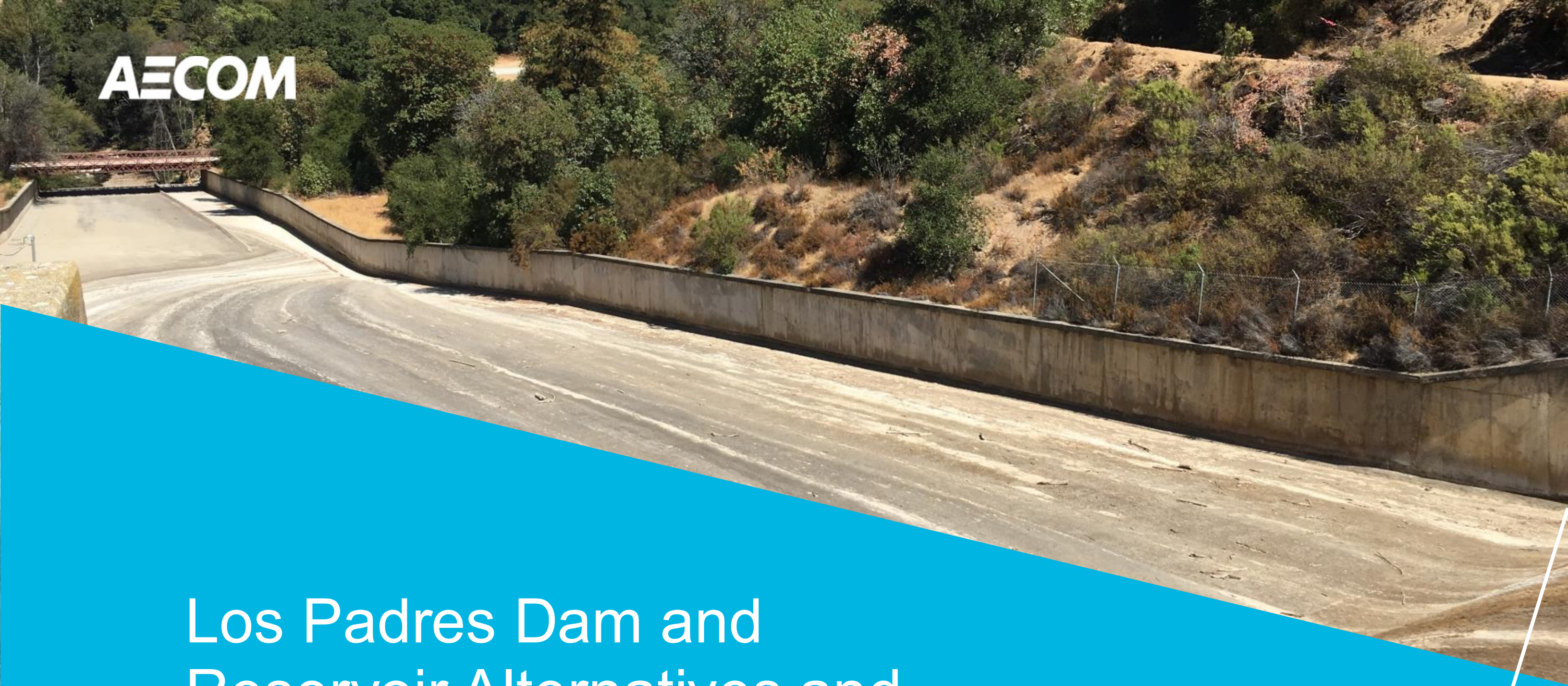

Los Padres Dam and Reservoir Alternatives and Sediment Management Study Study Preparation Technical Memorandum

Prepared by:

AECOM
300 Lakeside Drive, Suite 400
Oakland, CA 94612
USA
aecom.com

Prepared with assistance from:
HDR Engineering, Inc., Stillwater Sciences, and Balance Hydrologics

Prepared for:
Monterey Peninsula Water Management District

In cooperation with:
California American Water

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List of Acronyms and Abbreviations

AF	acre-feet
AFY	acre-feet per year
ASR	Aquifer Storage Recovery
BGS	Behavioral Guidance System
BLP	below Los Padres Reservoir
Cal-Am	California American Water
CDFW	California Department of Fish and Wildlife
CDMG	California Division of Mines and Geology
cfs	cubic feet per second
CRBHM	Carmel River Basin Hydrologic Model
DPS	Distinct Population Segment
DSOD	California Division of Safety of Dams
EIR	Environmental Impact Report
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FR	Federal Register
ft^2	square feet
FWC	Floating Weir Collector
HDR	HDR Engineering Inc.
IFIM	Instream Flow Incremental Method
Los Padres Fish Passage Study	Los Padres Dam Fish Passage Feasibility Study
LP Alternatives Study	Los Padres Dam and Reservoir Alternatives and Sediment Management Study
MOA	Memorandum of Agreement
MPWMD	Monterey Peninsula Water Management District
MPWSP	Monterey Peninsula Water Supply Project
NAVD88	North American Vertical Datum of 1988
NMFS	National Marine Fisheries Service
PIT	Passive Integrated Transponder
Plan	2014 *Los Padres Dam and Reservoir Long-Term Strategic and Short-Term Tactical Plan*
PMF	Probable Maximum Flood
Reclamation	United States Bureau of Reclamation
RM	River Mile
S-CCC steelhead	South-Central California Coast steelhead
SHW	Sleepy Hollow Weir
SWRCB	State Water Resources Control Board
TM	Technical Memorandum
TRC	Technical Review Committee
USACE	United States Army Corps of Engineers
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

1. Introduction

This Technical Memorandum (TM) is the primary deliverable for Task 1 of the Los Padres Dam and Reservoir Alternatives and Sediment Management Study (LP Alternatives Study). It is provided in draft form prior to Technical Review Committee (TRC) Meeting No. 1, and will be revised following TRC Meeting No. 1, based on feedback provided and additional information received at that meeting. The intent of this TM is to summarize the information needed to complete the technical analyses and engineering required for concept development; to allow TRC members to become familiar with the physical, operational, hydrologic, and biological setting of the Los Padres Dam and potential effects to the Carmel River; the range of options that could be considered; and draft criteria to evaluate concepts.

1.1 Report Organization

This report is organized into the following seven sections:

- Section 1, Introduction, provides an introduction to the LP Alternatives Study and this TM.
- Section 2, Project Setting, identifies or summarizes background information important for identifying concepts and alternatives that are compatible with hydrological and physical constraints, while meeting the LP Alternatives Study objectives.
- Section 3, Cost Considerations, summarizes primary considerations expected to drive the costs associated with the different types of alternatives.
- Section 4, Evaluation Criteria, presents preliminary criteria that may be used to evaluate alternatives to be developed in subsequent tasks.
- Section 5, Preliminary List of Alternatives, provides a preliminary list of alternatives that will be addressed during a subsequent task of the LP Alternatives Study.
- Section 6, Data Gaps, summarizes additional information that may be useful to complete the LP Alternatives Study.
- Section 7, References, provides a list of works cited as references in this report.

1.2 Study Objectives

The LP Alternatives Study will provide critical information to answer key questions related to Los Padres Dam, including:

- Are Carmel River steelhead (*Oncorhynchus mykiss*) better off with or without Los Padres Dam and Reservoir?
- Is Los Padres Reservoir critical for water supply on the Monterey Peninsula? Is it feasible to expand reservoir capacity, and what effects would this have on water supply and the environment?
- Are there feasible alternatives to manage existing sediment deposition and future sediment inflow to the reservoir?
- What would be the geomorphic response of the Carmel River to management actions considered, and will there be an increased erosion and/or flood risk?

1.3 Study Overview

A team of engineering and science consultants led by AECOM, and including Balance Hydrologics, Stillwater Sciences, and HDR Engineering Inc. (HDR), has been retained by the Monterey Peninsula Water Management District (MPWMD) to prepare a study that investigates the technical, biological, and economic feasibility of a broad suite of alternatives for Los Padres Dam and Reservoir that includes dam removal, retention of the existing reservoir with the addition of fish passage and sediment management, and reservoir expansion. The study is partially funded by California American Water (Cal-Am), and will be conducted in close coordination with the TRC, which consists of technical experts and representatives from the MPWMD, Cal-Am, the National Marine Fisheries Service (NMFS), and the California Department of Fish and Wildlife (CDFW). An important part of the study is evaluating how changes in sediment transport or management could affect the Carmel River. Potential dam and reservoir alternatives identified in the process will be evaluated and measured against a list of evaluation criteria, and all work will be summarized in a final report, with task information described in TMs at various points in the study.

The specific LP Alternatives Study work plan includes five tasks, outlined below:

- Task 1, Feasibility Study Preparation
  - Compile Background Information
  - Prepare Evaluation Criteria
  - Identify Critical Data Gaps
  - TRC Meeting No. 1
- Task 2, Sediment Management Options
  - Obtain and Analyze Reservoir Sediment Samples
  - Describe Alternatives
  - Evaluate Geomorphic Effects of Changes in Sediment Load
- Task 3, Evaluate Effects on Steelhead
  - Increases in Sediment Transport
  - No Increase in Sediment Transport
  - Incorporate Data from Alternative Water Supply Options
- Task 4, Identify Feasible Alternatives
  - TRC Meeting No. 2
  - Alternatives Development
  - TRC Meeting No. 3
- Task 5, Final Report

1.4 Limitations

This TM summarizes the results of AECOM's review of readily available data and the data made available to us by Cal-Am, MPWMD, and other TRC members, as well as data obtained from the California Division of Safety of Dams (DSOD) for Los Padres Dam. Professional services were provided to review previous data and reports, interpret the data for relevance to the Alternatives Study, comment on the validity of prior studies, identify data gaps, and provide recommendations for additional investigations. Data provided by others were summarized and interpreted, but not reviewed for accuracy. The conclusions, recommendations, and professional opinions presented herein were developed by AECOM for the MPWMD in accordance with generally accepted engineering principles and practices. We make no other warranty, either expressed or implied.

2. Project Setting

Available background information to address the physical environment and setting has been compiled and is presented in this section. Existing information of interest includes the dam, reservoir, facility operations, river channel, hydrology, and steelhead biology. Information in this section was drawn from the extensive background review presented in the LP Alternatives Study Request for Proposals (Cal-Am and MPWMD 2016), and supplemented with additional sources.

2.1 Overview

Los Padres Dam is located at River Mile (RM, measured from the ocean) 24.8 on the Carmel River, which flows into the Monterey Bay National Marine Sanctuary about 5 miles south of Monterey, California (Cal-Am and MPWMD 2016) (Figure 2-1). Los Padres Dam was built in 1948, and is currently owned by Cal-Am. Property immediately surrounding the dam and reservoir is owned by Cal-Am (Figure 2-2). The dam forms a 148-foot-high earth-fill barrier along the river, and includes a 600-foot-long concrete spillway with an apron that spills water over a drop into the Carmel River. It has been a known fish passage impediment for both upstream and downstream migrating South-Central California Coast (S-CCC) steelhead, and impacts downstream habitat for steelhead by blocking the natural sediment supply. Los Padres Dam and Reservoir can be accessed via Carmel Valley Road, Cachagua Road (or Tassajara Road to Cachagua Road), and then Nason Road to the dam site.

Due to episodic flows and the highly erosive nature of the contributing watershed, reservoir storage has shrunk about 40 percent, from 3,030 acre-feet (AF) to 1,809.9 AF, at the spillway level (Cal-Am and MPWMD 2016). Usable storage is estimated at about 1,450 AF, or about 48 percent of original storage capacity. In 1995, the State Water Resources Control Board (SWRCB) reduced Cal-Am's water rights associated with the dam to 2,179 AF, due to siltation in the reservoir. The long-term average siltation rate at the reservoir is estimated at approximately 21 acre-feet per year (AFY) (the range in the estimate is heavily influenced by a single year's worth of heavy siltation in 1978, when there was high sediment laden runoff following the 1977 Marble-Cone fire) (MWH 2013 and Matthews 1989). The reservoir has not been dredged since it was built, but several accidental sediment sluicing events occurred using the outlet works in October 1981, due to a buildup of silt in the reservoir after the 1977 Marble-Cone fire, and extreme low water conditions in the reservoir (MPWMD 1981).

Downstream of Los Padres Dam, there is significant armoring of the streambed and incision into floodplain deposits along the lower 16-mile alluvial portion of Carmel Valley as a result of sediment retention at both Los Padres Dam and the former site of the San Clemente Dam (RM 18.6) (Cal-Am and MPWMD 2016). San Clemente Dam, constructed from 1920 to 1921, and Old Carmel River Dam (approximately 1,700 feet downstream of San Clemente Dam), constructed in 1883, were removed in 2015. Their removal has improved steelhead passage, and allows sediment from the 80-square-mile watershed between San Clemente and Los Padres dams to be transported downstream.

During dry periods (normally from May through October), releases from Los Padres Reservoir constitute the majority of flow in the river downstream of Los Padres Dam, where significant numbers of threatened steelhead can be found in some years (Cal-Am and MPWMD 2016). Although Los Padres Dam and the associated reservoir currently has value as a water supply facility to meet municipal demand and enhance summer flow in the river, the reservoir does not provide flood protection to downstream reaches. The dam is routinely inspected by DSOD and is in satisfactory condition (i.e., it is safe in a maximum credible earthquake and can pass a probable maximum flood estimated at 36,000 cubic feet per second [cfs]).

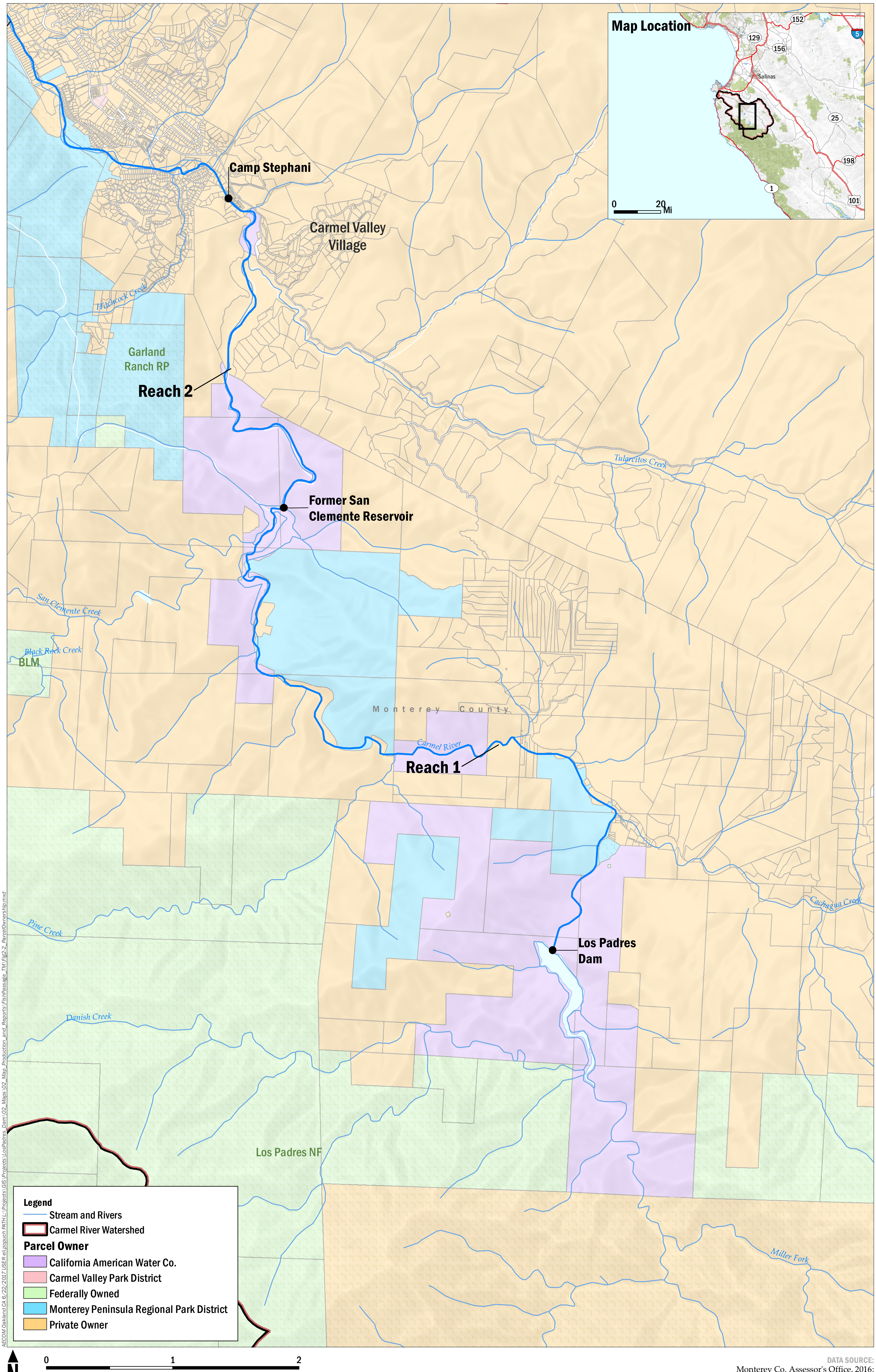
DATA SOURCE:
MPWMD 2004 and 2014.

AECOM

Los Padres Dam and Reservoir Alternatives and Sediment Management Study

FIGURE 2-1

Project Vicinity



DATA SOURCE:
Monterey Co. Assessor's Office, 2016;
MPWMD 2004 and 2014.

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Monterey Peninsula Water Management District

Los Padres Dam and Reservoir Alternatives and Sediment Management Study

FIGURE 2-2

Parcel Ownership

NMFS has strongly encouraged Cal-Am to resolve the steelhead passage issues and other potential take issues involved with Los Padres Dam (Cal-Am and MPWMD 2016). NMFS has also suggested that removal of Los Padres Dam should be considered; however, NMFS recognized in the S-CCC Steelhead Recovery Plan that Los Padres Dam is part of the regional water supply, and studies are required to come to a conclusion about the future of the dam. In 2013, a Cal-Am consultant evaluated dredging of reservoir sediments to recover storage (see Section 2.2.2 for a summary of this study); however, due to the high projected cost (up to $90 million), this alternative has not been pursued.

In summary, current impacts associated with Los Padres Dam and Reservoir sediment accumulation include (Cal-Am and MPWMD 2016):

- A disconnect in habitat and natural river functions between the upper and lower portions of the watershed;
- Impaired upstream and downstream steelhead passage through the reservoir and at the dam, and habitat degradation downstream of the dam due to sediment starvation and armoring of the channel bed;
- Reduced storage capacity, resulting in reduced dry season releases, loss of water rights, and inability to meet release requirements associated with the water right license for the dam; and
- Degradation in the water quality of dry season releases (i.e., increased temperature, decrease in dissolved oxygen, increase in anoxic releases, and increase in hydrogen sulfide).

Current benefits associated with Los Padres Dam and Reservoir include (Cal-Am and MPWMD 2016):

- Maintains a water right to help supply the Monterey Peninsula;
- Provides the only significant source of flow to the river downstream of Los Padres Dam during dry periods and augments natural flow during dry periods to improve the quantity and quality of steelhead habitat downstream of Los Padres Dam (Without reservoir releases, much of the river down to the confluence with Cachagua Creek would likely be dry or intermittent during the summer, in dry and critically dry water year types. Reservoir releases can also increase flow conditions during normal years, when unimpaired flows would likely be 1 or 2 cfs and augmented flows are 5 or 6 cfs); and
- Captures debris flows from the upper watershed that could affect downstream properties.

2.2 Summary of Previous and Ongoing Studies

This section provides an overview of previous and ongoing studies with emphasis on the data and results relevant to the LP Alternatives Study. These studies will likely either inform the development of alternatives for Los Padres Dam and Reservoir, or be used to evaluate the alternatives developed.

2.2.1 Sediment Transport Studies in Support of San Clemente Dam Removal

Between 2001 and 2007, MEI, Inc. evaluated release of up to 1,500 AF of sediment stored behind the former San Clemente Dam, and generally found that releases above the historic input would likely result in aggradation and potentially raise 100-year flood elevations in some locations along the alluvial reach; however, one of the constraints in the HEC-6T sediment transport model placed a scour limit of 1 foot. Essentially, the model allowed significant aggradation, but little degradation during periods when the system supply is limited. Although this was a conservative approach to estimating potential impacts, it is clear that periods of degradation result in a deeper channel that can store a significant volume of sediment without significantly raising flood elevations (MEI 2007).

Previous studies by MEI indicate that additional sediment delivered to the canyon reach should be transported through that upper reach relatively quickly (i.e., over the course of 6 to 41 years, depending on the volume of sediment) (MEI 2002a). Recent experience at the Carmel River Reroute project appears to confirm this, and shows that there are beneficial effects (e.g., establishment of excellent spawning habitat), as well as some negative effects (pools filled in with sand) of increased sediment delivery. In the canyon reach, an increase in flood elevations due to channel aggradation is likely not a significant issue, due to the lack of human infrastructure (Cal-Am and MPWMD 2016).

Conditions in the lower reach are more complex (Cal-Am and MPWMD 2016). In some areas with extensive urban development in the 100-year floodplain, any increase in flood elevations due to an increase in sediment supply could be considered a significant impact. In other areas, where long-term degradation has caused incision into floodplain deposits and infrastructure is exposed, an increase of sediment could have a beneficial effect. What is unclear is how much material can be transported through the channel without a significant adverse effect on 100-year flood elevations.

2.2.2 Los Padres Dam Sediment Removal Feasibility Study

MWH completed a study for Cal-Am in 2013 that considered a number of potential sediment management options for Los Padres Reservoir, and ultimately proposed three mechanical removal alternatives (MWH 2013). The study reviewed reservoir sediment management options recommended by the United States Bureau of Reclamation (Reclamation), the United States Society on Dams, and the H. John Heinz III Center for Science, Economics, and the Environment; and evaluated their applicability at Los Padres Reservoir (Table 2-1). The recommended and typically applied sediment management strategies, such as sediment re-routing, drawdown flushing, reservoir emptying, and siphoning, were determined to be impractical at Los Padres because of the dam configuration and design, and the reservoir operation constraints.

Mechanical removal methods were determined to be the only feasible sediment management strategy for restoring the reservoir capacity at Los Padres Reservoir. As a result, the following three alternative sediment removal alternatives were investigated and developed for evaluation:

- Alternative 1 would remove about 1.8 million cubic yards, or an equivalent of 1,134 AF, of sediment to almost restore full original reservoir capacity. This alternative would involve removing about 810,000 cubic yards of material in the upper reach of the reservoir in the dry, using conventional earth-moving methods when the reservoir is lowered during the construction season. In addition, approximately 1 million cubic yards of sediment below the reservoir pool would be removed using a wet dredging method. The removed material would be placed in a proposed disposal site in the upstream watershed beyond the southwestern end of the reservoir, in Cal-Am's property (Figure 2-3). Construction of this alternative would take 7 years at an approximate cost of $90 million. The cost range of recovered water supply would be $53,000 to $94,000 per AF, and would restore reservoir capacity to a total of 2,920 AF.

- Alternative 2 would remove a portion of the sediment in the upper reach of the reservoir using conventional earth-moving methods in the dry, when the reservoir is drawn down to an established minimum level. This alternative would remove approximately 810,000 cubic yards, or an equivalent of 502 AF of sediment. The removed material would be placed in a proposed disposal site in the upstream watershed beyond the southwestern end of the reservoir, in Cal-Am's property. Construction of this alternative would take 6 years, at an approximate cost of $47 million. The cost of recovered water supply would be $62,000 to $112,000 per AF, and would restore reservoir capacity to a total of 2,288 AF.

- Alternative 3 would remove a portion of the sediment in the lower reach of the reservoir using wet dredging methods from a barge. This alternative would remove approximately 900,000 cubic yards, or an equivalent of 558 AF of sediment. The removed material would be placed in a disposal site on a flat terrace area immediately downstream of the dam (Figure 2-4). Construction of this alternative would take 7 years, at an approximate cost of $50 million. The cost of recovered water supply would be $59,000 to $108,000 per AF, and would restore reservoir capacity to a total of 2,344 AF.

Table 2-1. Sediment Management Options Previously Evaluated at Los Padres Reservoir

Sediment Management Option	Description	Applicability at Los Padres Reservoir
No Action	No sediment removal would occur. This alternative is typically provided as a baseline for comparison against other removal methods.	No action will result in decreasing storage capacity and require planning for future change in operation.
Soil Conservation/ Sediment Inflow Reduction	Three methods are commonly used to reduce the sediment load entering the reservoir. Structural measures include terraced farmlands, flood interception and diversion works, bank protection works, check dams, and silt trapping dams. Vegetative measures include growing soil, water conservation forests, and reforestation. Tillage practice includes different farming practices.	Structural measures are impractical due to difficult access and impacts to steelhead spawning habitat. Vegetative measures are impractical due to steep, inaccessible terrain and disturbance to wilderness areas. Tillage is impractical because the watershed above the reservoir is not farmland.
Incoming Sediment Bypass/Sediment Routing	Bypassing heavily sediment-laden flows during the flood season through a channel or tunnel.	Difficult to implement, given the sediment transport characteristics of the watershed and the high cost of developing the bypass (includes notable environmental impact as well).
Density-Current Venting	A density current is a sediment-laden reservoir inflow, which will flow along the bottom and remain unmixed with the rest of the water body because of a difference in density. It can be vented by opening bottom outlets and letting the density current flow out of the reservoir.	Difficult to implement, given the sediment transport characteristics of the watershed. Also, it results in release of a high sediment concentration into the downstream river that significantly impacts habitat and species.
Drawdown Flushing/ Lateral Erosion	Includes the lowering of the reservoir table so that a riverine flow establishes along the impounded reach. The river erodes a channel through the deposited sediment, and the flushing transports the sediment through the outlet and downstream.	Releases a high sediment concentration downstream, which significantly impacts habitat and species. Not achievable, given the reservoir configuration and outlet size.
Reservoir Emptying with Sediment Flushing	In comparison with the drawdown flushing, the reservoir emptying loses the whole water storage. The sediment is also transported to the downstream river through a lower gate.	Results in release of a high sediment concentration into the downstream river that significantly impacts habitat and species.
Siphon and/or Suction Dredging	Siphon dredging uses the head difference between the upstream and downstream levels of a dam as the source of power. At the end of the pipe, the sediment deposits are either released directly downstream, or further processed to separate the sediment and water. Suction dredging requires conventional energy sources (diesel fuel) to run the dredger that physically evacuates sediments from the reservoir bottom.	Requires a significant supply of water for removal of sediments as slurry. Analysis revealed difficulty in implementing efficient slurry dewatering and water recycling.
Mechanical Removal	Partial or full removal of reservoir sediment and storage at an appropriate disposal site. Removal methods include conventional excavation, and hydraulic or mechanical dredging. Conveyance methods include transport by sediment slurry pipeline, truck, or conveyor belt.	Requires a combination of methods. Clamshell dredging would be used in the lower areas of the reservoir, and dry excavation with scrapers would be used in the upper reservoir areas.

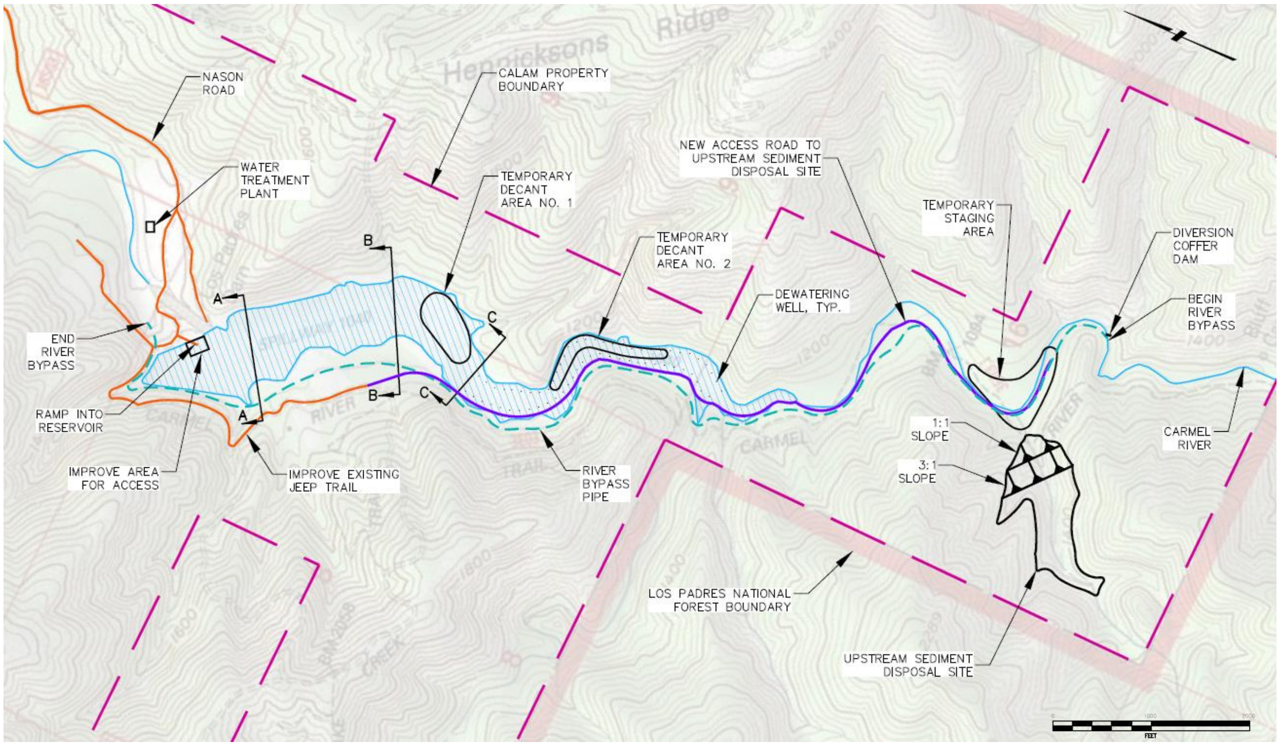


Figure 2-3. Potential Upstream Disposal Site

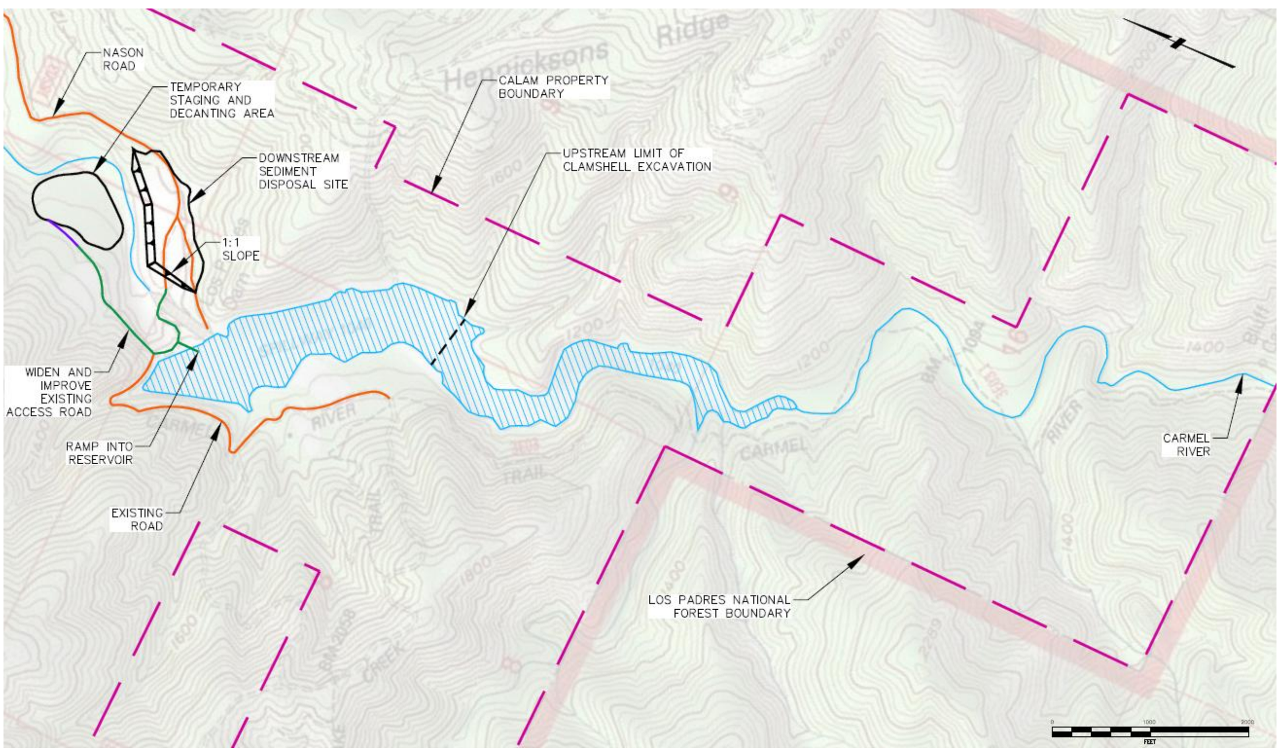


Figure 2-4. Potential Downstream Disposal Site

Evaluation of the sediment removal alternatives found that providing any meaningful increase to the reservoir storage capacity would be very challenging in constructability, due to steep terrain; lack of developed vehicle and equipment access to the upstream portion of the reservoir; limited feasible sediment disposal sites; inability to drain reservoir for construction; and a very short construction window. In addition, all alternatives would be difficult to implement, due to notable environmental impacts (e.g., steelhead and red-legged frog habitat) and very high costs relative to the gained benefits. The study recommended that any selected sediment removal concept undergo additional detailed study and careful planning that weighs the environmental impacts and project costs against the gained benefits of additional storage.

The alternatives contained in the MWH (2013) report have not been discussed or visited in a forum such as the policy and technical advisory committees set up between 2000 and 2012 to evaluate alternatives and designs for the removal of San Clemente Dam and construction of the rerouted Carmel River (Cal-Am and MPWMD 2016). Although dredging and placing material upstream of Los Padres Reservoir in one of the upper watershed side or box canyons may be physically possible, similar alternatives at the San Clemente Dam site were investigated, and potential sediment storage sites were found to be either unsuitable for off-channel storage, or too expensive (Entrix 2008). This alternative was discussed at the LP Alternatives Study TRC Meeting No. 1, and the consensus was that the upstream dredge disposal site is unlikely to be the preferred disposal site, because it would necessitate construction of a road that would eliminate a section of the Carmel River channel upstream of the reservoir. This option would also require construction of a large retaining structure in the steep, undeveloped valley upstream of the reservoir to prevent the sediment from mobilizing. Due to the availability of potential downstream dredge placement sites that do not present such logistical challenges, this alternative will not likely be carried through the LP Alternatives Study beyond the Alternatives Descriptions TM.

2.2.3 Los Padres Dam and Reservoir Long-Term Strategic and Short-Term Tactical Plan

The 2014 *Los Padres Dam and Reservoir Long-Term Strategic and Short-Term Tactical Plan* (Plan) was written by the MPWMD to assess options for water resource development and management of the upper Carmel River Watershed (MPWMD 2014). The Plan addressed the following three questions:

- Has MPWMD maximized the potential for water resources development in the watershed?
- What options or water development strategies are possible that—given today's requirements (e.g., consumptive demands, instream flows, fish bypass, water quality, and climate change sensitivity)—can serve a wider range of beneficial uses and better prepare for an uncertain future?
- How can any new water resource development effort integrate the current challenges and constraints posed by the basin's existing facilities?

The Plan identified the following water development alternatives:

- **Los Padres Reservoir Storage Enhancement**: This alternative could consist of dredging accumulated sediment or raising the dam by between 5 and 20 feet. As a temporary solution, this alternative would not resolve inevitable future sedimentation from natural erosion and sediment transport processes, including large-scale deposition events similar to the 1977 Marble-Cone fire.
  - **Dredging** would be conducted by diverting the Carmel River along the reservoir and dam site; drawing down the elevation to 1,000 feet (North American Vertical Datum of 1988 [NAVD88]); and mechanically excavating sediment using conventional earthmoving equipment, hydraulic dredging using a suction dredge, or a barge-mounted clamshell or long-arm excavator. The Plan referenced the three dredging options described in the *Los Padres Dam Sediment Removal Feasibility Study* (MWH 2013, Section 2.2.3) and discussed the challenge of locating a suitable disposal area that would not be washed out during a large-scale erosion event (such as those caused by high-intensity rainfall, slope failure, or wildfire).

  - The **dam raise** option would need to consider a variety of factors, including proposed yield enhancement volume, spillway modification, and/or completely new outlet designs; footprint expansion; earthen slope and abutment stability; the ongoing need to integrate improved fish passage; and ongoing reservoir sedimentation issues. Expansion of Los Padres Reservoir through a dam raise would likely be limited by the resulting inundation of a larger portion of the Ventana Wilderness. Los Padres Reservoir would be expected to fill every year even with the largest dam raise (20 feet); and the additional storage would only represent between 0.7 and 3 percent of median inflow.

- **Los Padres Dam Removal**: Dam removal would have impacts on fish passage, water diversions, recreation, and flooding in the Carmel River Watershed. Due to Los Padres Reservoir's high storage-to-yield ratio, removal of the dam would be unlikely to result in substantial effects on downstream hydrology and instream geomorphological response. However, the decision to remove Los Padres Dam is complicated by two primary factors. First, it is the only impoundment on the Carmel River, and therefore provides the only means of managed flow control from headwater annual yield. Second, given the river's episodic, temporal, and highly variable inter-annual flow regime and downstream minimum flow requirements, sustaining the ability to mete out appropriate releases over the summer season provides a benefit to fish and habitat. The Plan concluded that maintaining some kind of upstream flow release control appeared to be vital. Other factors considered in the Plan were that the dam provides instream flow, which contributes to limited recharge of subsurface aquifer units along the Carmel River; and that dam removal may release accumulated sediment, which can have negative impacts (e.g., reducing downstream water quality) and/or positive impacts (e.g., restoring stream habitat through deposition).

