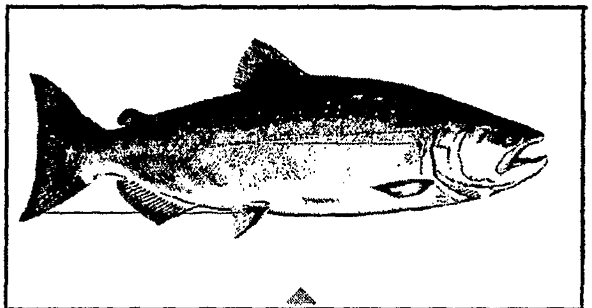
INTRODUCTION

The health of the Sacramento-San Joaquin Delta is largely dependent on the rivers and streams that compose its watershed. The Sacramento River is the largest element of the Delta's watershed, providing about 80% of the inflow to the Delta. Water, sediment, and nutrients from the Sacramento River are important factors governing the ecological health of the Bay and Delta. Many estuarine fish species and their foodweb depend on these factors that are input from the Sacramento River.

The Sacramento River is also an essential spawning, rearing, and migratory pathway for many anadromous fish populations of winter-run, fall-run, late-fall-run, and spring-run chinook salmon, steelhead, white sturgeon, green sturgeon, striped bass, and American shad. All of these populations must pass through the Delta and Bay during portions of their life cycle. Although the time spent in the Bay and Delta may be short, it represents an important part of the life-cycle. The abundance and health of the anadromous fish in the Sacramento River has been influenced by human activities in the Bay and Delta.

Ecological factors having the greatest influence on the anadromous fish in the Sacramento River include streamflow, natural sediment supply, stream channel dynamics (stream meander corridors), and riparian and riverine aquatic habitat. Stressors including dams, legal and illegal harvest, high water temperature during salmon spawning and egg incubation, toxins from mine drainage, hatchery stocking of anadromous fish, and unscreened or poorly screened irrigation diversions have affected the health of anadromous fish populations.



The vision for the Sacramento River Ecological Zone is to restore healthy populations of anadromous fish throughout the river and provide healthy conditions for populations from tributary streams that use the Sacramento River for feeding and migrating to and from the estuary and ocean. The pathway to this vision is through improving stream flow, spawning gravel recruitment, the river meander belt process, riparian and riverine aquatic habitats, and reducing the extent and influence of stressors. Healthy populations in the Delta will be attained when survival of anadromous fish is no longer threatened by human activity. The vision strongly focuses on restoration of the Sacramento River winter-run chinook salmon, a state-listed and federally listed endangered species, by providing winter-run chinook salmon with improved spawning, rearing, and migrating habitat and by reducing the adverse influences of stressors.

ECOLOGICAL PROCESSES

Central Valley streamflows - Healthy streamflows are natural seasonal patterns in late winter and spring that include peak flow events that support many ecological processes and functions essential to the health of the anadromous fish populations. The Sacramento River has only a marginally healthy streamflow because storage reservoirs in the upper watershed capture much of the winter-spring flows in dry and below-normal rainfall year-types.

Improvements in the flow patterns will require supplemental short-term releases from the major storage reservoirs to provide flow events that emulate natural peak flow events.

Natural sediment supply - Gravel recruitment on the Sacramento River is severely impaired by reduced inputs from tributaries and blockage of upstream sources by Shasta Dam, Keswick Dam, Anderson-Cottonwood Irrigation District diversion dam, and Red Bluff Diversion Dam. Spawning habitat of salmon and steelhead is controlled by the amount of gravel in the river.

Stream meander corridors - A natural stream meander process in the Sacramento River will provide much of the habitat required by anadromous fish populations that depend on the river for spawning, rearing, and migration. The meander belt of the upper portion of the river above Chico Landing is reasonably healthy and functioning, while the meander belt of the lower reaches of the river has been greatly limited by channelization of the river, by a network of confining levees, and associated development in the river floodplain.

Central Valley stream temperatures - High summer and fall water temperatures continue to threaten the health of anadromous fish populations in the river. Although actions have been taken to reduce high water temperatures, low flows, and the release of warm water from reservoirs in drought years remain a very serious threat to the anadromous fish populations of the Sacramento River.

HABITATS

Riparian and riverine aquatic habitats - Habitats important to anadromous fish production in the river are impaired not only by development along the river but by development in the healthy meander belt of the upper river. Improvements are needed in the upper meander belt section in addition to the leveed lower reach.

SPECIES

Splittail - Improvements in the riparian and stream meander corridors along the Sacramento River will improve spawning and early rearing habitat of splittail. Late-winter and early-spring streamflow improvements will provide attraction flows for spawning adults and increased spawning habitat.

White sturgeon and green sturgeon - Improved peak flows in late winter and early spring will benefit sturgeon spawning. Improved stream meander corridors should also benefit sturgeon.

Chinook salmon - All four races of chinook salmon should benefit from improved streamflows, gravel recruitment, water temperatures, riparian and riverine aquatic habitat, and stream meander corridors.

Steelhead trout - Steelhead will benefit from improved streamflows and gravel recruitment in the upper river and improved water temperature and riverine habitat in the upper, middle, and lower reaches of the river.

American shad - Improvements in late-winter and spring streamflows and stream meander corridors will benefit American shad spawning and rearing in the Sacramento River.

Swainson's hawk - Riparian woodland improvements along the Sacramento River will assist in the recovery of the Swainson's hawk.

Western yellow-billed cuckoo - Improvements in riparian habitat will benefit the western yellow-billed cuckoo.

Bank swallow - Protecting and isolating the stream meander corridor will benefit bank swallows.

STRESSORS

Water diversion - Water diversions ranging from several cubic feet per second (cfs) to several thousand cfs lead to the loss of millions of juvenile anadromous fish. Significant progress has been made in screening the larger diversions, but screens are needed on the remaining unscreened largest, many medium-sized, and small diversions. Losses at these diversions continue to threaten the health of the anadromous fish populations.

Levees, bridges, and bank protection - Diversion dams and other humanmade structures in the Sacramento River directly and indirectly impair the survival of adult and juvenile anadromous fish. Structures delay or prevent the upstream migration of adult fish during their spawning run, which lowers the reproductive success and viability of the entire population. These diversion structures can injure young fish as they migrate downstream or cause disorientation, making them more susceptible to predation. Predator fish that are not able to migrate upstream may congregate below these structures during times when prey species are abundant. For example, Sacramento squawfish congregate at the Red Bluff Diversion Dam (RBDD). The problem with fish passage and predators at RBDD has been partially solved, but fish passage is still constrained during the irrigation season.

Contaminants - Toxins from Spring Creek are a continuing problem for fish in the upper Sacramento River.

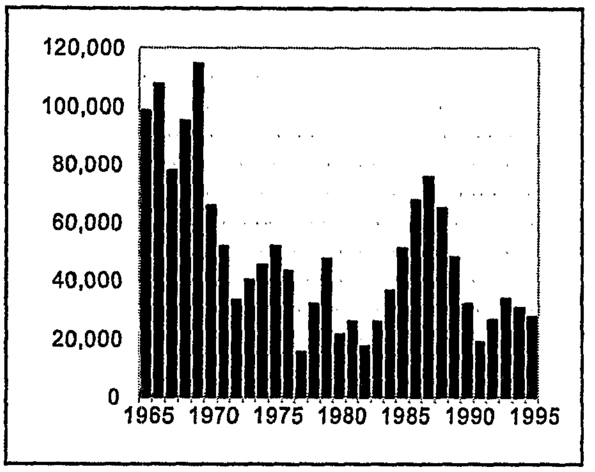
Harvest of fish and wildlife - The legal and illegal harvest of anadromous fish within the river, estuary, and ocean constrains recovery of wild populations of anadromous fish in the Sacramento River. Reducing the fraction of the wild population harvested will most likely be necessary to allow recovery of populations to a healthy condition.

Artificial propagation of fish - Stocking hatchery-reared salmon and steelhead in the Sacramento River and some of its tributaries supports important sport and commercial fisheries and mitigates loss of salmon and steelhead from the construction of large dams and reservoirs. Hatchery fish also supplement the numbers of naturally spawning salmon and steelhead in the river. However, hatchery salmon and steelhead may impede the recovery of wild populations by competing with wild stocks for resources. Hatchery-raised stocks, because of interbreeding, may be genetically inferior to wild stocks or may not have the instincts to survive in the wild. If these stocks breed with wild populations, overall genetic integrity suffers. Improvements in hatchery practices are necessary to ensure recovery of wild populations of salmon and steelhead.

BACKGROUND

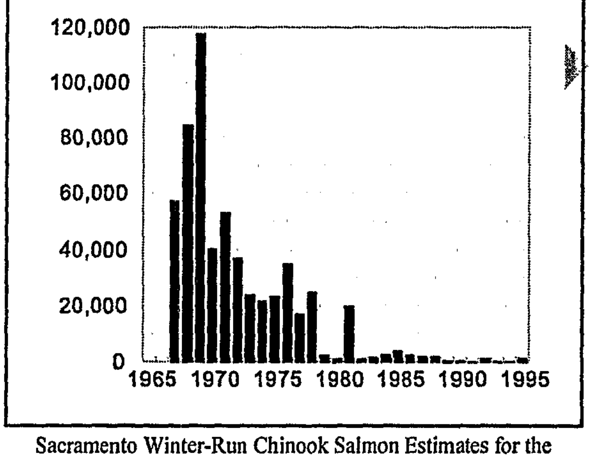
The Sacramento River supports a variety of anadromous species including four races of chinook salmon, green sturgeon, white sturgeon, steelhead trout, striped bass, and American shad. The National Marine Fisheries Service (NMFS) has determined that critical habitat for the endangered Sacramento winter-run chinook salmon includes the entire Sacramento River from Keswick Dam, river mile (RM) 302 to Chipps Island (RM 0).

