3.5 AQUATIC RESOURCES

From an ecosystem and historic perspective, this chapter describes the aquatic resources of the proposed project study area to provide a baseline by which potential impacts of the project can be evaluated. This description of existing aquatic resources elaborates on information contained in Chapter V of the *Environmental Report*, *Appendix 1* of the 1995 WQCP (SWRCB 1995b), and Chapter III of the 1997 Administrative Draft SWRCB EIR (SWRCB 1997), for the implementation of the 1995 Water Quality Control Plan for the Bay/Delta. This chapter is patterned on the CALFED Bay/Delta program characterization of aquatic ecological habitat elements and stressors (CALFED 1997) and the Central Valley Project Improvement Act review of factors affecting the recovery of aquatic resources in the San Joaquin River system (USBR 1997d).

During the past century, the aquatic resources of the San Joaquin River study area have undergone very significant changes due to human related activities. Virtually all native species have declined in abundance, and many introduced species have become excessively abundant. The decline of native species has become a matter of considerable public concern and has resulted in the proposed actions being considered in this document. These actions are intended to help stem the decline and actively promote the restoration of the chinook salmon, as well as the general ecological health of the San Joaquin River Basin and the Bay/Delta Estuary. The characterization of the baseline abundance and distribution of aquatic resources in this chapter emphasizes manageable factors that contribute to the restoration of selected fish species by the proposed actions of this project. The characterization places into context the impacts that will be described in Section 4.4 of this EIS/EIR.

3.5.1 Habitats and Ecological Zones

The project area encompasses unique Ecological Zones (Figure 3.5-1) characterized by their predominant physical habitats and species assemblages as defined by the Ecosystem Restoration Program Plan (CALFED 1997). These ecological zones relate directly to the rivers, tributaries, and reservoirs of San Joaquin River Basin and include:

- San Joaquin River Ecological Zone
- East San Joaquin Basin Ecological Zone
- West San Joaquin Basin Ecological Zone
- Sacramento-San Joaquin Delta Ecological Zone (Delta)

The following sections describe the demarcation lines of each ecological zone, the salient ecological features, major tributaries and species assemblages.

3.5.1.1 San Joaquin River Ecological Zone

The San Joaquin Valley, the southern half of the great California Central Valley, extends some 290 miles from the Sacramento-San Joaquin Delta in the north, to the Tehachapi Mountains in the south. It is bordered on the east by the high mountains of the Sierra Nevada and to the west by the Coast Ranges. The San Joaquin Valley is divided into two distinct hydrologic zones: the Tulare Lake Basin in the south, and the San Joaquin River Basin in the north. The Tulare Lake Basin is separated from the San Joaquin River except in wet years by a low geological divide and, consequently, is not considered part of the San Joaquin River Ecological Zone (Figure 3.5-1). The San Joaquin River traverses the approximate center of the San Joaquin Valley emptying into the Sacramento-San Joaquin Delta at Vernalis. The San Joaquin River Ecological Zone (Figure 3.5-1) includes all of the 185-mile length of the San Joaquin River below Friant Dam, its confluence with other rivers, and drainage from adjacent wetlands.

Snowmelt from the Sierra Nevada mountain range is the primary source of water entering tributaries of the San Joaquin River Basin. Unimpaired flows in normal water years characteristically peak in May, June, and July as the snowpack melts in the spring and summer. Unimpaired flows the rest of the year are typically very low. The overall effect of water development in the San Joaquin River Basin is that water is stored in large reservoirs and then released more evenly throughout the year with generally highest flows in the early spring (CALED 1997, SWRCB 1997).

Water quality in the San Joaquin River varies seasonally, but in periods of low flow is generally degraded due to high temperatures, heavy metals, and pesticides from drainage (Saiki et al. 1992; Kuivila and Foe 1995). During the irrigation season (March - October) and occasionally following the flushing of the drainage water from duck clubs (January and February), degraded quality drainage water makes up a significant portion of the total San Joaquin River flow.

Within the project area, the San Joaquin River Ecological Zone is further subdivided into two ecological units that include:

- Vernalis Station to Merced River Ecological Unit
- Merced River to Mendota Pool Ecological Unit

The first unit, Vernalis to the mouth of the Merced River, is the most significant from the standpoint of the proposed project and from the perspective of the anadromous fish (salmon, steelhead, and striped bass) that use the San Joaquin River for migration or spawning. This 43-mile reach includes the confluence of the Merced, Tuolumne, and Stanislaus rivers, the main tributaries to the San Joaquin River, entering on the east side of the drainage (Figure 3.5-1). Levees confine the river on both sides and have limited the extent of available floodplain, wetland, or shaded riverine habitat (CALFED 1997). On the west side, broad alluvial river channels and floodplains connect to the San

Joaquin, but water from these rivers rarely reaches the San Joaquin. Virtually all land adjacent to the river is under intensive agricultural development.

The Merced River to Mendota Pool Ecological Unit is 87 miles long and includes Salt and Mud sloughs, the Chowchilla River, and the Fresno River. It receives some flow from the Delta-Mendota Canal into the Mendota Pool (CALFED 1997). A significant amount of flow also comes from agricultural drainage via Salt and Mud sloughs. This reach is also used as a conduit for deliveries of irrigation water.

The reach of the San Joaquin River from Mendota Pool to Friant Dam contains two additional ecological units. Flows in this reach are governed under CVPIA Section 3406(c)(1) and are precluded from the project area and this document.

Shad and striped bass migrate from the Pacific Ocean via the Delta into the San Joaquin River to spawn in the spring. Splittail, squawfish, and other native species (Table 3.5-1) are also found in the San Joaquin River. However, this ecological zone is dominated by introduced species such as largemouth bass, silversides, green sunfish and brown bullhead (Brown and Moyle 1992). Introduced species dominate in terms of total numbers and biomass.

Table 3.5-1: SAN JOAQUIN RIVER BASIN AND DELTA NATIVE AND NON-NATIVE FISH SPECIES

Common Name	Scientific Name	Native	Status	Delta	Rivers[2]	Reservoir[3]
yellowfin goby	*Acanthogobius flavimanus*			X		X[4]
white sturgeon	*Acipenser transmontanus*	X		X	X	
green sturgeon	*Acipenser medirostris*	X		X	X	
American shad	*Alosa sapidissima*			X	X	X
goldfish	*Carassius auratus*			X	X	X
Sacramento sucker	*Catostomus occidentalis*	X		X	X	X
Pacific herring	*Clupea harengus pallasi*	X		X		
prickly sculpin	*Cottus asper*	X		X	X	X
riffle sculpin	*Cottus gulosus*	X		X		
carp	*Cyprinus carpio*			X	X	X
threadfin shad	*Dorosoma petenense*			X	X	X
mosquitofish	*Gambusia affinis*			X	X	X
threespine stickleback	*Gasterosteus aculeatus*	X		X	X	X
California roach	*Hesperoleucus symmetricus*	X			X	
Delta smelt	*Hypomesus transpacificus*	X	FT, ST	X		
wakasagi	*Hypomesus nipponensis*			X	X	

surf smelt	*Hypomesus pretiosus*			X		
tule perch	*Hysterocarpus traski*	X		X	X	

Table 3.5-1: SAN JOAQUIN RIVER BASIN AND DELTA NATIVE AND NON-NATIVE FISH SPECIES (CONT.)

Common Name	Scientific Name	Native	Status	Delta	Rivers[2]	Reservoir[3]
yellow bullhead	*Ictalurus natalis*			X		
channel catfish	*Ictalurus punctatus*			X	X	
black bullhead	*Ictalurus melas*			X		
brown bullhead	*Ictalurus nebulosus*			X	X	X
white catfish	*Ictalurus catus*			X	X	X
blue catfish	*Ictalurus furcatus*			X		
Pacific brook lamprey	*Lampetra pacifica*	X		X	X	
Pacific lamprey	*Lampetra tridentata*	X		X	X	
river lamprey	*Lampetra ayresi*	X		X	X	
hitch	*Lavinia exilicauda*	X		X	X	X
pumpkinseed	*Lepomis gibbosus*			X		
green sunfish	*Lepomis cyanellus*			X	X	X
warmouth	*Lepomis gulosus*			X	X	
redear sunfish	*Lepomis microlophus*			X		X
bluegill	*Lepomis macrochirus*			X	X	
staghorn sculpin	*Leptocottus armatus*	X		X		
inland silverside	*Menidia beryllina*			X	X	X[4]
spotted bass	*Micropterus punctulatus*					X
smallmouth bass	*Micropterus dolomieui*			X	X	X
largemouth bass	*Micropterus salmoides*			X		X
striped bass	*Morone saxatilis*			X	X	X
hardhead	*Mylopharodon conocephalus*	X		X	X	X
golden shiner	*Notemigonus crysoleucas*			X	X	X
red shiner	*Notropis lutrensis*			X		X
steelhead rainbow trout	*Oncorhincus mykiss*	X	FT	X	X	
chinook salmon	*Oncorhynchus tshawytscha*	X	FPT	X	X	
kokanee salmon	*Oncorhynchus nerka*	X				X
Sacramento blackfish	*Orthodon microlepidotus*	X		X		X
yellow perch	*Perca flavescens*			X		
bigscale logperch	*Percina macrolepida*			X	X	
fathead minnow	*Pimephales promelas*			X		
starry flounder	*Platichthys stellatus*	X		X		X[4]
Sacramento splittail	*Pogonichthys macrolepidotus*	X	FPT	X	X	
black crappie	*Pomoxis nigromaculatus*			X		X
white crappie	*Pomoxis annularis*			X		
Sacramento pikeminnow formerly Sacramento squawfish	*Ptychocheilus grandis*	X		X	X	X

brown trout	*Salmo trutta*					X
brook trout	*Salvelinus fontinalis*					X

Table 3.5-1: SAN JOAQUIN RIVER BASIN AND DELTA NATIVE AND NON-NATIVE FISH SPECIES (CONT.)

