5.5.1.6 CONSTRAINTS AND LIMITING FACTORS FOR STEELHEAD POPULATION AND POTENTIAL RESTORATION PROJECTS

The purpose of this section is to provide an assessment of constraints and limiting factors for the steelhead population in the Carmel River and to recommend projects for restoring and maintaining critical freshwater habitats in the Carmel River Basin. The following sections provide a review and update of the historical constraints and limiting factors, describe the relationships between returning adults and juvenile populations, develop indexes of juveniles and returning adults in key reaches, describe the existing and future limiting factors, and ends with a description of projects to restore and maintain freshwater habitats and steelhead production within the basin.

Review of Constraints and Limiting Factors – As mentioned in Section 5.5.1.4, past reviews of environmental problems in the Carmel River have led to a general understanding of the principal factors associated with the historical population decline in the Carmel River Basin[1], including the following factors:

1) Inadequate passage facilities for adults and juveniles at Los Padres Dam.
2) Dry season surface diversions at San Clemente Dam.
3) Subsurface diversion of percolating streamflow and groundwater.
4) A reduction in the extent and diversity of streamside vegetation, a reduction of the number of trees and the canopy in the riparian forest, and reduced amounts of large wood in the active channel downstream of Robles del Rio.
5) Retention in main stem reservoirs of sediment that is beneficial to steelhead and benthic macroinvertebrates (insects in the river bottom).
6) Chronic and episodic bank erosion in tributaries and the main stem that introduces fine sediments into spawning and rearing habitats.
7) Prior to 1997, the temporary or seasonal blockage of smolt emigration at San Clemente Dam in some years when flashboards were raised in the spring.
8) Sand deposition in the Lagoon that reduce habitats for adults during the winter, for smolts during the spring, and for juveniles during the summer and fall months.
9) Changes in dry season (late spring to fall) water quality, including increased water temperature, reduced oxygen levels, and higher salinity levels (Lagoon only).
10) Loss of surface storage in Los Padres Reservoir due to sedimentation.

The following sections review and update how each of these historical factors has affected the steelhead population. In addition, two new factors are discussed in light of future expected changes and impacts, including the release and deposition of fine-grained sand and silt from San Clemente Dam and the loss of surface storage in Los Padres Reservoir.

1. Inadequate passage facilities for adults and juveniles at Los Padres Dam – When Los Padres Dam was constructed in 1949, a wooden ladder and trap was built to collect adults that returned to the dam. According to anecdotal sources, the ladder and its supporting structure washed out during

[1] Kelley and Dettman, 1981; Kelley, Dettman, and Turner, 1982; Snider, 1983; and Dettman and Kelley, 1987; Dettman, 1991; Dettman; Dettman, 1992; Cramer, S. P., et al., 1995; Bryant, G. J. and J. Lynch, 1996.

the April 1958 flood, which peaked at about 12,500 cubic feet per second (cfs) at the USGS Robles del Rio stream gage. Subsequently, the wooden ladder was replaced with a 50-foot long Denil ladder, trap, and small holding tank. Adults were dip-netted, placed into a 100-gallon tank, and trucked upstream to Los Padres Reservoir. In 1982, a low flow fish gabion barrier made out of gabions (rock-filled baskets) was placed just upstream of the ladder entrance to prevent fish from passing into the plunge pool below the spillway. Fisheries engineer Charles Wagner[2] reviewed the design and operation of the existing facilities and noted several problems:

> "It was reported that at high river flows fish can and do pass over and around the left end of the barrier dam."
>
> "Observation of the high water marks led to the conclusion that at least part of the dam also becomes submerged at higher river flows and evidence of stream bed degradation downstream of the barrier dam was noted. Concern was expressed... over the possible short life of the wire in the gabion mesh and the gabion's ultimate collapse."
>
> "At the low river flow observed on September 7, 1983, the flow from the Denil fish ladder did produce good attraction flow into the river. It is not known whether this attractive flow condition continues at higher river flows, particularly when there is spill over the gabion dam."

When Los Padres Dam was constructed, no specific facilities were built to pass juvenile and adult steelhead downstream past the dam. Most biologists and engineers who have examined downstream passage conditions at Los Padres Dam agree the historical situation was detrimental for emigrating smolts and adults over a wide range of streamflow. Wagner[3] noted, "the spillway at Los Padres Dam is rough, particularly the ogee section, and fish probably suffer extensive abrasion at low flows. At low spillway flows, the depth of flow over the ogee and chute will be extremely shallow and much of the flow will fall on the rocks below … Particularly when water depth is not adequate for fish to avoid contact with the spillway surface, internal as well as external injuries are expected as they pass over this spillway."

Improvements to the spillway were made in 1986, when an eight-inch high sill was installed in the lower section of the spillway to concentrate and increase the depth of flow and lower the risk of abrasion. In addition, a metal extension was added to the end of the spillway and a large boulder below the spillway was blown up to prevent emigrating fish from landing on rocks as they passed into the plunge pool below the spillway. In 1992, MPMWD conducted an experiment with smolts to test whether these improvements were successful.[4] The results indicated that substantial mortality and injuries were still occurring due to impingement on rocks below the spillway, and this led to further improvement by Cal Am to remove additional rock from the plunge pool.[5]

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[2] Wagner, C. 1983. Study of upstream and downstream migrant steelhead passage facilities for the Los Padres Project and New San Clemente Project. Report prepared for the Monterey Peninsula Water Management District. 57 pp. + Appendix.

[3] Wagner, C. op cit.

[4] Dettman, D. H. and B. M. Hanna. 1993.

[5] As part of SWRCB Order 95-10, Cal Am was required to remove additional rock at the base of the spillway. This was completed in 1997.

In 1998, the Carmel River Steelhead Association received grants from the California Department of Fish and Game (CDFG) and the National Wildlife Foundation to design and build a new fish ladder and trap with an entrance in the plunge pool on the left bank of the stream (looking downstream). This project, which was completed in 1999, resulted in substantial improvements to the trap and haul operations at Los Padres Dam and has been used to effectively transport adult steelhead since winter 2000.

In 2003, Cal Am modified the gabion structure below the plunge pool to improve passage conditions, while retaining flexibility to use the older 50-foot Denil ladder on the right bank. This project involved removing rusted, broken sections of the gabion wire baskets, buttressing the fish ladder with boulders, removing several mid-channel willows and adjusting the gradient of the streambed above the older ladder. This project resulted in improved passage conditions, particularly at streamflows less than 65 cfs (**Figure 5.5.1.6-A**).

2. Dry season surface diversions at San Clemente Dam – Since construction of Old Carmel Dam in 1881-83, water has been diverted from the Carmel River for municipal use in Carmel Valley and the Monterey Peninsula. Beginning in 1921, surface flows were diverted at San Clemente Dam and piped along the river to the Cal Am filter plant about a mile downstream of the dam. Prior to the end of World War II, diversions ranged up to about 5,000 acre feet (AF) per year with a distinct increase in 1926, corresponding to an expansion associated with the construction of San Clemente Dam and the Filter Plant (**Figure 5.5.1.6-B**). The post-war expansion of the population on the Monterey Peninsula stimulated further diversions, ranging up to 7,500 AF during the mid 1950's. Additional growth during the late 1950's and early 1960's resulted in maximum surface diversions totaling 9,800 AF by 1965, or a mean annual value of 13.5 (cfs), which was close to the maximum capacity of the Filter Plant. Between 1966 and 1983 diversions averaged 7,400 AF/year, ranging from a minimum of 2,700 AF in 1977 to a maximum of 9,500 AF in 1967.

Prior to the 1983 water year (WY), Cal Am pursued an aggressive program to control leakage at San Clemente Dam, culminating in an ambitious project to replace wooden stoplogs that were used to raise the reservoir level with 24 steel encased concrete gates in the spillway openings. This effort, which virtually sealed the dam against leaks, combined with surface diversions at the dam periodically reduced flow in the river downstream to nearly zero during the dry season months. For example, in the 1981 dry season Cal Am diverted surface flows ranging from 15 to 7 cfs, as streamflow in the Carmel River declined from 1.5 to 0.33 cfs (**Figure 5.5.1.6-C**).

In most California streams south of San Francisco Bay the quality and quantity of late spring, summer, and early fall rearing habitats for juvenile steelhead are directly influenced by streamflow. Several investigators have studied this relationship in the Carmel River.[6] While their methods differed, their results strongly support a conclusion that dry season habitat is a crucial factor limiting the population of steelhead. For example, Snider (1983) observed,

> *"Under historic, natural conditions (i.e. no diversions and no development) the lower river provided abundant nursery habitat. Flow occurred throughout the lower river in 6 out of 10 years, and in the lower 3 to 6 miles, 8 out of 10 years. The riparian canopy maintained amenable temperatures; pool habitat was present; and even during years of*

[6] USWFS, 1980; Snider, 1983; Dettman and Kelly, 1986; Alley, Hoefler, and Mori, 1990;

no September flow, perennial surface water most likely sustained juvenile steelhead. A few perennial pools occurred in the lower river as late as 1975. Many of the 100,000+ young-of-the-year and yearling steelhead which are annually stranded and perish with the cessation of flow in later spring would survive to sea-run adults given natural flow."

In 1983, CDFG challenged Cal Am's insistence on diverting flow at San Clemente Dam, citing Section 5937 of the CDFG Code.[7] CDFG prevailed in its challenge, which set the stage for changes in the way inflow was allocated. As a result, in 1983 CDFG, Cal Am, and MPWMD negotiated a Memorandum of Agreement (MOA) regarding the magnitude of flow releases at the dam. Since 1983, the scope of the MOA has been expanded to include limitations on diversion rates through the Filter Plant, pumping from Upper Carmel Valley Wells during the dry season, the sequence of pumping water from Cal Am wells in Lower Carmel Valley, and how Cal Am supplies water to its customers in the Carmel Valley Village and the former Water West Service Area.[8]

Since 1983, the releases and limitations specified in the MOAs have resulted in increased streamflow during late spring, summer, and fall months. Increased flows have improved rearing habitats for juvenile steelhead and other aquatic resources below San Clemente Dam, as far downstream as the Narrows in all years, and to Via Mallorca during the wet hydrologic years. The importance of changing the operation of Cal Am facilities can be seen by comparing flows, diversions, habitat and juvenile populations in 1973-75 (pre-MOA) and 1999-2001 (post-MOA) (**Figure 5.5.1.6-D**). In 1975, Snider (1983) estimated there was a total of 5.3 acres (231,000 sq ft) of rearing habitat in a two-mile long reach below Tularcitos Creek and only 8,078 juvenile fish below San Clemente Dam. During this study, summer flows at Robles Del Rio averaged 1.9 cfs and ranged from 0.24 to 14 cfs[9], and the river extended only two miles below Tularcitos Creek to the vicinity of the Carmel Valley Trail and Saddle Club. At the same time, Cal Am diverted an average of 14 cfs at San Clemente Dam[10].

In contrast to the condition of the river in 1975, during the summer of 2000 the flows at Robles del Rio averaged 11.3 cfs and ranged from 6.4 to 28 cfs, while diversions at San Clemente Dam averaged 0.2 cfs.[11] As a result of reduced diversions at San Clemente Dam and changes to the lineal distribution of well water production (diversions were concentrated between RM 2 and RM 7), surface flow extended downstream to the vicinity of Cal Am's Cypress Well at RM 5.4, totaling a net increase of about 8.5 miles of stream habitat. The effect of these changes on the juvenile

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[7] Section 5937 of the CDFG Code states, " The owner of any dam shall allow sufficient water at all times to pass through a fishway, or in the absence of a fishway, allow sufficient water to pass over, around or through the dam, to keep in good condition any fish that may be planted or exist below the dam. During the minimum flow of water in any river or stream, permission may be granted by the department to the owner of any dam to allow sufficient water to pass through a culvert, waste gate, or over or around the dam, to keep in good condition any fish that may be planted or exist below the dam, when, in the judgment of the department, it is impracticable or detrimental to the owner to pass the water through the fishway".

[8] The MOA reflects conditions imposed by the SWRCB in Water Rights Orders 95-10, 98-04 and 2002-0002 and agreed to in the 2002 Conservation Agreement between Cal Am and the National Marine Fisheries Service.

[9] Range and average flow based on USGS data at Robles del Rio for July-October 1995.

[10] California American Company production records, July-October 1975.

[11] Range and average flow based on USGS data at Robles del Rio for July-October 2000 and Cal Am production records, July-October 2000.

steelhead population has been to increase the population by almost 100,000 fish (107,200 in 2000 compared to 8,100 in 1975).[12]

3. Subsurface Diversion of Percolating Streamflow and Groundwater from the Carmel Valley Aquifer Below San Clemente Dam

The nature of the relationship between surface flows and ground water in the Carmel River Basin was disputed for many years. Resolution of this dispute occurred in 1995, when the SWRCB declared,

> *"…we find that downstream of RM 15 the aquifer underlying and closely paralleling the surface water course of the Carmel River is water flowing in a subterranean stream and subject to the jurisdiction of the SWRCB."*[13]

While Order WR 95-10 clarified the legal relationship between groundwater, subsurface and surface flows, it only partially addressed a physical solution to the problems created by pumping groundwater and diverting subsurface flows.[14] Because of this, the diversions from the surface and subsurface from the Carmel Valley Aquifer continue to affect four distinct parts of the steelhead's lifecycle in the Lower Valley including: migration of juveniles during fall and winter, upstream migration of adult steelhead during winter, downstream emigration of pre-smolts and smolts during spring, and juvenile habitats during spring/summer.

