STATE WATER RESOURCES CONTROL BOARD
SAN FRANCISCO BAY/SACRAMENTO SAN JOAQUIN DELTA ESTUARY

MAY 16, 1994 WORKSHOP

COMMENTS OF EAST BAY MUNICIPAL UTILITY DISTRICT

East Bay Municipal Utility District ("EBMUD") offers these comments on the subjects listed for discussion in the State Water Resources Control Board Notice of Public Workshop issued April 15, 1994. These comments are based on information collected and research conducted by EBMUD as part of the extensive investigations sponsored by the District in connection with developing a fisheries management plan for the lower Mokelumne River. EBMUD's Lower Mokelumne River Management Plan ("LMRMP") was introduced into evidence during the State Board's 1992 Mokelumne River Hearing.[1]

Subject No. 1: **Endangered Species Act Issues**

Actions which may be proposed to protect a single listed species may be in conflict with what is needed for the protection of other species. For example, changes in operation of the Delta Cross-channel intended to protect the winter-run Chinook salmon could have a detrimental effect on anadromous stocks in the

[1] EBMUD Exhibit No. 32, Mokelumne River Hearing before the State Water Resources Control Board, November 1992.

Mokelumne River and the Central Delta. All actions related to protection of listed species must be evaluated in the broad context of overall impacts, costs and benefits. This will require balancing the needs of listed species and other important stocks, as well as water requirements for other beneficial uses.

A comprehensive and systematic approach is therefore needed to evaluate the full spectrum of fisheries needs, and their relationship to other beneficial uses. Providing water to meet Delta standards and salmon smolt out-migration criteria for a single river system may adversely affect water supplies needed to facilitate in-migration, spawning, rearing and out-migration of salmon fry and smolts on other river systems. For example, operations on the Mokelumne River under the District's LMRMP, which are designed to protect and enhance habitat conditions for various life stages of Mokelumne River salmon, may be jeopardized by operational requirements imposed for meeting Delta standards.

Subject No. 2: **Effects of Bay-Delta diversions on beneficial uses, including diversions other than the Central Valley Project (CVP) and the State Water Project (SWP).**

The District's LMRMP was developed for the purpose of protecting and enhancing anadromous fish in the Mokelumne River, in balance with other beneficial uses. The plan takes into consideration and accounts for existing conditions in the Delta which impact survival of Mokelumne River salmon. Present Delta conditions are seriously adverse to salmon survival. Any further degradation of conditions in the Central Delta will impair EBMUD's potential for success in restoring a Mokelumne River salmon run because of the serious impacts on salmon migrating to and from the Mokelumne River system. Further deterioration of Delta conditions will also impact other anadromous fish stocks passing through the Central Delta from other tributaries.

Based on an assessment of Delta conditions, as they impact and relate to development of a fisheries management plan for the lower Mokelumne River, EBMUD found that losses occurring to Mokelumne origin salmon migrating through the Delta are of major consequence. In general, the percentage of smolts that survive passage through the Central Delta ranges from 37 to 0, averaging 15 percent. In other words, Delta mortality averages 85% (Kjelson, Greene and Brandes 1989). Sixty-six percent of the variation in survival is related to temperature in conjunction with water exported by the Central Valley Project ("CVP") and State Water Project ("SWP"). During the peak of Mokelumne River smolt out-migration, from late May through June, survival is minimal because of temperature, reverse flows, increased predation, and other factors. Mortality is exacerbated in dry years because of reverse flows and increases in SWP and CVP diversions.

Diversions by the CVP and SWP are of sufficient magnitude to alter flow patterns within Delta channels, channels through which Mokelumne origin salmon must migrate en route to and from the ocean. These changes in flow can contribute to a redirection of young salmon into south Delta channels, thereby causing delay in out-migration and increases their susceptibility to predation and entrainment losses at the CVP and SWP facilities.

This redirection and delay can also increase the number of salmon potentially impacted by the large number of agricultural and industrial diversions and drains. There are hundreds of such diversion facilities within the Delta, many of which have no screening facilities to safeguard against entrainment.

Project impacts on Delta flow patterns can also influence upstream migration of salmon to the Mokelumne River. Changes in hydrologic and olfactory cues and the movement of large volumes of water from the Sacramento River across the Delta may contribute to delays in upstream migration and increased straying of adults from one tributary to another.

The impacts of Delta hydrology on Mokelumne River salmon were described in detail in evidence submitted by EBMUD in the Mokelumne River Hearings. For the State Board's convenience, those portions of EBMUD Exhibit 27 and EBMUD Exhibit 32 which describe the impacts of Delta conditions on Mokelumne River salmon are included herewith as Attachments 1 and 2.

One of the consequences of adverse fishery impacts associated with operation of the CVP and SWP pumps and the Delta Cross-channel is that salmon smolts are trucked around the Delta to reduce mortalities, instead of migrating naturally through the Delta from their streams of origin. For example, this year the Department of Fish and Game has notified EBMUD that approximately 650,000 Mokelumne River origin salmon smolts will be transported from the Mokelumne River Fish Hatchery to a release location near Antioch in order to avoid high mortalities associated with Delta conditions.

EBMUD is concerned that these Mokelumne River origin salmon smolts, if trucked from the hatchery to Antioch, will not be properly imprinted to the Mokelumne River and, upon their return migration, will stray to other river systems. Consequently, adverse conditions expected to result this year from project operations within the Delta, which necessitate trucking salmon that have not been imprinted to the Mokelumne River, are likely to substantially decrease the number of salmon that will return to the Mokelumne River. This is a significant impediment to EBMUD's ongoing efforts to rebuild the Mokelumne River salmon run as part of its Mokelumne River management plan.

It should be noted that the smolt survival standards suggested by the U.S. Environmental Protection Agency (Fed. Reg. Vol. 59, No. 4), such as the Sacramento River Salmon Index, are not applicable to Mokelumne River fish. Likewise, the San Joaquin River Salmon Index does not have a temperature factor or represent Mokelumne River fish. In essence, Mokelumne River fish are not being considered in the standards, even though EBMUD and others are continuing to make a considerable effort to maintain this run.

Substantial detriment can result to Mokelumne River fisheries if meeting proposed Delta objectives jeopardizes spawning and rearing conditions on the Mokelumne River, or depletes carryover storage needed to maintain flow in dry years. Additional detriment can result if high Mokelumne River flow requirements are imposed to meet Delta objectives before the normal out-migration periods in April and May. High flows too early in the season can force young salmon into the Delta before they are physiological ready and less able to withstand the stress of Delta conditions. The trade-offs between meeting proposed Delta objectives and potential adverse impacts to upstream fisheries must be comprehensively evaluated.

Using water year type indices based on current year runoff to determine requirements for Bay-Delta standards increases the risk of adverse impacts because they do not account for the necessity of providing carryover storage in the event of multiple dry years. Proper management of storage is critical to maintaining water quality conditions downstream of many reservoirs in the Sacramento Valley and adjacent foothills. Any plan to improve Delta water quality at the expense of water quality in and below reservoirs on tributaries must include consideration of the resulting adverse impacts to fisheries in those river systems, as well as impacts on water supply for other beneficial uses.

Subject No. 3: **Methods Available to Analyze Water Supply and Environmental Effects of Alternative Standards**

EBMUDSIM

In analyzing water supply and environmental effects of draft water quality standards, the State Board is urged to take into account the results of model studies performed by the East Bay Municipal Utility District's Operations Simulation Model (EBMUDSIM). EBMUDSIM is a valuable planning tool for assessing impacts of alternative operation proposals on the Mokelumne River system.

EBMUDSIM is a water balance model which operates on a monthly time step. It provides information which is similar to the types of information obtained from the Department of Water Resource's DWRSIM model. However, since the District's model focuses on simulating Mokelumne River operations, EBMUDSIM provides a more accurate assessment of impacts to the Mokelumne River.

EBMUDSIM models the Mokelumne River system, the Mokelumne Aqueducts, and EBMUD's terminal reservoirs. The model is used to simulate the operation of the District's water supply system and estimate the yield of its water entitlement, consistent with the constraints within which the District must operate. EBMUDSIM also accounts for water use by upstream users (Amador and Calaveras Counties) above Pardee Reservoir, and releases to meet water requirements below Camanche Reservoir. EBMUD's customer demands are met through Mokelumne Aqueduct drafts and by operation of the East Bay terminal reservoirs. The input assumptions used by the model and the output (results) produced by the model are illustrated in Figure 1. By changing input assumptions, the model can compare the effects of proposed operational alternatives.

EBMUDSIM allows the District to assess impacts associated with alternative instream flow standards or release requirements on the Mokelumne River system. As the State Board balances competing beneficial uses, accurate information on the impacts of proposed Bay-Delta standards and implementation measures on tributaries in the Delta watershed is essential. EBMUDSIM provides an important tool for assessing these impacts on the Mokelumne River.

The District and the State Board have used EBMUDSIM in previous proceedings. During the Mokelumne River Proceeding (November 1992), the District submitted study results assessing impacts of alternative instream flow proposals (EBMUD Exhibit 34).

Other Models

In assessing environmental effects of proposed Bay-Delta standards, several biological models are available. For example, the chinook salmon population (CPOP) family of models can assist the State Board in predicting the response of the salmon population to changes in the amount, location, and timing of water allocations. Trade-offs between spawning, rearing and out-migration flows can be evaluated, as well as multi-stock management and integration between river basins.

Non-flow factors such as impacts of hatchery operations, harvesting, Delta facilities operations and improved screening can also be evaluated. These models, which have been extensively peer reviewed, were developed for the California Department of Fish and Game and the National Marine Fisheries Service.

Specifically, within the CPOP family of models, the Fall-run Chinook Salmon Population Model (CPOP-3) has been developed for the Sacramento River. A similar model for winter-run chinook salmon (CPOP-W) is also available. These models operate on a daily time step and can comprehensively and systematically evaluate the effects of water management on salmon populations. By linking these models and adding a San Joaquin model, a comprehensive analysis can be completed. In addition, these models evaluate the use of water across the life stages of salmon at various locations in the Bay-Delta and its watershed and also considers the impacts of harvesting and hatchery management.

Integration of Models

In developing a balanced approach to the analysis of water supply and environmental effects on the Mokelumne River, EBMUD integrated both water supply and biological models in its Lower Mokelumne River Management Plan

(LMRMP). The following models were incorporated and integrated in the District's development of the LMRMP:

- Water supply and Hydrology models (EBMUDSIM - EBMUD Operations Simulation Model)
- Reservoir Water Quality models (WQRRS - Water Quality for River Reservoir Systems)
- River Water Temperature Models (SNTEMP - Stream Network Temperature)
- Fish habitat models (IFIM - Instream Flow Incremental Methodology)
- Models Integrating results from other biological models (SCIES - Stream Corridor Inventory Evaluation System)
- Life Cycle Population Model for salmon.

