San Clemente and Matilija Dam Removal: Alternative Sediment Management Scenarios

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ABSTRACT

San Clemente Dam on the Carmel River and Matilija Dam on Matilija Creek are located in coastal California watersheds comprised of highly erosive soils. Both dams are thin arch concrete structures constructed in 1921 and 1948 respectively, and both reservoirs have been filled with sediments, thereby eliminating their water storage capacity and any incidental flood control function. As a result, the removal of both dams is under consideration.

A major challenge to the removal of the San Clemente and Matilija Dams is the management of the approximately 2.5 and 6 million cubic yards of sediment impounded in their respective reservoirs. Mechanical removal of impounded sediments entails large economic and societal costs because of restricted access, distance to disposal sites, and the length of time to excavate and transport material. Natural flushing of sediments through the river system could adversely impact aquatic habitat, including their estuaries, as well as cause potential impacts to water supply systems and flooding of floodplain situated properties.

The San Clemente and Matilija Dam projects illustrate two basic approaches to the management of impounded sediments: (1) permanent stabilization of sediments off-site, or permanent stabilization of sediment within the reservoir behind San Clemente Dam and by-passing a short reach of the Carmel River through San Clemente Creek; and (2) controlled flushing of sediments through Matilija Creek and the Ventura River by temporary stabilization of coarse materials impounded behind the Matilija Dam and slurrying finer fractions of sediments through a conduit to downstream storage sites.

None of the sediment management alternatives is free of economic and societal costs, or environmental impacts; site specific circumstances will influence the best strategy for handling sediments to minimize adverse impacts and costs, and maximize benefits within an acceptable time-frame to achieve dam removal goals and objectives.

SAN CLEMENTE DAM

San Clemente Dam is located on the Carmel River, approximately 18.5 miles inland from the coastal community Carmel-by-the-Sea, Monterey County, California within a private land holding owned by the California-American Water Company. San Clemente Dam

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was constructed in 1921 by the California-American Water Company principally for local water supply and incidental flood control. San Clemente Dam is a concrete arch structure, approximately 106 feet high, 300 feet wide, and a thickness varying from 50 feet at the base to 8 feet at the crest. The San Clemente reservoir originally impounded approximately 2,150 acre-feet of water, but is currently over 90% filled with 2.5 million cubic yards of sediments (California Department of Water Resources, 1988; Entrix, Inc. 2006).

