State of California
The Resources Agency
DEPARTMENT OF FISH AND GAME

SACRAMENTO AND SAN JOAQUIN RIVER CHINOOK SALMON AND STEELHEAD RESTORATION AND ENHANCEMENT PLAN

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PART I INTRODUCTION

This plan is intended to outline the Department's restoration and enhancement goals for salmon and steelhead resources of the Sacramento and San Joaquin River systems and to provide direction for various Department programs and activities which may affect either of these systems or the resources they support. A large part of the Department's success in attaining these goals depends on the level of concern by the public, and the nature of decisions made by other governmental authorities and agencies. Therefore, this plan is also intended to provide the understanding and persuasive arguments for the restoration and enhancement of the State's salmon and steelhead resources.

The general goals of the Department are to (1) restore all depleted salmon and steelhead habitat to levels capable of sustaining population goals (2) at least double the natural salmon production by the year 2000 (3) develop an annual steelhead run in the Sacramento River system of 100,000 fish (4) ensure proper mitigation/ compensation of existing projects that have resulted in resource loss or which are continuing to cause resource damage (5) ensure that future projects avoid adverse impacts to salmon and steelhead and the habitats, or provide compensation where impacts cannot be avoided and (6) enforce the quality of fishing opportunities for inland sport and ocean sport and commercial users, and maintain populations at levels capable of supporting sustained year round harvest.

I-1 General Description of Resource and Area

I-1-A Geographic and Geologic Description

The Sacramento and San Joaquin rivers flow through what is referred to as the Great Central Valley (Figure 1). The Central Valley is a structural downwarp extending from Redding on the north more than 400 miles and spans 15,000 square miles (mi^2), or about one-tenth of the State.

The Valley is bordered on the west and south by the California Coast Ranges, on the north by the Klamath Mountains, and on the east by the Cascade Range and the Sierra Nevada. About the northern third of the Central Valley is known as the Sacramento Valley. The Sacramento River drains the Sacramento Valley southward along to its confluence with the San Joaquin River, near Suisun Bay and then westward through San Francisco Bay to the Pacific Ocean.

The Valley's southern part is called the San Joaquin Valley. Most of the San Joaquin Valley drains northward along the San Joaquin River, but the southern part is a basin of interior drainage tributary to ephemeral lakes (These lakes may spill into the San Joaquin River drainage during wet years).

The Central Valley is a depositional basin filled with a thick sequence of sedimentary rocks of Jurassic to Recent age. During Jurassic and early Cretaceous Periods, what is now the Valley were deep ocean and continental shelf areas. Subduction of ocean floor under the western margin of the North American Continent resulted in the uplift of the Sierra Nevada. Later, when subduction stopped, the Coast Ranges were uplifted. Over time, the structural trough between the two mountain ranges filled with a deep sequence of Cretaceous marine deposits followed by Tertiary to Recent continental deposits.

The present geomorphic configuration of the Valley includes a central zone of rich agricultural soils on the river floodplain. On both sides are extensive foothill areas that slope gently toward the valley floor. These are alluvial fan and stream deposits that are being eroded by the present stream systems.

I-1-B Chinook Salmon Natural History

Although five species of salmon are occasionally found in the Sacramento-San Joaquin River system, only chinook (or king salmon), Oncrohynchus tshawytscha (Walbaum), have hatchery and naturally reproducing populations. Because of their size and food quality, they are highly prized by both commercial and sport fishermen. The Sacramento-San Joaquin river system has historically been an important spawning area for this species.

Chinook salmon were formerly distributed from the Ventura River in southern California northward to the Canadian Arctic and they may migrate upriver to spawn in far inland areas. Within the historic geographic range of chinook salmon, California is the southernmost population. Environmental conditions in California are typically more variable than those encountered in more northern climes. Therefore, the species must be opportunistic in selecting spawning and rearing habitat in California.

Several distinct seasonal spawning migrations occur in California's Central Valley and are used to categorize different races of fish as follows:

1. Fall-Run Salmon. Fall-run salmon are presently the most numerous of the races. Fall run migrate into the river system from July through December and spawn from early October through late December. Peak spawning occurs in October and November although the timing of runs varies from stream to stream. Incubation occurs from October through March, and juvenile rearing and outmigration of smolts occur from January through June. Although the majority of young chinook salmon migrate to the ocean during their first few months following emergence, a small number remain in freshwater and migrate as yearlings. Chinook salmon mature at 3-4 years of age, although sexually mature 2-year-old males ("jacks") are common. Fortunately, much of the area in which fall run historically spawned was downstream from the construction sites for major dams; therefore, this race was not as severely impacted as spring- and winter-run salmon which spawned higher up in the stream systems.

2. Late-Fall-Run Salmon. Late-fall-run salmon migrate into the Sacramento River from mid-October through mid-April and spawn from January through April. Incubation occurs from January through June and rearing and outmigration of fry and smolts occur from April through mid-October. Late-fall-run salmon overlap during spawning migration with the fall run from mid-October through December. Although late-fall-run salmon were recognized prior to 1970, they were not included in Central Valley spawning stock inventories. Only after the construction of Red Bluff Diversion Dam was enumeration possible.

3. Winter-Run Salmon. Most winter-run salmon migrate into the Sacramento River system as 3-year olds, with about 90 percent spawning in the mainstem of the river. A run of several hundred winter-run salmon also spawns in the Calaveras River. Winter-run salmon enter the Sacramento River from

mid-December through mid-July and spawn primarily in the upper mainstem Sacramento River from mid-April to mid-July. The winter run usually appears in the Sacramento River near Red Bluff in December and often spends a relatively long holding period in the river before spawning. Incubation occurs from mid-April through mid-August, with outmigration of fry and smolts beginning in late July and ending the following June.

Historically, winter-run chinook spawned during May and June in the McCloud River. The completion of Shasta and Keswick dams in the early 1940's blocked access by salmon to this area. Winter-run salmon, however, were able to spawn successfully below Keswick Dam, taking advantage of cooler summer water temperatures afforded by water storage project releases. This run increased dramatically during the 1940's and 1950's, eventually surpassing the spring run in significance. Unfortunately, total salmon counts at Red Bluff Diversion Dam beginning in 1970 indicate a dramatic decline in winter-run stocks. From a high of 117,808 winter-run spawners in 1969, the populations declined to 1-2,000 spawners in recent years.

4. Spring-Run Salmon. Spring-run salmon were historically the most abundant race in the Central Valley. Now only the Sacramento River and its tributaries support a remnant run. This race migrated to higher elevation to spawn in areas upstream of the locations where major dams have been built; therefore, they were much more adversely affected by water development than were the fall-run. Construction of barriers to migration, higher water temperatures, and stream flow alteration have resulted in the extinction of the race of spring-run chinook in the San Joaquin River system. Spring-run salmon enter the Sacramento River from late March through September.. Many early arriving adults hold in habitats that maintain cool water temperatures through summer before spawning in the fall. Spawning occurs from mid-August through early October with a peak reached in September. Spring- and fall-run salmon spawning overlap in early October in the mainstem Sacramento River. Incubation occurs from mid-August through mid-January with rearing and outmigration of fry and smolts beginning in late November and continuing through April. Because this race is a fall spawner like the fall run, they have likely hybridized with fall run in the main stem upper Sacramento and Feather rivers. A genetically discrete strain may still exist in Deer, Mill, and Butte creeks where the two races are geographically separated when they spawn.

   Spawning generally occurs in swift, relatively shallow riffles or along the edges of fast runs where there is an abundance of loose gravel. The females dig spawning redds in the gravel and deposit their eggs in layers. The eggs are fertilized by the male and buried in the gravel by the female. Water percolates through the gravel and supplies oxygen to the developing embryos. Female chinook salmon produce 3,000 to 6,000 eggs depending on size and race of the fish.

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Salmon select spawning riffle areas within a narrow range of velocity and depth. Investigators have given much attention to developing information on depth-velocity preferences for spawning. Velocity is generally regarded as a more important parameter than depth for determining the hydraulic suitability of a particular site for spawning. The velocity determines the amount of water which will pass over the incubating eggs. Depths under 6 inches can be prohibitive for spawning activities. In general, optimum spawning velocity is 1.5 feet per second (fps), ranging from 1.0-3.5 fps. Salmon usually spawn at a depth ranging from 0.5 to 3 feet. Summer spawning winter-run salmon have been observed spawning at depths exceeding 21 feet, much deeper than other runs.

Substrate composition is another critical factor in determining the suitability of a section of river for spawning. Chinook salmon require clean, uncompacted gravel for building redds. The average size of chinook salmon redds is approximately 165 square feet (ft^2). The redds dug by late spawners may overlap those dug by early spawners by more than 60 percent. The territory required for a spawning pair has been estimated to be between 200 and 650 ft^2. Where spawning occurs throughout a protracted spawning season, as many as three or four redds may be dug in the area equivalent to the territorial requirements of one pair. A conservative range for the seasonal requirements for minimum spawning area per female is 75-100 ft^2. Requirements appear to be variable dependent upon the size of the fish and the characteristics of the stream.

It is important that the substrate composition be low in sand and fines so that its permeability to water remains high throughout the incubation and emergence sequence. The presence of fines inhibits the passage (percolation) of water around the eggs and thus reduces the oxygen supply to developing embryos. Water passage through a gravel bed tends to increase with increased water velocity above the substrate. Also, oxygen requirements of developing eggs and sack fry or alevins increase with increasing temperature. For these reasons (temperature, dissolved oxygen), the minimum percolation rate needed to ensure good survival rates can vary considerably and no single standard of maximum allowable fines can be applied to all situations. Transported sediments can become deposited on redds causing suffocation of eggs or alevins if the stream sediment load or sediment deposition increases after egg deposition. Several authors have proposed "optimum" streambed composition. Most propose 10 percent or 20 percent fines by volume as the maximum acceptable composition.

In general, the substrate chosen by chinook salmon for spawning is composed mostly of gravels from 0.75 inches to 4 inches in diameter with smaller percentages of coarser and finer materials. Although successful spawning will occur in suboptimal substrates, the degree of incubation success may be lowered depending on several factors. Gravel which has become cemented with clays and other fines, or is in an unstable position and in transport at some time during the spawning and incubation period are unsatisfactory and incubation will usually be unsuccessful. The preferred formula for gravel deposited for enhancement purposes is 80 percent .5 to 2.5 inches and 20 percent 2.5 to 4 inches diameter.

Water temperature is an important factor in determining the success of fish populations. When natural or artificial occurrences cause temperature shifts away from optimum ranges, salmon and steelhead populations are reduced. Unfortunately, as flows are reduced below dams, temperatures tend to increase. In general, the preferred temperature for chinook salmon spawning is 52°F with

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lower and upper threshold temperatures of 42°F and 57°F respectively. Acceptable temperatures during upstream migration may be somewhat higher, 57°F-67°F.

Eggs usually hatch in 40-60 days and the young "sac fry" usually remain in the gravel until the yolk-sac is completely absorbed. The rate of development is faster at higher water temperatures. Significant egg mortalities occur at temperatures in excess of 57.5°F with total mortality normally occurring at 62°F. A useful method of estimating time of emergence is calculation of degree-days. Chinook salmon eggs require approximately 750 degree-days for hatching and an approximate equal thermal period for resorption of the yolk sac for a total of 1,425 degree-days. Degree-days are computed by multiplying the incubation temperature (°F-32) by the number of elapsed 24-hour periods. Thus the total time from spawning to emergence at 50°F is approximately 79 days.

After emergence, chinook salmon fry attempt to hold position in the water column, and feed in low velocity area such as slack water and back eddies. They move to somewhat higher velocity areas as they grow larger. Movements of fry produced by fall-run adults occur during the December to March period. Timing of downstream migration of fingerling or pre-smolt juveniles varies according to run, but is typically during March, April, and May. In California most young salmon enter the ocean as 0-age smolts where they remain until their 3rd or 4th year when they return to their home stream to spawn (2- and 5-year old fish also participate in the spawning run in small numbers). Interchange of salmonid populations between stream systems may occur or be increased when adverse or confusing environmental conditions are encountered.

I-1-C Steelhead Natural History

The steelhead trout is an anadromous strain of rainbow trout, Oncrohynchus mykiss, that migrates to sea and later returns to inland rivers as an adult to spawn. In contrast to chinook salmon, not all steelhead die after spawning. With natural spawning greatly reduced in the Sacramento-San Joaquin river system, steelhead populations are mostly dependent on hatcheries to maintain fishable populations. Steelhead are highly prized and utilized by inland sport anglers.

Steelhead are generally distributed from southern California to the Aleutian Islands. Within California's Central Valley, a viable population of naturally produced steelhead are only found in the Sacramento River and its tributaries. No significant steelhead populations now occur in the San Joaquin River system.

In the Sacramento River, upstream migration occurs from early August through November, with the peak occurring in mid-September. Some upper Sacramento River steelhead runs peak in mid-winter. Sacramento system steelhead spawners are smaller than those found in other systems, averaging 2 to 3 years at maturity, and weighing one to 12 pounds. The Eel River strain of steelhead has been introduced into the American River at Nimbus Hatchery and has mixed with the American River strain; this has resulted in steelhead typically larger than the upper Sacramento River race. Mad River steelhead were also introduced in the American River but the results of that experiment are as yet unknown.

Spawning in the Sacramento River and its tributaries usually occurs from January through March and individuals which survive return to the sea between April and June. Females in this river system contain an average of 3,500 eggs, with a range of 1,500 to 4,500.

Like other salmonids, steelhead prefer to spawn in clean, loose gravel and swift, shallow water where the female steelhead are able to dig their redds in the gravel. Gravel from the excavation forms a mound or tail-spill on the downstream side of the pit. Eggs deposited along the downstream margin of the pit are buried in the gravel as excavation proceeds. An average of 550 to 1,300 eggs are deposited in each spawning redd. The males fertilize the eggs as they are deposited in the redd. Water percolating through the gravel supplies oxygen to the developing embryos.

River depth-velocity criteria for spawning and rearing steelhead differ slightly from those for salmon. Velocity appears to be about the same as for chinook salmon, 1.5 fps, but depth is slightly less, to about 0.75 foot. Gravel particle sizes selected by steelhead vary from about 1/4 to 3 inches diameter and are somewhat smaller than those selected by chinook salmon.

Steelhead seem to tolerate fewer fines than chinook salmon, probably because oxygen requirements for developing embryos are higher. A positive correlation between percolation rates of water through gravel containing eggs and survival rates of steelhead embryos is apparent. Oxygen content of the water is also positively correlated with egg survival.

The average size of a steelhead redd is smaller than that of chinook salmon. Redd sizes range from 22.5-121 ft^2 and average 56 ft^2. Female steelhead spawn in six to seven redds, however some overlap may occur as several females may spawn in the same area. Since most races of steelhead in the Sacramento system are considerably smaller than in other streams, their spawning area requirements are probably less.

Water temperatures required by various life stages of steelhead are lower than for chinook salmon. The preferred temperatures for rearing and for adult steelhead in the Sacramento River are between 50°F and 58°F although they will tolerate temperatures as low as 45°F. Studies show that the upper preferred temperature limit for rainbow trout in Sierra streams is 65°F. The temperature range for spawning is somewhat lower, ranging from 39°F to 49°F, and the preferred incubation and hatching temperature is 50°F. During the egg's "tender" stage, which may last for the first half of the incubation period, a sudden change in water temperature may result in excessive mortality.

Egg development in the Sacramento system takes place from December through April. The rate of development is a function of temperature with higher temperatures favoring faster development. At 50°F hatching occurs in 31 days; at 55°F hatching occurs in 24 days.

Newly hatched sac-fry remain in the gravel until the yolk-sac is completely absorbed, a period of 4 to 8 weeks. Emergence is followed by a period of active feeding and growth. The diet of newly emergent fry consists primarily of small aerial insects and invertebrate drift. As they grow, fry move from the shallow, quiet margins of streams to deeper, faster water.

Unlike juvenile chinook salmon, which typically emigrate soon after emerging from the gravel, juvenile steelhead in the Sacramento River typically remain in freshwater for a period of at least one year. Because rearing steelhead are present in freshwater all year, adequate flow and temperatures are important to the population at all times.

Generally, throughout their range in California, young steelhead spend from 1-2 years in freshwater before migrating downstream. In the Sacramento River, steelhead generally emigrate as one-year olds during spring and early summer months. Emigration appears to be more closely associated with size than age, 6-8 inches being the size of most downstream migrants. Downstream migration in unregulated streams has been correlated with spring freshets. However, in large regulated streams, spring freshets do not appear to be necessary to stimulate downstream migration.

Adult steelhead generally return to their parent stream to spawn. However, considerable straying occurs. About 2-3 percent yearly exchange of individuals in two neighboring coastal streams has been observed, demonstrating that population mixing can occur.

I-1-D Description of Chinook Salmon and Steelhead Resource

The Central Valley has supported average annual runs of 272,000 chinook salmon during the last 10 years and has contributed an average of 365,000 fish to ocean fisheries. Of the fish returning to spawn, 89 percent migrated up the Sacramento River system and spawned principally in the American River, Yuba River, Feather River, Battle Creek and the main stem of the upper Sacramento River (Figure 1). The remaining 11 percent migrated into the San Joaquin River system and spawned in the Cosumnes, Mokelumne, Stanislaus, Tuolumne, and Merced rivers.

Historically, the Central Valley salmon population was comprised mostly of spring-run chinook salmon. This race also probably made up most of the early inland commercial catch. The construction of dams on the major tributary streams prevented their access to historic spawning areas which resulted in their demise. Presently this race makes up only 5 percent of the total Central Valley run.

Fall-run salmon now make up 88 percent of the Central Valley salmon population. This race spawns at lower elevations than spring-run; therefore, they were less impacted by dam construction.

Almost all Central Valley steelhead return to the Sacramento River system. The average yearly run into this system is about 35,000 fish, most of which are produced at Coleman National Fish Hatchery (CNFH) on Battle Creek, at Nimbus Hatchery (NFH) on the American River, and at Feather River Hatchery (FRH) on the Feather River. Coleman Hatchery is federally owned and operated; NFH is federally owned, but operated by the State; and FRH is State owned and operated.

I-1-E History of Early Commercial Fisheries

Salmon were an important food item during the gold rush and railroad building era of the 1850's. Italian immigrants began to fish for salmon in the Sacramento and San Joaquin rivers to meet the demand.

The first salmon cannery was set up in 1864 under the name of Hapgood, Hume, and Company. The cannery was built on a floating scow and was located on the Sacramento River in what is now the town of Broderick. The young industry had some setbacks when initially skeptical Americans were hesitant to purchase the product. A market was developed in Australia and South America. By 1883, 21 canneries were established in California, most of them in the Bay Area. Gill netting, fyke netting and seining were the principal methods used prior to 1870. It was reported fishermen got as many as 700-800 pounds per day in fyke traps located at Rio Vista.

The newly formed State Board of Commissioners expressed concern for the fishery which had declined by 1870. This Board reported mining activity had almost destroyed runs in the American, Feather, and Yuba rivers. In response to this decline, the Board contracted with the U.S. Fish Commission to supply eggs for propagation purposes to stock the Sacramento River. Soon afterwards the commercial salmon catch began to increase and by 1880 reached almost 11 million pounds. This increase was attributed to improved fish cultural practices which gave great impetus to this phase of fishery management.

During the 1880's catches remained above 6 million pounds and by 1886 there were reported 3,000 persons fishing for salmon.

The Fish Commissioner's report for 1883-84 expressed concern about dams being placed on the Stanislaus, Tuolumne, and San Joaquin rivers and tributaries to the Sacramento River. The commission advocated a law to require screens on all diversions to prevent loss of young salmon migrating downstream.

Commercial cannery operations were terminated by the state legislature in 1920. The mean annual catch of the gill net fishery for the 1915-58 period was 1,984,931 pounds. This was about 4 million pounds less than the fishery annual fishery produced for the 1870-1914 period; the principal cause identified for this decrease was the large increase in the ocean troll fleet. Still as many as 6,463,245 pounds were landed in the inland fisheries as late as 1946; this equaled about 293,784 fish. The gill net fishery was terminated in 1957 by the state legislature.

Historically on their upstream migration, salmon populations endured intense fishing pressure from fyke traps, gill nets, and other presently banned harvest methods. Habitat destruction from mining, logging activities, and irrigation activities also exacted heavy tolls. Populations were periodically depressed but were able to make great rebounds from low numbers when advantageous environmental conditions occurred. Unfortunately, starting in the 1940's when high dams were constructed, resiliency of these populations was lost within their historic habitat when diversions reduced flows and migration routes to their spawning areas were blocked.

For a more complete description of the history of the early inland commercial fishing, refer to skinner 1962.

I-2 Present Restoration and Enhancement Program

Restoration and enhancement of salmon and steelhead fisheries in the Central Valley is a combined effort of the fisheries agencies, water distribution and land management agencies, and the public. Restoration is that part of fisheries improvement that seeks to raise fish production and population numbers in a debilitated salmon or steelhead stream to the levels that naturally occurred prior to a damaging incident or project. Mitigation is the degree to which adverse impacts are reduced by project design or resource restoration efforts.

By contrast, enhancement programs seek to improve on the existing condition financially and philosophically independent of previous factors that affected the fish population or habitat.

I-2-A Habitat Rehabilitation

The DFG, the United States Fish and Wildlife Service (USFWS), and the National Marine Fisheries Service (NMFS) are the fishery agencies principally involved with restoration in the Sacramento - San Joaquin river system. The DFG with its effort to create spawning and nursery habitat through expenditure of programmatic and bond funds, has the only significant fisheries enhancement program. The United States Bureau of Reclamation (USBR) and the USFWS attempted an enhancement project at Red Bluff Diversion Dam that has proven unsuccessful. The DFG and DWR have become extensively involved in a program to restore stream and riparian habitats in the upper Sacramento River drainage under the SB 1086 legislative mandate.

Several spawning habitat improvement projects have been implemented by DFG on the Sacramento River from Redding to Anderson and on tributaries such as Clear, Mill, and Deer creeks. Unless hydraulic controls are present, recreated spawning riffles are usually short lived. Most of the work to date has been experimental and long term benefits have not been documented.

Maintenance of screens and ladders on tributary streams saves many thousands of young salmon and steelhead each year. For example, all diversions on Mill, Deer, and Antelope creeks are provided with both screens and ladders and two natural falls on Deer Creek have been laddered. Attempts are being made to improve the ladder at McCormick-Saeltzer Dam on Clear Creek. Through relicensing procedures, Pacific Gas and Electric Company (P.G.& E.) constructed a new screen and ladder at their diversion on South Cow Creek. A new screen is planned for the Orwick diversion on Battle Creek. The Department constructed and operates a screen on the Anderson Cottonwood Irrigation District (ACID) diversion at Redding and operates the old fish ladder there.

In 1988 and 1989 the DFG placed a combined total of approximately 30,000 cubic yards of gravel in the upper Sacramento River near Keswick dam. Funding for these projects was partially provided by the USBR. DFG in cooperation with DWR, USFWS, and NMFS is currently planning for another project which will add 100,000 cubic yards of gravel to the river for replenishment of spawning beds downstream. Other gravel restoration projects are underway or being planned in the San Joaquin River system.

I-2-B Mitigation Projects

There have been numerous actions taken to prevent or mitigate impacts to the salmon and steelhead resources of California's Central Valley as a result of land and water use developments. These actions have generally been in the form of physical construction, legal actions, or operational procedures to minimize fishery losses.

The construction and operation of the SWP and the CVP has resulted in significant adverse impacts to the salmon and steelhead resources of the Central Valley. Anadromous fish hatcheries at the base of three project reservoirs were constructed to mitigate for the lost salmon and steelhead habitat upstream of those dams. To compensate and protect downstream resources, permit conditions or memoranda requiring minimum instream flows below project dams were established. Unfortunately, those flows have frequently proven inadequate to maintain healthy populations of salmon and steelhead. Operational features designed to minimize project impacts include controlling the rate of instream flow change to protect small fish on stream edges, trucking of smolts from hatcheries to the estuary, release of large pulses of water to assist and encourage downstream migration hatchery and naturally produced smolt migration, and the operation of major diversion dams to minimize impacts to upstream and downstream migrating fish.

Physical constraints typically are features of water development and delivery projects. Many of the major irrigation diverters have been required to screen their intake structures to minimize entrainment of downstream migrating juvenile salmon and steelhead. Grow-out ponds are being used at several locations to increase smolt production or produce larger smolts to replace those that would have naturally been produced were it not for dams and water diversions.

Legal and administrative measures taken to protect the salmon and steelhead resources include the passage of laws, establishment of fishing regulations, adoption of policies, binding agreements signed by resource agencies and resource developers, and the development and adoption of a variety of planning documents. The California Environmental Quality Act, National Environmental Protection Act, Federal Clean Water Act, and the Fish and Wildlife Coordination Act provide much of the legal basis for environmental protection and restoration for the State fishery resources.