- **New Lower Los Padres Dam and Reservoir**: MPWMD developed plans in the early 1990s to place a new Lower Los Padres Dam downstream from the existing Los Padres Dam. The new Lower Los Padres Dam would be similar in height to the existing Los Padres Dam. The new Los Padres Reservoir would extend 2.7 miles upstream, essentially inundating the current dam and reservoir, and extending a short distance up Danish Creek and into a small portion of the Ventana Wilderness. The new reservoir would provide additional water storage of up to 23,600 AF, and would increase the water surface area to 266 acres, compared to the 55 acres of the current Los Padres Reservoir. Due to potential impacts on species listed under the federal Endangered Species Act (ESA), the project was unable to secure support from NMFS in the 1990s. However, the Plan concluded that, with inclusion of state-of-the-art passage facilities, the new Lower Los Padres Dam could now meet NMFS fish passage criteria[1].

- **Other alternatives considered**: The Plan considered developing storage off the Carmel River in one of four potential locations: Pine Creek Dam and Reservoir, Boronda Creek Dam and Reservoir, San Clemente Creek Off-Mainstem Dam and Reservoir, and Cachagua Creek Dam and Reservoir. The Plan also considered importing water from external sources, a hybrid alternative that would be combined with the Monterey Peninsula Water Supply Project (MPWSP), and obtaining new water rights.

The Plan eliminated all alternatives, except the off-channel storage options, due to their failure to meet an environmental fatal flaw criterion, which was defined as alternatives that, "1) wouldn't return fish passage in the mainstem to its original state (a long-standing desire of NMFS); 2) wouldn't provide the capability for increased flow releases from storage (another NMFS requirement[2]); and 3) would require fully petitioning the SWRCB for a new water right" (MPWMD 2014). Ultimately, a hybrid alternative consisting of both removal of the Los Padres Dam and new off-mainstem storage development was determined to

[1] Further study and design would be required to determine the ability of a fish passage facility on the new Lower Los Padres Dam to meet NMFS fish passage criteria.

[2] During preparation of this TM, the authors confirmed that NMFS has never *required* MPWMD to increase their capability for releases from storage in the Carmel River Watershed. However, NMFS has consistently stated a preference for off-channel storage alternatives that would provide additional dry season flow. Page 7-12 of the Final South-Central California Steelhead Recovery Plan (NMFS 2013b) outlines the following critical recovery action for the Carmel River Basin: "*Develop and implement alternative off channel water supply projects to eliminate or decrease water extractions from the channel (including subsurface extractions)...*"

best meet the long-term needs of water supply, instream flows, and fish passage in the watershed, and represented the most effective means of maximizing beneficial use of the basin's available hydrology.

2.2.4 Los Padres Dam Fish Passage Feasibility Study

A team of engineering and fisheries science consultants consisting of HDR, R2 Resource Consultants, Inc., and AECOM has been retained by the MPWMD to prepare a study that investigates the technical feasibility and potential lifecycle costs of implementing permanent facilities at Los Padres Dam to facilitate the upstream and downstream migration of S-CCC steelhead. The purpose of the Los Padres Dam Fish Passage Feasibility Study (Los Padres Fish Passage Study) is to inform MPWMD, Cal-Am, NMFS, CDFW, and others regarding the feasibility, potential for fish passage success, level of effort, and cost of implementing viable fish passage facilities at Los Padres Dam. The specific study plan includes six tasks: four tasks to determine technical feasibility and identify fish passage alternatives, one task for alternative development and a decision point, and one task to complete a Final Report. There is substantial overlap among the consultant teams and TRC members for the Los Padres Fish Passage and Alternatives studies. The results of the Los Padres Fish Passage Study will be the primary information considered in the Los Padres Alternatives Study regarding fish passage for alternatives that retain Los Padres Dam and Reservoir.

2.2.5 Water and Steelhead Habitat Availability Analysis

Two important, ongoing studies managed by the MPWMD include a water availability study using the Carmel River Basin Hydrologic Model (CRBHM) and a steelhead habitat availability study using an Instream Flow Incremental Method (IFIM) hydrologic model.

MPWMD has developed the CRBHM, which is a linked surface flow and groundwater model using GSFLOW coupled to MODFLOW (Cal-Am and MPWMD 2016). The model covers the entire Carmel River watershed and includes historic precipitation, well, reservoir, and runoff data. Flow and aquifer levels are simulated on a daily time step at nodes throughout the watershed, and routed through the mainstem and/or through the aquifer. The United States Geological Survey (USGS) is currently calibrating the model, which is expected to be ready for use in simulations in 2017. MPWMD will provide results to be included in the LP Alternatives Study for the following scenarios:

1. Existing Conditions – Existing Los Padres reservoir storage (estimate as of August 2016) and existing Cal-Am diversions and operations in Carmel Valley. MPWMD will cooperate with Cal-Am to develop assumptions for Carmel Valley operations for the short-term (i.e., 2016 to 2021); model the Pure Water Monterey Project coming on line in 2018; and model Aquifer Storage Recovery (ASR) operations assuming the Monterey Pipeline is completed prior to the 2018 Water Year. This scenario will assume that reservoir operations do not change in 2022 and beyond, to compare conditions with and without completion of the MPWSP.

2. Storage Depletion – Existing Los Padres Reservoir storage and proposed Cal-Am diversions and operating protocol in Carmel Valley with MPWSP completed (i.e., operations from January 1, 2022, forward). This scenario will use an annual depletion of reservoir storage of 10 to 20 AFY.[3] MPWMD will cooperate with Cal-Am to develop assumptions for proposed Cal-Am operations.

3. Existing Storage – This scenario will use the existing Los Padres Reservoir storage from the model's start date until 2021, and will change to a new operating protocol in 2022. The scenario will maintain reservoir storage at the 2016 level.

[3] Sedimentation after the 1977 Marble-Cone fire significantly influenced the long-term sedimentation rate, which is 10 AFY without that event and 20 AFY with that event (Cal-Am and MPWMD 2016). A worst-case analysis would be a repeat of the Marble-Cone fire within the remaining expected project life of alternatives associated with surface storage at Los Padres Dam. A best-case analysis would be fire behavior that does not result in increased sedimentation. A 2016 bathymetric study confirms that there was virtually no increase in sediment runoff after the 2008 Basin Complex fire in the watershed (HDR 2016).

4. Dam Removal – No Los Padres Reservoir storage. The run will begin in 2026 (assuming it takes at least 10 years to complete dam removal) and will include proposed Cal-Am diversions and operation with MPWSP.
5. Recover Storage, Modified Operations – This scenario will recover Los Padres Reservoir storage (3,030 AF). The model run will begin in 2026 (assuming it takes at least 10 years to complete the project) and will include proposed Cal-Am diversions and operation with MPWSP, and periodic reservoir maintenance to maintain capacity.
6. Expand Storage – This scenario will expand reservoir storage to up to 9,000 AF. The model run will begin in 2026 (assuming it takes at least 10 years to complete the project) and will include proposed Cal-Am diversions and operation with MPWSP. This scenario will also have instream flow requirements included in existing SWRCB Permit 20808B, or a modified set of instream flows.

Using this water availability study, MPWMD will provide flow duration analysis for different, potential, future scenarios related to Los Padres Dam and Reservoir. MPWMD will also provide an assessment of how each alternative affects steelhead habitat availability by using an IFIM hydraulic model developed for the Carmel River. The IFIM model is being developed with 1-D and 2-D modeling capability to evaluate changes in steelhead habitat resulting from alternative water supply assumptions. MPWMD completed habitat mapping from the ocean to Los Padres Dam in 2014 and 2015; and established transects for flow measurements, which were completed in 2016. The 2-D hydraulic model is complete, and the 1-D model should be complete soon. Output from these two models will be used in assessing potential benefits and impacts from the alternatives to be studied.

2.2.6 Carmel River Basin Study – Climate Change

MPWMD is working with Reclamation on developing a Carmel River Basin Study, under the Reclamation Water Smart grant program, that would include development of a downscaled climate change model for the basin. If this work goes forward, MPWMD will work with Reclamation to develop a water availability analysis for various climate scenarios, and adaptation strategies that include balancing water needs for the environment, municipal, and industrial needs. One or more feasible alternatives from the LP Alternatives Study may undergo additional analysis, using data from the climate change model, to see how the alternative would function with a different climate. If data are available from the Basin Study, MPWMD will provide a flow duration analysis for each scenario for use as one of the criteria to compare sediment management alternatives in the LP Alternatives Study.

2.2.7 Carmel River Steelhead Fishery Science Study

NMFS' Southwest Fisheries Science Center is planning three scientific projects on Carmel River steelhead, including: 1) Passive Integrated Transponder (PIT)-tagging to examine limiting factors and estimate smolt production as a performance metric for river management; 2) Annual State of the Steelhead Fishery report to assess population response to ongoing conservation actions and freshwater conditions; and 3) evaluation of direct impacts of Los Padres Dam on smolt production and overall steelhead population (Boughton 2016; D. Boughton, Southwest Fisheries Science Center, pers. comm., 2017). These studies are now funded and moving forward (D. Boughton, Southwest Fisheries Science Center, pers. comm., 2017). The scope of work for the study (Boughton 2016) is summarized below.

1. PIT tagging to Estimate Smolt Production
   The goal of this element of the study is to use PIT-tagging to implement smolt production as a performance metric, providing faster and better information on the response of anadromous production to freshwater conditions and conservation actions (Boughton 2016). Specific objectives are listed below:
   a. Estimate wild smolt production from the entire Carmel stream network, using a random-stratified sample of reaches;

   b. Estimate wild smolt production from each of five parts of the stream network: valley mainstem, canyon mainstem, upper network (above Los Padres), southern tributaries, and eastern tributaries;

   c. Estimate smolt production from Sleepy Hollow Steelhead Rearing Facility;

   d. Estimate smolt production from relocation activities conducted by MPWMD and by Carmel River Steelhead Association; and

   e. Other benefits are information on the role of connectivity (at reroute site, in lower river) on juvenile movement to nursery habitats.

2. Annual Status of Steelhead Fishery Report
   The goal of this element of the study is to assess steelhead population response each year, using integrated life-cycle models (Boughton 2016). Specific objectives are listed below:

   a. Integrate new tagging data (this workplan), monitoring data (MPWMD), and other relevant data into a population life-cycle model;

   b. Use population model to identify limiting factors for anadromous production and population viability;

   c. Use population model to evaluate population response to captive rearing and relocation efforts; and

   d. Report findings and make scientific recommendations for adaptive management of Carmel River steelhead population.

3. Direct Impacts of Los Padres Dam on Smolt Production
   The goal of this element of the study is to evaluate direct impacts of Los Padres Dam and Reservoir on smolt production (Boughton 2016). Specific objectives are listed below:

   a. Tag additional juveniles in the upper stream network to estimate the numbers of smolts entering Los Padres Reservoir;

   b. Estimate the survival of smolts migrating through Los Padres Reservoir and across the Dam; and

   c. Estimate the proportion of smolts that use the smolt bypass rather than the spillway (D. Boughton, Southwest Fisheries Science Center, pers. comm., 2017).

Of these three study elements, the third element, or the tagging study that will look specifically at impacts of Los Padres Dam on smolt production, may have the most relevance to the Alternatives Study. The plan is to tag juvenile steelhead upstream of Los Padres Reservoir and monitor their movement and survival past the reservoir and dam (D. Boughton, Southwest Fisheries Science Center, pers. comm., 2017). Tagging will include a combination of PIT-tagging juveniles in the upper watershed during the summer and autumn prior to migration season; and trapping, tagging, and immediately releasing smolts in the Carmel River above Los Padres during the smolt migration season. Monitoring will include PIT-tag reader stations at three locations: the upstream entrance to the reservoir; at the smolt bypass facility (probably around the flexible pipe connecting the floating part of the facility to the dam face); and a flat pass-over plate on the spillway itself. Monitoring stations will be maintained in place for the smolt migration season—March through May. Monitoring stations will be established summer 2017, and the study should begin during the next smolting season (tagging fall 2017, monitoring spring 2018); although the first element of the study (PIT-tagging to Estimate Smolt Production) is NMFS' highest priority, so there is a possibility of delay.

2.3 Regulatory Setting

The regulatory setting at Los Padres Dam includes California Public Utilities Commission regulation that mandates Cal-Am serve its customers; and an annual operations Memorandum of Agreement (MOA) among Cal-Am, MPWMD, and CDFW. Actions taken by the SWRCB and NMFS in the past 25 years may be the primary regulatory drivers of fish passage (or other passage solutions such as dam removal) at Los Padres Dam. These actions are described in more detail below.

2.3.1 NMFS Interest and Involvement

NMFS has applied regulatory pressure on Cal-Am at Los Padres Dam. NMFS' jurisdiction is related to the presence of S-CCC steelhead. This Distinct Population Segment (DPS) steelhead was listed as federally Threatened in 1997, and was re-listed again as Threatened in 2006 (January 5, 2006; 71 Federal Register [FR] 834). Critical habitat was designated September 2, 2005 (70 FR 52488). The S-CCC steelhead DPS includes all naturally spawned steelhead populations in streams from the Pajaro River watershed (inclusive) south to, but not including, the Santa Maria River in northern Santa Barbara County, California, which includes the Carmel River.

On September 18, 2001, NMFS and Cal-Am entered into a Conservation Agreement that required Cal-Am to implement certain measures to reduce the impact of its operations in the Carmel River on steelhead and their habitat. Additionally, in the spirit of environmental stewardship, Cal-Am and its customers have paid for the MPWMD to implement steelhead mitigation measures over the years, including annual fish rescues; construction, maintenance, renovation, and operation of a rearing facility to hold rescued steelhead; monitoring of and improvements to the instream and riparian habitat; improvements to the Carmel River Lagoon; and monitoring fish numbers during migration (Cal-Am et al. 2009). In 2009, Cal-Am, NMFS, and CDFW negotiated a new agreement that modified the mitigation requirements and interim measures described in the original Conservation Agreement. With the 2009 agreement, Cal-Am committed to modifying operations to avoid take of steelhead, or obtain all necessary permits to authorize any remaining take before the expiration of the agreement.

On two occasions, NMFS has written letters to Cal-Am that clearly describe their opposition to maintaining Los Padres Dam without modification. In 2011, NMFS encouraged Cal-Am to study the feasibility of removing Los Padres Dam, and indicated that NMFS was opposed to building any new dams on the Carmel River (NMFS 2011). In 2013, NMFS expressed concern that Los Padres Dam may be causing take of S-CCC steelhead by impeding migration or altering downstream critical habitat (NMFS 2013a). In that 2013 letter, NMFS advised Cal-Am to determine the feasibility of:

1. Entirely removing the dam and restoring the reservoir area to its original environs; or
2. Improving the dam with appropriate permanent fish passage modifications that allow for unimpeded, safe, and effective upstream and downstream migration of all life stages of S-CCC steelhead.

In the *South-Central California Steelhead Recovery Plan* (NMFS 2013b), NMFS identified the Carmel River population of S-CCC steelhead as a Core 1 population. Core 1 populations have the highest priority for recovery, and form the nucleus of the recovery implementation strategy. Los Padres Dam is identified as causing or contributing to a number of threats to the Carmel River steelhead population, including blocking or inhibiting the natural pattern of upstream and downstream migration of adult and juvenile steelhead; impeding access to the majority of the spawning and rearing habitat of the Carmel River Watershed; altering the natural surface flow; and reducing the recruitment of essential spawning gravels and sediments to support rearing habitat in the middle and lower reaches of the Carmel River (NMFS 2013b).

The recovery plan identifies critical recovery actions for the Carmel River at Los Padres Dam (NMFS 2013b), including:

- Develop and implement operating criteria to ensure that the pattern and magnitude of groundwater extractions and water releases, including releases from San Clemente and Los Padres Dams, provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead.

- Remove or physically modify San Clemente, Los Padres, and Old Carmel River Dams (note: prior to the removal or modification of these dams, appropriate investigations and environmental review should be completed to address regional water supply and environmental issues, including, but not limited to, any effects on the existing steelhead resources of the Carmel River watershed) to provide natural rates of steelhead migration to upstream spawning and rearing habitats; passage of smolts and kelts downstream to the estuary and ocean; and restoration of spawning gravel recruitment in the lower mainstem.

- In the interim, ensure provisional fish passage of both adult and juvenile *O. mykiss* around Los Padres, San Clemente, and Old Carmel River Dams; seasonal releases from San Clemente and Los Padres Dams; and the provision of spawning gravel and large woody debris in the lower mainstem to support all *O. mykiss* life-history phases, including adult and juvenile migration, spawning, and incubation and rearing habitats.

Although actions described in the recovery plan are recommendations or advisory in nature, the recovery plan is likely to carry substantial weight with regulatory and permitting agencies, including NMFS. Specific recovery actions relevant to the Los Padres Fish Passage Study are listed below (NMFS 2013b).

- Car-SCCCS-4.1: Develop and implement water management plan for dam operations (or review and modify) (e.g., MPWMD Quarterly Water Budget and Low Flow MOA);

- Car-SCCCS-4.2: Develop and implement water management plan for diversion operations (or review and modify) (e.g., MPWMD Quarterly Water Budget and Low Flow MOA);

- Car-SCCCS-4.3: Provide fish passage around dams and diversions;

- Car-SCCCS-9.1: Develop and implement a watershed-wide plan to assess the impacts of nonnative species and develop control measures; and

- Car-SCCCS-9.2: Develop and implement a nonnative species monitoring program.

Cal-Am and NMFS continue to negotiate a new settlement agreement that includes addressing NMFS' concerns with effects to steelhead from Cal-Am's continued operation of Los Padres Dam. Removal of San Clemente Dam in 2016 has improved access for migrating steelhead to Los Padres Dam; regulatory pressure to remove the dam or provide improved fish passage, especially from NMFS, is likely to remain strong or increase.

2.3.2 Cal-Am and MPWMD Carmel River Water Rights

Cal-Am holds riparian, pre-1914 appropriative, and post-1914 appropriative water rights; and the MPWMD holds post-1914 appropriative water rights. Riparian water rights allow landowners whose parcels physically touch a water source to have a right to use water from that source as long as it has not been appropriated by another party. Appropriative water rights allow for water diversion at one point and beneficial use at a separate point. These rights do not require that the water right holder owns land adjacent to the water source. Pre-1914 water rights are appropriative rights acquired before the effective date of the Water Commissions Act (December 19, 1914). The Water Commissions Act formalized water appropriation in California and centralized appropriative water rights records under the SWRCB. Appropriative water rights issued after the creation of the Water Commissions Act are called post-1914 water rights. Obtaining post-1914 water rights requires the application for a permit from the SWRCB, and applicants must provide information on where and how the water will be used, and when and how it will be diverted.

The following list, as well as Table 2-2, summarizes Cal-Am's water rights in the Carmel River Watershed:

- Pre-1914 and Riparian Rights: Cal-Am has rights to 1,137 AFY from pre-1914 rights and 60 AFY from riparian rights. These rights are not subject to meeting instream flow requirements.
- 1985: SWRCB licensed Cal-Am (License 11866, Permit 7130A) to divert up to 3,030 AFY to Los Padres Reservoir and San Clemente Reservoir between October 1 of each year through May 31 of the following year for municipal, domestic, industrial, and recreational use. License 11866 requires Cal-Am to release and maintain a flow of greater than or equal to 5 cfs in the Carmel River channel directly below the outlet structure of the Los Padres Dam at all times during which water is being stored under this license. There are no instream flow requirements for downstream withdrawals under this license.
- 1995: SWRCB issued Order WR 95-10 to settle a number of complaints that had been filed against Cal-Am for its diversion of water from the Carmel River.
    1. This order states that Cal-Am has a legal right to 3,376 AFY total in the Carmel River Watershed (1,137 AFY from pre-1914 appropriative rights, 60 AFY from riparian rights, and 2,179 AFY from License 11866). The 2,179 AFY was a reduction in Cal-Am's original right to divert 3,030 AFY from the Carmel River under License 11866. This reduction was due to siltation at Los Padres Reservoir.
    2. This order further states that Cal-Am's actual total annual diversion is equal to 14,106 AFY.
    3. This order mandates that Cal-Am find an alternative supply for 10,730 AFY of water, and pending the implementation of an alternative water supply, limit its diversions from Carmel Valley to 11,284.8 AFY.
- 1998: SWRCB issued Order WR 98-04, which amended WR 95-10. Modifications to the original order included requirements for Cal-Am to maximize production from the Seaside aquifer, minimize diversions from the Seaside aquifer under certain flow conditions, satisfy water demands by extracting water from its most downstream wells, conduct feasibility studies on shifting water deliveries to different existing sources, provide monthly reports on water diversion and pumping, and provide quarterly water budget reports.
- 2009: SWRCB issued a cease-and-desist order (Order WR 2009-060) to Cal-Am that established a compliance timeline for cessation of Cal-Am's unlawful diversions from the Carmel River by December 31, 2016. This order was a follow-up to WR 95-10, and required Cal-Am to reduce its total diversion to 3,376 AFY and limit diversion to Los Padres Reservoir to 2,179 AFY. Conditions 1 through 3 of the order stated the following:
    1. "Cal-Am shall diligently implement actions to terminate its unlawful diversions from the Carmel River and shall terminate all unlawful diversions from the river no later than December 31, 2016."
    2. "Cal-Am shall not divert water from the Carmel River for new service connections or for any increased use of water at existing service addresses resulting from a change in zoning or use…"
    3. Cal-Am shall adjust its diversions from the Carmel River in accordance with the outlined minimal reductions.
- 2013: SWRCB issued Permit 21330 to Cal-Am to divert up to 1,488 AFY from the Carmel River at San Clemente Reservoir, and at 26 wells that draw from the Carmel River Watershed.
- 2016: SWRCB issued Order WR 2016-0016, which amended WR 2009-060. WR 2016-0016 extended the deadline for Cal-Am to terminate unlawful diversion from the Carmel River to December 31, 2021. WR 2016-0016 also allows for an ongoing diversion level as long as specified progress toward alternative supplies is met, but sharply drops allowable diversions should the progress toward these supplies slip.

Cal-Am is planning, for the long term, to replace the 10,730 AFY diverted from the Carmel Valley Aquifer with water produced via desalination, initially with the project identified as the Coastal Water Project (Cal-Am et al. 2009), and now with the MPWSP and others (SWRCB Order 2016-0016).

The following list, as well as Table 2-2, summarizes MPWMD's water rights in the Carmel River Watershed:

- 1995: SWRCB issued Decision Number 1632 and Permit 20808 to the MPWMD for 24,000 AFY for the New Los Padres Dam, which was proposed to be about 1,800 feet downstream of the existing Los Padres Dam. This water right contained minimum instream flow requirements for flow below the New Los Padres Dam, at the Carmel River Narrows and Lagoon, and at a new San Clemente Dam. In 1995, a public vote failed on a bond issue to finance the New Los Padres Dam, and the dam was never built.
- 1998: SWRCB issued Order WR 98-04, which amended Decision 1632. Modifications to the original decision included clarifying diversion periods for the New Los Padres Project, updating the construction start date, and limiting the total diversion of water in the Carmel River by Cal-Am and MPWMD combined to 16,000 AFY, or "such lesser amount identified in the Supplemental EIR [Environmental Impact Report] on the Carmel River Dam as annual beneficial use requirements associated with total project yield or the Cal-Am production limit."
- 2007: Permit 20808 was subsequently split into three water rights permits: 20808A, 20808B, and 20808C. All three permits are due for relicensing by the SWRCB by 2020. Diversion rights associated with Permit 20808 are junior to all other rights along the Carmel River. The 16,000 AFY diversion limit on Cal-Am and MPWMD diversions established in WR 98-04 were restated in these permits. Although Cal-Am and MPWMD's combined water rights exceed 16,000 AFY (see Table 2-2), the instream flow requirements applied to License 11866 and Permits 20808A, 20808B, and 20808C, and the instantaneous diversion rate requirements in Permits 20808A, 20808B, and 20808C, will effectively restrict total annual diversions to less than 16,000 AFY.
  - Permits 20808A and 20808C are jointly held between MPWMD and Cal-Am for diversion of excess winter season flows to storage in the Seaside Groundwater Basin (ASR). Permit 20808A allows for diversion of up to 2,426 AFY from the Carmel River at San Clemente Reservoir, and at 26 wells that draw from the Carmel River Watershed. Permit 20808C allows for diversion of up to 2,900 AFY from the Carmel River Watershed.
  - Permit 20808B is held by MPWMD for up to 18,674 AFY.

Table 2-2. Cal-Am and MPWMD Water Rights in the Carmel River Watershed

California American Water (Cal-Am)	Water Rights (AFY)
Appropriative Right (Pre-1914)	1,137
Riparian Right	60
Appropriative Right (WR 95-10)	2,179
Appropriative Right (Permit 21330)	1,488
Monterey Peninsula Water Management District (MPWMD)	
Appropriative Right (Permit 20808A*)	2,426
Appropriative Right (Permit 20808B)	18,674
Appropriative Right (Permit 20808C*)	2,900
Total	**28,864**

Notes:

* These water rights are held jointly by Cal-Am and MPWMD.

AFY = acre-feet per year
Cal-Am = California American Water
MPWMD = Monterey Peninsula Water Management District

2.4 Los Padres Dam, Reservoir, and Contributing Watershed

This section includes descriptions of Los Padres Dam, Los Padres Reservoir, and the contributing Los Padres Dam subwatershed.

2.4.1 Los Padres Dam

Los Padres Dam is on the Carmel River approximately 7.5 miles southeast of Carmel Village, and 24.5 miles upstream of the Carmel River mouth. The dam was constructed in 1948 and 1949 by Macco Construction Company for the California Water and Telephone Company. The dam came under the ownership of Cal-Am in 1966. The original purpose of the dam was primarily to provide water storage for municipal and domestic supplies for the Monterey Peninsula. Currently, flow releases are made from the reservoir for water supply downstream and to regulate and maintain flows in the Carmel River during the dry season.

There are three hydraulic structures that can convey water downstream of Los Padres Dam. The first is the Ogee spillway, the second is a low-level outlet pipe, and the third is the Floating Weir Collector (FWC).

1. The concrete Ogee spillway is approximately 110 feet wide and 600 feet long. The spillway extends from the crest elevation of 1,042.78 feet (NAVD88) to its downstream end at elevation 951.67 feet (NAVD88). Spillway flow drops approximately 30 feet from the end of the spillway to a deep-plunge pool created in bedrock below (see Figure 2-5 and Figure 2-9).
2. The low-level outlet consists of a 30-inch-diameter pipe that penetrates through the base of the dam on the western side. The upstream invert of the outlet pipe is located at approximately Elevation 953.13 feet (NAVD88) (see Figure 2-5).
3. The FWC consists of a 2-foot-wide overshot ramp gate on a floating barge. After flow passes over the weir, it enters an 18-inch-diameter pipe that discharges at the downstream end of the dam's tailrace pool. The FWC has a capacity of approximately 10 cfs, but can be increased to approximately 15 cfs with the adjustment of ballast (see Figure 2-10).

These features are described in more detail in the sections below.

2.4.1.1 Embankment

Los Padres Dam is a 148-foot-high, zoned, earth-fill dam with a crest length of 570 feet, a crest width of 12 feet, and crest elevation of 1,060.55 feet (NAVD88). The dam is shown in plan on Figure 2-5. The upstream side slopes are 1.5H (horizontal):1V (vertical) for the uppermost 10 feet of the embankment, and 2.35H:1V below. The downstream side slopes are 2H:1V for the uppermost 10 feet, and 2.25H:1V below. As shown on Figure 2-6, the dam consists of seven zones (DSOD 1980a):

- Zone 1 (dam) and Zone 2A (upstream cofferdam) impervious embankment. Impervious embankment materials were variously described in compaction tests during construction as "sandy soil," "organic soil," "sandy loam," or "sandy organic soil."
- Zone 2 (dam). Zone 2 is a 12-foot-thick, free-draining, reasonably well-graded, clean sand, gravel, and crushed or broken rock, with a maximum particle size of 6 inches.
- Zone 3 (upstream zone). Zone 3 is a pervious upstream shell material consisting of 6-inch minimum to 1-cubic-yard maximum size cobble, boulders, and rock.
- Zone 3A (upstream rock toe). Zone 3A consists of boulders up to 3 cubic yards in size, free of sand and silt.
- Gravel Drain (downstream blanket). The downstream blanket consists of an 18-inch-thick free-draining gravel placed on the bedrock foundation underlying a 6-inch-thick layer of fine gravel underlying a 6-inch-thick sand layer.
- Rock Paving and Downstream Rock Toe. These zones consist of 6-inch minimum size material for the rock toe and 200-pound maximum size for rock paving.

Figure 2-5

Los Padres Dam – Contour Map of Foundation for Dam and Spillway as Constructed

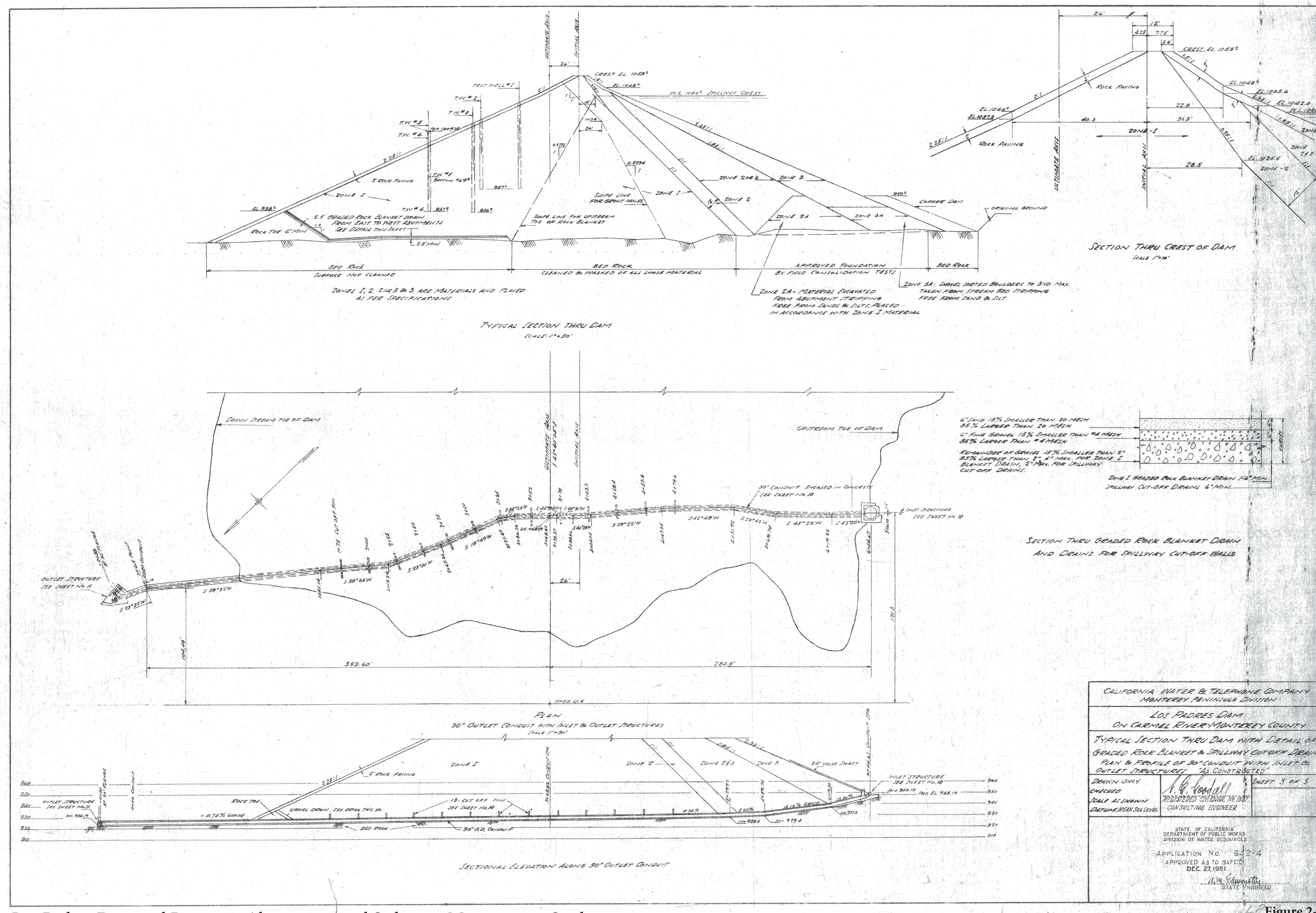


Figure 2-6
Los Padres Dam – Typical Section of Dam as Constructed

As described by DSOD (1980a), the downstream three-quarters of the dam foundation and extreme upstream toe were founded on bedrock. The rock at the right abutment is granitic rock with predominately vertical jointing. One 4-foot-wide bedrock fault on the lower right abutment containing an approximately 2-inch-wide gouge zone was treated by excavating a shaft, and backfilling with concrete to form a concrete plug. The rock at the left abutment is weathered mica schist and gneiss intruded by granitic rock. The contact between the mica schist and gneiss with the granitic rock is, in part, a 4-foot-wide faulted zone extending both upstream and downstream along the lower left abutment that has been partially healed by intrusive dikes. The rock in the channel section is largely extensively sheared and folded gneiss and mica schist. Portions of the rock foundation were grouted during construction at the locations shown on Figure 2-7.

The remaining dam, Zones 2, 2A, and most of 3A, are shown on the as-constructed plans to be on native material overlying bedrock that was “approved foundation by field consolidation tests.” DSOD (1980a) indicates that these tests were not available for preparation of that report. An average of 5 feet of material was excavated in this area down to what was considered sound foundation, and the thickness of the remaining native material was likely not greater than 5 feet. The construction reports reviewed by DSOD indicated that the native material consisted of sands and gravels that were very compacted, as indicated by the lack of settlement under the passage of heavily loaded trucks.

The right abutment foundation of the dam is topographically complex in that it includes an old stream channel separated from the main channel by a ridge with a top elevation of 1,013 feet (NAVD88) (see Figures 2-5 and 2-7) that was uncovered during construction. The old stream channel drops to the right of the ridge 50 feet down to Elevation 960 feet, and the main channel drops steeply to the left of the ridge 100 feet down to Elevation 910 feet. Also, as shown on Figure 2-7, the upper approximately 40 feet of foundation for Zone 1 is the left spillway gravity wall, which has a slope of 0.6H:1V that the Zone 1 was compacted against. Details of the gravity wall construction indicate that the surface of the gravity wall was formed with 6-inch-deep by 12-inch-wide grooves parallel to the alignment of the dam to create a longer seepage path along the Zone 1/concrete contact.

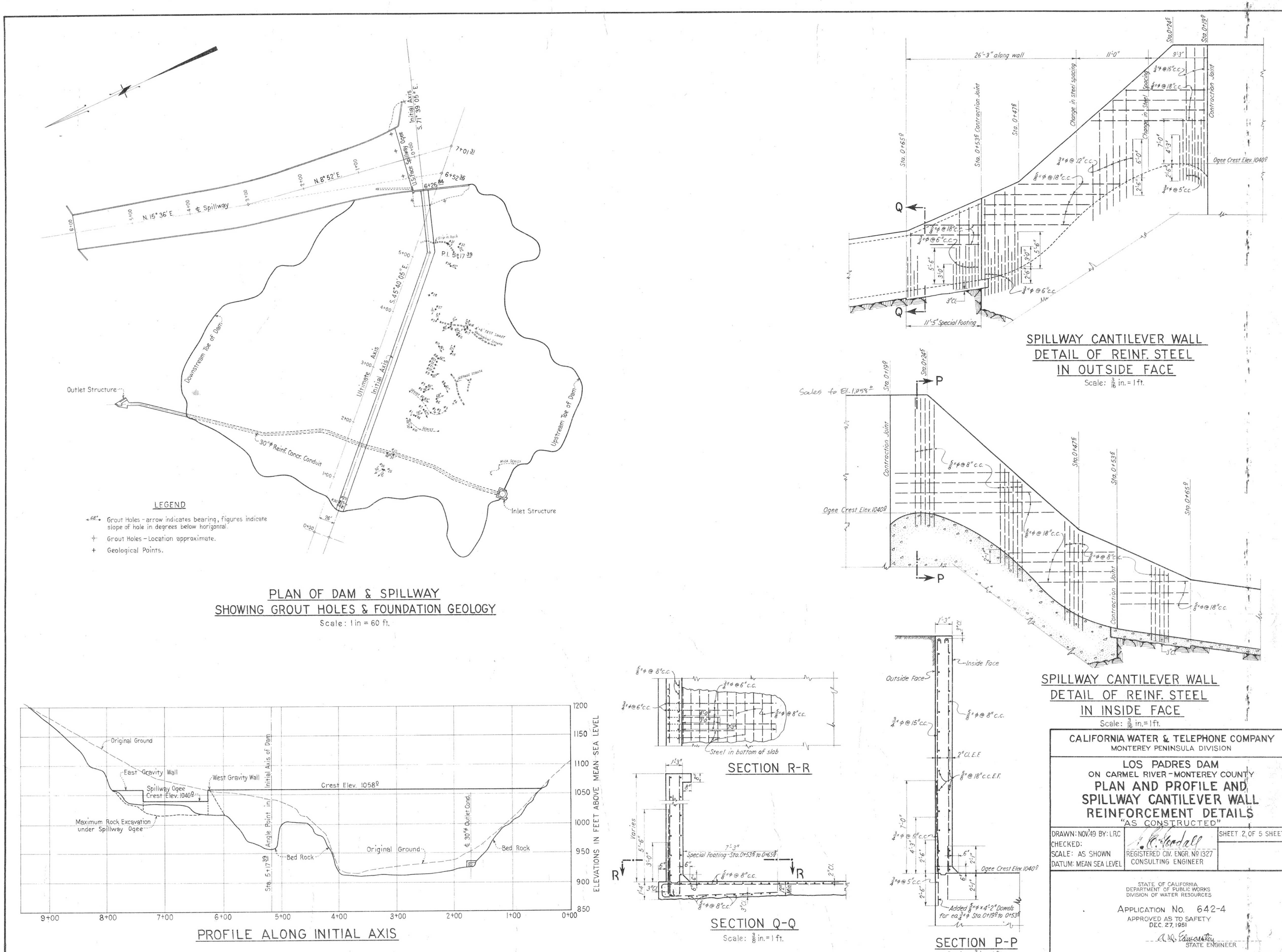
2.4.1.2 Spillway

The spillway consists of a 108.7-foot-long ungated ogee crest section at Elevation 1,042.78 feet (NAVD88) and a 581-foot-long spillway chute that has upper and lower straight sections with a transitional curved and super-elevated section between them (see Figure 2-5). The curve in the spillway alignment was required to avoid the old stream channel found during construction at the right abutment described in the previous section. The width of the spillway chute varies from 98 feet where it joins the ogee crest section, to 59 feet at its lower end. The walls on either side of the ogee crest consist of an approximately 28-foot-high gravity wall on the right (eastern) side, and an approximately 45-foot-high gravity wall on the left (western) side. Flows discharge from the end of the spillway chute (Elevation 951.67 feet [NAVD88]) into a deep erosion hole (approximate bottom Elevation 900 feet) that formed below the end of the chute following construction.