The Sacramento River flows more than 300 miles from Lake Shasta to Collinsville in the Delta where it joins the San Joaquin River. It is a major western river of the United States and the largest and most important riverine ecosystem in the State of California. It is also the largest tributary of the Bay-Delta ecosystem. The river corridor encompasses more than 250,000 acres of natural, agricultural, and urban lands upstream of Sacramento. Various cropland habitats occur on flat and gently rolling terrain adjacent to most of this zone. Irrigated crops are mostly rice, grains, and alfalfa and those produced in orchards. Most of this cropland is irrigated with water diverted from the Sacramento River or its tributaries.



Fall-Run Chinook Salmon Estimates for the Mainstem Sacramento River, 1965-1995

The Sacramento River Ecological Zone includes 242 miles of the mainstem Sacramento River from Keswick Dam near Redding to the American River at Sacramento. (The remaining 60 miles of the lower river downstream of Sacramento are included in the North Delta Ecological Unit). The mainstem river planning area includes the river channel, gravel bars and vegetated terraces, the



Sacramento Winter-Run Chinook Salmon Estimates for the Mainstem Sacramento River, 1967-1995

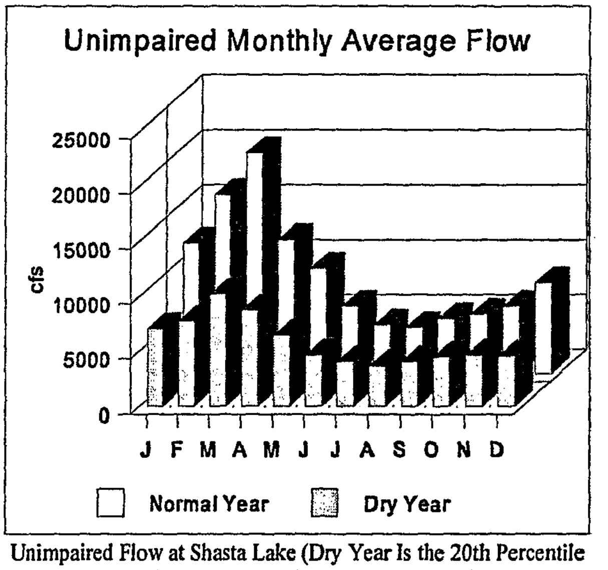
100-year river floodplain, and the geologically defined band of historic and potential river migration (i.e., the meander belt). In the artificially narrow, leveed reach downstream of Colusa and extending to Sacramento, an approximately 1-mile-wide band of river alluvium and historic and potential forest land that borders the levees is also included in this ecological zone. The entire ecological zone is shown in Figure 8.

RESTORATION NEEDS

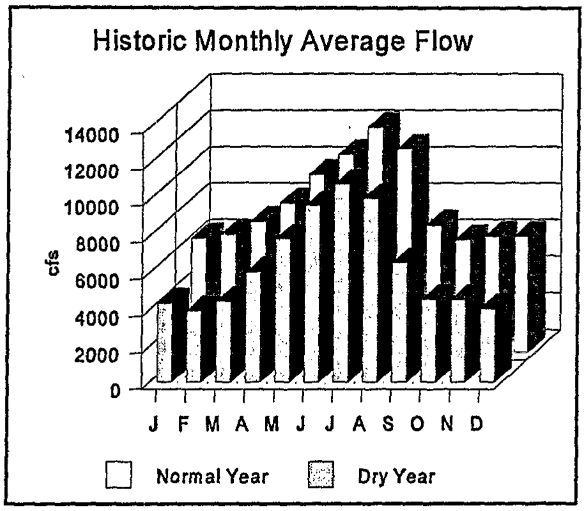
CENTRAL VALLEY STREAMFLOW

Sacramento River flow is controlled during much of the year by water releases at Whiskeytown, Spring Creek, and Shasta Dams. Tributaries, including many with no major storage dam, provide a significant quantity of flow accretion, particularly through winter and spring months. Prior to the construction of Shasta Reservoir, the river flows near Redding had a typical winter and spring high-flow period and a summer low-flow period. Dry-year flows typically reached a peak near a monthly average of 10,000 cfs in March. In more normal years, peak flows reached approximately 20,000 cfs in March. Low summer flows averaged less than 5,000 cfs in dry and normal years.

Since completion of Shasta and Trinity Dams, streamflows in the Sacramento River have



Unimpaired Flow at Shasta Lake (Dry Year Is the 20th Percentile Year; Normal Year Is the 50th Percentile or Median Year)



Historic Flow below Keswick Dam, 1972-1992 (Dry Year Is the 20th Percentile Year; Normal Year Is the 50th Percentile or Median Year)

changed markedly. Late-winter and spring flows in dry and normal years are stored in reservoirs and released during the late-spring through fall irrigation season. In addition to flows released for irrigation in recent years, flows in excess of 10,000 cfs have been released for temperature control in summer to protect winter-run chinook salmon spawning, egg incubation, and early rearing in the upper river.

Several water development and flood control projects have dramatically altered the river's natural flow regime, sediment transport capabilities, and riparian and riverine habitats. These projects include the Central Valley Project (CVP) and consists of Shasta, Keswick, and Whiskeytown Dams and RBDD. It also includes the Sacramento River Flood Control Project, which extends 180 miles south from Chico Landing and consists of a series of levees, weirs, and overflow areas, and the Chico Landing to Red Bluff Comprehensive Bank Stabilization Project, which is designed to control lateral river-channel migration and is about 54% complete but has not been worked on since 1984. The State Water Project (SWP), consisting of Oroville Dam and the associated diversion works, has altered the flow regime below the confluence of the Feather River.

NATURAL SEDIMENT SUPPLY

Gravel recruitment is limited by dams blocking downstream gravel transport, bank protection, and gravel mining on tributaries. Deficiency in spawning gravels reduces the productive capacity of the river. This is especially true in the 15- to 20-mile river reach below Keswick Dam. Spawning gravel may be adequate to support salmon and steelhead populations. As fish populations increase, gravel replenishment will be necessary. Natural gravel recruitment from tributary streams, particularly from Cottonwood Creek, needs to be protected to ensure that the gravel deficit does not increase. Spawning gravel needs protection from degradation caused by excessive silt entering the river from the tributaries. Watershed protection and comprehensive watershed management plans are needed in all the tributaries to reduce erosion of silts and sands that impair the quality of spawning gravels.

CENTRAL VALLEY STREAM TEMPERATURES

Water temperature in the river is impaired by increased water releases from Shasta and Keswick Dams in drought years. Low flows combined with warmwater releases cause the loss of many adult salmon and eggs spawned in the river.

Sacramento River temperature control requires the installation of a multilevel outlet structure on Shasta Dam and a minimum fall carryover storage in the reservoir of about 2 million acre-feet (MAF). Water temperature in the lower reach of the Sacramento River can be improved by redirecting the Colusa Basin drain and other agriculture return water to a receiving water other than the Sacramento River.

The Colusa Basin drain originates north of Willows in Glenn County. The drain captures waters from the two major diverters located on the west side of the Sacramento River, the Tehama-Colusa and Glenn-Colusa Irrigation Districts in

Glenn, Colusa, and Yolo Counties. Much of the water conveyed through the drain is recaptured and reused before being discharged into the Sacramento River at Knights Landing near RM 90. The combined volume of the water delivered by the two districts can exceed 5,000 cfs during the peak of the irrigation season.

Water temperature is also affected by overhanging vegetation, which shades and cools the water. This shaded riverine aquatic (SRA) habitat has been significantly altered by bank protection and flood control projects. Reestablishing this edge vegetation would improve water temperatures and significantly improve SRA habitat, woody debris, and other riparian habitat along the Sacramento River, which, in turn, should improve production and survival of salmon and steelhead.

Riparian and Riverine Aquatic Habitats

Historically, the riparian forest corridor along the river averaged 4-5 miles wide and encompassed a significantly large area, today only 5% of the forests remain. One-third of the river length has natural banks and floodplain terraces; the other two-thirds have been modified and confined by levees, riprap, and flood control projects. These structures limit the dynamic forces that promote natural habitat succession and regeneration along the river. Channelization and bank protection between Red Bluff and the Delta eliminate and degrade many habitats by increasing the depth and velocity of flow and reducing the hydraulic and substrate diversity associated with more natural or undeveloped river systems. Bank protection also reduces the amount of fresh gravel and shaded riverine aquatic habitat normally available to the river through bank erosion.