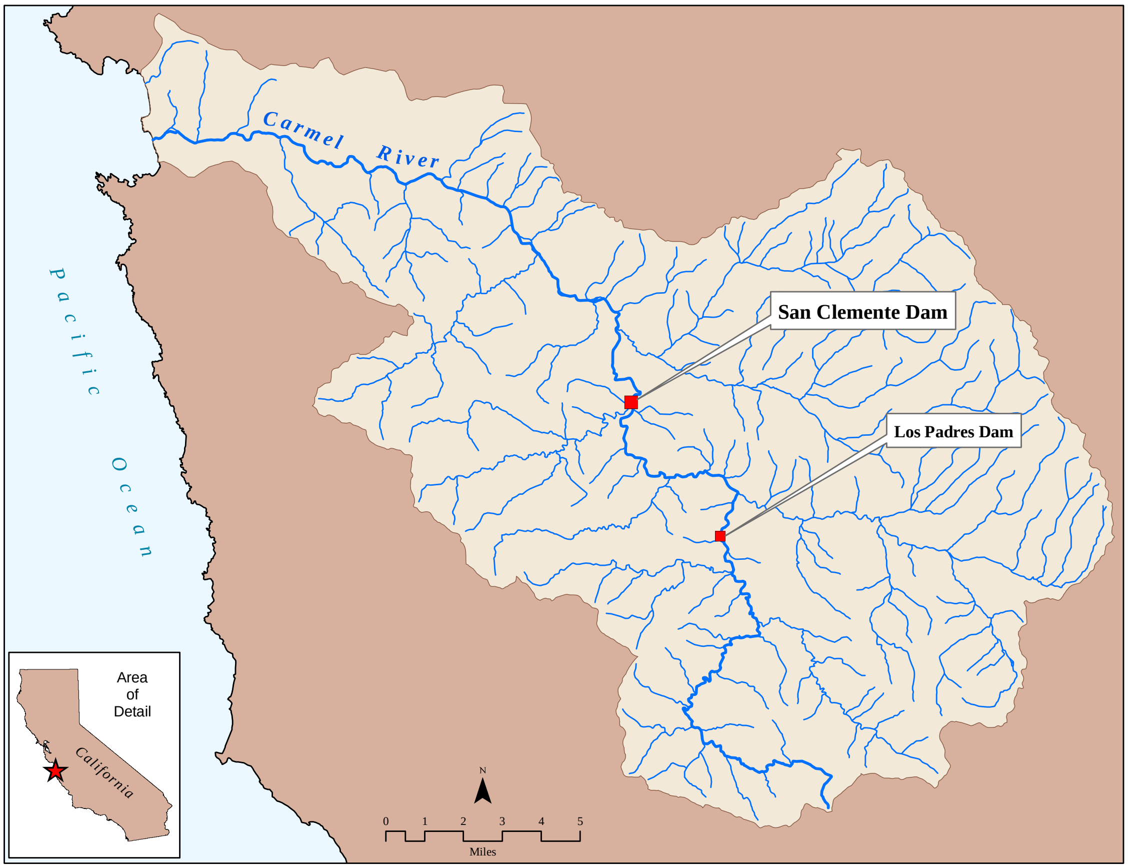

Figure 1 Regional Setting of San Clemente Dam and Carmel River

The Carmel River watershed encompasses 247 square miles of predominantly mountainous terrain within the Santa Lucia Mountains (Monterey, California). Portions of the northern watershed geologic formations are composed of uplifted, unconsolidated marine sediments which are highly erosive volcanics, while the southern watershed is characterized metamorphic and granitic formations, the latter of which provide important bedload material for fish habitat. The processes of erosion can be accelerated by periodic wildfires that denude the mixed conifer and grassland covered geologic formations, exposing these formations to short duration but intense winter rainfall and runoff.

The San Clemente Dam site is situated between several major seismic fault zones: San Andreas, Palo Colorado-San Gregorio, and the Monterey Bay. The nearest faults to the dam site are the Cachagua and Tularcitos faults, which pass within 0.125 and 1.25 miles of the dam respectively. Between 1800 and 1985 approximately 520 earthquakes larger than 4.0 on the Richter scale have been recorded within a 60-mile radius of San Clemente Dam. During this period the region has experienced on average three earthquakes of magnitude 4.0 to 4.9 each year, one magnitude 5.0 to 5.9 earthquake every three years, and one magnitude 6.0 to 6.9 earthquake every 20 years (Entrix 2006).

As a result of the level of seismic activity in the vicinity of the dam site and the design of San Clemente Dam, the California Department of Water Resources (Division of Safety of Dams) has determined that San Clemente Dam is not designed to withstand the seismic loading from a Maximum Credible Earthquake or to pass a Probable Maximum Flood. Consequently the dam's owner, California-American Water, is evaluating the long-term disposition of the San Clemente Dam. A Draft Environmental Impact Statement/Report prepared for the California Department of Water Resources and U.S. Army Corps of Engineers have identified four possible alternatives in dealing with the aging structure: (1) dam strengthening and in-place sediment stabilization; (2) dam notching with partial sediment removal; (3) dam removal with total sediment removal; (4) dam removal with in-place sediment stabilization and rerouting of the Carmel River (Entrix 2006). This paper focuses on the two dam removal options (with either sediment removal and/or rerouting of the Carmel River).

