A PLAN FOR THE PROTECTION AND MAINTENANCE OF SALMON AND STEELHEAD IN THE AMERICAN RIVER, CALIFORNIA, TOGETHER WITH RECOMMENDATIONS FOR ACTION.

Prepared jointly by
United States Fish and Wildlife Service
and the
California Department of Fish and Game

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREFACE</td>
<td>11</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>iv</td>
</tr>
<tr>
<td>PART ONE, NATURAL HISTORY AND NUMBERS OF AFFECTED ANADROMOUS FISHES</td>
<td>1</td>
</tr>
<tr>
<td>PART TWO, POSSIBILITY OF FISH LOSS AT NIMBUS DAM POWERHOUSE</td>
<td>15</td>
</tr>
<tr>
<td>PART THREE, STREAM IMPROVEMENTS, NATURAL AND ARTIFICIAL SPAWNING AREAS</td>
<td>18</td>
</tr>
<tr>
<td>PART FOUR, MAIN RIVER FISH WEIR, FISHWAY, HOLDING PONDS, AND RELATED FACILITIES REQUIRED FOR EXCESS ADULT SALMON AND STEELHEAD TROUT</td>
<td>24</td>
</tr>
<tr>
<td>PART FIVE, FISH HATCHERY</td>
<td>29</td>
</tr>
<tr>
<td>SUMMARY</td>
<td>38</td>
</tr>
<tr>
<td>RECOMMENDATIONS</td>
<td>42</td>
</tr>
<tr>
<td>Discussion of Recommendations</td>
<td>44</td>
</tr>
<tr>
<td>Specific Recommendations</td>
<td>47</td>
</tr>
<tr>
<td>SCHEMATIC MAP</td>
<td></td>
</tr>
</tbody>
</table>
This plan for the protection and maintenance of salmon and steelhead trout in the American River, California, is concerned with the effects of Nimbus Dam which is under construction by the Bureau of Reclamation as a part of the American River Division of the Central Valley Project. Folsom Dam, under construction by the Corps of Engineers, will also be operated by the Bureau as a part of the project. The latter dam is being constructed on the American River at a site approximately 30 miles above the confluence with the Sacramento River about 3/4 mile below the main fork of the American River. When completed, the dam will be a concrete-gravity and earthfill structure 281/4 feet high with an overall crest length of 21,500 feet (including auxiliary dikes). It will impound a maximum of 1,000,000 acre-feet of water and will be the main storage unit of the project division. Folsom Power Plant, under construction at the base of the main dam by the Bureau of Reclamation, will have a capacity of 198,000 k.v.a. in its three units. Nimbus Dam with a 15,000 k.v.a. power plant of two units and forming a combination re-regulating reservoir and diversion structure is under construction by the Bureau of Reclamation at a site 7 miles downstream from Folsom Dam. This concrete-gravity structure will be 75 feet high and 800 feet long when completed and will create a lake of 8,900-acre-feet.

A schematic map showing these project features is attached at the end of the report.

Of the more than 400,000 acres-feet of water to be developed by the American River Division, 272,000 acre-feet will be diverted from Nimbus Dam to service about 150,000 acres of newly irrigated lands.

The Fish and Wildlife Service has prepared a preliminary evaluation report on the Folsom Project dated June 1950 which contains additional data on the various project features mentioned above and discusses all fish and wildlife aspects of them. This Service report should be consulted for a
description of the American River area and for other, above mentioned, information. The present report considers only the effects of Nimbus Dam on anadromous fishery resources.
INTRODUCTION

The U. S. Fish and Wildlife Service and the California Department of Fish and Game have the responsibility under act of August 14, 1946 (60 stat. 1080; 16 U.S.C. 661) 79th Congress of preparing an action plan for the conservation of salmon and steelhead runs affected by the construction of Nimbus Dam on the American River. As a result of discussions between these agencies and with the Bureau of Reclamation, an investigative period of from February 1, to July 1, 1953 was originally selected to be devoted to the development of such a plan. An outline of the various items to be considered during this period was prepared and distributed to the agencies involved on February 2, 1953. As the investigation progressed it became apparent that effective salmon and steelhead salvage facilities must be in operation by the fall of 1954. To speed up preparations for handling the runs the deadline for the report on an action plan was advanced to May 15, 1953.

This report follows the outline as closely as possible. The investigation of a few of the items has not been completed because of the curtailment of the investigative period. It may be necessary to submit a supplementary report covering these points at a later date.
PART ONE

NATURAL HISTORY AND NUMBERS OF AFFECTED ANADROMOUS FISHES

Time And Size Of Adult Salmon Runs

The runs of salmon in the American River are made up entirely of one species, the king salmon (Oncorhynchus tshawytscha). Like other species of Pacific salmon, kings are completely dependent on fresh water streams for reproduction and upon the sea for growth to maturity.

King salmon enter the American River in well-defined spring and fall runs. The spring run arrives at old Folsom Dam mainly during the months of May, June and July and involves comparatively few salmon. Until recently spring salmon made use of the fish ladder at the old Folsom Dam in migrating to the deeper, cooler areas up river where they could spend the summer. Counts of these migrants (Table 1) were made at Folsom Dam in 1945, 1946 and 1947. In 1950 floods destroyed the ladder. No attempt was made to rebuild this structure since the new Folsom Dam, a complete block to migratory fish, was under construction a short distance upstream. Since 1950 spring-run salmon have been forced to remain in the pools below the old dam. Nothing is known of the size of these latter runs or of the numbers of salmon which survived high water temperatures during the summer.

The main salmon run in the American River takes place in the fall, beginning in late September, peaking in October, continuing in November and tapering off in December. Most of these fish spawn between Sacramento and Folsom Dam. A small portion of the run (Table 1) spawned upstream from Folsom Dam prior to the destruction of the fish ladder.

For three years, 1944 through 1946, the size of the fall salmon runs in
the American River was calculated by means of tagging and tag recovery programs. Each of these projects involved trapping and tagging a sample of the spawning run at a temporary weir located near the H Street Bridge at Sacramento. Subsequently, the dead spawned-out salmon, both tagged and untagged, were recovered on the spawning beds. The salmon population was estimated by assuming that the ratio between the number of tagged fish recovered to the total number tagged was the same as the ratio between the total number of dead fish recovered and total population.

Each fall since 1946, with the exception of 1947 and 1950, crews have patrolled the spawning beds of the American River counting the dead salmon and looking for tags which had been placed on fish caught and released in the ocean. From the numbers of dead salmon recovered and from observing the numbers of live fish on the riffles, it was possible to make reasonably accurate estimates of the size of the salmon runs. Table 2 shows the results of population studies made from 1944 to 1946 and the estimated runs in the following years. From these data the average annual salmon run is estimated to number 26,000 fish.

Sex Ratio

The sex ratio of the salmon in the American River is based on the dead fish recoveries. An experienced observer can tell the sex of most spawned-out salmon at a glance. Moreover, all dead salmon are cut in two with a machete to enable the observer to examine the body cavity and definitely establish the sex of the fish in case of doubt. Cutting the fish in two also prevents recounting the same individuals on later trips over the same area. A few salmon are so badly decomposed that it is impossible to determine their sex. These fish are classified as skeletons in the recovery records and are disregarded in calculating the sex ratio.

From Table 3 it would appear that the adult salmon population in the
American River is composed of only slightly more males than females. Observations made on the spawning beds, however, indicate that there was always a considerable surplus of males. Therefore, it was concluded that there was some difference in the rate of recovery between the sexes. This may be explained by the fact that males tend to wander off downstream after they complete spawning and often die in the deeper or more inaccessible places in the river. On the other hand females stay close to their nests until expiring and, consequently, are easier to locate. Furthermore, a considerable number of males (jacks) are extremely small and are apt to be overlooked.

A tagging experiment on the Stanislaus River in 1948 showed that when equal numbers of male and female salmon were tagged and released on the spawning beds only 82.2 males would be recovered for every 100 females. Some similar ratio probably holds true in most of the rivers in the Sacramento-San Joaquin system. When this ratio is applied to the American River dead salmon recovery data, we find that the population consists of 61.2 percent males and 38.8 percent females, or for practical purposes a 60-40 ratio.

**Fecundity**

No data are available on the fecundity of the king salmon in the American River, but it is assumed that it is no different from that of the same species in adjacent streams where egg counts have been made. Hanson, Smith and Needham (1940)\(^1\) found the average number of eggs per female in the run at Redding on the Sacramento River was 6,790. They used the round figure of 7,000 in calculating the total number of eggs in the run.

\(^1\)U.S. Fish & Wildlife Service Special Scientific Report No. 10. An Investigation of Fish Salvage Problems in Relation to Shasta Dam by Harry A. Hanson, Osgood R. Smith, and Paul R. Needham, 1940.
average egg yield of female king salmon at Coleman Hatchery on Battle Creek varies from 6,000 to over 6,500. King salmon from the Tuolumne River, a stream very similar to the American, produced an average of 6,700 eggs per female in studies made in 1947. For the purposes of this report the figure of 6,500 eggs per female was assumed for the American River king salmon.