Between Chico Landing and Red Bluff, natural riparian vegetation associated with the existing stream meander corridor plays a part in the natural floodplain process. In turn, the diversity of streamside vegetation and its overall condition are dependent on these same dynamic river processes. Riparian vegetation effectively creates a buffer to decrease local floodflow velocities. This increases deposits of suspended materials derived from eroding banks. This erosion-deposition process builds the midterrace and eventually the high-terrace lands that support climax forest and agriculture. Overbank flooding is essential for the continued health of the riparian system. As silt and seeds are deposited during these overbank water flow events, the native vegetation is rejuvenated.

The occurrence of the remaining riparian habitat in fragmented blocks greatly diminishes its ability to support viable wildlife populations. In addition, this remaining habitat is being further degraded by human activity and adverse land uses. The combined loss, fragmentation, and deterioration of riparian habitat has caused, or is leading to, the extinction or elimination of several wildlife species. The drastic decline of the Swainson's hawk, once one of California's most abundant raptors, is in part a result of the loss of riparian nesting areas. In 1987, surveys documented such a low number of yellow-billed cuckoos that the species appeared to be in danger of immediate extirpation. The elimination of the bank swallow appears likely if bank protection work continues and if mitigation measures are unsuccessful. Various other animal species and some plant species, including the California hibiscus, have population viability problems as a result of adverse human impacts on riparian habitat.

Reestablishing a viable riparian ecosystem along the upper Sacramento River region will increase the acreage and variety of riparian habitats and reverse the decline in wildlife, fishery, and human use values. The U.S. Fish and Wildlife Service (USFWS), the Wildlife Conservation Board (WCB), the National Audubon Society, The Nature Conservancy (TNC), and other private conservation groups are actively seeking to acquire conservation easements or fee ownership of high-priority riparian lands along the Sacramento River as a means to save these lands in perpetuity.

More than 100 miles of the Sacramento River between Red Bluff and Colusa are wholly or partially intact as a dynamic alluvial river meander belt. Although about 20% of its banks are armored by riprap that protects levees and orchards, the river continues to erode its banks naturally and form new banks from gravel and sediment deposits on point bars and terraces. These fluvial geomorphic features support a time-dependent succession of young- and old-growth forest and wildlife habitat that requires 65-100 years to reach full maturity (climax succession to valley oak woodland). New sediment and gravel that sustain this process is supplied by a combination of eroding banks along the mainstem river and input from unregulated upstream tributaries. New fish habitat is continually created by migrating gravel riffles and deeper pools formed at bendways, and by mature trees and roots that overhang or topple into the channel as the river naturally erodes through older alluvial deposits supporting climax vegetation.

WATER DIVERSION

Other problems in the Sacramento River affecting anadromous fish include poorly screened diversions, seasonal dams installed in rivers, small unscreened diversions, and a limited number of large diversions (>250 cfs). Two diversion dams operate on the river seasonally: ACID's flashboard dam in Redding that diverts approximately 400 cfs and impairs the upstream and downstream migration of salmon and steelhead, and RBDD, the gates of which are in place from mid-May to mid-September to allow diversions up to 3,000 cfs into the Corning Canal and Tehama Colusa Canal. Both the dams and diversions have fish passage facilities and fish screens. Fish passage facilities are inadequate at both facilities. The screen system at the ACID diversion is not adequate. Although predation problems associated with the dams have been lessened, they still occur.

All other water diversions along the river are shoreline diversions. The largest is GCID's Hamilton City Pumping Plant on an oxbow off of the Sacramento River. It diverts up to 3,000 cfs of water into the Glenn-Colusa Canal. Although many improvements have been made to its screening system, fish protection remains inadequate and improvement efforts continue. In addition, hundreds of unscreened diversions located along the river operate primarily in the spring-through-fall irrigation season. Approximately 20 of these are large (>250 cfs). Efforts are presently being made in cooperation with the irrigators and resource agencies to screen these larger diversions.

The GCID diversion on the Sacramento River near Hamilton City has been the cause of a significant loss of juvenile fish. The existing screens cause losses by impinging and entraining the fish. A permanent solution to the problem is needed, not only to protect winter-run chinook, but all other migratory fish as well. An environmental impact report is being prepared to describe actions involved in resolving the problem.

The damage to fisheries associated with each of the problems in the upper river varies according to the type of water-year and water delivery operations. The diverse and cumulative nature of these variables requires a holistic remedy to achieve salmon and steelhead restoration in the Sacramento River. The most important factors causing mortality are being addressed in various ways with interim or emergency actions.

CONTAMINANTS

Toxins from mine drainage on Spring Creek enter the river by way of Keswick Dam and threaten survival of salmon and steelhead when sufficient dilution flows are not available from Shasta Lake.

PASSAGE

Fish passage over the 80-year-old Anderson-Cottonwood Irrigation District (ACID) diversion dam must be improved. A feasibility study is being conducted to identify alternatives to achieve this goal. ACID canal operations need to be standardized to protect Sacramento River chinook salmon. This involves draining canal water through waste gates only on channels with fish barriers at their confluence with the river, limiting waste-gate releases to 5 or 10 cfs to minimize attraction of salmon from the river, and providing total containment of canal waters when toxic herbicides are present.

Fish passage at RBDD is a longstanding problem that has been partially solved through reoperation. This interim fix has constrained water diversion and the longer term resolution needs to incorporate fish passage and survival and water delivery. There is the potential that the U.S. Bureau of Reclamation (Reclamation) research pumping facility at RBDD will allow "gates up" operation at RBDD from mid-September through mid-May. With the gates raised, fewer squawfish congregate below the dam thereby reducing predation on juvenile salmon as they pass under the dam gates. This also provides unimpaired upstream and downstream migration for all anadromous fish in the river. Fish losses and delayed migration, however, will still occur during the 4 months the dam gates are lowered.

VISION FOR ECOLOGICAL UNITS

KESWICK DAM TO RED BLUFF DIVERSION DAM ECOLOGICAL UNIT

SUPPORTING INFORMATION

The Keswick Dam to Red Bluff Diversion Dam reach (59 miles from RM 302 to RM 243) includes the mouths of Ash, Bear, Cow, Inks, Battle, and Paynes Creeks draining Mount Lassen and Spring, Clear, and Cottonwood Creeks draining the Coast Ranges and Klamath Mountains. Much of the river in this reach flows through confined canyons, although portions have a broader floodplain. About 4 miles below Keswick Dam, the river widens to about 500 feet before entering the alluvial plains of the Sacramento Valley below Red Bluff. This reach includes much urbanized and residential river frontage, but is not contained by levees as is common on the downstream reach. Approximately 60% of naturally spawning chinook salmon in the Sacramento River use this reach, while the remaining 40% use the reach from RBDD to Princeton, near Colusa.

VISION

The vision for the Keswick Dam to Red Bluff Diversion Dam Ecological Unit includes maintaining a flow pattern that emulates the seasonal hydrologic regime to the extent possible given the high level of development of water and flood storage in the upper section. This includes cooperative efforts to restore some aspects of the natural hydrologic conditions of the upper Sacramento River. The Anadromous Fish Restoration Plan's (AFRP's) targets of 3,250-5,500 cfs from October 1 to April 30 are similar to the rates of natural flows. In addition to the AFRP base flow minimums, reservoir inflows should be released to the river to provide 8,000-10,000 cfs and 15,000-20,000 cfs flow events for approximately 10 days in March of dry and below-normal years, respectively. Such flow events would support natural processes in the upper river that depend on natural flow regimes.

The vision highlights the restoration of ecological processes that naturally create and sustain habitats needed to support and restore the endangered Sacramento winter-run chinook salmon and species of concern such as steelhead, spring-run chinook, fall-run chinook, and late-fall-run chinook. Important ecological functions of flow include maintaining and supplementing the natural stream meander and gravel recruitment processes, transporting and depositing sediment, protecting the limited riparian corridor, and preventing potential catastrophic fish losses resulting from an uncontrolled spill of toxic materials from Iron Mountain Mine (IMM) and Spring Creek debris dam overflow.

Because this ecological unit encompasses a significant portion of critical holding, spawning, and nursery area required by the endangered winter-run chinook salmon, most of the water diversions in this reach require positive-barrier fish screens installed to protect juvenile salmon and steelhead. A primary concern in this ecological unit is protecting and enhancing instream gravel resources supplied to the mainstem river by the tributaries.

Nursery areas for juvenile salmon would be improved by restoring or enhancing waterside emergent and riparian vegetation throughout this unit and particularly in areas immediately downstream of the mouths of some of the tributaries described above. This can be accomplished by a variety of measures including special riparian zone seasonal grazing management programs or, where landowners choose to participate, fenced exclosures.

Red Bluff Diversion Dam to Chico Landing Ecological Unit

Supporting Information

The Red Bluff Diversion Dam to Chico Landing Reach (49 miles from RM 243 to RM 194) includes the mouths of eastside tributaries of the Sacramento River that drain Mount Lassen and the northern Sierra Nevada including Antelope, Mill, Deer, Pine, Rock, and Big Chico creeks. Westside streams that drain the upper valley and parts of the Coast Range include Red Bank, Elder, and Thomes Creeks. South of Red Bluff is a broad alluvial river system controlled by its own water discharge and sediment deposits. Here, the river meanders over a broad alluvial floodplain confined by older, more consolidated geologic formations (i.e., more cohesive deposits resistant to bank erosion). The extent of river floodplain and active channel meander belt from Red Bluff to Chico Landing has remained relatively unchanged and includes a significant amount of riparian forest.