2.4.1.3 Outlet Works

The low-level outlet works, which are located along the foundation at the left abutment (see Figure 2-5), consist of the following:

- A three-sided open-top concrete intake structure equipped with a movable grated steel trash rack.
- A 30-inch hydraulically operated slide gate (DSOD 2014) with an invert elevation of 953.13 feet (NAVD88), inside the three-sided concrete intake structure.
- A 30-inch-diameter steel conduit encased in reinforced concrete founded on bedrock having a minimum thickness of 12 inches.



Los Padres Dam and Reservoir Alternatives and Sediment Management Study

Figure 2-7

Los Padres Dam – Plan and Profile and Spillway Cantilever Wall Reinforcement Details as Constructed

- The outlet encasement includes 13 concrete fins that jut out 5 feet from the encasement into the impervious zone of the embankment that serve the purpose of preventing seepage along the encasement. The fins were placed at a 25-foot spacing along the encasement.
- The downstream outlet works that divides into four outlet gates: a 30-inch butterfly valve, two 12-inch guard gate valves and regulating butterfly valves, and a 12-inch gate valve for habitat flow.

There is also a high-level outlet works that consists of a gated 30-inch-diameter concrete-encased outlet pipe through the left side of the spillway ogee crest, terminating at the spillway chute floor where it meets the downstream end of the ogee crest. The slide gate is controlled by an operating shaft connected to a hand wheel at the top of the right abutment gravity wall. The invert of the slide gate is Elevation 1,020 feet; 20 feet below the spillway crest.

Combined operation of the low- and high-level outlets allow the reservoir to be drained to 50 percent of the original storage in 7 days (DSOD 1980a).

2.4.1.4 Maintenance and Modifications

Significant maintenance or modification of the dam and its appurtenant structures that was noted in our review of the data for the dam is described in the following paragraphs.

1. 1951 Additional Grouting at Left Abutment – Additional grouting was performed in the left abutment in 1951 to reduce significant seepage through the left abutment that was observed in 1949 during initial filling of the reservoir (DSOD 1980a).
2. 1958 Slide in Right Side of Downstream Shell – In April 1958, a small shallow slide on the right side of the downstream shell occurred following about a week of heavy rain totaling about 9 inches. The slide was about 110 feet wide and 85 feet long in plan (DSOD 1958). The slide was repaired by installing a drain system, consisting of an approximately 160-foot-long, 3-foot-deep by 3-foot-wide trench with a 6-inch-diameter perforated asphalt-dipped pipe surrounded by gravel backfill in the area of the toe of the slide, and ballasting the lower half of the slide with a covering up to 12 feet thick of large rock.
3. 1985 Spillway Modification – The spillway was modified in September 1985 to improve fish survival off the end of the spillway chute (DSOD 1993). The modifications included construction of a steel apron at the end of the chute to direct fish into the pool under the end of the chute, and blasting of some rock below the steel apron.
4. 1992 through 1995 Spillway Modification – The spillway was modified to provide better fish passage across the ogee crest when flows across the spillway are low. The modifications included making a small notch, which—based on DSOD's Memorandum of Design Review (DSOD 1993)—was to include a 9-inch-deep, 3-foot-wide notch near the right side of the spillway crest with notches in the sides to allow the placement of stop logs. In 1994, the depth of the notch was modified with a concrete pour (D. Highland, CDFW, pers. comm., 2017). A section of bedrock below the spillway extension was removed with explosives in 1995 to allow downstream migrants to fall directly into the plunge pool instead of impacting on the rock.
5. 2003 and 2005 Dam Crest Maintenance – The spillway crest was raised approximately 1.5 feet in January 2003, and widened to a minimum of 12 feet in September 2005 (DSOD 2006). The work to restore the dam crest to the design elevation and width was required to address settlement of the crest that occurred after construction.
6. 2015 Fish Diversion Structure – A fish diversion structure was constructed in the upstream approach to the spillway ogee crest during 2015. The fish diversion structure includes the following features (DSOD 2015a):
    a. A Behavioral Guidance System (BGS) consisting of multiple 10-foot-deep, 20-foot-wide steel panels supported by floaters that stretch diagonally across the approach channel from the upstream right side of the channel downstream to the FWC at the left side of the approach channel, 50 feet upstream of the ogee crest. The BGS guides fish toward the FWC and is

designed to disengage during a 25-year event (DSOD 2015b) to not block the spillway during larger flows.

b. The FWC, which has a floating weir that supports a truss and 18-inch-diameter pipeline supported by four concrete-encased steel pipe piles drilled and embedded in rock that allows fish to pass from the BGS toward the spillway.

c. An upstream debris boom that provides protection to the BGS and FWC.

d. An 18-inch-diameter fixed pipeline that starts at the upstream face of the ogee crest, penetrates the crest structure, runs 125 feet in the spillway channel against the left wall supported on a shelf 2 feet above the spillway floor to spillway station 1+50, and then penetrates the left wall of the spillway and runs outside the spillway to the Carmel River to a point downstream of the plunge pool below the end of the spillway chute.

The impact of the fish diversion system to spillway capacity was evaluated by HDR (2012) and DSOD (2015a). Because the BGS is designed to disengage at flows greater than the 100-year event, the impact to passage of the Probable Maximum Flood (PMF) was determined to be minimal, given the uncertainty of a PMF analysis. The hydrologic analysis for the dam is further discussed below.

2.4.1.5 Dam Surveillance

Dam surveillance instrumentation at Los Padres Dam includes five test wells on the downstream slope of the dam, two 6-inch Parshall flumes measuring seepage, and six survey monuments along the crest of the dam. Four of the five test wells (Test Wells 1 through 4) and the two flumes are generally measured daily during the work week. The fifth test (Test Well 5) began to be measured again at a less frequent rate starting June 2014. The survey monuments are measured once every 2 years. The last survey reviewed was made on September 10, 2013 (Cal-Am 2015).

2.4.1.6 Hydrologic Analyses

The most recent analysis of the probable maximum precipitation for determining the PMF was performed using HMR-36 (DSOD 1980b). Based on the analysis, the peak inflow to the reservoir was determined to be 31,759 cfs.[4] Due to the relatively small size of the reservoir compared to the total flood volume, the peak outflow from the reservoir was assumed to be the design inflow for the spillway without consideration of reservoir attenuation. The spillway was judged to be adequate to pass the PMF with a residual freeboard of 0.3 foot.

Construction of downstream fish passage facilities, described above, was completed in November 2015. HDR (2012) concluded that the overall impact of the fish diversion system to the water surface elevations and velocities at the spillway crest during the PMF were negligible. DSOD (2015a) concurred that the fish weir would not significantly impact the capacity of the spillway or its ability to pass the PMF. MWH (2012) reviewed the capacity of the spillway through the use of a computational flow dynamics model. The results of the modeling indicate that the geometry of the spillway at the western retaining wall upstream of the ogee crest results in an asymmetric flow condition, consistent with past observed scouring of sediment at the western retaining wall that reduces the spillway capacity by an estimated 6 percent, suggesting that the spillway walls at the crest could be overtopped by about 0.3 foot.

2.4.1.7 Dam Safety Considerations

The Federal hazard classification for Los Padres Dam is high, and the total class weight for the dam is 32 (out of a maximum of 36) given its height, storage capacity, and the communities of Cachagua, Carmel Village, and Carmel downstream of the dam. Based on the data reviewed, the dam and its appurtenant works appear to be performing satisfactorily. Alternatives for Los Padres Dam will be reviewed by DSOD for their potential impact to dam safety. The areas of review could include the following:

4 We note that there are discrepancies in some of DSODs references, because DSOD (1980a) indicates a PMF of 32,607 cfs and 0 foot freeboard, while DSOD (1980b) and DSOD's most current Dam Statistics Summary Information sheet (dated July 14, 2015) for Los Padres Dam indicate a PMF of 31,759 cfs and 0.3 foot of freeboard.

- Proposed facilities that would directly impact the dam or its appurtenant structures and their interaction with the dam during normal operations, during extreme flooding conditions, or during a seismic event.
- Proposed facilities that have the potential for resulting in erosion of the dam if such facilities were to fail during normal operations, during extreme flooding conditions, or during a seismic event.
- Proposed facilities that could reduce the capacity of the spillway.
- Proposed facilities that have the potential for reducing the capacity of the spillway if such facilities were to fail during normal operations.

Hydrologic analyses that have been performed for the dam indicate that the ability of the spillway to pass the HMR-36 derived PMF is marginal. Significant modification of the dam may trigger a DSOD requirement to update the hydrologic analyses from HMR-36 to HMR-58/59, or some other agreed-on PMF, which could result in a finding that the spillway is undersized. Such a finding could require that the spillway be modified to handle the larger PMF.

2.4.1.8 Fish Passage Facilities

Fish passage at Los Padres Dam is currently provided via trap-and-haul in the upstream direction, and via the spillway and the FWC in the downstream direction. Trap-and-haul involves collection of the fish with a fish ladder and trap prior to transport. Approximately 250 feet downstream of the dam, on the left bank, a steeppass fish ladder is in operation that allows upstream migrating steelhead to ascend into a small trapping facility (Figure 2-8). Steelhead are transferred from the fish trap to a truck via water-to-water transfer, hauled upstream of the dam crest, and released into the reservoir.

Figure 2-8. Steeppass Fish Ladder below Los Padres Dam, with the Spillway in the Background

A water supply pipe provides water from the reservoir to the existing trap. The supply pipe used to have the ability to mix water from the surface via a siphon, and from the lower reservoir outlet. The siphon portion of the system was recently removed due to dam safety requirements, which leaves the low-level outlet as the only source of water. The water supply pipe discharges to two locations: the fish trap; and to a point about halfway up the steeppass ladder to provide attraction flow for migrating adult steelhead.

As described in Section 2.4.1.4, in 1984, Cal-Am modified the spillway with the addition of a concrete curb in the lower 200 feet of the spillway; added a 16-foot steel extension to the end of the spillway; and removed bedrock from the right bank of the downstream plunge pool (Figure 2-9). These improvements were intended to concentrate downstream passage of fish to the right side of the spillway, improve hydraulic depth, and to direct fish away from the bedrock at the end of the spillway and into the plunge pool.

Figure 2-9. Los Padres Dam Spillway Looking Upstream from the Bailey Access Bridge

In 2016, Cal-Am completed construction of the FWC upstream of the Los Padres Dam spillway to improve the safe downstream passage of out-migrating juvenile and adult steelhead (Figure 2-10). The FWC includes a gravity-fed, 30-foot-long by 22-foot-wide floating collection barge fixed into horizontal position on four steel pilings. An articulated pipe bridge support structure connects to the spillway face, which allows for a vertical floatation range of approximately 10 feet. Water and fish that enter the collector are conveyed downstream via a 1,100-foot-long steel fish bypass conduit to a release point approximately 175 feet downstream of the spillway. A fish guidance system at the collector inlet consists of a linear array of floats that support 10-foot-tall steel panels that hang vertically in the water column. A debris boom with 2-foot debris screens upstream of the fish guidance system help exclude debris from entering the fish bypass system. Prior to implementation of the FWC, all modes of downstream fish passage were eliminated when the reservoir level dropped below Elevation 1,042.65 feet (NAVD88). At reservoir elevations above 1,042.65 feet, the only downstream pathway was via the spillway, which was thought to be harmful to downstream migrants. The FWC provides downstream migration opportunities when river flows are at a low level and reservoir levels are below the spillway level—a capability that has not been available to previous generations of fish since the dam was built.

Figure 2-10. Floating Weir Collector for Downstream Fish Passage at Los Padres Dam

2.4.2 Los Padres Reservoir

The design plans for Los Padres Dam show that the Los Padres Reservoir originally had a storage capacity of 3,030 AF, whereas the dedication plaque on the east abutment states 3,100 AF. The former number is usually cited, which coincides with the water right license for the dam (Cal-Am and MPWMD 2016). A study in 2009 (Smith et al. 2009) estimated the storage at 1,786 AF, with reduced storage due to sedimentation. The most recent bathymetric survey was conducted in July 2016 (HDR 2016). The 2016 storage capacity estimates indicate the current storage in July 2016 was 1,809.9 AF. The relatively small difference between the 2009 and 2016 storage estimates may have been due to the 2016 survey, including approximately 700 feet of the upstream channel that were not included in the 2009 survey, differences in survey methods, or the use of different datum shifts (HDR 2016). The 2016 reservoir surface area and capacity are summarized by water surface elevations in Table 2-3. Figure 2-11 presents the results of the 2016 bathymetry survey and analysis graphically.

The reservoir surface area at the spillway elevation is about 51 acres (HDR 2016), with the maximum extent of reservoir inundation extending upstream to approximately the confluence with Danish Creek (Cal-Am and MPWMD 2016). Since the dam was built, approximately 40 percent of the original capacity has been lost to sedimentation, with the current capacity estimated at 1,809.9 AF at spillway elevation 1,042.9 feet (NAVD88).

The current usable capacity is approximately 1,450 AF; water in the lowest levels of the reservoir has either unacceptable quality for release, or is not recoverable via the lower outlets because reservoir silt deposits start head cutting and slumping, which can contribute to outlet clogging (Cal-Am and MPWMD 2016). The long-term estimated average annual storage volume loss (21 AFY) is significantly affected by the loss of 555 AF in a single season immediately after the 1977 Marble-Cone fire, which burned up to 90 percent of the vegetative cover over a large part of the upper Carmel basin (Hecht 1981). Absent that extreme event, an annual loss rate would be closer to 18 AFY (MWH 2013). A graph showing the rate of reservoir siltation is shown below in Figure 2-12. Fires burned the watershed again in 2016, with an extremely wet winter immediately following in 2017; it is possible that additional sedimentation has occurred. MPWMD is coordinating with California State University Monterey Bay to perform another bathymetric survey in summer or fall 2017.

Table 2-3. Reservoir Surface Area and Capacity Summarized by Water Surface Elevation

Elevation (feet, NAVD88)	Area (acre)	Volumetric Capacity (acre-feet)
953.13 (low level outlet)	0.00	0.0
962.93	0.01	0.0
967.93	3.17	4.6
972.93	6.86	31.0
977.93	9.78	72.4
982.93	12.23	128.1
987.93	13.64	192.8
992.93	14.99	264.4
997.93	16.90	343.9
1,002.93	18.61	432.8
1,007.93	20.48	530.3
1,012.93	23.19	638.9
1,017.93	28.51	766.3
1,022.93 (high level outlet)	35.38	926.8
1,027.93	41.07	1,117.2
1,032.93	44.87	1,332.3
1,037.93	47.71	1,564.6
1,039.33 (minimum operating water surface for fish bypass)	50.12*	1737.1*
1,042.65 (spillway crest, normal maximum water surface)	51.14	1,809.9
1,047.93	61.35	2,091.7
1,051.63 (maximum operating water surface for fish bypass)	63.52*	2177.1*
1,052.93	69.68	2,420.3
1,057.93	75.82	2,784.8
1,060.83 (dam crest elevation)	78.65	3,008.9
1,060.93	78.65	3,106.8

Source: HDR 2016

Note:

* Estimated by linear interpolation.

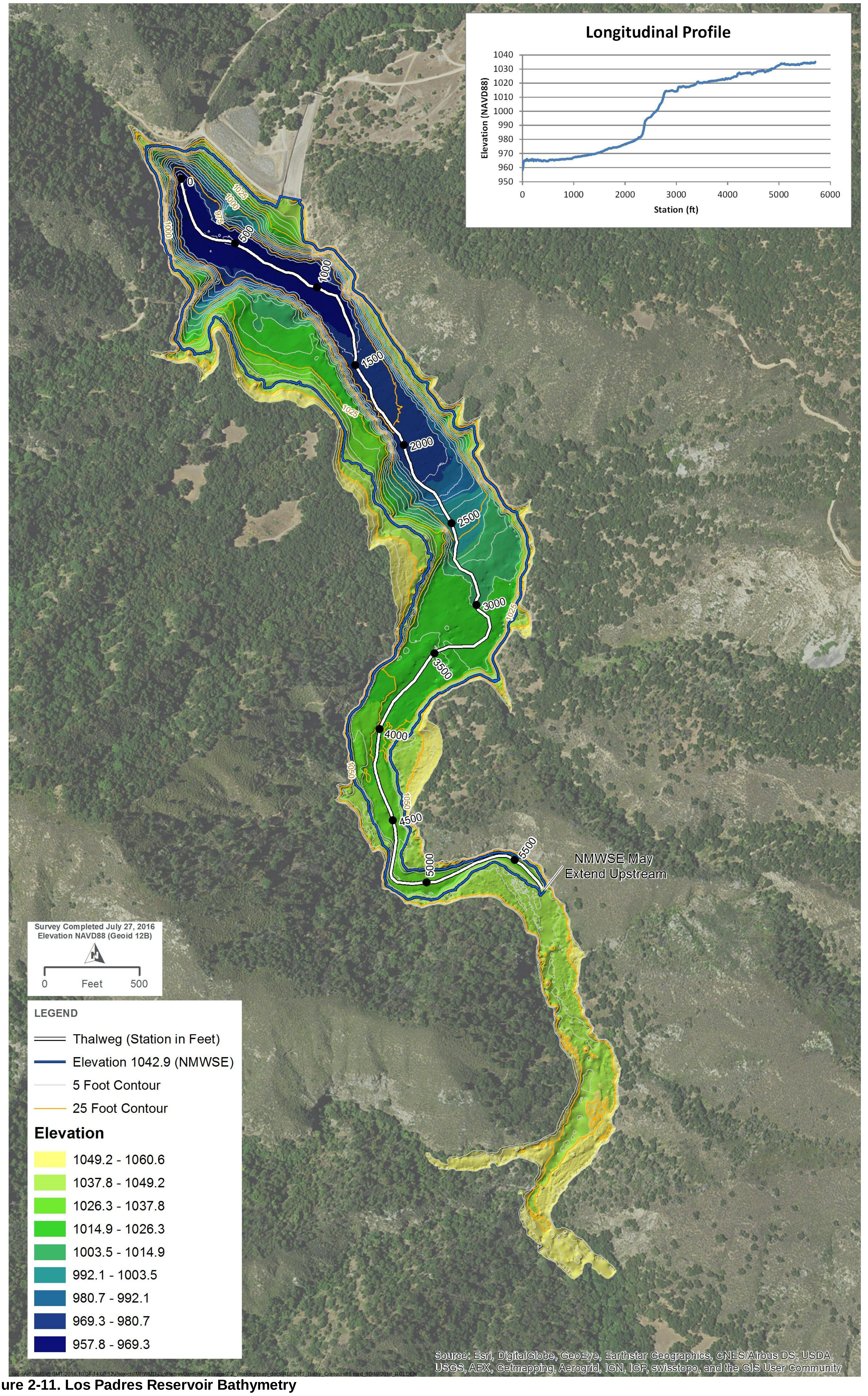


Figure 2-11. Los Padres Reservoir Bathymetry

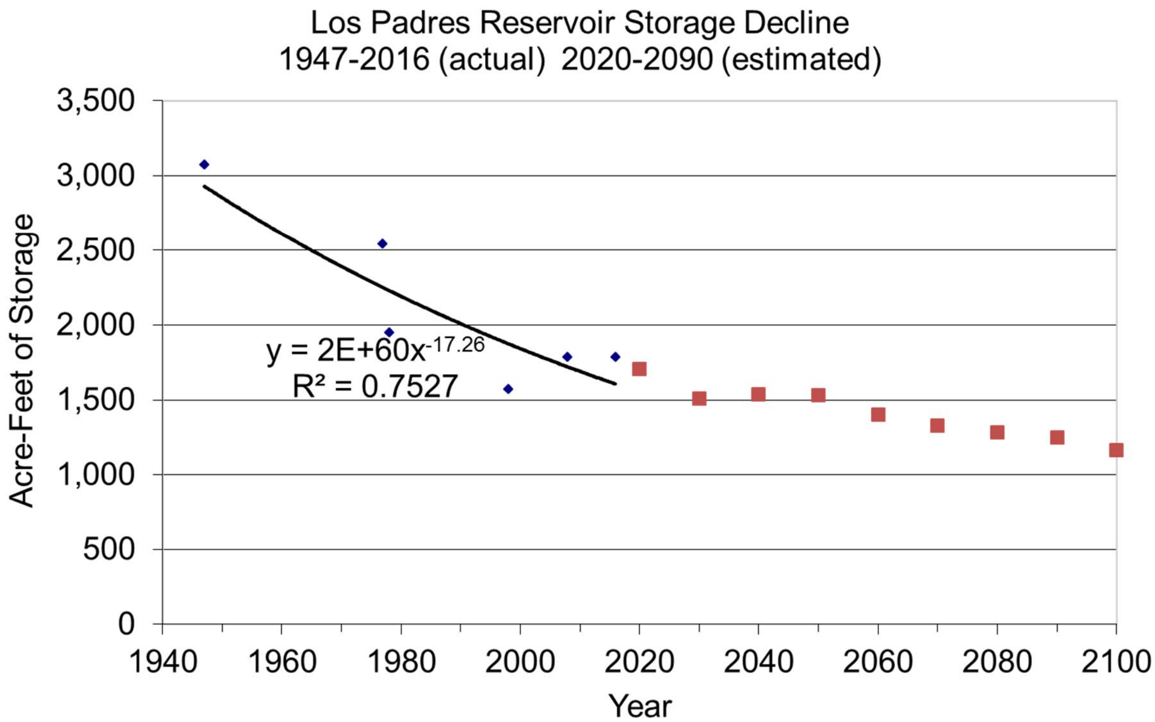


Figure 2-12. Los Padres Reservoir Storage Decline
(Source: Cal-Am and MPWMD 2016)

Current reservoir storage is small relative to median annual inflow (estimated at about 28,000 AFY), and the reservoir normally fills and spills each winter, resulting in the watershed being in an uncontrolled state with river flow responding directly to rainfall and runoff (Cal-Am and MPWMD 2016). The only recorded exceptions to this since 1949 were during the 1976-1977 drought, and 1 year during the 1987-1991 drought. During the most recent drought (2011-2016), the reservoir filled each winter. The reservoir provides little flood storage or attenuation.

The effect of the reservoir on water temperature in the river can be variable, and result in raising or lowering the water temperature in the river by several degrees (Cal-Am and MPWMD 2016). Releases during periods of very low storage can be both warmer than incoming river flow, and anoxic (low or no dissolved oxygen).

2.4.2.1 Reservoir Stage

Los Padres Reservoir stage data are available from an automated stage recorder that has been maintained since January 1, 1999. Prior to that date, stage recordings were logged manually. Stage data are provided in Section 2.6.4.

2.4.2.2 Water Supply Operations

Los Padres Dam operates under periods of unregulated spill and active outlet control depending on existing and anticipated annual water conditions. Spill occurs any time pool elevations exceed the elevation of the existing ogee spillway crest (1,042.9 NAVD88). In this scenario, inflow is typically equal to spillway flow with the exception of operational flows, which are used for the existing smolt bypass facility, fish ladder, and adult trap facilities. Operational flows for the existing fish facilities typically equate to a combined total of 10 to 20 cfs, which are conveyed through both surface water and low-level outlet infrastructure. Spill generally occurs between December and June, with only a few documented occurrences as early as October or November. The active outlet control scenario occurs whenever pool elevations decrease below 1,042.9 feet (NAVD88). During periods of active outlet control, flow downstream of Los Padres Dam is governed by the operational requirements of the existing fish passage facilities as agency-regulated targets set by committee for each individual water year. There is some uncertainty regarding the maximum, controlled release that can reliably be passed through the outlet. Estimates range from 30 cfs to 70 cfs and may be limited by the need to avoid erosion of sediment in the reservoir at the inlet to the outlet pipe, and also by potential erosion where the pipe empties into the old Carmel River channel below the dam.

Once the reservoir level drops below the spillway, releases from storage to the Carmel River mainstem are allocated in dry periods solely to augment flow downstream of the dam, and generally range from 5 to 15 cfs, depending on water-year type (Cal-Am and MPWMD 2016). There is no direct connection to a municipal supply system, and re-diversion of flow occurs at Cal-Am owned municipal production wells downstream of Carmel Valley Village, primarily between RM 3 and RM 8.

Releases are governed under a quarterly budget process set up by a MOA between CDFG (now CDFW), Cal-Am, and MPWMD. NMFS also participates in water budget decisions. CDFW, MPWMD, and Cal-Am have a mutual objective to maximize surface flow in the Carmel River to the extent feasible from June through December each year. CDFW, MPWMD, and Cal-Am therefore enter into an MOA each year that provides anticipated flow releases based on actual and projected Carmel Valley rainfall, runoff, storage, and production needs, with the intent of enhancing fishery habitats in the lower Carmel River. This is achieved by establishing a minimum storage pool at Los Padres Reservoir, and establishing a rate and schedule for the release of flows downstream of Los Padres Dam. The actual rate of drawdown is monitored, and the schedule for releases can be modified through facilitation of low-flow subcommittee meetings that occur on an as-needed basis throughout the operational season.

During dry periods, releases from storage typically constitute more than 50 percent and up to 90 percent of the flow in the river downstream of Los Padres Dam (Cal-Am and MPWMD 2016). In the 1990s, the SWRCB determined that flow downstream of RM 17.2 in the alluvial aquifer underlying the river is water flowing in a subterranean stream and subject to the jurisdiction of the SWRCB.[5] SWRCB orders state that the minimum bypass flow of 5 cfs measured just downstream of the dam shall be maintained when active storage is present in Los Padres Reservoir. In practice, low-flow rates vary depending on seasonal rainfall, and typically range between 3 and 8.5 cfs between May and December below Los Padres Dam when spill at the Los Padres Dam spillway is no longer present. In 2004, a minimum pool at Los Padres was set at elevation 980 feet, or approximately 91 AF of storage. However, an attempt is made each year to limit pool reduction at Los Padres Reservoir down to 1,003 feet. Slope instability and entrainment of debris and sediment have been known to occur when pool elevations are drawn down lower than 1,003 feet. These infrequent events have occluded the low-level outlet and required special maintenance strategies to correct.

In addition to Cal-Am diversions, there are a few surface diversions upstream of the Carmel River Reroute and about 300 private wells in the Carmel Valley Alluvial Aquifer. Most of the non-Cal-Am pumping is not subject to SWRCB jurisdiction at this time. MPWMD requires all non-Cal-Am pumpers to file annual production reports; collectively, these non-Cal-Am diversions total between 2,000 and 2,400 AFY, with about 60 percent of diversions occurring in the dry season (June 1 through November 30). Average annual outflow from the Carmel River watershed is about 72,000 AFY.[6] Median flow measured at Don Juan Bridge in Garland Park at RM 10.8 during the dry season is less than 3,700 AF,[7] whereas well production during the dry season has ranged from at least 6,000 AF up to 12,000 AF since the early 1960s. A portion of the lower river downstream of RM 8 has dried up in most years, which results in a cone of depression forming downstream of RM 8.

Currently, Cal-Am is under a Cease and Desist Order from SWRCB to reduce unauthorized diversions (see Section 2.3.2 for a description of SWRCB Order 95-10 and subsequent orders). These diversions result in a seasonal dewatering of between 4 and 8 miles of the lower river each year, except in very wet and extremely wet years (Cal-Am and MPWMD 2016). Although dewatering historically reached up to 50 percent of usable aquifer storage in extreme droughts, recent data show that Cal-Am annual production is less than at any time since the late 1950s. Even so, aquifer depletion due to Cal-Am and non-Cal-Am pumping results in an extended period when the river is disconnected from the lagoon. This

5 See SWRCB Orders 95-10 and 98-04.
6 Measured at the USGS near Carmel gauge for WY1962 to WY2015.
7 MPWMD gauge data for WY1993 to WY2016.

prevents juvenile steelhead from moving upstream away from poorer-quality water as the lagoon shrinks in the summer and late fall. Dewatering of the aquifer also delays conditions when juveniles can move downstream into the lagoon after the rainy season begins.

When replacement water supplies are available (proposed completion dates between 2018 and 2021), Cal-Am proposes to reduce dry-season diversions in the lower river to approximately 1 cfs—or about 600 AF between June 1 and November 30 (Cal-Am and MPWMD 2016). This proposed change in operations will significantly reduce dry-season diversions, and is one of the alternative production scenarios that will be modeled using the CRBHM.[8]

2.4.2.3 Inflow/Outflow and Operational Scenarios

Inflow/outflow and reservoir operations for four scenarios, including a normal water year, a wet water year, a single critically dry water year, and multiple dry (or critically dry) water years are desired for the purposes of understanding the performance of any proposed alternative during various water-year types. Water year classifications are as described in Section 2.6.1. Inflow/outflow and reservoir operations scenarios are anticipated to be developed as part of the CRBHM.

Estimated daily inflow, outflow, and reservoir elevation data for the years 2001 through 2015 were reviewed to identify any operational differences between the above four water-year types. In general, from the limited data reviewed, releases from the reservoir appeared to be similar for each water-year type except for wet years, when more water was released. Figure 2-13 shows the flow duration curve for low-level releases from Los Padres. The releases did not differ between water-year types, likely because the reservoir was equally full for all water-year types except wet years, as shown in Figure 2-14.

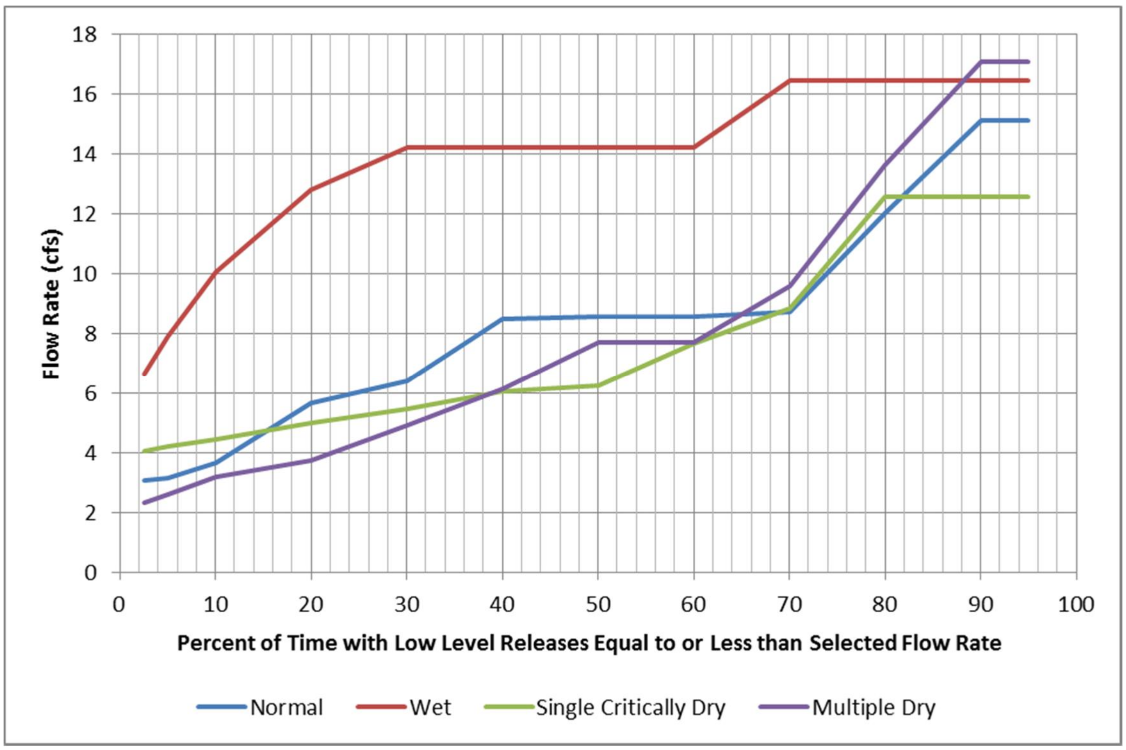


Figure 2-13. Low-Level Release Flow Duration Curve

[8] In addition to reduced Cal-Am diversions, recent agreements to forebear some Carmel River diversions will likely reduce non-Cal-Am pumping during the dry season to a range of 1,000 to 1,200 AF. After completion of proposed water supply projects for the Monterey Peninsula, total dry season diversions may drop to 1,600 AF to 1,800 AF. Median dry-season flow measured at the Don Juan Bridge in Garland Park at RM 10.8 is about 3,700 AF for the 1991 to 2016 period.

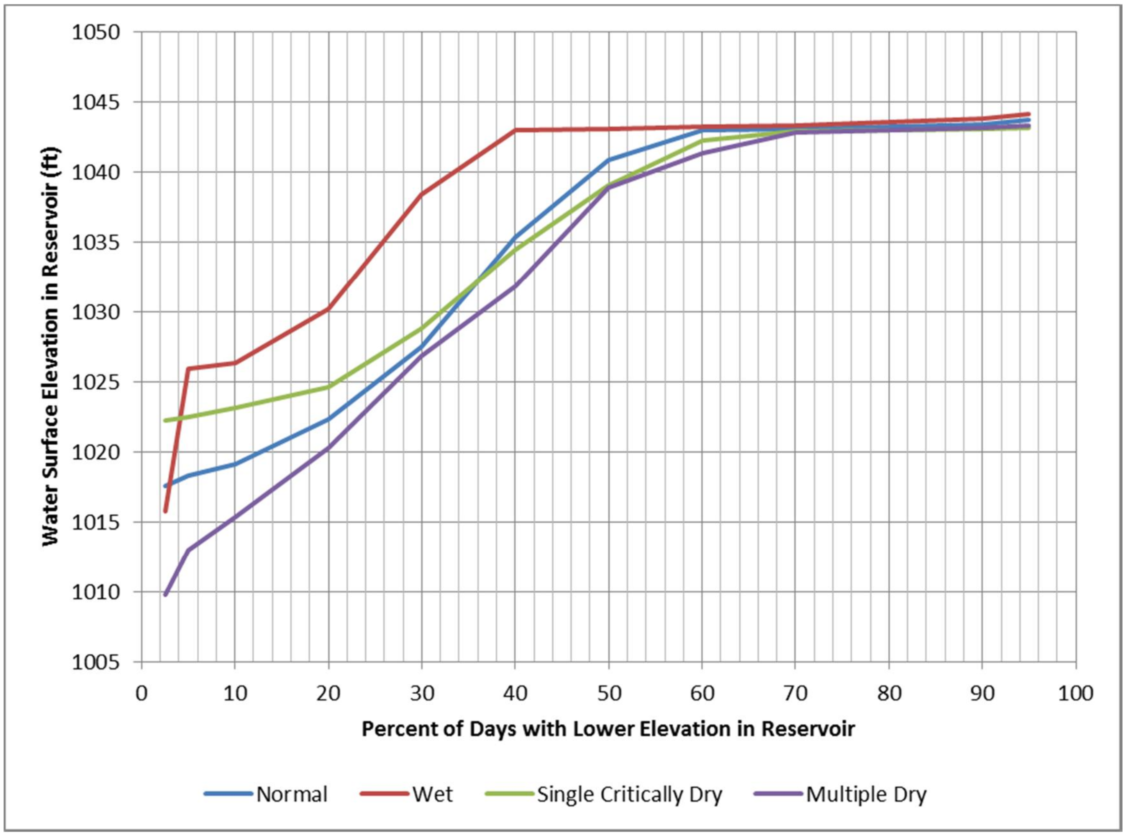


Figure 2-14. Frequency Curve for Daily Water Levels in Los Padres Reservoir

2.4.3 Los Padres Contributing Watershed

The contributing watershed drains a 44.8-square-mile area that is partly National Forest and partly Ventana Wilderness (Cal-Am and MPWMD 2016). The watershed is rural in nature, with approximately 0.3 percent of the watershed classified as developed; and 39.6 percent of the watershed covered by forest. The elevations in the watershed range from 920 to 5,050 feet, with a mean basin elevation of approximately 3,000 feet. The mean annual precipitation is 39.1 inches.

The upper watershed is steep and prone to episodes of erosion; periodic large wildfires can be followed by very wet periods with high rates of erosion. The United States Forest Service (USFS) manages virtually the entire contributing watershed. USFS land management policies—particularly for fire management—can have a direct effect on the volume of sediment and large wood that enters the reservoir. USFS is currently preparing a plan to maintain fuel breaks in the Wilderness area. The proposal is to maintain historical fuel breaks used to contain fires in the Wilderness area above Los Padres Dam and outside the Wilderness area. It is uncertain what effect the plan may have on fire recurrence interval and future erosion rates.

Most of the upper Carmel River watershed contributing to Los Padres Reservoir has been burned several times in the past few decades (Cal-Am and MPWMD 2016). The watershed above Los Padres Dam was burned severely in the 1977 Marble-Cone fire. Subsequent fires that have occupied the footprint of the Marble Cone fire include the 1999 Kirk Complex fire, 2008 Basin Complex fire, and 2016 Soberanes fire. An initial assessment of the 2016 fire impacts was completed in late September 2016. Portions of the Carmel River watershed south of the river and outside of the Los Padres Dam sub-watershed burned in the 2016 fire had no recent fire activity, and had the highest proportions of moderate and high soil burn severity. In the Los Padres Dam sub-watershed, the Basin Area Emergency Response team has estimated that up to 80 AF of debris could flow to Los Padres Reservoir as a result of a 10-year-magnitude storm. As of mid-October 2016, approximately 50 percent of the contributing watershed was burned; however, it appears that most of the burned areas that are considered high risk for debris and increased runoff are outside of the watershed contributing to Los Padres Dam (CALFIRE 2016). As of the end of October 2016, the fire was at 100 percent containment, and several early season storm events had passed through the burned areas with moderate to heavy rain.

