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Sutter Bypass Fisheries Technical Memorandum II: Avoidance of Potential Entrapment of Juvenile Chinook Salmon in the Proposed Gravel Mining Pond

Prepared for:

Teichert Aggregates
3500 American River Drive
P.O. Box 15002
Sacramento, CA 95851
916/484-3011
Contact: Dave Wayda

Prepared by:

Jones & Stokes Associates, Inc.
2600 V Street, Suite 100
Sacramento, CA 95818-1914
916/737-3000
Contact: Warren Shaul

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EXECUTIVE SUMMARY

Juvenile chinook salmon utilize flooded habitat in the Sutter Bypass. The peak abundance of juvenile fall-, winter-, and spring-run chinook salmon coincides with flood events that inundate the proposed gravel mining area. Juvenile salmon could be entrapped in the proposed gravel mining pond when flow recedes from temporarily flooded habitat.

Pond design criteria, based on the observed response of juvenile chinook salmon to environmental conditions over temporarily flooded habitat, may be implemented to reduce the potential for entrapment in the proposed gravel mining pond. The criteria include:

- a permanent connection between the proposed gravel mining pond and the adjacent sloughs and rivers would not be constructed,
- the connection between the west toe drain and the proposed gravel mining pond would be severed at as high an elevation as feasible,
- the surrounding areas would drain away from the pond, and
- temporary habitat (along the pond edge adjacent to the toe drain) would become available during receding events that attracts juvenile chinook salmon out of the pond and would provide access to an escape route.

INTRODUCTION

Teichert Aggregates (Teichert) is proposing to extract sand and gravel resources from approximately 1,000 acres of the southern portion of the Sutter Bypass near Verona, California (Figure 1). Teichert plans to integrate the mining, agricultural, flood control, and environmental elements into its project proposal. A project overview, available information on fisheries resources potentially affected by the proposed gravel mining, and potential project effects have been provided in a previous report (Jones & Stokes Associates 1992).

The purpose of this report is to evaluate the potential for entrapment of juvenile chinook salmon, identify major factors that affect the level of entrapment, and propose

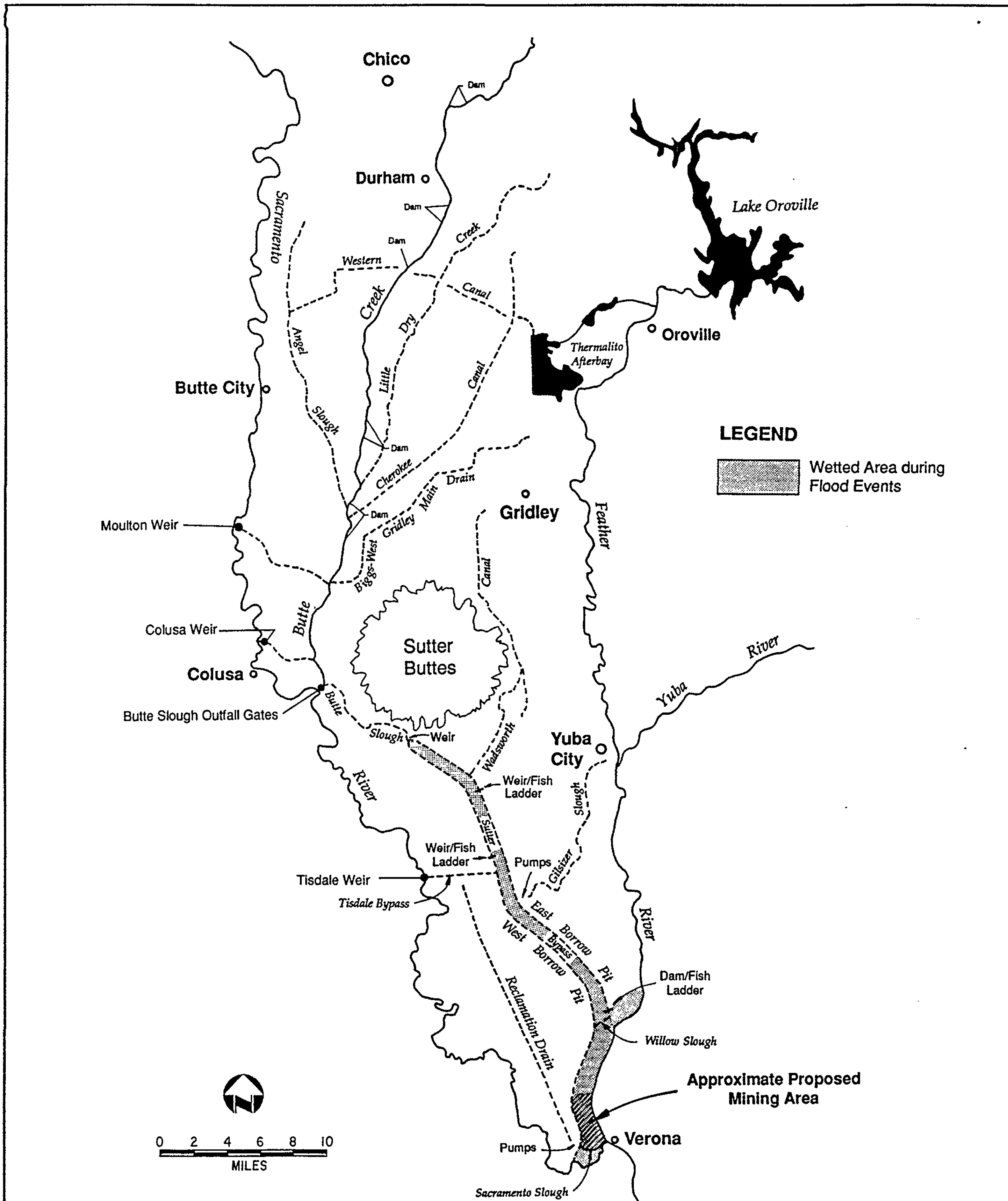

Figure 1. Butte And Sutter Basins Water Resources Study Area

design criteria that would minimize entrapment in the proposed gravel mining pond. This report addresses entrapment issues identified during meetings with the U.S. Fish and Wildlife Service, National Marine Fisheries Service, and California Department of Fish and Game (Jones & Stokes Associates, letter report dated February 4, 1993).

POTENTIAL FOR ENTRAPMENT OF CHINOOK SALMON

The potential for entrapment of chinook salmon in the proposed gravel mining pond is a function of the behavior of chinook salmon during flood events, timing and distribution of chinook salmon, and the occurrence of events that could result in entrapment.

Behavior during Flood Events

Flood events occur when river flow exceeds the capacity of the normal channel and overtops the containing banks. Flow outside of the containing banks provides temporary fish habitat. Flood events create minimal temporary fish habitat along most of the existing channels of the Sacramento and Feather Rivers and is restricted to the area between the containing banks of the river and the flood control levees. The Sutter Bypass, however, is an extensive low-lying area that receives floodflows that overtop the normal Sacramento River channel from Chico to the Tisdale Weir and the lower 9 miles of the Feather River (Figure 1).

Juveniles

Juvenile chinook salmon are the most susceptible of all life stages to entrapment in the proposed gravel mining pond. Juveniles are rearing and actively seeking habitat that provides optimal rearing conditions relative to meeting metabolic needs and avoiding predation and competition.

Flooding in the Sutter Bypass provides rearing habitat that may increase the survival of juvenile chinook salmon. The abundance of chinook salmon utilizing flooded habitat is a function of factors discussed below. Abundance may also be a function of flooding duration. Abundance may increase over the period of flooding or over sequential flooding events because juvenile chinook salmon would remain in the available habitat that is extensive and unlikely limiting. As long as environmental conditions in the flooded habitat are conducive to growth and survival, juveniles would be expected to leave only after they become smolt (i.e., they are physiologically ready to enter salt water).

Field surveys during 1993 flood events provided some information on the use of temporarily flooded habitat by juvenile chinook salmon in the Sutter Bypass (Appendix 1). Chinook salmon juveniles occurred in all habitat types that were sampled (flooded rice fields, other agricultural fields, and drainage ditches). The occurrence of juvenile chinook salmon in the available flooded area appeared dependent primarily on flow velocity and temperature, although depth, turbidity, and dissolved oxygen could also be important factors. Other factors may have caused the apparent increase in abundance, but the density of chinook salmon juveniles appeared to increase as the size of the flooded area was reduced during receding flows.

In general, juvenile chinook salmon usually occurred where velocity was detectable (Appendix 1). In rice fields that were isolated from the toe drain, except for drainage of receding flood water, chinook salmon occurred in the vicinity of inlets and outlets. Away from the inlets and outlets to the rice fields, occurrence of chinook salmon was substantially reduced. The response of chinook salmon to detectable velocity may reduce the vulnerability to entrapment in temporarily flooded areas that may become isolated from the normal channel as flow recedes.

Optimal growth and survival of juvenile chinook salmon occur at water temperatures between 50°F and 66°F, depending on food availability (Brett et al. 1982, Raleigh et al. 1986). Juvenile chinook salmon in the Sutter Bypass did not generally occur where water temperature exceeded 65°F (Appendix 1). The water temperature on March 8, 1993, ranged from 59°F to about 62°F over most of the habitats sampled. Water temperature exceeded 65°F only over flooded rice fields and in drainage ditches that had no inflow from the normal channels but continued to drain into the west toe drain.

Adults

As discussed in a previous report, adult chinook salmon may enter the Sutter Bypass from the south near the confluence of the Sacramento and Feather Rivers (Jones & Stokes Associates 1992). The adults migrate to upstream spawning areas. During flood events, adult salmon may leave the normal river channels and migrate over flooded terrestrial habitat. Adult salmon, however, are likely to maintain orientation with the normal channel and leave temporarily flooded terrestrial habitat when floodflows recede. Flow velocity over the proposed gravel mining pond would be near 0 feet per second (fps) (Appendix 1, Figure 1-3), and adult salmon would seek habitat with higher velocity before flows receded to a level that could entrap the salmon in the pond.

Smolt

Smolt are juvenile chinook salmon that have undergone physical and physiological changes that enable survival in salt water. Smolt may enter the Sutter Bypass during downstream migration (Jones & Stokes Associates 1992). Actively migrating chinook salmon are distributed in the part of the river channel where velocities are highest (Schaffter 1980). Smolt are actively migrating to the ocean and generally seek high flow velocity. Few smolt would occur over the flooded terrestrial habitat in the Sutter Bypass, especially as flows recede, because flow velocity over most of the habitat would be near 0 fps (Appendix 1, Figure 1-3). Smolt would not be trapped in the gravel mining ponds during receding flow events.

Movement of Juvenile Chinook Salmon into the Sutter Bypass

Although all chinook salmon spawning habitat is upstream of the Sutter Bypass and the adjacent river channels, part of the population of juvenile chinook salmon moves from the upstream spawning areas and rears in the Sutter Bypass and the adjacent river channels. Juvenile chinook salmon rearing in the Sutter Bypass would not be expected when water temperatures exceed about 65°F. Water temperature is normally less than 65°F during November-April; however, water temperature may sometimes be less than 65°F over parts of the Bypass from October through June.

Timing

The number of salmon utilizing habitat in the Bypass is dependent on timing of juvenile emergence from the gravel, the number of juveniles that emerge, and the movement of juvenile chinook salmon out of upstream spawning areas. The timing of emergence of juveniles from the gravel is a function of spawning time and water temperature during egg incubation. The Sacramento River and its tributaries support four runs of chinook salmon: fall, late fall, winter, and spring. Life history and time of spawning were described in a previous report (Jones & Stokes Associates 1992).

Juvenile chinook salmon move out of upstream spawning areas into downstream habitats in response to many factors, including inherited behavior, habitat availability, flow, competition for space and food, and temperature. The number of juveniles that move and the timing of movement are highly variable. Storm events and the resulting high flows cause movement of substantial numbers of juvenile chinook salmon to downstream habitats. In general, juvenile abundance in downstream habitat increases as flow increases (U.S. Fish and Wildlife Service 1992). Because the availability of flooded terrestrial habitat in the Sutter Bypass also increases as flow increases, the abundance of juvenile chinook salmon in flooded habitat would be expected to be greatest during high flow years.

Although the number of juveniles and the proportion of the annual brood utilizing downstream habitats cannot be estimated, the proportion of the annual brood comprised of juveniles can be used as an index of density relative to other runs and other months. The proportion of the annual chinook salmon brood comprised of juveniles was calculated by subtracting the cumulative proportion of the brood estimated to have become smolt from the cumulative proportion of the brood estimated to have emerged from nests by the end of a given month. The peak month of occurrence of fall-run juveniles in the Sacramento River system is March, the peak for the late fall run is after June, the peak for the winter run is November, and the peak for the spring run is January (Figure 2).