Vision

The vision for the Red Bluff Diversion Dam to Chico Landing Ecological Unit emphasizes maintaining the quantity and quality of the stream meander corridor and its associated riparian forest. The existing meander belt should be protected and improved to sustain the riparian component that is important habitat for winter-run chinook salmon and steelhead and other anadromous fish species.

Restoration of endangered species and species of special concern requires that water management activities be consistent with maintaining ecological processes. These include flows that emulate the natural hydrologic regime to the extent possible and are compatible with the high level of development of water in the upper section. Important considerations include flows needed to maintain natural stream meander processes and gravel recruitment, transport, and deposition.

Because this ecological unit encompasses an important portion of critical nursery and emigration area required by the endangered winter-run chinook salmon, water diversions in the section will require positive-barrier fish screens to protect juvenile fish.

The broad riparian corridors throughout the unit should be connected and should not be fragmented. These corridors connect larger blocks of riparian typically greater than 50 acres. These blocks should be large enough to support the natural convection currents of air flowing from the forests across the river causing evaporative cooling of the river. The riparian corridors should generally be greater than 100 yards wide and would support increased populations of neotropical migrants such as the yellow-billed cuckoo and unique furbearers such as the ring-tailed cat. Species such as the bank swallow will benefit from the restoration of processes that create and maintain habitat within this unit.

Nursery areas for juvenile salmon should be improved through the restoration of waterside emergent and riparian vegetation throughout the unit and particularly downstream of the mouths of some of the tributaries described above.

CHICO LANDING TO COLUSA ECOLOGICAL UNIT

SUPPORTING INFORMATION

The Chico Landing to Colusa reach (51 miles from RM 194 to RM 143) includes the mouth of Stony Creek and no other major tributaries. In this reach, most of the high flow during storm runoff events leaves the river along the east bank and enters the expansive floodplain of Butte Basin through three major flood relief outfalls at M&T Ranch, 3B's, and Parrot Ranch, and farther downstream through the Moulton and Colusa weirs near Colusa. Much of the river downstream of Chico Landing has been subject to flood control with an extensive system of setback levees, basin and bypass outflows, and streambank protective measures such as riprap. However, considerable riparian forest remains within the levees along the active channel. Levees in this reach are 0.25-1.0 mile apart.

In the Butte Basin overflow segment, more extensive bank revetment projects installed during the past 30 years by landowners and the U.S. Army Corps of Engineers (Corps) attempt to halt natural channel migration by fixing the river in a static position. It was believed that natural channel migration and meander cutoff might alter flow splits that divert a major portion of river floodflow over three major weirs into Butte Basin, where flooding volumes pose less risk to levee overtopping. Recent hydraulic simulation studies of this reach appear to indicate that the river is somewhat self-adjusting to maintain similar Butte Basin overflow volumes, in spite of specific meander cutoffs that may occur. However, bridge structures (e.g., Ord Ferry Bridge) may be more at risk to major adjustments of the channel position within the floodplain.

VISION

The vision for the Chico Landing to Colusa Ecological Unit provides improved habitat and increased survival of many important fish and wildlife resources.

Restoring endangered species and species of special concern requires that water management activities be consistent with maintaining ecological processes. These include flows that emulate seasonal patterns typical of the natural hydrologic regime, consistent with the high level of development of water in the upper section. Important considerations include flows needed to maintain natural stream meander processes and gravel recruitment, transport and deposition, and maintenance of the limited riparian corridor in this section.

Closing gaps in the shoreline riparian vegetation and nearshore aquatic habitat will be accomplished by natural colonization of expanded floodplain along channels, by a reduction of vegetation management by local reclamation districts (consistent with flood control requirements) and enhancement of channel banks by modifying levees and berms to incorporate habitat structures such as fish groins and low waterside berms supporting natural growth and woody debris.

Important elements needed to attain the vision for this unit include specific processes that maintain high-quality habitat for chinook salmon and steelhead as well as the other anadromous fish species. The continuance of the natural migration of the river within its meander zone is essential to create and maintain most of these habitats. A mix of solutions will be employed to reduce the need for future additional bank protection or separation of the channel from its floodplain. Floodplain management and detention measures that expand flood protection for valley residents by reducing peak flood stage within the leveed channel will also permit more undisturbed habitat to thrive within the river corridor. Measures will most likely include strategic levee setbacks, expanding flood basin outflow capacity, and new flood easements in basin lands that detain additional flood storage, thereby reducing river stage.

In this unit, broad riparian corridors should be interconnected with narrower corridors that are not subject to fragmentation. These corridors should connect larger blocks of riparian typically larger than 50 acres. These blocks should be large enough to support the natural evaporative cooling of the river by convection currents of air flowing from the cool, humid forests and across the river water. The wider riparian corridors should generally be greater that 100 yards wide to better support neotropical migrants such as the yellow-billed cuckoo. Cavity-nesting species, such as the wood duck, and special-status species, such as the bank swallow, will benefit from restoring the processes that create and maintain habitat within this unit. The narrower corridors would be 10-25 yards wide.

Nursery areas for juvenile salmon should be improved by restoring waterside emergent and riparian vegetation throughout this unit, particularly in areas immediately downstream of the mouth of the Feather River.

Because this ecological unit encompasses a significant portion of the critical migration habitat required by the endangered winter-run chinook salmon, positive-barrier fish screens should be used at water diversions in this section to protect juvenile fish.

In short, the vision for this and the previous unit combined could be summarized as preserving, managing, and restoring a functioning ecosystem to ensure the sustainable maintenance of:

- a mosaic of varying age classes and canopy structure types of riparian forest;
- a diversity of habitat types, including forest and willow scrub, cut banks and clean gravel bars, oxbow lakes and backwater swales with emergent wetlands, and floodplain valley oak/sycamore woodlands with grassland understory;
- uninterrupted gravel transport, deposition, cleansing, and replenishment; and
- a complexity of shaded and nearshore aquatic substrate and habitats with well-distributed instream woody cover and organic debris.

Colusa to Verona Ecological Unit

Supporting Information

The Colusa to Verona reach (63 miles from RM 143 to RM 80) includes the mouth of the Butte Slough outfall gate, but no important tributary inflow until the Colusa Basin drain enters the river near Knights Landing at RM 90. High flows leave the river by way of the Colusa and Tisdale weirs, and farther downstream most flow from the Sutter Bypass/Butte Slough and Sacramento River leaves the river again at the 3-mile-long Fremont weir and flows down the Yolo Bypass to the Delta at Rio Vista. Most of the levees in this reach are built close to the main river channel and little riparian forest or SRA habitat remains. Leveed banks are steep with extensive riprap and routine removal of volunteer vegetation by local reclamation districts to maintain levee stability on the confined river channel. At the turn of the century, levees were built close to the banks to help move sediment down the river to prevent natural shoals that obstructed commercial river navigation reaching Colusa and Red Bluff.

VISION

The vision for the Colusa to Verona Ecological Unit provides improved habitat and increased survival of many important fish and wildlife resources. Important elements needed to attain the vision for this unit include specific processes that allow the recovery of riparian forest and nearshore aquatic habitats and maintain high-quality habitat for chinook salmon and steelhead and other anadromous fish species. Because this reach is an important seasonal component of the critical migration habitat required by the endangered winter-run chinook salmon, positive-barrier fish screens should be used at water diversions in this section to protect juvenile fish.

The lack of channel capacity and proximity of levees to the river in the lower two units in this zone is the primary reason that many habitats are degraded, discontinuous, or absent from this part of the river. There is simply no more room to restore large habitat nodes or corridors without contributing to the flood risk. Major additional capacity of the system is needed to make room for the ecological recovery of the degraded river in this 85-mile stretch and to connect the Delta to a functional river system. This is an area where flood control and ecosystem restoration requirements must be carefully evaluated and integrated.

VERONA TO SACRAMENTO ECOLOGICAL UNIT

SUPPORTING INFORMATION

The Verona to Sacramento Ecological Unit (20 miles from RM 80 to RM 60) includes important tributary inflow from the Feather River (and from Sutter Bypass and Butte Slough during high flows) at RM 80 and from the American River at RM 60. High-flow outfall from the rivers and Sutter Bypass enters the Yolo Bypass by way of the Sacramento Weir. As with the upstream reach, most of the levees in this reach are built close to the main river channel and little riparian forest or SRA habitat remains.

VISION

The vision for the Verona to Sacramento Ecological Unit provides for many important fish and wildlife resources that depend on partially operational ecological processes and functions. Important elements needed to attain the vision for this unit include specific processes and conditions that maintain high-quality nursery and migration habitat for adult and juvenile winter-run chinook salmon and steelhead and other anadromous fish species.

Restoring endangered species and species of special concern requires that water management activities be consistent with maintaining ecological processes. These include flows that emulate the natural hydrologic regime to the extent possible. Important considerations include flows to maintain natural stream meander processes and gravel recruitment, transport and deposition, maintaining a limited but continuous riparian corridor, and reducing potential fish losses resulting from toxic residues from agricultural tailwater. Because this ecological unit encompasses a significant portion of critical nursery area required by the endangered winter-run chinook salmon, positive-barrier fish screens should be used at water diversions in this section to protect juvenile fish.

