A STUDY TO DETERMINE THE FEASIBILITY OF ESTABLISHING SALMON AND STEELHEAD IN THE UPPER KLAMATH BASIN

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TABLE OF CONTENTS

	PAGE
INTRODUCTION	1
DESCRIPTION OF STUDY AREA	2
Physical	2
Climatology	3
HISTORY OF KLAMATH RIVER SALMON AND STEELHEAD	5
Published Reports	5
Archeological investigations	5
County history	6
Newspaper reports	7
Biological investigations	14
Miscellaneous reports	15
Personal Interviews	18
Fish Counts for Klamath River	21
LIFE HISTORY OF KLAMATH RIVER SALMON AND STEELHEAD	27
Salmon	27
Upstream migration	27
Spawning	28
Downstream migration	28
Age at maturity	28
Steelhead	29

	PAGE
ENVIRONMENTAL REQUIREMENTS OF SALMON AND STEELHEAD	31
Temperature	31
Dissolved Oxygen	33
Water Velocity for Spawning	35
Water Depth for Spawning	36
Gravel Quality	37
Migration Schedules	39
SURVEY RESULTS AND EVALUATION	43
Survey Methods	44
Lower Klamath River	49
Iron Gate Reservoir	49
Jenny Creek	51
Copco No. 2 Dam	51
Copco No. 1 Reservoir	51
Shovel Creek	53
Klamath River from Copco Reservoir to J. C. Boyle Dam	54
J. C. Boyle Dam and Reservoir	62
Spencer Creek	63
Klamath River to Old Needle Dam at Keno	70
Klamath River from Keno to Klamath Falls	71
Link River	72
Upper Klamath Lake	74
West Side Tributaries	75
Fourmile Creek and Crane Creek	75
Sevenmile Creek	75

PAGE

SURVEY RESULTS AND EVALUATION (cont.)

- Wood River 76
- Williamson River 77
- Spring Creek 80
- Sprague River to Lone Pine 80
- Sprague River from Lone Pine to the Forks 81
- South Fork of Sprague River 83
- North Fork of Sprague River 91
- Tributaries of Sprague River 99
  - Sycan River 99
  - Five Mile and Meryl Creeks 99
  - Fishhole Creek 99
  - Deming Creek 99

FUTURE AGRICULTURAL AND INDUSTRIAL USE OF WATER IN RELATION TO FISH LIFE 101

FACILITY REQUIREMENTS AND COSTS 104

- Passage Around Dams 104
  - Power dams 104
  - Irrigation dams 106
- Screening Irrigation Diversion Ditches 107
- Log Jam Removal 108

REVIEW AND DISCUSSION OF SALMON AND STEELHEAD TRANSPLANT 108

EXPERIMENTS ELSEWHERE IN RELATION TO SUGGESTED INTRODUCTION OF SALMON AND STEELHEAD IN UPPER KLAMATH BASIN

SUMMARY 112

ACKNOWLEDGMENTS 123

LITERATURE CITED 124

APPENDIX 174

INTRODUCTION

Copco Dam permanently barred passage of anadromous fish to the Upper Klamath Basin in 1917 and ever since there has been continued interest in the re-introduction of salmon and steelhead. Because of this interest, Pacific Power & Light Company in 1964 consented to finance a study to consider the feasibility of this project. The work was undertaken by personnel of the Oregon State Game Commission, with the aid of a Pacific Power & Light Company biologist. The study was directed by a steering committee composed of one member from the Klamath Salmon and Steelhead Advisory Committee, Bureau of Sports Fisheries and Wildlife, Bureau of Commercial Fisheries, California Department of Fish and Game, Fish Commission of Oregon, Oregon State Game Commission, and Pacific Power & Light Company.

The scope of the project included compiling historical information on the past fish runs and environmental conditions, and a survey to determine the status of potential spawning areas, rearing areas and migration routes in the Upper Klamath Basin. Also, estimates were to be made, of the cost of construction for required fish passage facilities and account taken of possible future water use.

This report presents the results of the investigation as well as a review of the life histories and requirements of chinook salmon, *Oncorhynchus tshawytscha* (Walbaum) and steelhead trout, *Salmo gairdneri* (Richardson). A discussion of related experimental transplants of Pacific salmon and steelhead is included.

DESCRIPTION OF STUDY AREA

Physical

The geographical area encompassed in this report is the Klamath River drainage upstream from Iron Gate Dam. The watershed above Iron Gate Dam to Link River shall be referred to as the Mid-Klamath Basin. Klamath Lake and its tributaries will be called the Upper-Klamath Basin (Figure 1, Page 132).

In its easternmost reaches, the streams of the Basin arise on timbered western slopes of fault block mountains bordering the Great Basin. The Williamson River and its tributary, the Sprague, flow westerly at elevations of 7,000 to 4,140 feet through timbered areas and broad, flat valleys before reaching Upper Klamath Lake. From the north, spring-fed Wood River and Sevenmile Creek are the major tributaries flowing from the eastern slopes of the Cascade Range to Agency Lake. Agency and Upper Klamath Lakes are connected by a narrow strait. Both lakes are relatively shallow and biologically rich.

Some 28 miles south of the mouth of Wood River and 18 miles south of the mouth of Williamson River, Link River forms the outlet of Upper Klamath Lake. A dam at the head of Link River regulates the level of the lake. Mile-long Link River feeds Lake Ewauna, which is formed by a dam across Klamath River at Keno and stretches through the broad reclaimed bed of Lower Klamath Lake.

Lost River, a natural tributary to Tule Lake, has been connected to Klamath River via a man-made diversion canal which is part of the system of drains and canals of the 190,000 acre Klamath Reclamation Project.

Below Keno, the Klamath River enters the narrow, steep canyons that typify most of its 254 miles before entering the Pacific Ocean on the California coast about 32 miles south of the Oregon border. Along its course in the mid-basin, Klamath River flows through three major impoundments. The first is J. C. Boyle Reservoir, about 10 miles below Keno. Spencer Creek enters near the head of the reservoir. The next impoundment is made by Copco Dam about 36 miles below Keno. The last reservoir is formed by the Iron Gate Dam about 45 miles below Keno. Three of the more important tributaries in the lower area are Jenny Creek and Fall Creek which enter Iron Gate Reservoir, and Shovel Creek, which flows into Klamath River about three miles above Copco Reservoir.

Climatology

The climate of the Upper Klamath Basin may be exemplified by the records of the Klamath Falls weather station[1]. Some variations within the basin may be expected on the basis of differences in elevation and proximity to mountains.

Fairly low winter temperatures result from an elevation of 4100 feet though the nearness of the Pacific Ocean and the general movement of air from that direction into the basin greatly modifies

1 U. S. Department of Commerce Environmental Science Weather Station, Kingsley Airfield, Klamath Falls, Oregon. Weather Summaries 1907-65.

the more extreme temperatures of summer and winter. The most extreme temperatures during the period 1907-1956 were 16 degrees below zero and 105 above. However, in the years 1927-1956, there was no minimum below zero or maximum above 96 degrees. Since then, a low of 25° below zero was recorded in January 1962. Nights are cold even during the warmest weather. During periods of high and low temperatures, the relative humidity is usually low.

The air masses moving in from the west, upon which this area is dependent for its precipitation, are forced across the Coast Range and Cascade Mountains. As a result, much of the available moisture has been condensed out before reaching the Klamath area. Annual totals of precipitation over the fifty years prior to 1956 varied from a low of 8.31 inches in 1949 to a high of 20.91 in 1948. Eighty percent of that time, the annual precipitation ranged between 9.5 and 17.00 inches. Approximately 70 percent of the annual total falls in the six months of October through March; less than 11 percent within the months of June through August. A substantial portion of the winter precipitation is in the form of snow.

Temperature and precipitation records for the study period, 1965, are presented and compared with long-range averages in Figures 2, 3 and 4 (Pages 133 and 134).

HISTORY OF KLAMATH RIVER SALMON AND STEELHEAD

Published Reports

The existence of anadromous salmonid fishes in the Mid- and Upper-Klamath Basins is substantiated by published reports on archeological investigations, early explorations, county history and in newspaper articles. Most accounts refer to the presence of these fish in the Mid-Klamath Basin, but there are sufficient reports to indicate that salmon and possibly steelhead were present in the Upper Klamath Basin.

Archeological investigations

Through his archeological investigations, Cressman and his colleagues (1956, 1962) deduced that 3500 years ago, fish constituted the major item in the diet of the inhabitants of the Klamath Basin. Bones found in excavations in the Sprague River valley have been tentatively identified as those of chinook salmon. Gatschet (1890), in his work on the Klamath Indians, makes several references to salmon, including words in the Klamath language to describe the fish and the following statement on the time of the runs. "The salmon are an important food fish of the Maklaks[2] Indians, ascending twice every year into the lakes and rivers of the Klamath Highlands, the first run being in June, the other in Autumn."

[2] Maklaks - true name of the Klamath tribe.

A description of the location of a dam for salmon near the mouth of Sprague River was given by Spier (1930). Spier also stated:

> "The time of the salmon runs in the river is not clear. Gatschet's statement is that salmon ascend the Klamath River twice a year. This bears out the statement -- that runs came in the middle finger months, May-June, and that the large fish run in fall. Pat Kane did not know whether there is more than one variety of salmon, which he called tciales. They ascend all the rivers leading from Klamath Lake (save Wood River) going as far up Sprague River as Yainax, but were stopped by falls below the outlet of Klamath Marsh."

In explaining the fishery methods used by the Klamath tribe, Spier wrote that fishing with nets was the primary method. Spears were not used much because of the dark water of Williamson River and Klamath Lake, other than the Pelican Bay area. Salmon were sometimes speared from river banks and from the rocks at Klamath Falls. Hooks were used chiefly for large fish like salmon and "salmon trout".

County history

In a history of Klamath County compiled by Rachel Good (1941), she cited the explorer, Fremont, (1846) as finding the Indians' main camp at Link River where they fished for salmon. She also related the recollections of Mrs. Addie Walker who arrived in the Sprague River Valley in 1879. "In winter the Indians brought us the large salmon trout from springs along the river on the reservation."

The following excerpts are from a History of Central Oregon, 1905:

> "In the Upper Klamath Lake and Link River seven varieties of the steelhead trout have been caught, ranging in weight from a few ounces to sixteen pounds which raise to a fly readily during the summer months, take a spoon in the spring and fall and minnow at all seasons of the year. - - - In Klamath River which flows from Klamath Falls to the Pacific Ocean, the fall fishing for salmon, salmon trout and silverside trout is exceptionally fine."

Newspaper reports

Articles from the files of Klamath Falls newspapers relate most recent history of salmon and possibly steelhead in the Mid- and Upper-Klamath Basins.

Klamath Republican - September 28, 1899

> "Soon will be the best season for fishing in Klamath County lakes. And then there will be rare sport. Large salmon trout, excellent candidates for the frying pan, will be caught in abundance and though catching them may seem cruel to the fish, it will be a joyful season to the fisherman..."

Klamath Republican - February 21, 1901

"Salmon and lake trout are now being caught in great abundance."

Klamath Republican - March 21, 1901

" - - - mullets, rainbow trout and salmon - splendid fish, giants in size and apparently anxious to be caught. The phenomenon will last a month - - -."

Klamath Republican - September 18, 1902

"Roy Wright has caught four large salmon from the river at this place (Klamath Falls) the last week. He pulled one out yesterday that weighed 25 pounds. Lots of them are in the river, he says. Salmon have not been this far up the Klamath before in ten or twelve years. We are told that dams in the lower waters have prevented the fish from running up, but are now enabled to do so by the aid of fish ladders constructed over the obstructions by order of the Fish Commission of California."

Klamath Republican - October 16, 1902

"It is reported that the fish ladder at Klamathon is a poor arrangement and has not accommodated the salmon during their run, thousands of them have been killed in attempting to go over it. If sufficient ladders were provided, there would be an abundance of salmon in the river here."

Coots (1962) gives the probable identification of the above-mentioned dam by citing Dowling (1948). A log crib, rock-filled dam was constructed by the Klamath River Improvement and Lumber Company in 1889, forming a mill pond on the Klamath River at Klamathon. This operation continued until 1902. The dam was reported to be 10 or 12 feet in height and apparently an obstacle to migrating fish.

On September 10, 1903, the Klamath Republican reported that salmon were running in the Klamath River at that time and several loads had been brought to town from down river.

An article on fish stocking appeared in the Klamath Republican on April 30, 1908.

> "Fish Commission of California stocked one million small salmon, 1/2 million rainbow and Eastern brook trout each in the vicinity of Klamath Hot Springs (near the mouth of Shovel Creek) . . . The planting of these fish is a direct help to the streams of this immediate section as the fish of the Klamath River find their way to almost every stream in this country."

Klamath Republican - September 10, 1908

"The first run of ocean salmon up the Klamath River have reached Keno, a number of the fish being caught there on Friday. Several of the salmon were sent to parties in this city and are in fine shape. They are good eating at this season of the year."

Klamath Republican - December 24, 1908

"The snow Wednesday stopped fishing on the lake below town, which reached extensive proportions the past few days. Holes were cut in the ice and with the aid of an ordinary hook and line, a string of 15 to 20 fish could be secured in an hour or so. The fish were a species of salmon trout and are said to have a good flavor - - -."

The presence of natural barriers to fish passage was revealed in The Evening Herald, a Klamath Falls paper, on September 24, 1908.

"Parties coming in from Keno state that the run of salmon in the Klamath River this year is the heaviest it has ever known. There are millions of fish below the falls near Keno, and it is said that a man with a gaff could easily land a hundred of the salmon in an hour, in fact they could be caught as fast as man could pull them in. The law, however, prohibits the catching of salmon above tidewater except with hook and line.

"There is a natural rock dam across the river below Keno, which it is almost impossible for fish to get over. In their effort to do so, thousands of fine salmon are so bruised and spotted by the rocks that they become worthless. There is no spawning ground until they reach the upper lake, as the river at this point is very swift and rocky.

"It is stated that at a very small expense an opening could be made in the rocks to allow the passage of the salmon. If this is not done, at least some effort should be made to have a fish ladder built, as it is nothing less than a crime to allow millions of these fish to be destroyed every year. The attention of the State Fish Warden will probably be called to this condition and something done to allow the salmon to reach the lake to spawn; what few fish get past the rapids at Keno are so bruised up they are worthless."

The exceptionally low flow in the river in 1908 is evident from the report of September 22 in The Evening Herald which described "old Indian fish runways uncovered by low water in Link River." They were dam-like structures with runways for the fish to pass and be caught. They had been in use when white men first came to the area, but the Indians using them at that time did not recall their construction.

Two more articles, Klamath Republican, October 14, 1909, and The Evening Herald, October 6, 1911, told of salmon being present in the Upper Klamath Basin.

The fact that there was at least some confusion or lack of continuity in the identity of salmonid fishes is borne out by items in The Evening Herald, April 8, 1912.

"- - - Irving Wilson, State Fish Culturist, states: There is a need for pamphlets setting forth all the species of fish to be found in the waters of this state. To the majority of fishermen, a rainbow, dolly varden, or steelhead does not mean any more than a salmon trout."

Fuel was added to the controversy on April 9, 1912, when The Evening Herald carried a statement by David Starr Jordan classifying all trout on the Pacific Coast as salmon trout. On the same day, the paper printed a letter from W. H. Shebly, Superintendent of Hatcheries, California, to Harry Telford, Oregon Deputy Game and Fish Warden.

> "The name salmon trout is only a local name applied to any species of larger trout. There is not any such fish as a salmon trout, considered from a scientific standpoint. The large fish in the Klamath are called salmon trout. The large fish in Pyramid Lake, an entirely different variety, are known locally as salmon trout. It is a name given to any large trout, but scientifically there does not exist any such fish."

Klamath fishermen apparently supported Jordan, using the term "salmon trout" in order to fish when trout season was closed, as there was no closed season on "salmon trout".

The first reference to the construction of Copco Dam appeared in The Evening Herald, March 17, 1913.

> "An effort will be made by the Oregon State Game and Fish Commission to secure the cooperation of the California Commission in forcing the California-Oregon Power Company to make provision for salmon to pass the dam now being constructed in the Klamath River about

forty miles from this city and on the California side.

"The dam, it is expected, will be completed this year. It is feared that unless a fish ladder is provided, there will be a notable falling off in the number of fish in this part."

The scarcity of salmon was being felt in the Upper Basin by 1913 and on October 28 of that year, it was written in The Evening Herald that A. J. Sprague, State Fish Expert; Corey Ramsby, Deputy District Game Warden, and George J. Walton, Division Superintendent of the Power Company, left to visit the Copco Dam site in an effort to determine the cause for this paucity of salmon.

As a result of this investigation, Messrs. Sprague and Ramsby wrote the following statement published October 30, 1913, in The Evening Herald:

"The question of why the annual run of salmon has not made its appearance in Klamath River as usual has been investigated and the cause determined beyond any question of doubt. There has been discussion as to the cause of a lack of salmon runs into the headwaters for the purpose of reproduction and as a result, the COPCO was insistent on an investigation to determine if the cause lay at the Klamath River Dam under construction in California.

"At the request of the Company and in the interest of the fishing industry in Southern Oregon, a thorough investigation was made. No salmon were found below the dam.

"This led to further investigation being made and the cause was located at Klamathon, where the U.S.B. of F. has established racks, traps and field stations for the taking of salmon eggs.

"We found that there were two separate racks extending entirely across the river from bank to bank, thus effectively cutting off the entire run of salmon.

"In justice to the Power Company, we can say that they are in no way responsible for no salmon being in the river."

According to Shebly (1918), the Federal Bureau of Fisheries began operating fish racks at Klamathon in 1910, leaving little chance for passage of upstream migrants after that time.

Snyder (1931) noted that Williamson River and the entire Klamath Lake basin were closed to the migration of salmon and steelheads when Copco Dam became an effective barrier on October 25, 1917.

Biological investigation

Ichthyologists made collections and studies of fishes in Upper Klamath Basin and vicinity. None of them reported collecting salmon or steelhead from that area. It is possible that their studies were made at a time of year when the anadromous species were not present.

Cope (1879) gave the following description of Upper Klamath Lake:

"The Upper Klamath Lake is more prolific in animal life than any body of water known to me, the proportion of alkali which it contains appears most favorable to development of life. Its waters are full of vegetable impurities, living and dead, and mollusca and crustacea abound everywhere. These sustain a great population of fishes which though not numerous in species, is so in individuals."

Cope went on to describe Salmo purpuratus, which fits the native Klamath rainbow, saying that it varied in color-shades and therefore was thought by fishermen to include several species. Specimens from Link River were reportedly silvery-white while those in Williamson River were a darker color. They were an important food fish, sometimes reaching 10 pounds in Klamath Lake.

Large rainbow trout were recovered from Upper Klamath Lake by Everman and Meek (1897). The fish they examined were thought to be lake-dwelling.

In June, 1894, Gilbert (1897) sampled rainbow trout from Klamath River and Upper Klamath Lake. He was unable to distinguish them from typical Salmo gairdneri, stating that the larger specimens had the characteristics of sea-run or land locked fish with a few spots and a truncate tail. He described the smaller specimens as having fewer spots and more silvery appearance than S. gairdneri from coastal streams.

Miscellaneous reports

One of the few references found which mentioned steelhead by name is a publication of Southern Pacific by Cumming and Dunn, (1911). In a section called "The Klamath Region," which expounds the virtues of fishing in the Upper Klamath Basin, the article attributes the great number of fish in Klamath River to the fact that the stream had uninterrupted access to the ocean. The authors cite the past controversy of whether steelhead are sea-going rainbow trout or whether rainbow trout are steelhead kept from the ocean by some means. Since Klamath River has constant access to the sea, they believed that the fish there may be considered steelhead all the time. There is mention of catching steelhead in the Klamath Hot Springs area (mouth of Shovel Creek) from the first of April. They also reported: "In May, there is good sport with the silver trout which spawn in the fall. They are the last run up from the ocean and are full of life." Extensive description was made of the trout fishing in Upper Klamath Lake and its tributaries.

Finally, mention was made of "silver salmon that run in the Klamath River during August and September. During August the trout in the river cannot be persuaded to look at any lure. These salmon put up a fine fight and leap, breaking water continuously."

One bit of conclusive evidence that chinook salmon did run to the Upper Klamath Basin is a picture of some fish taken from Link River. Dr. C. E. Bond, Professor of Fisheries at Oregon State University, examined the picture and positively identified a chinook salmon. Other fish pictured were rainbows, some appearing to be native Klamath residents and others like steelhead, but positive separation of these races cannot be made from a picture.

From the information at hand, it is evident that a run of chinook salmon entered the Mid- and Upper-Klamath Basins during the months of September and October. There might also have been a run of salmon in the spring months before the time when white men came to the area. From published reports, neither the magnitude of the runs nor the quality of the fish can be determined. No information is available on exact spawning areas, although it is known that the fish entered the Williamson River and its major tributary, Sprague River. Nothing is known of the life history of the juvenile fish. Though it is possible that the steelhead trout did migrate to the upper basin, no conclusive evidence of such runs can be derived from the reports examined. Since many of the statements are conflicting and at odds with present knowledge, many of the reports must be disregarded.

The last runs of fish destined for the Mid- and Upper-basins were curtailed after 1910 when the Bureau of Fisheries installed their racks at Klamathon. The completion of Copco Dam in 1917 finally blocked upstream migration. At the time of construction, fish ladders over high dams were not considered feasible. No federal license was required prior to the enactment of the Federal Power Act in 1920 and a state license was not necessary. The power company did build and equip a hatchery near Fall Creek at the request of California, to mitigate for the loss of upstream production of salmon.

A newspaper article in the Klamath Falls Evening Herald, 1918, indicated that a portion of the hatchery production was to be supplied to

Oregon. A California Commissioner in office at the time reported that no written agreement ever existed, but that a Department employee had verbally promised Oregon an allotment of fry whenever requested.[3]

No evidence has ever been found of such an agreement and apparently no attempt at mitigation or requests for fish were made by Oregon. In 1940, the Bureau of Indian Affairs became interested in construction and operation of fish facilities and hatcheries on Klamath River. This drive was dropped when the availability of fish from Fall Creek Hatchery failed to materialize and the fact became apparent that without provisions for downstream migrants at Copco Dam, planting of young fish in the upper basin would not be feasible.

Personal Interviews

In 1918, J. O. Snyder (1931), then an employee of the United States Bureau of Fisheries, interviewed many fishermen and old residents of the Klamath Lake region to learn of the past salmon runs. As a result, he reported:

> ". . . testimony was conflicting and a lack of ability on the part of those offering information to distinguish between even trout and salmon was so evident, that no satisfactory opinion could be formed as to whether king salmon ever entered Williamson River and the smaller tributaries of the lake. However this may be, large numbers of salmon

3 In a letter from Mr. E. L. Bosqui to Mr. H. Phleger, Attorney for California Oregon Power Company, dated December 6, 1940.

annually passed the point where the Copco Dam is now located."

Interviews made in the spring of 1965 with people who lived in the Klamath Basin before 1912 revealed some of the same difficulties that Mr. Snyder encountered. Nevertheless, there is enough agreement among the statements that some general information can be derived from them.

Progressing upstream through the watershed, seven interviewees told of salmon in the Upper Klamath River near Keno, with all recalling the fish being present in the fall - September, October and November. One person said an additional run came in March. The condition of the salmon was reported by two people as dark and fungused. Salmon were known in Spencer Creek in the fall months of September and October, as reported by four people.

Eight people remembered salmon in Link River from August through October. Another thought they ran in March.

One person reported catching salmon at the head of Wood River, another recalled what he believed to be a salmon in Crooked Creek, a tributary to Wood River. A long-time resident of the Wood River area was positive that no salmon entered that stream.

According to four people, salmon entered the Williamson River in the fall, possibly as early as August. One interviewee told of salmon spawning in the Williamson River below the confluence of Sprague River. One resident observed that after salmon passed Link River, it took them 5 or 6 days to make their way through Klamath Lake and enter Williamson River.

Sprague River was apparently the most important spawning stream, on the basis of the testimony received. Six individuals reported salmon in Sprague River and the forks of the Sprague during the months of September and October, with some during August and November. Salmon were reported to have spawned in the Sprague in the vicinity of Beatty, upstream on the South Fork past Bly to the headwaters and on the North Fork as well.

Little information about the history of steelhead in the Upper Klamath streams was gained from interviews. There was apparently some confusion in identity between steelhead and the large resident rainbow trout. One person placed steelhead runs in Klamath River during March and again in mid-September. Two people talked of steelhead in Wood River, one giving the time of the run as December, January and February. Spencer Creek was said to have a run of steelhead in September and October, while on the Williamson and Sprague Rivers, the sea-run rainbows were reported to be present in April and May.

Fish Counts for Klamath River

There is little information concerning the Klamath River salmon and steelhead fishery prior to 1912. Those records that were kept have apparently been destroyed.

One of the earliest references to the Klamath salmon fishery is from a paper by R. D. Hume cited by Snyder (1931).

> "In 1850 in this river during the running seasons, salmon were so plentiful, according to the reports of the early settlers, that in fording the stream it was with difficulty that they could induce their horses to make the attempt, on account of the river being alive with the finny tribe. At the present time the main run, which were the spring salmon, is practically extinct, not enough being taken to warrant the prosecution of business in any form. The river has remained in a primitive state, with the exception of the influence which mining has had, no salmon of the spring run having been taken except a few by Indians as a reservation by the Government has been maintained, until within a few years, and no fishing has been allowed on the lower river by white men; and yet the spring run has almost disappeared, and the fall run reduced to very small proportions, the pack never exceeding 6000 cases, and in 1892 the river producing only 1047 cases."

Beginning in 1910, the Federal Bureau of Fisheries maintained racks and fish trapping facilities at Klamathon on Klamath River, (Shebly, 1918). A hatchery was established by the Bureau at Hornbrook in 1913. The operation began by raising rainbow trout, but was changed to salmon within two years and closed by 1919, (U. S. Commissioner of Fisheries Report, 1911-1919). The output of Hornbrook Hatchery is given in Table 1.

A hatchery was built at Fall Creek in lieu of fish passage facilities over Copco Dam. At that time the Bureau of Fisheries relinquished their right on Klamath River, leaving the California Fish and Game Commission the sole manager of the fishery. Releases of young salmon made before the change are summarized in Table 2.

Periodic counts of salmon were made at Klamathon from 1925 through 1961 by California personnel. The counts and the corresponding egg takes are shown in Table 3. These counts should probably be looked upon as a trend only, since smaller salmon were able to pass through the racks. Therefore these counts do not represent the total run at that point.[4]

Releases of fry and fingerlings into Klamath River are summarized in Table 4.

In one of the most comprehensive studies of Klamath River salmon, Snyder (1931) expressed the opinion that the runs were diminishing before and after the construction of Copco Dam. He laid the cause to excessive exploitation of the fishery and the advent of placer mining in the Klamath Basin. Though commercial catch records for 1918-28 give the

[4] Personal correspondence from Millard Coots, California Department of Fish & Game, November 15, 1965.

impression there was no serious decline in the fishery, Snyder noted that the increase in effort represented by an increasing number of boats indicated a diminishing resource.

Table 1. Chinook and Coho Salmon Production at the U. S. Bureau of Fisheries, Hornbrook Hatchery on Klamath River, 1912 - 1918.

	Number of Fish	
Fiscal Year	Chinook	Coho
1912	—	117,320
1913	—	—
1914	1,795,580	2,632,300
1915	2,831,925	2,375,770
1916	15,872,340	2,169,050
1917	2,168,000	61,000
1918	275,900	—

Table 2. The Numbers of Chinook and Coho Fry and Yearlings Released Into Klamath River and Tributaries from U. S. Bureau of Fisheries Hatcheries from 1890 - 1919.

	Chinook		Coho	
Calendar Year	Fry	Yearlings	Fry	Yearlings
1890	90,000			
1891	30,000			
1892	147,600	25,000		
1893	487,000			
1895			300,000	160,000
1898	16,000			
1903	40,000			
1911			2,060,910	
1913			17,320	
1914	2,155,100		2,548,960	
1915	5,820,000		1,098,000	
1916	7,733,135	368,000	2,169,000	11,000
1917	1,728,000		50,000	
1918	3,675,000			
1919	1,148,000		178,000	

Table 3. Chinook Counts and Egg Takes at Klamathon Racks, Klamath River, 1925 - 1961.

Year	Number of Fish Counted	Number of Eggs Taken
1925	10,420	6,735,000
1926	9,387	18,042,000
1927	No Count	11,797,000
1928	No Count	4,621,000
1929	4,031	5,016,000
1930	2,392	3,103,000
1931	12,611	13,643,000
1932	13,740	4,085,000
1933	No Count	1,779,000 (a)
1934	10,340	6,316,000
1935	14,061	7,541,000
1936	10,398	3,349,000
1937	33,144	7,334,000
1938	16,340	7,629,700
1939	No Count	7,056,000
1940	14,965	8,414,000
1941	11,204	3,760,000 (a)
1942	13,038	3,643,000 (a)
1943	No Count	3,640,000 (a)
1944	No Count	3,383,000 (a)
1945	No Count	4,682,706 (a)
1946	No Count	4,302,560 (a)
1947	No Count	798,765 (a)
1948	5,821	165,600 (a)
1949	11,504	165,600 (a)
1950	21,584	665,000 (a)
1951	17,857	1,261,000 (a)
1952	6,591	1,422,000 (a)
1953	6,267	1,097,080 (a)
1954	2,042	202,000 (a)
1955	14,946	3,271,750 (a)
1956	6,770	1,553,600 (a)
1957	2,436	260,572 (a)
1958	1,950	21,250 (a)
1959	3,546	1,404,600 (a)
1960	6,353	1,372,800 (a)
1961	9,021	3,704,000

(a) Eggs taken at Fall Creek, others at Klamathon.

Table 4. Chinook, Coho and Steelhead Fry and Fingerling Plants into Klamath River by California Fish and Game Department, 1896 - 1959.

	CHINOOK					
Year	Fall Creek Hatchery Fingerling	Mt. Shasta Hatchery Fry[b]	Mt. Shasta Hatchery Fingerling	Prairie Creek Hatchery Fingerling	Coho Salmon Fingerling	Steelhead[a] Fingerling
1896		1,400,000				
1907		600,000				
1911		350,000				
1913		1,350,000				
1914		880,000				
1915		7,563,000				
1916		928,000				
1917		1,050,000				
1920	2,854,000					
1921	3,132,000					492,000
1922	3,331,000					495,000
1923	3,550,000					363,000
1924	2,307,000					50,000
1925	5,249,000					888,000
1926	3,765,000					332,000
1927	3,762,000					239,000
1928	3,251,000					371,000
1929	3,603,000					415,000
1930	2,939,000					1,420,000
1931	2,030,000					669,000
1932	3,601,000		7,455,000			618,000
1933	3,419,000					815,000
1934	1,489,000				73,380	290,475
1935	3,961,000					1,178,272
1936	3,981,223					1,715,172
1937	4,086,000					2,307,748
1938	4,113,000		2,219,000			1,400,000
1939	3,907,000		2,263,040			1,914,000
1940	4,132,430		1,960,000		20,000	1,237,601
1941	4,976,000		1,874,000		20,000	1,298,600
1942	3,189,790					648,700
1943	3,011,400			491,920		615,055
1944	2,598,720			497,900		365,140
1945	2,526,220			487,360		93,661
1946	3,265,073			496,080		401,986
1947	3,237,150			470,700		351,240
1948	755,908					8,000
1949						214,500
1950						262,650
1951			213,200			228,060
1952			582,608	507,250		249,700
1953			947,296	309,750		145,200
1954			803,153			
1955			202,150			
1956			2,599,863			
1957			1,482,305			
1958			263,500			
1959			35,580			

(a) Incomplete records.