Juvenile Migration During The Fall And Winter – In the Carmel River, initial flows of the year often spill over San Clemente Dam and percolate into the downstream aquifer to replace water that was pumped during the previous dry season(s). At the same time, many juvenile steelhead that have reared upstream or in the vicinity of San Clemente Dam begin to move downstream toward the Lagoon. As flows decline following storms, the juveniles who have moved below the Narrows face a risk of being isolated and stranded. For example, as **Figure 5.5.1.6-E** shows**,** the storms in WY 1991 on March 4th and 13**th** increased the mean daily flow at the USGS Robles del Rio gage from 2 to 357 cfs on March 5th and from 44 to 131 cfs on March 15th. During this period flows at the USGS Near Carmel gage remained at zero, but the river advanced to within a few hundred feet of the Near Carmel gage. Following the advance, the river retreated at an average rate of two miles per day as flow percolated into the aquifer upstream of the gage. The risk of stranding as the river retreats is exacerbated during years when the Carmel Valley Aquifer is drawn down during the preceding summer.

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[12] Estimates of the total juvenile steelhead population below San Clemente Dam during the post MOA era (1990-on) are illustrated in Figure 5.5.1.4-E and range from 9,000 to 107,200. During the period from 1990 to 1994 the population was affected by low numbers of returning adults. Since 1995, the population has ranged from 35,700 to 107,200 fish, likely in response to increased streamflow, total suitable habitat area, improved substrate conditions, and suitable water temperatures.

[13] SWRCB, July 1995. Order No. WR 95-10. Page 12

[14] In Order No WR 95-10 the SWRCB placed an annual limit of 11,285 AF on Cal Am's diversions from the Carmel River Basin, which had averaged 14,106 AF during the ten-year period from 1979 to 1988. This represents a 20 percent reduction. Of the average 14,106 AF of historical diversions, the SWRCB determined that Cal Am has legal water rights to 3,376 AF, meaning that Cal Am currently diverts about 10,730 AF from the Carmel River or its subsurface flow without a valid basis of right.

Adult Migration During The Winter – The extraction of subsurface flow and groundwater during summer months results in a delay or elimination of flows needed for the upstream migration of adults during the following January, February, and March. The impact is most prevalent during extended droughts. For example, during the 1987-1991 drought, the withdrawal of groundwater completely eliminated the only available flows for attraction and migration of steelhead for three years in a row (**Figure 5.5.1.6-F**).

Emigration Of Pre-Smolts And Smolts During Spring – Adequate March, April, May and early June streamflows are needed to rear steelhead smolts below San Clemente Dam and to allow their successful emigration from the lower river into the ocean or lagoon. Prior to the early 1960s, the diversion of normal springtime flow was a minor problem for steelhead in the Carmel River because the surface diversion at the Filter Plant was most often a small fraction of the total spring flow in the river. Beginning in 1959, when the first major production wells were installed in the Carmel Valley Aquifer, there was a gradual, but steady, increase in the water demand that was met from subsurface diversions (**Figure 5.5.1.6-B**). As overall water production increased, spring flows in the lower river declined in response to increased pumping and the river dried up earlier, as steelhead smolts were emigrating downstream. Currently, the diversion of spring flows interferes with or eliminates the emigration of steelhead smolts into the ocean, threatens emigrating fish by stranding them in drying pools, and reduces habitat for juveniles and other aquatic life. The degree of interference varies from year to year, depending on total runoff and occurs most frequently during below normal, dry, and critical years, when the rate of groundwater production exceeds the combination of flow releases from San Clemente Dam and natural accretion from tributaries below the dam.[15] The varying impacts are illustrated in **Figure 5.5.1.6-G** for 1994, a critically dry year, and in **Figure 5.5.1.6-H** for 2002, a below normal year. In Water Year 1994 (WY1994), runoff totaled only 13,300 and the streamflow declined rapidly, well before the major smolt emigration period in April and May, and as a result the last opportunity for successful emigration to the ocean was on March 29, 1994 (**Figure 5.5.1.6-G**). Moreover, flows were so low in spring 1994 that rescues of smolts from the lower river were required throughout April, May and early June. In WY 2002, runoff totaled 32,500 AF and the emigration period extended until May 25 with the last opening of the rivermouth on May 26, 2002 (**Figure 5.5.1.6-H**). Even with higher flows experienced in below normal years, opportunities for successful emigration are limited due to the reduced frequency and duration of time that the rivermouth is open. For example, in 2002 the lagoon was closed a number of times during May, as shown in **Figure 5.5.1.6-H**.[16] The flow changes and reduced opportunities for successful emigration habitat for pre-smolts and smolts tend to reduce the overall survival of emigrating smolts and ultimately reduce the population of returning

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[15] In the Carmel River runoff classifications are based on selected exceedence frequency values computed from the long-term reconstructed unimpaired flow record at the San Clemente Dam site (1902-2003). "Extremely Wet" refers to flows exceeded 12.5% of the time (>=129,600 AF); "Wet" refers to flows exceeded between 12.5% and 25% of the time (101,800 to 129,500 AF); "Above Normal" refers to flows exceeded between 25% and 37.5% of the time (71,500 to 101,700 AF); "Normal" refers to flows exceeded between 37.5% and 62.5% of the time (41,700 to 71,400 AF); "Below Normal" refers to flows exceeded between 62.5% and 75% of the time (29,500 to 41,600 AF); "Dry" refers to flows exceeded between 75% and 87.5% of the time (14,700 to 29,400 AF); and "Critically Dry" refers to flows exceeded less than 87.5% of the time (<14,700 AF). Source: D. Fuerst, 2003. MPWMD files.

[16] In general surface inflow in the range greater than 20 cfs keeps the rivermouth open frequently, depending on tide and wave action. The rivermouth closes finally as inflow declines below 10 cfs. A detailed assessment of the relationship between inflow and rivermouth openings is provided in James, G. 1994. Surface hydrology of the Carmel River Lagoon, Water Years 1991 through 1994. Technical Memorandum 94-05. MPWMD.

adults. Although these factors have been partially mitigated by changes to Cal Am operations, the spring diversions remain as a primary factor limiting the population of steelhead in the Carmel River.[17]

Juvenile Steelhead During Late Spring and Summer – Currently, the aquatic habitats above Robinson Canyon are maintained in most years by releases of stored water from Los Padres Reservoir, but aquatic habitat in the reach below Robinson Canyon Road is reduced to zero in nearly all years by the diversion of surface and subsurface flow during late spring and summer. By mid- to late- summer, streamflow usually ceases at the USGS Near Carmel gage. Aquatic habitats in the lower river are reduced to critical levels at a flow of about one cfs; pools become separated by long, shallow glides and riffles. Below one cfs, the continuity of the river is broken, and by the end of summer the riverbed is dry. This situation impacts juvenile steelhead and other aquatic biota by restricting their movement, by isolating them in discontinuous pools, by subjecting them to increased predation, and finally by suffocation as the pools dry up. Since 1990, this impact has been mitigated by annual rescues of juvenile steelhead in the reach from Highway One to a location upstream where riverflow can sustain steelhead.[18]

4. Extent and diversity of streamside vegetation, the number of trees and canopy of the riparian forest, and reduction of large wood downstream of Robles del Rio – The number of trees, species composition, and the extent of the riparian forest canopy are three important factors which influence steelhead populations. This importance relates to three ecological aspects of juvenile steelhead life in the river, including:

Habitats – Scour and eddies around limbs and roots of living riparian trees and around woody debris from dead riparian trees creates critical rearing habitat for juvenile steelhead. The absence of such features often results in little or no habitat, even when streamflow is adequate.

Temperature Control – The overhanging canopy of the riparian forest shades the stream from direct sunlight, thereby reducing the heat gained from solar radiation and ameliorating water temperatures that approach, and occasionally, exceed lethal levels.

Sources of Food – Riparian trees are habitat for a diverse assemblage of terrestrial insects and for many aquatic insects that use overhanging trees during their adult breeding phase and

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[17] Impacts from Cal Am spring diversions have been partially mitigated by SWRCB WRO 95-10 (Conditions 3 & 5) and SWRCB Order WR 98-04 (Conditions 1 & 2). These conditions require: Cal Am to pump no more than 11,285 AF from the Carmel River Basin each Water Year; Cal Am to maximize production from the Seaside Aquifer for the purpose of serving existing connections, honoring existing commitments and to reduce diversions from the Carmel River to the greatest practicable extent during periods of low flow; Cal Am, to the maximum extent feasible without inducing sea water intrusion or unreasonably affecting the operation of other wells, to satisfy the water demands of its customers by extracting water from its most downstream wells.

[18] Between 1989 and 2004 a total of about 215,000 steelhead were rescued from the drying reaches by the Monterey Peninsula Water Management District and another 5,000 to 16,000 per year were rescued by the Carmel River Steelhead Association. These fish were released into permanent habitats upstream of Robinson Canyon Road Bridge or reared over the summer months at MPWMD's Sleepy Hollow Steelhead Rearing Facility. The rescue program is required by the SWRCB as a condition for temporarily allowing Cal Am's diversions to continue at 11, 285 AF per year.

for incubating eggs. These insects are an important source of food for juvenile steelhead in the Carmel River.[19] The extent of riparian vegetation and the proximity of the trees to the edge of the stream are important because the insects usually must fall into the water before they can be eaten. For example, experimental manipulation of insect drift has shown nearly seven times as many organisms, and three times the biomass of organisms, in the Carmel River adjacent to canopied areas versus open areas.[20]

Since the late 1950's, the riparian forest along the lower Carmel River has experienced several episodic changes, including a general historic decline in the number of trees and extent of the riparian forest along the banks of the Carmel River. Li (1986) documented the decline between 1956 and 1982, and McNeish (1989) summarized the historical changes prior to 1956 and following 1982.[21] [22]

Prior to the 1959-61 drought, an average of 78 percent of the riverbanks between the Lagoon and the Robles del Rio Bridge were covered by riparian vegetation. By 1980 the average had been reduced to about 44 percent, with several reaches having only 15 to 20 percent coverage (**Figure 5.5.1.6-I**). These historical changes reduced the tree canopy along the Carmel River, reduced the food available to juvenile steelhead, increased water temperatures, and reduced the quality and quantity of juvenile and adult steelhead habitat. More recently, an inventory of the riparian vegetation by Christensen (2003) shows that the wooded riparian area has increased by 139 acres, or 46%, from about 300 to 438 acres during the period from 1986 to 2001.[23] Much of the increase has occurred in the reach between Via Mallorca Road and Robles del Rio, where massive vegetation die-off and bank erosion followed the 1976-77 drought and 1978-1983 floods. This change has directly benefited juvenile steelhead by providing more overhead cover along the streambanks and increasing habitats for aquatic and terrestrial insects. For example, a detailed analysis of the change in riparian vegetation in a portion of the Valley Hills Restoration Project shows that the area of riparian vegetation increased from 1.4 to 4.1 acres within the 5.3-acre site (**Figure 5.5.1.6-J**).[24] Importantly for steelhead habitats, this recovery has increased the vegetated lineal streambank cover from 676 feet to 1,143 feet, or by 69 percent in the approximately 1,000-foot long study reach. This change indicates that tree coverage along the streambanks has increased to nearly the level that was extant during the 1950's and 1960's (**Figure 5.5.1.6-I**).

The overall increase in riparian area downstream of San Clemente Dam since the early 1980's can be attributed to several factors including relatively normal rainfall amounts, changes in Cal Am's pumping and diversion regimen that have allowed natural recruitment in the active channel between

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[19] Fields, W.C. 1986. The invertebrate Fauna of the Carmel River System and Food Habits of Fish in the Carmel River. Appendix C to D. H. Dettman and D.W. Kelley. 1986. Assessment of the Carmel River Steelhead Resource, Vols. I and II. D.W. Kelley and Associates, Newcastle, CA.
[20] Op. cit.
[21] Li, S.K. 1983. Application of the Theurer-Voos Instream Water Temperature Model to the Carmel River. Appendix D to D. H. Dettman and D.W. Kelley. 1986. Assessment of the Carmel River Steelhead Resource, Vols. I and II. D.W. Kelley and Associates, Newcastle, CA.
[22] McNeish, C.M. 1989. An Inventory of the Riparian Vegetation Resource of the Carmel Valley. Report to Monterey Peninsula Water Management District.
[23] Christensen, T. 2003. Using GIS To Quantify Riparian Area Overlying The Carmel River Alluvial Aquifer. Technical Memorandum 2003-02. Monterey Peninsula Water Management District. 10 pp.
[24] Watters, P.J. 2004. The Valley Hills Restoration Project: Quantification of Riparian Vegetative Cover, A GIS project for the Monterey Peninsula Water Management District.

San Clemente Dam and the Narrows, and in the reach that is annually dewatered, to revegetation and irrigation projects by the District and others.