Common Name	Scientific Name	Native	Status	Delta	Rivers[2]	Reservoir[3]
longfin smelt	*Spirinchus thaleichthys*	X		X		
shimofuri goby	*Tridentiger bifasciatus*			X		
chameleon goby	*Tridentiger trigonocephalus*			X		

Notes:

FT = Federally listed Threatened, FPT = Federally Proposed Threatened, ST = State listed Threatened

1. Delta is the legal delta from Vernalis to Chipps Island.
2. Rivers is from Vernalis up to the first major dam.
3. See Table 3.5-3 for a compete list of reservoirs.
4. San Luis Reservoir only.

References:

DFG. 1997. Endangered and Threatened Animals of California. April.

McGinnis, S.M. 1984. Freshwater Fishes of California. University of California Press, Berkeley, California.

USFWS. 1997a. Federal Register, 50 CFR Part 17, Endangered and Threatened Species; Review of Plant and Animal Taxa; Proposed Rule. 19 September.

USFWS. 1997b. Federal Register, 50 CFR Part 17, Endangered and Threatened Wildlife and Plants. 31 August.

Wang, J.C.S. 1986. Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California Guide to the Early Life Histories. Technical Report 9. Interagency Ecological Study Program.

3.5.1.2 West San Joaquin Basin Ecological Zone

This area comprises the west side of the San Joaquin Valley from the Delta in the north and Panoche Creek in the south (CALFED 1997). It is bounded by the interior coast range on the west side, which supports a few naturally flowing, small streams that flow into the San Joaquin River. The eastern slopes of the coast range mountains are arid, while the few remaining wet land areas adjacent to the San Joaquin River are remnants of a once vast floodplain. Most of the remaining wetlands lie in a topographic trough between the Mendota Pool and the Community of Gustine. These important wetlands are an intregal part of the Pacific Flyway for millions of waterfowl which migrate through the Central Valley each spring and fall. The wetland sloughs scattered along the San Joaquin River in this zone are valuable resources for threatened and endangered wildlife. Many native species of fish no longer inhabit this area and introduced species such as striped bass, crappie, and catfish are now established in the San Luis Reservoir, O'Neill Forebay, and Los Banos Reservoir.

The San Luis Reservoir, the largest west side aquatic ecosystem, does not drain into the San Joaquin River. The San Luis Drain was designed to carry agricultural subsurface drainage from collectors along the west side of the San Joaquin River to the Sacramento-San Joaquin Delta for ultimate discharge to the ocean. However, only a portion of the drain was constructed, and it presently terminates in Mud Slough at the north end of Kesterson National Wildlife Refuge and carries drainage from the Westlands Water District only. Accumulations of selenium in the drainage water and sediments at Kesterson resulted in the closure of the refuge and the drain after 1985 (SWRCB 1987). The drain now serves as a conveyance facility for subsurface drainage water that would otherwise flow through the wetlands areas and then to the San Joaquin River.

3.5.1.3 East San Joaquin Basin Ecological Zone

This ecological zone (Figure 3.5-1) includes all the major east side tributaries of the San Joaquin River. The hydrographic elements of this zone include major rivers and many reservoirs of varying size in the upper parts of the watershed. The largest reservoirs are New Melones, New Don Pedro, and Lake McClure. The East San Joaquin River Ecological Zone has been divided into three riverine ecological units, representing the three major tributaries of the San Joaquin River:

- Stanislaus River Ecological Unit
- Tuolumne River Ecological Unit
- Merced River Ecological Unit

Stanislaus River Ecological Unit. The Stanislaus is the northern most major tributary to the San Joaquin River. Average monthly unimpaired flows at New Melones are approximately 96,000 acre-feet. These flows are reduced to approximately 57,000 acre-feet at Ripon, near the confluence with the San Joaquin River, due to flow diversion and regulation at Goodwin Dam.

New Melones Dam is located 60 miles upstream from the confluence of the Stanislaus and San Joaquin Rivers, and is operated by Reclamation as a key element of the CVP. New Melones Reservoir has a capacity of 2,420,000 acre-feet and is currently operated under the New Melones Interim Plan of Operation (USBR 1997c). Releases from New Melones are used for agricultural irrigation and water supply purposes, to meet water quality control standards at Vernalis, provide beneficial fishery flows, and for the positioning of the freshwater/saltwater interface in the Delta.

Goodwin Dam is located approximately 15 miles below New Melones. It serves as the terminus for the upstream migration of chinook salmon. Salmon spawn below the dam and the early life stages grow and develop in the river between the dam and the San Joaquin River before emigrating. There are approximately forty small, unscreened pump diversions (for agricultural purposes) along the river. The channelization of the river below Goodwin Dam has resulted in impaired rearing habitat for juvenile salmon.

Water temperatures in the Stanislaus River are related to seasonal air temperatures and flow releases. Reclamation has developed a stream temperature model for the Stanislaus River that can be used to predict water temperatures given various flow and climate conditions.

The Stanislaus River, as well as the Tuolumne and Merced rivers, may have suitable habitat conditions to support steelhead even if steelhead are not present.

Tuolumne River Ecological Unit. The Tuolumne River is the largest of the San Joaquin River tributaries and has an average annual unimpaired flow of approximately 1.8 million acre-feet. The Tuolumne has a series of dams diverting water for municipal and irrigation uses as well as the generation of electric power. The City of San Francisco constructed the O'Shaughnessy Dam forming the Hetch-Hetchy Reservoir and another smaller dam to form Lake Eleanor in the 1920s. Cherry Dam, forming Lake Lloyd, was completed in 1956. Flow down the lower Tuolumne is regulated at the New Don Pedro Dam operated by the Turlock and Modesto Irrigation Districts. Don Pedro Reservoir has a maximum storage of approximately 2 million acre-feet.

La Grange Dam (built in 1893) is the upstream barrier to salmon migration. Spawning now takes place in the 25-mile reach below the dam, and juvenile rearing takes place throughout the lower river. The quantity and quality of habitat for salmon in the Tuolumne River has been degraded over the years by many factors including loss of riparian habitat due to cattle grazing, instream gravel mining, reduced instream flows, and elimination of upstream sources of gravel recruitment.

In 1995, a settlement agreement was signed by federal and state agencies, local irrigation districts, the City and County of San Francisco, and local environmental groups as part of an amendment to Article 37 of the FERC license for the operation of the New Don Pedro Project (TID/MID 1996). One of the results of this agreement is increased flow releases from New Don Pedro as part of a strategy for recovery of Tuolumne River chinook salmon.

Merced River Ecological Unit. The Merced River drains over 1, 200 square miles of Sierra Nevada range including the southern part of Yosemite National Park and has an annual average, unimpaired runoff of approximately 1 million acre-feet per year (CALFED 1997). The unimpaired monthly flow peaks in April, May and June and then abruptly drops to flows of less than 100 cfs from August through November. Flow is regulated by a series of dams that allow for flood control, irrigation and power production. The New Exchequer Dam, operated by the Merced Irrigation District, blocks off the higher elevations of the Merced River creating Lake McClure with over one million acre-feet of storage capacity. Further downstream the McSwain Dam acts as an afterbay for New Exchequer Dam.

Habitat quantity and quality within the lower reaches of the Merced River are extensively degraded due to cattle grazing, removal of bank side vegetation, gravel mining in the river bed, agricultural return flows into the reaches used by juvenile salmon and trout, low flows resulting in siltation of the spawning gravel, and lack of recruitment of new spawning gravel. Low flows in the lower reaches of the Merced River result in significantly degraded fish rearing habitat. The Merced Falls and Crocker-Huffman agricultural diversion dams divert approximately 500,000 acre-feet a year. Six major diversions in the salmon spawning reach from Crocker-Huffman to Snelling deplete virtually all available flow (CALFED 1997).