Habits Of Young Salmon

Salmon eggs which have been deposited in the gravel riffles in the American River incubate for a period of from one to three months depending on water temperatures. After hatching the fry remain in the gravel until the yolk sac is almost absorbed. The downstream migration begins as soon as the fry emerge from the gravel. The speed with which the migrants move out of the American River is influenced by fluctuations of the river, weather, and by water temperatures.

The seaward migration of young salmon was sampled by means of fyke nets for three seasons, from 1945 through 1947. Two types of nets were used in the study. A round fyke net with a five-foot diameter opening was fished in deep water and a riffle type net with a three-foot by five-foot rectangular opening was used in shallower water on a riffle. The nets were located near the Maggin Gravel Company about six miles upstream from the H Street Bridge at the edge of Sacramento. Practically all spawning takes place above this point.

Figures 1 and 2 show the duration and intensity of the downstream migration as indicated by the two fyke nets. The seaward migration starts about February 1, and continues into June. The peak of the migration occurs between April 1 and May 15. A number of variables make it impossible to compare directly the results obtained with a net one year with catches made the following year. Such factors as water fluctuations, current, amount of debris, and condition of the net change the fishing success from day to day.
Obviously, quantitative data obtained through the use of gear as inefficient and selective as a fyke net cannot be used to give an accurate estimate of the total numbers of downstream migrants passing the net site.

The rate of growth of the migrants trapped in the fyke nets is shown in Figures 3 and 4. In February and March the average total length of the migrants does not vary a great deal since the catch is dominated by large numbers of small fish which are constantly emerging from the gravel. However, from the first of April until the conclusion of the migration in June an extremely rapid growth rate is evident.

**Distribution Of Adult Salmon In The American River**

The numbers of salmon which spawned above and below Nimbus Dam site were estimated from the dead salmon recovery records. These figures were available for each year from 1944 through 1952 with the exception of 1947 and 1950, and are presented in Table 4. From this information it was calculated that an average of 72.5 percent of the annual salmon run spawns in the area above the Nimbus Dam site.

In obtaining the distribution of salmon above and below Nimbus from the dead salmon recovery figures some allowance had to be made for the fact that dead fish are carried downstream by the current before they become stranded. The distance some fish are washed downstream is well illustrated the first time the river is covered each year on the dead fish survey. The section of the river between Folsom and Fair Oaks is patrolled first and all dead salmon recovered are cut in two with a machete. The following day the crew covers the section of the river between Fair Oaks and the Haggin Gravel Co., some four miles downstream. Some of the dead salmon which had been cut in two the day before, in the upper section are now seen throughout the lower area. For this reason in analyzing the recovery data all the dead salmon recovered above the Fair Oaks bridge were
classified as spawning above the Nimbus Dam site and those found between Fair Oaks and Sacramento were recorded as spawning below Nimbus. Using the Fair Oaks bridge as a dividing point should make the estimate of the number of fish spawning above Nimbus a conservative figure.

In Table 5 the number of female salmon that would have been blocked at Nimbus are listed by years. This figure was obtained by multiplying the estimated total run passing Nimbus by 38.8 percent. From the table it can be seen that the number of female salmon spawning above Nimbus Dam site in recent years varied from 3,000 to almost 12,000. To obtain the number of eggs produced above Nimbus, the number of females was multiplied by 6,500. The average number of eggs deposited annually in this area was found to be 47,570,000.

**Numbers Of Fish At And Below Nimbus Dam With Artificial Spawning Channel And With Stream Improvement**

There is no possibility of estimating the number of salmon which could be handled in an artificial spawning channel until studies are made with a test channel. The segment of the salmon population which could be accommodated on improved spawning beds below Nimbus Dam cannot be determined until after Folsom Dam is in operation.

**Advisability Of Counting Adult Runs In 1953**

It appears unnecessary to spend time and effort in obtaining further detailed data on the salmon run in the American River in 1953 since adequate information is already available on the time and size of the runs (Table 2). A tagging and tag recovery project to estimate the salmon population in 1953 would involve the construction of a temporary weir at the lower end of the salmon spawning area where the fish could be trapped and tagged. In addition the services of a biologist and four assistants would be required for at least four months to install and maintain the weir and to recover the dead salmon on the spawning beds. It is estimated that such a program
would cost $20,000.00. Furthermore, experienced crew will be counting the
dead salmon on the spawning beds of the Central Valley rivers while search-
ing for tagged or marked fish. The numbers of dead fish recovered in the
American River will provide the basis for a reasonably accurate estimate of
the size of the 1953 fall salmon run.

In the event that Nimbus Dam blocks salmon in the fall of 1953, some
method, such as a fish ladder or trapping and hauling by truck will be used
to get the fish past the barrier. If such is the case it would be advisable
to check the number of salmon passing the dam either by counting the fish
through a ladder or keeping accurate records of the number of fish hauled
by truck.

Time And Size Of Adult Steelhead Runs

Little is known of the natural history of the steelhead trout (*Salmo
gairdneri*) in the American River. The only available material on the steel-
head of this stream are the counts that were made at the fish ladder at the
old Folsom Dam from 1943 through 1947. A study of Table 6 shows that some
steelhead pass Folsom in every month of the year with the exception of
August and September. The peak of the run, however, occurs in May and June
and part of July. The largest count was made in 1946 when 1,287 steelhead
passed through the ladder.

Since the destruction of the fish ladder at Folsom Dam in 1950 the
steelhead runs probably have been virtually eliminated. It is necessary
that these fish migrate upstream considerably past Folsom Dam to reach
the small tributary streams where they spawn. There is no evidence that
steelhead have ever spawned in the main stream between Sacramento and
Folsom. With the main portion of the run arriving below the dam in May and
June it is unlikely that these fish could have endured the high summer water
temperatures in the lower river and remain to spawn the following winter,
Fortunately steelhead runs build up rapidly when conditions are favorable. Lower water temperatures and a more stable flow after the construction of Folsom and Nimbus Dams may produce an environment favorable to these fish. Yet it may be necessary to maintain the runs through artificial propagation if the area below Nimbus Dam proves unsuited for steelhead spawning.

**Habits of Young Steelhead**

It can be safely assumed that young steelhead in the American River migrate to sea in their second year as is the case in other streams. If any of these fish moved downstream in their first year while they are still very small they certainly would have appeared in the fyke net catches along with the young salmon. Yearling steelhead are too large and active to be trapped in a standard fyke net.
TABLE 1

Numbers of King Salmon Counted Through the Fishway of Old Folsom Dam, American River; 1944-1947

<table>
<thead>
<tr>
<th>Month</th>
<th>1944 Spring</th>
<th>1944 Fall</th>
<th>1945 Spring</th>
<th>1945 Fall</th>
<th>1946 Spring</th>
<th>1946 Fall</th>
<th>1947 Spring</th>
<th>1947 Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Feb.</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>March</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>April</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>May</td>
<td>198</td>
<td>24</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>June</td>
<td>808</td>
<td>18</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>July</td>
<td>132</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Aug.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sept.</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Oct.</td>
<td>299</td>
<td>547</td>
<td>263</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nov.</td>
<td>1851</td>
<td>1686</td>
<td>152</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dec.</td>
<td>50</td>
<td>13</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td>1138</td>
<td>2202</td>
<td>42</td>
<td>2246</td>
<td>16</td>
<td>421</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

-92-
TABLE 2

Estimated Size of King Salmon Runs of the American River for the Period 1944-1952

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Salmon</th>
</tr>
</thead>
<tbody>
<tr>
<td>1944</td>
<td>30,592*</td>
</tr>
<tr>
<td>1945</td>
<td>38,656*</td>
</tr>
<tr>
<td>1946</td>
<td>38,388*</td>
</tr>
<tr>
<td>1947</td>
<td>***</td>
</tr>
<tr>
<td>1948</td>
<td>15,000</td>
</tr>
<tr>
<td>1949</td>
<td>12,000</td>
</tr>
<tr>
<td>1950</td>
<td>***</td>
</tr>
<tr>
<td>1951</td>
<td>22,000</td>
</tr>
<tr>
<td>1952</td>
<td>25,000</td>
</tr>
</tbody>
</table>

Average 25,948

*Calculated from tagging and tag recovery program.
**No data were collected in these years.
<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Males**</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
<td>Percent</td>
</tr>
<tr>
<td>1944</td>
<td>1,542</td>
<td>799</td>
<td>51.8</td>
</tr>
<tr>
<td>1945</td>
<td>2,343</td>
<td>1,669</td>
<td>71.2</td>
</tr>
<tr>
<td>1946</td>
<td>6,809</td>
<td>3,640</td>
<td>53.5</td>
</tr>
<tr>
<td>1947</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1948</td>
<td>1,324</td>
<td>758</td>
<td>57.3</td>
</tr>
<tr>
<td>1949</td>
<td>1,947</td>
<td>947</td>
<td>48.6</td>
</tr>
<tr>
<td>1950</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1951</td>
<td>1,315</td>
<td>796</td>
<td>60.5</td>
</tr>
<tr>
<td>1952</td>
<td>1,014</td>
<td>585</td>
<td>57.7</td>
</tr>
<tr>
<td>Total</td>
<td>16,294</td>
<td>9,194</td>
<td>56.4</td>
</tr>
</tbody>
</table>

*Skeletons recovered in the surveys are omitted from this table.