<u>5. Blockage and entrapment of beneficial sediment</u> – The existing dams on the main stem have blocked the transport of gravel, cobble and boulder substrates since 1921 at San Clemente Dam and since 1948 at Los Padres Dam. While entrapment of fine-grained sediment behind the dams has generally improved substrate conditions for spawning adults and rearing juveniles, the blockage of larger-sized particles has caused a decline in the quality of spawning habitats below both main stem dams.[25] In the reach between the Narrows and San Clemente Dam, the suitability of spawning habitats is generally poor with available gravels on the coarse end of the spectrum of sizes utilized by adult steelhead (**Figure 5.5.1.6-K)**.

While the physical suitability of rearing habitats below Los Padres Dam has not yet been reduced, the extent and quality of rearing habitats below San Clemente Dam has been affected by scour for a longer period and shows evidence of a decline in some areas where deep, slow moving water predominates. Although not completely unsuitable, this type of habitat is not preferred by juvenile steelhead, which thrive in channels predominated by riffles separated by short, deep pools.

To alleviate the long-term effects of gravel entrapment and increase spawning habitat, MPWMD received a grant in 1991 from the California Wildlife Conservation Board (CWCB) to restore spawning habitats in a 7.4-mile long reach between Los Padres Dam and the Sleepy Hollow area below San Clemente Dam. The contract with the CWCB called for placing gravel into selected spawning sites and maintaining the sites over a ten-year period. [26] Over the 10-year duration of the project, the District has injected a total of 2,444 cubic yards of gravel into the Carmel River and steelhead have used this material throughout the reaches below both dams. Injection of spawning sized material over the ten-year period has not been sufficient to reverse the long-term reduction in the amount and extent of cobble sized material that is favored by juvenile steelhead and preferred habitats for aquatic insects. This level of restoration would require significant increases in the annual amount injected and a wider range of sizes. If long-term trends are to be reversed below each dam, a program to pass large fractions of the naturally transported gravel and cobble bedload at each dam should be considered and implemented.

<u>6. Increased erosion of sand and fine-grained sediments</u> – A primary constraint to high quality steelhead habitats in most California coastal streams is the deposition of sand and finer sediments on the stream bottom. The sediment fills in spaces between gravel, cobbles and boulders that are critical habitat for juvenile steelhead and aquatic insects. The impact of sediment on steelhead habitat is quantified by an index of sedimentation known as "embeddedness", which was developed

[25] Dettman, D.H. and B.M. Hanna. 1991. Development of a Substrate Suitability Curve for Adult Spawning Habitat in the Carmel River, Downstream of San Clemente Dam. Tech. Memo. 91-04. MPWMD. 5 pp + Figures and Tables.

[26] The District acquired a Section 404 permit from the U. S. Army Corps of Engineers (No. 19958S09, dated May 26, 1993), which was valid for a five-year period until 1998 to allow the District to add gravel below each dam for maintenance of spawning habitats. In August 1998, the District applied for a renewal of its permit, which was granted in October 1998. The renewal authorized injection of spawning gravel until spring 2003. Currently, the District is preparing another permit application to dredge spawning sized gravel from the San Clemente Reservoir inundation zone and inject up to two acre feet of this material below San Clemente Dam.

for streams in the Rocky Mountains of Idaho.[27] Kelley and Associates applied and tested the embeddedness index in steelhead streams in several central California and found excellent correlations between the density of the steelhead population, embeddedness, and cobble abundance.[28] [29]

Currently, embeddedness influences rearing habitats predominantly in the reach downstream of the Robinson Canyon where limited amounts of cobble and boulder are often covered by extensive deposits of sand, especially following episodic floods that mobilize and transport fine-grained sediment from major tributaries basins, including the Tularcitos Basin. Curry and Kondolf concluded that most of the sand which impaired steelhead habitat in the lower Carmel River, prior to 1983, originated from riverbanks which had lost the protective cover of riparian vegetation and were washed away during high winter flows following the 1976-77 drought.[30] Since that time, most of the open, unprotected river banks upstream of the Narrows have healed or been repaired, but sand from isolated sections below the Narrows still washes into the reach below the Robinson Canyon where it forms extensive flats in shallow glides and riffles and fills pools. When this sand embeds more than one-half the vertical dimension of the cobble, the number of steelhead reared during late summer declines from about 0.10 to less than 0.02 fish per square meter, a five-fold reduction. Because of this, most juveniles in embedded sections of the river are distributed along the banks where they can hide under overhanging vegetation, emergent cover, or woody debris.

Upstream of the Narrows, where cobble and boulders are more abundant, embeddedness is usually lower and most often influences habitat quality only in long, slow moving runs and glides. This pattern of lower embeddedness in the reach upstream of the Narrows has been influenced by San Clemente Reservoir, which has trapped and prevented transport of most fine-grained sediment into the reach below San Clemente Dam. In habitats between San Clemente Reservoir and Los Padres Dam the embeddedness levels are usually within the ideal range for rearing high population densities of juvenile steelhead, except in the one or two years following episodic floods that cause erosion and sediment transport from the Cachagua Creek Basin (**Figure 5.5.1.6-L**).

7. Mobilization of sand and silt within the inundation zone at San Clemente Dam, transport and deposition in the main stem downstream of San Clemente Dam – Currently, San Clemente Reservoir is nearly filled with sediment (**Figure 5.5.1.6-M**). In the near future, the late fall, winter, and spring runoff between the dams will increase the transport and passage of fine-grained sediments and suspended sediments through the reservoir and over the dam. In addition, the

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[27] Review of the development and application of the embeddedness index is provided in Bjourn, T.C. et al., 1977. Transport Of Granitic Sediment In Streams And Its Effects On Insects And Fish. Completion Report, Project B-036-IDA, Bulletin 17, Idaho Cooperative Fishery Research Unit, University of Idaho, Moscow, ID. The index is a measure of the relative depth to which coarse-grained material (gravel, cobble, and boulder) is buried in sand and finer-grained material. For example, an index of 0.5 means that one-half of the diameter of coarse-grained material is buried by finer-grained material.

[28] Kelley, D. W. and D. H. Dettman. 1980. Relationships between rearing habitat, substrate conditions, and juvenile steelhead populations in Lagunitas Creek, Marin County, 1979. Report submitted to Marin Municipal Water District, Corte Madera, CA. Steelhead population density was inversely related to embeddedness levels with about one-fifth the number of fish reared per unit area in habitats where embeddedness increased from 0.2 to 0.5 units.

[29] Kelley, D. W. and D. H. Dettman. 1981. The Zayante Dam Project, measures to make it compatible with fish and wildlife resources. Report submitted to the City of Santa Cruz Water Department, Santa Cruz, CA.

[30] Curry, R. and G.M. Kondolf. 1983. Sediment Transport and Channel Stability, Carmel River, CA. (draft)

California Department of Water Resources Division of Safety of Dams has ordered Cal Am to bring San Clemente Dam up to current standards for seismic safety of dams. All of the alternatives currently being considered to meet this order have the potential to exacerbate the problem of passage fine sediments.

The linkage between benthic macroinvertebrate populations that exist in channel substrates and the steelhead population in a stream is well established in the literature. Juvenile steelhead are known to opportunistically feed on drifting aquatic insects and their larvae. In systems similar to the Carmel River, where water temperatures are a challenge to steelhead during summer months, more food (i.e., drift and benthos) in the system increases the energy available to the juvenile population as a whole. Scant food supplies, which are associated with highly embedded streams, combined with high temperatures, would be highly detrimental, leading to low growth and survival and lower overall production. This type of impact would reduce the adult returns in the Carmel River to even lower levels than existing conditions, similar to those found in the main stem and tributaries of the Salinas and Pajaro Rivers.

The level of suspended and fine-grained sediment will soon increase in the river below San Clemente Dam, increasing the likelihood that the streambed will become sandier and more embedded. Depending on the alternative selected to achieve a safe condition at San Clemente Dam and on the mitigation measures implemented with the project, the increased passage and deposition of fine-grained sediment may reduce the suitability of rearing habitats and production of the juvenile steelhead population. A thorough analysis of these alternatives in relation to sediment mobilization, sediment transport and potential streambed deposition is needed to make an informed decision on the best alternative for the seismic retrofit. This task is beyond the scope of the current biological assessment.

Regardless of the alternative selected for San Clemente Dam, it may be important to manage the sediment production from selected tributaries, canyons, and roadsides in the basin downstream of Los Padres Dam as a way to minimize the impacts of increased transport of fine material through San Clemente Reservoir. MPWMD sampled grain sizes and cobble embeddedness at key sites in the main stem in 1990 and other discrete measurements were made in 1984 and 1989.[31] This historical monitoring shows that embeddedness is generally low and that in riffles the predominance of cobble and boulder particles is similar in the reaches below both dams (**Figure 5.5.1.6-N**). In the pool and glide habitats between the dams, the predominance of cobble and boulder has not equaled the levels immediately below San Clemente Dam, presumably due to the greater period of time that San Clemente Reservoir has trapped sediment. In 2000, monitoring of substrate sizes and embeddedness was added as a regular component of the benthic macroinvertebrate and juvenile population surveys. In the future, this data can be used as a baseline for historical conditions, comparisons to other streams, and the development of management goals.

<u>8. Historical interruption of streamflow at San Clemente Dam</u> – Prior to 1997, Cal Am annually raised the spillway gates and installed stoplogs at San Clemente Dam during the spring to increase the usable storage in the reservoir. The period between initial closure of the gates and

[31] D. H. Dettman. 1999. Inventory of Substrate Data for the Carmel River, Monterey County, Ca. Technical Memorandum 99-01. Monterey Peninsula Water Management District. 5pp + Tables and Figures.

subsequent spill lasted from several days to several weeks and as the reservoir filled, the streamflow declined in the river downstream of the dam, thereby blocking migration at the dam and reducing the frequency of openings of the rivermouth. Historically, this flow decline reduced habitats, increased water temperatures, and probably reduced the number of smolts that successfully emigrated to the ocean. Since 1997, this practice has been modified to leave the flashboards out of the spillway gates. This has allowed free passage either over the spillway or down the fish ladder throughout the spring and reduced delays in emigration. Overall, this probably resulted in significant improvements to smolt survival, but the effect has not been well studied with experimental data or observations.

9. Deposition of sand in the Lagoon and lack of surface and subsurface inflow – The combination of no surface freshwater inflow, low subsurface inflow and extensive sand deposits in the Lagoon results in undesirably high water temperatures, low dissolved oxygen (DO) levels, high salinities, and shallow water depths. The shallow water, low DO, and high temperature interact to encourage high levels of bird predation on steelhead and reduce habitats in the lagoon for adults during the winter, for smolts during the spring, and for juveniles during the summer and fall months. These interactions have been known since 1982, or earlier, and were most recently manifested in summer 2004 at the same time that the California Department of Parks and Recreation was constructing a restoration project to increase the area of aquatic, riparian and wetlands habitats in the lagoon.

A long-term solution to the ecological problems caused by the lack of freshwater inflow may involve major reductions in diversions from the Carmel River Basin. In the short term, some relief may be possible by directly injecting surplus reclaimed water into the wetlands surrounding the lagoon. This option is being developed and studied by the Carmel Area Wastewater District, as part of their current project to retrofit the Treatment Plant located next tot he Carmel River and Forest Lake facilities for storing water. Under emergency conditions, it may be possible to use wells in the vicinity of Highway One to temporarily inject water directly into the lagoon, as was done during summer 2004.

Ultimately, the long-term solution to the lack of dry-season surface and subsurface inflows to the Lagoon needs to be addressed as part of a project(s) to reduce the export of groundwater out of the Carmel River Basin, particularly during summer months. The level of reduction needed to result in meaningful improvements is probably on the order of several thousand acre-feet per year. Efforts by Cal Am, MPWMD, and Monterey County to develop either a Desalination Project or large Aquifer Storage and Recovery project in the Seaside Basin to offset a major portion of Cal Am's summer diversions from the basin would improve conditions in the Carmel River Lagoon for steelhead and other aquatic resources.

10. Loss of surface storage in Los Padres Reservoir and impacts on extent of aquatic habitats and water temperature below the dam – Currently, the maintenance of surface streamflow during the dry season is managed through a cooperative Memorandum of Agreement (MOA) signed by Cal Am, the CDFG, and MPWMD, and is affected by Cal Am's Conservation Agreement with NOAA Fisheries. While the MOA specifies releases of natural inflow and a portion of water stored in Los Padres Reservoir, the success of this management approach is directly linked and dependent on the maintenance of existing storage volume in Los Padres Reservoir. Currently, no program exists to maintain the storage in the reservoir, so it is gradually filling with sediment at the average rate of about 20 acre-feet per year. Importantly, this average rate is rarely realized and filling tends to fluctuate widely in response to episodic floods, droughts and fire. For example, following the 1987-1991drought and 1995-98 floods, the reservoir lost about 600 acre-feet of storage as storage was reduced from 2,179 AF to 1,569 AF.

The impacts of this storage loss are manifested in two important ways for steelhead and all other aquatic life that depend on surface flow. First, as the storage gradually diminishes, the ability to release sufficient flows to balance evaporative losses and diversions is reduced. This impact has been well studied in several MPMWD EIRs on water supply alternatives and most recently was described as an impact of the No Project Alternative in the December 2003 Administrative Draft EIR on Water Supply Projects in Volume II, Appendix C.[32] Second, as the storage is depleted, the ability and flexibility to maintain suitable water temperatures for cool water species including steelhead, California red-legged frogs, and other native invertebrate species is reduced.