Closing gaps in the shoreline riparian vegetation and nearshore aquatic habitat will be accomplished (consistent with flood control requirements) by reducing vegetation management by local reclamation districts, and enhancing channelbanks by modifying levees and berms that incorporate habitat structures (such as fish groins and low waterside berms) supporting natural growth and woody debris. Nursery areas for juvenile salmon would be improved by restoring waterside emergent and riparian vegetation nodes throughout this unit, particularly in areas immediately downstream of the mouth of the American River.

In this unit, narrower riparian corridors should be connected and should not be fragmented. These corridors would connect larger blocks of riparian typically greater than 50 acres. These blocks would be large enough to support the natural convection currents of air flowing from the forests across the river causing evaporative cooling of the river. The riparian corridors would generally be 10-25 yards wide and would support cavity-nesting species, such as the wood duck, and provide perch and nest sites for raptors such as the Swainson's hawk. Significant expansion of riparian habitat is only possible if lower river peak floodflow can be reduced, or where levees can be set back several hundred feet at constricted bends to create expanded floodplain nodes within the levees.

LINKAGE TO OTHER RESTORATION PROGRAM

Attaining the vision for the Sacramento River Ecological Zone requires near-term funding and implementing actions to achieve the targets. This includes managing water project operations, purchasing title or easements of land from willing sellers, cooperatively developing and implementing a phased fish screening program, acquiring and placing gravel, and performing engineering studies to improve fish passage at diversions dam.

A number of actions should be taken to preserve and begin restoring riparian habitat on the Sacramento River. Appropriate land use and policy documents should be prepared that identify riparian restoration and preservation areas. This information would be useful in working with appropriate cities and counties to amend general plans to preserve stream corridors as important fish and wildlife habitat and to restrict inappropriate uses. Another preservation method would be to consider purchasing, in fee title or through conservation easements, appropriate riparian habitat along the Sacramento River. Both USFWS and Reclamation are pursuing acquisition of lands adjacent to the Sacramento River.

Concurrent with the near-term actions, the vision includes cooperation and support of existing ecosystem and species restoration efforts and programs. Parallel efforts include developing and integrating local land use plans that embrace and foster the objectives and concepts of this plan.

Longer term efforts that will enhance the vision for the Sacramento River Ecological Zone and provide for durable ecosystem restoration involve developing and implementing watershed management plans by land use agencies, evaluating flood management options, and restoring the important stream meander channel of the Sacramento River.

Overall, this plan anticipates that the vision for the Sacramento River Ecological Zone will augment other important ongoing and future restoration efforts for the zone. In particular, the vision will greatly supplement the NMFS's and the Department of Fish and Game's (DFG's) need for restoring the endangered winter-run chinook salmon and other potential salmon and steelhead stocks presently under status review for inclusion in the list of endangered species. The vision for the Sacramento River Ecological Zone will also build on the benefits from the AFRP, which strives to double the natural production of anadromous fish in the system over the average production from 1967 through 1991. Likewise, the vision will help DFG as it progresses toward doubling the number of anadromous fish over the number present in 1988.

State and federal agencies responsible for flood control and natural river resources should collaborate with local jurisdictions, landowners, and river conservation organizations, to seek systemwide solutions. In particular, the Corps should develop a physical model of the river system and its floodplain (similar to the Butte Basin study, but on a larger scale) to test hypotheses for complex rerouting, detention, and bypassing of floodwater. A Sacramento Valley hydraulic and sediment transport model will be integrated with an evaluation of ecological functions dependent on these physical processes and on the interaction of elements of the ecosystem recovery and land use with floodway capacity.

Completion of studies and subsequent implementation of the U.S. Environmental Protection Agency (EPA) remedies for the IMM Superfund site are needed to attain the safe metal concentrations identified in the basin plan. Pollution control remedies are required at the IMM portal discharges from remaining sulfide ore deposits inside the mountain, the discharges from tailing piles, and the metal sludge in Keswick Reservoir.

Finally, the vision for this important ecological zone will rely on the Upper Sacramento River Advisory Council's Riparian Habitat Committee (SB1086 committee) as it progresses with its plan to restore a naturally sustained riparian corridor, including a designated meander belt and extensive forests, between Keswick Dam and Verona.

In reaching the vision for this ecological zone, many cooperative programs need to be developed with federal, State, and local agencies, as well as local interests such as watershed groups and individual landowners. The cooperative approach also applies to efforts to redirect some industries, such as the aggregate resource industry, to areas outside the active stream channel. These efforts also require support from and for the local counties to undertake new programs.

LINKAGE TO OTHER ECOLOGICAL ZONES

The Sacramento River Ecological Zone is dependent on virtually all its adjacent ecological zones, which cumulatively contribute to the maintenance of important ecological processes and functions, particularly water, sediments, and nutrients. However, many large, westside streams no longer provide significant sediment and gravel to the mainstem river because of the placement of large reservoirs or sediment control basins, and instream gravel mining that depletes gravel sources in the channel for downstream transport.

Restoring and maintaining ecological processes and functions in the Sacramento River Ecological Zone are highly dependent on actions and conditions in adjacent zones. For example, maintaining the riparian forests and stream meander quality of the Sacramento River above Chico Landing is highly dependent on input of largely unregulated flow and sediments from Cottonwood Creek and several undammed tributaries draining Mount Lassen and the northern Sierra Nevada. Therefore, restoring and maintaining important ecological processes in Cottonwood Creek and other nonregulated tributaries is essential to maintaining the ecosystem health of the Sacramento River.

Cottonwood Creek is the most important watershed component in the upper river downstream of Shasta Reservoir and controls and supports the maintenance of ecological processes and functions in the upper Sacramento River. The Cottonwood Creek Ecological Zone is discussed separately, but its importance to the ecological health of the upper Sacramento River is emphasized here because it is the largest remaining undammed tributary with natural hydrologic conditions and sediment characteristics. In the winter 1986 flood, more than half the flow (and presumably gravel and sediment) in the Sacramento River originated in Cottonwood Creek, greater than the volume represented by all other north-valley streams combined.

Likewise, some fish species depend exclusively on the Sacramento River for migration, spawning, and nursery habitat, while some species that use other ecological zones for spawning use the Sacramento River as primary migration, nursery, and emigration habitat. Other important ecological zones dependent on the resources of the Sacramento River include the Sacramento-San Joaquin Delta Ecological Zone and the Suisun Marsh/San Francisco Bay Ecological Zone. These zones, in turn, provide essential foodweb prey species and critical rearing habitat for outmigrating anadromous fish that spawn in the Sacramento River and its major tributaries.

Additionally, stressors important to fish and wildlife species using the Sacramento River during at least part of their life cycle occur outside the identified ecological zones. For example, ocean recreational and commercial salmon fisheries remove a large portion of the potential spawning adults from the population each year. New harvest management strategies for the ocean fisheries will be needed to augment improvement to inland ecological processes and functions that maintain key habitats for salmon. Water quality of agricultural tailwater throughout the Colusa Basin that reenters the Sacramento River at Knights Landing or Prospect Slough (Yolo Bypass) affects the health and survival of juvenile fish and prey species in the river, depending on the temperature, toxicity level, dilution ratios, and contaminant concentrations and presence of loadings.

Implementation Objectives, Targets, and Programmatic Actions

Central Valley Streamflows

Implementation Objective

Restore basic features of the hydrograph to reactivate and maintain ecological processes and functions that create and maintain habitat required to sustain healthy fish, wildlife, and plant populations.

Target 1: More closely emulate the seasonal streamflow patterns in dry and normal year- types by allowing a late-winter or early-spring flow event of approximately 5,000-10,000 cfs in dry years and 15,000-20,000 cfs in below-normal and above-normal water-years to occur below Keswick Dam.

Programmatic Action 1a: Provide a flow event by supplementing normal operating flows from Shasta and Keswick Dams with releases from Lake Shasta (and Trinity Lake) in March during years when no flow event has occurred during winter or is expected to occur. Flow events would be provided only when sufficient inflow to Lake Shasta is available to sustain the prescribed releases. This action can be refined by evaluating its indirect costs and the overall effectiveness of achieving objectives.

Target 2: Maintain base flows of 6,000-8,000 cfs during fall.

Programmatic Action 2a: Provide flow releases from Shasta Lake and Keswick Dam when necessary to provide the target base flows. Releases would be made only when inflows equal or exceed prescribed releases.

RATIONALE: Increasing releases from Shasta Reservoir is the only means of maintaining base flows in the upper river. Late-winter or early-spring flow events of sufficient magnitude attract and sustain adult salmon, steelhead, sturgeon, and American shad; improve transport of juvenile fish downstream; sustain riparian habitat; and sustain gravel recruitment, transport, and cleansing processes. The target flows are consistent with historic and unimpaired flows for the Sacramento River in dry and normal years. These flows may not occur in some years under the present level of project development and operation. Implementing the target level of the flow event must necessarily be on a conservative basis because of the potential cost to water supply. If a flow event of equal or greater magnitude has not occurred between Keswick Dam and Red Bluff by March, then supplementing base flows or augmenting small natural releases or reservoir spills with additional reservoir releases is the only means to provide flow events. Such releases would be used only if there is an equivalent or greater inflow to Lake Shasta. March is the logical month to provide such flows because it is the month when "natural" flow events occurred historically in dry and below-normal years, and because opportunities for such flow to occur "naturally" as a function of normal project operation would have been exhausted by then. Water forecasts as to the water-year type (critically dry, dry, below normal, above normal, or wet) are available by February and March. The flow event in March would be expected to proceed unimpaired downstream to the Delta because few or no diversions from the Sacramento River occur during March. (Note that additional flow events are prescribed for the Feather River in March, which will further enhance Sacramento River flows below its confluence with the Feather River.) A March flow event could also help satisfy Delta outflow requirements.

