Revised

FISH RESOURCES TECHNICAL REPORT

FOR THE ENVIRONMENTAL IMPACT STATEMENT/ ENVIRONMENTAL IMPACT REPORT

Cachuma Project Contract Renewal

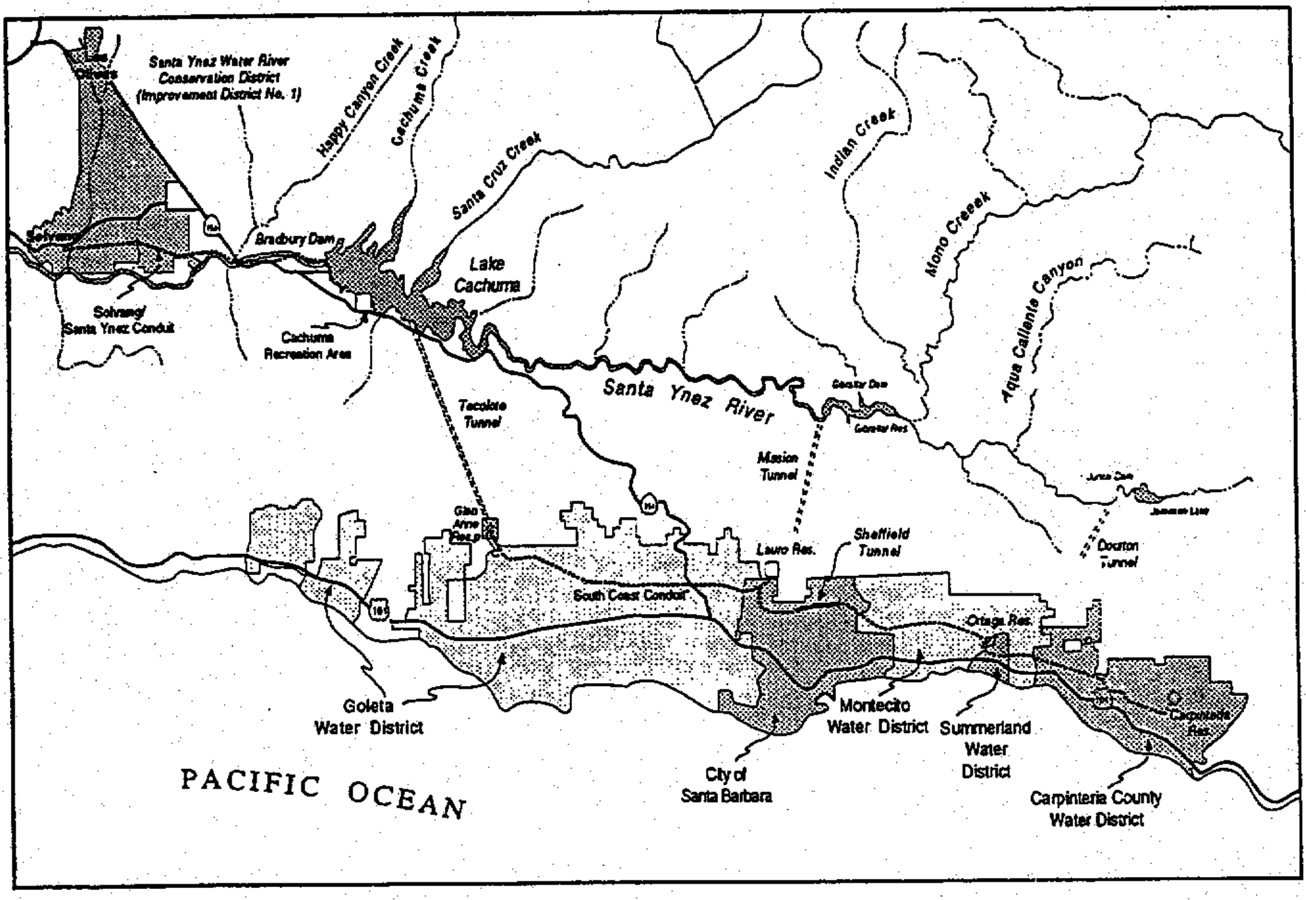

EXHIBIT CT 35

December1995

Bureau of Reclamation
Cachuma Project Authority
Santa Barbara County Water Agency

CACHUMA CONTRACT RENEWAL
FISH RESOURCES
TECHNICAL REPORT

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Project No. 307809

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In developing the alternative scenarios we requested a flushing flow of 500 cfs not less than once in every three years. Santa Ynez River Model runs indicated that such flows would occur with this frequency.

2.5.3 HABITAT-FLOW RELATIONSHIPS

2.5.3.1 IFIM

Introduction

The basic framework of our habitat analysis was adapted from the Instream Flow Incremental Method (IFIM)/Physical HABitat SIMulation (PHABSIM) method (Bovee 1982, Milhous *et al.* 1984). The IFIM was developed by the United States Fish and Wildlife Service (USFWS) during the late 1970s to evaluate impacts of water development projects on riverine fish habitat and to improve communication between fishery biologists and water managers. The IFIM links several elements of fisheries science and hydraulic engineering to forecast the availability of fish habitat under alternative streamflow, stream temperature and/or channel conditions. This instream flow assessment method is based on the concept that changes in riverine fish habitat can be described by evaluating the relative importance of changes in streamflow and associated fluvial processes using species-specific habitat suitability criteria.

The quality of the physical habitat in a river is a function of flow and channel geometry and therefore, varies in quality and quantity over the range of the flow regime. Simulation of physical habitat is accomplished using the channel geometry of the stream and streamflow. The purpose of the PHABSIM models is to simulate a relationship between streamflow and physical habitat for various lifestages of a species of fish.

Santa Ynez River Model

DWR Model

In 1988, as part of the evaluation of the proposed Cachuma Enlargement Project, the California Department of Water Resources (DWR) employed the IFIM to model steelhead habitat on the Santa Ynez River below Bradbury Dam (DWR, 1989). This report includes a complete description of their methodology. A total of 40 transects were placed in six locations from the area of San Lucas Ranch downstream to Buellton (see Figure 2.5-5). At each transect, one set of velocity and depth data was collected at the highest flow measured, and water surface elevations were collected at this flow and at two or three additional flows. These data were used to create single flow models on a representative reach basis.

The representative reach modeling approach taken by DWR involved the selection of an area of the river which is "representative" of the study reach as a whole. This representative measurement area should have approximately the same proportion of habitat types as the overall study reach, and each of the habitat units in the measurement area should be similar to most of the habitat units of that same type throughout the study reach. This study reach is modeled as a whole and the results of this modeling are assumed to apply to the river as a whole. This was the modeling approach recommended by the Instream Flow Group when the IFIM was first introduced. The major weakness of this approach is the difficulty of finding a study area which is truly "representative". A second difficulty is that only a small number of transects are generally placed across any particular habitat type so that the extent that the model transects fail to represent the habitat of the entire reach is magnified through the extrapolation of results to the entire study reach.

Model Recalibration

Since 1984, the Instream Flow Group has been recommending an alternate approach to modeling with the IFIM based on the proportion of each habitat type within the study reach (Milhous 1984). Using this method, several transects are placed across each habitat type and each transect is viewed and modeled independently. These transects are then weighted to reflect the actual proportion of each habitat type as assessed through habitat mapping. This weighting may be done either within the modeling program or after the fact. The CDFG currently endorses this approach to IFIM modeling.

For this evaluation, we updated the DWR models and reconfigured them as habitat-based models. The DWR reach models were broken apart into individual transects. The data entered in each model were rechecked against the original field notes and corrected as necessary. Each transect was recalibrated, and placed into habitat-based models by segment. In these models the transects were weighted by the proportion of each habitat type present within each segment according to the proportions defined by the habitat mapping results (Section 2.5.1).

Our review of the DWR IFIM models indicated that at 10 transects significant portions of the channel had been omitted from the models. These areas were backwaters or side channels, and may provide substantial rearing habitat for young steelhead/rainbow trout. For this analysis these areas were entered back into the models. On two additional transects, the stage-discharge relationship was poor due to missing stage of zero flow measurements. The stage of zero flow was estimated based on the existing stage-discharge points. When these corrections were made, the stage-discharge relationships were brought into an acceptable range of error (<10 percent, Appendix B).