Reservoirs of the East San Joaquin River Ecological Zone. Reservoirs have become a major type of fish habitat in the east side tributaries since the development of the region's surface water projects. The nature of each reservoir and its fish fauna is determined by its elevation, size, water management regime, water quality and fisheries management practices. Many of the reservoirs lie at mid-level elevations in the Sierra Nevada foothills and have characteristics of both warm-water and cold-water ecosystems. Reservoir ecosystems include: 1) littoral, or edge habitats down to the lower limit of the penetration of light; 2) the epilimnetic, or open water zone; 3) the hypolimnetic zone of cold water below the warmer surface water; and 4) benthic, or bottom zone. The east side reservoirs provide considerable recreational fishing diversity, although extensive drawdowns tend to limit species that are dependent on relatively stable shallow-water habitat for some component of their life cycle.

3.5.1.4 Sacramento-San Joaquin River Delta Ecological Zone

The Sacramento-San Joaquin Delta Ecological Zone (Figure 3.5-1) includes all of the legal delta from the Carquinez Straights, to the mouth of the American River in the north, to Vernalis on the San Joaquin River in the south. The proposed project alternatives primarily affect the southern and central portions of the Delta through changes in the magnitude and timing of flows at Vernalis. The Sacramento-San Joaquin Delta Ecological Zone is characterized by a mosaic of habitat types that support a diverse community of aquatic organisms (CALFED 1997; SWRCB 1997). This zone is also a key element linking the Pacific Ocean with the tributary rivers in the watershed on the east side of the coast range and the western side of the Sierra Nevada Mountains. Based on the aquatic habitat nomenclature of CALFED (1997), the main types of aquatic habitat found in the Delta include:

- shaded riverine aquatic (SRA)
- vegetated and non-vegetated shallow shoal areas
- open-ended sloughs
- dead-end sloughs
- large, open river channels

Inflow to the Delta primarily comes from the large, open river channels of the Sacramento River with lesser amounts coming from the San Joaquin and Mokelumne rivers. The Sacramento River contributes approximately 75–80 percent of the water entering the Delta; the San Joaquin River contributes 10–15 percent of total inflows (SWRCB 1997). The cumulative flows of the Mokelumne and other east side rivers make up the balance of Delta inflows. Flows into the Delta vary greatly by water year type but on the average approximately 21 million acre-feet of water drains into the Delta each year (SWRCB 1997). Unimpaired monthly Delta outflows peak in March and drop off to their lowest levels in September. Development of water resources has greatly altered flow, resulting in significantly reduced spring peaks and higher flows in the late summer months. Flows are now regulated to maintain the 2 parts per thousand (ppt) isohaline (commonly referred to as X2) in Suisun Bay to prevent saltwater intrusion and benefit aquatic species.

The Delta is home to numerous species of aquatic plants and animals. Some of the fish species found in the Delta are migratory, using the Delta as a passage through which they move back and forth between Central Valley rivers and the ocean, while others spend their entire life there. Chinook salmon and striped bass are examples of anadromous, migratory species, while delta and longfin smelt are resident species.

3.5.2 Factors Affecting the Distribution and Abundance of Aquatic Resources in the San Joaquin River Basin and Bay/Delta Estuary

The aquatic resources of the San Joaquin River Basin and Delta are greatly reduced from their former status. The decline in distribution and abundance, and the causes of decline, have been documented extensively (SWRCB 1995b). This section will summarize the factors associated with the decline in fishery resources. These factors include: natural environmental variability; water development; introduction of non-native aquatic organisms; food supply limitations; harvest; pollution; and reservoir issues (DFG 1994; SFEP 1992a).

3.5.2.1 Natural Environmental Variability

The flow of fresh water to the San Joaquin River Basin and ultimately the Bay/Delta Estuary is primarily determined by the amount and timing of precipitation in the Central Valley watershed along with the rate of runoff generated by snowmelt. Just as total precipitation varies each year, the volume of water annually flowing through the basin will also vary. Inflows to the southern Delta from the San Joaquin River basin are measured at the USGS Vernalis gauging station. For planning and regulatory purposes, the SWRCB has developed a water year classification system that provides a relative estimate of the amount of water originating in the San Joaquin hydrologic basins from seasonal runoff and reservoir storage. The system has five types of water years: wet, above normal, below normal, dry, and critical. Table 3.5-2 shows the water year types for the San Joaquin River system for the period 1930–1997.

Table 3.5-2: WATER YEAR TYPES AND HISTORICAL SUMMARY FOR THE SAN JOAQUIN RIVER BASIN, 1930–1997

Water Year	Type	Comments
1930	C	Lyons Reservoir on the Stanislaus River operational
1931	C	
1932	AN	
1933	D	
1934	C	
1935	AN	
1936	AN	
1937	W	
1938	W	Hetch Hetchy Reservoir on the Tuolumne River operational
1939	D	Friant Dam construction begins
1940	AN	
1941	W	
1942	W	
1943	W	
1944	BN	Friant Dam is allowed to regulate San Joaquin River flow
1945	AB	
1946	AB	
1947	D	Friant Dam construction completed, Millerton Reservoir on the San Joaquin River operational
1948	BN	
1949	BN	
1950	BN	Redinger Reservoir on the San Joaquin River operational
1951	AN	Friant Dam begins full operation, USBR Tracy Pumping Plant
1952	W	
1953	BN	
1954	BN	Thomas Edison Reservoir on the San Joaquin River operational
1955	D	

W = Wet, AN = Above normal, BN = Below normal, D = Dry, C = Critical

Table 3.5-2: WATER YEAR TYPES AND HISTORICAL SUMMARY FOR THE SAN JOAQUIN RIVER BASIN, 1930–1997 (CONT.)

Water Year	Type	Comments
1956	W	Cherry Reservoir on the Tuolumne River operational
1957	BN	Beardsley, Tulloch, and Donnells reservoirs on the Stanislaus River operational
1958	W	
1959	D	Mammoth Pool Reservoir on the San Joaquin River operational, drought year
1960	C	Drought year
1961	C	State Water Rights Board adopted Water Rights Decision 990 approving water rights for the CVP
1962	BN	
1963	AN	
1964	D	
1965	W	
1966	BN	New Exchequer Dam on Merced operational
1967	W	Water Rights Decision 1275 approving water rights for the SWP including agricultural salinity standards. McSwain and McClure reservoirs on the Merced River operational
1968	D	Banks Pumping Plant operational
1969	W	
1970	AN	Merced River Fish Facility
1971	BN	D-1379 requiring SWP and CVP comment fish and wildlife use in additional to agricultural, municipal, and industry. Don Pedro Reservoir on the Tuolumne River operational
1972	D	
1973	AN	
1974	W	
1975	W	
1976	C	Drought year

W = Wet, AN = Above normal, BN = Below normal, D = Dry, C = Critical

Table 3.5-2: WATER YEAR TYPES AND HISTORICAL SUMMARY FOR THE SAN JOAQUIN RIVER BASIN, 1930–1997 (CONT.)

Water Year	Type	Comments
1977	C	Drought year
1978	W	D-1485 requires DWR and USBR to meet Bay/Delta standards. New Melones Reservoir on the Stanislaus River operational.
1979	AN	
1980	W	
1981	D	
1982	W	
1983	W	
1984	AN	
1985	D	
1986	W	Federal/State Coordinated Operation Agreement for operation/export pumps is signed
1987	C	drought year
1988	C	drought year
1989	C	drought year
1990	C	Formation of San Joaquin River Management Plan Advisory Council, Spicer Meadows Reservoir on the Stanislaus River operational, drought year
1991	C	drought year
1992	C	drought year, CVPIA enacted, electric barrier on San Joaquin River
1993	W	NMFS Biological Opinion on winter run chinook salmon
1994	C	Bay/Delta Accord and the creation of CALFED Delta Smelt Biological Opinion by USFWS
1995	W	May 1995 SWRCB Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary
1996	W	
1997	W	January flood, very dry spring
1998	W	El Niño

W = Wet, AN = Above normal, BN = Below normal, D = Dry, C = Critical

Variation in the amount of flow to the Bay/Delta Estuary is the most commonly cited factor controlling abundance, distribution, and reproductive success of many aquatic species in the project area (SWRCB 1995a; USBR 1997d). Drought and low flow conditions can have wide-ranging impacts on aquatic resources, depending on the species and life stage requirements. For many fish species, drought conditions can reduce the amount of habitat available, elevate water temperatures, reduce the food supply, increase susceptibility to predation, and degrade spawning and rearing habitats. Impaired habitat conditions result in reduced egg and young survivals for that year and a diminished year class in the adult population. The combination of floods and severe drought in the 1980s and 1990s contributed to, and accelerated the declines in populations of aquatic resources in the San Joaquin River Basin and the Bay/Delta Estuary (SWRCB 1995b).