With existing storage of about 1,569 AF, streamflow and adequate temperature can be maintained downstream of the Narrows to Robinson Canyon or Schulte Road during most years. But, as the reservoir fills during the next 15-30 years, these attributes would be lost if flow at the Narrows declines below the combined levels of groundwater pumping associated with Cal Am's recognized rights (3,376 AF/yr) and other private water systems (about 3,000 AF/yr). Should this occur, the persistence and extent of habitats downstream of the Narrows will fade as there would be only brief periods of early summer flow for a little more than a mile, or so, of stream. In the reach upstream of the Narrows, streamflow is likely to be higher than natural (unimpaired) conditions for the next 15 years. But, after this period flows between San Clemente Dam and the Narrows will likely decline below natural levels. Eventually, the benefits of surface storage will be lost, as the value of aquatic habitats are reduced to essentially zero when the streamflow drops to lethal levels, especially in below normal, dry, and critically-dry years (**Figure 5.5.1.6-O**). Preventing the impact over the medium- to long-term will require a project to maintain, recover or perhaps slightly increase storage in the reservoir, depending on how long it takes to implement the project. Though not well studied, it may be possible to increase the storage to levels somewhat above the 1948 as-built level by excavating within the watermark of the original reservoir.

Recommended List of Projects to Restore/Maintain Freshwater Habitats and Steelhead Production – The purpose of this section is to recommend a range of specific projects designed to improve the environment for steelhead and other native aquatic species that depend on or interact with steelhead in the Carmel River. The list and a brief description of projects follow:

1) Streamflow Restoration and Supply Augmentation – As highlighted in the last section and referenced throughout this assessment, steelhead and other native aquatic species in the Carmel River depend on adequate levels of streamflow. For the Carmel River, this is important because the existing annual diversions exceed inflow in several months of most years, resulting in drying of the lower river. Addressing this impact at the annual level of 10,700 acre-feet as required by the SWRCB will require development of a relatively large alternative source, which is likely to take at least several more years. In the meantime, significant restoration of aquatic

[32] Jones and Stokes. 2003. Draft Environmental Impact Report, Volumes I &II. Prepared for the Monterey Peninsula Water Management District. 18 Chapters (Volume I) and 7 Appendices (Volume II).

habitats could be realized by one or more projects. For example, expansion of MPWMD's Pilot Aquifer Storage and Recovery Project in the Seaside Basin, which utilizes excess/surplus winter flows from the Carmel River Basin as a source of recharge in the Seaside Coastal Aquifer. This project, though relatively small at the present time, could be expanded to divert up to ~1,000 to 1,500 acre-feet per year. This quantity of stored water in the Seaside Basin, if made available at nominal rate of 2-3 cfs during the dry season, could obviate the need for Cal Am pumping upstream of Schulte Bridge in most years and extend aquatic habitats downstream by an additional one to three miles depending on the water year. Dredging at Los Padres Reservoir, particularly if instituted as a long-term maintenance/restoration project would augment surface storage in a system that depends on storage for creating perennial flow in the reach upstream of the Robinson Canyon.

2) Erosion Control and Sediment Management – Embryos, fry and juvenile steelhead depend on relatively clean substrate to complete their lifecycle phases in freshwater habitats and are sensitive to small changes in the quality of substrate, especially the degree of sedimentation on the streambed. For a myriad of reasons, projects that are designed to reduce soil erosion at the source, or lessen the risk that fined-grained sediment, once mobilized, deposits on the streambed, will have direct beneficial effects on steelhead and other sensitive aquatic species. Based on a review of the results outlined in the chapters on Hydrology and Geology, it is appropriate to focus on small to medium scale erosion control projects in several main tributaries and sub-basins including Tularcitos, San Clemente, and Cachagua Creeks. A primary challenge in the near term will be managing the sediment flux through San Clemente Reservoir as it fills with sediment and a seismic retrofit project proceeds. It is likely that the alternative which allows the most flexibility in controlling transport and release of fine-grained sediment at the retrofitted dam and deposition in the river below the dam will be the most successful in restoring and maintaining critical habitats for steelhead sensitive species. It is beyond the scope of this biological assessment to fully evaluate this situation and recommend the best retrofit project. However, it is reasonable to conclude that additional erosion control projects in tributaries throughout the watershed will assist future management activities at the San Clemente dam site.

3) Gravel/Substrate Management – Projects that are designed to improve passage and transport of coarse-grained sediment around or through both of the dams will directly improve the quality and quantity of spawning habitats for steelhead. While the MPWMD's spawning gravel restoration project has improved spawning habitats below both dams and fish have utilized much of the material added, continuing observations of spawning adults and data from the juvenile population surveys indicates that addition of larger quantities of gravel would benefit steelhead. This is especially the case below San Clemente Dam, where many "restored" gravel patches were perched above the lower water channel by floods in 1995 and 1998, and the material added since that time has moved only a short distance downstream.

4) Barrier Modification and Habitat Expansion – A thorough, detailed survey needs to be completed of all potential barriers to steelhead migration. Nonetheless, there are several known locations were modification of barriers would result in expansion of spawning and rearing habitats for steelhead, including Danish and Black Rock Creeks, where natural barriers limit the passage of adult steelhead. In addition, man-made partial barriers, many road culverts, and some stream crossings in many tributaries could be modified to improve passage and expand spawning

habitats. Specific locations are known on Tularcitos, Potrero, Garzas, San Clemente, and Cachagua Creeks, and Hitchcock Canyon.

5) Large Woody Debris Restoration and Management – Steelhead adults and juveniles rely on woody debris as critical habitat components in freshwater. Small-scale restoration projects to increase the smaller sized fraction of this material can result in direct improvements to steelhead habitats, although by nature, the smaller sized material tends to scour and wash away with high flows. While CDFG has tended to not fund small-scale projects, because the material is not permanent, this logic should be reevaluated in light of widely published literature documenting that the mobility of this material does not lessen its importance in maintaining ecological function for steelhead and other sensitive macroinvertebrates. By its nature, the small sized fraction of LWD is more abundant and although it moves through alluvial systems more rapidly, it is important in the energy budget and habitat forming processes. A major advantage is that it can be added to large-scale restoration projects at a very moderate cost because it does not need to be anchored. For these reasons, and the fact that historical efforts to remove living riparian vegetation may have affected the abundance, distribution and diversity of smaller sized fractions, it is important to implement a range of projects to increase the abundance of all sizes of LWD. Fortunately, this is relatively easy to do with small tool/hand cutting and placement and is ideally suited to groups of volunteers.

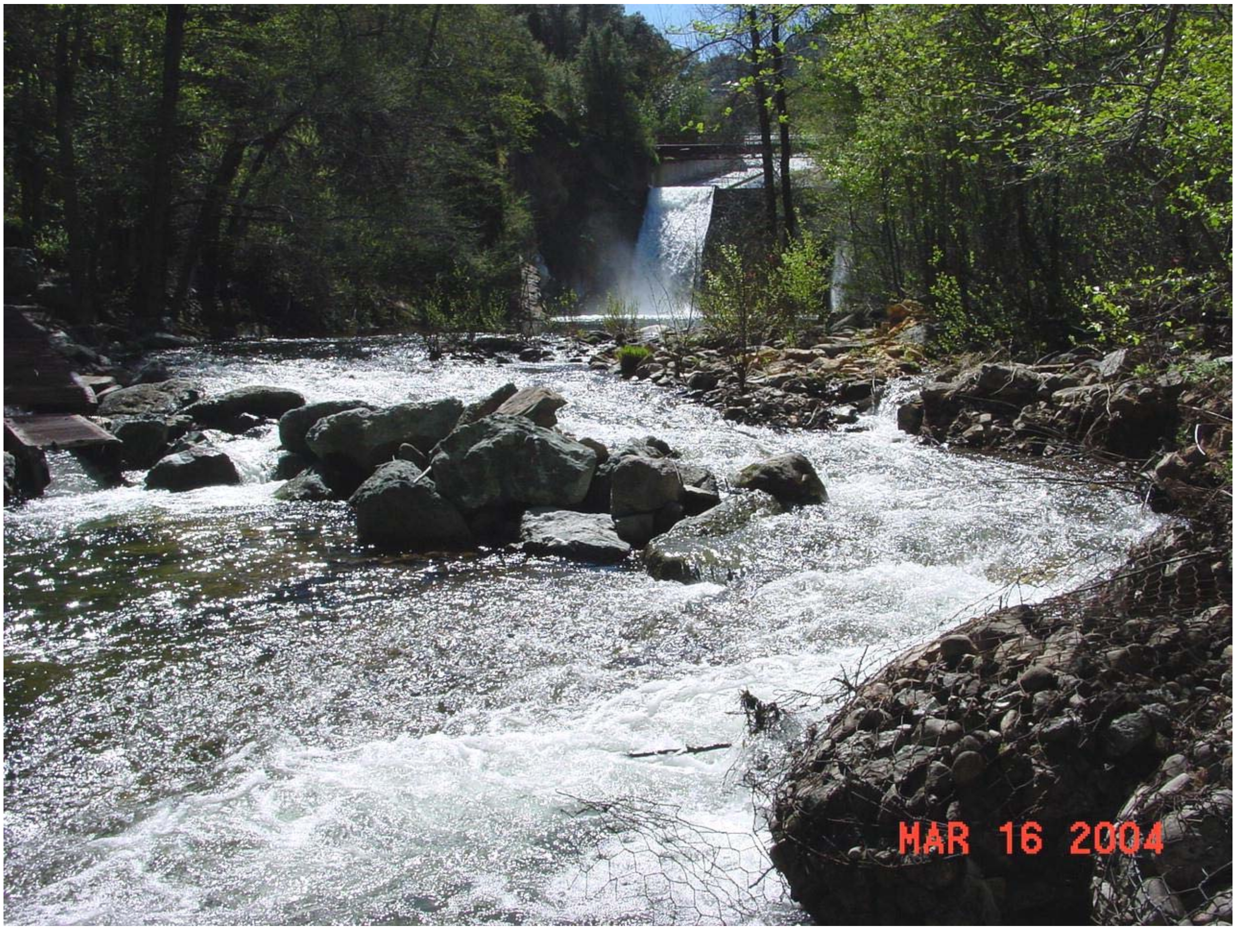
6) Lagoon Restoration and Water Levels – The California Department of Parks and Recreation recently completed Phase I of a project to expand the quantity of aquatic habitats at the Carmel River Lagoon. Depending on how the expanded lagoon interacts with surrounding groundwater and subsurface seeps, the quality of the new and original habitats may be improved. The CDPR should monitor water quality in the lagoon and adaptively manage the situation to maintain improved environmental conditions for steelhead and other sensitive species, notably the California red-legged frog. Other projects to increase surface inflow during critical periods should be investigated and implemented, if feasible. This includes the CAWD's concept of discharging tertiary treated water onto the surrounding wetland habitats and the CDPR's temporary, emergency discharge from their wells near the Highway One Bridge. Another project worthy of implementation would be a surface drain on the lagoon to allow a moderate level of control on the water surface elevation during late fall and early winter, when it becomes necessary to breach the river mouth for flood protection. Operation of a drain could effectively forestall the need to open the lagoon too early, when steelhead juveniles are not adapted to seawater and it could be used to somewhat regulate salinity levels by preferentially releasing highly, saline bottom water.

8) Water Temperature Management – The need to manage water temperature will become more important as Los Padres Reservoir fills with sediment. Currently, the water released during late summer and early fall is often too warm good growth of steelhead and may affect the abundance and distribution of benthic macroinvertebrates. Compounding the high temperature water is the tendency to release hydrogen sulfide laden water, especially just prior to the fall turnover in the reservoir. One project for effectively dealing with these problems is to increase reservoir storage, but this could be time consuming and take several decades to implement. An alternative project to manage water quality would be construction and operation of a "cooling tower" similar in concept and design to the tower used by the MPWMD to cool intake water at

Sleepy Hollow Steelhead Rearing Facility. This device would be very efficient in cooling water, especially in the hotter, drier climate at Los Padres Dam and would eliminate the problem with hydrogen sulfide and accompanying low dissolved oxygen.

9) Enhancement of Benthic Macroinvertebrate Production – Increasing the abundance and diversity of aquatic insects species will enhance benthic macroinvertebrate production and lead to higher growth rates and production in the juvenile steelhead population and other species that feed on the invertebrates. This can be accomplished by implementing three projects specifically designed to improve steelhead habitats, including restoration of gravel deposits, planting riparian vegetation along the stream edge and in the floodplain terraces, and direct placement of smaller sized fraction of LWD into the stream. The latter two projects are especially important in sandy reaches downstream of the Robinson Canyon where overhanging vegetation and LWD function as critical habitats for steelhead and the insects that form the base of the food chain. Enhancement of benthic production in these areas functions to provide higher food resources for steelhead in habitats where the water temperature is outside of the optimal range for growth and dampens the detrimental effects of warmer water.