The District evaluated several water management alternatives using these modeling tools. A preferred management alternative was developed that maintains reservoir and river water quality as well as suitable conditions for salmon in-migration, spawning, rearing and smolt out-migration. The LMRMP also incorporated the impacts of hatchery management. All of these factors were balanced with other beneficial uses. Alternatives were evaluated in terms of habitat scores (Weighted Usable Area and temperature) as a percentage of optimum for all life stages, including spawning, fry, juvenile for chinook salmon and steelhead trout. Out-migration mortality and attraction flows were considered and escapement, harvest, and juvenile production were also evaluated. In developing the LMRMP, the

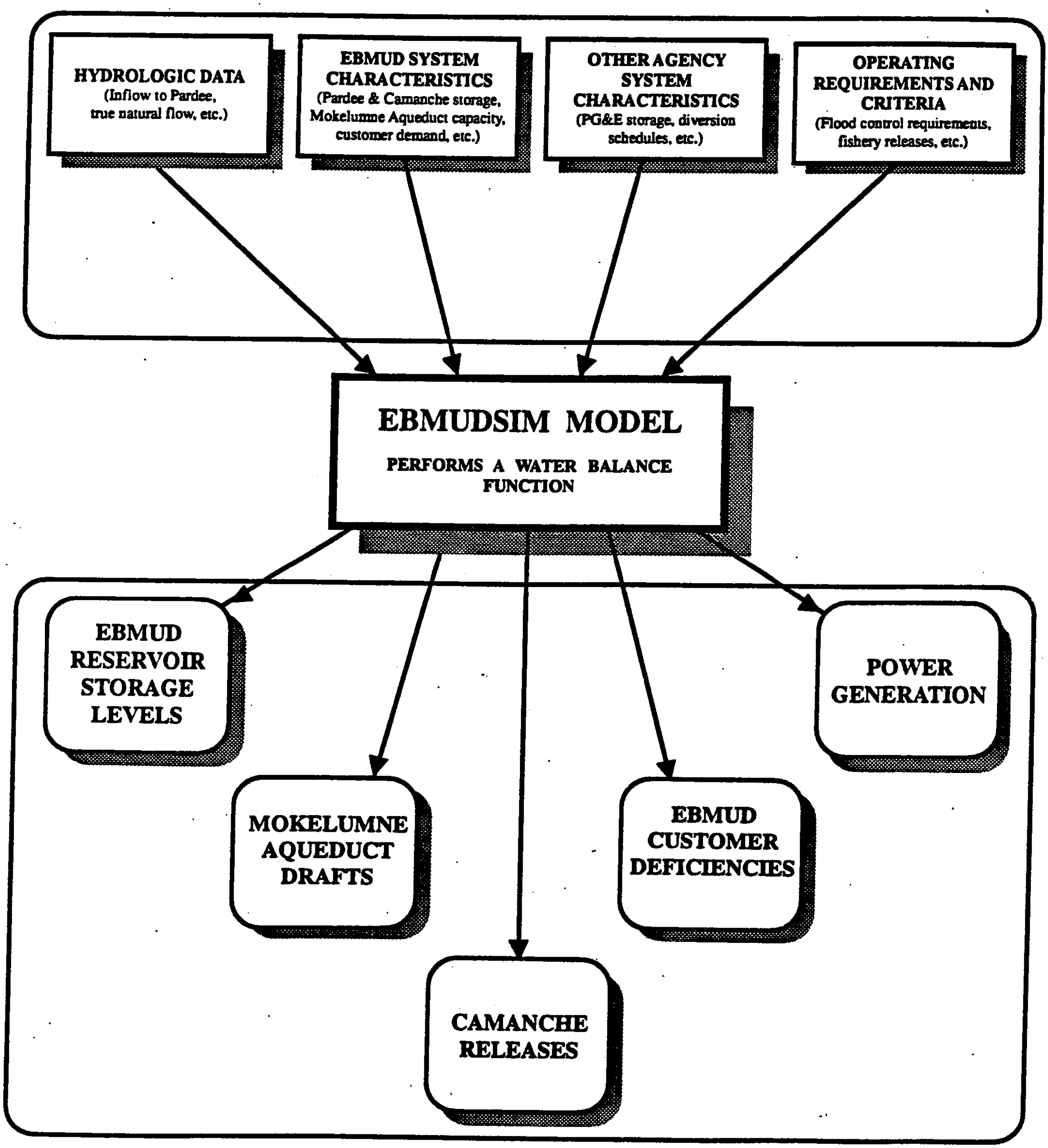
District also evaluated the effects of water supply and cost. As a result of these analyses, a near optimal allocation of water was derived.

The SCIES analysis in the LMRMP is particularly useful since it is readily transferable to other data sets and complicated trade-off analyses.

The models and analytical tools applied in development of the LMRMP are available to evaluate the effects of the proposed Bay-Delta standards on Mokelumne River fish and water supply.

Similar models are available for other watersheds, but they have not been integrated. For example, IFIM and temperature models have been completed for many tributaries of the Sacramento and San Joaquin Rivers. However, these models need to be integrated in order to facilitate a comprehensive and systematic analysis of the impacts of Bay-Delta standards.

Figure 1
EBMUDSIM
Inputs and Outputs



Source: EBMUD

Attachment 1

Excerpts from EBMUD Exhibit No. 27

Submitted in the Mokelumne River Hearing

Before the State Water Resources Control Board

November 1992

Mokelumne River Fisheries - Testimony of Chuck H. Hanson

MOKELUMNE RIVER HEARING

BEFORE THE
STATE WATER RESOURCES CONTROL BOARD

EBMUD

EAST BAY MUNICIPAL UTILITY DISTRICT

MOKELUMNE RIVER FISHERIES

TESTIMONY OF CHARLES H. HANSON

NOVEMBER 1992

EBMUD Exhibit No. 27

SECTION 3
DELTA HYDROLOGIC CONDITIONS INFLUENCING CHINOOK SALMON AND STEELHEAD POPULATIONS ON THE LOWER MOKELUMNE RIVER

Chinook salmon and steelhead produced within the lower Mokelumne River rely, to a large extent, on hydraulic cues within San Francisco Bay and the Delta for successful migration of both juveniles and adults. Salmon and steelhead are anadromous species in which adults spawn in freshwater river areas such as the lower Mokelumne River. Juvenile salmon and steelhead migrate downstream to enter the marine waters of the Pacific Ocean where they reside and grow to adults which then migrate upstream from the marine habitat returning to their natal tributaries for spawning. As a result of the anadromous lifecycle both adult and juvenile salmon and steelhead must successfully migrate through the Bay-Delta system. Adult salmon and steelhead utilize hydraulic and olfactory cues to guide their upstream spawning migration while juveniles primarily use hydraulic cues during their downstream migration (Hoar and Randall 1971).

The Delta environment has undergone a number of modifications, with the greatest changes occurring within the past 40 years, associated with such activities as island reclamation, flood control, and an increasing demand for the diversion and export of fresh water for municipal, industrial, and agricultural usage (Herbold *et al.* 1992). These modifications have included changes in channel configuration through dredging activity, construction of levees, and changes in hydrologic flow patterns within Delta channels as a result of operation of the State Water Project (SWP) and Central Valley Project (CVP). Diversions from the SWP and CVP occur from locations within the south Delta (Figure 3-1) at a combined diversion capacity of up to 14,900 cfs. Exports from the SWP and CVP are of sufficient magnitude to alter hydrologic flow patterns within many of the Delta channels (DWR 1986). Figure 3-2 illustrates natural Delta hydrology patterns in the absence of the influence of the SWP and CVP diversions. Figure 3-3 shows the influence of SWP and CVP diversions on Delta hydrology including increased flows from the Sacramento River across the Delta and reverse flow conditions within the lower San Joaquin River. The influence of SWP and CVP diversion operations on Delta hydrology changes between seasons and between years in response to changes in Delta inflow and export demand.

Changes in Delta hydrologic patterns have the potential for adversely impacting chinook salmon and steelhead produced on the Mokelumne River in several ways (Hallock *et al.* 1970;Meyer 1982; CDFandG 1992a; USFWS 1992). Changes in Delta hydrology may contribute to a redirection of juvenile fish into south Delta channels and delays in juvenile emigration which increase susceptibility to predation and entrainment losses at the SWP and CVP facilities as well as a number of agricultural, industrial, and municipal diversions which occur within the Delta. Kjelson *et al.* (1991) however found no statistically significant relationship between reverse flows in the western Delta (Jersey Point) and survival of Sacramento fall-run smolts migrating through the Delta.

Changes in Delta hydrology may also influence the upstream migration of adult salmon and steelhead (Hallock *et al.* 1970; Meyer 1982). Changes in hydraulic cues and the movement of large volumes of water from the Sacramento River across the Delta may contribute to delays in upstream migration and increased straying of adults from one tributary to another. Increased mortality of downstream migrating juveniles and delays and increased straying of upstream migrating adults adversely impact the lower Mokelumne River fisheries.

BACKGROUND

As part of the Central Valley Project, which included development of upstream impoundments for water storage and water export facilities from the southern Delta, a channel was constructed connecting the Sacramento River with the North and South forks of the lower Mokelumne River (Figure 3-1). The channel, referred to as the "Delta Cross-channel", allows for diversion of water from the Sacramento River into the central Delta. The Delta Cross-channel is operated and managed for both water diversion and flood control purposes by a set of radial gates located at the confluence between the Delta Cross-channel and Sacramento River. The Delta Cross-channel was constructed to increase the quantity and quality of freshwater flowing from the Sacramento River across the Delta to the SWP and CVP diversions. When the Delta Cross-channel is closed the quantity of water which can be diverted from the SWP and CVP is restricted as a result of compliance with State Board Bay-Delta water quality standards by salinity intrusion from San Francisco Bay within the lower San Joaquin River (D. Schuster, Pers. Comm.). The flow of water from the Sacramento River through the Delta Cross-channel varies between seasons and years based, in part, on variation in Sacramento River flows (DWR 1986).

The influence of SWP and CVP operations on Delta hydrology also varies substantially between seasons and years, largely in response to variation in Delta inflow and Delta export rates. During high flow periods within the Sacramento and San Joaquin Rivers the volumes of water diverted by the SWP and CVP through interior Delta channels represents a lower percentage of total flow through the Delta (reduced percentage diverted) than during dry years and low flow periods when operation of the SWP and CVP have a greater relative effect (increased percent diverted) on hydrologic conditions within Delta channels (DWR 1986; Herbold *et al.* 1992).

As a result of concern over potential adverse effects of operation of the Delta Cross-channel and changes in hydrologic patterns within the Delta on the survival of juvenile chinook salmon a series of investigations were undertaken by the U.S. Fish and Wildlife Service to assess, in part, the relationship between juvenile salmon mortality and diversions at the Delta Cross-channel (Kjelson *et al.* 1989). These studies, under the supervision of Dr. Marty Kjelson, provide, in part, the scientific foundation for assessing potential adverse impacts of interior Delta hydrology and Delta Cross-channel operations on increased mortality of juvenile chinook salmon produced within the lower Mokelumne River. In addition, East Bay Municipal Utility District has also sponsored scientific studies to provide additional information on mortality rates of juvenile chinook salmon emigrating from the lower Mokelumne River during their migration downstream through the Delta.

ANALYSIS AND RESULTS

Delta hydrology affects chinook salmon and steelhead produced within the lower Mokelumne River during the fall (September-December) period of adult upstream migration and during the spring (March-June) period of juvenile emigration. Average monthly flow (cfs) during the fall period of adult migration and spring period of juvenile migration through the Delta are summarized in Tables 3-1 and 3-2 for the Mokelumne River, passing through the Delta Cross-channel, and the percentage of Delta inflow diverted at the SWP, CVP, and Contra Costa Water District intake at Rock Slough (percent diverted). The influence of SWP and CVP operations on hydrologic flow patterns within the lower San Joaquin River (Jersey Point) are presented in Tables 3-1 and 3-2 as the number of days per month when reverse flow conditions occurred.

