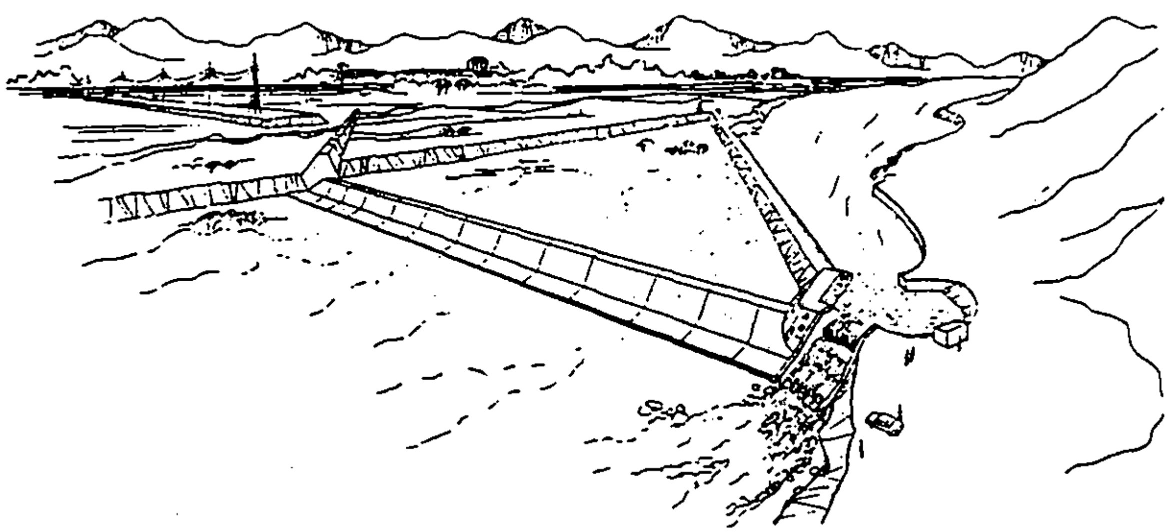
AN ASSESSMENT OF THE IMPACTS OF THE PROPOSED IMPROVEMENTS TO THE VERN FREEMAN DIVERSION ON ANADROMOUS FISHES OF THE SANTA CLARA RIVER SYSTEM, VENTURA COUNTY, CALIFORNIA



JULY, 1980

PREPARED FOR THE VENTURA COUNTY ENVIRONMENTAL RESOURCES AGENCY

UNDER CONTRACT NUMBER 670

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BY

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SUMMARY

The Santa Clara River is one of the southernmost rivers in Calfornia which still supports a run of steelhead and Pacific lamprey. Historically, the Santa Clara River probably supported an average annual run of 9000 spawning adult steelhead, and an unknown number of Pacific lamprey. The contemporary runs of anadromous fishes are believed to represent only a remnant of the former runs.

A number of factors have contributed to the decline of anadromous fish populations in the Santa Clara River system, including the reduction of instream flows, blockage of spawning and rearing tributaries, degradation of water quality, and alteration of the stream bed for flood control and sand and gravel extraction. However, the single most important factor affecting steelhead and Pacific lamprey populations has probably been the initiation and expansion of the Vern Freeman Diversion operation on the lower Santa Clara River which has increasingly impeded the up and downstream migration of anadromous fishes between spawning and rearing tributaries and the ocean. This diversion has significantly reduced the magnitude and duration of flows necessary for the migration of anadromous fishes, particularly smolt steelhead emigrating to the ocean, and has resulted in the induction of downstream emigrant spent adult steelhead and smolts into the diversion intake and percolation basins.

Without adequate mitigation measures, the proposed improved Vern Freeman Diversion would further reduce the magnitude and duration of sur-

face flows in the lower Santa Clara River and thus further impede or completely prohibit the migration of anadromous fishes between upstream spawning and rearing tributaries and the ocean. The improved diversion facilities could also adversely impact downstream riparian vegetation, associated resident fish and wildlife, and estuarine habitat at the river's mouth.

To avoid further depressing the anadromous fish populations in the Santa Clara River system, the following mitigation measures must be incorporated into the proposed improved Vern Freeman Diversion:

1. Installation of a seasonally operative and functional fishway.
2. Installation of a seasonally operative and functional fish screen.
3. Provision of adequate by-pass flows (or some alternative mechanism) to facilitate the transportation of fishes between the ocean and upstream spawning and rearing tributaries during critical migratory periods.

The fishway and fish screen should be designed with the cooperation and final approval of the California Department of Fish and Game, and provisions made for the monitoring, subsequent modification, and maintenance of the facilities. An initial by-pass flow schedule should be established and then mointored by either the California Department of Fish and Game or the State Water Resources Control Board, or a private consultant selected jointly by these agencies for a period of not less than five years before a final by-pass flow schedule is established.

Additionally, a smolt steelhead rearing facility could be incorporated into the Ventura Eastside Sewage Treatment Plant adjacent to the Santa Clara River esturary; such a facility could serve to replace degraded or permanently blocked spawning and rearing habitat and enhance the steelhead sport fishery in the lower Santa Clara River.

The above mitigations, if properly designed and effectively operated, could not only mitigate the impacts of the proposed improvements to the Vern Freeman Diversion, but could also serve to partially restore the historic anadromous fish resources of the Santa Clara River system. However, the extent to which these mitigations could off-set the impacts of the improved diversion and reverse the trend in the decline of the steelhead and Pacific lamprey populations in the Santa Clara River system cannot be accurately determined until after the project and the mitigation measures have become operational, and subsequent monitoring and evaluation studies have been conducted.

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PROJECT BACKGROUND

The United Water Conservation District operates a diversion facility on the lower Santa Clara River near Saticoy for the purpose of recharging the groundwater basins of the Oxnard Plain and providing direct deliveries of water to Pleasant Valley. (See Figure 1.) The diversion works consist of a diversion intake located on the south bank of the Santa Clara River and a series of percolation basins near Saticoy and El Rio. Water from the river is diverted into the intake by constructing an earthen training dike across the river annually to capture higher flows. Initially, the dike was constructed directly across the river, but as the river bed has degraded below the level of the intake, it has been necessary to construct the dike diagonally upstream to a point where the river bed elevation is greater than the downstream intake in order to ensure the gravity feed of river flow into the intake.

The proposed improvement of the Vern Freeman Diversion on the Santa Clara River is the latest in a series of efforts to improve both the reliability and capacity of water diversion from the Santa Clara River for more effecient groundwater recharge on the Oxnard Plain (Mann, 1973). The first major diversion works were constructed and put into operation in 1928 by the Santa Clara River Water Conservation District, the predecessor agency to the United Water Conservation District. The original capacity of these diversion works was 45 cubic feet per second. In 1934, a new diversion and a series of percolation basins were completed with a diversion capacity of 150 cubic feet per second. The percolation basins were subsequently expanded in 1939 and again in 1945, though the capacity of the diversion intake and canal remained the same.

In 1954, the United Water Conservation District made major modifications to the diversion facility, enlarging the diversion capability of the intake and canal to 375 cubic feet per second; the following year, additional percolation basins were constructed near El Rio. In 1956, a pipeline and storage reservoir to serve Pleasant Valley was completed and put into operation in 1958. In 1967, a new diversion structure was constructed, and then reconstructed in 1969 following the record floods of that year (United Water Conservation District, 1970).

Until recently, these modifications to the Vern Freeman Diversion had made possible increasing diversions from the Santa Clara River for out-of-stream uses. However, since 1969 the Santa Clara River bed has been lowered to such an extent that the capacity of the diversion works has been significantly impaired. Presently, the earthen training dike is regularly washed out when flows in the Santa Clara River reach or exceed 1600 cubic feet per second, thus interrupting the diversion operation. Reconstruction of the dike is not begun until the river flow drops to approximately 800 cubic feet per second. Because of the lowered river bed, however, the training dike must be constructed a considerable distance upstream in order to divert water to the diversion intake, which is 10 to 15 feet above the river bed at the diversion point. As a result of the verticle degradation of the river bed, the time required to reconstruct the training dike is increasing, thus reducing further the District's ability to divert river flows of suitable water quality to the percolation basins. Additionally, because flood waters with a high silt content impedes percolation in the basins, the lack of adequate desilting basins presents another constraint on the diversion operation. Under the present diversion operation criteria, river flows which exceed approximately 800 cubic feet per second are generally considered too silty for percolation. The proposed desilting basin would enable the silt criteria to be relaxed, thus increasing the amount of water which would potentially be available for diversion. Recent floods have further damaged the diversion facility to the extent that only a portion of the historic annual diversion (approximately 36,000 acre feet per year) can now be realized.

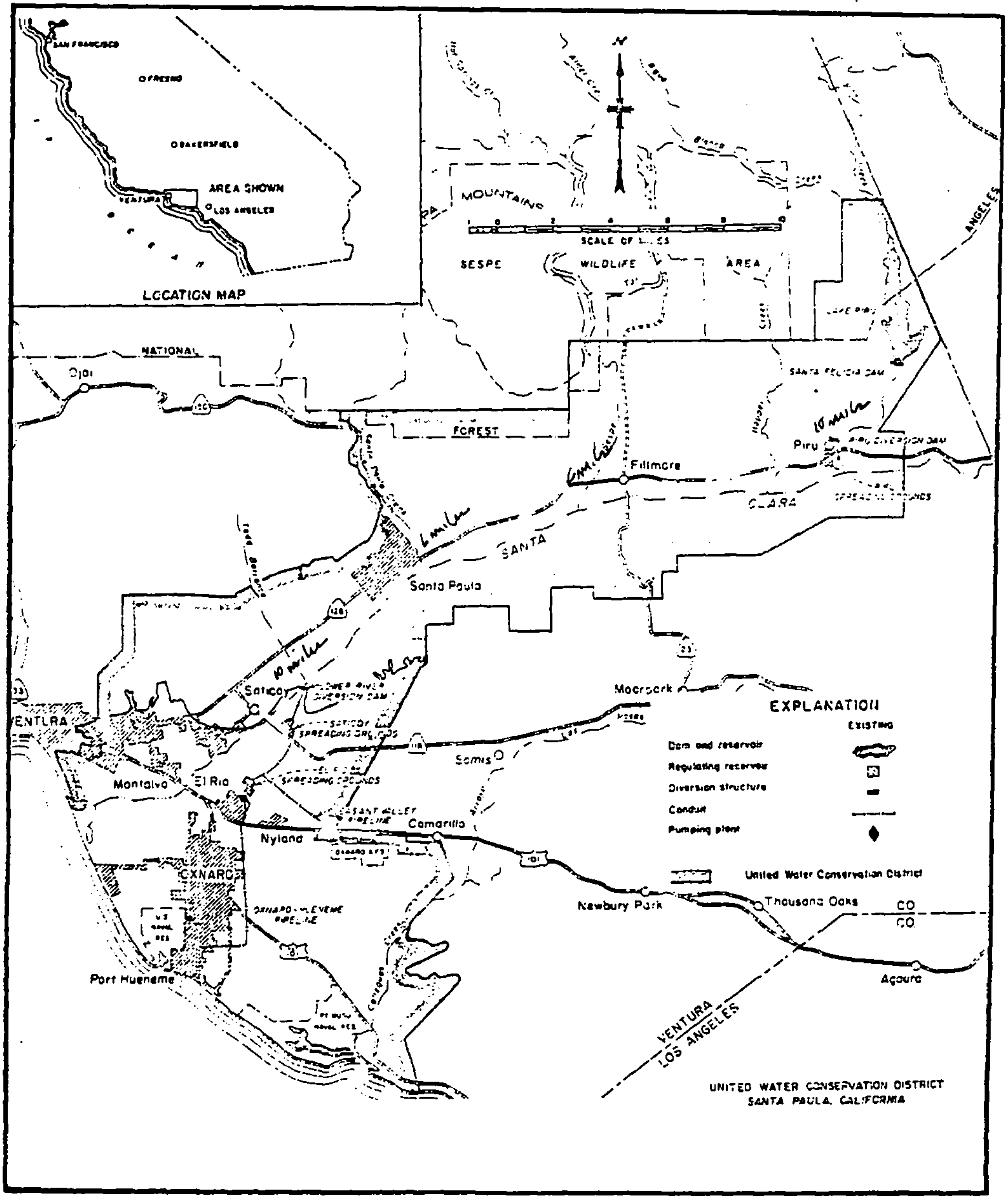


FIGURE 1. REGIONAL MAP

PROJECT DESCRIPTION

The proposed improvements to the Vern Freeman Diversion consist of two basic components (See Figure 2): a new diversion facility and a desilting basin (Toups, 1979).