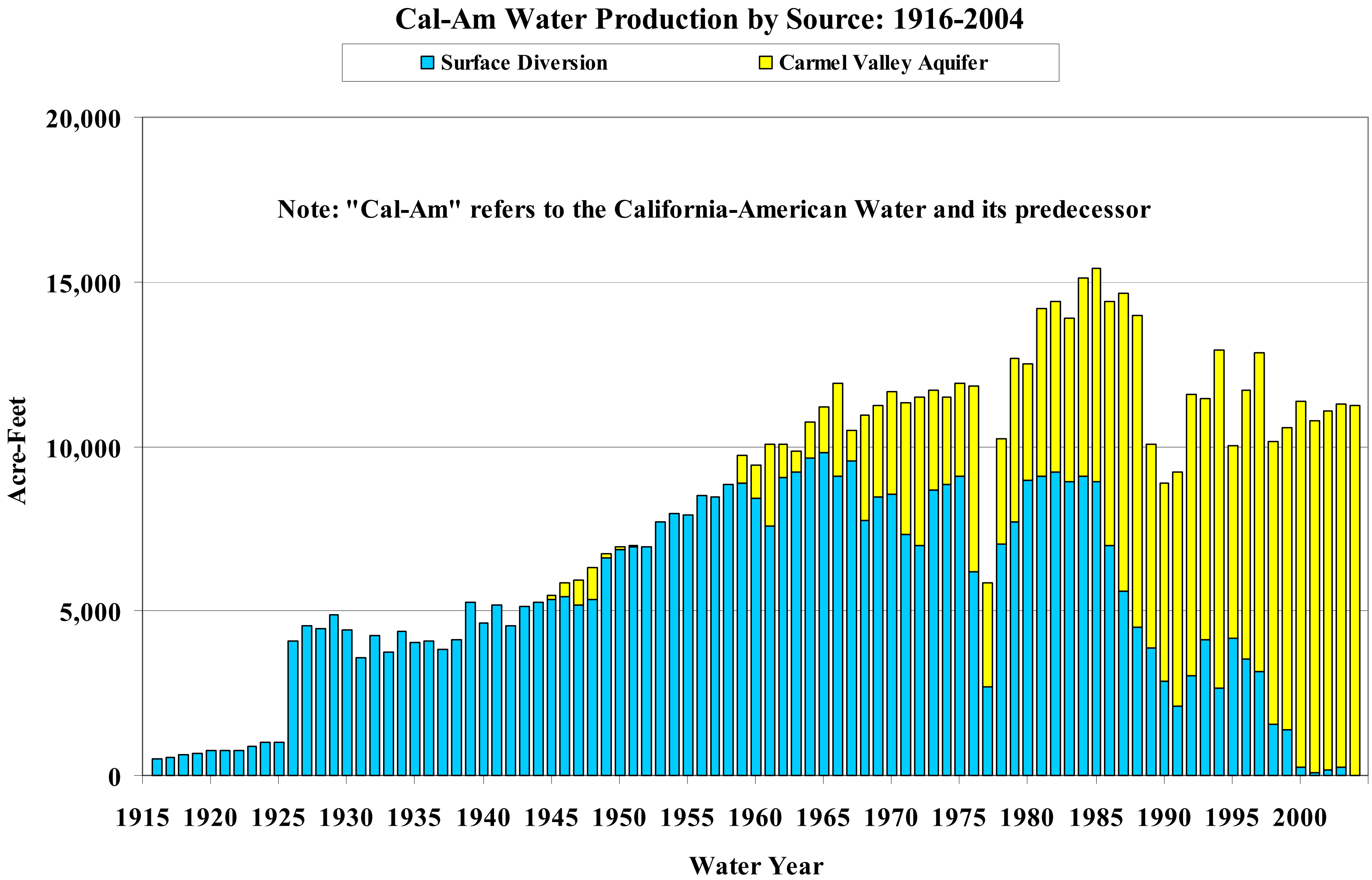
Figure 5.5.1.6-A



Source: Dave Highland, CDFG

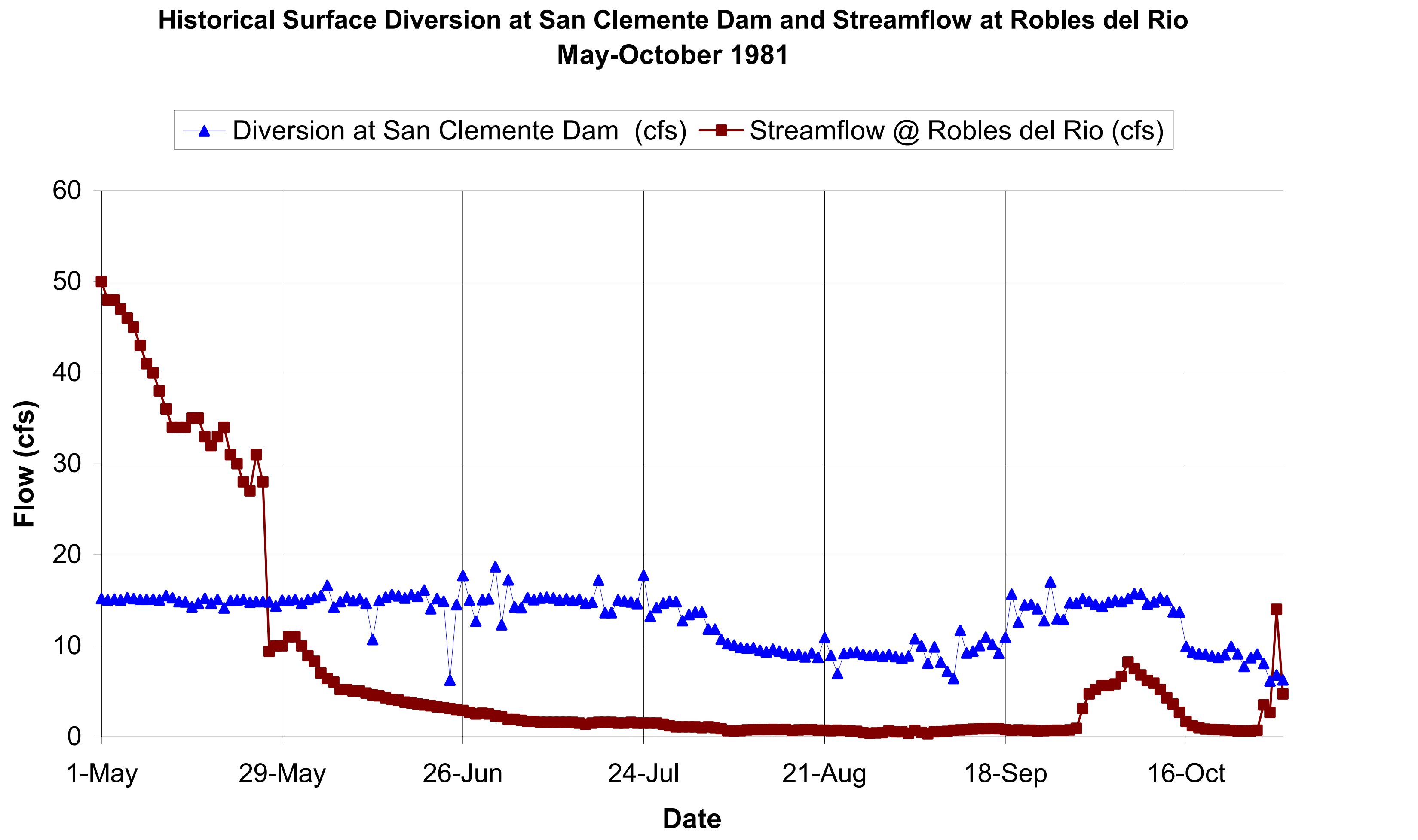
Photo of Rock Gabion Structure below Los Padres Dam, constructed in spring 2004 to guide steelhead around old fish ladder and into plunge below the dam. Streamflow at time of photo was 67 cfs. Note: old wire basket material in lower right-hand corner was removed on March 29, 2004.

Figure 5.5.1.6-B



Production values for the 1916-1978 period from Cal-Am Exhibit 90 at the 1992 State Water Resources Control Board hearings regarding Cal-Am's diversions from the Carmel River system. Production for the 1978-2004 period were compiled by the Monterey Peninsula Water Management District from monthly production reports submitted by the Cal-Am's Monterey Division.

Figure 5.5.1.6-C



Source: Daily Cal-Am report of net system delivery and USGS historical streamflow data for station No.11143200

Figure 5.5.1.6-D

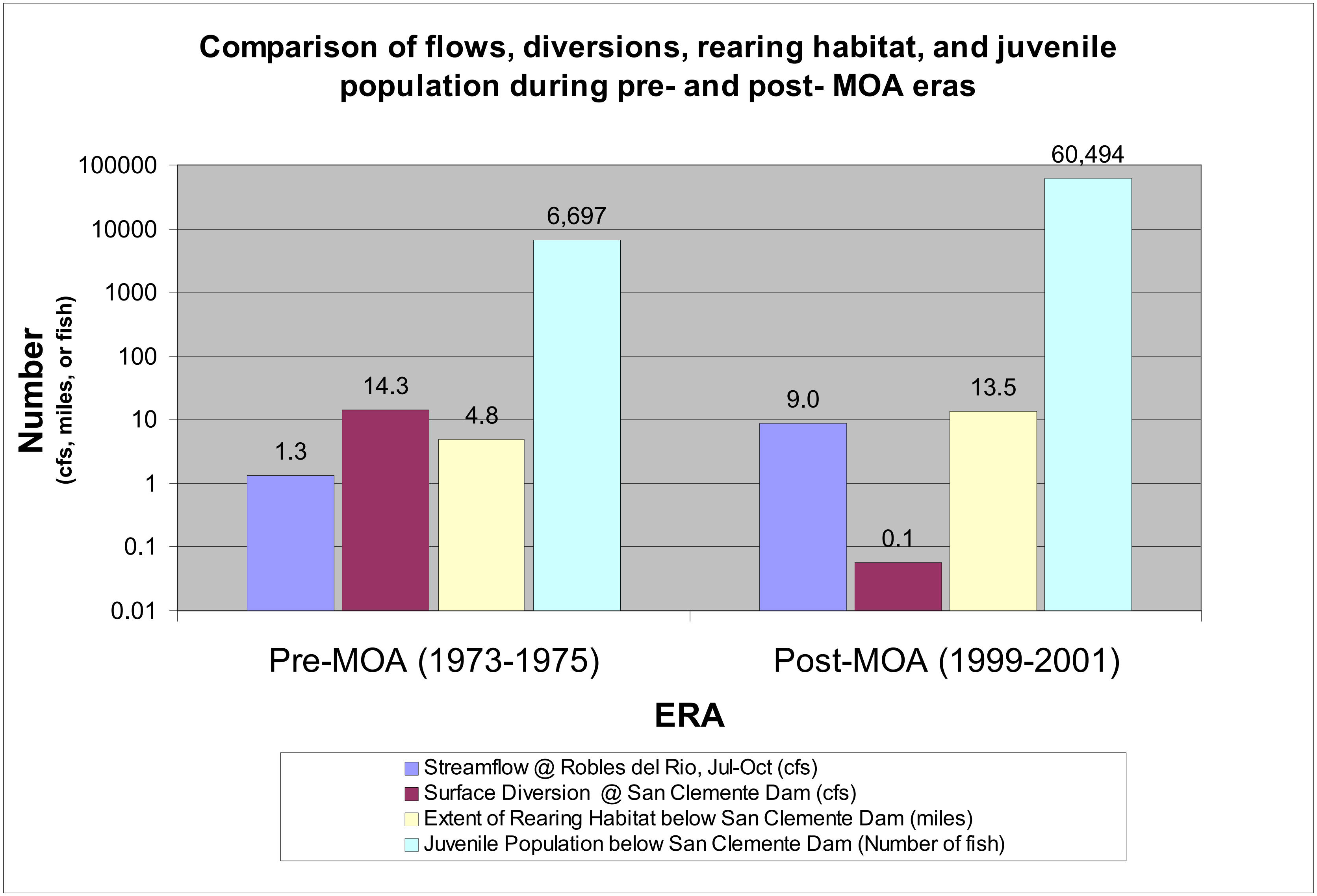
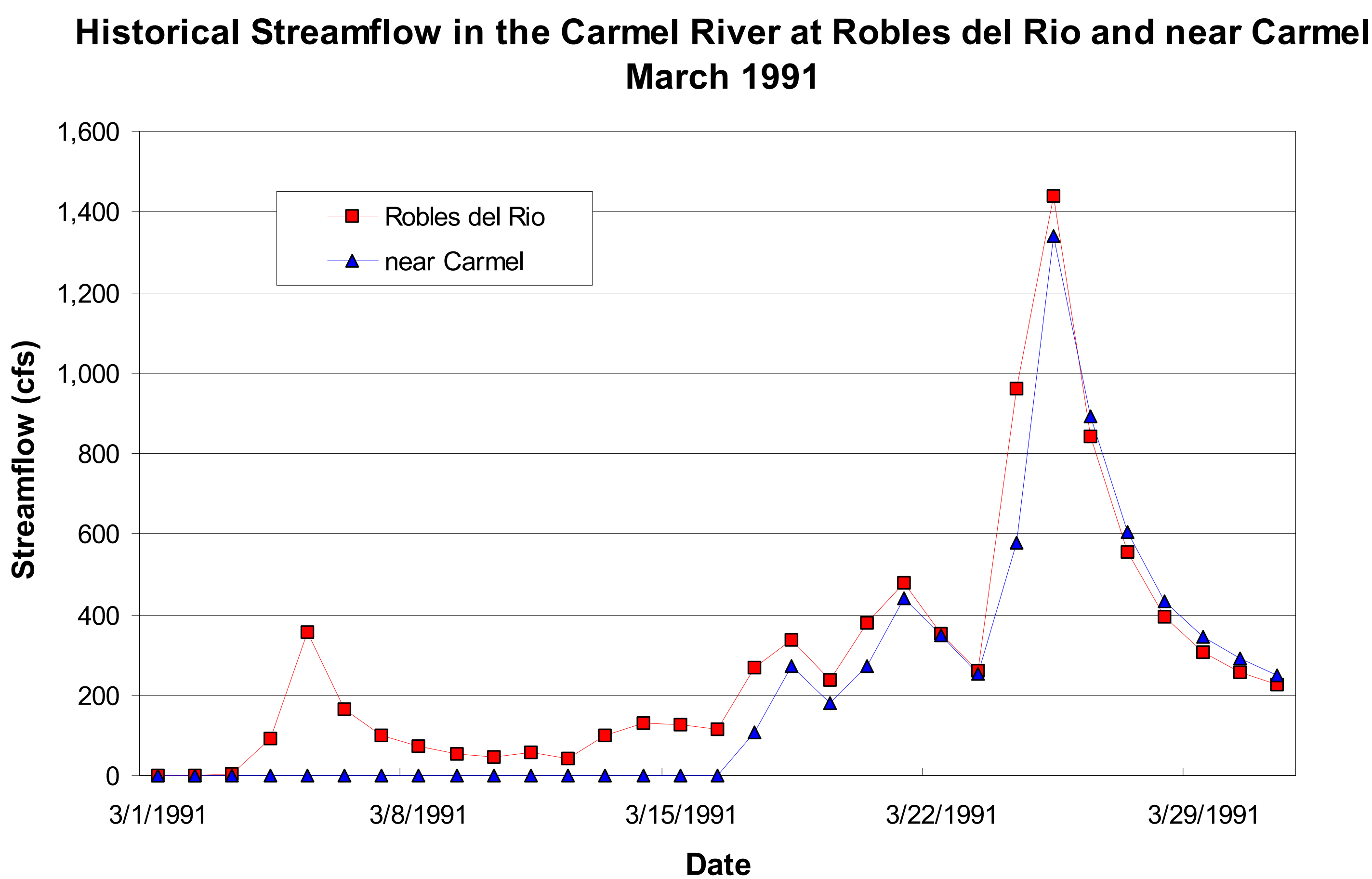