No scientific studies have been conducted to quantitatively evaluate the effects of reverse flow within the lower San Joaquin River and the increased flow of Sacramento River water through interior Delta channels on the timing or migration patterns of either adult chinook salmon or steelhead. Indirect evidence is available, however, from coded-wire tagging studies in which hatchery produced juvenile chinook salmon are marked prior to release into the Bay-Delta system and the return of the marked individuals to the natal stream as adults is assessed (F. Meyer, CDFandG, Pers. Comm.). Results of these investigations have shown that adult chinook salmon migrating into the lower Mokelumne River frequently represent strays from other drainage systems including the upper Sacramento River, Feather River, and American River. Chinook salmon and steelhead produced within the Mokelumne River Fish Hatchery have also been observed migrating as adults into other river systems (Table 6-3). Although precise estimates of adult straying from one drainage system to another cannot be made since many hatchery-produced, and virtually all salmon and steelhead produced naturally within Central Valley River systems, have not been tagged the data available from hatchery releases demonstrate that straying is relatively high within the Central Valley system.

The high straying rates of adult salmon and steelhead may reflect the contribution of several factors including changes in Delta hydrology, the movement of Sacramento River water through the Delta Cross-channel and interior Delta channels, and hatchery management practices in which juvenile chinook salmon and steelhead are trucked from the hatchery to release points downstream of the Delta to avoid high mortalities occurring during migration of juveniles through the Delta. The high straying rate of migrating adults from the Mokelumne River and the observance of Sacramento River Basin adults (Sacramento, Feather, and American river stocks) within the Mokelumne River may in part reflect modifications in Delta hydrology which influence or obscure olfactory and hydraulic cues utilized during upstream migration. The high cross-Delta flows of Sacramento River water occurring within the North and South forks of the lower Mokelumne River as a result of Delta Cross-channel and water project operations may also adversely effect the attraction of Mokelumne River chinook salmon and steelhead. Flows from the Mokelumne River during the fall represent from 1 to 25%

of the flow passing through the Delta Cross-channel (Figure 3-4: approximately 1-15% passing through the Cross-channel and Georgiana Slough combined; Table 3-1) which is likely to contribute to low adult attraction into the lower Mokelumne River and increasing difficulty for the Mokelumne River stock to effectively locate (olfactory cues) and be attracted into the Mokelumne River. Reverse flow conditions within the lower San Joaquin River during the fall (Figure 3-4) may also influence adult upstream migration. High straying rates of adults and reduced adult attraction into the lower Mokelumne River contribute to considerable uncertainty regarding the effectiveness of flows during the fall in attracting upstream migrating adult salmon given changes in Delta hydrology which have occurred.

Flow conditions occurring within the lower Mokelumne River (below Woodbridge), the Delta Cross-channel, and the lower San Joaquin River and the percentage of Delta inflow diverted at major export facilities during the spring period of juvenile salmon and steelhead emigration (March-June) are summarized in Table 3-2. Delta Cross-channel flows and the percentage of Delta inflow diverted (Figure 3-5) are relatively high during the spring emigration period which may result in the redirection of juvenile salmon and steelhead migrating downstream from the Mokelumne River into southern Delta channels.

Kjelson *et al.* (1989; Appendix B) reported results of biological studies demonstrating a significant increase in juvenile chinook salmon mortality between groups of fish released immediately above and below the Delta Cross-channel diversion point on the Sacramento River (Figure 3-6). Survival estimates for juvenile chinook salmon within the Central Delta, representative of mortality rates which may be experienced by juvenile chinook salmon migrating downstream from the lower Mokelumne River, have also been demonstrated to be low (Figure 3-7).

The relatively low survival rates for juvenile chinook salmon migrating through the central Delta (survival indices typically less than 0.25; Figure 3-7) are consistent with generally low survival estimates for salmon released within the Mokelumne River system:

Juvenile Survival Index to Chipps Island

Release Location Year	North Fork(1)	South Fork(1)	Lower Mokelumne(2)
1983	-	-	1.13
1984	0.51	0.86	-
1985	0.28	0.23	-
1986	0.36	0.26	-
Mean	0.38	0.45	-

(1)Released at Thornton Road
(2)Released 2 miles above junction with San Joaquin River
(Source: USFWS 1987)

Studies were also conducted during the spring of 1991, sponsored by the USFWS and by EBMUD, to estimate survival of juvenile chinook salmon migrating from the lower Mokelumne River through the Delta. Coded-wire tagged salmon were released into the lower Mokelumne River at Thornton and recaptured downstream of the Delta at Chipps Island. Results of these investigations are summarized below:

Release Date	Number Released	Number Recaptured	Estimated Survival(1)	Agency
April 18	47,289	79	1.56	USFWS
April 23	80,041	139	1.63	EBMUD
May 6	45,706	84	0.64	USFWS
May 9	101,980	48	0.45	EBMUD

(1)Uncorrected Survival
(Source: USFWS 1992)

A variety of environmental factors, including hydrologic conditions and SWP/CVP diversion rates, may have contributed to the substantially higher survival rate indices observed during late April than those observed for juvenile chinook salmon during early May releases. To examine the potential influence of Delta hydrology on the observed survival rates for these two sets of coded-wire tag release groups average daily flow rates (cfs) were compiled from DWR dayflow for the San Joaquin River, Sacramento River, Cross-channel and Georgiana Slough, Jersey Point, and SWP and CVP diversions (Table 3-3). Average flow rates for the various monitoring locations reflect conditions during the period from the date of release of the coded-wire tag group to the date that the last recapture for each tag group occurred at Chipp's Island. Results of these analyses failed to identify a significant correlation between hydrologic and export conditions and estimated juvenile chinook survival rates. For example the survival rate index for juvenile chinook salmon released at New Hope on the lower Mokelumne River on April 23 (survival index 1.63) were similar (Table 3-3) to environmental conditions occurring during the May 9 release (survival index 0.45). San Joaquin River flows, Sacramento River flows, average flow at the Delta Cross-channel and Georgiana Slough, and combined SWP and CVP exports did not vary substantially between late April and early May and therefore do not appear to account for the large difference observed in juvenile chinook salmon survival rates.

Other environmental factors, in addition to and in combination with hydrologic conditions and Delta exports, including exposure to elevated water temperatures within the Delta during the period of emigration, variation in tidal conditions, and salinity regimes may have contributed to the observed difference in survival rates observed in these tests. Water temperature has been identified as a major factor influencing survival of juvenile chinook salmon emigrating through the Sacramento and San Joaquin rivers and Delta (USFWS 1992; Kjelson *et al.* 1989). Water temperatures within the central Delta channels during the spring-summer (April-June) period of salmon smolt emigration from the Mokelumne River system may reach the mid- to upper 70's F which would contribute to high smolt mortality.

Although the factors contributing to the high mortality of juvenile chinook salmon within the Central Delta have not been isolated or individually quantified, juvenile salmon released within the lower Mokelumne River have been subsequently collected in the fish salvage operations of the SWP and CVP demonstrating the susceptibility of these fish to direct entrainment losses at the water diversions (CDFandG 1991; USFWS 1992; see Section 4). Although the influence of Delta Cross-channel flows, reverse flows, increased susceptibility to predation and entrainment at various water diversion sites cannot be quantitatively assessed, available data clearly demonstrate that mortality rates of juvenile chinook salmon migrating through Central Delta channels, including fish emigrating from the lower Mokelumne River, are high. The substantial mortalities occurring to juvenile chinook salmon (and presumably steelhead) within the Delta represent a major factor influencing the chinook salmon and steelhead populations on the lower Mokelumne River.

In summary, there exists a high likelihood that changes in Delta hydrology as a result of operation of the Delta Cross-channel and the influence of water diversions from the SWP and CVP contribute to delays in upstream migration and increased straying of both adult chinook salmon and steelhead returning to the Mokelumne River. Reverse flow conditions in the lower San Joaquin River and the relatively high flow of Sacramento River water through Central Delta channels may obscure the olfactory and hydraulic cues utilized by upstream migrating salmon and steelhead returning to the lower Mokelumne River. Fall flows from the Mokelumne River represent a relatively small contribution (generally less than 15%) of the flow of water passing from the Sacramento River into the interior Delta through the Delta Cross-channel and Georgiana Slough (Table 3-1). The existing hydrologic conditions within the Delta contribute significantly to the uncertainty in the effectiveness of fall flows in attracting adult salmon and steelhead into the Mokelumne River.

Relatively high Delta Cross-channel flows and changes in hydrologic conditions associated with SWP and CVP export operations during the spring (Table 3-2) represent a potentially significant factor contributing to high mortality rates of juvenile salmon migrating downstream through the Delta. Although the cause-and-effect mechanisms contributing to the high observed juvenile salmon mortality rates within the Delta (Figure 3-7) have not been isolated the overall effect of these mortality rates is to reduce the contribution of chinook salmon and steelhead production from the Mokelumne River.

Based upon these analyses of the potential effects of changes in Delta hydrology associated with operation of the Delta Cross-channel, water management practices, and diversions from the south Delta it can be concluded that:

- A high degree of uncertainty exists in the relationship between Mokelumne River fall attraction flows and either adult salmon or adult steelhead escapement;

- Modifications to Delta hydrology during the fall contribute to high straying rates of adults and difficulties in maintenance of a Mokelumne River-specific steelhead and chinook salmon stock;

- High mortality of downstream migrating juveniles within the Delta negatively impacts the effectiveness of improved flow conditions on the lower Mokelumne River;

- High juvenile mortality rates within the Delta support management decisions to release hatchery-reared juvenile chinook salmon and steelhead downstream of the Delta in an effort to improve survival rates and the contribution of hatchery production to the ocean fishery and adult stock;

- High juvenile mortality within the Delta, particularly during low-flow periods when percentage diversion associated with SWP and CVP operations is high, supports a management plan decision to trap juvenile chinook salmon and steelhead emigrating from the lower Mokelumne River and truck the juvenile fish to release locations downstream of the Delta, and the release of yearlings into the Mokelumne River during the fall when water temperatures and diversion are reduced, in an effort to improve juvenile survival and the contribution of production from the lower Mokelumne River to ocean stocks and adult escapement.