Figure 2. San Clemente Dam

Carmel River Steelhead

Prior to the construction of the San Clemente Dam in 1921 the Carmel River was reported to support an annual steelhead run of 20,000 adults per year, which was the largest reported run along the Central Coast of California between San Francisco Bay and Point Conception. While the San Clemente Dam was equipped with a fish ladder, the inefficiency of the ladder coupled with the construction of an additional dam (Los Padres) further upstream in the watershed has resulted in a severe decline in the annually runs of steelhead. The current size of the Carmel River steelhead runs varies from 0 to several hundred fish per year, representing a decline of over 90% of the historic runs. Steelhead within the Carmel River system were listed as a Threatened Species under the U.S. Endangered Species Act by the National Marine Fisheries Services in 1997. In 2005, the Carmel River was designated as critical habitat for the Threatened Steelhead (NMFS 2005b) Removal of San Clemente Dam is viewed as one of the most effective means of restoring access to steelhead spawning and rearing habitat between the San Clemente and Los Padres Dams, as well as restoring habitat currently buried under sediments impounded behind San Clemente Dam, and therefore contributing to recovering and ultimately delisting this Threatened species (National Marine Fisheries Service, 1997, 2003, 2005a, and 2006).

Sediment Management

A major challenge to the removal of San Clemente Dam is the management of approximately 2.5 million cubic yards of sediment impounded upstream of the facility. The upper portion of the watershed lies within the Santa Lucia Mountains, and with the exception of several rural communities above San Clemente Dam, remains largely undeveloped. Portions of the lower Carmel River floodplain have been developed with a variety of residential, commercial, and recreational (including golf courses) uses, some of which are subject to periodic inundation from the Carmel River. This flood hazard could be exacerbated by the release of sediments impounded behind San Clemente Dam. Additionally, sediments (particularly finer materials) could severely impact steelhead spawning and rearing habitat within the lower Carmel River below San Clemente Dam. Because of the large number of trucks required to removal impounded sediments would create significant traffic impacts in established communities, as well as additional costs, this option was determined to be both undesirable and infeasible.

San Clemente Dam is constructed at the confluence of San Clemente Creek and the Carmel River, and the reservoir itself has several minor drainages which feed directly into the reservoir immediately upstream of the dam. This topographic setting offers several unique options for handling impounded sediment in the reservoir which obviates the need for long-distance transport, either mechanically or naturally.

Off-Site Storage Option

Before San Clemente Dam is removed, provision must be made for disposition of impounded sediments. Under the off-site sediment storage option, approximately 2.5 million cubic yards of accumulated sediment in San Clemente Reservoir would be removed from behind the dam over three years by excavation, and transported via a conveyor belt system to a site within less than one-half mile of the Carmel River arm of the San Clemente reservoir. Sediment removal operations would take place during a five-month construction window from June through October to avoid the Mediterranean Climate rainy season. Prior to the sediment removal and dam de-construction, the reservoir would be de-watered and the Carmel River and a tributary, San Clemente Creek, would be temporarily diverted around the reservoir and dam site. The river channel of the Carmel River exposed as a result of the removal of impounded reservoir sediment would be restored. The entire project is expected to take seven years, but the schedule could be affected by annual river flows in response to winter/spring precipitation.

By-Pass Option

Prior to removal of San Clemente Dam under the in-situ sediment storage option, approximately 380,000 cubic yards of sediment accumulated in the San Clemente Creek arm of the reservoir would be relocated to the Carmel River arm of the reservoir, where the majority of the accumulated sediment behind San Clemente Dam has been naturally deposited. A portion of the Carmel River would be permanently bypassed by cutting a 450-foot long channel through a ridge separating the Carmel River and San Clemente Creek approximately 2,500 feet upstream of San Clemente Dam. The portion of the Carmel River by-passed by rerouting the Carmel River through San Clemente Creek would be used as a sediment disposal site for accumulated sediment. The spoils from the by-pass channel construction (approximately 235,000 cubic yards) would be used to construct a diversion dike at the upstream end of the bypassed Carmel River reservoir