In the revised models, the transects from the San Lucas site and the Highway 154 site were used to model the habitat above Refugio Road, while the transects from the remaining sites were used to model the habitat of the segment below Refugio Road. The winter steelhead habitat suitability criteria of Bovee (1978) were used to interpret the results of the hydraulic simulations and calculate weighted usable area versus flow relationships. These criteria were selected in consultation with the USFWS and CDFG. Weighted usable area (WUA), an index of habitat, is given in square-feet per 1000 feet of stream channel and provides an index of habitat availability for the different lifestages of fish. It must be emphasized that this number is an index and not an absolute area. WUA does allow different flow regimes within a single river to be compared in a relative sense, and thus provides a valuable tool for comparing alternative water use recommendations.

Habitat Relationships

The WUA versus flow functions for the Santa Ynez River above Refugio Road are presented in Figure 2.5-6. This figure indicates that the index of habitat (WUA) for adult

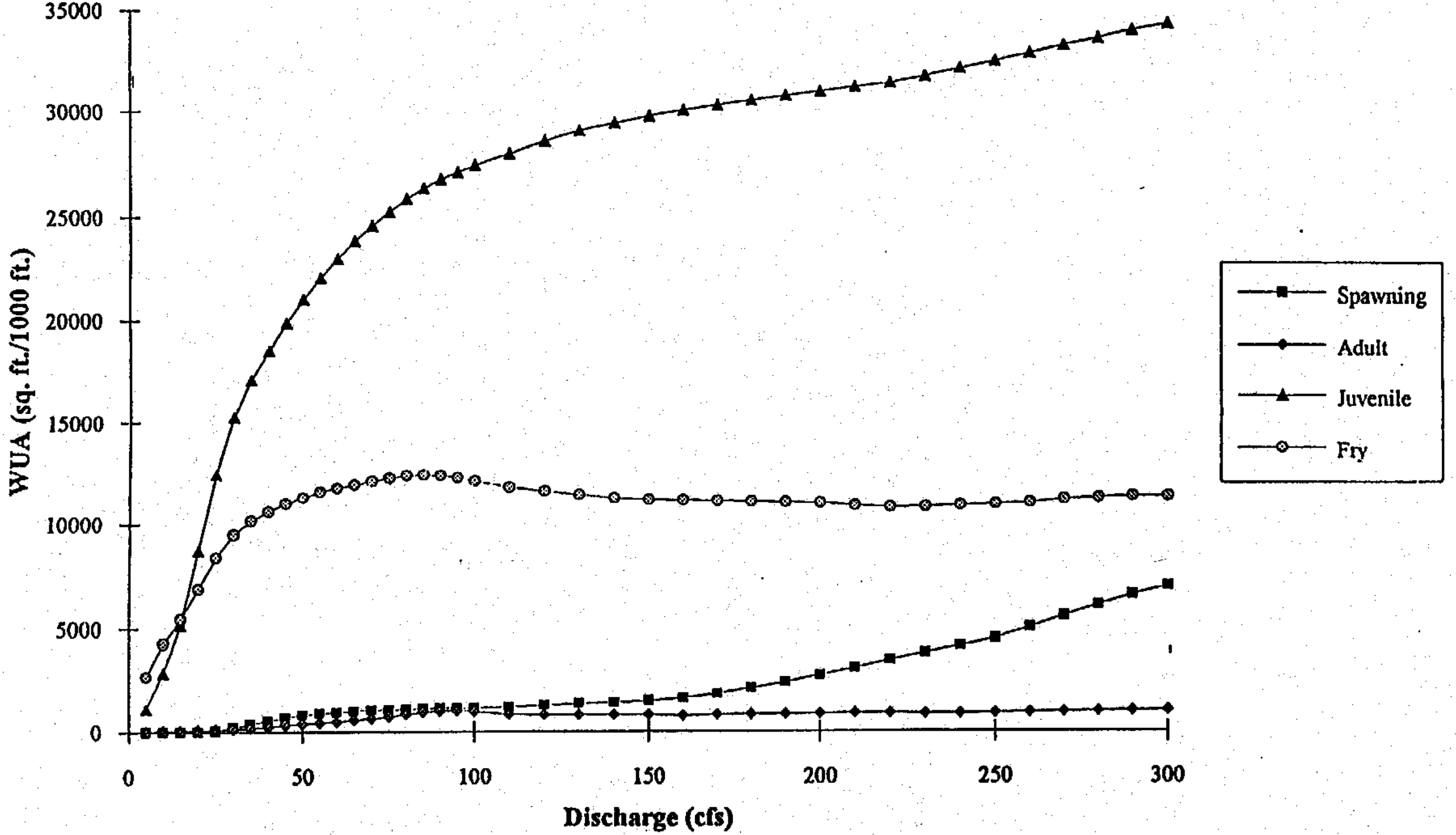

Figure 2.5-6. WUA for Steelhead on the Santa Ynez River Between Refugio Road and Bradbury Dam.

steelhead and for spawning increases very slowly with increases in flow and that it is of limited availability across the entire range of flows modeled. Spawning WUA was run both including and excluding the contribution of deep pool habitats. Figure 2.5-7 reveals that no differences in total spawning area exists with and without deep pools until flow exceeds 80 cfs. The difference between the two is slight up to flows of 150 cfs.

To evaluate the effect of substrate on the spawning WUA above Refugio Road, the hydraulic models for this section were run with "ideal" substrate for spawning (gravel) in all locations. This represents the maximum potential enlargement of spawning substrate in existing channels, regardless of feasibility. This results in velocity and depth suitability functions controlling the WUA. WUA with "ideal" substrate increases more rapidly than WUA with existing substrate (Figure 2.5-8). At 50 cfs "ideal" substrate WUA is 33 percent greater than existing substrate WUA, at 70 cfs it is 41 percent greater and at 100 cfs it is approximately 59 percent greater (Table 2.5-2). While "ideal" substrate does increase WUA values, this substrate may be infeasible to place and difficult or impossible to maintain throughout this entire reach based on the current composition of the river substrate.

The fry habitat index increases rapidly as flow increases from 5 to 30 cfs (see Figure 2-5.6). Above this flow, fry WUA remains fairly stable. Juvenile steelhead WUA increases rapidly with flow to about 80 cfs. The rate of WUA increase then declines substantially. Fry WUA was run with "ideal" substrate (cobble) throughout the reach in a similar manner as was done for spawning. The "ideal" WUA was substantially greater than that under existing substrate conditions, even under conditions of relatively low flow (Figure 2.5-9).

Based on the Bovee (1978) winter steelhead criteria, the "ideal" substrate for fry is composed of bed elements ranging from 2.75 to 10 inches in median diameter. These substrate elements provide fry with cover from predators and refugia from high water velocities. To maintain this function, the interstitial spaces between the substrate elements must not be filled with sand, silt or other fine materials so that small fish and invertebrates can utilize these areas. Under current flow regimes on the Santa Ynez River, these interstitial spaces are largely filled, and thus unsuitable for these purposes. Therefore it is inappropriate to use the "ideal" substrate fry WUA functions for habitat analysis. Although these functions do indicate a possible avenue for enhancement, we did not use the "ideal" substrate condition WUA values for spawning or fry in conducting the analyses of the alternatives in Section 2.5.3.3. The "ideal" substrate should be viewed as the maximum potential enhancement of fry habitat. As stated above, it would be infeasible to actually achieve this level of enhancement.

Because the area of habitat required to support one fish varies with lifestage, it is impossible to determine limiting lifestage from WUA plots alone. Using an analysis of habitat area in conjunction with a review of the literature for specific habitat area requirements and survival rates, it appears that the amount of fry habitat is most limiting to the steelhead population of the Santa Ynez River. This means that fry habitat is more limiting to the population than the low availability of either adult or spawning habitat. The results of the limiting factor analysis are presented in Section 3.3.

The WUA functions for the Santa Ynez River below Refugio Road are presented in Figure 2.5-10. In this segment spawning WUA is zero below 15 cfs and then increases with flow up to about 75 cfs. Spawning WUA then declines as flow increases further. Adult habitat is fairly constant increasing only slightly with flow up to about 80 cfs. Juvenile habitat increases with flow to 40 cfs and remains constant as flows increase further. Fry habitat increases with flow up to about 20 cfs and then declines as flows increase further.