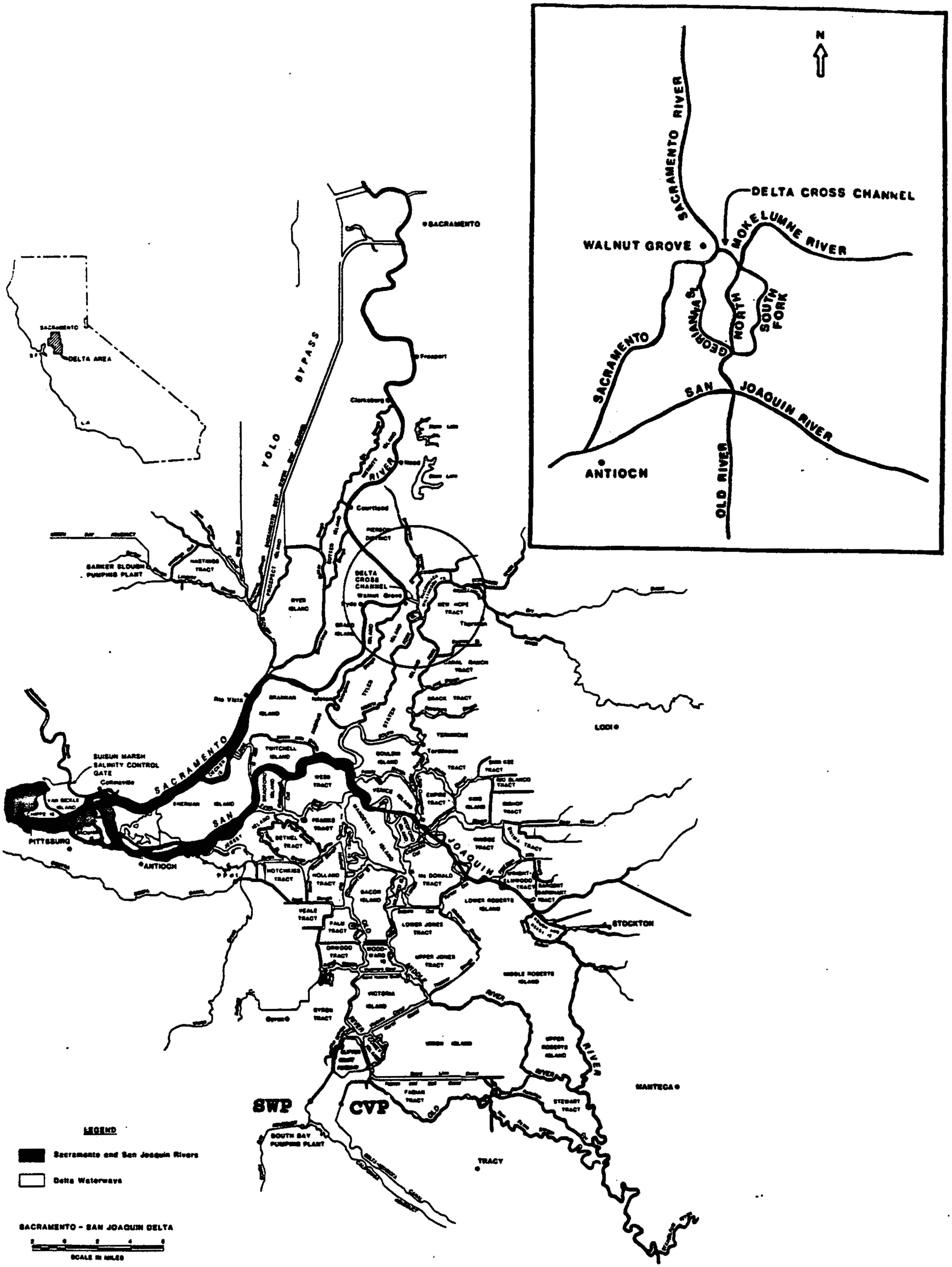


Figure 3-1. Sacramento - San Joaquin Delta.

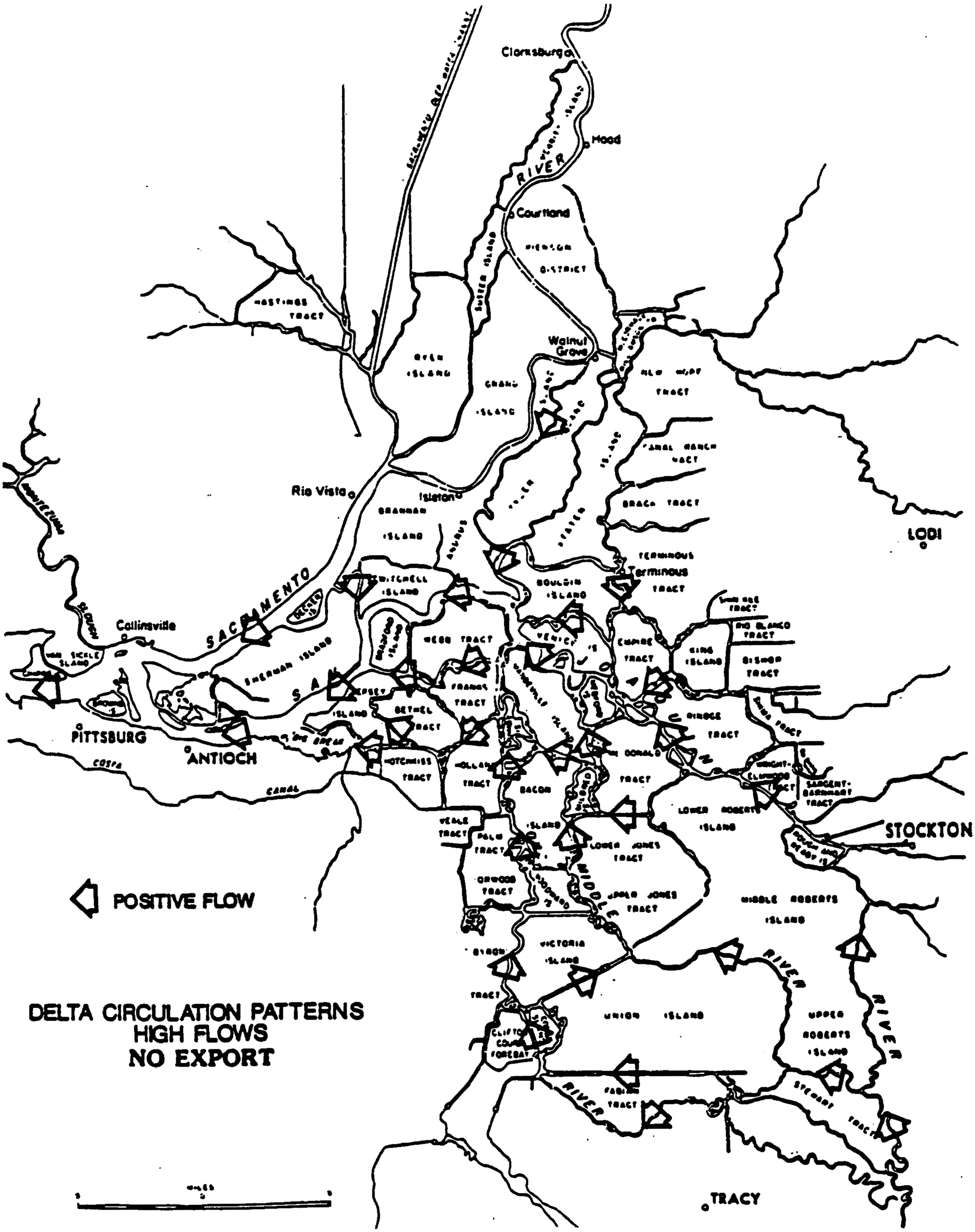


Figure 3-2. Hydrologic flow patterns within the Delta in the absence of diversions at the State Water Project, Central Valley Project and Delta Cross-channel.

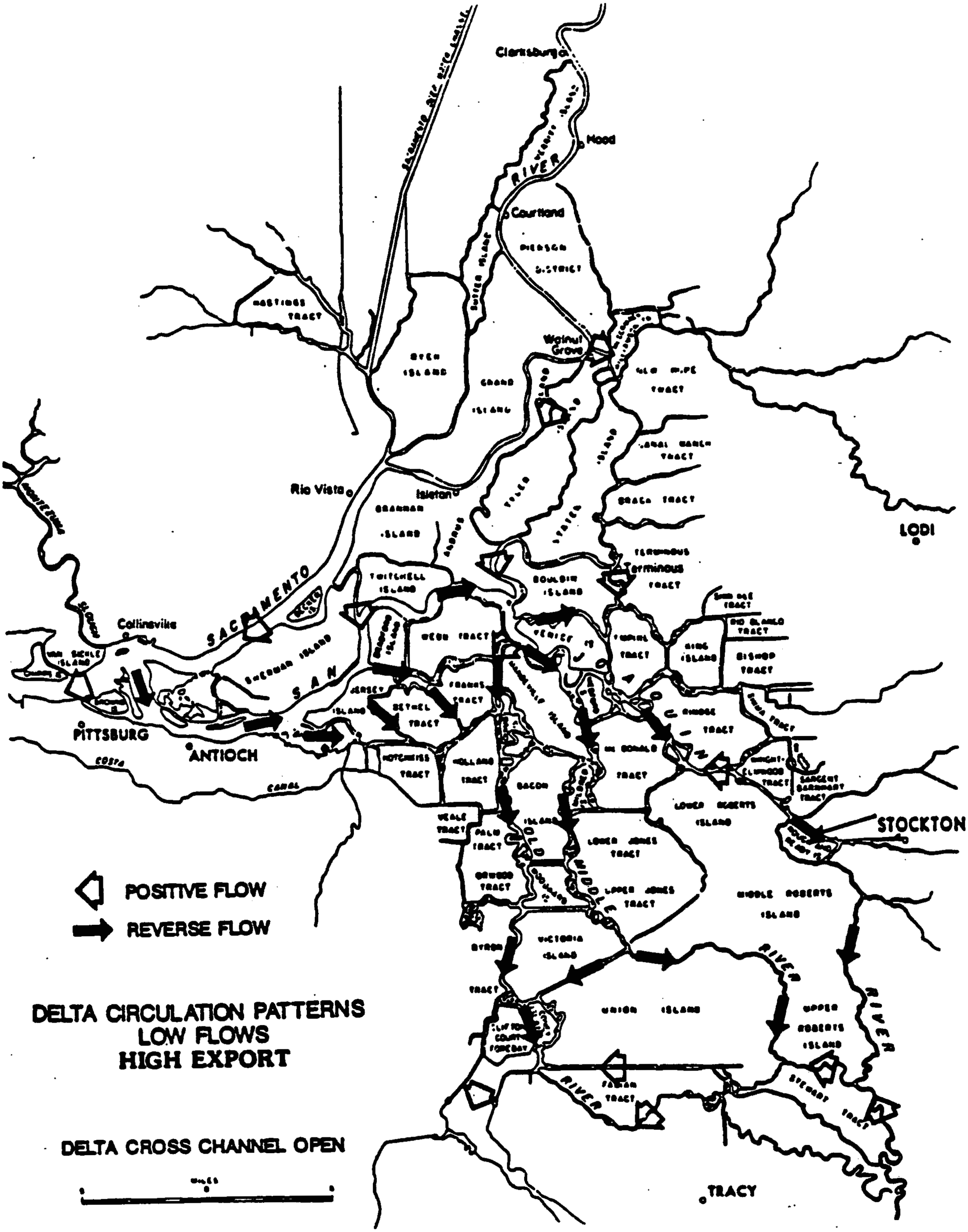
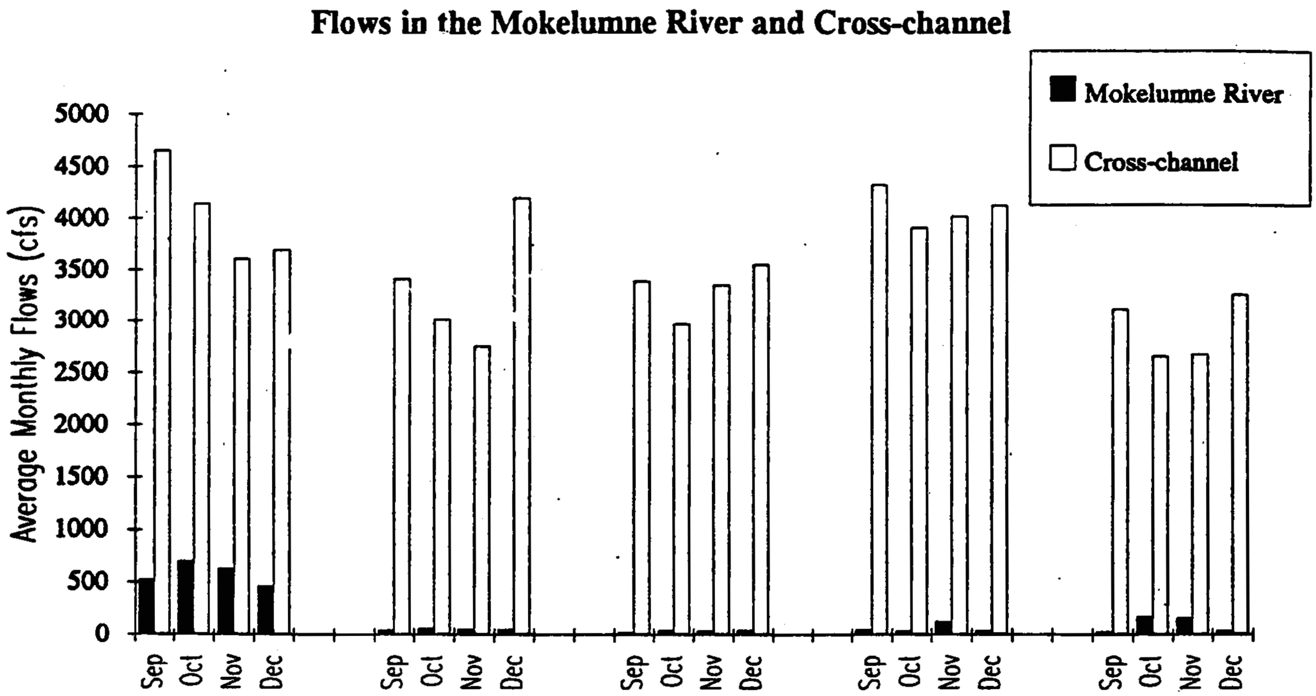


Figure 3-3. Hydrologic flow patterns within the Delta as influenced by State Water Project and Central Valley Project operations.