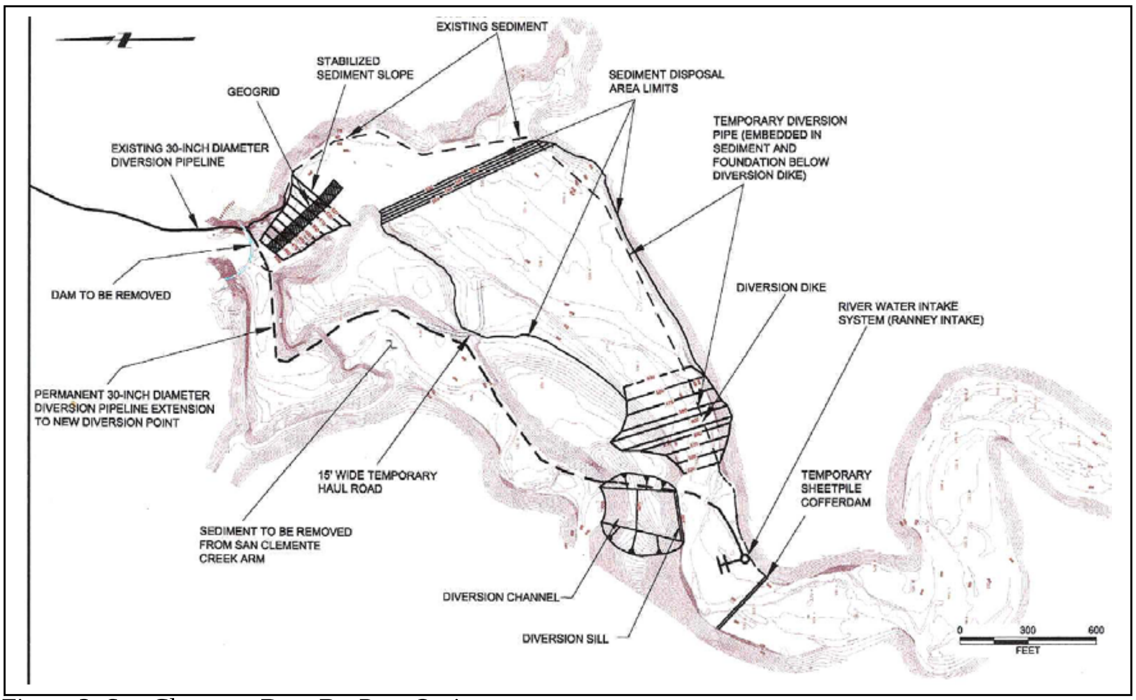

Figure 3. San Clemente Dam By-Pass Option

arm. Accumulated sediment in the San Clemente Reservoir would be removed from immediately behind San Clemente Dam by excavation and transported to a disposal area within the by-passed portion of the San Clemente Reservoir. The sediment at the downstream end of the bypassed San Clemente reservoir arm would be stabilized and protected against bank erosion.

During construction, the Carmel River and San Clemente Creek would be diverted around the San Clemente Reservoir and San Clement Dam, and the reservoir would be de-watered. Following the removal of San Clemente Dam, San Clemente Creek would be reconstructed and re-connected with the Carmel River near the San Clemente Dam site. The project is expected to take four to five years, but the schedule could be affected by annual river flows in response to winter precipitation.

Both the off-storage and by-pass options avoid the complications associated with mechanically removing sediments to distant spoils disposal locations as well as the impacts (short-term and mid-term) and uncertainties of naturally flushing impounded reservoir sediments down the Carmel River channel to the Pacific Ocean. The estimated costs of the off-storage and by-pass options are $118,000,000 and 75,000,000 respectively (MWH 2006).

MATILIJA DAM

Matilija dam is located on Matilija Creek, a tributary to the Ventura River, approximately 16 miles inland from the coast near the City of Ojai (Ventura County, California). Matilija Dam is a concrete arch structure, approximately 200 feet high, over 600 feet wide, and a thickness varying from 50 feet at the base to 8 feet at the crest. Matilija Dam was constructed in 1946 by the Ventura County Flood Control District (now the Ventura County Watershed Protection District), principally for local water supply and incidental flood control. The Matilija reservoir originally stored approximately 7,000 acre-feet of water, but is now 90% filled with 6 million cubic yards of sediments. (Brauner, 1998; U.S. Bureau of Reclamation, 1999, 2000) Matilija Dam is currently leased to the Casitas Municipal Water District and operated in conjunction with the Robles Diversion on the mainstem of the upper Ventura River and the Casitas Dam on Coyote Creek, a tributary to the lower Ventura River.