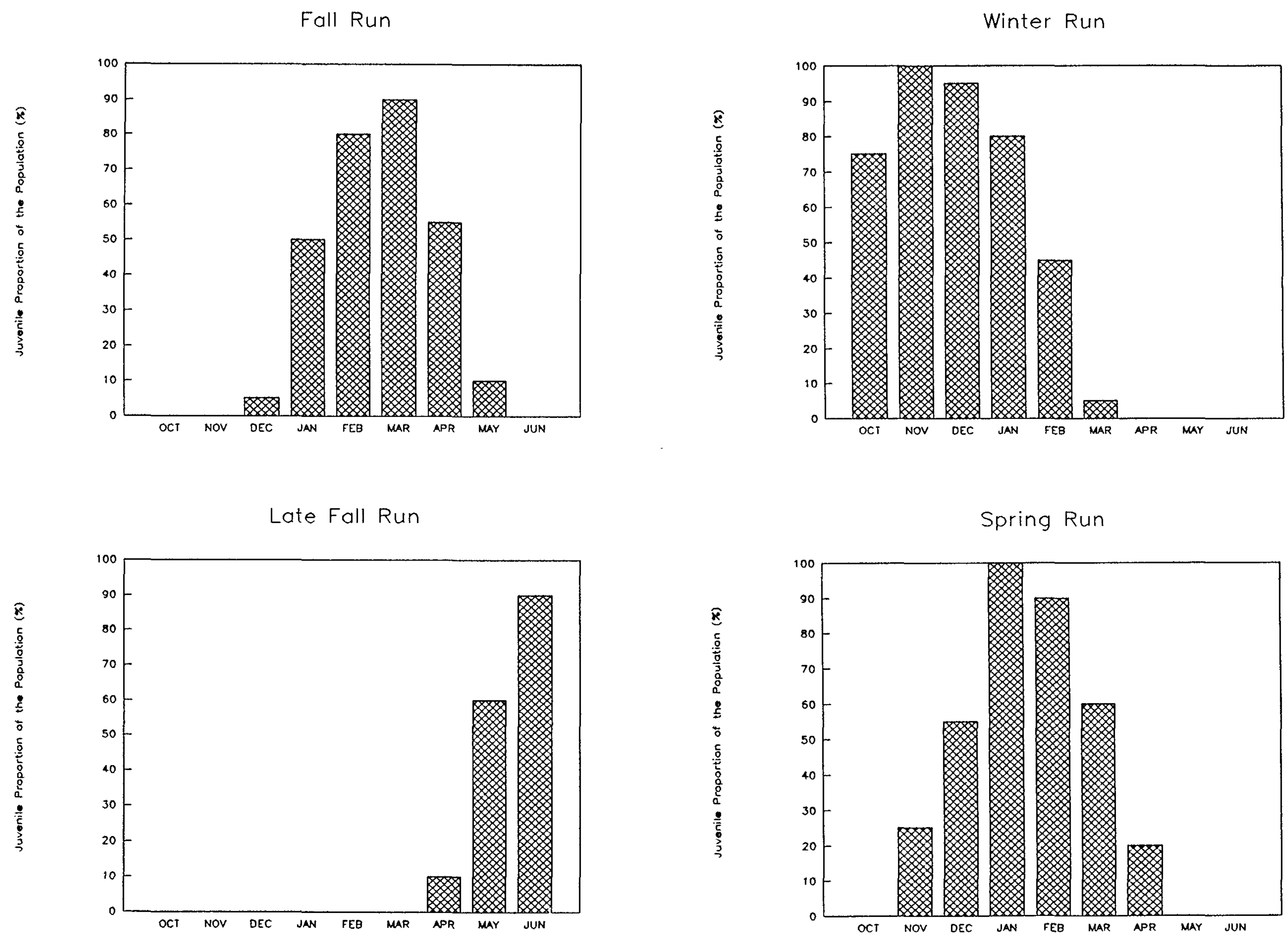

Figure 2. The Monthly Proportion of the Annual Juvenile Production of Fall-, Late Fall-, Winter-, and Spring-Run Chinook Salmon Residing in the Sacramento River System

Distribution

Juvenile chinook salmon from the Sacramento River (and tributaries upstream of Chico), the Feather River, and Butte Creek may rear in the Sutter Bypass during flood events. The Sacramento River supports all four runs of chinook salmon (i.e., fall, late fall, winter, and spring) (Jones & Stokes Associates 1992). The Feather River and Butte Creek support primarily spring and fall runs.

Sacramento River. Juvenile chinook salmon from the Sacramento River may enter the Sutter Bypass at the confluence of the Sacramento and Feather Rivers, either through the Sacramento Slough or over flooded areas when flow exceeds the capacity of the normal river and slough channels.

Juvenile chinook salmon from the Sacramento River also enter the Sutter Bypass during flood events that result in spill through flood control facilities on the Sacramento River south of Chico, including Tisdale Weir, Colusa Weir, and Moulton Weir (Jones & Stokes Associates 1993) (Figure 1). The proportion of monthly Sacramento River flow diverted into the Sutter Bypass during 1941-1991 varied from 0% for drier years to over 70% for wetter years. Assuming juvenile chinook salmon move down the Sacramento River and into the Sutter Bypass in proportion to flow, the greatest proportion would be diverted during December through March, with peak diversion during February (Figure 3).

The potential for diversion of a substantial proportion of Sacramento River flow coincides with the peak occurrence of juvenile chinook salmon from fall-, winter-, and spring-run populations. The probability that a substantial proportion of Sacramento River flow will be diverted, however, is relatively low. During February, diversion of more than 20% of the flow would occur about 20% of the time (Figure 4). No Sacramento River flow would be diverted about 75% of the time during February. Diversion of Sacramento River flow into the Sutter Bypass during other months is less frequent.

Butte Creek. Although some of the flow from Butte Creek enters the Sacramento River at the Butte Slough outfall gates, most of the flow continues south to the Sutter Bypass (Hillaire 1992). During flood events, especially when Sacramento River flow exceeds channel capacity and enters Butte Sink, nearly all of the Butte Creek flow would continue south to the Sutter Bypass (Figure 1). All juvenile chinook salmon moving down Butte Creek (spring and fall runs) are assumed to use available flooded habitat in the Sutter Bypass when migration timing coincides with flood events.

Feather River. Juvenile chinook salmon from the Feather River may enter the Sutter Bypass at the confluence of the Sacramento and Feather Rivers, either through the Sacramento Slough or over flooded areas when flow exceeds the capacity of the normal river and slough channels. During major flood events, Feather River flow enters the Sutter Bypass at Nelson Slough, immediately south of Willow Slough (Figure 1). The proportion of Feather River flow entering the Sutter Bypass through overtopping of the normal channel north of the confluence with the Sacramento River cannot be determined from available data. Juvenile chinook salmon moving down the Feather River (spring and fall run) likely

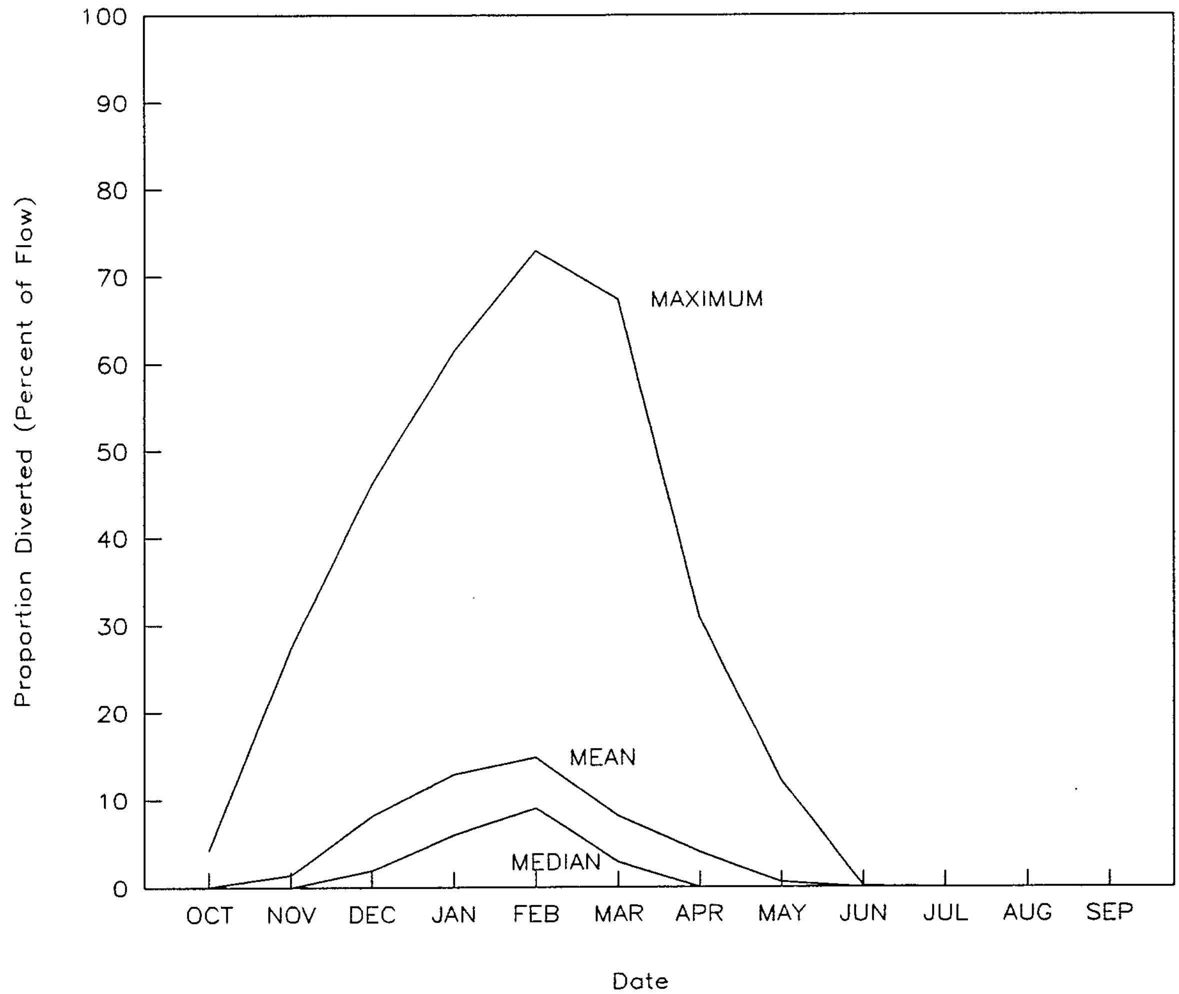

Figure 3. The Maximum, Mean, and Median Monthly Proportion of Sacramento River Flow Diverted into the Sutter Bypass (1942-1992)