2.5 Carmel River Downstream of Los Padres Dam

This section describes the Carmel River Downstream of Los Padres Dam based on the characteristics of specific reaches. Based on factors including geology, channel width, and slope, the Carmel River was divided into two main reaches: the Canyon (Upper) Reach, and the Alluvial (Lower) Reach. These two main reaches were further subdivided as described below (and shown in Figure 2-15) to better describe geomorphic effects of changes in sediment loads for the Task 2 sediment studies, and to address potential impacts to steelhead.

2.5.1 Canyon (Upper) Reach

The canyon reach of the Carmel River extends from Los Padres Dam at RM 25 downstream to Tularcitos Creek at RM 16. For the Task 2 sediment studies, the canyon reach was subdivided at the former San Clemente Dam to form the upstream Reach 1 and downstream Reach 2. The canyon reach is predominantly steep, confined in a canyon, dominated by bedrock outcrop control, and has more capacity to transport sediment than there is supply (Cal-Am and MPWMD 2016). Tributary inputs of sediment are highly episodic. In this reach, active channel alluvial deposits are typically shallow, frequently scoured and re-deposited, and generally much coarser than in the downstream alluvial reach.

2.5.1.1 Reach 1 (Los Padres Dam to Former San Clemente Dam)

The basin upstream of the San Clemente Reservoir is approximately 125 square miles, and is extremely rugged, with peaks rising up to about 5,000 feet above sea level. The mainstem in this upper basin passes through steep, V-shaped canyons underlain by Sur Series metamorphic rocks and by Mesozoic granitic rocks. The channel through this reach is a gravel-cobble stream, with limited areas of sand and silt. Sediment thicknesses in the upper basin are not well documented, but are estimated to be 5 to 15 feet thick, except in the reservoir inundation areas, where the sediment thickness increases dramatically (MPWMD).

The two main tributaries to Reach 1 are Cachagua Creek and Pine Creek. Even though Pine Creek has a drainage area one-sixth the size of Cachagua Creek’s, it produces more runoff, because the Cachagua Creek watershed is in a rain shadow (MPWMD 1989). The total annual tributary bedload input from the two creeks was estimated to range from 265 to 1,920 tons per year for events with recurrence intervals ranging from 1.5 to 10 years (MPWMD 1989).

There is some low-lying housing in proximity to the river near the confluence with Cachagua Creek.

2.5.1.2 Reach 2 (Former San Clemente Dam to Tularcitos Creek at RM 16)

With the removal of San Clemente Dam in 2015, the river is able to capture some of the sediment that was stored in the upper portion of the reservoir, and transport it downstream. This occurred in the winter of 2016, with the effect being formation of several gravel bars in the reroute reach, and sand deposition further downstream (CSUMB 2016). It is uncertain how fluvial processes will change downstream of the former dam site. Early indications after an average winter in 2015-2016 were that with the increase of sediment supply, fine material winnows quickly out of steeper runs, leaving gravel behind; but the fine material collects in deeper pools (Cal-Am and MPWMD 2016). The average grain size of bed material between San Clemente Dam and Sleepy Hollow (near RM 17) was characterized as 203 millimeters (Appendix L in Entrix 2008).

DATA SOURCE:
MPWMD 2004 and 2014.

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Monterey Peninsula Water Management District

Los Padres Dam and Reservoir Alternatives and
Sediment Management Study

FIGURE 2-15
Response Reaches

Alluvium begins to deepen near the Sleepy Hollow Bridge at RM 17.3 (the only bridge across the river in this reach), and reaches a depth of about 50 feet near the Cal-Am Russell wells at RM 16.2 (Cal-Am and MPWMD 2016). The average grain size of bed material between Sleepy Hollow and Tularcitos Creek was characterized as 152 millimeters (Appendix L in Entrix 2008).

Estimates of available sediment supply in this reach are associated with estimates of reservoir sedimentation rates based on periodic bathymetric surveys at San Clemente Reservoir, and direct measurement of sediment transport (Matthews 1989, Hampson 1995). The average annual sediment load at the former San Clemente Dam site is estimated to vary between about 5 and 20 AFY, with some years considerably higher (Hampson 2011). As is the case with the long-term sedimentation rate of Los Padres Reservoir, the long-term rate of sediment inflow in the mainstem at San Clemente Reservoir was heavily influenced by two discrete events: the Miller Canyon fire in 1924; and the Dormody slide in the late 1970s and early 1980s.

Between episodes of erosion, the mainstem develops into an armored gravel-cobble bed stream with complex stretches of riffles, runs, and deep pools (Cal-Am and MPWMD 2016). This is the present state of the stream (2016), except in the reach immediately downstream of the former San Clemente Dam site, where sand from the Carmel River Reroute project has deposited in many of the pools (CSUMB 2016).

2.5.2 Alluvial (Lower) Reach

The alluvial reach extends from Tularcitos Creek at RM 16 downstream to the Pacific Ocean. For the Task 2 sediment studies and to address effects on steelhead, the alluvial reach was subdivided at the Narrows at RM 9.8, and at the Carmel River Lagoon just upstream of the mouth to form Reach 3 (from Tularcitos Creek to the Narrows), Reach 4 (from the Narrows to the Lagoon), and Reach 5 (from the Lagoon to the ocean).

2.5.2.1 Reaches 3 and 4 (Tularcitos Creek to Carmel River Lagoon)

The Carmel River exits from the highly confined canyon- and bedrock-controlled reach after the confluence with Tularcitos Creek at RM 16. Between the 1920s and 1960s, the river and adjacent floodplain were converted from a wide, shallow, meandering system that was braided in sections to a moderately incised, less-sinuous, single-thread channel (Cal-Am and MPWMD 2016). Dam building, gravel mining, road building, floodplain development, and channel maintenance activities (bulldozing to remove vegetation) combined to constrain the active channel alignment. Sinuosity in the lower 16 miles is estimated to have dropped from about 1.3 at the beginning of the 20th century, to about 1.15 currently. Degradation in the active channel of up to 15 feet has been documented (Kondolf 1983). Many of the previously allowed development activities in the channel and floodplain are now either prohibited or severely restricted.

Although no episodic or chronic erosion has occurred since 1998, the lower 16 miles of the Carmel River are likely not in a state of equilibrium (Cal-Am and MPWMD 2016). It is more likely that vegetation introduced into the streamside environment over the past several decades has raised the threshold flow at which chronic erosion occurs, and hardscape prevents episodic erosion that would cause a shift away from the present-day meandering single-thread system. Tributary sediment inputs have been shown to be a minor component of the sediment load, so most of the main-stem load (when it is present) is attributable to bed and bank erosion.

Alluvium progressively deepens from less than 50 feet at the confluence with Tularcitos Creek, to more than 200 feet near the mouth of the river (Cal-Am and MPWMD 2016). After flowing past the Tularcitos Creek confluence at RM 16, the valley progressively widens, the river’s transport ability diminishes, and the alluvial aquifer reaches a maximum width of about 0.5 mile. This lower reach can be placed in the transition zone between being a single-thread or braided channel (Kondolf and Curry 1986). There are few bedrock outcrops in this reach. Changes in sediment supply, diversions for municipal supply, health of streambank vegetation, floodplain development, and the presence of hardscape on the streambanks combine to influence the form of the active channel. Since the late 1960s, about 40 percent of the left streambank and 47 percent of the right streambank along the lower 16 miles of the river have had at least one form of hardscape protection introduced, and are somewhat to highly resistant to erosion[9] (Cal-Am and MPWMD 2016). Degradation in the lower 10 miles (Reach 4) was estimated at 0.25 foot per year in the mid-1960s to mid-1970s (USGS 1983); more recently, the long-term rate appears to be a little less than 0.2 foot per year (Graham Matthews and Associates 2008).

Due to sediment retention at the two main-stem reservoirs,[10] long-term sediment transport capacity in the lower reach remains greater than supply, and the lower reach is considered sediment-starved (Cal-Am and MPWMD 2016). This has resulted in armoring in the active channel, formation of a meandering single-thread channel in the alluvial reach, and historical degradation of the thalweg, as evidenced by periodic field surveys. However, as described below, periods of episodic erosion have occurred in which the alluvial reach was transport-limited, and long reaches of the river became braided and were destabilized.

Most of the streambanks in the lower 16 miles of the Carmel River are formed of unconsolidated sands and gravels that are easily eroded in the absence of vigorous vegetation or other stabilizing component such as hardscape (Cal-Am and MPWMD 2016). This reach is flanked by housing and other property development, and is currently crossed by 18 bridges. Gravel mining operations between the 1920s and the 1970s removed an unknown, but significant, quantity of material from the active channel[11](CDMG 1966). Operations to clear the active channel of riparian vegetation were routine up until the early 1980s. Diversions for municipal use annually dewater several miles of the river, and cause stress and mortality of streamside vegetation.

In the lower 16 miles of the river, there were two notable periods with episodic erosion during which the stream had an excess supply of sediment (i.e., 1978-1983 and 1993-1998) (Cal-Am and MPWMD 2016). The first episode occurred after severe drought; increased well production in 1976-1977 brought aquifer levels between RM 5 and RM 15 to as much as 50 feet below the riverbed. Most streamside vegetation in this reach died by the end of 1977, and several areas were subsequently cleared of dead vegetation by bulldozer. In the ensuing wet period, about 8 miles of the river's streambanks were destabilized (Kondolf 1983). Testimony given before the SWRCB in 1992 and 1994 established a clear link between Cal-Am's pumping, and the loss of vegetation along the streamside corridor (Cal-Am and MPWMD 2016). After most of Cal-Am's well pumping was transferred downstream in the mid-1980s to between RM 3 and RM 8, the lower portion of that reach became destabilized. Following the second notable episode of erosion, caused by high flows in 1993, 1995, and 1998, intensive restoration efforts were required, including use of rock slope protection that incorporated native riparian vegetation.

During these periods of episodic erosion, the river generally responded by widening through streambank avulsion and forming depositional areas in the active channel downstream of eroded sections (Cal-Am and MPWMD 2016). The erosion and depositional process continued in a feedback loop that moved downstream over a period of years. This process tends to shift the active channel toward a sand-bed stream. In some reaches, a stable single-thread channel with an active width of 70 to 100 feet and fringed with dense vegetation was transformed into wide, braided reaches of up to 800 feet wide, with little or no vegetation remaining (e.g., the widening of the area upstream of Schulte Bridge at RM 6.7 between 1977 and 1980; and the erosion and widening that occurred at Rancho Cañada golf course in 1998 at RM 3).

Subsequent to these periods, the stream returned to being supply limited (Cal-Am and MPWMD 2016). Therefore, the "frequent flows" of up to the 10-year magnitude served to winnow out material smaller than gravel-sized, and create vertical complexity in the lower 16 miles; however, in general, the limits of the active channel are shaped by infrequent large-magnitude floods coupled with installation of hardscape to restrain the river after high flows. The typical reaction to episodic erosion has been to fortify unstable

[9] Looking downstream, based on unpublished estimate by MPWMD using River Work Permits issued, restoration project plan sets, and field inspections (Cal-Am and MPWMD 2016).

[10] Between 1921 and 2015, San Clemente Dam and Reservoir retained about 1,500 AF (or about 2.4 million cubic yards) of sediment from the upper watershed (Cal-Am and MPWMD 2016). Between 1948 and 2016, Los Padres Reservoir retained about 1,255 AF (or just over 2 million cubic yards).

[11] A 1966 California Division of Mines and Geology report described several gravel mining operations in the Carmel River and listed estimates of production capability in tons/day. In addition, in a personal communication to Larry Hampson in 1991, John and Bruno Odello described that "the Granite Rock Company mined several hundred thousand cubic yards of sand" near Highway 1 on two occasions in the 1970s—once for material to build the Crossroads Shopping Center, and another for building materials. It is conceivable that up to about 100,000 cubic yards may have been removed. It can be inferred that perhaps ½ to 1 million cubic yards of material may have been mined before prohibition in the late-1970s.

streambanks with hardscape, including reinforcing streambanks by placing riprap, gabions, concrete rubble, post and wire, car bodies, and even car tires along the river's banks. Since 1983, many of these practices have been prohibited, and MPWMD and other regulatory agencies have encouraged biotechnical stabilization, with rock riprap and gabions allowed under limited circumstances.

Many of these treatments have occurred on the outside of meanders (Cal-Am and MPWMD 2016). Due to requirements since the early 1980s to mitigate for some of the impacts from installing hardscape, riparian vegetation is incorporated into the hardscape. Areas that are dewatered during dry periods are irrigated to reduce stress on riparian vegetation. The result is that most of the lower 16 miles of the river are fringed with riparian vegetation and encroachment into the center of the active channel is common. MPWMD conducts an annual program to selectively remove vegetation in areas where debris dams could form; however, few trees are wholly removed and the vegetation quickly grows back.

Most of the lower 16 miles of river are currently a single-thread channel due to supply limitations, or "sediment starvation" (Cal-Am and MPWMD 2016). In some reaches, degradation since the late 1990s has reached up to 6 feet, and the stream has been transformed from a sand bed to gravel-cobble bed. With one exception between RM 3 and RM 4, the lower 16 miles of the alluvial reach have not undergone significant erosion since 1998. This relatively stable period has occurred despite several peak flows that previously would have caused widespread erosion and streambank collapse. Some reaches in the lower 16 miles in the alluvial portion of the river are notable for their bedrock outcrops along the channel that impose lateral and vertical controls to channel migration.

Tributary input of sediment in the lower reach appears to coincide with episodes of erosion in the mainstem (Cal-Am and MPWMD 2016). It is likely that low-flow years with chronic erosion in the tributaries result in deposits of material that are stored in the active channels, and moved down to the mainstem only during relatively high-flow years.

2.5.2.2 Reach 5 (Carmel River Lagoon to the Ocean)

The Carmel River Lagoon and its associated wetlands cover an area of approximately 100 acres at the mouth of the Carmel River (MPWMD 2005). The lagoon area is shown on Figure 2-16. The lagoon morphology varies by season. In the summer and fall, lagoon levels are generally static, except for occasional filling events from ocean waves overtopping the beach berm. After filling events, when the mouth is still closed, lagoon levels gradually lower through infiltration and evapotranspiration. The lagoon generally begins to fill after runoff from winter storms is able to advance downstream to the lagoon. Once it fills, the Monterey County Public Works Department will use bulldozers to artificially breach the sand bar at the mouth to allow runoff to discharge to the ocean. The outlet typically remains open (or has temporary closures) through early spring. As flows in the Carmel River decrease in the spring or summer, the beach berm forms to close off the mouth of the lagoon until the following rainy season (MPWMD 2005).

Figure 2-17 shows the range of flows measured when the mouth of the lagoon was open to the ocean.

2.6 Hydrology

Flows in the Carmel River vary from year to year and by season. Over 90 percent of the average annual precipitation typically occurs between November and April, with the highest rainfall amounts occurring in January and February (Entrix 2008). Inflows to Los Padres Reservoir are generally lower for the rest of the year, from May to October. Inflow to Los Padres Reservoir is measured once a month by MPWMD upstream of Los Padres Dam (MPWMD 2008). Figure 2-18 shows monthly inflows from June through December for years in which inflow fell below 5 cfs during at least one month as measured by MPWMD. Figure 2-19 shows monthly inflows from June through December for years in which inflow never fell below 5 cfs. These figures show that, for a little more than half of years between 1990 and 2012, inflow to Los Padres Reservoir fell below 5 cfs for at least a few months of the year. During the dry season, downstream reaches of the Carmel River can go dry due to groundwater withdrawals and low tributary inflow (Entrix 2008).

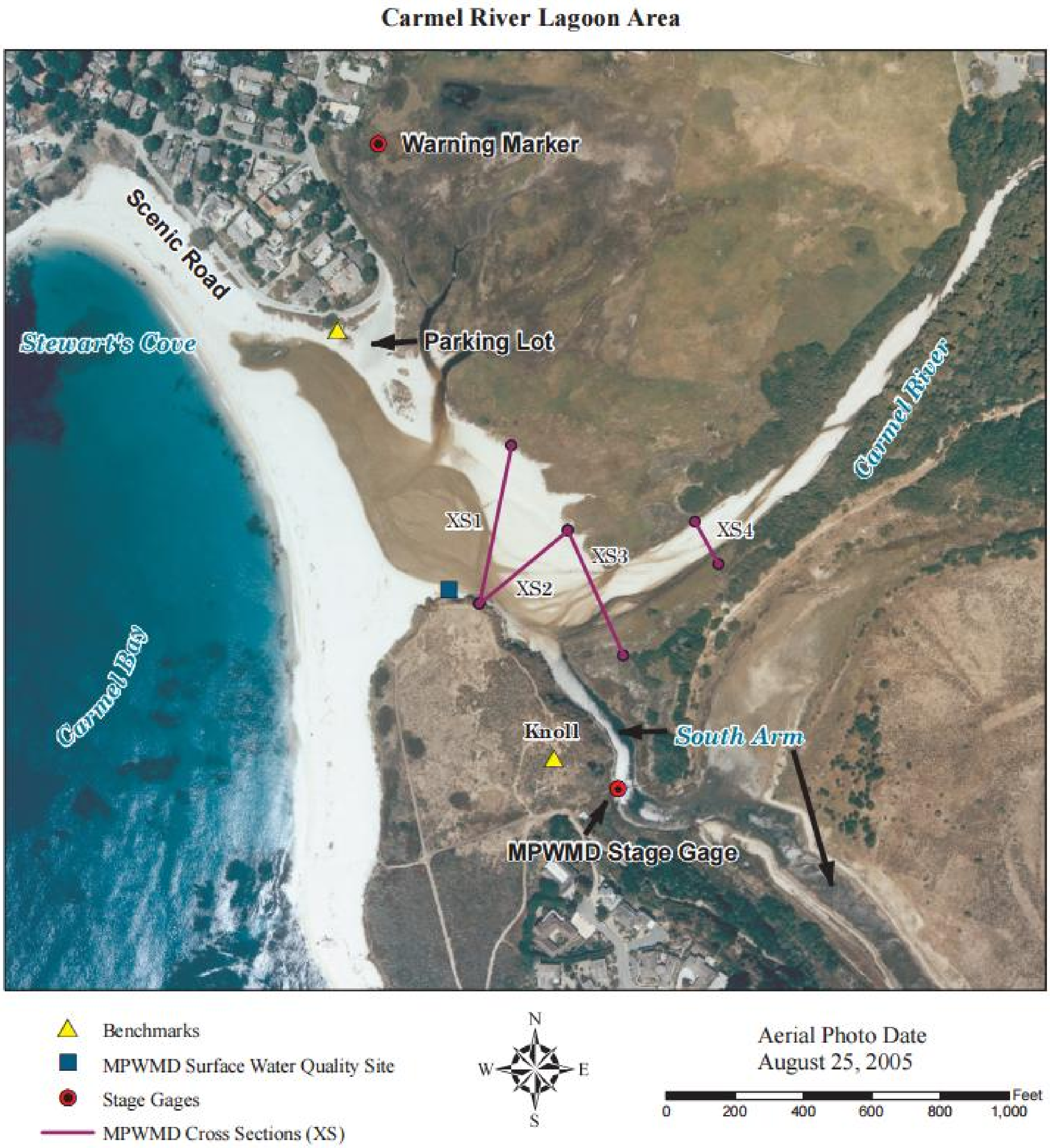
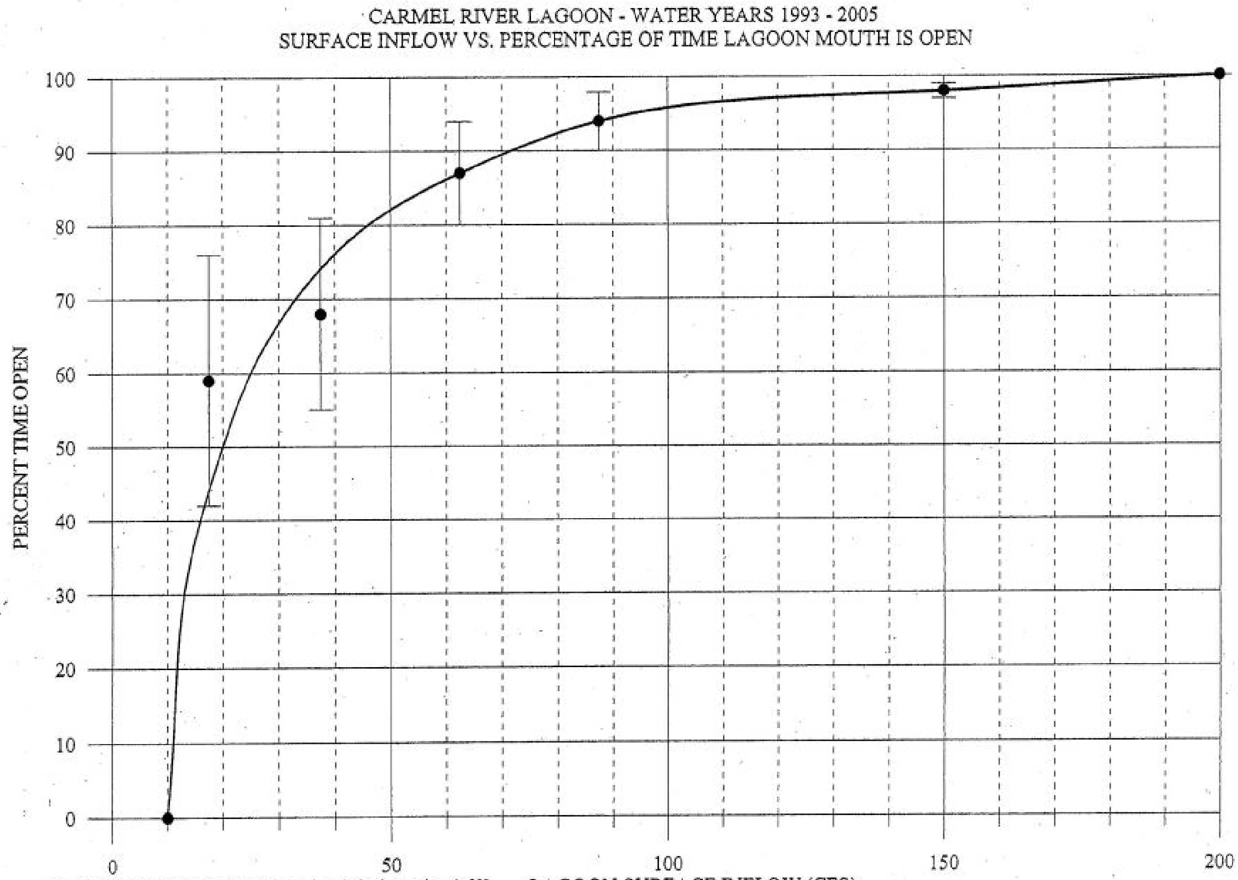


Figure 2-16. Carmel River Lagoon Area
(Source: MPWMD 2005)



Notes: (1) Data points derived from hydrograph analysis of approximately 200 identified lagoon mouth closure events during the 1993-2005 period
(2) Error bars indicate 95% confidence limits.
(3) Inflow measured at Carmel River at Highway 1 Bridge gage.

Source: MPWMD 2005

Figure 2-17. Carmel River Discharge when Lagoon Mouth is Open

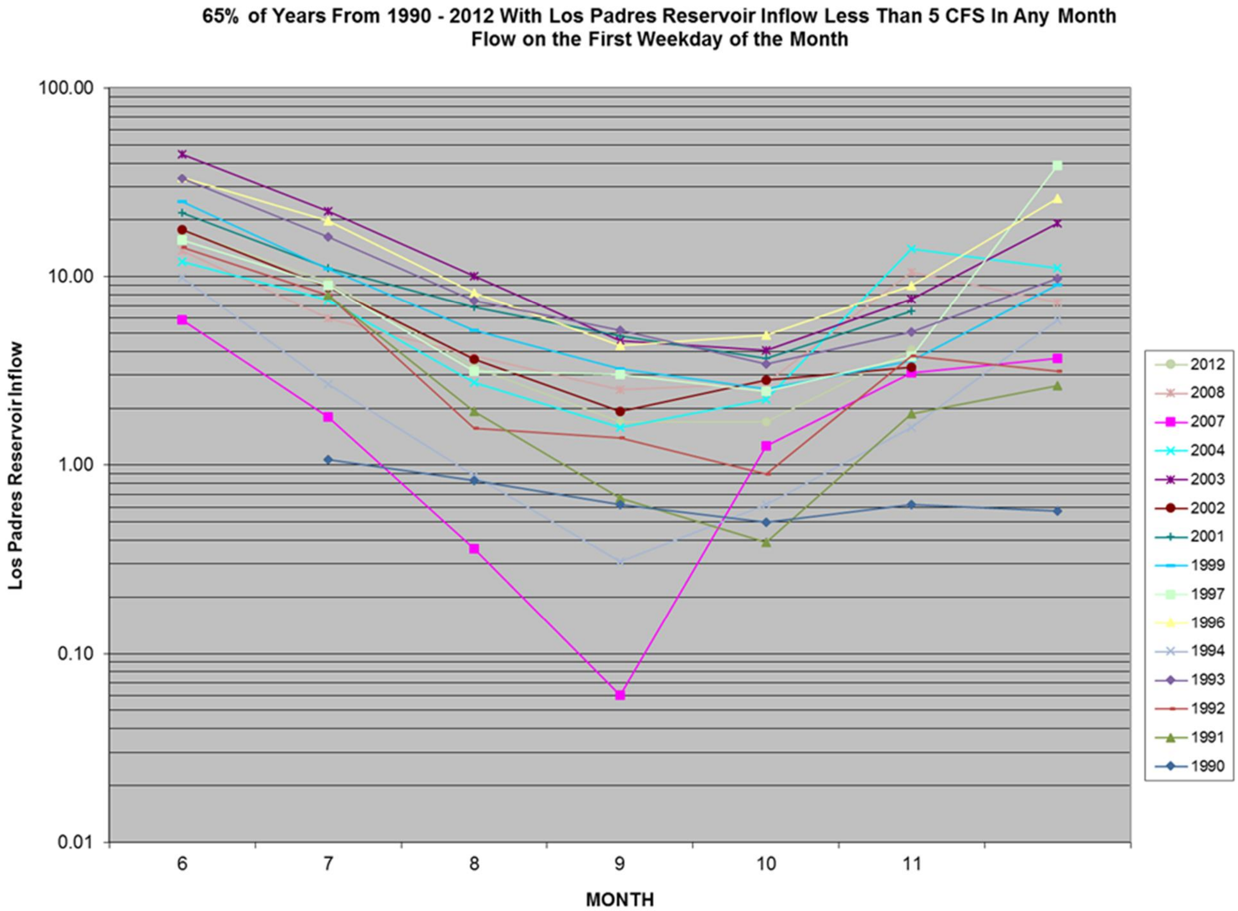


Figure 2-18. Carmel River Inflow (cfs) to Los Padres Reservoir during Years in which Inflow Fell Below 5 cfs.
(Source: MPWMD 2017a)

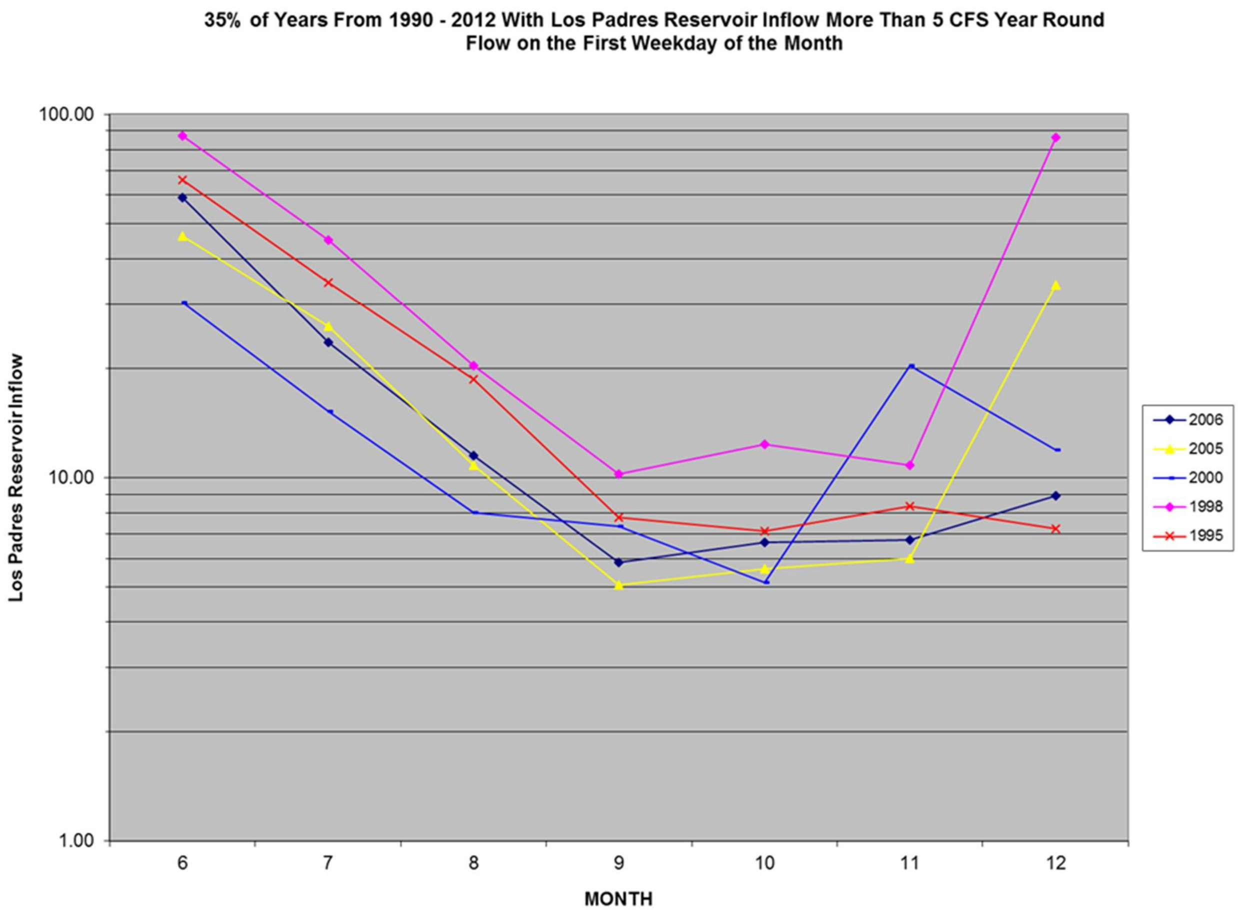


Figure 2-19. Carmel River Inflow (cfs) to Los Padres Reservoir during Years in which Inflow did not Fall Below 5 cfs.
(Source: MPWMD 2017a)

Preliminary analyses were performed using available hydrologic data to support the Fish Passage Study (HDR et al. 2017). The information has been provided below with some updates and revisions.

Streamflow data for the Carmel River are available at several locations downstream of Los Padres Dam. There are two streamflow gauges operated by USGS (USGS No. 11143250, Carmel R Nr Carmel CA, which is approximately at RM 4; and USGS No. 11143200, Carmel R. at Robles del Rio, which is approximately at RM 14). The gauge near Carmel has been operating since 1962, and the gauge at Robles del Rio has been operating since 1957. There is also a gauge operated by MPWMD directly below Los Padres Dam with data available since 2001. Figure 2-20 illustrates the variability of all annual hydrographs (instantaneous flow) of the Carmel River flows for water years 2002 through 2016 from the MPWMD gauge below Los Padres Dam. The gauge below Los Padres Dam is calibrated on a regular basis by MPWMD, and is typically within 5 percent of the actual streamflow at that location (HDR et al. 2017).

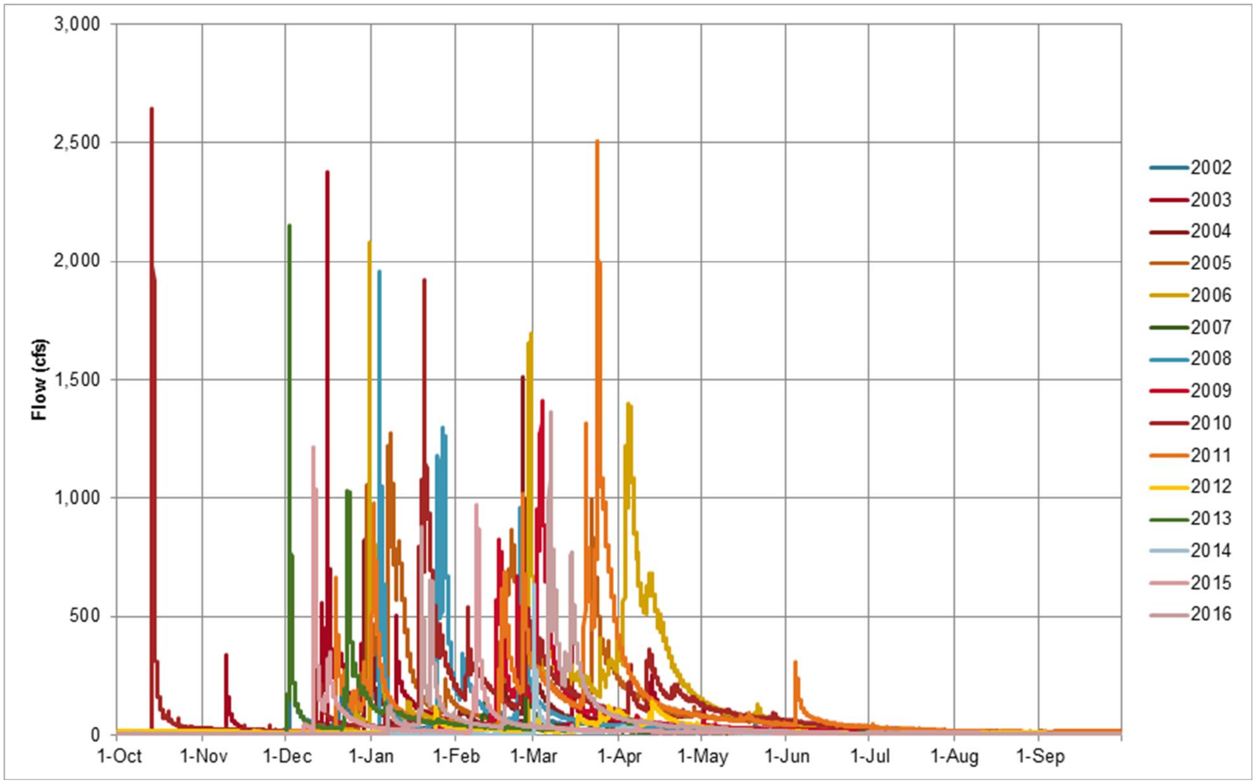


Figure 2-20. Carmel River Flows at the MPWMD Gauge Below Los Padres Dam (Water Years 2002 – 2016)

2.6.1 Water Year Classification

Water years of the Carmel River are classified based on the Carmel River Basin Runoff Index. Seven independent classifications are enumerated based on selected exceedance frequency values computed from the long-term, reconstructed, unimpaired flow record at the San Clemente Dam site. Classifications for water years 1999 through 2015 are presented in Table 2-4.

Per the Carmel River Basin Runoff Index:

- "Extremely Wet" refers to flows exceeded 12.5 percent of the time;
- "Wet" refers to flows exceeded between 12.5 and 25 percent of the time;
- "Above Normal" refers to flows exceeded between 25 and 37.5 percent of the time;
- "Normal" refers to flows exceeded between 37.5 and 62.5 percent of the time;
- "Below Normal" refers to flows exceeded between 62.5 and 75 percent of the time;
- "Dry" refers to flows exceeded between 75 and 87.5 percent of the time; and
- "Critically Dry" refers to flows exceeded less than 87.5 percent of the time.

Table 2-4. Water Year Runoff Classification for Unimpaired Carmel River Flows at San Clemente Dam Site

Water Year	Runoff at San Clemente Dam (acre-feet)	Classification
1999	51,222	Normal
2000	73,499	Above Normal
2001	44,981	Normal
2002	30,888	Below Normal
2003	59,434	Normal
2004	36,910	Below Normal
2005	112,153	Wet
2006	107,217	Wet
2007	12,542	Critically Dry
2008	49,017	Normal
2009	47,506	Normal
2010	98,419	Above Normal
2011	101,769	Wet
2012	20,025	Dry
2013	27,303	Dry
2014	6,970	Critically Dry
2015	22,209	Dry
2016	44,923	Normal
2017	196,359*	Extremely Wet

* Projected values used for September 2017

2.6.2 Watershed Characteristics

The Carmel River contributing basin area above Los Padres Dam is approximately 44.2 square miles. The watershed is rural in nature, with approximately 0.3 percent of the watershed classified as developed and 39.6 percent of the watershed covered by forest. The elevations in the watershed range from 920 to 5,050 feet, with a mean basin elevation of approximately 3,000 feet. The mean annual precipitation is 39.1 inches. The contributing basin area for Los Padres Dam is illustrated in Figure 2-21.

2.6.3 Flood Frequency Analysis

A flood frequency analysis was performed on the USGS Robles del Rio gauge data of annual peak instantaneous flows for water years 1956 through 2017 (n = 61) within the guidelines of Bulletin 17B (United States Interagency Advisory Committee on Water Data 1982, USGS 2011) using HEC-SSP 2.1 (USACE 2016). A weighted skew methodology was used in the analysis, with a calculated station skew of -0.859, a regional skew of -0.469, and regional skew mean square error of 0.13. Calculated flood flows at the USGS Robles del Rio gauge are summarized in summarized in in Table 2-5. The flow frequency plot is shown on Figure 2-22.