**1948 Stanislaus River population study indicated that when equal numbers of tagged male and female King salmon were released on the spawning beds only 82.2 males were recovered for every 100 females.

Applying this ratio to the American River recovery figures we find 9194 males : .822 = 11,184 or 61.2 percent males and 7,100 or 38.8 percent females, which for practical purposes is a 60-40 ratio.
<table>
<thead>
<tr>
<th>Year</th>
<th>Total Salmon Run</th>
<th>Estimated Run Above Nimbus</th>
<th>Percent</th>
<th>Estimated Run Below Nimbus</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1944</td>
<td>30,592</td>
<td>23,762</td>
<td>77.7</td>
<td>6,830</td>
<td>22.3</td>
</tr>
<tr>
<td>1945</td>
<td>38,656</td>
<td>24,815</td>
<td>64.2</td>
<td>13,841</td>
<td>35.8</td>
</tr>
<tr>
<td>1946</td>
<td>38,388</td>
<td>30,684</td>
<td>79.7</td>
<td>7,704</td>
<td>20.3</td>
</tr>
<tr>
<td>1947</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1948</td>
<td>15,000</td>
<td>12,060</td>
<td>80.4</td>
<td>2,940</td>
<td>19.6</td>
</tr>
<tr>
<td>1949</td>
<td>12,000</td>
<td>8,028</td>
<td>66.9</td>
<td>3,972</td>
<td>33.1</td>
</tr>
<tr>
<td>1950</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1951</td>
<td>22,000</td>
<td>13,684</td>
<td>62.2</td>
<td>8,316</td>
<td>37.8</td>
</tr>
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<td>1952</td>
<td>25,000</td>
<td>19,050</td>
<td>76.2</td>
<td>5,950</td>
<td>23.8</td>
</tr>
<tr>
<td>Averages</td>
<td>25,943</td>
<td>18,860</td>
<td>72.5</td>
<td>7,079</td>
<td>27.5</td>
</tr>
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</table>


<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Salmon Above Nimbus*</th>
<th>No. of Female Salmon Above Nimbus</th>
<th>No. of Eggs**</th>
</tr>
</thead>
<tbody>
<tr>
<td>1944</td>
<td>23,762</td>
<td>9,220</td>
<td>59,900,000</td>
</tr>
<tr>
<td>1945</td>
<td>24,815</td>
<td>9,628</td>
<td>62,600,000</td>
</tr>
<tr>
<td>1946</td>
<td>30,604</td>
<td>11,905</td>
<td>77,400,000</td>
</tr>
<tr>
<td>1947</td>
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</tr>
<tr>
<td>1948</td>
<td>12,060</td>
<td>4,679</td>
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<td>8,028</td>
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</tr>
<tr>
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</tr>
<tr>
<td>1951</td>
<td>13,684</td>
<td>5,309</td>
<td>34,500,000</td>
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<tr>
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<td>19,050</td>
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<td>48,000,000</td>
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<tr>
<td>Average</td>
<td>18,869</td>
<td>7,079</td>
<td>47,600,000</td>
</tr>
</tbody>
</table>

*Calculated on the basis that 38.8 percent of the total number of salmon are females. See footnote Table 3

**Calculated on the basis of 6,500 eggs per female. The total is rounded to the nearest 100,000 eggs.
### TABLE 6

Numbers of Steelhead Trout Counted Through the Fishway at Old Folsom Dam, American River, 1943-1947

<table>
<thead>
<tr>
<th>MONTH</th>
<th>1943</th>
<th>1944</th>
<th>1945</th>
<th>1946</th>
<th>1947</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>47</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Feb.</td>
<td>0</td>
<td>5</td>
<td>49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>0</td>
<td>6</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>5</td>
<td>87</td>
<td>577</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>53</td>
<td>294</td>
<td>669</td>
<td>254</td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>142</td>
<td>1</td>
<td>6</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Aug.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sept.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct.</td>
<td>62</td>
<td>10</td>
<td>3</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Nov.</td>
<td>12</td>
<td>12</td>
<td>25</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Dec.</td>
<td>14</td>
<td>0</td>
<td>2</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>88</td>
<td>269</td>
<td>112</td>
<td>1287</td>
<td>526</td>
</tr>
</tbody>
</table>
Downstream Migration of King Salmon Fry as Determined by Catch per Hour.

American River Round Fyke Net 1945-47

Salmon Per Hour (average)

Weeks

1945
1946
1947
NET NOT FISHED
Figure 2
Downstream Migration of King Salmon Fry as Determined by Catch per Hour.
American River    Riffle Fyke Net    1945-47

Salmon Per Hour

11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5

Weeks

Jan 15-21
Jan 22-Feb 4
Feb 5-Feb 11
Feb 12-Mar 4
Mar 5-Mar 11
Mar 12-Mar 25
Mar 26-Apr 1
Apr 2-Apr 8
Apr 9-Apr 15
Apr 16-Apr 22
Apr 23-May 6
May 7-May 14
May 15-21
May 22-June 3
June 4-June 10
June 11-June 17
June 18-24

1945
1946
1947
NET NOT FISHED
Figure 3
Average Length of Downstream Migrant King Salmon Plotted by Weeks.
American River Round Fyke Net 1945-47

Salmon—Total Length in Millimeters (average)

Weeks

1945
1946
1947
NET NOT FISHED
Figure 4
Average Length of Downstream Migrant King Salmon Plotted by Weeks.
American River Riffle Fyke Net 1945 - 47
PART TWO

POSSIBILITY OF FISH LOSS AT NIMBUS DAM POWERHOUSE

(Ability of Adult Salmon to Enter the Power Plant Turbines)

Two points were considered in investigating the possibility of adult salmon entering the power plant and being destroyed by the turbines at Nimbus Dam. They were the swimming ability of the fish and the water velocities expected at the powerhouse.

To find the maximum velocity a salmon might swim against, a study was made of the flows into the Helm Canal at Mendota Dam on the San Joaquin River. Here, small numbers of spring run king salmon which had strayed into the canal system on their upstream migration attempted to re-enter the river through the headworks of the canal. This occurred in the years prior to 1948 before Friant Dam was completed and operated in such a manner as to entirely eliminate the salmon runs spawning in the San Joaquin River.

Water from the lake behind Mendota Dam discharges through corrugated iron conduits running 60 feet through the levee into the Helm Canal. The two main tubes have a diameter of \( \frac{1}{4} \) feet and four auxiliary tubes are 2 feet in diameter. The outlets of the conduits are partially or entirely submerged, depending on the volume of water released. The salmon trapped in the canal continually attempted to swim through the larger pipes to get back into the river. The stronger salmon had the ability to negotiate the entire 60 feet of pipe against the maximum discharge. Others, probably weakened by high water temperatures, were unable to leave the canal. A flow of 125 cubic feet per second is discharged through each of the \( \frac{1}{4} \) foot diameter pipes with the maximum head and with the gates wide open. This means that some king salmon are able to swim 60 feet against velocities of at least 10 feet per second, where the course is uninterrupted and the fish are not required to jump.

-15-
In Bulletin III of the International Pacific Salmon Fisheries Commission,\textsuperscript{1} spring salmon were reported to be able to swim through a flume against velocities ranging from 12.5 to 14.5 feet per second. This flume was 23 inches wide, 20 inches deep and 650 feet long. Sockeye salmon were unable to swim against the same velocities.

According to the Bureau of Reclamation the following water velocities may be expected when the powerhouse at Nimbus Dam is operating at capacity: 23 feet per second at the turbines, 15 feet per second in the draft tubes, and 8 feet per second in the tailrace. When the plant is operating at less than capacity the water velocities in the draft tubes and tailrace are reduced in proportion to the reduction of the power load on the turbine. Thus, at a 50 percent load, the water velocity in the draft tubes would be lowered to 7 or 8 feet per second. However, the velocity at the turbines remains at 23 feet per second regardless of the power load. This is caused by the partial closing of the Kaplan blades on the turbine when the plant output is reduced. The volume of water is then restricted, but the high velocity is maintained.

From these data it appears that salmon could swim through the tailrace and enter the draft tubes; especially when the powerhouse is running at reduced loads. It seems improbable, however, that many salmon could swim through the entire 45 feet of draft tube against increasing velocities, make a 90° degree turn and swim vertically for almost 20 feet to hurl themselves into the turbine blades, where the water velocity is 23 feet per second. Salmon should suffer no ill effects from swimming into the draft tubes if they are overpowered and ejected by high water velocities short of the turbines.

