the specific areas sampled. These observations included physical measurements of water temperature, specific conductance, and dissolved oxygen. These measurements were made using either a Hydrolab Quanta or Horiba U-10 water quality meter. Water quality meters were calibrated at least once a day prior to use, to correct for altitude and dissolved oxygen saturation among sites.

1.3.7 Reservoir Sampling

Reservoirs (large and mid-sized diversions) were sampled through a variety of techniques including electrofishing, minnow traps, and trap nets set in shallow areas. Gill and trap nets were set in deeper areas. All sample locations for each method were recorded by GPS coordinates. Set and retrieval times for each method also were recorded to provide Catch-per-Unit Effort (CPUE) estimates for nets.

Hydroacoustic surveys (see CAWG 7 Appendix A) were used to characterize overall fish density and distribution in large reservoirs (e.g., Lake Edison, Florence Lake, Shaver Lake, and Mammoth Pool Reservoir).

Appendix B

Summary of Fish Abundance by Stream and Location

APPENDIX B
SUMMARY OF FISH ABUNDANCE BY STREAM AND LOCATION

The CAWG 7 Study collected data to characterize the abundance, distribution, and structure of fish populations in the Big Creek ALP Project Area (Project). Sampling was conducted in the summer and fall of 2002 within study streams, which include 1) Project bypass reaches, 2) reaches above small diversions, and 3) flow augmented stream reaches. The data were used to estimate fish abundance, biomass, densities and condition factors in streams. Summaries of fish species collected from study streams, as well as estimates of fish densities, biomass and condition factors, are summarized in Table CAWG 14 Appendix B-1.

Table CAWG 14 Appendix B-1. Summary of Fish Abundance by Stream and Location.

Drainage Sub-Basin		South Fork San Joaquin River Basin							
	Stream	South Fork San Joaquin River							
	Order	5	5	5	5	5	5	5	5
	Reach	Upstream of Florence Lake	Florence Lake to Bear Creek		Bear Creek to Mono Crossing			Mono Crossing to Rattlesnake Creek	Rattlesnake Creek to SJR
	Rosgen Level I Channel Type	B	B	C	G	C	B	B	G
Species	Estimate of								
Brown Trout	Density (#/km)	206	522	303	306	226	220	350	385
	Density (#/ha)	225	713	312	261	137	123	174	262
	Biomass (kg/ha)	N/A	35.1	11.1	8.6	9.3	8.3	4.7	10.2
	Condition Factor		1.37	1.45	1.38	1.35	1.32	1.24	1.27
Rainbow Trout	Density (#/km)		174	21	32	632	700	984	837
	Density (#/ha)		238	22	27	382	391	490	571
	Biomass (kg/ha)		13.0	2.0	0.4	6.7	23.9	5.8	9.3
	Condition Factor		1.31	1.84	1.44	1.60	1.31	1.38	1.43
Brook Trout	Density (#/km)								
	Density (#/ha)								
	Biomass (kg/ha)								
	Condition Factor								
Rainbow x Golden Trout Hybrid	Density (#/km)								
	Density (#/ha)								
	Biomass (kg/ha)								
	Condition Factor								
Sacramento Sucker	Density (#/km)								
	Density (#/ha)								
	Biomass (kg/ha)								
Hardhead	Density (#/km)								
	Density (#/ha)								
	Biomass (kg/ha)								
	Condition Factor								
Sacramento Pikeminnow	Density (#/km)								
	Density (#/ha)								
	Biomass (kg/ha)								
Prickly Sculpin	Density (#/km)								
	Density (#/ha)								
	Biomass (kg/ha)								

[1] Data collected in 2002 for Portal Hydroelectric Power Project Relicensing
[2] In 2001, brook trout were also captured with a density estimate of 1,299 fish/km
[3] Data collected in 2000 for Vermilion Valley Hydroelectric Project Relicensing

Table CAWG 14 Appendix B-1. Summary of Fish Abundance by Stream and Location (cont).