The Ventura River watershed encompasses 228 square miles of predominantly mountainous terrain, within the Los Padres National Forest. The principal geological formations are composed of recently uplifted, unconsolidated marine sediments, which are highly erosive. The processes of erosion are accelerated by periodic wildfires that denude the chaparral covered rock formations, exposing these formations to short duration but intense winter rainfall and runoff which in some circumstances can produce large debris flows.

The upper portion of the watershed lies within the Los Padres National Forest, and with the notable exception of the City of Ojai (within the San Antonio Creek watershed), remains largely undeveloped. Portions of the lower Ventura River floodplain has been leveed on the east and west and developed with a variety of industrial, residential and recreational facilities.

A major challenge to the removal of Matilija Dam is the management of approximately 6 million cubic yards of sediment impounded upstream of the facility. While Matilija Dam has been notched several times to address deteriorating concrete near its crest, these modifications have not lowered the level of the dam to the level of impounded sediments.

Further notching, however, would expose these sediments to the hydraulic action of Matilija Creek, and therefore requires consideration of the deliberate management of these mobilized sediments. (Gray, 1999)   Several options have been identified for the disposition of this sediment: permanent stabilization in situ; mechanical removal and natural flushing.

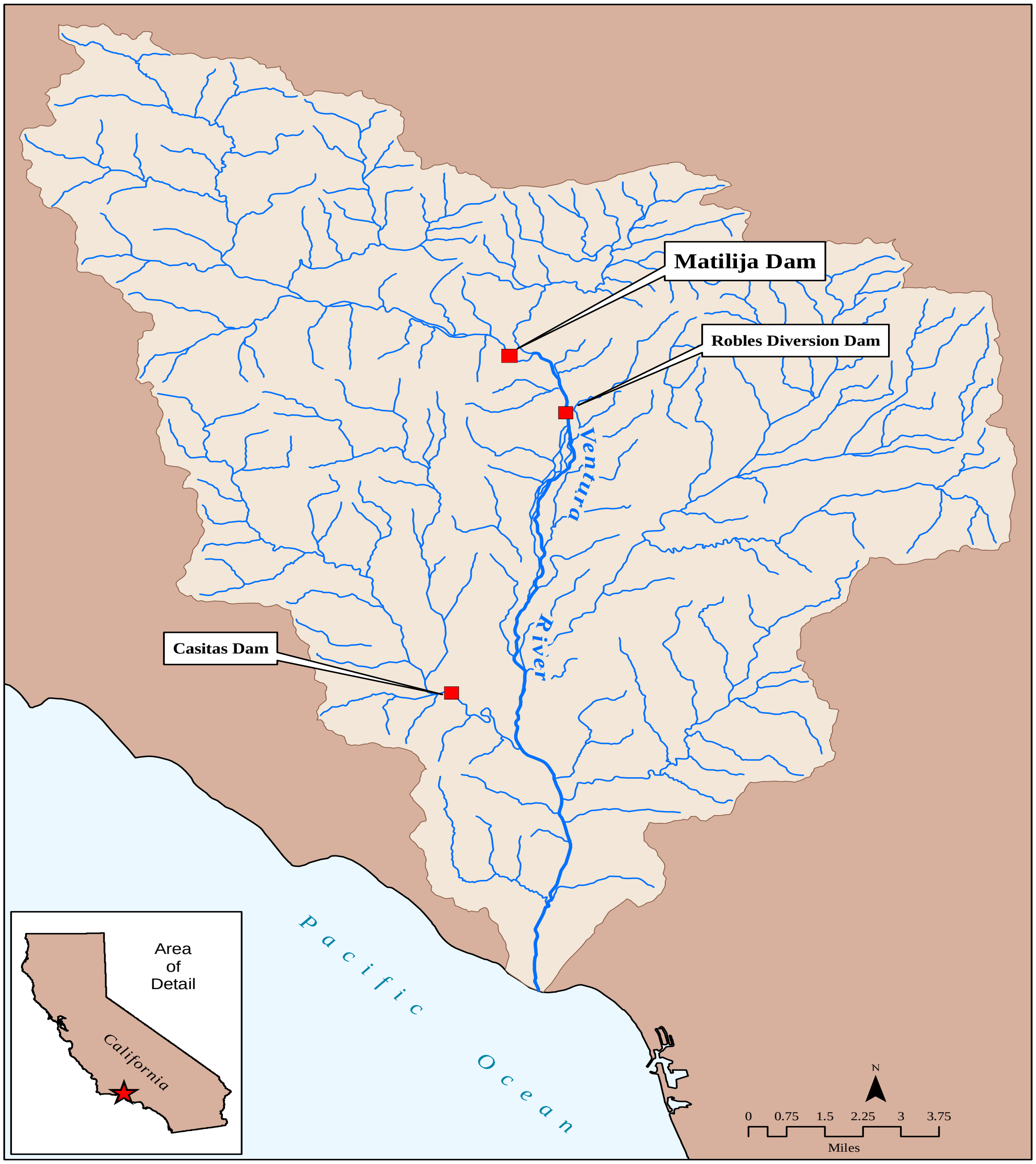

Figure 4. Regional Setting for Matilija Dam and the Ventura River.

In 1999, the Ventura County Flood Control District proposed removing Matilija Dam in anticipation of the complete sedimentation of the reservoir, and expiration of the lease agreement in 2009 between the Flood Control District and the Casitas Municipal Water District. The U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers conducted an Appraisal Level Study and Preliminary Environmental Impact Analysis of the removal of the Matilija Dam. Both preliminary assessments identified management of the sediment impounded behind Matilija Dam as the major challenge to the dam's removal. (U.S. Bureau of Reclamation, 2000; U.S. Army Corps of Engineers, 2004b)