The Fish and Game Code contains many sections which either specifically or generally provide for the protection and continued existence of the native stocks of salmon and steelhead in California. Some of these Code sections and key provisions are:

Section 1505 - Provides for the protection of certain spawning areas on State-owned lands as necessary to protect fishlife. Requires the Director to, " . . . disapprove any alterations of any prime salmon and steelhead spawning areas when in his opinion such alterations would prove deleterious to fishlife."

Section 1600 - Identifies the importance of California's fish and wildlife and begins by stating, "The protection and conservation of the fish and wildlife resources of this state are hereby declared to be of utmost public interest."

Section 2760 et seq. - Provides policy relative to protection and restoration of the State's fishery resources and makes specific findings relative to the impacts caused by water development and the significant values associated with fish and wildlife. The Act (Keene-Neilson Fisheries Restoration Act of 1985) states that "California intends to make reasonable efforts to prevent further declines in fish and wildlife, intends to restore fish and wildlife to historic levels where possible, and intends to enhance fish and wildlife resources where possible".

Section 5900 et seq. - The laws found within this chapter deal with dams, conduits, and screens as they relate to protection fishery resources. Project developer responsibilities for providing adequate fish flows, fish ways and fish screens are identified.

Section 6100 - This section gives the Department of Fish and Game the authority to require screens and screen maintenance on any new water diversion after 1971 which the Department finds to be deleterious to salmon or steelhead.

The Fish and Game Commission has adopted various regulations and policies which are designed to protect the State's salmon and steelhead resources. Regulations restrict size and numbers of sport-caught fish to ensure that sufficient numbers of fish survive to spawn. Commission policies for the protection of salmon and steelhead have been adopted to guide the Department in their review of land and water development proposals. The tremendous public value of salmon and steelhead is recognized and the protection of this resource has, therefore, been given a very high priority by the Commission. A number of federal acts and projects which affect fisheries are appended in the published Fish and Game Code and Title 14.

Many water or hydro power distribution agencies receiving water or power from the Central Valley are directly or indirectly involved with restoration of salmon and steelhead fisheries through mitigation requirements and power development costs. These mitigation measures include, minimum flow releases, hatcheries, spawning channels intake screening and temperature control.

There are four hatcheries in the Central Valley that raise chinook salmon and steelhead trout and one hatchery that raises only chinook salmon.

<u>Coleman National Fish Hatchery.</u> This federally operated hatchery is located on Battle Creek about 15 miles northeast of the town of Red Bluff. This hatchery was built by the USBR as part of the salvage plan to mitigate for the loss of historical spawning areas where access for salmon and steelhead was blocked by construction of Keswick and Shasta dams. This hatchery has been in operation since 1943 (at about the same time the older Battle Creek Hatchery was closed) and is funded and operated by the USFWS. Its present yearly production goal is 12 million 90/lb. (fingerling) fall-run chinook, 2 million 40/lb. (fingerling) late fall-run chinook, and 1 million 7/lb. (yearling) steelhead. After planned improvements are successfully completed, it may also have the capability to rear spring and winter-run chinook.

<u>Feather River Hatchery.</u> This DFG operated salmon and steelhead hatchery is located in the town of Oroville. The hatchery was built by the California Department of Water Resources (DWR) to mitigate for the loss of historical spawning areas when access for chinook salmon and steelhead trout was blocked

by construction of Oroville Dam. The facility started operation in 1967. The cost of rearing mitigation fish is paid by the DWR. The hatchery has an annual production goal to raise 8.0 million 30/lb. (fingerling) fall-run chinook, 2.0 million 50/lb. (fingerling) chinook, and 0.4 million 3-4/lb. (yearling) steelhead. An adjunct to the hatchery, the thermolito, has a goal of rearing 2.6 million 30/lb (fingerling) chinook paid for principally from Salmon Stamp and Salmon Landing tax receipts.

Nimbus Hatchery. This DFG operated salmon and steelhead hatchery is located on the American River about 20 miles east of the City of Sacramento. This hatchery was built by the USBR to compensate for the loss of access to historical spawning areas resulting from the construction of Nimbus and Folsom dams. It started operation in 1955 and has been run by the DFG; the cost of rearing mitigation fish is paid by the USBR. Its present yearly production goal is to raise 4.5 million 50/lb. (fingerling) fall-run chinook and 0.5 million 3-4/lb. (yearling) steelhead.

Mokelumne River Fish Installation. This fish rearing facility is located near the town of Clements. This hatchery was built by the East Bay Municipal Utility District (EBMUD) to mitigate for the loss of access to historical spawning areas resulting from the construction of Camanche Dam. It started operation in 1965. The hatchery is operated by the DFG. The cost of rearing mitigation fish (100,000 salmon or steelhead) is paid by EBMUD. Its present annual production goal is to raise 2 million 30/lb. (fingerling) chinook and 40,000 yearling steelhead. The cost of rearing the non-mitigation fish is paid for by salmon stamp money and DFG.

Merced River Fish Facility. The most southerly hatchery is located about 5 miles east of the town of Snelling. It was constructed with Davis-Grunsky funds by the Merced Irrigation District (MID) to enhance runs in the Merced River which had been depressed for many years. The facility has been in operation since 1971. It is operated and primarily funded by the DFG with partial facility maintenance paid by the MID from the Davis-Grunsky account. The annual production goal is 0.4 million 8-10/lb. (yearling) and 0.6 million 70/lb. (fingerling) fall-run salmon.

During the late 1950's and early 1960's, artificial spawning channels were believed to be a viable method of producing salmon. A few spawning channels were built in California including ones on the Feather and Mokelumne rivers and the large Tehama-Colusa Fish Facility (TCFF) built in conjunction with the Red Bluff Diversion Dam (RBDD) on the Sacramento River.

Although artificial spawning channels work for some species of Pacific salmon, they have not been successful for chinook. All of the above spawning channels have been converted to rearing ponds. Very small spawning channels with short raceways for rearing may have some potential for limited use.

I-2-C Citizens' Participation

Citizens play a major part in management of salmon and steelhead in California. The popularity of salmon and steelhead can be measured both by the sport and commercial fisheries and by the public interest in nature films, books, magazines, and nature education. A recent survey conducted for the DFG found the vast majority of the public to be interested in protection of fish and wildlife. Salmon and steelhead are associated by the public with clean natural streams, and have been widely considered the mark of a healthy environment.

Commercial fishermen's and sportsmen's organizations take an active part in debates over harvest regulations and frequently participate in hearings and negotiations over land and water project mitigation and restoration. They have shown strong support for government funding for restoration and enhancement programs.

The following is a list of some of the principal private groups involved in salmon and steelhead restoration and management in the Sacramento-San Joaquin river system:

United Anglers of California
California Sportfishing Protection Alliance
American Fisheries Society
California Striped Bass Association
California Trout
Sacramento River Preservation Trust
Salmon Unlimited
San Joaquin River Systems Committee
Trout Unlimited
Upper Sacramento River Salmon & Steelhead Advisory Committee

Part II RIVER SYSTEM AND RESTORATION NEEDS

II-1 Upper Sacramento River System

II-1-A Physical Environment

The Sacramento River is the largest river system in California and the State's most important chinook salmon river. The basin represents about 17 percent of California's land area, yet yields 35 percent of the water supply. The upper Sacramento River comprises the section from the mouth of the Feather River to Keswick Dam including all tributaries.

The Sacramento River and its numerous tributaries drain parts of the Coast Ranges, Klamath Mountains, Cascade Range, Sierra Nevada, and Great Valley geomorphic provinces. From its headwaters in the Klamath Mountains, the Sacramento River is a cool, clear and sparkling mountain stream. As it flows southward, it is joined by numerous small tributaries draining the metamorphic rocks of the Klamath Mountains on the west and the volcanic Cascade Range on the east. Near Redding the river is broader and slower, but below Jellys Ferry it enters Iron Canyon and forms a series of rapids (Figure 2). At Red Bluff, the river enters the valley proper. Above, it is a bedrock stream controlled by the underlying geology. Below, it is an alluvial stream flowing through the Sacramento Valley, controlled by its own water and sediment discharge.

Between Red Bluff and Colusa, the Sacramento River is a typical meandering gravel-bed stream, eroding its banks on the outside of bends and depositing gravel bars on the inside. Below Colusa to Sacramento, the river is a sand-bed stream. Here, both natural and man-made levees control the river. Only low flows stay in the river while flood flows are diverted through an overflow and bypass system.

Geography. The Sacramento Valley in the reach from the mouth of the Feather River to Keswick Dam ranges up to 50 miles wide with relief ranging from 170 feet above mean sea level near Hamilton City to 300 feet near Red Bluff (Figure 2). The reach from Red Bluff to Chico Landing lies in a region of agricultural bottomlands and low, flat-topped ridges generally covered with grass, brush, and trees. Downstream, past the Sutter Buttes, the river meanders through intensively cultivated fields, and the City of Sacramento into the Delta. About 4 miles below Keswick Dam, the river widens to about 500 feet. Near Redding the river is broader and slower, but below Jellys Ferry it enters Iron Canyon and forms a series of rapids before entering the alluvial plains of the Sacramento Valley near Red Bluff.

Geology. Above Redding, the Sacramento River drains the Klamath Mountains geologic province on the north and west. Here the Klamaths consist mostly of Jurassic and older metamorphic and ingneous basement rocks that are generally hard and erosion resistant. Tributaries such as the Pit and McCloud rivers, drain the Cascade Range on the east. The Cascade Range consist mostly Tertiary to Recent volcanic rocks, generally tuffs, breccias, and flows.

Below Redding the Sacramento enters the Great Valley geologic province. Between here and Jellys Ferry, the river flows across older alluvial deposits. From Jellys to Red Bluff, the river flows through the deep and narrow Iron Canyon, a zone of recently uplifted volcanic rocks. Tributaries entering in this reach include Clear and Cottonwood on the west, and Stillwater, Cow, Ash, Bear, Battle, and Paynes creeks on the east (Figure 2).

Below Red Bluff the Sacramento River flows over deep alluvial deposits of the Sacramento Valley. Near the river, Quaternary alluvial fan deposits from tributaries surround a central belt of stream alluviun and flood plain deposits. Soils here are deep, rich and widely used for agriculture.

On the west side, rolling valley foothills are underlain by the Tertiary-Quaternary Tehama Formation, mostly silt and clay with interbedded sand and gravel. Quaternary terrace deposits and the reddish, cemented gravels of the Pleistocene Red Bluff Formation cap the Tehama in places. Cretaceous shales outcrop along the western valley rim. Westside streams include Red Bank, Elder, Thomes, and Stony creeks.

On the northeast side, the valley merges with the Cascade Range of volcanic breccias, volcanic cones and basalt plateaus, rugged foothills, and deep stream-cut valleys. This area contains a large portion of Lassen Volcanic National Park. The lower foothills consist of erosion-resistant volcanic mudflows and stream-deposited fanglomerates. Eastside tributaries of the Sacramento River that drain this area include Antelope, Mills, Deer, and Big Chico creeks.

Tributaries draining the westside generally carry large quantities of sediment while eastside tributaries carry considerably less.

Hydrology. The climate has moderate, wet winters and hot, dry summers. Eighty-five percent of the precipitation occurs between November and April. The mean seasonal precipitation is 36 inches at Redding, 22 at Red Bluff, and 19 near Colusa, however, precipitation in much of the headwater area may reach 60 inches or more.

Since December 1943, flows in the Sacramento River have been regulated by Shasta and Keswick dams. The mean annual runoff is about 6.3 million acre feet. Since 1963, the river has received an average of over one million acre feet of water from the Trinity River basin. The maximum release since Shasta Dam began operation was 81,400 cubic feet per second (cfs) in April 1, 1974, although the minimum flows since 1960 have been determined by the flow agreement with the Department (minimum 2000 cfs) and have ranged down to about 2300 cfs, with the lowest daily average of 2460 cfs.

Winter flows in the river at Redding are largely determined by flood control operations during normal and wet years. Flows during critically dry years are determined by the DFG agreement.

Summer flows are generally determined by downstream needs for irrigation and at times for salinity control. Normal summer flows range from about 12,000-14,000 cfs.

Two major diversions occur in the river at Red Bluff DIversion Dam immediately downstream from Red Bluff and at Glen Colusa Canal near Hamilton City.

II-1-B Salmon Resources

There are four distinct races of chinook salmon that spawn in the upper Sacramento River. They are named for the time period they first enter fresh water. Fall-run fish usually spawn within a few weeks of their arrival in the fall. Late-fall-run spawn in the winter. The spring-run spend the summer in deep, cool pools and spawn in the fall. True winter-run fish enter the river in the winter and spawn early the following summer.

Past. Both spring-run and fall-run chinook were abundant in the upper Sacramento River prior to Federal-State water development, although significant declines were noted by 1929. Causes of the declines were thought to include overharvest, blockage by irrigation dams (ACID during 1917-1927), and habitat degradation (railroad construction and hydraulic mining). There is limited information on the magnitude of the salmon runs prior to the construction of the CVP and the early decline of the populations. However, in 1905 the combined chinook salmon egg collection at three upper Sacramento River egg stations located off the main river represented a trapping of at least 30,000 adult spawners which would indicate that the total from all other tributaries and main stem could easily exceed that number by more than tenfold. From the total catch data for the Sacramento-San Joaquin rivers it has been estimated that the peak chinook salmon runs in the Sacramento River system may have been as large as 800,000 to 1,000,000 fish, with an average run size of about 600,000 fish prior to 1915.

The first serious effort to determine the size of the chinook salmon run in the upper Sacramento began just prior to the construction of Shasta Dam as part of an effort to evaluate the project's impact. Estimates of fall and spring-run chinook are considered low for the upper Sacramento River during the pre-project sampling period due to inefficient sampling.

The spring-run and winter-run chinook were both headwater spawners prior to the placement of Shasta Dam as a complete barrier to migration. The winter run was well established in McCloud River.

Present. Beginning in 1950, complete data on the distribution of fall spawning chinook salmon became available for the Sacramento River system. A peak value of 403,000 spawners was observed in 1953 which was speculated to be the highest escapement during the period 1939 to 1969. Based on an analysis of the Department's annual salmon stock reports from 1956 to 1985 for mainstem Sacramento River (excluding tributaries), on the average there has been about a 50 percent decline in the spawning population in the last 15 years, primarily in the reach above Red Bluff.

The first estimates of spring-run populations began in 1967 through counts at RBDD. These counts show dramatic fluctuations in run sizes over the last 20 years with the average annual run size being 12,600 fish. It is doubtful that the spring run on the mainstem Sacramento River continues to be a truly distinct stock because of the overlap of time and place of spawning with the present fall run. This overlap was forced on the populations by Shasta Dam. Genetically pure populations of spring-run chinook may exist in the upper reaches of a few Sacramento River tributaries including Mill and Deer creeks. Mill and Deer creeks spring-run populations have undergone drastic declines (80-85 percent) in the past two decades.

Late-fall-run chinook counted at RBDD show a dramatic decline over the last 20 years. The runs during the 1980's are only one-third of those observed during the late 1960's.

Winter-run chinook have suffered a severe decline since the beginning of counts at RBDD. The runs during the 1980's have been only 5 percent of those recorded during the 1960's. The decline prompted conservation groups to file separate petitions to list the winter run as a federal threatened and as a state endangered species. The listing for both designations has been denied. Implementation of protective actions are planned by federal and state agencies to restore the winter run.

During the period of 1976 through 1985, the combined average annual run of chinook salmon in the upper Sacramento River including all tributaries has been 233,888.

Salmon Fisheries. During recent years the Central Valley river systems have been the origin of 90 percent of he commercial catch landed between San Francisco and Monterey, 40 percent of California north coast landings, and

40 percent of the Oregon landings. Of the total population upon which this harvest is based, about 50 percent of the fish originate in the upper Sacramento River.

The market value of the average size run of fall chinook in the upper Sacramento River during the period 1980 to 1985 was approximately 22 million dollars. This is based on economist Phil Meyer's actual business revenue and profit estimates without considering estimates of income multipliers for the community at large which could increase this value by 39 percent. If the restoration efforts for the fall run were successful, and the increased stock were utilized by the fishery, the market value of the production would be 79 million dollars annually without considering income to the community at large. The difference between the economic yield from restored and present populations shows significant benefits to the economy of communities along the coast, San Francisco Bay and the Sacramento and San Joaquin rivers where significant sport fishing occurs.

Potential. The long-term objectives for production of each race of adult salmon in the upper Sacramento River and its tributaries are displayed below. Restoration of chinook salmon stocks to these levels would be comparable to the levels of the 1950's. These goals are expressed as spawning escapements that are needed to maintain the sustainable catches.

Restoration goals for production of adult chinook salmon from the upper Sacramento River (figures in thousands of salmon).

Stock	Escapement	Stock Catch	Ratio of Catch to Escapement	Total
Fall	300	600	2:1	900
Late Fall	25	50	2+:1*	75
Winter	70	42	0.6:1	112
Spring	70	105	1.5:1	175
Total	465	797		1,262

* Although the catch/escapement ratio for Sacramento River late-fall- run chinook has not been ascertained, it is estimated to be substantially higher than the ratio for fall-run.

The methods selected for achieving the production goals should concentrate on restoring the stream environment to high productivity and high survival of smolts to the ocean. The hatchery production objective should be to augment natural production while holding competition with natural production and potential loss of genetic stock identity to a minimum. There is legislative intent contained in the Fish and Game Code that affirms the goal of maintaining natural habitat in a condition that allows high productivity of all types of fish and wildlife (sections 1505, 2601, 1301, 2761, 2762, 2765, 5937, 5900, 1600, and 1400). Fish and Game Commission policy also directs the

Department to make natural rearing of salmon and steelhead a priority over hatchery production. Additionally, Water Code section 1243 establishes the intent to preserve fish and wildlife resources in natural systems.

II-1-C Steelhead Resources

Steelhead provide an important recreation resource in California. Central Valley populations are almost entirely the result of an aggressive hatchery production program, but opportunities exist for increased natural production.

Past. There is little information on the magnitude of the steelhead trout population prior to construction of Shasta Dam.

Present. There was a notable increase in the size of the steelhead trout populations in the upper Sacramento River below Shasta after completion of the Shasta project. This may have been due, in part, to the favorable flow and temperature conditions created by the dam during the summer rearing period for steelhead and displacement of upriver populations down to the Redding area.

The estimated annual population of adult steelhead in the upper Sacramento ranged up to 28,000 fish during mark and recapture studies conducted in the the 1950's. The number of adult steelhead passing RBDD since 1966 shows a steady decline in the steelhead population down to less than 5,000 fish per year in the 1980's. In 1983 the count reached an all time low of 2,000 fish. The present steelhead stocks are predominately a hatchery product. The status of the wild stocks is largely unknown, but the numbers of late-spawning winter steelhead in Mill and Deer Creeks are known to be very low.

Steelhead Fisheries. The estimated sport catch of steelhead during studies conducted in the 1950's was as high as 11,000 fish. During the late 1960's the estimated sports catch ranged as high as 7,000 fish. These historical catches represent market values in the vicinity of 2 million dollars annually without considering community induced benefits. Presently, the actual counts over RBDD represent only one-fifth of the estimated sport catch during the 1950's. Thus, the present sport catch is less than one-tenth of the historical, indicating loss of significant benefits to the economy and communities along the upper Sacramento River.

Potential. The long term objective for production of adult steelhead in the upper Sacramento and its tributaries is 20,000 fish. Improved or expanded hatchery production may be necessary to attain this goal. Improvement of conditions in Clear Creek could be expected to contribute significantly toward this goal.

II-1-D Natural Production

Chinook salmon natural production occurs predominantly in the main stem upper Sacramento River. The natural production of chinook accounts for approximately 70 to 90 percent of the total run since 1967.

Steelhead production in the upper Sacramento is predominately hatchery maintained. Most of the natural production of steelhead occurs in tributaries to the upper Sacramento River. Successful spawning in the mainstem of the Sacramento River is limited by the lack of smaller sized gravel, which is principally confined to wide braided areas in the river. Additionally, the discharge of a dilution of metals from Spring Creek Debris Dam is adjusted to limits that are partially protective of salmon juveniles but not of steelhead juveniles (which are more sensitive).

II-1-E Hatcheries

The role of the Coleman National Fish Hatchery (CNFH) for juvenile chinook production is displayed below for both current and future production goals.

Chinook Species	Size at Release (Fish/lb.)	Present Number	Future Number	River Distribution
Fall	90	12,000,000	11,000,000	upper Sacramento
Late Fall	40	2,000,000	1,000,000	upper Sacramento
Winter			1,500,000	upper Sacramento
Spring			2,000,000	upper Sacramento

Trucking experiments with the CNFH product indicate that planting fish downstream from the upper Sacramento River results in extremely poor returns to the hatchery. These returns are sufficiently poor to result in insufficient broodstocks to meet the hatchery goals. Some compromise between direct hatchery releases and trucked downstream releases will probably be developed to meet future production goals.

The steelhead population is predominately maintained by CNFH. Approximately 65 percent of the steelhead migrating past the RBDD appear, based on fish sampling at the dam, to be hatchery propagated fish. The long-term objective of CNFH is to produce and release sufficient yearling steelhead to contribute 5,000 hatchery produced adults.

II-1-F Environmental Problems and Preferred Solutions

Inadequate Instream Flow Releases From Keswick Dam. It is generally held that the existing flows from Keswick Dam are inadequate for salmon. The flows are stipulated for the Shasta project in a 1960 Agreement that is included as a term in the State Water Rights License 9956 dated 1972. Minimum fish flow releases described in the water rights license are:

"Bypass or release at Keswick Dam at least:

January 1- February 28	2,600 cfs
March 1 - August 31	2,300 cfs
September 1 - November 30	3,900 cfs
December 1 - December 31	2,600 cfs "

(There is an unofficial modification of the schedule allowing a stable flow of 3250 cfs from September through February, except during dry years when flows may be reduced.)

In practice, these stipulated flows are always exceeded during the export phase (April through September) of reservoir operations and generally during the storage and flood control phase of reservoir operations.

The stipulated flows do not adequately protect against the dewatering of redds because stable flows are not required during the incubation periods. Typically, releases of 6,000 cfs occur at Keswick during the onset of fall spawning due to requirements in the Delta and other water and power needs. As these needs diminish during the late fall and early winter, the need to store water can initiate a reduced or stipulated minimum streamflow release affecting redds of fall, late-fall-, and spring-run salmon and rearing of winter-run juveniles. Additionally the agreement lacks a flow reduction rate that will minimize stranding of young salmon and steelhead.

After completion of the present instream flow study being conducted for the DFG, the final flow recommendations for fish production will be developed. These recommendations will include stable flow regimes for prevention of dewatering of redds and a combination of the different flow needs for the life stages for four races of salmon. Collectively, the early life stages of these four races are present in the river year-round and must be accommodated. Recommendations will be provided to reduce stranding of young fish during periods of flow reductions.

The flow needs could be provided through a formal Memorandum of Agreement between the USBR, DFG, and the USFWS. The Agreement should replace the existing Agreement and be included as a term in State Water Rights License 9956.

Although fishery maintenance is not a stated purpose in Congressional authorization for the Shasta Project, the Department of Interior recognized fish protection as a miscellaneous project function in a report forwarded to Congress February 24, 1947 (Interior Department 1946).

Inadequate Water Quality for Fish Production. There are intermittent problems of lethal concentrations of dissolved metals discharged to the river at Keswick from Iron Mountain Mine. Releases from Shasta Dam are made to manage against toxicity in the river by dilution together with limited storage of toxins in Spring Creek Debris Dam; however, limited availability of dilution water has resulted in major fish kills in some years during the wet season when leaching and overflow occur. Every year the levels of metals in the river in the Redding area exceed the safe levels for salmon and steelhead determined by toxicity tests conducted by the Department and other workers. These chronic exposures can reduce the growth rate and disease resistance in young salmon. The existing scheme for dilution manipulation is stipulated in a Memorandum of Agreement between the DFG, USBR, and the State Water Resources Control Board (SWRCB).

There are also intermittent problems of temperatures released from Shasta Dam that are lethal to incubating salmon eggs (temperatures greater than 57°F). Shasta Dam has a fixed mid-level outlet to the river which can release stored heat from the upper layers of the reservoir when the reservoir is drawn down to low levels during below normal water years. Increasing water demands on the CVP will increase the frequency and intensity of the temperature problem in the future.

The water quality control plan for the Sacramento River basin established by the Central Valley Regional Water Quality Control Board (CVRWQB) and approved by the SWRCB specifies a water temperature objective of 56°F be attained in the salmon spawning area. Available temperature records in the river between Red Bluff and Redding show there has been a significant failure to attain the temperature objective.

During extremely wet years a prolonged turbidity problem occurs in the upper Sacramento River long after tributary streams have cleared during the summer. Turbid silt-laden waters are stored in the reservoir and released to the river over long periods of time. Persistent turbidity can reduce the growth rate of juvenile salmon, reduce production of food items for fish, and interfere with angling.

The pollution from Iron Mountain Mine complex is planned to be remedied by the Environmental Protection Agency Superfund Program (EPA 1986). The program calls for completion of source control features by 1991 that could reduce metal loading by up to 80 percent. Dilution manipulation would still be a required feature but the demands for dilution water should be substantially reduced.