(b) Snyder, J.O. Salmon of the Klamath River, Calif. Fish & Game Bul. [illegible]

LIFE HISTORY OF KLAMATH RIVER SALMON AND STEELHEAD

Salmon

Taking into account the papers of Hume (Snyder 1931), Gatschet (1890) and Spier (1930), there is evidence that there was once a strong run of chinook salmon in the spring months. By 1900 the spring run had become so reduced as to be of little importance. Suggested causes of the decline are placer mining, overfishing, irrigation withdrawals and other causes.

Upstream migrations

The spring run began entering Klamath River in late February, materially increased in numbers in late March or early April and decreased before mid-June. The river was generally in flood condition at the time of the spring run. Upon entry, the chinook were immature and either migrated to the extremes of the basin or held over, spawning at the same time as the summer fish.

A few spring-run salmon still enter Klamath River, but few go as far as Klamathon. Most use the Trinity and Salmon River, Coots (1962).

The timing of the present fall-run chinook salmon, as described by Coots (1962), corresponds well with the statements of Snyder (1931) for the fall migrations of the early 1900's. The first fish appear at the mouth of Klamath River in July, then reach maximum numbers in August and decline during September. During this period, the river is experiencing its highest temperatures and lowest flows. The fish reach Klamathon, 183 miles upstream, by the last of August, the majority in the last of September and early October. By late October, the run is normally complete, but in years of large escapements, the runs may extend well into November.

Spawning

Spawning by the existing run begins early in October, continuing into November and sometimes December, especially during years of large escapements. Spawning in the main stem of Klamath River occurs above the confluence of Shasta River, some 187 miles from the sea, (Coots, 1962). Chinooks did run into Fall Creek and Jenny Creek before Iron Gate Dam became a barrier and they presently use Bogus Creek, immediately below Iron Gate.

Downstream migrations

Salmon fry begin appearing in the Klamathon area in January. The downstream migration peaks during March and April. By the end of May, nearly all young salmon have departed from the upper end of their present range in the Klamath. None of the seaward migrants have been recovered downstream during the summer and their presence there at that time is doubtful, (Coots, 1962). Water temperatures in the river during the summer are generally higher than those described by Brett (1952) as being preferred by young salmon.

Age at maturity

Klamath River chinook salmon were found to mature at ages ranging from one to six years by Snyder (1931). He based his findings mainly on fish taken in the commercial catch. Precocious males of one and two years of age were known to exist, but did not enter the catch and were difficult to obtain.

Four-year old fish represented the largest class in the 1919 catch. The fishing season of 1919 lasted into mid-October. The composition of that run is exhibited in Table 5. The older fish entered the catch as the season progressed. The three-year-olds appeared in greatest numbers in mid-August. The four-year-old fish were most numerous in early September; five-year-old fish showed in late September, and six-year-old fish in mid-October. According to Snyder, maturity of arriving fish was more advanced as the season progressed.

Snyder reported the length range of four-year salmon as between 24.0 - 40.9 inches, with a mean near 31.5 inches. Fish under 25.6 inches or over 37.4 inches were uncommon.

Steelhead

Information on the life history of Klamath River steelhead trout is not known for years prior to the early 1900's. Snyder (1931) mentions that runs of steelhead accompanied the runs of fall chinook salmon. He also quotes G. R. Field as saying the winter run of steelhead ended in late March. At that time, young steelhead normally remained in the river for two years before migrating to the ocean. They occasionally left after one year and rarely after three years in fresh water.

Recently, the first run of steelhead, known as the "summer run", begins entering the river in mid-August. This group consists mainly of the small, so-called "half-pounders." The winter run of progressively larger fish first enters the river shortly after the end of the early fall migration. This run may extend into the following spring or early summer and hold over there until the following spring to spawn. Periods of steelhead spawning vary in upper range of the Klamath system, with some spawning observed in Shasta River during December. Generally, spawning occurs earlier in the intermittent and warmer streams and as late as May or June in the cooler tributaries.[5]

Table 5. Age Composition of 1919 Run of Chinook Salmon in Klamath River[(a)].

	Year Class by Percent			
	Three	Four	Five	Six
July 11 - 19, 1919	9.9	86.5	3.6	--
July 21 - 26, 1919	9.3	74.3	16.4	--
July 28 - August 2, 1919	14.3	62.5	22.2	--
August 4 - 9, 1919	25.8	60.2	14.0	--
August 11 - 16, 1919	24.4	64.4	10.8	0.4
August 18 - 23, 1919	28.3	64.7	7.0	--
August 25 - 30, 1919	23.7	64.8	11.5	--
September 1 - 5, 1919	10.8	73.0	15.9	0.3
September 20 - 27, 1919	5.5	42.7	44.6	7.2
September 30 - October 4, 1919	12.2	38.7	38.7	10.4
October 6 - 11, 1919	2.8	41.0	43.5	12.7
October 14 - 18, 1919	4.8	37.5	51.5	6.2

(a) Table taken from Salmon of the Klamath River, California Snyder (1931).

5 Personal communication from Millard Coots, California F&G, November 15, 1965.

ENVIRONMENTAL REQUIREMENTS OF SALMON AND STEELHEAD

Temperature

For the fishes of the genus *Oncorhynchus*, the Pacific salmon, Brett (1960) summarized the thermal limitations required for survival and growth at various stages of their life history. The following ranges were taken from a graph depicting these limits.

Stage	Survival	Growth
Egg	34-62° F	38-55° F
Hatching	35-56	40-53
Emergence	34-62	42-55
Migration	37-75	42-65
Yearling-Adult	32-75	42-65
Spawning	42-58	

Burrows (1963), dealing with adult Pacific salmon during the freshwater period, gave the optimum temperature range of 42.5 to 55° F for maximum adult survival, egg viability, time of spawning, and spawning efficiency.

Chinook salmon in Washington were found by Chambers et al[6] to spawn primarily within the range of 48 to 52° F.

During 1947, spring chinook salmon in the Willamette Basin spawned between 43.5 and 64.5° F (Mattson, 1948). The daily water temperatures during the peak of spawning by spring chinooks on the

6 Chambers, J.M., R. T. Pressy, J. R. Donaldson, W. R. McKinley, 1954. Research relating to study on spawning grounds in natural area. State of Washington. Dept. of Fisheries, Annual Report to U.S. Corps of Engineers, unpublished.

Imnaha River ranged from 49 to 57° F between August 10 and 20, 1957 (Oregon State Game Commission, 1957).

Slater (1963) stated the lower and upper temperature limits for spawning winter-run chinooks in the Sacramento drainage was 42.5 and 57.5° F during the spawning period of May through August.

When describing the temperature conditions for most efficient hatchery production of Pacific salmon, Hagen (1953) gave the ideal range as 45 to 55° F. He also noted that prolonged temperatures below 34° F result in a long incubation period and product abnormal fry, while temperatures above 60° F cause excessive mortalities. Johnson and Brice (1953) and Olsen and Foster (1957) concur that 60° F is the upper limit for successful incubation of chinook salmon eggs. Cooler temperatures are required on American River where Hinze (1963) found that water warmer than 56° F produced severe losses of chinook eggs.

Combs and Burrows (1957) give the range of suitable hatching temperatures for chinook salmon eggs as 42.5 - 57.5° F. Low egg survival was also found above 58° F by Seymour (1956).

Using Entiat River chinook salmon eggs, Combs and Burrows (1957) noted that mortality did not exceed two percent after the eggs were held in 42° F water for a month, then cooled to 33° F and held for several weeks.

Combs (1965) conducted experiments to evaluate the effects of water temperature on incubation to develop more precisely the stage of development at which salmon could tolerate winter temperatures. These tests revealed that chinook salmon eggs which had developed to the 128-cell stage (6 days) in 42.5° F water could tolerate water at 35° F for the remainder of the incubation period.

In an experiment, female chinook salmon, nearly ready to spawn, all died before spawning when held in water of 34 - 38° F, (Leitritz 1959).

Burrows (1963) stated that optimum growth of juvenile Pacific salmon occurs within a range of 50 to 59° F.

While conducting an experiment, Chapman (1938) observed that 452 of 1000 chinook fry died while being held in water of 67.1 to 68.9° F, even though there was always ample oxygen and flow. At the same time, there were no deaths among similar fish held in water of the same source, but having a temperature range of 45.5 - 57.3° F.

Leitritz (1957) wrote that it is generally agreed that yearling and adult rainbow trout can withstand temperatures up to 78° F for short periods without harm. However, it has also been shown, in order to produce good quality eggs, rainbow spawners must be held at water temperatures below 56° F for at least six months before spawning.

The temperature limitations used as criteria in this report are 42.5 - 57.5° F for the spawning period, 33 - 58° F for the incubation period, and 32 - 75° F as the limits of survival and 42 - 68° F as the optimum limits for maintenance and growth of salmon and steelhead.

Dissolved Oxygen

One of the most critical factors governing the suitability of a water to support salmonids is the quantity of dissolved oxygen.

When discussing the problem of developing criteria for environmental requirements needed by an animal, Jones (1964) wrote that they "may realistically be half the difference between the basic level needed at rest and the level required at maximum activity ...." He pointed out that oxygen concentrations permitting existence for limited periods in laboratory experiments cannot suffice in nature, but do indicate the resistance of a species to temporary shortages.

Davidson, et al. (1959) found that coho fingerlings could survive at 2 ppm of dissolved oxygen, but ate sluggishly and lost weight. At 3 ppm, they fed as well as fish held in well-aerated water.

Growth and food consumption by juvenile coho salmon declined with reduction of oxygen concentration from 8.3 to 6 and 5 ppm, and declined more sharply with further reduction of oxygen concentration in a study by Herrmann, Warren and Doudoroff (1962).

Katz, Pritchard and Warren (1959) observed that chinook fingerlings could swim for at least a day against a current of 0.8 fps at a dissolved oxygen concentration of 2.99 ppm.

Davis, et al (1963) found that reduction of oxygen concentration from air-saturation levels to 7, 6, 5, 4, and 3 ppm usually resulted in a reduction of maximum sustained swimming speed of chinook salmon fingerlings by approximately 10, 14, 20, 27, and 38 percent, respectively.

M. M. Ellis, et al. (1946) found that in 1300 water samples from areas having large faunas of fish, dissolved oxygen concentrations ranged from 4 to 12 ppm, but 84 percent fell within 5-9 ppm. They stated that three ppm is approximately the lethal point for freshwater fishes at summer temperatures, but respiratory difficulties develop below five ppm.

The lowest safe level for trout is five ppm, seven ppm is preferable.

According to Tarzwell (1958), salmonid fishes are not usually found where the minimum dissolved oxygen concentration is less than 4 or 5 ppm. Five ppm are required for normal feeding and growth and at least 6 ppm are needed for the development of eggs and fry. Tarzwell added that the oxygen level may be lower than 6 ppm in sections of habitat where the fish don't live permanently or in seasons when incubation and fry development is not occurring. He stated that salmonids can survive short periods at 1.5 to 2.0 ppm, but these levels are not satisfactory for continued existence.

An oxygen block was defined by Fish (1950) as any level of oxygen less than 5.0 ppm.

While studying the reactions of salmonids to low oxygen concentrations, Whitmore, Warren and Doudoroff (1960) found that chinook salmon fingerlings avoided 2 ppm oxygen 60 per cent of the time; 3.2 ppm 40 per cent of the time; 4.6 ppm 27 per cent of the time; and 6.0 ppm was not avoided.

In this report, the appraisal of potential environment is based on a minimum of 5.0 ppm of dissolved oxygen for basic survival and migration, and a minimum of 7.0 ppm during the incubation period.

Water Velocity for Spawning

Salmon usually spawn in flowing water within a fairly narrow range of velocities. There are no universally accepted standard measurements, but several studies have been made to indicate the velocities selected by salmon and steelhead. Velocity measurements are taken at "fish depth", the space occupied by the spawning fish, usually 0.3 foot above the stream bed.

Burner (1951) found the average velocities over redds in Toutle and Kalama Rivers to be 1.3 and 2.0 feet per second, respectively. Sams and Pearson (1963) discovered chinook salmon spawning in velocities of 0.45 to 3.1 fps, averaging 1.53 fps. Chinooks in Deschutes River, Oregon, spawned in faster water 2.0 to 3.7 fps, (Aney 1964). In streams other than the Columbia, Chambers, Allen and Pressey (1955) calculated average velocities of 1.0 to 1.75 fps over fall chinook redds. In estimating the amount of usable spawning area on Cosumnes River, California, Westgate (1958) used 0.5 to 3.5 fps as the velocity limits. Hamilton and Remington (1962) regarded one foot per second as the minimum required for spawning on Coquille River. Measurements over steelhead redds yielded ranges of 1.2 to 3.4 fps (Sams and Pearson, 1963) and 1.3 to 4.2 fps (Aney 1964).

The range of suitable water velocities adopted for use in this study was 1.0 to 4.0 feet per second.

Water Depth for Spawning

The depth of water over gravel beds is also a factor to be considered when evaluating spawning grounds. The average water depth over fall chinook redds in Columbia River tributaries was found to be 1.25 to 2.25 feet by Chambers, Allen and Pressey (1955). Briggs (1953), studying fall chinook redds in small California streams, calculated an average depth of 12.7 inches. Redds on Toutle River averaged 11.6 inches beneath the surface while those on Kalama River were 14 inches, as observed by Burner (1951). In studies by Sams and Pearson (1963), they found chinook redds at depths of 0.3 to 2.0 feet, averaging 0.96 feet; steelhead redds ranged in depth from 0.5 to 2.4 feet, averaging 2.12 feet. On Deschutes River, Aney (1964) found chinooks spawning in an average depth of 1.7 feet within a range of 0.9 to 2.6 feet. At the same location, steelhead were digging redds at water depths between 0.5 and 2.5 feet at an average of 1.3 feet. Water depths of 0.5 to 4.0 feet were accepted by Westgate (1958) when evaluating spawning areas in California. The average depth of water over redds dug by fall chinook on South Fork Coquille River was 0.8 and 1.2 feet on successive years (Hamilton and Remington, 1962).

In the Klamath Basin study field work, a minimum water depth of 0.5 feet was used while estimating the amount of usable gravel available.

Gravel Quality

The quality of gravel used by spawning fish has been found to be critical in determining production. The gravel mixture must be of such composition as to allow adequate circulation of water yet give support to the eggs and be easily manipulated by the spawning fish. Sheridan (1962) states that the major source of oxygen containing intragravel water is the stream itself. Anything interfering with the interchange of stream and intragravel water decreases the amount of dissolved oxygen available to the eggs plus lowering the rate of flow past the embryos. Silting of stream beds, thus lowering permeability of gravel beds, can definitely interfere with interchange. An algae cover is another factor which can markedly reduce intragravel circulation.

In a study under simulated conditions, Shelton (1955) recovered fry representing only 13 per cent of the eggs planted in gravel less than one inch in diameter while 87 per cent of the chinook eggs survived to emergence in gravel of one to three inches in diameter.

Hamilton and Remington (1962) required that at least 60 per cent of the gravel fall within the range of one to six inches in diameter to be suitable for chinook salmon on Coquille River, Oregon.

Not more than 20 per cent gravel less than one inch and not more than 30 per cent in the six to 12 inch group were the limits set by Westgate (1958) for California streams.

A gravel size range of one to six inches in diameter was also used while estimating usable gravel in this study of the Klamath Basin.

The potential of a gravel area is dependent on the number of spawning females it will support. From studies on the Sacramento River system, Hanson, Smith and Needham (1940) determined the average size of chinook salmon redds to be 4.4 square yards. On the Trinity River, Moffett and Smith (1950) found that chinook redds averaged about 7.0 square yards. Burner (1951) measured chinook redds on tributaries of the Columbia River. He calculated the average redd size as 6.1 square yards for summer and fall-run fish and 3.9 square yards for spring chinooks. From his observations, Burner suggested a factor of four times the average redd size to allow for interredd space when estimating the carrying capacity of a gravel area.

An average size of 6.6 square yards for steelhead was determined by Shapovalov and Taft (1954) on Waddel Creek, California.

Spawning areas of 21 square yards for chinook salmon and 26 square yards for steelhead were used in estimating the capacity of potential spawning grounds included in this report.

Migration Schedules

Over many generations, salmon and steelhead have become adapted to their environment through natural selection. This has resulted in rather precise schedules for migration of adults, spawning, incubation, emergence and seaward migration. These schedules are established to provide for maximum survival.

In a discussion of migratory delays caused by reservoirs, Haas (1965) outlined the following points which could lead to reduced survival.

1. Delay may result in weakening of the migratory urge through diminution of saltwater preference in smolts[7] which appear to reach a peak around the time of smolting.

2. Delayed entry into saltwater may reduce the survival rate due to smolt inability to make the physiological transition to ocean environment after a certain fixed period of time during smolting.

3. Delay may permit surface layers of the reservoir to heat and create a temperature blanket through which smolts will not migrate.

7 Life history stage of salmon and steelhead when young fish undergo complex physiological changes in preparation for an ocean environment.

4. Smolts may become residual and suffer mortality from over-summering in adverse environment of the reservoir.

5. Delay may lessen ability of smolts to cope with other stresses encountered in downstream migration such as turbine passage, delay at other reservoirs and dams, temperature adversities, etc.

6. Delay beyond the time of major out-migration in the spring may make smolts vulnerable to predation by fish since predator activity would be expected to increase with an increase in water temperature.

7. Delay and subsequent migration of smolts after water temperature increases would increase the chances of disease contraction.

Predicting delay to sockeye smolts through a proposed reservoir, Andrews and Geen (1960) state that under natural stream conditions, juvenile sockeye migrate downstream passively. Sockeye smolts were found to migrate about 30 miles a day on Chilko River, B. C. Other work indicated they migrated about 0.7 miles per day through Cultus Lake and one or two miles per day through Seton Lake, B. C. Migration in lakes is active rather than passive as in streams. Similar effects might be expected on the rate of migration of young chinook and steelhead when encountering bodies of water such as Klamath Lake and Klamath River reservoirs.

As Haas (1965) relates, there is evidence that reservoirs created in the path of downstream migrant salmon and steelhead may increase the number of residuals, i.e., juvenile fish that remain an unusual length of time in freshwater. As a result, in Brownlee Reservoir, seaward migrant chinook have changed largely from fish of the year to year-old smolts. The ultimate effects of this change are not known.

While summarizing recent fish-passage research, Collins and Elling[8] noted that passage of downstream migrants has been marginal at best through large impoundments.

1. At Brownlee Reservoir (57 miles long) passage of juvenile salmonoids has not been successful. Adverse water quality conditions exist there during the summer. There is evidence that the smolts stay upstream in the inflowing river water until the spring when they move out with high inflows and discharges from the reservoir. Spring chinooks have better success than fall chinooks and both do better than steelhead at Brownlee.

2. Plants of chinook fry have not passed successfully through Shasta Reservoir (25 miles long). The fish disappear from the surface with the advent of warm weather and there is evidence of predation by resident fishes. Residual chinooks have reached

[8] Collins, Gerald B. and Elling, Carl H., "Summary, Progress in Fish Passage Research, 1964," December 1964, unpublished report by the Bureau of Commercial Fisheries, Seattle, Washington.

three to five pounds in one year in Shasta Reservoir.

3. At ten-mile long Merwin Reservoir in Washington, passage of yearling coho via a surface collector has been quite good, but predation by rainbow trout and squawfish has reduced survival. Counts of downstream migrants accounted for 65 per cent of the fish released in the reservoir.

4. Surface collectors at Upper Baker Reservoir (9.75 miles) and Lower Baker Reservoir (9.0 miles) have passed an estimated 95 per cent of yearling sockeye and coho salmon.

5. In Oregon, fish runs are being maintained on the Clackamas River through North Fork Reservoir (4.0 miles), but not through Pelton (7.5 miles) and Round Butte (7.0 miles) on the Deschutes River. Success of maintaining fish runs there is thought to be related to the survival from fry to smolts, and success of passage by smolts. The survival of fry to smolts in Pelton Reservoir was less than one per cent while in North Fork Reservoir, it was more than eight per cent. The difference seems related to the presence of squawfish, centrarchids and other predators in Pelton which are not found in North Fork Reservoir. The mere presence of these fish may imply

that the environment is marginal for salmonoids. Success of passage from Pelton is marginal (13 to 69 per cent), good at North Fork (70 to 90 per cent), and poor at Round Butte immediately upstream from Pelton. The difference may be attributed to water quality. North Fork is least alkaline, stays colder in the spring and has a greater rate of water replacement.

Delays in upstream migration of salmon and steelhead, particularly fall and winter run fish, may be critical. The fish may become mature and ready to spawn before reaching their destination. In such cases, the fish may die before spawning, or spawn in a substitute location usually with inferior results.

According to Haas (1965), tagging experiments at Brownlee Reservoir indicated no significant difference in survival of upstream migrant chinook salmon between fish released in the reservoir and those transported around the reservoir and released in the Snake River, about 65 miles further upstream. This information seems to indicate that mature fish are better able to migrate through reservoirs than smolts.

SURVEY RESULTS AND EVALUATION

Eight streams in the Klamath Basin above Copco Reservoir have been found to contain potential spawning areas for salmon and steelhead. Some of these are located above Klamath Lake. It is the intent of this section to assess the quality of the migration route from the mouth of Klamath River to the several potential spawning areas and to provide an appraisal of these spawning grounds and associated rearing environment for salmon and steelhead.

The most obvious obstacles to upstream and downstream migration on the Klamath River are dams and diversions. Both occur in the study area and will be discussed in greater detail later.

A considerable number of water rights have been filed for in the Middle and Upper Klamath Basins. A compilation of these rights has been made and summarized. Records were obtained from the State Engineer of Oregon and the Klamath County Clerk. It is not known what percentage of the total rights these records represent. There may be some riparian rights that are not recorded; such is the case for diversions along Klamath River within California.

Summations of water rights held in 1917 and at the present time were made to compare relative water use for those periods. The totals are printed in Table 6 (Page 45).

The irrigation season in the Upper Klamath Basin usually begins sometime in April and ends by mid-October. Table 7 (Page 46) shows the percentages of the seasonal irrigation demand by month for the Klamath Project and the remainder of the Klamath Basin.

Survey Methods

Stream surveys were accomplished either on foot, horseback, or by boat. In each case, spawning areas were measured by pacing off the dimensions whenever possible. In the event that a gravel bar was inaccessible, a visual estimation was made. Generally, gravel size-composition, water depth, and water velocity were evaluated visually.

Measured surface water velocities and total stream flows were

Table 6. Total Water Rights on File from Streams in the Upper Klamath Basin for the Years of 1917 and 1965.

Stream	1917 CFS	1965 CFS	
Klamath River	763.88	833.2	
Jenny Creek		15.96	327.8 cfs on Keene Creek System
Fall Creek		9.05	
Odessa Creek		8.1	
Varney Creek		3.75	
Fourmile Creek		22.69	Not including Fourmile Lake
Cherry Creek		9.37	
Sevenmile Creek and Tributaries	120.88	291.88	
Wood River and Tributaries	416.59	665.88	
Williamson River and Tributaries		322.14	Below Klamath Marsh only
Sprague River and main stem tributaries	3.25	252.45 555.5	Includes 100 cfs for BIA AF AF-acre feet of storage
Sucan River and Tributaries	19.09	55.16	
N.F. Sprague River and Tributaries	94.39	168.02	
S.F. Sprague River and Tributaries	195.07 1559.6 AF	242.86 6085.5	 AF AF-acre feet of storage
	1951.95 1559.6 AF	2893.15 6641 AF	

Table 7. Estimated Monthly Irrigation Demand by Per Cent of Seasonal Total for Klamath Basin (a)

Month	Klamath Project(b)	Remainder of Klamath Basin
October	1.4	0
November	0.4	0
December	0.3	0
January	0.5	0
February	0.5	0
March	1.2	0.1
April	8.4	10.2
May	14.6	18.3
June	18.6	16.6
July	25.3	21.3
August	19.5	20.1
September	9.3	13.4
Totals	100.0	100.0

(a) Table taken from California Department of Water Resources Bulletin No. 83.

(b) Bureau of Reclamation Irrigation Project made either by the "cork method" described by Robins and Crawford (1954) or with a Gurley current meter. In water less than a foot deep, the current meter readings were taken at 0.6 of the total depth measured from the bottom. Two readings were taken in deeper water, one each at 0.2 and 0.8 of the total depth measured from the bottom. Water velocities at fish depth were taken with the meter set 0.3 feet over the gravel.

Water samples were obtained with a Kemmerer water bottle and analyzed for dissolved oxygen content by the azide modification of the Winkler method.

Water temperatures in streams were obtained with hand thermometers and continuous-recording thermographs. In J. C. Boyle Reservoir, water temperatures were read on an electric thermister, while at Iron Gate and Copco Reservoirs, a bathythermograph provided temperature profiles.

Stream surveys were done at various times between May and November at different stages of stream flow. Therefore, there may be a difference in the amount of potential spawning gravel found at the time of the survey and that available during possible spawning seasons. Table 8 (Page 48) contains the time of the survey for each stream section where gravel was found and a comparison of the mean flow for the month of the survey and the mean monthly flows over the past several years.

Stream mileages used for surveys and referred to in this report all begin with 0.0 at the mouths of each individual stream of major fork.

Figure 5 (Page 132) shows the locations of the sampling stations used in this study.

Table 8. A COMPARISON OF FLOWS (cfs) AT THE TIME OF STREAM SURVEY WITH THE AVERAGE FLOWS IN RECENT YEARS.

Stream Section	Date of Survey	Mean Flow for month of survey.		Mean monthly flow at nearest gauging station: Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Klamath River			(a)												
Frain Ranch Area	Jun 28 1965	350 (d)		1751	2103	2403	2076	1718	1668	1968	1351	900	852	952	1399
below Calif. line	June 28 1965	350-1103 (d)													
Spencer Creek	May 24 1965	----No flow data available													
Sevenmile Creek	Oct. 1965	----No flow data available													
Wood River		----No flow data available													
mile 9-13	Sept. 1964	----No flow data available													
mile 13-17	Apr. 1964	----No flow data available													
mile 17-18	Apr. 1963	----No flow data available													
Williamson River	Oct. 1965		(b)	830	954	1223	1193	1636	1816	2762	2274	1345	777	638	657
Sprague River															
near Chiloquin	Oct. 1965	(Sept) 299	(b)	387	410	565	566	882	934	1774	1510	777	360	270	285
near Beatty	Oct. 1965	(Sept) 140	(c)	193	198	378	250	390	402	684	723	364	166	125	132
N.F. Sprague (e)															
canyon	July 1965	269													
upper	Aug. 1965	166													
lower	Aug. & Nov. 1965	(Aug) 140													
S. F. Sprague (e)	Aug. 1965	166													

(a) Flow data from years 1959-64
(b) Flow data from years 1951-64
(c) Flow data from years 1954-64
(d) Flow present at time of survey.
(e) Flow data from Beatty station on Sprague River, no data available for Forks of Sprague River.

Lower Klamath River -- Milepoint 0.0 - 192.0

Fish passage in the Lower Klamath River from the Pacific Ocean to Iron Gate Dam in California is not impaired by physical obstructions. Klamath River from its confluence with Shasta River, approximately 13 miles below Iron Gate, to its mouth is closed to any development which would necessitate the construction of a dam or an obstruction to the flow of the river. This portion of the river was set aside by an initiative act, approved by the electroate of the State of California in 1924.

Iron Gate Reservoir -- Milepoint 192.0 - 199.0

Iron Gate, a re-regulating dam on Klamath River to stabilize flows from Copco No. 2 and 2, was constructed by Pacific Power & Light Company in 1960-61. The structure is 173 feet high and forms a reservoir seven miles long, having a maximum depth of 145 feet. There are no fish passage facilities present. There are salmon and steelhead holding ponds and an egg-taking station operated by the California Department of Fish and Game at the base of the dam to provide eggs for a 32-pond hatchery at that site.

Daily surface water temperatures were taken by hand thermometer at Iron Gate Reservoir and the weekly means are presented in Figure 6 (Page 133). Temperatures for the month of July were the highest recorded and ranged from a low of 67° F to a high of 70° F. The major limiting factor for these data is that they were taken between 8:00 a.m. and 9:00 a.m. and not at the warmest period of the day.

Dissolved oxygen measurements and temperatures were taken monthly from June through November, 1965, at Iron Gate Reservoir. The results are graphically presented in Figures 7A and 7B (Pages 134 and 135). Samples were collected at two stations, one in deep water near the dam and the other at the upper end in shallow water. Sampling results indicate that in the months of July and August, conditions are unsatisfactory for salmonoids in daytime hours except in a stratum between 10-20 feet. The limiting factors are either high water temperatures from 72° F to 80° F in the upper levels or low dissolved oxygen from 0.00 ppm to 5 ppm in the deep, colder water. These conditions did not persist during the remaining months as temperatures in the shallower depths declined and dissolved oxygen content increased in the deep water.

Except for the months of July and August, water quality conditions in Iron Gate Reservoir appear to be satisfactory for the rearing of juvenile salmonoids. Predation may occur on the young fish as the following species are present in the reservoir:

Rainbow trout	_Salmo gairdneri_ Richardson
Largemouth bass	_Micropterus salmoides_ (Lacepede)
Yellow perch	_Perca flavescens_ (Mitchell)
Klamath smallscale sucker	_Catostomus rimiculus_ Jordan & Snyder
Tui chub	_Siphateles bicolor bicolor_ (Girard)
Blue chub	_Gila bicolor_ (Girard)
Speckled dace	_Rhinichthys osculus klamathensis_
Brown bullhead	_Ictalurus nebulosis_ (LeSueur)
Cottids	_Cottus_ sp.
Lamprey	_Lampetra tridentata_ (Gairdner)

The major physical obstacle to downstream passage of migrant fishes is the unscreened submerged penstock orifices at the dam.

If fish passage facilities and screening were provided, water quality is adequate for the movement and rearing of salmonoids except during July and August, when temperatures and dissolved oxygen limit the habitable area of the reservoir to the 10-20 foot stratum.