Once again the WUA functions do not tell the entire story. Other factors which are thought to potentially affect steelhead populations in the Santa Ynez River are temperature, predation and water quality, none of which were incorporated by the WUA functions. Water temperature may be too warm to support steelhead fry and juveniles in this segment (Section 2.5.4.1) without selective releases of cool hypolimnetic waters. Predation by bass and sunfish in this segment may also reduce the quality of habitat for young steelhead/rainbow trout. Low dissolved oxygen levels have been measured in the Santa Ynez River during summer, which also may affect the potential habitat quality of this area.

Split Channels

Much of the length of the Santa Ynez River between Buellton and Bradbury Dam is composed of areas where the flow of the river is split between two or more channels over some range of flow. DWR placed four transects in these split channel areas. Three of

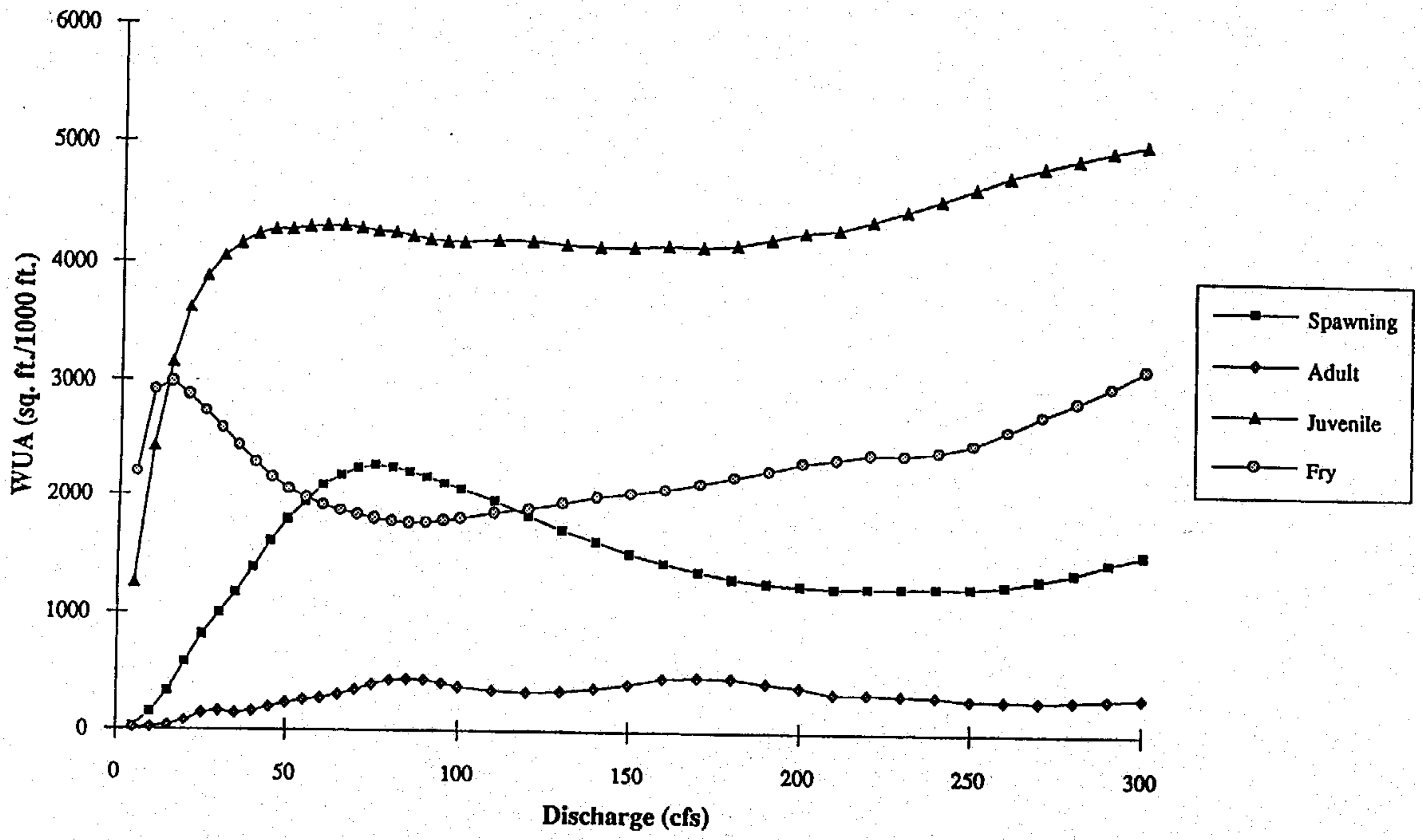

Figure 2.5-10. WUA for Steelhead on the Santa Ynez River Between the Highway 101 Bridge and Refugio Road.

these splits were located above Refugio Road and the remaining transect was downstream of Refugio Road. These transects were placed in riffle and run habitat types. Information was lacking in these models as to at what discharge the side channels began to flow, what the proportion of different habitat types was in split channels, and what the proportion of the total river length was composed of split channel areas. To answer these questions ENTRIX conducted additional studies on several split channel areas along the river.

To take advantage of flow releases being made in the summer of 1994, transects were placed at four split channel areas along the Santa Ynez River prior to the commencement of the flow release. In each area, one transect was placed upstream of the split, and separate transects were established for each potential side channel. In all, a total of 12 transects were placed. Of these four split channel areas, the river flow was divided among two channels at three sites. Flows during 1994 were not high enough to water the fourth split channel area.

These channels were surveyed to determine the proportion of each habitat type in the side channels. Flow and water surface elevations were measured on 12 occasions over the course of approximately two months. During this period, flows were ramped down from 130 cfs (the initial discharge rate from the dam) to 30 cfs (the discharge from the dam on October 1st when studies were concluded).

The length of the river which had significant side channels was determined based on aerial photography taken on May 15, 1994. Because there was not continuous flow in the river during this time, this determination was made from patterns of riparian growth and geomorphic indications of past side channel activity. This evaluation indicated that approximately twenty and twenty-seven percent of the segment lengths (above and below Refugio Road, respectively) were side channel areas.

The habitat composition in the side channels which became wetted during the side channel studies was determined when mainstem flows ranged from approximately 122 cfs at the upper site (about 1.5 miles upstream of Refugio Road) to about 106 cfs at the lower site (near the golf course in Solvang). Flows in the side channels themselves ranged from 10 to 44 cfs. This survey found that runs composed approximately 64 percent of the side channel habitat, while riffles made up an additional 34 percent. Pools composed a relatively insignificant proportion of the side channel habitat, comprising only 2 percent.

Based on the data developed for split channel areas in 1994 and a review of DWR's split channel models, two of three side channels begin to flow when the total discharge in the river adjacent to them is approximately 25 to 30 cfs. In the final transect, side channel flow begins at approximately 15 cfs, but does not represent a significant proportion of the total flow until flows reach about 20 to 25 cfs.

The proportion of flow in the side channels was determined for all of the 1994 side channels studied and for the four DWR split channel transects. One of the DWR splits did not hold a significant proportion of the flow (<5 percent) even when flows in the mainstem were over 75 cfs. Flows in the remaining side channels appeared to be relatively constant, once a certain threshold was reached. Three of the six remaining side channels generally held approximately 20 percent of the total flow over a wide range of flows studied, one side channel contained just less than half of the total flow (48 percent), while another carried about 15 percent. The final side channel had a somewhat different pattern with the proportion of flow in the side channel being inversely proportional to the total flow from 114 to 36 cfs. This proportion ranged from 22 to 39 percent.

DWR's split channel models were used to complete a WUA function for side channel areas (DWR's split channel transect below Refugio Road was not used in this analysis because it lacked enough data to obtain a stage discharge relationship). DWR did not place a split channel transect across a pool area, but as pools represented only 2 percent of the side channel areas, this lack is probably not significant. This analysis began with the determination of which of DWR's paired split channel models represented the main channel and which represented the side channel. The WUA function for the main channel and side channel transects were computed individually and then were added together to form a combined WUA function. The combined WUA functions were based on the empirical apportionment of flow between the two models of 75:25 percent as was indicated by the side channel studies.