DIVERSION FACILITY The diversion facility is composed of several elements; 1) river bed stabilization structure, 2) wasteway, 3) fabridam, 4) earthen dike, and 5) river bank stabilization structures. The river bed stabilization structure would extend across the river from the south to the north bank and be designed to maintain the river bed at an elevation of 149 feet above sea level. The structure would rest on a foundation of sheet piling driven to a depth of fifteen feet and consist of a low drop chute spillway with a reinforced crest and chute section, a grouted rock stilling basin and end sill, and a derrick stone downstream cut-off apron. The wasteway would be located at the south bank of the river and be approximately 100 feet wide; it would have a design capacity of 20,000 cubic feet per second. The fabridam would be situated within the deep wasteway structure and would be operated by inflating it with water to trap flows for diversion to the percolation basins or by deflating it to allow flood flows up to 20,000 cubic feet per second to travel through the wasteway structure and downstream. An earthen dike would also be constructed across the river from the vicinity of the wasteway at an approximately 45 degree angle. This dike would include a soft plug with a top elevation of 162 feet above sea level (or 13 feet above the stabilized river bed). With the dike in place, all river flow up to 20,000 cubic feet per second would be directed through the wasteway ad-

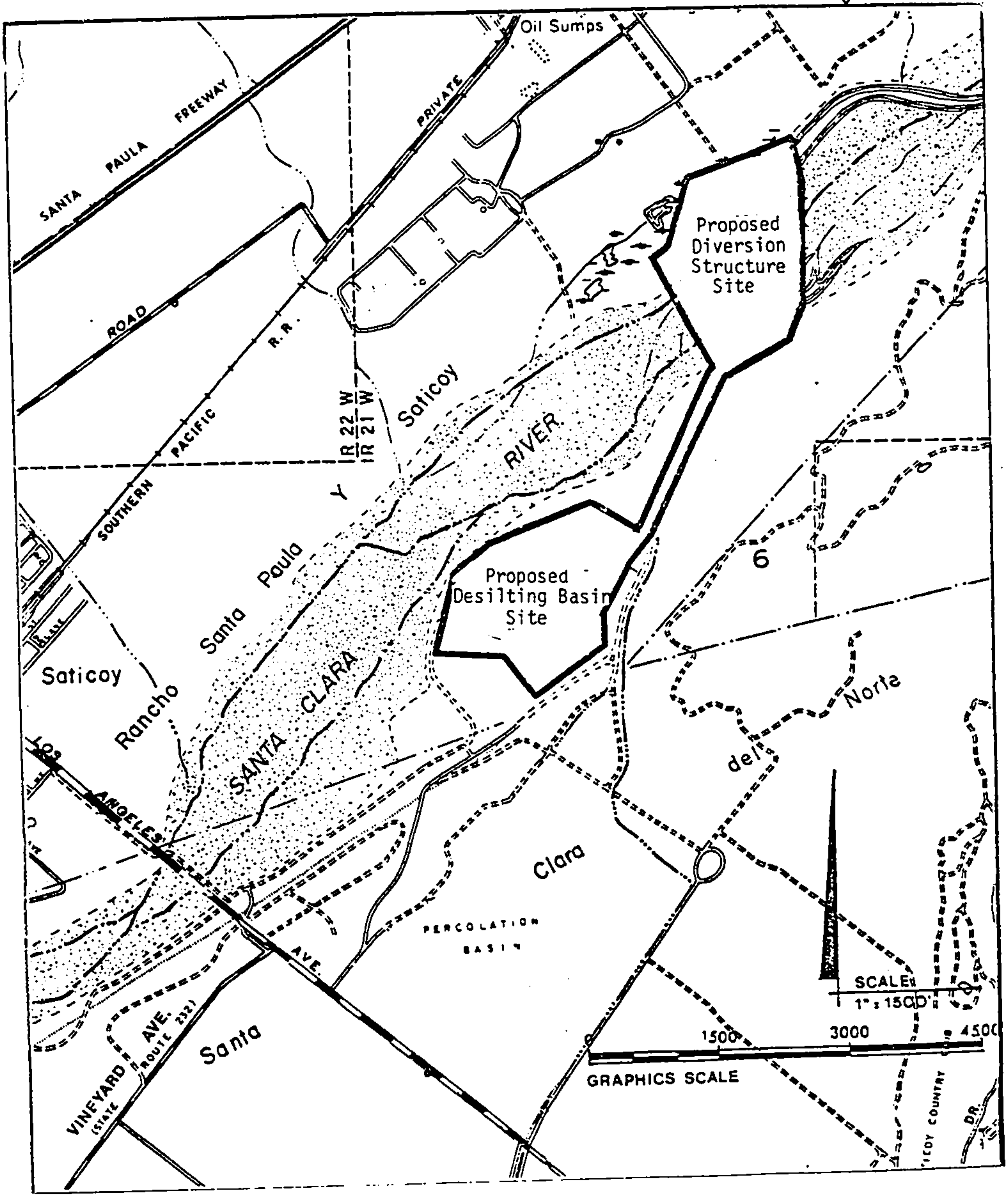


FIGURE 2. PROJECT SITE MAP

jacent to the diversion intake. An additional element of the proposed improvements would include bank stabilization downstream from the diversion structure on both the north and south banks of the river, as well as bank stabilization upstream. A levee would be built from the north end of the main river sill in an easterly direction upstream to an elevation sufficient to confine flows in a standard project flood; this structure is intended to prevent washouts at the north bank from occurring during major floods. (See Figure 3.)

DESILTING BASIN A desilting basin would be constructed approximately 2000 feet downstream from the diversion structure. The basin would encompass approximately 70 acres and be used to temporarily detain turbid waters which must now be by-passed downstream because of excessive silt before being directed into the percolation basins.

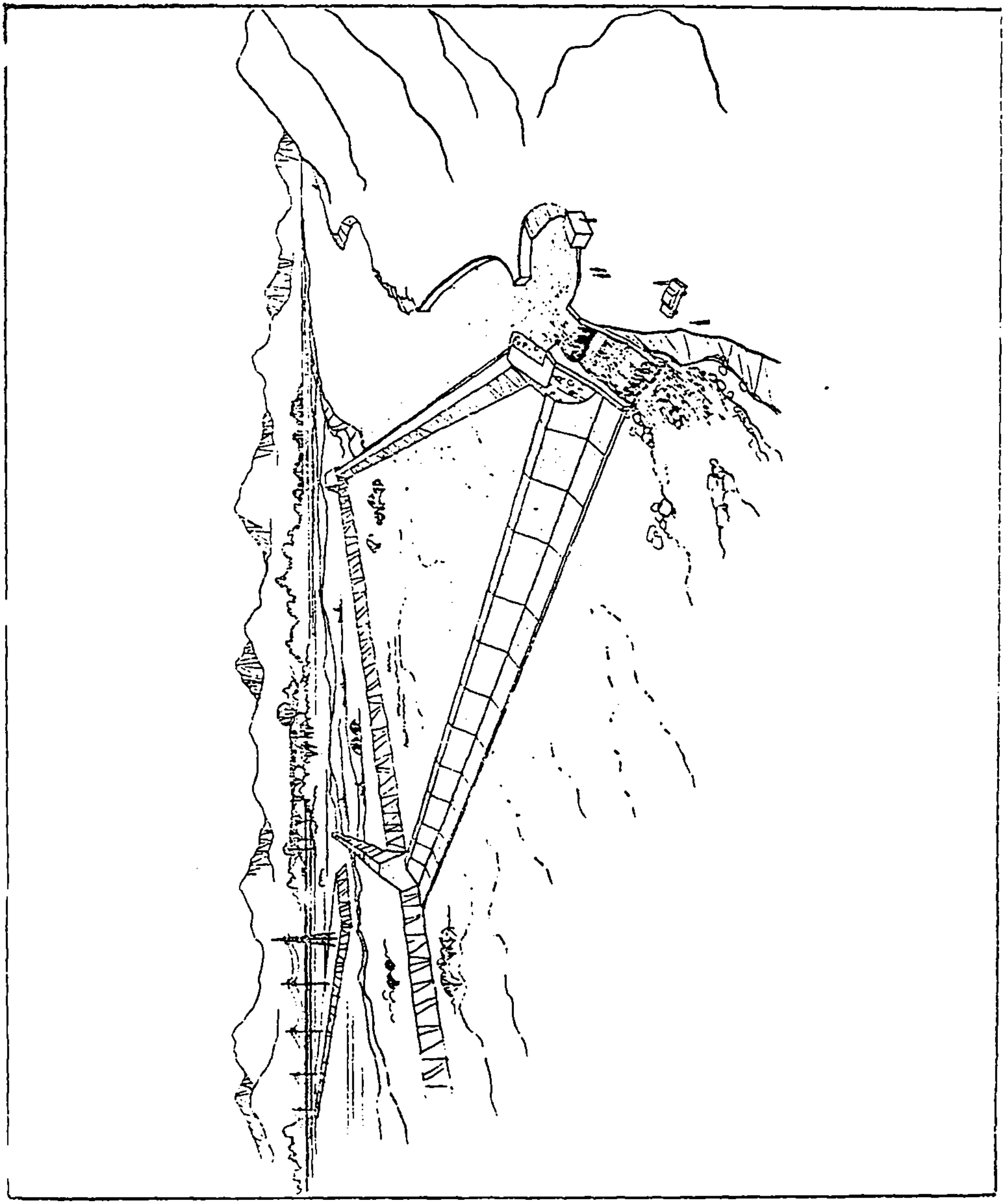


FIGURE 3. IMPROVED VERN FREEMAN DIVERSION FACILITY

SUMMARY OF STEELHEAD AND PACIFIC LAMPREY LIFE HISTORY

The proposed improvements to the Vern Freeman Diversion will impact the anadromous fishes of the Santa Clara River system by impeding or blocking the passage of fishes between the ocean and upstream spawning and rearing grounds in the tributaries of the Santa Clara River. In order to better understand the nature of these impacts, a general description of the life histories of the two anadromous species utilizing the Santa Clara River (Steelhead rainbow trout Salmo gairdneri gairdneri and Pacific lamprey Entosphenus tridentatus) is provided below. For a more detailed treatment of the life histories and habitat requirements of steelhead and lamprey see Fry (1939), Mc Afee (1956), and Shapovalov and Taft (1954). A list of the fishes associated with the Santa Clara River system is included as Appendix 1.

STEELHEAD RAINBOW TROUT Steelhead are one of the most widespread and important anadromous game fishes in California. They are found at sea from northern Baja California to the Bering Sea and Japan. Before the advent of extensive water development and urbanization, coastal streams from Baja California to Alaska supported runs of spawning adult steelhead. According to Swift (1979) the current spawning range is from the Santa Margarita River, San Diego County northward. Spawning steelhead, however, are not common in coastal streams south of Point Conception.

Steelhead are a subspecies of rainbow trout (Salmo gairdneri) which exhibit a stronger migratory urge than other strains of rainbow trout, though not all steelhead depend upon an anadromous existence. In coastal streams (where the migratory urge is the strongest) some individuals mature and spawn without migrating to the ocean. However, this is an exception to the typical anadromous pattern exhibited by a majority of steelhead within a given population. It should also be noted that resident rainbow trout (including planted rainbow trout) have the ability and occasionally the inclination to migrate to the ocean and return as adult steelhead to spawn. This is most likely to occur in streams which are close to the ocean and subject to heavy flooding capable of displacing otherwise resident rainbow trout to the ocean.

Steelhead spawn in fresh water where the young spend the first stage of their life cycle; after a period of from one to three years, the young emigrate to the ocean where they grow to maturity and finally return to their parent stream as adults to spawn.

Adult steelhead along the central and southern California coast ascend coastal rivers and streams to spawn during the wet winter months (November through March). Unlike salmon and Pacific lamprey, steelhead do not necessarily die after spawning; some individuals may return to spawn a second, and occasionally, a third time, though the rigors of migration and spawning results in many deaths. Juvenile steelhead, after emerging from the spawning gravels, remain in freshwater for one to four years before migrating to the ocean. More southern populations, however, may spend as little as one year in fresh water before emigrating to the ocean. This downstream emigration takes place from late winter through spring (February through June). When juvenile steelhead are ready to emigrate, they undergo physiological changes which enable them to adapt to salt water; this change is called smol tification and the juvenile ocean-bound steelhead are called smolts. Juvenile steelhead typically spend from one to four years at sea where their rate of growth is accelerated. After reaching maturity, the majority of steelhead return to the stream of their birth to spawn. This homing characteristic is important because it generally limits the adult steelhead spawning run in a particular river system to those individuals which had previously been successfully spawned and reared in the parent stream, and then emigrated to the ocean.

The percentage of orginally hatched fry able to complete their life cycle is less than 1%. Only 3% to 5% of the smolts successfully emigrating to the ocean survive the ocean phase of their life cycle to return as spawning adults. Consequently, any reduction in the natural juvenile population or the number of smolts able to successfully emigrate to the ocean can significantly reduce the size of an adult run in a river system.

Naturally occurring steelhead populations exhibit genetically determined life history patterns and habitat tolerances (e.g. timing of migrations, water temperature limits, etc.) which reflect the conditions characteristic of the particular river system to which they are native. In general, the life cycle of the steelhead is adapted to the seasonal rainfall and run-off patterns of the Pacific coast, with both upstream migration of adults and downstream emigration of smolts and spawned out adults coinciding with high flows and cooler water temperatures. Unobstructed access to spawning and rearing grounds and the ocean is essential for the successful completion of the steelhead's life cycle. In addition, spawning tributaries and rearing grounds must contain well flushed cobbles and gravels, exhibit suitable water quality and temperature characteristics, and maintain an adequate flow regime. The impairment or elimination of any of these requisite conditions can elminate or significantly reduce the size of an adult run of steelhead in a river system.

PACIFIC LAMPREY The Pacific lamprey is the largest and most common lamprey found along the Pacific coast. Pacific lamprey are found at sea from southern California to the Alaskan Penisula. It has also been recorded at sea off Baja California, in the Bering Sea, and off Japan. According to Hubbs (1967), Bell (1978), and Swift (1979), the Pacific lamprey orginally occurred in coastal rivers and streams from Baja California northward. Hubbs (1967) indicates that the Santa Clara River is the southernmost stream currently supporting a run of Pacific lamprey.