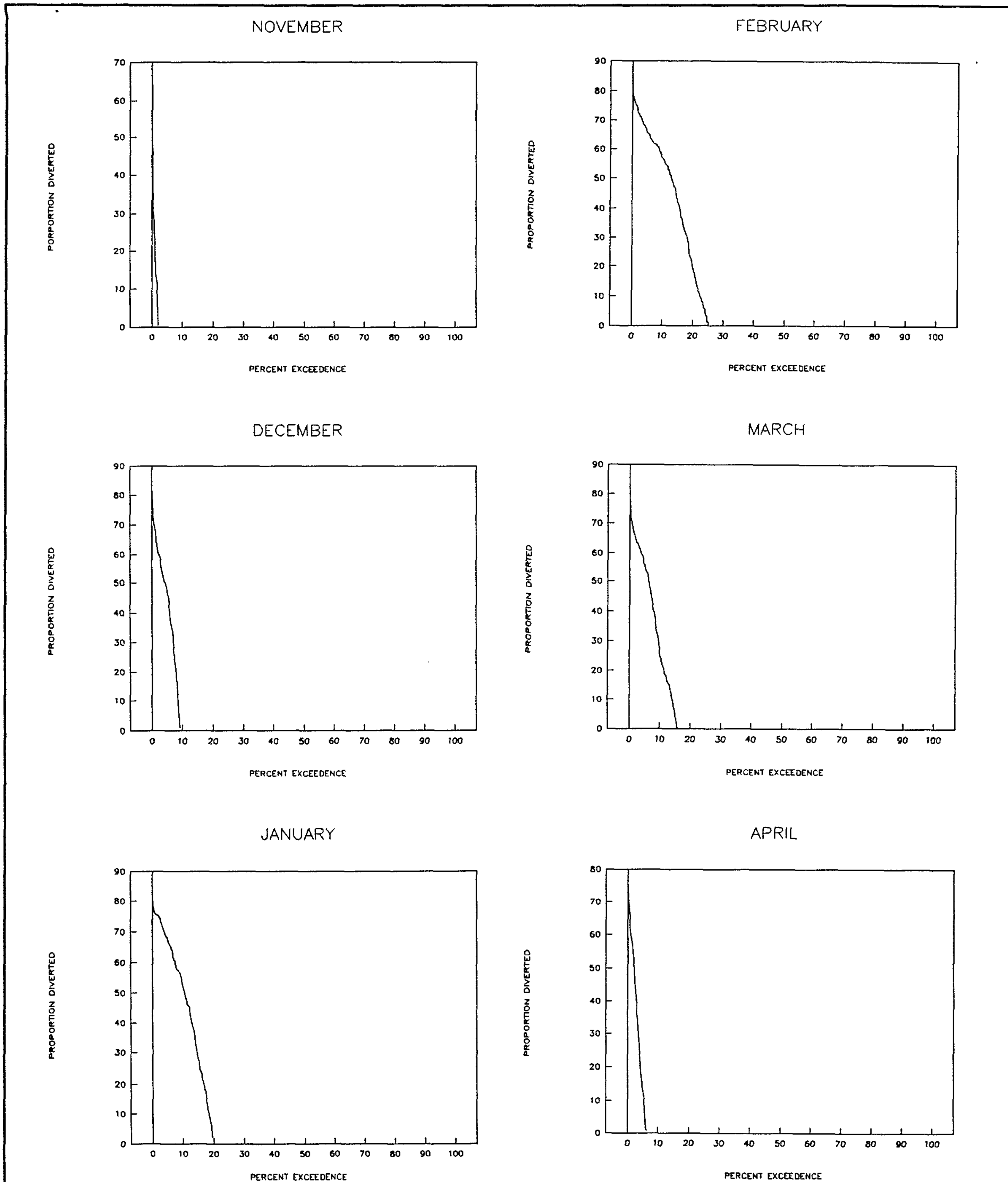

Figure 4. The Percent of Time That a Given Proportion of Sacramento River Flow Was Diverted into the Sutter Bypass (1942-1992)

continue downstream to the Sacramento River. Some use of flooded habitat in the Sutter Bypass would be expected, but the habitat is not as accessible to juveniles from the Feather River as it is to juveniles from the Sacramento River and Butte Creek.

Receding Flow Events

Entrapment of juvenile chinook salmon in the proposed gravel mining pond could occur only during receding events that leave the pond isolated from the adjacent river and slough channels. The extent of entrapment would depend on two factors: the abundance of salmon utilizing the flooded habitat over the proposed gravel mining pond and the response of juvenile chinook salmon to receding flow events.

Probability of Flooding and Receding Events

During March, the proposed gravel mining area has about a 70% chance of being flooded to 20 feet (ft) above mean sea level (MSL) and about a 60% chance of being flooded to 25 ft above MSL (Figure 5) (Meridian Consulting Engineers 1993). At 20 ft above MSL, only about 10% of the proposed gravel mining area would be flooded (Figure 6). At 25 ft above MSL, about 80% of the proposed gravel mining area would be flooded.

The probability of one receding flow event during a given month is less than the probability of a flooding event because flooding may continue for several months, and the receding flow event may occur only during 1 month. The highest monthly probability of recession (about 40% chance of flow receding below 20 ft above MSL) occurs during March, the same as for flooding events.

When flooding of the Sutter Bypass occurs, there are likely to be several flooding and receding events during the same year (Meridian Consulting Engineers 1993). Fish entrapped in the proposed gravel mining pond by recession could escape during the following flood event. Survival in the pond would depend on suitable environmental conditions (e.g., temperature) over the period between receding and flooding events. For the historic record (1968-1992), the probability that recession will occur and that it will be the last receding event of the year is substantially less than the probability of a receding flow event, especially during the months preceding March (Figures 5 and 7).

Duration of Receding Events

The duration of the receding event is the period of time required for the water surface elevation over the proposed gravel mining pond to drop from 27 ft above MSL to below 20 ft above MSL. For the historic period (1968-1992), recession from 27 ft above MSL to 20 ft above MSL averaged 6 days, with a maximum of 11 days and a minimum of 5 days. Recession rates of over 1 foot per day are common, but rates in excess of 2 feet per day are rare (Meridian Consulting Engineers 1993). Recession rates are remarkably similar

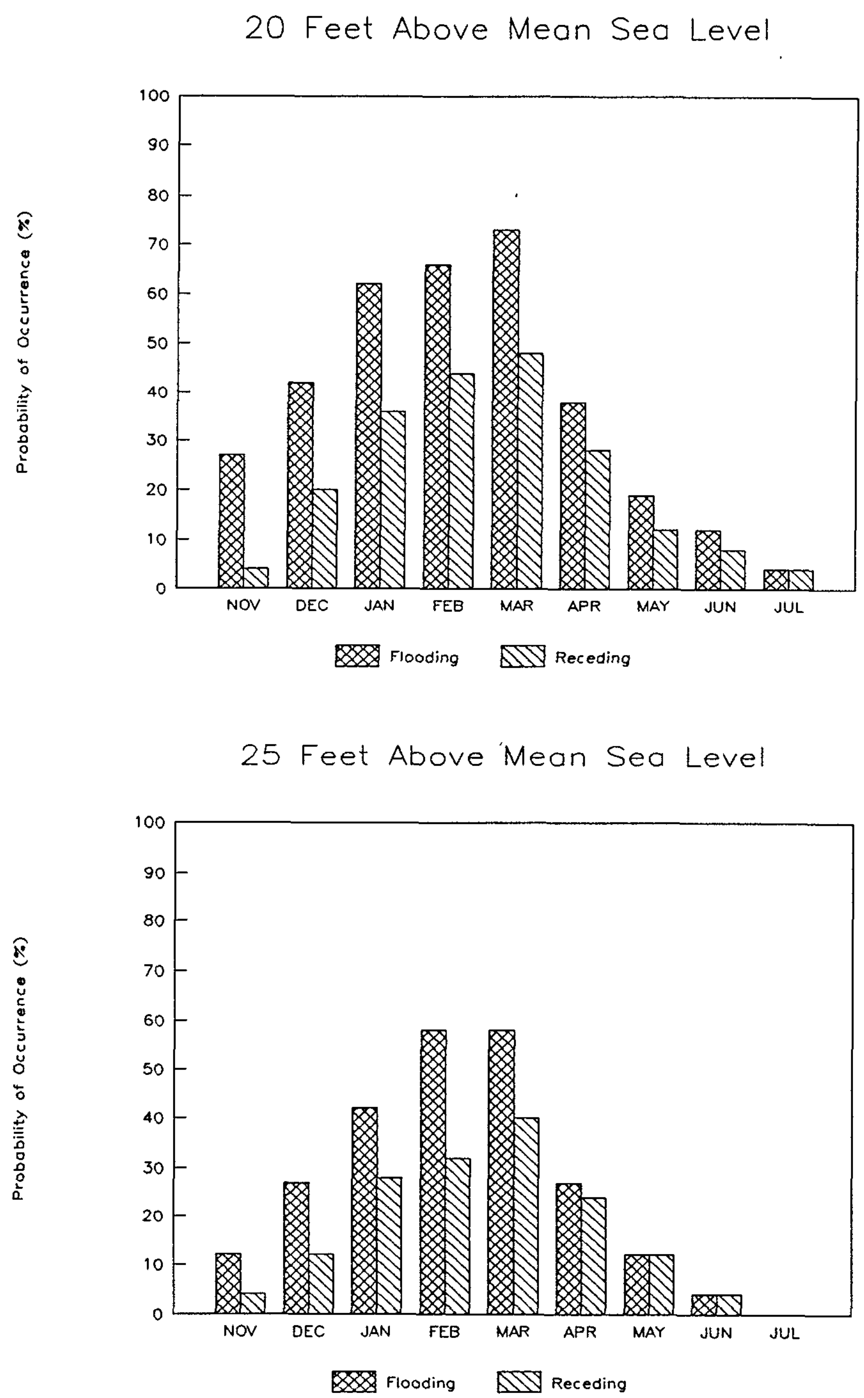

Figure 5. The Probability of Flooding and Receding Events at 20 and 25 Feet above Mean Sea Level

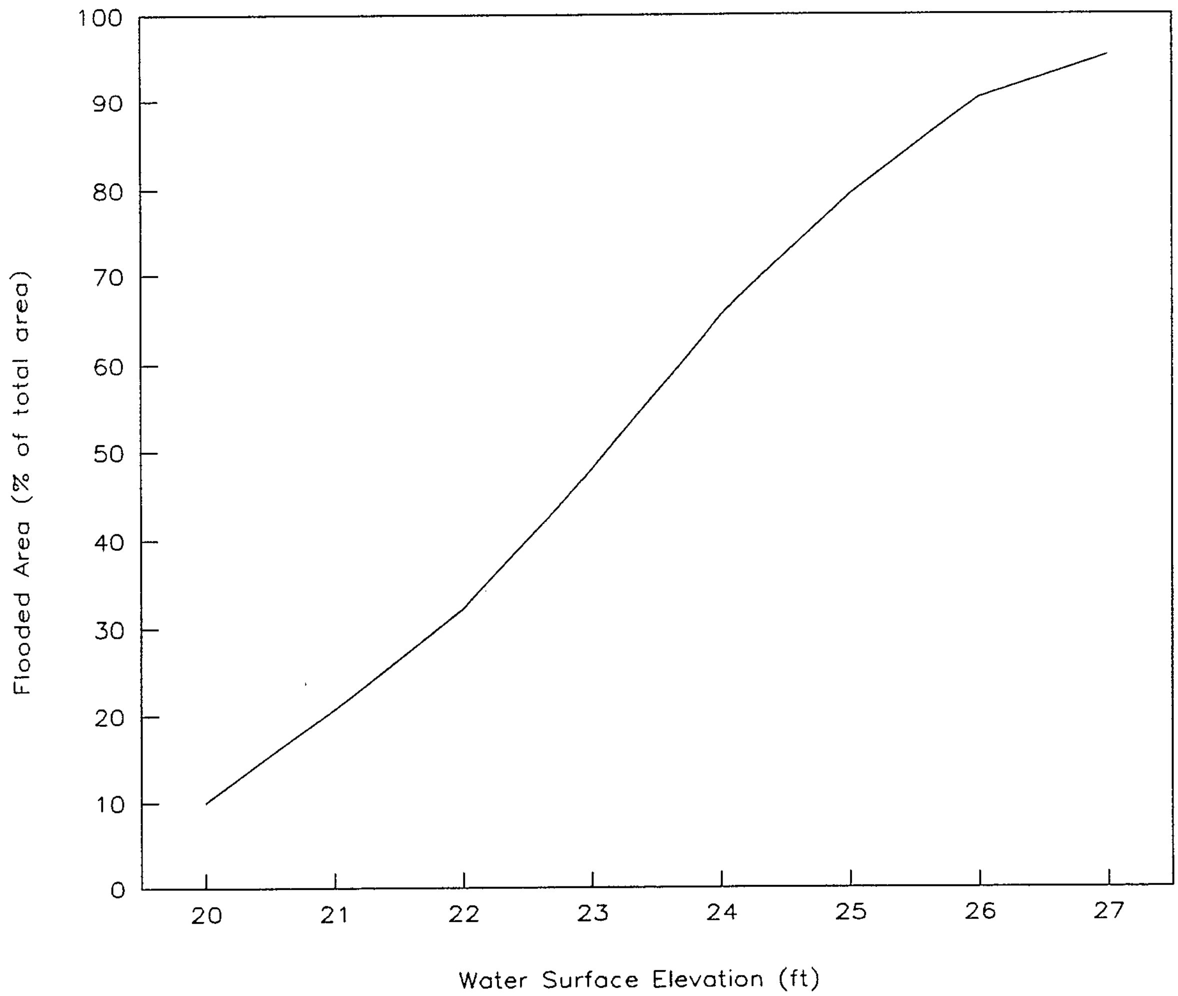

Figure 6. The Cumulative Proportion (%) of the Proposed Gravel Mining Area that Is Flooded at Water Surface Elevations from 20-27 Feet above Mean Sea Level