Drainage Sub-Basin		South Fork San Joaquin River Basin						
	Stream	Tombstone Creek			South Slide Creek		North Slide Creek	
	Order	1	1	1	1	1	1	1
	Reach	Above Diversion	Below Diversion		Above Diversion	Below Diversion	Above Diversion	Below Diversion
	Rosgen Level I Channel Type	Aa+	Aa+	C/E	Aa+	Aa+	Aa+	Aa+
Species	**Estimate of**							
Brown Trout	Density (#/km)	No Fish	416	No Fish	No Fish	No Fish	No Fish	No Fish
	Density (#/ha)		2,960					
	Biomass (kg/ha)		188.4					
	Condition Factor		1.37					
Rainbow Trout	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
	Condition Factor							
Brook Trout	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
	Condition Factor							
Rainbow x Golden Trout Hybrid	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
	Condition Factor							
Sacramento Sucker	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
Hardhead	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
	Condition Factor							
Sacramento Pikeminnow	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
Prickly Sculpin	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							

[1] Data collected in 2002 for Portal Hydroelectric Power Project Relicensing
[2] In 2001, brook trout were also captured with a density estimate of 1,299 fish/km
[3] Data collected in 2000 for Vermilion Valley Hydroelectric Project Relicensing

Table CAWG 14 Appendix B-1. Summary of Fish Abundance by Stream and Location (cont).

Drainage Sub-Basin		South Fork San Joaquin River Basin					
	Stream	Hooper Creek		Crater Creek			
	Order	3	3	1	1	1	1
	Reach	Above Diversion	Below Diversion	Above Diversion	Below Diversion	Below Diversion	Diversion Channel
	Rosgen Level I Channel Type	Aa+	Aa+	Aa+	Aa+	C	Aa+
Species	Estimate of						
Brown Trout	Density (#/km)					No Fish	
	Density (#/ha)						
	Biomass (kg/ha)						
	Condition Factor						
Rainbow Trout	Density (#/km)						
	Density (#/ha)						
	Biomass (kg/ha)						
	Condition Factor						
Brook Trout	Density (#/km)			547	276		1,193
	Density (#/ha)			1,495	1,919		3,872
	Biomass (kg/ha)			21.2	29.8		81.4
	Condition Factor			1.46	1.05		1.33
Rainbow x Golden Trout Hybrid	Density (#/km)	663	962				
	Density (#/ha)	2,029	4,229				
	Biomass (kg/ha)	71.3	124.9				
	Condition Factor	1.23	1.31				
Sacramento Sucker	Density (#/km)						
	Density (#/ha)						
	Biomass (kg/ha)						
Hardhead	Density (#/km)						
	Density (#/ha)						
	Biomass (kg/ha)						
	Condition Factor						
Sacramento Pikeminnow	Density (#/km)						
	Density (#/ha)						
	Biomass (kg/ha)						
Prickly Sculpin	Density (#/km)						
	Density (#/ha)						
	Biomass (kg/ha)						

[1] Data collected in 2002 for Portal Hydroelectric Power Project Relicensing
[2] In 2001, brook trout were also captured with a density estimate of 1,299 fish/km
[3] Data collected in 2000 for Vermilion Valley Hydroelectric Project Relicensing

Table CAWG 14 Appendix B-1. Summary of Fish Abundance by Stream and Location (cont).

Drainage Sub-Basin		South Fork San Joaquin River Basin					
	Stream	Bear Creek		Chinquapin Creek		Camp 62 Creek	
	Order	4	4	1	1	2	2
	Reach	Above Diversion	Below Diversion	Above Diversion	Below Diversion	Above Diversion	Below Diversion
	Rosgen Level I Channel Type	B	A	Aa+	Aa+	Aa+	Aa+
Species	**Estimate of**						
Brown Trout	Density (#/km)	470	1,406				
	Density (#/ha)	514	3,211				
	Biomass (kg/ha)	18.6	131.3				
	Condition Factor	1.20	1.23				
Rainbow Trout	Density (#/km)						
	Density (#/ha)						
	Biomass (kg/ha)						
	Condition Factor						
Brook Trout	Density (#/km)			665	2,034	945	1,162
	Density (#/ha)			5,452	13,094	5,928	6,780
	Biomass (kg/ha)			122.3	215.8	152.3	124.4
	Condition Factor			1.35	1.01	1.21	1.21
Rainbow x Golden Trout Hybrid	Density (#/km)						
	Density (#/ha)						
	Biomass (kg/ha)						
	Condition Factor						
Sacramento Sucker	Density (#/km)						
	Density (#/ha)						
	Biomass (kg/ha)						
Hardhead	Density (#/km)						
	Density (#/ha)						
	Biomass (kg/ha)						
	Condition Factor						
Sacramento Pikeminnow	Density (#/km)						
	Density (#/ha)						
	Biomass (kg/ha)						
Prickly Sculpin	Density (#/km)						
	Density (#/ha)						
	Biomass (kg/ha)						