\textsuperscript{1}\textit{International Fisheries Commission Bulletin III, Part 2. Variations of Flow Patterns at Hell's Gate and Their Relationship to the Migration of Sockeye Salmon. Page 105.}
Mr. Harlan B. Holmes, of the U. S. Fish and Wildlife Service, in a letter commenting on the possible loss of salmon at the Nimbus Powerhouse states in part, "Such theoretical possibility of salmon swimming into a turbine and being injured would apply at Bonneville and many other power plants. There have been a very few instances of injured fish observed at Bonneville that were cut in a manner that was suggestive of being caused by a turbine. There is no proof, however. I know of no evidence elsewhere of salmon being injured in this way. It must be recognized, however, that there has been no systematic search for evidence of such."

With the evidence at hand the expense of constructing some type of screen at the outlet of the Nimbus Dam Powerhouse can not be justified. Furthermore, it seems probable that the installation of a rack or weir across the river below Nimbus will be necessary to trap salmon for an egg-collecting station, an artificial spawning channel, or a hatchery. Such a structure should effectively prevent most salmon from reaching the powerhouse.
PART THREE

STREAM IMPROVEMENTS, NATURAL AND ARTIFICIAL SPA\'NING AREAS

Plans to assure full utilization of the spawning area remaining below Nimbus Dam should be made. Full utilization of these remaining areas can be furthered by making all practicable improvements calculated to increase the available spawning gravels. Other improvements such as devices to assure equitable distribution of the fish on the remaining riffles should also be considered and installed if found practicable.

In addition to planning for full utilization of the remaining spawning areas, experiments should be carried out to evaluate the feasibility of using artificial spawning channels and planting beds to supplement or replace other methods of propagating the fish. Such an experiment would have to be very carefully planned so that all known factors are brought under control and unknown factors are eliminated insofar as possible. A standard, tested method of artificial propagation should be used as a comparable control utilizing the same stock of eggs, the same water supply, and insofar as possible, the same methods and manipulations. Comparison of the methods must be essentially on the basis of economics, but physical and biological limitation such as impracticibility of supplying sufficient water to spawning channel or marked inferiority of propagation under the experimental methods may be the cause of uneconomic operation of a method.
As with all methods of propagating the displaced salmon population, it is necessary to estimate the numbers of salmon that will be required to be accommodated by each of the suggested methods. The total size of the runs is being estimated and an estimate is being made of the number that have spawned above Nimbus Dam site based on recent historical runs, but the numbers to be accommodated with full operation of the project by each selected method will have to be determined during an interim period including one full year of operation of Folsom Reservoir so that plans for permanent management can be laid.

The carrying capacity of the remaining spawning riffles below Nimbus Dam should be carefully estimated at various practicable flow stages to facilitate estimation of the numbers of fish that can be depended upon to be accommodated by this method during the interim period. Observation of the spawning areas during the interim period will permit dependable determination of these numbers for purposes of permanent management. These estimates and determinations will have to be correlated with the planning for improvements and partitioning racks in order to estimate the expected utilization of the riffles with and without any proposed improvements (including partitioning racks.) And in addition these estimates can serve as a basis for formulating schedules of releases to streamflow below Nimbus Dam which will be most favorable to fish production (including trout) under all expected conditions with the project. Two flow schedules will have to be devised; one to be used during the period prior to the diversion of water from Nimbus Forebay (through Folsom North and South Canals), and one for the period following diversion. Both schedules will have to be flexible; the former to take advantage of any extra water available in wet years, and the latter to provide for gradual reduction of releases from year to year as the diversion demand builds up to ultimate conditions.
Existing flows below Nimbus Dam (Fair Oaks Gage) are extremely variable and not conducive to the management of anadromous fishes. Flows during July, August, and September are frequently low and occasionally very low - a minimum instantaneous flow of 4.6 second-feet was recorded September 29, 1924. Flash rain floods interrupt spawning activities and destroy the deposited spawn in many years particularly in late November and December. These floods destroy the spawn by actual physical destruction, displacement and exposure of spawn to predation, and smothering it by silt. Snow-melt floods interrupt the upstream migration of adult steelhead in April, May and June. The run-off of the American River at Fair Oaks is presented in Table 7.

TABLE 7
Run-off of the American River at Fair Oaks for the Period 1921-22 through 1946-4

<table>
<thead>
<tr>
<th>Month</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>October</td>
<td>100</td>
<td>683</td>
<td>1,220</td>
</tr>
<tr>
<td>November</td>
<td>85</td>
<td>2,920</td>
<td>1,095</td>
</tr>
<tr>
<td>December</td>
<td>330</td>
<td>8,792</td>
<td>2,465</td>
</tr>
<tr>
<td>January</td>
<td>619</td>
<td>11,480</td>
<td>3,170</td>
</tr>
<tr>
<td>February</td>
<td>1,260</td>
<td>13,900</td>
<td>5,720</td>
</tr>
<tr>
<td>March</td>
<td>879</td>
<td>16,100</td>
<td>6,030</td>
</tr>
<tr>
<td>April</td>
<td>2,000</td>
<td>13,510</td>
<td>7,580</td>
</tr>
<tr>
<td>May</td>
<td>1,490</td>
<td>16,310</td>
<td>7,830</td>
</tr>
<tr>
<td>June</td>
<td>206</td>
<td>9,846</td>
<td>4,190</td>
</tr>
<tr>
<td>July</td>
<td>27</td>
<td>2,402</td>
<td>865</td>
</tr>
<tr>
<td>August</td>
<td>16</td>
<td>1,633</td>
<td>285</td>
</tr>
<tr>
<td>September</td>
<td>25</td>
<td>486</td>
<td>245</td>
</tr>
</tbody>
</table>

Releases to streamflow from Nimbus Dam will be dictated mainly by demands of power, flood control, navigation, salinity repulsion, and fish. Operation of Shasta and Keswick Reservoirs and Folsom and Nimbus Reservoirs will be coordinated to effect Central Valley Project purposes. In their operation studies, the Bureau of Reclamation has assumed a firm demand for fish-water releases past Nimbus Dam on the minimum flow schedule recommended in the Service's Folsom Project Preliminary Evaluation Report. This schedule calls for a minimum release of 500 second-feet during the king salmon spawning.
period - September 15 through December 31 - and a minimum release of 250 second-feet for the remainder of the year. The releases to streamflow past Nimbus Dam as estimated by the Bureau's Operation Study 65-F are presented in Table 8.

**TABLE 8**

Releases to Streamflow Past Nimbus Dam under Coordinated Central Valley Project operation, Based on the Historical Water Supply of the Period 1921-22 Through 1940-41.

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean Monthly Discharge in second-feet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>October</td>
<td>500</td>
</tr>
<tr>
<td>November</td>
<td>500</td>
</tr>
<tr>
<td>December</td>
<td>500</td>
</tr>
<tr>
<td>January</td>
<td>250</td>
</tr>
<tr>
<td>February</td>
<td>250</td>
</tr>
<tr>
<td>March</td>
<td>250</td>
</tr>
<tr>
<td>April</td>
<td>250</td>
</tr>
<tr>
<td>May</td>
<td>250</td>
</tr>
<tr>
<td>June</td>
<td>350</td>
</tr>
<tr>
<td>July</td>
<td>250</td>
</tr>
<tr>
<td>August</td>
<td>300</td>
</tr>
<tr>
<td>September</td>
<td>250 (1-15)</td>
</tr>
<tr>
<td></td>
<td>500 (16-30)</td>
</tr>
</tbody>
</table>

It will be noted that flows would be firmed up during the months of September and October and smoothed out during the months of November and December in the average year under the assumed schedule of releases with the project. Flows would be reduced during the greater part of the average year, but the smoothing out of flood discharges and reduction of temperatures during the existing low-flow period may balance this reduction to an important extent, particularly for resident trout. However, the reduction of spawning area (at least half of the gravelled riffles formerly available to anadromous fishes would be eliminated by Folsom and Nimbus Dams) can not be more than partially compensated by the improved conditions in the remaining spawning area.
It is anticipated that it will be impossible to accommodate more than a fraction of the adult salmon on the remaining spawning riffles below Nimbus Dam. Other means of accommodating the displaced salmon will have to be provided. It appears to be entirely feasible to construct an artificial spawning channel taking off the Nimbus Forebay from the Folsom South Canal headworks and running down the left (south) bank of the river some 8,000 feet to connect with an entrance fishway and holding pond set-up required in connection with artificial propagation. A thorough study should be made of this possibility by means of experiments designed to furnish cost-of-production data based on returns of marked fish to the fishery.

A spawning channel could be constructed so as to provide almost, if not complete control of flows and distribution of the salmon, and the entrance to it could be located where most of the fish are expected to congregate. But many factors will have to be weighed before it can be stated definitely whether or not such a channel is feasible. The certainty of an adequate water supply under ultimate project conditions does not appear to be in question, but potential project operations should be studied with this in mind. The channel may prove too costly as compared to alternative methods of propagation on the basis of returns to the fishery (returns may be low in relation to annual costs.) Further, since such a channel, to our knowledge, has not previously been utilized for intensive salmon propagation, many difficulties, now unknown, will probably arise. The most efficient carrying capacity of such a channel as measured by production of young salmon is not known although evidence from natural streams indicates that relatively low concentrations of adults (say, 1 pair to each 200 square feet) may be most efficient. Reworking of the nests is generally considered to be the cause of inefficiency at high concentrations of adults, but it may be possible to improve the efficiency and the carrying capacity by manipula-
tion of partitioning weirs or by other methods. Criteria for design of the channel including velocity of flow, depth of water, composition of the gravel, depth of gravel, etc., are known only from natural stream surveys; all such information that is available will have to be analyzed to provide a guide for construction and experimentation.