The uncontrolled release of impounded sediment following the removal of the Matilija Dam has the potential to adversely impact a number of natural riverine and coastal resources as well as roads, bridges, flood control structures, and residential properties along the Ventura River floodplain. Additionally, the elevation of sediment levels in the mainstem of the Ventura River could adversely affect the operation of major water supply facilities such as the Casitas Municipal Water District's Robles Diversion on the upper mainstem of the Ventura River. Some of these identified impacts would be relatively short-term, but others could be longer-term, and present unacceptable threats to either life or property, if not adequately addressed through design or mitigation measures. (U.S. Bureau of Reclamation, 2000; U.S. Army Corps of Engineers, 2004)

Coastal Beach Restoration

The coastal beaches of Ventura County are naturally maintained by the transport of inland sediments to the coast via coastal river systems. The amount of sediment annually contributed by the Ventura River before the construction of Matilija Dam has been estimated between 213,000 and 230,000 cubic yards. The construction of Matilija Dam in 1946 effectively trapped the majority of sediments originating from the upper watershed, and reduced the transport capacity of the river to transport sediments entering the system from downstream tributaries. (The construction of Casitas Dam on Coyote Creek tributary to the lower Ventura River in 1958 further reduced sediment transport and delivery to the mainstem of the Ventura River and ultimately to the coast.) The current annual sediment contribution of the Ventura River to littoral sediment transport is estimated at between 56,000 and 100,000 cubic yards. (Bailard, 1999; Brownlie and Taylor, 1981; U.S. Bureau of Reclamation, 2000; U.S. Geological Survey, 1988)

As a result of these impoundments beaches downcoast of the Ventura River have experienced rapid erosion and retreat, eliminating coastal dune habitat, as well as recreational sand beaches. This impact has been partly off-set by the construction of a series of groins, but the beaches near the mouth of the river continue to experience significant coastal retreat. The removal of Matilija Dam and the remobilization of sediments impounded in the reservoir would re-introduce impounded sediments to the coast, and partly restore the natural sediment transport capacity of the Ventura River system. The removal of Matilija Dam therefore has the potential to rejuvenate coastal beaches with a portion of the 6 million cubic yards of sediment impounded in the reservoir site (approximately half of which is sand or gravel sized sediments), as well as to restore an estimated 16 percent of the pre-dam background sediment transport to the coast. (Moffat & Nichols, 2003; Noble Consultants, 1989)