[1] Data collected in 2002 for Portal Hydroelectric Power Project Relicensing
[2] In 2001, brook trout were also captured with a density estimate of 1,299 fish/km
[3] Data collected in 2000 for Vermilion Valley Hydroelectric Project Relicensing

Table CAWG 14 Appendix B-1. Summary of Fish Abundance by Stream and Location (cont).

Drainage Sub-Basin		South Fork San Joaquin River Basin							
	Stream	Bolsillo Creek			Adit No. 2[1]		East Fork Camp 61[1]	West Fork Camp 61[1]	Camp 61 Creek[1]
	Order	1	1	1	1	1	1	1	1
	Reach	Above Diversion	Below Diversion	Below Diversion	Upper Site	Lower Site	Above Portal Forebay	Above Portal Forebay	Below Portal Forebay[2]
Rosgen Level I Channel Type		B	Aa+	B	Aa+	Aa+	Aa+	Aa+	B
Species	**Estimate of**								
Brown Trout	Density (#/km)				No Fish	601	49		940
	Density (#/ha)								
	Biomass (kg/ha)								
	Condition Factor					1.07	1.00		1.07
Rainbow Trout	Density (#/km)						81	65	
	Density (#/ha)								
	Biomass (kg/ha)								
	Condition Factor						0.90	1.00	
Brook Trout	Density (#/km)	2,187	143	1,509			1,299	2,040	
	Density (#/ha)	20,503	1,087	12,378					
	Biomass (kg/ha)	431.9	22.6	216.5					
	Condition Factor	1.11	1.22	1.24			0.97	1.02	
Rainbow x Golden Trout Hybrid	Density (#/km)						16		
	Density (#/ha)								
	Biomass (kg/ha)								
	Condition Factor						1.11		
Sacramento Sucker	Density (#/km)								
	Density (#/ha)								
	Biomass (kg/ha)								
Hardhead	Density (#/km)								
	Density (#/ha)								
	Biomass (kg/ha)								
	Condition Factor								
Sacramento Pikeminnow	Density (#/km)								
	Density (#/ha)								
	Biomass (kg/ha)								
Prickly Sculpin	Density (#/km)								
	Density (#/ha)								
	Biomass (kg/ha)								

[1] Data collected in 2002 for Portal Hydroelectric Power Project Relicensing
[2] In 2001, brook trout were also captured with a density estimate of 1,299 fish/km
[3] Data collected in 2000 for Vermilion Valley Hydroelectric Project Relicensing

Table CAWG 14 Appendix B-1. Summary of Fish Abundance by Stream and Location (cont).

Drainage Sub-Basin		South Fork San Joaquin River Basin						
	Stream	Cold Creek[3]	Mono Creek			Boggy Meadow Creek[3]	Warm Creek[3]	
	Order	4	4	4	4	2	2	2
	Reach		Above Lake Edison	Below Lake Edison	Below Diversion		Upper	Lower
	Rosgen Level I Channel Type	B	C	B	B	C/G	G	G
Species	**Estimate of**							
Brown Trout	Density (#/km)	632	2,462	1,259	64	848		
	Density (#/ha)				113			
	Biomass (kg/ha)				3.3			
	Condition Factor	1.01	1.07	1.17	1.10	1.08		
Rainbow Trout	Density (#/km)	74	393	259	11	141		
	Density (#/ha)				19			
	Biomass (kg/ha)				0.9			
	Condition Factor	1.05	1.09	1.20	0.91	1.02		
Brook Trout	Density (#/km)	11	243			576		
	Density (#/ha)							
	Biomass (kg/ha)							
	Condition Factor	N/A	1.07			1.05		
Rainbow x Golden Trout Hybrid	Density (#/km)	11					440	374
	Density (#/ha)							
	Biomass (kg/ha)							
	Condition Factor	N/A					1.06	1.08
Sacramento Sucker	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
Hardhead	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
	Condition Factor							
Sacramento Pikeminnow	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
Prickly Sculpin	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							

[1] Data collected in 2002 for Portal Hydroelectric Power Project Relicensing
[2] In 2001, brook trout were also captured with a density estimate of 1,299 fish/km
[3] Data collected in 2000 for Vermilion Valley Hydroelectric Project Relicensing

Table CAWG 14 Appendix B-1. Summary of Fish Abundance by Stream and Location (cont).