Despite all of the unknowns, an artificial channel would have definite advantages. Operation and maintenance costs other than costs associated with water supply would be low. Natural conditions could be approximated so that the young fish could follow their natural tendencies of migration. Such a completely controlled channel has possibilities of improving production over that prevailing under natural conditions, but as indicated above, cost of production would have to be compared with alternative methods of propagation on the basis of returns to the fishery. The channel could be used to make a thorough study of the factors contributing to variations in production which would be applicable to natural spawning areas as well as to similar situations below other dams such as below the proposed Oroville Afterbay Dam on the Feather River. Part of the channel could be used as an artificial planting bed. The practical uses of such a channel in this instance may in fact be secondary to its uses for experimental purposes. Such a channel has long been needed for experimental study of the freshwater life history and management of the salmon.

If a spawning channel is proved feasible and desirable, plans for construction of at least a pilot model will have to be worked up in detail with the Bureau of Reclamation as soon as possible so that it can be used in the fall of 1954.

Improvements to the main-river spawning areas below Nimbus Dam possibly can be made although there is no assurance that the salmon will efficiently utilize even the existing ones. Study should be made of the possibilities
of improvement, and plans should be laid in sufficient detail to allow construction of any desirable improvements if and when it becomes evident that they would be beneficial. It is anticipated that a better distribution of the adults on the available riffles will occur after Folsom Reservoir is fully operating than during the year or two when little or no water is stored (probably 1954 and 1955.) Such was the experience downstream from Shasta and Keswick Dams. Allowing for these changing conditions, it appears wise to make only such definite plans for improvements as have probability of being immediately beneficial. Improvements to the riffles above Fair Oaks Bridge and as near as possible to the dam should probably be planned in detail for use during the fall of 1954. Planning for other areas should be restricted to reconnaissance and preliminary planning until it can be expected that definite benefits will accrue.

In addition to plans for physical improvements of the riffles themselves, the feasibility of installing partitioning racks or weirs should be studied and definite plans made for them if they appear to be economically and biologically feasible of installation. The determination of feasibility should be on the basis of controlled fall flows (with Folsom Reservoir operating) and the use of temporary, demountable structures designed to accomplish the purpose at lowest annual cost.

All cost comparisons that are made as a part of the planning for management of the fishery resources affected by Nimbus Dam should be made on the basis of total annual costs, including the amortized capital costs of providing a unit return (1 adult fish or 1 pound of adult fish) to the fishery (both sport and commercial.) In the case of comparisons involving natural spawning area improvements, only the reasonably expected increase in return to the fishery can be used to obtain the total annual cost per unit returned for comparison with unit costs of alternative methods of
propagation since no annual costs are associated with the returns to the fishery from these natural areas in the unimproved state. (Although some water costs may be associated with these natural areas, higher priority uses will usually determine the releases to stream flow so that separable water costs for this purpose will be small.)

Preliminary capital costs for a full-scale artificial spawning channel 8,000 feet long by 50 feet wide, including partitioning racks, fry traps, and a buried impervious lining, have been estimated by the Bureau of Reclamation to be $500,000.00. The channel would require a flow of about 200 second-feet during the spawning period and somewhat less (perhaps as little as 100 second-feet) during the incubation and migration periods. Operation and maintenance costs for the spawning channel, including one-half of such cost associated with the main weir, fishway, and holding ponds and providing for experimental operation the first 10 years as well as production operation of the channel, is estimated at about $34,600.00 annually. Without the experimental operation, the estimate of operation and maintenance costs is about $22,500.00 annually. These annual costs include cost of water for the channel (amount of reduction in power revenues) which is estimated at about $10,000.00 annually assuming 5 months flow at 200 second-feet and a power value of $0.004 per KWH. Amortization of the $500,000.00 capital costs, assuming a 50-year life for the channel and interest at 3 percent per annum, yields an equivalent annual cost of $19,400.00. Total annual costs are thus estimated to be:

<table>
<thead>
<tr>
<th>Type</th>
<th>Experimental Period</th>
<th>Operation Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>O &amp; M</td>
<td>$34,600.00</td>
<td>$22,500.00</td>
</tr>
<tr>
<td>Capital</td>
<td>19,400.00</td>
<td>19,400.00</td>
</tr>
<tr>
<td>Total</td>
<td>$54,000.00</td>
<td>$41,900.00</td>
</tr>
</tbody>
</table>

No cost estimates have been prepared for improvements to the natural river spawning areas since definite plans have not been developed.
PART FOUR

MAIN RIVER FISH WEIR, FISHWAY, HOLDING PONDS, AND RELATED FACILITIES REQUIRED FOR EXCESS ADULT SALMON AND STEELHEAD TROUT.

It is uncertain now (June 20, 1953) whether or not construction of Nimbus Dam will proceed rapidly enough to interfere with salmon migration in the fall of 1953. Recent flood conditions have definitely delayed construction of the dam and powerhouse. The contractor now plans to build his coffer dam up to elevation 100 feet which will protect his work from inundation up to a river discharge of about 8,000 second-feet when only the two 18-foot openings in the dam are carrying the flow. Prior to the closing off of the main river channel by the coffer dam, larger flows can be safely carried past the work if the accessory coffer dams are built to 100 foot elevation. With the coffer dam blocking the main river channel, possibility of partial blocking conditions (1 to 3 days duration) will be large; complete blocking conditions (4 or more days) would have occurred but rarely under historical conditions of flow assuming that a flow of 1,500 second-feet will result in practically impassable conditions through the two 18-foot openings. Since there is some doubt that construction will have reached a stage permitting closing off of the main river channel prior to the end of November, more than the two openings may be available for river discharge and salmon passage; but the possibility of blocking of salmon remains. The probability of a complete block (defined above) occurring in the first 20 days of November is 5 in 47 years based on historical flows confined by the 100-foot coffer dam and the two 18-foot openings. In an additional 16 years a block of 1 to 3 days duration would have occurred. Although the risk of complete blocking conditions is not great,
plans for accommodating the fish under block conditions must be devised. Reliance cannot be placed on makeshift seining and trucking. If at all possible, the adult salmon should be provided access to usable passageways through the dam so that they can ascend to the upstream spawning areas by their own efforts. If a temporary ladder cannot be installed in the openings through the dam, then other means for getting the fish past the dam must be standing by. Trapping and hauling or brailing facilities should only be considered as a last resort; such facilities not only are unduly harmful to the fish, but they are costly to provide and operate as compared to a simple fishway.

Although conditions are uncertain for the fall of 1953, there is little doubt that adult salmon and steelhead trout will be blocked by Nimbus Dam in 1954. If the dam is a barrier in the spring of 1954, steelhead trout will be blocked with little possibility of their being accommodated by any practical means, unless they can be removed to off-stream holding ponds supplied with cold water. Permanent facilities including a rack across the river, a fishway leading to off-channel holding ponds, the holding ponds, and spawntaking pens will all have to be functioning by September 15, 1954. Detailed plans for these facilities should be developed as soon as a definite site for the hatchery has been selected. Plans for two types of weir design have been obtained so that planning for this facility can be expedited. Plans for the fishway and connecting holding ponds and spawntaking pens will have to be developed. These facilities should be adaptable to both temporary and permanent operation since gravity water from Nimbus Reservoir will not be obtainable in 1954. Pumped water will have to relied on for 1954 not only for the operation of these facilities but also for the hatchery supply. Plans for all these facilities should be closely coordinated with the hatchery plans to afford the best arrange-
ment for purposes of economical and practical operation. Planning has not progressed sufficiently to permit discussion of any more than a few details of design.

The weir design should be such as to operate under all flow conditions, that is, it should be designed to operate in the usual fashion up to flows of about 5,000 second-feet and to operate with some effectiveness while being overtopped at higher flows. This type of operation is dictated by the conditions which will exist downstream from Nimbus Dam. The possibility of the weir becoming ineffective during the peak of the fall migration (by washout or removal) cannot be considered since no spawning area will remain above the weir and no means will be available for removing escaped fish from this area. Further, steelhead trout and spring-run salmon will be moving upstream during the period when streamflow will be relatively high, especially in wet years, so that great difficulty can be anticipated if it is attempted to install or maintain a higher rack designed to operate in the usual fashion during these high-flow periods. The weir should be designed to facilitate installation and removal consistent with other requirements mentioned above. A movable gantry crane (running on tracks in the apron) or a high-line crane should be provided for this purpose.