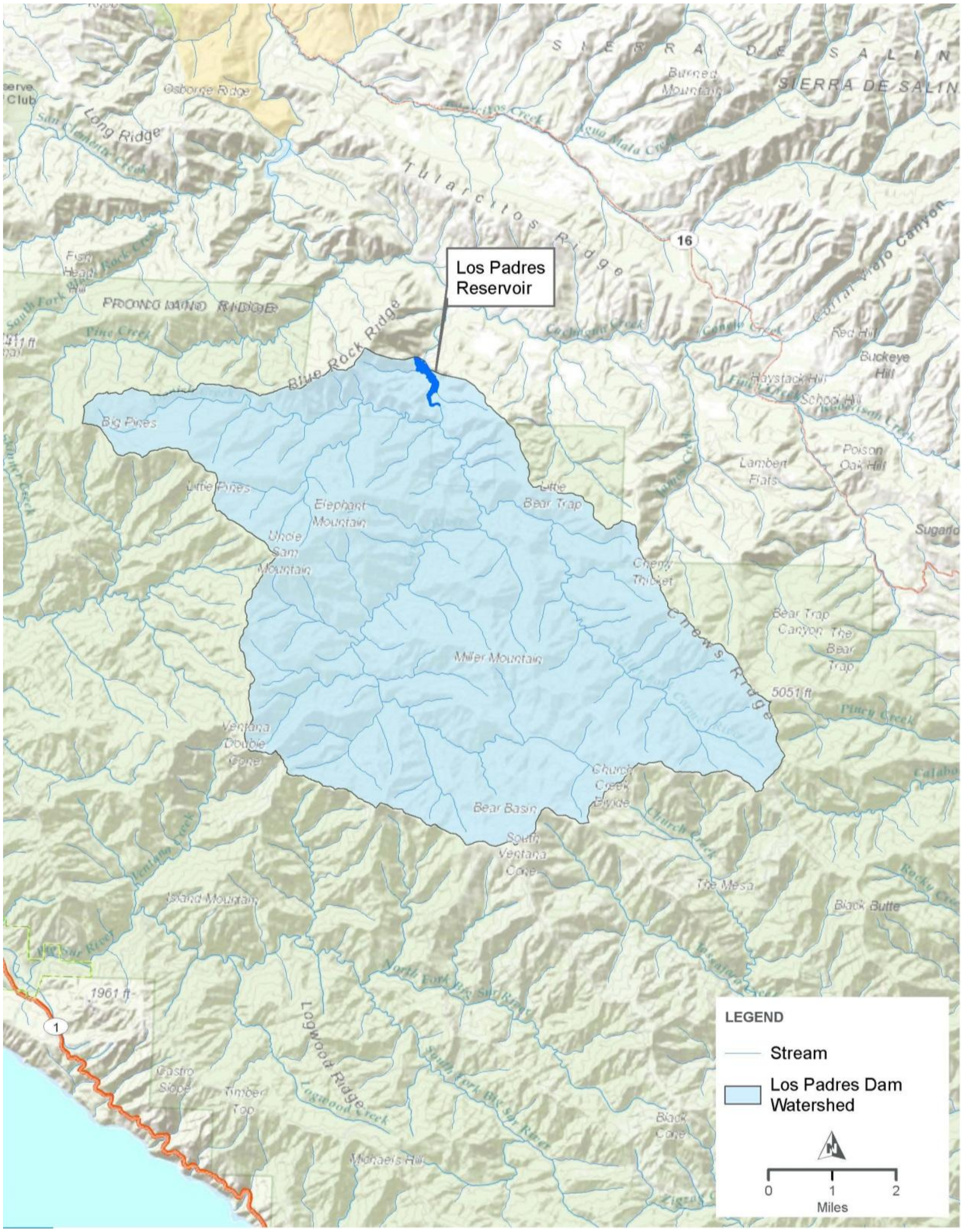


Figure 2-21. Contributing Basin Area for Los Padres Reservoir

Table 2-5. Annual Instantaneous Peak Flows for Carmel River at USGS Robles del Rio Gauge No. 11143200 (water years 1956 – 2017) Using the Bulletin 17b Procedures

Recurrence Interval (years)	Annual Exceedance Probability (%)	Peak Discharge (cfs)
2	50	2,400
5	20	5,500
10	10	8,100
20	5	10,700
50	2	14,100
100	1	16,800

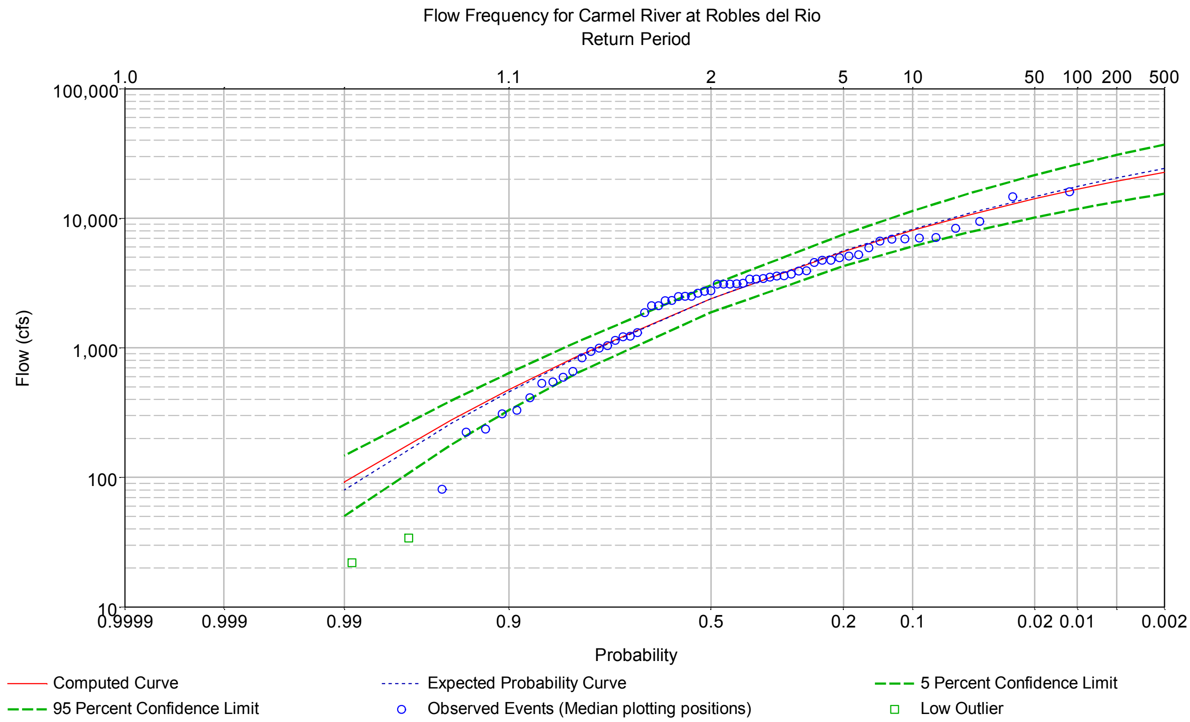


Figure 2-22. Flow Frequency for USGS Robles del Rio Gauge No. 11143200

A flood frequency analysis was also performed on annual peak instantaneous flows for the MPWMD gauge location for water years 1958 through 2017, within the guidelines of Bulletin 17B (United States Interagency Advisory Committee on Water Data 1982, USGS 2011). MPWMD extended the period of record for the gauge location by estimating peak flows prior to 2001 based on water surface elevations recorded at the Los Padres Dam and the spillway rating curve. A weighted skew methodology was used in the analysis with a calculated station skew of -0.8, a regional skew of -0.469, and regional skew mean square error of 0.13 (USGS 2011). Using this methodology, Los Padres Dam is expected to contribute approximately 56 percent of the peak flows measured at the USGS Robles del Rio gauge.

A second analysis was also performed. The second analysis was a precipitation-weighted basin area reduction. The Carmel River contributing basin area above the USGS Robles del Rio gauge was calculated to be 193.4 square miles, while the contributing basin area above Los Padres Dam was calculated to be 44.2 square miles. Therefore, the contributing basin area for Los Padres Dam is 22.9 percent of the total contributing basin area of the USGS Robles del Rio gauge. Mean annual precipitation in the Los Padres basin is 39.1 inches per year versus 30.5 inches per year for the entire basin at the USGS Robles del Rio gauge. Using a precipitation-weighted basin area reduction, Los Padres Dam is expected to contribute approximately 29.3 percent of the peak flows measured at the USGS Robles del Rio gauge.

Flood flow estimates below Los Padres Dam are presented in Table 2-6. Instantaneous peak flows for both the USGS gauge and MPWMD gauge used in the Bulletin 17B analyses are provided on Figure 2-23.

Table 2-6. Annual Instantaneous Peak Flows for Carmel River at Los Padres Dam

Recurrence Interval (years)	Annual Exceedance Probability (%)	Peak Discharge (cfs) Bulletin 17b	Peak Discharge (cfs) Basin Area Reduction
2	50	1,500	700
5	20	3,200	1,600
10	10	4,500	2,400
20	5	5,800	3,100
50	2	7,600	4,100
100	1	8,900	4,900

The exceedance flows statistically represent the flow equaled or exceeded a certain percentage of the time. An annual flow duration analysis was performed on the Los Padres gaging station. A summary of the annual exceedance flows based on mean daily flow data at the Los Padres Dam gauging station are provided in Table 2-7.

2.6.4 Reservoir Stage

Los Padres Reservoir stage data are available from an automated stage recorder that has been maintained since January 1, 1999. Prior to that date, stage recordings were logged manually. For this study, analysis was performed on the data collected between October 1, 2001 and July 29, 2016 at Los Padres Reservoir. Reservoir elevations are plotted for water years 2002 through 2016 on Figure 2-24.

2.6.4.1 Los Padres Reservoir Stage-Duration Analysis

A stage-duration analysis of the data was conducted to assess the range of reservoir levels during anticipated migration periods, as well as annually. The analysis was performed on four data sets: all available water years, wet water years, normal water years, and dry water years. Water years were grouped per their Carmel River Basin Runoff Index. The wet water years' group includes the classifications of "Extremely Wet," "Wet," and "Above Normal." The normal water years' group includes the classification of "Normal." The dry water years' group includes the classification of "Critically Dry," "Dry," and "Below Normal." See Table 2-8 for a summary of the classification of wet, normal, and dry water years used for the reservoir stage-duration analysis.

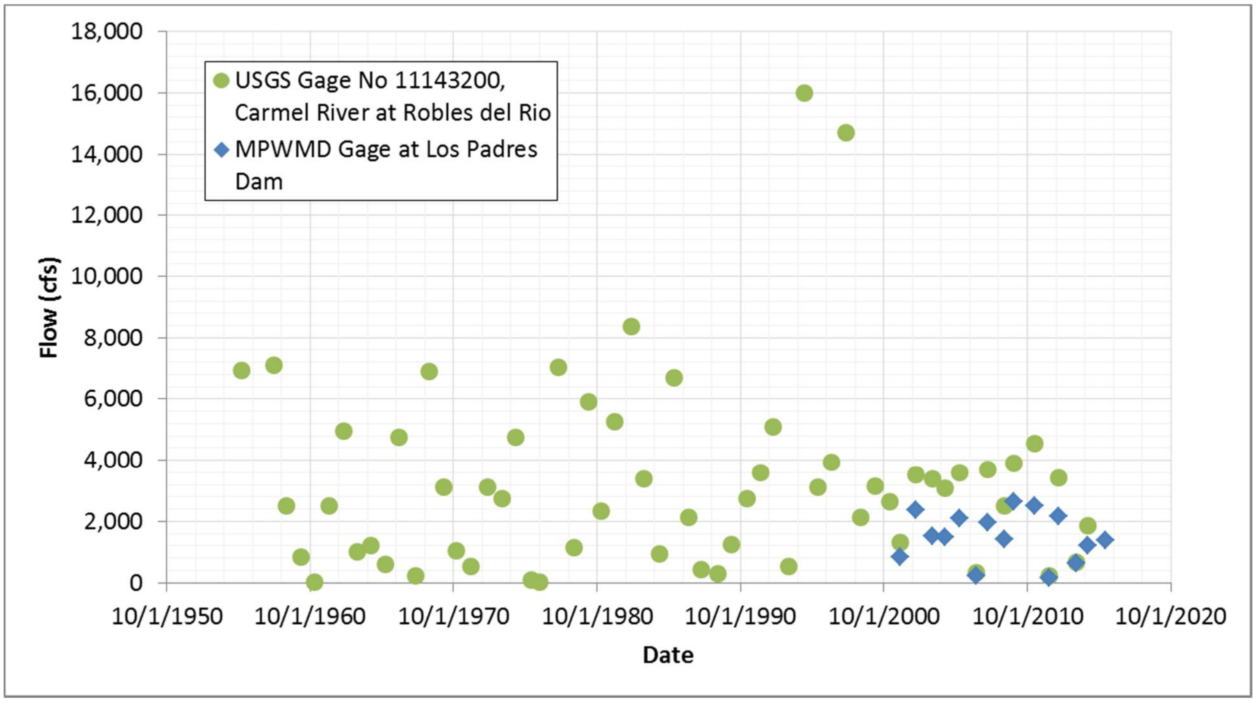


Figure 2-23. Annual Instantaneous Peak Flows for the Carmel River at USGS Gauge No. 11143200 and MPWMD Gauge Below Los Padres Dam

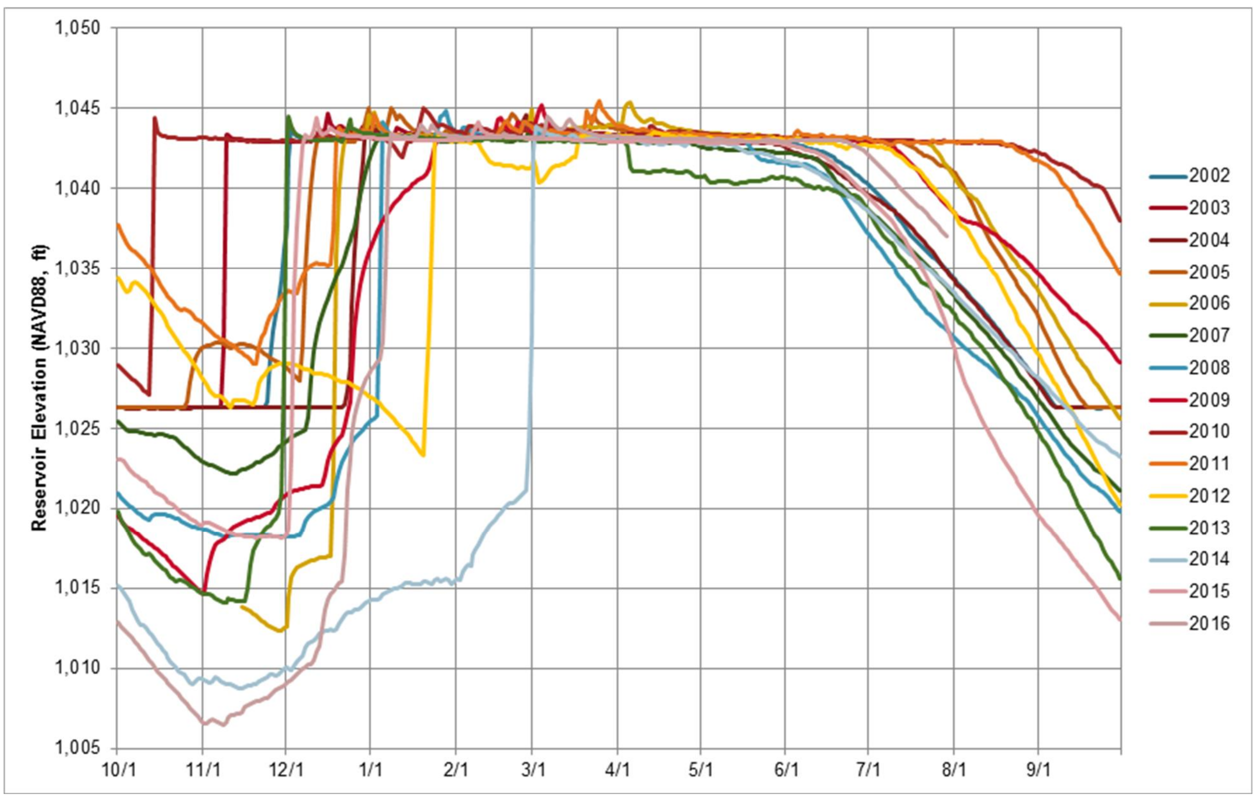


Figure 2-24. Los Padres Reservoir Elevations for Water Years 2002 through 2016

Table 2-7. Estimated Mean Daily Annual Exceedance Flows at Los Padres Gauging Station (October 1, 2001 through July 28, 2016)

Percent of Time Exceeded (percent)	Flow at Dam Site (cubic feet per second)
99.9	2
99.0	2
95.0	3
90.0	5
80.0	6
70.0	8
50.0	14
40.0	19
25.0	43
15.0	78
10.0	121
5.0	226
2.0	403
1.0	624
0.1	1,213

Table 2-8. Summary of Wet-, Normal-, and Dry-Year Categories Used in the Reservoir Stage-Exceedance Analysis

All Water Years	Wet Water Years	Normal Water Years	Dry Water Years
2002 – 2016	2005	2003	2002
	2006	2008	2004
	2010	2009	2007
	2011	2016	2012
	2017		2013
			2014
			2015

Table 2-9 summarizes the results for the annual reservoir stage-duration analysis. The data show that the median pool elevation on an annual basis is approximately 1,042.4 feet. Eighty percent of observed reservoir levels have been between the elevations of 1,019.7 and 1,043.4 feet. From 5 to 95 percent exceedance—which accounts for 90 percent of historical conditions—the range of elevations was determined to be from 1,015.4 to 1,043.7 feet.

Table 2-9. Annual Percent Exceedance of Mean Daily Pool Elevations for Los Padres Reservoir

Percent of Time Exceeded (%)	All Water Years	Wet Water Years	Normal Water Years	Dry Water years
99.9	1,006.6	1,012.3	1,014.6	1,008.8
99.0	1,009.0	1,013.6	1,015.8	1,009.4
95.0	1,015.4	1,026.3	1,018.3	1,015.0
90.0	1,019.7	1,029.9	1,019.0	1,019.0
80.0	1,026.3	1,036.2	1,022.3	1,026.2
70.0	1,031.8	1,042.5	1,027.5	1,027.6
50.0	1,042.4	1,043.1	1,040.9	1,039.8
40.0	1,043.0	1,043.2	1,043.0	1,042.2
25.0	1,043.1	1,043.4	1,043.1	1,043.0
15.0	1,043.3	1,043.6	1,043.3	1,043.1
10.0	1,043.4	1,043.8	1,043.4	1,043.1
5.0	1,043.7	1,044.0	1,043.7	1,043.3
2.0	1,044.0	1,044.4	1,044.1	1,043.5
1.0	1,044.3	1,044.7	1,044.4	1,043.7
0.1	1,045.1	1,045.4	1,045.2	1,044.4

2.7 Water Quality

This section provides a summary of available water quality data from Los Padres Reservoir and downstream of Los Padres Dam, including temperature, turbidity, dissolved oxygen, and other constituents affecting steelhead. The following sources were identified that describe existing data: the 2015-2016 Annual Report for the MPWMD Mitigation Program (MPWMD 2017b); the CRRDR Final EIR/EIS (Entrix 2008); and the *Working Draft Los Padres Dam Fish Passage Study, Interim Compendium of Background Information* (HDR et al. 2017).

MPWMD and Cal-Am measure various water quality parameters at Los Padres Reservoir. Los Padres Reservoir temperature and dissolved oxygen profiles have been recorded throughout the years at irregular intervals, with more frequent measurements taken in recent years (HDR et al. 2017). Temperature and dissolved oxygen profiles in Los Padres Reservoir, as well as measured temperature and dissolved oxygen upstream and/or downstream of Los Padres Reservoir, were plotted to support the Fish Passage Study. The temperature and dissolved oxygen profiles have been reproduced on Figure 2-25 and Figure 2-26, respectively.

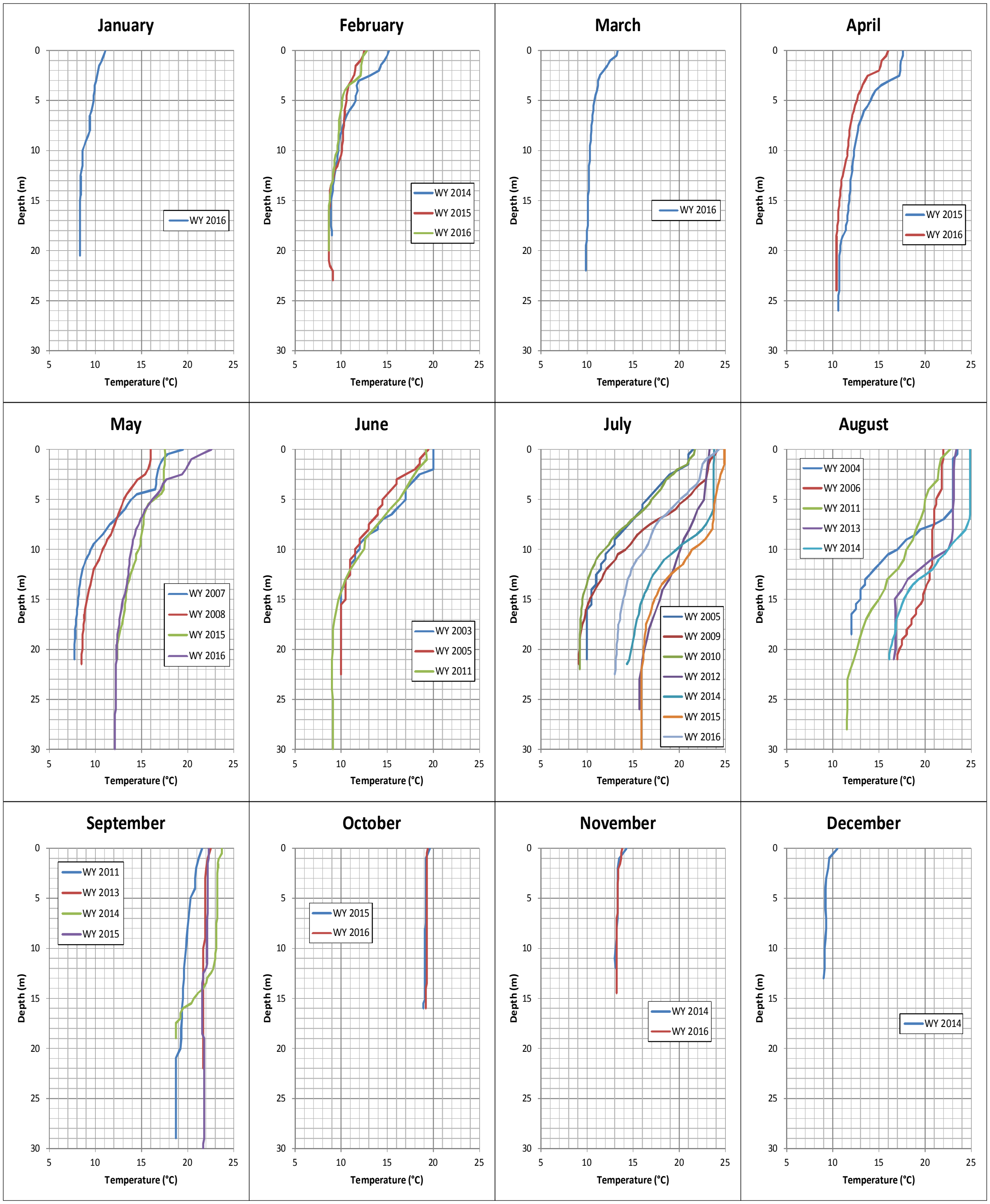


Figure 2-25. Los Padres Reservoir Water Temperature Profiles (Source: HDR et al. 2017)

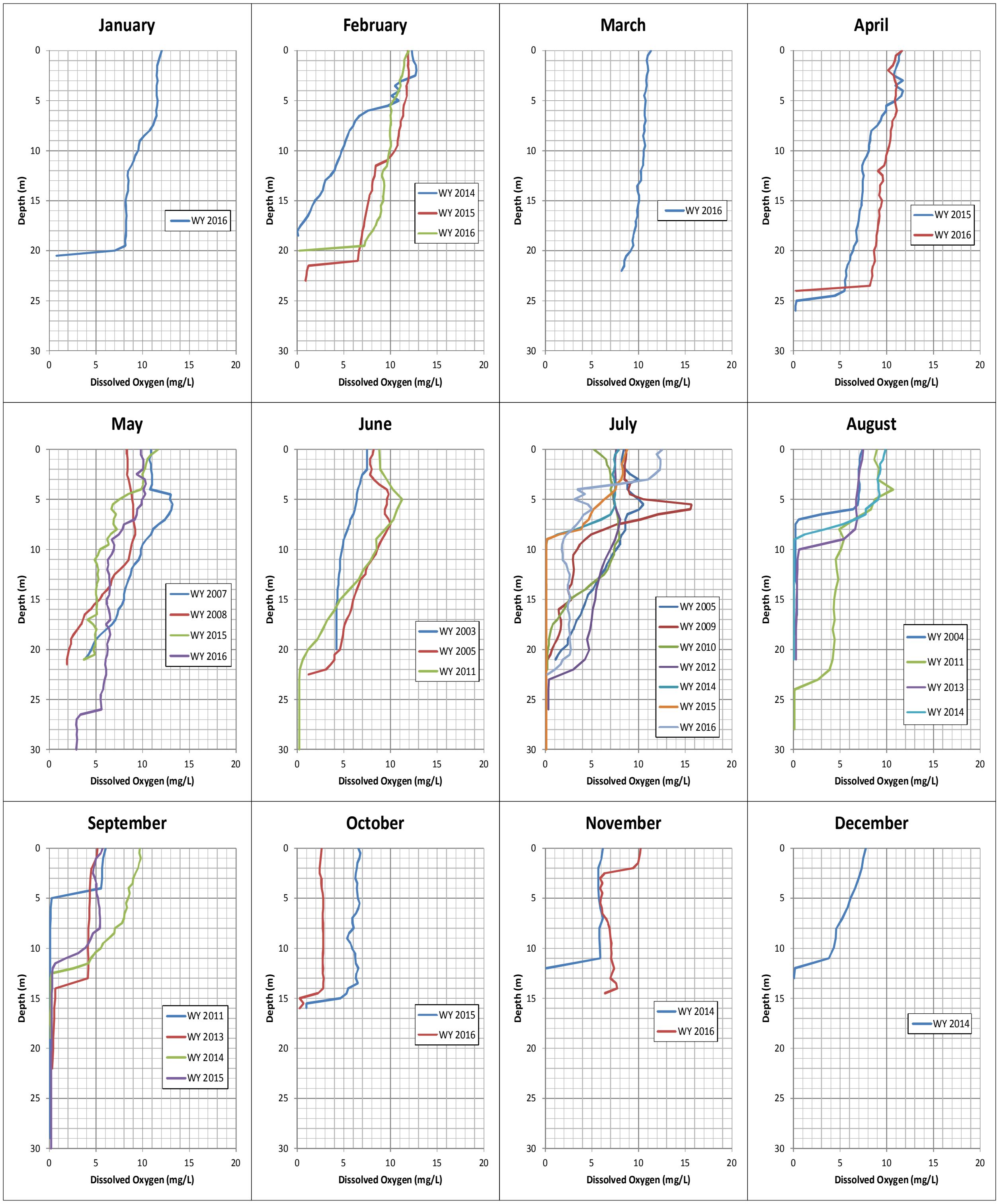


Figure 2-26. Los Padres Reservoir Dissolved Oxygen Profiles
(Source: HDR et al. 2017)

The temperatures measured in the Carmel River upstream and downstream of Los Padres Reservoir are shown on Figure 2-27. Temperatures measured above Los Padres Reservoir are generally a few degrees cooler, as compared to below the reservoir. Dissolved oxygen measured below Los Padres Reservoir is shown on Figure 2-28. Figure 2-28 shows that dissolved oxygen concentrations are generally above 8 milligrams per liter, which is considered a minimum level for steelhead without causing impairment (Bjornn and Reiser 1991). However, some measurements were as low as 4 milligrams per liter.

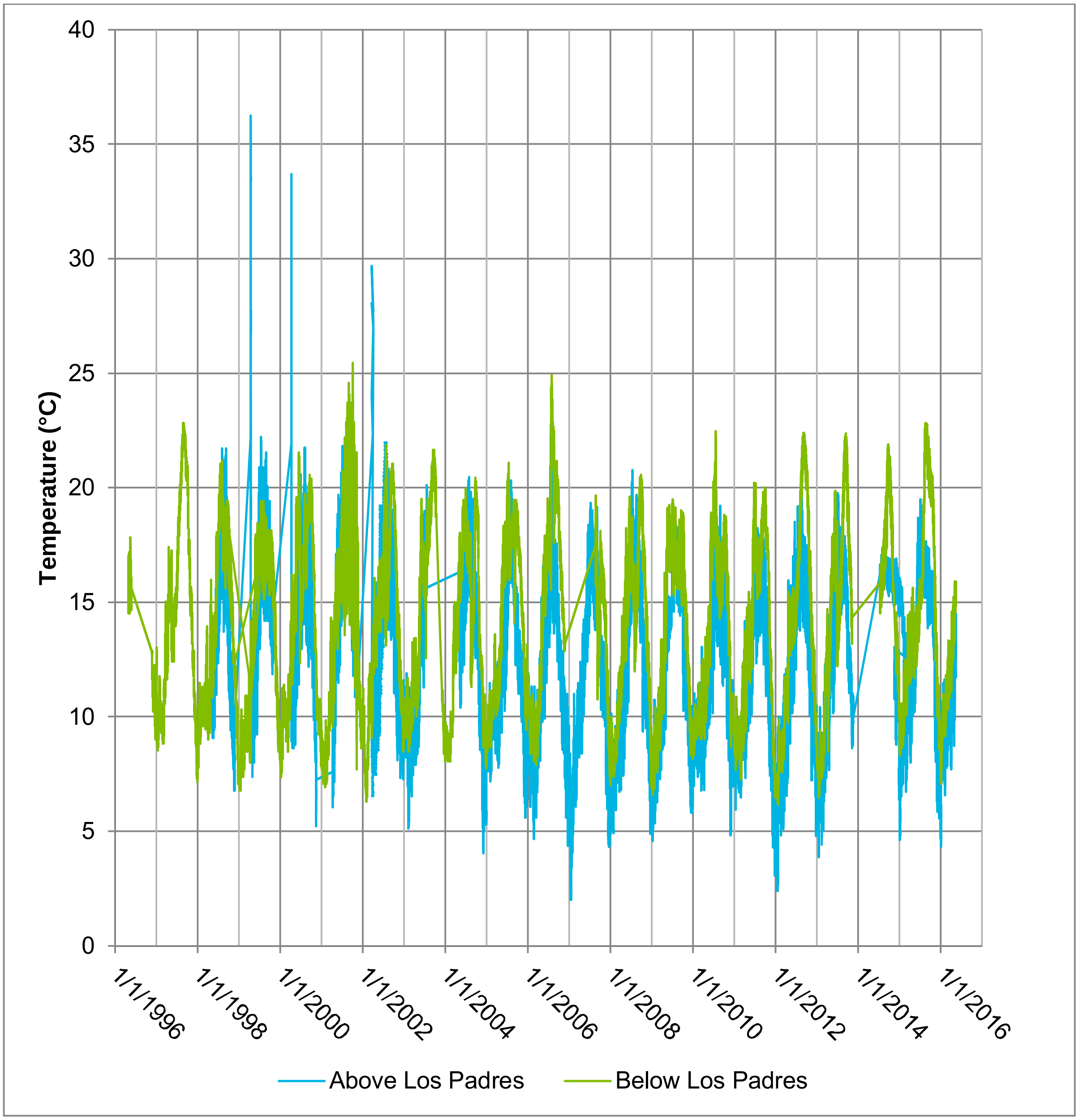


Figure 2-27. Carmel River Water Temperature Above and Below Los Padres Reservoir (Source: HDR et al. 2017)

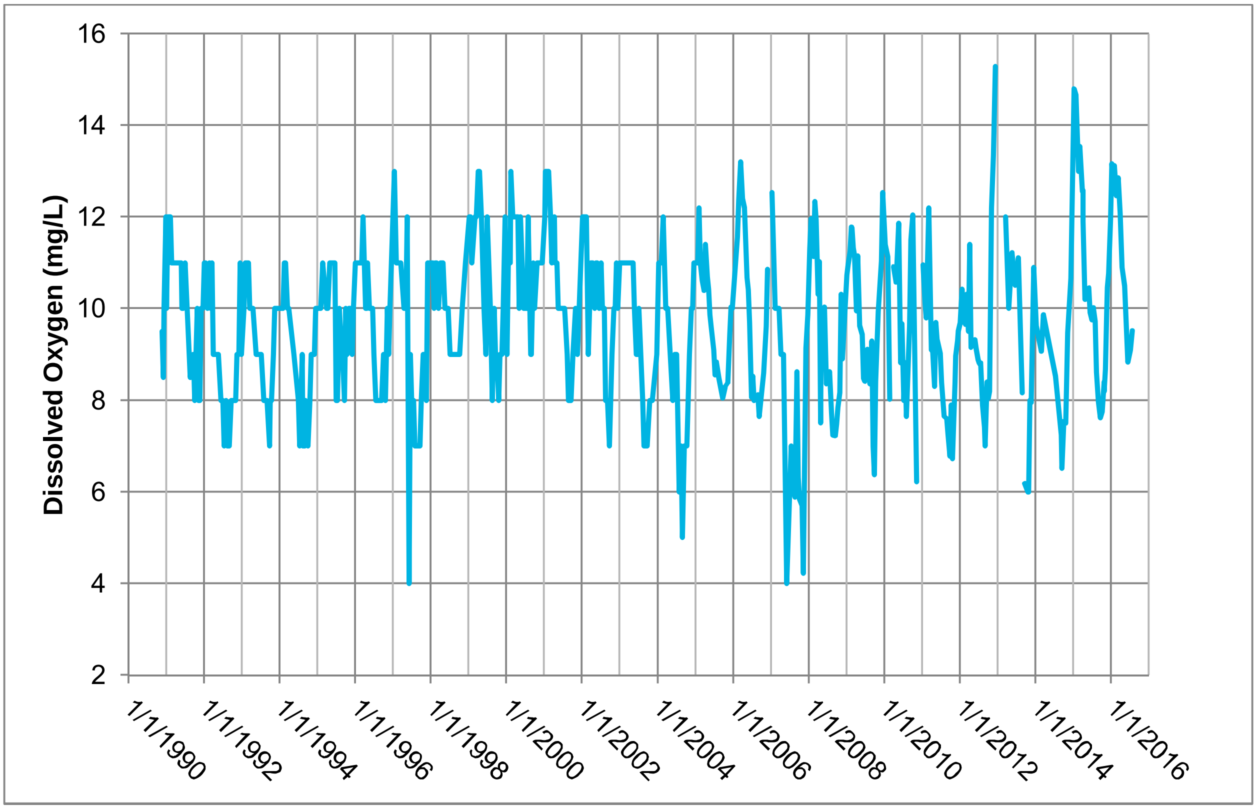


Figure 2-28. Carmel River Dissolved Oxygen Below Los Padres Dam
(Source: HDR et al. 2017)

MPWMD performs continuous temperature monitoring at the following six stations (MPWMD 2017b):

1. ALP Above Los Padres Dam (RM 27.0)
2. BLP Below Los Padres Dam (RM 25.4)
3. ASC Above San Clemente Dam (RM 18.5)
4. SHW Sleepy Hollow Weir (RM 17.1)
5. GAR Garland Ranch Regional Park (RM 10.8)
6. SAL South Arm Lagoon (RM 0.1)

Figure 2-29 and Figure 2-30 show monthly average temperature in the Carmel River at five of these locations before and after removal of San Clemente Dam, respectively. These data show that water temperatures at the most upstream station (above Los Padres Dam) are consistently the coolest of all the stations. During certain times of the year (e.g., September and October before removal of San Clemente Dam), water temperatures below Los Padres Dam are the highest of all the stations. In some months (e.g., April), water temperatures consistently warm as water moves downstream, while in other months (e.g., September), water temperatures fluctuate as water moves downstream, and there may be a cooling effect on water warmed in Los Padres Reservoir as it moves downstream, depending on air temperature, riparian shading, and hyporheic exchange. This cooling effect may have been reduced by the presence of the former San Clemente Dam, where water may have again been subject to reservoir warming. Since removal of San Clemente Dam, summer water temperatures appear slightly cooler while winter temperatures appear slightly warmer; however, with less than 2 years of temperature data since the dam was removed, these differences cannot yet be attributed to dam removal and a new pattern may emerge over time.