Drainage Sub-Basin		San Joaquin River Basin					
	Stream	Mammoth Reach		Rock Creek		Stevenson Reach	
	Order	6	6	3	3	6	6
	Reach	Upper Site	Lower Site	Above Diversion	Below Diversion	Upper Site	Lower Site
	Rosgen Level I Channel Type	B	B	Aa+	Aa+	G	G
Species	**Estimate of**						
Brown Trout	Density (#/km)	125	52	930	481	7	7
	Density (#/ha)	83	46	2,407	1,155	5	6
	Biomass (kg/ha)	2.0	4.7	91.5	42.4	0.1	0.0
	Condition Factor	1.09	1.18	1.31	1.30	1.22	1.16
Rainbow Trout	Density (#/km)	91	384	241	432	100	
	Density (#/ha)	61	340	623	1,037	76	
	Biomass (kg/ha)	2.1	12.5	29.5	29.0	0.3	
	Condition Factor	1.69	2.25	1.19	1.46	1.36	
Brook Trout	Density (#/km)						
	Density (#/ha)						
	Biomass (kg/ha)						
	Condition Factor						
Rainbow x Golden Trout Hybrid	Density (#/km)						
	Density (#/ha)						
	Biomass (kg/ha)						
	Condition Factor						
Sacramento Sucker	Density (#/km)	498	1,197			514	15
	Density (#/ha)	331	1,061			389	12
	Biomass (kg/ha)	29.3	35.7			3.6	2.5
Hardhead	Density (#/km)						295
	Density (#/ha)						233
	Biomass (kg/ha)						2.2
	Condition Factor						0.97
Sacramento Pikeminnow	Density (#/km)						597
	Density (#/ha)						471
	Biomass (kg/ha)						4.6
Prickly Sculpin	Density (#/km)					43	
	Density (#/ha)					32	
	Biomass (kg/ha)					0.2	

[1] Data collected in 2002 for Portal Hydroelectric Power Project Relicensing
[2] In 2001, brook trout were also captured with a density estimate of 1,299 fish/km
[3] Data collected in 2000 for Vermilion Valley Hydroelectric Project Relicensing

Table CAWG 14 Appendix B-1. Summary of Fish Abundance by Stream and Location (cont).

Drainage Sub-Basin		**Big Creek Basin**						
	Stream	Big Creek						
	Order	4	4	4	4	5	5	5
	Reach	Dam 1 to Powerhouse 1				Dam 4 to Powerhouse 2	Dam 5 to Powerhouse 8	
Rosgen Level I Channel Type		B	G	A	Aa+	A	A	Aa+
Species	**Estimate of**							
Brown Trout	Density (#/km)	320	648	1,214	497	363	602	160
	Density (#/ha)	462	1,852	3,572	1,579	811	946	331
	Biomass (kg/ha)	16.0	50.9	N/A	117.6	N/A	N/A	N/A
	Condition Factor	0.92	1.17		1.42			
Rainbow Trout	Density (#/km)					363	930	769
	Density (#/ha)					811	1,463	1,594
	Biomass (kg/ha)					N/A	N/A	N/A
	Condition Factor							
Brook Trout	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
	Condition Factor							
Rainbow x Golden Trout Hybrid	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
	Condition Factor							
Sacramento Sucker	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
Hardhead	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
	Condition Factor							
Sacramento Pikeminnow	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
Prickly Sculpin	Density (#/km)		14					
	Density (#/ha)		41					
	Biomass (kg/ha)		0.5					

[1] Data collected in 2002 for Portal Hydroelectric Power Project Relicensing
[2] In 2001, brook trout were also captured with a density estimate of 1,299 fish/km
[3] Data collected in 2000 for Vermilion Valley Hydroelectric Project Relicensing

Table CAWG 14 Appendix B-1. Summary of Fish Abundance by Stream and Location (cont).