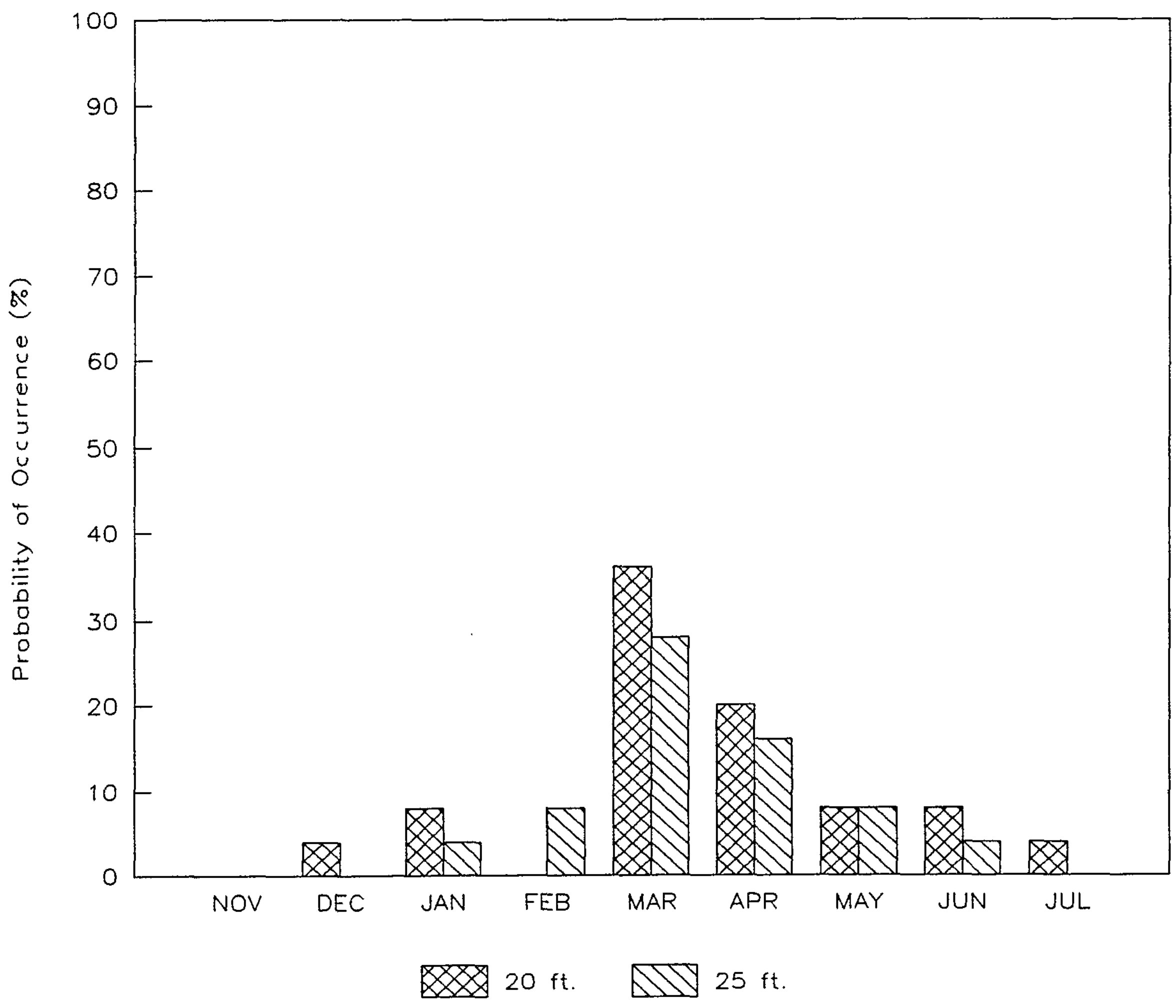

Figure 7. Probability That a Receding Event Will Occur at 20 and 25 Feet above Mean Sea Level and Will Be the Last Receding Event of the Year

between events, and the receding event that occurred during March 1993 is a representative event (Figure 8).

PROJECT DESIGN TO AVOID ENTRAPMENT OF JUVENILE CHINOOK SALMON

As discussed above, entrapment of juvenile chinook salmon in the proposed gravel mining pond is a concern because juvenile chinook salmon use temporarily flooded habitat in the Sutter Bypass. Peak use of temporarily flooded habitat by fall-, winter-, and spring-run chinook salmon potentially coincides with peak availability of flooded habitat and, for fall and spring run, the highest probability of flow recession that could result in entrapment. Pond design criteria may be implemented to reduce the potential for entrapment in the proposed gravel mining pond.

Connections to Adjacent Rivers and Sloughs

The proposed gravel mining pond should not have a permanent connection to the toe drain, Sacramento Slough, the Sacramento River, or the Feather River. Although a permanent connection may allow movement of juvenile chinook salmon out of the proposed gravel mining pond after a recession event, it would also enable movement into the pond any time juvenile chinook salmon were present in the rivers. Without a permanent connection, juvenile chinook salmon could enter the proposed gravel mining pond only during flood events that inundate the pond area.

Juvenile chinook salmon that may be entrapped in the pond would not necessarily exit through a permanent connection because the connection would be shallow (the bottom would be about 10 ft above MSL) relative to the depth of the proposed gravel mining pond (the bottom would be over 100 ft below MSL). Water temperature below the thermocline of the pond (that would likely form during spring when flooding ceases) may provide more suitable conditions to entrapped salmon than water temperatures in adjacent rivers and sloughs, where water temperature during late spring may exceed 65°F. Also, juvenile chinook salmon may have difficulty locating a permanent connection to adjacent rivers and sloughs.

A permanent connection, depending on design, could also provide habitat that is attractive to juvenile chinook salmon during flooding and receding events. Flow would recede from the proposed gravel mining pond through the permanent connection. The field studies indicated that chinook salmon are more abundant in areas of detectable velocity. Areas of detectable velocity during receding events could increase the abundance of fish entrapped in the proposed gravel mining pond.

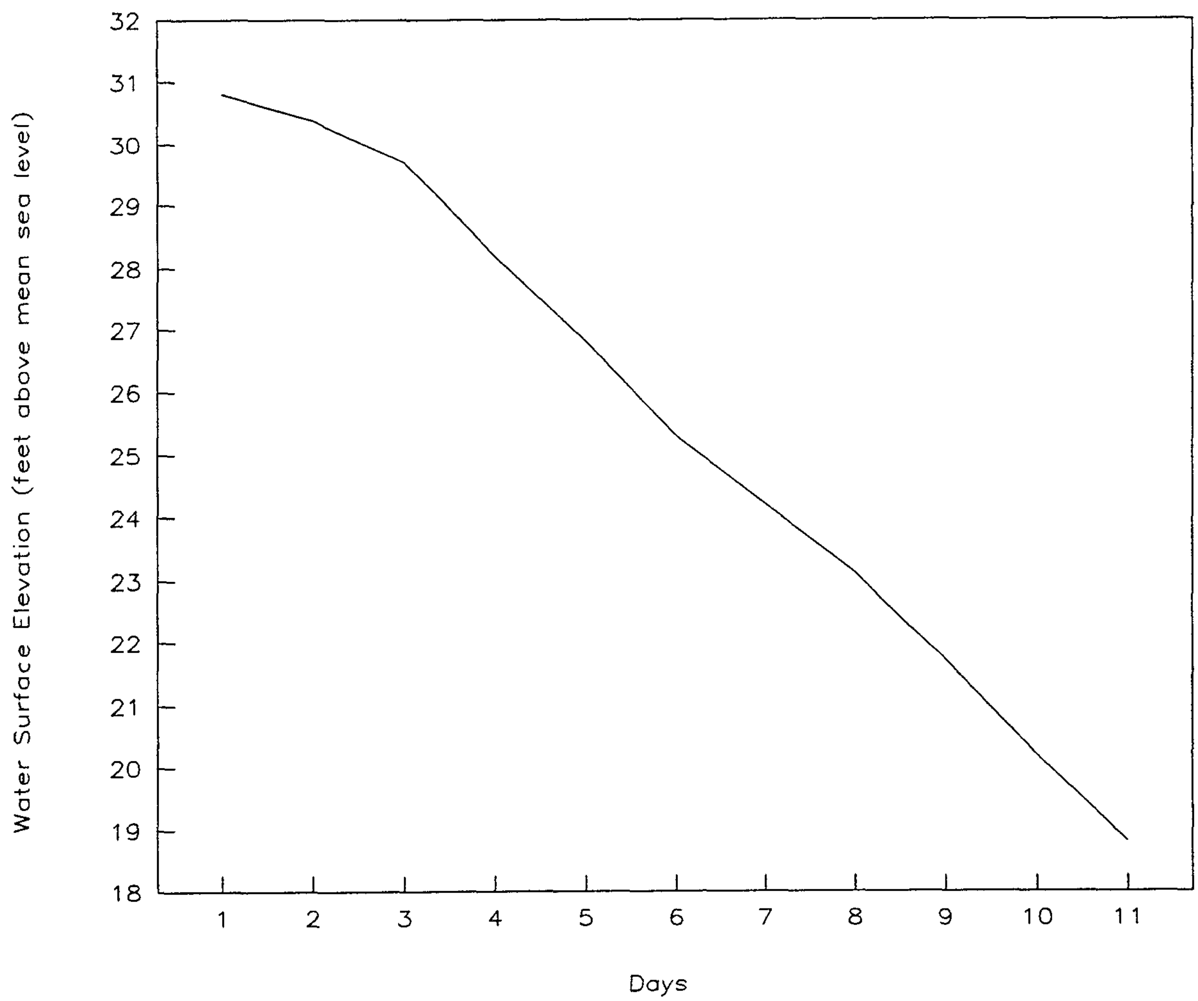

Figure 8. Daily Change in Water Surface Elevation That Occurred during a Receding Event Beginning on February 25, 1993

Temporary Connection to the East Toe Drain

The connection between the west toe drain and the proposed gravel mining pond should be severed at as high an elevation as possible. Under existing conditions, the maximum flooded area in the proposed gravel mining area occurs when the water surface elevation exceeds 27 ft above MSL. The gravel mining pond will provide access to habitat area dependent on the elevation that the pond is connected to the toe drain. The connection should be at the highest practical (in accord with flood control concerns) elevation because higher elevations are flooded slightly less frequently, and severance of the connection would occur when substantial habitat remains flooded (i.e., the density of fish in the remaining habitat is lower when more area is flooded).

Surrounding Topography

Surrounding areas should slope away from the pond. Juvenile chinook salmon and other fish will move toward deeper water as flow recedes. Slopes that drain toward the pond would increase potential entrapment.

The side of the proposed gravel mining pond adjacent to the toe drain should include a shelf area (50 to 150 ft wide) that is level with maximum water surface elevation in the pond when the pond is isolated from adjacent rivers and sloughs. During receding events, the shallow area would provide temporary habitat that would attract juvenile salmon from the deep pond habitat and concentrate them at potential escape routes.

Alternating raised and depressed areas (or dikes with extensive openings) along the side of the shelf toward the toe drain would provide areas where increased velocity may attract fish off the shelf area during receding flow events. The slope toward the toe drain would be similar to existing topography.

CITATIONS

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Appendix 1. Sutter Bypass Fisheries Field Surveys

EXECUTIVE SUMMARY

During flooding and receding events, fish responded to changes in physical factors. The discrete effects of physical factors (i.e., temperature, velocity, flooded area, habitat type, water depth, turbidity, substrate, and cover) were not clearly defined because all factors are interrelated.

Water temperature and velocity were important to the distribution of all species, especially chinook salmon. Metabolic needs and limitations and specific lifestage requirements (i.e., spawning habitat) were likely the main determinants for response to temperature. The response to velocity may be a behavioral adaptation that enables fish to exploit flooded habitat and avoid entrapment during receding flow.

INTRODUCTION

Teichert Aggregates (Teichert) has acquired nearly 6,000 acres of land in and adjacent to the Sutter Bypass in Sutter County and is currently exploring the feasibility of wet pit mining of aggregate deposits within an area of 500-1,000 acres. The proposed mining area is at the southern end of the Sutter Bypass, near the junction of the bypass and the Sacramento River (Figure 1-1), and is on an elevated floodplain that is currently under intensive agricultural cultivation and that is part of a constructed flood control system.

One of the potential effects on fisheries resources is entrapment of fish, especially chinook salmon, in the ponds created by the proposed gravel mining operation (Jones & Stokes Associates 1992). Juvenile chinook salmon would enter the ponds during flood events that inundate the mining area and remain in the ponds after flows recede. The number of fish entrapped would depend on the coincidence of receding inundation events with the migration timing of juvenile chinook salmon and on the behavior of juvenile chinook salmon. The purpose of the fisheries surveys was to gather information on the behavior of juvenile chinook salmon during flooding and receding flow events and the effect on distribution and abundance.