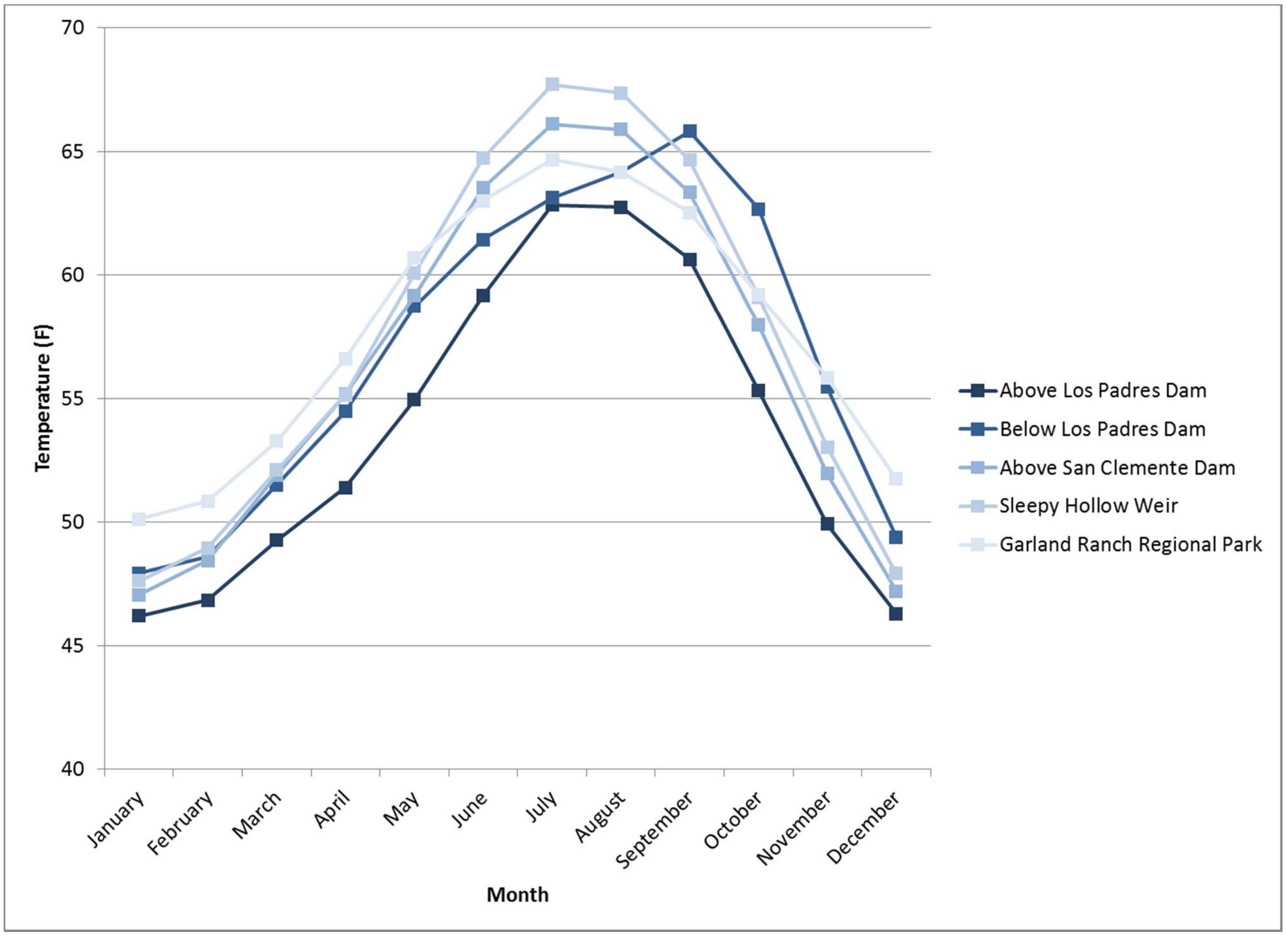


Figure 2-29. Carmel River Temperature before San Clemente Dam Removal (Jan 1996-May 2014)
(Source: MPWMD Unpublished Data)

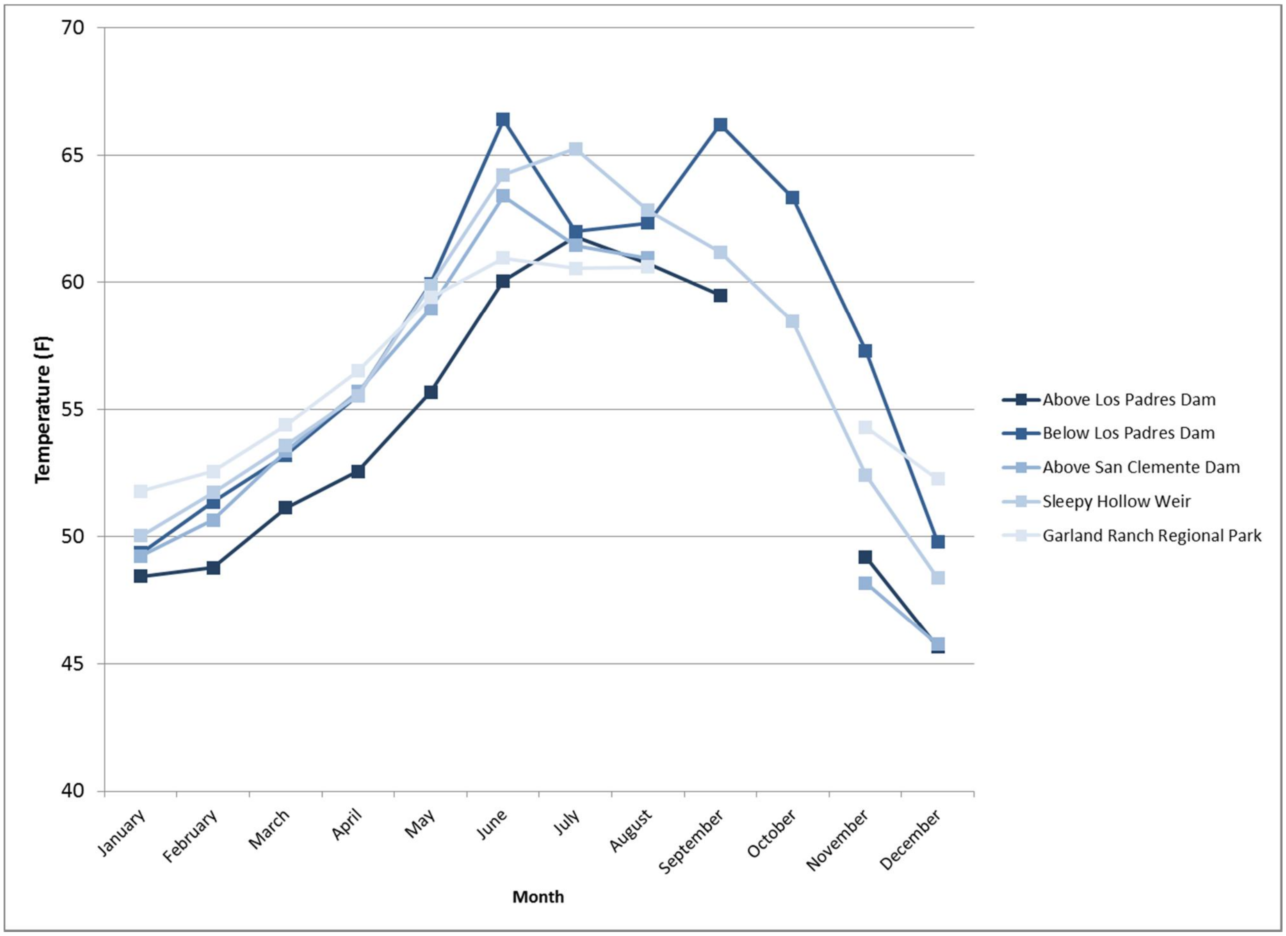


Figure 2-30. Carmel River Temperature after San Clemente Dam Removal (Nov 2015-Aug 2017)
(Source: MPWMD Unpublished Data)

During warm, summer months, extensive algae blooms have been observed at Los Padres Reservoir (Figure 2-31).With the recent change in operations to release of water from closer to the reservoir surface through the downstream fish bypass, in summer 2017 algae from the reservoir's surface waters was translated downstream and was noticeable in the Carmel River. The noticeable change in water clarity and temperature resulted in complaints to the MPWMD and a decision was made to turn off the fish bypass and switch back to releasing water from the lower outlet until conditions improved. It is currently unknown whether the recent algae blooms in Los Padres Reservoir are of the toxic, blue-green variety (cyanobacteria) that have been found in many California waterways but the algae does appear visually similar to that variety.

The MPWMD has also measured surface water quality at three sampling locations in the Carmel River on a semi-monthly basis since 1991. The locations are: 1) below Los Padres Reservoir (BLP) at RM 25.4; 2) below the former San Clemente Reservoir at the Sleepy Hollow Weir (SHW) at RM 17.1; and 3) at the Carmel River Lagoon at RM 0.1. The following chemical and physical parameters were measured: temperature, dissolved oxygen, carbon dioxide, pH, specific conductance, salinity, and turbidity. These locations provide water quality information (with an emphasis on suitability for rearing juvenile steelhead) for releases below the dams and in the surface layer of the lagoon (MPWMD 2017b).

Vertical profiles of salinity, dissolved oxygen, and temperature are measured in the Carmel River Lagoon by MPWMD. Figure 2-32 shows the sampling locations in the lagoon.

Figure 2-31. Algae in Los Padres Reservoir, August 31, 2017

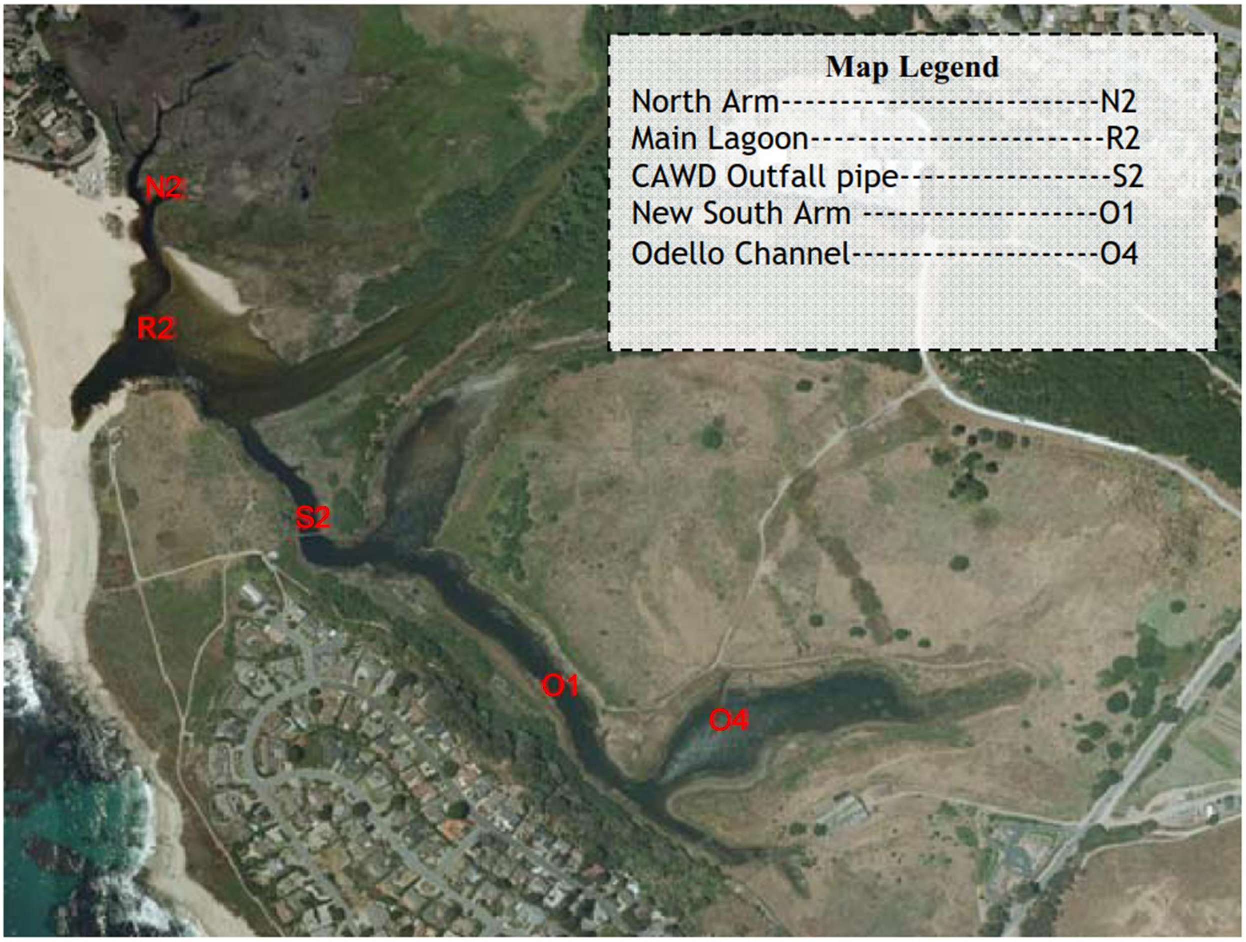


Figure 2-32. Locations in Carmel River Lagoon where Vertical Profiles of Water Quality Parameters Are Measured
(Source: MPWMD 2017b)

Some of the negative water quality factors that have been observed include chronic poor water quality in the Carmel River lagoon, especially in the fall; and high fall temperatures and episodically detectable hydrogen sulfide levels below Los Padres Dam. The increase in suspended sediment since the removal of San Clemente Dam can also negatively affect juvenile steelhead (MPWMD 2017b).

In addition to water quality monitoring performed by MPWMD, monitoring of the Carmel River and San Clemente Reservoir was also performed to support studies prior to the removal of San Clemente Dam. In 2002, pore water and surface water measurements were collected to characterize conditions in the Carmel River and San Clemente Creek upstream of the former San Clemente Reservoir. Analyzed parameters included metals, hardness, total dissolved solids, pH, specific conductivity, and ionic chemistry. From 2003 to 2006, daily measurements were made for periods of 5 weeks or more during reservoir drawdown periods. Measured water quality parameters included temperature, dissolved oxygen, pH, specific conductivity, and turbidity (Entrix 2008).

Most results for metals were below the laboratory's reporting limits. Detected metals were below established criteria for aquatic life and human health protection. Hardness results indicated a good buffering capacity against changes in pH and metals concentrations (Entrix 2008). The results of the studies showed that the water quality in the measured reaches was generally good during the monitoring periods, and the quality was not affected by the drawdown activities (Entrix 2008).

2.8 Additional Geomorphic Data and Considerations

This section identifies or summarizes relevant geomorphic background information specific to Los Padres Dam and Reservoir and the Carmel River that is not addressed in other sections.

2.8.1 Past Geomorphic Analyses of the Carmel River

- Recent Channel Instability and Historical Channel Change of the Carmel River, Monterey County, California (Kondolf 1983): This study examined flow records, pumping history, water table records, aerial photos, and cross-section survey data from the lowest 8 miles of the Carmel River, and correlated large-scale bank erosion events in 1978 and 1980 to nearby groundwater withdrawal and associated riparian vegetation removal.

2.8.2 Past Analyses of Fire Effects

- Analysis of Erosion Following the Marble Cone Fire, Big Sur Basin, Monterey County, California (Cleveland 1977): Erosion conditions in the Big Sur drainage basin were analyzed based mainly on interpretation of geologic features, vegetation, and geomorphology observed in aerial photography. A map of the Big Sur drainage basin was prepared showing erosion propensity following the Marble Cone fire.

- Sequential Changes in Bed Habitat Conditions in the Upper Carmel River Following the Marble-Cone Fire of August 1977 (Hecht 1981): Four habitat descriptor measurements (net fill and scour, particle-size distribution, percentage of bed area occupied by sand and finer material, and percent of the bed covered by material of sizes suitable for spawning) were repeatedly taken in riffles in the upper Carmel River during the 3 years following the Marble-Cone Fire. This study found that habitat values were largely restored by the end of the first winter, and experienced virtually complete recovery after 3 years.

- Post-Fire Channel Response: A Comparison Between the 1977 Marble-Cone Fire and 2008 Basin Complex Fire on the Upper Carmel River (Richmond 2009): This study measured the effects of the 2008 Basin Complex Fire on dry ravel, surface lowering, and channel elevation. Unlike the 1977 Marble Cone Fire, the 2008 Basin Complex Fire had a relatively small impact on channel elevation, potentially due to the differences in post-fire storms.

- San Clemente Dam Removal Sediment Impacts: Year One Report (CSUMB 2016): This study identified possible sources of sediment and estimated the total sediment volume that accumulated downstream of the former San Clemente Dam following its removal in 2015. The report outlines the history of fires in the watershed and their impact on sediment transport. Results from this study could be used as a baseline for evaluating the impacts of the 2016 Soberanes Fire to the Carmel Watershed.

- Soberanes Fire Watershed Emergency Response Team Report (CALFIRE 2016): This report primarily focuses on the effects of the Soberanes Fire, and includes a discussion on areas and communities of interest that were affected by the fire; a soil burn severity analysis; modeled post-fire debris flow, sediment production, and flood flow; and a history of post-fire debris flow in the watershed.
- Water Resources Data, California, Volume 2, Water Years 1992 – 1996 (USGS 1993-1997): These are the water resources data reports presenting collected bedload and suspended sediment data collected in the northern portion of coastal California, including the Carmel River, at Via Mallorca, gage 11143250.
- Sediment Transport Analysis Carmel River Near Carmel (Hampson 1997): This study summarizes previously presented bedload and suspended sediment transport data, including data collected by MPWMD and USGS.

2.8.3 Active Channel Data

This section identifies active channel data of relevance to the Alternatives Study, including particle-size distributions, thalweg and cross-section surveys, bedload and suspended-load data, and sediment transport and stream power relationships.

- Sediment Transport and Channel Stability, Carmel River, California (Curry and Kondolf 1983): This study included sampling suspended and bedload sediment at a variety of flows in five mainstem and six tributary stations, measuring discharge, and measuring the distribution of tracer gravels released in riprap on the Schulte and Boronda Road bridge abutments. Study data were used to generate rating curves for suspended and bedload sediment, and calculate the total sediment budget for the watershed. The report also discussed sources of sediment in the watershed.
- Baseline Characterization of Sediment Transport and Sedimentation at the Santa Lucia Preserve, Monterey County: Interim Report (Hecht and Napolitano 1995): This study presents bedload data collected at five sites in four tributaries, as well as summarizes sedimentation data for both the Los Padres and San Clemente Reservoirs.
- Carmel River Sediment-Transport Study (MEI 2002a): This study consisted of a field investigation, geomorphic and hydraulic analysis, and a sediment-routing analysis to evaluate the potential impact of various scenarios for releasing sediment stored in San Clemente Reservoir into Carmel River downstream of the dam.
- Hydraulic and Sediment-Transport Analysis of the Carmel River Bypass Option, California (MEI 2005): This study included a hydraulic model to aid in developing the diversion channel and reconstructed reach of San Clemente Creek as part of the San Clemente Dam Removal project. The study also modeled sediment transport downstream of San Clemente Reservoir under historic conditions (with no dam present), baseline conditions (with the dam present), and with a river bypass alternative. The model was used to predict reach-averaged bed elevation change, and effects of sediment storage on flood conditions.
- Final EIR for the San Clemente Dam Seismic Safety Project, Volume 4, Appendices H-Z (Entrix 2007): Appendices H through Z include sediment transport modeling, a summary of the hydraulic and sediment-transport analysis of residual sediment, suspended sediment concentration exceedance for the project alternatives, and water quality in the Carmel River above San Clemente Dam.

- 2007 Carmel River Surveys (Graham Matthews and Associates 2008): This study consisted of collecting longitudinal thalweg profile data from the mouth of the Carmel River upstream to the Robinson Canyon Bridge and in the Carmel Valley Village reach, and cross-section data from the main bridges passed during the profile survey. Data from 2007 were also compared with previous longitudinal profile and cross-section data.

- Pre-San Clemente Dam Removal Morphological Monitoring of the Carmel River Channel in Monterey County, California (Leiker et al. 2014): This study collected cross-section and pebble-count data in five reaches on the Carmel River below the San Clemente Dam to record baseline geomorphological data prior to the dam removal.

- 2015 Pre-San Clemente Dam Removal Morphological Monitoring of the Carmel River Channel in Monterey County, California (CSUMB 2016): This study re-surveyed the sites from the Leiker et al. (2014) study, as well as one additional site upstream of the dam, and one additional site downstream of the dam. The study found no substantial geomorphic change between 2013 and 2015, although substrate grain size showed considerable change at some sites.

2.8.4 Sedimentation Rates and Reservoir Trap Efficiency

- Sequential Changes in Bed Habitat Conditions in the Upper Carmel River Following the Marble-Cone Fire of August 1977 (Hecht 1981): Four habitat descriptor measurements (net fill and scour, particle-size distribution, percentage of bed area occupied by sand and finer material, and percent of the bed covered by material of sizes suitable for spawning) were repeatedly taken in riffles in the upper Carmel River during the 3 years following the Marble-Cone Fire. This study found that habitat values were largely restored by the end of the first winter, and experienced virtually complete recovery after 3 years.

- Evaluation of the Reservoir Sedimentation Rates in the Upper Carmel River Watershed (Matthews 1989): This study presented existing data on reservoir sedimentation in San Clemente and Los Padres Reservoirs, analyzed existing data to develop sediment yield and trap efficiency values, and provided the basis for calculating sediment storage volumes in a proposed new reservoir.

- Baseline Characterization of Sediment Transport and Sedimentation at the Santa Lucia Preserve, Monterey County: Interim Report (Hecht and Napolitano 1995): This study presents bedload data collected at five sites in four tributaries, as well as summarizes sedimentation data for both the Los Padres and San Clemente Reservoirs.

- Carmel River Sediment-Transport Study (MEI 2002a): This study was conducted to analyze how much sediment could be released from San Clemente Dam before it becomes a flood risk/property loss problem, and to analyze how much sediment could be released before it significantly adversely affected steelhead and riparian habitat. The study included topographic mapping of a 19-mile river reach, developing a sediment-transport model, and running the model under 11 scenarios.

- San Clemente Reservoir and Carmel River Sediment-Transport Modeling to Evaluate Potential Impacts of Dam Retrofit Options (MEI 2003): This study was conducted to obtain up-to-date mapping of the San Clemente Reservoir, perform a detailed sediment investigation of the reservoir deposits, develop a sediment-transport model for sediment in the reservoir that can be used to evaluate erosion and deposition processes, and incorporate that model into the existing river model.

- Hydraulic and Sediment-Transport Analysis of the Carmel River Bypass Option, California (MEI 2005): This study consisted of developing a step-backwater model to evaluate the rigid-boundary hydraulic conditions through the reconstructed reach of San Clemente Creek; applying the model to refine the dimensions of the diversion channel and the restored reach; updating the previously developed sediment transport model and applying several scenarios; and evaluating the model results to understand the short- and long-term response of the Carmel River upstream of the diversion, the reconstructed reach of San Clemente Creek, and the Carmel River downstream from the existing dam.

2.8.5 Flood Maps

This section identifies frequently flooded areas based on existing maps and data. Existing data sources identified include the following:

- Carmel River Sediment-Transport Study (MEI 2002a): This study was conducted to analyze how much sediment could be released from San Clemente Dam before it becomes a flood risk/property loss problem. The study included topographic mapping of a 19-mile river reach, developing a sediment-transport model, and running the model under 11 scenarios.
- Evaluation of Flood Hazards Associated with Seismic Retrofit Alternatives for San Clemente Dam (MEI 2002b): This study included the development of a floodplain model of the reach downstream from San Clemente Dam to evaluate potential flooding impacts of different sediment release scenarios. In addition, the relative increase in property damage under each scenario was evaluated, and a reconnaissance-level identification of feasible alternatives for mitigating increases in damage was conducted.
- San Clemente Reservoir and Carmel River Sediment-Transport Modeling to Evaluate Potential Impacts of Dam Retrofit Options (MEI 2003): For this study, models were developed to simulate erosion processes in the San Clemente Reservoir under three dam retrofit/removal scenarios. Results from this model were evaluated to estimate the impact of each scenario on flooding, channel stability, and habitat conditions in the river downstream from the dam.

Federal Emergency Management Agency (FEMA) flood insurance rate maps were reviewed to identify areas in a FEMA 100-year or 500-year floodplain. Other resources listed above were reviewed to identify areas that may be in floodplains subject to more frequent flooding.

The nearest community to Los Padres Dam is the small community of Cachagua, about 1 mile downstream from the dam. Most of the community is in a FEMA 100-year “A” flood zone. An “A” flood zone is considered approximate, so the actual flood zone may be larger or smaller. The only instance of significant flooding identified for this community was in 1995, when about 100 to 150 residences were damaged by a large flood in March (Monterey County 2003). No other descriptions of flooding in the community were found. The March 1995 storm is the largest storm of record out of 60 years of data at the Robles Del Rio USGS gaging station on the Carmel River (#11143200). There are no other communities between Cachagua and the former location of San Clemente Dam, although there are a few scattered homes along the river downstream of Cachagua.

According to testimony by Larry Hampson, Water Resources Engineer with MPWMD, flooding starts in Carmel Village when river flows exceed about 7,000 cfs (Hampson 2008). According to data in Section 2.6.3, this corresponds to about a 10-year event at the Robles Del Rio gage. He also reported that there were 94 repetitive-loss structures (structures with two or more flood insurance claims of $1,000 or more within a 10-year period) in the Carmel River Valley. Sixty-nine of these are in Mission Fields area (just downstream of the Highway 1 Bridge), and the remaining 25 are scattered along the length of the river in Carmel Valley. Most of the repetitive loss properties are included on the list because of loss during the January and March 1995 storms. Only 14 properties had losses during other events. Eight properties had more than two losses.

The largest event on record, March 1995, resulted in 400 residences and 68 businesses damaged in Carmel Valley, with 2,500 evacuations. In Mission Fields, 220 residences were damaged, and all residences were evacuated. In addition to these damages, 80 residences in Robles Del Rio were damaged, plus the residences in Cachagua mentioned above (Monterey County 2003). A similar storm in February 1998 resulted in much less damage due to improvements after 1995 (Hampson 2008).

2.8.6 River-Bank Structural Protection

MEI's (2002) Carmel River Sediment-Transport Study provides descriptions of several reaches along the Carmel River, including whether the banks are armored. The following descriptions of reach location and armoring are excerpted from that report. Note that the subreach numbers below are from MEI (2002), and are not the same reach numbers used in this study; their locations are shown on Figure 2-33.

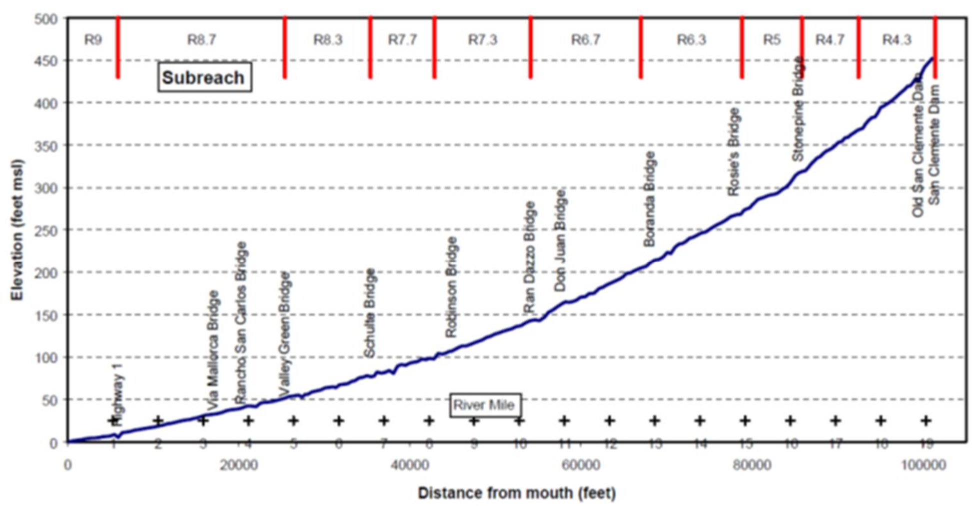


Figure 2-33. Longitudinal Profile of the Carmel River
(Source: Figure 2.1 from MEI 2002a)

- Subreach 4.3 extends from San Clemente Dam at Station 101,400 to approximately 0.3 mile downstream from Sleepy Hollow (Station 92,400). This approximately 1.7-mile-long subreach is confined in a narrow canyon with significant bedrock control.
- Subreach 4.7 extends from Station 92,400 to the mouth of Tularcitos Creek (Station 85,800), a distance of about 6,600 feet. The Tularcitos Creek alluvial fan provides lateral control at the downstream end of the reach.
- Subreach 5 extends from the mouth of Tularcitos Creek (Station 85,800) to the mouth of Hitchcock Canyon Creek (Station 78,800), a distance of about 7,000 feet. In this subreach, the river generally has a single-thread channel that is controlled by bedrock outcrop in many locations. The left bank of the river in the vicinity of Camp Stephani is against the valley wall and is bedrock-controlled; the right bank is an alluvial terrace that is overtopped during large floods. In addition, a substantial amount of bank protection has been installed along this subreach. According to data provided by MPWMD and NMFS, about 30 percent of the left bank (looking downstream) and more than 80 percent of the right bank have been hardened in the downstream approximately 0.3 mile of this reach. Additionally, a floodwall has been constructed on the right bank in the upstream portion of the Camp Stephani area.
- Subreach 6.3 extends from the mouth of Hitchcock Canyon Creek (Station 78,800), which is about 900 feet upstream from Esquiline Bridge (a.k.a. Rosie's Bridge and Robles del Rio) to the mouth of Garzas Creek (Station 67,000), a reach length of about 11,800 feet. The planform of the river is affected by bedrock outcrop controls at specific locations along the subreach, where it abuts the left valley wall. An example occurs at Station 70,500, just downstream from the Saddle Club, where the bedrock outcrop causes a sharp right bend that results in significant energy loss at high flows. The energy loss and associated backwater causes a large gravel bar to form and persist upstream from the bend. In addition, the deDampierre Park area is near the middle of the

subreach. At this location, a restoration project emphasizing the use of riparian vegetation for bank stabilization was constructed in the mid-1980s to mitigate the effects of bank erosion.

- Subreach 6.7 extends from the mouth of Garzas Creek (Station 67,000) to Randazzo Bridge (Station 54,100), a reach length of about 12,900 feet. Portions of the reach appear to be aggraded, particularly in the Garland Park area; and riparian vegetation encroaches into the low-flow channel at some locations.

- Subreach 7.3 extends from Randazzo Bridge (Station 54,100) to the mouth of Robinson Canyon Creek (Station 42,900), a distance of about 11,200 feet. The left bank of the river abuts the valley wall in the upstream approximately 5,000 feet of the subreach. A substantial length of the channel banks has been protected in this reach; data provided by MPWMD and NMFS indicate hardening along approximately 40 percent of the total bank length on both sides of the channel.

- Subreach 7.7 extends from the mouth of Robinson Canyon Creek (Station 42,900) to Schulte Road Bridge (Station 35,400), a distance of about 7,500 feet. Bedrock outcrops control the planform of the channel in several locations along the reach, including the left bank just downstream from Robinson Canyon Creek and at the Steinbeck Pool. A channel restoration project has been constructed in the right overbank upstream from the Schulte Bridge at the downstream end of the subreach. This project consists of bank armoring over an approximately ¾-mile-long reach, and re-vegetation of the overbank areas. According to the MPWMD and NMFS data, approximately 30 percent of the left channel bank and 60 percent of the right channel bank in this subreach have been hardened.

- Subreach 8.3 extends from Schulte Road Bridge (Station 35,400) to the Valley Green Bridge (Station 25,400), a distance of about 10,000 feet. The narrowing is likely due to the significant bank protection that has been installed along the reach; more than 60 percent of the right bank and more than 50 percent of the left bank have been hardened.

- Subreach 8.7 extends from Valley Green Bridge (Station 25,400) to Highway 1 (Station 5,900), a distance of about 19,500 feet. About 40 percent of the total bank length is protected along this reach.

- Subreach 9 extends from Highway 1 (Station 5,900) to the mouth. This reach consists of the Carmel River Lagoon, an estuary formed by a bedrock outcrop and barrier bar at the mouth. The bedrock outcrop forms a positive vertical control at the mouth of the river, and the tributary mouth bar periodically blocks the mouth during low flows. A significant amount of bank protection has been installed in the upstream portion of the reach.

Overall, about 40 percent of the total length of bank has been hardened. Figure 2-34 shows the percentage hardened in each reach described above.

2.9 Steelhead Biology

Steelhead found in the Carmel River watershed belong to the S-CCC DPS, which is listed as threatened under the ESA (62 FR 43937, 71 FR 834), and is a CDFW Species of Special Concern. The Carmel River watershed historically produced one of the largest run sizes in the S-CCC DPS during years of high rainfall and runoff (NMFS 2013b). The Carmel River population of S-CCC steelhead also likely acts as a source population to the smaller coastal drainages, which are not considered viable by NMFS and may not be able to persist without straying from the Carmel River population (NMFS 2012). Moreover, the Carmel River Watershed is considered unique from the other watersheds supporting the DPS in that the Carmel River population possesses both interior and coastal population attributes. These attributes may provide more resistance to environmental variability, as well as maintain genetic diversity. Therefore, the Carmel River population of S-CCC steelhead is considered highly valuable compared to other populations in the DPS (NMFS 2013b).

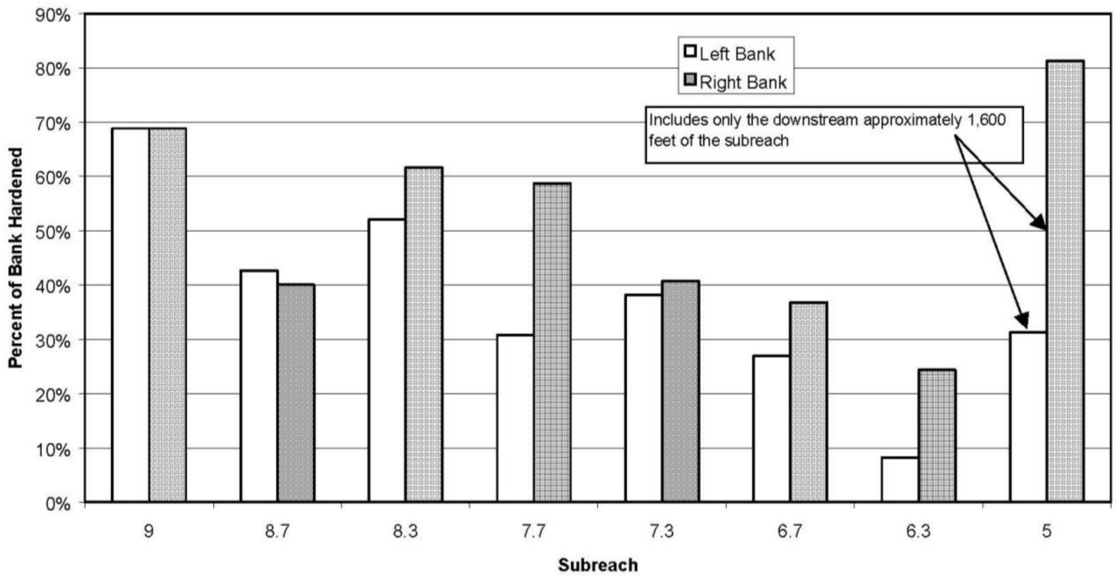


Figure 2-34. Percent of Total Bank Length with Hardened Bank Protection, by Subreach (Source: Figure 2.4 from MEI 2002a)

The Carmel River Watershed contains abundant suitable habitat for S-CCC steelhead. Access to much of this habitat is currently influenced by the presence of Los Padres Dam, although a trap-and-haul facility currently provides upstream passage, and a bypass pipe provides downstream passage. The watershed contains extensive (>50 miles) steelhead spawning and rearing habitat in the mainstem and tributaries (MPWMD 2004).

2.9.1 Abundance

Adult steelhead return annually to the Carmel River Watershed. The following section describes their abundance in the lower Carmel River (downstream of Los Padres Dam), in Los Padres Reservoir, and in tributaries upstream from the Reservoir. To maintain consistency with Tasks 2 and 3, abundance data specific to the five response reaches in the lower Carmel River (downstream of Los Padres Dam) are presented, where available, as follows: 1) the inter-dam reach between Los Padres Dam and the former San Clemente Dam; 2) the former San Clemente Dam to Tularcitos Creek at RM 16; 3) Tularcitos Creek to the Narrows at RM 9.8; 4) from the Narrows to the Carmel River lagoon; and 5) from the lagoon to the ocean (Figure 2-15).

2.9.1.1 Lower Carmel River (downstream of Los Padres Dam)

The historical population of S-CCC steelhead in the Carmel River Watershed prior to the construction of San Clemente Dam (built in 1921) and Los Padres Dam (built in 1949) was estimated to be between 1,500 and 8,000 adults annually (Becker et al. 2010). Other qualitative estimates place the pre-dam population closer to 12,000 (Snider 1983). In their Biological Opinion for the Carmel River Reroute and San Clemente Dam Removal Project, NMFS (2012) estimated that habitat in the Carmel River Basin could support roughly 4,000 adult steelhead annually, with the habitat upstream of Los Padres Reservoir potentially supporting around 2,000 fish, habitat between Los Padres and San Clemente reservoirs potentially supporting 1,000 fish (Response Reach 1), and habitat downstream of San Clemente Dam potentially supporting around 1,000 fish (Response Reaches 2–5).

Ongoing steelhead adult migration counts at both San Clemente and Los Padres Dams indicate that, despite large annual fluctuations in abundance, steelhead in the Carmel River Watershed have undergone a steady decline since monitoring began (Figure 2-35) (MPWMD 2015a).[12] CDFW and MPWMD 3-pass

[12] Figure 2-35 was recreated from MPWMD 2015a and updated with counts from the MPWMD online database. Counts are based on Snider (1983), Dettman and Kelley (1986), and CDFW and MPWMD files. The 1962-1973 and 1991-1993 counts at San

electrofishing survey data on juvenile steelhead density at annually sampled index sites in the Carmel River also show large annual fluctuations, periods of juvenile steelhead absence during droughts, and a generally declining trend in juvenile abundance from 2000 to 2013 (Figure 2-36)[13] (MPWMD 2015a). The decline of steelhead in the watershed was likely due in part to the presence of Old Carmel River Dam (RM 18.3), San Clemente Dam (RM 18.6), and Los Padres Dam (RM 24.8) (which have been partial barriers to historic spawning and rearing habitat); streamflow reductions due to water diversion from wells downstream of San Clemente Dam; and habitat fragmentation and degradation (MPWMD 2004; NMFS 2012). In addition, multiple droughts have adversely affected adult steelhead abundance. During the 1976 to 1977 drought, no adult steelhead were captured in the Los Padres Dam ladder trap, and none were observed at the San Clemente Dam fish ladder (MPWMD 2004). A comparison of returns before and after 1980 indicates the adult return to the reach between San Clemente Dam and Los Padres Dam has not recovered to levels that were common to the Carmel River population prior to the 1976-1977 drought (MPWMD 2004). Adult steelhead abundance also declined after a drought in the early 1990s, although steelhead numbers rebounded and then appeared to stabilize in the range of 400 to 800 fish annually (MPWMD 2004); until more recently, when adult steelhead returns decreased. Counts at the former location of San Clemente Dam are potentially biased by all adults that spawn in mainstem and tributary habitat downstream of the counting station, which has increased as habitat conditions in the lower river improve (MPWMD 2015a). Dettman and Kelley (1986) estimated that only about half (55 percent) of the adult steelhead that enter the Carmel River migrate upstream past the site of the previous San Clemente Dam; but instead, spawn in mainstem or tributary habitat downstream of RM 18.6 (the site of the counting station).