Jenny Creek, Mile Point 196.0

Jenny Creek, a small tributary of Iron Gate Reservoir, enters near the upper end. Because of limited spawning areas and blockage of fish passage by two falls, 20 feet and 60 feet high, this stream was deleted from study.

Copco No. 2 Dam, Mile Point 200.3

Copco No. 2 is a 43-foot high diversion dam on Klamath River and is one mile upstream from Iron Gate Reservoir and approximately 1,000 feet downstream from Copco No. 1. No fish passage facilities or screens are present at the structure.

No water quality data are available for the section of river between Copco No. 2 and Copco No. 1, but water temperatures and dissolved oxygen should be favorable since the water is taken from the deep portion of Copco No. 1 reservoir.

Copco No. 1 Reservoir, Mile Point 200.3 - 205.8

Copco Dam No. 1 was completed to a height of 126 feet in 1922. No fish passage facilities or screens are present at the structure. The reservoir formed by the dam is five miles long and 126 feet at its deepest point. The forebay elevation of Copco No. 1 fluctuates up to six feet.

Daily water temperatures were taken at the forebay of the dam by hand thermometer between 8:00 a.m. and 9:00 a.m. Highest temperatures were recorded during the last three weeks of July and the weekly means were 69° F. The range of mean temperatures for the months of May through October was from 54° to 69° F. These data for Copco No. 1 are presented in Figure 6 (page 133).

Dissolved oxygen and water temperatures were obtained at two stations on Copco No. 1. Reservoir, one near the dam in deep water and the other in shallow water at the upper end. The minimum and maximum amount of dissolved oxygen in the waters of the reservoir for the months of June through October varied. The minimums at the deep station ranged from 0.00 ppm to 1.1 ppm, while at the upper end they were from 2.2 ppm to 6.0 ppm, Figures 8A and 8B (Pages 136-37.) The maximums at the sampling stations were from 6.1 ppm to 9.4 ppm near the dam, and 7.4 ppm to 9.1 ppm at the upper end. Although oxygen content is high in the upper portion of the reservoir, only the stratum between 10-20 feet was habitable for salmonoids as water temperatures from the surface to 10 feet were too high during July and August.

Water quality in Copco No. 1 reservoir was satisfactory for the rearing of juvenile salmonoids except for two months of the year, July and August. During these months conditions were found to be good only in the stratum between 10-20 feet.

Many species of fish are residents in this reservoir and a problem of predation may occur. The types of fish present are the same as those found in Iron Gate Reservoir with the addition of:

Shortnose sucker -- Chasmistes brevirostis Cope

Lost River sucker -- Catostomus luxatus Cope

If fish passage facilities and screening were provided, water quality is adequate for the movement and rearing of salmonoids except during July and August when temperatures and dissolved oxygen limit the habitable area of the reservoir to the 10-20 foot stratum.

Shovel Creek, Mile Point 208.0

The following appraisal of Shovel Creek is based on a stream survey report made by California Department of Fish and Game.

Shovel Creek is a small tributary that enters the Klamath River approximately one mile above Beswick. Flows during the summer months are diverted for irrigation. Residual flows of 2.8 cfs in 1961 and 4.2 cfs in 1962 were recorded. Temperatures from over 70° F to freezing have been recorded. A falls, 2.5 miles upstream, blocks all migration of fish.

High water in December 1964 altered the stream bed and banks of Shovel Creek. The first mile of stream was channeled. Though the bed of the channel is of excellent gravel, this work may have been detrimental because of the loss of shelter and pools.

Low winter temperatures, fall flows, and susceptibility to flooding appear to make Shovel Creek unacceptable for fall spawning fish such as chinook salmon. It may better lend itself to spring spawning steelhead if competition from native trout is not excessive.

Spring flows and water quality in Shovel Creek are probably adequate to maintain a run of downstream migrants over the short distance to Klamath River.

There are two unscreened diversion ditches which would need facilities before introduction of anadromous fishes could be considered.

Klamath River from Copco Reservoir to J. C. Boyle Dam, Mile Point 205.8 - 227.5

Klamath River from the head of Copco Reservoir upstream to J. C. Boyle Dam is a distance of approximately 22 miles, and at the present time, no barriers are present to block fish passage. It is a fast-moving stream and the gradient is steep, rising from an elevation of 2608 at the head of the reservoir to 3793 at J. C. Boyle Dam.

Daily river flows fluctuated considerably in the lower 17 miles as the result of operations of the J. C. Boyle project. The Federal Power Commission license for the project stipulates that the powerhouse operations cannot vary the river flow by more than nine inches an hour (Table 9). Mean monthly flows for a period from 1959-1965 were obtained from the Surface Water Division of the U. S. Geological Survey and are presented in Figure 9 (Page 138). The data were gathered at a station established in 1959 approximately one mile downstream from the J. C. Boyle powerhouse. The major peak flows occur during the months of December and April and vary from 1900 cfs in 1959 to a high 8,730 in February, 1965. The lowest flows recorded are during the months of July and ranged from 340 cfs in 1965 to 950 cfs in 1959.

River conditions above J. C. Boyle powerhouse have been changed considerably by the power project and at the dam the flow is maintained at a constant 100 cfs. Eight-tenths of a mile downstream from this point a series of springs enter the river which increase the flow to 390-488 cfs in the remaining four-mile section to the powerhouse. Flows in this reach of the river remain constant except at times of high flow from Klamath Lake which require the release of excess water through the spillway

Table 9. Maximum and minimum flows, as specified by Hydroelectric Commission of of Oregon and Federal Power Commission permits.

Plant or Area	Hydroelectric Commission of Oregon	Federal Power Commission
	J. C. Boyle (Formerly Big Bend)	
J. C. Boyle - immediately below diversion dam in old channel.	Minimum release for 1st year - 100 c.f.s. a. Hearing each year for 5 years. b. Not less than 50 c.f.s. and not more than 150 c.f.s. for duration of license. Note: Large spring inflows commence adding to flow 1/4 mile below diversion dam and totaling up to 250 c.f.s.	Construct, operate and maintain fishways at diversion dam and screens at intake to conduit. Licensee shall maintain for fish life in natural channel below dam reasonable minimum flow consistent with primary purpose of project after a hearing.
J. C. Boyle - immediately below Big Bend Power House	Maintain 200 c.f.s. immediately below Power House. Plant operated not to exceed fluctuations of 9"/hr. measured at a point 1/2 mile below Power House.	
	Iron Gate	
	State of California	
Iron Gate	Minimum flows below Iron Gate September 1 to April 30 -- 1,300 c.f.s. May 1 to May 31 -- 1,000 c.f.s. June 1 to July 31 -- 710 c.f.s. August 1 to August 31 -- 1,000 c.f.s. Rate of change not to exceed 250 c.f.s./hr. or not more than 3"/hr. (whichever produces the least amount of fluctuation) measured at a gauge 1/2 mile below the plant.	

at J. C. Boyle Dam.

Water temperatures were obtained by a constant recording thermograph at Beswick, approximately two miles above Copco Reservoir and by hand thermometer at four stations upstream. Dissolved oxygen analyses were made at the upper four stations. These data are presented in Figure 10, (Page 139) and Figures 11A and 11B (Pages 140 and 141). Dissolved oxygen samples have been taken at the Beswick Station in the past by the California Department of Water Resources and their data indicates that in the summer months, dissolved oxygen content in this area is high and in 17 samples taken in 1962-1965, the mean was 9.5 ppm and the range was from 8.4 ppm to 10.5 ppm. Maximum water temperatures from May through October varied from a low of 58° F to a high of 73° F and in the months of July and August, remained above 68° F.

Temperatures and dissolved oxygen samples taken in Klamath River at the Frain Ranch and below the J. C. Boyle Powerhouse show that high water temperatures occur in the months of July and August and that high dissolved oxygen concentrations are present throughout the sampling period of May through October. The presence of an excellent trout fishery in this area indicates that although water temperatures are high, salmonids remain in the area and flourish. Samples obtained above the powerhouse reflect the large flow of spring water into the river and low water temperatures and high dissolved oxygen concentrations were recorded. At the upper station below the dam, water temperatures show the effect of the reservoir and an increase in temperature is recorded. Studies made

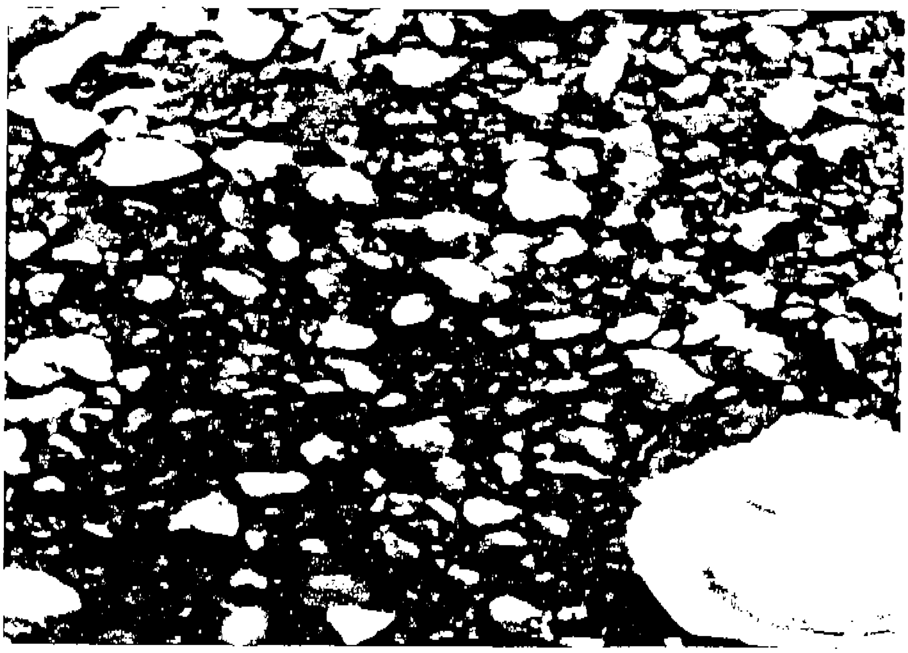

Plate 1. Gravel exposed at minimum flow on Klamath River at the Frain Ranch area, June 28, 1965.

Plate 2. A gravel bar exposed at minimum flow on Klamath River at Frain Ranch area, June 28, 1965

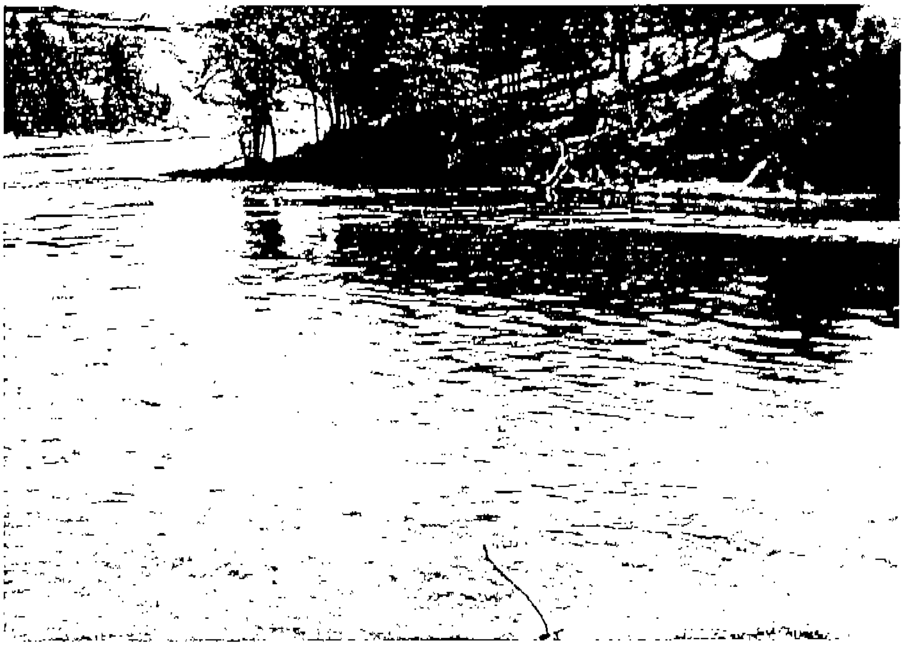

Plate 3. Sampling station at gravel area on Klamath River Frain Ranch area, September 16, 1965

in 1962-1963 did not reveal any problem in this area, provided flows of 100 cfs or higher were maintained (Gerlach and Hanel, 1963).

Potential spawning areas on Klamath River are confined to one short section near the Frain Ranch, just above the Salt Caves Dam site, and spots between the California-Oregon border and Copco Reservoir.

Approximately 13,400 square yards of gravel was observed in the Frain Ranch area. Most of this gravel is of fair to good quality from 1 to 4 or 1 to 6 inches in diameter. There are some fines interspersed and partial weed growth over the surface, but chinook salmon are known to use areas similar in appearance in the lower river (Plate 1 and 2).

At least 950 square yards of good gravel are located between the state line and the mouth of Shovel Creek. Below the mouth of Shovel Creek to Copco Reservoir there is a minimum of 19,000 square yards of good gravel with other possibilities in deeper water.

Flows on this section of Klamath River are normally adequate, but are subject to fluctuation because of power production operations at the J. C. Boyle project. At extreme low flows, a portion of the gravel areas is exposed. Conditions were checked weekly on a gravel bar in the Frain Ranch area. The observations made are shown in Table 10. Plate 3 is a picture of this station. During the period of September 9 through December 14, 1965, encompassing the historical spawning period, the depth of water over the gravel varied 1.5 feet to about 3.5 feet. The latter

Table 10. Water quality and flow measurements on a potential spawning area of Klamath River near the Frain Ranch for the period of September 9 to December 14, 1965.

Date	Time	Air Temp.	Water Temp.	D.O. PPM	Flow CFS	Velocity FPS(a)	Turbidity	Remarks
9- 9-65	1330		64	8.4		3.0		18" of water over gravel
9-16-65	1110	59	61	8.25		3.6		19" of water over gravel
9-24-65	1120	80	62	9.0		3.3		18" of water over gravel
9-30-65	1155	75	57	8.7		3.3		19" of water over gravel
10-15-65	1050	45	57	9.7		4.0		22" of water over gravel
10-22-65	1300	70	54	9.3		2.9	1' vis.	1.8" water depth
10-28-65	1300	73	55	9.3		1.75	1.5' vis.	1.9" water depth
11- 8-65	1415		50	8.8				About 3' deep, water depth prevented velocity measurements
11-16-65	1330	60	46	9.6			1' vis.	Water depth 3-3.5'
11-29-65	1245	45	38	11.3			1' vis.	Water depth 3-3.5'
12- 7-65	1245	46	38	10.9		2.23	1' vis.	Water depth 2.0'
12-14-65	1130	35	36	10.9		2.03	1' vis.	Water depth 1.9'

(a) Measurements prior to October 22 made on surface by "cork method", others at 0.3 feet with Gurley meter.

depth occurred when water was being spilled from J. C. Boyle Dam in November. The water velocity, 0.3 feet over the gravel, fell within a range of 1.72 to 2.9 fps. The mean water temperature during the period was 51.5° F within extremes of 36° and 64° F. The temperature held up well for spawning until late November when it fell to 38° F. The lowest concentration of dissolved oxygen observed was 8.25 ppm, averaging 9.5 ppm.

All conditions appeared to be adequate for spawning and rearing of eggs with the possible exception of flow fluctuations. Flow changes at the J. C. Boyle project are limited to 9 inches in river elevation per hour. However, it has been reported by personnel of California Department of Fish and Game that the rate of change is considerably greater in the down-river areas.

Although mid-summer temperatures reach into the 70's, Klamath River probably would provide a good rearing area for young fish. A fine trout population in the river is evidence of its productiveness.

The only limiting factor for downstream migration is the presence of eight unscreened irrigation diversion ditches. One ditch has a screen installation but is inoperative.

No physical barriers or poor water quality conditions exist to hinder the migration, spawning or rearing of salmonids in this section of Klamath River. The maximum potential numbers of fish calculated to use this area was 1,990 female chinook salmon or 1,620 female steelhead. Of this total, 640 female chinook salmon or 520 female steelhead would utilize gravel found in Oregon. Stream temperatures limit the chinook spawning period to October and early November.

J. C. Boyle Dam and Reservoir, Mile Point 227.5 - 229.8

J. C. Boyle Dam was completed in 1958 and is approximately 38 feet high and forms a reservoir three miles long. The maximum depth is 40 feet. A fish ladder sufficient to pass steelhead and salmon is in operation on the structure. Water temperatures and dissolved oxygen were taken at the top and bottom steps of the ladder and are presented in Figure 12 (Page 141).

Water temperatures were taken by hand thermometer at the forebay of the dam and the weekly means are presented in Figure 6 (Page 133). The range of temperatures varied from a high of 74° F in July to a low of 54° in October. As at the other reservoirs, these temperatures were taken between 8:00 a.m. and 9:00 a.m.

Dissolved oxygen samples and water temperatures were obtained from five stations on J. C. Boyle Reservoir during May through August and the profiles calculated are depicted in Figures 13 and 14 (Pages142-43) The data indicates that during June and July the reservoir is not suitable for salmonids.

On September 1-2, an all-night sampling program for dissolved oxygen and water temperatures was conducted on the reservoir at five stations and the results are shown in Figures 15, 16 and 17 (Pages 144-5). Data from three of the stations, all in the shallow sections of the reservoir, show little variation in the dissolved oxygen content. The two stations at the deep end of the reservoir show definite oxygen sags caused by large amounts of decaying organic matter.

Water quality conditions for rearing and migration of juveniles are acceptable except during the months of June, July and the first part of August. The diversion for turbine water is screened and fitted with a bypass pipe. Predation may occur on the young fish as the following species are present in the reservoir:

Rainbow trout -- Salmo gairdneri Richardson

Largemouth Bass -- Micropterus salmoides (Lacepede)

Black crappie -- Pomoxis nigromaculatus (LeSueur)

Bluegill -- Lepomis macrochirus Rafinesque

Pumpkinseed -- Lepomis gibbosus (Linnaeus)

Brown bullhead -- Ictalurus nebulosus (LeSueur)

Klamath Largescale sucker — Catostomus snyderi Gilbert

Klamath Smallscale sucker — Catostomus rimiculus Jordan and Snyder

Lost River sucker -- Catostomus luxatus Cope

Tui chub -- Siphateles bicolor bicolor (Girard)

Blue chub -- Gila bicolor (Girard)

Speckled dace -- Rhinichthys osculus klamathensis

Cottids -- Cottus sp.

Lamprey -- Lampetra tridentata (Gairdner)

Spencer Creek, Mile Point 229.5

Spencer Creek, an important tributary of Klamath River, enters the system at the upper end of J. C. Boyle Reservoir. The stream is

Plate 4. Section of Spencer Creek near the mouth, December 14, 1965

Plate 5. Section of Spencer Creek near mile 3.0, May 24, 1965

Plate 6. Section of Spencer Creek upstream from road crossing near mile 7.25, September 16, 1965

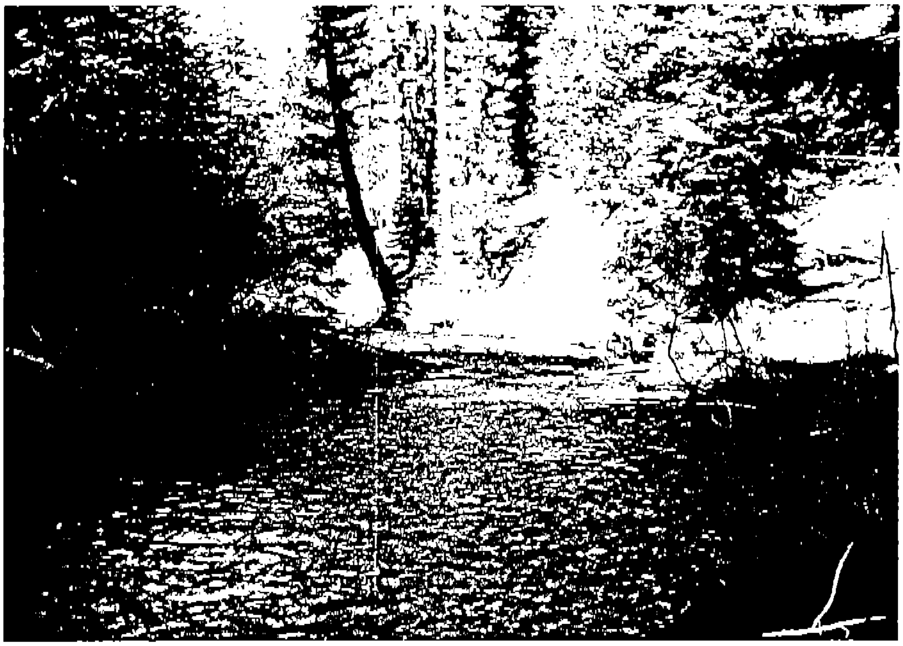

Plate 7. Spencer Creek sampling station near mile 7.25, September 16, 1965

approximately 12 miles long. The flows measured during the low periods in the fall varied from 16.7 cfs to 23.4 cfs. The mean for the period was 20.7 cfs.

Barriers to fish passage consist of seven small log jams, a number of beaver dams and a large culvert that had been passable until the flood in December 1964 washed a deep hole on the downstream side.

Dissolved oxygen samples and water temperatures taken from June through October reveal that water conditions are excellent for salmonoids. Data collected are illustrated in Figure 18 (Page 146).

Nine miles upstream from the mouth, fish passage is blocked by a series of small falls. It would be possible to make them passable, but the stream above is marginal and would not be worth the expense.

Gravel areas in Spencer Creek are found from the mouth upstream for about 9 miles, Plates 4-6. There are 2300 square yards of good and about 300 square yards of marginal gravel suitable for spawning salmon and steelhead.

The water depth over many of the gravel areas is 4 to 6 inches. Velocities are one foot per second or greater. Stream flows were taken weekly from September 9 to December 14, 1965, at a station at mile 7.25. This station is pictured in Plate 7. For the sampling period, the mean stream flow was 20.71 cfs, ranging from 16.69 to 23.39 cfs. The average water temperature was 41.8° F, with extremes of 31 and 52° F. During the same period, the lowest dissolved oxygen concentration recorded was 9.0 ppm; the high was 12.0 ppm. The mean oxygen level was 10.38 ppm for the sampling period. All observations are given in Table 11.

Table 11. Water quality and flow measurements on potential spawning area of Spencer Creek at Mile 7.25 for the period of September 9 to December 14, 1965.

Date	Time	Air Temp.	Water Temp.	D.O. PPM	Flow (a) CFS	Mean Velocity FPS	Turbidity	Remarks
9- 9-65	1530		52.0	9.00	22.0	2.5	Clear	
9-16-65	1245	48	48.5	9.35	17.71	1.97	Clear	
9-24-65	1245	82	51.0	9.30	18.05	2.0	Clear	
9-30-65	1320	67	46.0	10.00	19.22	2.13	Clear	
10-15-65	1215	41	42.0	10.30	16.96	1.88	Slight	
10-22-65	1450	63	42.0	10.60	22.54	1.99	Clear	
10-28-65	1420	60	44.0	9.90	23.39	1.94	Clear	
11- 8-65	1600	42	41.0	10.60	21.61	1.92	Clear	
11-16-65	1500	47	40.0	10.20	21.97	2.03	Clear	
11-23-65	1515	38	38.0	10.80	23.19	2.09	Slight	
11-30-65	1400	33	34.0	11.20			Clear	Ice along shores. Flow appeared to be down slightly.
12- 7-65	1430	34	34.0	11.70	21.23	1.92	Clear	Ice along shores.
12-14-65	0945	24	31.0	12.00			Clear	No significant change in flow. Ice along shores and over pools. Anchor ice beginning to form.

(a) Estimates prior to October 22 made by "cork method", others with Gurley meter.

Plate 8. Minor ice conditions at Spencer Creek sampling station, November 30, 1965

Plate 9. Anchor ice forming in Spencer Creek near the mouth, December 14, 1965

Plate 10. Anchor ice forming over gravel in Spencer Creek near mile 7.25, December 14, 1965

Beginning in the last of November when water temperatures dropped to 33° F, ice formed along the shore line of Spencer Creek, Plate 8. On December 14, anchor ice was forming in the entire length of the stream, Plates 9 and 10. Water temperature on that day was 31° F. Since that was the last day observations were made, it is not known how long such conditions existed.

There is no reason to believe that Spencer Creek would not provide a good rearing area. The stream has a history of a good trout population. It also supports a spawning run of suckers. The highest temperature observed during the summer was 68° F near the mouth. Oxygen levels were in excess of 7.0 ppm the entire year, Figure 18 (Page146).

Spencer Creek presents a fine environment for salmonoids. The stream could accommodate an estimated 110 chinook redds or 90 steelhead redds. The relatively shallow water depth may reduce the capacity for chinook salmon. The spawning period for salmon would be limited to the month of September by water temperature.

Klamath River to Old Needle Dam at Keno, Mile Point 229.8 - 236.3

Klamath River in this section is wide, with a steep gradient. The distance covered in this reach of river is approximately 6.5 miles. No barriers are present at this time, but in March, 1966, Pacific Power & Light Company will begin construction of a dam to replace the one built in 1931 at Keno. A fish ladder is included in the plans.

No water quality data is available for this part of the river, but an excellent trout fishery is present and is indicative that conditions are suitable for salmonoids.

Figure 19 (Page 147) presents the monthly mean stream flow conditions from 1951-1965 and compares them with data taken from 1904-1914. In seven of the ten years that data are available for both periods, the peak flows in 1951-1965 exceed the peaks in 1904-1914. The lowest recorded flow for the two sets of data occurred in July 1964 with a mean low of 365 cfs. The highest was recorded in December 1964 and was 8,780 cfs.

No significant amount of spawning gravel was observed in this area of the river.

This section of the river contains no known barriers to downstream migrants, provided that adequate flows as determined by future studies are maintained below the new structure.

This segment is suitable for migration and rearing.

Klamath River from Keno to Klamath Falls, Mile Point 236.3 - 254.3

Klamath River from Keno to Klamath Falls is a wide, slow-moving stream that has a drop of one foot in the 18 miles of water course. No barriers other than the Old Needle Dam at Keno are present in the river. This barrier will be removed after completion of the new dam in 1966. The level of the river is maintained at a prescribed height throughout the summer months so that ranches along the way may be irrigated.

Water quality conditions are poor during the summer months because of high temperatures, tremendous algae blooms, industrial pollution and the slow rate of flow. These factors cause the level of dissolved oxygen to drop below the minimum productive level of 5.0 ppm for salmonoids. Figure 20 (Page 148) graphically presents the results of weekly sampling of the river at two stations for the months of

August through November. Figures 21-31 (Pages 149-159
gathered by the Oregon State Sanitary Authority for the years 1953-1963. An all-night sampling program was conducted on September 1-2, 1965, at three stations on Klamath River from the Main Street Bridge at Klamath Falls downstream to Keno. A low of 2.5 ppm of oxygen was recorded at 0400 a.m. at the Highway 97 Bridge. Lows at the other two stations were 6.5 ppm at Link River and 5.5 ppm at Keno, and occurred at 0715 hours and 0815 hours respectively. The results of the analyses are presented in Figure 32 (Page 160).

Daily water temperatures were taken by hand thermometer at Keno and the weekly means are presented in Figure 6 (Page 133). Temperatures over 70° F occurred in only one week for the months checked.

Stream flow in this section is generally equal to that of Link River, but is subject to inflows from the Lost River Diversion Canal and "F" Canal from Lower Klamath Lake. Samples taken by the Federal Water Pollution Control Administration in 1965 show adequate temperatures and dissolved oxygen concentrations in water from these drains.

Results of water quality samples taken from 1953-1965 show that dissolved oxygen concentrations in the reach of the river are usually below the minimum of 5.0 ppm during the months of July through October. During the remaining part of the year, water quality is suitable for salmonids.

<u>Link River</u>

Link River is approximately one mile long and connects Klamath Lake with Lake Ewauna and Klamath River. One barrier, Link River Dam, constructed in 1921, is present but does not form a block to fish passage, as a ladder is present. This ladder is not adequate at present for the passage of salmon but could be, with minor revisions.

A continuous recording thermometer was installed on the river in the fall of 1964 and Figure 33 (Page 161) presents the weekly maximum and minimum temperatures. From June through August, maximum temperatures were at 70° F or higher and the peak was 76° F. During the same period, minimum temperatures exceeded 70° F in three different weeks. Temperatures started to decline rapidly in September and by the end of the month, were in the low sixties.

Stream flow data from 1904-1917 are compared with that recorded in 1951-1965 and are presented in Figure 34 (Page162). Flow conditions were approximately the same in 1951-1959 as found in the years 1904-1912, but since then, the flows have leveled off because of drought conditions. The lowest flow recorded, 400 cfs, occurred three times, once in March 1962 and twice in May-June 1964.

No appreciable amount of spawning gravel was found in Link River.

There are three large water diversions at the outlet of Klamath Lake, all of them are unscreened. The "A" canal diversion to the Bureau of Reclamation's Klamath Project has a maximum flow of 1200 cfs and begins drawing water in April. On each side of Link River, there are intakes for power production at Pacific Power & Light Company's Eastside and Westside plants. All three diversions would have to be screened to guarantee safe downstream passage. The present fish ladder and spillway would provide paths of egress over the dam.

If necessary fish passage facilities were provided, migration through Link River should be possible throughout the year.

Upper Klamath Lake

Upper Klamath Lake is composed of two lakes: Klamath Lake and Agency Lake. The two bodies of water are connected by a mile-long waterway called "The Straits." The combined surface acreage at peak level is approximately 94,000 acres. Overall average depth is 8 feet, with maximums of 56 feet in Klamath and 14 feet in Agency. No physical barriers exist on the lake.

Water quality is varied throughout both lakes because of springs and algae conditions. Time did not permit an extensive study. An excellent trout fishery is present in both lakes and is indicative that water quality conditions are adequate.

Lake levels are fluctuated annually for irrigation and power generation. The maximum drop that has been recorded was three feet.

Klamath and Agency Lakes might possibly be deterrents to successful out-migration on the basis of size alone. The distance from the mouth of Wood River to the outlet at Link River is approximately 28 miles via Agency and Klamath Lakes. It is 18 miles from the mouth of Williamson River to the outlet of Klamath Lake. The flow pattern in the lakes is unknown and may be barely perceptible. The combination of distance, stationary water and the attractiveness of a productive environment may cause sufficient delay for the migrants to become residual. The effect of this on production and survival is unknown.

Survival in the lake may be reduced by predation. The fish fauna of Upper Klamath Lake is similar to that of J. C. Boyle Reservoir except largemouth bass, crappies and bluegills have not been found. Fishes found in Upper Klamath Lake that have not been recorded from Klamath River are:

Brown Trout --	Salmo trutta (Linnaeus)
Brook trout --	Salvelinus fontinalis (Mitchell)
White Sturgeon --	Acipenser transmontanus (Richardson)

Salmon were reported to have spawned in several large springs on the west side of Klamath Lake, but pumice sand presently obliterates all gravel suitable for spawning.