The temperature problem can be abated through optimum use of available cold water reserves in Shasta Reservoir and Trinity River trans-basin diversion. This can be accomplished through structural modification of the outlet system at Shasta Dam and modification of the Whiskeytown Reservoir outlet to Spring Creek Powerhouse.

A multi-level outlet structure has the advantage of managing against turbid water releases from the reservoir during the spring when upper reservoir waters are cool enough to be released.

<u>Mainstem Sacramento River Spawning Gravels.</u> In the river near Keswick Dam, many historic salmon spawning riffles are armored by cobbles that are large and difficult to move. Spawning gravel recruitment from upriver areas has been eliminated by the dam. The available spawning gravels in the river are derived from bank erosion (about 85 percent), tributaries, and chute cut-offs. These sources have been reduced by gravel mining and bank protection projects. Increased losses are threatened due to proposed increases in these activities.

The following are actions that could contribute to correcting the inadequacy of spawning gravels:

1. Acquire gravel rich streambanks or deposits from willing sellers and allow them to erode into the stream.

2. Place artificial spawning habitat in suitable side channel areas.

3. Employ alternative methods of river channel management that do not include armoring the stream banks.

4. Place additional restrictions on gravel mining in tributaries that provide valuable gravel recruitment.

5. Purchase the spawning gravel component of gravel mined by commercial extractors.

6. Purchase gravel rights and/or riparian lands as is under negotiation for Clear Creek.

7. Periodically place additional gravel in the river immediately downstream from Keswick Dam for natural distribution downstream.

Fish Passage Problems at Anderson-Cottonwood Irrigation District (ACID Dam. The operation of this seasonal flash board dam mandates that the release from Keswick Dam be reduced temporarily (3 or 4 days) to allow installation, removal or adjustment of flashboards to provide the desired water delivery rate to the canal (Agreement between the USBR and ACID). These reductions, which sometimes exceed 8,000 cfs, occur during the spawning and incubation period of the winter-run chinook. As a result, winter-run fry and juveniles are stranded and killed along with other young salmonids. The flashboards are typically in place from early April to early November.

There are also water quality impacts associated with the flow reductions including increased heating of the river at lower flow and decreased dilution of downriver waste waters (including rice field drainage during the spring herbicide season).

The Anderson-Cottonwood Irrigation District Dam does not allow efficient passage of upstream migrating adults over the existing ladder. The ladder is a 1920's design that does not provide adequate attraction flows and approaches the dam at a 90° angle. As a result, mortality occurs and passage of winter-, spring-, and fall-run chinook is delayed, sometimes to the point that fish have to spawn below the dam.

The following are alternatives for correcting the ACID Dam fisheries problem:

1. Reconstruct ACID Dam to allow head adjustment without altering Keswick Dam release. This design would incorporate an efficient fish ladder. Operation and maintenance of this partially remodeled structure would be stipulated in an agreement between the District, the USBR, and the DFG.

2. Change the point of Diversion for ACID to Clear Creek via a release from Whiskeytown Reservoir. The increased releases would additionally benefit anadromous fish production in Clear Creek. Alternative diversion systems are:

   a) Supply the Districts entitlement of 400 cfs entirely from Clear Creek and thereby eliminate the Sacramento River diversion. The only economic method of diversion would be construction of 5 miles of canal from Seltzer Dam on Clear

Creek. Lost power production equates to approximately 425 feet of head. The water would not represent lost yield since releases at Keswick Dam exceed minimum fish flows by approximately 300 percent during the irrigation season.

b) Supply only that portion of the District's entitlement that is needed to prevent flashboard adjustment at the Sacramento River Diversion. This could be accomplished by pumping from Clear Creek into the District's Canal for limited periods during the start and finish of the irrigation season. The instream flow recommendations for Clear Creek restoration would probably provide most of the needed flow for the canal with little fishery impact to lower Clear Creek during the summer period.

c) Install and operate pumps to supply the District's entitlement from the Sacramento River and eliminate the necessity of operating the dam during critical salmon production periods.

d) Construct a new fish ladder with adequate fish attraction and passage flow.

Coleman National Fish Hatchery/Insufficient Compensation for Shasta Project Impacts. Over 187 miles of stream that had spawning habitat capable of supporting 118,000 salmon were blocked by Shasta Dam. The estimated run above the dam at the time of project construction was 60,000 salmon, excluding winter-run. Later counts indicated that the salmon run was on the increase from previous declines, and therefore the 60,000 figure was below the normal annual population number. The Shasta Salmon Salvage Plan goal, however, was officially established at 25,000 to 26,000 fish, including artificial propagation objectives; this plan was part of the 1949 agreement between USBR and USFWS. The current production goal for CNFH of 18,650 returning adult spawners is 41,350 salmon less than the estimated run of 60,000 fall spawners.

In 1949, the USFWS identified features of the Shasta project that they thought would offset the tremendous loss of spawning and rearing habitat; these were increased fall streamflow and cooler water temperature below the dam. Since 1949, however, long-term impacts have manifested themselves including: lost gravel recruitment, armoring of riffles in upper river reaches, dewatering of redds from winter flow reductions, increased summer and fall water temperatures as increasing water demands maximized demands for seasonal reservoir yield, and continued fish mortality from insufficient dilution of acid mine drainage.

The Salvage Plan also called for the construction of propagation facilities for handling up to 30 million spring-run chinook eggs at Darrah Springs in addition to the construction of a Keswick Fish Trap. An alternate and less expensive mitigation plan was attempted including propagation of spring-run at CNFH and hauling trapped spawners to Deer Creek. Both of these mitigation measures failed completely due to unsuitable water temperatures at CNFH and habitat conditions at Deer Creek that limit population size.

In 1949 a Memorandum of Agreement between the USBR and the USFWS waived the USBR obligation to carry out any further elements of the Salmon Salvage Plan with the exception of maintaining the Keswick Fish Trap. Under the Memorandum, the USFWS accepted responsibility for all operational funding of the hatchery with the exception of the power supply.

The following are alternative actions that could lead to offsetting the net Shasta Project annual fisheries losses of approximately 100,000 adult chinook salmon:

1. Implement the CNFH Development Plan (a USFWS plan to upgrade Coleman fish production facilities).

2. Fix the Keswick Fish Trap to operate at higher river flows and reduce stress on fish. It is questionable whether or not winter-run salmon can be handled successfully in the trap.

3. Build additional hatcheries at sites that have suitable water available without the necessity for chillers, and located farther upriver than CNFH. Hatchery operations at the upper end of the river would better distribute the fish in the river for sport fishing and in-river spawning. Siting a new hatchery on Clear Creek, for example, is superior to improvements at Battle Creek because: 1) Cold water is available from Whiskeytown Reservoir 2) There are no upstream hatcheries and their associated disease problems in the watershed 3) Water use is compatible with other purposes such as restoring 16 miles of anadromous fish habitat on Clear Creek and providing water for solving the ACID problem (discussed separately).

4. Restore adversely impacted habitat for spring-run chinook on Deer Creek to increase natural production. Deer Creek continues to have inadequate flows below diversions identified as impacting spring-run salmon nearly 50 years ago. Mill Creek also offers habitat rehabilitation potential and a restoration project should be developed.

5. Funding for improvement and operation of CNFH, and construction and operation of a new hatchery satellite at a suitable location, along with other necessary modifications of the Shasta Project, should be provided in a long-term contract similar to all other cooperative projects and hatcheries in California. Similarly, the hatchery could be operated by the DFG along with all other mitigation hatcheries in California.

<u>Inadequate Instream Flows and Insufficient Screening of Diversions On Important Tributary Streams.</u> The streams having the most apparent problems with the best restoration potential include: Battle, Mill, Deer, Clear, Antelope and Butte creeks. In the springtime agricultural diversions entrain juvenile outmigrants and fail to provide sufficient water for downstream passage to the ocean. During the fall and spring upstream migration and spawning periods, some agricultural diversions are barriers and hydroelectric diversions on Clear and Battle Creeks do not provide adequate flows for spawning and rearing in the affected reaches.

The following are solutions to the widespread problems in upper Sacramento River tributaries:

1. Instream flow studies have been completed on Clear Creek and will soon be completed on Battle Creek. Recommended streamflows for fish production based on these studies should be included in the Federal Energy Regulatory Commission License for Battle Creek Projects and the Water Rights Permit for the Clear Creek Project. Restoration would be directed toward fall- and spring-run chinook and steelhead. Providing just a 30 percent increase in the annual flow of Clear Creek, as recommended in the instream flow study, provide 16 miles of restored anadromous fish habitat in that stream. By subtracting the small additional Whiskeytown Dam releases from the Keswick Dam release the project would not consume significant conservation storage.

   There are limited opportunities to procure streamflow by-pass on the diversions on the other tributaries due to the age of the existing water rights. Minimum flows could possibly be achieved by petitioning the State Water Resources control Board to reopen the license for these diversions. Alternately, flows could be provided through the use of water transfers groundwater pumping or to provide for the needs of the water diverters while maintaining flow conditions necessary for production of fish.

2. Adult salmon passage problems can be eliminated through construction of new ladders or replacement of ineffective ladders on diversions on Butte, Clear, and Deer creeks. Mill Creek has three diversion dams which could be consolidated into two diversion dams. This would reduce the migration delay caused by barriers and expose a significant amount of spawning area previously inundated by a dam.

3. Install modern effective screens on Mill, Battle, and Butte creek diversions and obtain needed by-pass flows for the Antelope Creek screens. Other major Sacramento River tributaries, such as Cow and Chico creeks, should be thoroughly surveyed to identify barrier or screening problems.

Water Quality Problems on Tributaries. Sediment discharges are extremely high in some tributaries to the detriment of salmon and steelhead production. During the conduct of development activities on private or public land, approved best management practices should be required for sediment control. The Department should work cooperatively with the Soil Conservation Service, CVRWQCB, Department of Forestry, and county and local government to achieve reduction of sediment discharge from private lands.

Gravels made unusable due to compaction resulting from sedimentation can be temporarily restored or replaced by stream channel modifications including: ripping gravels with heavy machinery, emplacement of catchments for gravels, installation of hydraulic control structures to flush compacted gravels, and construction of spawning riffles.

Red Bluff Diversion Dam Causes Passage Problems for Both Adult and Juvenile Salmonids. Red Bluff Diversion Dam and the Tehama-Colusa Canal were justified in large part by the salmon enhancement that was anticipated from the TCFF and planned water turnouts in Thomes and Stony creeks. According to a 1967 USFWS report, the combined production from the single purpose and dual purpose channels was to be 37,000 spawners, including 3,000 that were displaced by Lake Red Bluff. In addition, water turnouts to Thomes and Stony creeks were to support 5,000 and 15,000 salmon, respectively. The economic benefits expected from an additional 54,000 salmon were instrumental in justifying construction of the dam and canal for irrigation purposes. A recent report prepared for the Citizen's Advisory Committee on Salmon and Steelhead Trout estimates that RBDD has resulted in an annual loss of 114,000 chinook salmon and 6,000 steelhead. Extended over the life of the project, the loss of salmon to date is estimated to be 2,508,000 adult fish.

The Tehama-Colusa spawning channels have not worked because of a myriad of problems; the turnouts to Thomes and Stony creeks were never implemented. So, not only wasn't the promised enhancement ever realized, the project created very serious passage problems for both adult and juvenile salmon.

Adult salmon are delayed below the dam and a portion of the adults never pass. Blockage or excessive delay of winter-run chinook forces spawning below Red Bluff where eggs are exposed to lethal water temperatures during the summer incubation period. Delay time for fall spawning fish reduces reproductive success due to reduced egg viability, over-ripe females and prespawning mortality. The length of the delay increases with higher flow due to difficulties associated with finding the fishway. After operation of RBDD began (1966), the proportion of salmon spawning below Red Bluff significantly increased over the pre-project condition.

Department of Fish and Game studies have indicated that survival of downstream migrant juvenile salmon and steelhead that do not pass the dam is respectively, 46 and 25 percent greater than those that must pass through the dam complex. The turbulence below the dam disorients the fish and increases predation on the juveniles. Other documented losses of juveniles result from entrainment into the Tehama-Colusa and Corning canal intakes due to ineffective screens.

A 5-year Fish Passage Action Program for RBDD problems was initiated by the involved fishery and water agencies in October 1983. The program is developed to identify and implement corrective measures.

The following are partial solutions to the RBDD fish passage problem and are being implemented:

1. Raise gates during the non-irrigation season (December through March) to provide undelayed passage of winter-run chinook, and juvenile outmigrants.

2. Screen Tehama-Colusa Canal headworks as presently planned by the USBR.

3. Reduce predation through alterations of the dam gates or operations procedures.

4. Implement solutions identified in the Fish Passage Program presently under development.

5. Monitor implemented solutions and continue studies to solve any remaining problems.

A complete and thorough followup report will be needed on RBDD and TCFF. The report should document the expected level of enhancement which was not met, and define the problems caused by the dam and associated facilities. A cooperative state and federal plan for correcting the problems and providing the resource restoration and enhancement promised need to be developed and implemented.

For example, fish passage problems would be lessened if the RBDD gates were raised for a greater length of time; and, alternative water supplies could include pumping part of the year and/or tributary storage developments on Red Bank and South Fork Cottonwood creeks.

The Tehama-Colusa Fish Facility Fails to Meet Production Objectives. The lake impounded by RBDD inundates a spawning area that formerly accommodated approximately 3,000 salmon. The loss of this habitat was to be mitigated by the Single Purpose Spawning Channel portion of the TCFF. There are algae and sediment problems that intermittently reduce the capabilities of this facility to meet its production goals. Opening of the RBDD gates for passage of winter-run chinook salmon presently forgoes water delivery to the TCFF and precludes rearing of fish during the spring months.

An additional production goal to provide 54,000 fall-run adult chinook was established as an enhancement and mitigation feature and incorporated into the overall feasibility and cost analysis for the project. The production of salmon in the Dual Purpose Canal at the TCFF as originally anticipated is not now expected to occur. Results of experimental use of this canal-like spawning facility indicate many major problems would need to be solved to salvage its usefulness. It could be used as a rearing facility, a net benefit of 5,000 fish may result over planting the fish directly from CNFH.

Because it appears necessary to keep the gates open at RBDD for winter-run chinook passage and the facility has not proved feasible for economic spawning, incubation, or rearing the Single Purpose Canal should be moth-balled and the Dual-Purpose Canal should be abandoned as a fish production area.

Rearing of fish in the upper Sacramento River could be increased over existing levels to provide the promised mitigation and enhancement that is associated with the RBDD facility. Spawning gravel could be salvaged out of the Dual Purpose Canal to complement in-river spawning. Hatchery production could be accomplished in part by construction of a facility at Keswick or Clear Creek and increased production at CNFH.

Mortality at Unscreened Diversions and Problem Screens on the Sacramento River. Between Redding and Sacramento there are over 300 diversions on the Sacramento River. In total the diversions take over 1.2 million acre feet and unknown numbers of juvenile fish annually from the river. Small fish are extremely vulnerable to entrainment in large diversions that are located near the streambank.

Only four diversions on the main river have fish screens; of these, two are adequate. The Glenn Colusa Irrigation District (GCID) operates one of the largest diversions (3,000 cfs) and has screen by-pass deficiencies and overall design deficiencies. Red Bluff Diversion Dam screens are being improved.

Interagency coordination and funding should be established to inventory the water diversions, including their design, location and construction. A uniform screening policy and specification should be established among agencies and the Department. Installation or reconstruction of screens should be accomplished at private diversions with assistance from public funds. The diversions currently under permit with the US Army Corps of Engineers (COE) could require full installation and maintenance of facilities to comply with adopted screening specifications.

<u>Adult Salmon Stray Into Irrigation System and Flood Bypass Drains.</u> Fall-run chinook enter the large Colusa Drain outfall at Knights Landing as well as canal systems and waste gate outfalls on tributaries, including Stony Creek, Butte Creek, Chico Creek, and other stream.

An appropriate program to construct and maintain barriers at the Colusa drain outfall and where possible on other drain discharges needs to be funded and implemented.

<u>Bank Protection Decreases Rearing Habitat and Increases Predation.</u> The U.S. Fish and Wildlife Service has surveyed rearing habitat in the river between Red Bluff and Chico. Important rearing habitat includes natural eroding banks, edges of gravel bars, small backwaters and eddys close to laminar flow, and structures in the river where laminar flow occurs. The placement of riprap bank protection eliminates these important rearing habitats adjacent to natural banks and gravel bars. In addition, the riprap provides cover for fish species that prey on juvenile.salmon and steelhead.

Where bank protection projects must occur, the best way to limit the associated habitat loss is to use the palisade-type structure instead of riprap. Riprap bank protection can be partially mitigated for habitat loss by the following measures:

1. Construct the project at a slope of 5:1 or 6:1 with placement of gravel between rock rubble on an annual basis.

2. Provide escape cover structures on the riprap by cabling logs or trees to the bank.

3. Allow erosion of natural gravel banks and only riprap areas where absolutely necessary for public safety.

4. The preferred solution is to limit bank protection activity to that which is absolutely necessary, and, if possible, establish a meander belt which, even if levied, would permit no permanent developments.

II-1-G Enhancement Opportunities

Upper River Gravel Improvement. There are substantial deposits of gravel suitable for salmon and steelhead in pool areas and in high flow channels and gravel bars along the upper Sacramento River. This gravel represents the remnant of gravel that was in long-term transport down the system prior to Shasta Dam. The portion of this gravel that would normally have been in sites suitable for salmon spawning has been carried downstream or deposited on areas only inundated during the highest flows. Replacement of this gravel in excess of the needs for restoration of historic runs could constitute enhancement.

Improvement could be accomplished through frequent deposition of the smaller size component of gravel needed by salmon and steelhead in areas historically used for spawning. More permanent gravel deposits can be created by installation of retaining weirs. The needs for restoration of the historic runs can be expected to require use of most of the areas appropriate for this method of habitat improvement.

Hatchery Production. There are potential hatchery sites along the upper Sacramento River and on the major tributaries. Of the tributaries, Clear Creek appears to have the greatest potential for an enhancement hatchery. Beyond the production necessary for restoration of the historic runs, a hatchery could result in significant economic benefits from both the ocean and inland fisheries.

II-2 Lower Sacramento River System

II-2-A Physical Environment

The major tributaries to the Lower Sacramento River System are the Feather, Yuba, and American rivers; minor tributaries include Cache, Putah, and Dry creeks and Bear River (Figure 3).

Geology. Below Ord Ferry to Sacramento, the geology is dominated by fluvial deposits. The area surrounding the Sacramento River includes stream channel and floodplain deposits. These consist of sand, gravel, silt, and minor amounts of clay. East and west of the alluvium are flood basin deposits that are unique to this reach. These deposits are fine grained material, chiefly silt and clay, deposited in the low-lying overflow areas adjacent to the river.

Further west near Woodland and Yolo are alluvial fan deposits. The fan deposits are fluvial sediments deposited on a gently sloping plain by streams draining the sedimentary and metamorphic rocks of the Coast Ranges. Most of the streams are small and ephemeral. Cache Creek is the only substantial westside tributary in the Verona to Sacramento reach of the Sacramento River.

East of the Sacramento River are somewhat similar deposit consisting mostly of sand and gravel stream channel deposits. These, known as the Victor Formation, were deposited by the ancient Feather, Yuba, Bear, and American rivers. Today, these streams drain the granitic and metamorphic rocks of the Sierra Nevada basement complex.

Hydrology. The Feather River is primarily a snowmelt runoff stream controlled by the SWP Oroville Reservoir (Figure 3). Oroville Reservoir has a storage capacity of 3.5 million acre feet. About 3,600 mi of watershed drain into Oroville Reservoir. The Department of Water Resources operates the project which includes FRH and its adjunct Thermalito Facility. The Feather River is a moderately fertile river with the northern part of the drainage coming from rich volcanic soils and the southern tributaries in more sterile granitic areas. Releases from Oroville Dam are made through a multilevel outlet works which allows selection of suitable water temperature. After release from Oroville Dam, the river flow is split with a constant 600 cfs going through the new powerhouse at the Thermalito Diversion Dam into the low-flow reach of the river and the hatchery. The majority of the flow goes through the Thermalito Forebay/Afterbay complex where it generates power and is warmed for use in rice culture. Warmed flow is then returned to the river at the Thermalito Afterbay outlet. The end result is about 10 miles of cool river in the low-flow section and about 50 miles of river in the high-flow reach.

The Yuba River is the largest tributary to the Feather River. It is primarily a snowmelt runoff stream with low fertility. Salmon and steelhead can ascend the Yuba River only to Englebright Dam or about 25 miles from the mouth at Marysville. Flows are controlled by Englebright Dam. Englebright Dam has a storage capacity of 70,000 acre-feet and New Bullards Bar Dam has a storage capacity of 1 million acre-feet. About 1,100 mi^2 of watershed drain into Englebright Dam. These two dams are operated by the Yuba County Water Agency for irrigation and power production. Cool water is released from Englebright Dam for the year round diversion at Daguerre Point Dam. This release provides good rearing habitat for yearling steelhead and lengthens the period fall-run salmon can migrate.

The American River is a snowmelt stream with a large amount of storage in its higher elevations for hydroelectric power. This storage results in the rainfall runoff in the lower elevations having more significant impacts on flows in the lower river. The American River drains the granitic soils of the Sierra and, therefore, has low fertility. Flows in the lower American River are controlled by Folsom and Nimbus dams. Folsom Dam has a storage capacity of 1 million acre-feet. Nimbus Dam provides an afterbay for Folsom Dam. About 1,800 mi^2 of watershed drain into Folsom Reservoir.

Nimbus Dam is the diversion point into Folsom South Canal for water stored in Folsom Dam. Releases below Nimbus Dam are controlled by the USBR. The Bureau also constructed NFH below Nimbus Dam and contracts with the California Department of Fish and Game to operate the fish facility. Minimum flows in the river are almost always above 1,250 cfs, but the legal required minimum is only 500 cfs between September 15 and January 1, and 250 cfs the remainder of the year.

II-2-B Salmon Resource

The lower Sacramento River system provides a major part of the chinook population of the Central Valley and most of the steelhead production. It historically supported natural runs and provided a major cultural and economic resource.

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The lower Sacramento River system supports fall and spring-run chinook. As with many California stream systems, spring run were historically more numerous, but now the run is almost entirely a fall run.

Past. Salmon populations in the Feather River prior to construction of Oroville Dam were estimated to average 1,700 spring-run and 39,100 fall-run chinook salmon. Yuba River populations averaged about 20,000. Spring-run chinook were eliminated from the American River prior to 1950; fall-run populations were estimated to average about 26,500 prior to completion of the Folsom Project.

Present. The fall-run population in the Yuba River has averaged 18,000 adults over the past 5 years.

Feather River runs in the last 5 years have averaged 1,660 spring run (now defined as salmon entering the hatchery in September) and 50,200 fall run. Because of straying caused by the trucking program, FRH salmon make a significant contribution to the runs in the American and upper Sacramento rivers, and a number of smaller streams with the drainage.

Salmon spawning escapement to the American River over the last 10 years has averaged 46,700 fish. This increase in the salmon run has occurred for several reasons including improved flows, improved operational procedures at Nimbus Hatchery, increased straying from Feather River and Mokelumne River hatcheries, and increased production at Feather River and Mokelumne hatcheries.

Salmon Fisheries. About 10,000 salmon are harvested annually by about 40,000 angler-days of effort on the Feather River. Salmon from the Feather River are also harvested in the Delta, Sacramento River, and other Delta tributaries.

There is very little access to the Yuba River. The majority of the fishing occurs from boats that have motored up from the mouth and at the three access areas. No estimate of angling use and harvest is available.

Cursory creel census surveys indicate 100,000 angler-days are expended on the American River each year and estimates of annual chinook salmon have ranged from 5,000-20,000 fish. American River salmon also contribute to the Sacramento River fishery. The last comprehensive creel census-angler effort survey on the American River occurred during the 1971-74 period; results of this study indicated anglers caught about 5-6,000 salmon annually.

Potential. Improved flows in the Yuba and Feather rivers could provide opportunities for gravel and nursery area enhancement and could result in a natural production net increase of 40,000 adult fish. Improved flow consistency would also aid in returning adults to the hatchery on the Feather River. Nimbus Hatchery was constructed in 1955 with the technology of that time. It is badly in need of modernization. The holding pond design now restricts the timing of taking salmon into the hatchery because of unacceptably high losses of adult salmon and steelhead before they can be spawned. Dirt ponds now used are difficult to clean and lead to poor water quality in the lower part of the series. There are plans for doubling production of fall-run chinook upon completion of modernization. Increasing flow releases into the American River at Nimbus Dam to provide about 3,000 cfs during the April 15 through June 15 period would maximize smolt rearing and migration habitat.

II-2-C Steelhead Resource

Steelhead are found throughout the system, but are almost entirely a hatchery product. The stocks in the American River are probably not endemic to the area, but the result of importations from the Eel River. The endemic populations were largely extirpated after the dams were constructed on the American River and flows were curtailed through diversions in other lower river and Delta tributaries.