The weir should be located as far upstream as possible consistent with other requirements in order to conserve as much as possible of the natural spawning areas. It may be desirable to orient the weir at an angle to the stream to aid in leading the fish to the entrance of the fishway adjoining the left bank. The weir pickets should be such as to offer the least possible resistance to flow and to permit passage of leaves and other small water-borne debris. The openings between the vertical pickets should be not more than 1\(\frac{1}{2}\) inches in horizontal dimension. A small fishway lengthwise in the apron should be provided along the down-
stream face of the weir to permit fish to swim up to the foot of the ladder
during low-flow periods. To achieve this end, this small fishway should
connect the lower end of the ladder with a low-flow channel crossing the
apron. The low-flow channel across the apron should be near the approxi-
mate location of the present natural channel. Accessory low-flow channels
across the portion of the apron upstream from the fishway might be needed
at some points particularly near the ladder entrance. The weir should be
provided with a gate near the low-flow channel to provide for any down-
stream movement of steelhead trout previously escaped upstream during high
flows.

The ladder should be of conventional design consisting of an ascending
series of pools. It should provide for easy ascent to the holding ponds;
the rise between pools should be not more than 1 foot. It is believed
that the ladder should be at least 20 feet wide with pool at least 6 feet
deep by 10 feet long. The pools should be connected by underwater openings
about 18 inches square. The underwater openings should be chamfered or
beveled on the downstream edges at an angle of 45 degrees, and the position
of successive openings should be staggered to interrupt the water flow. The
lower pools may require accessory flow through a diffusion grating in the
bottom so as to provide necessary attraction. The entrance to the fish
ladder should be in the angle between the weir and the bank, and it should
face directly or at least at an angle downstream. An accessory entrance
on the river side of the ladder may be required if it faces directly
downstream.

The holding ponds and the spawntaking facilities should be contiguous,
and they should be designed to permit sorting and spawntaking with the
least possible expenditure of labor. These facilities should be located
as near as possible to the hatchery consistent with other requirements.
The water supply to the holding ponds should enter each pond through a diffusion chamber in the bottom near the upper end so as to still the flow and eliminate unnecessary activity of the fish. The holding ponds should provide adequate capacity to accommodate the portion of the fall run which does not spawn naturally in the river downstream from the weir. Pumped water will have to be supplied to these facilities until such time as the permanent gravity supply from Nimbus Dam is available.

Plans and design criteria for the holding ponds and spawntaking facilities cannot be supplied now, but plans of existing facilities of this type will be obtained and information bearing on applicable plans will be gathered as soon as possible.
PART FIVE
FISH HATCHERY

Introduction

In view of the unproved nature of stream improvement, artificial spawning channels and some other possible methods of insuring the spawning success of salmon runs obstructed by high dams, the need for a hatchery to mitigate the loss of fish spawning area resulting from the construction of Nimbus and Folsom Dams has been recognized for some time. The Bureau of Reclamation has acknowledged responsibility for maintenance of that part of the American River salmon and steelhead run to be affected by the construction of Nimbus Dam. The Bureau has already made plans for the headworks of a conduit to supply water in the amount of 50 c.f.s. for a hatchery.

Because a hatchery appears essential to any program for the maintenance of the American River salmon and steelhead runs, the following information is presented and is based on the investigations conducted to date.

Water Supply

Temperature of the water released through Folsom penstocks into Nimbus Reservoir is expected to range for the most part from 49°F. to 58°F. except for periods affected by low water years or heavy drawdown of Folsom Reservoir when temperatures of 66°F. or above may be expected. The frequency of this high range will probably be not more than three times in twenty years, as anticipated from United States Bureau of Reclamation Water Surface Fluctuation — Operating 65°F. dated February 16, 1951, unless operation schedules change. Study of this chart shows that the water level of Folsom Reservoir
may drop to the 330 to 325-foot elevations during the months of October and November. Under actual operating conditions this range may be extended somewhat. The penstocks located at the 307.0-foot elevation would indicate water would be drawn from only 18 to 23 feet below the surface at such times. Under normal seasonal temperatures, water reaching 66°F. or higher may be expected during the latter part of September and the month of October. Seasonal reduction in air temperatures should reduce water temperatures during the latter part of October. The anticipated operations schedule as above mentioned was compiled on expected full capacity operation. There is no assurance that these low surface levels, combined with high air and surface water temperatures, will not occur more frequently and be more widespread under actual operating schedules.

Nimbus Reservoir, with its capacity of approximately 8,700 acre feet, will have a turnover of water from Folsom release of once in every 17.4 days under minimum operation of 250 c.f.s. release to the American River and with no diversion for irrigation. (Reference Nimbus Reservoir Weekly Operating Rule Curve. Power Division C.V.P.O. 2/3/53-2/9/53 - 2/10/53-2/11/53 - 2/12/53 and 2/17/53 -- 10 pages, of which 3 pages are appended.) This rate of turnover will increase to once daily under maximum operation. The minimum operation during the salmon migration and spawning period (500 c.f.s. release to the American River) will cause a turnover in Nimbus Reservoir of once in 8.7 days. A rise of several degrees in surface temperature of Nimbus Reservoir waters may be expected during these minimum operating periods which would bring them up to near critical ranges for downstream hatchery operations, at least for short periods of time in late September and most of October.

The foregoing probability of high temperature ranges will be the exception rather than the rule, depending upon the final operational program.
of Folsom and Nimbus Reservoirs. To date, the operations of Shasta and Millerton Reservoirs, from which considerable data have been collected, have not caused reductions to minimum operating levels, thus the temperature results of such drawdowns can only be theoretically projected.

Study of the surface elevation charts indicates only short periods of spill over Folsom Dam. With most releases being made through the penstocks and conduits, the direct introduction of turbid runoff water to Nimbus Reservoir will be minimized.

No serious problem is expected from turbidity. Any extended periods of turbidity would be considered undesirable for hatchery operations.

It is anticipated that normal infestation of fish diseases will be present in the waters from Nimbus Reservoir because of resident and planted populations of fish. The hatchery supply waters will be drawn from as far below the surface of Nimbus Reservoir as practicable. The hatchery water supply intake from Nimbus must be screened with a mechanically operated screen that will prevent any downstream drift of fishes, and remove all debris. A by-pass channel from the screen to the American River below the dam will be required to return all fish and debris to the natural stream channel.

A fish screen similar or equal to the perforated plate type with 5/32 inch opening and mechanically operated wiper bar, recently installed on the Shasta River at the Grenada Pumping Plant in Siskiyou County, California by Mr. Murphey of the California Department of Fish and Game, should be provided. Estimated cost of a screen of this type to be constructed in the conduit system immediately below the dam is approximately $6,000.00.

The feasibility of bringing water to the hatchery site from Folsom Dam has been described as nearly prohibitive both from a physical and economic standpoint. Cost of openings through the dam and conduit to the hatchery
site would probably exceed one-half million dollars. The loss of power entailed through by-passing the generators with the hatchery water would amount to about $3,000 per month or $36,000 annual loss of revenue to the Bureau of Reclamation. In view of these facts, the possibilities of deriving a hatchery water supply directly from Folsom Dam have not been given further consideration.

Preliminary investigation and consultations with Bureau of Reclamation officials indicate that it would be physically and economically feasible to divert water for hatchery operation from the south end of Nimbus Dam near the proposed south canal diversion outlet. The design and location of the hatchery conduit intake should be such that independent operation is possible at all times. The base elevation of this diversion should be at the 100 foot contour, or about two feet below the Nimbus Dam spillway sill which is at the 102.4 foot elevation. A type of gate or intake that would permit water to be drawn from lowest possible level below the surface should be used. The waters from Nimbus Reservoir, after passing the diversion gate and the mechanical screening device, should be conveyed to the hatchery site in a closed conduit to prevent further temperature changes, and local contamination of leaves, debris, etc. A closed conduit would also eliminate the necessity of protective fencing which would be required on any open type conduit. The estimated cost of this conduit ranges from $65,000.00 to $85,000.00, depending upon the site chosen.

Hatchery Site

Data obtained from the U. S. Bureau of Reclamation indicate that flood stages in the American River immediately below Nimbus Dam may reach elevation 105 on occasions of 115,000 c.f.s. flow. It is also indicated that elevation 115 will be the minimum operating level of Nimbus Reservoir (cf. Nimbus Reservoir Weekly Operating Rule Curve).
It is therefore necessary to locate properties that are above flood elevation and sufficiently under the 115 foot elevation to promote gravity flow from Nimbus Reservoir to the site.

There are properties located about 6,000 to 8,000 feet below the Nimbus Dam site on the left or south side of the river which can be graded to the proper elevation. Flood elevations in this area are projected to the 90-foot elevation with 115,000 c.f.s. river flow. It would be necessary to purchase this property as it lies outside the boundary of the present Bureau of Reclamation properties and is probably owned by the Natomas District or is under other private ownership. It is recommended that not less than 40 acres and not more than 60 acres with ample river frontage be acquired for a hatchery site.

It is desirable from both a physical, operational, and an economical standpoint to have the fish trapping and egg collecting facilities (racks, holding and spawning ponds) adjacent to or a part of the hatchery site. The site selected should provide for the acquisition or use of sufficient properties on the north (right) bank of the American River to operate such traps and racks. Road access to both these properties should also be provided.