Ventura River Steelhead

Prior to the construction of Matilija Dam in 1946 the Ventura River system supported one of the largest and most consistent runs of steelhead trout in Southern California; this run was estimated between 4,000 and 5,000 adult fish annually. This run of adult fish, and the juveniles which occupied the mainstem and major tributaries, supported an important winter and summer sport fishery valued at the time at $100,000 per year. The construction of Matilija Dam cutoff one of the principal spawning and rearing tributaries in the Ventura River system, estimated to account for over half of the spawning and rearing habitat in the system, and resulted in the virtual elimination of the steelhead run, and the related recreational fishery. The remnant steelhead run was further diminished by the construction in 1958 of Casitas Dam on Coyote Creek (the other major spawning tributary of the Ventura River) and the Robles Diversion on the mainstem of the Ventura River, which eliminated access to the upper Ventura River and North Fork of Matilija Creek. (Capelli, 1999; McEwan and Jackson, 1996; Meyer Resources, 1988). Steelhead within the Ventura River system were listed as an Endangered Species under the U.S. Endangered Species Act by the National Marine Fisheries Services in 1997.


Figure 4. Matilija Dam

In 2005, the Ventura River was designated as critical habitat for the Endangered Steelhead (National Marine Fisheries Service, 1997, 2003, 2005b) Removal of Matilija Dam is viewed as one of the most effective means of restoring access to steelhead spawning and rearing habitat upstream of Matilija Dam as well as restoring habitat currently buried under sediments impounded behind Matilija Dam, and therefore contribute to recovering and ultimately delisting of this Endangered species. (National Marine Fisheries Service, 2006) Removal of Matilija Dam, in conjunction with the recent provision of fish passage at the downstream Robles Diversion, would re-establish access to one of the prime steelhead spawning and rearing habitats in the headwaters of Matilija Canyon, and contribute significantly to the restoration of the historic steelhead runs of the Ventura River system.

Sediment Management

Management of sediment impounded behind Matilija Dam has been the single biggest factor shaping the dam removal project. After consideration of various options for dealing with the impounded sediments, a preferred alternative has been developed and would result in the full removal of the dam structure and the phased transport of the impounded sediments out of Matilija Canyon and eventually back to the riverine and coastal environment. The basic components in the identified preferred alternative include the following:

1. Slurrying approximately 2.1 million cubic yards of fine sediments downstream to a temporary disposal site;
2. Excavation of a 100-foot wide channel through the coarse sediments and temporarily stock-piling this material within the reservoir site;
3. Temporary stabilization of the coarse sediments to permit their phased erosion and transport through the natural channel to the coast;
4. Installation of a high-flow sediment bypass at the Robles Diversion to allow mobilized coarse sediments to be transported downstream of the diversion facilities;
5. Installation of a temporary fine-sediment catchment basin with a capacity of approximately 22 acre feet along the Robles-Casitas Diversion Canal;
6. Enlargement of several existing flood control levees along the mainstem of the Ventura River to off-set any temporary reduction in channel capacity as the result of natural transport of coarse sediments impounded behind Matilija Dam;
7. Retrofitting of several bridges to accommodate increased flood flow elevations;
8. Acquisition of selected properties immediately downstream of Matilija dam for use as project staging and public access.
9. Removal of Matilija Dam in single phase.