Drainage Sub-Basin		Big Creek Basin						
	Stream	Pitman Creek			Balsam Creek		Ely Creek	
	Order	3	4	4	3	3	1	2
	Reach	Above Diversion	Below Diversion		Above Diversion	Below Diversion	Above Diversion	Below Diversion
Rosgen Level I Channel Type		B	B	Aa+	Aa+	Aa+	Aa+	Aa+
Species	**Estimate of**							
Brown Trout	Density (#/km)	338	22					
	Density (#/ha)	780	50					
	Biomass (kg/ha)	45.4	3.2					
	Condition Factor	1.12	1.23					
Rainbow Trout	Density (#/km)	1,066	613	1,647	1,335	12	190	266
	Density (#/ha)	2,458	1,426	5,496	8,101	33	1,605	1,635
	Biomass (kg/ha)	57.3	38.2	77.5	171.6	2.3	133.9	76.7
	Condition Factor	1.20	1.71	1.45	1.56	2.07	1.25	1.38
Brook Trout	Density (#/km)	82	22					
	Density (#/ha)	189	50					
	Biomass (kg/ha)	1.5	1.0					
	Condition Factor	1.00	1.06					
Rainbow x Golden Trout Hybrid	Density (#/km)							102
	Density (#/ha)							629
	Biomass (kg/ha)							31.4
	Condition Factor							1.40
Sacramento Sucker	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
Hardhead	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
	Condition Factor							
Sacramento Pikeminnow	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
Prickly Sculpin	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							

[1] Data collected in 2002 for Portal Hydroelectric Power Project Relicensing
[2] In 2001, brook trout were also captured with a density estimate of 1,299 fish/km
[3] Data collected in 2000 for Vermilion Valley Hydroelectric Project Relicensing

Table CAWG 14 Appendix B-1. Summary of Fish Abundance by Stream and Location (cont).

Drainage Sub-Basin		Big Creek			
	Stream	Adit No 8	Rancheria Creek[1]		
	Order	1	3	3	3
	Reach	Below Diversion	Above Energy Dissipater	Below Energy Dissipater	Below Energy Dissipater
	Rosgen Level I Channel Type	Aa+	B	B	A
Species	Estimate of				
Brown Trout	Density (#/km)	No Fish	132	110	22
	Density (#/ha)				
	Biomass (kg/ha)				
	Condition Factor		1.71	1.40	1.11
Rainbow Trout	Density (#/km)		963	679	580
	Density (#/ha)				
	Biomass (kg/ha)				
	Condition Factor		1.39	1.39	1.18
Brook Trout	Density (#/km)		569	154	33
	Density (#/ha)				
	Biomass (kg/ha)				
	Condition Factor		1.40	1.12	1.06
Rainbow x Golden Trout Hybrid	Density (#/km)				
	Density (#/ha)				
	Biomass (kg/ha)				
	Condition Factor				
Sacramento Sucker	Density (#/km)		307	88	33
	Density (#/ha)				
	Biomass (kg/ha)				
Hardhead	Density (#/km)				
	Density (#/ha)				
	Biomass (kg/ha)				
	Condition Factor				
Sacramento Pikeminnow	Density (#/km)				
	Density (#/ha)				
	Biomass (kg/ha)				
Prickly Sculpin	Density (#/km)				
	Density (#/ha)				
	Biomass (kg/ha)				

[1] Data collected in 2002 for Portal Hydroelectric Power Project Relicensing
[2] In 2001, brook trout were also captured with a density estimate of 1,299 fish/km
[3] Data collected in 2000 for Vermilion Valley Hydroelectric Project Relicensing

Table CAWG 14 Appendix B-1. Summary of Fish Abundance by Stream and Location (cont).