Past. Pre-Oroville Dam Feather River steelhead populations were estimated to average about 1,000 fish above the damsite. Prior to construction of Folsom Dam, the American River steelhead run had been reduced by upstream developments to less than a 1,000 fish. Prior to 1970, steelhead runs were estimated to average about 5,000 fish.

Present. The average number of Feather River steelhead entering the hatchery in the 4 years from 1982 through 1985 was 1,600 fish. The total steelhead population of the Feather River before the angler harvest takes place is between 15,000 and 20,000 fish. Essentially all of the steelhead are derived from Feather River Hatchery yearling releases.

The Yuba River above Daguerre Point Dam has produced sufficient yearling steelhead to maintain runs of about 2,000 steelhead. The critical factor in this area is appropriate flow and water temperature for juvenile rearing.

Because of operational improvements at Nimbus and other Central Valley hatcheries, steelhead runs in the American River are now 15,000 to 20,000 fish annually. Of this number, about half are fall-run steelhead with several thousand being strays from Coleman and Feather River hatcheries. Fall-run steelhead enter the river starting in July, peak in November, spawn in late December and January, and end by mid-February. Fall run are relatively small steelhead with half the run being 2-year olds of 2-4 pounds and half the run 3-year olds of 5-10 pounds; 4-year olds to 12 pounds are rare. The other half of the run are winter-run steelhead. Winter-run come in from mid-December through February, spawn in late January through early March and the run is over by April 1. Winter-run are larger with 90 percent of the run being 3-year olds of 6-12 pounds, 5 percent 2-year olds of 3-5 pounds and 5 percent 4-year olds of 12-20 pounds. Essentially all of the winter run are derived from yearlings reared at Nimbus Hatchery.

Steelhead Fisheries. About 8,000 steelhead a year are harvested in the Feather River as the result of about 30,000 angler days of effort. An additional 1,000-2,000 Feather River steelhead are harvested annually in the American River, Sacramento River, Delta and Carquinez Strait fisheries.

No estimate of the steelhead harvest in the Yuba River is available. Both the salmon and steelhead fisheries in the Yuba can be categorized as unintensive but highly valued by anglers.

Cursory creel census surveys indicate over 20,000 angler days are expended on the American River annually to harvest 5,000-8,000 steelhead. Hundreds of American River steelhead are also harvested in the Delta and Carquinez Strait fisheries.

Potential. Opportunities exist to increase natural production through improved water conditions and improvement of spawning and rearing habitat. Such improvements could probably result in a net increase of 10,000 adult steelhead to lower Sacramento River tributaries. Hatchery production is only limited by demand and economics. There is strong support from the angling public for increased production including suggestions for importation of stocks from outside the Sacramento-San Joaquin drainage. This probably would not threaten any endemic strains, but could result in importation of diseases or of less disease-resistant fish. The magnitude of the run is dictated by water conditions and the magnitude of hatchery production.

II-2-D Natural Production

Natural production of returning adult steelhead appears to be negligible but the thousands of steelhead that spawn in the Feather River no doubt contribute to the "trout" fishery. Feather River natural production of salmon smolts has not been quantified.

The majority of the salmon and steelhead populations in the Yuba River are attributed to natural reproduction. A small number of salmon and steelhead from FRH are known to occur in the Yuba River runs because tagged fish from Feather River have been recovered there.

Natural spawning of steelhead in the American River does not make a significant contribution to subsequent steelhead runs but does provide a trout fishery of resulting yearlings.

Natural reproduction of chinook salmon in the American River provides a significant contribution to subsequent runs when environmental conditions are favorable for smolt production and emigration. Because of unfavorable water temperatures in the Delta and lower Sacramento River, smolt survival is depressed in some years.

II-2-E Hatcheries.

Feather River Hatchery and the Thermalito Facility rear about 400,000 yearling steelhead (3-4/lb.) and about 10 million salmon smolts. All of the steelhead are planted in the Feather River downstream from Yuba City. All of the salmon, except for 2,000,000 yearlings planted in the Feather River, are trucked to the estuary (Carquinez Strait in recent years). Feather River Hatchery releases are intensively used for tagging experiments for survival comparisons of fish released at various points from the hatchery to the Golden Gate.

Nimbus Hatchery has a capacity to rear about 4 million smolt salmon and 400,000 yearling steelhead. These fish are largely released downriver in the upper and lower bays.

II-2-F Environmental Problems and Preferred Solutions

Feather River. The major problem facing the salmon and steelhead resources of the Feather River is the continuing decline in water quality in the lower Sacramento River during the April through June smolt emigration period. Flow releases into the Feather River could be used to alleviate this problem and as a side benefit attract American shad into the Feather River for the sport fishery. Minimum flow releases measured at Verona of about 3,000 cfs during the April 15 through June 15 period would improve smolt production, improve the shad fishery and assist smolt emigration.

Yuba River. The major problem facing salmon and steelhead, just as it is on the Feather River, is the low spring flow. Minimum flow of 1,500 to 2,000 cfs measured at Marysville during the April 1 through June 15 period would create good conditions for smolt rearing and emigration as well as attract American shad into the river for the sport fishery. Coordinated releases on normal and wet years with releases from Oroville Reservoir could optimize the fisheries benefits of spring flows. With limited capacity, smolts are being trapped and trucked on dry years from the Hallwood-Cordua fish screen/trap. Dry years without adequate fish flows will continue to depress runs.

American River. The major problem with the American River fisheries is the lack of good spring flows for smolt rearing and emigration. If minimum flows of 3,000 cfs could be maintained at the mouth of the American River, salmon smolt production and survival could be greatly increased. It is during the period of April 15 through June 15 that the salmon fingerlings are growing the fastest and require the greatest amount of living space. It is also during the May 15 through June 15 period that the salmon smolts are heading downstream to the ocean. High flows are needed then to keep lower river areas cool and to assist smolts in avoiding predators, diversions, and debilitating warm water.

II-2-G Enhancement Opportunities

Added hatchery capacity at the Feather River would provide greater salmon and steelhead runs. Securing eggs from late running salmon races (late-fall and winter run) may allow greater salmon production with the same facilities and extend the river angling season. At present, the only source of these late-running salmon is in the Upper Sacramento River. Because of their

reduced numbers, the USFWS has been unable to provide eggs to start a program. If Sacramento River production and survival were improved, straying might produce the necessary parent stock.

Hatchery Production. A small hatchery on the Yuba River would maintain the existing runs and create an enlarged potential for production in good water years.

Nimbus Hatchery could be enlarged. Added rearing capacity for 2,000,000 salmon smolts and 100,000 yearling steelhead would add 10,000 salmon and 5,000 steelhead to the annual average run.

Habitat Improvement. Natural production of salmon could be increased by the following actions:

1. Maintain suitable water temperatures by controlling the discharge of irrigation return and sewage affluent water to avoid increases in the temperature in the main stem and major tributaries.

2. Place barriers at the mouths of dead end channels to prevent entrance by adult salmon during their upstream migration.

3. Add and manipulate gravel to improve conditions for successful spawning of salmon and steelhead.

4. Manipulate flows to improve spawning, incubation, and nursery conditions.

II-3 Eastside Delta Tributaries

II-3-A Physical Environment

The eastside Delta tributaries drain the central Sierra Nevada foothills through the east edge of the valley and immediately enter the complex waterway of the Delta.

Geography. The Mokelumne River drains from the west slope of the Sierras and empties into the Delta near the town of Walnut Grove (Figure 4). Salmon spawn in the section of stream between Elliot Road Bridge near the town of Lockeford and Camanche Dam, a distance of about 10 miles.

The Cosumnes River is a tributary to Mokelumne River and empties into it near the town of Thornton. Salmon spawn in the section of stream between Cosumnes Falls near Latrobe Road Bridge and Sloughhouse, a distance of 15 miles.

The Calaveras River flows past the City of San Andreas and is captured by New Hogan Dam. It then flows through low hills to the point where it enters the Delta in the City of Stockton. Most of the winter-run salmon spawning activity occurs between New Hogan Dam and Bellota Weir, a distance of about 18 miles.

Geology. These watersheds lie along the western tilled mountain portion of the Sierra Nevada Range which has been uplifted along its eastern margin. Bedrock in this region consists of metamorphic and granitic rocks. The major spawning areas of these streams are located at lower elevations and flow through broad alluvial valleys.

Hydrology. The Mokelumne River drains from the western slope of the Sierra Nevada Range. The majority of the runoff is derived from snowmelt with peak flows occurring in the spring. Flows in the lower 35 miles of the Mokelumne River are controlled by Camanche Dam located 35 miles northeast of the town of Lodi. This dam and Pardee Dam, located about 12 miles upstream, are operated by the East Bay Municipal Utility District (EBMUD) for domestic water supply, irrigation, and power production. Camanche Reservoir has a storage capacity of 400,000 acre-feet. About 630 mi^2 of watershed drain into Camanche Reservoir.

The Cosumnes River is a tributary to the Mokelumne River and joins it from the north near the town of Thornton. The headwaters are at a lower elevations than the Mokelumne River system and most of the runoff is from rainfall. Flows in the lower Cosumnes River are not regulated by a dam.

The Calaveras River watershed lies to the south of the Mokelumne River watershed. Its headwaters are also at a lower elevation than those of the Mokelumne River watershed and most of the runoff is from rainfall. Flows in the lower river are controlled by New Hogan Dam located 25 miles northeast of the City of Stockton. About 360 mi^2 of watershed drain into New Hogan Reservoir. New Hogan Reservoir is operated by the Army Corps of Engineers and provides flood protection, power production, and water for irrigation.

II-3-B Salmon Resource

The Mokelumne and Cosumnes rivers presently support only fall-run chinook salmon. The Calaveras has supported a run of a few hundred winter-run salmon in recent years; the present status of this population is unknown. Annual chinook salmon escapement surveys and estimates have been made by the DFG since 1952 for fall-run salmon in the Mokelumne and Cosumnes rivers. Because the lower river runs through very rugged terrain, only occasional efforts have been made to survey the Calaveras River.

Past. The Mokelumne River salmon population was made up of spring-run salmon which migrated to the headwaters to spawn. The construction of Pardee Dam in 1929 prevented the adults from reaching their upstream holding and spawning areas and greatly impacted the population. The construction of dams, along with sedimentation caused by gold mining and poaching in the summer holding areas, destroyed the spring-run population in the Mokelumne River. By 1963, when Camanche Reservoir began falling, the residual fall-run population averaged about 6,000 fish. The population had ranged between 100 fish in 1961 to 11,600 fish in 1941. The loss of these 6,000 fish was to be mitigated by Mokelumne River Fish Installation (MRFI) and flow released below Camanche Dam. A spawning channel was constructed, but was unsuccessful, and later converted to rearing ponds. Unfortunately, MRFI and the flow releases were not enough to maintain the salmon population at the 6,000 fish level, and the populations averaged only 2,000 for the first 10 years after Camanche Dam was built. Salmon populations in the Cosumnes River have continued to dwindle averaging 1,700 in the 1950's, 1,000 in the 1960's, and 500 in the 1970's.

Winter-run populations were first observed by the DFG in the Calaveras River in 1972 when an estimated 500 salmon migrated up this stream. The historic magnitude of this run is unknown.

Present. Annual escapements in the Mokelumne River have averaged 6,600 fall-run spawners during the present decade. The increase in population has been due to several wet springs, which increased the survival of smolts, and to rearing two million juvenile salmon at MRFI. The rearing of these fish is funded by a combination of Salmon Stamp and Preservation Fund money.

Annual escapement in the Cosumnes River has averaged 200 fish during the present decade. Although there have been several wet years this past decade, the stream has been dry during three annual spawning seasons. The dry years preclude perpetuation of a natural run.

The present status of winter-run salmon in the Calaveras River is unknown. Habitat conditions may limit the run to a few fish during most years.

Salmon Fisheries. The 2 million salmon reared at MRFI with Salmon Stamp money and planted into the Bay contribute significantly to ocean fisheries. When these fish return inland to spawn, a sport fishery is provided in the Delta and stray fish contribute to fisheries in other streams.

The spawning runs in the Cosumnes and Calaveras rivers are usually a few hundred fish and, therefore, contribute proportionally to the fishery.

Potential. Natural production in the Mokelumne River could be substantially improved with increased spawning and rearing flows. Increased rearing capacity at MRFI would allow for increased fish release to the river to reduce straying associated with fish releases in the San Francisco Bay.

II-3-C Steelhead Resource

Occasionally, steelhead are caught in the Mokelumne River. Large rainbow trout are caught in the Calaveras River below New Hogan Reservoir which may be steelhead that strayed from other river systems.

Past. Prior to the construction of Camanche Dam, anglers in the Mokelumne River caught rainbow trout that were in the 12 to 20 inch range that they called steelhead. Hatchery development therefore included concrete raceway ponds to rear 100,000 steelhead yearlings. Steelhead eggs came mainly from Nimbus Hatchery of the American River. The steelhead yearling program was unsuccessful, with steelhead runs in the 60's and early 70's of 200 fish or less, mostly less. The program was therefore altered in 1973 to produce 50,000 yearling steelhead and 50,000 yearling salmon.

Present. The present program for the river calls for about 30,000 yearling or older steelhead planted on a weekly basis in the river at the hatchery during the recreation season of April 1 through September 30. This has provided a fishery for 12 to 20 inch trout. The program is very popular with anglers and is limited only by the small amount of public access to the river, primarily the one-half mile county park below the hatchery and a boat access at Mackville Road.

The primary goal of this program is to provide a catchable trout fishery using young steelhead obtained from Nimbus Hatchery. Few of these fish return to the Mokelumne River as adults.

Steelhead FIsheries. Occasional adult steelhead are caught in the Mokelumne River. Few, if any, adult steelhead are taken in the Cosumnes River. Large trout or steelhead have been taken by anglers in the Calaveras River below New Hogan Dam.

Presently, 30,000-40,000 yearling steelhead are planted in the county park adjacent to the hatchery during the recreation season (April 1 to October 1). Stocking is done on a weekly basis. The primary goal of this program is to provide a catchable trout fishery using steelhead from Nimbus Hatchery; these fish provide a minor contribution to the Central Valley fishery as returning adult steelhead.

The program is very popular with anglers. Improved flows would result in greater return of adult steelhead and help to build a true steelhead fishery. Only occasional steelhead (or large rainbow trout) are taken by anglers in the Consumnes and Calaveras rivers. These streams probably do not support any significant steelhead populations.

Potential. Improved spawning and rearing flows in the Mokelumne River will improve the steelhead population as well as, recreation at fishing opportunities. By improving public access through creation of a Mokelumne River Parkway, the trout planting program could be increased. Improved attraction flows for adult steelhead would probably result in an increase in return and could develop a true steelhead fishery.

II-3-D Natural Production

Wet springs and high spring flows lead to good smolt production and good survival of Mokelumne River fish through the Delta. Naturally produced adult salmon can make up the majority of the Mokelumne River run under favorable water conditions (the peak run of 1983 was mainly naturally produced fish). After a series of low spring outflows, however, the greatest part of the resulting runs will be hatchery produced fish. The Cosumnes River supports a small natural run of salmon.

II-3-E Environmental Problems and Preferred Solutions

Low flows and problems in the Delta. Allocated flows in Mokelumne River for adult immigration, spawning, egg incubation, smolt rearing, and smolt emigration are only 13,000 acre-feet on normal years and 5,400 acre-feet on dry years. A study will be completed by 1990 that will refine our understanding of flow needs for salmon in that system. Smolt emigration flows are a complex issue because sufficient flow to provide good survival out of the Mokelumne River may not be sufficient to get the fish safely past the hazards at the Delta diversions.

The preferred solutions to these problems are to improve flow conditions in the Mokelumne River and provide accumulated flows in the San Joaquin River for upstream migration and save emigration of juveniles.

Survival of juveniles could also be improved under current dry year flow releases by trucking them to a site below the Delta water diversions. At present, a trapping and trucking program is undertaken in dry years with a smolt trap at Woodbridge Dam.

The lack of adequate flows and holding areas preclude the restoration of spring- run salmon in the Mokelumne River. Historically spring run salmon would migrate to higher elevations during the spring, hold over is deep pools, then spawn in the fall. Sufficient cool water and holding areas presently do not exist in the lower river. In addition, it would be difficult to maintain a pure race of spring-run salmon through natural production when spring-run and fall-run salmon are spawning in the same area at the same time.

The goal of the DFG, in this case, should be to increase the production of this stream using a hybridized spring/fall-run salmon now present in the upper Sacramento and Feather rivers. The progeny from this group would migrate to the ocean earlier in the spring and their survival will be increased.

Increase population numbers to a level that insures continued survival of this race in the Calaveras River. Survey efforts in recent years, although limited, indicate few salmon migrate in the Calaveras River. Low flows, fish passage problems, and poaching threaten their existence. The precarious statute of winter run salmon in the upper Sacramento river increases the need for their protection in the Calaveras River.

Adequate flow releases from Hogan Dam were not sought before the project was constructed. This race was likely overlooked in earlier investigations because winter-run were not known to exist in Central Valley except for the upper Sacramento River. The existence of winter run was not recognized until 1972 when several hundred salmon were observed during March below Bellota Weir on the Calaveras River. A rescue operation was carried out to transport these fish upstream.

During the next few years, several hundred salmon were observed below Bellota Weir. Recently, this race has been only occasionally sited. A thorough annual survey effort has not been conducted on this stream.

The preferred solution to maintain this run is to provide adequate flows for spawning, incubation, and outmigration, to correct passage problems at various small dams and weirs and to screen all water diversions which are capable of entraining juvenile salmonids.

II-3-F Enhancement Opportunities

Spawning habitat could be improved. Heavy equipment to loosen compacted gravel would enhance the quality of spawning gravels on the Mokelumne River. Camanche and New Hogan dams now prevent the natural recruitment of gravels from upstream; therefore, efforts are needed to artificially replenish the dwindling supply of gravel.

Survival of downstream migrants could be improved for young salmon. Presently, outmigrants from the Mokelumne, Calaveras, and Cosumnes rivers may be adversely affected by Delta pumping. Although East side tributaries salmon are not frequently observed at the pumping plants, they may be detoured into a less direct route to the ocean and experience increased mortalities as a result. The cessation of pumping during the period of outmigration may be found to greatly increase survival.

Mokelumne River Fish Installation could be enlarged to rear more salmon and steelhead. Additional water has to be secured from East Bay Municipal Utilities District. Water going through the hatchery cannot be released through their Camanche power plant and, therefore, bypass water is necessary. The capacity of MRFI could be increased to rear at least an additional

2,000,000 chinook (30/lb.) and 50,000 yearling steelhead (2-5/lb.). Adequate stream flows are also necessary to provide passage for upstream and downstream migration.

II-4 San Joaquin River System

II-4-A Physical Environment

The San Joaquin River drains high mountain snow packs and semi-arid low ranges and meanders through the intensely cultivated San Joaquin Valley to the Delta.

Geography. The 250 mile long San Joaquin Valley comprises the southern end of the 400 mile long Central Valley. The Tulare Lake Basin to the south is normally considered a separate drainage basin but has historically, during wet years, contributed occasional flood overflows and subsurface flows into the San Joaquin River. The San Joaquin River Basin is bounded on the west by the Coast Range and on the east by the Sierra Nevada. Rivers of the basin drain northward into the Sacramento-San Joaquin Delta. The San Joaquin River drains to the west from the Sierra Nevada and turns sharply north as it enters the valley floor. The upper San Joaquin River forms the southern boundary of the San Joaquin River Basin and the Delta forms the northern boundary. Numerous large tributaries draining the Sierra Nevada join the San Joaquin River before it enters the Delta. About 2 million acres in the San Joaquin River Basin and over 3 million acres in the Tulare Lake Basin are presently devoted to irrigated agriculture.

Geology. The San Joaquin River Basin history is similar to that of the rest of the Great Valley. It was formed by the upheaval of the Sierra Nevada and Coast ranges and bounded by the rise in elevation to the Tehachapis. The valley has been inland marine environment on several occasions and, through factors including glacial formation and tectonic upheaval, has been a semi-arid or freshwater environment at various times.

The uplands on the east and west edges of the valley are principally erosion terraces and fanglomerates. The sedimentary soils are deepest in the western portions of the valley and generally coincide with the major stream courses.

Hydrology. On the arid west side of the basin, relatively small, ephemeral streams drain the eastern flanks of the coast Range but rarely reach the San Joaquin River. On the east side, numerous streams and several major rivers drain from the west slopes of the Sierra Nevada and contribute to flows in the lower San Joaquin River. The major east side tributaries, south of the Delta, are the Merced, Tuolumne, and Stanislaus rivers (Figure 4). Extensive alluvial floodplains were created in the past by these rivers where they entered the lowlands and joined the San Joaquin River.

Precipitation in the San Joaquin River Basin averages about 50 inches per year. Snowmelt runoff is the major source of water to the upper San Joaquin River and eastern tributaries. Historically, peak flows occurred in May and June and flooding occurred in most years along all the major rivers. When flood flows reached the valley floor, they spread out over the lowlands, creating several hundred thousand acres of permanent tule marshes and over 1.5 million acres of seasonally flooded wetlands. The rich alluvial soils of

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natural levees once supported large, diverse riparian forests. It has been estimated that as much as 2 million acres of riparian vegetation grew on levees, the foodplains,and along small stream courses. Above the floodplain, the riparian zone graded into valley oak savannah and native grasslands interspersed with vernal pools.

Agricultural development began in the 1850's and since then dramatic changes in the hydrological system have occurred.

1. The San Joaquin River drainage area above Friant Dam totals 1,650 square miles (mi^2). There are seven power generation reservoirs that alter the flow in the upper San Joaquin River Basin, all of which are above the Millerton Lake, CVP facility near Fresno (Figure 4). Friant Dam was completed in 1946 and is operated by the USBR for flood control, irrigation, and power generation. Millerton Lake, formed by Friant Dam, has a gross storage capacity of 520,000 acre-feet and provides for deliveries into the Friant-Kern Canal, and CVP facilities. Friant-Kern Canal Provides service to Fresno, Tulare and Kern counties in the Tulare Lake Basin while Madera Canal provides service to Madera County in the San Joaquin Basin. A streamflow of 35 cfs in the river below Friant Dam sustains resident fisheries.

2. The lower Merced River is regulated by Exchequer Dam, and Lake McClure, formed by the dam, has a gross storage capacity of 1,024,000 acre-feet. Exchequer Dam was rebuilt in the late 1960's and is operated by MID for power production, irrigation, and flood control. The Merced River drainage area above Exchequer Dam totals 1,040 mi^2. The Merced River is also regulated by McSwain (an afterbay for Exchequer) and Merced Falls and Crocker-Huffman dams located downstream from Exchequer Dam. In addition to MID diversions, there are six gravity riparian diversions and numerous pump diversions which take water from the Merced River; these diversions are located along both banks between Merced Falls Dam and the confluence with the San Joaquin River. Streamflow requirements are provided in Davis-Grunsky Agreement #17 and Federal Energy Regulatory Commission (FERC) License 32179. The SWRCB permits have no fishery maintenance flow requirements.

3. The Tuolumne River is regulated by Don Pedro Dam which is jointly operated by Modesto Irrigation District (MoID) and Turlock Irrigation District (TID). The reservoir has a gross storage capacity of 2,030,000 acre-feet, the Tuolumne River has a drainage area of about 1,540 mi^2. The enlarged Don Pedro Dam, completed in 1970, provides power, irrigation, and flood control protection. The river above Don Pedro Reservoir is regulated by three reservoirs owned and operated by the City and County of San Francisco. Over the past 10 years Tuolumne River water has been exported to San Francisco at the rate of about 220,000 acre-feet per year. LaGrange Dam, located downstream from Don Pedro, diverts approximately 900,000 acre-feet per year for power, irrigation, and domestic purposes. The FERC License #2299 allocates 123,210 acre-feet for fisheries maintenance (64,000 in dry years). The permits from the SWRCB have no fishery maintenance flow requirements.

4. The lower Stanislaus River is regulated by New Melones Dam, which has a gross storage capacity of 2,420,000 acre-feet (Figure 4). The Stanislaus

River has a drainage area of about 900 mi^2. New Melones Dam was constructed in the 1970's and is now operated by the USBR for power, irrigation, and flood control. Downstream from New Melones, Tulloch Reservoir with a gross storage capacity of 68,400 acre-feet, regulates New Melones water releases. Goodwin Dam also diverts water for power, flood control, and irrigation to south San Joaquin Irrigation District (SJID) and Oakdale Irrigation Districts (OID). A recently signed agreement between USBR and DFG provides for interim improvements in streamflow on schedules selected by DFG and a sliding scale between 98,000 to 302,000 acre-feet annually. The SWRCB permits require that 98,000 acre-feet of water be released on a schedule provided by DFG.

One million acre-feet of water is imported into the San Joaquin Valley by means of the CVP and SWP pumps in the south Delta and thus affect water resources within the valley.