Natural variability in the cycle of Pacific oceanic currents also may have contributed to the decline of some of the anadromous species. El Niño conditions disrupt the natural upwelling that occurs off the coast, reducing the amount of nutrients brought up from deep, nutrient rich strata of the ocean. Fewer nutrients result in greatly reduced plankton blooms and, therefore, less food for juvenile salmon and striped bass. While such natural variation is beyond the control of resource managers, these events accentuate and focus attention on the need to create robust aquatic ecological habitat so that essential species can survive the natural range of irregular geoclimatic conditions.

3.5.2.2 Water Development

Land reclamation projects and waterway modifications have caused major ecological changes throughout the San Joaquin River Basin and in the Delta. These practices have removed most of the seasonally-flooded wetlands on the valley floor and the tidal marshes in the Delta. The loss of wetland habitat greatly reduced the critical habitats for many riverine and delta species at all trophic levels, and has resulted in a significant reduction in population sizes, especially of those species that utilize shallow, back-water habitats, sloughs, or intertidal zones during all or part of their life cycle. Species that utilize flooded vegetation for spawning habitat, have either become extinct or greatly declined in abundance (CUWA 1994).

The progressive losses of habitat that have occurred throughout the Central Valley have reduced the ability of certain populations to rebound from natural and man-induced environmental changes. The following changes associated with water development have affected aquatic resources: alteration of seasonal flow regimes, diminished flow, modification of the entrapment zone location, export of water from the Delta, and modification and use of the Delta as a water conveyance facility.

The use of the Delta to convey water to South Delta export facilities (see Section 3.2) has played a particularly large role in modifying natural flow patterns. When export rates are high and Delta inflows are low, water from the central Delta and San Joaquin River is drawn into the channels that feed the CVP and SWP pumping plants. This net upstream flow of water toward the export pump is known as reverse flow. Reverse flows occur primarily in the south and central delta. The magnitude, duration, and extent of reverse flows varies with season, water year type, and stream inflow to the Delta. Reverse flows reportedly disorient anadromous fish as they migrate either upstream or downstream following the salinity gradient (SWRCB 1997). Reverse flows carry young fish into the central or southern Delta, where habitat may not be as good or where they may be more susceptible to entrainment (DWR 1992). Entertainment losses also occur as a result of pumps used at many of the agricultural diversions found throughout the San Joaquin River Basin and Delta.

3.5.2.3 Introduced Species

The San Joaquin River Basin and the Bay/Delta Estuary is home to more than 150 introduced aquatic species of plants and animals. About 28 of these introduced species are non-native fish, and over 100 are non-native invertebrates (BDOC 1994). A list of the native and non-native fish species is presented in Table 3.5-1. Introduced species affect native species through a wide variety of mechanisms including competition for food and space, predation, habitat alteration, disturbance, hybridization, and acting as pathways for and sources of diseases (BDOC 1994).

3.5.2.4 Food Supply

Food supply can affect the abundances of aquatic organisms at all trophic levels. Food may be limited in various ways, including decreased availability of nutrients and decreased abundance and availability of food items. Orsi et al. (1996) reported a strong correlation between changes in the Delta food web base and the decline in the aquatic resources of the Bay/Delta Estuary. Dams, levees, enlarged river channels, and filling tidal wetlands have all reduced the loadings of land-derived detritus and dissolved organic carbon, which are primary nutrient sources for the lowest members of the food web (DWR 1994). These changes may affect the foraging success of fish species using the San Joaquin River Basin and Delta during all of parts of their life cycle.

3.5.2.5 Harvest

The legal harvest of various fish decreases the number of spawning adults and the average age of adults. The possibility of overharvesting is greatest for game species (e.g., striped bass, white sturgeon, chinook salmon). While current federal and state fisheries management regulations should prevent over fishing, even with full enforcement of these statutes, some species may be over harvested.

Management of salmon fisheries is complicated because of sport, commercial, and illegal fishing in the ocean, the presence of several regulatory agencies, and the support of populations by hatchery production. While ocean harvests of salmon substantially reduce spawning escapement, resource agencies maintain that harvests (legal or illegal) are not the principal limiting factor for salmon abundance. Similar to many other fisheries in decline around the globe, increased fishing efforts (despite hatchery production) would result in over harvesting of wild salmon stocks (DFG 1994), including those occurring within the San Joaquin Basin.

Over harvest of game species in reservoirs by sport fishing is controlled not only by regulations but also by stocking reservoirs on an annual basis or when fish populations begin to decline. Reservoirs rarely provide sufficient habitat quantity or quality for game fish species, and most game fish species in reservoirs are not considered to be part of self-sustaining populations.

3.5.2.6 Pollution

As urban, industrial, and agricultural activities expanded throughout the Central Valley watershed, pollutant loads and associated impacts on aquatic resources increased. By the early 1900s, pollution contributed to the decline in salmon, sturgeon, and striped bass commercial fisheries (SFEP 1992b). There is growing concern about non-urban runoff in the San Joaquin Basin watersheds, particularly the agricultural component (SFEP 1992b). Agricultural return flows, which contain pesticides, trace elements, and solvents, may contribute most of the flow of the San Joaquin River in the summer (SFEP 1991).

Recently, the dormant spray pesticide diazinon, which is applied to orchards in the winter, has been identified in the San Joaquin River at levels that are acutely toxic to some aquatic organisms. The elevated concentrations of pesticides in the river immediately followed rainfall events, when runoff from agricultural and urban areas is most pronounced (DWR 1994; SFEP 1992b). The pesticides can also result in chronic toxicity to aquatic fauna in the river. Secondary adverse impacts also can occur due to pesticide toxicity to zooplankton, resulting in malnutrition of the fish.

In addition to being a source of pesticides, agricultural return flows can increase the salinity of receiving waters to levels which adversely affect some aquatic species. This occurs in the lower San Joaquin River where striped bass spawning habitat is impacted as the result of a combination of saline agricultural return flows and reduced freshwater flows.

It is unlikely that pollution is the principal cause of the widespread declines in fishery resources over the last 20 years because of the major pollutant abatement actions that have occurred during that period (DFG 1994). But it is still reasonable to conclude that toxic pollutants have been, and continue to be, among the factors which contribute to the decline of many species, in spite of an increased awareness of pollution and its impact on the aquatic resources of the San Joaquin River Basin.

3.5.2.7 Reservoir Issues

The project area and vicinity include 36 reservoirs of various size. Table 3.5-3 summarizes the reservoirs by name, watershed, and principal species. The three major reservoirs in the project area

Table 3.5-3: SAN JOAQUIN BASIN RESERVOIRS BY NAME, WATERSHED, AND PRINCIPAL SPECIES

Reservoir Name/Date	Watershed	Principal Species
Beardsley Lake (1957)	Stanislaus River	rainbow trout, brown trout, and brook trout
Donnells Reservoir (1957)	Stanislaus River	rainbow trout, brown trout, and brook trout
Goodwin Reservoir (1912)	Stanislaus River	not known
Lake Alpine (1908)	Stanislaus River	rainbow trout
Lake Tulloch (1957)	Stanislaus River	rainbow trout, smallmouth bass, largemouth bass, bluegill, catfish, and crappie
Lyons Reservoir (1930)	Stanislaus River	not known
New Melones (1979)	Stanislaus River	rainbow trout, brown trout, largemouth bass, smallmouth bass, bluegill, catfish, and crappie
Pinecrest Lake (1916)	Stanislaus River	rainbow trout, brown trout, and brook trout
Relief (1910)	Stanislaus River	not known
Spicer Meadows Reservoir (1990)	Stanislaus River	rainbow trout, brook trout, brown trout, black bass, and channel catfish
Union Reservoir (1902)	Stanislaus River	rainbow trout, brook trout, brown trout, black bass, and channel catfish
Utica Reservoir (1910)	Stanislaus River	rainbow trout, brook trout, brown trout, black bass, and channel catfish
Eleanor Lake (1918)	Tuolumne River	not known
Hetchy Hetchy (1938)	Tuolumne River	not known
LaGrange (1893)	Tuolumne River	not known
Lloyd Lake (1956)	Tuolumne River	rainbow trout, brown trout, and brook trout
New Don Pedro (1971)	Tuolumne River	trout, catfish, bluegill, crappie, sunfishes, silver salmon, and black bass
Crocker-Huffman Dam (1910)	Merced River	not known
Lake McClure (1967)	Merced River	trout, salmon, catfish, bluegill, crappie, sunfishes, and black bass
Lake McSwain (1967)	Merced River	trout, salmon, catfish, bluegill, crappie, sunfishes, and black bass
Merced Falls (1910)	Merced River	not known
Bass Lake (1901)	San Joaquin River	rainbow trout, brown trout, catfish, bluegill, sunfishes, crappie, black bass, and kokanee salmon
Florence Lake (1925)	San Joaquin River	rainbow trout, brown trout, and brook trout

Table 3.5-3: SAN JOAQUIN BASIN RESERVOIRS BY NAME, WATERSHED, AND PRINCIPAL SPECIES (CONT.)