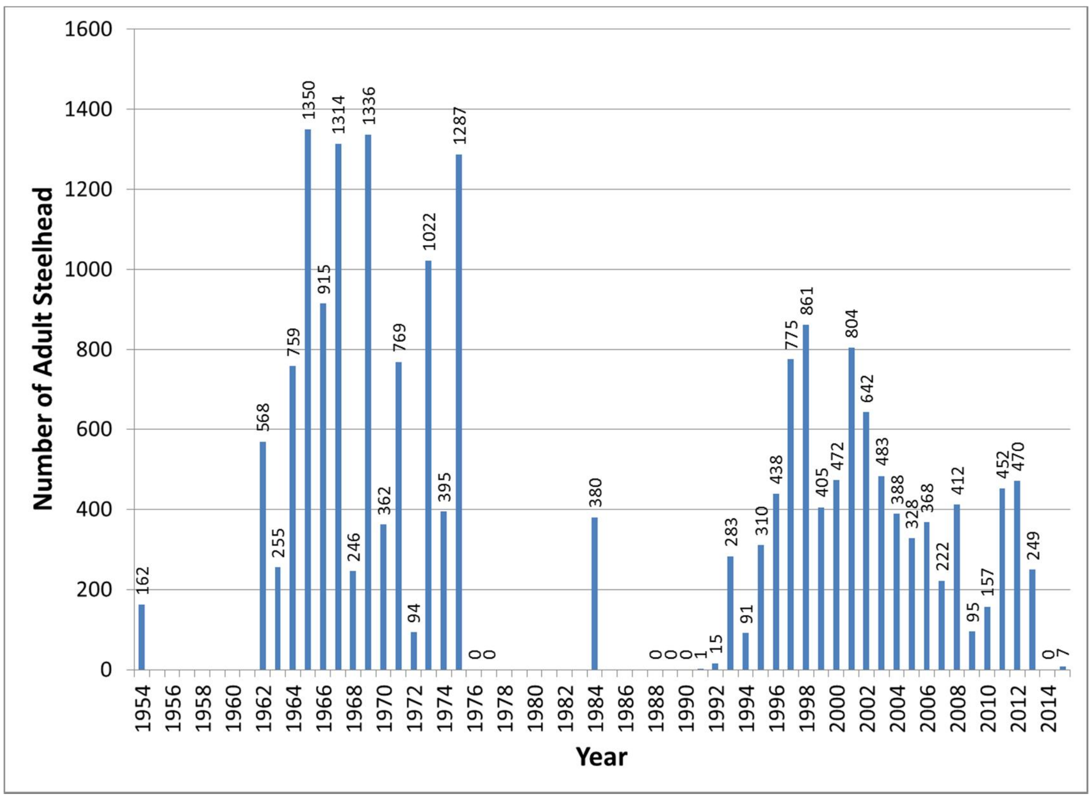


Figure 2-35. Number of Adult Steelhead at the San Clemente Dam (1954 – 2015) (1973 to 1987 data are from CDFW files; 1989 to 2013 data are from MPWMD files)

Clemente Dam are the sum of daily numbers of fish observed by shutting off the flow in the fish ladder. The 1974, 1975, 1984, and 1994 to present are complete counts registered on an automatic counter. The 1997 counts are incomplete; low flows caused the MPWMD to pull the counter on April 2.

[13] Figure 2-36 was recreated from MPWMD 2015a and updated with counts from the MPWMD online database. 1973 to 1987 data are from CDFW files; 1989 to 2013 data are from MPWMD files.

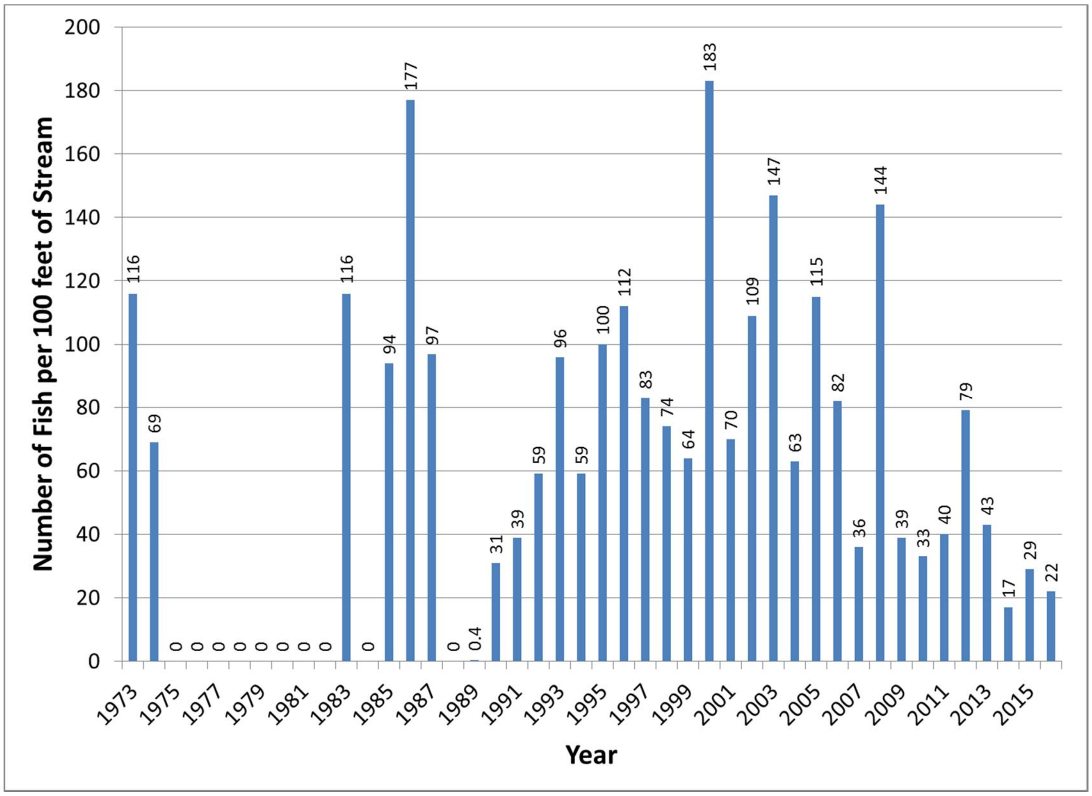


Figure 2-36. Fall Density of Juvenile Steelhead in Carmel River (1973 – 2016)

In 2016, the successful removal of San Clemente Dam enhanced the ability for both upstream and downstream migrant steelhead to move through that reach of the river. Removal of this dam is expected to reestablish natural river processes throughout approximately 25 miles of critical habitat for steelhead in the Carmel River, and have a number of benefits on the Carmel River steelhead population (NMFS 2012). With the dam removed, natural processes are expected to redistribute and sort instream substrate material, resulting in a higher proportion of the river channel having substrates suitable for steelhead spawning, compared to recent past conditions. More than 3,000 linear feet of habitat that were controlled by the reservoir or had low velocities and extensive deposition of sands have been replaced by a low-flow channel that provides holding areas for migrating adults and juveniles, habitat for juveniles and smolts, increased foraging opportunities, and improved cover from predators. Removal of the dam will allow a diversity of substrates, including fines, sand, gravel, and cobble, to pass downstream of the reservoir, which should in turn increase benthic macroinvertebrate diversity through creation of instream habitat complexity. Dam removal may also increase the crest elevation of the seasonal sand berm at the mouth of the Carmel River lagoon through the action of additional sediment transport from areas upstream of the former San Clemente Dam, and additional sediment deposition at the river mouth, which would help maintain water quality parameters in the lagoon required for ideal rearing conditions. Removal of the dam has enhanced downstream passage conditions for juveniles, kelts, and smolts—and upstream passage for juveniles and adults—improving juvenile and adult mobility in the dam removal project area, as well as providing access to a greater range of habitat. The many benefits of removing San Clemente Dam could, in time, result in a greater number of adult steelhead arriving at Los Padres Dam.

2.9.1.2 Los Padres Reservoir

Annual adult steelhead counts at the Los Padres Dam fish trap range from 0 to 558 fish (Figure 2-37 Number of Adult Steelhead Counted at the Los Padres Dam (1949 – 2017)) (MPWMD 2017c[14]). Several

[14] Figure 2-37 was recreated from MPWMD 2015a, and updated with counts from the MPWMD online database.

of the years in which no adult steelhead were captured in the Los Padres fish trap were drought years (1976 to 1977, the early 1990s, and 2014 to 2016).

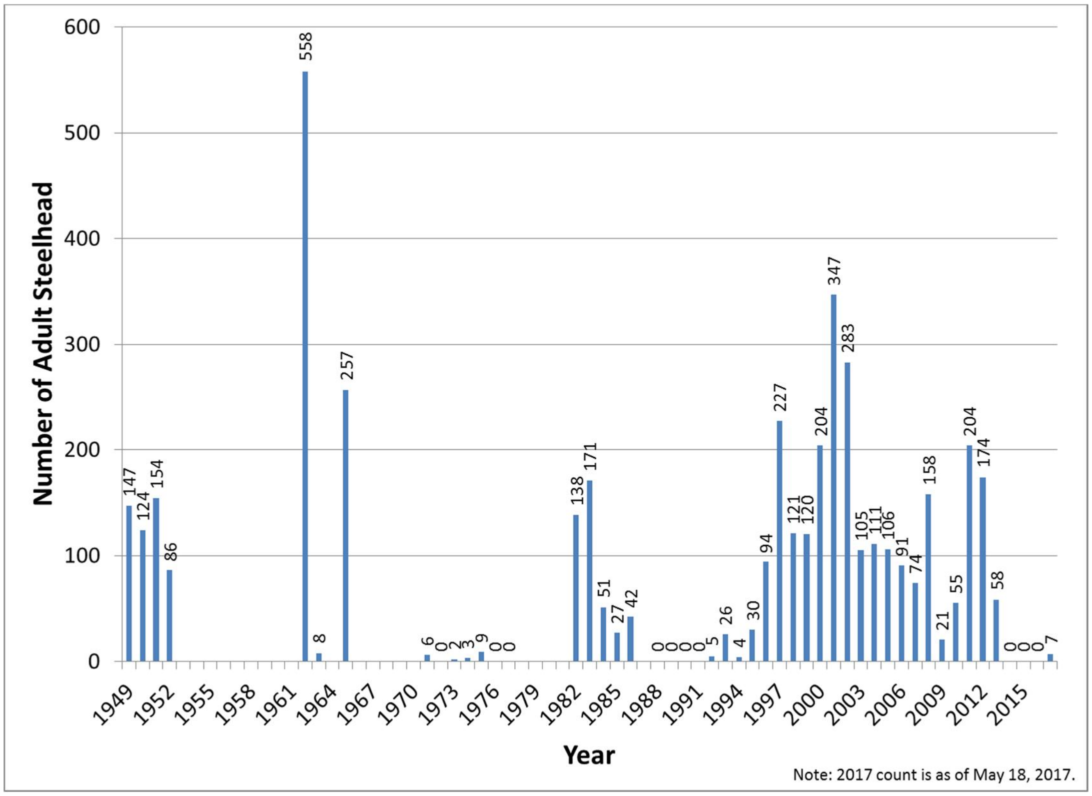


Figure 2-37. Number of Adult Steelhead Counted at the Los Padres Dam (1949 – 2017)

2.9.1.3 Upstream of Los Padres Reservoir

The life history strategy of steelhead upstream of Los Padres Reservoir is not well understood. The Los Padres Dam and Reservoir are partial barriers to both upstream and downstream steelhead passage, so it is possible that the *O. mykiss* population upstream of Los Padres Dam expresses a resident life history strategy more frequently than it would in the absence of the dam. A 1993 CDFW report found a yearling-dominant population after several years of either no adult steelhead passing Los Padres Dam (1988 – 1991) or very few passing the dam (1992), and suggested that inadequate flows prevented outmigrating juvenile steelhead and kelts from passing over Los Padres Dam, trapping them in the reservoir, and causing adults to seek suitable spawning habitat in the upper river (CDFW 1994). However, a CDFW report on surveys conducted 1 year later concluded that the population upstream from Los Padres Dam, which was found to be dominated by juveniles less than 6 inches in length, was likely exhibiting an anadromous life history strategy due to the lack of larger individuals that had presumably outmigrated (CDFW 1995). In addition, Los Padres Dam fish trap data show that, since the early 1990s, tens to hundreds of adult steelhead are collected in the fish trap and are passed over the dam annually; and a 1996 and 1999 MPWMD study on smolt migration through Los Padres Reservoir showed that smolts do successfully emigrate through the reservoir and over the dam (MPWMD 2015b). Therefore, it appears that some portion of the population upstream of Los Padres Dam maintains anadromy. The recent addition of the downstream floating weir collector and smolt bypass should improve the ability of juvenile steelhead to migrate downstream past Los Padres Dam.

The density of juvenile steelhead upstream of Los Padres Dam has been estimated periodically. Electrofishing surveys upstream of Los Padres Dam conducted in 1973 and 1974 were used to estimate the total population of juvenile steelhead upstream of the dam at just over 20,000 fish (1973) and close to 18,000 fish (1974), at an average density of 3,351 juveniles per mile of stream (Snider 1983). CDFW electrofishing surveys conducted in 1993 and 1994 estimated a density of 4,688 and 4,528 juvenile steelhead per mile upstream of Los Padres Dam, respectively (CDFW 1994, 1995). CDFW conducted an electro-fishing survey upstream of Los Padres Reservoir in November 1999 and observed young-of-year and age 1+ steelhead; several year-classes of steelhead in 2003; and in 2005, they observed young-of-year and smolt-sized steelhead (D. Highland, CDFW, pers. comm., 2017).

2.9.2 Distribution

Steelhead are distributed throughout the Carmel River watershed. The discussion of steelhead distribution below is intended to be consistent with analysis in Tasks 2 and 3, and is therefore focused on summarizing available data for the five identified response reaches in the lower mainstem Carmel River downstream of Los Padres Dam, tributaries to the lower mainstem, and the mainstem Carmel River and tributaries upstream of Los Padres Dam. Table 2-10 shows the estimated length and proportion of habitat accessible to steelhead in the response reaches and in the tributaries to the Carmel River.

Table 2-10. Summary of the Carmel River Watershed Accessible to Steelhead for Adult Migration, Spawning, and Juvenile Rearing

Reach[1]	Length accessible (miles)	Proportion of total accessible habitat (%)
Response Reach 1	5.4	7
Response Reach 2, 3, and 4	16.9	22
Total in mainstem Carmel River downstream Los Padres Dam	21.9	30
Tributaries to Carmel River downstream Los Padres Dam	38.0	51
Total downstream Los Padres Dam	59.9	81
Carmel River and tributaries upstream of Los Padres Dam	14.4	19
Total in watershed	**74.3**	

Note:

[1] Response reaches are: 1) the inter-dam reach between Los Padres Dam and the former San Clemente Dam; 2) the former San Clemente Dam to Tularcitos Creek at RM 16; 3) Tularcitos Creek to the Narrows at RM 9.8; 4) from the Narrows to the Carmel River lagoon; and 5) from the lagoon to the ocean.

Sources: MPWMD 2004, MPWMD unpublished data

2.9.2.1 Spawning

Steelhead spawning distribution is related to annual instream flow conditions. During normal (or wetter) water years, fewer impediments to fish migration occur, and steelhead can potentially spawn in approximately 74.3 miles of the Carmel River watershed, including 28.7 miles of the Carmel River mainstem, 34.8 miles of primary tributaries, and 10.8 miles of secondary tributaries (MPWMD unpublished data). In low-water years, adult migrants are more restricted in their distribution, and likely use less of the tributary habitat. However, even in low-water years, the 28.7 miles of mainstem habitat have been observed to be used for spawning (MPWMD 2004).

Spawning habitat suitability in the watershed is strongly related to suitable spawning gravel. Prior to its removal, San Clemente Dam trapped suitable gravel from transporting downstream; and under current conditions, spawning gravel is trapped in Los Padres Dam, although the contribution of sediment supply from Cachagua Creek downstream of Los Padres Dam ameliorates the effects of that dam (MPWMD 2004). MPWMD has occasionally placed suitable spawning gravel in the Carmel River downstream of both dams to mitigate for trapped sediment.

Based on surveys of suitable spawning gravel conducted in the 1980s (MPWMD 2004), spawning habitat is widely distributed throughout the watershed (Figure 2-38). These surveys indicate that about half the suitable spawning habitat is upstream of Los Padres Dam, and approximately 40 percent in the mainstem Carmel River downstream of Los Padres Dam, with the remainder in tributaries to the lower mainstem (Table 2-11). However, no surveys were conducted in key tributaries downstream of Los Padres Dam, including Pine, Tularcitos, Garzas, and Robinson Canyon Creeks. In addition, since these surveys were conducted habitat has improved in the lower river (downstream of Shulte Road), and at least 5.5 miles of additional spawning gravel are present in the lower mainstem (Cory Hamilton, MPWMD, personal communication, May 23, 2017). Therefore, a greater percentage of spawning habitat occurs downstream of Los Padres Dam than reflected in Table 2-11.

Table 2-11. Summary of Spawning Habitat Distribution in the Carmel River Watershed

Reach[1]	Estimated spawning habitat (ft^2)	Estimated number of potential redds	Proportion of total available spawning habitat (%)
Response Reach 1[2]	10,751	215	7
Response Reach 2	2,439	49	2
Response Reach 3	45,445	909	31
Response Reach 4	Not surveyed	Not surveyed	Not surveyed
Response Reach 5	0	0	0
Total in mainstem Carmel River downstream Los Padres Dam	58,635	1,173	40
Tributaries to Carmel River downstream Los Padres Dam[3]	14,657	292	10
Total downstream Los Padres Dam	73,292	1,465	50
Carmel River and tributaries upstream of Los Padres Dam	72,272	1,446	50
Total in watershed	**145,564**	**2,911**	

Notes:

1 Response reaches are: 1) the inter-dam reach between Los Padres Dam and the former San Clemente Dam; 2) San Clemente Dam to Tularcitos Creek at RM 16; 3) Tularcitos Creek to the Narrows at RM 9.8; 4) from the Narrows to the Carmel River lagoon; and 5) from the lagoon to the ocean. Note that spawning gravel data for Response Reach 2 are based on data ending at RM 17.6, and therefore potentially more gravel is in Reach 2 than is presented here.

2 Does not include spawning habitat that was previously inundated by former San Clemente Reservoir.

3 Survey of tributaries downstream of Los Padres Dam did not include potential spawning habitat in tributaries including Pine, Tularcitos, Garzas, and Robinson Canyon Creeks.

ft^2 = square feet
RM = River Mile

Source: MPWMD 2004

As discussed above, Dettman and Kelley (1986) estimated that about half (45 percent) of the adult steelhead that enter the Carmel River spawn in mainstream or tributary habitat downstream of RM 18.6 (the site of the counting station). For example, in a 2008 redd survey, MPWMD (2008) counted 99 redds downstream of the San Clemente counting station (Response Reach 3), and 36 redds downstream of the Narrows (Response Reach 4). In the mainstem downstream of Los Padres Dam, spawning occurs in four of the five response reaches.

DATA SOURCE:
MPWMD 2004 and 2014, and unpublished data.

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FIGURE 2-38

Potential Steelhead Spawning Habitat

Detailed spawning surveys from the tributaries downstream of Los Padres Dam are infrequent. Adults have been observed in Hitchcock and Potrero Canyon Creeks during above-average water years (Cory Hamilton, MPWMD, personal communication, May 23, 2017); and presumably, spawning occurs in tributaries with suitable spawning habitat, including Robinson Canyon, Garzas, San Clemente, Tularcitos, Pine, and Cachagua Creeks.

2.9.2.2 Juvenile Rearing

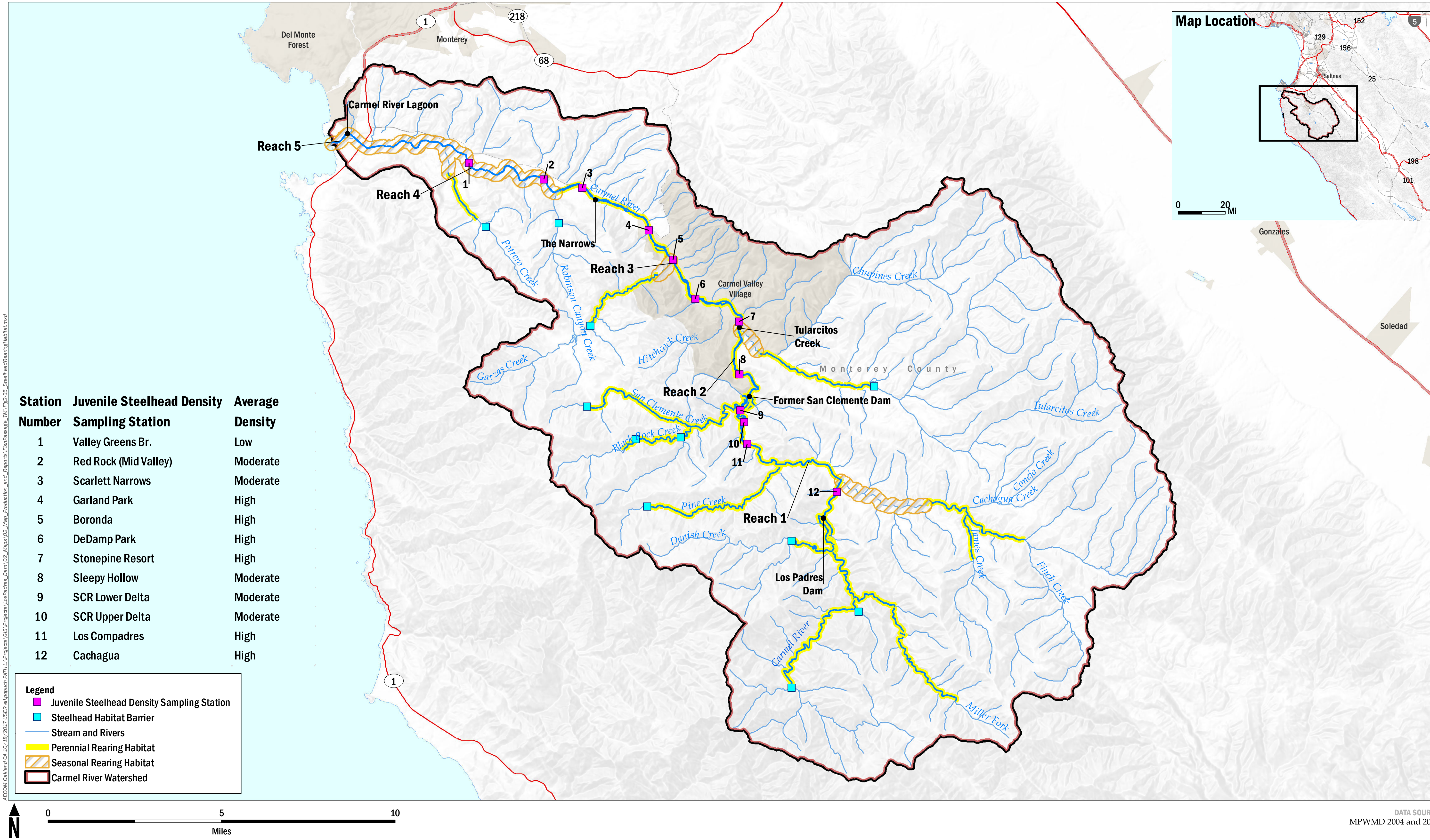
In a natural river environment, the physical habitat requirements for different age classes of steelhead are relatively similar, except that as fish age and grow they require more space for foraging and cover (Bjornn and Reiser 1991). Subsequently, rivers can typically support far fewer older and larger age-1+ juveniles than age-0+, resulting in a large mortality of age-0+ during their first year of life as habitat limitations constrain the number of older fish that can be supported (Elliott and Hurley 1998). Therefore, this summary of juvenile rearing habitat focuses on conditions that support age 1+ and older life stages, which are in shorter supply and more limiting for the Carmel River steelhead population (Dettman 1990, as cited in MPWMD 2004).

Several assessments of juvenile rearing habitat quantity and quality have been conducted in the Carmel River Watershed, and are well summarized in MPWMD (2004). Rearing habitat for steelhead is widely distributed throughout the watershed (Figure 2-39), with about 36 percent of measured suitable rearing habitat upstream of Los Padres Dam, and around 64 percent in the mainstem Carmel River downstream of Los Padres Dam, with the remainder in tributaries to the lower mainstem (Table 2-12). As for spawning habitat, available data on rearing habitat are from the 1980s. The surveys from which data presented here were obtained did not include key tributaries downstream of Los Padres Dam, and therefore underestimate available habitat there. Instream flows strongly affects rearing habitat in the watershed, and large reaches that are only seasonally wetted restrict rearing habitat in the lower mainstem downstream of Red Rock (RM 7.7), and the lower reaches of most of the key tributaries (Figure 2-39). In the mainstem downstream of Los Padres Dam, rearing habitat occurs perennially in four of the five response reaches (Table 2-12).

MPWMD has conducted regular fish sampling from established index sites since 1990. Although there are significant annual fluctuations in results, patterns in areas with low to high density are evident (Table 2-12), and confirm that rearing is occurring in the areas with mapped suitable rearing habitat. Although details on size distributions are not published, a fish rescue in the plunge pool downstream of Los Padres Dam provides an indication of age classes in the mainstem (ESA 2015). Of the nearly 500 steelhead captured, 18 percent were young-of-year, 72 percent were age 1+ or 2+, and 10 percent appeared to be age 3+ or older residents. Twenty-nine brown trout were also captured, including several large enough to be piscivorous. Juvenile rearing observations are not available from tributaries downstream of Los Padres Dam.

2.9.2.3 Los Padres Reservoir

There is limited information on juvenile steelhead occurrence in, and emigration through, Los Padres Reservoir; however, a pair of studies conducted by the MPWMD (2015b) provides some insight. In 1996 and 1999, a box trap and weir were installed just upstream of the Los Padres Reservoir, and a screw trap was installed below the Los Padres Dam spillway. The results of this study are presented in Table 2-13. The box trap upstream of the reservoir captured all of the flow into the reservoir, so the number of steelhead caught reflects the total smolt migration during the period the trap was operational. Because the screw trap downstream of the spillway only covered a fraction of the total flow, an estimate of the total number of migrating smolts was calculated, based on the number of smolts caught, and the proportion of the river covered by the trap. During both years of the study, the number of smolts caught downstream of the spillway was greater than the number of smolts caught upstream of the reservoir. This suggests that the reservoir either serves as a rearing area for juvenile steelhead, or as a temporary holding area for smolts that migrate into the reservoir from upstream rearing habitat prior to April (MPWMD 2015b).



Station Number	Juvenile Steelhead Density Sampling Station	Average Density
1	Valley Greens Br.	Low
2	Red Rock (Mid Valley)	Moderate
3	Scarlett Narrows	Moderate
4	Garland Park	High
5	Boronda	High
6	DeDamp Park	High
7	Stonepine Resort	High
8	Sleepy Hollow	Moderate
9	SCR Lower Delta	Moderate
10	SCR Upper Delta	Moderate
11	Los Compadres	High
12	Cachagua	High

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FIGURE 2-39

Steelhead Rearing Habitat

Table 2-12. Summary of Juvenile Rearing Habitat Distribution in the Carmel River Watershed

Reach[1]	Estimated age 1+ rearing habitat (ft^2)	Proportion of total available rearing habitat (percent)	Rearing density (low, moderate, high)[2]
Response Reach 1 (at 5–16 cfs)	590,553	23	High
Response Reach 2 (at 5.6 cfs)[3]	284,787	11	Moderate
Response Reach 3 (at 5.6 to 8.5 cfs)	629,562	24	High
Response Reach 4	Seasonally dry	0	Low
Response Reach 5	No data	No data	High[4]
Total in mainstem Carmel River downstream Los Padres Dam	1,469,093	57	
Tributaries to Carmel River downstream Los Padres Dam[5,6]	180,421	7	Moderate to high
Total downstream Los Padres Dam	1,649,514	64	
Carmel River and tributaries upstream of Los Padres Dam[6]	937,623	36	Low to high
Total in watershed	**2,587,137**		

Notes:

[1] Response reaches are: 1) the inter-dam reach between Los Padres Dam and the former San Clemente Dam; 2) San Clemente Dam to Tularcitos Creek at RM 16; 3) Tularcitis Creek to the Narrows at RM 9.8; 4) from the Narrows to the Carmel River lagoon; and 5) from the lagoon to the ocean (Figure 2-15).

[2] Based on 3-pass MPWMD electrofishing surveys at index sites (MPWMD 2015a); low (< 0.50 fish/foot), moderate (0.51 to 0.75 fish/foot), high (>0.76 fish/foot)

[3] Does not include rearing habitat that was previously inundated by former San Clemente Reservoir.

[4] Productive rearing observed, Alley & Associates (2014)

[5] Survey of tributaries downstream of Los Padres Dam did not include potential habitat in tributaries including Pine, Tularcitos, Garzas, and Robinson Canyon Creeks.

[6] Density data based on Snider (1983, as cited in MPWMD 2004).

cfs = cubic feet per second

ft^2 = square feet
MPWMD = Monterey Peninsula Water Management District
RM = River Mile

Source: Alley & Associates 2014, MPWMD 2004, MPWMD 2015a, Snider 1983.

Table 2-13. Results of MPWMD Steelhead Smolt Study at Los Padres Dam

Study Year	Trap Location	Dates of Trap Operation	Number of Steelhead Smolt Caught
1996	Upstream of reservoir	April 6–May 15 (40 days)	52
1999	Upstream of reservoir	March 13–24; April 28–June 2 (44 days)	37
1996	Downstream of spillway	March 17–May 23 (68 days)	96 (estimated 423 migrating smolts total)
1999	Downstream of spillway	March 2–June 2 (91 days)	1,275 (estimated 4,089 migrating smolts total)

2.9.3 Migration Timing and Life History

In the Carmel River, steelhead migration at all anadromous life stages generally occurs in the winter and spring. Detailed information on migration periodicity is provided in the following subsections, with a summary of anticipated migration timings provided in Table 2-14.

Table 2-14. Summary of Steelhead Life History Timing in the Carmel River

Life Stages	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
Adult upstream migration						Light	Light	Light	Dark	Dark	Dark	Dark	Dark	Dark	Light	Light	Light							
Kelt downstream migration						Light	Light	Light	Light	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Light	Light	Light					
Smolt downstream migration					Light	Light	Light	Light	Light	Light	Dark	Dark	Dark	Dark	Dark	Dark	Light	Light						
Juvenile rearing	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light

Note: Light gray cells represent the general period of anticipated migration, while dark gray cells indicate the anticipated periods of peak migration.

2.9.3.1 Adult Upstream Migration

Adult steelhead migration in the Carmel River Watershed is correlated with the following environmental factors: (1) breaching of the Carmel River Lagoon; (2) minimum migration flows; (3) attraction flows (e.g., attraction from the ocean into the mouth of the Carmel River); and (4) other physical and biological factors. The sand bar at the mouth of the Carmel River Lagoon must breach to allow entry to the watershed; in the 3-year period between 1988 and 1990, the sand bar did not breach, and as a result, no steelhead entered or left the watershed. Based on discussion at the Los Padres Fish Passage Study TRC Meeting No. 1, the sandbar at the lagoon is typically not breached until 1 to 14 days after Los Padres Dam spills, never before; and it rarely breaches without a spill from the dam (MPWMD 2017d).

More information is available to describe minimum transportation flows in the lower Carmel River than is available to describe further upstream. Evaluation of minimum transportation flows is typically based on a very conservative set of criteria that is meant to be protective of fish in the event that the flow numbers are used to guide the release of water from storage to support fisheries in regulated rivers. However, a motivated steelhead may be able to migrate past critical riffles or other impediments at flows lower than the minimum estimated using established criteria and methods. Based on discussion at the Los Padres Fish Passage Study TRC Meeting No. 1, minimum migration flows, or flows required for steelhead to pass natural and anthropogenic barriers, are thought to be at least 40 cfs in the lower river (Response Reaches 3–5); at least 45 cfs just downstream of the point where San Clemente Dam was located (Response Reach 2); and at least 10 cfs between the point where San Clemente Dam was located and Los Padres Dam (Response Reach 1) (MPWMD 2017d). Similar minimum migration flows for the Carmel River have been estimated at other points in time: a USFWS instream flow study reported that 30 cfs were sufficient to allow for passage in the lower reach of the Carmel River (USFWS 1980); and Kelley and Dettman (1981, as reported in Snider 1983) identified 50 cfs as the minimum migration flow for the river.

Attraction flows, or flows required to encourage steelhead to migrate upstream, are typically greater than the minimum transportation flows (Snider 1983). Snider (1983) noted that, from 1964 to 1975, arrival of the first adult steelhead at San Clemente Dam was almost always preceded by flows of 200 cfs or greater in the Carmel River; and that years where peak flows did not exceed 100 cfs had the lowest numbers of adult migrants. Adult migration is also influenced by preceding flows and climatic conditions, the proportion of the run that has already migrated, and possibly other factors like sexual maturity and turbidity (Shapovalov and Taft 1954).

The daily count data for adult steelhead captured at the Los Padres Dam fish trap are presented on Figure 2-40 (MPWMD 2016). Although present in the river, no adult steelhead were collected from the Los Padres Dam fish trap in 2014 or 2015. Data collected at the Los Padres Dam adult fish trap shows that upstream migration past the dam occurs from mid-December to the end of May, with peak migration occurring between February and April (Table 2-14) (MPWMD 2016). The termination of migration at the end of May could be due to the San Clemente Dam ladder being closed by late April or early June due to low flows, or the San Clemente Dam Safety Drawdowns that began in 2003 and continued until dam removal.

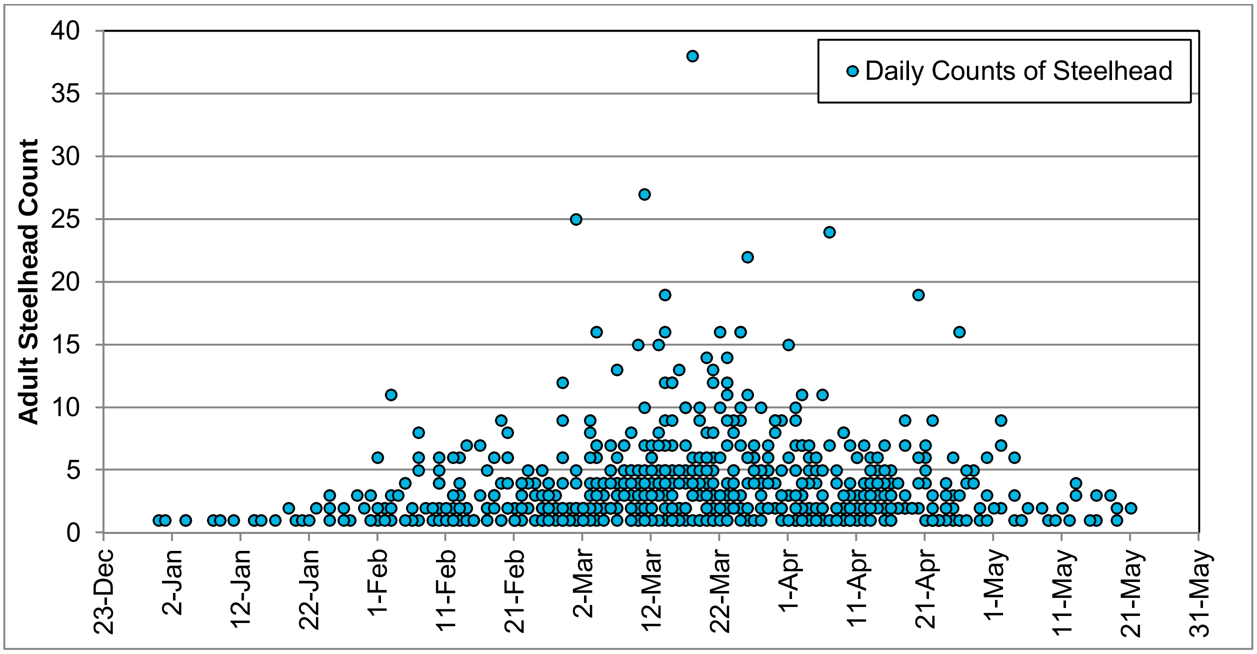

Figure 2-40. Daily Counts of Adult Steelhead at the Los Padres Dam Trap (1995 – 2015)

2.9.3.2 Post-Spawning Adult Downstream Migration

Kelt downstream migration in the Carmel River is expected to occur between mid-December and mid-July (Table 2-14). Only kelts that had been landlocked (e.g., due to channel-drying) the previous year are anticipated to migrate between December and the first half of February. The period of peak migration rates is anticipated to occur between mid-February and the end of May (Table 2-14) (Kevan Urquhart, MPWMD, personal communication, July 14, 2016).

2.9.3.3 Juvenile Downstream Migration

There are three principle life-history groups in the S-CCC steelhead DPS: fluvial-anadromous (fish that rear in the mainstem and tributary streams prior to smolting), lagoon-anadromous (fish that migrate downstream to rear in the Carmel River Lagoon during their first or second summer prior to smolting), and freshwater resident (juveniles rear and mature in freshwater without smolting) (NMFS 2013b). Lagoon-anadromous steelhead typically only require one growing season to reach smolt size, while fluvial-anadromous fish generally grow more slowly and may rear for up to 3 years before undergoing smoltification (Alley & Associates 2014, Moyle 2002). The period of active steelhead smolt downstream migration begins in December and continues through June, with the majority migrating in March, April, and May (Table 2-14) (Kevan Urquhart, MPWMD, personal communication, July 14, 2016). Larger fish tend to emigrate earlier in the season, and Snider (1983) found that juvenile steelhead in the lower Carmel River Watershed emigrated earlier than those above Los Padres Dam, which was likely due to more favorable growing conditions producing larger fish in the lower watershed.