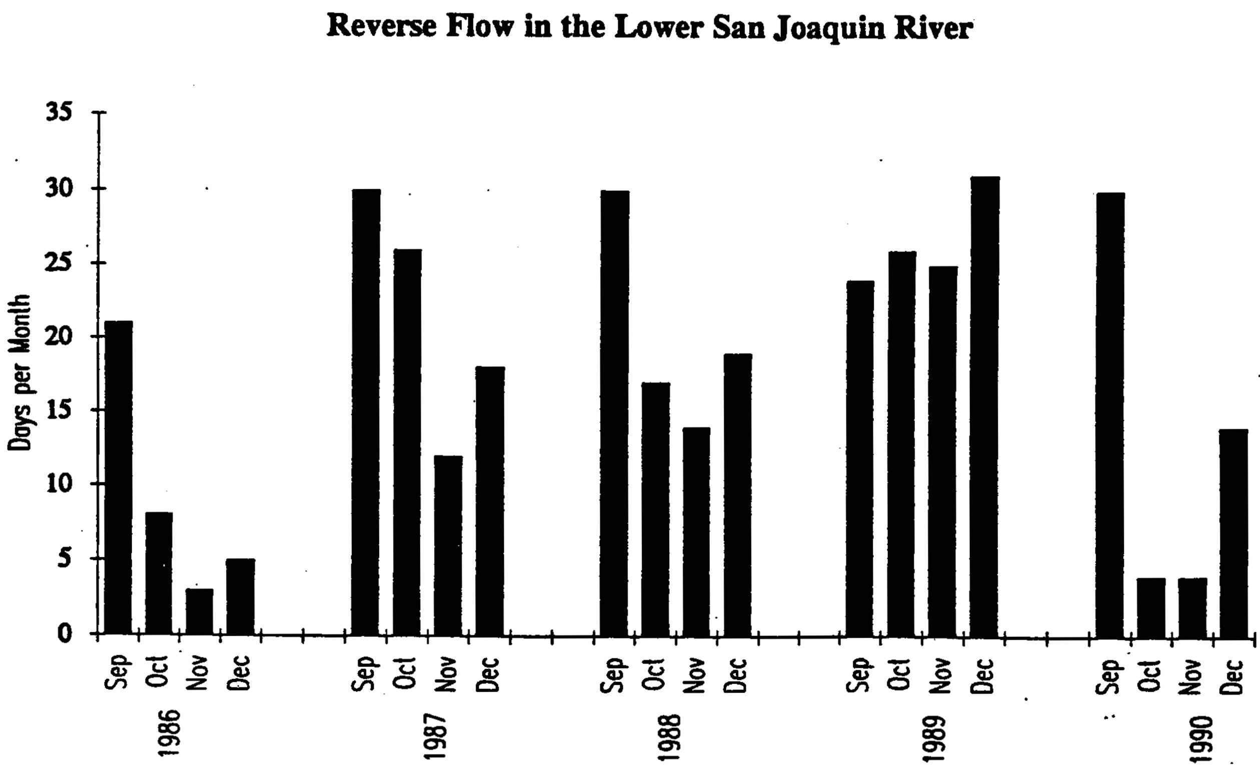
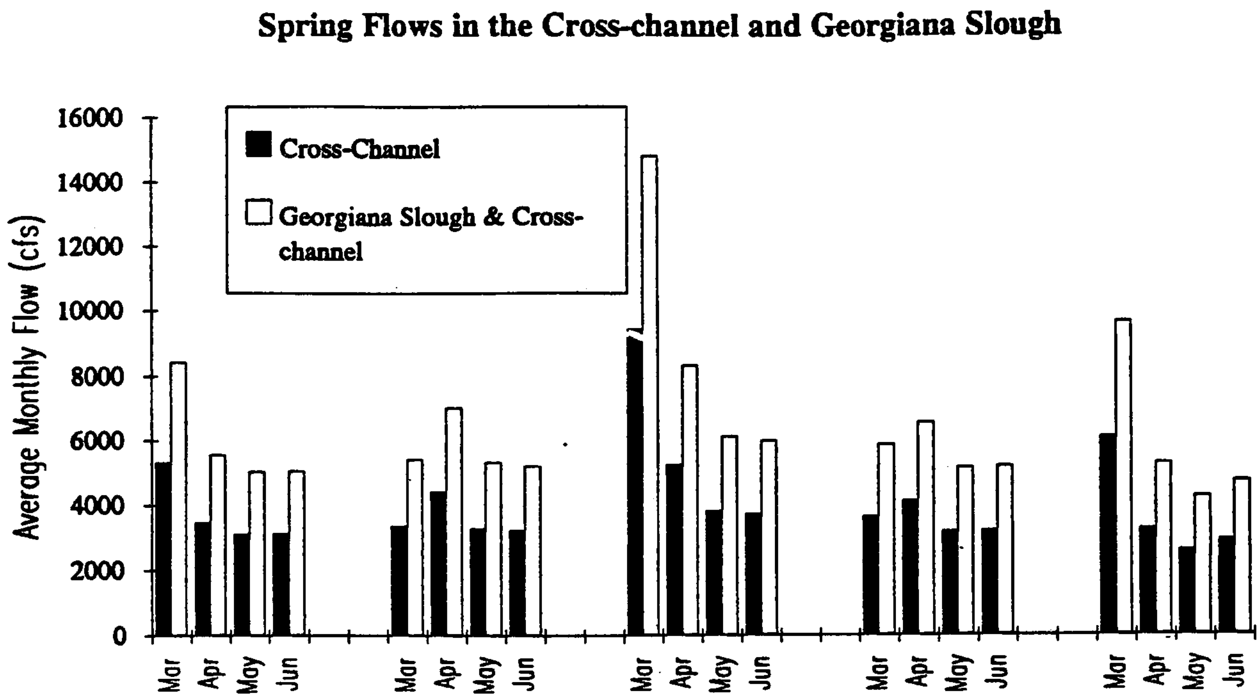


Figure 3-4. Average monthly flow during the fall (September-December) within the Mokelumne River below Woodbridge and Delta Cross-channel, and number of days of reverse flow in the lower San Joaquin River - 1986 to 1990.



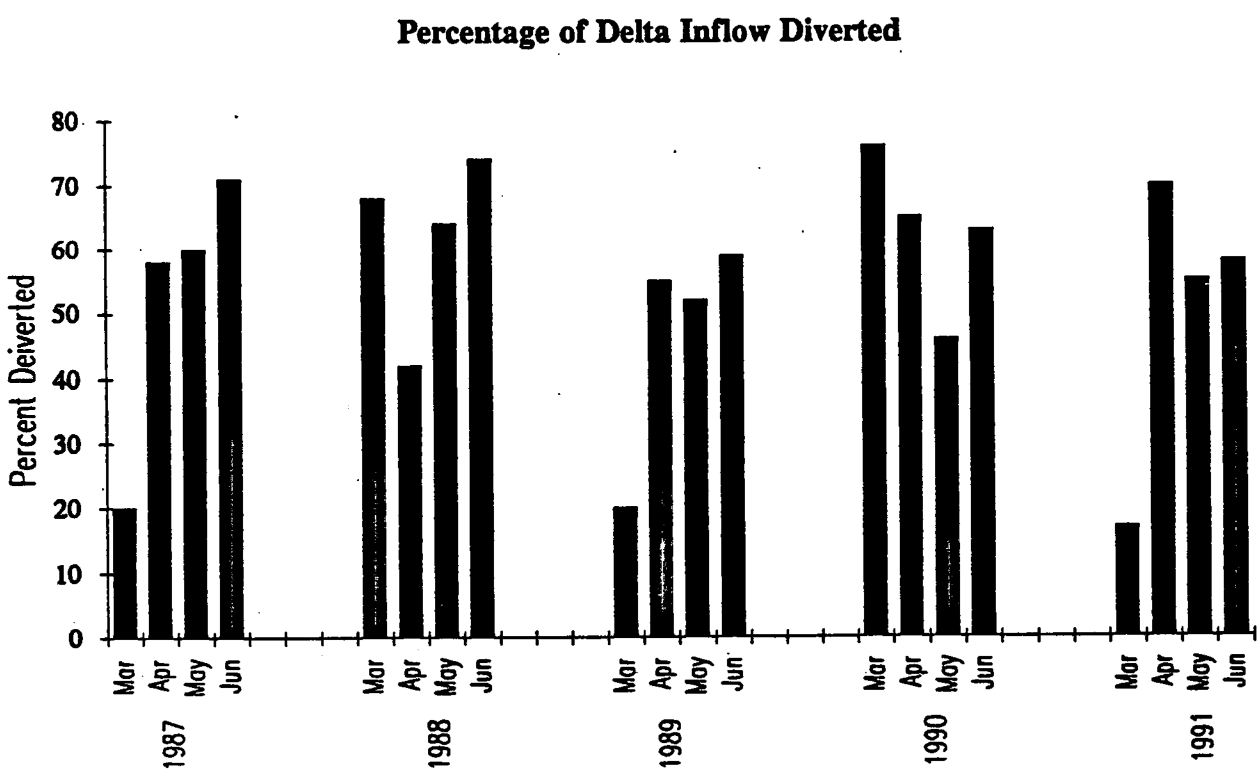


Figure 3-5. Average monthly flow during the spring (March-June) within the Delta Cross-channel and percentage of Delta inflow exported at major diversions - 1987 to 1991.