Maintaining natural base flows will help promote natural channel forming, riparian vegetation, and foodweb functions. Base flows also serve to attract steelhead and fall-run and late-fall-run chinook salmon. Unimpaired base flows in fall are approximately 4,000 cfs and 6,000 cfs in dry years, and up to 8,000 cfs in wetter years. Natural base flows are prescribed only for fall because, under present project operation, flows in excess of 10,000 cfs are maintained in summer for irrigation and to lower water temperatures for winter-run salmon.

NATURAL SEDIMENT SUPPLY

IMPLEMENTATION OBJECTIVE

Establish an adequate sediment supply to riverine and estuarine systems to restore or reactivate stream channel meander and point bar formation, provide for sediments to rebuild wetlands and shallow water habitats, and provide for nutrient transport.

TARGET 1: Increase gravel recruitment in the upper Sacramento River between Keswick Dam and the RBDD by 10,000-20,000 cubic yards annually to provide adequate spawning habitat for targeted levels of salmon and steelhead and to sustain stream meander processes below Red Bluff. This is the estimated amount of spawning-sized gravel captured annually by Shasta Dam.

PROGRAMMATIC ACTION 1A: Develop a cooperative program to stockpile gravel at strategic locations along the Sacramento River below Keswick Dam where riverflow will move gravel into the river channel to mimic natural gravel recruitment into the upper river. Determine the adequacy of this action and adjust amount and locations as necessary.

PROGRAMMATIC ACTION 1B: Develop a cooperative program to reactivate gravel recruitment to the river by exposing existing sources of river gravel on islands, bars, and banks that have become armored to riverflows. This action should be implemented on a conservative basis because the availability of such inchannel gravel, costs of activating the gravel, indirect impacts, and potential effectiveness have not been determined.

RATIONALE: Replenishing gravel supplies to a level sufficient to support target populations of salmon and steelhead will help to improve populations to desirable levels and to maintain such levels once achieved. Replenishing gravels to maintain channel-forming processes and stream meanders in the upper Sacramento River will help to maintain fish and wildlife habitats, aquatic algae and invertebrate production, and streamside vegetation. A predevelopment level of gravel recruitment should be adequate to restore the natural ecological processes supported by gravel recruitment, but may require experimenting, monitoring, and experience to determine the exact amount of gravel supplies necessary to meet the objective.

STREAM MEANDER CORRIDOR

IMPLEMENTATION OBJECTIVE

Maintain, improve, or restore natural stream meander processes to allow the natural recruitment of sediments and creation of habitats, and promote natural riparian succession processes.

TARGET 1: Preserve and improve the existing stream meander belt in the Sacramento River between Red Bluff and Chico Landing by purchase in fee or through easements of 8,000-12,000 acres of riparian lands in the meander zone.

PROGRAMMATIC ACTION 1A: Remove riprap from banks to the extent possible consistent with flood control requirements and reduce effects of other structures, such as bridges, that inhibit meander process.

PROGRAMMATIC ACTION 1B: Purchase easements to offset losses to property owners for land lost to meander process.

RATIONALE: Preserving and improving the stream meander belt below Red Bluff will ensure that this important natural process is maintained in the Sacramento River. This reach is important for spawning and rearing salmon and steelhead. A natural meander process will provide near-optimal habitat for spawning (through gravel recruitment), rearing (channel configuration, cover, and foodweb), and migration. There is limited potential natural channel above Red Bluff. Below Chico Landing, flood control levees limit the potential of restoring the natural meander of that reach.

NATURAL FLOODPLAIN AND FLOOD PROCESSES

IMPLEMENTATION OBJECTIVE

Modify channel and basin configurations to improve floodplain functions along rivers and streams in the Sacramento-San Joaquin River basin.

TARGET 1: Increase and maintain floodplains in conjunction with stream meander corridor restoration.

PROGRAMMATIC ACTION 1A: Develop a cooperative program, consistent with flood control requirements, to evaluate the feasibility of altering river channel configurations in leveed reaches of the Sacramento River to increase the areal extent of floodplains inundated during high-flow periods.

RATIONALE: *Floodplain inundation is a secondary ecosystem process related to water and sediment flow through the Sacramento-San Joaquin River basin in combination with geomorphology. Floodplain inundation is the* *seasonal flooding of floodplain habitats, including riparian and riverine aquatic. Flooding of these lands provides important seasonal habitat for fish and wildlife and provides sediment and nutrients to both the flooded lands and aquatic habitats that receive the returning or abating floodwater. The flooding also shapes the plant and animal communities in the riparian, wetland, and upland areas subject to flooding. Opportunities to restore or enhance this process are possible by changing landscape features, geomorphology, and seasonal distribution of flow volume through the system.*

CENTRAL VALLEY STREAM TEMPERATURES

IMPLEMENTATION OBJECTIVE

Maintain, improve, and restore water temperature regimes to meet life-history needs of aquatic organisms.

TARGET 1: Maintain mean daily water temperatures at levels suitable for maintenance of all life-history stages of chinook salmon and steelhead in the Sacramento River between Keswick Dam and RBDD.

PROGRAMMATIC ACTION 1A: Cooperatively develop and implement a balanced river regulation program that provides sufficient carryover storage at Shasta Dam to ensure that suitably low water temperatures are reached to protect chinook salmon spawning, incubating eggs, and young fish.

RATIONALE: *The temperature objective for the upper Sacramento River is less than or equal to 56°F from Keswick Dam to RBDD for operation of CVP in the State Water Resources Control Board's (SWRCB's) Order 90-5. However, these criteria cannot be met on a consistent basis, and other structural facilities and operation measures are needed. These facilities and operational measures must be developed and implemented to enable the long-term attainment of the SWRCB-required temperature criteria.*

A temperature control or "shutter device" has been designed to permit the selective withdrawal of water from Shasta Reservoir over a wide range of depths and temperatures. With this device, warm water could be withdrawn from the upper lake levels when needed, while conserving the deeper, cold water for release when it would most benefit chinook salmon. Presently, water can be selectively withdrawn from Shasta Reservoir to some extent for temperature control, but these withdrawals require the bypass of power turbines, resulting in major losses in electrical power revenues and power generation. Operating the temperature control device would allow Reclamation greater effectiveness and flexibility in temperature control operations while maintaining hydroelectric power generation. The temperature control device would also provide a secondary benefit to anadromous fish by controlling turbidity. After the temperature control device is installed and operational, operations and carryover storage requirements must be reassessed and new criteria established to optimize attainment of water temperature objectives.

RIPARIAN AND RIVERINE AQUATIC HABITATS

IMPLEMENTATION OBJECTIVE

Restore riparian scrub, woodland, and forest habitat along largely unvegetated riprapped banks of Delta island levees, along the Sacramento and San Joaquin Rivers, and along major tributaries of the Sacramento and San Joaquin Rivers to create corridors of riparian vegetation that provide SRA cover for anadromous and other fish species and to create high-quality habitat for associated special-status plant and animal species, and other associated wildlife.

TARGET 1: Provide conditions for growth of riparian vegetation along channelized portions of the Sacramento River.

PROGRAMMATIC ACTION 1A: Develop a cooperative program to plant vegetation on unvegetated, riprapped banks consistent with flood control requirements. Because the technical feasibility and cost-effectiveness of such actions will need to be determined, pilot projects will be conducted. Further implementation will be subject to adaptive management and will depend on results of these experiments.

PROGRAMMATIC ACTION 1B: Setback levees may be constructed on leveed reaches of the river to provide a wider floodplain and greater development of SRA habitat. Because of the potential indirect impacts on land use and uncertainty of cost and technical feasibility of setback levees, such development will be experimental and conservative, and will depend on adaptive management.

TARGET 2: Increase the ecological value of low- to moderate-quality SRA habitat by changing land use and land management practices.

PROGRAMMATIC ACTION 2A: Purchase property or easements and allow habitat to improve naturally. Properties to be considered should be developed through a process of prioritizing based on quality and importance of habitat, technical feasibility and cost of purchase and improvement, and consensus of stakeholders.

PROGRAMMATIC ACTION 2B: Provide incentives and technical support for private landowners to protect and improve existing SRA habitat.

TARGET 3: Maintain existing streamside riparian vegetation.

PROGRAMMATIC ACTION 3A: Through purchase, conservation easement, and voluntary participation of landowners, protect SRA habitat from development. Where high-priority properties are already in government ownership or available for purchase or easement, preservation efforts should be undertaken as experiments to develop technical details, cost-effectiveness, and overall approach and consensus for the program. Full implementation of this program would depend on results of experiments and subject to adaptive management.