Drainage Sub-Basin		Stevenson and North Fork Stevenson Reach						
	Stream	North Fork Stevenson Creek				Stevenson Creek		
	Order	2	2	2	2	3	3	3
	Reach	Upstream of Tunnel 7 Outlet	Downstream of Tunnel 7 Outlet			Downstream of Shaver Lake Dam		
Rosgen Level I Channel Type		Aa+	Aa+	G	C	B	Aa+	A
Species	**Estimate of**							
Brown Trout	Density (#/km)	No Fish		305	430			
	Density (#/ha)			703	2,170			
	Biomass (kg/ha)			43.7	33.2			
	Condition Factor			1.23	1.39			
Rainbow Trout	Density (#/km)			210	314	751	966	128
	Density (#/ha)			485	1,588	2,829	3,161	309
	Biomass (kg/ha)			13.5	29.8	52.3	74.9	N/A
	Condition Factor			1.27	1.27	1.04	1.34	
Brook Trout	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
	Condition Factor							
Rainbow x Golden Trout Hybrid	Density (#/km)		583	11				
	Density (#/ha)		487	24				
	Biomass (kg/ha)		9.0	1.3				
	Condition Factor		0.98	1.35				
Sacramento Sucker	Density (#/km)			11	42			
	Density (#/ha)			24	212			
	Biomass (kg/ha)			13.5	65.9			
Hardhead	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
	Condition Factor							
Sacramento Pikeminnow	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							
Prickly Sculpin	Density (#/km)							
	Density (#/ha)							
	Biomass (kg/ha)							

[1] Data collected in 2002 for Portal Hydroelectric Power Project Relicensing
[2] In 2001, brook trout were also captured with a density estimate of 1,299 fish/km
[3] Data collected in 2000 for Vermilion Valley Hydroelectric Project Relicensing

Appendix C

Summary of Fish Population Status Relative to Big Creek Facilities

APPENDIX C
SUMMARY OF FISH POPULATION STATUS RELATIVE TO BIG CREEK FACILITIES

Results from the CAWG 7 Technical Study Report (SCE 2003c) are summarized to characterize the status of existing fish populations. Populations are considered self-sustaining if there is evidence of successful reproduction and recruitment to the population. Moyle et al. (1998) defined good condition for a species at the population level: "…good condition means that each population must have (1) multiple age classes (evidence of reproduction), (2) a viable population size, and (3) healthy individuals."

Information collected for the CAWG 7 study plan addressed these characteristics. Age class structure within populations indicates whether the population is likely to be self-sustained. The presence of young-of-the-year fish indicated reproduction occurred in the vicinity of the area where fish were collected. The presence of multiple age classes indicated that recruitment to the population occurred and continues to occur. In populations that are stocked with catchable-sized trout, the presence of young-of-the-year fish indicates natural reproduction also occurs. (Rainbow trout are currently stocked in some drainages, brown and brook trout are not). The presence of multiple age classes of trout, despite the lack of recent stocking, indicates that reproduction occurred in the vicinity of the area that fish were collected. In some cases, only a few fish of a particular species were captured, and it was likely that the local population may have been sustained by seeding from upstream reaches. In some cases, there is clear evidence of recruitment, but young-of-the-year may not have been sampled. This may be due to several mechanisms including predation by piscivorous fish or cannibalism, in the case of brown trout. Since sampling occurred in the fall in many locations, young-of the-year-fish may have dispersed from some locations, as well. It also is possible for some smaller streams to sustain partial or complete year class failure, especially in dry water years. Both 2001 and 2002 were dry water years, sampling took place during 2002.

Densities of fish numbers and biomass were calculated to address abundance. Target fish species were examined in the field, condition factors were calculated to characterize growth patterns and individual "health." Signs of disease or injury were noted when encountered. These characteristics also were used to assist in the interpretation of the general status of target fish populations.

Table CAWG 14 Appendix C-1 summarizes the status of fish populations within Project study streams and impoundments based on data collected for the CAWG 7 Technical Study Report (SCE 2003c), the Vermilion Valley Hydroelectric Project (SCE 2001b), and Portal Power Plant Project License Applications (SCE 2003d).

Table CAWG 14 Appendix C-1. Summary of Fish Population Status Relative to Project Facilities.