West Side Tributaries

West side tributaries of Upper Klamath Lake consist of a number of small streams of which Cherry Creek, Three-mile Creek and Nannie Creek are the largest. Flows of these are intermittent in the fall and therefore they are not considered as potential spawning streams.

Fourmile Creek and Crane Creek

Fourmile Creek and Crane Creek are tributaries of Agency Lake, but are small with no suitable gravel present.

Sevenmile Creek, Mile Point 0.00 - 19.00

Sevenmile Creek, a tributary of Agency Lake, is 19 miles long and originates in the Sevenmile Marsh. Water quality data taken and presented in Figure 35 (Page 163) reveal that stream conditions are good. Upstream from mile point 14.25 to 16.75, there are approximately 1700 square yards of good spawning gravel, but in this section there are nine impassable log jams. Below Mile Point 14.25, there are several beaver dams, one impassable log jam, three unscreened water diversions and numerous drains hindering the migration of fish.

Because of the many obstacles, Sevenmile Creek was considered marginal as a potential spawning stream.

Wood River, Mile Point 0.00 - 18.25

Wood River, a tributary to Agency Lake, originates in springs, and has a major tributary, Annie Creek, draining from Crater Lake National Park.

Two barriers are present but are passable to fish except during the irrigation season of June through August. There are four diversion ditches on the stream. Two have rotary screen installations that are not presently in use. The other canals are not fitted with screen facilities.

Though considerable water is diverted for irrigation, a generous flow is maintained throughout the year. The river contains about 11,000 square yards of good, and 1,300 square yards of marginal gravel, all in the upper half of its 18.25-mile length. Water depths and velocities over gravel bars are excellent for either salmon or steelhead. Water temperatures remain quite cool all year. The highest temperature recorded between March and October 1965 was 52° F; the lowest was 38° F. Dissolved oxygen concentrations remained between 9.0 and 11.0 ppm the entire period, Figure 36 (Page 163).

Wood River has good habitat for rearing young fish, but the temperature regime and the relatively low productivity may not produce growth comparable to other streams in the basin. The river supports a resident population and a spawning run of trout which live most of the year in Agency or Klamath Lake.

This stream has good potential for fish which would spawn before mid-September or after mid-April, provided that necessary fish-passage facilities were available. The areas of good gravel in Wood River could accommodate about 520 chinook or 420 steelhead redds.

Williamson River, Mile Point 0.00 - 21.00

Williamson River is the major tributary to Klamath Lake and includes both the Williamson and Sprague River drainages. The major portion of the river flow during the summer months comes from Spring Creek and Sprague River, as the Williamson River goes dry approximately 25 miles upstream from the mouth. A series of falls, at Mile Point 21.00, form a barrier to fish passage.

Water quality studies were made below the falls and downstream to the mouth and are presented in Figure 37 (Page 164). The most important stations are those below the confluence with the Sprague River. At both sites dissolved oxygen content and water temperatures were ideal for salmonids.

A continuous temperature recorder was installed at the Highway 97 bridge-crossing of the Williamson River seven miles upriver from Upper Klamath Lake. The mean weekly maximum and minimum temperatures are illustrated in Figure 38 (Page 165). The highest reading, 67° F, occurred once each in June and July.

Plate 11. Gravel bar on Williamson River below Highway 97 crossing, October 4, 1965

Plate 12. Exposed gravel adjacent to potential spawning area on Williamson River below Highway 97 crossing, October 4, 1965

Mean monthly flows were recorded downstream from the confluence of the Sprague River; data from 1951 - 1965 are presented in Figure 39 (Page 166). Since 1959, flows have been low with August and September monthly means near 500 cfs.

Most of Williamson River below the confluence of Sprague River, is deep and slow-moving. The major position of the gravel is in riffles scattered along the stream. Above Sprague River, the stream bed consists mainly of bedrock, sand, pea gravel, and rubble. There is an estimated 5,200 square yards of good, usable gravel qualifying for use by salmon or steelhead. Most of this gravel lies in a large bar below the Highway 97 crossing, Plates 11 and 12.

Thermograph records for 1965, taken at the site of the largest gravel bar, show that water temperatures below 40° F prevailed through mid-February and after mid-November. Low temperatures of 32° F were recorded during those periods, Figure 38 (Page 165).

Trout of fry and fingerling size were seen in Williamson River, so it would probably provide an adequate rearing area for young salmon or steelhead.

There are no obstructions or diversions which would endanger downstream migrants. The level of Klamath Lake influences the rate of flow in the lower end of Williamson River. This condition may tend to slow the rate of travel of the departing fish.

Williamson River has a potential for approximately 240 chinook or 200 steelhead redds. The only qualification is that salmon must have completed spawning by the last week of October.

Spring Creek

Spring Creek, a spring-fed tributary of the Williamson River, is 2.5 miles long. Dissolved oxygen and water temperatures are excellent, but the bottom of the stream, except for the first 100 yards, is composed of pumice sand or bed rock. The stream was not considered because of the lack of spawning gravel.

Sprague River to Lone Pine, Mile Point 0.00 - 31.00

The Sprague River from its confluence with the Williamson River to Lone Pine, a distance of 31 miles, has a gentle gradient. The only barrier in this section is the Sprague River Dam, located approximately one mile upstream from the mouth. This structure is owned by the Bureau of Indian Affairs and is used by the Modoc Irrigation District to divert water into its distribution system. The fish ladders on the dam are impassable.

Dissolved oxygen was sampled at two stations, one located at the downstream end at the U.S.G.S. flow gauge and the other at the Lone Pine Bridge. Oxygen levels remained above 7.0 ppm throughout the sampling months of March through November, Figure 40 (Page 167).

The maximum and minimum water temperatures occurring each week in the Sprague River were obtained from temperature charts of a thermograph installed at the U.S.G.S. flow station above Chiloquin. The data are for a period from February through November and are graphed in Figure 41 (Page168). High temperatures, above 70° F, were recorded from the second week of June through the last week of August.

Monthly mean flows in the Sprague River near Chiloquin for the years 1951 - 1965 are presented in Figure 42 (Page169). The minimum flows for those years occurred in August and varied from 200 to 300 cfs. This chart depicts the same drought conditions from 1959 to present times, as have the other flow charts.

All of the gravel found in this section of Sprague River was classified as marginal. Between mile 2.0 and 6.0, there is about 7,500 square yards of 1-6 inch diameter gravel mostly compacted with sand and silt and an algae growth over the surface. The remainder of the section contains 600 square yards of gravel less than two inches in diameter.

Rearing conditions in this reach of the river are fair to good, although water temperatures exceed 70° F during the summer months. A good trout population is present in this section of the river.

The only barrier to downstream migration is one unscreened diversion at the Sprague River Dam.

Water quality conditions are adequate for the rearing and migration of salmon and steelhead. Spawning potential for this section of the river is limited because all gravel is of marginal quality.

Sprague River from Lone Pine to the Forks,
Mile Point 31.00 - 79.00

This section of the Sprague River, 48 miles long, is very crooked. Gradient is gentle and no barriers are present.

Two dissolved oxygen sampling stations, one at the Sprague River Bridge at the town of Sprague River and the other at the Piaute Crossing, U.S.G.S. Flow Station near Beatty, were visited from March through October. The results are shown in Figure 40 (Page 167). The lowest dissolved oxygen concentration determined at the two sites was 6.6 ppm.

A thermograph was installed at the U.S.G.S. Flow Station, above Beatty, and the maximum and minimum temperatures occurring each week from February into December are shown in Figure 43 (Page170). Maximum temperatures exceeding 68° F were recorded in six weeks of July and August. It is believed that the minimum temperatures at this station are tempered by warm springs located somewhere in the first 3.5 miles upstream.

Monthly mean flows obtained from data recorded at the Piaute Crossing flow gauge demonstrated the same patterns as those from other stations in the system, Figure 44 (Page171). Records for the years 1914-1918 are compared with those from 1954 through 1965. Maximum flows for the early years ranged from 340-890 cfs, while those in recent years were from 290-5,670 cfs. The minimum ranges for the same periods were 110-140 cfs and 97-200 cfs, respectively.

This section contains 2,500 square yards of marginal gravel less than two inches in diameter.

As a rearing area for young salmonids, Sprague River may be somewhat marginal in the warmest months of summer. The section of river between Beatty (mile 67.0) and Lone Pine (mile 31.0) is practically all slow, meandering, silt-bottomed, with little or no cover. There are no thermograph records for that stretch of the river. The highest temperatures recorded from weekly samples, Figure 40 (Page167), taken between 1100-1200 hours was 72° F at Sprague River bridge and 74° F at Lone Pine. The lowest dissolved oxygen concentration observed was 6.6 ppm. Oxygen levels fell below 7.0 ppm in five samples, once in April and June, and three times in July. Considering the characteristics of this section, there is probably a rather large daily fluctuation in temperature and oxygen concentration. There is no history of a significant resident trout population in this area.

No problems exist for downstream migration, as no barriers are present.

This portion of the river poses no problems for the migration of salmon and steelhead, but is of little value for spawning and rearing.

South Fork of Sprague River, Mile Point 0.00 - 31.25

The first ten miles of the stream is in poor condition, as it is used extensively for irrigation and eight dams form impassable barriers. Above this section of stream, conditions improve and only one jam at mile point 11.25 may block migration.

Water temperatures and dissolved oxygen samples were taken at two stations on the South Fork. The highest water temperature, 81.5° F, was taken during the month of July at Ivory Pine Crossing, the lower sampling station. Temperatures for July and three weeks of August exceeded 70° F. Dissolved oxygen concentrations at the lower site remained above seven ppm. Conditions in the month of September improved when water temperatures ranged from 53° F - 66° F. See Figure 45 (Page172).

Water temperatures at the upper station at the South Fork Campground presented an improved picture. Temperatures were much lower and 70° F was exceeded only once during the sampling series.

Stream flows in the South Fork of the Sprague River at the

Plate 13. Typical section of South Fork of Sprague River near mile 18.0, August 25, 1965.

Plate 14. Gravel adjacent to South Fork Sprague River near mile 18.0, August 25, 1965

Plate 15. South Fork Sprague River sampling station near mile 10.0, September 24, 1965.

Ivory Pine Crossing and upstream to the campground are low. In the irrigation season, June - September, there are times that parts of the stream will be dry because of withdrawals. By the time flows reach the Ivory Pine Crossing, most of the water has been used at least once for irrigation. Flow conditions above the South Fork Campground are improved and no irrigation withdrawals are made.

Potential spawning grounds on South Fork Sprague River all lie in the canyon section of the stream above mile 9.0. From mile 9.0, just below the Sprague Canyon Campground, to the confluence of Brownsworth Creek (mile 13.75), there is an estimated 6,900 square yards of good and 1700 square yards of marginal gravel. Between Brownsworth Creek and the mouth of Whitworth Creek (Mile 20.25), areas of good gravel contain about 12,200 square yards. Plate 13 shows a typical section of this stretch of river. The gravel is mainly 1 to 4 inches in diameter, Plate 14.

From September 17 to December 30, 1965, observations of water quality and flow were made at a station near mile 10.0, Plate 15. The average flow during that time was 20.71 cfs, with extremes of 16.08 and 26.47 cfs, Table 12. On October 18, the flow in the South Fork near mile 18 was estimated to be 10.0 cfs. Though there is gravel present in the lower end of Whitworth Creek and in the South Fork above Whitworth, the water flows are considered inadequate for spawning salmon or steelhead. Water depths and velocities over gravel bars in the river below Brownsworth Creek meet the requirements of both chinook salmon and steelhead, Table 13. Above Brownsworth Creek, velocities are good throughout, but the water is shallower.

Table 12. Water quality and flow measurements on a potential spawning area of South Fork Sprague River at Mile 10, for the period of September 17 to December 30, 1965.

Date	Time	Air Temp.	Water Temp.	D.O. PPM	Flow(a) CFS	Mean Velocity FPS	Turbidity	Remarks
9-17-65	1020	39	41	10.1	16.08	2.18	Slight Color	
9-24-65	1515	74	58	8.6	19.26	2.44	Slight Color	
9-30-65	1015	54	45	10.1	20.02	2.58	Slight Color	
10- 8-65	0935	59	48	9.1	20.80	2.58	Slight Color	
10-16-65	1500	46	42	10.2	23.75	2.60	Slight Color	
10-20-65	1030	46	42		19.30	1.18	Slight Color	
10-29-65	1120	55	42	10.1	17.85	1.14	Slight Color	
11- 5-65	1200	53	42	10.3	18.86	1.13	Slight Color	
11-15-65	1200	52	42	10.4	23.50	1.44	Slight Color	
11-22-65	1450	49	40	10.9	22.29	1.44	Slight Color	
11-29-65	1440	33	33	11.6			Slight Color	Ice covering over pools and slow areas, anchor ice present.
12- 6-65	1300	49	36	10.9	20.36	1.4	Slight Color	No ice
12-13-65	1045	32	32	11.5			Slight Color	Flow about same, maybe down slightly. No ice.
12-30-65	1130	36	34	11.0				Complete ice cover except for small spots over riffle areas, no anchor ice observed in open riffles.

(a) Estimates prior to October 20 made by "cork method", others with Gurley meter.

Plate 16. Ice and snow conditions over South Fork Sprague River, December 30, 1965

Plate 17. Ice conditions at sampling station near mile 10.0 of South Fork Sprague River, December 30, 1965

The average water temperature found at the sampling station was 41.2° F varying from 32 to 58° F, Table 13. In late November, freezing conditions occurred, dropping the water temperature to 33° F and forming ice over pools and slower areas. Anchor ice was also seen in the slower areas at that time. In early December the ice melted, but late in that month there was a complete ice cover except for small openings over the faster riffles, Plate 16 and 17. No anchor ice was seen in the open spots.

Dissolved concentrations of oxygen were never below 8.6 ppm, averaging 10.4 ppm during the months of September through December.

The canyon section of the South Fork would provide a good rearing area for juvenile salmon or steelhead. That section now supports a fine trout population. The valley portion of the South Fork is rendered uninhabitable to salmonoids by high summer temperatures, extensive water diversion, and adverse streambed conditions. Water temperatures as high as 81° F were recorded in 1965, Figure 45 (Page172). At times, the entire flow of the stream is diverted for irrigation. Much of the stream has been channeled and diked, leaving a silt or hardpan bottom and hardly any cover.

Successful downstream migration would be threatened by ten irrigation ditches in the lower nine miles of the South Fork. Water diversion through head-gates is also practiced on this section of the river. During periods of heavy water use, portions of the stream in this area will have no flow.

The South Fork of Sprague River above mile 9 has the potential

Table 13. Water depths in inches over gravel bars on South Fork Sprague Upstream from Canyon Campground - November 3, 1965.

	Measurement Number						
Bar No.	1	2	3	4	5	6	Mean
1	5.5	7.0	9.0	9.0	6.0	3.0	6.8
2	7.0	8.0	12.0	15.0	11.0	6.0	10.4
3	4	7	9	9	13	8	9.2
4	9	12	13	8	8	7	9.6
5	6	9	6	6	7	6	6.8
6	7	7	8	10	9	9	8.6
7	8	8	10	10	9	6	8.6
8	5	9	12	12	10	7	10.0
9	4	6	10	12	15	12	11.0
10	7	9	9	8	10	12	9.6
11	7	10	10	12	8	4	8.8
12	5	12	12	11	12	15	12.4
13	5	6	8	9	10	12	9.0
14	5	10	14	17	16	15	14.4

Overall Average Depth: 9.9 inches

to support salmon and steelhead with room for 920 or 750 redds of each species respectively. For greatest survival, spawning would have to be completed by the first week of October.

Several deterents to fish passage would have to be corrected in the lower river before this stream would sustain these anadromous fish. Adequate flows would have to be maintained in order to improve water quality and pass migrating fish. Ladders over dams, screens for ditches and the removal of log jams would be necessary to facilitate safe fish passage.

North Fork of Sprague River, Mile Point 0.00 - 32.00

The North Fork of the Sprague River is 32 miles long, but the section above mile point 27.5 was not considered because of stream size and lack of suitable gravel.

One impassable dam, three feet high, is located at mile point 8.

Dissolved oxygen and water temperatures were taken at three stations on this stream and throughout the study, conditions were satisfactory for upstream passage of salmon and steelhead. Figure 47 (Page 173) presents water quality data for the North Fork.

The North Fork of Sprague River has more potential spawning area than any other stream in the upper basin. The section of river below the North Fork Canyon contains an estimated 23,900 square yards of good quality gravel. Most of the gravel lies in the stream between mile 6.0 and 11.0. Within the canyon, miles 11.0 to 18.75, there are

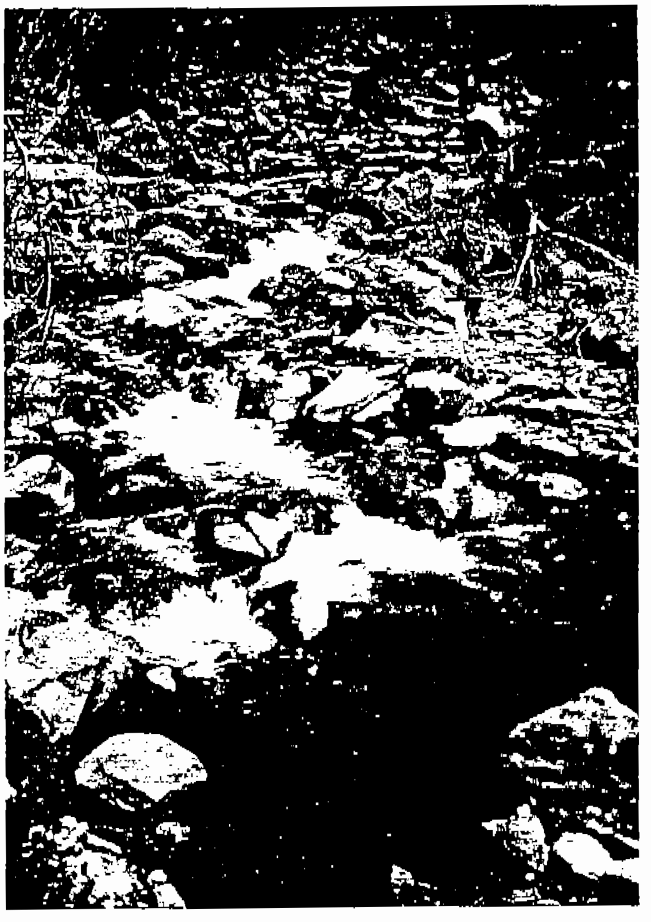

Plate 18. Typical section within the North Fork Sprague River Canyon, July 15, 1965

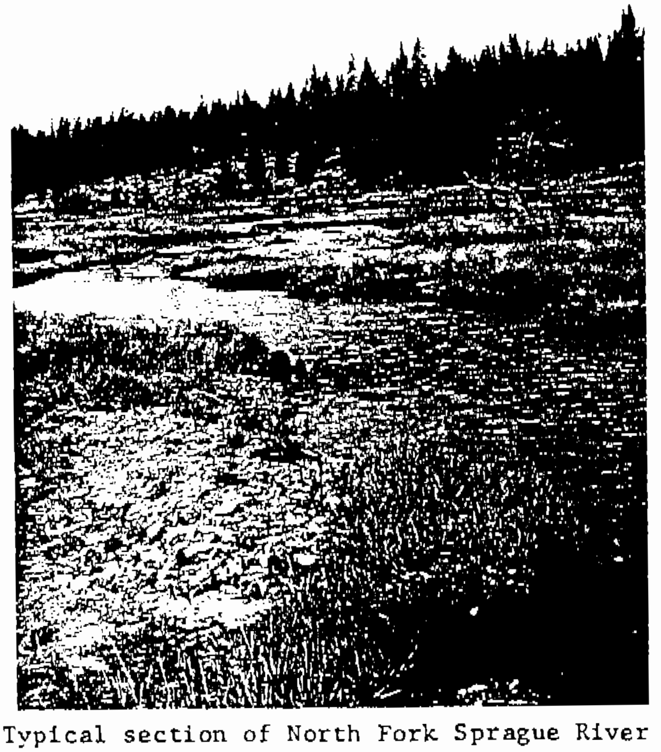

Plate 19. Typical section of North Fork Sprague River above Sandhill Crossing, August 23, 1965

Plate 20. North Fork Sprague River sampling station near mile 10.0, October 29, 1965

Plate 21. Gearheart Creek at Confluence with North Fork Sprague River near mile 20.0, July 14, 1965

Plate 22. Sheep Creek at confluence with North Fork Sprague River near mile 16.75, July 14, 1965

Plate 23. Boulder Creek at confluence with North Fork Sprague River near mile 15.0, July 14, 1965

600 square yards of good gravel scattered in spots among the boulders which create a long series of rapids and pools, Plate 18. Another 6,000 square yards of good and 4,000 square yards of marginal gravel were found above mile 18.75. This section of stream is mainly in meadow land, Plate 19. The gravel classified as marginal is good quality, but composed of stones smaller than two inches in diameter.

Weekly observations of water quality and flow (Table 14) were made from September 10 to November 15, 1965, at a station near mile 10.0, Plate 20. During that period, the stream flow averaged 38.16 cfs, varying from a low of 26.47 to 46.4 cfs. On July 21, 1965, some stream flow estimates were made using the "cork method." At that time, the flow at Sandhill Crossing (mile 22.75), was about 25 cfs; above the North Fork diversion (mile 11.5), 71 cfs; and at Ivory Pine Road (mile 5.0), 46 cfs. A number of springs and small tributaries, Plates 21 - 23, enter the North Fork below Sandhill Crossing, accounting for the increased volume. By October 27, the flow at Sandhill Crossing had decreased to 12.7 cfs.

Water velocities and depths over gravel in the lower river would be excellent for spawning salmon or steelhead. Depth measurements made November 3 on some of the best area revealed an average of 12.5 inches of water over the gravel, Table 15. In the upper river, water depths probably average somewhat shallower, but were considered adequate for spawning salmon and steelhead during the fall of 1965.

Water temperatures at the sampling station and at Ivory Pine Road averaged 42.9° F for the September-December period, Table 14. The

Table 14. Water quality and flow measurements on a potential spawning area of North Fork Sprague River at Mile 10, for the period of September 10 to December 30, 1964 (a).

Date	Time	Air Temp.	Water Temp.	D.O. PPM	Flow (b) CFS	Mean Velocity FPS	Turbidity	Remarks
9-10-65	1440		56	9.1	31.12	1.58	Clear	
9-17	1115	52	40	10.4	26.47	1.38	Clear	
9-24	1415	74	52	9.5	32.17	1.59	Clear	
9-30	1115	65	46	10.1	31.65	1.48	Clear	
10-8	1030	70	46	9.7	36.19	1.65	Clear	
10-16	1400	47	41	10.8	44.53	1.78	Clear	
10-20	1300	61	43		43.50	1.59	Clear	
10-29	1415	72	44	10.0	45.34	1.48	Clear	
11-5	1420	56	42	10.3	44.27	1.33	Clear	
11-15	1330	52	42	10.3	46.40	1.33	Clear	
11-22	1510	45	41	10.4			Clear	Road impassable to Lee Adkins. Sample taken at Ivory Pine Rd
11-29	1510	34	33	11.9			Clear	Ice covering and ancho ice in slow areas.
12-6	1330	54	41	10.8			Clear	No ice.
12-13	1120	36	34	11.4			Clear	No ice.
12-30	1200	36						Complete ice cover.

(a) Samples taken at Ivory Pine Road (Mile 5) beginning November 22.
(b) Estimates prior to October 20 made by "cork method;" others with Gurley meter.

Table 15. Depth of water over gravel and gravel area on North Fork Sprague River between 9.25 and 10.85. Measurements taken in middle of 25 yard sections, November 3, 1965.

Section No.	Water Depth Side I Inches	Water Depth Center Inches	Water Depth Side 2 Inches	Average Water Depth Inches	Stream Width Yards	Gravel Sq. Yards
1	14	14	12	13.3	10.0	250
2	6	14	8	9.3	8.1	202
3	6	12	9	9.0	11.0	275
4	6	9	6	7.0	14.0	350
5	5	4	20	9.6	20.0	500
6	6	10	9	8.3	15.0	375
7	9	12	4	8.3	10.2	255
8	4	11	24	13.0	12.0	300
9	36	26	14	25.3	6.2	155
10	12	36	48	32.0	6.2	155
11	7	10	13	10.0	15.0	375
12	8	18	9	11.6	12.0	300
13	7	15	23	15.0	12.0	300
14	8	9	14	11.0	11.0	275
15	6	17	18	13.6	12.0	300
16	8	15	13	12.0	13.0	325
17	10	8	12	10.0	9.0	225
18	13	21	15	19.6	10.0	250
19	12	20	20	17.3	7.1	177
20	12	16	10	12.6	10.0	250
21	10	6	6	7.3	13.1	327
22	6	14	20	13.6	8.0	200
23	18	20	13	17.0	8.0	200
24	8	12	14	11.3	12.0	300
25	9	12	8	9.6	10.0	250
26	9	15	24	16.0	8.0	200
27	6	8	11	8.6	8.0	200
28	15	14	16	15.0	10.0	250
29	17	17	6	13.0	10.0	250
30	8	12	13	10.6	10.0	250
31	9	10	9	9.3	10.0	250
32	14	19	12	15.0	8.0	200
33	10	10	6	8.6	9.0	225
34	10	19	12	13.6	10.0	250
35	10	10	10	10.0	6.0	150
36	10	8	6	8.0	11.0	275
37	14	12	8	11.3	10.0	250
38	14	10	6	10.0	9.0	225
39	24	18	10	17.3	8.0	200
40	10	10	8	9.3	13.0	325
41	10	12	9	10.3	12.0	300
42	12	14	12	12.6	6.2	155
43	14	12	10	12.0	7.1	177
			Total	537.1	440.2	11,003 sq. yds.
			Mean	12.49 in.	10.23 yds.	

highest temperature, 56° F, was recorded on September 10, and 41° F on October 16 was the lowest observed through November 15, when poor access precluded further observations at the sampling station. Additional samples were made at the Ivory Pine Road crossing where, on November 29, the water temperature was 33° F. An ice covering and anchor ice had formed in the slower areas of the stream. In early December, there was no ice, but by December 30, ice covered the entire stream in that vicinity.

During the fall sampling period, dissolved oxygen levels fell within the range of 9.1 to 11.9 ppm, with a mean of 10.36 ppm.

The entire North Fork maintains an excellent population of rainbow and brown trout. Based on the trout production and the general environmental conditions observed during the year, the North Fork would probably provide a fine rearing habitat for salmon and steelhead. One observation made on July 15 may detract from that statement. At Sandhill Crossing, there was a daily temperature pulse of 22° F. The water cooled from 70° F at 1600 to 48° F at 0700 hours.

There are three water diversions for irrigation on the lower end of the North Fork. All of these ditches would have to be screened to provide safe passage for young migrants. No other obstacles to emigration were detected.

The North Fork of Sprague River has promise as a salmon and steelhead stream, provided that spawning by salmon could be completed by the end of the first week in October. The quantity of good gravel below the canyon has space for 1140 chinook redds or 920 steelhead redds.

Within the canyon and above, chinooks and steelhead could make 310 and 250 redds, respectively. This potential may be reduced somewhat in the upper section during years of low stream flow.

Before the introduction of anadromous fishes could be accomplished, corrective measures would be necessary at the impassable dam and the three open diversion ditches.

Tributaries of Sprague River

Sycan River

The Sycan River has been rejected as a possible home for salmon and steelhead. Although water quality was fair to good throughout the sampling period (Figure 46, Page 172), suitable spawning gravel is scarce. In addition, stream-flow conditions are poor within and below Sycan Marsh during most of the summer and fall. Plate 24 is an illustration of this stream.

Five Mile and Meryl Creeks

Five Mile and Meryl Creeks, tributaries to the North Fork of Sprague River, were not surveyed, but may have some potential habitat for salmon or steelhead.

Fishhole Creek

Fishhole Creek, tributary to the South Fork of Sprague River, was not considered in the study because the lower end of the stream is used for irrigation and no definite channel is evident.

Deming Creek

Deming Creek, tributary to the South Fork of the Sprague River, is small and would not support salmon or steelhead.

Plate 24. Sycan River near mile 27, September, 1964

FUTURE AGRICULTURAL AND INDUSTRIAL USE OF WATER IN RELATION TO FISH LIFE

A comprehensive study of the Klamath Basin has been made by the California Department of Water Resources and reported in its Bulletin Number 83. In this report, the present water use within the Basin has been defined and predictions of the future ultimate water use have been made. It concluded that with proper development and utilization, the water supplies of the Klamath River Basin are adequate to satisfy all estimated ultimate requirements of the Basin. Proper development includes conservation works in the Upper Klamath Basin to provide about one-half million acre feet of storage to meet the ultimate requirements of the area. The required storage would be provided by the possible projects of Beatty and Chiloquin Narrows Reservoirs on Sprague River and Boundary Reservoir on Lost River. An alternate to Chiloquin Narrows Reservoir would be increased storage capacity in Upper Klamath Lakes.

The possible Chiloquin Narrows Reservoir would be on Sprague River just above its confluence with Williamson River and have a gross storage capacity of 440,000 acre feet behind a 135-foot dam. Beatty Reservoir, with a possible storage of 150,000 acre feet, would be formed behind a 55-foot dam about two miles east of the town of Beatty.

According to Bulletin 83, the average seasonal impaired flow of Klamath River at Keno, based on the 1953 use level, was about 870,000 acre feet. Under ultimate water requirements and proposed developments, the probable ultimate impaired flow would be about 487,000 acre feet. Consumptive water uses at the 1953 level and the probable ultimate level for the Upper Klamath Basin, showing an increase of 158,000 acre feet, are presented in Table 16.

The main agricultural water use forseeable in the future of the Upper Klamath Basin is increasing demands for irrigation. Under the present circumstances, such demands could be critical for fish on the Sprague River system. Most water rights in Klamath County have not been adjudicated and no minimum flows are enforced. The fish environment could suffer severely if these conditions persist.

Future industrial developments in the Upper Klamath Basin may be in the form of further hydroelectric projects and pulp processing plants.

Pacific Power & Light Company has proposed the future construction of four power projects on Klamath River between Klamath Falls and Copco Dam. One, Keno Dam for regulation and diversion, is scheduled for construction starting in 1966. It is located about two miles downstream from Keno and will replace the old needle dam for regulation of Lake Ewauna. The Keno Project will have the necessary fish passage facilities. Three other dam-diversion-power house projects have been proposed for the future when the demand for electric power justifies their construction. All of these proposals are located between Copco Reservoir and J. C. Boyle (formerly Big Bend) Dam.