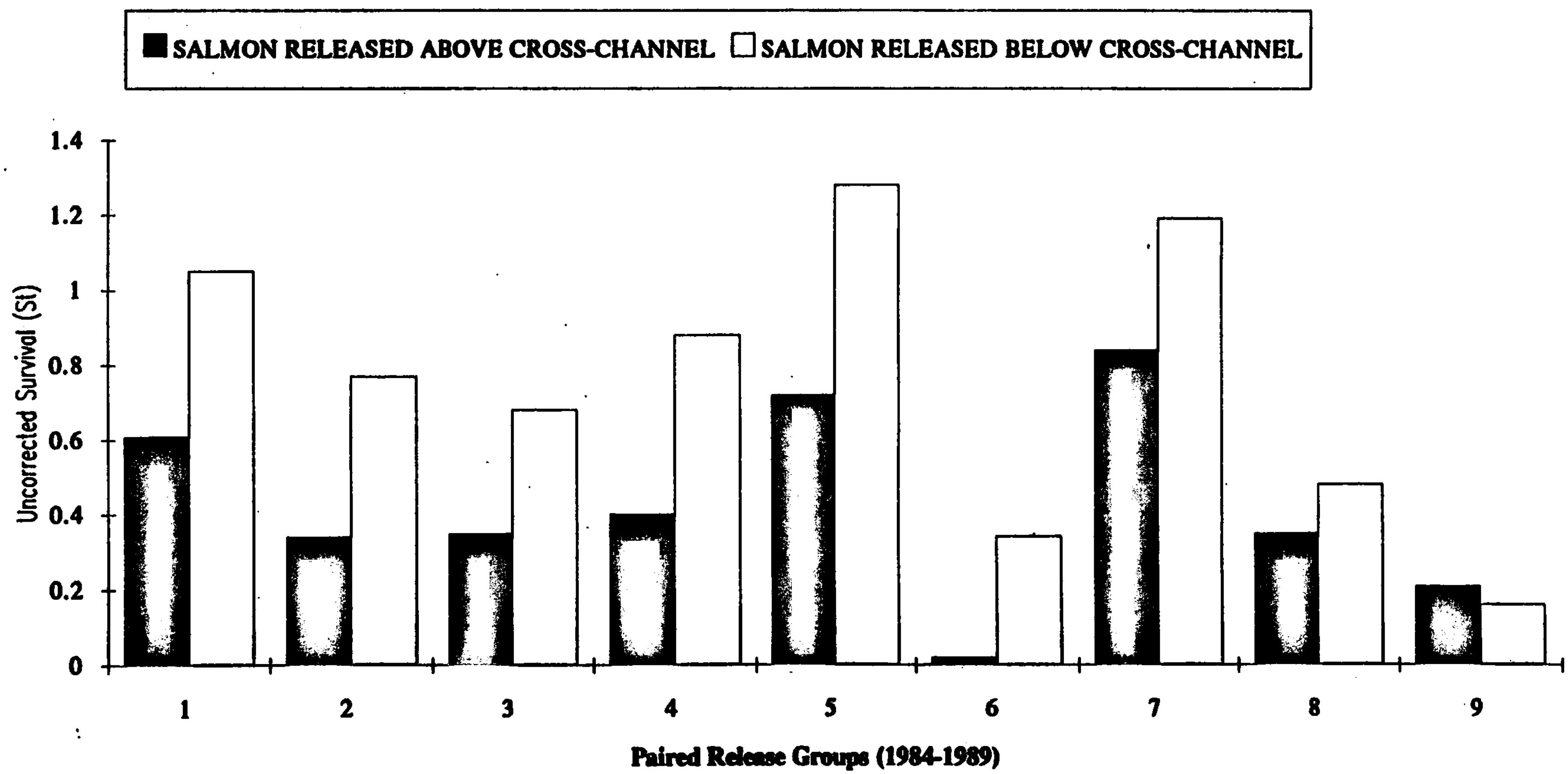


Figure 3-6. Estimated survival of juvenile chinook salmon released within the Sacramento River above and below the Delta Cross-channel (Source: Kjelson *et al.* 1989).

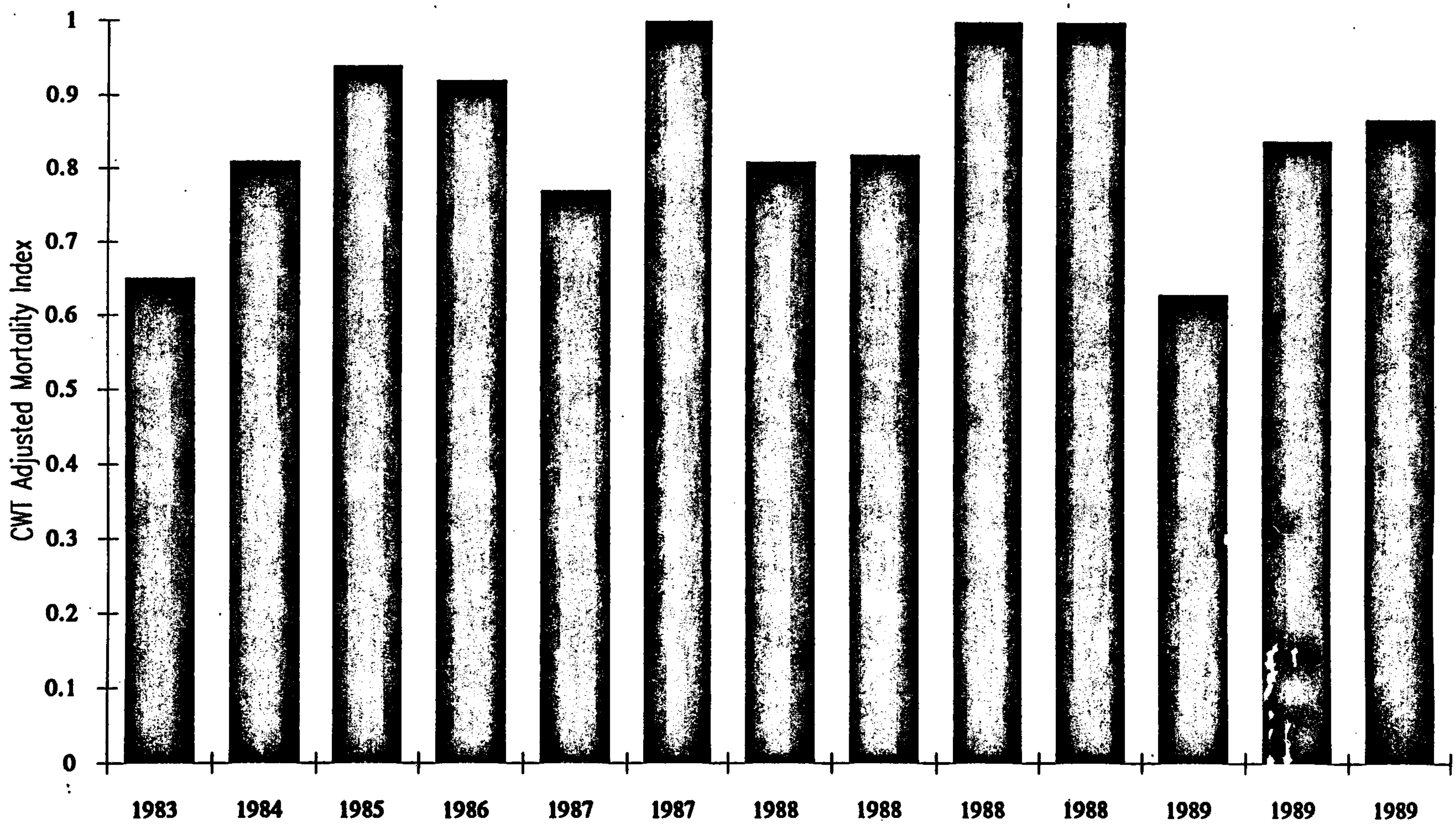


Figure 3-7 Estimated mortality of juvenile chinook salmon emigrating through Central Delta Channels (Source: Kjelson *et al.* 1989).

Table 3-1. Average monthly flows (cfs) at various Delta locations and percentages during the fall (September - December) period of adult salmon and steelhead migration into the Mokelumne River, 1980-1990. (Source: DWR Dayflow).

	SJ River Flow	Mokelumne River	Delta Exports	Days of Reverse Flow	Sacramento River	Cross-Channel	%Mokelumne/ Cross-channel	Georgiana Slough/ Cross-channel	%Mokelumne/ GS & XC	Percentage Diverted
1980										
Sep	3602	347	7663	10	15887	4224	8	6745	5	51
Oct	4072	355	6694	4	11344	3360	11	5414	7	54
Nov	3278	541	6456	20	10879	3272	17	5278	10	55
Dec	2949	227	6763	0	16687	4376	5	6979	3	37
1981										
Sep	1182	42	6797	30	12797	3636	1	5840	1	67
Oct	1386	76	5930	17	9895	3085	2	4989	2	57
Nov	1564	94	4717	2	32909	7458	1	11732	1	22
Dec	1851	1017	5166	0	62349	13051	8	20358	5	9
1982										
Sep	6122	481	5284	0	24917	5939	8	9391	5	19
Oct	8179	1074	5285	0	19229	4859	22	7724	14	21
Nov	6974	1564	6073	0	31523	7194	22	11326	14	13
Dec	16494	2300	8428	0	57735	12175	19	19006	12	10
1983										
Sep	11310	1077	4203	0	24617	5882	18	9303	12	16
Oct	13223	1285	2496	0	21148	5223	25	8286	15	11
Nov	10876	1979	1754	0	48820	10481	19	16394	12	3
Dec	19126	2825	2142	0	75384	15528	18	24178	12	0

Table 3-1. Continued

	SJ River Flow	Mokelumne River	Delta Exports	Days of Reverse Flow	Sacramento River	Cross-Channel	%Mokelumne/ Cross-channel	Georgiana Slough/ Cross-channel	%Mokelumne/ GS & XC	Percentage Diverted
1984										
Sep	2917	553	5498	0	17693	4567	12	7274	8	36
Oct	4029	596	5605	0	13235	3720	16	5968	10	34
Nov	2865	676	7996	1	26280	6198	11	5849	12	18
Dec	4775	752	8464	4	32558	7391	10	5159	15	22
1985										
Sep	1929	85	8719	30	12192	3521	2	5662	2	78
Oct	2072	112	7703	27	9711	3050	4	4566	2	72
Nov	1929	149	7329	16	10418	3184	5	4698	3	46
Dec	2205	165	9858	21	16106	4265	4	5824	3	51
1986										
Sep	4181	523	10490	21	18140	4652	11	6224	8	53
Oct	3741	704	7566	8	15445	4140	17	5373	13	47
Nov	2842	631	6860	3	12680	3614	17	5805	11	52
Dec	3706	459	7260	5	13110	3696	12	5244	9	48
1987										
Sep	1597	45	9070	30	11625	3414	1	5496	1	86
Oct	1370	65	5908	26	9509	3012	2	4188	2	65
Nov	1548	48	5460	12	8129	2750	2	4223	1	56
Dec	1278	50	8986	18	15744	4196	1	6703	1	47
1988										
Sep	1452	18	8119	30	11537	3397	1	5470	0	82
Oct	1127	47	5631	17	9314	2975	2	4819	1	68
Nov	1274	36	6087	14	11356	3363	1	5417	1	55
Dec	1372	44	7184	19	12388	3559	1	5720	1	54

Table 3-1. Continued

	SJ River Flow	Mokelumne River	Delta Exports	Days of Reverse Flow	Sacramento River	Cross-Channel	%Mokelumne/ Cross-channel	Georgiana Slough/ Cross-channel	%Mokelumne/ GS & XC	Percentage Diverted
1989										
Sep	1353	50	10753	24	16463	4333	1	6914	1	67
Oct	1401	35	10529	26	14274	3917	1	6272	1	72
Nov	1404	124	10379	25	14830	4023	3	6435	2	68
Dec	1381	39	10442	31	15397	4130	1	6601	1	74
1990										
Sep	876	27	5918	30	10029	3111	1	5029	1	78
Oct	993	173	3549	4	7620	2653	7	4323	4	61
Nov	1115	158	3857	4	7723	2672	6	4353	4	50
Dec	918	41	5205	14	10818	3260	1	5260	1	46

Table 3-2. Average monthly flow (cfs) at various Delta locations during the spring (March - June) period of juvenile salmon and steelhead emigration from the Mokelumne River, 1980-1991. (Source: DWR Dayflow)