**Capacity and Size of Hatchery**

With reference to Part One of this report entitled "Natural History and Numbers of Affected Anadromous Fishes", indications are that we may expect a maximum of 77 million salmon eggs to a possible minimum of 20 million, with an annual average of 47-1/2 million salmon eggs to be handled with a maintenance program. In order to be equipped to handle a program with such quantity variations, it is recommended that a hatchery building containing 200 trough units similar in construction and capacity to those now in use at Coleman Hatchery and 100 troughs of a design equal to those currently in
use in the State of California hatcheries be constructed. The 200 Coleman-type hatchery troughs would handle approximately 38,000,000 salmon eggs for hatching. The State design troughs would handle an additional 10,000,000 salmon eggs when necessary to bring the salmon egg capacity up to 48,000,000 or about the historical average run. The latter type troughs are particularly adapted to hatching and rearing steelhead.

The number of steelhead eggs to be handled is not known as studies on this species in this river are quite incomplete at present. It is the belief, however, that in most years of normal runs, the eggs could be handled through a hatchery of the above-described size. In years of exceptional migrations, surplus eggs could be transferred to Coleman or some State hatchery for hatching and rearing.

A meeting was held April 15, 1953 at the Department of Fish and Game offices, 926 J Street, in Sacramento, attended by representatives of the Fish and Wildlife Service, Bureau of Reclamation and the Department of Fish and Game. Proposals were made that initial salmon egg eyeing and hatching facilities would be in order for an interim period which is considered to include the period beginning when Nimbus Dam becomes a block and extending through the first full year of Folsom Reservoir operation.

It was determined that any installation, initial or permanent, must be ready to begin operation with the start of the 1954 salmon migration.

It was mentioned that the Coleman Hatchery could probably handle some of the eggs for hatching. Transportation of green or newly taken eggs can not be effected without loss and it would, therefore, be necessary to eye all eggs to be transferred to Coleman Hatchery at the American River site. Therefore this transfer does not appear practical as part of the routine operation.
It is suggested and recommended that the troughs, water supply line and as many other items as possible for any initial station be designed for incorporation in a permanent hatchery.

The 200 trough units of the Coleman Hatchery design, as previously mentioned, housed in a building of ample structure to provide protection to personnel and the trough units would be required. This capacity would permit the eyeing and hatching of some 38,000,000 salmon eggs. Surplus troughs as a standby measure could provide an expedient means of handling runs in excess of the above number. Care of the fry would have to be accomplished in ponds.

At least 16 rearing ponds must be completed for use by January 1955. These would be used in handling the newly hatched fish.

The ponds and the water supply line should be installed on a permanent basis and in such a manner that future construction to complete the project can be readily tied in. This would eliminate further cost of remodeling at the end of the interim period.

In view of possible detrimental factors in the proposed hatchery water supply including diseases, turbid waters, and high temperatures, it is recommended that a test well be sunk on the hatchery grounds for the purpose of securing better quality water for use during periods when these unsatisfactory conditions prevail. Well water would be quite desirable, if not necessary, for domestic service at the hatchery establishment. A well would provide water supply for the station during the early stages of the hatchery construction period and for the interim period prior to the completion and operation of the Folsom Reservoir. Well water would be desirable, if not absolutely necessary, for hatchery operations during upstream construction of both dams and the Nimbus-to-hatchery conduit as well as the period when Folsom Reservoir is filling. Supply of hatchery
water from a well would avoid the high turbidities, flow fluctuations, and high temperatures which will occur in river waters in this period.

Drilling of wells to supply 7 to 10 c.f.s. should be completed early in 1954. If an adequate amount of water can not be obtained from wells, it may be necessary to pump the balance of the needed supply directly from the river. During periods of high turbidity it may be necessary to filter any water being pumped directly from the river to augment the well water supply.

Thirty-two rearing ponds approximately 100 feet long by 15 feet wide will be required to care for the hatched salmon and steelhead. They should be installed in series of not more than four in tandem. This pond system would permit a brief feeding program to advance the salmon and steelhead to stages of growth comparable to the size of natural downstream migrants and compatible with water releases and downstream diversions.

It is estimated that the water necessary to operate the hatchery, ponds, and any attached holding ponds, fishways, etc., connected directly with the hatchery operations will require a firm water supply of not less than 50 c.f.s.

Cost of Hatchery

A rough, over-all cost estimate for a water supply system, test water well, hatchery building, rearing ponds, fish holding and spawning ponds, fish food preparation and storage facilities, trucks, machinery and equipment, housing for personnel and all other necessary appurtenances is $1,000,000.

This estimate does not include site acquisition cost, ground leveling, access roads, or construction of any fish racks or fishways which may be adjacent to the hatchery establishment.

A rough estimate of constructing an initial unit as previously described including water supply system, water well, hatchery building
with gravel floor, installation of permanent type eyeing troughs, food
preparation facilities, quarters for minimum on-call personnel and other
appurtenances of minimum requirements and including 16 ponds is $250,000.00,
not including site, etc. as stated above.

It is suggested that under initial operating conditions, commercial
storage facilities in nearby Sacramento can be rented for fish food storage.
Facilities for housing personnel other than at least two on-call men, who
should be housed on the grounds, can be arranged in nearby communities.

The present situation is not unlike one on the McKenzie River, Oregon,
where the agency responsible for the obstruction to the natural habitat of
anadromous fishes is also responsible for the necessary salmon maintenance
program which includes the Leaburg Hatchery, and its operation and main-
tenance. It is therefore recommended that in addition to the construction
costs of the American River Hatchery, the responsible Federal agency should
pay the hatchery operation expenses. The State of California would staff
and operate the American River Hatchery.

Consideration should be given to the possibility that the State of
California, Department of Fish and Game may find it desirable to operate
a trout hatchery in conjunction with the salmon maintenance program. This
would probably alter some of the features such as water supply conduit,
ponds, hatchery building, fish food preparation and storage, and other
appurtenances. It is understood that any cost of expansion, conversions
or alterations of the hatchery unit for the purpose of operating a trout
hatchery will be borne by the State of California, Department of Fish and
Game.
Nimbus Reservoir
Weekly Operating Rule Curve

250 CFS

Operating Rule Curve

Folsom Daily Release
Monday - 700 AF
Tuesday - 700 AF
Wednesday - 700 AF
Thursday - 700 AF
Friday - 700 AF
Saturday - 0 AF
Sunday - 0 AF
Total - 3500 AF

Folsom Discharge

Nimbus Daily Release
500 AF per day
3500 AF per week

Nimbus Discharge
SUMMARY

Part One - Natural History and Numbers of Affected Anadromous Fishes

1. King salmon enter the American River in well-defined spring and fall runs.

2. Estimates of the king salmon population of the American River are based on the following evidence:
   a. Counts of spring and fall-run king salmon passing old Folsom Dam were made each year from 1944 through 1947.
   b. For three years, 1944 through 1946, the size of the fall salmon runs in the American River was calculated by means of tagging and tag recovery programs.
   c. Since 1946, with the exception of 1947 and 1950, crews have patrolled the spawning beds of the American River counting the dead salmon. Population estimates were based on these counts.

3. The distribution of spawning king salmon above and below Nimbus Dam site was estimated from the dead salmon recovery records. An average of 72.5 percent of the annual salmon run has spawned in the area above the Nimbus Dam site.

4. A sex ratio for king salmon of 60 males to 40 females was calculated from the dead salmon recovery figures.

5. The average egg yield of American River king salmon was estimated to be 6,500.

6. The numbers of female salmon spawning in recent years above the Nimbus Dam site has varied from 3,000 to almost 12,000. The average number of eggs deposited annually in the spawning gravel above Nimbus was calculated to be 47.5 million.

-38-
7. There is no possibility of estimating the numbers of salmon which could be handled in an artificial spawning channel or by stream improvement until these methods of salmon conservation have been tested.

8. The seaward migration of salmon fry in the American River starts about February 1, and lasts into June. The peak of the migration occurs between April 1, and May 15.

9. With the exception of counts made at old Folsom Dam little is known of the natural history of the steelhead trout in the American River. At the present time there are probably few steelhead in the American River. Steelhead runs build up rapidly when conditions are favorable.

Part Two - Possibility of Fish Loss at Nimbus Dam Powerhouse

1. In investigating the possibility of fish loss at Nimbus Dam Powerhouse the water velocities at the plant and the swimming ability of the salmon were considered.

   a. Some king salmon were able to swim 60 feet in uninterrupted course against velocities of 10 feet per second at Mendota Dam on the San Joaquin River. The International Pacific Salmon Fisheries Commission reported that spring-run salmon had the ability to swim 650 feet through a flume against velocities ranging from 12.5 to 14.5 feet per second.

   b. The water velocity at the turbines is expected to be 23 feet per second regardless of the plant load.

2. The fish rack proposed for installation at a site downstream from Nimbus Dam will prevent salmon from approaching the powerhouse.

3. There appears to be little possibility of salmon being harmed by the Nimbus Powerhouse turbines.
Part Three - Stream Improvements, Natural and Artificial Spawning Areas

1. Full, efficient utilization of the spawning areas remaining below Nimbus Dam should be the first objective of the maintenance plan.