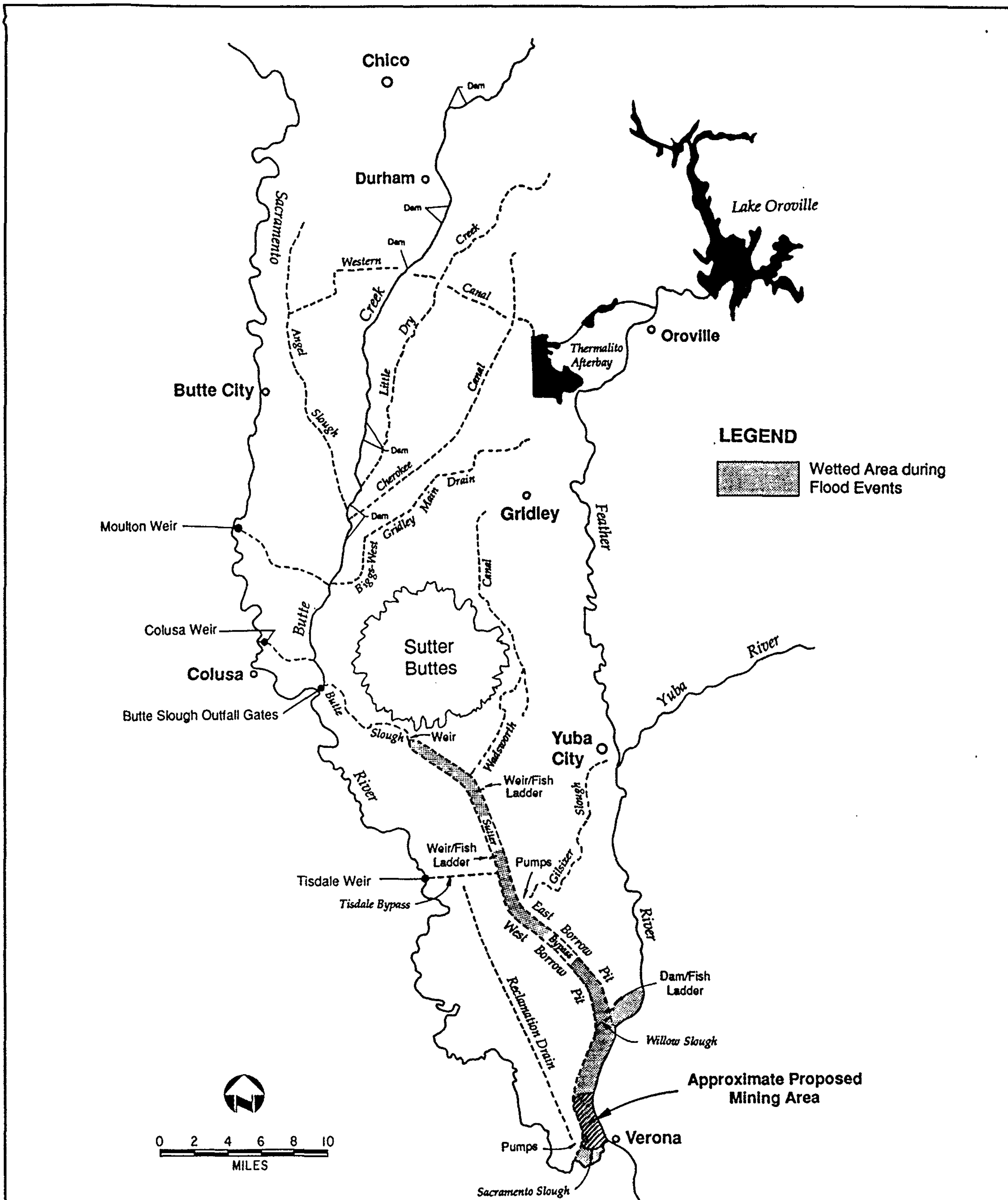

Figure 1-1. Butte And Sutter Basins Water Resources Study Area

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OBSERVATION OF FLOODING AND RECEDING EVENTS

During January-March 1993, flow in the Sacramento River and the Sutter Bypass was sufficient to flood the area in the southern portion of the Sutter Bypass where Teichert is proposing to extract sand and gravel resources. Ground elevation in the proposed gravel mining area is between 17 and 30 feet above mean sea level (MSL). Most of the area lies between 20 and 27 feet above MSL (Table 1-1) (Meridian Consulting Engineers 1993). Water surface elevation over the proposed gravel mining area during flood events exceeded 30 feet above MSL (Figure 1-2).

The proposed gravel mining area was visited seven times during three flood events (Figure 1-2). Flow direction was observed and flow velocity was estimated. When the stage is greater than 26 feet and less than 30 feet, most of the proposed gravel mining area is flooded (Meridian Consulting Engineers 1993). Flow in the Sutter Bypass is southerly and enters Sacramento Slough and the Sacramento River via overbank flow (Figure 1-3). Water velocity over much of the proposed mining area is near 0 feet per second (fps) (Figure 1-3).

At about 25 feet, a ridge of high ground is exposed along Sacramento Slough and blocks flow to the south. Flow direction shifts to the west and water drains toward the toe drain on the west side of the bypass (Figure 1-4). The toe drain carries flows into Sacramento Slough, and the Sacramento Slough drains toward the Sacramento River. Water velocity in both the toe drain and Sacramento Slough increases relative to water velocity that occurred when the stage was 26 to 30 feet (Figure 1-4).

As stage continues to recede to below 20 feet, only the west side of the bypass north of Sacramento Slough remains flooded (Figure 1-5). Connections between the west toe drain and flooded agricultural land (i.e., rice fields) are maintained primarily through agricultural drainage ditches.

FISH SURVEYS

During three visits to the Sutter Bypass, fisheries surveys were conducted. The purpose of the fisheries surveys was to gather information on the behavior of juvenile chinook salmon and other species during flooding and receding flow events. The occurrence and distribution of fish in the flooded areas was recorded. Physical parameters (i.e., depth, velocity, turbidity, and temperature) were also recorded.

Table 1–1. Area Flooded at Variable Water Surface Elevations Relative to Mean Sea Level

Water Surface Elevation (feet)	Cumulative Area Inundated	
	Acres	Percent of Total Area
20	140	10%
21	290	21%
22	450	32%
23	670	48%
24	915	65%
25	1,110	79%
26	1,265	90%
27	1,335	95%
Total	1,400	100%

Source: Meridian Consulting Engineers 1993.

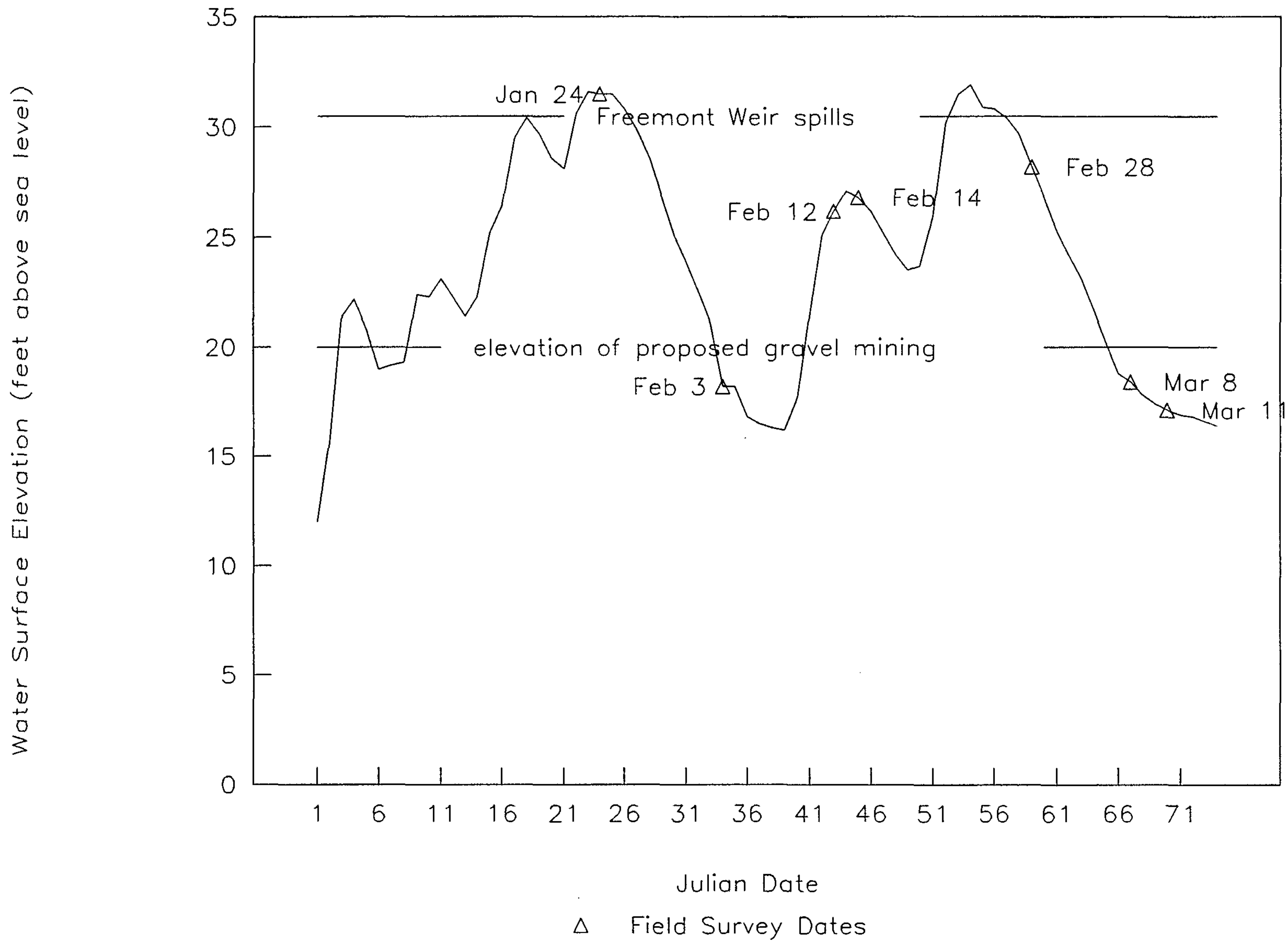

Figure 1-2. Sutter Bypass Water Surface Elevation during 1993

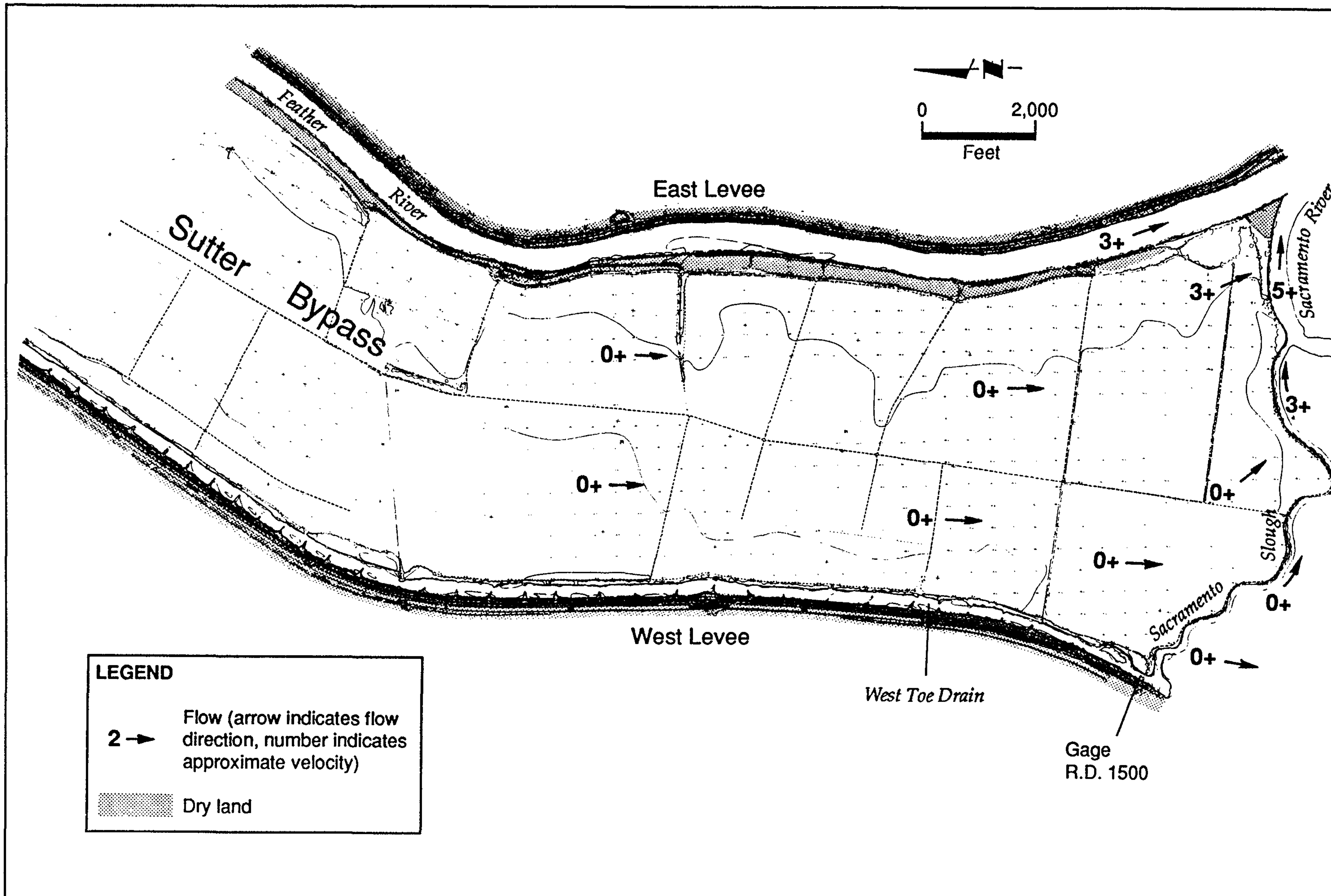

Figure 1-3. Flow Velocity and Direction when Water Surface Elevation is about 32 feet at Gage R.D. 1500 (January 24, 1993)