	SJ River Flow	Mokelumne River	Delta Exports	Days of Reverse Flow	Sacramento River	Cross-Channel	%Mokelumne/ Cross-channel	Georgiana Slough/ Cross-channel	%Mokelumne/ GS & XC	Percentage Diverted
1980										
Mar	25232	2282	4341	0	55339	11719	19	18304	12	4
Apr	10249	856	5343	0	22587	5497	16	8708	10	17
May	9912	1063	4630	0	15894	4225	25	6747	16	24
Jun	5305	1143	5961	0	17813	4589	25	7309	16	39
1981										
Mar	3122	35	4834	5	24494	5859	1	9267	0	9
Apr	2532	26	8090	17	17224	4478	1	7137	0	42
May	1967	38	4478	5	13781	3823	1	6128	1	43
Jun	1499	55	4032	11	10729	3244	2	5234	1	63
1982										
Mar	10062	2809	10417	0	62813	13139	21	20494	14	8
Apr	22963	3001	9603	0	76580	15755	19	24528	12	6
May	18654	3507	5994	0	42358	9253	38	14501	24	13
Jun	7584	1882	3935	0	26076	6159	31	9730	19	21
1983										
Mar	40035	3667	5371	0	78290	16080	23	25029	15	1
Apr	36447	3641	3814	0	60500	12700	29	19817	18	3
May	31771	2338	3293	0	62303	13043	18	20345	11	5
Jun	26083	2735	5010	0	48380	10397	26	16265	17	11

Table 3-2. Continued

	SJ River Flow	Mokelumne River	Delta Exports	Days of Reverse Flow	Sacramento River	Cross-Channel	%Mokelumne/ Cross-channel	Georgiana Slough/ Cross-channel	%Mokelumne/ GS & XC	Percentage Diverted
1984										
Mar	7502	891	6916		31426	7176	12	11298	8	17
Apr	4285	401	7685		17933	4612	9	7344	5	38
May	3240	271	5929		15406	4132	7	6604	4	43
Jun	2297	348	6165		14990	4053	9	6482	5	55
1985										
Mar	2743	53	8616	16	14310	3924	1	6283	1	42
Apr	2445	95	7342	10	12495	3579	3	5751	2	56
May	2134	96	6215	10	13432	3757	3	6026	2	54
Jun	1751	70	6530	25	13310	3734	2	5990	1	66
1986										
Mar	25035	4799	2231	0	74984	15452	31	24060	20	0
Apr	19590	2479	3273	0	25827	6112	41	9657	26	7
May	8764	1414	5361	0	12761	3630	39	5829	24	32
Jun	6233	792	6076	0	11820	3451	23	5553	14	51
1987										
Mar	3415	110	5600	5	21577	5305	2	8412	1	20
Apr	2867	38	7021	10	11826	3452	1	5555	1	58
May	2178	28	5313	12	9996	3104	1	5019	1	60
Jun	1990	44	5183	19	10067	3118	1	5040	1	71

Table 3-2. Continued

	SJ River Flow	Mokelumne River	Delta Exports	Days of Reverse Flow	Sacramento River	Cross-Channel	%Mokelumne/ Cross-channel	Georgiana Slough/ Cross-channel	%Mokelumne/ GS & XC	Percentage Diverted
1988										
Mar	2241	29	8441	26	11348	3361	1	5415	1	68
Apr	2146	22	8570	10	16887	4414	0	7038	0	42
May	1781	15	6263	20	10974	3290	0	5305	0	64
Jun	1711	17	5900	26	10578	3215	1	5189	0	74
1989										
Mar	2023	9	10261	11	43374	9446	0	14799	0	20
Apr	1915	11	10447	30	21273	5247	0	8323	0	55
May	1949	31	6220	19	13799	3827	1	6133	1	52
Jun	1583	13	5271	17	13287	3730	0	5983	0	59
1990										
Mar	1760	19	10558	28	12868	3650	1	5860	0	76
Apr	1309	21	9667	29	15271	4106	1	6564	0	65
May	1279	30	3391	1	10402	3181	1	5138	1	46
Jun	1116	25	3492	8	10519	3204	1	5172	0	63
1991										
Mar	1779	44	9763	17	25755	6098	1	9636	0	17
Apr	1168	30	7499	23	10879	3272	1	5278	1	70
May	1049	26	2685	7	7332	2598	1	4238	1	55
Jun	568	30	1925	8	8930	2902	1	4706	1	58

Attachment 2

Excerpts from EBMUD Exhibit No. 32

Submitted in the Mokelumne River Hearing

Before the State Water Resources Control Board

November 1992

EBMUD Lower Mokelumne River Management Plan

MOKELUMNE RIVER HEARING

BEFORE THE
STATE WATER RESOURCES CONTROL BOARD

EBMUD

EAST BAY MUNICIPAL UTILITY DISTRICT

EBMUD LOWER MOKELUMNE RIVER MANAGEMENT PLAN

NOVEMBER 1992

EBMUD Exhibit No. 32

LOWER MOKELUMNE RIVER MANAGEMENT PLAN

Prepared for:

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Prepared by:

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September 1992
J720/13

Factors Influencing Migration Success - Mortality of emigrating smolts and fry can occur throughout the downstream migration from the rearing habitat near Camanche Dam to the ocean (Figure 3-9). There is no data on the mortality of fry migrating from the Mokelumne River. Factors influencing smolt migration success are not constant but are related to environmental variables such as river flow, timing of out-migration, operation of the WID Dam and Canal, operation of Camanche Dam, pumping rates, and other factors in the Delta. In general, survival increases if out-migration occurs earlier in the season because of lower water temperatures and diversion rates.

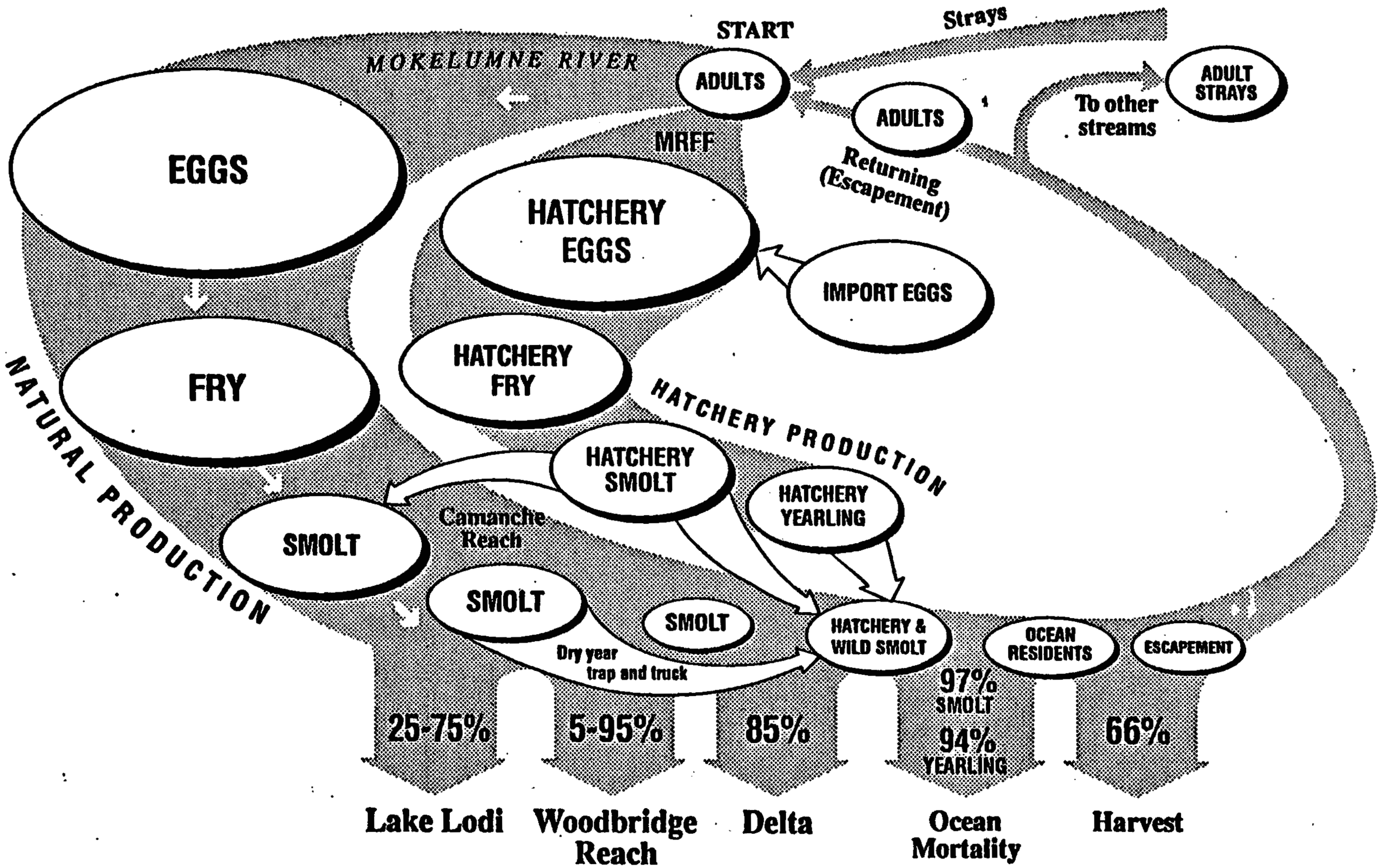

Figure 3-9. Mokelumne chinook salmon life cycle. 9/2/92

The success of migration through Camanche Reach may be influenced by pump diversions and predation. From the rearing areas near Camanche Dam downstream to Lake Lodi, over 50 river pumps withdraw water from the river for irrigation (EBMUD data files, Lodi, California). Few, if any, of these pumps are screened and their impact on migrating salmon has not been quantified. In-river smolt mortality, however, is low compared to mortality observed in the lower reaches of the Mokelumne River and Lake Lodi. Studies conducted by BioSystems in 1991 showed that smolts marked and released at three release sites (Camanche Dam, Bruella Road, and the WID Canal) experienced similar recapture rates (Appendix A). If river pumping was contributing to high mortality, a higher mortality rate in smolts released in the river as compared to smolts released further downstream would be expected.

In Lake Lodi, warm water temperatures, predators, and the large WID diversion may influence migrant mortality. Water temperatures during out-migration can exceed 18° C toward the end of the out-migration, especially in low flow years. Elevated temperatures can indirectly increase mortality by decreasing swimming and feeding efficiency and thereby increasing susceptibility to predation by warmwater fishes such as Sacramento squawfish and largemouth bass. Under extreme conditions, temperatures may become lethal. Entrainment at the WID screens is not well documented; however, salmon up to about 40 mm FL can pass through the screens (Fisher 1976). Recent observations at the screens revealed several potential problems including inefficient fish guidance structures (pier noses prevent movement along the screen face), debris accumulation in front of the screens and in the bypass, improper seals at the screen joints, and faulty design or alteration of the by-pass intake (Vogel 1992).

During low flow years, these impacts can result in substantial smolt mortality (over 60%) in Lake Lodi (Appendix A). Based on studies conducted by BioSystems, survival through the lake is more than three times higher in early May (35-40%) than in early June (5-15%) (Appendix A). Speculatively, high mortality rates may be caused by elevated water temperatures and reduced attraction flows through the lake during low flow conditions. Since no mortality research was conducted in the lake before 1990, the mortality rates associated with passage through Lake Lodi during normal and wet water years are unknown.

Conditions downstream from Woodbridge Dam (Woodbridge Reach) pose significant problems related to high temperature, predation, and water diversions, especially during dry years. Instream conditions probably deteriorate as the out-migration season progresses, because temperatures rise and the rate of diversions increase. In years when little water passes Lake Lodi, the temperatures in the Woodbridge Reach can exceed the lethal limits for juvenile salmon (25° C, Brett 1952) during most of the out-migration period (temperature modeling results, Appendix C). Sub-lethal temperatures can increase predation by warmwater fishes in Woodbridge Reach, such as squawfish, black bass, catfish, and large sunfish (Appendix A).