Four high dams are listed as possible future installations included in the California Water Plan, according to the California

Table 16. Present estimated mean seasonal consumptive use and probable ultimate mean seasonal consumptive use of applied water within hydrographic units in the Klamath River Basin, in acre feet.[a]

Hydrographic Unit	Irrigated Lands	Urban Lands	Misc. Water Service Areas	Swamps Marshlands	Principal Reservoirs	Totals
Present						
Williamson River	95,500	300	300	54,000	0	150,000
Sprague River	53,700	300	300	25,000	0	79,300
Wood River	53,200	100	900	75,000	13,000	142,200
Klamath Lake	16,000	0	200	34,000	150,000	201,000
Klamath Project	215,800	7,900	4,300	17,000	29,900	274,900
Sub-total	434,200	8,600	6,000	205,000	192,900	847,500
Ultimate						
Williamson River	71,000	700	1,400	21,000	0	94,000
Sprague River	114,000	800	1,900	15,400	73,700	206,700
Wood River	99,900	600	1,300	20,500	13,000	135,300
Klamath Lake	47,600	200	500	0	150,000	198,300
Klamath Project	298,300	9,000	5,800	28,500	29,900	371,500
Sub-total	630,800	11,300	10,900	85,400	266,600	1,005,800

(a) From California Dept. of Water Resources, Bul. 83, Klamath River Basin Investigation. 1964.

Department of Water Resources. The reservoirs of Humbolt Dam, 410 feet; Slate Creek Dam, 775 feet; Happy Camp Dam, 625 feet; and Hamburg Dam, 445 feet, would encompass nearly all of the Klamath River. However, a 1924 initiative measure prohibits the construction of dams on Klamath River. It is thought that these projects will be part of later stages of the plan and their construction remains many years in the future.

Three pulp processing mills have been proposed adjacent to Williamson River near the Highway 97 crossing. One or more of these plants may be put into operation in the near future and will obtain water from the Williamson River or wells. The release of the effluent from these mills into waters of the Basin could seriously affect the aquatic life, unless adequately treated.

FACILITY REQUIREMENTS AND COSTS

Economic aspects necessary for providing safe passage for migrating fish must also be considered when assessing the feasibility of introducing anadromous fish in Mid- and Upper-Klamath Basin. Potential barriers to fish passage have been located within the Basin and cost estimates have been made for required facilities.

Passage Around Dams

Power Dams

These are, at the present time, four major dams in the path of the potential migration route. Two of these are provided with fishways. The construction of another dam is to be started early in 1966.

Two basic plans have been devised which would provide passage for salmon and steelhead over the unladdered dams. Briefly, Plan A proposes the use of ladders to bypass Iron Gate Dam and the complex of Copco Dams 1 and 2. Ladders are already in operation on J. C. Boyle (Big Bend) Dam and Link River Dam. Fish ladders will be constructed as an integral part of the new Keno Dam. Under Plan A, for downstream passage, traveling screens would be installed at Link River Dam to block diversions at that point. A similar installation will be provided at Keno Dam, and J. C. Boyle Dam has these facilities. A diversion dam would be constructed at the head of Copco Reservoir under this plan. At that point, screens would block passage into the reservoir and divert downstream migrants, either into a conduit which would carry the young fish to the base of Iron Gate Dam, or trapping and hauling facilities to transport the young migrants.

Plan B substitutes trapping and transport facilities for the ladders and flume around the Iron Gate and Copco projects. Otherwise, the two plans are alike. Ladder and screening facilities would also be installed on three other proposed dams on Klamath River between Copco Reservoir and J. C. Boyle Dam.

Mr. Milo Bell, a consulting engineer and specialist on fish passage facilities was engaged to provide estimates of cost for the required facilities in the two plans. Details of the estimate and schematic drawings of the plans are provided in Appendix D.

A summary of estimated costs for present installations under Plans A and B are:

Plan A

Item	Initial Cost	Annual Operation & Maintenance
Iron Gate Fish Ladders	$ 624,000	$ 37,000
Copco Dam Fish Ladders	753,000	45,000
Copco Res. Screens & Ladder	1,956,000	135,000
Link River Screens	214,000	15,000
Trucking*	55,000	13,000
Totals	$3,602,000	$245,000

* A conduit or pipeline from the head of Copco Reservoir to the base of Iron Gate Dam (14.5 river miles) is a possible alternative to trucking of downstream migrants.

Plan B

Copco Reservoir Screens	$1,829,000	$127,000
Link River Screens	214,000	15,000
Iron Gate Trapping Facilities	280,000	22,400
Trucking	55,000	25,500
Totals	$2,378,000	$189,000

Including the costs for the ladders and screens at the three proposed dams, Warm Springs, Salt Caves and Bear Springs, the total estimated costs for all facilities, present and future, is $6,566,000 for Plan A and $5,397,000 for Plan B, with estimated annual operation and maintenance costs of $431,000 and $390,700, respectively.

Irrigation Dams

Nine irrigation diversion dams, all on the Sprague River system, would be barriers to passage of salmon or steelhead. The largest is Sprague River Dam at Chiloquin. The fish ladders there are inadequate and would have to be replaced by a new facility. The estimated cost of construction is $18,000

There are seven smaller dams on the South Fork of Sprague River ranging in height from 4 to 10 feet. The total cost estimated for laddering these barriers was $75,000.

One small dam on the North Fork of Sprague River would require about $4,500 for a ladder.

The total cost to provide passage facilities past irrigation dams is estimated at $97,500. These estimates were made by the staff of the Engineering Department of the Oregon Game Commission, based on the gross measurements of the individual dams. The costs are based on the average experienced for such installations, not on studied specifications. Based on Mr. Bell's figures, the annual cost for operation and maintenance of these structures would be approximately $5,850.

Screening Irrigation Diversion Ditches

Water diversion ditches must be screened to prevent downstream migrants from entering irrigation ditches and being lost in the fields. There are irrigation diversions on all the potential salmon and steelhead streams, except Spencer Creek.

Personnel of the Oregon Game Commission Engineering Department estimated the cost of rotary screen and paddle wheel installations for each of the diversions. Their estimates were based on average cost of the 'facilities by ditch size (Table 17).

Table 17. Number of Ditches and Total Estimated Cost Screen Facilities Per Stream.

Stream		Number of Ditches	Estimated Cost
Klamath River		8	$8170
Shovel Creek		2	1740
Wood River		2	2120
Sprague River		1	7500
South Fork Sprague		10	8270
North Fork Sprague		3	2990
	Total	23	$30,790

In one or more places on the South Fork of Sprague River, water is diverted to the fields by flooding or through head gates directly off the reservoir area without ditches. In these instances, either new methods of screening would have to be devised or the methods of diversion changed.

A large diversion leaves Klamath Lake just north of Link River Dam. The "A" canal of the Bureau of Reclamation's Klamath Project has a capacity of 1200 cfs. Based on Mr. Bell's unit cost for traveling screen installations, $174,700 would be required for screen facilities.

The total cost of screening irrigation water withdrawals would be about $205,490. About 12,330 would be required annually for operation and maintenance of these installations.

Log Jam Removal

Impassable log jams occur on Spencer Creek and South Fork of Sprague River. Based on current prices, the engineers of the Oregon State Game Commission estimated a total cost of $18,000 for removal of seven small jams on Spencer Creek and three others on the South Fork. One jam about 75 feet long, 50 feet wide and 10 feet high would require about $6,500 for removal. An additional cost of $1000 would be charged for each work area.

REVIEW AND DISCUSSION OF SALMON AND STEELHEAD TRANSPLANT EXPERIMENTS ELSEWHERE, IN RELATION TO SUGGESTED INTRODUCTION OF SALMON AND STEELHEAD IN UPPER KLAMATH BASIN.

This section reviews the results of some attempts to establish or augment runs of Pacific salmon. It is meant to illustrate the degree of success gained by different methods of transplant and some of the

". . . Currently, the weaknesses of hatchery methods and the ecological characteristics of artificial spawning and incubation channels are being studied so that new methods for transplanting sockeye populations can be developed which should have a higher probability of success. Small runs of sockeye have been initiated by eyed egg transfers in a few once-barren streams and their future progress under natural reproduction will be of scientific and, possibly, of economic importance, IPSFC (1964)."

There are accounts of significant runs of transplanted Pacific salmon being maintained. But, in nearly all cases, these runs are reproduced by artificial propagation. Such is the case on Wind River, Washington (Darvin and Smith, 1963) and Eagle Creek, Oregon (Zimmer, Wahle and Maltzeff, 1963) where chinook salmon are returning in good numbers.

From the results of the above cited experiments, several factors are illustrated which are prerequisite to the success of any transplant of Pacific salmon or steelhead.

The most apparent factor is the importance of matching the fish to the stream in every way possible. The Pacific salmon tend to build up races which are adapted to the environment of their parent stream.

Since probably no two streams are totally alike, transplanted fish are at a disadvantage and must adapt or perish. This point is emphasized by the many experiments producing better returns from native stock than from imported stock. The introduced fish must have the stamina and physiological capacities to complete the necessary migrations. The timing of migration and spawning inherent in a race of fish must be suited to the temperature and hydrological regime of the stream of release. Even with seemingly well adapted stock, as in recent Fraser River trials, significant returns are not assured.

Other factors weighed with an eye to unsuccessful transplants are for one, allowing sufficient time for the embryo or young fish to become impressed with the characteristics of the stream so that their homing traits will bring them back to the stream of release. Obstacles or barriers which tend to delay migration, especially upstream, may seriously curtail or cause failure of the transplant.

In an attempt to introduce kokanee, a lake-dwelling race of sockeye salmon, to Copco Reservoir, the California Department of Fish and Game stocked fry. On April 30, 1953, the reservoir was planted with 10,700 kokanee weighing 107 per ounce. These fish were distributed throughout the lake by boat. A year later, another release of 95,580 kokanee weighing 295 per ounce, was made at the head of the reservoir. Searches for several years after the stocking revealed no survivors within the lake or tributaries.[10]

10 Letter from Millard Coots, California Department of Fish and Game, November 12, 1965.

SUMMARY

Published reports and personal interviews indicate that chinook salmon were present in the Mid- and Upper-Klamath Basin during the months of September, October and November, until the early 1900's. A photograph substantiates the presence of chinook salmon in Link River. These runs were first curtailed around 1889-1902 when log crib dams were constructed near Klamathon by the Klamath River Improvement and Lumber Company. These dams, constructed with no or inadequate fish ladders, seriously limited the migrations of salmon into the Upper Basin, and in 1910 the Bureau of Fisheries installed its racks at Klamathon, further curtailing them. In 1917, the construction of Copco Dam formed a complete block to upstream migration. The Power Company constructed a fish hatchery on Fall Creek below Copco #2 Dam, at the request of the California Department of Fish and Game Commission, to mitigate for the loss of upstream production.

Because of difficulty in differentiating steelhead from large rainbow trout, accurate information on the history of steelhead migrations was impossible to obtain. It can be said that an intrastream migration of large rainbow trout or sea run steelhead did occur, appearing in the Upper Basin in the fall and again in the spring. An intrastream migration of resident rainbows now occurs during the spring in the section of the Klamath River from the Frain Ranch (River mile 217) to Klamath Lake area and from Klamath Lake up the Williamson-Sprague River systems. A smaller migration occurs in the fall in the Klamath River upstream over the J. C. Boyle fish ladder.

Runs of fall chinook and steelhead have been maintained below Copco #2 dam and Iron Gate dam which is the upper end of their migration since 1962. Limited runs of spring chinook and coho salmon are also present. There is some evidence there once was a strong run of spring chinook, but it had declined to its present level before 1890. Artificial propagation of salmon and steelhead has been practiced on the Klamath River since 1910. Between 1925 and 1961, counts of chinook salmon averaged 10,455 fish per year at Klamathon.

Early studies indicate that excessive exploitation of the fishery and the advent of placer mining in the Klamath Basin were the two principal causes of the decline of the Klamath River fishery.

Present runs of chinook salmon begin entering the mouth of the Klamath River in July and reach the limit of upstream passage from September to November. Spawning peaks in mid-October, and in years of large escapement may extend into December.

Runs of steelhead enter the Klamath River in late summer and fall and again during the winter months with spawning taking place from December through May.

The peak downstream migration of juvenile chinook salmon generally occurs in March.

The environmental requirements of chinook salmon and steelhead used as a basis for the evaluation of potential habitat in the Upper Klamath Basin are:

Temperature:

Adult migration	Survival limits	32-75° F
Juvenile rearing	Optimum for growth	
Juvenile migration	and maintenance	42-68° F

Temperature: (Cont.)	
Spawning	42.5 to 57.5 F
Incubation	33 to 48° F
Dissolved oxygen:	Minimum 5.0 ppm Incubation minimum 7 ppm
Water velocity for spawning:	1.0 to 4.0 fps
Minimum water depth for spawning:	0.5 ft.
Spawning gravel size:	1 to 6 inches diameter

Barriers along the migration route to the Upper Klamath Basin occur in several areas. Three impassable dams, Iron Gate at river mile 192, Copco No. 2 at river 200.3 and Copco No. 1 at river mile 200.5 prevent upstream migration. Water quality in Iron Gate and Copco Reservoirs from mid-summer to the fall months becomes marginal for salmonid fishes. The stratification of the reservoirs creates oxygen levels below the minimum requirement in all but the 0-20 foot stratum of the reservoir; temperatures in the upper 0-10 feet exceed the maximum preferred during much of the summer period. Klamath River between Keno and Lake Ewauna has dissolved oxygen concentrations below 5 p.p.m. in July - October. Klamath Lake, because of its size, may present a deterrent to a successful spawning migration by delaying time of passage. The Sprague River dam is impassable because of inoperable fish ladders. Stream flow in the lower South Fork Sprague River is low and intermittent during the summer because of irrigation withdrawals. There are seven impassable dams on the South Fork and one small impassable dam on the North Fork Sprague River. In addition, there are seven small log jams on Spencer Creek and three on the South Fork Sprague River.

The downstream migration period of fall and spring chinook salmon would be expected to occur during March, April and May, when temperatures and flows would be suitable for downstream fish migrations along the entire route. It is expected that coho salmon and steelhead seaward migrants would migrate at the same time.

In June, water quality begins to deteriorate in Iron Gate, Copco and J. C. Boyle reservoirs, and in Klamath River from Keno to Lake Ewauna. Diversions of water for irrigation and power production present the greatest hazards to successful seaward migration. There are ten unscreened irrigation diversions on the South Fork Sprague River, three on the North Fork Sprague River, one on Sprague River, four on Wood River, two on Shovel Creek, and eight on Klamath River. The "A" canal diversion from Klamath Lake is also unscreened. Open diversions or penstocks are located at Link River, Copco I, Copco II, and Iron Gate dams. The effect of Upper Klamath Lake on the behavior of downstream migrants is unknown. Large impoundments have been shown to impair seaward migration and cause residualism.

Potential spawning areas for salmon and steelhead have been found on seven streams in the Upper Klamath Basin. Table 18 summarizes the estimated amount of gravel available. On Klamath River, 13,500 square yards of suitable gravel was found in Oregon (near the Frain

Table 18. Estimated totals of potential spawning gravel in streams of the Klamath Basin above Copco Reservoir.

	Square Yards of Gravel		
Stream	Good	Marginal	Total
Klamath River			
California	28,500		28,500
Oregon	13,500		13,500
Shovel Creek	(a)	(a)	(a)
Spencer Creek	2,300	300	2,600
Wood River	11,000	1,300	12,300
Williamson River	5,100		5,100
Sprague River		10,600	10,600
South Fork Sprague River	19,400	1,900	21,300
North Fork Sprague River	30,500	4,000	34,500
TOTALS	110,200	18,500	128,700

(a) No total gravel estimates available.

Ranch, River mile 217) and 28,500 square yards of gravel was found near and below Shovel Creek (River mile 208) in California.

By early fall, water temperatures in the Upper Basin fall below the minimum for successful spawning of chinook salmon.

There are approximately 166 miles of stream that are suitable for rearing young salmon and steelhead. Miles of rearing habitat by stream are included in Table 19.

Forseeable future water uses include an increased irrigation demand. These demands may bring about reforms in irrigation practices as well as new storage dams on the Sprague River system.

Keno Dam, one of four proposed power dams on the Klamath River above Copco Reservoir, is to be constructed beginning in 1966. At first, it will be a regulating facility only, controlling the Lake Ewauna area, but eventually will divert water to a powerhouse at the head of J. C. Boyle reservoir. When the project is completed for water diversion, adequate flows will need to be assured in the river channel to provide fish passage. Three other dam-diversion-powerhouse projects are proposed that would create similar situations. Laddering and screening facilities would be required at these projects to provide fish passage.

There are proposals for three pulp processing plants near the Williamson River.

Some pertinent experimental transplants of Pacific salmon were reviewed. The results of these experiments in North America are of extremely limited success or complete failure. The runs that have been established are maintained mainly by artificial propagation.

Table 19. Summary of potential stream-miles of rearing habitat in the Klamath Basin above Copco Reservoir.

Stream	Suitable Rearing Habitat (Miles)	Minimum Flow (cfs)	Spawning Gravel Above or Within Rearing Area
Klamath River	27.00	340	Yes
Spencer Creek	2.50	2.8	Yes
Sevenmile Creek	16.75	--	Yes
Wood River	18.75	--	Yes
Williamson River, Mile 0.0 to 10.75	10.75	500	Yes
Mile 10.75 to 21.0	10.25	--	No
Spring Creek	2.50	--	No
Sprague River	31.00	200	Yes
South Fork Sprague River	11.25	10	Yes
North Fork Sprague River	27.50	12	Yes
Total	166.75		

Cost estimates have been made by consultants on the work necessary to facilitate migrations of anadromous fish in the Upper Klamath Basin. Estimated costs for the two basic plans are:

PLAN A

	Capital Expenditure	Annual O&M
All power dams laddered with screened diversions	$ 3,602,000	$245,000
Irrigation dams laddered	97,500	5,850
Irrigation diversions screened	205,490	12,330
Log jams removed	25,500	--
	$ 3,930,490	$263,180

PLAN B

	Capital Expenditure	Annual O&M
Trapping and transport facilities around Iron Gate and Copco Reservoirs, dams laddered and screened above Copco	$ 2,378,000	$189,000
Irrigation dams laddered	97,500	5,850
Irrigation diversions screened	205,490	12,330
Log jams removed	25,500	--
	$ 2,706,490	$207,180

A summary by survey section listing the important migration, spawning and rearing conditions for the Mid- and Upper-Klamath Basins is presented in Table 20.

Table 20. Summary and conclusions on biological and physical conditions limiting the potential of the Mid- and Upper-Klamath Basins for salmon and steelhead.

			Spawning			
Survey Section	Mile Point	Migration	Water Quality	Sq. Yds. Gravel	Fish Potential (Pairs)	Rearing
Iron Gate Reservoir	192.0 - 199.0	Water quality good except during June-Sept., when limited to 10-20 ft. stratum. No fish facilities present.		No gravel		Water quality same as migration. Predation may occur from resident species.
Jenny Cr.	196.0			No gravel		
Copco No. 2 Forebay	200.3	Water quality good. No fish facilities		No gravel		Conditions good.
Copco No. 1 Reservoir	200.5 - 205.8	Water quality good except during June-Sept. when limited to 10-20 ft. stratum. No fish facilities present.		No gravel		Water quality same as migration. Predation may occur from resident species.
Shovel Creek	208.0	Water quality cond. poor summer and fall. Barrier falls at mile 2.5	Poor during summer and fall.	Limited	Steelhead	Fair. Diversions, low flows and predation from resident trout.
Klamath River from Copco 1 to J. C. Boyle Dam	205.8 - 227.5	Water quality conditions good. No barriers. Eight unscreened diversions.	Good. Oct. - Nov. and Mar.-May	28,500 (Calif.) 13,500 (Ore.)	1,350 Chinook 1,100 Steelhead	Good. Predation may occur from resident fish population.
J. C. Boyle Dam and Res.	227.5 - 229.8	Water quality conditions poor from June-July and first part August.		No gravel		Water quality same as migration. Predation from resident species.

Cont.

Table 20. Summary and conclusions on biological and physical conditions limiting the potential of the Mid- and Upper-Klamath Basins for salmon and steelhead.

Survey Section	Mile Point	Migration	Spawning: Water Quality	Spawning: Sq. Yds. Gravel	Spawning: Fish Potential (Pairs)	Rearing
Spencer Creek	229.5	Water quality good. Small log jams and beaver dams. Barrier at mile pt. 9.0	Temp. good during Sept. and Mar.-May	2,300	110 Chinook 90 Steelhead	Good
Klamath River to Keno	229.8 - 236.3	Good		No gravel		Good
Keno to Klamath Falls	236.3 - 254.3	Water quality cond. poor, July - Oct.		No gravel		Water quality poor, July-Oct.
Link River		Water quality cond. good. Fish ladder needs work. Three diversions unscreened.		No gravel		Good
Upper Klamath Lake		Water quality good. Fish delays		No gravel		Good. Predation from resident species
West side tributaries, Fourmile Creek, Crane Creek				No gravel		
Sevenmile Creek	00. - 19.00	Water quality good. Many log jams, beaver dams, and 3 unscreened diversions.		Marginal		Good

Cont.

Table 20. Summary and conclusions on biological and physical conditions limiting the potential of the Mid- and Upper-Klamath Basins for salmon and steelhead.

			Spawning			
Survey Section	Mile Point	Migration	Water Quality	Sq. Yds. Gravel	Fish Potential (Pairs)	Rearing
Wood River	0.00 - 18.25	Water quality good. 4 unscreened diversions.	Temp. good from Mid-April to Mid-Sept.	11,000	520 Chinook 420 Steelhead	Good. Predation by resident species.
Williamson River	0.00 - 21.00	Water quality good. Blocked at Mile pt. 21 by series of impassable falls.	Salmon by Mid-Oct. Steelhead cond. good.	5,200	240 Chinook 200 Steelhead	Excellent
Spring Creek				No gravel		
Sprague R. to Lone Pine	0.00 - 31.00	Water quality good. One impassable barrier. One unscreened diversion.		Marginal		Adequate
Lone Pine to the Forks	31.00 - 79.00	Water quality good.		Marginal		Of little value.
S.F. Sprague R.	0.00 - 9.00	Water quality poor June-Sept. Eight impassable dams. No flows at times. 10 unscreened diversions		No gravel		Poor during summer months.
S.F. Sprague R.	9.00 31.50	Water quality good on log jam.	Salmon by first Oct. Steelhead cond. good	19,400	920 Chinook 750 Steelhead	Good
N.F. Sprague R.	0.00 - 32.00	Water quality good. One impassable dam. 3 unscreened diversions.	Salmon by 1st Oct. Steelhead cond. good	30,500	1450 Chinook 1170 Steelhead	Good

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LITERATURE CITED

ANDREWS, F. J. and G. H. Geen. 1960. Sockeye and pink salmon production in relation to proposed dams in Fraser River system. Bull. Int. Pac. Salmon Fish. Comm. 9;259.

ANEY, Warren W. 1964. Lower Deschutes flow study. Progress Rept. No. 2 Oregon State Game Commission.

BRETT, J. R. 1952. Temperature tolerance in young Pacific salmon genus Oncorhynchus. J. Fish. Res. Bd. Canada. 9(6): 265-323.

__________. 1960. Thermal requirements of fish- three decades of study, 1940-1970. In Biological problems in water pollution. U. S. Public Health Service. The Robert Taft Sanitary Engineering Center. Tech. Rep. W 60-3.

BRIGGS, John C. 1953. The behavior and reproduction of salmonoid fishes in a small coastal stream. Calif. Dept. of Fish and Game. Fish Bul. No. 93. 62 p.

BURNER, Clifford J. 1951. Characteristics of spawning nests of Columbia River salmon. U. S. Fish and Wildlife Serv. Fish Bull., 52 (61): 97-110.

BURROWS, R. E. 1963. Water temperature requirements for maximum productivity of salmon. In Proceedings of 12th Pacific Northwest Symposium on Water Pollution Research. p. 29-38.

CALIFORNIA DEPARTMENT OF WATER RESOURCES. 1964. Klamath River Basin Investigation. Bull. No. 83.

CHAMBERS, JOHN S., George H. Allen and Richard T. Pressey. 1955. Research relating to study of spawning grounds in natural areas. Annual report, 1955. Rept. to U. S. Army, Corps of Eng. by Wash. State Dept. Fish. Contract No. DA 35026-Eng. 20572. 175 pp. (mimeo)

CHAPMAN, Wilbert M. 1938. The oxygen consumption of salmon and steelhead trout. Biol. Rep. Dept. Fish. State of Washington No. 37A:22 p.

COMBS, Bobby D. 1965. Effect of temperature on the development of salmon eggs. Prog. Fish Cult. 27(3): 134-137.

__________ and Roger E. Burrows. 1957. Threshhold temperatures for the normal development of chinook salmon eggs. Prog. Fish Cult. 19(1); 3-6.

COOTS, Millard. 1962. Klamath River 1957 and 1958 king salmon counts, Klamathon racks, Siskiyou County. Calif. Dept. Fish and Game. Marine Resource Admin. Rep. No. 63.1.

COPE, E. D. 1879. The fishes of Klamath Lake, Oregon. Amer. Natur. 13: 784-785.

CRESSMAN, L. S. W. Haag and W. Laughlin. 1956. Klamath Prehistory; The prehistory of the culture of the Klamath Lake area, Oregon. Ameri. Phil. Soc., Trans. New Series. 46: pt. 4

__________ 1962. The sandal and the cave. Beaver Books, Champoeg Press Inc., Portland, Oregon

CUMMING, A. M. and Allen Dunn. 1911, California for the Sportsman. Southern Pacific. San Francisco, California, pp. 20-26.

DARVIN, John and Marvin Smith. 1963. Salmon and steelhead runs at the Eagle Cr. National Fish Hatchery. Prog. Fish. Cult. 25(2):97.

DAVIDSON, R. C., W. P. Breese, C. E. Warren, and P. Doudoroff. 1959. Experiments on the dissolved oxygen requirements of cold water fishes. Sewa. and Inds. wastes. 31:950-966.

DAVIS, Gerald E. Jack Foster, C. E. Warren and Peter Doudoroff, 1963. The influence of oxygen concentration on the swimming performance of juvenile Pacific salmon. Trans. Amer. Fish. Soc. 92(2):111-124.

DOWLING, E. 1948. Klamathon. Siskiyou County Hist. Soc. Yearbook, 1948, 1(3):1-6.

EVERMAN, B. W. and S. E. Meek, 1897. Bulletin, U. S. Fish Commission. 17:72.

ELLIS, M. M. B. A. Westfall and Marion D. Ellis. 1946. Determination of water quality. U. S. Fish and Wildlife Serv. Res. Rep. No. 9, 122 pp.

FISH, F. F. 1950. Oxygen block in the main-stem Willamette River. U. S. Fish and Wildlife Serv. Spec. Sci. Rep. Fisheries No. 41.

GATSCHET, A. S. 1890. The Klamath Indians of Southwest Oregon. Reports of U. S. Geographical and Geological Survey. Contract to N. A. Ethnology, 2: part 1.

GERLACH, A. R. and C. J. Hanel. 1964. Klamath River Flow study at J. C. Boyle project. Admin. rep. Oregon State Game Comm. and Pacific Power & Light Company.

GILBERT, C. H. 1898. The fishes of the Klamath Basin. U. S. Fish Commission Bul. 17(1897): 1-13.

GOOD, Rachel. 1941. History of Klamath County, Oregon, Klamath Falls, Oregon Priv. Publ. Limited Ed.

HAAS, James B. 1965. Fishery problems associated with Brownlee, Oxbow and Hells Canyon Dams on the Middle Snake River. Fish Comm. of Oregon. Invest. Rep. No. 4.

HAGEN, William, Jr. 1953. Pacific salmon, hatchery propagation and its role in fishery management. U. S. Fish and Wildlife Circular No. 24.

HAMILTON, J. A. R. and J. D. Remington. 1962. Salmon and trout of the South Fork Coquille River in relation to the Eden Ridge Hydroelectric Project. Pacific Power & Light Co., Portland, Oregon.

HANSON, Harry A., Osgood R. Smith and Paul R. Needham. 1940. An investigation of fish-salvage problems in relation to Shasta Dam. U. S. Fish and Wildlife Serv. Spec. Sci. Rept. No. 10: 200 p.

HERRMANN, R. B., C. E. Warren, and P. Doudoroff. 1962. Influence of oxygen concentration on the growth of juvenile coho salmon. Trans. Amer. Fish. Soc. 91(2):155-167.

HINZE, James. 1963. Temperature tolerance of adult King salmon and their eggs and studies on the control of American River temperatures. In An inventory of research on Pacific Salmon. Second Governor's Conference, Seattle, Washington, Jan. 8-10, 1963.

INTERNATIONAL PACIFIC SALMON FISHERIES COMM. 1954. Annual Report, p. 34-39.

________________, 1963. Annual Report. p. 18-22.

________________, 1964. Annual Report. p. 17-19.

JOHNSON, H. E. and R. F. Brice. 1953. Efforts of transportation of green eggs, and of water temperature during incubation on the mortality of chinook salmon. Prog. Fish. Cult. 15(3); 104-108.

JONES, J. R. E. 1964. Fish and River Pollution. Butterworth, Inc., Washington, D. C. 203 p.

KATZ, Max, A. Pritchard and C. E. Warren, 1959. Ability of some salmonoids and a centrarchid to swim in water of reduced oxygen content. Trans. Amer. Fish. Soc. 88(2):89-95.

KLAMATH REPUBLICAN, newspaper. Issues: Sept. 28, 1898; Feb. 21, 1901; Mar. 21, 1901; Sept. 18, 1902; Oct. 16, 1902; Sept. 10, 1903; April 30, 1908; Sept. 10, 1908; Dec. 24, 1908; Oct. 14, 1909.

LEITRITZ, Earl. 1959. Trout and salmon culture. Calif. Dept. of Fish and Game Fish. Bul. No. 107.

MATTSON, Chester R. 1948. Spawning ground studies of Willamette River spring chinook salmon. Fish Comm. of Oregon, Res. Briefs, 1(2):21-32.

MOFFETT, J. W. and Stanford H. Smith. 1950. Biological investigations of the fishery resources of Trinity River, California. U. S. Fish and Wildlife Serv. Spec. Sci. Rep.-Fish. No. 12.

OLSEN, P. A. and R. F. Foster. 1957. Temperature tolerance of eggs and young of Columbia River chinook salmon. Trans. Amer. Fish. Soc. 85:203-207.

OREGON STATE GAME COMMISSION. 1951. Fisheries Division Annual Report.

ROBINS, C. R. and R. W. Crawford. 1954. A short accurate method for estimating the volume of stream flow. J. Wildlife Mgt. 18(3); 366-369.