The Pacific lamprey depends completely upon an anadromous existence. It must spawn in freshwater where the young (which are called ammocoets) must initially develop. After several years the young metamorphose into an adult form (developing eyes, teeth, and a disk mouth), become predacious, and descend to the ocean. As Pacific lamprey approach sexual maturity, they return to freshwater to spawn, but unlike steelhead, not always to their parent stream. After spawning, all adult lamprey die. The dead and dying lamprey are often trapped on sand and gravel bars and along stream banks where they provide a seasonal food source for black bear, racoons, foxes, and other scavenging animals.

With the exceptions noted above, the habitat requirements and migration patterns of the Pacific lamprey in the Santa Clara River system closely parallel those of the steelhead. For ease of presentation and to reduce duplication, therefore, the following assessment of the impacts of the proposed improvements to the Vern Freeman Diversion on anadromous fishes and the means of mitigating the impacts of the proposed improvements will be presented in terms of the steelhead.

OUTLINE OF HISTORIC STEELHEAD RUNS IN THE SANTA CLARA RIVER SYSTEM

The Santa Clara River system historically supported larger numbers of adult steelhead than today. Jordan and Evermann (1923), Hubbs (1946), and Kreider (1948) have recorded steelhead from the Santa Clara River system. Hubbs, citing the California Department of Fish and Game reported "large and consistent runs" into the Santa Clara River. Kreider included the Santa Clara River in a list of Pacific coast steelhead fishing streams having a regular annual migration when water conditions were normal. An Internal Memorandum (1952) prepared by the California Department of Fish and Game reported that during wet years a run of steelhead trout migrated into the Santa Clara River, with the majority of the adults spawning in the high reaches of the river's tributaries, including Santa Paula, Sespe, and Piru Creeks.

Estimates of the size of the historic annual adult steelhead runs into the Santa Clara River are not available. However, an historic projection can be made for the Santa Clara River based upon a comparison of the numbers of steelhead reported before 1948 in the upper Ventura River system which lies several miles to the north of the Santa Clara River and exhibits similar rainfall and run-off characteristics as well as habitat conditions. According to Clanton and Jarvis (1946) the Matilija Creek drainage in the upper Ventura River system produced an estimated average annual run of 2000 to 2500 adult steelhead. The pre-1948 Matilija drainage provided approximately 18 miles of steelhead spawning and rearing habitat. By comparison, the Santa Paula, Sespe, and Piru drainages (which constituted the major spawning tributaries in the Santa Clara River system) provided approximately 89 miles or five times as much spawning and rearing habitat of comparable or superior quality. Based upon a comparison of the habitat characteristics of the respective spawning areas (i.e., flow levels, water quality and temperature, riparian cover, availability of food organisms, type of substrate, etc.) it is reasonable to project that the average annual run in the Santa Clara River before access to these tributaries was blocked or impeded was approximately 9000 adult steelhead. This projection is probably conservative because it does not reflect the spawning and rearing habitat which exists in the minor tributaries of Sespe, Santa Paula, and Piru Creek, or the small streams directly tributary to the Santa Clara River such as Hopper and Pole Creek. A recent survey (Moore, 1979) of these tributaries indicates that they presently provide significant resident rainbow trout habitat and probably also served as spawning and rearing habitat for the historic steelhead run.

It should also be noted that projecting the size of anadromous fish runs in terms of averages can be misleading, particularly in river systems such as the Santa Clara which are subject to extreme flow fluctuations from year to year. The size of fish populations will respond to the rainfall pattern of a basin, increasing during years of abundant rainfall and contracting during drought years to adapt to the available suitable habittat.

No systematic investigations have been made of the current run of anadromous fishes in the Santa Clara River system. However, there are scattered contemporary reports of both steelhead and Pacific lamprey occurring in the Santa Clara River system during the winter months. Arita (1976) recorded two adult Pacific lamprey captured near the Vern Freeman Diversion. Bell (1978) has reported taking two adult Pacific lamprey in Sespe Creek. Wilsrud (1980) reported capturing an adult Pacific lamprey in the lagoon at the mouth of the Santa Clara River. Cooper (1976) reported a stranded adult steelhead specimen approximately one mile south of the Highway 118 bridge (or three miles below the Vern Freeman Diversion). In addition to these verifiable reports by qualified observers, local newspapers(Fillmore Herald, 1974) have run stories of anglers taking adult steelhead in the Santa Clara River system. Photographs of steelhead specimens taken from the Santa Clara River have also been examined for positive identification. These reports and accounts indicate that the Santa Clara River system still supports at least a remnant run of anadromous fihes. The precise magnitude of these runs in not known at this time, however, and the determination of their size and regularity was not possible within the limits of this study.

FACTORS EFFECTING THE DECLINE OF STEELHEAD RESOURCES

The steelhead population in the Santa Clara River system, like those in numerous other coastal rivers in California, have been seriously depressed over the past fifty years. The principal factors contributing to the decline of steelhead populations include:

1. Increased demands on surface and groundwaters during critical migratory periods for off-stream uses.
2. Reduction of useable spawning and rearing habitat due to dams, diversions, and channelization projects for flood control.
3. Degradation of surface water qualtiy as a result of siltatatin, run-off from non-point agricultural and urban sources, and point waste discharges.

The construction of San Felicia Dam in 1955 and Pyramid Dam in 1973 on Piru Creek cut-off two steelhead spawning and rearing streams in the Piru Creek drainage and reduced migratory flows in the Santa Clara River. The construction of Castaic Dam in 1973 on Castaic Creek also reduced migratory flows in the Santa Clara River, though it did not effect a major spawning and rearing tributary. Sespe Creek, which is historically and presently the most important spawning and rearing tributary to the Santa Clara River, has not been damned or subjected to major diversions, though its accessibility to migrating steelhead has been directly impaired by the operation of the Vern Freeman Diversion, and indirectly by the regulation of flood flows through the operation of Piru, Pyramid, and Castaic reservoirs. Santa Paula Creek has also remained undamned, but its value as steelhead spawning and rearing habitat has been reduced by diversions, artificial barriers, point waste discharges, and channelization of its lower reaches. Figures 4 and 5 show major historic and current steelhead spawning and rearing habitat in the Santa Clara River system.

A review of published accounts, newspaper reports, file documents from the California Department of Fish and Game, and interviews with local anglers, indicates that the Santa Clara River system supported a fairly regular run of adult steelhead up until 1948. A number of factors and developments since 1948 have probably contributed to the decline of anadromous fishes in the Santa Clara River system. From 1945 to 1951 the Santa Clara River basin was subjected to a series of drought years which substantially reduced the level and duration of flows to the ocean, thus reducing the ability of adults to enter the river and gain access to spawning and rearing tributaries, and perhaps more importantly, the ability of juveniles to escape to the ocean. In 1951, a more normal rainfall pattern resumed, with fewer and less severe periodic drought years. Table1 presents the average annual rainfall totals for the Santa Clara River basin for the years 1940-1972. Figure 6 shows the accumulated annual rainfall departure from the long term mean for the Santa Clara River basin at Station #32 for the years 1875-1974.

Other developments appear to have off-set the improved water conditions in the Santa Clara River after 1951 and prevented the natural recovery of the anadromous fishery which might have been expected with the resumption of improved habitat conditions. The construction of San Felicia Dam in 1955 cut-off two spawning and rearing tributaries (Piru and Agua Blanca Creek) and reduced the level and duration of mid-range flows in

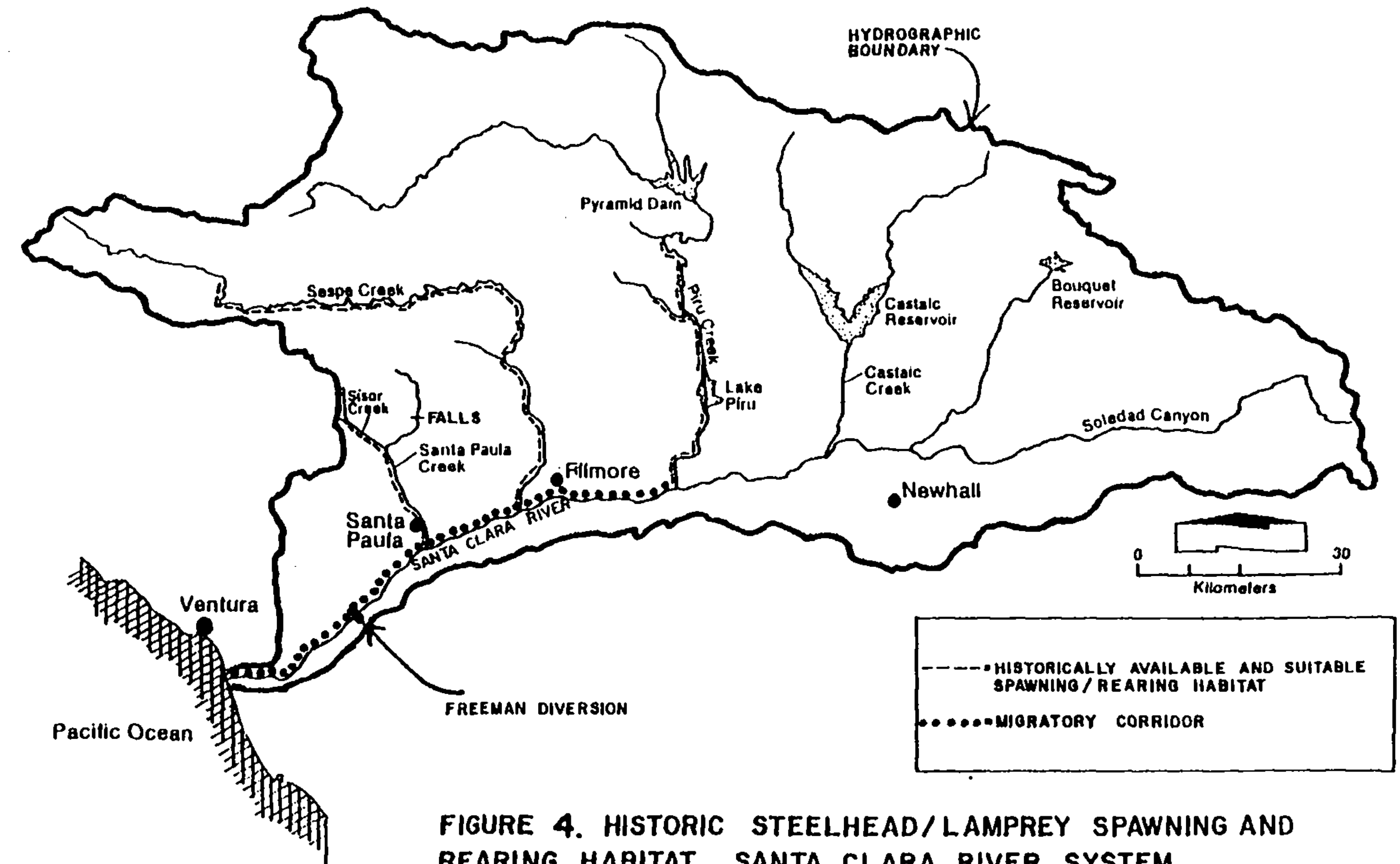


FIGURE 4. HISTORIC STEELHEAD/LAMPREY SPAWNING AND REARING HABITAT, SANTA CLARA RIVER SYSTEM.

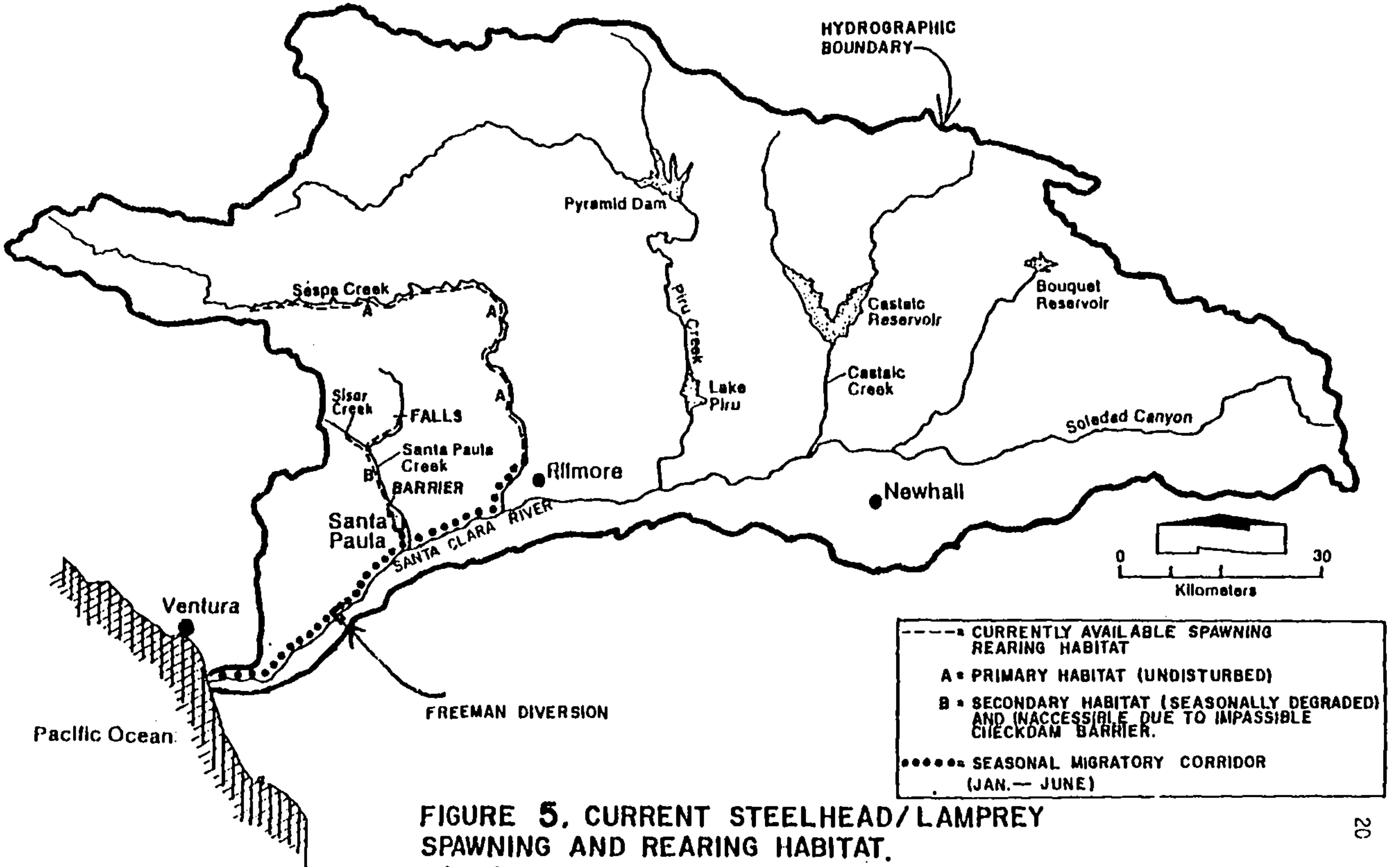


FIGURE 5. CURRENT STEELHEAD/LAMPREY SPAWNING AND REARING HABITAT. SANTA CLARA RIVER SYSTEM.