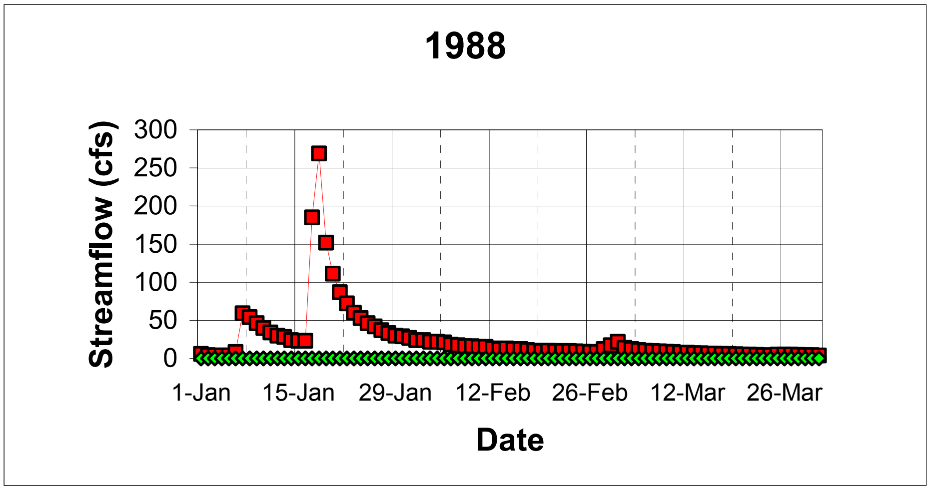
Figure 5.5.1.6-E

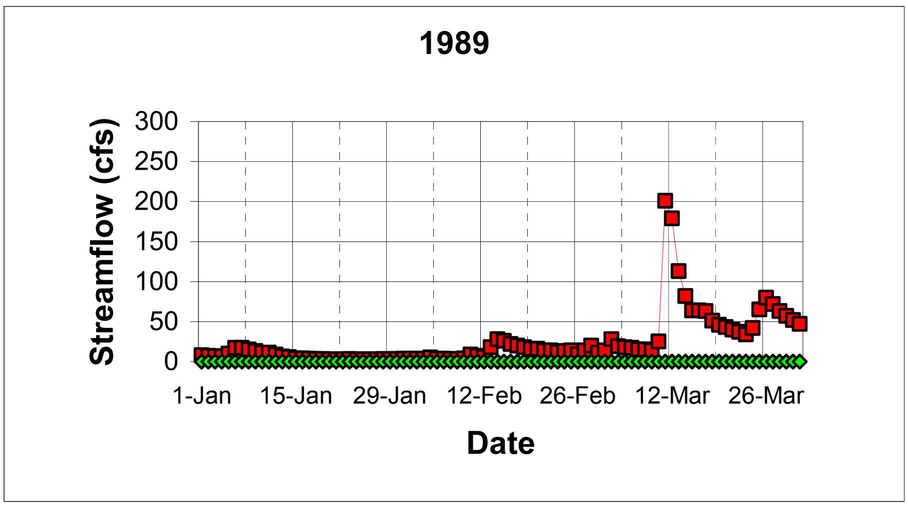


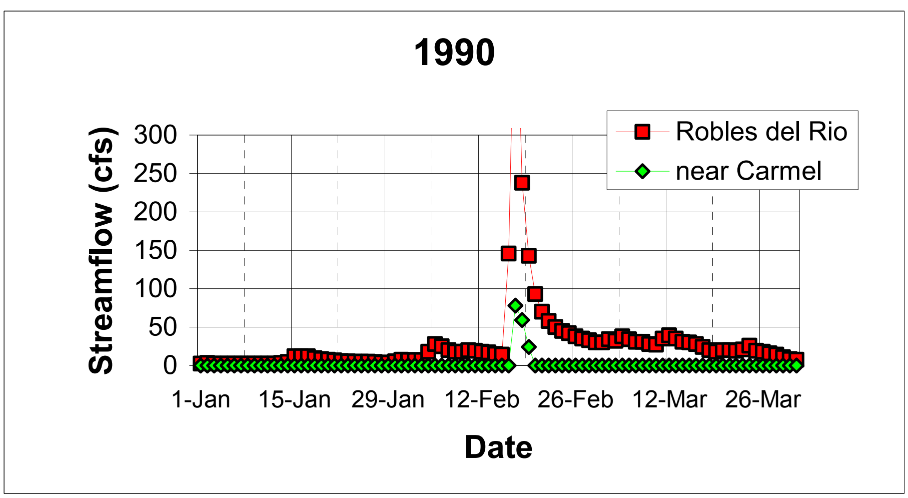
Source: Trujillo, L.F. 1992. Water Resources Data, California, Water Year 1991. Volume 2. Report No. CA-91-2. USGS, 315 pp.

Figure 5.5.1.6-F

Historical streamflow in the Carmel River at Robles del Rio and Near Carmel January-March 1988, 1989, and 1990[33]



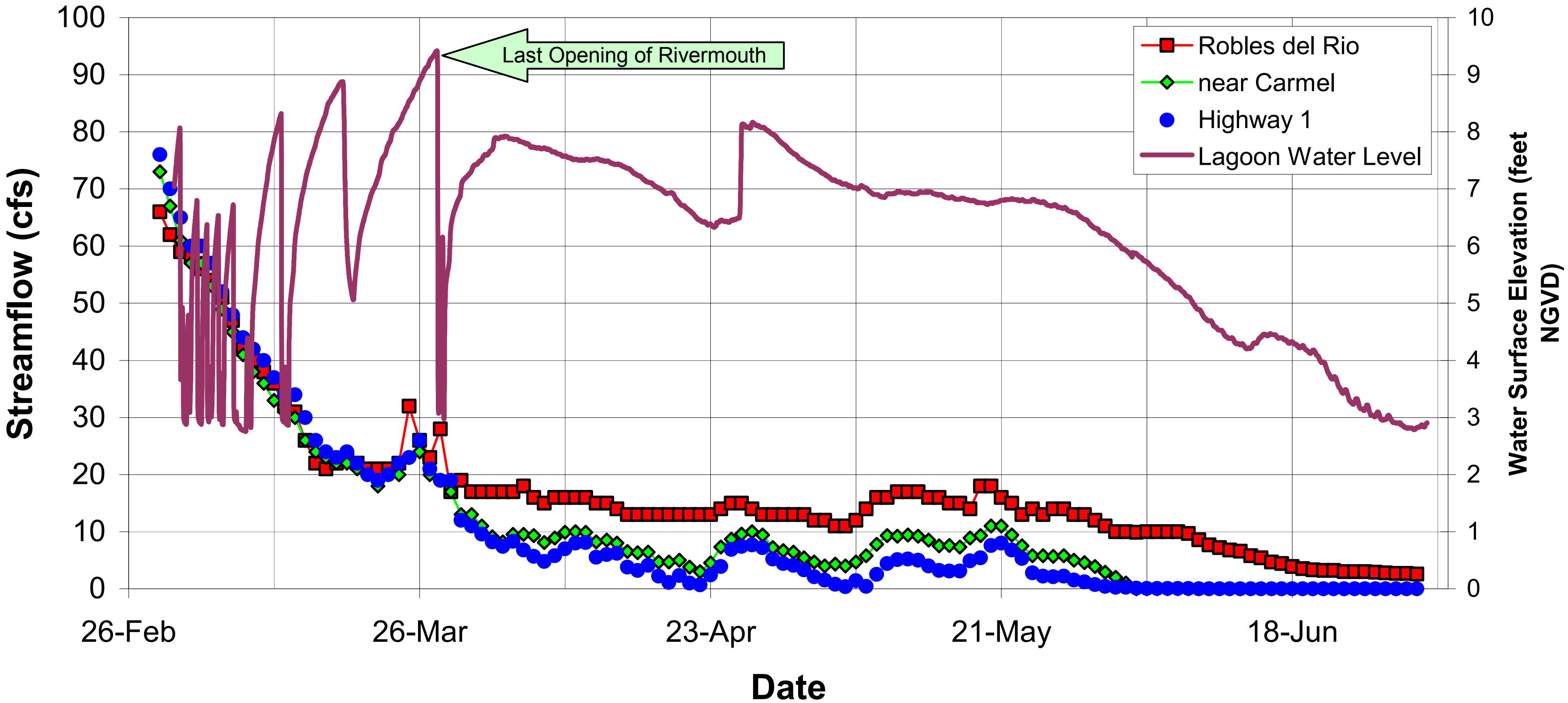




[33] Trujillo, L. F. 1992 Water Resources Data, California Water Years 1988, 1989, & 1990. Report Nos. CA-88-2; CA-89-2; and CA-90-2. U.S. Geological Survey.