If adequate releases to streamflow downstream from Nimbus Dam are provided under full project operation, a part of the king salmon run can be accommodated on the natural spawning areas that will remain and steelhead trout and resident trout management can be practiced. Practicable schedules of releases for purposes of fish maintenance and management will have to be developed during the initial study and evaluation period.

2. The feasibility of construction and operation of an off-stream spawning channel as part of the maintenance plan should be determined by experiment.

3. With Nimbus Dam in place the spawning areas between the proposed main-river weir and Fair Oaks Bridge are expected to become overpopulated; consequently they should be improved prior to September 15, 1954 through redistribution of gravels and other means calculated to produce the most efficient use of these areas. Improvement of main-river spawning areas should be delayed for the most part until observations can be made on the distribution of spawning fish under conditions with Folsom Reservoir operating fully.

Part Four - Main River Fish Weir, Fishway, Holding Ponds, and Related Facilities Required for Excess Adult Salmon and Steelhead Trout

1. The probability of salmon being completely blocked below Nimbus Dam in the fall of 1953 is large enough to require definite protective measures to assure passage of the fish.

2. Permanent facilities including a rack across the river, a fishway leading to off-channel holding ponds, the holding ponds, and spawntaking pens
will have to be functioning by September 15, 1954.

3. Pumped water will have to be supplied to the holding ponds and fish ladders until gravity water is available from Nimbus Forebay.

Part Five - Fish Hatchery

1. Water from Nimbus Reservoir appears generally suited for a hatchery water supply.

2. It is feasible to divert water from the south end of Nimbus Reservoir and convey it to the hatchery in a closed conduit. It is not feasible to supply the hatchery from Folsom Reservoir.

3. There are properties located on the left or south side of the river 6,000 to 8,000 feet below Nimbus that are suitable for a hatchery site.

4. It is presently estimated that a permanent hatchery establishment should consist of a 300 trough hatchery, 32 rearing ponds, a cold storage and food preparation plant, garage and general storage building, and housing. The rough over-all cost estimate for this establishment is $1,000,000. Re-evaluation studies during a two-year period with Folsom Reservoir in full operation may alter this estimate.

5. An initial hatchery establishment should consist of 200 troughs housed in a shelter, 16 rearing ponds, a food preparation plant with a cold storage room, equipment storage shed and housing for 2 families. The rough cost estimate for these facilities is $250,000.

6. Well water and, if needed, supplementary facilities for pumping water from the river should be available by September of 1954 for a hatchery water supply.
RECOMMENDATIONS

Discussion of Recommendations

The U. S. Fish and Wildlife Service and the California Department of Fish and Game have assembled and reviewed the information gathered by both agencies while investigating a program for the maintenance of the salmon runs in the American River. In view of the many items under consideration the investigative period from February 1 to May 15, 1953 has been short, even though much information was already available. However, with the construction of Nimbus Dam proceeding at a rapid rate, it is imperative that an action plan for the conservation of the salmon runs be developed and submitted to the Bureau of Reclamation at the earliest possible date.

In formulating an action plan we have considered only the problems related to maintaining the salmon runs in the American River at their present level. It is generally acknowledged that since Nimbus Dam is a threat to these runs it is the obligation of the Bureau of Reclamation to undertake such salmon conservation measures as are necessary. We have not assumed that the federal government is in any way obligated to build up the salmon population.

All agencies concerned must recognize that until the new Folsom Dam is completed and can release a large sustained flow during the spawning season we cannot anticipate heavier use of most of the natural spawning area below Nimbus. There will be some increase in spawning activity on one or two riffles directly downstream from the dam. If increased flows after the completion of Folsom Dam, possibly in 1956, result in the greater use of the spawning gravel below Nimbus, this condition will be only temporary. As soon as a canal system is constructed to draw water from Nimbus Reservoir we
may expect the improved flows to be drastically reduced. We take a skeptical view of predictions that it will be many years before water from Nimbus is used for irrigation. In light of recent trends in water use in California it appears likely that diversion of water at Nimbus Dam will not be long delayed. In any event, 1954 and 1955 will be critical years for salmon in the American River.

At the present time artificial propagation is the only proved method of maintaining a salmon run cut off from its natural spawning area. However, it is not our intention to demand that the Bureau of Reclamation construct a large hatchery to handle the maximum yield of eggs which could be expected from the salmon runs blocked at Nimbus. To us the practical approach to the salmon salvage problem would be for the Bureau of Reclamation to construct an initial hatchery so that we would be assured of salvaging the main portion of the salmon runs. During the period the initial hatchery is operating, studies could be carried on with an artificial spawning channel and with stream improvements. Surveys of the natural spawning areas in the river below Nimbus could also be conducted to determine to what extent the salmon use this area. The results of all these investigations would determine the size of the permanent hatchery and the feasibility of other plans for salmon conservation.

The California Department of Fish and Game and the U. S. Fish and Wildlife Service firmly believe that an action program must be undertaken immediately in order to have facilities available by September of 1954 to handle the salmon which are certain to pile up at Nimbus Dam. A "do nothing policy" or a "wait and see what happens attitude" will certainly cause irreparable damage to the salmon runs and subject all agencies concerned to well deserved public criticism.

We respectfully submit to the Bureau of Reclamation the following
recommendations for an action program with the belief that they are sound, practical, and worthy of immediate acceptance.

Specific Recommendations

1. A hatchery site be acquired.

   The site proposed in Part Five of this report should be purchased immediately to accommodate an initial hatchery and later a permanent hatchery. Not less than 40 acres or more than 60 acres of land should be purchased.

2. A permanent fish rack be constructed by September 15, 1954 to divert the salmon approaching Nimbus Dam into holding ponds.

   The amount of debris in the river from dam construction upstream from the hatchery site would make it impossible to maintain a temporary weir of webbing. If retrenching of the river channel in later years proceeds as far as the selected rack site, the rack foundation may have to be replaced. However, it appears that the rack structure could be so located and designed as to reduce this possibility to a minimum.

3. A suitable initial hatchery water supply be developed from wells by September 1954.

   The extraction of aggregates upstream from Nimbus and the construction work on Folsom Dam have made the river water unsuitable for a hatchery water supply at the present time. Later it is possible that the well supply could be used for domestic water at a permanent hatchery and serve as a standby water supply in case river water proved temporarily unsuitable for hatchery use.

4. A permanent hatchery water supply be provided from Nimbus Forebay by the fall of 1955.

   This permanent, gravity water supply should be conveyed to the hatchery site in a closed conduit.
5. An initial hatchery to handle eggs from salmon and steelhead blocked at Nimbus Dam should be constructed prior to September 1954.

Construction of adequate facilities for an initial hatchery as determined in Part Five of this report should proceed rapidly to be ready for the 1954 fall salmon run. The initial hatchery should be designed to handle 50,000,000 salmon eggs and the resultant fry, approximately 38 million of which would be accommodated in the proposed 200 trough structure which could later be incorporated into a permanent hatchery. Any eggs over and above the hatchery capacity (including any steelhead trout eggs) would be placed in temporary troughs on a purely expedient basis until such time as the true hatchery requirements become known. Such requirements may be determined after a study and re-evaluation of conditions under the full operation of the Folsom Reservoir.

6. Consideration be given to testing of an artificial spawning channel and further investigation of stream improvement.

If, from an economic standpoint, the Bureau of Reclamation finds that the proposed artificial spawning channel is a feasible method of maintaining a segment of the salmon population, it should be tested. Until further studies are made there is no way of determining how successful either an artificial spawning channel or stream improvements would be in maintaining the American River salmon runs. During the testing period it is understood that the initial hatchery would handle the bulk of the salmon affected by the construction of Nimbus Dam. The natural spawning beds below Nimbus should be patrolled during the salmon runs to determine what use the fish make of this area. This survey should be continued for a season after the completion of Folsom Dam to evaluate any beneficial effects from increased stable flows and any stream improvements accomplished.

7. The Bureau of Reclamation agrees to construct a permanent hatchery.

Construction of a permanent station should begin after Folsom Dam has
been in operation and as soon as the size and needs of a permanent installation have been determined. Every effort should be made to make this determination as soon as possible after Folsom Dam has been in operation.

8. The Bureau of Reclamation enter into an agreement with the California Department of Fish and Game whereby hatchery facilities at Nimbus, initial and permanent, will be operated by the State and the Bureau will pay an annual operating cost.
SCHEMATIC MAP OF LOWER AMERICAN RIVER IN RELATION TO NIMBUS DAM FISH MAINTENANCE

Lowermost Spawning Riffle (1.1 mi. below bridge)

Fair Oaks Bridge and Gaging Station

Proposed Fish Weir Site

Uppermost Spawning Riffle

Sacramento River

6.4 mi.

13.5 mi.

17 mi.

Spawning Ground Study Area (about 1 mi. long)

AMERICAN RIVER

Proposed Hatchery Site

NIMBUS DAM

Folsom Bridge

N: North

↓ indicates location of spawning areas,

→ indicates location of U.S.D.S. gaging station,

← indicates limit of river reach for which mileage is given.