TABLE 1. AVERAGE ANNUAL RAINFALL TOTALS FOR THE SANTA CLARA RIVER BASIN FOR THE YEARS 1940-1972.*

1940	36.71	
1941	12.77	
1942	19.88	
1943	18.02	
1944	11.23	
1945	8.67	Prolonged Drought 1945-1951
1946	8.98	
1947	5.63	
1948	5.91	
1949	9.94	
1950	7.08	
1951	23.78	
1952	10.16	
1953	13.17	
1954	12.53	
1955	15.19	
1956	9.39	
1957	25.81	
1958	6.74	
1959	11.04	
1960	6.42	
1961	23.84	
1962	10.82	
1963	13.07	
1964	14.97	
1965	13.07	
1966	16.41	
1967	13.86	
1968	22.06	
1969	10.98	
1970	14.52	
1971	7.29	
1972	19.49	

* Note: Rainfall amounts at individual guaging stations will vary considerably depending on topography and altitude, but the relative amount of rainfall from year to year between stations is generally constant. Source: Ventura County Star-Free Press and Ventura County Public Works Department.

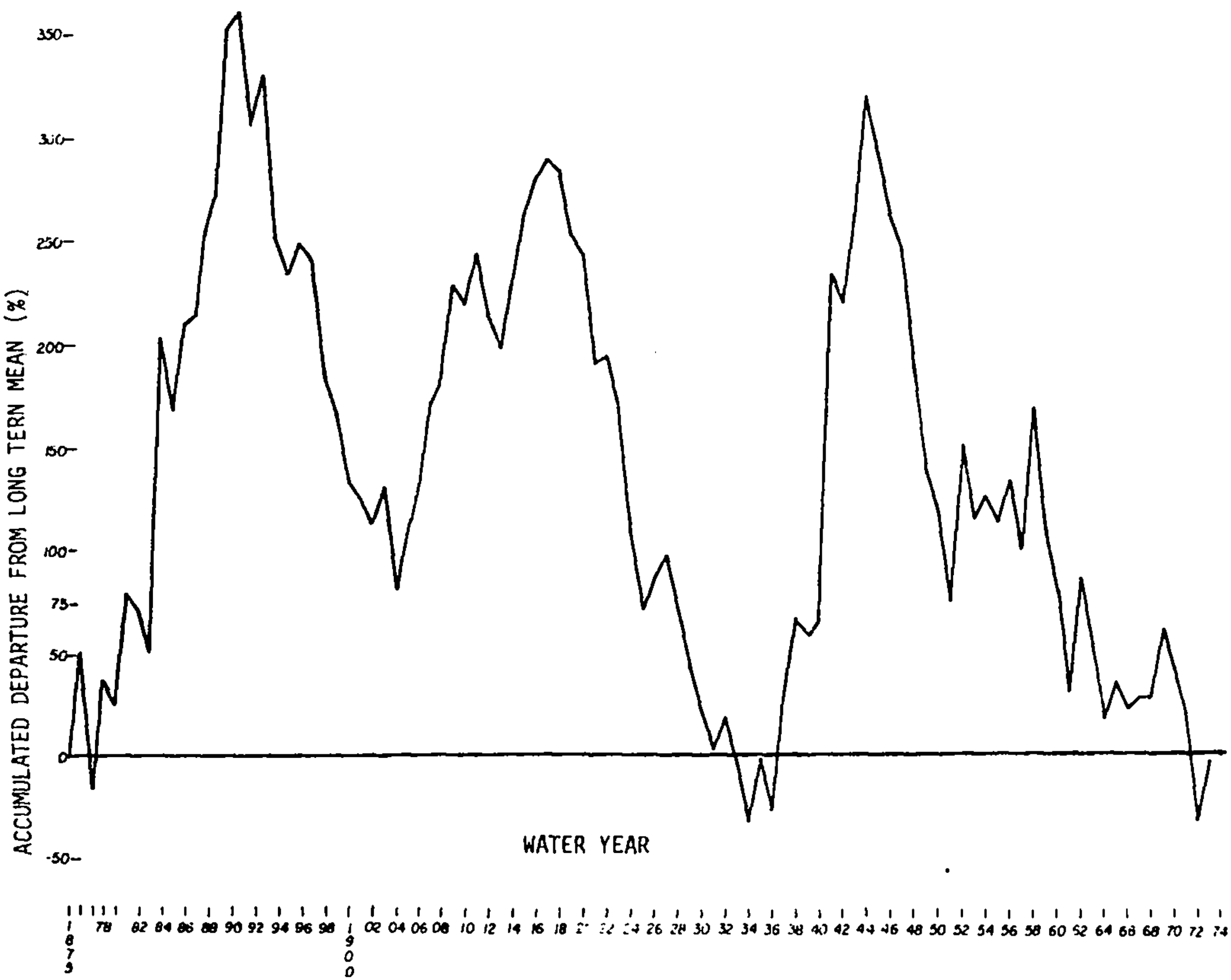


FIGURE 6. ACCUMULATED ANNUAL RAINFALL DEPARTURE FROM THE LONG TERM MEAN FOR THE SANTA CLARA RIVER BASIN, STATION 32, 1875-1974. Source: Ventura County Public Works Department.

in the lower Santa Clara River utilized by migrating steelhead. More significant, however, was the enlargement of the Vern Freeman Diversion operation following the drought in 1954. The operation of this diversion facility has resulted in the control and diversion of low and mid-range flows (0 to 375 cubic feet per second) which may provide the critical vehicle for the passage of juvenile steelhead to the ocean. This operation has also resulted in the induction of smolts into the percolation basins. The relationship between surface flows, diversions, and steelhead migration is discussed in more detail in the following section.

RELATIONSHIP BETWEEN SURFACE FLOWS, DIVERSIONS, AND STEELHEAD MIGRATIONS

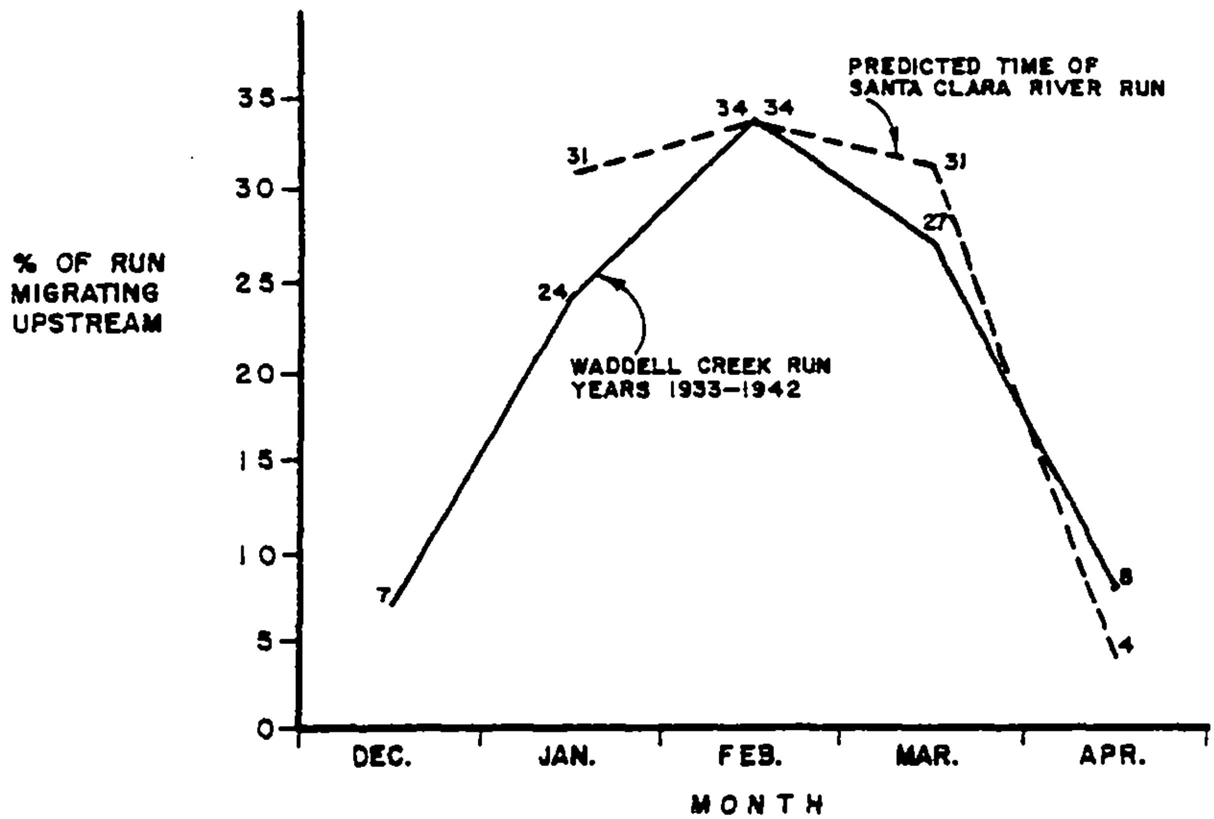
The main stem of the Santa Clara River is used primarily as a migration corridor by anadromous fishes moving between the ocean and upstream spawning and rearing tributaries. Presently, river flows between the ocean and Sespe Creek are the most important for the transport of anadromous fishes in the Santa Clara River system. As noted above, steelhead attempt to enter and leave the river system during times of high or moderate flows. The timing, volume, and duration of surface flows in the Santa Clara River varies from year to year, depending upon the rainfall and run-off pattern in the basin. In general, upstream migration of adult steelhead occurs from January through March. Downstream emigration of smolts and spawned out adult steelhead occurs from April through June.

IMMIGRATION It is believed that steelhead populations in the southern extent of their range begin migrating upstream to spawn later in the water year than more northerly steelhead populations, but still during the period January through March. Shapovalov and Taft (1954) noted in their nine year steelhead study of Waddell Creek, California that adult steelhead ascended both during rising and falling stream levels, but ceased movement during flood peaks. Over the span of their study (1933-1942) peak upstream adult migration occured during the months of January, February, and March. Eight-four percent of the run entered Waddell Creek during this period. Ninety-six percent of the adult upstream steelhead migration occurred between December 3 and May 5. According to Shapovalov and Taft, within any of these twenty-two weeks, steelhead may be expected to ascend suitable California coastal streams, depending upon seasonal weather and water conditions.

The Santa Clara River experiences peak flows during the months of January through March, with occasional high storm run-off in November, December, and April. Migration of steelhead into the Santa Clara River and its spawning and rearing tributaries most likely coincides with these peak discharges, primarily during their ascending and descending phases, with little movement during flood peaks. It is significant to note here that it is during these migratory phases that turbidity levels are lowest and diversions at the Vern Freeman Diversion are most likely to be made. Figure 7 shows the timing of upstream adult steelhead migration in Waddell Creek over a nine year period, 1933-1942, and the predicted timing of upstream adult steelhead migration into the Santa Clara River system. Note the slight shift to a later period in the case of the Santa Clara River, reflecting the delayed arrival of winter storms and consequent run-off in the basin, and the shortened migratory period resulting from the earlier cessation of winter storms.

EMIGRATION Typically, the emigration of juvenile steelhead occurs over a longer period than does the immigration of adult steelhead into a river system. Shapovalov and Taft (1954) also found that downstream emigration started earlier during years of low stream flow. They indicate that the effects of absolute stream levels on the timing of emigration are probably modified by the rate of stream level drop and sudden freshets. In their Waddell Creek study, Shapovalov and Taft found that 72% of the emigrating juvenile steelhead moved out of Waddell Creek between April and July, with the escapement of the remaining 28% spread out over the remainder of the year. Figure 8 shows the timing of emigrating steel-

FIGURE 7. TIMING OF ADULT STEELHEAD MIGRATION, WADDELL CREEK AND SANTA CLARA RIVER CALIFORNIA.



head smolts and spawned out adults in Waddell Creek.