A sensitivity analysis of flow proportions between side channels and the mainstem was conducted by assuming different proportions of flow in the side channels to determine the effect on the final WUA function. For riffles, this analysis indicated that the WUA function was relatively insensitive to the amount of flow in the side channels for fry and juveniles (Figures 2.5-11 and 2.5-12). Spawning in riffles showed a somewhat greater sensitivity to the amount of flow apportioned to the side channels, but this response was fairly small in the range of flows considered under the alternatives for spawning (less than 70 cfs) (Figure 2.5-13). As the proportion of flow most commonly found in side channels (during side channel studies and in the DWR data) was near the mid-point of the range of flow apportioned in the sensitivity analysis, this is not likely to affect the outcome of the analysis.

Runs were somewhat more sensitive to the amount of flow apportioned to the side channel (Figures 2.5-14, 2.5-15 and 2.5-16), particularly for fry (see Figure 2.5-14) and spawning (Figure 2.5-16). Fry showed a declining WUA with increasing flow, indicating that velocity in side channel runs rapidly exceeded the suitable velocities for this lifestage as indicated by the preference criteria. This is supported by the increase in spawning WUA with increasing flow, although this is likely to be a result of rapidly increasing depth, as well. With fry, the differences in WUA at different flow apportionment levels is small at the flows being considered under the various alternatives (less than 20 cfs), and thus the effects of the amount of flow apportioned to the side channels is unlikely to significantly affect the results of the alternative analysis. Juvenile WUA in split-channel runs has a relatively flat relationship with flow, and exhibits only moderate sensitivity to flow apportionment between channels. Therefore, split-channels appear unlikely to affect the results of the alternative analysis. Spawning WUA in runs is more sensitive to changes in flow apportionment than any of the other WUA functions, with different levels of flow apportionment resulting in more than a two-fold difference in WUA at the lower range of flows. This has the greatest probability of altering the WUA functions in the comparison of alternatives. It is interesting to note that the side channels provide higher WUA values than do the mainstem areas under most of the flows simulated. This is likely to be the result of a faster increase in depth and velocity with increase in flow than in mainstem areas. This may indicate that if an increase in spawning habitat is desirable, the creation of spawning channels may be more feasible than attempting mitigation in the existing mainstem channels.

A comparison was made between the preliminary WUA functions without side-channels and the new WUA functions which include the side-channels. To combine mainstem and side-channel WUA functions into one WUA function for the entire segment, the segment was broken up into 2 reaches, based on the proportion of side-channel habitat. Aerial photographs indicated that side-channel areas made up approximately 20 percent of the segment length. Therefore, 80 percent of the segment length was undivided channel. The average division of flow in split channel areas was 75 percent of the flow remained in the main channel while 25 percent of the flow went into the side channel. Therefore, to combine the WUA functions we estimated the mainstem WUA using 100 percent of the flow and weighted it by 0.8. To this we added the split channel areas WUA. This was calculated by computing the mainstem WUA at 75 percent of the flow and the side channel WUA at 25 percent of the flow. These WUA values were each weighted by 0.2 (the proportion of the segment which was split channel). The sum of these three WUA's would be the WUA for the segment in square feet per 1,000 feet of stream. This quantity was then extrapolated to obtain the total WUA for the segment.

This comparison revealed only very minor differences in the total amount of WUA as indicated in Figure 2.5-17. Juvenile and fry WUA increased only very slightly, while increases in spawning WUA were nearly undetectable. The addition of side channels to the modeling process did not modify the shape of the WUA function. The addition of side channel habitat to the WUA functions based on mainstem habitats did not result in any modification of the scores for the various alternatives.

2.5.3.2 Current Habitat Conditions

Based on the WUA versus discharge functions and flow exceedance data collected at the USGS gage near Solvang from January 1954 through September 1991, WUA values above Refugio Road indicate that habitat availability has been low for steelhead spawning except in wet years (20 percent exceedance, Table 2.5-3). Fry habitat is available from April through June in wet years, and in April in normal years. Fry habitat appears to be unavailable during dry years. The lack of juvenile habitat from July through November in even wet years, as indicated by WUA values, may restrict steelhead habitat to refuge areas that are accessible during periods when the river dries up. Such refuge areas may be available in scattered pools such as the Long Pond, however, introduced predators such as bass and sunfish reduce the value of these refuge areas for fry and juvenile steelhead.

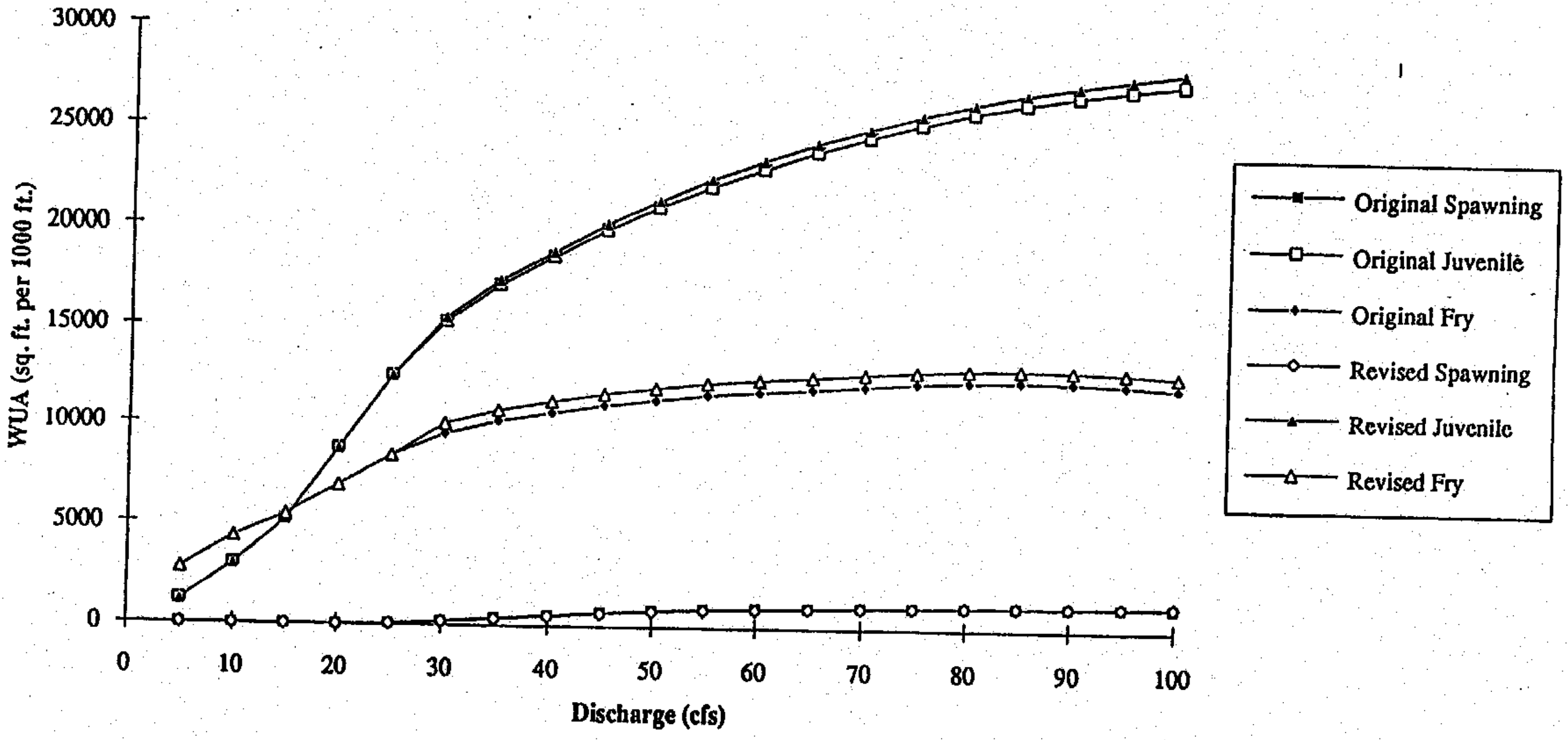

Figure 2.5-17. Effects of the Addition of Side Channel Habitat on the Overall WUA Function Above Refugio Road.