Current salmon management practices address the problem in capturing out-migrating juveniles at Woodbridge Dam and releasing them below the Delta or San Francisco Bay during low flow years. This strategy increases the rate at which Mokelumne River stock strays to other river systems. During wet and normal water years, temperatures in the Woodbridge Reach are more conducive to successful out-migration, so trapping operations are not necessary.

In recent years, the survival index of Mokelumne River smolts migrating from the lower Mokelumne River through the Delta has ranged from approximately 20-100 percent with an average of 52 percent (USFWS 1988). This is based on releases of CWT smolts in the North and South Forks of the Mokelumne River in 1983-1986. Smolts were recovered by trawl in the Lower Sacramento River at Chipps Island. Survival of Mokelumne smolts migrating through the lower Mokelumne River and Delta has also been estimated from releases of CWT smolts in the Sacramento River above the Delta Cross Channel and subsequent recoveries at Chipps Island (Kjelson et al. 1989). Modeled survival in this study averaged 15 percent with a range of 0-37 percent for CWT releases in 1983-1989 (Kjelson et al. 1989). Mortality rates have been correlated with water temperatures and water diversions in the central Delta and are believed to be influenced by Delta outflow (Kjelson et al. 1989). In many years, large scale water exports by the Delta pumps reverse the flow in the San Joaquin River. This results in smolts being drawn away from the sea and towards the export pumps (USFWS 1987). Delta conditions for out-migrating smolts are also discussed in Section 3.3.1.1.

3.2.2.7 Conclusions

Based on the data and analysis presented, it was concluded that under the present management strategies:

- There is presently no distinct run of native Mokelumne River salmon.

- The Mokelumne River salmon run is composed largely of strays from other river systems, primarily the Feather and American rivers.

- Since the early 1970s, sustained fall flow in the Mokelumne River has been correlated to the size of the salmon run in the River. This could be because of intercorrelation with other variables, biased data, or the attraction of stray salmon to the Mokelumne. In any case, the amount of water required to attract salmon is large, and these salmon are likely to spawn elsewhere if not attracted to the Mokelumne.

- Short-term (from one to several days duration) flow fluctuations appear to have little influence on the size of the Mokelumne River salmon run, whereas longer-term flow conditions (monthly or migration season averages) appear to be influential. In 1990 and 1991, the salmon run began when flow below Woodbridge Dam was increased to 250 or more cfs. Flow changes after the run was initiated appeared to have little influence on the salmon migration rate.

- Precipitation during the migration season appears to influence short-term (daily) movement of salmon but probably has little effect on the overall run size.

3.3.1.1 Chinook Salmon Out-migration

Production of Mokelumne River salmon is greatly influenced by their successful out-migration through the Delta. A recent model has been developed by the USFWS and DWR to assess the mortality of fall-run chinook salmon smolts in the Sacramento River delta between Sacramento and Chipps Island (Kjelson et al. 1989). This multiple regression model estimates mortality rates among salmon smolts passing through three reaches of the Sacramento River and central Delta. Of most relevance to this analysis is the reach from Walnut Grove on the Sacramento through the Delta Cross Channel, Georgiana Slough, and the lower forks of the Mokelumne River and out through the lower San Joaquin River to Chipps Island (Reach 2). This is the most likely route for smolts migrating out of the Mokelumne River to the ocean.

Kjelson et al. (1989) looked at several environmental variables that may influence smolt mortality in this reach. These included water temperature at the release site (Walnut Grove on the Sacramento), water temperature at Freeport (also on the Sacramento), flow in the lower San Joaquin at Jersey Point, flow at Chipps Island, and daily CVP and SWP exports.

Mortality of smolts in Reach 2 was positively correlated to water temperature at Freeport and water temperature at the release site (both of these temperature factors are significantly correlated with water temperature in the Mokelumne River system; $r = 0.92$ and 0.97, respectively). Outflow at Chipps Island and flow at Jersey Point showed a weak negative correlation (Figure 3-10). A combination of water temperature at Freeport and total SWPplus CVP exports explained 66 percent of the variation in smolt mortality in Reach 2.

Mortality of salmon smolts in this reach was uniformly high, averaging 85 percent and ranging from 63-100 percent. Mortality rates do not appear to be influenced by flow in this reach; Kjelson et al. state that reverse flows in the lower San Joaquin River may increase smolt mortality but errors in estimating these flows may obscure any such relationship. Also, mortality was significantly correlated with water temperature and water temperature is usually correlated with flow at the time of salmon smolt migration. Flow in the Mokelumne River will influence smolt mortality to the extent that it alters water temperatures in the central Delta reach. This colinearity of water temperature and flow may prevent identification of a flow/mortality relationship, if one exists (Brandes pers. comm. 1991). No water temperature modeling has been conducted to address this issue.

Flow management in the Mokelumne River will have little effect on Delta temperatures because it is a relatively small component of Delta inflow (Section 5.6). The best management strategy needs to focus on getting adult salmon into the river and spawning as soon as temperature conditions are acceptable, and getting the smolts back out as early as possible in the spring. When conditions in the Delta are adverse (high temperatures and diversions), transporting migrants around the Delta or holding them in the MRFH may be a useful strategy for rebuilding the run.

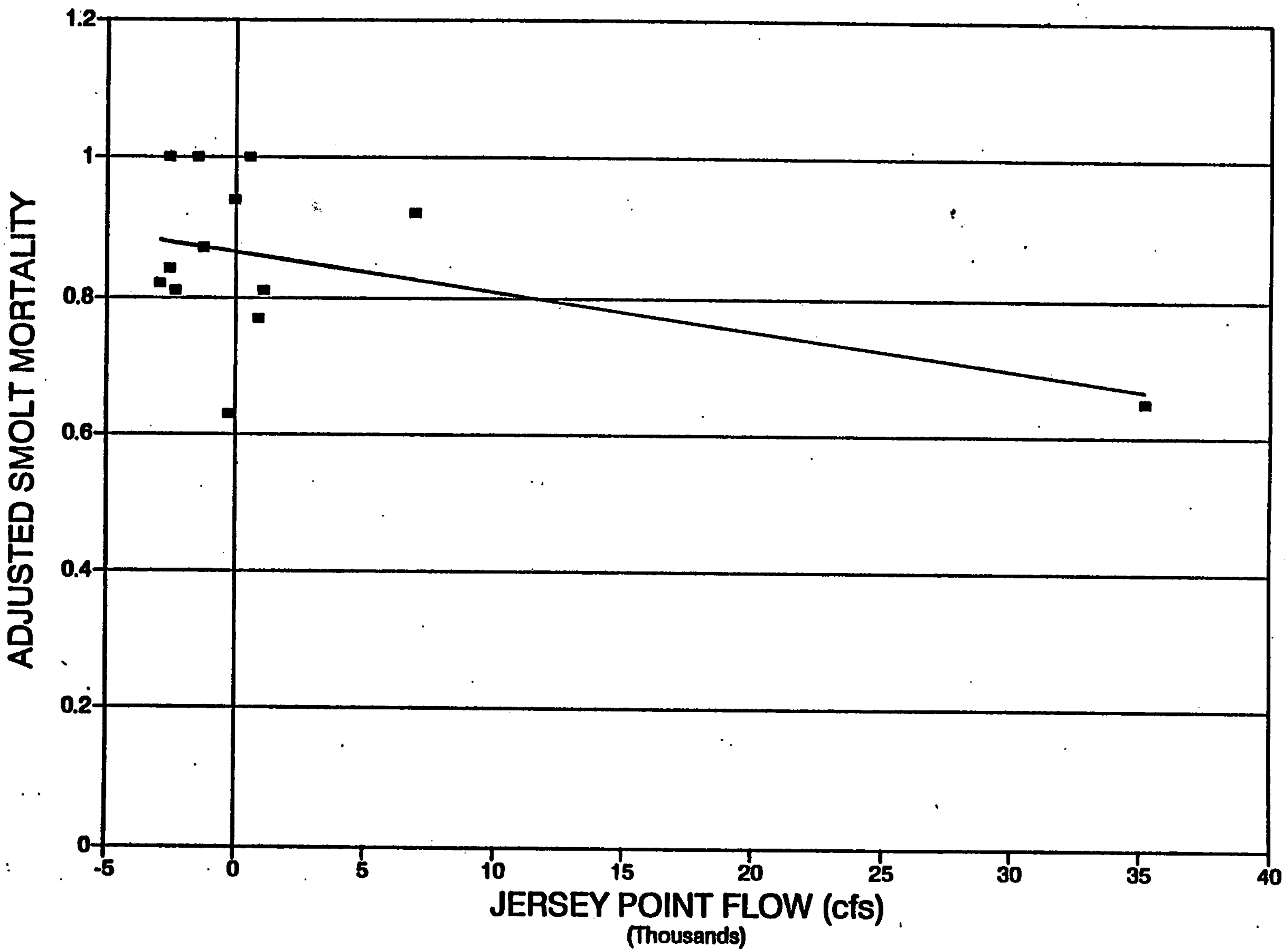

Figure 3-10. **Adjusted salmon smolt mortality in reach from Walnut Grove to Chipps Island compared to flow at Jersey Point, 1983-1989.**

3.3.1.2 Entrainment

Entrainment refers to the incidental capture or loss of fish at diversion facilities. Young fish are especially susceptible to entrainment, as they may be unable to swim against flows created by diversion.

Entrainment is a substantial cause of mortality for young salmon, steelhead trout, and other fish living in the Delta. Flow conditions affect Delta hydraulics, out-migration time, and entrainment. Entrainment at the CVP and SWP export facilities are of particular concern, because of the large amounts of water diverted there.

Change in Mokelumne river flow could potentially affect entrainment of fish at the CVP and SWP export facilities through change in Delta flow patterns. The striped bass and salmon loss model developed by Glen Rothrock (1990) and EBMUDSIM results were used to estimate the potential for entrainment impacts. Striped bass entrainment is estimated by monthly equations (June, July and August) using mean levels of exports, the striped bass index, striped bass size, and flow at Jersey Point.

Flow at Jersey Point consists of Delta Cross Channel flow, Georgiana Slough and eastside streams, including the Mokelumne River, adjusted downward for diversions and 65 percent of net channel depletions. The DAYFLOW database (Greene 1987) provides QWEST, an estimate of flow at Jersey Point. For this entrainment simulation, QWEST data from 1976 through 1990 were used as a base case. For the modified scenarios, LMRMP and CDFG Plan Delta inflows in excess of the base case (Section 5.5.6) were added to the QWEST flows. QWEST can be negative, representing reverse flows toward the export pumps.

Results indicated that the CDFG or LMRMP plan could have small to insignificant effects on entrainment of striped bass eggs. Both plans are estimated to reduce average entrainment in June (.8 and 3.1 percent for the LMRMP and CDFG Plan, respectively). From Table 5.20, both plans would increase Delta inflow in June and, in Rothrock's model, this reduces entrainment. In July and August, the model estimates that entrainment would be affected by less than one percent in either plan; certainly insignificant given the uncertainties in simulated hydrology and the modeling process.

3.3.1.3 Delta Smelt, Splittail, and Other Species

Alteration of the Delta environment has resulted in conditions that are vastly different than those under which the Delta's native fish and other aquatic organisms have evolved. In an evolutionary sense, these changes have been rapid and extreme. Some species may benefit from the changes and a few may be relatively unaffected. For other species, the Delta is becoming an increasingly hostile environment and, under present conditions, we should expect to witness the continued decline of these species.