In more southern rivers such as the Santa Clara with shorter periods of continuous surface flows to the ocean, the emigratory period may be concentrated into a shorter period to take full advantage of the naturally occurring water conditions. Figure 9 shows the predicted timing of emigrating steelhead smolts and spawned out adults in the Santa Clara River. Note that while the initiation of emigration conincides with more northern streams, the conclusion of the emigration period is at least a month earlier than the more northern steelhead streams. It may be that with further investigation the present emigratory period is discovered to be even shorter than is shown in Figure 9, giving increasing significance to the present and proposed diversion schedule at the Vern Freeman Diversion.

FIGURE 8. TIMING OF DOWNSTREAM MIGRATING STEELHEAD SMOLTS AND SPAWNED OUT ADULTS IN WADDELL CREEK CALIFORNIA, YEARS 1933-1942*

* SOURCE: SHAPOVALOV AND TAFT, 1954

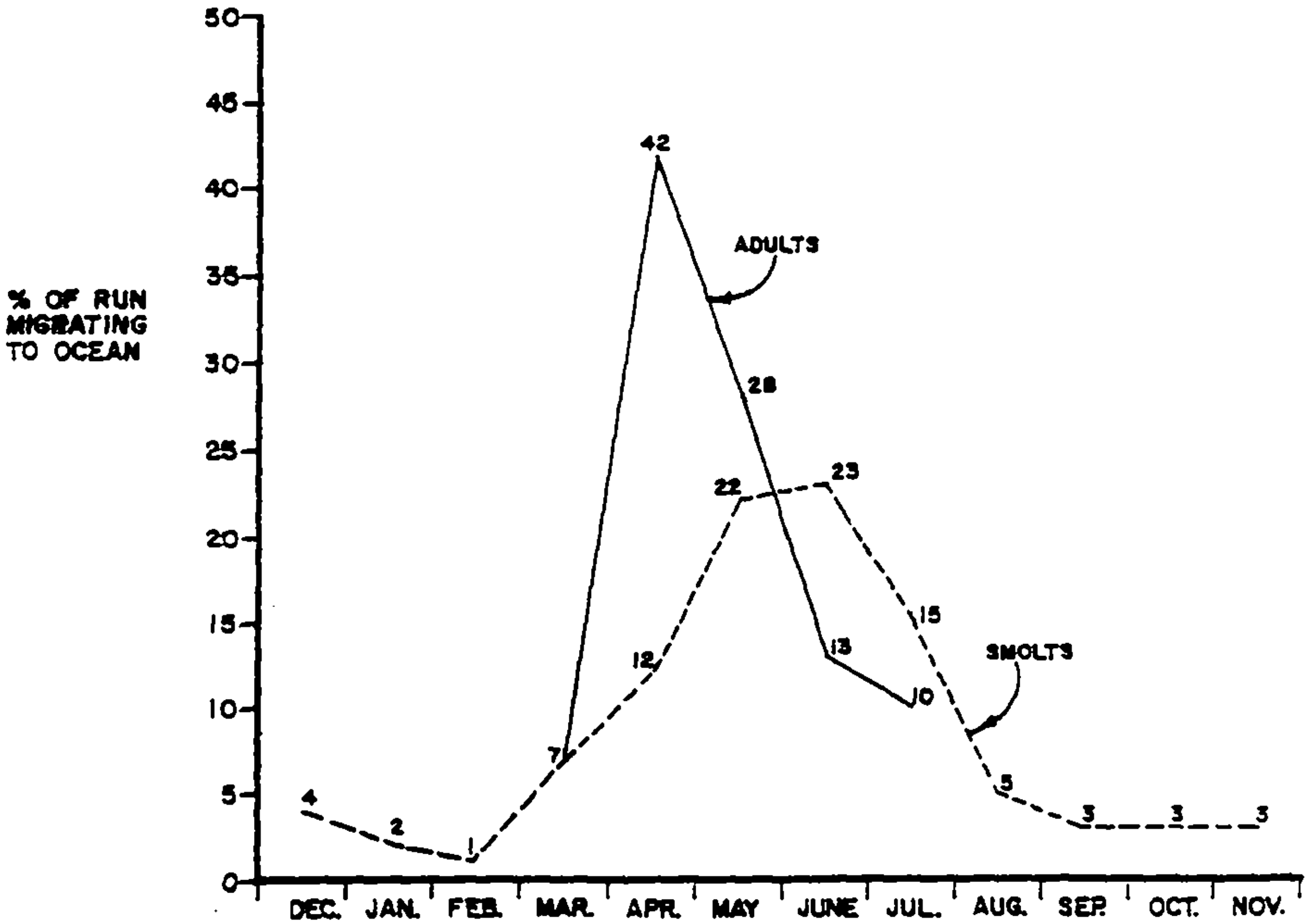
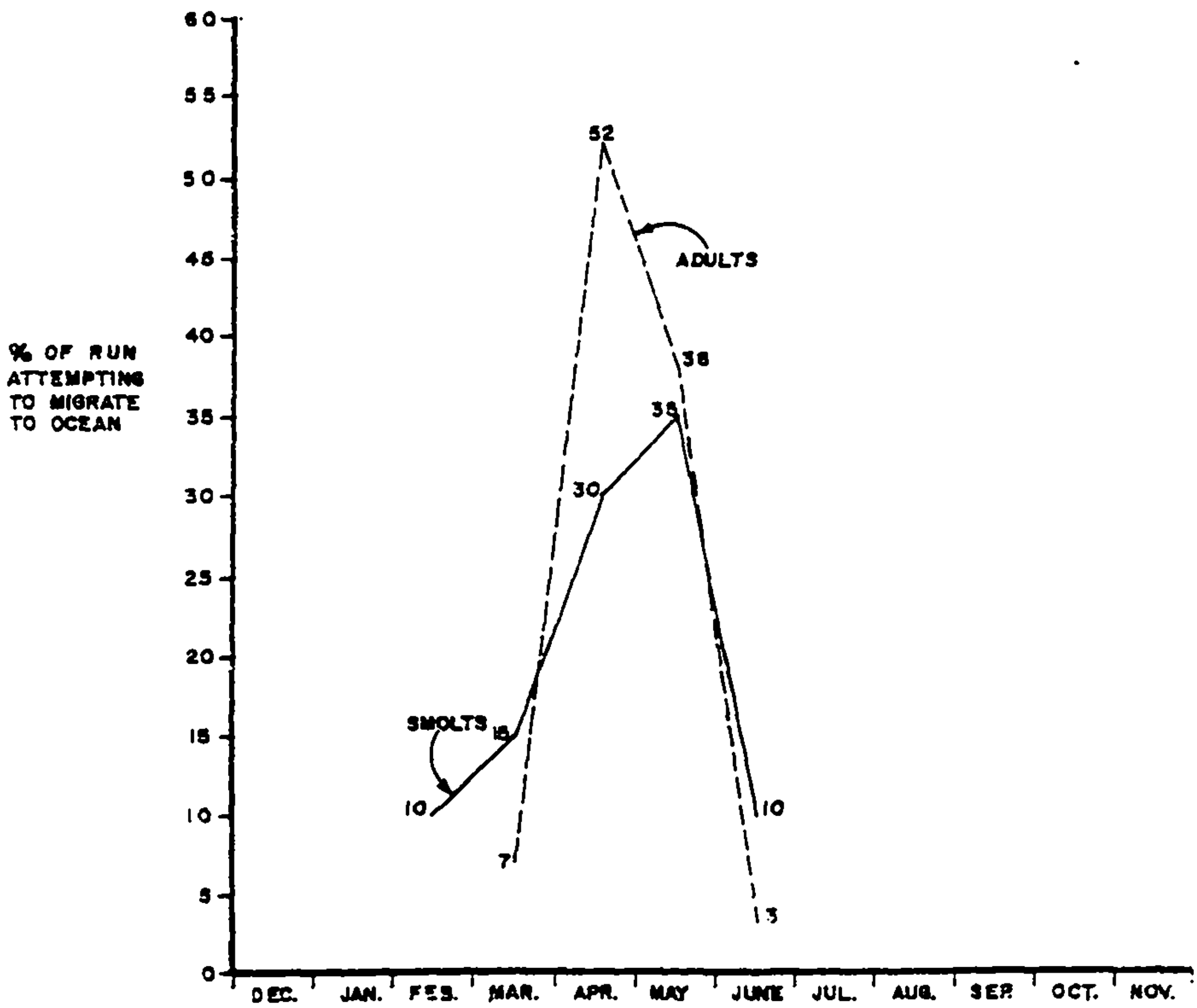


FIGURE 9. PREDICTED TIMING OF DOWNSTREAM MIGRATING STEELHEAD SMOLTS AND SPAWNED OUT ADULTS IN SANTA CLARA RIVER, CALIFORNIA



IMPACTS OF VERN FREEMAN DIVERSION OPERATION ON STEELHEAD MIGRATION

From the model life history of steelhead shown in Figures 10 and 11, it is evident that interruptions in the migratory phases of the steelhead's life cycle can critically affect the survival of a population in a particular river system. Sufficient numbers of adults must be able to reach spawning and rearing grounds to produce an adequate number of juveniles. A significant number of juveniles must then be able to successfully pass to the ocean to produce a large enough number of adults to ensure an adequate size spawning population of returning adults to produce the next generation of juveniles. As indicated above, the natural mortality of juvenile and smolt steelhead is high. The percentage of successfully hatched juveniles reaching maturity and returning as adults to spawn is less than 1%. Any additional stress on the juvenile population, or reduction in the number of smolts able to reach the ocean can therefore critically depress a population in a river system.

Table 1 presents the number of miles of suitable and seasonally accessible steelhead spawning and rearing habitat currently available in the Santa Clara River system. Given the current magnitude and duration of surface flows in the Santa Clara River and the presently available spawning and rearing habitat in its' tributaries, the numbers of adult steelhead utilizing the Santa Clara River system should be considerably greater than it is believed to be at present.

Peak diversion activity at the Vern Freeman Diversion has closely paralleled peak migratory periods for anadromous fishes, significantly altering flow regimes at critical times of the year and resulting in a short-

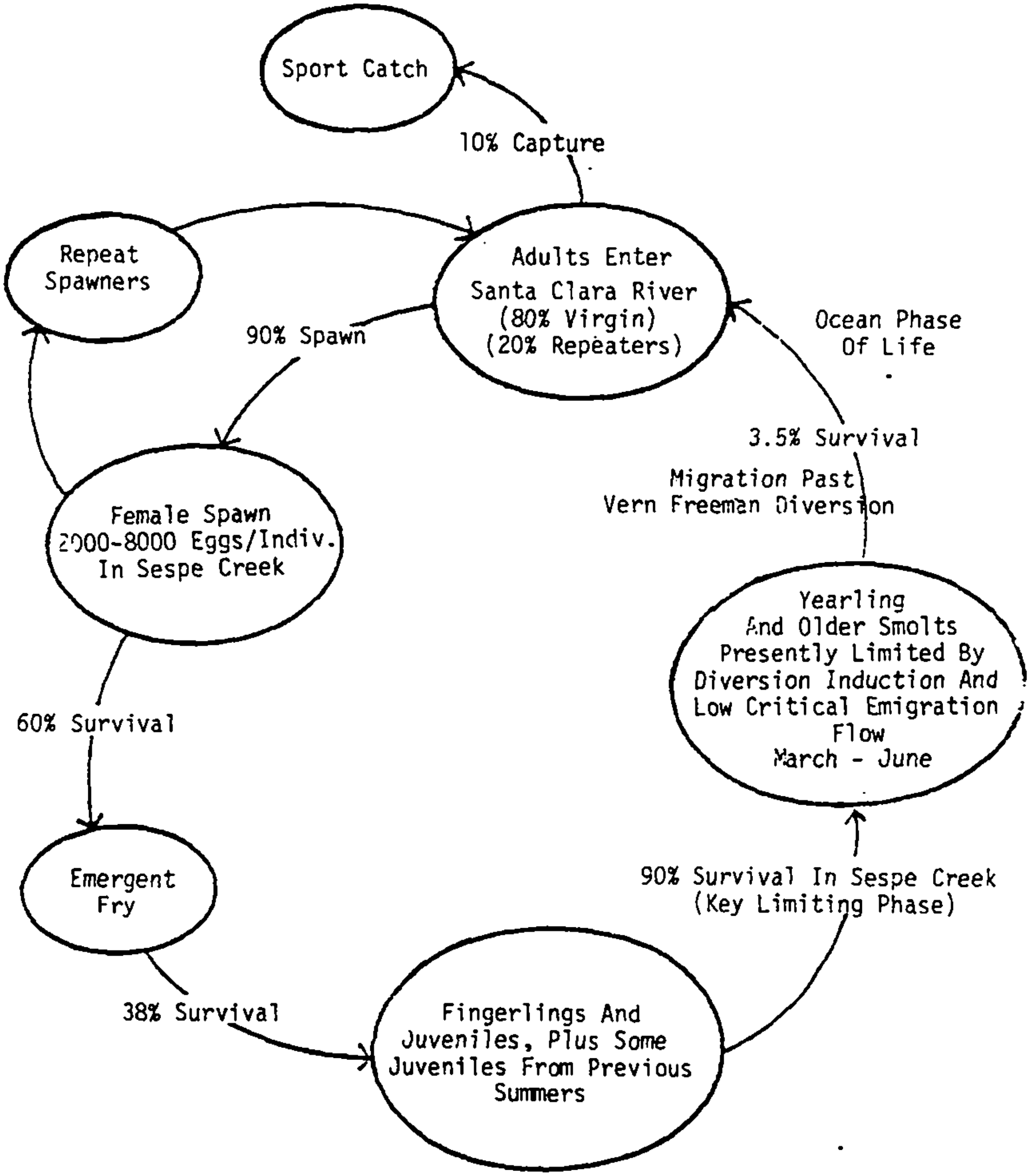


FIGURE 10

Steelhead Life History

MODEL OF THE PREDICTED STEELHEAD LIFE HISTORY IN THE SANTA CLARA RIVER AND SESPE CREEK. (Modified from Kelley, 1978)