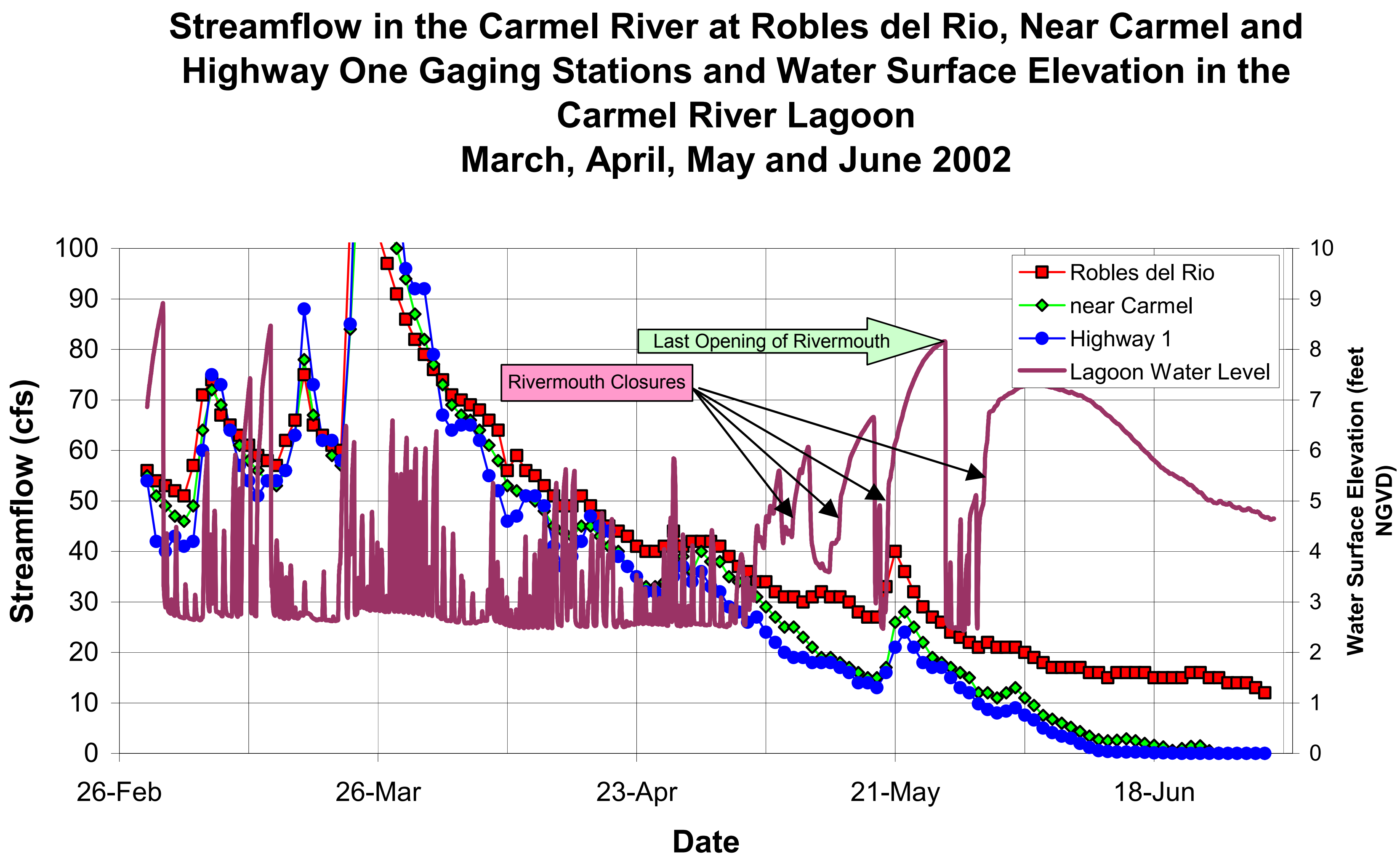
Figure 5.5.1.6-G

Streamflow in the Carmel River at Robles del Rio, Near Carmel and Highway One Gaging Stations and Water Surface Elevation in the Carmel River Lagoon
March, April, May and June 1994



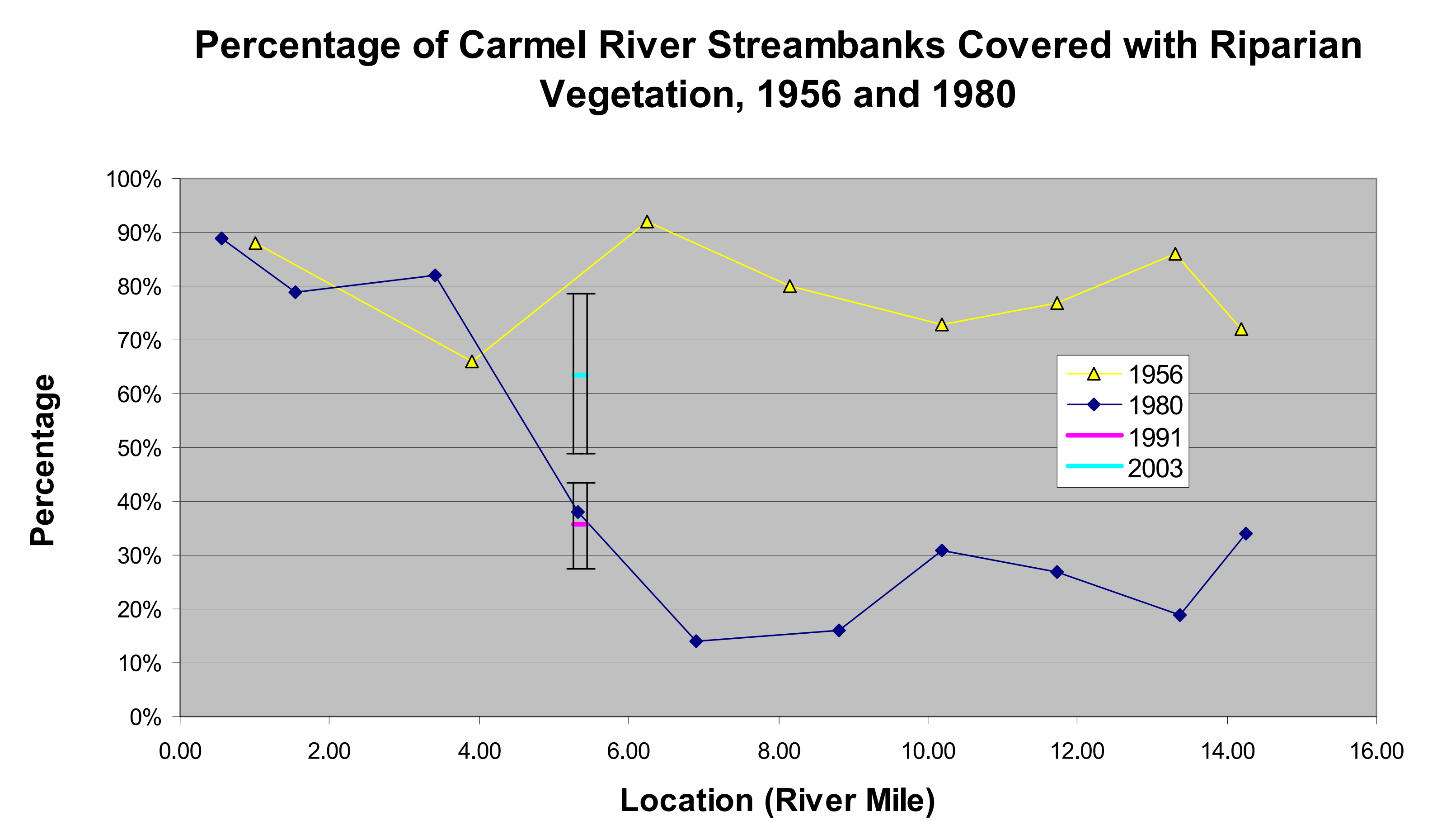
Source: U.S. Geological Survey and Monterey Peninsula Water Management

Figure 5.5.1.6-H



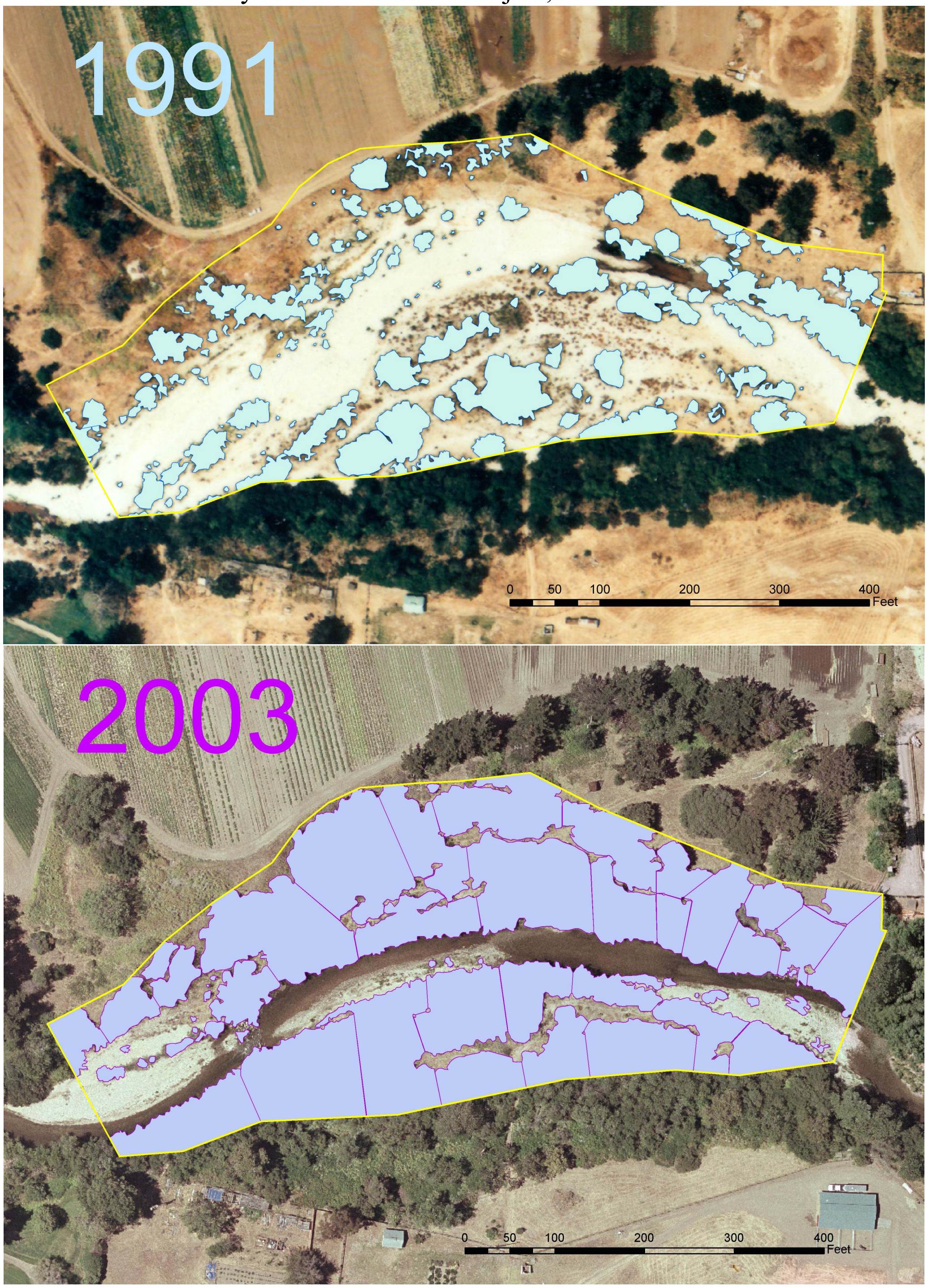
Source: U.S. Geological Survey and Monterey Peninsula Water Management District

Figure 5.5.1.6-I



Adapted from Figure D-5, Li (1983) and based on measurements of the lineal extent of vegetation from aerial photographs. Data for 1991 and 2003 based on measurements from delinated riparian vegetation on aerial photos of the Valley Hills Project by P. Watters. Range of values for 1991 and 2003 shows variation from right to left streambanks.

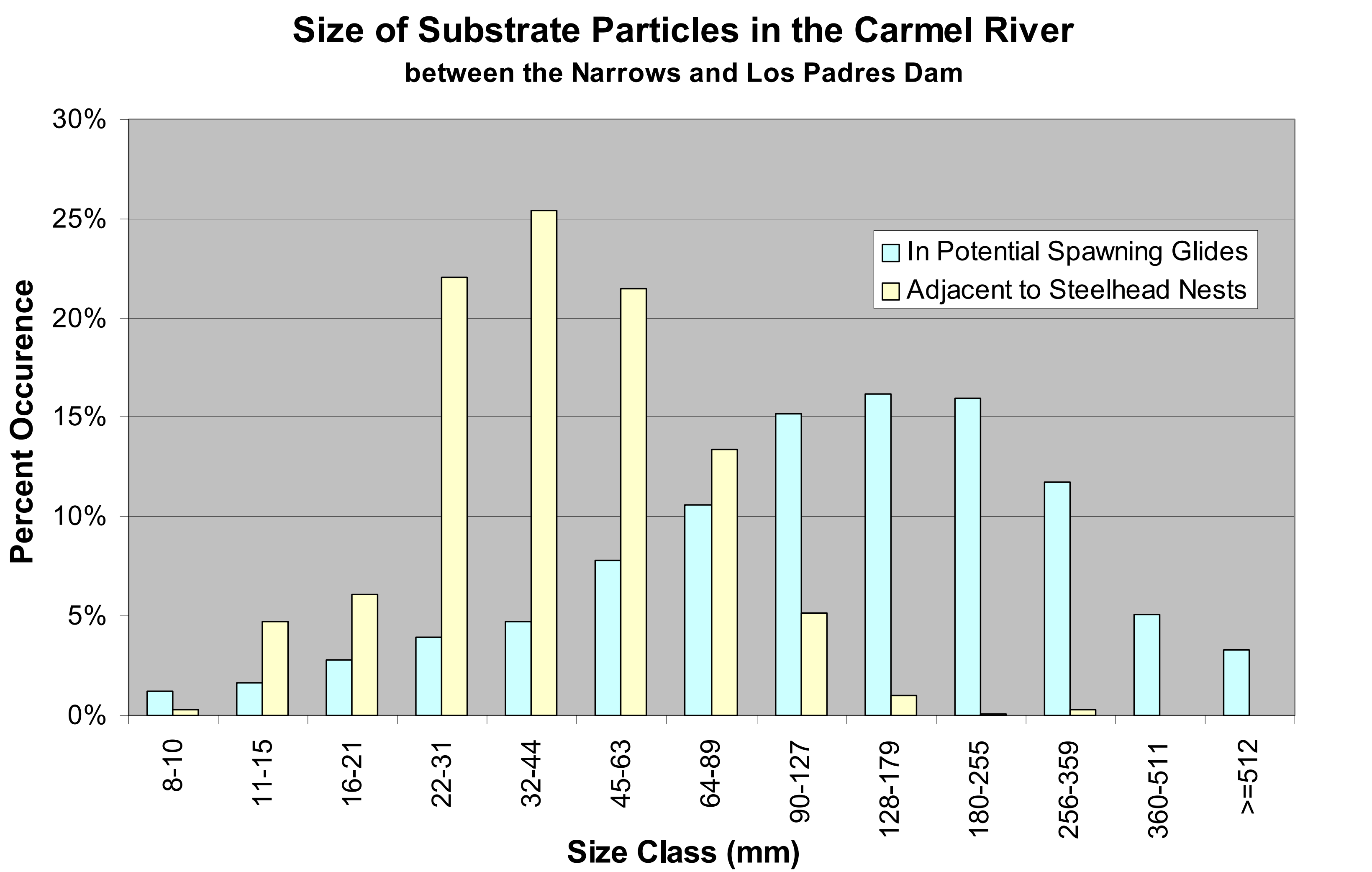
Figure 5.5.1.6-J
Valley Hills Restoration Project, 1991 and 2003[34]



The areal coverage of the riparian forest increased from 1.4 acres in 1991 to 4.1 acres in 2003 and the percentage of streambank covered with riparian vegetation along the low water channel increased from 36% to 63% as a result of this restoration project.