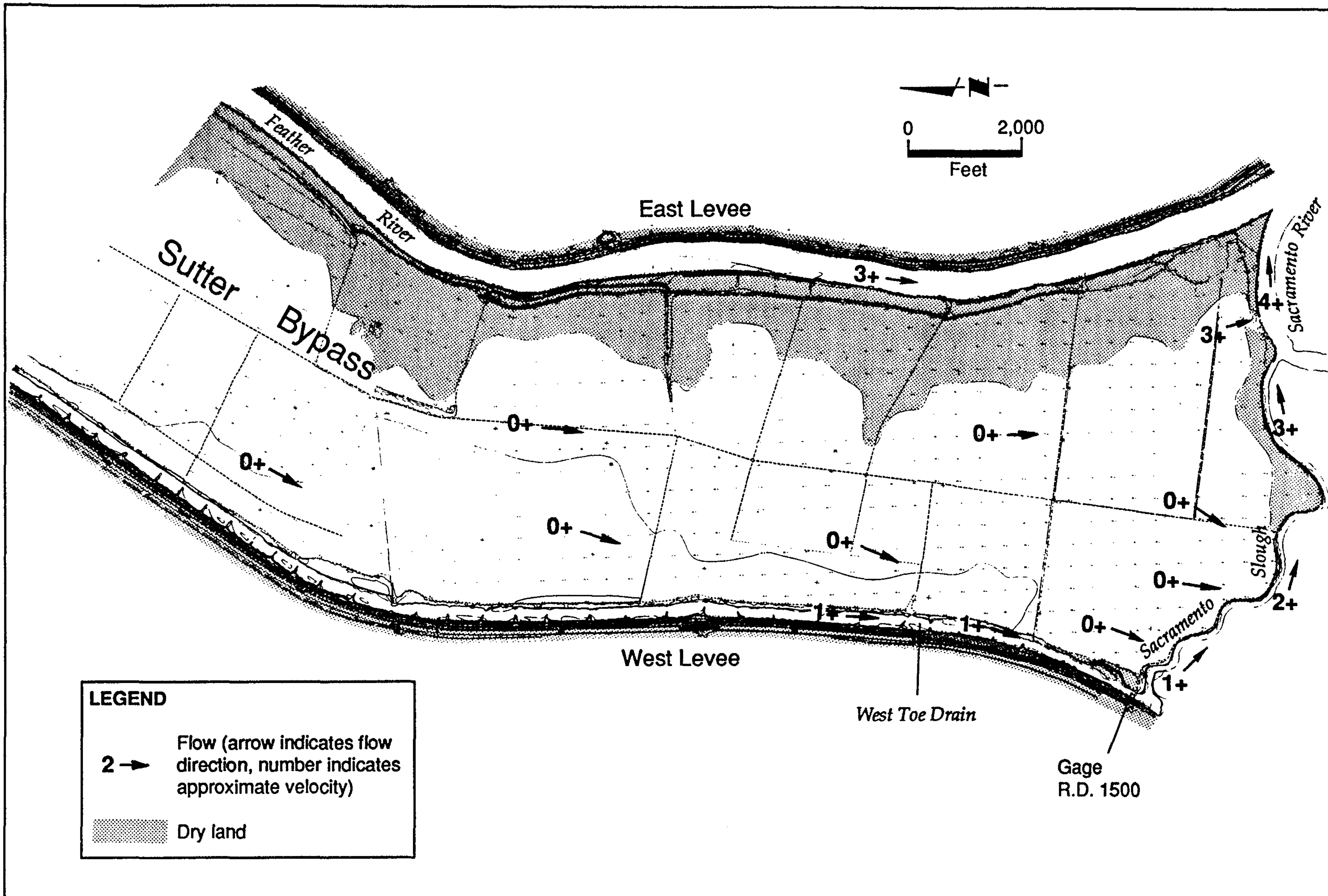

Figure 1-4. Flow Velocity and Direction when Water Surface Elevation is about 25 feet at Gage R.D. 1500 (February 15, 1993)

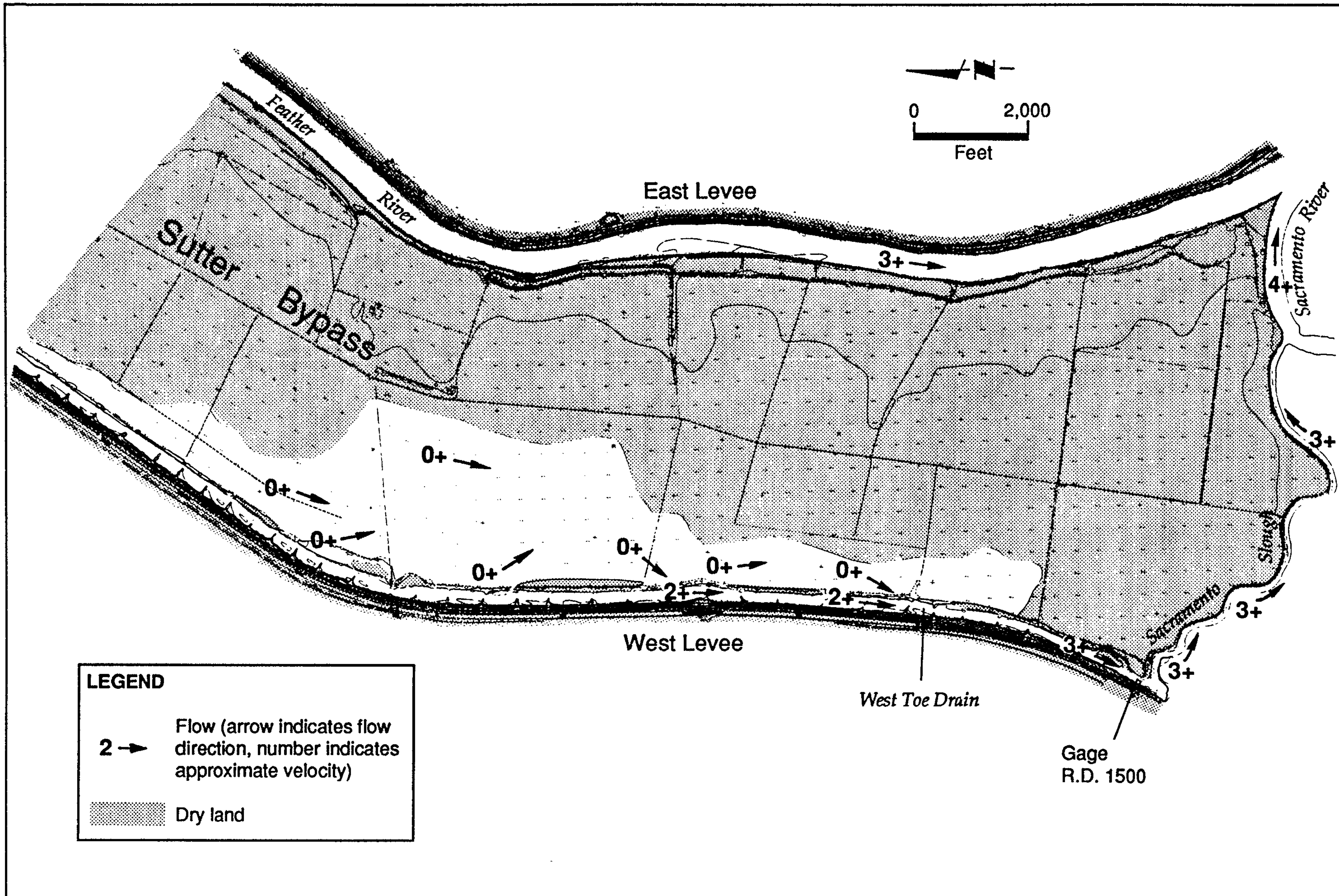

Figure 1-5. Flow Velocity and Direction when Water Surface Elevation is about 20 Feet at Gage R.D. 1500 (March 6, 1993)

Methodology

Gear

Fish samples were taken with a beach seine (50 feet long, 6 feet deep, with a 3/16-inch mesh opening) at 23 locations (Figure 1-6). The beach seines were usually drawn parallel to the shore for 100-200 feet, then turned and drawn onto the beach. The beach seine had a weighted bag in the center of the net that measured about 10 feet across.

On the February 14 survey, a 4-foot-diameter hoop net was set in a high-velocity area (about 4 fps) to sample fish moving with the flow (sample 0214A, Figure 1-6). The net was about 30 feet long, and the diameter gradually decreased from 4 feet at the head to 1.5 feet at the tail. The mesh size was 3/16 of an inch. There were no fykes in the hoop net.

Data Records

Captured fish were identified to species, and fork lengths were measured to the nearest millimeter (mm). The data were recorded separately for each sample. All fish were released immediately after measurement and enumeration. For threadfin shad and inland silversides, fork lengths of the first 10 fish were always recorded for each sample. The remaining threadfin shad and inland silversides were enumerated by species, but fork length was not always taken.

Results

Physical Data

Fisheries surveys were taken on February 14, March 8, and March 11, 1993. Including the one hoop net sample, 24 samples were taken (Table 1-2). The water surface elevation ranged from 26.7 feet above MSL down to 17.1 feet. Water depth ranged from less than 1 foot to 4 feet. The area of flooded agricultural land over the project area on February 14 was about 1,300 acres. On March 8, the flooded area was roughly estimated at 400 acres, including rice fields that were still flooded and slowly draining. On March 11, the flooded area was probably less than 200 acres and most of the rice fields had completely drained.