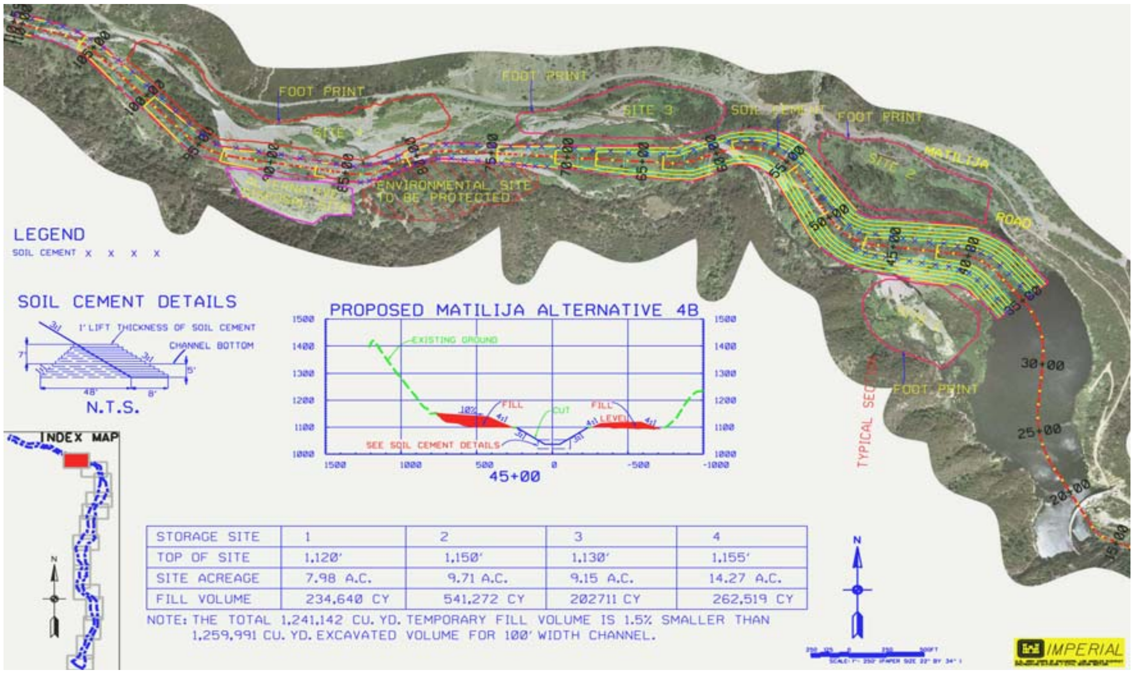

Figure 6. Temporary Sediment Storage Plan in Matilija Reservoir.

The principal objective of this combination of components is to deliver the impounded coarse sediments to the mainstem of the Ventura River and eventually to the coastal beaches in a manner which reduces the potential adverse impacts to downstream infrastructure (principally water supply and transportation facilities) and developed properties. Eventual removal of the sediments impounded behind Matilija Dam will also result in restoration of the pre-dam riverine geomorphology of the reservoir site and restoration of the ecological functions of the riverine, riparian, and floodplain terrace habitats of Matilija Canyon (extending approximately one mile upstream of the dam) that are now inundated with sediments. The estimated cost of this option is $130,000,000 (U.S. Army Corps of Engineers 2004a).

DISCUSSION

The physical removal of San Clemente and Matilija Dams can be accomplished by using relatively straightforward de-construction techniques for cutting, blasting, breaking up, and removing concrete. However, the removal and disposal of the large amount of sediment impounded behind the dams has complicated the planning for the removal of both structures. Locating suitable nearby sediment disposal sites, re-routing and reconstructing natural channels, designing temporary sediment storage sites, and providing for the protection of existing infrastructures increase the complexity of the projects. The presence of contaminants (including organic materials) in the sedimentary material impounded behind the dams also becomes a major consideration if the materials are to be re-deposited or transported through natural channels. Finally, the disposition of the impounded sediments (whether impounded on site or a controlled release through the natural river channel) adds substantial additional costs to dam removal.

The San Clemente Dam removal options (both off-site and sediment bypass) minimize the temporary adverse affects of relocating large amounts of sediments to a remote location or transporting impounded sediments down the natural channel of the Carmel River. However, they also preclude the restoration of natural channel habitats where the sediments would be permanently impounded. Further, neither approach fully restores sediment transport processes (or makes available permanently impounded sediments to redress beach erosion due to reduced sediment transport). The removal of Matilija Dam, with a natural sediment transport option, permits the restoration of the stream channel within the reservoir site, as well as re-nourishment of coastal beaches with currently impounded sediments. The two outstanding sediment management issues which remain to be further explored in the Matilija Dam removal project are the response of the temporarily stabilized impounded sediments within the reservoir site to hydraulic forces created by the removal of the dam, and the transport of mobilized sediments downstream to the coast. Modeling of the latter has been performed, but final design and engineering of temporary sediment control structures (and other infrastructure) remains to be completed. The successful management of the estimated 2.5 and 6 million cubic yards of sediments impounded behind the San Clemente and Matilija Dams, respectively, is essential to meeting the basic community objectives: re-establishing access to historic steelhead spawning and rearing habitats; restoring natural beach nourishment processes; and protecting existing infrastructures and riparian properties.

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