SAMS, Roy E. and Lincoln S. Pearson. 1963. A study to develop methods for determining spawning flows for anadromous salmonoids. Fish Commission of Oregon. (uncirculated draft).

SEYMOUR, Allyn H. 1956. Effects of temperature upon young chinook salmon. Ph.D. Thesis. College of Fisheries, Univ. of Wash.

SHAPOVALOV, Leo, 1937. Experiments in hatching steelhead eggs in gravel. Calif. Dept. of Fish and Game. Bul. 23(3); 208-214.

SHAPOVALOV, Leo, and Alan Taft. 1954. The Life histories of the steelhead, rainbow trout(Salmo g.g.)and silver salmon (O. kisutch). Calif. Dept. of Fish and Game. Fish. Bul. 98, 575 pp.

SHAVER, F. A., A. P. Rose, R. F. Steele and A. E. Adams, 1905. An illustrated history of Central Oregon Part VIII. Klamath County. Western Historical Publ. Co. Spokane, Wasington.

SHELTON, Jack M. 1955. Hatching of chinook salmon eggs under simulated stream conditions. Prog. Fish. Cult. 17(1):20-35.

SHEBLY, W. H. 1918. Report of the Dept. of Fish Culture. Calif. Fish and Game Comm. 25th Biennial Report for the years 1916-1918, pp. 23-49.

SHERIDAN, William L. 1962. Water flow through a salmon spawning riffle in Southeast Alaska. U. S. Fish and Wildlife Serv. Spec. Sci. Rep. Fish. No. 407.

SLATER, D. W. 1963. Winter-run chinook salmon in the Sacramento River, California, with notes on water temperature requirements at spawning. U. S. Fish and Wildlife Serv. Spec. Sci. Rep; Fish No. 461, 9 p.

SNYDER, J. O. 1931. Salmon of the Klamath River, California, Calif. Div. Fish and Game. Fish Bul. No. 34.

SPIER, Leslie. 1930. Klamath Ethnography. University of Cal. Press. Berkeley, Calif.

TARZWELL, Clarenice M. 1958. Dissolved Oxygen requirements for fishes. In Oxygen Relationships in streams. U. S. Dept. Health, Ed. Welfare. Public Health Serv. Robert A. Taft. San. Eng. Center Tech. Rep. W58-2. pp. 15-20.

THE EVENING HERALD. Newspaper, issues: Sept. 24, 1908; Sept. 22, 1908; Oct. 6, 1911; April 8, 1912; April 9, 1912; March 17, 1913; Oct. 28, 1913; Oct. 30, 1913.

U. S. Bureau of Fisheries. 1912-1921. Report of U. S. Commissioner of Fisheries 1911-1916.

WESTGATE, John. 1958. The relationship between flow and usable salmon spawning gravel, Cosumnes River, 1956. Calif. Dept. of Fish and Game. Inland Fish. Rep. No. 58-2.

WHITMORE, C. M., C. E. Warren, and P. Doudoroff. 1960. Avoidance reactions of salmonoids and centrarchids to low oxygen concentrations. Trans. Amer. Fish. Soc. 89:17-26.

ZIMMER, Paul D., Roy J. Wahle and E. M. Matlzeff. 1963. Progress report spring chinook salmon transplantation study, 1955-61. U.S. Fish and Wildlife Serv. Spec. Sci. Rep. - Fish No. 443. 24 p.

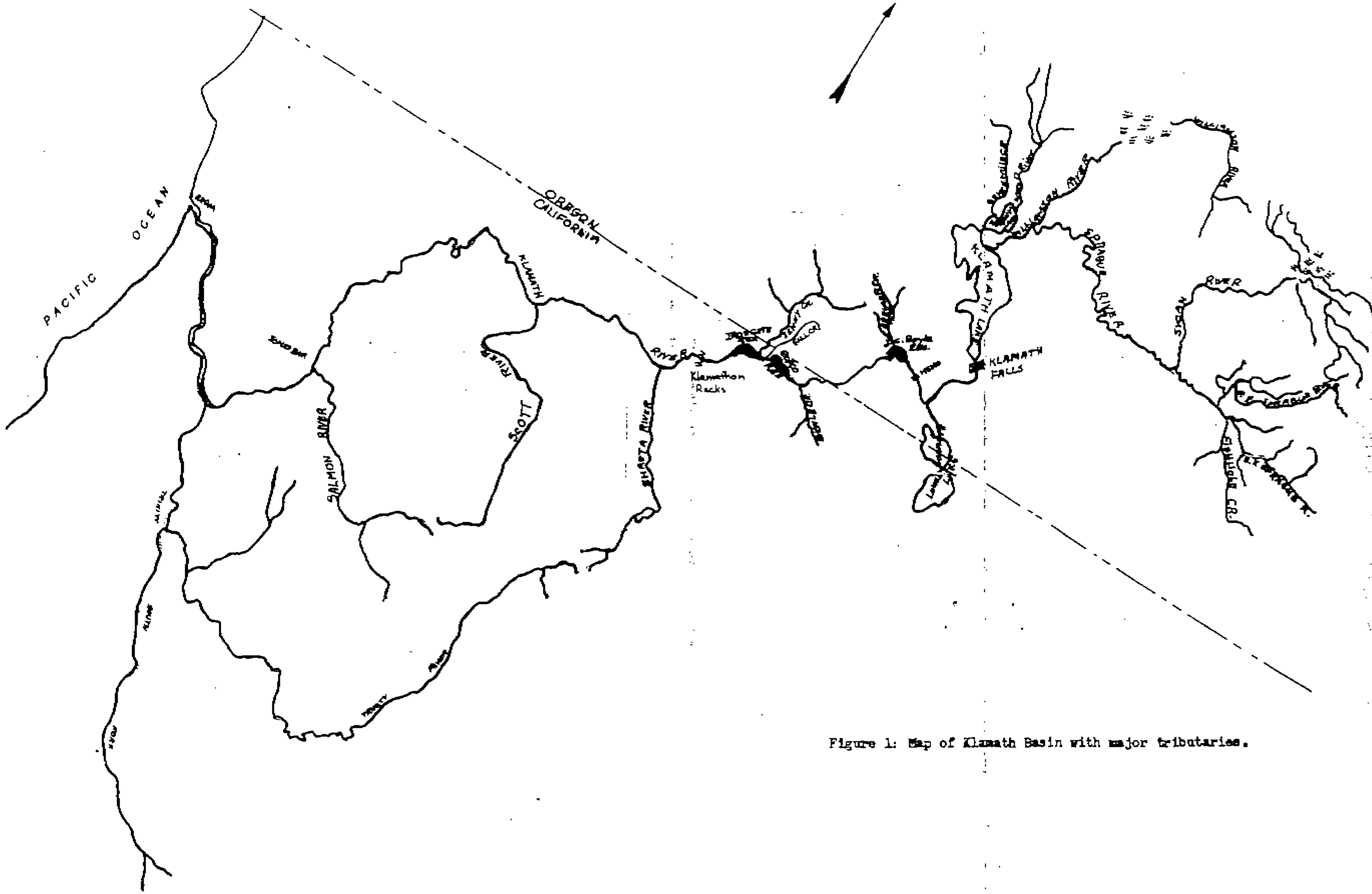


Figure 1: Map of Klamath Basin with major tributaries.

Figure 2. A comparison of the monthly mean maximum air temperatures for 1965 with the 33year monthly mean temperatures.

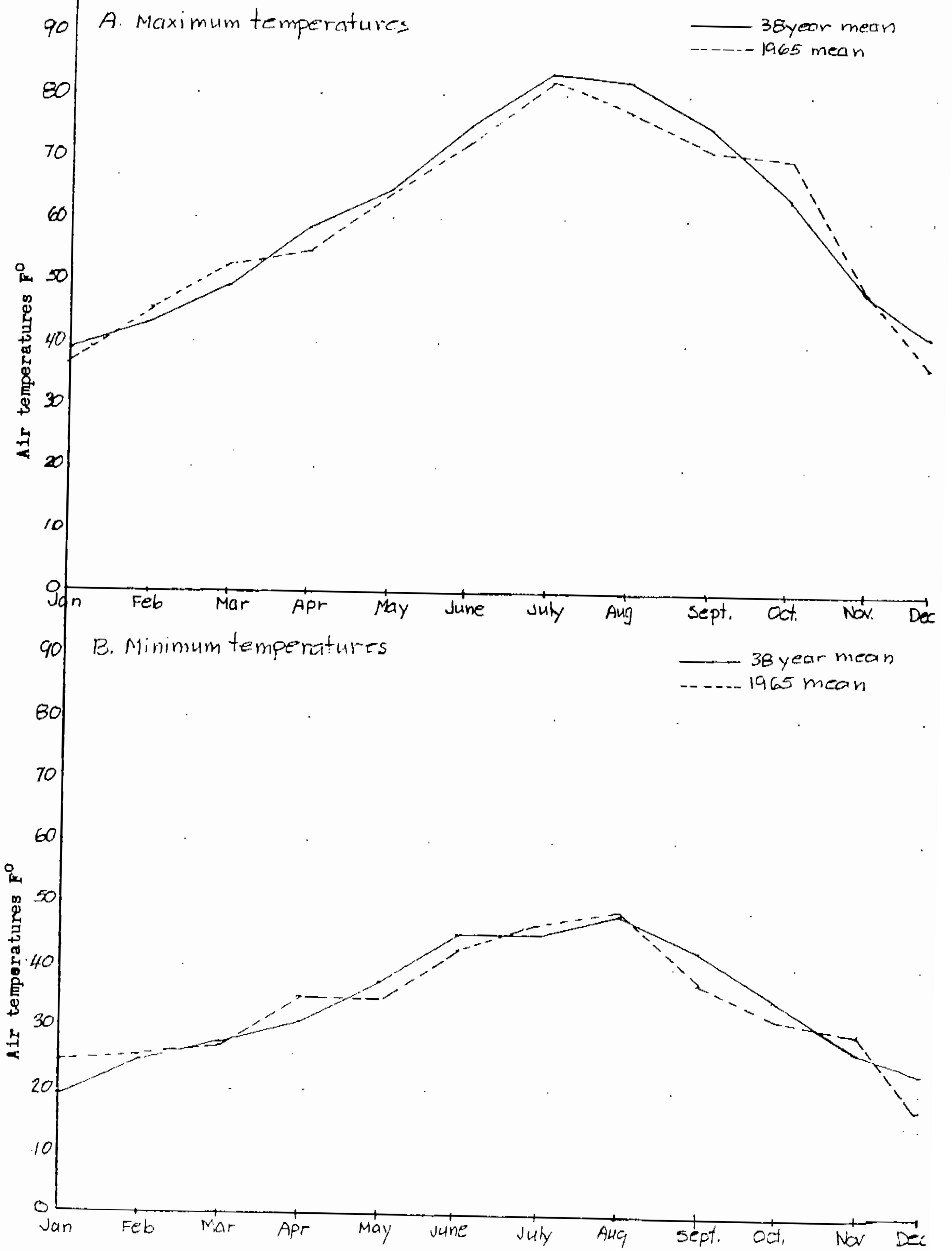


Figure 3. A comparison of the 1965 monthly mean air temperatures with 38 year monthly mean temperatures.

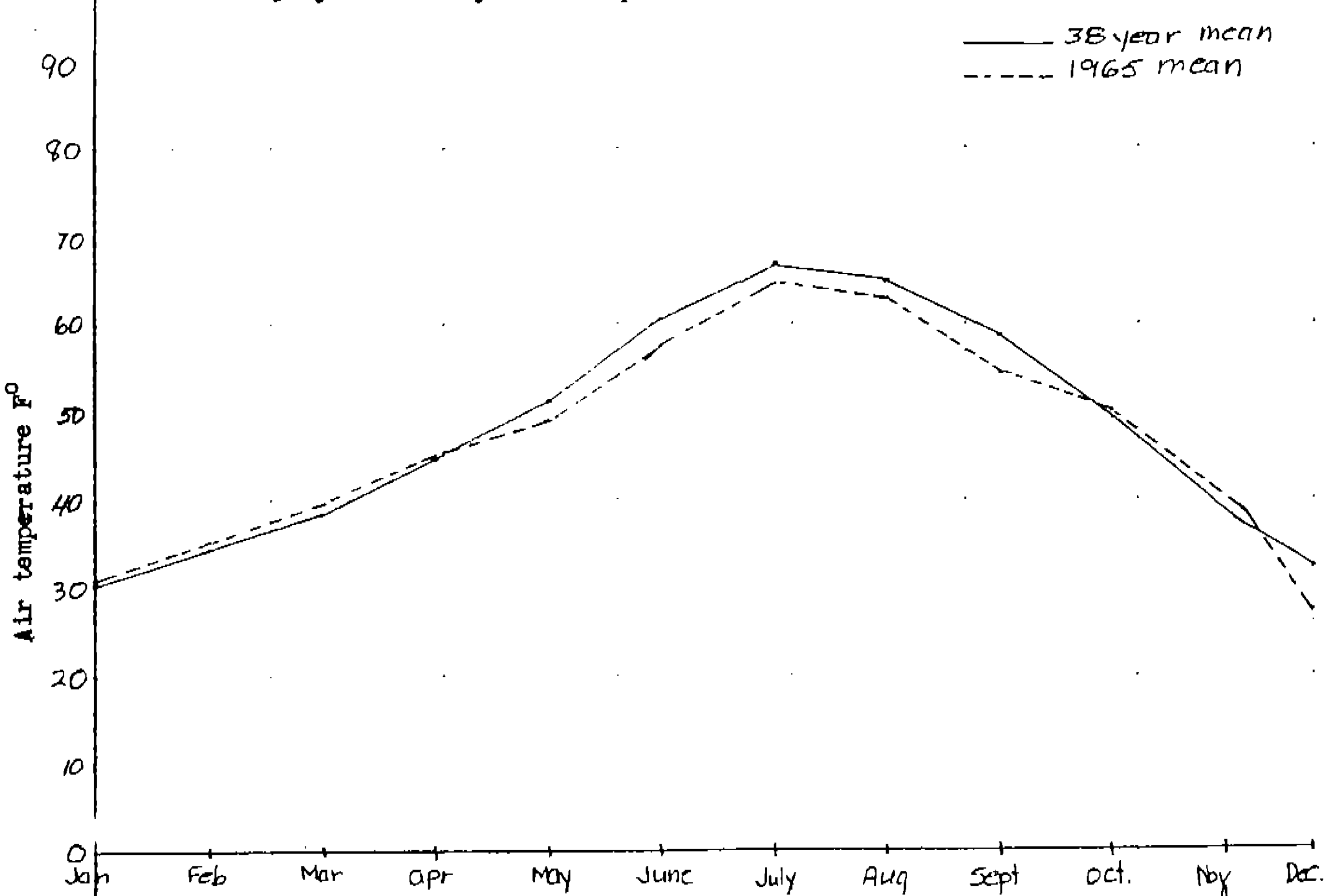
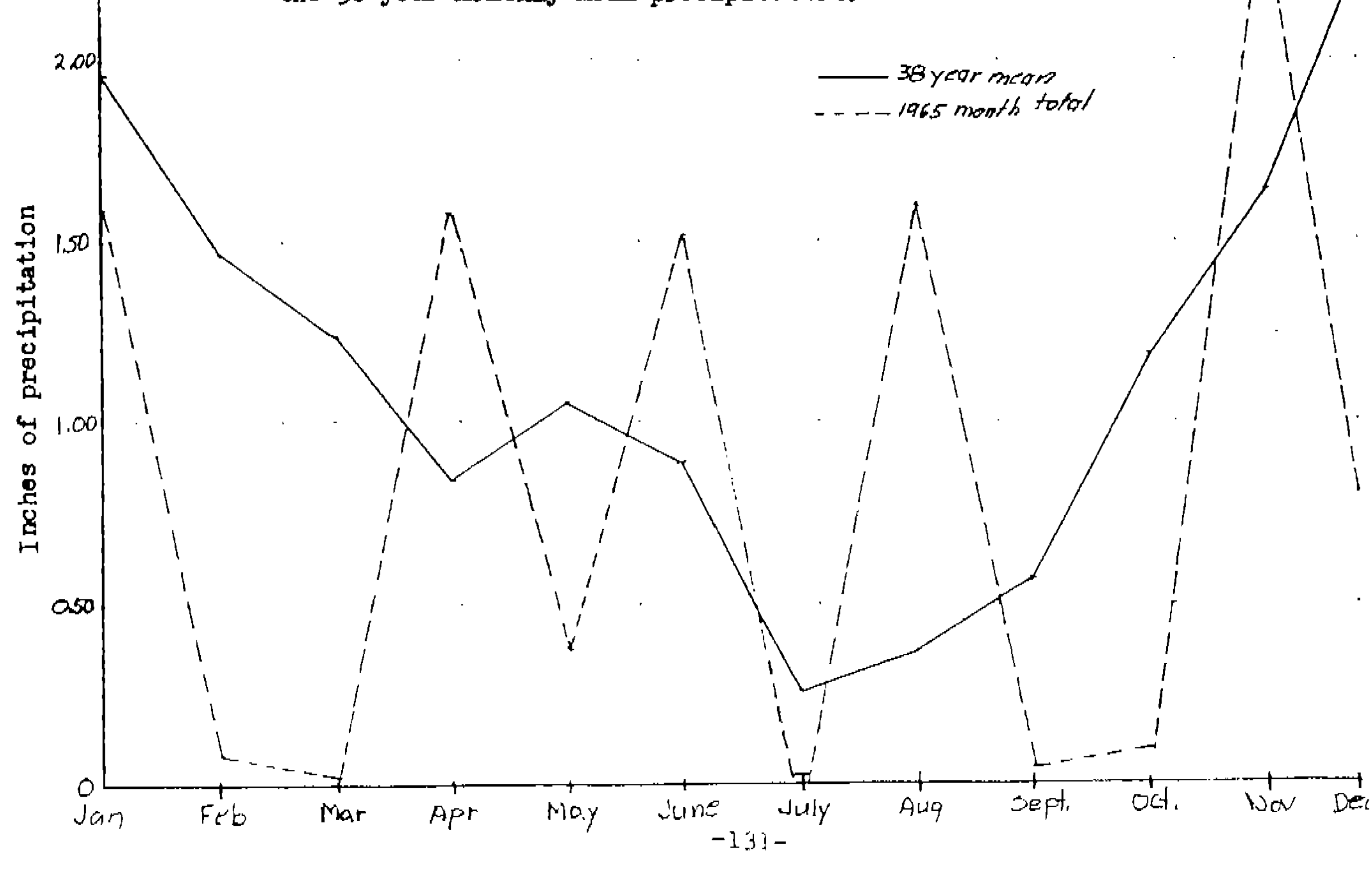


Figure 4. A comparison of the 1965 monthly precipitation in inches with the 38 year monthly mean precipitation.



SAMPLING STATIONS

1. Irongate Reservoir
2. Copco Reservoir
3. Beswick
4. Frain Ranch
5. Below J.C.Boyle powerhouse
6. Above J.C.Boyle powerhouse
7. Below bypass, J.C.Boyle Dam
8. J.C.Boyle Reservoir
9. Spencer Creek, mouth
10. Spencer Creek, mile 7.45
11. Keno flow gauge
12. Keno bridge
13. Highway 97 crossing
14. Link River
15. Sevenmile Creek
16. Wood River, first county bridge
17. Williamson River store
18. Williamson River, 97 crossing
19. Williamson River flow gauge
20. Williamson River, Chiloquin
21. Williamson River, above Spring Cr.
22. Sprague River, near Chiloquin
23. Sprague River, Lone Pine
24. Sprague River bridge
25. Sprague River, near Beatty
26. Sycan River
27. S.F.Sprague, Ivory Pine
28. S.F.Sprague, campground
29. N.F.Sprague, Ivory Pine
30. N.F.Sprague, Lee Adkins Place
31. N.F.Sprague, Sandhill Crossing

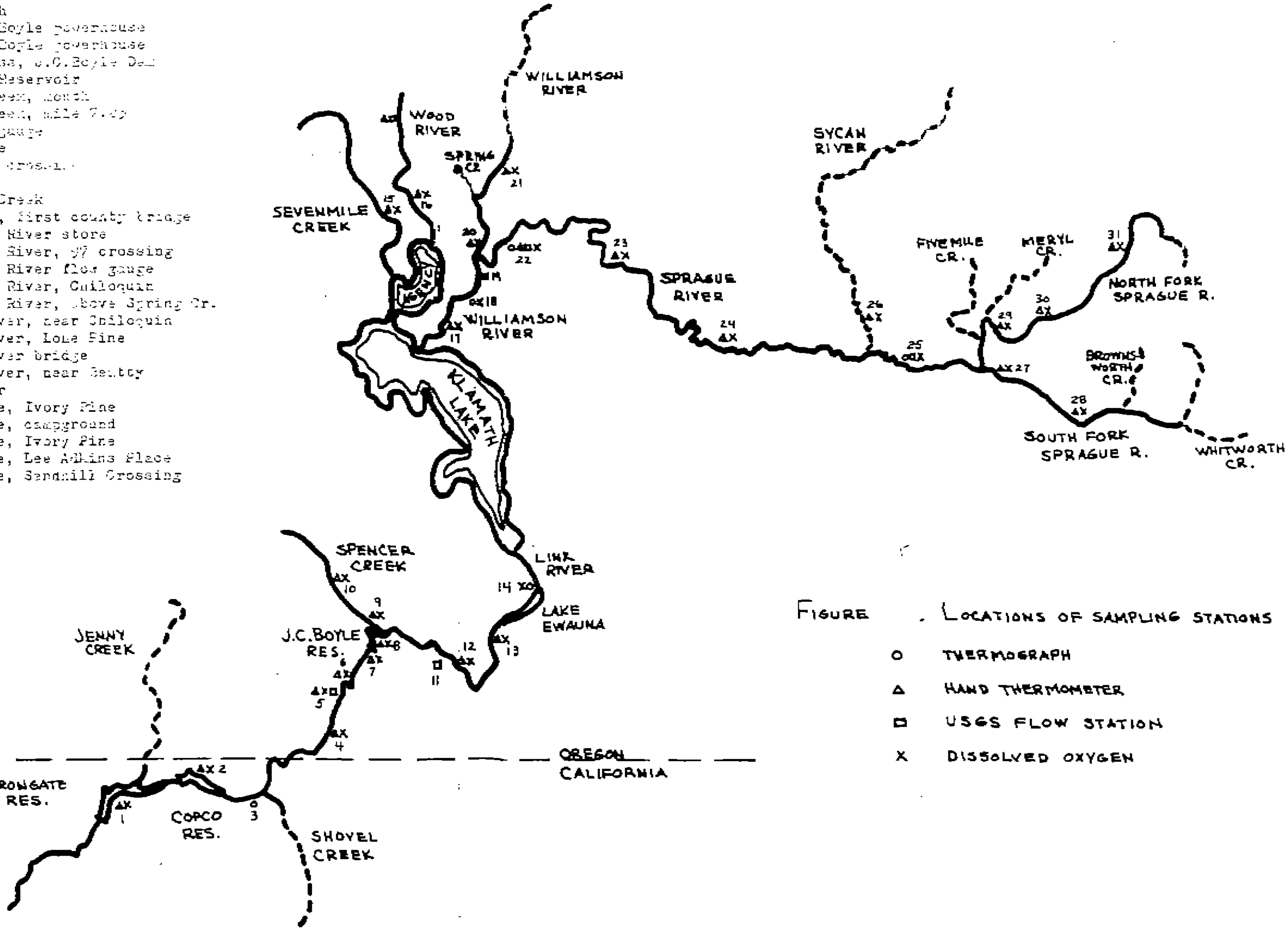


FIGURE . LOCATIONS OF SAMPLING STATIONS

Figure 6. Weekly mean water temperatures taken at four stations on Klamath River by hand thermometer.

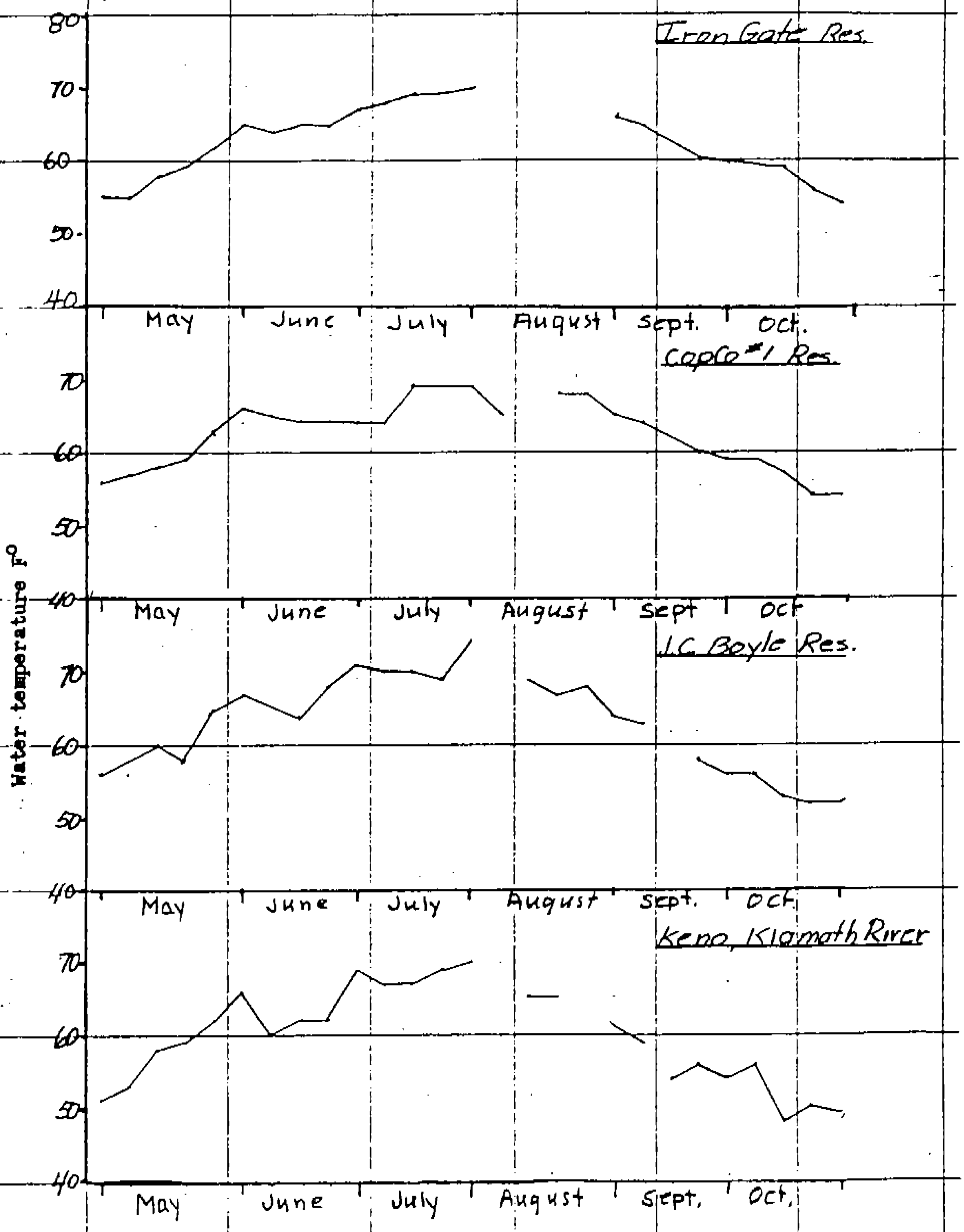


Figure 7A.--Dissolved oxygen and water temperatures taken from two stations on Iron Gate Reservoir, 1965.

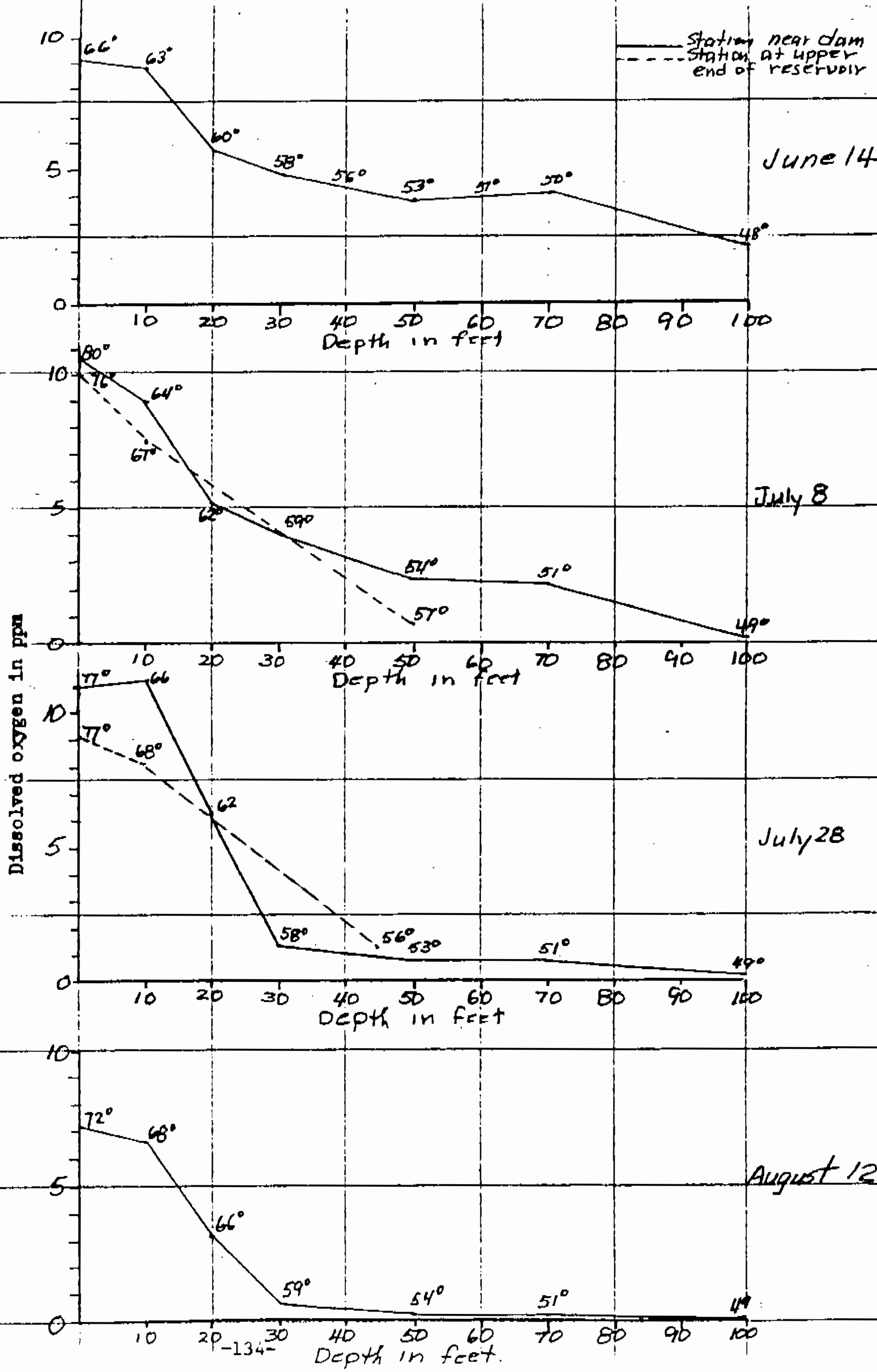


Figure 7B. Dissolved oxygen and water temperatures taken from two stations on Iron Gate Reservoir, 1965.