II-4-B Salmon Resource

The San Joaquin River system supports only fall-run chinook salmon. The population numbers vary widely from year to year depending upon the timing and magnitude of the flows for migration, spawning and rearing. San Joaquin salmon populations are also affected by pumping operations in the Delta which divert all San Joaquin River flow most of the year. Chinook salmon escapements have been documented by the DFG and the U.S. Bureau of Sport Fisheries (now USFWS) using various techniques on one or more San Joaquin River tributaries since 1939. Generally, only sparse or incomplete estimates are available prior to 1953. These estimates, however, provide the best indicator of the chinook spawning population trend over time during the period 1939 through 1952.

Past. Chinook salmon production in the San Joaquin drainage (ocean harvest plus spawning escapement) historically approached 300,000 adults but probably averaged nearer 150,000 adults prior to inception of recent water storage project developments.

Escapement averages of fall-run salmon for 4 decades in the three tributaries to the San Joaquin are provided in the following table:

Decade	Merced River	Tuolumne River	Stanislaus River	Total
1940's	1,100	63,000	8,000	72,100
1950's	1,200	23,000	11,000	35,200
1960's	240	10,300	5,000	15,540
1970's	2,200	5,400	3,100	10,700

Large runs in the early 1940's in the mainstem San Joaquin River near Fresno were predominantly comprised of spring-run fish. This run was completely eliminated after 1949 as a result of the Friant Dam closure and operation of the CVP.

Documented accounts of spring run salmon entering the upper San Joaquin River above Fresno are as follows:

Year	Count
1943	35,000
1944	5,000
1945	56,000
1946	30,000
1947	6,000
1948	2,000
1949	no count
1950	no fish

all run escapement in the main stem, which averaged about 1,000 spawners in the 1940's, was also eliminated by Friant Dam.

Present. Recent adult salmon escapements to the San Joaquin River tributaries have increased as a result of fortuitous high streamflow conditions. Average escapement during the 1980's for the Merced, Tuolumne, and Stanislaus rivers have been respectively 13,000; 14,000; and 5,500 chinook for a total average of 32,500. Good outmigration survival occurs for juvenile fish concurrent with high spring outflow. Fall flows are usually adequate for the upriver migration. Spawning runs corresponding with preceding favorable flow conditions occurred in 1983, 1984, and 1985 totaled 33,500, 60,000, and 70,000 fish, respectively. These relatively high escapement numbers in the drainage that had previously been supporting a fall run of approximately 11,000 provided a good example of the resiliency of San Joaquin River chinook when adequate flows occur.

The Merced River has adequate spawning habitat to support a fall run of 25,000 adults. A run of 25,500 adults was observed in 1984. Screens on the riparian diversions are now being rebuilt; this will increase the survival of juvenile salmon. The Tuolumne River presently has adequate spawning habitat to support 40,000 adults. A run of 39,000 adults was observed in 1985. Revised flow releases have been negotiated with the irrigation districts as a part of FERC's licensing of a fourth generator at the New Don Pedro Dam. The DFG is seeking improved habitat conditions for salmon, especially better spring flows. The Stanislaus River has adequate spawning habitat to support 20,000 fall-run adults. A run of 12,000 adults was observed in 1984. Negotiations for improved flow releases were recently completed with the USBR. As with other tributaries, the DFG is emphasizing more suitable spring flow releases. Opportunities exist on the Stanislaus for winter- and spring-run chinook. This stream has large deep pools which could provide holding area for these races. Spring and summer flows of suitable temperatures currently exist. The stream could potentially support steelhead. If so, there would be good recreation opportunities which are enhanced by good public access to the stream.

Salmon Fisheries. Salmon are a popular sport fish in the San Joaquin River and the lower reaches of its major tributaries. The angling season is relatively short because only the fall run is present in the drainage.

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Although angling access is limiting, this provides about 2 months angling from late summer into fall. San Joaquin River salmon also provide angling opportunity in the Delta and Bay.

The ocean fisheries have been fairly well documented in recent years as a result of the coded-wire tagging of fish from the MRFF. The harvest rate is comparable to other Central Valley fall-run stocks, but the low average population size has made it a minor contributor to the overall harvest except during years following exceptionally high spring river flows. Sports and commercial fishing organizations have shown strong interest in restoring and enhancing the runs to the San Joaquin River tributaries and have helped obtain funds for MRFF improvements.

Potential. Recent high spring flows in the San Joaquin River system have shown that, even under present conditions with numerous diversions along the migratory route down the river and through the Delta from the Stanislaus, Tuolumne, and Merced rivers, a return of 70,000 adult fish can be expected with adequate seasonal flow conditions. Natural production can be increased through flow and regulation and gravel manipulation. The migratory routes can be improved by removing barriers (including temperature barriers), eliminating false migration routes, and screening o modifying entrainment hazards.

With improved flow regimes in the major tributaries and the main stem San Joaquin River, an annual production of 200,000 adult chinook and 5,000 steelhead may be possible. Implementation of all improvements of the habitat could result in an additional production of 75,000 adult chinook and 5,000 steelhead. The addition of a hatchery on the Stanislaus River and improvements to the MRFF could result in an additional production of 200,000 adult chinook (ocean harvest and escapement) and 10,000 steelhead in the system. A hatchery on the Stanislaus River would have the added benefit of sustaining a base run even during very dry years.

II-4-C. Steelhead Resource.

Occasional large rainbow trout are caught in the Stanislaus and Tuolumne rivers which may be steelhead that have strayed from other river systems.

Past. The San Joaquin River system has not supported a viable population of steelhead in the past 50 years. It is not known if a significant steelhead run historically existed.

Present. There are no viable steelhead populations in the San Joaquin River system at this time.

Steelhead Fisheries. Occasionally, steelhead or large rainbow trout are caught in San Joaquin River tributaries. In recent years juvenile steelhead have been captured in travel nets at Mossdale indicating that some natural production may occur in the system.

Potential. With sufficient flows and a hatchery, a significant steelhead population could be maintained on the Stanislaus River. Our goal is to produce 1/2 million yearling steelhead at new hatchery facilities and to improve habitat for natural production capable of sustaining an annual run of 20,000.

II-4-D Natural Production.

Streamflow, water temperature and entrainment or impingement at water diversions are the principal limiting factors for natural production in the system. Although gravel mining has severely reduced the useful spawning gravel, the spawning areas could be restored by reliable methods developed in more northerly salmon and steelhead streams. With reliable streamflows adequate to meet salmon and steelhead life history requirements, natural production of fall-run chinook could potentially be restored to levels approaching historic levels; and steelhead, winter- and spring-run chinook populations could be developed where over-summering water conditions are maintained.

In the San Joaquin River and its tributaries, wet springs and high spring flows lead to good smolt production and good survival through the Delta.

II-4-E Hatcheries.

The only hatchery in the upper San Joaquin River drainage is MRFF. Although production could be increased, it presently produces 200-400,000 yearlings annually.

II-4-F Environmental Problems and Preferred Solutions

Lack of sufficient flow releases for salmon. Inadequate spawning, rearing, and emigration flow is the single factor that has contributed most to the decrease in fall-run salmon populations of the San Joaquin River system. This along with Delta pumping has caused total fall-run salmon escapement for the San Joaquin tributaries to decline from 72,100 spawners during the 1940's to 10,700 in the 1970's.

Historically, not only were flows higher during the spring, but they lasted much longer. Much of the downstream migration occurred during June. Fish migrating downstream were provided a much longer period to migrate and were able to rear to a larger size prior to entering the Delta and saltwater. Therefore, the survival of those fish reaching the Delta was probably better and they provided a greater contribution to fisheries and subsequent spawning populations.

Reductions in flow have caused higher temperatures, which are unsuitable or lethal to salmon, to occur earlier in the year adversely affecting juvenile salmon. Adult fish are also affected by temperature during their upstream migration; lack of cool water delays their upstream migration. Two interim potential solutions to partially overcome this temperature problem in the lower river and main stem are: (1) trap and truck part of the naturally produced fish to the estuary, or (2) confine young salmon to upstream ponded areas during the summer where temperature is suitable, then release them in the fall when the water temperature has cooled.

The preferred solution to deficient flows in the Merced, Stanislaus, Tuolumne, and mainstem San Joaquin rivers is negotiation of better fishery flows. Recently negotiated agreements for the Stanislaus and Tuolumne rivers may provide for improved flow conditions.

Lack of screens on main stem San Joaquin River diversions results in significant entrainment and loss of juvenile salmonids. When screens were in operation on some of the diversions, they were not effective and were abandoned because of the cost of maintenance and operation (about $25,000 annually). Their inability to economically save young salmon was in part due to the low runs and flow irregularities. If runs in the San Joaquin system continue to increase as they have in the last few years, the benefits of rescreening should be evaluated. The preferred solution is probably to obtain an alternate water supply for the irrigation districts during the salmon migration periods. This may be able to be done with water from the Delta Mendota Canal.

The Department is pursuing an alternate diversion site for the Patterson, El Soyo, West Stanislaus, and Banta-Carbona water diversions. If the service areas could be irrigated with water from the California Aqueduct, it would result in increased survival of young salmon migrating downstream in the San Joaquin River. Since the inflow of water to the Delta will be increased by an amount equal to the export, the change in diversion sites will have no effects on the salmon and steelhead resources of the Sacramento River systems.

Delta water diversion. During most years all of the spring flow in the San Joaquin River is diverted into the Delta pumping plants. This decreases the survival of young salmon because they must pass through the screen apparatus or become lost in the Delta channels.

The ideal method for reducing fish losses would be cessation of pumping during the spring and fall, a solution which is most unlikely. A partial mitigation of conditions caused by Delta pumping would be installation of a barrier in Old River to shunt young salmon around the pumps and help to provide a positive flow in the main stem for adults.

Other Problems adversely impacting the salmon resource are listed as follows:

1. Fluctuations in flows due to power production requirements cause the stranding of eggs and young salmon. This condition could be alleviated by improved water release agreements and modification of streambeds where stranding is a chronic occurrence.

2. Flow reversal in the southern Delta detours adult salmon during their upstream migration. This problem has been greatly alleviated by the placement of a temporary barrier in the Old River to provide a flow in the main stem of the San Joaquin River. Other flow direction corrections are needed.

3. Maintenance of flow releases for salmon in the tributaries are not carried through from the point of release downstream to the confluence with the main stem. Presently, there are several riparian diversions on the Merced River between the dam where the flow is released and the gauge where flow is measured. Under these circumstances, if the flow is deficient, responsibility for this deficiency is not easily determined. The diverters should be held responsible for maintenance of continuity of fish release flows.

II-4-G Enhancement Opportunities

Enhancement opportunities are greatly limited because mitigation and restoration needs remain throughout the drainage. The severely degraded condition of the habitat in most areas will require substantial restoration before any enhancement can be identified and benefits can be achieved.

Runs in the San Joaquin River system could be enhanced with hatchery facilities. This conclusion is based on the results in other Central Valley streams where fall-run numbers have increased in spite of adverse environmental conditions. The increased reliance on hatchery production may decrease genetic variability and, therefore, is a concern for the long-term welfare of the resource.

Hatchery facilities on the Stanislaus River could potentially provide production of fall-, winter-, and spring-run chinook, and steelhead trout. The greatest enhancement can only result from restoration of consistent streamflow suitable for chinook. Enhancement opportunities for natural production lie primarily in improvement of spawning gravel and establishment of suitable migration corridors.

II-5 Delta

II-5-A Physical Environment

Geography. The Sacramento-San Joaquin estuary, comprised of the Delta, Suisun Marsh, and the San Francisco Bay system, supports major fish and wildlife resources (Figure 5). The Delta is essentially a fresh water environment, while the marsh and bay are brackish and salt water environments, respectively. The three provide a gradual transition from fresh to saltwater which is important to anadromous fish.

The Delta, an important agricultural area, is generally bordered by the cities of Sacramento, Stockton, Tracy, and Pittsburg. The 738,000 acres in the statutory Delta, as defined in California Water Code section 12220, are part of the largest estuary in California. The former swamplands in the Delta have been reclaimed into more than 50 islands and tracts largely devoted to farming. The islands, many of which lie below sea level, are bordered by levees for protection against high tides and floods. The islands are subject to seepage from the surrounding channel water and inundation if the levees fail.

The Delta is interlaced with about 700 miles of waterways which provide a major recreation area for fishing, boating, water skiing, hunting, and scenic enjoyment. There are 125 marinas and two State parks. The waterways and islands provide habitat for many fish and wildlife species, and migration corridors for anadromous fish including chinook salmon and steelhead.

The Suisun Marsh, an important area for wildlife, is located on the northern edge of Suisun Bay just west of the confluence of the Sacramento and San Joaquin Rivers. The area consists of 57,000 acres of managed marshlands and 27,000 acres of intertidal bays and sloughs. Most of the managed wetlands are enclosed within levee systems. About 80 percent of the marsh is privately owned by more than 150 duck clubs. The Department of Fish and Game owns and manages more than 10,000 acres and another 2,000 acres is owned by the Federal Government.

San Francisco Bay covers about 450 mi^2 at mean tide, a considerable reduction from its original size. This reduction is due to fill and marshland reclamation. The volume of water in the bay changes by about 21 percent from mean higher-high tide to mean lower-low tide. The depth of the bay averages only 20 feet with the deeper water lying from the Bay Bridge to Point Richmond.

Numerous tributaries to San Francisco Bay and the upper bays leading to the Delta also support salmon and steelhead resources. In addition to chinook, coho are found in some of these drainages. Production of salmon and steelhead in these streams is minor in comparison to the Sacramento and San Joaquin rivers.

Fish produced upstream from the Delta commonly stray into the bay tributaries and have reestablished themselves in a few streams over the past 10 or 20 years. Although the flows in these streams are largely seasonal and have been greatly depleted over the course of agricultural and urban development in this century, cleanup and restoration efforts have greatly improved their capability to support salmon and steelhead.

The streams where salmon or steelhead have been observed over the past few years are Napa River, Petaluma River, Alameda Creek, Guadalupe River, Ledgewood Creek, Walnut Creek, Sonoma Creek, Nathanson Creek, Tolay Creek, San Antonio Creek, Novato Creek, Miller Creek, Corte Madera Creek, Coyote Creek, Stevens Creek, and San Francisquito Creek.

Geology. To describe the nature of the levee system, which comprises the core of the Delta, it is first necessary to briefly review the history of Delta reclamation and the nature of the soils, floods, and related factors. Much of this information is taken from Department of Water Resources reports.

Beginning in the 1850's, creation of the levee system resulted from the demand for agricultural land with ready water supplies. Settlers first constructed low barriers of earth on the higher "natural levees" formed by high flow deposits. These low barriers, called "shoestring levees", were built primarily to keep tilled soil from washing away. Settlers rarely tried to prevent high tides from easing water over the lower portions of their land. Exclusion of tidal water awaited complete enclosure of the tracts.

The Federal Swamp and Overflow (Arkansas) Act of 1850 provided for title transfer of the wetlands from the Federal Government to the states. In 1861, California established a State Commission to facilitate reclamation for landowners. It was not, however, until 1868, when the responsibility for carrying out reclamation was turned over to landowners and their reclamation districts, that reclamation began on a large scale. Sherman Island is the site of the first coordinated levee system; this took place in 1868-69.

The first levees were built with two purposes in mind. Levees built around the islands of the central Delta were intended primarily to exclude tidal water from the tracts underlain by peat; those built along the sedimentary banks of the rivers were expected to protect the reclaimed land, not just from high tides, but against all but the highest flood stages as well. Levee work was primarily done by Chinese laborers teamed to handle four basic tasks: dig with an iron spade; fork and shovel peat blocks into wheelbarrows; push the wheelbarrows along planks; and lay the embankment.

Between 1871 and 1879, most of the swamp and overflow lands were enclosed by a levee system. Although considerable land was cleared for crops, much of it was used for pasture. At that time, about 47 square miles of marsh between Venice Island and Middle Roberts Island remained unleveed. About 100 square miles of the central Delta's peaty tracts that had been leveed were abandoned to the tides by 1875. During the 1870's, all but one tract (near Courtland) experienced flooding. The development of dredges to build levees more quickly and at greatly reduced cost helped to reclaim most of the Delta marsh between 1880 and 1916. By 1930, all but minor areas of the swamplands had been leveed and were producing a wide variety of crops.

Although dredges have replaced hand labor in levee construction, the two techniques have some things in common. Neither is susceptible to a rigorously applied engineering approach, and both methods evolved over time on a trial and error basis. In fact, because of the unstable and widely varying character of peat soils, engineers have been unable to develop rigorous technical approaches to Delta levee design and construction. There are modern examples of "engineered" Delta levees that have taken years to stabilize (or have never stabilized) following construction. The U. S. Army Corps of Engineers has been unable to turn over some levees along the Yolo Bypass to non-federal interests for operation and maintenance because they continue to sink and must be reconstructed or raised almost annually. The Department of Water Resources is having similar experience on relatively short reaches of levee in the Suisun Marsh at Roaring River Slough, where the levees overlie 60 feet of peaty soils (Figure 5).

Delta soils are typically organic, mineral, or a mixture of both. The organic soils are largely composed of or derived from peat, which is thickest in the western and central portions of the Delta, where it reaches a maximum depth of more than 50 feet at Sherman and Andrus Islands. Mineral soils (sand and silt) occur along the margins of the Delta and as channel and natural levee deposits.

The physical and chemical properties of the organic soils make them susceptible to oxidation, anaerobic decomposition, wind erosion, and flamability. These properties create continual subsidence problems. Peat areas of most islands subside at average rates of from 1 to 3 inches per year.

About 80 percent of the shallow subsidence of the organic soils is due to oxidation. Recognizing that before reclamation, the surface elevation of organic soils was about sea level, the magnitude of negative elevations (that is, elevations below sea level based on 1978 topography) is an approximate measure of the maximum amount of subsidence that has taken place on each island since initial reclamation. Limited available data seem to indicate that most Delta subsidence is shallow and related to depletion of the organic soils rather than deep-seated regional subsidence. (Experts do not agree on whether tectonic subsidence is occurring. If it is, the rate is very small in comparison to other causes).

Thus, the depletion of organic soils is a major controlling factor in determining the future of the Delta. Complete depletion of organic soils would not necessarily be adverse to Delta farming, but it may reduce farm income, leaving less money for levee maintenance. Depletion would probably signal the end of shallow subsidence. Organic soils in some of the southern and eastern portions of the Delta have already been depleted.

Hydrology. Much of the information related here is taken from Department of Water Resources reports. The aquatic environment of the Delta is influenced by many factors. The hydraulics of its complex arrangement of channels entails consideration of tides, stream flow, and diversions. The quality of its waters are affected by the quality of inflowing tributaries, salinity intrusion from San Francisco Bay, industrial and municipal wastes, marine wastes, and irrigation return flows. The cyclic (horizontal and vertical) movement of water in Delta channels resulting from Pacific Ocean tides complicates the determination of direction and quantity of flow necessitating the consideration of differential or net flows in any given direction.

Tides in the Delta are transmitted from the Pacific Ocean through San Francisco Bay. The great energy of tidal action is illustrated by the fact that except during times of high floodflows from the central valley, tidal effects are apparent throughout the entire Delta. The average diurnal range at the entrance to San Francisco Bay is 5.7 feet. At Collinsville, near the western limit of the Delta and 40 miles from San Francisco, the range is 4.3 feet (Figure 5). At Sacramento, the northernmost point of the Delta, the mean diurnal range is 2.9 feet and at Mossdale Bridge on the San Joaquin River, which is the southernmost point, the range is 2.4 feet.

Instantaneous rates of flow due to tidal action can be substantial. For example, at Chipps Island during one ebb or floodtide period (one quarter of a tidal cycle or a little more than 6 hours), the average volume of flow is about 78,000 acre-feet, equivalent to an average flow rate of more than 150,000 cfs during this 6-hour period. This tidal flow changes direction each quarter tidal cycle, and is in addition to the flow due to river runoff or diversions. Tidal flows in a downstream direction are called positive, while upstream flows are called negative. The difference between the upstream and downstream flows at a station during a tidal cycle is called the net flow during the cycle. Tides may induce net circulations in the Delta channel network that do not depend on any inflows or diversions of water.

An important property of tidal action is its propensity to disperse dissolved substances. The back-and-forth water motion induced by tides has a mixing or dispersive action which tends to equalize differences in concentrations between points. It is the reason the Delta's waters can effectively dilute waste discharge, and it is the instrument of seasonal intrusion of saline ocean water through the bays into the Delta.

Precipitation in California's Central Valley is typically concentrated in the winter months, while the summers are relatively dry. Most of the valley is tributary to the Delta, and so the volume of water entering the Delta usually undergoes large seasonal variations. In addition, the total valley runoff varies substantially from year to year. These seasonal and annual variations result in variations in the magnitude and distribution of flows in the Delta channel network. Other factors causing Delta flows to vary are precipitation within the Delta, consumption of water by agriculture, and the operations of water transport and diversion projects within the Delta and on tributary streams.

Based on a DWR review of water years 1921-22 through 1953-54, Delta inflow from the entire central valley is estimated to average 19,794,000 acre-feet per year at the 1970 water project development level. The inflow for the median hydrologic year (1924-25) was 15,251,000 acre-feet. The degree of variation in inflows extended from a minimum of 9,456,000 acre-feet (1923-24) to a maximum of 46,152,000 acre-feet (1937-38).

Delta inflow is dominated by the Sacramento River which accounts for 80 percent of the total, on the average. The San Joaquin Valley contributes 15 percent, and the eastside streams account for the remaining 5 percent. Internal net use of water within the Delta includes the combined effect of consumptive use by agriculture and evaporation from water surfaces which peaks in the summer, and precipitation which is greatest during the winter. Use in the Delta uplands might be estimated from records of water pumped at individual farms, however, much of the water used by crops seeps through the levees surrounding the many islands and cannot be measured. Therefore, estimates of water consumed by various crops are based on field or laboratory measurements of unit consumptive use (designated in acre-feet per acre) and varies with the type of crops and time of the year. These figures when multiplied by the acreages of the various crops show the probable consumptive water use in acre-feet. The consumptive use modified by precipitation results in a calculated net use from Delta channels.

The maximum net use of 268,000 acre-feet occurs in July and is equivalent to an average of over 4,300 cubic feet per second. Delta net use, therefore, has a substantial effect on flows in the network of channels during the summer months.

Delta Exports began in 1940 with the beginning of operation of the Contra Costa Canal of the CVP. Export by the CVP Tracy Pumping Plant began in 1951, and the SWP's Delta Pumping Plant began in 1967. Minor exports are also made by the City of Vallejo.

The total of these exports is increasing from year to year as the water requirements of the service areas to which they supply water increase. The amount exported in any given month in a year, however, depends on the hydrology of that year. Exports are dominated by those at the Tracy and Delta Pumping Plants and are greatest in the spring and summer, and least during the winter. The maximum exports have a great effect on the magnitudes and directions of flow in the Delta channels.

Delta flow distribution at a given point in the Delta is in a state of continuous change, reversing about four times daily, but the flow can be summed during a complete tidal cycle to give the net flow. The magnitude and direction of net flows throughout the Delta channel network affects the aquatic environment, both from the standpoint of chemical water quality and of the biota, particularly migratory fish.

Flow distributions in the Delta depend on the combined influences of inflows, use within the Delta, and exports. They are further dependent on the divisions of flow which occur at channel intersections. Inflows and exports are routinely measured with some accuracy. Internal Delta use must be estimated and is subject to uncertainty. Measurement of net flow divisions at the most important channel intersections has been attempted but has not been entirely successful. Therefore, our understanding of flow distributions are somewhat qualitative rather than quantitative.

Water in the Sacramento River channel is subject to diversion into other channels at several major points. The first diversion occurs at Sutter Slough, near Courtland, where water flows west. A short distance to the south, Steamboat Slough causes an additional westerly diversion. The two sloughs pass among a group of islands devoted to agriculture, merge, and rejoin the Sacramento River at Junction Point, north of Rio Vista. The net flows in Sutter and Steamboat Sloughs are influenced by the operation of the gated Delta Cross Channel; the flows being higher when the Channel is closed than when it is open, other conditions being the same.

The Delta Cross Channel diverts water eastward from the Sacramento River into Snodgrass Slough. From there, the water passes into the north and south forks of the Mokelumne River and flows southward toward the San Joaquin River. This artificial channel was completed in 1951 by the USBR for the purpose of providing increased amounts of good quality Sacramento River water in the central part of the Delta where it is available for export by the CVP Tracy Pumping Plant and the SWP Delta Pumping Plant. The gates on the Delta Cross Channel are normally open when flow in the Sacramento river is less than 30,000 cubic feet per second. When open, it has a marked effect on tidal action in the Mokelumne River system and has a much greater impact on net flow in the north fork than on the south fork. This is because the south fork is somewhat smaller and has a restricted section near its north end.

At Walnut Grove, Georgiana Slough diverts flow from the Sacramento river southward to the Mokelumne River and the central Delta. The effect of Georgiana Slough is thus similar to that of the Delta Cross Channel (Figure 5).