Below Refugio Road spawning habitat as indicated by the WUA versus discharge function is available during wet years, but is low during normal years (Table 2.5-4). During dry years no spawning WUA is present. Fry WUA is highest from April through June in wet years. In normal years there is little WUA for fry except in April. In dry years, there is little or no fry habitat (as indicated by the WUA functions).

In wet years, the WUA function indicates that the amount of juvenile habitat available is highest from January through May. The WUA values for December and June are less than half of the January through May values. From July through November, WUA values are very low. In normal years WUA is highest in March and about half the March value in February and April. During the rest of the year, WUA values are low. During dry years, WUA values for juveniles are low throughout the year. This section of river goes dry during August and September even in wet years, and from May through December in dry years. During these periods, fish may move into refuge pool areas.

Tables 2.5-5 and 2.5-6 present the exceedance flows and WUA for the two segments based on the flows at the USGS gage at the Highway 154 bridge for its period of record after the construction and operation of Cachuma Dam (January 1954 through September 1976). We have presented these tables because the flows at the Highway 154 bridge are actual flows measured in the segment above Refugio Road, whereas the Solvang gage represents flows in the segment below Refugio Road. These flow records were not used in our primary analysis because the gage was removed from service in 1976 and therefore does not reflect current flow conditions within the river, nor does it reflect the drought years of 1977-78, and 1987-91. We also ran exceedance values for the Solvang gage over the same period as the Highway 154 gage to provide a comparison of flow at these two points in the river over the same period of record (Tables 2.5-7 and 2.5-8).

Comparisons of these tables with Tables 2.5-5 and 2.5-6 reveals that the December through June flows for the same exceedance level at Highway 154 were substantially lower than they were at Solvang during the same period of record. However, flow was higher at Highway 154 in June through November. The WUA values for the segment above Refugio Road based on flows at the Solvang gage presented in our primary analysis overestimates the amount of habitat available in February through June, particularly for juvenile fish. The Highway 154 records provide one less month of little or no habitat (based on WUA) for fry and juvenile fish. The river still goes dry, however, from September through January in normal years. Differences in WUA below Refugio Road for the different periods of record at the Solvang gage are insignificant.

Upstream Migration Criteria

Upstream migration is a critical event in the steelhead lifecycle. Steelhead, like the other anadromous salmonids, return from the sea to their natal streams to spawn. This migration may be impeded by a number of factors such as turbidity (Bell 1986) and low dissolved oxygen, or physical passage barriers such as falls, high velocities, or shallow depths. Dissolved oxygen concentrations are discussed in Section 2.5.4.3, and turbidities must be very high to impede migration (4,000 NTU) and therefore are not thought to be a problem on the Santa Ynez River. During the habitat survey, the river between Buellton and Bradbury Dam was examined for passage barriers. Similar surveys were conducted by DWR and Thomas R. Payne in 1991 for the river reach between Lompoc and Buellton. No falls or velocity barriers were observed, but areas with insufficient depth for upstream migration were observed. This section examines the amount of flow required to provide sufficient depth to allow steelhead to migrate past such areas.

The passage surveys indicated that all of the potential passage barriers would be of concern only at low flows. These barriers were always related to shallow riffles or gravel bars, and not to permanent hydrological features (i.e., bedrock sills, weirs, etc.). As such, it is unlikely that these potential passage problem areas are consistent from year to year or in the same locations from year to year. As a result, the approach taken assumes that the passage problems can be assessed through the assumption that similar passage problems are present each year, and that these passage problems are always represented by riffles. While the actual location of the problem riffles may change from year to year, the hydraulic characteristics of the riffles remain similar. This concept is termed a state of "dynamic equilibrium". In a river, such as the Santa Ynez, which has a mobile bed, this approach is as valid as is setting up specific transects on observed passage problems (Morhart *et al.*, 1983). It is likely any given passage problem will change after the next large flow event. But it is also likely that a similar problem will develop elsewhere on the river. To assess the amount of flow required for steelhead to successfully navigate such passage barriers we have used the riffle transects in the reach below Refugio Road and a set of passage criteria for steelhead developed by Thompson (1972). A second potential passage problem was the numerous beaver dams observed in the Lompoc area, but steelhead can generally get around, over, or through beaver dams and steelhead are common in rivers and streams where beaver are numerous.

Thompson (1972) defined passage criteria for steelhead as a depth of greater than 0.6 feet over 25 percent of the wetted channel width, with at least 10 percent being contiguous, and velocities of less than eight feet per second. Because Thompson's work was done in the Pacific Northwest and the steelhead of that region are somewhat larger than the southern steelhead of the Santa Ynez River (Withler, 1966; Shapovalov, 1944a), the minimum passage depth was reduced to 0.5 feet. To evaluate the amount of flow needed for passage, the depth-flow relationships for riffles below Refugio Road were reviewed. Riffles were selected for evaluation because they represent the shallowest habitat type and thus would most likely represent the low flow passage barriers that were identified during habitat mapping. Those in the segment below Refugio Road were evaluated because the river was wider in this area than above Refugio Road, and hence would be shallower and would represent the most critical passage areas.

Four riffle transects were evaluated, one in the Lower Alisal IFIM site and three in the Buellton IFIM site. These cross sections and their water surface elevations at 10 and 25 cfs are presented in Figures 2.5-18 through 2.5-21. Moving from downstream to upstream, examination of Figures 2.5-18 and 2.5-19 shows that passage is not a problem at these two Buellton transects even at flows as low as 10 cfs. The third Buellton riffle transect does indicate that passage is a problem at 10 cfs, and is marginal at 25 cfs (Figure 2.5-20). The situation is similar at the Lower Alisal site riffle which was modeled (Figure 2.5-21). The passage criteria were not met at 10 cfs, but were adequately met at 25 cfs.

Based on the foregoing analysis, a minimum flow criterion of 25 cfs was adopted for the passage of adult steelhead in the Santa Ynez River. This criterion was used to establish the binary passage scores discussed in the alternatives analysis section.

2.5.3.3 Limiting Factors for Steelhead

Ecological theory tells us that all populations are limited at a given level by some factor. Limiting factors are physical or biological factors that constrain biological populations by preventing an increase above a certain level or by causing mortality. The identification of limiting factors is important in determining the types of fishery and habitat management activities that will help us to achieve a particular goal. Usually in fisheries management, the goal is to produce more fish. To achieve that goal, we need to know what is preventing the population from increasing. Once we have identified the limiting factor(s), we can decide if there is some action that we can take to alleviate the constraint. This is the approach currently recommended by the U.S. Fish and Wildlife Service National Biological Survey (formerly known as the Instream Flow Group or IFG).

The low populations of steelhead/rainbow trout in the Santa Ynez River likely derive from a number of factors. Among these are lack of access to sufficient suitable spawning and rearing habitats (especially those blocked by the construction of Bradbury Dam), irregular flows affecting passage to areas containing suitable habitat downstream of Bradbury Dam, insufficient flows to provide suitable habitat in the mainstem downstream of Bradbury Dam, irregular passage flows from spawning areas to the lagoon for emigrant adults and juveniles, degradation of mainstem habitats due to alterations in sediment transport and flow regimes, and the presence of numerous warmwater predators downstream of Bradbury Dam. In addition, when populations are very small, they may be unable to exploit episodic good conditions when they occur. Therefore, in an irregular flow and habitat environment, a population may become too small to recover to greater abundance on its own.

One of the consequences of the construction and operation of Bradbury Dam was the reduction in seasonal habitat available to steelhead/rainbow trout in the mainstem downstream of Bradbury Dam. This included a reduction in the area of suitable habitat available and a decrease in the frequency with which the fish could gain access to it.

A limiting factor analysis integrates information on life history features, sources of mortality, and habitat requirements with the environmental conditions encountered by the species of interest, steelhead. The limiting factor analysis has several parts. It usually begins with the evaluation of life history. The timing of events is important because different life history stages have different habitat requirements. For example, habitat requirements for young fish differ from those needed for spawning. Data are needed from both the scientific literature (habitat requirements) and from site-specific studies (habitat availability as indicated by IFIM).