RATIONALE: *Riprapped banks in the leveed section of the river below Chico Landing downstream to Sacramento are the greatest cause of SRA fragmentation. Restoring vegetation will benefit juvenile salmon rearing by providing cover and food, spawning substrate for other fish such as Sacramento splittail, and refuge for juvenile fish during periods of high water. Improving low- to moderate-quality SRA habitat will benefit juvenile salmon and steelhead by providing improved shade, cover, and food. Wildlife will also benefit from improved habitat. Protecting and improving existing SRA habitat may involve changes in land use. Limited available funds may require that priorities be set, with high-priority, low-cost sites developed initially. For sites where consensus exists, immediate action can be taken on an experimental basis. Because of the importance and limited distribution and abundance of SRA habitat, all existing quality habitat should be protected.*

WATER DIVERSION

IMPLEMENTATION OBJECTIVE

Reduce entrainment of juvenile fish into water diversions by screening or consolidating diversions or by altering diversion timing to increase survival and cohort replacement levels.

TARGET 1: Reduce entrainment of juvenile salmon and steelhead into water diversions to levels that will not impair stock rebuilding.

Emphasis should be on the upper river from Keswick Dam downstream to Chico Landing.

PROGRAMMATIC ACTION 1A: Develop a cooperative program to screen all diversions greater than 250 cfs and one- to two-thirds of all smaller unscreened diversions. This programmatic level of action should be sufficient to provide the data necessary to modify this target through adaptive management. Determining which diversions need to be screened will be based on appropriate monitoring and evaluation, with decisions made with agency and stakeholder involvement, and with consideration given to appropriate alternatives. Actions will be taken on a case-by-case basis with consideration given to results of pilot experiments to determine technical feasibility and cost-effectiveness of screening diversions of different size, type, and location. Priority will be given to screening diversions that pose the most threat and where screening has been determined to be cost effective.

PROGRAMMATIC ACTION 1B: Develop a cooperative program to upgrade screening at diversions with ineffective screening. Where existing screening has proven less than effective and entrainment problems continue, immediate action should be taken to upgrade screens.

PROGRAMMATIC ACTION 1C: Develop a cooperative program to reduce diversions when and where juvenile salmon are present in large or significant numbers. Even with screens, some diversions may pose a threat to young salmon and steelhead, and it may be necessary to modify operations of the diversion. Such determinations will be made after necessary monitoring and evaluation, and on a case-by-case basis, with decisions made with agency and stakeholder involvement, and with consideration given to appropriate alternatives.

TARGET 2: Reduce blockage to fish migrations at the ACID dam and RBDD.

PROGRAMMATIC ACTION 2A: Upgrade fish passage facilities at the ACID dam and RBDD.

RATIONALE: *Juvenile chinook salmon, steelhead, green sturgeon, white sturgeon, Sacramento splittail, and American shad are lost at water diversion sites all along the Sacramento River during the spring-to-fall irrigation season. (Note that diversion losses include direct loss into unscreened diversions and other losses associated with the screened and unscreened intake facilities such as from predators, including squawfish and striped bass.) Reducing entrainment losses to minimal levels is a reasonable target for the short term, given the existing poor health of many of the fish populations that use the Sacramento River and its tributaries for spawning and rearing of young. Emphasis should be on the upper river above Chico Landing because this is the reach where winter-run chinook young rearing coincides with the spring-to-fall irrigation season.*

LEVEES, BRIDGES, AND BANK PROTECTION

IMPLEMENTATION OBJECTIVE

Reestablish or reactivate geomorphological processes in artificially confined channel reaches to maintain hydrologic connectivity with natural floodplains.

TARGET 1: Construct setback levees along leveed reaches of the river as part of the stream meander corridor.

PROGRAMMATIC ACTION 1A: Develop a cooperative program, consistent with flood control requirement, to evaluate potential sites for establishing setback levees along leveed reaches of the Sacramento River.

RATIONALE: *Levees, bridges, and bank protection structures inhibit overland flow and erosion and depositional processes that develop* *and maintain floodplains, and allow stream channels to meander. Levees prevent floodflows from entering historic floodplains behind levees, stopping evolution of floodplain habitats dependent on overbank flows. Confining floodflows to channels with levees and bank protection structures also increases the fluvial energy of flows that scour or incise channel beds and reduces or halts the rate of channel migration and oxbow formation.*

PREDATION AND COMPETITION

IMPLEMENTATION OBJECTIVE

Reduce the loss of juvenile anadromous and resident fish and other aquatic organisms resulting from predation to maintain sustainable populations.

TARGET 1: Reduce the adverse effects of predatory fish by identifying and eliminating humanmade instream structures or operational conditions that allow unnatural rates of predation.

PROGRAMMATIC ACTION 1A: Selectively evaluate areas and make physical changes to structures in the Sacramento River, such as bridge abutments, diversion dams, and water intakes, that currently may attract predators and provide them with additional advantages in preying on juvenile salmon and steelhead. Pilot studies and evaluations are needed to determine the types of changes required and the potential degree of implementation.

RATIONALE: Upgrading fish passage facilities at the two diversion dams will reduce delays to upstream migrating winter-run chinook salmon and hindrance of downstream migrating juvenile winter-run chinook salmon.

During operation of RBDD, juvenile chinook are adversely affected while approaching the dam, passing the dam, and moving downstream of the dam. As juveniles migrate toward the dam, they experience increased predation in Lake Red Bluff from predatory fish and birds. Juveniles passing under the lowered dam gates become disoriented because of high water velocities and turbulence, and are subject to heavy predation downstream by squawfish and striped bass. Juveniles bypassed around the dam through the Tehama-Colusa fish bypass system may have improved survival because of new facilities and positive-barrier fish screens, but complete evaluations are needed.

To help protect winter-run chinook, the dam gates have been raised for varying durations since the end of 1986. At present, the dam gates are in the raised position from September 15 through May 14, allowing free passage to about 85% of the spawning run (based on average run timing from 1982-1986). This may have reduced the number of redds being built below the dam. The remaining portion of the run migrating upstream after May 15 is likely to be delayed or blocked from passing the dam.

Adults that are obstructed from passing the dam are forced to spawn downstream where temperature conditions are typically unsuitable during the spawning and incubation period. Temperatures of 56°F usually cannot be maintained below RBDD without severely depleting Shasta carryover storage during the winter-run chinook incubation period; eggs and larvae usually have 100% mortality.

Adults that must make repeated attempts to pass the dam but eventually are successful undergo physiological stress that may contribute to their reduced fecundity. Because migration of these adults is delayed, the fish are likely to spawn farther downstream where suitable temperatures for spawning and incubation may not be attainable.

Juvenile chinook suffer mortality in passing the dam from squawfish predation and disorientation or injury when passing beneath the dam gates or through the fish bypass system. Under the present *schedule of gate operations, about 26% of the juvenile outmigrants must pass the dam when the gates are lowered and are susceptible to mortality associated with that passage. In a 1988 study, juvenile hatchery salmon were released above and below the dam to estimate total mortality during dam passage. In all, 16-55% fewer fish were recaptured from the releases made above dam than those made below. USFWS determined predation, primarily by squawfish, as the major cause of mortality to juvenile salmon migrating past the dam, whereas death from physical injury received while passing under the dam was minor.*

Adult chinook salmon must negotiate fish ladders at the ACID dam during the irrigation season (typically April through November) to reach upstream spawning habitat. However, an antiquated ladder on the east abutment of the dam is ineffective in providing safe passage, and a recently installed denil ladder on the west abutment has proved only marginally successful. The ladders at this facility do not provide suitable flows to attract adults, and the ladders are not easily adjustable to compensate for varying flow conditions. A feasibility study is being conducted by the ACID to identify, develop, and evaluate alternatives to resolve adult passage problems.

CONTAMINANTS

IMPLEMENTATION OBJECTIVE

Reduce concentrations and loadings of contaminants in the aquatic environment and the subsequent bioaccumulation by aquatic species to increase survival and eliminate public health concerns.

TARGET 1: Reduce losses of fish and wildlife resulting from pesticide, hydrocarbon, heavy metal, and other pollutants in the Sacramento River.

PROGRAMMATIC ACTION 1A: Develop a cooperative program to remedy heavy metal pollution from IMM to meet basin plan standards and implement reliable and proven remedies that ensure continued treatment and control of heavy metal waste before water is discharged to the Sacramento River.

PROGRAMMATIC ACTION 1B: Develop a cooperative program to eliminate scouring of toxic metal-laden sediments in the Spring Creek and Keswick Reservoirs.

PROGRAMMATIC ACTION 1C: Control contaminant input to the Sacramento River system by constructing and operating stormwater treatment facilities and implementing industrial best management practices (BMPs) for stormwater and erosion control.

PROGRAMMATIC ACTION 1D: Develop a cooperative program to assess and monitor contaminant input from agricultural drainages in the Sacramento River watershed.

RATIONALE: The drainage from inactive mines on IMM represents the largest source of pollutant discharge to the Sacramento River. This discharge is at least equal to all the combined industrial and municipal discharges of metal to the San Francisco Bay and estuary system. This mine water is among the most acidic in the world and contains extremely elevated concentrations of copper, zinc, cadmium, and other metals known to be toxic to fish and wildlife. On occasion, fish deaths (including salmon) have been documented in the upper Sacramento River as a result of IMM waste. More frequently, there are documented instances of metal concentrations that exceed toxic levels considered safe for early life stages of salmon.