Five habitat types were identified during the surveys, including rice fields, inlet and outlet areas of rice fields, agricultural drainage ditches, agricultural fields, and temporary channels (Table 1-2). Although most of the samples were taken over flooded agricultural fields, rice fields were classified as a separate habitat type because of reduced runoff rates caused by existing dikes and the potential for stranding fish within the dikes. Rice field inlet and outlet areas were treated separately because flow was detectable in those areas. Outlets

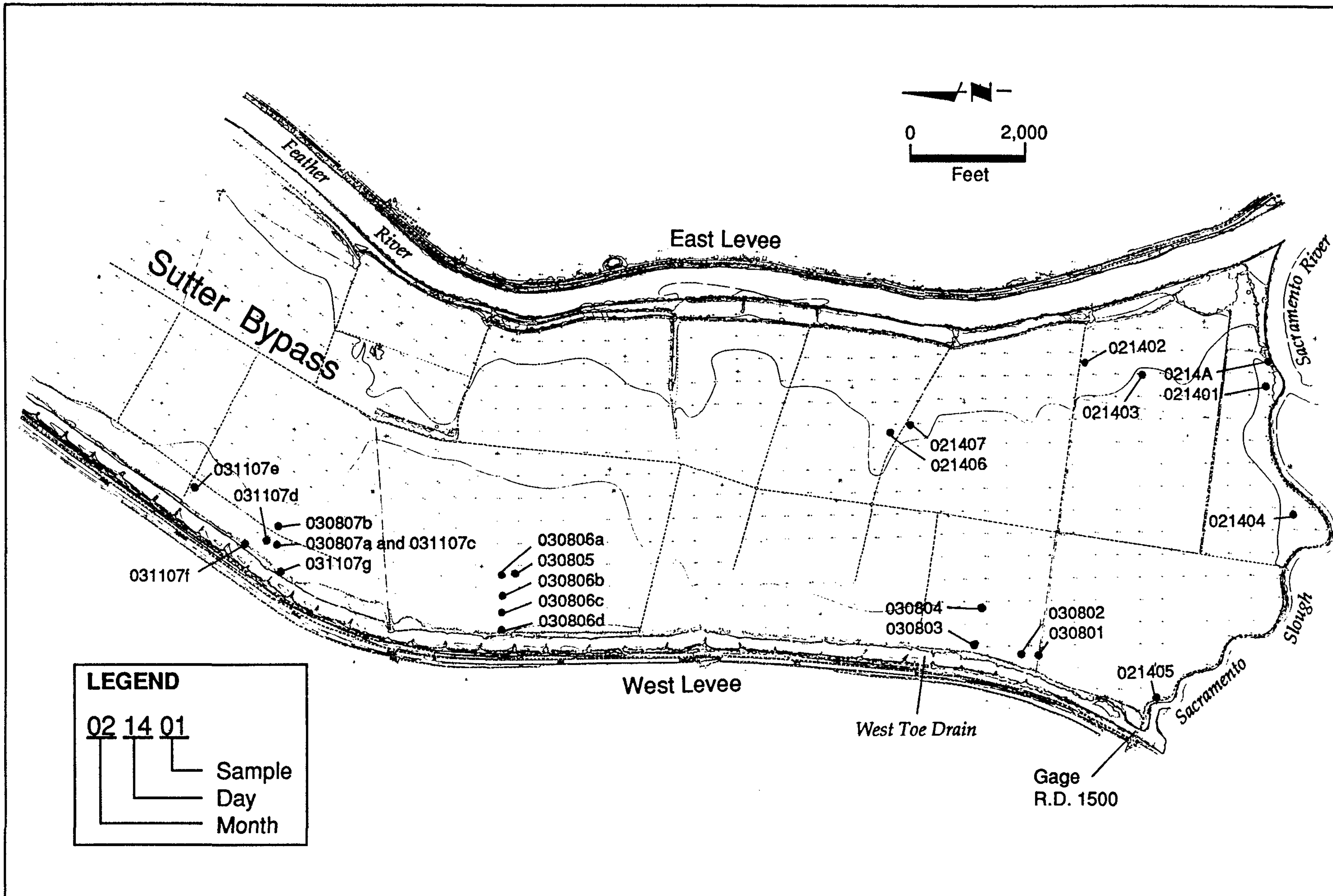

Figure 1-6. Location of Samples Taken during Three Surveys, February and March 1993

Table 1-2. Physical Data for Fisheries Samples Taken in the Sutter Bypass, February-March 1993

Sample	Type	Sample Orientation	Stage (feet)[a]	Habitat Type[b]	Area Sampled (square feet)	Depth (feet)	Velocity (feet/second)[c]	Water Temperature (°F)	Secchi Disk (feet)
0214 A	hoop net	parrallel to current	26.7	temporary channel	4.7 [d]	1.1	4	51	0.5
021401	beach seine	parallel to shore	26.7	agricultural field	5,250	2-3	0.5-1	51	0.5
021402	beach seine	parallel to shore	26.7	agricultural field	7,000	3	0	51	0.5
021403	beach seine	mid-water	26.7	agricultural field	3,500	3	0	51	0.5
021404	beach seine	parallel to shore	26.7	agricultural field	7,000	1.5	None	51	0.5
021405	beach seine	parallel to shore	26.7	agricultural field	3,900	3-4	0	53	0.5
021406	beach seine	parallel to shore	26.7	agricultural field	4,900	3	0	53	0.5
021407	beach seine	parallel to shore	26.7	agricultural field	4,900	3	None	53	0.5
030801	beach seine	parrallel to current	18.2	ditch	1,520	4	0	57	1.1
030802	beach seine	parallel to shore	18.2	agricultural field	7,000	<1	None	62	>1
030803	beach seine	parallel to shore	18.2	agricultural field	8,050	2	0.3	61	1.1
030804	beach seine	right angle to shore	18.2	agricultural field	10,500	1-1.5	0	61	>1
030805	beach seine	parrallel to current	18.2	ditch	720	4	0	70	1.1
030806a	beach seine	parallel to shore	18.2	rice field inlet	3,150	1	0	72	>1
030806b	beach seine	parallel to shore	18.2	rice field inlet	3,150	1	0	72	>1
030806c	beach seine	parallel to shore	18.2	rice field inlet	3,150	1	0	72	>1
030806d	beach seine	parallel to shore	18.2	rice field inlet	3,150	1	0	72	>1
030807a	beach seine	parallel to shore	18.2	rice field	6,650	2.5	0	66	1.1
030807b	beach seine	parallel to shore	18.2	rice field	6,650	0.8	None	72	>1
031107c	beach seine	parallel to shore	17.1	rice field	6,650	1-1.5	None	59	>1
031107d	beach seine	parallel to shore	17.1	rice field	6,650	1-1.5	None	59	>1
031107e	beach seine	parallel to shore	17.1	rice field inlet	8,750	1-1.5	None	59	>1
031107f	beach seine	parallel to shore	17.1	rice field outlet	7,000	1-2	0	59	>1
031107g	beach seine	parallel to shore	17.1	rice field	7,000	1-1.5	None	59	>1

[a] Elevation is in feet above mean sea level.

[b] Unless otherwise indicated, samples were taken over bare ground in agricultural fields.

[c] None means no detectable velocity, 0 means no measurable velocity.

[d] The volume sampled by the hoop net is in acre feet.

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allowed water to drain from all the rice fields included in the survey. Only the hoop net was fished in a temporary channel.

Water temperature ranged from 51°F to 72°F (Table 1-2). The maximum difference between water temperature in the toe drain (61°F) and water temperature over the rice fields (72°F) was about 11°F at 3:00 p.m. on March 8, 1993.

Although flow direction was detectable, flow velocity was usually not measurable (i.e., velocity was less than the sensitivity of the meter). Only three samples were taken where velocity was measurable (Table 1-2).

The turbidity was usually high, especially during the peak of the flood event. Turbidity generally declined as the water receded to the toe drain. The greatest depth for the Secchi disk reading was 1.1 feet (Table 1-2). Where the bottom was visible, the Secchi disk reading was recorded as >1 foot.

Fisheries Data

Over 700 fish representing 16 species were captured during the three surveys (Table 1-3). The most abundant species captured were threadfin shad, inland silversides, chinook salmon, Sacramento squawfish, and fathead minnow. Sacramento squawfish and chinook salmon occurred in 14 of the 24 samples, more often than all other species.

Chinook salmon and Sacramento squawfish were all juveniles. Chinook salmon were the only species where size exhibited a statistically significant difference between fish captured in February and fish captured in March. The average size of chinook salmon in February was 44 mm and the average size in March was 57 mm (Figure 1-7).

The average size of Sacramento squawfish for all samples was 71 mm (Figure 1-8). The inland silversides, threadfin shad, and fathead minnows were primarily adult fish, and the average size was 66 mm, 86 mm, and 51 mm, respectively (Figure 1-8).

The only large fish (>200 mm) captured were three adult carp, seven Sacramento splittail, one channel catfish, and one redear sunfish. The splittail were in two size groups: two fish measured about 340 mm in length and 5 measured about 220 mm. The splittail that measured 220 mm had orange pectoral and pelvic fins. Of the seven splittail captured, six were captured in one seine in an area where carp were spawning, and the water temperature was 72°F.

Discussion and Conclusions

The purpose of the fisheries surveys was to gather information on the behavior of juvenile chinook salmon and other species during flooding and receding flow events and the effect on distribution and abundance. The physical and biological data presented above

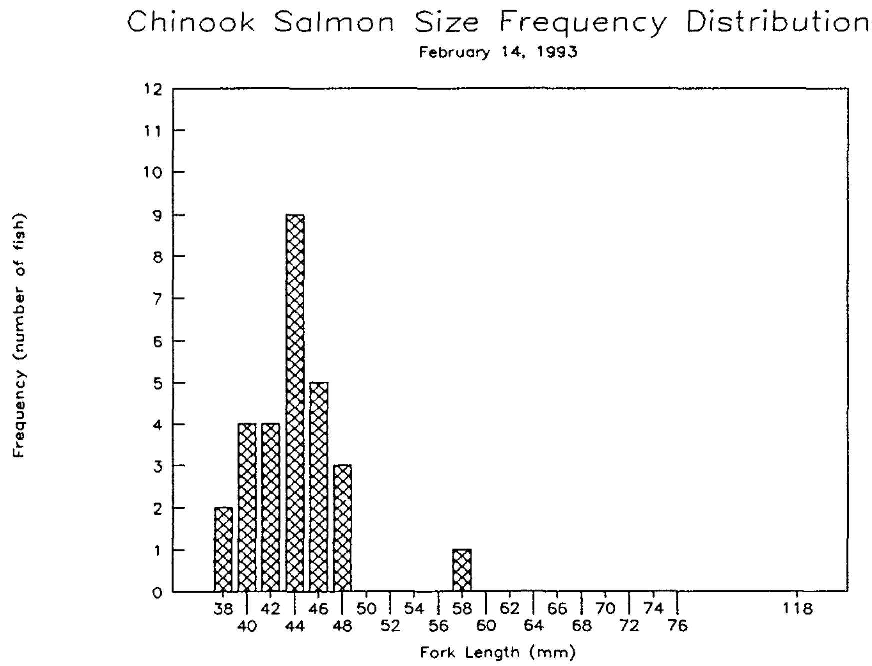
Table 1–3. Fish Captured during the Field Surveys in the Sutter Bypass, February–March 1993

Sample	Fish Sampled by Species[a]																Total Individuals Sampled[b]	Total Species Sampled[c]
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16		
0214 A	1	3							1								5	3
021401	21	7			1												29	3
021402		1			1						1						3	3
021403																	0	0
021404	1																1	1
021405	3	3			2						1						9	4
021406	2									2		6	1				11	4
021407		4	1							1	1	1					8	5
030801	5	23			20	1		1	8	2		8		1		2	71	10
030802	1					1				6							8	3
030803	6									5	1	54					66	4
030804	41	12			2				4	1	1	3				1	65	8
030805		1			2	2										1	6	4
030806a		4									1	1					6	3
030806b	1	3										11				1	16	4
030806c												3					3	1
030806d		11	6		1	3										2	23	5
030807a	7														2		9	2
030807b		1									3						4	2
031107c																	0	0
031107d					1		1			1							3	3
031107e	18	3			9	1	1				18	6					56	7
031107f	16	13		1	1			2		1	172	107				2	315	9
031107g	3									2	1						6	3
Total Fish Sampled	126	89	7	1	40	8	2	3	13	21	200	200	1	1	2	9	723	

[a] Species Key:
Chinook salmon = 01
Sacramento squawfish = 02
Sacramento splittail = 03
Hitch = 04
Fathead minnow = 05
Carp = 06
Red shiner = 07
Golden shiner = 08
Sacramento sucker = 09
Mosquito fish = 10
Inland silversides = 11
Threadfin shad = 12
Channel catfish = 13
Logperch = 14
Redear sunfish = 15
Bluegill = 16

[b] Represents the total number of individual fish in each sample.

[c] Represents the total number of species in each sample. Sixteen species were captured during the surveys.