Reservoir Name/Date	Watershed	Principal Species
Huntington Lake (1913)	San Joaquin River	rainbow trout, brown trout, brook trout, kokanee salmon
Kerckhoff Reservoir (1920)	San Joaquin River	striped bass
Mammoth Pool Reservoir (1954)	San Joaquin River	rainbow trout, brown trout, and brook trout
Millerton Lake (1947)	San Joaquin River	spotted bass, largemouth bass, smallmouth bass, and catfish
Redinger Lake (1950)	San Joaquin River	striped bass
Salt Springs Reservoir (1882)	San Joaquin River	rainbow trout, brown trout, and brook trout
Shaver Lake (1927)	San Joaquin River	rainbow trout, brown trout, brook trout, largemouth bass, smallmouth bass, catfish, and redear sunfish
Thomas Edison Lake (1954)	San Joaquin River/Mokelumne River	rainbow trout, brown trout, and brook trout
San Luis Reservoir (1967)	California Aqueduct	catfish, bluegill, crappie, striped bass, black bass, sturgeon, and shad

References:

DFG Exhibit 15 Bay/Delta Hearing, 1987.

Dirksen, D.J. and R.A. Reeves. 1990. Recreation Lakes of California. Ninth Edition. Recreation Sales Publishing, Inc., Burbank, California.

DWR. 1993b. Draft California water plan update. Volume 1. California Department of Water Resources. Sacramento, CA. Bulletin 160-93. 402pp. Volume 2. Bulletin 160-93. November 1993. 347 pp.

U.S. Geological Survey Water Data Report, CA-91-3.

that regulate flow in the Stanislaus, Tuolumne, and Merced rivers are New Melones, New Don Pedro, and Lake McClure, respectively. Factors limiting optimal sport fishery development in the project area reservoirs include periodicity and magnitude of water level fluctuation, quality and extent of riparian habitat, over fishing, and bank erosion (Leidy and Meyers 1984). Water-level fluctuation is a direct result of reservoir management operation decisions that are designed to meet water user needs. Reservoirs in the project area are operated to store water during winter and spring and to release water in summer and fall to meet agricultural and other requirements. Surface water elevation fluctuations may exceed 20 feet annually depending on the reservoir, precipitation, and demand.

Drawdowns directly affect reservoir productivity in several ways. As the reservoir surface elevation drops, the surface area decreases, reducing the areas of primary production and the living space of fish. The reduction in the extent of littoral area is the most adverse effect for nest building fish. Largemouth bass, crappie, and many other species tend to build nests and spawn in the littoral areas during the spring months, just as the reservoirs are being drawn down to provide water for other beneficial uses. The drawdown also affects temperature stratification, as well as mineral and gas distribution, thereby decreasing usable habitats for cold water fish such as trout. The drawdown also draws off plankton and small fish, and prevents stabilization of fish and invertebrate communities.

3.5.3 Indicator Species Population Trends

The San Joaquin River Basin, its associated tributaries and reservoirs, and the Delta contain approximately 58 species of native and non-native fish. Table 3.5-1 lists the species, the ecological zone(s) they inhabit, and any applicable designation of State or Federal status.

The fish species discussed in this report are considered indicator species because they are dominant within their habitat or have unique value to the ecosystem or regional economy due to their importance as a commercial or recreational target species. Three native species, the splittail, delta smelt, and longfin smelt, are included because of their decline over the last two decades. Sensitive fish species found in the San Joaquin River Basin are listed in Table 3.5-4. A complete listing of all Federal and State listed threatened and endangered species, including plants and animals, is found in Appendix D.

Table 3.5-4: SENSITIVE FISH SPECIES IN THE SAN JOAQUIN RIVER BASIN

		Status	
Scientific Name	Common Name	State	Federal
Acipenser medirostris	Green sturgeon	SSC	
Hesperoleucus symmetricus	California roach	SSC	
Hypomesus transpacificus	Delta smelt	ST	FT
Lampetra ayresi	River lamprey	SSC	
Lampetra hubsii	Kern brook lamprey	SSC	
Mylopharodon conocephalus	Hardhead	SSC	
Oncorhynchus tshawytscha	Fall-run chinook salmon	SSC	FPT
Oncorhynchus mykiss	Central Valley steelhead	SC	FT
Pogonichthys macrolepidotus	Splittail	SSC	FPT

STATE: ST=threatened; SC=candidate for listing; SSC=special concern.

FEDERAL:	FT=threatened; FPT= proposed threatened.

3.5.3.1 Chinook Salmon

Chinook salmon are an anadromous species that spend most of their adult life in open ocean waters and return to freshwater inland streams to spawn. As adult salmon migrate upstream, water must be cool enough and have sufficient dissolved oxygen to avoid stressing the fish. If these conditions are not met, adult fish may delay their migration (USFWS 1995b). Adult chinook salmon in the San Joaquin Basin typically spawn in upper reaches of the major tributaries. They select areas with gravel substrates and prefer loose, clean gravel about 1 to 4 inches in diameter, with preferred water depths ranging from 0.5 to 3.0 feet, and preferred water velocities of 1 to 3 feet per second (USFWS 1995b). For optimal development of embryos and survival of alevins (very young salmon with a yolk sac attached), water should contain high concentrations of dissolved oxygen and range in temperature from 41 to 55 degrees Fahrenheit (Vogel and Marine 1991 as cited in USFWS 1995b). Adult salmon typically do not feed while in freshwater, and all adult salmon die after spawning.

Fall-run chinook salmon in the San Joaquin Basin return to their natal streams to spawn from mid-October through December, with most spawning occurring in November. Eggs are fertilized and buried in gravels where they develop for a period of 40-60 days. After the eggs hatch, the alevins remain in the gravels for up to 30 days prior to emerging. Most salmon fry (young salmon with yolk sac absorbed) emerge from the gravels and rear in the streams from mid-January through March prior to emigrating back to the ocean as smolts from April through early June. In high flow years, fry may be displaced downstream or begin to migrate downstream earlier than in other years. For example, during the high flows of 1998, many fall-run fry emigrated from the San Joaquin tributaries to the lower San Joaquin River and Delta in January and February, according to the NMFS. Chinook salmon from the San Joaquin Basin spend two to four years maturing at sea before returning to spawn.

Four separate races of Central Valley chinook salmon have been identified: the fall, late-fall, winter, and spring runs, based on the timing of the upstream migration. Spring-run chinook salmon in the San Joaquin River Basin became extinct following the construction of impassible dams on major tributaries. Currently, the entire chinook salmon population in the San Joaquin River is made up of fall-run chinook salmon that spawn between October and December (USFWS 1995). Small numbers of spawners have been observed in the Tuolumne River as late as February. Although it has been suggested that these represent a distinct late-fall run, these late-fall salmon are more usually viewed as stragglers, or strays from other river systems (ORNL 1994; Yoshiyama and Moyle 1995).

San Joaquin fall-run chinook are usually regarded as forming a distinct stock, on the basis of geographical distribution and life-history timing. Evidence of genetic separation between Sacramento and San Joaquin fall chinook salmon is weak. Tag returns indicate straying from the Sacramento River system to the San Joaquin (USFWS 1996a). Mixing of genetic stocks has also occurred due to the initial use of Stanislaus River brood stock at the Merced River Fish Facility (MRFF), and the outplanting of MRFF-reared smolts and yearlings in the Stanislaus, Tuolumne, and San Joaquin rivers, and in the Delta (USFWS 1995a).

Population Trends

The annual spawning escapement of fall-run chinook salmon in the San Joaquin River basin has been estimated for most years since 1940, but early estimates are often incomplete and based on subjective methods (USBR 1986). Table 3.5-5 shows the estimated run sizes in each of the tributaries since 1940 (Ford 1997, personal communication). Methods for estimating the number of returning adults have improved over the last five decades, and the estimates show a pattern of cyclical returns, as indicated in Figure 3.5-2. Recent spawning escapement of chinook salmon in the Merced, Tuolumne, and Stanislaus rivers is highly variable. Higher returns are strongly correlated with above normal and wet water year types. Similarly, lower spawning escapements are correlated with normal, dry, and critically dry water years (USFWS 1995a). Very low spawning escapements since 1990 are related to recent drought conditions (1987–1992).

Low returns of fall-run chinook salmon to all three tributaries in the 1960s (Figure 3.5-2) were attributed to low San Joaquin River flows, flow reversals, and low dissolved oxygen levels in the lower San Joaquin River and south Delta channels. Nearly complete run failures occurred in 1962 and 1963. The failures appeared to be related to low spring flows in 1959, 1960, and 1961 rather than to fall migration conditions (Hallock et al. 1970). Similar run failures occurred in 1990 and 1991.