The next step is to evaluate the habitat requirements for each species and life history stage. This information then permits an evaluation of the adequacy of habitat conditions in the Santa Ynez River downstream of Bradbury Dam to support a particular lifestage.

Once the factors affecting important lifestages have been identified, then we can find the lifestage that is limiting the population. If we can take some action to remove this restriction, then we can increase the population. The amount of increase that can be achieved will depend on at what point the next limiting factor takes effect. One way of evaluating limiting habitat factors is to examine whether the habitat available, as indicated by IFIM results, for a specific lifestage can potentially support fewer fish than an earlier or later lifestage can. The habitat that supports a lower number of fish may limit the ultimate number of fish that can be produced and is known as the "habitat bottleneck". By identifying the "habitat bottleneck" we can identify what habitat and lifestage is constraining population growth.

The IFIM habitat analyses discussed above provides an index of the amount of habitat potentially available for steelhead lifestages as a function of flow. By examining the availability of habitat, we can gain insight into potential of the habitat to support steelhead. By examining the habitat area available for spawning, we can roughly estimate the number of steelhead redds that can be accommodated. As discussed above, the majority of mainstem spawning habitat downstream of Bradbury Dam appeared to occur upstream of Refugio Road. Table 2.5-2 shows spawning WUA for existing substrate in the reach above Refugio Road. Considering the length of the reach and an average redd size of 48 ft^2, a rough estimate of the number of potential steelhead redds may be obtained. That estimate is about 651 redds based on the habitat present at a flow of about 48 cfs. Using an estimated fecundity of 4,600 eggs per redd, approximately three million eggs would be obtained. Based on an embryo survival to emergence of 40 percent, about 1,200,000 fry potentially could potentially be produced in this portion of the mainstem.

The number of fry that can be accommodated in that area is somewhat flow dependent. Based on an USFWS (pers. com.) estimate of one fry per three square feet of WUA, Table 2.5-9 presents the number of fry that potentially could be accommodated in rearing habitat upstream of Refugio Road. Values are presented for existing substrate or the number that could be accommodated under existing conditions.

Table 2.5-9. Fry Rearing Potential and Ratio of Potential Fry Habitat to Fry Production from Potential Spawning Habitat.

Discharge (cfs)	Fry Habitat Rearing Potential	Ratio of Potential Fry Habitat to Habitat needed by Potential Fry Production
5	37,895	3%
10	60,345	5%
15	76,013	6%
20	96,559	8%
25	117,321	10%
30	133,100	11%
35	142,392	12%
40	148,772	12%
45	154,339	13%
50	158,446	13%
55	162,508	14%
60	165,110	14%
65	167,462	14%
70	169,931	14%
75	172,270	14%
80	173,999	15%
85	174,396	15%
90	174,117	15%
95	172,587	14%
100	170,376	14%
110	165,866	14%
120	163,105	14%
130	160,521	13%
140	158,528	13%
150	157,440	13%
160	156,892	13%
170	156,662	13%
180	156,081	13%
190	155,766	13%
200	155,305	13%
210	153,664	13%
220	152,414	13%
230	152,990	13%
240	154,004	13%
250	154,765	13%
260	155,733	13%
270	157,937	13%
280	159,106	13%
290	160,116	13%
300	160,407	13%

Note: Estimated Fry Production at 48 cfs
(Assuming 40 Percent Embryo Survival to Fry Stage)

We can then compare the habitat needed by the potential number of fry that can be produced at the spawning flows being evaluated with the fry rearing habitat available to support them. The second column of Table 2.5-9 clearly shows that existing fry rearing habitat available is insufficient to support the number of fry that could potentially be produced from spawning. The third column of that table presents the fraction of the potential fry production that can be accommodated by fry rearing habitat through a range of flows. No more than 15 percent of the fry that could be potentially produced could be accommodated at any flow.

This means that fry rearing habitat will generally be more limiting than spawning under the project alternatives being considered (See Section 3.1). It should be kept in mind that even before the construction of Bradbury Dam, the availability of fry rearing habitat may often have been a problem. Hydrologic modeling suggests that the mainstem of the river frequently went dry. Fish rescue operations were described by Shapovalov (1944a). He indicated that young-of-the-year steelhead became stranded in the mainstem during dry years before the construction of Bradbury Dam. Perennial tributaries must have played an important role for both fry and juvenile freshwater rearing.

The conclusion that can be drawn from the above is that mainstem fry habitat will need to be increased substantially or that fry will need to rear somewhere else. Lagoon rearing is important to steelhead in other river systems (Smith 1990) and can provide rearing habitat when insufficient area is available in the mainstem of the river. One of the places that Shapovalov (1944a) placed rescued young-of-the-year fish was in the Santa Ynez River lagoon.

Improvement of mainstem fry rearing habitat is possible. PHABSIM simulations of fry habitat with improved cover (substrate) (described in Section 2.5.3.1) suggest that fry habitat could be increased substantially. Although, IFIM analyses suggest that substantial improvements in fry habitat could be obtained with substrate improvements (providing cobble), it is likely infeasible to achieve more than a fraction of what is theoretically possible. This is due to the size of the reach that must be "improved" and the need to maintain the large substrates without embedding by sand or other fine sediments.

Juvenile steelhead may rear for up to a year or more in freshwater. Historically, mainstem rearing habitat has not been available on a dependable basis. This is because flows have not been present each year in the mainstem, nor have they persisted throughout the year.

Hydrologic modeling and historical accounts suggest that this was true before the construction of Bradbury Dam, as well. In order for there to be adequate juvenile rearing habitat, both sufficient physical habitat and adequate water quality need to be maintained.

The relationship of juvenile rearing habitat to flow was analyzed using IFIM (Section 2.5.3.1). Table 2.5-10 shows the potential number of juvenile steelhead that could be accommodated by rearing habitat based on IFIM results in column three. The second column indicates the maximum potential number of fry that could be available to become juveniles. That number would be attained if the full rearing potential of the existing fry habitat was realized, all of those fry stayed in the river mainstem and 25 percent of the resultant fry survived to become juveniles. This is likely an overestimate of resultant fry production. The fourth column presents the ratio of juvenile habitat needed to accommodate the resultant fry and juvenile habitat available with flow. At a flow of 10 cfs 81 percent of the resultant fry could potentially be accommodated as juveniles. At 15 cfs, there would be sufficient habitat to accommodate more than the potential resultant fry. At a higher flow, such as 40 cfs, there would be twice as much habitat available as potentially would be needed.

Juvenile habitat downstream of Bradbury Dam (at flows over 10-15 cfs) has the potential to accommodate more juveniles than can be produced by the existing fry habitat. Therefore, it is less limiting to the steelhead population than fry habitat. Spawning habitat downstream of Bradbury Dam (at a flow of 48 cfs and assuming passage is provided) has the potential to produce more fry than fry rearing habitat has the potential to accommodate. Therefore, spawning habitat is potentially less likely to be limiting than fry habitat given flows in the Santa Ynez mainstem in the range discussed. This suggests that mainstem fry habitat is likely to be more limiting than either of the other two habitat types. It is likely to be a "habitat bottleneck", if all fry rearing is to occur in the mainstem.

The limiting factors analysis discussed above, suggests that if adequate passage and spawning flows are provided, only a portion of the resultant fry can be accommodated in mainstem rearing habitat. This suggests that mainstem fry rearing habitat should be improved to increase the potentially available suitable habitat. It also suggests that emigration passage flows should be provided to allow fry to move to the lagoon to rear. Access to other habitat areas should also be considered to expand potential rearing areas. In addition, rearing area that may be used by fry or juveniles during the warmer months will need to have suitable DO and water temperatures.

Water Temperature Monitoring - Below Gibraltar Dam

Water temperatures also are being monitored in the reach upstream of Lake Cachuma. These recorders are located as shown in Figure 2.5-28. Water temperatures recorded upstream of Lake Cachuma during 1994 are presented in Figure 2.5-29. During May, there was an approximately 1.8°F (1°C) increase in water temperature between the dam and Los Prietos Campground. During the remainder of the summer, daily mean water temperature continued to increase reaching 24°C below Gibraltar Dam and near 26°C at Los Prietos Campground. This resulted in water temperatures over 68°F (20°C) in late May. It does not appear that water temperatures in this reach will likely be suitable for adequate growth of trout during the summer months.