Threemile Slough, a few miles south of Rio Vista, is another channel the Sacramento River intersects on its way to San Francisco Bay. This slough, named for its length, connects the Sacramento and San Joaquin Rivers.

The pressure of winter floods on the Sacramento River levees is relieved by diverting excess waters into the Yolo Bypass above Sacramento. These floodwaters rejoin the Sacramento and enter the Delta through Cache and Prospect Slough and the Sacramento Ship Channel north of Rio Vista.

Along the eastern side of the Delta, the Mokelumne and Cosumnes rivers and Dry Creek join and enter the Delta as the Mokelumne River a few miles east of Walnut Grove. These waters flow southward in the two forks of the Mokelumne

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and discharge into the San Joaquin River in the central Delta. Other streams entering the Delta along its east side include the Calaveras River, Bear Creek, Littlejohns Creek, and Mormon Slough.

The San Joaquin River enters the Delta at its southern limit near Vernalis and flows toward Stockton. A major flow division occurs north of Mossdale, where a portion of the San Joaquin River flows west in Old River. The proportion of flow thus diverted is strongly influenced by the export pumps near Tracy. If the pumps are not operating, about half of the San Joaquin River flows into Old River. When the pumps are in operation, however, they may draw the entire positive flow into Old River.

The federal and state pumping plants, located close together on Old River near Tracy, exert a major influence on flow distributions in the southern and western portions of the Delta. A smaller, more localized effect is caused by the operation of the Contra Costa Canal which exports water from Rock Slough.

The effect of the exports depends on their magnitude relative to Delta inflows and internal net uses. The several general cases are summarized as follows:

1. If there is sufficient flow in the San Joaquin River at Mossdale to meet the total exports and internal uses in the southern Delta, then seaward flow will be maintained in all Delta channels.

2. If the San Joaquin River does not meet the exports and the southern Delta internal uses, the deficit may be made up by inflows from the eastern stream group and by Sacramento river water flowing through Georgiana Slough and the Delta cross Channel. In this case, the net flow in Old and Middle Rivers and the channels connecting them will be reversed; that is, the flow will be southerly, toward the export pumps. If the pumping is sufficiently larger than the San Joaquin River inflow, the direction of net flow in the San Joaquin River between Stockton and Old River will be reversed; that is, the net flow will be southerly toward the head of Old River.

3. If the export and internal uses are greater than the combined inflows from the San Joaquin River and the eastern streams, together with the flows in Georgiana Slough and the Delta Cross Channel, then the balance is made of water from the Sacramento River, flowing southerly through Threemile Slough, or by Sacramento River water which passes the westerly end of Sherman Island and travels easterly up the San Joaquin River past Antioch. In this case, net flow in the San Joaquin River is reversed from Collinsville (near Suisun Bay) to False River.

   Because net flows in the San Joaquin River near Antioch and in Threemile Slough cannot be measured, the distribution of flow between these channels under varying hydraulic conditions is not known, and the degree of any reversal in the San Joaquin remains uncertain.

The Contra Costa Canal, with its diversion from Old River via Rock Slough, contributes to the reversal of flows in the southern and western Delta.

II-5-B Salmon Resource

In the last 40 years, as a result of water development and resulting flow curtailments, salmon runs in the San Joaquin system have declined to less than one-fifth of their prior abundance. Water projects have caused similar effects in the Sacramento River and its tributaries however, maintenance of minimum streamflows and extensive hatchery production have helped maintain most of the population albeit at reduced levels. Still in recent years the Sacramento system has produced over 90 percent of the Central Valley's Chinook salmon.

Past. Historically, the San Joaquin River system supported both a fall and a spring run of chinook salmon. Spring-run chinook salmon disappeared from the San Joaquin system in the 1940's after construction of Friant Dam.

Three distinct runs of chinook salmon were recognized in the Sacramento River system. These runs were termed the fall, winter, and spring runs, with the fall and spring runs predominant. As with the San Joaquin River stocks, habitat destruction, which accompanied construction of dams, and subsequent alteration of downstream water temperatures have reduced the size of the Sacramento River stocks and rearranged the timing of their migrations. The Sacramento River and most of its major tributaries supported steelhead populations.

The Delta provided a migratory corridor and nursery area for the various races and populations of salmon and steelhead from its tributary streams.

Present. San Joaquin River chinook salmon adults commonly appear in the Delta in early October with most spawning occurring in November and December. Outmigration of young occurs primarily in the spring. The success of juvenile outmigration determines the size of the returning adult population 2 1/2 years later and is directly correlated with March through June flow in the San Joaquin River.

In most years, spring flow is severely reduced by upstream water development. Young salmon have less space in which to grow and many young salmon fail to leave their homestream nursery areas in time and eventually succumb to high summer water temperatures. The later the outmigrants start their seaward journey, the greater the chance they will encounter unfavorable conditions in the lower San Joaquin River and the Delta. Fall releases of chinook salmon yearlings from the Mokelumne and Merced River fish installations operated by the Department of Fish and Game augment natural production.

Fish spawned in fall and early winter move into the lower river and estuary in January, February, and March as fry, with the peak of the smolt migration occurring in May and June. Outmigrants from the late fall-run follow a pattern similar to the fall run but about one month later, and the winter-run progeny even later. A smaller, though readily identifiable, outmigration of large yearling chinook salmon has been identified in October and November at both Chipps Island and the state and federal fish protective facilities. Thus chinook salmon outmigrants from the various runs may now be found in the estuary year-round, with the bulk of the movement occurring during the spring.

Salmon Fisheries. Salmon are not heavily fished in the Delta. The fish have not proven particularly vulnerable to anglers, except to a few specialists and as the fish congregate to enter the main river channels. Salmon angling has become popular in the bay during the fall and early winter months as the fish begin their spawning migration. No recent figures are available for angling use or harvest.

Potential. Improved flows could greatly improve passage of adults upstream to the spawning areas and survival of outmigrants and rearing juveniles in the Delta. Scheduling appropriate flows to coincide with critical needs of salmon has shown great promise for improved production.

II-5-C Steelhead Resource

Steelhead were probably never very abundant in any of the drainages except the Sacramento River. They typically are found in the Delta as outmigrating juveniles and as 2-year old or older returnees from the ocean.

Past. Steelhead were found throughout the major perennial streams tributary to the Delta and San Francisco Bay. The fishery was principally in the smaller tributaries during the fall and winter months, although juvenile steelhead were probably heavily fished as "trout" during the spring and summer. The major recognized populations were found in the Sacramento River system.

Present. Steelhead found in the Delta are largely produced in the Sacramento River drainage hatcheries. The balance of the population is natural production from the Sacramento River drainage. Steelhead occasionally appear in other drainages and natural production still occurs in some tributaries to the Bay. Flow curtailment and dams have greatly reduced the suitable habitat in the Sacramento-San Joaquin river system.

Steelhead Fisheries. Steelhead are harvested incidentally in the Delta by anglers seeking other species. The bulk of fish caught are juveniles or early returning yearling or 2-year old fish. The major fishery for adult fish occurs in the lower and middle reaches of the major tributaries to the Sacramento River and in the upper Sacramento River.

Potential. Improved flows in the Delta could result in increased survival of outmigrants past water diversion points and predators.

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The nursery value of the Delta is not well understood for steelhead, but all indications are that improvement could lead to improved survival and natural production.

II-5-D Environmental Problems and Preferred Solutions

Water Temperature. Water quality (temperature and dissolved oxygen) has been shown to be critical to successful migration. Monitoring in the San Joaquin River between 1964 and 1967 demonstrated that adult fall-run chinook salmon bound for San Joaquin River tributaries seldom moved upstream until water temperatures fell below 66°F. Water temperature in this area is inversely proportional to flow, and is directly proportional to both the net heat gain or loss and to the surface area of the river reach. Thus, for any given reach, a reduction in flow will magnify the effect of the heat gain or loss.

Studies on the San Joaquin River have also demonstrated the importance of dissolved oxygen level in the river. Water with dissolved oxygen concentrations of less than 5 mg/L constituted a virtual barrier to upstream migrant salmonids. Dissolved oxygen is probably a more absolute constraint than temperature, as salmon migrated past Stockton in 1971 when dissolved oxygen conditions became satisfactory, even though the temperature was about 70°F.

Chinook salmon smolts from fall-run stock migrate through the Delta mainly in April, May, and June. Their movement through the estuary is fairly rapid. Mark-recapture data from the Delta indicate that smolts migrate 6 to 11 miles per day. Survival of smolts migrating through the Delta is influenced by water temperatures and/or flow rates. Survival has been observed to increase as flow rate increases and temperature decreases.

Increased flow through the Delta with emphasis on times of the year critical to the species and races of fish involved would result in increased survival. Increases in bypassed flow should be coordinated with spring- and fall-pulse flows in the tributary streams.

Straying and Migration Delay. Once an upstream migrant salmonid has entered a river system, orientation depends primarily on olfactory perception of homestream water. Thus, a "homing" or "parent" stream odor gradient is required to assure the fish's return to the spawning grounds. The presence of Sacramento River water in the southern Delta channels caused by reverse flows in the lower San Joaquin River has resulted in straying and an accompanying delay of upstream migrant chinook salmon bound for the Sacramento River and its tributaries. Many salmon migrating to the Sacramento River are now led to use the lower San Joaquin River and return to the Sacramento River through Georgiana Slough and the Delta Cross Channel.

Reverse streamflow and large amounts of Sacramento River water in the southern Delta also confuse San Joaquin River adult migrants, resulting in delays and substantial straying of San Joaquin salmon into the Sacramento River system. The minimum amount of homestream water required for successful migration in either the Sacramento or San Joaquin River is unknown. Salmon have migrated successfully up the San Joaquin River past Stockton at flows of 500 cubic feet per second, but higher flows may be necessary for optimum migration.

Two distinct groups of juvenile chinook salmon grow in or migrate through the estuary; these are fry and smolts. Each has particular habits and associated environmental requirements.

Fry abundance in the estuary is greatest during February and March, but they can appear as early as November. The number of eggs produced by the spawning population and subsequent environmental conditions, mainly flow, influence the abundance and timing of fry traveling through the Delta into the estuary.

The spacial as well as temporal distribution of fry in the estuary appears to be related to the magnitude and timing of storm runoff. Fry were primarily restricted to the northern and central Delta in 1981 (a dry year) but some were collected as far downstream as central San Francisco Bay in 1980 (a wet year).

The complex changes in Delta flows that have resulted from the major water diversions in the south Delta can increase travel distance and the time required for fry and smolts to move through to the estuary. This rerouting and delay exposes the outmigrants to greater hazards from water quality, entrainment at diversion points, and predators. Survival of Sacramento River smolts is closely correlated to the proportion of flow that is diverted into the interior Delta through the Delta Cross Channel and Georgiana Slough; the higher the proportion, the lower smolt survival. San Joaquin River smolts appear to have a high rate of survival when routed directly down the San Joaquin River.

The survival of downstream migrant salmon may also be affected by the availability of food. The food habits of young salmonids in the system have been reported by several authors. Insects compose the main food item in most young salmon examined; however, in specific locations, other items become important. In the lower portion of the estuary, crustaceans were significant diet items. In the upper portion of he estuary, Daphnia sp., Cladocera and Diptera were more common. Juvenile chinook salmon seem to be opportunistic feeders, eating mostly insects, but are capable of shifting to other food sources if necessary.

Pulse flows have proven successful in the tributary river systems to provide attraction flows to enable upstream migrants to find their way to spawning grounds and hatcheries. These pulse flows (block flows) have also proven effective for speeding outmigrants on their way and reducing the dangers of entrainment at water diversion points and from predators. Pulse flows could also prove valuable for transporting fish through the Delta if complicating factors such as large pump diversions, were curtailed during the period of increased flow. Care would be necessary to time such flows to best coincide with the seasonal need of the various species and races concerned.

Part III Attaining the Goals

III-1 Restoration and Enhancement Needs.

The major losses of salmon and steelhead production that resulted from the disregard and degradation of the Sacramento-San Joaquin river system persist. Naturally reproducing populations continue to be depressed throughout most of the system.

Several unique races of salmon and steelhead have been severely affected by dam construction. Spring-run chinook in the upper San Joaquin River were eliminated by Friant Dam. The American River spring-run steelhead was extirpated and the fall-run steelhead, which provided a fishery beginning in September in the American River, was severely decimated by Nimbus Dam. The fisheries these races supported have been partially replaced in the American River by fall-run chinook and the introduction of later run steelhead from the Eel River.

Winter-run chinook salmon in the upper Sacramento and Calaveras rivers have been adversely affected by Shasta, Red Bluff Diversion, and Hogan dams. Spring-run chinook salmon in the upper Sacramento and Feather rivers have been confined to the same spawning grounds used by fall-run and have hybridized with them; the mixing of these races which spawn at the same time has probably greatly reduced the number of pure spring-run in the Central Valley. A pure strain of this race hopefully still occurs in Deer and Mill creeks. In these streams, spring-run are able to migrate to their historical spawning areas which are at higher elevation and spacially separated from fall-run salmon.

Overall production of the stream sections still available to salmon and steelhead can be improved through a variety of methods. The minimum requirements for salmon and steelhead production are water quality and quantity suitable to meet their life history needs. Other needs include suitable spawning and nursery area, migratory corridors, and reasonable protection from overharvest.

Hatchery production can be employed to augment natural production and has been used to offset losses of production of natural spawning and nursery areas. When broodstock is carefully chosen, hatchery production can also be used to maintain or rebuild depleted races. This may become the only means of maintaining any significant population of spring-run salmon whose historic habitat has been dramatically reduced and now must complete with the fall run for habitat.

The hatchery system of the Central Valley has helped maintain the fall-run chinook fishery and supported a steelhead fishery in the American River and lesser fisheries in other parts of the Sacramento River system and the Delta. Restoration of fish populations through hatchery production alone recognizes the risks inherent in concentrating the bulk of the resource within narrow confines subject to mechanical or biological catastrophes and the potential loss of genetic integrity and characteristics of the individual races. For instance, the hatcheries on the American, Feather, and Mokelumne rivers have produced a fall-run of chinook strong enough to expand throughout the accessible drainage, and which may overwhelm the races previously occupying those other areas. If present trends continue, habitat losses and interactions with hatchery produced chinook will result in the disappearance of the winter-run, late fall-run, and spring-run chinook salmon. The prudent alternative for restoring and maintaining the Central Valley salmon and steelhead resources is to utilize extensive restoration of environmental conditions to maximize natural production in combination with limited and carefully planned hatchery augmentation.

Restoration of habitat lost as the result of appropriations of lands or waters almost always requires some modification of the development and concessions on the part of the developer. For this reason, significant restoration of habitat is a complex process of evaluation, arbitration, and reconciliation. Successful methods of habitat restoration include restoration of water quality and quantity during critical life stages for the species or race(s) involved, improvement of spawning gravels and nursery habitat, and development of safe migratory corridors.

III-1-A Water Quality and Flows

Achievement of water quality objectives for salmon and steelhead in California is largely dependent on the quantity of water available. Temperature, turbidity, and non-point pollution sources are most easily controlled by flow regulation. Also, flow is necessary to dilute point sources of pollution where onsite control is not currently in effect, such as Iron Mountain Mine in the volume of instream flows are important considerations for maximizing fish production with available water supplies. These factors must not only be considered for fish passage needs, but also for the instream residency requirements of the fish.

"The survival of aquatic life in surface waters subjected to a waste discharge or other controllable water quality factors, shall not be less than that for the same water body in areas unaffected by the waste discharge . . ." This objective for inland surface waters is from the Water Quality Plan Report of the SWRCB and the CVRWQCB. This objective of no loss of aquatic resources due to water quality impacts clearly supports Fish and Game Commission policies as they relate to salmon and steelhead. The maintenance of quality habitat to allow recovery of salmon and steelhead resources is essential if the goal of restoration is to be realized.

Perhaps the most critical water quality element to the successful recovery of the anadromous salmonids in the Central Valley is temperature. Historically, the fish were able to migrate upstream to areas with constant supplies of cool water. Now, however, the dams restrict the fish to low elevation warm climates which are susceptible to lethal water temperatures - particularly in dry or critically dry water years. This situation is exacerbated by irrigation schedules which demand large quantities of water in spring and early summer, thereby depleting the cool water stored in most reservoirs which is needed by the fish in late summer and early fall. The key to solving the water temperature problems at the various reservoirs is to achieve sufficient releases of cool late spring, late summer, and early fall flows to allow anadromous fish safe passage to and from the spawning grounds.

Reserving cool water through the summer may be partially achieved by developing offstream storage south of the Delta so that winter flood flows can be diverted and later used for south valley irrigation and domestic supplies. Operationally, this would allow increased upstream storage of cool water for release later in the year. Another ancillary action to offstream storage would be installation of temperature control structures on any reservoirs that do not currently have them. This would allow the dam operators to select or save cooler water as needed.

Temperatures critical to salmon inland life history are as follows:

Critical Factor	°F
Spawning	42-57.5
Incubation	53-57.5
Preferred Rearing	53-57.5
Maximum Growth	54-60
Growth Ceases	65-69
Lethal	77

Depending upon the river reach and the timing for each life stage of each race of chinook salmon, the objectives for various river reaches will differ to accommodate the fish. However, to ensure growth and to control the virulence of common fish diseases, rearing temperatures must be maintained below 65°F and in no case should water temperatures be allowed to reach 77°F. For incubation of eggs, 56°F may not be exceeded.

Other water quality parameters such as heavy metals, turbidity, DO, etc., are thoroughly addressed in the Water Quality Plan Report. The attainment of these objectives would benefit salmon and steelhead and should be strongly supported.

Flow objectives, like temperature, will be specific for each river to maximize salmon and steelhead production. Generally, however, flows must be sufficient to allow successful migration, spawning, incubation, rearing, and emigration of smolts to the ocean.

Migration. Flows must be sufficient to allow fish to safely pass all critical riffles, fish ladders, channel bifurcations, diversions or any other obstruction they may encounter during their upstream migration.

Spawning. Successful spawning flows are determined by depth and velocity of water over the spawning beds. The general goal for spawning habitat, therefore, is a water depth of 1.5-3 ft. and a velocity of 1-3.5 fps. Winter-run chinook salmon spawning preference may significantly vary from this standard.

Incubation. Flows must be sufficient to maintain water over the redds with a velocity less than that which would displace the gravels. Intergravel flow should be at least 26 feet per hour to provide adequate oxygen and removal of metabolic wastes.

Rearing. Water flows needed for successful rearing must be sufficient to provide the young fish shallow water areas to escape predation and, also, sufficient to raise aquatic invertebrates upon which the young fish rely for food. Each river will require different flow regimes to attain these standards.

Emigration. Successful downstream migration of salmonid smolts is critical for the restoration of wild stocks of salmon and steelhead. The flows must be sufficient to carry the fish past all major diversions. Each river will require a different flow regime to maximize smolt survival. In some cases, such as the San Joaquin system, these flows may be timed in each river to provide a cumulative downstream flow increase (i.e., time the fish flow releases from all storage reservoirs to coincide with one another in the San Joaquin River). This would minimize total necessary flow releases while maximizing juvenile survival during emigration from the San Joaquin River). This would minimize total necessary flow releases while maximizing juvenile survival during emigration from the San Joaquin River through the Delta.

III-1-B Salmon and Steelhead Losses to Water Diversions

Losses of Juveniles. Losses of juvenile chinook salmon, and to a lesser degree steelhead, can occur at all water diversions on the migratory pathways. The losses become smaller as fish progress out of the Delta into the wider bays further downstream.

The magnitude of loss at any given point of diversion depends on a complicated set of relationships which include the size of the fish, the timing of their migration in relation to the flow continuing past the diversion.

For example, evaluations at the CVP and SWP screened intakes provided combined loss estimates as high as 2.3 million juvenile chinook salmon during 1986. Studies at the P.G.&E. power plants in the Estuary during a comparable period, however, showed juvenile chinook salmon and steelhead losses were relatively minor but still significant. These power plants are located further downstream, where the direct effects of the facilities are small in relation to the volume of the bodies of water from which they draw.

The losses at the federal and State projects are most significant to fish migrating from the San Joaquin River system, although fish diverted from the Sacramento River by the Delta-cross channel are lost also. There are both the direct losses at the facilities and the indirect losses of fish diverted from their normal path and subjected to predation, delays, and stress, including higher water temperatures.

The Department and the NMFS are consulting with the USBR and DWR regarding modifications of facilities and operations of the CVP and the SWP to reduce juvenile fish entrainment in the Delta. Ultimately both projects will have to be modified to utilize a common intake or intakes with positive fish screens with sufficient by pass flows. The current trapping and trucking practice at the Delta facilities as at some other diversions are only a stop gap measure.

Also, the Department is attempting to set-up field crews by 1990 to identify, evaluate, and implement remedies to fish entrainment at water diversions.

Increased flows, pumping curtailments, appropriate screens, and appropriate operating criteria are the solutions to these problems.

Losses of Adults. The direct loss of adult upstream migrants at water diversions is relatively insignificant, however, the indirect effects can be significant. San Joaquin River migrants have been shown to experience substantial delays when flows are low, and low dissolved oxygen and/or high water temperatures result. These delays are significant since the timing of migration is crucial if the adults are to reach the spawning gravels in good enough condition to spawn successfully.

A somewhat different problem exists for Sacramento River upstream migrants which can be diverted to a greatly lengthened pathway by being confused by the rerouted water flows, or have their migration blocked by the Delta Cross-channel. Here, operations of the project can cause Sacramento River fish to enter the San Joaquin River side of the Delta attracted by Sacramento River water drawn across the Delta by the pumps of the two large water projects. They migrate up the Mokelumne River system but can be blocked if the Delta cross-channel gates were closed after this migration began. Many will then fall back downstream to Georgiana Slough and begin a delayed migration. Some fish may stray to the Mokelumne or Cosumnes rivers.

Adult migrants also face the problem of irrigation dams that retard their progress and return canals that empty confusing mixes of water into the main channels. Fish can be attracted into these canals to a maze of dead end drains or to the point that flow is inadequate for further travel. These fish are seldom able to spawn successfully.

Positive outflow from the Sacramento and San Joaquin rivers, minimize mixing of the flows above Threemile Slough and maintenance unobstructed migration corridors should be provided through statutory and mechanical procedures.

III-1-C Spawning Habitat

In the Sacramento-San Joaquin drainage most salmon spawn in both the main stem of rivers and in the largest of tributaries while steelhead spawning tends to take place primarily in the tributaries. Spawning salmonids exhibit a preference for certain water velocities, depths, and gravels. Typical redd construction sites are in swift, shallow areas at the head of riffles. As a general rule, the larger races of fish choose spawning locations of higher water velocity and coarser gravel than smaller fish.

The Department has authority under several Fish and Game Code provisions to protect spawning habitat and participate in the regulatory function of other agencies. Code section 1505 directs the Department to manage, control, and protect spawning areas in certain streams on State-owned land. These appear to include much of the prime salmon spawning habitat in the Sacramento-San Joaquin river system. The principal effect of this section is to give the Department authority to prevent dredging or other instream work that would be harmful to fish habitat. The usefulness of the action, however, has been limited by uncertainty regarding the extent of State ownership of the streambed in the various spawning streams.

Additional regulatory authority over streambed alterations is given to the Department in section 1601 of the Code. In general, these sections require public and private agencies to notify the Department if they are going to divert, modify, or change the natural flow or level of any river, stream, or lake that has an existing fish or wildlife resource. The Department can suggest modifications in such projects to protect resources.

Gravel Enhancement. Some methods for improving salmonid spawning gravels are: (1) cleaning silt and fine sediments from existing spawning gravels, (2) instream gravel placement, (3) Gravel replenishment or, (4) creating artificial spawning channels. The details of these methods are as equally important as the concept and implementation and design requires careful planning and design by experienced or specially trained technicians.

1. Gravel cleaning may be appropriate in some streams where all conditions are present for successful spawning except that the gravels contain large amounts of fine silts. The gravels may be "cemented" and impossible for

the fish to move. This condition can be alleviated by mechanical means. The gravels may be ripped with crawler tractor and spike rippers. This allows the finer sediments to be separated from spawning-size gravels and moved downstream by a flushing flow. There are also mechanical screening devices that separate fines from usable gravels and then deposit the silts off-site. Both methods work fairly well, but may have only a short-term effect.

2. Instream gravel placement may be appropriate in some locations where gravel quality has deteriorated. This approach requires that it be feasible to import spawning size gravels and place them in areas where they can be expected to remain and be used by salmon or steelhead for spawning. The process involves careful consideration of hydrologic parameters to locate and design the most useful structure.

   The Department has an inventory of 29 possible sites on the Sacramento River. Of these, six have excellent potential. Construction at one site has been completed and a second has been scheduled.

   Other streams have been investigated for spawning habitat restoration or enhancement. Clear Creek enters the Sacramento River near the city of Anderson, and if a secure increased water flow and appropriate lands can be obtained, this stream offers excellent spawning habitat improvement opportunity. Virtually all rivers in the San Joaquin River drainage have potential for this technique.