Causes of decline for chinook salmon populations have been attributed to: isolation from historical spawning areas; loss of habitat; impaired conditions for smolt emigration, including decreasing flows and increased water temperatures; legal and illegal harvest; introgression with hatchery stocks; presence of pesticides and agricultural chemicals; and entrainment of smolts in SWP/CVP water export system (USFWS 1995b). All the major rivers of the San Joaquin basin have dams at fairly low elevations which are impassable to salmon, preventing their migration into the tributary streams of the Sierra Nevada mountains.

In addition to physically blocking access to upstream habitat, the many dams and reservoirs in the basin have altered natural hydraulic regimes on the rivers, resulting in changes in river morphology, prevention of gravel recruitment, sedimentation of fines into the spawning gravels, and changes to seasonal patterns of flow and water temperatures (USFWS 1995).

Table 3.5-5: SAN JOAQUIN BASIN FALL-RUN CHINOOK SALMON ESCAPEMENT ESTIMATES (THOUSANDS), 1940-1996

	River System			
Year	**Stanislaus**	**Tuolumne**	**Merced**	**Total**
1940	3	122	1	126
1941	1	27	1	29
1942		44		44
1943				
1944		130		130
1945				
1946		61		61
1947	13	50		63
1948	15	40		55
1949	8	30		38
1950				
1951	4	3		7
1952	10	10		20
1953	35	45	0.5	81.5
1954	22	40	4	66
1955	7	20		27
1956	5	6	0	11
1957	4	8	0.4	12.4
1958	6	32	0.5	38.5
1959	4	46	0.4	50.4
1960	8	45	0.4	53.4
1961	2	0.5	0.1	2.6
1962	0.3	0.2	0.1	0.6
1963	0.2	0.1	0	0.3
1964	4	2.1	0	6.1
1965	2	3	0.1	5.1

Table 3.5-5: SAN JOAQUIN BASIN FALL-RUN CHINOOK SALMON ESCAPEMENT ESTIMATES (THOUSANDS), 1940-1996 (CONT.)

	River System			
Year	**Stanislaus**	**Tuolumne**	**Merced**	**Total**
1966	3	5	0	8
1967	12	7	0.6	19.6
1968	6	9	0.6	15.6
1969	12	32	0.6	44.6
1970	9	18	5	33
1971	14	22	4	39
1972	4	5	3	12
1973	1.2	2	1.2	4.4
1974	0.8	1.2	2	4
1975	1.2	1.6	2.4	5.2
1976	0.6	1.7	1.9	4.2
1977	0	0.5	0.4	0.9
1978	0.1	1.3	0.6	2
1979	0.1	1.2	2.1	3.4
1980	0.1	0.6	3	3.7
1981	1	14	10	25
1982		7	3	10
1983	0.5	15	18	33.5
1984	11	14	27	52
1985	13	40	16	70
1986	6	7	6	19
1987	6	15	4	25
1988	12	6	3	21
1989	2	1.3	0.2	3.5

Table 3.5-5: SAN JOAQUIN BASIN FALL-RUN CHINOOK SALMON

ESCAPEMENT ESTIMATES (THOUSANDS), 1940-1996 (CONT.)

	River System			
Year	**Stanislaus**	**Tuolumne**	**Merced**	**Total**
1990	0.5	0.1	0.1	0.7
1991	0.3	0.1	0.2	0.6
1993	0.4	0.4	1.8	2.6
1994	1.1	0.5	3	4.6
1995	0.6	1	2.6	4.2
1996	0.2	3	6	9.2

Source: T. Ford, Biologist, Turlock Irrigation District, personal communication, 19 August 1997.

Streamflow is an important factor affecting the productivity of the remaining habitat in the basin. Fall flows provide access to the spawning gravels and may be important in attracting returning spawners to the San Joaquin system. Spring flows may stimulate and transport migrating smolts out of the tributaries, provide suitable conditions for migrants in the San Joaquin River, and maintain acceptable water temperatures for juveniles (SWRCB 1995b). Increased flows for the benefit of salmon have been negotiated on the Stanislaus River, as part of the New Melones Interim Operation Plan, and on the Tuolumne River, as part of the re-evaluation of instream flows from the New Don Pedro Project by the Federal Energy Regulatory Commission (FERC). Increased flows are also being negotiated for the Merced River (CALFED 1997).

In-river gravel mining has left many large, deep pools in or adjacent to the tributaries. These pools provide habitat for salmon predators, particularly black bass, and are believed to be responsible for significant losses to out-migrating smolts (EA 1992). Some efforts are underway to isolate the pits or to restore the channel geometry (McBain and Trush 1998).

Additional factors leading to the decline of salmon populations include inadequate flow conditions during smolt emigration and adult immigration, and excessive water temperatures during spawning, incubation, and rearing life stages. Salmon migrating to and from the spawning tributaries must pass through the San Joaquin River upstream of the Delta. During the normal smolt emigration period, in low flow years, mean water temperatures in these reaches may exceed levels thought to be harmful to chinook salmon smolts. Stream temperatures are recorded at USGS and DWR gauging stations located in the San Joaquin Basin. In addition, the California Department of Fish and Game is compiling a database of stream temperatures from a series of thermographs (temperature recorders) located in each of the major tributaries (DFG 1995). TID and MID have compiled a database of their thermograph data for the Tuolumne River and San Joaquin River. Temperature models that show predicted water temperatures under various flow conditions have also been developed, or are being developed, for each major tributary.

Other water quality problems which are potentially of concern for salmon include high salinities and low dissolved oxygen in the San Joaqin River and Delta (USFWS 1995a). Dissolved oxygen levels less than 5 ppm (parts per million) and water temperatures higher than 66°F near Stockton have been identified as the cause of delays in the migration of adult chinook salmon (Hallock et al. 1970). Improved waste water treatment facilities at Stockton and the installation of a physical barrier at the head of Old River in dry years, which directs San Joaquin flows down the mainstem of the San Joaquin River, appear to have benefited the returning adult salmon to some extent.

At low river flow, high diversion rates at the CVP/SWP export facilities increase the proportion of San Joaquin River flow drawn toward the pumps via the Old River branch of the San Joaquin. Most chinook salmon reaching the CVP/SWP export facilities in the south Delta are from the San Joaquin River Basin (USBR 1986). Juvenile salmon, diverted towards the central Delta, experience reduced survival due to increased emigration time, high water temperatures, predation, entrainment in unscreened agricultural diversions, and Delta export pumping.

Mark-recapture studies since 1985 demonstrated that chinook salmon smolts released in the San Joaquin River downstream of the head of Old River survived better than those released into Old River (DFG 1992a). Maximum survival benefits are expected as a result of reduced exports, increased San Joaquin flows at Vernalis, and a barrier at the head of Old River during the spring emigration period (USFWS 1993). The barrier prevents salmon smolts from entering the south delta and avoids the influence of the export pumps at the spring.

Short-term increases in freshwater flows are termed pulsed flows. Pulsed flows in the tributaries are intended to benefit salmon by providing cues for salmon that stimulate migratory behavior. In spring, pulse flows can trigger the emigration of smolts from the tributaries to the ocean. In the fall, pulse flows signal the upstream migration of adults and may aid adults in identifying their natal systems. Pulsed flows also increase turbidity, thereby reducing visibility and predation losses during smolt emigration (EA 1992).

Since 1970, the Merced River run has been sustained in part by production of yearling fall-run salmon at the Merced River Fish Hatchery (DFG 1987). Because of low flows on the Merced, there has been a tendency for returning adult salmon to stray into agricultural drainage ditches, especially at Mud and Salt sloughs, and lose the opportunity to spawn. In the fall of 1991, an estimated 35 percent of the San Joaquin River salmon strayed into westside canals (DFG 1993). Since 1992, electrical and physical barriers have been installed to keep the migrating adults in the Merced River and out of the sloughs.

3.5.3.2 Steelhead/Rainbow Trout

Steelhead/rainbow trout have a broad range of life history strategies that include strains that always emigrate to the ocean and other strains that generally do not. Strains that do emigrate to the sea are called steelhead, and strains that remain resident in freshwater are termed rainbow trout. Both adult steelhead and rainbow trout typically survive after spawning, though it is rare that adults will spawn more than twice. Adult steelhead are generally larger than adult rainbow trout.

Steelhead have a life history similar to salmon. The primary difference is that juveniles will remain in the tributaries for at least one year before smolting. The majority of the spawning for winter-run steelhead generally occurs in December. Steelhead eggs are deposited in gravels and hatch in 30-60 days. Fry generally emerge during April and May, and juvenile steelhead will spend 1–3 years in freshwater before emigrating to the ocean, where they will spend 2–4 years before returning to spawn. Adults that survive spawning return to the ocean from April through June. Juveniles will usually emigrate from November through May.