2.5.4.2 Stream Temperature Model

Introduction

A water temperature model was calibrated for the mainstem of the Santa Ynez River downstream of Bradbury Dam. The purpose of the model was to estimate daily mean water temperatures that could be obtained downstream of Bradbury Dam by releasing flows associated with the various alternatives. Another key reason for using the model was to determine the benefits that could be obtained from the release of cool water from Lake Cachuma's hypolimnion (bottom water) in conjunction with the minimum flows associated with the alternatives.

One of the reasons for using a stream temperature model was to analyze conditions other than those that were present during the time of data collection. For example, during 1993, air temperature conditions in the Santa Ynez River area were extremely warm. During the spring and summer, air temperatures were among the hottest recorded in the area.

Model Description

Water temperatures were estimated using the USFWS' SSTEMP model. This model is a PC-based model prepared by the USFWS' Instream Flow Group (Bartholow, 1991). The model is based on physical relationships. There are two additional models that are used with SSTEMP. These include the SSSOLAR and SSHADE models. The SSSOLAR model predicts solar radiation and day length based on the latitude of the stream basin, time of year, basin topographic characteristics, and prevailing meteorologic conditions.

Stream shading is computed from measurements of the stream azimuth, stream width, topographic altitude, vegetation crown diameter, vegetation height, vegetation offset (the average distance of the vegetation from the water's edge), and the vegetation density. The stream shading sub-model allows accounting of the effects of topographic and vegetative shading.

Data Requirements and Calibration

Three sets of data are required as input to the model: (1) meteorologic, (2) hydrologic, and (3) stream geometry. Meteorologic data consist of solar radiation coefficients (atmospheric dust and ground reflectivity), air temperature, relative humidity, possible sunshine, and wind speed.

Hydrologic data consist of discharge data throughout the stream system, initial temperatures of the mainstream and significant tributaries, and estimates of the temperatures of distributed inflows (groundwater or overland).

Stream geometry consists of a definition of the stream system network (latitudes, elevations, and distances), stream widths, stream shading, and hydraulic retardance. Stream shading is computed from measurements of the stream azimuth, stream width, topographic altitude, vegetation crown diameter, vegetation height, vegetation offset (the average distance of the vegetation from the water's edge), and the vegetation density. The degree of detail provided with IFG's stream shading sub-model is unique and allows precise accounting of the effects of topographic and vegetative shading.

The model was calibrated based on structural and shade field data collected during 1994 and meteorological, hydrological, and water temperature data collected during 1993. The data set was divided into two subsets. One subset only was used to calibrate the model, the second subset only was used to check the calibration and calculate "fit" statistics. The validation data set was used independently of the calibration.

Stream Structure Data Collection

Stream structure data are necessary for calibration of the stream temperature model. A field trip was conducted during July 1994 to estimate the topographic and vegetative shading. Data were converted to the model input format using our program SHADECALC.

Areas for collection of structure data were determined initially from maps and aerial photographs. Each area was then characterized from on-site measurements.

System geometry and stream gradient were determined from aerial photography and USGS maps. Stream width measurements were taken during the stream shading field trip and during the course of the IFIM studies. Width functions were derived for each structural reach for the range of flows studied. Manning's (roughness coefficients) was determined from data collected during the IFIM studies.

Hydrology data were obtained from the USGS for the Alisal Bridge location in Solvang. This was the only active gaging station operated in the study reach. Release flow data were obtained from the U.S. Bureau of Reclamation.

Meteorological data were obtained from local stations. Air temperature data were collected near Lake Cachuma (NCDC reporting station), Santa Ynez (CIMIS reporting station), Lompoc (NCDC reporting station), Santa Maria Airport (NCDC reporting station), and Santa Barbara Airport (NCDC reporting station).

The air temperature data obtained from the meteorological station for the duration of the meteorological monitoring period was compared with the historical means (normals) and the average daily extremes in order to assess whether the meteorology was different from the means or the extremes.

The meteorological data from these stations also was used to derive the relative humidity, wind speeds, and cloud cover. These values were used as input for the stream temperature model.

Water temperature data were collected by CDFG and SYRTAC during 1993 as described above. Data for July through August were used for model calibration and validation. Complete data sets including meteorology, water temperature, and hydrology data were available for the period. Complete data sets are needed for either calibration or validation. Additional data were collected during 1994 by CDFG and SYRTAC, the SYRTAC data set was not available in time to be used in model calibration.

The calibration used nodes at Bradbury Dam (0 mi. downstream), the "long pool" (0.3 mi. downstream), San Lucas Ranch (1.0 mi. downstream), and Alisal Bridge in Solvang (9.8 mi. downstream). These locations correspond to sites where water temperatures were recorded.

The 1993 data sets for all parameters were assembled and all days for which there was incomplete data were removed. The remaining data set was divided into two independent subsets. A random selection was made to designate one subset for calibration and the other set for model validation. The model was calibrated using the calibration data subset. Upon completion of calibration, the model was used with the validation data set to calculate fit and model performance. Figure 2.5-30 shows examples of measured and estimated water temperatures used in model validation. The validation statistics are presented below for each of the calibration nodes.

Statistic	Long Pool	San Lucas Ranch	Alisal Bridge
Average Bias °F (°C)	0.12(0.07)	-0.41(-0.23)	-0.46(-0.26)
Standard Deviation of the Bias	0.48(0.27)	1.60(0.89)	1.81(1.01)

The statistics indicate that the model, on average, predicts water temperatures about 0.07°C warm at the Long Pool, about 0.23°C cool at San Lucas Ranch, and about 0.26°C cool at Alisal Bridge. The standard deviations indicate decreased precision of estimates