[34] Watters, P.J. 2004. The Valley Hills Restoration Project: Quantification of Riparian Vegetative Cover, A GIS project for the Monterey Peninsula Water Management District.

Figure 5.5.1.6-K



Source: Adapted from Dettman, D. H. 1990. Spawning Habitat Mitigation Plans for Alternative Water Supply Project in the Carmel River Basin. Technical Memorandum 90-01. MPWMD. Based on measurements of surface substrate particle size in 18 potential spawning glides between the Narrows and Los Padres Dam (3,200 particles total, 1989-1991) and adjacent to 15 steelhead nests between Robinson Canyon and San Clemente Dam (1,300 particles total, 1982).

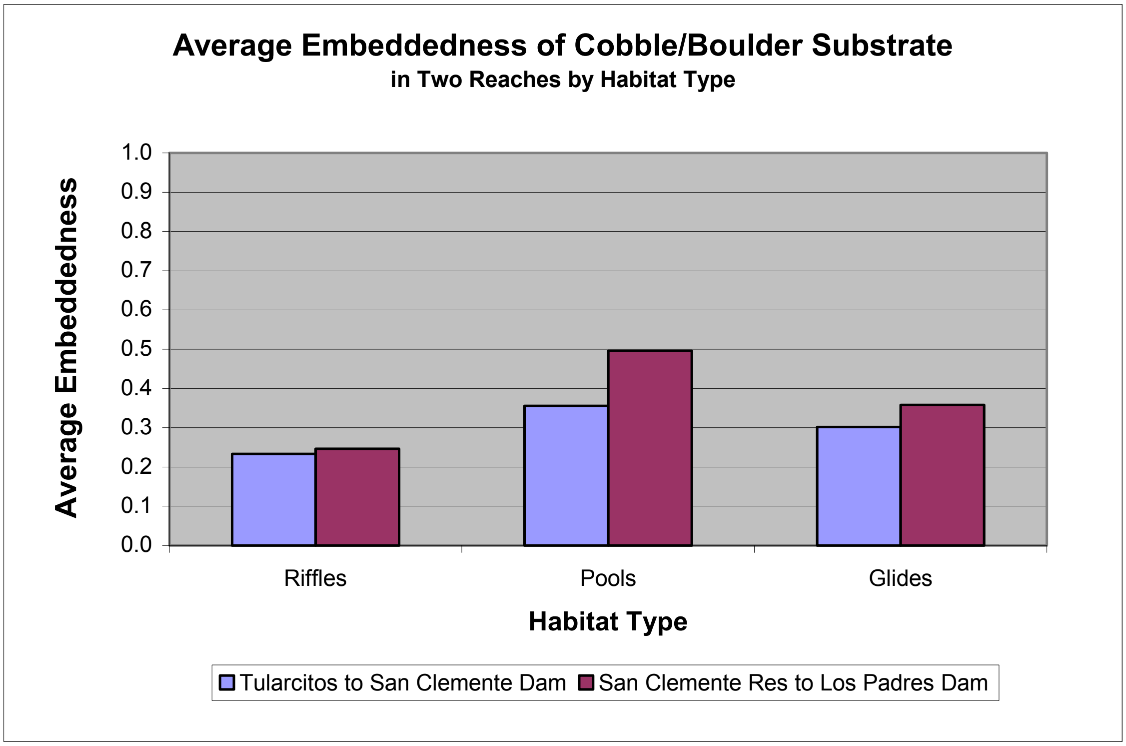
Figure 5.5.1.6-L. Photos of sediment deposition in riffle [upper right], run [upper left] and pool [lower right] habitats of the Carmel River, just upstream of the confluence with Pine Creek, July 1995.

Figure 5.5.1.6-M

San Clemente Dam Inundation Zone
July 13, 2004

Original Photos by David Norris, Cal Am Water
Mosaic by David H. Dettman, MPWMD

Figure 5.5.1.6-N



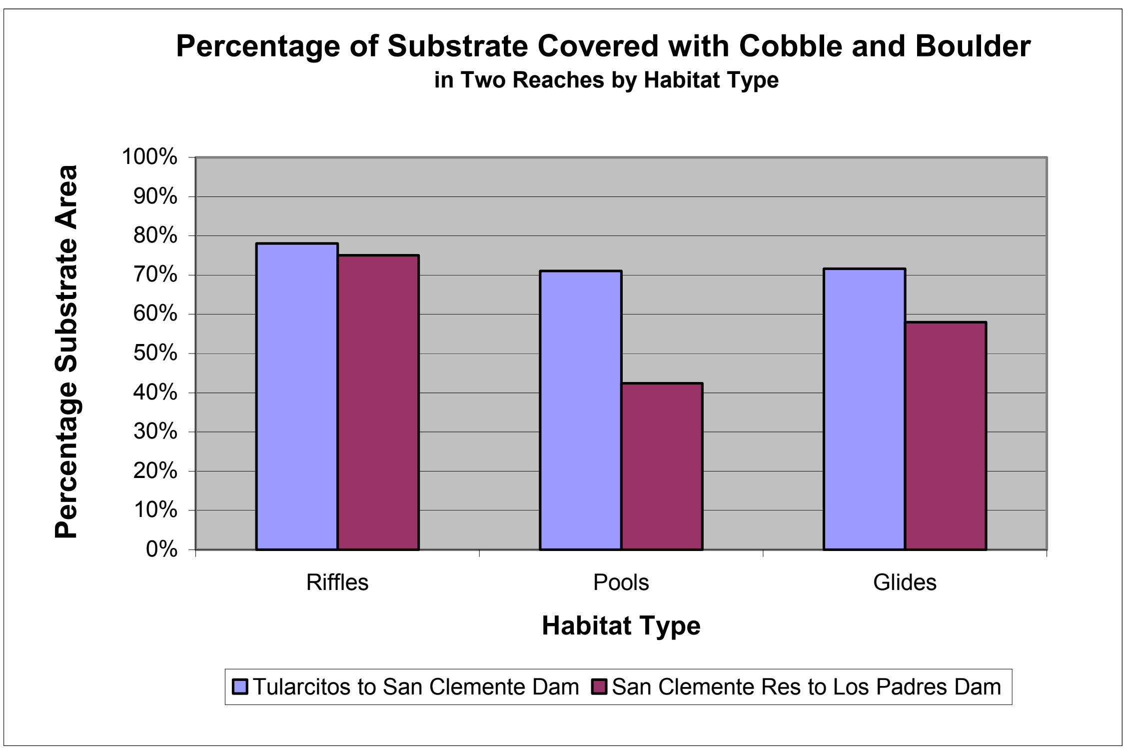
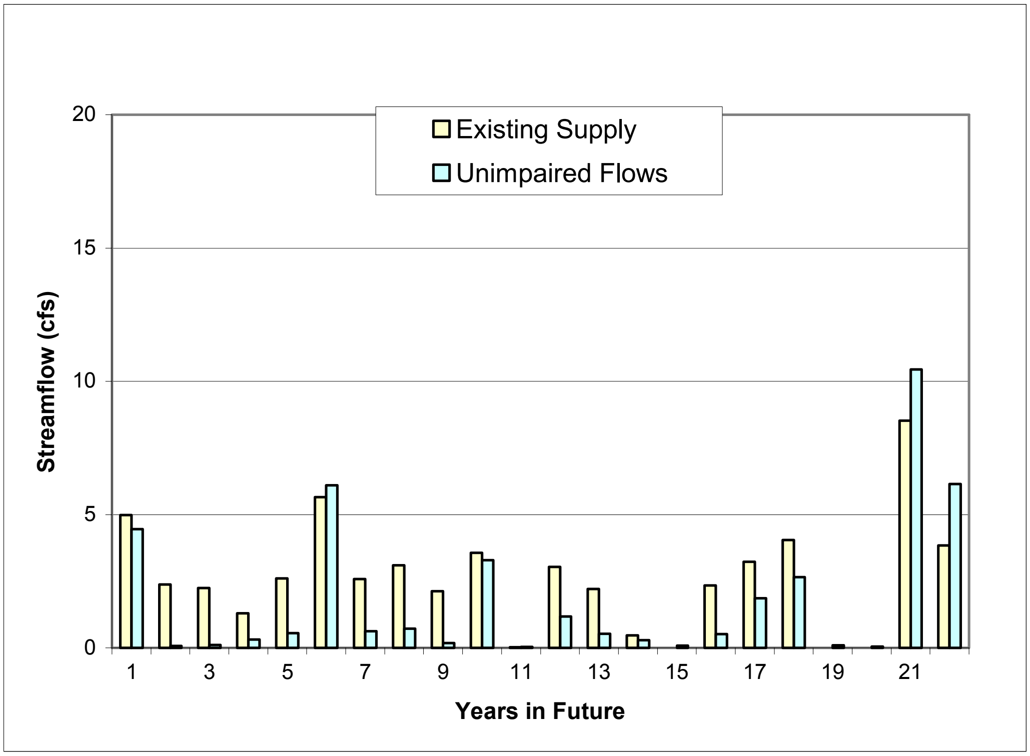
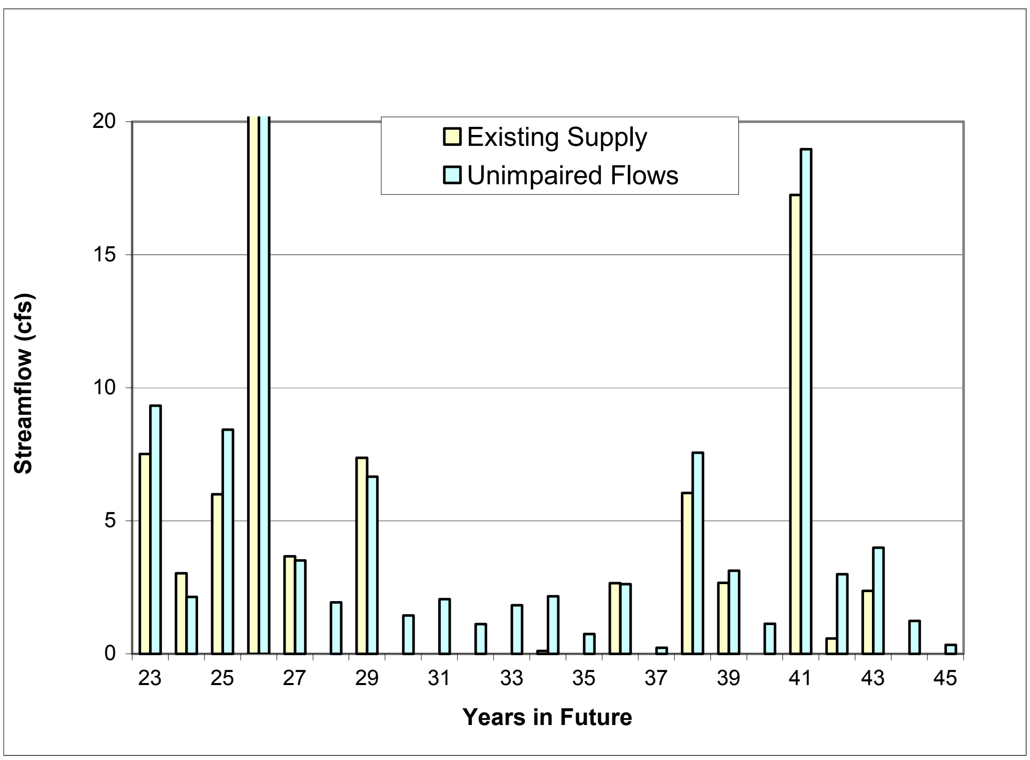


Figure 5.5.1.6-O





Seasonal Minimum 30-day Average Streamflow in the Carmel River at the Narrows with Natural Flows and the Existing Supply Development in the Carmel River Basin,
Years in Future: 1 to 22 (upper graph); 23 to 45 (lower graph).