3. Gravel replenishment may be the feasible approach to enhancing spawning gravels. Where the construction of a dam has occurred, natural replenishment of gravel from upstream areas has been interrupted. Gravels from upstream of the dam may be transported by truck or railroad and stockpiled below the dam. Under the proper flow conditions the gravels are moved into the river for natural drk to prevent backwater entering the channel during floods. Appropriate size gravels are placed in the channel and water depth and velocity are kept at optimum levels during the spawning and incubation period.

   This type of enhancement has not always been successful in California. spawning gravels will become smothered with silt if an adequate filter system, flushing velocities, or an adequate settling basin is lacking. Spawning fish may be too high in the channel because of lack of shade. Prespawning mortality of adults may be excessive if conditions are not acceptable to the fish and/or they exhaust themselves trying to escape the system.

None of these problems are insurmountable. However, while there may be some locations where artificial spawning channels are feasible, it must be recognized that the cost of solving problems with this method may exceed the value derived from increased production.

A separate authority under section 5663 also allows regulation of suction dredging and this authority should be reviewed for adequacy. Section 2014 and 5650 provide for action against pollution and littering. The Department also cooperates with Regional Water Quality Control Boards to control pollution.

The California State Lands Division should be re-petitioned to affirm the position that all stream channels in the system shall be construed to be under State control until otherwise litigated, and to provide DFG with a map depicting all stream channels legally held other than by the State. The DFG should continue to register strong opposition to any project detrimental to salmon or steelhead spawning, or nursery habitat and require any feasible alternative available to avoid such damage. Where damage occurs, full restitution (on-site if possible) should be required through administrative or litigative action by the DFG (section 12015)).

The construction of large dams has interrupted the transport of course sediments which replenish spawning areas. bank protection and levee construction has also reduced the recruitment of gravels. The result has been a reduction of available spawning areas upstream of major tributaries or a meandering river channel. The Department has been evaluating methods of adding new gravels in deplete areas. Early efforts had limited success while more recent attempts seem to be working well. In 1988 and 89 the USBR provided funds to the Department to continue this effort. One of the challenges for the future is to find adequate gravel sources. possible sources may be from rivers upstream of the dam that is causing the problem. Another source is from downstream areas below areas used for spawning.

Structural Barriers to Migration. Every river and most large tributaries in the Sacramento-San Joaquin drainage that support spawning populations of salmonids have a portion of their watershed blocked by dams. Some of these barriers are low enough that fish passage structures are provided to allow upstream access. Other barriers remain impassable. Some of these impassable dams have fish mitigation facilities in conjunction with the dam complex to replace the wild fish production lost above the barrier structure. Other dams do not provide for any fish mitigation. When the DFG has the opportunity to review the operation of any dam, the status of anadromous fishes affected by the structure should also be reviewed, and recommendations made for appropriate mitigation measures. IT is appropriate to required mitigation for lost access to spawning habitat above Englebright Dam on the Yuba River, Goodwin Dam on the Stanislaus River, La Grange Dam on the Tuolumne River, Crocker-Huffman Dam on the Merced River, and Friant Dam on the San Joaquin River. Although laws were not in place, or not clearly interpreted to require mitigation when the projects were first constructed, any renewal or modifications will be subject to the current laws.

There sometimes exist problems at barriers that have fish passage facilities. Adult salmonids may have difficulty in locating the fish ladder. Stream flows may be too low for fish to reach the dam location. Because of water diversion at the dam, water temperatures in the stream below may be too high to support anadromous fish. Progeny of fish that have migrated past a barrier and successfully spawned might be lost down water diversions that have ineffectiv fish screens.

Every effort should be made to identify and correct fish passage operational problems at dams. Application for a new barrier structure must be reviewed and provide in its operating scheme for passage of anadromous fish passage or continuation of fish runs. DFG should continually review existing structural barriers and require modification of operating procedures or fish passage facilities at structures that adversely affect fish passage. Lost salmon or steelhead populations should be restored any time an opportunity for DFG action occurs.

Gravel Recruitment. Spawning gravel recruitment is affected by interception at large dams, commercial gravel extraction, and by bank erosion protection practices. As an example, the DWR determined the gravel budget, an accountin of the general gravel inflow and outflow, for the Sacramento River between Keswick Dam and Hamilton City, and concluded:

1. Shasta and Keswick Dams now trap all coarse materials originating upstream. Approximately one-third of the pre-dam bed load is now denied the Sacramento River below Keswick Dam.
2. Gravel extraction, primarily in tributary streams, is a thriving business in this river reach. Almost 2 million cubic yards of gravel material are removed annually that would have had the opportunity to add to the spawning gravel resource.

3. Approximately 85% of the gravel recruitment comes from bank erosion in th main stem river. Bank protection practice, typically rip-rapping, reduce this natural recruitment process.

4. The river system is in dynamic balance, i.e., gravel inflow and outflow are about equal. Any increase in gravel extraction or in bank protection over present levels will result in a reduction in spawning gravel.

These conclusions are typical for rivers in the Central Valley.

Without gravel replenishment from above dams or from bank erosion, gravel bed in the river tend to armor with large cobble and rock and usable gravels are swept downstream. The same logic that is used to require mitigation as a substitute for spawning habitat lost above an impassable dam should also require mitigation for spawning habitat lost through gravel deterioration below a dam. Such mitigation should be gravel replacement with retention structures to reduce gravel erosion.

The conflict between commercial gravel operations and salmon spawning gravel is difficult to resolve. There is little area for compromise. Every effort must be made to keep gravel mining operations out of stream beds and existing commercial operations should be monitored closely to see that these activitie have a minimum effect on salmonids. Replacement or compensation must be required for any deterioration of gravel quality or loss of habitat caused by gravel mining.

In some stream reaches bank protection is slowly eliminating the principal source of spawning gravel. Except for absolute reasons of public health or safety, rip-rapping or other forms of bank protection that prevent gravel recruitment should not be allowed. Instead, the DFG and cooperating agencies should require alternate measures to bank protection. For example, levee setbacks and/or allowing the stream to meander within 100-yards or wider buffer strips can achieve equivalent public benefits while protecting fisheries. Gravel deposits accessible to the river or the spawning gravel component should be purchased in fee or easement.

III-1-D Riverine Rearing Habitat

Until the early 1970's, very little was known about riverine rearing habitat needs and it was not assumed to be a problem. Recent information suggests, however, that rearing habitat may be equally as important or more important than spawning habitat.

Newly emerged salmon fry attempt to seek out moderately shallow, slack water areas. In controlled flow streams, this type habitat is encroached upon by riparian vegetation and is eventually lost as the channel becomes more U-shaped. This type of encroachment is common on the Sacramento River above Cow Creek, a reach of the river that has suffered the greatest declines in habitat.

As the young salmon grow and move downriver, they begin to prefer steep, cut banks and the cover of exposed roots of terrestrial vegetation. This type of habitat, which frequently forms as a result of bank cutting, is a prime candidate for riprap bank protection. Recent studies have shown that young salmon largely avoid riprap areas and predators favor those areas. In some cases, attempts have been made to modify the riprap banks to include a relatively flat slope on part of the bank where small gravel is placed. Studies to determine if this type of modification is effective are not conclusive.

As the young fish move further downriver past Knights Landing, they encounter summer water temperatures that may become excessive. Some of the temperature increase is due to return flows from agricultural drains and some is due to the loss of dense riparian forest which once shaded the channel. There is evidence of substantial summer warming of the river near Sacramento which may reduce the juvenile salmon rearing capacity of the river.

III-1-E Hatcheries

Chinook salmon — Estimates of the contributions of Central Valley hatcheries to the statewide ocean catch of chinook salmon have ranged from 16% in 1986 to 40% in 1983. The variation seems to be related to the success of natural reproduction, with poor survival of naturally produced juveniles occurring in dry spring conditions. Almost all Central Valley hatcheries can demonstrate success in maintaining the runs in their rivers, and supporting significant inland fisheries. This success is partly due to the results of various coded-wire tagging studies that led to strategies to increase survival of hatchery fish and partly due to an increase in the magnitude of the overall hatchery program. Studies have shown that rearing chinook to advanced fingerlings (30/lb.) size and trucking those fish to the estuary gives about the same return to the fisheries (about 4%) as rearing those fish to yearling (10/lb.) size for release above the Delta. Because advanced fingerlings are one-third the size of yearlings, a hatchery can produce almost three times as many. Trucking advanced fingerlings (50/lb.) chinook to the estuary also gives far better returns (1-2%) than planting those fish in the river (0-1%). Recent studies have as goals the identification of the optimum planting location in the Bay. Partial tag returns to date indicate the best planting location may be in the upper Bay because overall returns are the same as planting at the Golden Gate and planting expenses are substantially less. Another partly completed study indicates that planting at night gives better returns than the normal procedures of daytime planting.

Hatchery production goals for Feather River, Nimbus, and Mokelumne River hatcheries have been set at rearing as many healthy 60/lb. advanced fingerlings as possible, trucking smolts to the Bay to provide growing room, and planting all of their production in the Bay when the salmon reach 30/lb. Merced River Fish Facility and CNFH do not share these methods because their desired end result includes maximum return to the hatcheries. Feather River Hatchery has not been able to meet its goal because of a lack of trucking capacity and has planted yearlings in the Feather River each year.

Over 90 percent of the Central Valley's steelhead (trout over 15.4 in. fork length) are derived from hatcheries. Coded-wire tagging studies using Feather River and Nimbus hatchery steelhead yearlings have shown that increased survival of planted yearlings is most closely related to increased size at planting; optimum size for hatchery production seems to be from 3.0-5/lb. Planting Feather River yearling steelhead in the estuary also leads to greater returns to the fishery overall, but results in greater straying rates to the American River with lower returns to the home stream. For this reason, only

Nimbus Hatchery steelhead are planted in Carquinez Strait. Feather River steelhead yearlings are planted below Yuba City to avoid harvest of juveniles by trout anglers during their outmigration in the Feather River. Time of planting may also increase survival, but normally steelhead yearlings must be planted prior to April 1 to make hatchery space available for rearing chinook salmon fingerlings. Steelhead yearlings reared at Mokelumne River Fish Installation survive well, but return as adults mainly to the American River. Hatchery programs are maintaining runs of 15,000 to 20,000 steelhead in both the American and Feather rivers. The U.S. Fish and Wildlife Service is testing other measures, such as trucking Coleman Hatchery yearlings for planting downstream as far as Princeton.

The needs for the Central Valley Hatchery for salmon and steelhead are:

1. A new hatchery in the upper Sacramento River near Keswick Dam to be used to rebuild winter run and spring-run salmon and steelhead. Long term use may be for maintaining a distinct spring-run in the mainstem river.

2. A large hatchery on the Stanislaus River to rear salmon and steelhead for the San Joaquin system. Minimum size should be 2 million yearlings and 600,000 advanced fingerling salmon, and 500,000 yearling steelhead. This hatchery will create a floor on the low runs of salmon and thereby raise

the high runs by fully utilizing the habitat in wet years. It will also create the opportunity to establish new runs of spring-run salmon and steelhead.

3. A planting base in the Berkeley area capable of holding up to one million smolts with a ramp for direct planting in emergencies. The base would be used to acclimate advanced fingerlings to the Bay water temperature and salinity in a gradual way and to plant the fish after dark on an outgoing tide to minimize predation on the newly planted fish.

4. Added rearing capacity at nimbus Hatchery for steelhead to produce another 100,000 3/lb. yearlings for planting in March.

5. A firm source of eggs on the Mokelumne River. Mokelumne River Hatchery has frequently had to rely on eggs from Nimbus or Feather River hatcheries. One means of assuring an egg source would be to ensure that spawning adults can return to the hatchery. Increased instream flows for migration are needed from Camanche and Pardee Reservoirs.

III-2 Studies and Evaluations

Studies have been carried out by the DFG, DWR, Department of Parks and Recreation, the Department of Boating and Waterways, and their predecessors relating to salmon and steelhead populations and habitat. Federal agencies including the USFWS, NMFS, USBR, USCOE, the United States Forest Service and their predecessors have also carried out studies of the fish populations and their habitats. The studies have ranged from original biological surveys, through assessment of the effects of hydraulic mining and subsequent channelizations, to the present assessment of Delta water needs and the status of the Sacramento River winter-run chinook. There still remains many gaps in our knowledge of our salmon and steelhead resources and how best to restore, enhance, and manage for future generations. Continued monitoring of those fishery populations, their utilization and their life history needs is essential to our efforts.

III-2-A Monitoring of Fish Populations

Delta Diversion/Flow Effects. Studies on the effects of the CVP and the SWP are being conducted by the Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. These studies are intended to demonstrate the direct and indirect effects of flows and diversions on outmigrant chinook salmon. The initial study emphasis was on the Sacramento River side of the system, and although those studies are continuing, work on the San Joaquin River side of the system recently commenced in cooperation with Region 4.

Results of the studies to date have been presented to the SWRCB at their ongoing Delta hearings.

Direct Losses of Salmon and Steelhead. Direct losses of salmon and steelhead at the State and federal intakes in the south Delta are estimated from fish salvage at the State facility. Salvage records are maintained by the operators at the two facilities under the scrutiny of a DFG biologist. These records are used, along with the results of experiments with marked fish, to estimate the direct losses.

Indirect Losses of Salmon and Steelhead. Estimates of indirect losses are constrained by a lack of information regarding the size of outmigration in each river. Studies to date have documented the relative loss attributable to the various locations and factors, but estimates of the actual numbers lost cannot be made with any degree of precision. Quantification of the loss will require an additional study to quantify the magnitude of the juvenile population entering the Delta on any given year. Mitigation for indirect losses resulting from the south Delta California Water Project pumps await this quantification.

Upper Sacramento River Monitoring. The Red Bluff Diversion Dam adult fish count is an ongoing study conducted year-round in the fish ladders. Personnel of the USFWS and the DFG jointly conduct the counts. The USFWS enumerates fish moving through the fish passage facility during daylight hours. The Department of Fish and Game samples a portion of the day run to identify the proportions of the four races of chinook present, makes night counts for night correction factor, and adjusts the counts for angler catch to obtain an estimate of spawning escapement.

A method of procedure is needed for counting fish during periods of high and turbid flows or whenever the dam gates are raised and the ladders are not operating.

We suspect that we are underestimating angler catch and therefore overestimating escapement. The present estimates of angling mortality are base on surveys made in the mid-1970's. The nature and distribution of fishing effort has changed significantly in the interim. An intensive angler survey on the Sacramento River is being setup for implementation in the fall of 1990. A similar angler survey will be needed in the future within the San Joaquin system.

Aerial flights over principal spawning areas are made during he spawning period of each chinook race. These are always conducted on the main stem Sacramento River but also include some tributary streams. The location, distribution, and density of spawning is noted on maps during each flight. This information is used to evaluate the effects of water projects or construction upon salmon spawning, to help describe the effects of physical conditions upon salmon, and to assist in estimating the proportions of spawning salmon in the mainstem Sacramento River above and below RBDD.

The flight schedule for fall-run chinook is every 2 weeks. Usually one flight per season is made for late-fall and for spring-run chinook. Some flights give relatively little information because of poor visibility due to bad weather or turbid water. Weekly observations during peak spawning periods would increase the probability of accurate estimates.

The principal estimate of spawning stock escapement above Red Bluff is derived from the counts at RBDD described above. The estimate of the segment of the run spawning in tributary streams, however, is made by carcass survey. Presently, only three tributaries Mill and Deer creeks below RBDD, and Battle Creek above RBDD are examined with sufficient frequency to obtain escapement estimates. Several additional creeks above Red Bluff have annual runs of chinook and will be included in annual carcass survey being in 1989.

Another reason to conduct the tributary surveys is to correct the annual estimate of chinook spawning in the main stem Sacramento River below the RBDD. This estimate is made by proportional comparison with the area above RBDD. It has been biased in the past because some tributaries were not surveyed. The ratio of known count past RBDD to percent of total river redds above RBDD is compared with the ratio of unknown count below RBDD and the observed percent of total redds there. The error in estimate occurs because the estimated number of fish using the mainstem above RBDD includes fish that actually spawned in tributaries but were not deducted from the mainstream population.

Each spring, in cooperation with the USFWS, the DFG makes adult fish counts at fishways in dams on the lower reaches of Deer and Mill creeks. In some years the USFWS does a diving survey over the summer residence area, and the DFG conducts a carcass recovery program in the principal spawning areas. In future years, adult counts will be made with recently purchased electronic fish counters.

Part of the State's responsibilities in the winter-run chinook recovery program is to monitor the angler catch in fresh water to assure sufficient number of fault winter-run chinook survive to spawn. The Department has conducted a census in the river reach from Knights Landing to Red Bluff during the months April through June. The census will be included in the proposed Sacramento River angler survey to be implemented in the fall of 1990.

Another part of the winter-run chinook studies is to find out where and when spawning takes place. Weekly helicopter flights from May through mid-July are made over the river from the mouth of Deer Creek to Keswick Dam. Spawning distribution is aides to evaluate the effects of raising the RBDD gates for fish passage and to maintain a relative index of the spawning population.

The Department will capture, tag, and release wild winter-run chinook fry to monitor the contribution of winter-run salmon to the ocean catch and monitor other factors in their life history.

Fall-run chinook and steelhead are tagged at CNFH on Battle Creek. This is a cooperative effort between the USFWS and the DFG to evaluate CNFH production. Date of release, size of fish at release, and location of release as well as other aspects of hatchery production are being investigated.

Other studies needed to adequately monitor salmon and steelhead fisheries in the upper Sacramento River include:

1. Because over 75% of the steelhead monitored past RBDD are of Coleman Hatchery origin, it is of paramount importance to the fishery that hatchery steelhead production be successful. Success of the fishery includes the need for adequate escapement back to the hatchery. Because there is no current watershed-wide census of steelhead anglers, a tag study with reward tags that will give an indication of harvest as well as a location of catch should be conducted.

2. New angler catch statistics from the entire Sacramento River system are needed for adult salmon and steelhead. No coordinated census program has taken place since the mid-1970's. Over the years, the nature of the

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fishery has changed, i.e., the number of anglers, boat ramps, fishing guides, and resorts have all increased. The proposed Sacramento River angler survey must be implemented as scheduled for the fall of 1990.

Red Bluff Diversion dam Evaluation. Based on results of the previous studies conducted at RBDD, the USBR, USFWS, DFG, NMFS, and DWR initiated a 5-year Fish Passage Action Program in 1983 to develop methods to improve upstream and downstream anadromous fish passage at RBDD.

The United States Bureau of Reclamation immediately began a program. The USFWS is performing the field studies and will propose recommendations. The primary concerns are: 1) mortality to juvenile salmonids migrating downstream past RBDD, and 2) delay of upstream migrating adult salmonids below RBDD.

Studies concerning possible causes of downstream migrant salmonid mortality include:

1. Determination of losses attributable to diversion into the Tehama-Colusa and Corning canals and evaluation of the new intake screen.

2. Measurement of direct injury from passing under the dam gates or through the fish louver bypass facility.

3. Evaluation of predation resulting from concentration of predaceous fishes and birds in Lake Red Bluff or immediately below the dam.

4. Measurement of delay of juvenile salmonids downstream migration in Lake Red Bluff.

These studies are ongoing and measures identified to improve juvenile fish passage will be implemented as they are developed.

Studies of possible delay to migration of adult salmonids at RBDD are continuing. A program to determine optimum operation of RBDD for upstream passage of adult salmonids is being conducted by USFWS. Principal goals are to identify the effects of gate operations and flows on fish behavior. Chinook are radio tagged and their movements monitored under different operation scenarios. Winter-run chinook are also being radio tagged to monitor their behavior in relation to the raised dam gates during the period December through April.

The National Marine Fisheries Service was investigating a proposal to help solve juvenile salmonid predation at RBDD. An attempt was made to develop a commercial fishery for squawfish that would not be detrimental to adult salmon and steelhead. However, dioxin concentration in resident squawfish prohibit human consumption or use.

The Department of Fish and Game participates in predation evaluation through cooperative coded-wire tag programs using CNFH produced salmon. Part of these juvenile salmon and steelhead programs required marked fish releases above and below RBDD. This study is to discover the best place to release fish to maximize survival as well as return to the hatchery.

The Department also helps evaluate the effect that raising the RBDD gates has upon winter-run chinook. Aerial surveys are conducted over the river to identify the location and abundance of spawning winter-run fish both above and below RBDD.

The 5-year evaluation program ends in October 1988. While progress has been made in improving upstream and downstream fish passage at RBDD, need for additional investigation and solutions is clearly indicated. Work that should be continued includes:

1. Evaluation of predation upon juvenile salmonids. Predation is still by far the major source of downstream migrant mortality at RBDD. It remains unknown if, or under what dam operating conditions, predation becomes a problem in the lake created above RBDD. We suspect, but do not know to what degree, predation occurs in the RBDD fish ladders. Further efforts to reduce these losses could result in considerable benefits to the resource.

2. Evaluation of dam gate manipulation for adult fish passage. More work is needed before operational changes at RBDD can be made to optimize fish passage. River conditions have not been sufficiently variable during the present studies to test all critical spill configurations. Several experimental designs remain to be evaluated.

   Evaluation is needed to determine the effects of raising the gates during the non-irrigation season for winter-run chinook adult fish passage. Results from a modest evaluation effort made during the first year the gates were raised were encouraging. Further investigation will be required each year that the gates are raised to assure that significant benefits are being realized for the winter-run chinook.

3. Investigation of special dam gate modification for downstream migrants. Evaluate the use of an overflow weir in Gate 11 that will reduce the tendency of steelhead to take temporary residence above the dam.

4. Evaluation of potential Gate 6 fish ladder. An additional fish ladder in mid-river demonstrated promise for reducing delay of dam passage by adult salmonids. Evaluation should be made of any ladder configuration proposed or installed.

III-2-B Habitat Studies

The habitat requirements of juvenile outmigrating salmon and steelhead in the Sacramento-San Joaquin rivers and Delta are not fully understood. Information has been developed on water temperature needs and spawning flow requirements. However, the overall requires for rearing and outmigration need further investigation.

The USFWS has conducted limited evaluations of the value of natural river bank habitat versus stabilized riprap banks. Since extensive reaches of the main river channels are already rip rapped, further evaluations are needed to assess current impacts and if appropriate develop alternatives which recreate rearing habitat and cover while maintaining bank and levee integrity.

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Steelhead populations have not been able to sustain significant levels without extensive hatchery supplimentation. Further research is into habitat requires and habitat availability is needed to understand the continuing decline of naturally produced steelhead and to correct those habitat deficiencies.

The DFG will begin an evaluation by monitoring hatchery reared steelhead yearlings by releasing representative lots of fish with reward tags. Returns will be obtained from anglers, creel census crews, and field sampling.

III-2-C Instream Flow Quantification Studies

With the onset of water projects in California, stream flows began to diminish or to be dramatically changed to meet water demands or to provide flood protection. In most cases inadequate flow releases were required or agreed to for political reasons or for lack of knowledge about instream flow needs. Today our knowledge on instream flow needs has increased substantially. Through the use of standard hydraulic simulations of various waterway combined with extensive data files on micro habitat use of various life stages offish we are able to quantify habitat conditions provided at various increments of flow. Studies, employing state of the art methodologies have been completed or are underway on both mainstem rivers and nine of the larger tributaries.

Upper Sacramento River Instream Flow Study. The Upper Sacramento River Instream Flow Study is designed to provide information which will guide development of USBR modifications of flow releases from its project facilities to optimize fisheries values on the river. The study is designed and funded by the Department and DWR.

The study area extends from Redding to Hamilton City on the upper Sacramento River. This area is most directly under the influence of the USBR project, and is of primary importance to chinook salmon on the river. The tributaries are not included because they are the subject of other studies. The study area has been segmented to best account for incremental flows from the major tributaries, as well as for various project features and major tributaries, as well as for various project features and major diversion points. The study is expected to be completed in 1989.

The primary study objective is to develop a model for upper Sacramento River chinook salmon spawning and rearing habitat requirements. Greatest emphasis is placed on the fall and winter runs, but an attempt will be made to gather information on all races of salmon, as well ass other species, if the opportunity presents itself. Information gathered on habitat preferences will be used in a habitat simulation model. Measurements of flow and stage will be made at one river discharge, with at least two more stage measurements to allow the predication model to be used. The results of the investigation will be prepared in a report and a series of curve charts, which will allow the agencies to reach their own conclusions and provide a basis for comparison to other study results. Diurnal changes will not be included, and information on seasonal changes will be restricted by the limited presence of the fish, and the ability to sample under high flow conditions.

Spawning habitat preference information will include water depth, velocity, cover and substrate. Rearing habitat preference will be collected by free diving, and will include water depth, velocity, cover and substrate. Collection and analysis of this information should be complete by the fall of 1988.

The separate segments of the river to be evaluated are:

1. Hamilton City to Tehama (S1) 30 miles - Chosen because of sinuosity and slope changes.

2. Tehama to Red Bluff (S2) 14 miles - Changes in river width, slope, flow, sinuosity and bank and bottom composition.

3. Red Bluff to Cottonwood Creek (S3) 30 miles - Flow change, change into canyon type river, slope and change in bottom materials.