Based on downstream migrant trapping during March through June, and fish rescue during late September and October (MPWMD 2015a), it appears that juvenile steelhead age 0+, age 1+, and older rear in the mainstem Carmel River in all response reaches downstream of Los Padres Dam. Presumably, rearing is occurring in key tributaries year-round as well, although little data exist on rearing patterns in the tributaries.

Timing of smolt emigration is influenced by numerous factors in addition to fish size, including streamflow, water temperature, photoperiod, food availability, and chemical factors like dissolved oxygen levels (MPWMD 2015b, Shapovalov and Taft 1954). Snider (1983) reported that high spring flows lasting at least through June appeared to be necessary to allow smolt emigration; and a 1996 MPWMD study of smolt emigration found that two storm events correlated with large increases in the number of captured smolts (MPWMD 2015b). These studies support the conventional wisdom that smolt emigration timing correlates with large flow events in the winter and spring (Cramer and Lichatowich 1978, NMFS 2012). However, there is also evidence that smolts may initiate migration earlier in the season in response to lower-than-average flows. Shapovalov and Taft (1954) found that low flows and high water temperatures, which are typically correlated with dry water years, advance the timing of smolt emigration. The complex hydrological patterns and numerous environmental and biological factors that influence smolt emigration make predicting emigration timing and understanding emigration cues difficult, because there are multiple simultaneous and sequential events that trigger emigration.

2.9.4 Brown Trout in the Carmel River Watershed

Although steelhead have been relatively well-studied, there are limited data on the abundance and distribution of other fish species, including the predatory nonnative brown trout (*Salmo trutta*), in the Carmel River Watershed. CDFW electrofishing studies upstream of Los Padres Reservoir found brown trout at a density of 8 trout per mile in 1993 (CDFW 1994). There seemed to be a downward trend in brown trout composition upstream of Los Padres Reservoir; brown trout made up 12 percent of the trout population in 1989, 2 percent in 1992, and only 1 percent in 1993 (CDFW 1994). However, when the surveys were repeated in 1994, the brown trout density had risen to 754 trout per mile, and brown trout comprised 9 percent of the trout population (CDFW 1995). CDFW electro-fished upstream of Los Padres Reservoir in 2003 and observed brown trout up to 7 inches fork length; and again in 2005, and observed a few brown trout up to 14 inches (D. Highland, CDFW, pers. comm., 2017). A fish capture and relocation effort in the plunge pool downstream of Los Padres Dam from June 29 to July 2, 2015 found 20 brown trout, 5 of which were larger than 20 inches, and 1 was in the 14- to 16-inch range (ESA 2015). No recent surveys of brown trout were conducted in the Carmel River Watershed, but they are believed to occur throughout the watershed, and there are anecdotal reports that they are abundant in Los Padres Reservoir.

3. Cost Considerations

This section describes high-level cost considerations for the Los Padres Alternatives Study, and provides a few examples of implementation costs associated with relevant dam removal or sediment management projects that may provide insight into the potential costs of the concepts being considered for Los Padres Dam and Reservoir.

For dam decommissioning or removal projects, the implementation cost is often driven by the character and volume of sediments that have accumulated in the reservoir over time. In most cases, the sediment is a mixture of coarse and fine sediments, and whether the sediment is physically removed from the reservoir prior to dam removal (via dredging or excavation), or flushed downstream using natural river flows (often requiring downstream flood control and water supply mitigation projects), the approach to managing sediment is typically one of the primary drivers of project implementation costs.

The Elwha and Glines Canyon dam removals on the Elwha River in Washington are an example of how management of accumulated sediment can constitute a relatively high percentage of the overall project implementation costs. Both dam removals relied on natural river flows to flush nearly 40 percent of the nearly 35 million cubic yards of accumulated sediment into the downstream river system, resulting in major mitigation projects for both flood control and water supply. Those mitigation projects constituted more than 60 percent of the nearly $200M construction cost. Another relevant example is the Matilija Dam Removal and Ecosystem Restoration project, where downstream flood and water supply mitigation components are estimated to account for over 65 percent of the approximately $80 million construction cost (see Table 3-1).

The San Clemente Dam Removal project involved relocation of a significant portion of the 2.5 million total cubic yards of accumulated sediment onsite, where it could be permanently stabilized and protected from the active river channel. Sediment excavation, dewatering and fill placement costs constituted approximately 50 percent of the approximately $65 million construction contract.

For dam decommissioning alternatives, a more comprehensive list of cost considerations is provided below:

- Accumulated sediment character and volume: this will help determine the most cost effective sediment management approach (removal versus flushing); either approach will be a primary driver of implementation costs.
- Proximity to available sediment disposal locations: when considering removal and hauling of accumulated reservoir sediments, hauling any significant distance could greatly increase implementation costs.
- Ease of construction access: many dam sites are fairly isolated and may require new or improved access roads; the topographic constraints at isolated sites may also limit the size of the access roads limiting productivity and cost of construction.
- Downstream flood conditions: both the existence of existing downstream flooding concerns, or the potential for flooding concerns with development in or adjacent to the river channel, can result in significant flood control mitigation should sediment be flushed from the reservoir into the downstream reach.
- Downstream water supply conditions: the number and type of downstream water supply diversions and infrastructure is a consideration when assessing impacts of releasing accumulated reservoir sediments into the downstream reach; mitigating lost supply and/or improving water supply infrastructure to accommodate higher sediment loads could significantly impact cost.
- River flow during the instream construction window: the amount of dry season flow will impact the size and cost of diversion and dewatering systems required for construction.

Table 3-1. Dam Removal Case Study Summary

Dam	Year	River	Dam Height (feet)	Accumulated Sediment Volume (CY)	Accumulated Sediment Composition	% of Reservoir Sediment Mobilized	Time to Mobilize Sediment	Construction Cost
Marmot	2007	Sandy, OR	50	980,000	~50% gravel, 50% sand	40%	3 months	~$15M[1]
Savage Rapids	2009	Rogue, OR	40	200,000	~70% sand, 30% gravel	Data on sediment not readily available	2 years for sediment to reach furthest downstream reach	~$40M
Condit	2011	White Salmon, WA	125	2.5 million	~60% sand, 35% silt and clay, 5% gravel	~50%	15 weeks	~$37M
Elwha	2011–2012	Elwha, WA	108	6 million	~70% silt and clay, 25% sand, 5% gravel	~40%	2 years	~$200M in various construction contracts [2]
Glines Canyon	2011–2014	Elwha, WA	210	29 million	~50% silt and clay, 35% sand, 15% gravel	~40%	2 years	
San Clemente	2012-2015	Carmel, CA	105	2.5 million	~60% fines; 40% coarse	sediment removed	sediment removed	~$65M
Matilija	—	Matilija, CA	168	7 million	~43% silt and clay, 32% sand, 25% coarse	—	—	~$80M [3]

Notes:

1. Keller 2009.
2. Reclamation 2013. Does not include real estate acquisition.
3. Estimated. Project in planning and design phase. Does not include real estate acquisition.

For dredging and sediment removal alternatives, recent studies (MWH 2013) considered a number of potential sediment management options for Los Padres Reservoir, and ultimately proposed three mechanical removal alternatives. The study and cost estimates are summarized in Section 2.2.2. Similar to dam removal projects, key consideration include the following:

- Accumulated sediment character and volume: this will help determine the most cost effective sediment removal approach (excavation versus flushing); either approach will be a primary driver of implementation costs.
- Proximity to available sediment disposal locations: when considering removal and hauling of accumulated reservoir sediments, hauling any significant distance could greatly increase implementation costs.
- Ease of construction access: many dam sites are fairly isolated and may require new or improved access roads; the topographic constraints at isolated sites may also limit the size of the access roads limiting productivity and cost of construction.
- River flow during the instream construction window: the amount of dry season flow will impact the size and cost of diversion and dewatering systems required for construction.

For reservoir expansion projects, key cost considerations are listed below. Reservoir expansion could include dam modification, to make an existing dam taller, or dam replacement, to create a new, larger dam.

- Local geology: if expanding laterally or building a new dam, the local geologic conditions could impact the extent and cost of excavation and any potential slope stability improvements.

- Age and type of existing dam: the age and type of dam will drive the feasibility and extent of improvements necessary for a modification or raise.
- Ease of construction access: many dam sites are fairly isolated and may require new or improved access roads; the topographic constraints at isolated sites may also limit the size of the access roads limiting productivity and cost of construction.
- Existing biological and cultural resources within project footprint: impacts to existing resources could result in significant mitigation efforts and costs.
- Water rights: as discussed in Section 2.3, water rights should be considered when evaluating expansion or new reservoir projects, and may affect the feasibility of obtaining regulatory permits.

Any alterative that maintains a dam at Los Padres will also have costs associated with improvements to fish passage facilities. Fish passage for Los Padres Dam is currently being evaluated as part of the Los Padres Dam Fish Passage Feasibility Study, and cost estimates will be developed as part of that study. Those fish passage solutions and their costs will be considered as part of the Los Padres Alternatives Study.

4. Evaluation Criteria

This section provides a description of the process that will be used to evaluate alternatives developed during the LP Alternatives Study. A grid analysis technique, or multiple-criteria analysis, will be used, which breaks down the alternatives into discrete elements for comparison, evaluation, and optimization. The first subsection describes the evaluation process, and the second presents preliminary evaluation criteria.

4.1 Evaluation Process

A multiple-criteria analysis is a tool that is often used to help develop consensus around a group of potential design solutions. This type of analysis will help to develop a mutual understanding of each alternative, develop an understanding of other decision-makers' values and points of view, and ultimately help to optimize alternatives. Table 4-1 is a simplified schematic example of the multiple-criteria analysis. The LP Alternatives Study evaluation will consist of several categories of criteria—engineering, biological, economic, geomorphic, water supply, and water rights.

Table 4-1. Schematic Example of Multiple-Criteria Analysis

Weight	Default Choice	Alternative #1	Alternative #2	Alternative #3
Criteria #1	1	0		
Criteria #2	1	0		
Criteria #3	1	0		
Totals				

The following is a list of benefits of using the multiple-criteria analysis method to evaluate alternatives:

1. Quantitative technique that can be used to rank multi-dimensional options
2. Increases objectivity of evaluation
3. Develops a clear common understanding of options being considered
4. Helps diverse stakeholders understand each other's values and issues
5. Allows for testing of sensitivity of objectives and project features
6. Rational and consistent
7. Can be a framework for consensus-building

The process of the analysis is as follows. The process is explained further below.

1. Define evaluation criteria
2. Weight criteria (optional)
3. Describe alternatives
4. Score alternatives for each criterion
5. Multiply each score by the criteria weight (optional)
6. Sum the score-weight products for each alternative
7. Optimize alternatives

4.1.1 Define Evaluation Criteria

Each criterion is a positive attribute, and they can be considered an objective of the project by which the alternatives will be evaluated. Some of the criteria may be pass/fail (e.g., meet a threshold score), although most are likely to be satisfied to different degrees by various alternatives. Ideally, criteria are quantitative metrics that have a specific value for each criteria and alternative (e.g., miles of river, acres of habitat, construction cost, etc.). Each criterion can have a different associated metric or unit type. Criteria may have different levels of importance, and can be weighed as part of the alternatives comparison (see Section 4.1.2). Preliminary criteria for the LP Alternatives Study are described below in Section 4.2, and will be refined through the LP Alternatives Study process. For the analysis, the evaluation criteria will be entered as rows, with the alternatives arranged in columns across a spreadsheet.

4.1.2 Weighting Factors

Weighting the criteria allows the user to place more emphasis on certain criteria over others, depending on the focus of the analysis. For example, criterion No. 1 could be weighted at 60 percent, No. 2 at 30 percent, and No. 3 at 10 percent. The weights of all criteria must sum to 100 percent; however, using weighting factors is optional. Often, with a wide group of stakeholders, selecting the weighting factors can be as challenging as deciding on an alternative. There are methods and approaches to developing the weighting factors such as rank ordering and pair-wise comparisons, but often stakeholders choose an equal-weighting approach or a hierarchical approach.

In an equal-weight approach, all criteria have the same weight. In a hierarchical or nested setup, criteria are grouped into categories where each category has equal weight. If category 1 has 10 criteria, and category 2 has 5 criteria, then by design the criteria in category 2 have more individual weight in the total score. Additional tiers to the hierarchy can be added as desired for the project (e.g., grouping categories together). The hierarchical approach tends to relieve the stakeholders of the decision of which individual criteria are most important versus least important.

Weighting can also be used as a way to test the sensitivity of the overall results to scores for any single criterion. For example, depending on how a certain alternative may be scoring across the various criteria, the weighting of a certain controversial criterion may not change the answer.

4.1.3 Describe Alternatives

Alternatives description and evaluation will be an iterative process for the LP Alternatives Study. Initially, brief alternative descriptions will be developed and evaluated for fatal flaws. The TRC should come to a consensus about criteria that are considered essential and must be satisfied to a high degree, or the alternative might be fatally flawed. For example, alternatives that do not ensure dam safety would likely be fatally flawed. Alternatives that pass the fatal flaw screening are acceptable for moving forward to the multiple-criteria analysis stage. Once the fatal flaw stage is complete, the fatal flaw criteria are documented as a screening tool, but they are not typically included in a multiple-criteria analysis matrix. Although these criteria may be useful for documentation purposes, they are not helpful for discriminating between alternatives because all alternatives that move through to evaluation will have passed the fatal flaw criteria.

The alternatives that pass the fatal flaw screening will be developed further and described in more detail;, then they will be formally evaluated using the methods described in this TM. It is assumed that all alternatives that move through to the multiple-criteria analysis will have passed all fatal flaw criteria.

4.1.4 Score Alternatives

The next step is to determine the values for each criterion and each alternative. Available data or analyses included as part of the LP Alternatives Study will develop these values. Because criteria are likely to all have different units (e.g., miles, acres, dollars) with widely varying values, the results will be statistically normalized across their range to bring all the results into a ten-point (zero to ten) scoring system. For example, a cost criterion may have results ranging from $200,000 to $5 million across alternatives, and a length criterion may have results ranging from 250 feet to 600 feet across alternatives. To mathematically compare alternatives across these two criteria, the numerical results need to be normalized to a 0 to 10 scale. That way, a normalized score of 5 on the cost criterion is comparable to a score of 7 on the length criterion. This also allows the scores of all criteria to be summed for each alternative, allowing comparison of alternatives at the highest level, as well as at intermediate tiers in a hierarchical approach (see Section 4.1.2). In addition, this process will allow an alternative to be incrementally improved by modifying it.

4.1.5 Multiply Scores by Criteria Weight (optional)

If weighting factors are used, then the normalized scores are multiplied by the weighting factors. Large differences among the products of individual scores and weights highlight differences that most affect the final results, and that therefore merit discussion. Large differences may be due to various factors, each of which should be addressed. Each alternative and criterion should be thoroughly understood by each person ranking the alternative. The point is to achieve a true common understanding of each score, not just to agree on a number.

4.1.6 Sum Score-weight Products

The score-weight products for each alternative are added together to create a cumulative score for each alternative. Relative ranking of alternatives can be considered using all categories, or can also be considered using specific categories.

4.1.7 Optimize Alternatives

Using simple math to score alternatives offers an opportunity to focus on strengths and weaknesses of alternatives, and can be a starting point for a discussion of how to improve an alternative or how to exclude an alternative.

4.2 Preliminary Evaluation Criteria

The decision criteria for determining feasibility include a combination of technical, geomorphic, and biological (e.g., steelhead) evaluations that will provide information on the applicability of alternatives to the issues to be studied. Technical feasibility is governed by engineering aspects, including the physical dam and reservoir characteristics, hydrology, water storage and release operations, and fluvial processes in the river. Steelhead responses to alternatives are influenced by flows and water quality, availability and characteristics of habitat, and migratory pathways. These factors will be integrated into the LP Alternatives Study and assessed iteratively so that intermediate results from each analysis will be used to refine and optimize alternatives throughout the study.

The following are potential criteria for consideration in evaluating alternatives for Los Padres Dam and Reservoir. As the LP Alternatives Study proceeds, other evaluation criteria may be included. Criteria will be refined and changed as information on alternatives and conditions specific to the study are gathered.

4.2.1 Engineering

This section presents criteria proposed to evaluate and score alternatives based on their engineering feasibility.

4.2.1.1 Dam Safety

- Does the alternative require measures to address dam stability that are not primary to the alternative to obtain DSOD approval?
  A yes/no threshold criterion where alternatives that require measures to address dam stability that are not primary to the alternative in order to obtain DSOD approval, such as removal, penetration, or alteration to the dam or abutments, would result in a yes.

- What is the cost/schedule implication of dam safety mitigation?
  A quantitative criterion where either the cost of dam safety mitigation measures (if separately quantifiable) or schedule implications of obtaining DSOD approval are measured.

4.2.1.2 Constructability

- Estimated Construction Cost.
  A quantitative criterion of the estimated construction cost for each alternative.

- Estimated Construction Timeline.
  A quantitative criterion of the number of months required to complete construction for each alternative.

4.2.1.3 Operations and Maintenance

- Estimated Operations and Maintenance Cost.
  A quantitative criterion of the estimated operations and maintenance cost for each alternative either on an annual basis or summed for a certain length of time (e.g., 30 years).

4.2.1.4 Acreage of Construction Impacts

- Area of Permanent Impacts.
  A quantitative criterion of the estimated area of permanent construction impacts from the project footprint for each alternative. If desired, areas for upland and riverine footprints can be differentiated.

- Area of Temporary Impacts.
  A quantitative criterion of the estimated area (or length) of temporary construction impacts resulting from the project for each alternative.

4.2.2 Geomorphic

This section presents criteria proposed to evaluate and score alternatives based on the impact on sediment processes and the resulting geomorphic changes downstream of Los Padres Dam. These criteria focus on aspects of geomorphic change not captured in the biological criteria described below, which will consider how geomorphic change may affect steelhead. When quantitative scoring is required, impacts or changes relative to an agreed on baseline may be appropriate.

4.2.2.1 Risk to Downstream Owners

- Increase in Potential Flooding Near Developed Properties
  A semi-quantitative criterion of the estimated length of river that is affected by sufficient sediment deposition to potentially cause increased flooding along developed properties. River reaches with no adjacent development will not be considered. Flood modeling is not included in the LP Alternatives Study, so the area of potential increased flooding will be based on reaches with relatively significant sediment deposition to potentially increase flooding. The TRC will need to select which event frequency is of interest for this criteria. A typical frequency would be the 0.01 probable flood (a.k.a. 100-year event), but other events may be of interest depending on the current flood conditions along the river.

4.2.2.2 Sediment Yield

- Will the sediment released be greater than the natural annual sediment load?
  A qualitative criterion where alternatives that result in the release of sediment in exceedance of the natural annual sediment load would be rated qualitatively according to the anticipated amount of sediment increase. This criterion is important as alternatives that release sediment exceeding the natural annual sediment load could have flood liability issues, depending on the type of sediment released.

4.2.2.3 Confidence in Sediment Transport Predictions

- Sediment Transport Prediction Certainty
  A qualitative criterion of how confident the TRC is regarding predicted sediment transport and downstream channel morphology, which in turn would affect confidence in other criteria such as sediment effects on steelhead and the effects to properties and infrastructure downstream. It

should be based on the combined knowledge of characteristics of the site, hydrology, sediment transport, channel morphology, and precedents of other similar projects.

4.2.2.4 Adaptability of Sediment Management

- Sediment Management Adaptability
  A qualitative criterion of the flexibility in design and/or operation to allow project changes to promote increased/decreased sediment release, decreased downstream effects, or decreased effects on steelhead.

4.2.3 Biological

Biological feasibility will focus on the effects alternatives may have on the population of S-CCC steelhead, including: short-term impacts of implementing the alternative, long-term effects of the alternative on habitat availability, passage from the ocean through the reservoir area, water quality in the reservoir, and quality of water and sediment releases from the reservoir. In some cases, impacts to steelhead above a certain threshold may be considered a fatal flaw; for example, an alternative that would be expected to lead to a jeopardy opinion from NMFS during the ESA Section 7 consultation. It is recognized that alternatives may also have effects on other sensitive species such as western pond turtle and California red-legged frog; however, study of effects to these species is beyond the scope of this study.

Sediment management actions at Los Padres Dam and Reservoir have the potential to affect passage of juvenile and adult steelhead into and out of the upper Carmel River watershed. The Los Padres Dam Fish Passage Feasibility Study, another effort associated with the long-term plan for the dam and reservoir, is evaluating alternatives for upstream volitional passage at Los Padres Dam. Generally at Los Padres Dam, after the rainy season ends and the reservoir is drawn down below spillway level, storage is metered out to augment downstream flow—often at levels below 10 cfs. The effect of sediment management alternatives on migration over the dam and through the reservoir, including dam removal, will be compared with alternatives proposed in the Los Padres Dam Fish Passage Feasibility Study. Scoring for passage will reflect the degree of passage; long-term, pure volitional alternatives for both juveniles and adults would be scored the highest possible score. Both short-term and long-term effects will be considered. A no-action alternative that results in the reservoir silting in and sediment periodically blocking passage facilities may result in a low rating for fish passage.

When quantitative scoring is required, impacts or changes relative to an agreed on baseline may be appropriate.

4.2.3.1 Long-term Adult Steelhead Passage

- Upstream Adult Steelhead Passage
  A qualitative criterion on whether the alternative includes volitional fish passage for up-migrating adult steelhead; or if not, whether the alternative can be paired with a feasible alternative in the Los Padres Dam Fish Passage Feasibility Study to provide that passage, and the relative degree of difficulty of the passage.

- Downstream Adult Steelhead Passage
  A qualitative criterion on whether the alternative includes volitional fish passage for down-migrating adult steelhead; or if not, whether the alternative can be paired with a feasible alternative in the Los Padres Dam Fish Passage Feasibility Study to provide that passage, and the relative degree of difficulty of the passage.

4.2.3.2 Long-term Juvenile Steelhead Passage

- Upstream Juvenile Steelhead Passage
  A qualitative criterion on whether the alternative includes volitional fish passage for up-migrating juvenile steelhead; or if not, whether the alternative can be paired with a feasible alternative in the

Los Padres Dam Fish Passage Feasibility Study to provide that passage, and the relative degree of difficulty of the passage.

- Downstream Juvenile Steelhead Passage
  A qualitative criterion on whether the alternative includes volitional fish passage for down-migrating juvenile steelhead; or if not, whether the alternative can be paired with a feasible alternative in the Los Padres Dam Fish Passage Feasibility Study to provide that passage, and the relative degree of difficulty of the passage.

4.2.3.3 Short-Term Effects of Sediment on Steelhead

- Short-Term Effects on Steelhead Present During Sediment Release
  An estimate of the effects on steelhead of various life stages (adult, juvenile, alevin, and redds), based on severity, present in reaches where suspended sediment events resulting from an alternative exceed typical levels.
- Proportion of Steelhead Affected by Short-Term Sediment Release
  An estimate of the proportion of steelhead of various life stages (adult, juvenile, alevin, and redds) present in reaches where suspended sediment events exceed typical levels, and are expected to result in severe effects to steelhead.

4.2.3.4 Effects of Sediment on Steelhead Habitat

- Changes to Instream Pool Volume
  A qualitative estimate of the proportion of steelhead-populated pools potentially filled with sediment released by reach.
- Changes in Spawning Habitat
  A qualitative estimate of the increase or decrease in the amount of available steelhead spawning habitat by reach.
- Changes in Floodplain Habitat Access
  A qualitative estimate of the increase or decrease in the amount of available accessible floodplain habitat by reach.
- Duration of Negative Habitat Effects
  A qualitative estimate of the duration of any negative habitat effects in each reach estimated by the previous three criteria.

4.2.3.5 Flow Availability for Steelhead

- Migration Period Flow Availability
  A quantitative assessment of the effect of an alternative on flows available during steelhead migration based on flow availability analysis from the CRBHM (CRBHM results to be completed by others).
- Rearing Period Flow Availability
  A quantitative assessment of the effect of an alternative on flows available during steelhead rearing (especially during the summer low-flow period) based on flow availability analysis from the CRBHM (CRBHM results to be completed by others).

4.2.3.6 Habitat Availability for Steelhead

- Spawning Habitat Availability
  A quantitative assessment of the amount of spawning habitat available upstream of Los Padres Dam.

- Rearing Habitat Availability
  A quantitative assessment of the amount of rearing habitat available upstream of Los Padres Dam.

4.2.3.7 Rearing Habitat Quality

- Quality of Rearing Habitat Upstream of Los Padres Dam
  A qualitative assessment of the quality of rearing habitat in the reach upstream of Los Padres Dam (i.e., the reservoir reach) focusing on juvenile survival as a function of predation pressure and water quality. Assumptions regarding juvenile survival in Los Padres Reservoir will be consistent with the Biological Performance Tool model developed by R2.

4.2.3.8 Effects on Ecosystem Connectivity

- Ecosystem Connectivity
  A qualitative criterion on whether the alternative provides additional ecosystem connectivity, representing benefits to aquatic and terrestrial organisms that would use the river corridor.

4.2.3.9 Attraction, Passage, and Flows for Nontarget Species

The target species for fish passage is adult and juvenile steelhead. There might be added ecological value or risk in providing for or blocking passage of other species and life stages. Risks could include the passage of nonnative species, including resident brown trout. Enhanced flows from reservoir dredging or reservoir expansion could improve habitat for such nonnative species as bullfrogs and striped sea bass. Reduced dry season flows could reduce habitat for the same species.

4.2.3.10 Quality of Water Passed Downstream

- Quality of Water Passed Downstream
  A qualitative criterion describing the relative quality of water (e.g., water temperature and dissolved oxygen) that would be released to downstream reaches based on the presence of the reservoir or the depth of outlet facilities in the reservoir.

4.2.4 Water Supply

Los Padres Dam and Reservoir are an important source of water supply for the Monterey Peninsula. The risk of losing this supply, either due to inaction or from a dam removal project, must be balanced with the risk that a replacement supply may not be feasible, or may not be available in a timely fashion. Increases in water supply from dredging or reservoir expansion can be important in the short term, and for such long-term effects as predicted climate change.

4.2.4.1 Annual Water Yield

- Maximum Potential Water Yield at Los Padres Reservoir
  The results of water availability modeling from the CRBHM (CRBHM results to be completed by others).

4.2.4.2 Quantity of Water Stored

- Los Padres Reservoir Storage Capacity
  A quantitative estimate of the volume of available storage in Los Padres reservoir after completion of an alternative.

4.2.4.3 Sustainability of Water Supply

- Future Los Padres Reservoir Storage Capacity
  A quantitative estimate of the future volume of available storage in Los Padres reservoir at the end of the planning horizon (e.g., 20, 30, or 50 years).

4.2.4.4 Need for Water Supply Replacement

- Replacement Water Supply
  A yes/no criterion on whether implementation of an alternative would create the need for replacement water supply sources (e.g., if Los Padres Reservoir is allowed to fill with sediment or is removed).

4.2.5 Water Rights

A significant portion of MPWMD and Cal-Am water rights along the Carmel River are assigned at or near the Los Padres Dam site. Recovery to original capacity could involve a Change Petition to the SWRCB. A reservoir expansion alternative could involve mixing water rights with different instream flow requirements (i.e., License 11866 and Permit 20808B). For a dam removal alternative, the loss of existing water rights and potential need for replacement supply needs to be considered. The feasibility of changing the location of diversions needs to be considered, and the conditions under which future diversions could be allowed. A submittal of a Petition for Change to the SWRCB could trigger a re-examination of Public Trust and ESA issues involved with impacts to S-CCC steelhead from diversions.

Because existing riparian properties with rights to divert Carmel River surface flow and underflow do not have a right to divert stored water released to the river, it is not anticipated that increases in surface storage at Los Padres Dam would have an effect on downstream rights; however, for the dam removal alternative, the analysis will explore the effect that dam removal has on the availability of flow during dry periods.

4.2.5.1 Water Rights

- Need for Petition to Change Water Rights
  A yes/no criterion on whether the alternative would require a petition to SWRCB for changes to the rights.

- Effects on Cal-Am and MPWMD Water Rights
  A qualitative criterion on the degree to which the alternative would affect water rights.

- Water Right Petition Process
  A qualitative criterion on the anticipated level of controversy involved in revising the water rights.

4.2.6 Community Response

There are numerous residential communities in the Carmel River Watershed downstream of Los Padres Dam and Reservoir and members of these communities may be affected by implementation of the alternatives described in this TM. Anticipating and considering the potential community responses to each of the alternatives will help direct community outreach and communication as the alternatives are refined, a preferred alternative is selected, and the project is ultimately implemented.

4.2.6.1 Community Response

- Anticipated Community Objection
  A qualitative criterion on the anticipated level of community objection to each alternative.

5. Preliminary List of Alternatives

This section includes a preliminary list of alternatives that may be considered during Task 2, Describe Alternatives. The following four alternatives will be among those addressed, as well as a sediment management program:

1. No Sediment Management (Alternative 1) may become the baseline for comparing alternatives. This alternative will focus on the effect of taking no action to manage the existing sediment accumulation in the reservoir or future sediment inputs. Considerations include:
   a. Effects on the downstream BGS;
   b. Effects on steelhead migration over Los Padres Dam and through Los Padres Reservoir;
   c. Effects to downstream channel geometry and habitat for steelhead;
   d. Compliance with SWRCB water rights permit conditions;
   e. Effects to the water supply for the Monterey Peninsula; and
   f. Dam safety.
2. Dam Removal (Alternative 2) includes sediment management and dam removal. Considerations include:
   a. Disposal, stabilization, or dispersal of existing reservoir sediment;
   b. Potential improvements to steelhead passage and restoration of river habitat in the reservoir area;
   c. Potential for public ownership of reservoir property;
   d. Expected response of the active channel, potential impacts to downstream properties from resumption of the natural sediment load, and the need to develop a riparian vegetation management plan;
   e. Reduction in dry season flow and the effect on riparian diversions and steelhead habitat below Los Padres Dam;
   f. The effect to water rights and municipal water supply;
   g. Impacts to local residents from construction traffic; and
   h. For phased removal, dam safety assuming a PMF of 36,000 cfs.
3. Recover Storage (Alternative 3) includes two sub-alternatives that involve removing sediment from Los Padres Reservoir, but differ in the location where sediment is disposed:
   a. Sub-alternative 3a: Recover reservoir storage capacity by dredging sediment and placing it on Cal-Am property downstream of Los Padres Dam. This alternative involves reviewing a previous sediment disposal evaluation (MWH 2013) and evaluating whether the downstream sediment disposal site can be expanded to accommodate dredging the reservoir to its original capacity. Considerations include:
      i. maintaining dam safety;
      ii. DSOD requirements for disposal containment;
      iii. sustainability;

iv. impacts to local residents from construction traffic;

v. effects to downstream channel geometry and habitat for steelhead;

vi. effects on steelhead passage over Los Padres Dam and through the reservoir; and

vii. municipal and environmental benefits from an increased water supply.

b. Sub-alternative 3b: Recover reservoir storage capacity by dredging sediment and placing it off the Cal-Am property. This alternative will describe dredging the reservoir to original capacity and transporting some or all reservoir sediment to an off-site disposal area. With this alternative, existing public roads in Cachagua Valley would not be used (i.e., Nason Road, Cachagua Road, and Tassajara Road); however, the concept of building a new road or conveyor system on private property will be evaluated. This concept could be combined with placement of a portion of material on the Cal-Am property, and the remainder off site. It is expected that many of the same considerations as Sub-alternative 3a would apply.

4. Storage Expansion (Alternative 4) includes four sub-alternatives that differ in the type and location of the upgraded dam or dams.

   a. Sub-alternative 4a: Expand reservoir storage with a rubber dam. This sub-alternative will describe the use of a rubber dam, which would increase the water surface elevation and associated reservoir storage. A rubber dam can be inflated or deflated to adjust the reservoir water surface elevation. Considerations include:

      i. maintaining dam safety and passage of the PMF;

      ii. sustainability, especially of surface storage;

      iii. local impacts from traffic and noise;

      iv. effects to downstream channel geometry and habitat for steelhead;

      v. effects on steelhead passage over a dam and through the reservoir;

      vi. water availability analysis (i.e., what effects would alternatives have on instream flows); and

      vii. municipal and environmental benefits from an increased water supply.

   b. Sub-alternative 4b: Small dam raise at the existing dam. This sub-alternative will describe an expansion of surface storage with a small dam raise at the existing dam. It is expected that many of the same considerations as Alternative 4a would apply.

   c. Sub-alternative 4c: Construction of a new dam downstream at the elevation of the existing dam (i.e., elevation = 1042.9 NAVD 88). This alternative will describe an expansion of surface storage, with a new dam downstream. It is expected that many of the same considerations as those for Alternative 4a would apply.

   d. Sub-alternative 4d: Expand surface storage with a combination of two or three methods described above, an alternative that could provide an opportunity to use the original reservoir to continue capturing sediment, allowing a lower reservoir to trap less.

5. Sediment Management Program: A Sediment Management Program would be relevant to alternatives involving retention or expansion of Los Padres Dam, and would include evaluation of a long-term sediment management program. The evaluation will describe levels of sediment management that could result in either maintaining the existing surface storage capacity, or increasing surface storage over time up to the original reservoir capacity. In addition to reviewing options previously developed for dredging, this evaluation will consider if there are additional

feasible alternatives for removing material from the reservoir and transporting it to a disposal site. The evaluation might consider periodic dredging and removal off site; periodic dredging and placement downstream of Los Padres Dam, with the intent to allow the material to be captured and entrained by the river at high flows; constructing a sediment capture area in the reservoir; sluicing fine sediment during high flows; or construction of a bypass tunnel for incoming sediment. Other combinations could be evaluated. Considerations include:

a. Maintaining dam safety;

b. DSOD requirements for placement of sediment downstream of the dam, a sediment capture area, sediment sluicing, and bypass tunnel;

c. Sustainability (how frequently would sediment management be required?);

d. Effect of fire/landslides in the watershed;

e. Beneficial effects to downstream aquatic habitat (e.g., from restoring a more natural sediment load);

f. Harmful effects on steelhead passage (e.g., from increased bedload and suspended load during high flows);

g. Effects to downstream channel geometry;

h. Effects on flood elevations; and

i. Municipal and environmental benefits from an increased water supply.

6. Data Gaps

Table 6-1 summarizes missing or additional desired information, and appropriate steps to acquire the information or data. This is a working list, and some data gaps identified previously have already been filled. Some desired information may ultimately not be obtained if the LP Alternatives Study timeline or funding constraints do not allow for its development, in which case a plan to complete the LP Alternatives Study without the additional information will be developed. Outstanding data gaps will be discussed at TRC meetings, and the list will be updated as data gaps are filled or new data gaps are identified.

Table 6-1. Working List of Data Gaps Identified Relative to the LP Alternatives Study

Item No.	Description	Purpose	Proposed Action	Decision Date	Decision Participants	Status
1	New Los Padres design reports, geotechnical information, EIR, and other project information (e.g., stage storage curves)	Inform alternatives that involve reservoir expansion	L. Hampson to look for relevant documents and share with AECOM	2/17/2017	J. Stead, L. Hampson	Done
2	Reports describing structural integrity and safety of Los Padres Dam	Inform evaluation of alternatives on the basis of dam safety	A. Gonzales to provide latest assessment recently shared with DSOD	3/3/2017	J. Stead, A. Gonzales	Done
3	Summary of NMFS plans for Los Padres Reservoir Steelhead Transit Study	Identify information regarding steelhead in the reservoir that will be available in the future, include in Study Preparation TM	NMFS to provide description of study plans	4/20/2017	D. Boughton, J. Stead	Done
6	Kondolf and Curry, 1983, Sediment Transport and Channel Stability, volume 1 (we have volume 2), for MPWMD	Sediment transport model	L. Hampson to scan and provide to AECOM.	6/7/2017	J. Stead, L. Hampson	Done
7	Graham Matthews, 1983, Discharge and sediment load for tributaries to the Carmel River: Carmel River Watershed Management Plan Working Paper No. 5, for MPWMD	Sediment transport model	L. Hampson to check archives.	6/7/2017	J. Stead, L. Hampson	Done
4	Carmel River cross sections from recent Normandeau and Balance Hydrologics surveys for IFIM.	Sediment transport model	Mark Allen from Normandeau to provide to AECOM	6/9/2017	J. Stead, L. Hampson	Done
5	2015-2016 Carmel River profile	Sediment transport model	Whitson Engineers, consultant to MPWMD, is completing the profile and MPWMD will share with AECOM.	6/6/2017	J. Stead, L. Hampson	Done
8	Robert Curry, 1981, Sediment Transport and Analysis Between Los Padres and San Clemente Reservoirs	Sediment transport model	L. Hampson to check archives.	6/7/2017	J. Stead, L. Hampson	Done
9	Accumulated sediment characteristics	Characterizing sediments will help understand mobilization and transport, as well as potential dredging or excavation feasibility and cost	LP Alternatives Study includes a geotechnical investigation to help characterize accumulated sediments	2/16/2017	J. Stead, L. Hampson	Done

Item No.	Description	Purpose	Proposed Action	Decision Date	Decision Participants	Status
11	Quantitative data to compare steelhead habitat upstream of Los Padres Dam to other areas in the watershed	Comparing benefits of dam removal to benefits of summer flow releases from reservoir, for steelhead	Analysis will move forward with available data	8/3/2017	TRC Meeting Attendees	Done
12	Anticipated response of brown trout in Los Padres Reservoir to dam removal	Evaluating potential for nonnative dispersal following dam removal	Keep analysis simple based on limited information available	8/3/2017	TRC Meeting Attendees	Done
13	Detailed information regarding inflow, outflow, and operations of reservoir in various water year types	Understanding the performance of each alternative during various water- year types.	This was intended to be more something compared among alternatives rather than documentation of exact numbers	8/3/2017	TRC Meeting Attendees	Done
14	Surface Bed Material Characterization of the Carmel River, Monterey County, California: Pebble Count Data Compilation, Collection, and Recommendations (Eischeid 1998)	Sediment transport model	L. Hampson to scan and provide to AECOM	7/10/2017	J. Stead, L. Hampson	Done
10	Sediment transport data plotted in Matthews 1987 (MPWMD TM 87-13) and mentioned in Hampson 1997 for water years 1984-1986	Sediment transport model	L. Hampson to check	2/16/2017	J. Stead	In Progress

7. References

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