Historically, winter-run steelhead are the only race found in the Central Valley and are native to the Sacramento and San Joaquin River Basins (USBR 1997g). In the San Joaquin River Basin, steelhead populations have been reduced to remnant levels. However, there is some evidence of a distinct anadromous run of steelhead in the Stanislaus River. Large rainbow trout are present in the upper reaches, and juvenile rainbow trout showing signs of smolting are trapped in the lower reach during studies designed to sample emigration of salmon smolts. Genetic studies are underway to determine whether these fish are part of a reproducing steelhead population within the Stanislaus River, strays from another basin, or resident rainbow trout (CALFED 1997). Past monitoring efforts have been inconclusive in determining the presence or absence of steelhead populations in the Tuolumne and Merced rivers, or the San Joaquin River upstream of the Stanislaus River. Recently, Central Valley steelhead were listed by the Federal government as a threatened species (USFWS 1998).

Resident rainbow trout can be found in the San Joaquin River, its tributaries, the Delta, and San Joaquin Basin reservoirs, but in numbers that are greatly reduced from their historical abundance in those areas (Yoshiyama et al. 1996).

Population Trends

There are a variety of indications that self sustaining stocks of rainbow trout continue to exist in the San Joaquin River system. Evidence is not as clear, however, concerning steelhead. DFG records contain reference to a small population characterized as emigrating steelhead smolts that are captured at the DFG Kodiak trawl survey station at Mossdale on the lower San Joaquin River each year. A few ripe rainbow trout which could be large enough to be small steelhead enter the fish traps at the Merced River Fish Hatchery every year.

There is some evidence of a distinct run of steelhead that may be using the Stanislaus river for spawning and rearing based on the presence of adult-sized rainbow trout in the upper part of the river and a small number of smolt-sized trout captured near the mouth of the river in 1996-1997 (Demko 1995).

3.5.3.3 Striped Bass

The striped bass (*Morone saxatilis*) is native to streams and bays of the Atlantic Coast. It was first introduced into the Bay/Delta Estuary in 1879. Within 10 years, this highly fecund and voracious predator was supporting a commercial fishery (SFEP 1992a).

California striped bass spend most of their life in the Bay/Delta Estuary and along the Pacific Coast, within a few miles north and south of the Golden Gate (DWR 1992). Landlocked populations of striped bass are also found in the Millerton and San Luis reservoirs.

Approximately one-half to two-thirds of bass spawning occurs in the Sacramento River system, while the remainder spawn in the Delta and the lower San Joaquin River below Vernalis (BDOC 1993). Important spawning areas include the area between Antioch Bridge and the mouth of Middle River in the San Joaquin River. Striped bass begin spawning in the Delta in spring, during April and May, when water temperatures reach about 60°F; most spawning occurs when water temperatures are between 61 and 69°F (BDOC 1993).

Striped bass spawn in fresh water where there is moderate to swift current. In slower currents, many eggs (which are slightly heavier than water) sink to the bottom and die (DFG 1993). The semi-buoyant striped bass eggs drift with river currents and are carried downstream. Larvae hatch two to three days after spawning. Initially, the larvae receive nourishment from the yolk sac, which is absorbed in five to ten days. As they move downstream toward the Delta, larvae begin feeding on small zooplankton. Upon reaching the western Delta, which is presently their primary rearing area, larvae are large enough to begin feeding on larger organisms such as the opossum shrimp (*Neomysis mercedis*). *Neomysis* remains the main food source until the striped bass reach their second year, when they become large enough to feed on bay shrimp and small forage fish. They reach maturity at 3–4 years of age and may live to 20–30 years of age. In recent years, most of the adult striped bass in the Bay/Delta system have been in the 4–7 year age classes. The older, more fecund fish, are no longer present in great numbers (DWR 1993c).

Population Trends

Beginning in 1982, the DFG stocked striped bass in the Estuary, largely as mitigation for various projects, in an effort to maintain the population. The stocking program was stopped in 1992 due to concerns that the effort was adding predators which might eat the endangered winter-run chinook salmon (BDOC 1994).

The decline in young bass is predominately due to a decreased survival rate during the first year of life. Increased mortality of striped bass eggs and larvae is due to increased entrainment losses at the CVP and SWP export facilities and at agricultural pumps in the Delta (DFG 1992b; DWR 1992).

Losses to export and entrainment are affected by freshwater diversion, specifically by the proportion of water diverted for export and within-Delta use (Jassby et al. 1994). Higher outflows move a higher percentage of eggs and larvae away from potential entrainment, while diversions lead to higher percentages of entrainment of eggs and embryos (SFEP 1992a). Higher outflows may also shift the entrapment zone to a location downstream of the Delta, where larval striped bass appear to survive better (DWR 1992).

Measurements, dating back to 1959, indicate that young striped bass survival increases in proportion to Delta outflow during April through July. There is also evidence that Delta outflow continues to influence bass survival through December. The DFG's statistical model for striped bass indicates that the survival of striped bass during their first year is directly correlated with the magnitudes of Delta outflow and State and Federal exports in the southern Delta, and that these first year conditions could determine subsequent abundance of adult bass (BDOC 1993). Besides reducing the likelihood of entrainment at diversions, higher outflows provide additional benefits for striped bass by increasing low salinity nursery habitat in Suisun Bay, increasing primary productivity (food supply), increasing turbidity (reduces predation on young), and diluting pollutants (SFEP 1992a).

Other factors contributed to the decline in abundance of striped bass are; food supply, competition with other species, toxicity, and illegal harvest.

3.5.3.4 Splittail

The splittail *(Pogonichthys macrolepidotus)*, or Sacramento splittail as it was formerly named, is a large minnow endemic to the Bay/Delta Estuary and San Joaquin Basin. It is presently proposed for listing under the Federal Endangered Species Act as a threatened species. Once found throughout low elevation lakes and rivers of the Central Valley, from Redding to Fresno, this native species is now confined to the lower reaches of the Sacramento and San Joaquin rivers, the Delta, Suisun and Napa marshes, and tributaries of north San Pablo Bay. Although the splittail is generally considered a freshwater species, the adults and sub-adults have an unusually high tolerance for saline waters for a member of the minnow family. Therefore, the splittail is often considered an estuarine species.

The splittail, which has a high reproductive capacity, can live 5–7 years and generally begin spawning at 1–2 years of age. Spawning, which is triggered by increasing water temperatures and day length, occurs over beds of submerged vegetation in slow-moving stretches of water, such as flooded terrestrial areas and dead-end sloughs. Year class strength has been highly variable over the last decade, with particularly strong year classes associated with seasonally flooded wetlands that provide optimum spawning and larval rearing habitat. Adults spawn from March through May in sloughs of the Delta, Napa Marsh, Suisun Marsh and on the inundated floodplains of large rivers during wet years. Hatched larvae remain in shallow, weedy areas until they move to deeper offshore habitat later in the summer. Young splittail may occur in shallow and open waters of the Delta and San Pablo Bay, but they are particularly abundant in the northern and western Delta (DFG 1992c; DWR 1992).

Splittail are benthic foragers that feed extensively on opossum shrimp (*Neomysis mercedis*) and opportunistically on earthworms, clams, insect larvae, and other invertebrates. They are preyed upon primarily by striped bass.

Population Trends

Population levels appear to fluctuate widely from year to year, but since 1980 splittail numbers have declined steadily, reaching their lowest recorded numbers in 1994. The overall decline in splittail numbers can be attributed to a variety of factors including: modification of spawning habitat, changed estuarine hydraulics, climatic variation, toxic substances, introduced species, predation, and exploitation (NHI 1992b). Splittail have disappeared from much of their native range because dams, diversions, and agricultural development have eliminated or drastically altered much of the lowland habitat these fish once occupied. Splittail foraging and spawning habitat has been lost due to land reclamation activities (CUWA 1994; DFG 1992c). The construction of levees where flood waters formerly inundated low lands has prevented the splittail from moving into habitat critical for its spawning and early life history.

Successful reproduction is strongly associated with high outflows preceding, during, and following spawning, as demonstrated by high correlations between abundance of splittail in the fall mid-water trawl survey and various monthly combinations of Delta outflow from the previous winter through early summer (DFG 1992b). The strong correlation of the abundance of young Sacramento splittail with freshwater outflows during the late winter and spring accounts, in part, for the observed decline in juvenile production during the recent drought period (NHI 1992b; DFG 1992b; Hanson 1994).

3.5.3.5 Reservoir Species

The reservoirs of the San Joaquin Basin have a wide variety of fish species (Table 3.5-1). Reservoir communities of fish are highly stratified by preferred habitat. In general, reservoirs are less productive per surface acre than lakes because their typically deep, steep-sloped basins and fluctuating water levels greatly limit habitat diversity.

The exact species composition in any given reservoir varies. Commonly introduced species include game fish such as largemouth bass, bluegill, black crappie and brown bullhead. Native species present may include Sacramento sucker, hitch, and tui chub. Hatchery strains of rainbow trout along with hatchery strains of chinook and kokanee salmon are often introduced into larger reservoirs.