4. Cottonwood Creek to ACID (S4) 25 miles - Slope, bank and bottom type changes, flow and channel morphology changes.

San Joaquin River Studies. The major problem facing the San Joaquin River fisheries is flow depletion. Together with flow depletion, the entrainment of fish in water diversions, the outflow of agricultural domestic and municipal return water and conditions can create an almost completely lethal condition for salmon and steelhead populations. Present studies include evaluation of variations in reservoir release patterns and survival of outmigrants through the system.

Needed additional or expanded studies include:

1. Development of flow standards to maximize spawning, incubation and survival of juvenile salmon.

2. Development of flow volumes and patterns to provide access for adult salmon to spawning grounds and to MRFF. The study would develop strategies to prevent straying of upstream migrants into drainage channels and canals.

3. Development of a comprehensive spawning and rearing habitat restoration program. The study would entail thorough identification and quantification of existing and potential habitat.

4. Evaluation of legal flow constraints and opportunities for improved water releases. The study would identify all opportunities for flow augmentation, water use transfer, and improved flow timing.

5. Identification and quantification of water diversions and associated fish losses.

6. Evaluation of available data on the effects of drainwater constituents on aquatic species including anadromous fish.

8. Hatcheries shall be operated under a genetic stock management plan to perpetuate and restore naturally occurring and endemic stocks of fish to provide the broadest seasonal distribution of fish use in the river system.

9. Hatcheries shall be operated according to a set of Department goals and constraints for the facility consistent with this plan.

IV-3 Positions on Issues

The following are Department of Fish and Game position statements on specific issues affecting the welfare of Sacramento-San Joaquin river salmon and steelhead:

IV-3-A Salmon and Steelhead

It is the policy of the Fish and Game Commission:

I. To maintain an adequate breeding stock, suitable spawning areas, and provide for the natural rearing of the young to migratory size. Hatchery production shall be limited to areas where it is necessary to supplement natural production in coastal streams.

II. That resident fish will not be planted or developed in coastal steelhead and salmon streams, except after prior Commission approval (a) where the stream is no longer adaptable to anadromous runs, or (b) during the mid-summer period in those individual streams considered on a water-by-water basis where there is a high demand for angling recreation and such planting or development has been determined by the Department not be be a detrimental to the anadromous species.

III. That salmon and steelhead may be rescued whenever the water supply in a stream is inadequate to maintain fish life.

It is the policy of the Fish and Game Commission that:

I. The steelhead rainbow trout in California is recognized as a valuable resource with strict environmental requirements and a limited range.

Steelhead waters include all streams or stream sections accessible to steelhead along the California coast and in the Sacramento-San Joaquin River drainage above the Delta, and such other waters as the Commission may designate.

II. The greatest fishery value of this resource is its potential to provide recreational angling for sea-run fish. management shall be directed toward providing such angling and maintaining a vigorous, healthy resource. Angling for juvenile steelhead will be restricted to the extent necessary to insure optimum spawning stock and angling opportunity for sea-run fish.

III. Resident fish will not be planted or developed in steelhead waters. Resident fish will not be planted or developed in drainages of steelhead waters, where, in the opinion of the Department, such planting or development will interfere with steelhead populations. programs on threatened or endangered species, within the species natural range, are excepted.

IV. California's steelhead resources are largely dependent upon the quality and quantity of habitat. Because of damage and threats to this restricted habitat, emphasis shall be placed on management programs to inventory and protect and, wherever possible, restore or improve the habitat of natural steelhead stocks.

V. The Department shall seek prevention or alleviation of those aspects of projects, developments, or activities which would or do exert adverse impact on steelhead habitat or steelhead populations. All available steps will be taken to prevent loss of habitat, and the Department shall oppose any development or project which will result in irreplaceable losses of fish.

VI. The Department shall develop and implement plans and programs to improve the protection of steelhead habitat including, but not limited to, assessment of habitat status and adverse impacts, land use planning, acquisition of interests in streams threatened with adverse developments, and research needs on effects on habitat changes caused by activities such as overgrazing, gravel extraction, logging, road construction, urbanization, and water development.

VII. artificial propagation of steelhead, except for mitigation, shall be for the purpose of improving angling for sea-run fish, and should include strains or varieties of steelhead which have the greatest potential to contribute to recreational angling. Artificial production of rearing and stocking programs shall be managed to produce minimal interference with natural salmonid stocks, and such programs shall be periodically reviewed to assess their effects on these stocks.

VIII. Juvenile steelhead rescue shall be limited to instances where habitat conditions are temporarily inadequate to maintain fish life and when suitable rearing areas are available with the capacity to rear rescued fish to smolts without impairment of other steelhead populations. Rescue should be undertaken only in special circumstances where it can be demonstrated to be economic or where large numbers or steelhead of special significance are involved.

IX. The following streams or stream sections are deleted from the steelhead waters described in item I of this policy and may receive supplemental or catchable fish plants:

1. Big Lagoon, Humboldt County
2. Stone Lagoon, Humboldt County
3. Arroyo Seco Creek, Monterey County
4. Nacimiento River, San Luis Obispo County
5. North Fork Battle Creek, Shasta County, upstream from Manton
6. Cow Creek, Shasta County, upstream for Fern Road and Ingot
7. Middle Fork Cottonwood Creek, Shasta County, upstream from Platina
8. Antelope Creek, Tehama County, upstream from Ponderosa Way
9. Beegum Creek, Tehama County, upstream from Beegum

10. Deer Creek, Tehama County, upstream from Highway 32 at Windy Cut
11. Mill Creek, Tehama County, upstream from Hole in the Ground Camp

IV-3-B Publicly Operated Rearing Programs for Salmon and Steelhead

It is the policy of the Fish and Game Commission to:

(I) Support the utilization of the State's salmon and steelhead resources for public rearing programs, within the following constraints:

A. Only those fish surplus to the needs of the Department's programs shall be utilized for such programs.

B. The suitability and appearance or rejection of proposed programs shall be determined by the Department.

C. Priority of allotment of available surplus fish among acceptable programs shall be based on past performance on existing programs and the Department's evaluation of the potential of proposed new programs.

D. Routine care and food costs shall be the financial responsibility of the sponsoring group. The Department will provide technical advice and counsel and special assistance as appropriate.

(II) It is recognized that natural production provides the great bulk of the State's salmon and steelhead resources. The Department's goals of maintaining and improving this production shall not become subservient to the goals of publicly operated rearing programs.

IV-3-C Sacramento and San Joaquin River Salmon Survival

It is the position of the Department of Fish and Game that the SWRCB should take the following actions:

I. The Board should adopt a position that restoration and enhancement of salmon and steelhead of the Central Valley to historic levels is of equal importance as the maintenance or expansion of agriculture in the valley.

II. Sacramento River Salmon Survival

1. The Board should adopt an objective of maintaining the survival rate of each race of salmon smolts passing through the Estuary at the historical level.

While we recommend adopting the concept for all races of salmon, information exists only for fall run. Hence, the objective for other races should be in the form of planning guidance.

The first priority to achieve the objective should be to implement reasonable measures to improve survival within the Estuary. Measures to be considered should include:

a. Maintaining minimum flows at Rio Vista

b. Curtailing exports at peak outmigration periods

c. Close or screen the Delta Cross Channel

d. Screening Georgiana Slough

e. Screening agricultural diversions

f. Decreasing water temperatures

g. Construct a new combined CVP/SWP Delta intake facility with a screen and a position downstream bypass flow

If the objective cannot be fully attained through such measures in the Estuary, then actions outside the Estuary might be considered to provide equivalent benefits, with habitat improvement having priority.

The most directly affected parties should jointly develop a mutually acceptable plan before Phase III of the Bay-Delta Hearing starts. Board staff participation would be welcomed during the process.

2. The Board should establish, as a planning objective, the principle that any further water development projects in the Delta should be directed toward attaining the above objective while maintaining an unobstructed route for the upstream migration of salmon through the estuary.

III. San Joaquin System Salmon Production

1. The Board should direct major upstream water right holders in the San Joaquin System (i.e., Bureau of Reclamation, City of San Francisco, Oakdale Irrigation District, South San Joaquin Irrigation District, Modesto Irrigation District, Turlock Irrigation District, and Merced Irrigation District) to work with DFG, FWS, and NMFS to prepare a plan the restoration of salmon in the San Joaquin system upstream from the Delta and submit it to the Board by 1992 for consideration relative to their water rights. The Board should institute improved flows in the interim to begin restoration.

2. For planning purposes, the Board should adopt an objective of maintaining the survival of salmon smolts passing through the Estuary at the Historical Level. Sufficient information is not going to be currently available to establish Historical Levels for the San Joaquin River. Hence, we recommend that the Board adopt a group of interim measures designed to improve survival substantially.

Measures to be considered should include:

a. A minimum flow at Mossdale at least in normal and wet years.

b. Coordination of spring releases made pursuant to existing agreements to achieve a pulse flow into Delta in late April and/or early May.

c. Restrict total exports from the Delta to something less than the San Joaquin River inflow when flows are being augmented pursuant to (b).

d. Provide that physical modifications be made so that the proportion of the flow in the San Joaquin River which enters the head of Old River from April 1 to June 15, can be controlled. We believe a reasonable objective is that not more than 20% of the flow should enter Old RIver, except during floods.

e. Provide physical modifications so that the portion of the flow remaining in the San Joaquin River at the head of Old River is sufficient to maintain dissolved oxygen above 5 ppm in the San Joaquin River between Stockton and Turner Cut.

f. Measures to minimize losses of salmon in diversions in the Delta and replacing those salmon unavoidably lost in diversion.

The Department is willing to work with other parties to develop specific interim objectives to recommend to the Board.

3. The Board should establish an objective of eliminating flow reversals in the San Joaquin River by 1995. From the standpoint of the protection of salmon using the San Joaquin system, it would be preferable to isolate the diversion of Sacramento River water from the San Joaquin Delta, but we do not consider that a likely objective during the period covered by the decision expected from this hearing.

IV-4 Salmon and Steelhead Stock Management Policy

IV-4-A Policy and Goal

It is the policy of the Department of Fish and Game to maintain the genetic integrity of all identifiable stocks of salmon and steelhead in California. To protect the genetic integrity of California salmon and steelhead stocks, each salmon or steelhead stream shall be evaluated by the Department and the stocks classified according to their probable genetic source and degree of integrity. Each stream shall then be classified by the Department according to salmon or steelhead stocks compatible with maintaining or restoring endemic genetic integrity, and to the level of artificial production compatible with long-term management toward this goal.

IV-4-B Classification and Management System

The following classification system shall be employed to define the appropriate stocks and the role of artificial production for management of each salmon and steelhead stream in California. This classification may be applied on drainages, individual streams, or segments of streams as necessary to address discrete stocks of salmon or steelhead. Only designated appropriate stocks may be placed or artificially produced in any stream within the limitations specified under this classification system. Exceptions to these management constraints may be allowed only under emergency conditions that substantially threaten the long term welfare of the fishery. Exceptions may only be granted upon submission of a written request which details the emergency conditions by a region or an Inland Fisheries Division Assistant Chief to the Chief of the Inland Fisheries Division and written approval by the Deputy Director for Fisheries.

Salmon and Steelhead Stream Classification System Terms:

1. Salmon or steelhead stocks stream management goal.

   The stream shall be managed for the following appropriate stock and only those stocks may be placed in the stream (each term is progressively inclusive of the preceding terms):

   a. Endemic - Only historic naturally reproducing fish originating from the same stream or tributary.

   b. Naturally reproducing stocks within drainage - Naturally reproducing stocks from the drainage of which the stream is part.

   c. Hatchery stocks within basin - Stocks which may include hatchery produced fish from streams within the drainage.

   d. Naturally reproducing stocks from out of basin - Naturally reproducing stocks from streams outside the basin of which the stream is part.

   e. Hatchery stocks out of basin - Stocks which may include hatchery produced fish from streams outside the basin.

   f. Any stock - Any stock which appears to exhibit characteristics suitable for the stream system.

2. Artificial production limitations shall be defined according to the following terms:

   a. None - No artificial production or fish planting permitted. Manage for natural reproduction. Rearing habitat fully occupied by natural production in most years.

   b. Supplementary - Artificial production is less desirable than natural production and is allowed only to the extent that it provides for full stocking of the stream. Artificial production shall be construed to be a temporary measure until such time as the Department determines the stream to be fully stocked, but shall not continue beyond 6 years without formal review by the appropriate Regional Fisheries Management Supervisor and Inland Fisheries Division representative. Releases of artificially reared fish shall be distributed to minimize disruption of naturally produced salmon or steelhead.

c. Complementary - Artificial production is as important for fishery Management purposes as natural production and hatchery production may be used on a permanent basis to complement natural production. The level of hatchery production shall not preclude or significantly interfere with natural reproduction and survival.

d. Hatchery - Managed principally for hatchery production with natural production protected but considered secondary.

IV-4-C Department of Fish and Game Fish Screen Policy

It is the policy of the Department of Fish and Game to provide all necessary measures to minimize fish losses to entrainment or other hazards associated with diversion of water from streams, lakes and reservoirs. Measures may include fish screens, cessation of diversion entirely or during critical periods, or location or relocation of diversion points to avoid conflict with fish populations.

Sections 5980-5993, 6020-6028, and 6100 of the Fish and Game Code, provide authority for the Department to require fish screens to protect fish and for requiring adequate bypass flow to make fish screens effective.

The Department will construct and operate, or require construction and operation of, adequate fish screens on legally authorized and operated water diversions where other equally effective measures are not employed to protect fish from the adverse effects of the diversions.

The Department will seek public funding support for construction of fish screens or other appropriate fish protection measures where the owner of the diversion is not responsible for costs. Where necessary to avoid losses until financial responsibility for a diversion or fish screen is established, the Department may proceed with construction and operation with public funds and require appropriate restitution upon allocation of responsibility. The Department will expeditiously pursue prudent allocation of financial responsibility for existing and new fish screens and other measures employed to reduce adverse fishery effects of water diversion facilities.

The Department will provide advice and technical assistance to assist owners of water diversions in development of appropriate measures to minimize adverse effects on fisheries. Where financial responsibility is allocated to the owner of a diversion, the Department may be reimbursed for technical or construction assistance beyond that required for preliminary problem identification and planning.

IV-5 Recommended for Immediate Action

IV-5-A Habitat Restoration Project Proposals

Although there are innumerable potential opportunities for habitat restoration or enhancement projects, identification of individual projects requires a substantial commitment of manpower resources. Additionally, each project requires design, engineering, construction, and administration. Accomplishment of habitat development projects by DFG requires a specific allocation of personnel and materials.

In many cases, substantial benefits from habitat improvement projects require improved firm water releases from water impoundment projects. The DFG first priority for salmon and steelhead restoration and enhancement is improved water flow and quality throughout the Sacramento-San Joaquin/Delta system.

The following is a list of projects that should be accomplished prior to 1993 by DFG in cooperation with other agencies and private interests:

Sacramento River System

1. Mainstem River

(a) Work with USBR to expedite the design and construction of a multi level intake structure on Shasta Dam to optimize water temperatures in the Sacramento River downstream as far as Red Bluff Diversion Dam.

(b) Work with the EPA and USBR to expedite the clean-up and continued dilution of heavy metals in acid mine wastes originating from Iron Mountain Mine.

(c) Evaluate alternative designs for modifying ACID dam to eliminate or minimize flow flucutation and to provide unimpaired fish passage. Implement the best alternative.

(d) Develop and implement a continuous gravel replenishment program for the upper Sacramento River from Keswick Dam to Cottonwood Creek. Quantities of gravels should be sufficient to replenish gravels lost since the construction of Shasta Dam and that which will continue to be lost on an annual basis in perpetuity.

(e) Improve in-river flows and flow release patterns in the mainstem Sacramento River to maximize habitat conditions and minimize adverse impacts. The soon-to-be-complete instream flow study results should be used in determining modified flow releases.

(f) Work with USBR, NMFS, and USFWS to design and construct a new fishway on the east bank at RBDD. The new fishway is intended as an alternative to raising the gates to facilitate up and downstream migration. Therefore, the new facility must meet the following criteria:

- Flow capacity must be between 5000 and 10,000 cfs.
- Provide passage for both adult and juvenile migration

- Both the upstream and downstream headworks for the new fishway must be immediately adjacent to the respective faces of the dam
- Be equiped with trapping and fish handling facilities and gates for shutting down individual channels within facility
- The gates on RBDD will continue to be opened until the facility has been demonstrated to work properly

(g) Evaluate fish losses associated with the 300 water diversions along the Sacramento River. Identify and implement corrective measures where appropriate. Costs of screening most of the larger diversions may exceed $7,000,000.

(h) Gravel sources should be acquired adjacent to, or in the river or its major tributaries in areas where runs of 200 or more fish occurred. Where purchase or other methods of acquisition are infeasible, constraints to protect the spawning gravel component should be placed on exploration or other actions that would render these gravel unusable by salmon or steelhead. Constraint should be accomplished through identification of State lands, negotiation with sponsors of detrimental projects, consultation with local government, and application of Fish and Game and Water Codes.

(i) Correct the Problem of Water Temperature Associated with Colusa Drain Overflow

Sacramento River temperatures in the lower reach become marginal or excessively warm in May, June, and July. High mortality and cessation of successful outmigration of outmigrating juvenile salmon occurs each year in June or July.

In 1985, 843,000 acre/ft. of drain water was discharged to the Sacramento River during the period April to September from two sources — the Colusa Drain and Sacramento Slough. Regional Water Quality Control Board Standards allow the water discharge to be no warmer than 68°F. It would be extremely difficult to keep the discharge water at or below that temperature and to avoid increasing the temperature of the main river. The water should be recycled for agricultural uses or diverted into a holding area until it can be safely released. If DFG is not successful in achieving this solution, the USBR and the SWRCB should be requested to develop measures to greatly reduce the volume of discharge.

(j) Examine all return channels such as Colusa Drain and Sutter Slough to determine if adult salmon stray into such channels and die, or whether they are able to reach suitable spawning habitat in areas such as Stoney Creek or other small tributary streams. If fish are lost, then permanent migration barriers should be constructed at the return channel outfall. If fish are successfully spawning then implement measures to improve immigration and outmigration of fish.

(2) Clear Creek. Implementation of the following actions could annually produce more than 30,000 adult fall-run chinook, 5,000 adult spring-run chinook, and 5,000 adult steelhead.

(a) Request USBR to make releases from Whiskeytown Dam in order to maintain the following flows at McCormick-Saeltzer Dam: 200 cfs October 15 to March 1, 150 cfs April 1 to October 14, these flow will improve habitat conditions for fall and spring-run chinook and steelhead.

(b) Construct a new fish ladder at McCormick Saeltzer Dam to provide passage for adult salmon and steelhead to the upper 10 miles of the creek.

(c) Construct a fish screen on the diversion canal at McCormick Saeltzer Dam to prevent entrainment of juvenile outmigrating salmon and steelhead.

(d) Purchase riparian and main channel lands and gravel leases in selected reaches of Clear Creek and restore channel and gravel bar productivity through weir and gravel palcement, channel alignment, and revegetation. Purchase, trade, accept as mitigation, or provide pumped ground water in lieu of, water necessary to modify present water delivery schedules and rates to meet salmon and steelhead seasonal and year-round water needs. Land and gravel lease purchase and initial habitat development will cost $6.5 million. Annual operation and maintenance would cost $250,000, and the water costs are presently unknown but could exceed $500,000 per year if other arrangements are not made.

(3) Battle Creek

(a) Work with PG&E to screen five major Battle Creek diversions. Substantial losses of both spring and fall-run chinook juveniles will be avoided by this action. This preliminary cost estimate is $300,000.

(b) Construct a physical barrier to prevent adult salmon and steelhead from entering the Grover Ditch bypass. A minimum estimate of 100 adult fish are losses in this ditch annually. The cost is estimated at $50,000.

(c) Request FERC to modify PG&E's license for their Battle Creek project to obtain adequate flows to maximize instream habitat and spawning conditions.

(4) Mill Creek

(a) Purchase property belonging to the holders of water rights served by the diversion at Clough Dam. Remove Clough Dam and specify has not provided the 3,000 annual mitigation escapement. The total deficit should be compensated by the project beneficiaries through cooperative development and implementation of a comprehensive fishery restoration program.

Coleman National Fish Hatchery provides partial replacement of fish production lost as the result of closing Shasta Dam. This facility suffers from poor water supply, inefficient design, poor siting for main stem salmon runs, and degenerated equipment and structures. Some of these problems can be corrected through restoration and an update of the facility; but its water supply for year-round production of fall-, late-fall-, winter-, and spring-run chinook and its off-river sitting probably cannot be completely overcome. The State should consider assuming operation responsibilities for the upper Sacramento River federal facilities and urging the federal government to construct and fund operation of a new production facility on Clear Creek or another suitable site in the Sacramento River drainage to augment the existing facilities.

Flow Fluctuation Rates. Rapid flow fluctuations result in erosion of redds, dewatered redds, isolated adult fish, and stranded (or grounded) juvenile fish. A study should be conducted to determine the optimal rates for flow fluctuation and to develop specific criteria and recommendation for each river in the system. These recommendations should be submitted to the water management agencies and be incorporated into any future flow agreements.

Central Valley Project. A complete review and analysis should be conducted for the CVP water development and delivery system to quantify salmon and steelhead losses. The review should include the Sacramento and San Joaquin rivers, the Delta, the pumping plant and screens, and the effect of agriculture return water.

A summary of the accumulated fish losses, enhancement failures, and ongoing losses should be compiled. Based on the analysis and summary of losses, the DFH should work with the USBR, USFWS, and NMFS to request appropriations to provide full restitution for all accumulated fish losses and to take corrective action to significantly reduce ongoing losses or produce a net benefit.

Straying of San Joaquin River Salmon and Steelhead. Diversion return flows can constitute a major part of San Joaquin River flows and create significant attractions for migrating adult salmonids. The confusing mixture of river waters and large volumes have resulted in a major loss of potential spawners. This situation should be thoroughly evaluated and an action program developed to rectify or mitigate the problem.

Complimentary Flow Schedules. River and Delta fish production and survival could be greatly improved with improved and complimentary flow schedules. Development of comprehensive complimentary flow schedules would require careful compilation and analysis of the factors and alternatives potentially affecting fish production and fisheries.

The study would necessarily involve compilation of all the significant flow schedules and legal mandates for all Sacramento River, San Joaquin RIver, and upper Delta tributaries. The study team should include full-time services of a fishery biologist, a water rights expert/legal advisor, a computer programmer, and a study leader. The object of the study would be development of computer software and user instructions compatible with water agency programs that could analyze the fishery benefits in the rivers and the Delta of infinitely variable flow schedules from the tributaries. The effort would require the cooperation of USBR, USCOE, U. S. Geological Survey, DWR, and the local water agencies. The potential benefit would be to reduce fish losses to stranding, water quality, and entrainment; and to increase spawning, rearing, and angling success.

San Joaquin River Hatchery. A major salmon and steelhead production facility is needed to culture San Joaquin River stocks to increase total production by 100,000 chinook and 10,000 steelhead. The Tuolumne River has been identified as one possible location but other sites are also under consideration for a hatchery that could provide production of this magnitude.

Plans and specifications including costs for construction and operation and a benefit analysis are needed prior to fully committing to construction. The hatchery would have to produce approximately 2 million yearling and 600,000 advanced fingerling chinook and 0.5 million 3-4/lb. (yearling) steelhead.

Merced River Fish Facility. A development plan should be completed for Merced River Fish Facility to increase production sufficiently to result in 20,000 additional adult chinook salmon. An adequate water supply, and a feasible method for assuring an adequate egg supply of Merced River stock need to be identified and secured before facility enlargement is funded.

Part V Conclusions

The Sacramento and San Joaquin rivers have the potential to produce, through natural spawning and hatchery production, as many chinook salmon and steelhead as were ever known prior to the large water developments and human modifications of the system. These fish will be largely different stocks than those that were endemic to the system's upper tributaries. Together with the hatchery system there is a potential for major expansion of the fishery.

This plan proposes retention and restoration of all known stocks, and enhancement of steelhead and fall-run chinook salmon populations.

Emphasis will be placed on restoration and enhancement of natural habitat and naturally produced fish. Intensive habitat management will be required throughout the system, but especially within the Delta and Estuary where outmigrant survival and adult upstream passage are presently the most important limiting factors.

The public together with all levels of government must work in concert to reach the goals of this plan. The Department of Fish and Game clearly has the constitutional and lead responsibility for implementation of the plan. Mitigation will normally be accomplished by the lead agencies for specific projects with assistance and encouragement, when necessary, by the DFG.

This plan will be updated biennially to keep it current as progress is made toward meeting the restoration goals. Details of the specific actions to be taken within each river section, tributary, and in the Delta will be prepared and distributed as appendices to this report. These appendices will be updated as needed.