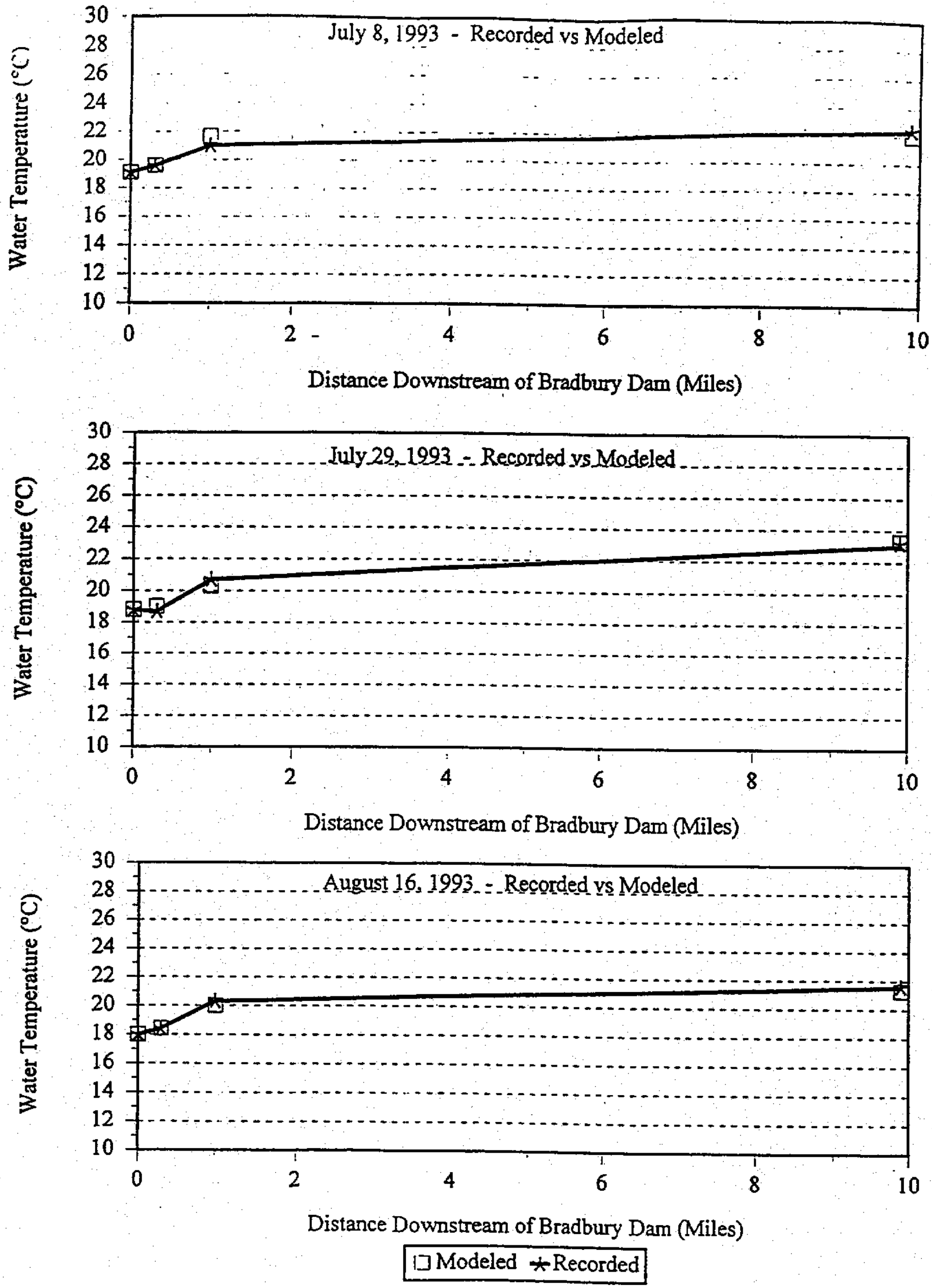

Figure 2.5-30. **Santa Ynez Water Temperatures.**

at stations further downstream. As described by Theurer *et al.* (1984), the 50 percent confidence interval at each of the nodes is described below.

Statistic	Long Pool	San Lucas Ranch	Alisal Bridge
Upper C.I. °F(°C)	0.27(0.15)	0.83(0.46)	0.64(0.36)
Lower C.I. °F(°C)	-0.03(-0.02)	-1.65(-0.91)	-1.56(-0.87)

Although the model provided a reasonable fit for the data sets used to calibrate and validate it, it should be kept in mind that the 1993 data set represented extreme meteorological conditions. Based on air temperatures, the summer of 1993 was extremely warm, one of warmest on record. The use of an extreme data set for calibration may result in some predictive bias for other conditions compared to the same model calibrated to more varied or more normal conditions.

Simulation

The model was used to estimate daily mean water temperatures in the Santa Ynez River downstream of Bradbury Dam during the warmer months, May through September. An additional node was added at Refugio Road to add additional detail to the results. Simulations were performed for normal meteorological conditions (median air temperatures) for each month. Water temperatures were estimated for each of the 3A alternatives that were under consideration for the "environmentally preferred alternative". The principal target of estimating water temperatures was predicting habitat conditions for steelhead/rainbow trout.

Estimates of release water temperatures potentially available from the release of hypolimnetic (bottom) lake water were provided by CH2MHill (Everett, pers. comm.). Release water temperatures were related to storage levels in Lake Cachuma. Release water temperatures associated with each alternative's storage levels were used with the calibrated model to estimate downstream water temperatures for each alternative. The water temperatures available from hypolimnetic lake water are presented in Table 2.5-13.

Median flows were calculated from simulations of alternatives resulting from the hydrological model. Flows used in water temperature simulations were median flows for

Table 2.5-13. Hypolimnetic Release Water Temperatures Used for Water Temperature Simulations.

	Water Temperature (°F)				
Alternative	May	June	July	August	September
Alt 1	58.3	60.1	61.9	66.0	67.8
Alt 3A1	58.9	60.7	62.5	66.2	68.0
Alt 3A2	57.5	59.3	61.1	64.3	66.1
Alt 3A3	59.0	60.8	62.6	66.3	68.1
Alt 3A4	57.5	59.3	61.1	64.5	66.3
Alt 3A5	59.2	61.0	62.8	66.6	68.4
Alt 3A6	59.2	61.0	62.8	66.5	68.3
Alt 3A7	59.2	61.0	62.8	66.5	68.3

	Water Temperature (°C)				
Alternative	May	June	July	August	September
Alt 1	14.60	15.60	16.60	18.88	19.88
Alt 3A1	14.97	15.97	16.97	18.98	19.98
Alt 3A2	14.17	15.17	16.17	17.97	18.97
Alt 3A3	14.99	15.99	16.99	19.07	20.07
Alt 3A4	14.16	15.16	16.16	18.05	19.05
Alt 3A5	15.13	16.13	17.13	19.22	20.22
Alt 3A6	15.10	16.10	17.10	19.19	20.19
Alt 3A7	15.12	16.12	17.12	19.17	20.17

each month simulated for each alternative. Median flows used in simulations are presented in Table 2.5-14.

Meteorological data are also needed for predicting water temperatures. Median air temperatures must be based on a sufficiently long period of record. Although several of the reporting stations had long-term data available, the Santa Ynez station did not. Correlations between long-term NCDC climatic data and the local air temperatures enabled us to produce historical climatic data which was then transposed to the study area.

An r^2 value of 0.75 was obtained between air temperatures recorded the Santa Ynez meteorological station and Cachuma. These transposed data were ranked to obtain the 50th percentile air temperature. Corresponding wind speed, humidity, and cloud cover were obtained, as well. The meteorology corresponding to the 50th percentile (median) was used for stream temperature simulations of alternate flow regimes (normal conditions). Median air temperatures used in simulating the alternatives are presented in Table 2.5-15.

The long-term historical median air temperatures were used with average values for other meteorological values for which only shorter periods of record were available. Values for other meteorological values are presented in Table 2.5-16. Solar radiation and day length were calculated using the USFWS SSOLAR submodel. Average monthly shade values (Table 2.5-17) were calculated from the USFWS SSHADE submodel.

The daily mean water temperatures estimated using the model were tabulated for comparisons between alternatives. These results are presented in Table 2.5-18. This table presents the estimated daily mean water temperature at each node location. It also presents the distances downstream of Bradbury Dam that are below 20°C and 22°C, respectively. The 20°C temperature was presented since this represents a temperature that has been identified as providing for acceptable growth of rainbow trout stocks in Central and Southern California. The 22°C temperature was selected since it represents a temperature slightly above that identified for no net growth (21.5°C) of northern *O. mykiss* stocks (Hokanson *et al.*, 1977). This temperature may represent a temperature where little or no net growth may occur for southern rainbow trout stocks, but may not result in stress or mortality.

The water temperature estimates should be interpreted in light of the validation statistics. That is where the bias estimate indicates the estimates were too warm or too cool, the predicted temperature should be interpreted as likely to have the same bias, on average. These water temperatures also are presented as part of enhancement discussion for each alternative in Section 3.0.

2.5.4.3 Dissolved Oxygen

Dissolved oxygen levels in the mainstem of the Santa Ynez River were measured at streamflow releases of approximately 10 cfs on 8 and 9 July, 5 cfs on 13 and 14 October and 1 cfs on 9 and 10 November 1993 between the stilling basin and Highway 154 bridge (SYRTAC, 1994). There were substantial daily fluctuations in the DO levels between pre-dawn and late afternoon readings (Table 2.5-19). The early morning readings showed DO in the Santa Ynez River could decrease to levels that are stressful to several species of fish inhabiting the river, including steelhead/rainbow trout. The daily fluctuation in DO levels is the result of a natural process of respiration and photosynthesis involving algae. Large mats of algae were observed covering the surface of several large pools upstream of the Highway 154 bridge. Through the processes of photosynthesis and respiration, algae alternatively produces and uses oxygen. During daylight hours (photosynthesis) DO would be released, resulting in high DO levels. However, at night, respiration may result in very low DO levels during the early morning hours.

Daytime measurements recorded in March 1994, suggest that dissolved oxygen levels in the Santa Ynez River were sufficient (≥8.0 ppm) to allow steelhead and rainbow trout to migrate and spawn in the river. However, during the critical summer/fall rearing season in 1993, daily minimum levels of 3.0 ppm or lower (minimum of 1.8 ppm) were recorded in SYRTAC Sampling Sites 1, 4 and 15 during spot checks in July, October and November. Although these data are limited in scope, they indicate that dissolved oxygen, under existing conditions, can drop to levels which are stressful and possibly lethal to rearing steelhead/rainbow trout.