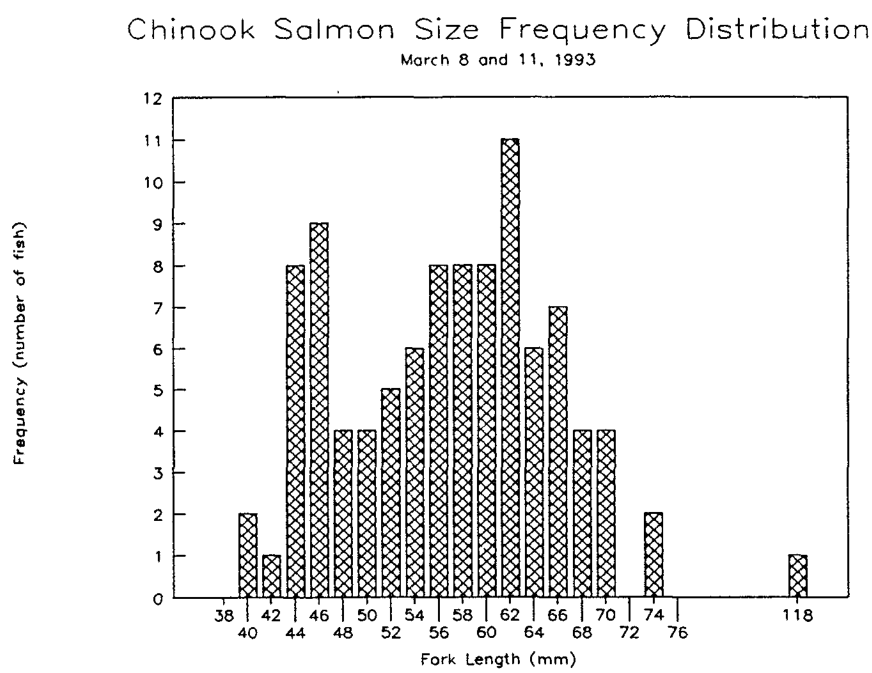


Figure 1-7. Size Frequency Distribution of Chinook Salmon

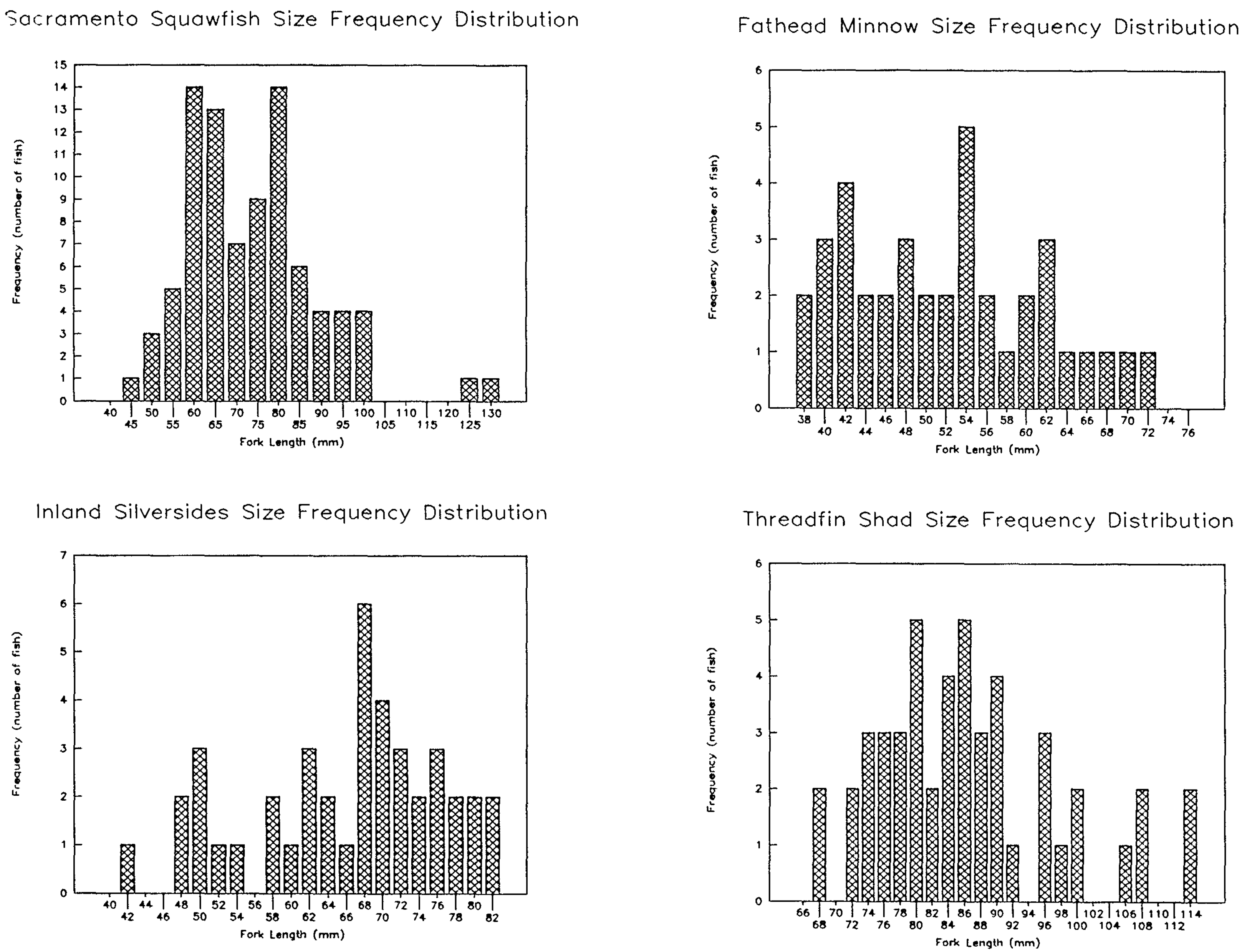


Figure 1-8. Size Frequency Distribution of Sacramento Squawfish, Inland Silversides, Fathead Minnow, and Threadfin Shad

were evaluated to determine the response of fish (i.e., change in distribution and abundance) to conditions during receding events. Statistically valid conclusions were difficult to obtain under the existing time and cost constraints because the study area was relatively large (>1,500 acres), physical conditions (flooded area, available habitat type, depth, velocity, turbidity, and temperature) were highly variable and interrelated, and the occurrence of some species (including chinook salmon and Sacramento splittail) was partially dependent on the coincidence of migration with the inundation of the Sutter Bypass.

Biological Factors

As indicated by the species composition of the fisheries surveys, fish intentionally use flooded habitat and are not randomly distributed by currents during flood events. Most of the fish captured over the flooded habitat are either juveniles (chinook salmon and Sacramento squawfish) or adults of small forage species (inland silversides, threadfin shad, and fathead minnow). Few of the species that commonly occur in the toe drain (catfish, largemouth bass, bluegill, redear sunfish, goldfish, and carp) were captured over the flooded habitat.

Fish are assumed to use flooded habitat in the Sutter Bypass in response to factors that affect growth, survival, and spawning success. The assumption is supported by the analysis of the response to physical factors discussed in the following section, especially the response to temperature.

Growth. Fish growth is primarily a function of factors inherent to each species and life stage, water temperature, and food availability. Improved growth rates may be realized through movement into habitats where water temperature enables optimal metabolism of the available food. As flow recedes, water temperature is generally higher over the flooded area than in the adjacent rivers and the toe drain. Food may also be more available over the flooded areas.

The difference in size of juvenile chinook salmon between the February and March surveys may indicate that substantial growth occurred (Figure 1-7). The juveniles that averaged about 62 mm in length during March may be the same juveniles that averaged about 44 mm during the previous month. If the change is representative of growth, the approximate 18-mm increase in length is substantially greater than the 10-mm increase that would be expected for juvenile chinook salmon in upstream habitats (National Marine Fisheries Service 1993).

The 62-mm juvenile chinook salmon captured in March, however, may not be the same group of juveniles that were in the bypass during February. An additional flood event occurred after February 14 that may have enabled migration of a new group into the Sutter Bypass. The occurrence of chinook salmon less than 50 mm in length during March indicates that at least some of the chinook salmon present in March arrived after the February flooding.

Survival. Fish use of flooded habitat may also improve survival. One channel catfish and one redear sunfish were the only fish captured in the survey that would have been feeding on the relatively abundant small fish (including juvenile chinook salmon). The density of predatory fish is likely much greater in the toe drain and the adjacent river channels than over the flooded agricultural fields.

Predation by fish may be avoided when prey fish move into flooded habitat. Western grebes, great blue herons, and great egrets, however, were observed feeding in flooded agricultural fields, and white pelicans were observed resting in flooded rice fields. The abundance of fish-eating birds was greater during March when flows had receded from most of the agricultural fields (possibly because fish density appeared to have increased) and turbidity was lower.

Spawning. Flooding in the Sutter Bypass may provide important spawning habitat for some species. Carp were observed spawning and were captured in one of the samples in a flooded rice field. Adult Sacramento splittail were captured in the same sample. The elevated temperature of water flowing out of the flooded fields during a receding event may have stimulated spawning. The additional habitat and the occurrence of spawning conditions earlier than would have occurred in the toe drain during March may be important to spawning success.

Response to Physical Factors

Physical factors that affect the distribution and abundance of fish over flooded areas of the Sutter Bypass include available flooded area, available habitat type, water depth, flow velocity, turbidity, temperature, substrate, and cover. All of the factors were measured, at least qualitatively, except substrate and cover. Substrates were fine, consisting of clay-silt-loam mixtures, and were relatively similar at all sample locations. Many areas did not have cover. Cover, where it existed, consisted primarily of grasses (rice fields). Areas with large woody cover were not sampled.

The response of species to discrete factors was difficult to identify because factors are interrelated. The available flooded area was determined by the water surface elevation in the Sutter Bypass. A reduction in available area was accompanied by changes in available habitat types, reduced depth, reduced or increased velocity (depending on the location relative to the toe drain and Sacramento Slough), reduced turbidity, and increased variability in water temperature (depending on ambient air temperature and isolation from the toe drain).

Available Flooded Area. When the water surface elevation was about 18 feet above MSL (about 400 acres flooded, including rice fields), the total number of individuals captured per unit effort was much greater than the number captured when the water surface elevation was about 27 feet above MSL (about 1,300 acres flooded). The difference in catch may be attributable to increased density (because of reduced area), time of year (the lower elevation was sampled a month later), and proximity of the samples to the toe drain.

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Habitat Type. As discussed above for availabile flooded area, the response to habitat types is difficult to separate from responses to interrelated factors. The number of individuals captured per unit effort was greatest for ditch habitat. The primary reason that high numbers were captured in ditch habitat is probably because all other habitats drain into the ditches, and densities are at least temporarily high relative to other areas. The abundance of fish in ditches is dependent on area drained, timing of sample relative to habitat area that remains flooded, flow velocity, water temperature, and probably other factors. Water temperature may be a major factor that moves fish out of the ditches (see "Temperature" section below).

The least number of fish captured per unit effort occurred in the rice field samples (not including samples near inlets and outlets). The reduced number of fish may be attributable to shallow depth, absence of flow, and increased variability in water temperature. Response of fish to velocity is probably the main factor, considering that fish were concentrated at rice field inlets and outlets.

Although the catch per unit effort of most species was greater for rice field inlets and outlets than for rice fields and agricultural fields, catch per unit effort for chinook salmon was greater over agricultural fields. The lower abundance of chinook salmon at rice field inlets is probably in response to greater temperature variability and daily occurrence of water temperatures exceeding 65°F.

Depth. The response of fish to changes in depth could not be evaluated because depth and available flooded area were interrelated in this survey. Part of the interrelationship is attributable to gear limitations and experimental design; however, both available depth and available habitat area are dependent on water surface elevation in the Sutter Bypass. Generally, the sampling depth was 1-2 feet when the water surface elevation was about 18 feet above MSL and 3-4 feet when the water surface elevation was about 27 feet above MSL.

Velocity. The total number of individuals captured per unit effort when velocity was detectable was about six times greater than the number of individuals captured when velocity was not detectable. All species were more abundant where velocity was detectable. The response of species to velocity may reduce the vulnerability to entrapment in temporarily flooded areas that become isolated from the toe drain as flow recedes.

Turbidity. The response of fish to changes in turbidity could not be evaluated because turbidity and available flooded area were interrelated in this survey. Turbidity, available depth, and available habitat area are dependent on water surface elevation in the Sutter Bypass. Generally, as indicated by Secchi disk readings, turbidity was greatest during the initial flooding and declined as flow receded (Table 1-2).

Temperature. The response to water temperature is dependent on the metabolic needs inherent to each species. The total number of individuals captured per unit effort when water temperature was less than 65°F was about three times greater than the number of individuals captured when water temperature was 65°F or higher. Some species, however, were most abundant where water temperature was greater than 65°F.

Chinook salmon appeared to be the most sensitive species to temperature, and nearly all were captured where water temperature was less than 65°F. The response is expected because chinook salmon is a cold water species. Optimal growth and survival of juvenile chinook salmon occur at water temperatures between 50°F and 65°F, depending on food availability and other factors (Brett et al. 1982, Raleigh et al. 1986). The response of chinook salmon to temperatures greater than 65°F is supported primarily by samples in ditch and rice field inlet and outlet habitat. Chinook salmon were generally absent from these habitats when the water temperature exceeded 65°F.

Squawfish and other species (threadfin shad, inland silversides, and fathead minnows) appeared to be more tolerant of water temperature above 65°F, but like chinook salmon, were most abundant where water temperature was less than 65°F.

The data indicate that carp and Sacramento splittail were more likely captured where temperature exceeded 65°F. Both carp and Sacramento splittail are warm water species, and the individuals captured were primarily adult fish. Warmer water may provide the preferred spawning habitat.

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