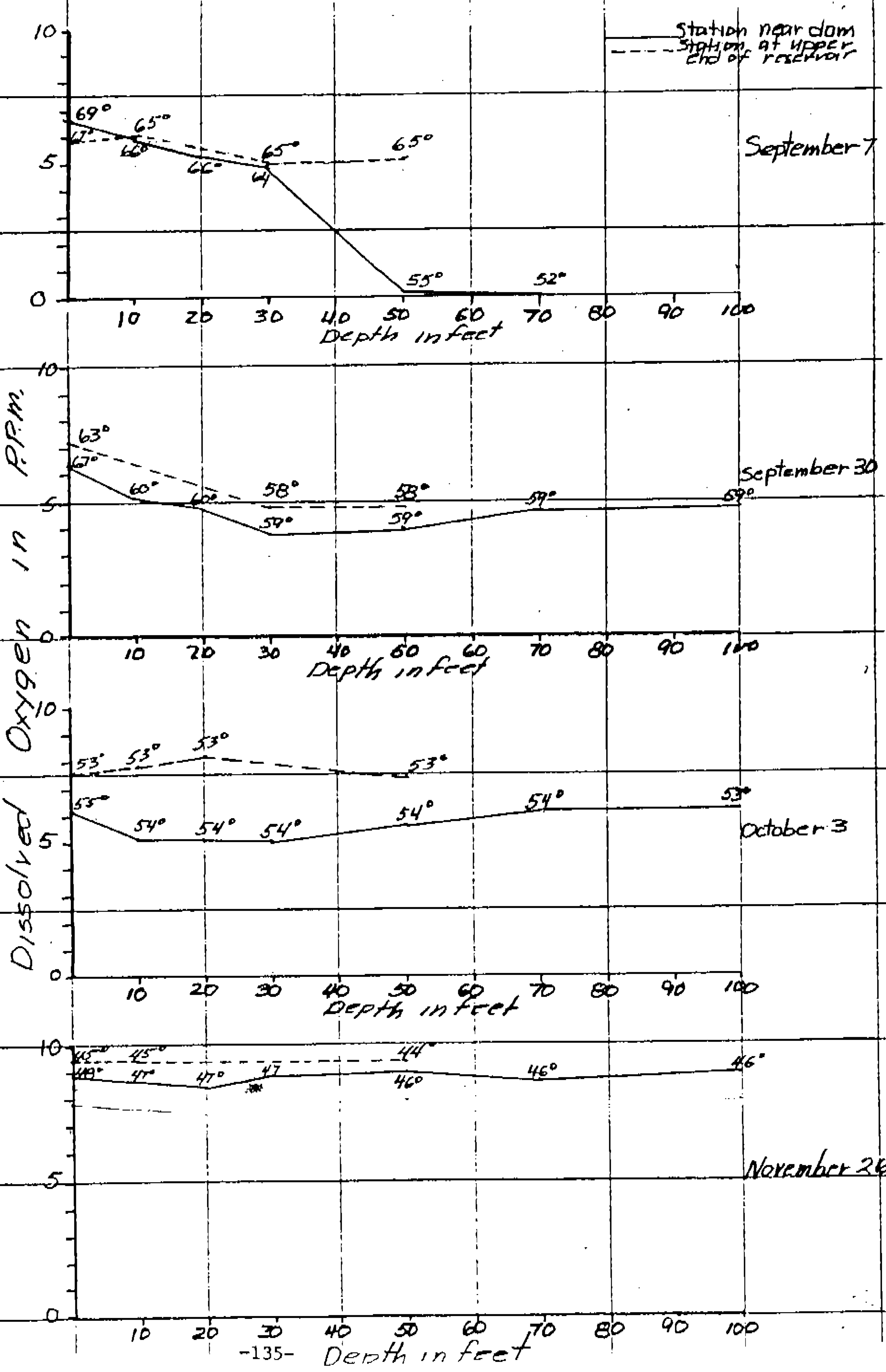


Figure 8A. Dissolved oxygen concentrations and water temperatures (F°) taken at two station on Copco Reservoir, 1965.

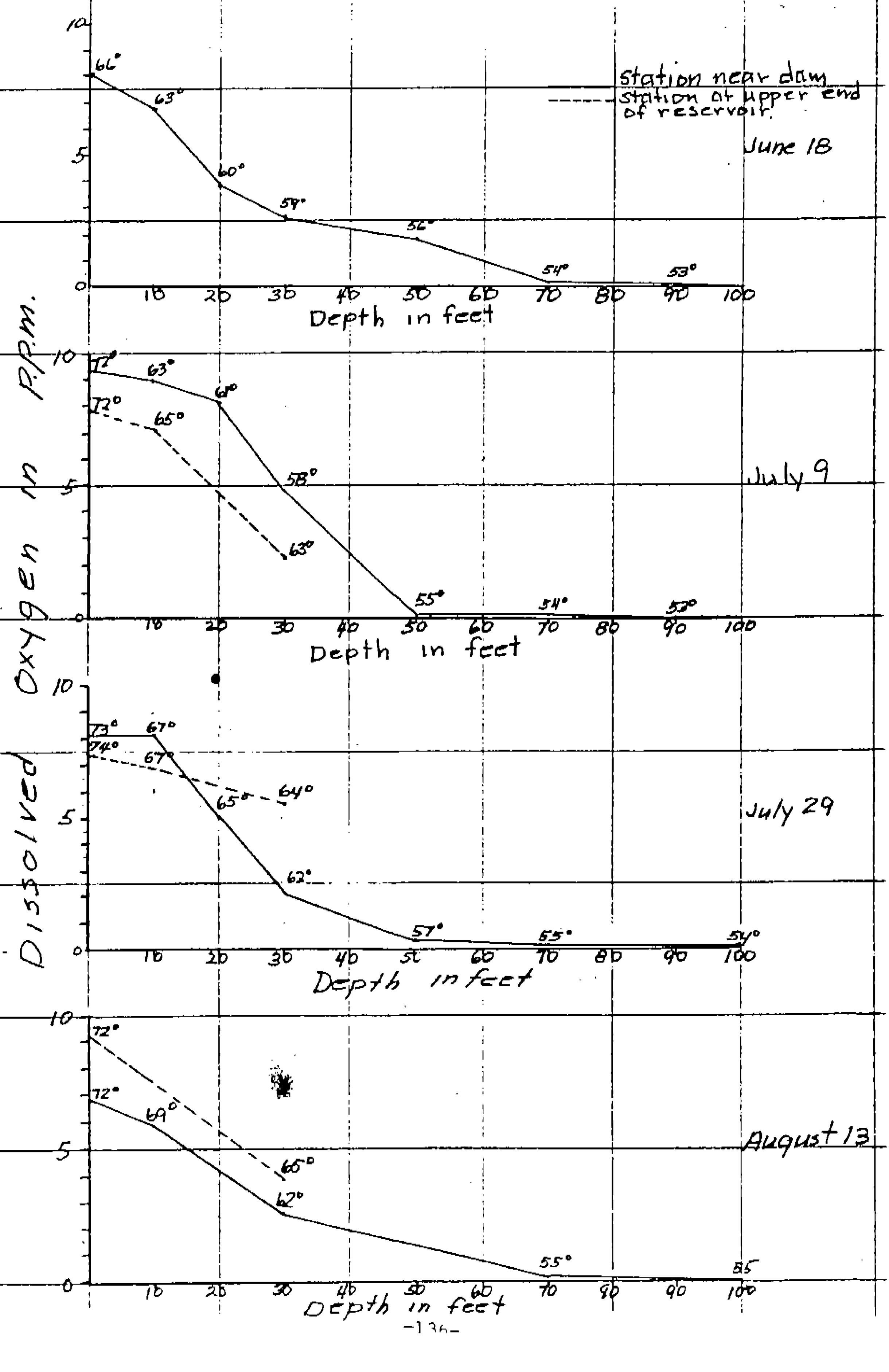
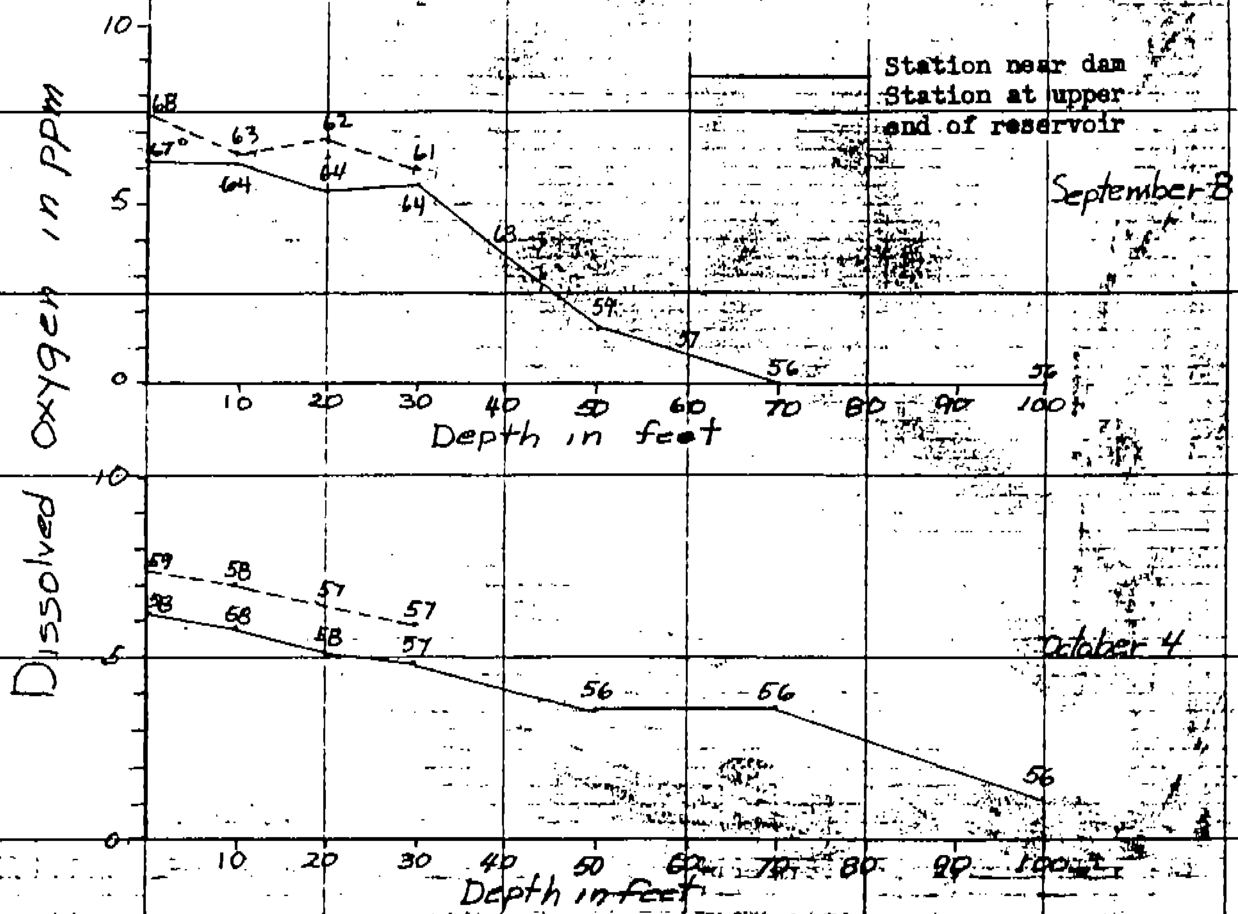


Figure 8B. Dissolved oxygen concentrations and water temperatures (F°) taken at two stations on [illegible] Reservoir, 1965.



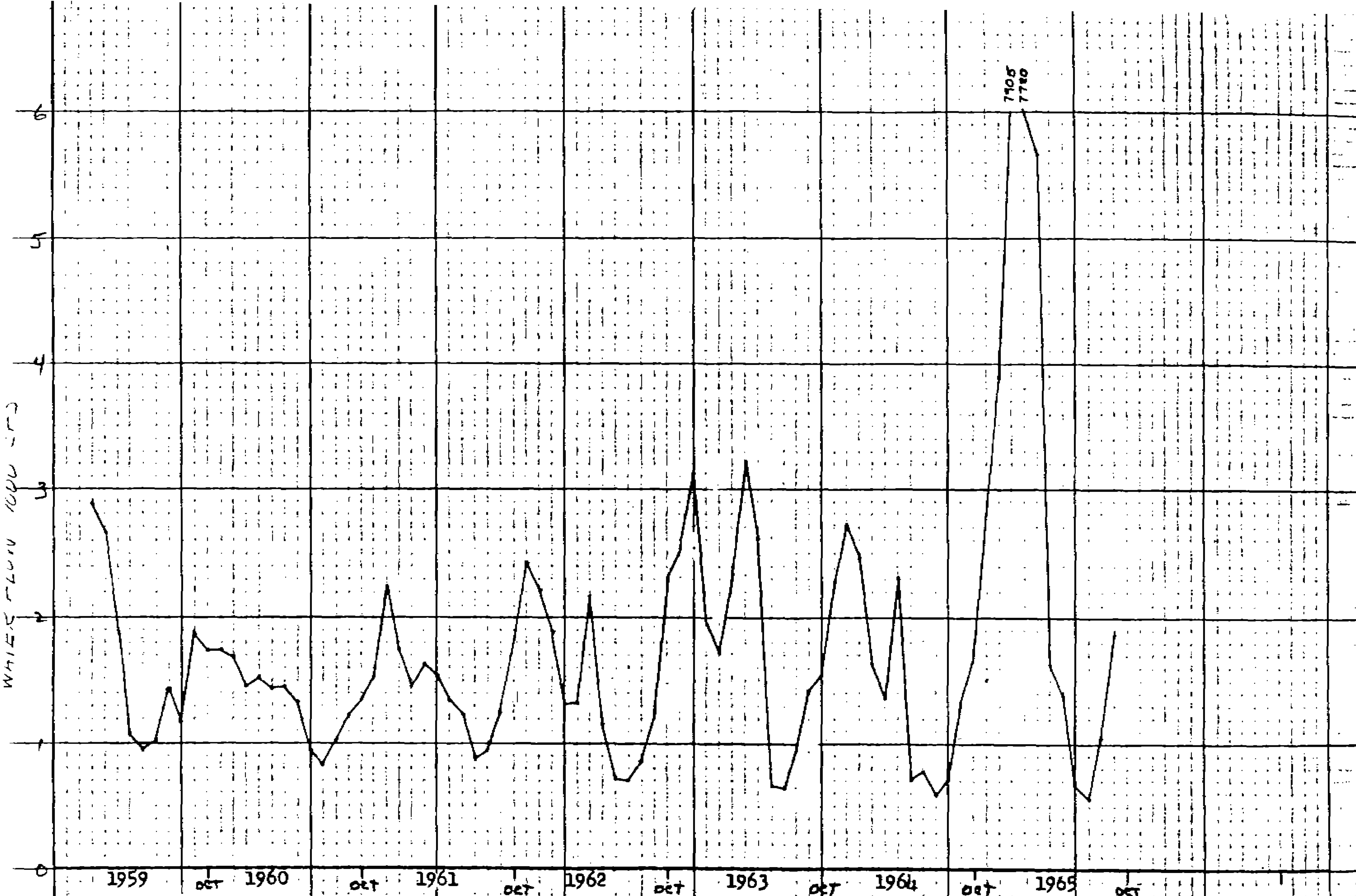


Figure 9. Monthly mean flows in Klamath River below J.C. Boyle power plant for water years 1959 - 1965 (from USGS).

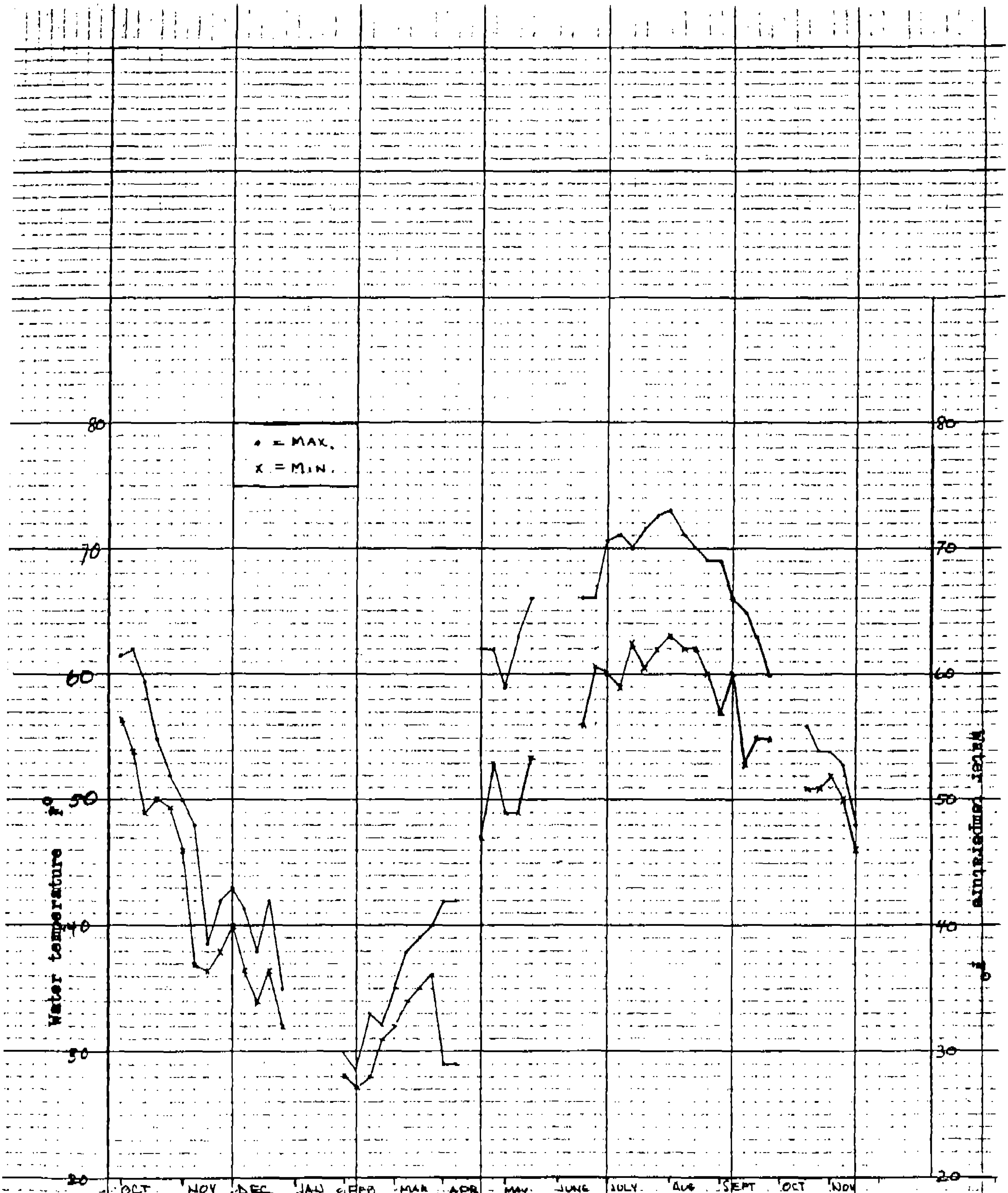


Figure 10. Weekly maximum and minimum water temperatures for Klamath River at Beswick, 1964-5.

Figure 11A. Dissolved oxygen concentrations and water temperatures (F^o) from three stations on Klamath River below J.C. Boyle Dam, 1965.

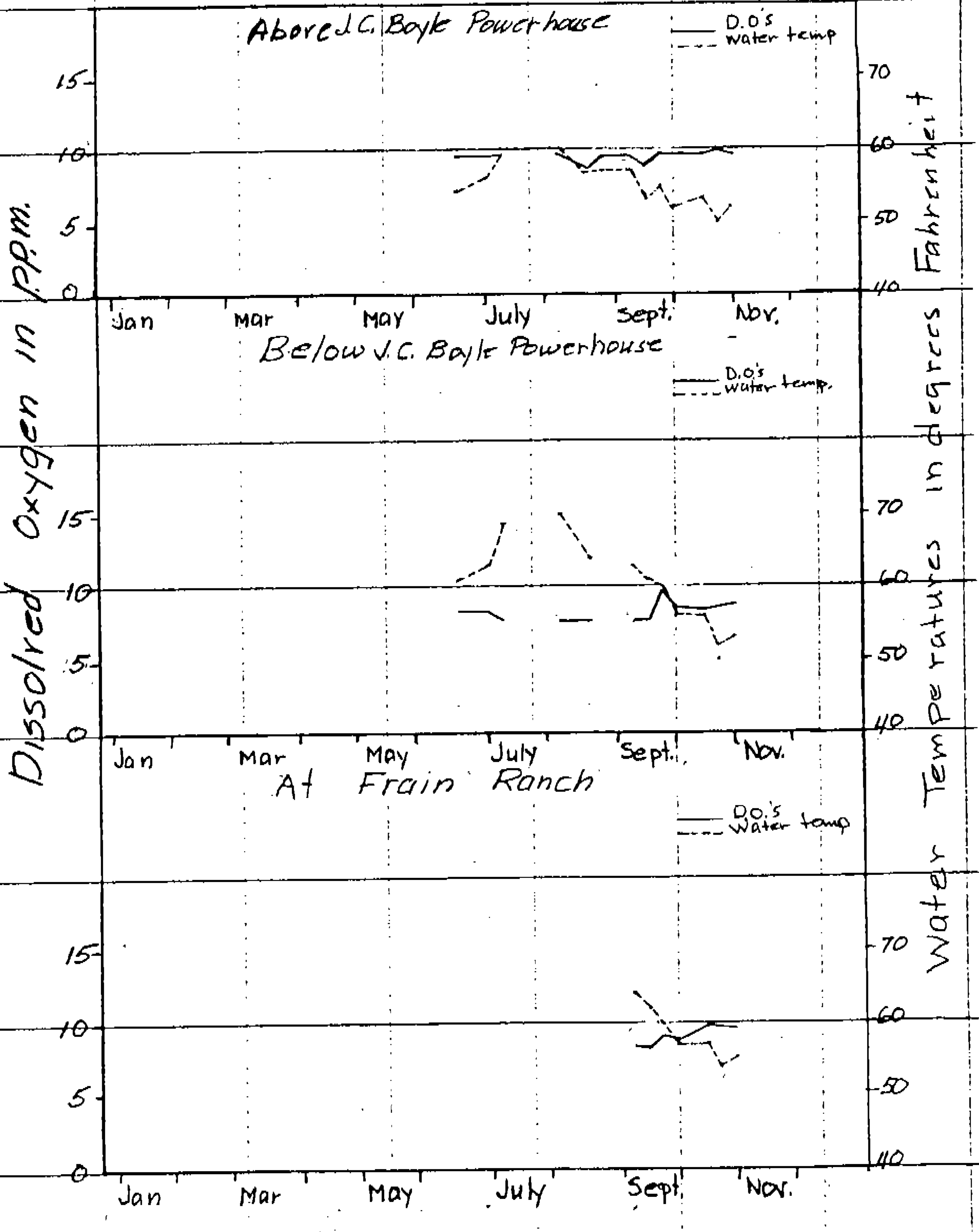


Figure 12. Dissolved oxygen concentrations and water temperatures (F°) taken from upper and lower ends of fish ladder at J.C. Boyle Dam, 1965.

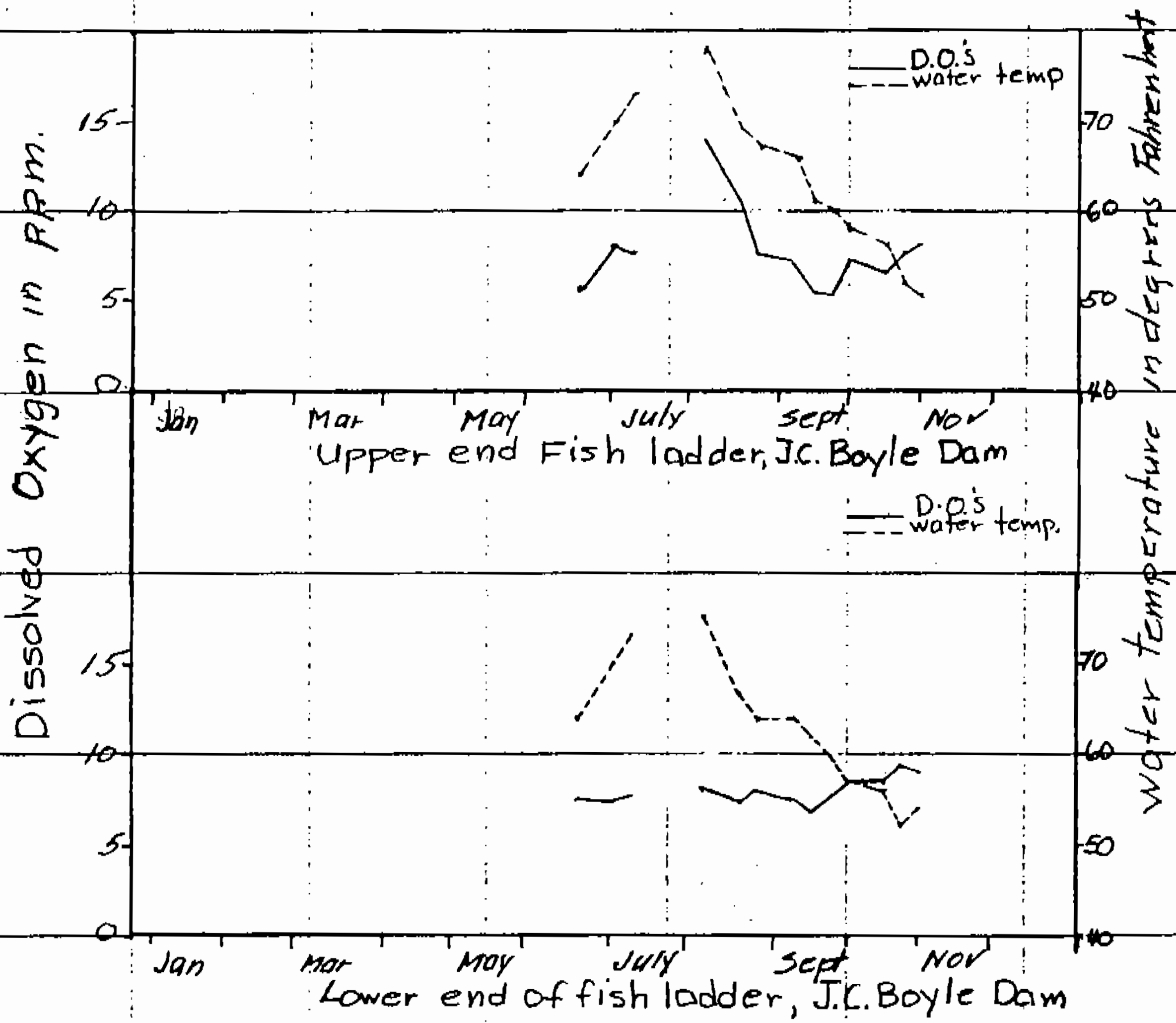


Figure 11B. Dissolved oxygen concentrations and water temperatures from Klamath River below fish by-pass at J.C. Boyle Dam, 1965.

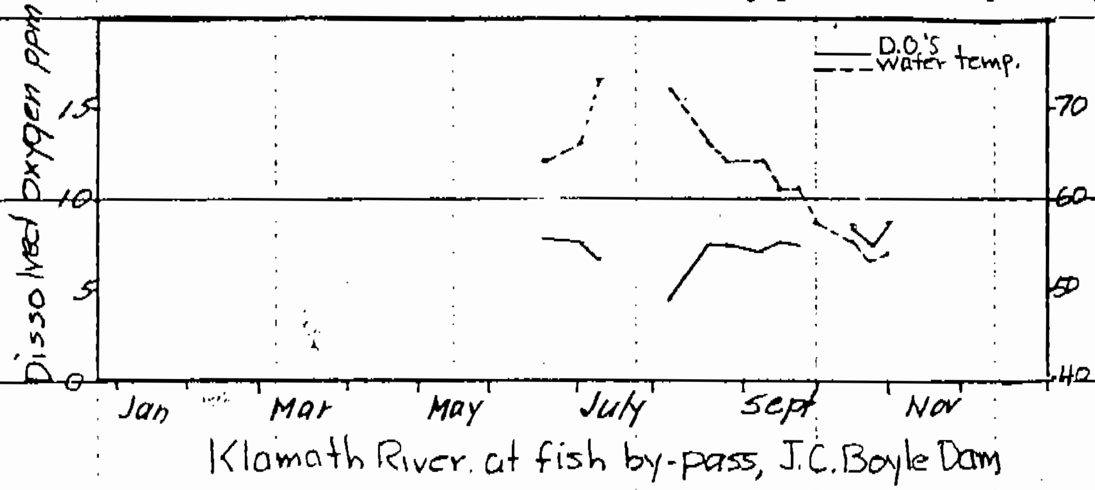


Figure 13. Dissolved oxygen profiles with water temperatures in J.C. Boyle Reservoir, 1965.