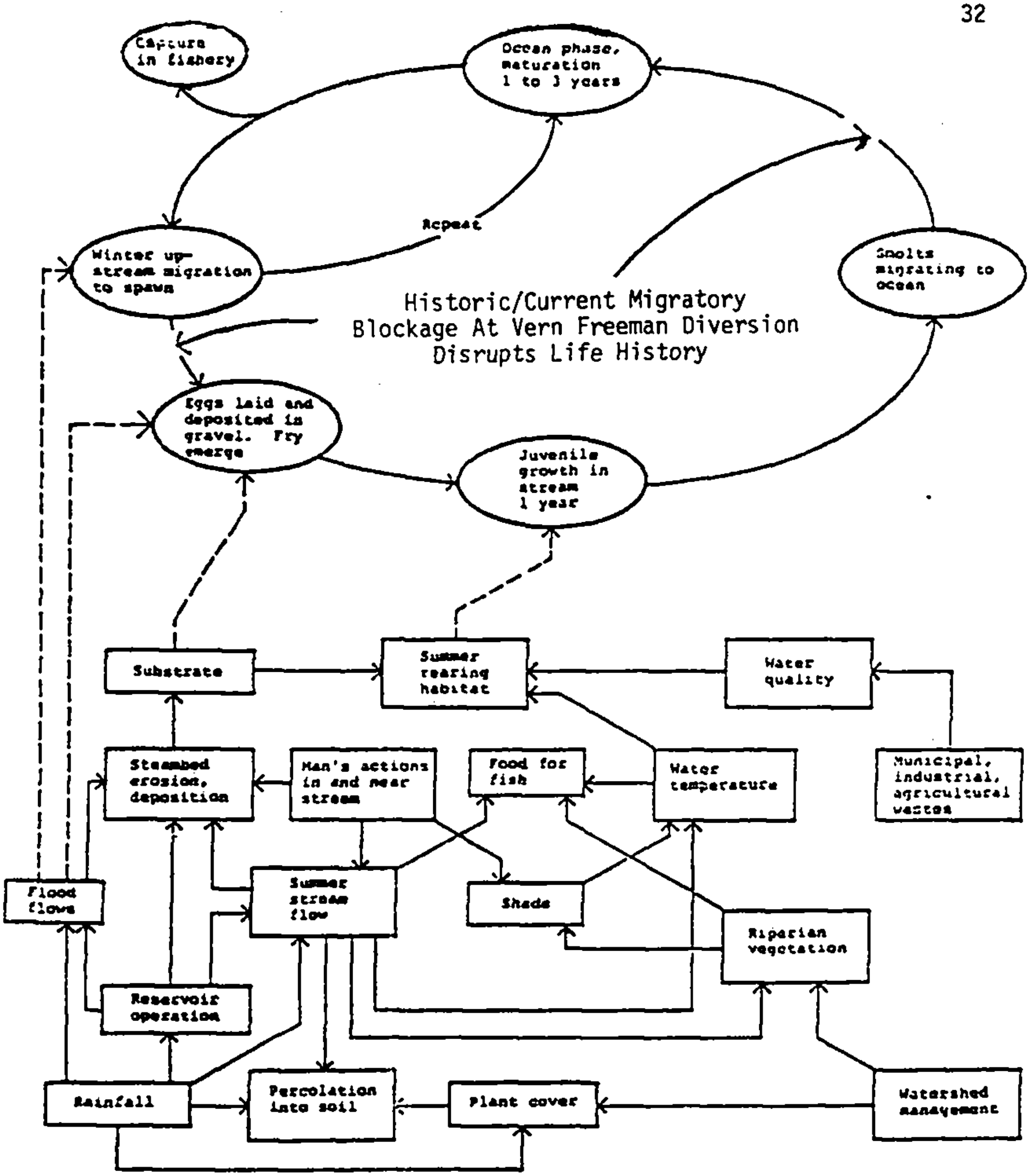


FIGURE 11

Factors Influencing the Steelhead Population

CONCEPTUAL MODEL OF THE FACTORS INFLUENCING THE STEELHEAD POPULATION IN THE SANTA CLARA RIVER SYSTEM (Modified from Kelley, 1978)

TABLE 2. HISTORIC AND CURRENT MILES OF SUITABLE AND SEASONALLY ACCESSIBLE STEELHEAD SPAWNING AND REARING HABITAT, SANTA CLARA RIVER SYSTEM*

Drainage	Santa Paula Creek	Sespe Creek	Piru Creek
Miles of Historical Habitat	11	53	25+
% Of Total Historical Habitat in the Santa Clara River System	12	60	28
% Of Total Current Habitat in the Santa Clara River System	8	92	0
% Loss of Historical Habitat in the Santa Clara River System	64	11	100
Miles of Current Habitat	2**	47	0

* Conservative estimate; does not include smaller tributaries such as Hopper Creek.

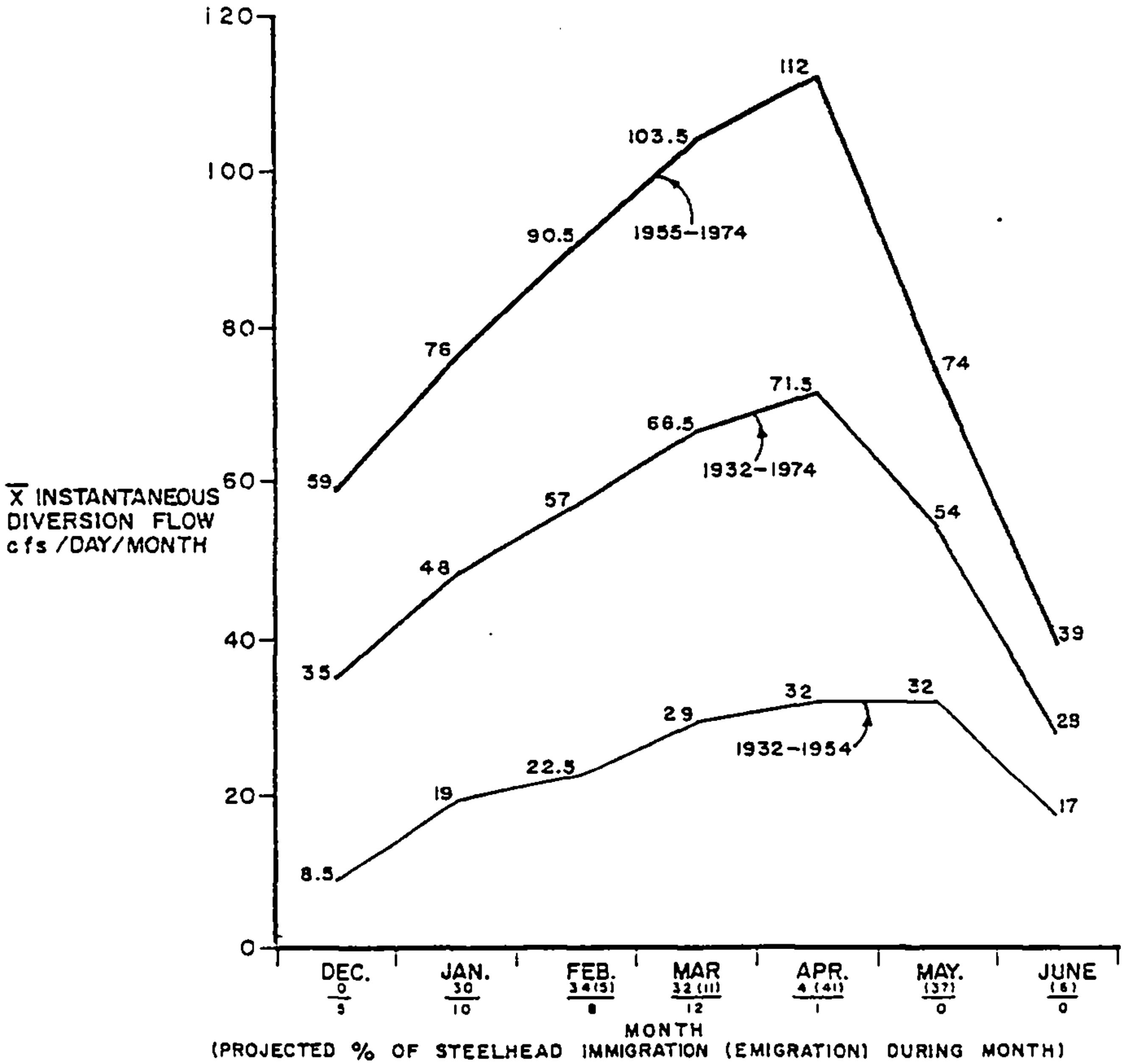
** Seasonally degraded.

ened migratory period, or when peak river flows were inadequate to breach the Vern Freeman Diversion training dike for prolonged periods, completely blocking the up and downstream migration of fishes. Figures 12 and 13 show the relationship between the timing of the Vern Freeman Diversion operation, steelhead migration, and river flows. Additionally, smolts have apparently been inducted into the unscreened diversion intake, even during periods when there were by-pass flows adequate to transport smolts to the ocean. Without base-line data and subsequent monitoring, it is not possible to accurately measure the magnitude of these impacts, though they are believed to be significant given the life history requirements of steelhead and the nature of the diversion operation. For these reasons, it is believed that the operation of the Vern Freemand Diversion is one of the principal factors contributing to the decline of the Santa Clara River steelhead run.

The proposed improvements to the Vern Freeman Diversion would result in greater control of river flows, particularly moderately high flows which are utilized by migrating steelhead, and therefore worsen the existing situation. If the project incorporates effective anadromous fish mitigation measures (including a fishway, intake screening, and minimum by-pass flows), these impacts may be avoided and a significant increase in the size of the adult steelhead run could be realized. Any increase, however, would occur gradually over a period of years rather than immediately until the run of adults reached a maximum size consistent with the quantity and quality of the available spawning and rearing habitat.

Also, as suggested above, the size of the run would not be static, but would fluctuate in response to future rainfall and run-off patterns in

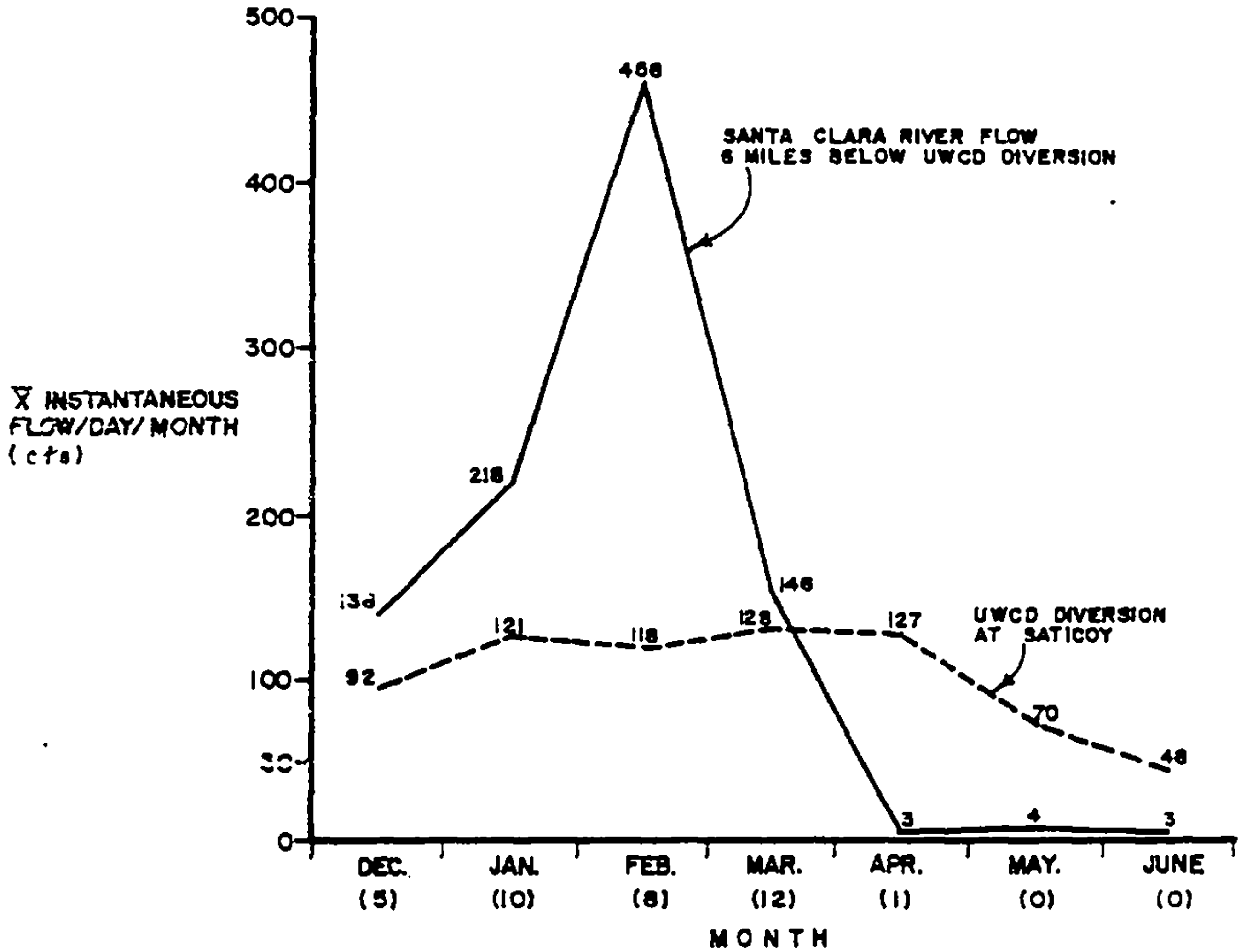
FIGURE 12. AVERAGE INSTANTANEOUS UNITED WATER CONSERVATION DISTRICT DIVERSION AT SATICOY (FREEMAN DIVERSION) DURING MONTHS OF STEELHEAD/LAMPREY MIGRATION 1932-1974



X̄ NO. DAYS WITH ADEQUATE SURFACE FLOW (30-50+ cfs)
FOR ANADROMOUS FISH MIGRATION BETWEEN FREEMAN DIVERSION AND OCEAN 1968-1974 *

* 1969 FLOOD YEAR NOT INCLUDED

FIGURE 13. A COMPARISON OF UNITED WATER CONSERVATION DISTRICT $\bar{X}$ INSTANTANEOUS DIVERSION AT SATICOY (FREEMAN DIVERSION) AND $\bar{X}$ INSTANTANEOUS DAILY SANTA CLARA RIVER FLOW 6 MILES BELOW DIVERSION, 1968-1974*



($\bar{X}$ NO. OF DAYS WITH ADEQUATE SURFACE FLOW (30-50+ cfs) FOR ANADROMOUS FISH MIGRATION)

*1969 FLOOD YEAR NOT INCLUDED

the basin. The planting of smolts could serve to shorten the time required for the Santa Clara River to achieve its' modified steelhead production potential.