The wastes from IMM, located in the Spring Creek watershed, are collected in the Spring Creek Reservoir and metered out into the releases of clean water from Shasta and Whiskeytown Reservoirs to achieve the best water quality *possible. However, because of the extremely large waste load (averaging more than 1 ton of copper and zinc per day), it has not always been possible to consistently attain the water quality objectives for copper, cadmium, and zinc in the basin plan, and interim criteria have been established until pollution control is completed. Highly toxic conditions are exacerbated when heavy winter rains induce uncontrolled spills from Spring Creek Reservoir, and flows from Shasta and Whiskeytown Reservoirs are not made available for dilution because of other CVP constraints.*

Within the lower portion of the IMM site, remediation must be developed for the metal sludge deposits in Spring Creek Reservoir and in Keswick Reservoir adjacent and downstream of the Spring Creek power plant tailrace. Preliminary monitoring in the Keswick Reservoir has documented that the sludge is highly toxic and that the deposits are extensive and up to 15 feet thick. Under certain conditions, flows from the Spring Creek power plant can mobilize large quantities of the sludge into the river, creating an acute toxicity risk to aquatic species. The sludge deposits can also contribute to chronic toxicity when combined with other sources.

Major sources of pollution include industries, municipalities, and agriculture, which discharge such contaminants such as herbicides, pesticides, organic compounds, inorganic compounds, and warm water. Pollution is described as originating from point sources, such as discharge pipes or other localized sources, or from nonpoint sources, which are dispersed and largely uncontrollable. Individual sources of nonpoint pollution may be insignificant, but the cumulative effects can be significant and can contribute high levels of pathogens, suspended solids, and toxins. Major contributors of nonpoint-source pollution to the Sacramento River, Sacramento-San Joaquin Delta, and San Francisco Bay include sediment discharge, stormwater and erosion, and agricultural drainage.

A primary point source of pollution is from municipal treatment plants, which release heavy metal contaminants, thermal pollution, pathogens, suspended solids, and other constituents. Implementing enhanced treatment, pretreatment programs, and tertiary treatment should help to reduce contaminant input.

Sediments constitute nearly half of the materials introduced into rivers from nonpoint sources, such as plowed fields, construction and logging sites, and mined land, and are mainly generated during storm events. Stormwater runoff in urban and developing areas is another major source of sediments and contaminants. Sedimentation from nonpoint sources should be reduced by implementing BMPs for urban and nonurban pollution, and implementing appropriate treatment and technological options that reduce pollutant loads.

An assessment of water quality and impacts from various other agricultural drainages to the Sacramento River is needed. Based on results from these evaluation programs, recommendations for corrective actions should be developed and implemented. Top priority should be given to the Sutter Bypass, which receives drainwater from rice growing areas and has outflows on par with those from the Colusa Basin drain. Assessments should also be conducted on Butte Slough, Reclamation District 108, and Jack Slough.

HARVEST OF FISH AND WILDLIFE

IMPLEMENTATION OBJECTIVE

Reduce the level or incidence of harvest of wild, naturally produced Bay-Delta fish populations and focus harvest on hatchery produced fish to protect and increase the productive potential of wild fish populations.

TARGET 1: Reduce illegal harvest of fish species to a minimum to maintain or increase populations by increasing enforcement efforts by 50-100%.

PROGRAMMATIC ACTION 1A: Increase enforcement efforts.

PROGRAMMATIC ACTION 1B: Develop a cooperative program to educate the public on the threats to populations from illegal harvest. Various actions include ad campaigns, signs along streams, and various types of outreach programs to schools and groups.

PROGRAMMATIC ACTION 1C: Provide additional funding for the poaching hotline and rewards for arrest and convictions of poachers.

TARGET 2: Manage the legal harvest of chinook salmon, steelhead, and sturgeon by shifting harvest from natural stocks to hatchery-reared stocks where possible or reducing harvest of wild stocks until the naturally produced populations recover.

PROGRAMMATIC ACTION 2A: Develop a cooperative program to mark all hatchery salmon and steelhead, allowing selective harvest of hatchery fish while limiting harvest of wild fish. This action should be implemented on a short-term and experimental basis to ensure that it meets its objective and is cost effective.

PROGRAMMATIC ACTION 2B: Encourage regulatory agencies to change fishing regulations (i.e., by restricting seasons, limits, and gear and reducing harvest of wild fish) to further reduce legal harvest and any ancillary effects of fishing gear or techniques. Restrictions should be severe in the short term. Long-term restrictions would depend on response of populations and effectiveness of restrictions and the degree of effectiveness of the action.

RATIONALE: *Some populations of salmon and steelhead in the Sacramento River are at such depressed levels that drastic reductions in any factors that contribute to mortality are necessary. Illegal harvest is known to occur along the Sacramento River. This target will be subject to adaptive management.*

ARTIFICIAL PROPAGATION OF FISH

IMPLEMENTATION OBJECTIVE

Protect and restore the genetic diversity of naturally producing populations of salmon and steelhead in the Sacramento River to sustain long-term viability of the populations.

TARGET 1: Minimize the likelihood that hatchery-reared salmon and steelhead in the upper Sacramento River will stray into non-natal streams to protect naturally produced salmon and steelhead.

PROGRAMMATIC ACTION 1A: Develop a cooperative program to evaluate the benefits of limiting stocking of hatchery-reared salmon and steelhead in the upper Sacramento River. Stocking may be reduced in years when natural production is high in selected populations.

TARGET 2: Limit hatchery stocking to populations that cannot be sustained through natural production.

PROGRAMMATIC ACTION 2A: Augment winter-run, spring-run, and late-fall-run chinook salmon and steelhead with hatchery-produced smolts during the short-term rebuilding phase of restoration efforts and only when alternative measures are deemed insufficient to provide recovery of the populations. Stocking of hatchery-reared fish will be undertaken as experiments and adjusted or terminated as necessary depending on results.

TARGET 3: Employ methods to limit straying and loss of genetic integrity of wild and hatchery supported stocks.

PROGRAMMATIC ACTION 3A: Rear salmon and steelhead in hatcheries on natal streams to limit straying. If hatchery augmentation of Sacramento River populations of salmon and steelhead is necessary, then hatcheries should be built on the Sacramento River for that purpose.

PROGRAMMATIC ACTION 3B: Limit stocking of salmon and steelhead fry and smolts to natal watersheds to minimize straying that may compromise the genetic integrity of naturally producing populations.

TARGET 4: Minimize further threats of hatchery fish contaminating wild stocks of salmon and steelhead.

PROGRAMMATIC ACTION 4A: Where hatchery production is underway and continues, methods should be adopted and improved for the selection of an appropriate cross section of the adult population for spawning at the hatchery.

PROGRAMMATIC ACTION 4B: Select spawning adults of appropriate genetic makeup to minimize genetic contamination of existing hatchery and naturally producing stocks of salmon and steelhead. Given the present difficulty of determining genetic makeup of spawning adults selected for hatcheries, this action will necessarily be experimental. Hatchery-reared adults may be preferentially selected or not selected if they are adequately marked or tagged, or have other identifiable feature. Other methods may be developed to genetically categorize naturally produced or hatchery fish.

RATIONALE: *In watersheds such as the Sacramento River where dams and habitat degradation have limited natural spawning, some hatchery supplementation may be necessary to sustain fishery harvest at former levels and to maintain a wild or natural spawning population during adverse conditions such as droughts. However, hatchery augmentation should be limited in extent and to levels that do not inhibit recovery and maintenance of wild populations. Hatchery-reared salmon and steelhead may directly compete with and prey on wild salmon and steelhead. Straying of adult hatchery fish into non-natal watersheds may also threaten the genetics of wild stocks. Hatchery fish may also threaten the genetic makeup of stocks in natal rivers. Some general scientific information and theory from studies of other river systems indicate that hatchery supplementation may limit recovery and long-term maintenance of naturally producing populations of salmon and steelhead. Further research and experimentation are necessary to determine the degree to which this issue is addressed. Long-term hatchery augmentation of healthy wild stocks may genetically undermine that stock and threaten the genetic integrity of other stocks. Augmenting production of fall-run chinook salmon, the only healthy population in the upper Sacramento River, may be necessary despite its healthy state, because spawning and rearing habitat are limited and because adverse conditions may occur in drought or flood years that would undermine the population without additional hatchery production.*

Adults straying into non-natal streams may result in their interbreeding with a wild population specifically adapted to that watershed, possibly leading to the loss of genetic integrity in the wild population. Release of hatchery-reared fish into the upper Sacramento River and its tributaries could lead to a loss in the genetic integrity of wild salmon and steelhead populations. Although some irreversible contamination has occurred in salmon and steelhead populations, measures are necessary to minimize further deterioration of contaminated populations and to protect populations that are not contaminated.

Some stocking of hatchery-reared fish may be necessary in the short term to rebuild naturally spawning populations; however, there is a lack of consensus among agencies and stakeholders as to *the degree of stocking that is detrimental or necessary to sustain sport and commercial fisheries. This action will necessarily be conducted on a short-term and experimental basis with subsequent efforts dependent on results and effectiveness.*