Drainage	Stream (facility)	Reach or Location	Fish Species Collected	Population Status
South Fork San Joaquin River	Florence Lake	Reservoir	Brown trout	Self Sustained
			(Rainbow trout observed, not collected)[1]	
	SFSJR mainstem	Upstream of Florence Lake	Brown trout[2]	Self-sustained
	SFSJR mainstem	Florence Lake to SJR	Brown trout	Self-sustained
			Rainbow trout	Self-sustained and stocked
	Tombstone Creek	Above diversion	No fish	
		Below diversion	Brown trout	Self-sustained
	North Slide Creek	Above and below diversion	No fish	
	South Slide Creek	Above and below diversion	No fish	
	Hooper Creek	Above diversion	Golden x rainbow trout hybrid	Self-sustained, multiple age classes[3]
		Below diversion	Golden x rainbow trout hybrid	Self-sustained
	Crater Creek	Above diversion	Brook trout	Self-sustained
		Below diversion	Brook trout	Self-sustained
	Crater Creek Diversion Channel		Brook trout	Self-sustained
	Bear Creek	Above diversion	Brown trout	Self-sustained
		Below diversion	Brown trout	Self-sustained
		Forebay	Brown trout	Self-sustained
			Rainbow trout	Self-sustained
	Chinquapin Creek	Above diversion	Brook trout	Self-sustained
		Below diversion	Brook trout	Self-sustained
	Camp 62 Creek	Above diversion	Brook trout	Self-sustained
		Below diversion	Brook trout	Self-sustained
	Bolsillo Creek	Above diversion	Brook trout	Self-sustained
		Below diversion	Brook trout	Self-sustained
	Lake Thomas A. Edison		Brown trout	Self-sustained
			Rainbow trout	Stocked
			Brook trout	Self-sustained

[1] Last stocked in 1998.

[2] Adults observed moving upstream, population may consist of younger rearing fish with adults rearing in Florence Lake.

[3] No young-of-year found, but no other source for recruitment than local population.

Table CAWG 14 Appendix C-1. Summary of Fish Population Status Relative to Project Facilities (cont).

Drainage	Stream (facility)	Reach or Location	Fish Species Collected	Population Status
	Mono Creek	Above Lake Edison	Brown trout	Self-sustained
			Rainbow trout	Unknown[4]
			Brook trout	Self-sustained
	Boggy Meadow Creek		Brown trout	Self-sustained[5]
			Rainbow trout	Unknown[4]
			Brook trout	Self-sustained
	Mono Creek	Below Lake Edison to diversion	Brown trout	Self-sustained
			Rainbow trout	Stocked
		Forebay	Brown trout	Self-sustained
			Rainbow trout	Stocked[6]
		Below diversion	Brown trout	Self-sustained
			Rainbow trout	Self-sustained
	Warm Creek	Above diversion	Golden X rainbow trout hybrid	Self Sustained
		Below diversion	Golden X rainbow trout hybrid	Self Sustained
San Joaquin River	Mammoth Pool	Reservoir	Brown trout	Self-sustained
			Rainbow trout	Stocked
	SJR mainstem Mammoth Reach	Mammoth Pool to Mammoth Pool Powerhouse	Sacramento sucker	Self-sustained
			Brown trout	Self-sustained
			Rainbow trout	Self-sustained
	Rock Creek	Above diversion	Brown trout	Self-sustained
			Rainbow trout	Self-sustained and stocked
		Below diversion	Brown trout	Self-sustained
			Rainbow trout	Self-sustained and stocked
	Ross Creek	Above diversion	Not sampled	
		Below diversion	Not sampled	
	Dam 6 (Big Creek Powerhouse 3)	Forebay	Sacramento sucker	Self-sustained
			Brown trout	Self-sustained
			Rainbow trout	Self-sustained

[4] May move from Lake Edison.

[5] Age 3+ predominant.

[6] Hatchery rainbow trout collected.

Table CAWG 14 Appendix C-1. Summary of Fish Population Status Relative to Project Facilities (cont).