RECOMMENDED MITIGATIONS

The following mitigations are considered to be necessary to mitigate the impacts of the proposed improvements to the Vern Freeman Diversion on the anadromous fishes of the Santa Clara River system. Because of the complexity of the river system and the lack of detailed information regarding the historic and current steelhead and Pacific lamprey populations of the Santa Clara River system, the effectiveness of these mitigations cannot be accurately determined until after the project and the mitigation measures have become operational and subsequent monitoring and evaluation studies have been conducted.

FISH LADDER The basic purpose of a fish ladder (also refered to as a fishway) at the Vern Freeman Diversion would be to allow both the up and downstream passage of steelhead and Pacific lamprey during migratory periods.

A variety of factors must be considered in designing and operating a fishway. It should also be emphasized that the proper design of a fishway is not itself enough to ensure the effective passage of fish over and through an hydraulic barrier. The location, operation, and maintenance of a fishway is also extremely important. Each situation presents its own special set of problems which must be successfully met if the facility is to function effectively.

The outline of general considerations presented below for the design and placement of a fishway at the proposed improved Vern Freeman Diversion is based upon work done by Vande Sande (1966).

Cooperation between fishery biologists and the designing engineers is essential for the successful design, construction, and operation of a fishway. In developing a design, the following information must be provided to the project biologists:

1. The kinds, sizes, and timings of the runs.
2. The probable route of the fish to the barrier.
3. The exact place where fish will congregate below the barrier.
4. The type and quantity of debris.
5. The conditions to be provided for fish at various water stages.
6. The frequency, duration, timing and magnitude of river flows, particularly peaks and lows.

The following general design considerations should guide the project engineers in the design of the fishway:

1. The entrance should be as close as possible to the places where fish will congregate at the barrier.
2. Entrance flows should be substantial enough to attract fish at all water stages.
3. When fish will be swimming through high velocity water, changes in direction should be minimized.
4. Energy dissipation must be complete, with no carry-over from pool to pool.
5. The fishway must provide adequate depth for swimming and turning.
6. Resting spaces for fish must be adequate.
7. Flow patterns in the fishway must be stable.
8. A debris deflector should be incorporated where water enters

the fishway.

9. A velocity control devise is needed where fish enter the fishway.
10. The exit should be located so that fish will not be easily swept back downstream.
11. Everything feasible should be done to reduce the need for cleaning the facility.

Even the most suitable type of fishway may not pass fish if the pools are too small, the slope is too steep, resting areas are inadequate, hydraulic conditions are unsatisfactory, or if the entrance does not attract fish. Locating the entrance of the downstream end of the fishway where it will attract upstream migrating fish is particularly important. Common errors include placing it too far downstream from the barrier, too far from the mainstream flow (or in a back eddy), or too high for easy entrance. Opportunities to combine the various types of fishways to facilitate fish passage under a wide range of flow conditions and to reduce operating and maintenance costs should be also be considered.

Several design and operational aspects of the proposed improved Vern Freeman Diversion present special problems for the passage of anadromous fishes. The complete control of low to moderately high flows (0 - 20,000 cubic feet per second) through the proposed wasteway would affect a significant percentage of the flows utilized by migrating anadromous fishes in the lower Santa Clara River. Because of the size of the drop and the downstream apron on the wasteway and river stablization structure, fish would not be able to navigate successfully up stream over either of these facilities. Consequently, in order for anadromous fishes to successfully pass over the Vern Freeman Diversion and reach upstream spawning and rearing tributaries, a fishway must be provided to carry a portion of the flows passed through the wasteway structure.

Steelhead typically will attempt to navigate up the heaviest flow. Large flows passed through the wasteway as a result may compete with smaller flows passed through the fishway causing fish to congregate below the wasteway rather than entering the fishway. (High flows passed through the wasteway may in some circumstances create a velocity barrier which would divert fish away from the wasteway and towards the fishway.) The design and location of the fishway, therefore, must ensure that migrating fishes utilize the fishway. Several techniques may be effective in solving this problem, including locating the entrance of the fishway immediately adjacent to the base of the wasteway structure, placing baffles at the base of the fishway, designing a fishway capable of carrying a wide range of flows so that a larger percentage of the wasteway flows may be passed through the fishway, and passing wasteway flows through the fishway at operational levels whenever sufficient wasteway flows exist.

In order to resolve these specific fishway problems, it is important that personnel from the California Department of Fish and Game with expertise in fishways make an on-site inspection of the project and prepare detailed recommendations for the final design, location, and operation of the fishway. Also, the subsequent operation of the facility should be monitored by Department personnel to determine the effectiveness of the fishway and recommend any necessary modifications in its design or operation.

Contingency funds should be made available to make modifications to the fishway necessary to improve its utility to migrating anadromous fishes.

The recommended fishway at the Vern Freeman Diversion should be operated during the migratory periods of anadromous fishes. Operation of the fishway would therefore occur principally during the winter and spring months when the majority of adult steelhead and Pacific lamprey migrate into the Santa Clara River system to spawn, and when adult and smolt steelhead and juvenile Pacific lamprey emigrate downstream to the ocean. It may also be necessary to operate the fishway during the early summer when late emigrating spent adult steelhead, smolts, and juvenile Pacific lamprey may be passing downstream to the ocean. Reduction of flows through the fishway during these periods should be accomplished gradually to approximate the natural decreases in the river's discharge and to lessen the possibility of stranding fish in the river between the Vern Freeman Diversion and the lagoon at the river's mouth.

Annual operation dates for the fishway would vary to coincide with the fluctuating winter and spring rainfall and run-off conditions in the Santa Clara River basin. Optimal operational dates cannot be determined definitively until more is known about the timing of the peak up and donwstream migration of anadromous fishes in the Santa Clara River system. However, based upon the limited knowledge of historical steelhead and Pacific lamprey migratory habits in the Santa Clara River system, comparable runs in other California Coastal streams, and discharge records for the Santa Clara River, an initial ladder operation schedule can be established. Tentative primary operation of the fishway should begin with the first winter rains which cause a natural river discharge of 500 cubic feet per second or more (as measured at the Vern Freeman Diversion) and continue until the second week in April. Additional secondary operation of the fishway may extend from the third week in April until the beginning of July to accomodate late emigrating steelhead and Pacific lamprey.

A related operational consideration is the construction and re-construction of the earthen training dike. The training dike is designed to fail at flows above 20,000 cubic feet per second. This would result in the disruption of by-pass flows through the wasteway and fishway. Peak and receding flood flows would pass over the proposed riverbed stabilization structure until the training dike had been re-constructed. During this period, because of the downstream drop from the base of the stabilization structure, an impassible barrier would exist for anadromous fishes attempting to migrate upstream to spawning and rearing tributaries. It is therefore important that reconstruction of the training dike be completed as quickly as possible so that the operation of the fishway may be resumed. Also, the flows passing through the fishway and the wasteway should be directed to provide for the natural re-establishment of a suitable migratory channel between the fishway and the potentially larger main river channel which would be created by the passage of flood flows over the river stabilization structure. Table 3 shows that this condition would have occurred during 31% of the twenty-nine years beetween 1950 and 1979 had the improved Vern Freeman Diversion facility been in operation, resulting in significant disruption of upstream anadromous fish migration.

In order to ensure the proper functioning of the fishway, periodic inspection and maintenance of the facility must be provided. To the extent

TABLE 3. YEARS BETWEEN 1950 AND 1979 DURING WHICH PEAK SANTA CLARA RIVER DISCHARGES EXCEEDED 20,000 cfs (PROPOSED TRAINING DIKE THRESHOLD) AT FREEMAN DIVERSION*

DATE	FLOW (cfs)
1-15-52	45,000
4- 3-58	52,000
2-11-62	47,700
12-29-65	51,900
12- 6-66	35,000
1-21-69	32,100
1-25-69	165,000
1-26-69	25,800
2-24-69	23,500
2-25-69	92,300
11-29-73	28,800
2-11-73	58,200
2- 9-78	21,100
2-10-78	44,600
2-11-78	20,000
3- 4-78	60,700
3- 5-78	30,300

SOURCE: USGS FLOW RECORDS, SANTA CLARA RIVER possible, the fishway should be self-cleaning to prevent the build-up of debris, sand, gravel, rubble, or rock which would impede the passage of fishes through the facility. Contingency funds should be available for periodic cleaning and maintenance of the fishway. A lists of references on the design, construction, and operation of fishways is provided in Appendix 3.

FISH SCREEN A fish screen on the diversion intake is necessary to prevent the induction of downstream emigrating spent adult steelhead, smolts, and juvenile Pacific lamprey into the diversion canal and ultimately the desilting and percolation basins. Prior to 1928, escapement of anadromous fishes to the ocean was limited primarily by the gradual natural reduction of late winter and spring run-off, or by an accelerated reduction of run-off caused by periodic droughts. With the development of a permanent diversion facility, downstream migrant anadromous fishes became subject to reduced river flows to the ocean and induction into the diversion intake when diversion operations were being conducted. As indicated above, the proposed improved Vern Freeman Diversion would divert flows ranging from 0 to 20,000 cubic feet per second through the wasteway; flows above this level would breach the earthen training dike and pass over the river stabilization structure. Under this mode of operation, downstream emigrant anadromous fishes would pass by the diversion intake and be subject to induction into the diversion canal and desilting and percolation basins. During the winter and spring months, when a maximum diversion of 375 cubic feet per second is possible, the ratio of water diverted through the intake to water by-passed through the wasteway would be 1:1 at 750 cubic feet per second. and greater than 1:1 with river flows under 750 cubic feet per second. Based upon historic diversion and stream flow records, this situation would prevail for considerable periods during most years. Downstream emigrating anadromous fishes typically follow the river channel carrying the greatest flow, as do upstream migrating anadromous fishes. During peak emigration periods, it is likely that diversion flows will exceed by-pass flows a majority of the time, and the induction and consequent loss of a proportionately high number of emigrating fish will occur without effective screening. Under these conditions without effective screening of the diversion intake, emigrating fish would be permanently trapped in the diversion canal, desilting, and percolation basins.

As in the case of fishways, the design and location of fish screens must take into account a number of considerations. According to Burns (1966) the following factors must be considered in the development of an effective fish screen:

1. Amount of water to be diverted.
2. Availability of excess water.
3. The swimming ability, behavoir, and size of the fish to be screened.
4. The quantity and size of debris which may reach the screen.
5. The frequency, duration, timing, and magnitude of flows, particularly peaks and lows.
6. The frequency, duration, timing, and magnitude of fish movements.

Given the location and design of the existing intake at the proposed improved Vern Freeman Diversion, the screen should be located immediately adjacent to the fishway and upstream of the present intake to ensure the

the immediate passage of emigrating fish into and through the fishway. A screen located downcurrent from the fishway entrance could concentrate and trap fish in the dead-end velocity area against the screen. It is important that this condition be avoided. Specific design of the fish screen should only be made after an on-site inspection by the California Department of Fish and Game personnel with expertise in the design and operation of fish screens. A list of references on the design, construction, and operation of fish screens taken from Burns (1966) is presented in Appendix 4.

MINIMUM BY-PASS FLOWS The successful operation of the recommended fishway and fish screen will depend upon the provision of adequate downstream by-pass flows during migratory periods, or some other method of transporting anadromous fishes to and from the ocean. Because the main stem of the Santa Clara River acts primarily as a transportation corridor for anadromous fishes (not as spawning or rearing habitat) continuous year round flows in the river are not necessary to sustain, restore, or improve the present anadromous fish populations in the Santa Clara River system. The precise level of flows necessary to allow the successful passage of a sufficient number of adults upstream to spawning and rearing areas, and a sufficient number of juveniles downstream to the ocean cannot be determined without additional research and monitoring. However, based upon the stream morphology of the lower Santa Clara River and the flow requirements recommended by the California Department of Fish and Game for other coastal streams, the following interim flow levels may be considered the minimum necessary to allow the migration of anadromous fishes in and out of the Santa Clara River.