Population Trends

Extensive draw down of reservoirs and fluctuating water levels are the primary causes of declines in reservoir fish species populations. Habitat quantity and quality are affected by reservoir operational practices during seasonal periods of irrigation, power generation, or reservoir recharge. However, reservoirs represent a highly managed ecosystem where naturally reproducing populations rarely exist and where most reservoir species populations are sustained by artificial means.

3.5.3.6 Delta Smelt

The delta smelt (*Hypomesus transpacificus*) is a small, short-lived, native fish which is found only in the Bay/Delta. Typical adults are nearly transparent and generally only 2–3 inches long. They formerly were one of the most abundant species in the Delta. Delta smelt tend to school in open waters adjacent to areas with aquatic vegetation (DWR 1992; SFEP 1992a). Delta smelt have been found as far upstream as Mossdale, on the San Joaquin River. Their normal downstream limit appears to be western Suisun Bay. Although, during periods of high outflow, they can be washed into San Pablo and San Francisco bays, they do not establish permanent populations there (SFEP 1992a). They usually inhabit the upper portion of the water column near the interface between intruding water from San Francisco Bay and water flowing out of the estuary (entrapment zone), where salinities range from 2 to 10 ppt (DFG 1992d).

Delta smelt typically live only one year and have low fecundity (SFEP 1992a). The location of delta smelt spawning varies from year to year, ranging from the lower San Joaquin and Sacramento rivers out to Suisun Marsh (DFG 1992d; USFWS 1994a). Though delta smelt larvae may be found almost anywhere in the Delta, they generally do not spawn in abundance in the southern Delta. Based on ongoing sampling programs, it appears that a significant portion of delta smelt spawning takes place in the northern and western Delta (DWR 1992).

The spawning season also varies from year to year and may occur from late winter (December) to early summer (July). In 1989 and 1990, peak spawning occurred in late-April and early-May (USFWS 1994a). The adhesive eggs descend through the water column and attach to submerged substrates such as tree roots, vegetation, and gravel (DFG 1992d). After hatching, the planktonic larvae are transported downstream to the entrapment zone where they feed on zooplankton (USFWS 1994b).

Population Trends

Information from independent data sets have demonstrated a dramatic decline in the delta smelt population, with particularly low levels since 1983 (DFG 1994). The exact timing of the decline is different in most of the sampling programs but falls between 1982 and 1985 (SFEP 1992a). The delta smelt was listed as a Federal threatened species by the USFWS in March 1993 and as a State threatened species by the DFG in December 1993.

Declines in delta smelt have been attributed primarily to restricted habitat and increased entrainment losses at Delta export facilities and diversions (DWR 1992; SFEP 1992a; USFWS 1994b). Reductions in available habitat occur when the entrapment zone moves out of the productive shallows of Suisun Bay and into the channels of the lower Sacramento and San Joaquin rivers as a result of low Delta outflow. The movement of the entrapment zone to the river channels potentially decreases the amount of area that can be occupied by smelt, and may also result in decreased production of phytoplankton and zooplankton (SFEP 1992a). When low flows result in movement of the entrapment zone into the central Delta, the delta smelt become more vulnerable to entrainment by the pumps of the SWP and the CVP, as well as by local agricultural riparian pumps (DWR 1992; NHI 1992a; SFEP 1992a).

The decline in delta smelt coincides with increases in the proportion of water diverted upstream of and within the Delta in recent years. Since 1984, the proportion of the water diverted at the export pumps from October through March has been higher, and has stayed higher for longer periods of time, than during any previous period, including the severe 1976–1977 drought. In order to avoid the effects of reversed flows, it is believed that higher Delta outflows are needed during February-June to transport larval and juvenile delta smelt into low salinity, productive rearing habitat in Suisun Bay and Suisun Marsh (USFWS 1994a).

Other contributing factors to the decline in the delta smelt population include: the presence of toxic compounds in the water, displacement of native copepods by introduced species, invasion of the Bay/Delta Estuary by the Asian clam (*Potamocorbula amurensis*), predation, very high floodflows, and low spawning stock (DFG 1992d, SFEP 1992a, USFWS 1994a).

The 1995 U.S. Fish and Wildlife Service (USFWS) Biological Opinion on the delta smelt called for a variety of measures to protect this species, including an intensified sampling program for all life stages. These surveys provide data on the distribution of eggs, larvae, and adults so that action can be taken to help move the smelt away from the zone of pump influence in the central and southern Delta. In addition, limits have been set for incidental take of delta smelt at the pumps and Federal/State sampling programs. When excessive numbers of delta smelt are taken, export and sampling operations must be reduced to conform to agreed limits, as occurred in 1997. Investigations of the delta smelt population have continued, and the species remains listed as threatened by state and federal agencies.

3.5.3.7 Longfin Smelt

The longfin smelt (*Spirinchus thaleichthys*) is a small, planktivorous fish that is found in several Pacific Coast estuaries from San Francisco Bay to Prince William Sound, Alaska. Within California, longfin smelt have been reported in Humboldt Bay and the mouth of the Eel River, but the largest population inhabits the Bay/Delta Estuary. Longfin smelt can tolerate salinities ranging from fresh water to sea water. Spawning occurs in fresh to brackish water over sandy-gravel substrates, rocks, or aquatic vegetation. In the Bay/Delta Estuary, the longfin smelt life cycle begins with spawning in the lower Sacramento and San Joaquin rivers, the Delta, and freshwater portions of Suisun Bay. Spawning may take place as early as November and extend into June, with the peak spawning period occurring from February to April.

The eggs are adhesive and, after hatching, the larvae are carried downstream by freshwater outflow to nursery areas in the lower Delta, and Suisun and San Pablo bays (Wang 1991; DFG 1992b). Longfin smelt form a gas bladder shortly after hatching which keeps them near the surface as they migrate downstream past the entrapment zone, and into the more saline waters of San Pablo and San Francisco bays. This is in contrast to the delta smelt, which does not form a gas bladder until several months after hatching. The lack of a gas bladder keeps delta smelt near the bottom and on the freshwater side of the entrapment zone. Adult longfin smelt are found mainly in Suisun, San Pablo, and San Francisco bays, although their distribution shifts upstream during years of low outflow.

Although both longfin and delta smelt spawn adhesive eggs in river channels of the eastern Delta, and have larvae that are carried to nursery areas by freshwater outflow, the two species differ substantially. Consistently, a measurable portion of the longfin smelt population survives into a second year. During the second year of life, they inhabit San Francisco Bay and, occasionally, the Gulf of the Farallones; thus, longfin smelt are often considered anadromous. Longfin smelt are also more broadly distributed throughout the Estuary and are found at higher salinities than are delta smelt.

Because longfin smelt seldom occur in fresh water except to spawn, but are widely dispersed in brackish waters of the Bay, their range formerly extended as far up into the Delta as salt water intruded. The easternmost catch of longfin smelt in fall mid-water trawl samples has been at Medford Island in the central Delta. Utilization of different water depth is a pronounced difference between the two species in their region of overlap in Suisun Bay.

The main food of longfin smelt is the opossum shrimp, *Neomysis mercedis*, although copepods and other crustaceans are important at times, especially to small fish. Longfin smelt, in turn, are eaten by a variety of predatory fishes, birds, and marine mammals.

Population Trends

Longfin smelt were once one of the most common fish in the Sacramento-San Joaquin estuary. Their abundance has fluctuated widely in the past, reaching their lowest levels during drought years but quickly recovering when adequate winter and spring flows were available. Since 1982, longfin smelt abundance has plummeted and remained at record low numbers. Their numbers also have declined in relative abundance to other fishes, dropping from first or second in abundance in most trawl surveys during the 1960s and 1970s, to being seventh or eighth in abundance.

The potential causes of decline are multiple and synergistic including: reduction in outflows, entrainment losses to water diversions, climatic variation, toxic substances, predation, and introduced species. Though longfin smelt have declined significantly in the last two decades, a petition to list them under the Federal Endangered Species Act was rejected by the USFWS in 1994 (USFWS 1994b). Currently the longfin smelt is listed as a Federal and State species of special concern.

3.5.4 Summary

Aquatic resources in the San Joaquin River Basin and Delta are varied and form complex interactions of species assemblages and habitats. Water development projects, the introduction of non-native species, and the creation of dams and large reservoirs over the past century have dramatically altered the habitats and reduced the abundance and distribution of many fish species.

By characterizing the ecological habitats and the factors affecting the recovery of these species within the project area, the potential impacts of the project can be evaluated. Specific habitats, such as spawning, rearing, and those used for migration of anadromous species have been identified as being vital to the species of prime importance and those which are considered indicators of a functional ecosystem. Factors identified as manageable and that contribute to the overall ability of a species to recover include habitat restoration, streamflow, and water quality.