Drainage	Stream (facility)	Reach or Location	Fish Species Collected	Population Status
	SJR mainstem Stevenson Reach	Upper site	Brown trout	Self-sustained
			Rainbow trout	Self-sustained
			Sacramento sucker	Self-sustained
			Sculpin	Self-sustained
		Lower site	Brown trout	Self-sustained
			Sacramento sucker	Self-sustained
			Hardhead[7]	Self-sustained
			Sacramento pikeminnow[7]	Self-sustained
Big Creek	Huntington Lake	Reservoir	Brown trout	Self-sustained
			Rainbow trout	Self-sustained and stocked
			Kokanee	Stocked[8]
			Sacramento sucker	Self-sustained
			Sculpin	Self-sustained
	Rancheria Creek	Above and below energy dissipater[9]	Brown trout	Self-sustained
			Rainbow trout	Self-sustained
			Brook trout	Self-sustained
			Golden x rainbow trout hybrid	Self-sustained
			Sacramento sucker	No YOY, no recent reproduction[10]
	Big Creek Dam 1 to Powerhouse 1 (Dam 4)	Big Creek Upstream of PH 1	Brown trout	Self-sustained
			Sculpin	Self-sustained
		Big Creek PH 2 (Dam 4) Forebay	Brown trout	Self-sustained
			Rainbow trout	Self-sustained
			Sculpin	Self-sustained
	Pitman Creek	Above diversion	Rainbow trout	Self-sustained
			Brown trout	Self-sustained
			Brook trout	Self-sustained
		Below diversion	Rainbow trout	Self-sustained
			Brown trout	Limited[11]
			Brook trout	Limited[11]

[7] Population may include or be part of fish originating from Redinger Lake.

[8] Natural reproduction also occurred. However, contribution is unknown.

[9] Accessible by fish from Huntington Lake, may represent spawning and juvenile rearing area.

[10] It is unknown whether the Sacramento suckers move from Huntington Lake into Rancheria Creek to spawn, or if rearing and spawning occurs in Rancheria Creek.

[11] Population may have originated from upstream of the diversion.

Table CAWG 14 Appendix C-1. Summary of Fish Population Status Relative to Project Facilities (cont).

Drainage	Stream (facility)	Reach or Location	Fish Species Collected	Population Status
	Big Creek Dam 4 to Powerhouse 2 (Dam 5)	Big Creek Upstream of PH 2	Brown trout	Self-sustained
			Rainbow trout	Self-sustained
		Big Creek PH 8 Forebay (Dam 5) Forebay	Brown trout	Self-sustained
			Rainbow trout	Unknown[12]
			Sculpin	Unknown[12]
	Balsam Creek	Above diversion	Rainbow trout	Self-sustained
		Below diversion	Rainbow trout	Limited[13]
	Balsam Meadow Forebay	Forebay	Rainbow trout	Stocked[14]
			Brown trout	Only age 6+ and older[14]
			Sacramento sucker	Self-sustained or seeded[14]
			Sculpin	Self-sustained
			Kokanee	Rearing and seeded[14]
	Big Creek Dam 5 to Powerhouse 8	Big Creek upstream of PH 8	Brown trout	Self-sustained
			Rainbow trout	Self-sustained
	Ely Creek	Above diversion	Rainbow trout	Self-sustained, multiple age classes[15]
		Below diversion	Rainbow trout	Self-sustained
			Rainbow trout x Golden trout	Self-sustained
	Adit No. 8 Creek[16]	Below diversion	No fish	

[12] Only one fish was collected.

[13] Population may have originated from upstream of the diversion.

[14] All species could pass from Huntington Lake or Shaver Lake.

[15] No young-of-year found, but no other source for recruitment than local population.

[16] Ephemeral stream.

Table CAWG 14 Appendix C-1. Summary of Fish Population Status Relative to Project Facilities (cont).

Drainage	Stream (facility)	Reach or Location	Fish Species Collected	Population Status
Stevenson Creek	Shaver Lake	Reservoir	Rainbow trout	Stocked and Self-sustained
			Kokanee	Stocked
			Sacramento sucker	Self-sustained
			Cyprinids	Self-sustained
			Centrarchids	Self-sustained
	North Fork Stevenson Creek	Upstream of Tunnel 7 Outlet	No fish	
		Downstream of Tunnel 7 Outlet	Brown trout	Self-sustained
			Rainbow trout	Self-sustained
			Golden x Rainbow trout hybrids	Self-sustained
			Sacramento sucker[17]	No YOY - no recent reproduction[18]
	Stevenson Creek	Downstream of Shaver Lake Dam	Rainbow trout	Self-sustained

[17] May originate from Huntington Lake

[18] No sucker younger than age 4+ identified

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