November - March: 150 - 200 cfs

April - June: 50 - 75 cfs

This interim by-pass flow schedule should be monitored by either the California Department of Fish and Game or the State Water Resources Control Board, or a private consultant selected jointly by these agencies for a period of not less than five years before a final by-pass flow schedule is established. Additionally, if the downstream riparian vegetation and resident fishes below the Vern Freeman Diversion are to be maintained, flow must be provided from July to the onset of the following winter rains. Consideration of the magnitude of flows necessary to sustain these resources was beyond the scope of this study.

Because of the magnitude of natural occurring flows in the Santa Clara River, upstream transportation flows will often be available even with the proposed improvements to the Vern Freeman Diversion. The flow requirements for downstream emigrant steelhead smolts may present a more serious conflict between the proposed diversion schedule and the migration requirements of anadromous fishes. However, it may not be necessary to maintain the flow levels suggested above on a continuous basis through the migratory period: periodic flushing flows may be effective in moving either adult fish which have congregated at the mouth of the river or smolts and spent adult steelhead which have congregated at the Vern Freeman Diversion between the diversion and the ocean. It may be possible that the conjunctive use of water regulated by the three upstream reservoirs (Piru, Pyramid, and Castaic) could provide a means of producing the necessary transportation flows in the lower river during critical migratory periods. The percentage of potentially divertable flows which it would be necessary to by-pass for fish transportation in the lower river (and the amount to be provided by releases from upstream reservoirs) could vary from 0% to 100% depending upon the rainfall and run-off pattern in the basin, the amount which is finally determined to be necessary to provide adequate transportation, and the actual diversion capacity of the intake, desilting, and percolation facilities. An average annual percentage or range of annual percentages cannot be projected without knowning the historic amount of river flow which has been available for diversion, the theorectical diversion capacity of the Vern Freeman Diversion, and the amount of flow (levels and duration) necessary to provide adequate transportation for anadromous fishes in the lower Santa Clara River. The determination of these values was beyond the scope of this study, but must be made prior to making a final decision on the best method of providing transportation flows between the Vern Freeman Diversion and the ocean.

In this connection it should be recognized that the amount of water necessary for the maintenance of an adequate unbroken flow from the Vern Freeman Diversion to the ocean will depend to a large extent on the configuration of the river channel. The Santa Clara River often runs in a braided channel which spreads flows out over a wider area than if they were confined in a single continuous channel, thus reducing the depth of the river flow and its suitability for navigation by migrating fish. This situation has been worsened to some extent by stream-bed alterations for sand and gravel operations and flood control activities. It may be possible to construct a single confined pilot channel in the flood-way to carry spring low flows and facilitate the downstream movement of fishes to the ocean, thus making more efficient use of natural occurring river flows and reducing the amount of additional natural or supplemental bypass flows necessary to transport emigratory fishes to the ocean.

To assure optimal river channel configuration for the passage of anadromous fishes along the entire length of the Santa Clara River, the following guidelines should be used in performing stream-bed alterations:

1. River flow should be maintained in a single, continuous unbraided channel.
2. Construction of artificial channels should be allowed only between June 15 and the onset of the first winter rains resulting in a natural river discharge of 500 cubic feet per second.
3. Artificial channels should be constructed in a manner which incorporates natural stream characteristics, including meanders, pools, and riffles into a single unbraided channel.
4. A minimum 60 foot wide buffer on both sides of the low flow channel should be maintained free of all excavation or other activities to protect existing riparian vegetation and eliminate artificial sedimentation.
5. Whenever activities require crossing any river flows, a temporary culvert should be installed and maintained to: a) minimize sedimentation in the channel and adjoining habitat; and b) allow the free up and downstream passage of fishes. A sufficient number of culverts should be incorporated into each crossing to prevent the creation of a high water velocity fish barrier.
6. Whenever water diversions are made for washing sand and gravel

or other purposes, diversion facilities should be installed in such a manner as to: a) prevent the induction of fishes; b) minimize sedimentation; and c) provide for the free up and downstream passage of fishes.

Additionally, monitoring under actual project conditions will be necessary to determine the most efficient means of transporting anadromous fishes in the Santa Clara River between upstream spawning and rearing tributaries and the ocean.

STEELHEAD FISHERY ENHANCEMENT OPPORTUNITY

An opportunity may exist to mitigate the loss of some of the historic spawning and rearing habitat lost through habitat destruction and the permanent blockage of access to spawning and rearing grounds through the rearing of steelhead smolts in an aquaculture facility. Effluent from the Ventura Eastside Sewage Treatment Plant, located at the mouth of the Santa Clara River, could be used in rearing juvenile steelhead to smolt size. Such a rearing facility would consist of a series of ponds added to or incorporated into those currently existing adjacent to the sewage treatment plant. The treatment plant's effluent would be mixed with seawater to provide a buffered rearing environment for juvenile steelhead. Upon reaching smolt size, the steelhead would be released directly into the river's lagoon during the winter and spring months. Returning adult steelhead would re-enter the estuary during subsequent winter and early spring months, thus enhancing the adult steelhead sport fishery in the lagoon. An unknown porportion of these returning adults would also be expected to increase the adult run in the upstream spawning tributaries.

A system similar to the one proposed here is currently operating at Arcata in Humboldt County. For additional information on artificial steelhead rearing facilities a list of relevent wastewater aquaculture references is included as Appendix 5.

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APPENDIX 1

FISHES OF THE SANTA CLARA RIVER SYSTEM AND ESTUARY*

A = ABUNDANT C = COMMON R = RARE
E = RARE AND ENDANGERED
N = NATIVE I = INTRODUCED

1 - Primarily lake dwelling; may occur in slow moving or stillwater areas of the Santa Clara River system. Spawn: spring - summer.

2 - Primarily stream dwelling; occurs in perennial and some emphemeral stream flow portions of the Santa Clara River system. Spawn: spring-summer.

3 - Anadromous; adults enter Santa Clara River in winter and early spring, migrate into principal tributaries to spawn. Juveniles live in tributaries and some perennial stream flow portions of the Santa Clara River from 1 - 3 years, then migrate to the ocean during the winter and spring.

4 - Juveniles of marine species enter Santa Clara River estuary and lower river in winter; adults may be present in the estuary any time of the year, though primarily found in spring and summer.

5 - Estuarine; permanent residents of the Santa Clara River estuary and lower Santa Clara River. Spawn: late spring - early summer.

SPECIES	COMMON NAME (KEY)
Atherinops affinis	Topsmelt (4NC)
Carassius auratus	Goldfish (1IC)
Catostomus fumiventris	Owens Sucker (1IR)
Catostomus fumiventris x santannae	Hybrid Sucker (2IR)
Catostomus santannae	Santa Ana Sucker (2IC)

*Source: Areta and Wilsrud (1980); Bell (1978); Sasaki (1980); Swift (1980)

SPECIES	COMMON NAME (KEY)
Clevelandia ios	Arrowy Goby (5NR)
Cottus asper	Prickley Sculpin (4NC)
Cymatogaster aggregata	Shiner Perch (4NC)
Cyprinus carpio	Common Carp (1IC)
Dorosoma petenense	Threadfin Shad (1IC)
Engraulis mordax	Northern Anchovey (4NC)
Entosphenus tridentatus	Pacific Lamprey (3NC)
Eucyclogobius newberryi	Tidewater Goby (5NR)
Fundulus parvipinnis	California Killifish (5NC)
Gambusia affinis	Mosquitofish (1IC)
Gasterosteus aculeatus microcephalus	West Coast Threespine Stickleback (2NA)
Gasterosteus aculeatus williamsoni	Unarmored Threespine Stickleback (2NE)
Gila orcutti	Arroyo Chub (2IA)
Gillichthys mirabilis	Longjaw Mudsucker (4NC)
Hypsopsetta guttulata	Diamond Turbot (4NC)
Ictalurus melas	Black Bullhead (1IC)
Ictalurus nebulosus	Brown Bullhead (1IC)
Lepomis cyanellus	Green Sunfish (1IC)
Lepomis gibbosus	Pumpkinseed (1IC)
Lepomis marochirus	Bluegill (1IC)
Lepomis microlophus	Redear Sunfish (1IC)
Leptocottus armatus	Pacific Staghorn Sculpin (4NC)
Micropterus dolomieui	Smallmouth Bass (1IR)

SPECIES	COMMON NAME (KEY)
Micropterus salmoides	Largemouth Bass (1IC)
Morone saxatilis	Striped Bass (landlocked (1IC)
Mugil cephalus	Striped Mullet (4NC)
Notemigonus crysoleucas	Golden Shiner (1IC)
Pimephales promelas	Fathead Minnow (1IC)
Platichthys stellatus	Starry Flounder (4NC)
Pomoxis annularis	White Crappie (1IC)
Pomoxis nigromaculatus	Black Crappie (2IR)
Rhinichthys osculus	Speckled Dace (2IR)
Salmo gairdneri	Rainbow Trout (2NC)
Salmo giardneri gairdneri	Steelhead Rainbow Trout (3NR)
Salmo trutta	Brown Trout (2IR) (spawns in the fall)

APPENDIX 2

FLORA ASSOCIATED WITH THE SANTA CLARA RIVER AND IMMEDIATE FLOOD PLAIN NEAR THE VERN FREEMAN DIVERSION SITE*

A = AQUATIC   S = SEMI-AQUATIC   T = TERRESTRIAL
N = NATIVE   I = INTRODUCED

SPECIES	COMMON NAME (KEY)
Amaranthus retoflexus	Amaranth (IT)
Ambrosia acanthicarpa	San-Bur (NT)
Ambrosia psilostachya californica	Rag-Weed (NT)
Anagalis arvensis	Pimpernel (IT)
Artemisia californica	Coastal Sagebrush (TN)
Artemisia douglasiana	Mugwort (SN)
Arundo donax	Giant Reed (IS)
Atriplex lentiformes breweri	Saltbush (NT)
Atriplex patula hastata	Saltbush (NS)
Baccharis glutinosa	Mule Fat (SN)
Baccharis pilularis consanguinea	Coyote Bush (TN)
Brassica nigra	Black Mustard (TI)
Calystegia macrostegia intermedia	Morning Glory (NT)
Cammissonia hirtella	Evening Primrose (NT)
Chenopodium album	Lambs Quarters (IT)

* Source: Modified from Farrel and Fox (1979)

SPECIES	COMMON NAME (KEY)
Chenopodium ambrosioides	Mexican Tea (ITS)
Chenopodium botrys	Jerusalem Oak (IT)
Cirsium occidentale	Thistle (NT)
Conium maculatum	Poison Hemlock (IS)
Cotula coronopifolia	Brass Buttons (IS)
Cynodon dactylon	Bermudagrass (NST)
Cyperus erythrorhizos	Unbrella Sedge (NA)
Datura meteloides	Jimsonweed (NT)
Distichlis spicata	Saltgrass (NAS)
Eleocharis parishii	Spike Rush (NAS)
Elymus condensatus	Rye Grass (NT)
Eremocarpus setigerus	Dove Weed (NT)
Foeniculum vulgare	Sweet Fennel (IT)
Helianthus annus lenticularis	Sunflower (NT)
Heliotropium curassavicum oculatum	Heliotrope (NT)
Heterotheca grandiflora	Telegraph Weed (NT)
Lemna minor	Duckweed (NA)
Leptochloa uninerva	Sprangletop (NS)
Lotus strigosus	Bird's-Foot Trefoil (NT)
Marrubium vulgare	Horehound (IST)
Melilotus albus	Sweet Clover (ITS)
Melilotus indicus	Sweet Clover (ITS)
Mimmulus cardinalis	Monkey Flower (NS)
Nicotiana glauca	Tree Tobacco (IT)
Plantago lanceolata	English Plantain (IST)

SPECIES	COMMON NAME (KEY)
Polygonum amphibium stipulaceum	Water Smartweed (NA)
Polygonum lapathifolium	Smartweed (NS)
Populus fremontii	Fremont Cottonwood (NT)
Populus trichocarpa	Black Cottonwood (NT)
Portulaca oleracea	Purslane (IT)
Ricinus communis	Castor Bean (IT)
Rorippa nasturtium-aquaticum	Water Cress (IA)
Salix hindsiana leucodendroides	Sandbar Willow (NS)
Salix lasiolepis lasiolepis	Arroyo Willow (NS)
Salix lasiandra lasiandra	Pacific Willow (NS)
Salsola iberica	Russian Thistle (IT)
Salvia leucophylla	White Sage (NT)
Scirpus robustus	Tule (NA)
Solanum douglasii	Nightshade (NT)
Solanum nigrum	Nightshade (NT)
Sonchus oleraceus	Sow Thistle (IT)
Spirodela polyrhiza	Greater Duckweed (NA)
Suaeda californica	Sea Blite (NA)
Toxicodendron diversilobum	Poison Oak (NT)
Tribulus terrestris	Puncture Vine (IT)
Typha latifolia	Cat Tail (NA)
Urtica holosericea	Nettle (NS)
Verbena menthaefolia	Vervain (NT)
Veronica anagallis-aquatica	Water Speedwell (IA)
Xanthium strumarium canadense	Cocklebur (NST)

SPECIES	COMMON NAME (KEY)*
Chara sp.	- - -
Cladophora sp.	- - -
Enteromorpha sp.	- - -
Rhizoclonium sp.	- - -
Zygnema sp.	- - -

* Algal genera common to the Santa Clara River at the Vern Freeman Diversion site.

APPENDIX 4

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APPENDIX 5

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