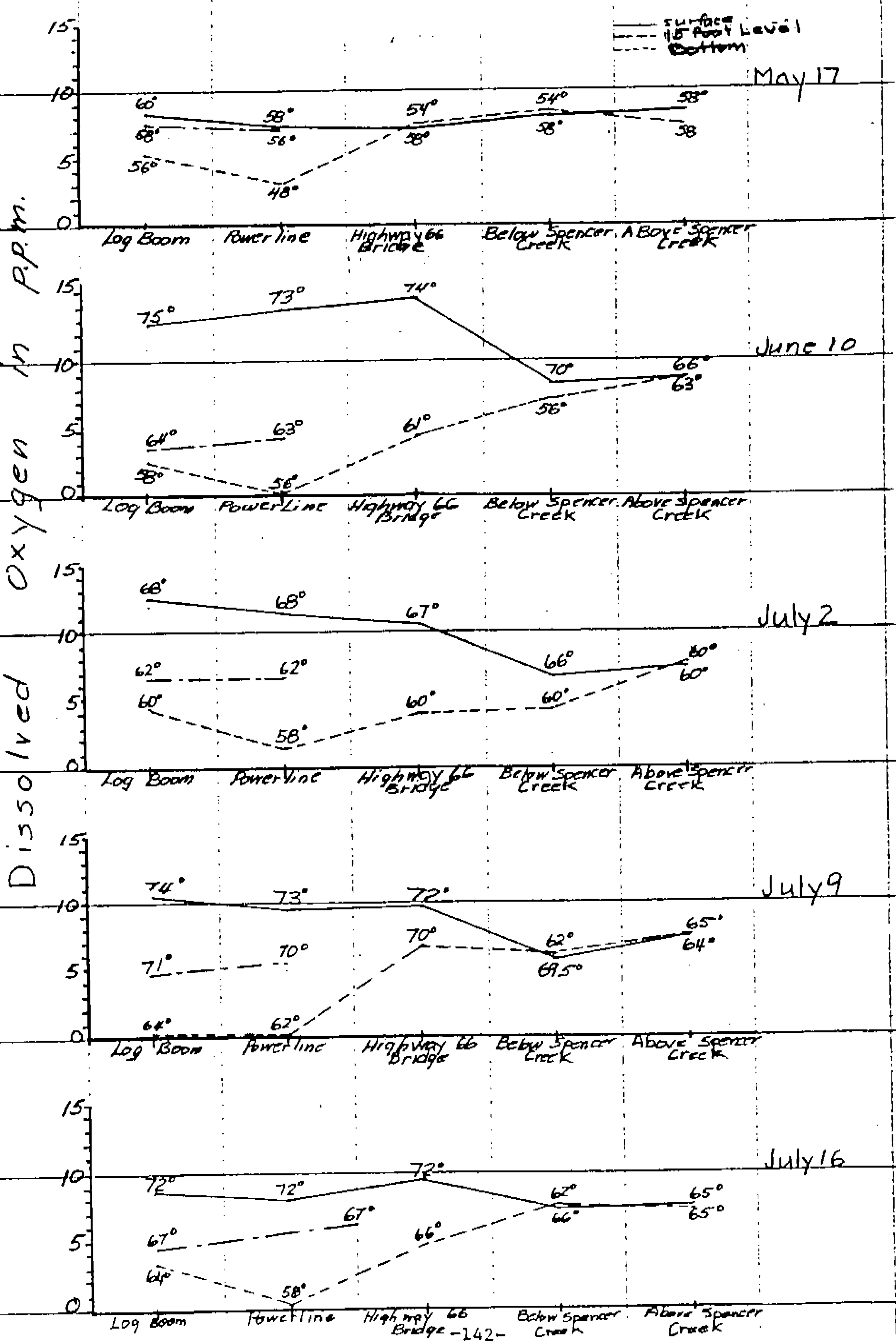


Figure 14. Dissolved oxygen profiles and water temperatures in J.C. Boyle Reservoir, 1965.

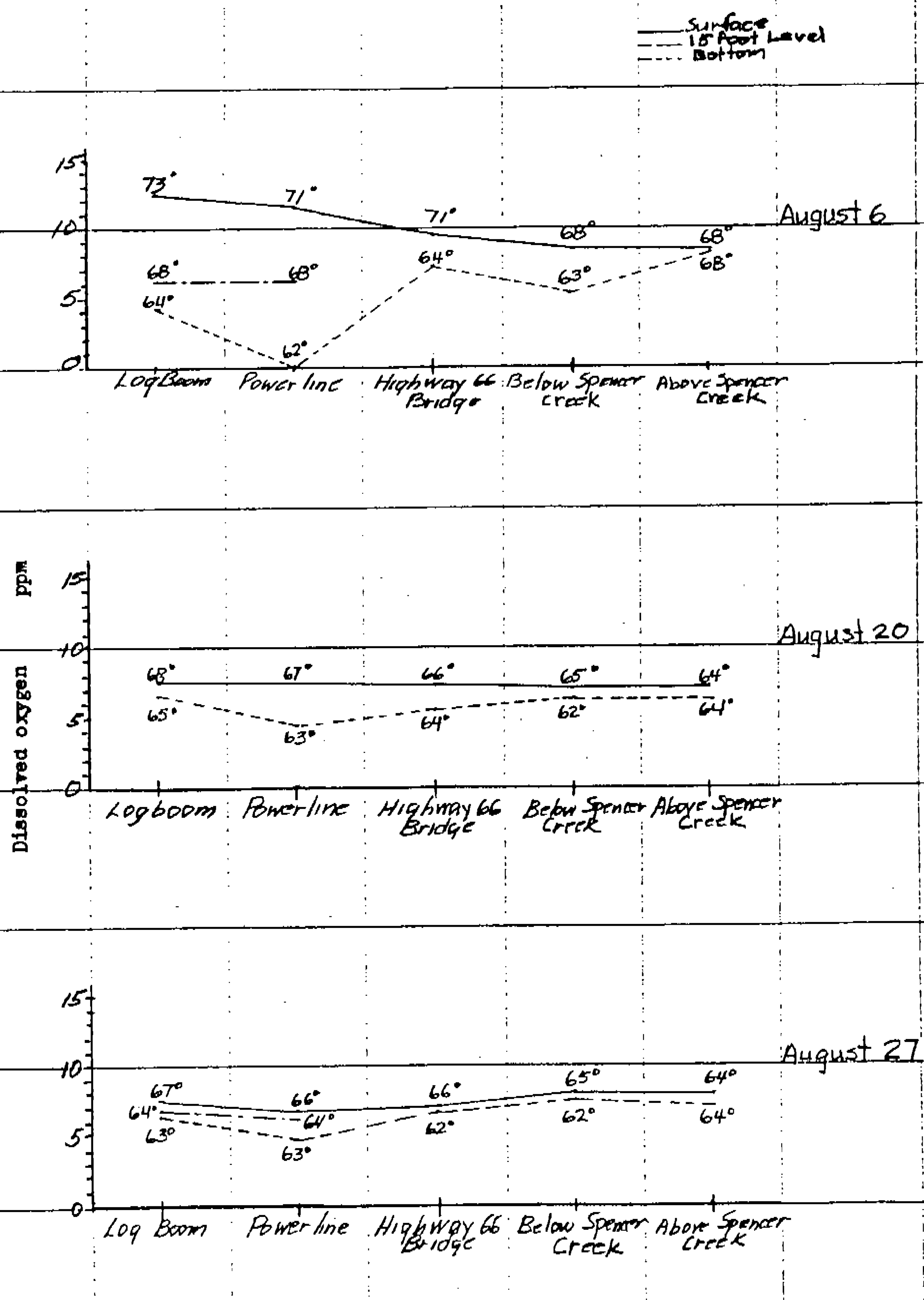


Figure 15. Dissolved oxygen concentrations with water temperatures (F°) found during 12 hour period at J.C. Boyle Reservoir, September 1-2, 1965.

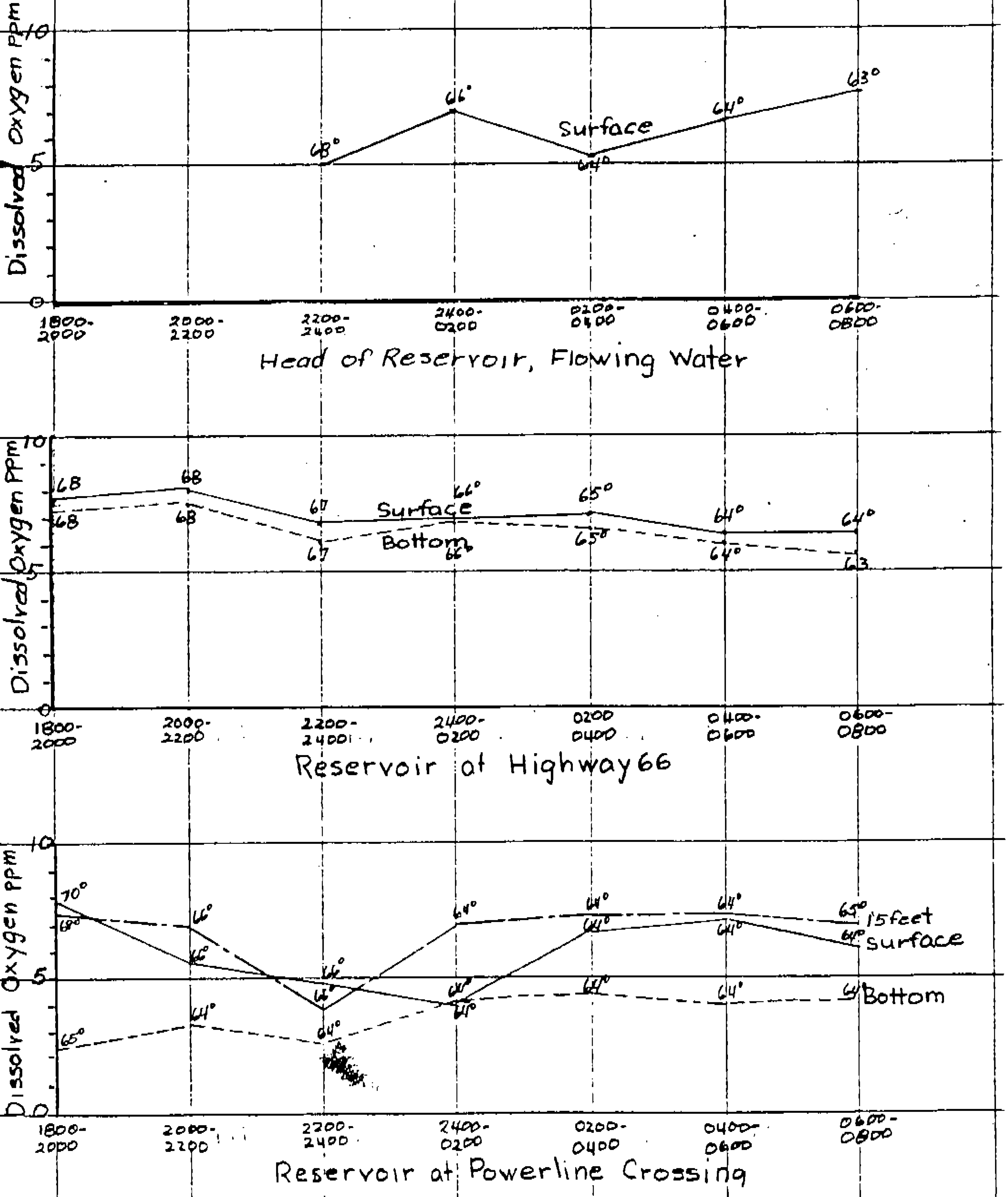


Figure 16. Dissolved oxygen concentrations with water temperatures (F°) found during 12 hour period on J.C. Boyle Reservoir September 1-2, 1965. (a)

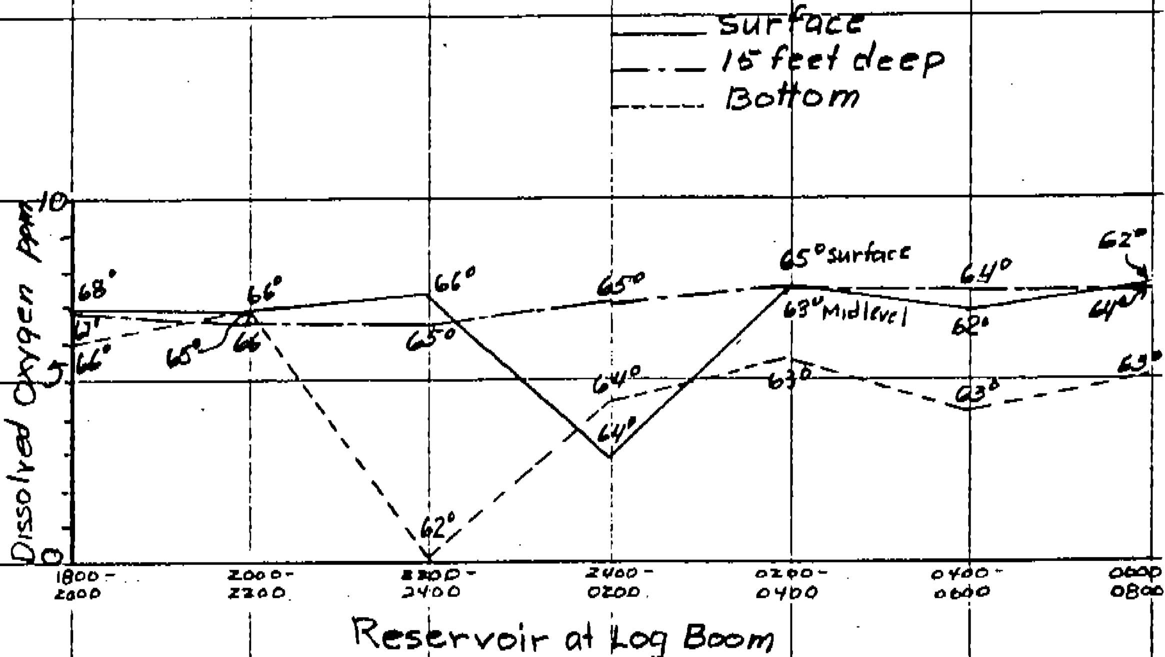
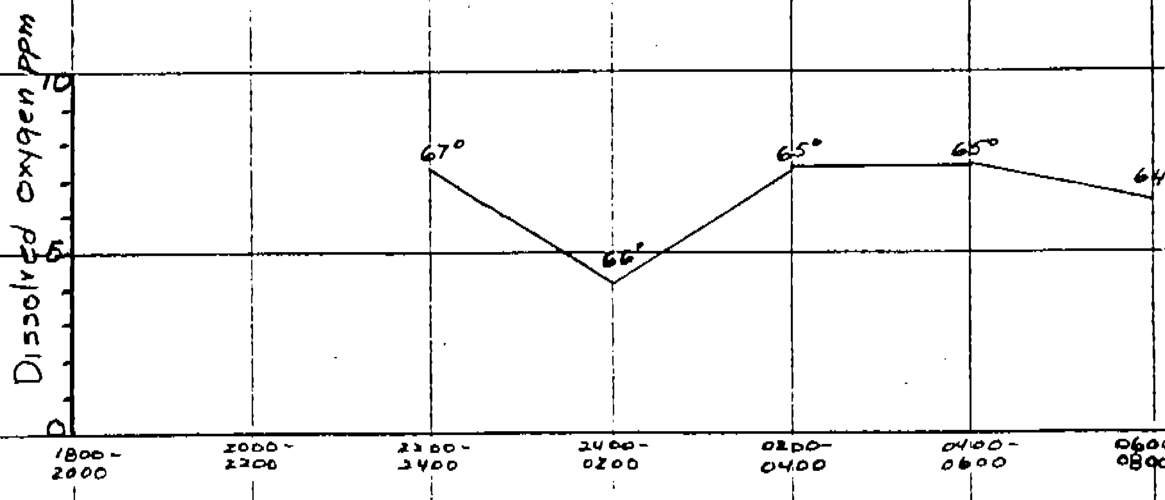


Figure 17. Dissolved oxygen concentrations with water temperatures (F°) found in Klamath River at bridge below J.C. Boyle Dam during 12 hour period, September 1-2, 1965. (a)



(a) The sag that occurs between 2200 and 0200 hours is because of the depletion of oxygen by the deterioration of a large algae bloom in the river.

Figure 18. Dissolved oxygen concentrations and water temperatures found at two stations on Spencer Creek, 1965.

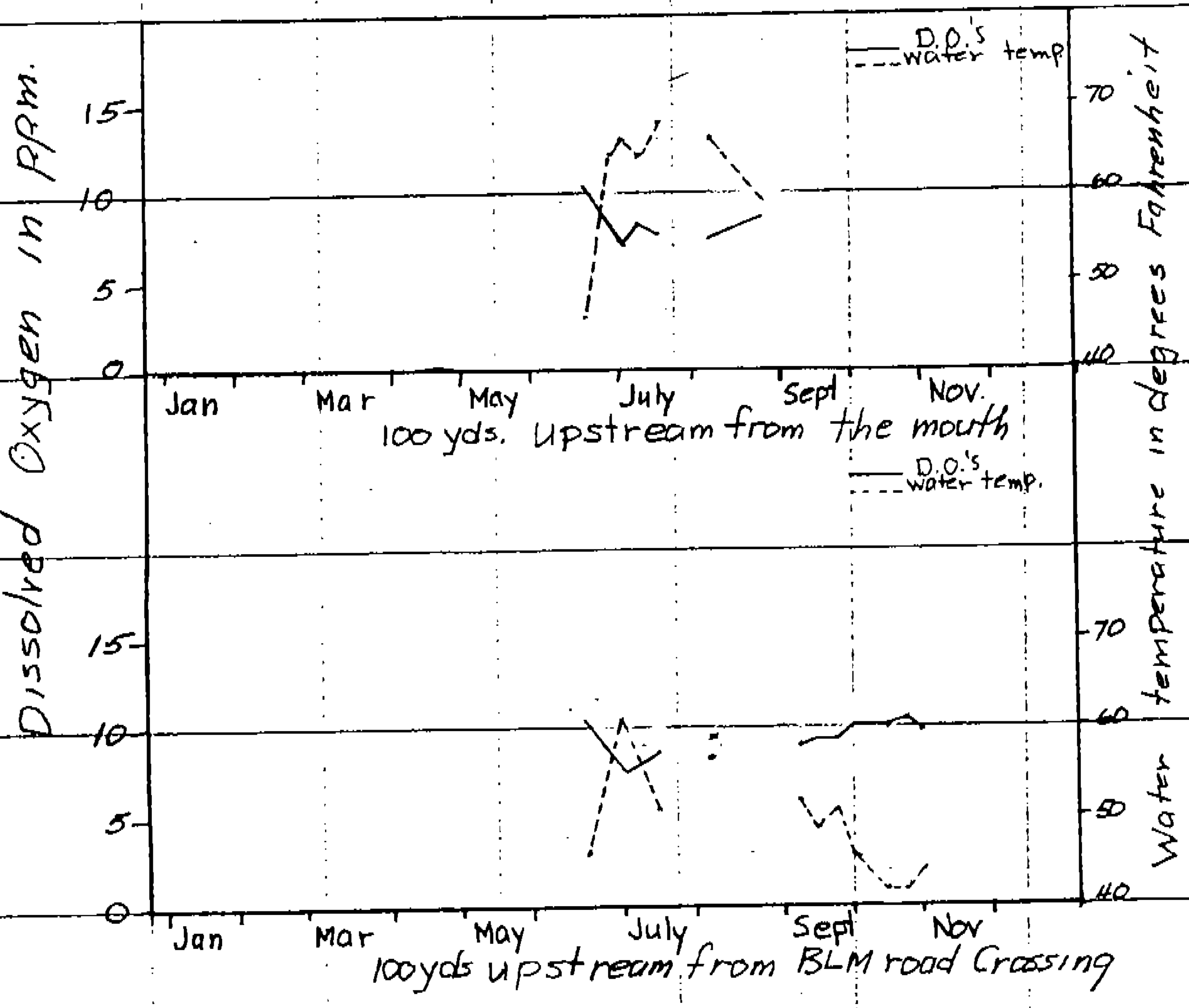


Figure 19. Weekly maximum and minimum water temperatures for Link River beginning January 6, 1965.

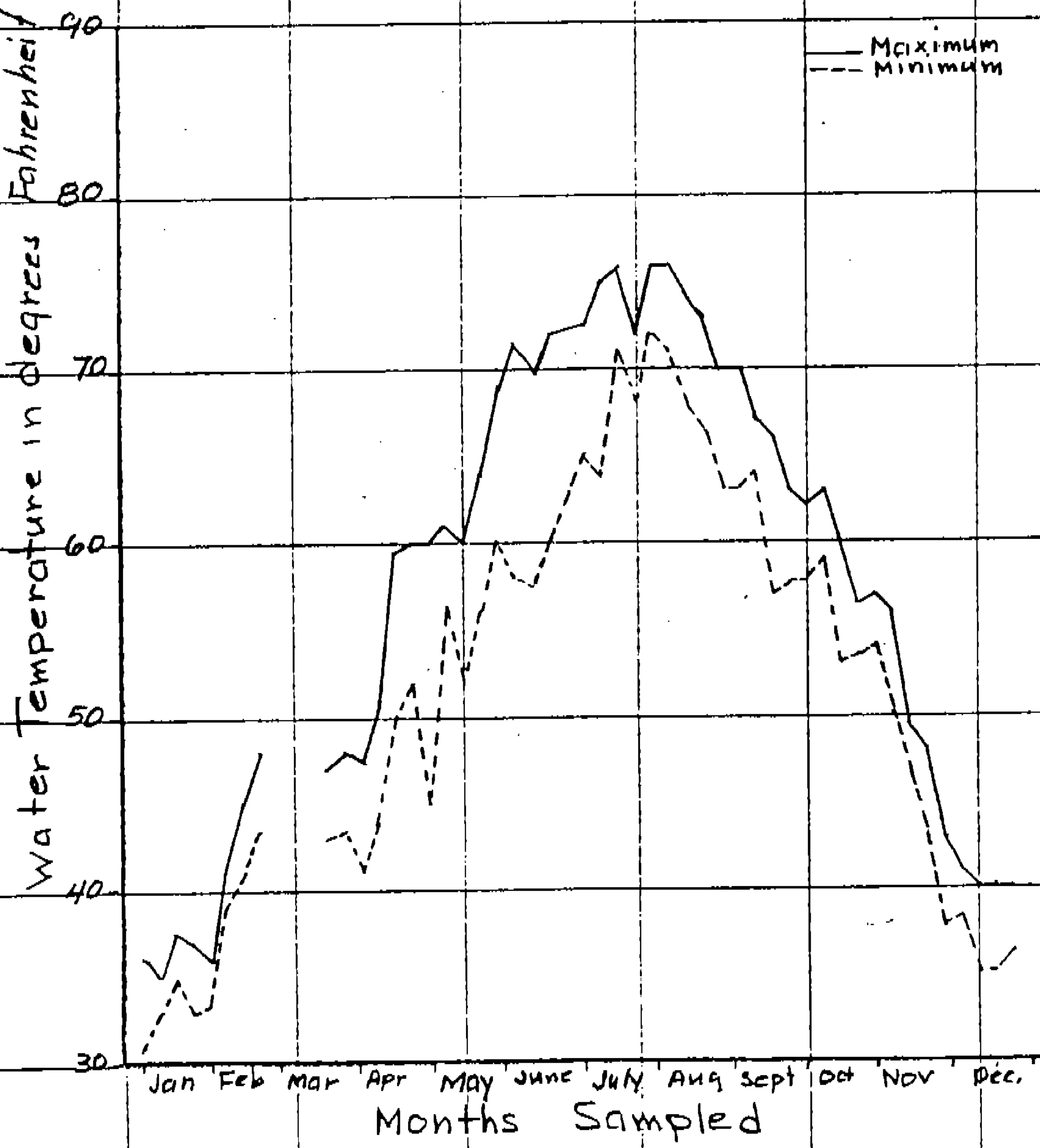


Figure 20. Dissolved oxygen concentrations with water temperatures (F^{o}) taken at three stations on Klamath River from Highway 97 downstream to Keno, 1965.

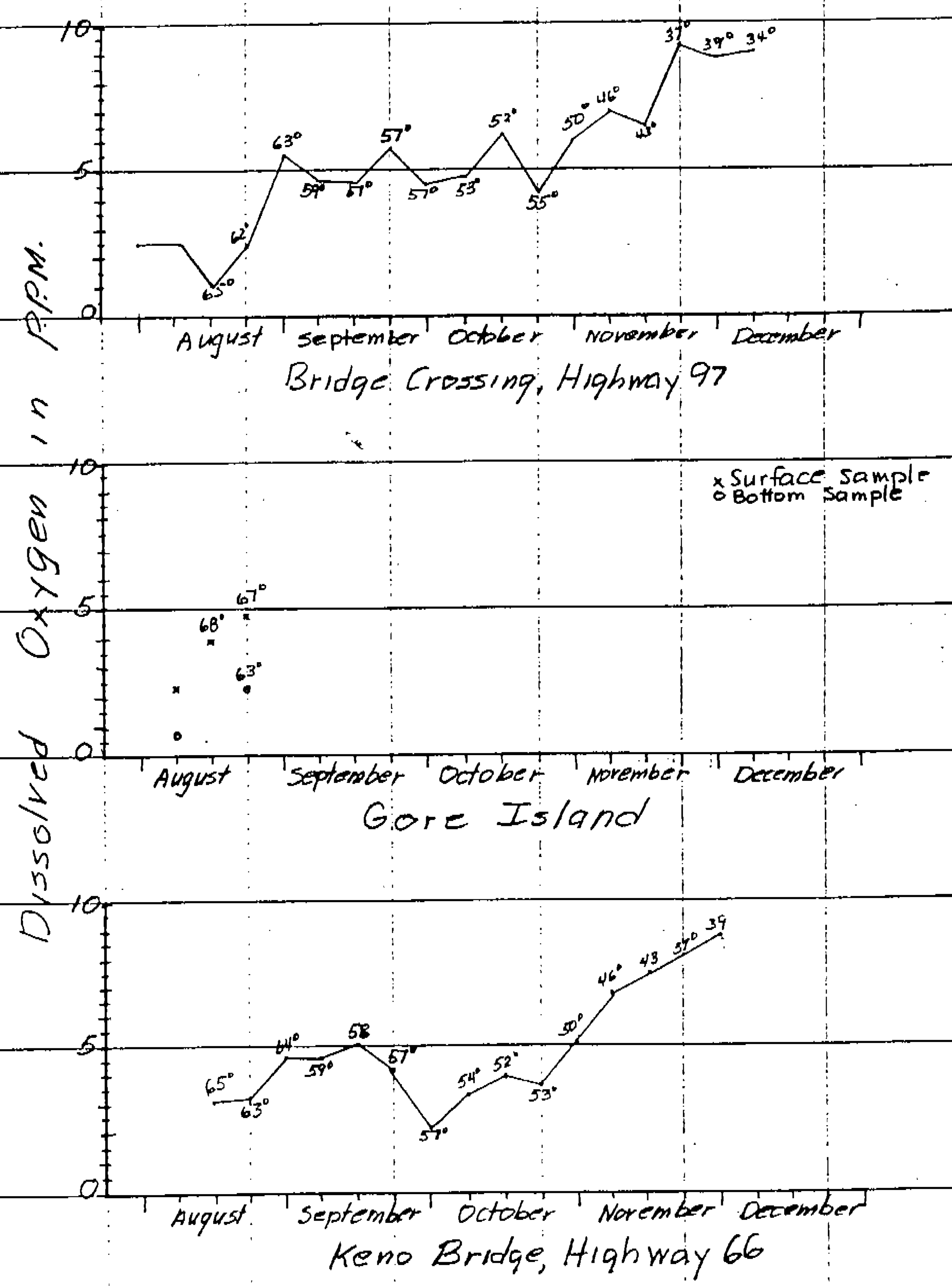


Figure 21. Dissolved oxygen concentrations found by the Oregon State Sanitary Authority at stations between Klamath Lake and Keno, 1953.

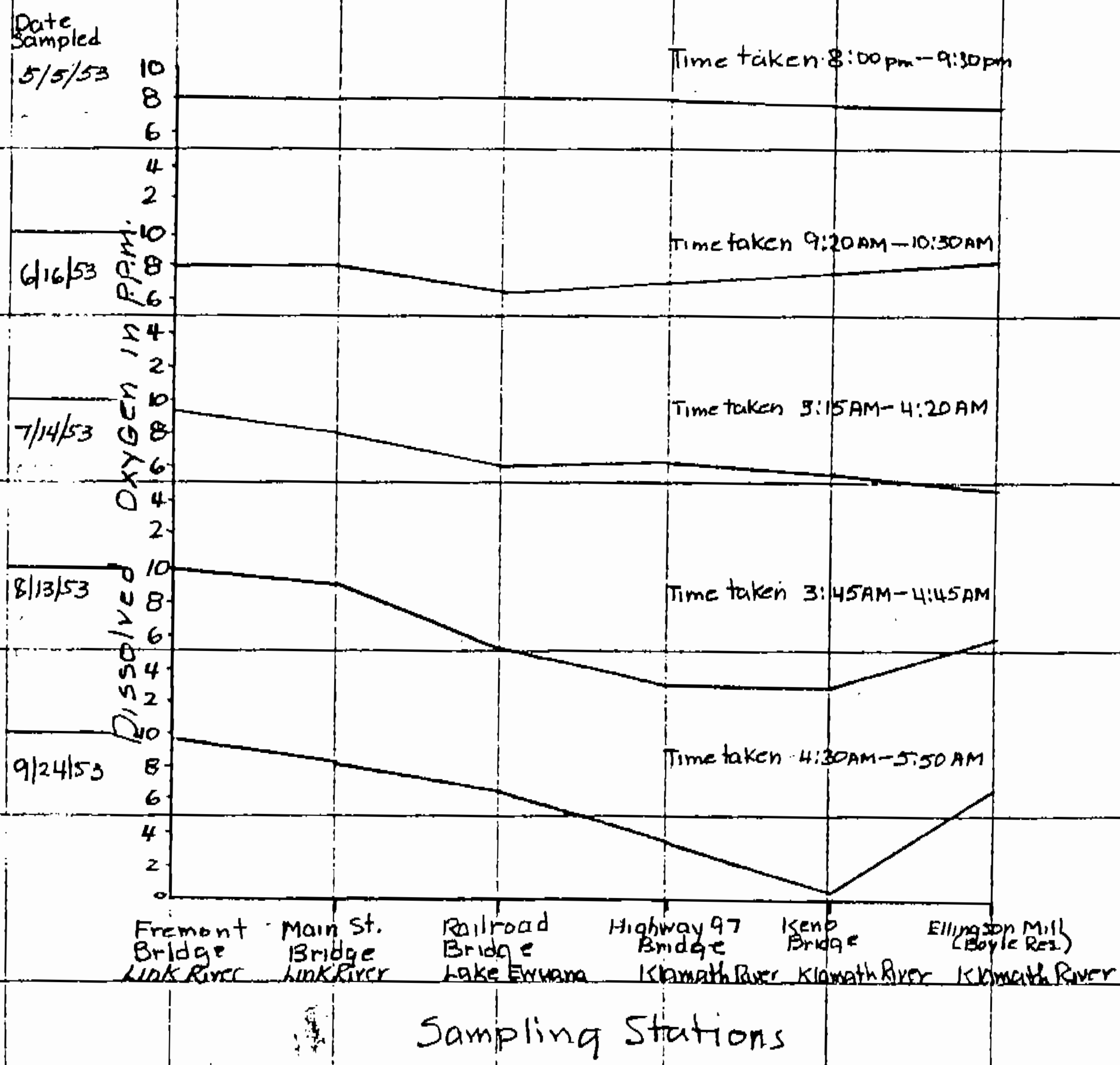


Figure 22. Water quality and flow measurements for Klamath River from Oregon State Sanitary Authority survey, September 24, 1953.

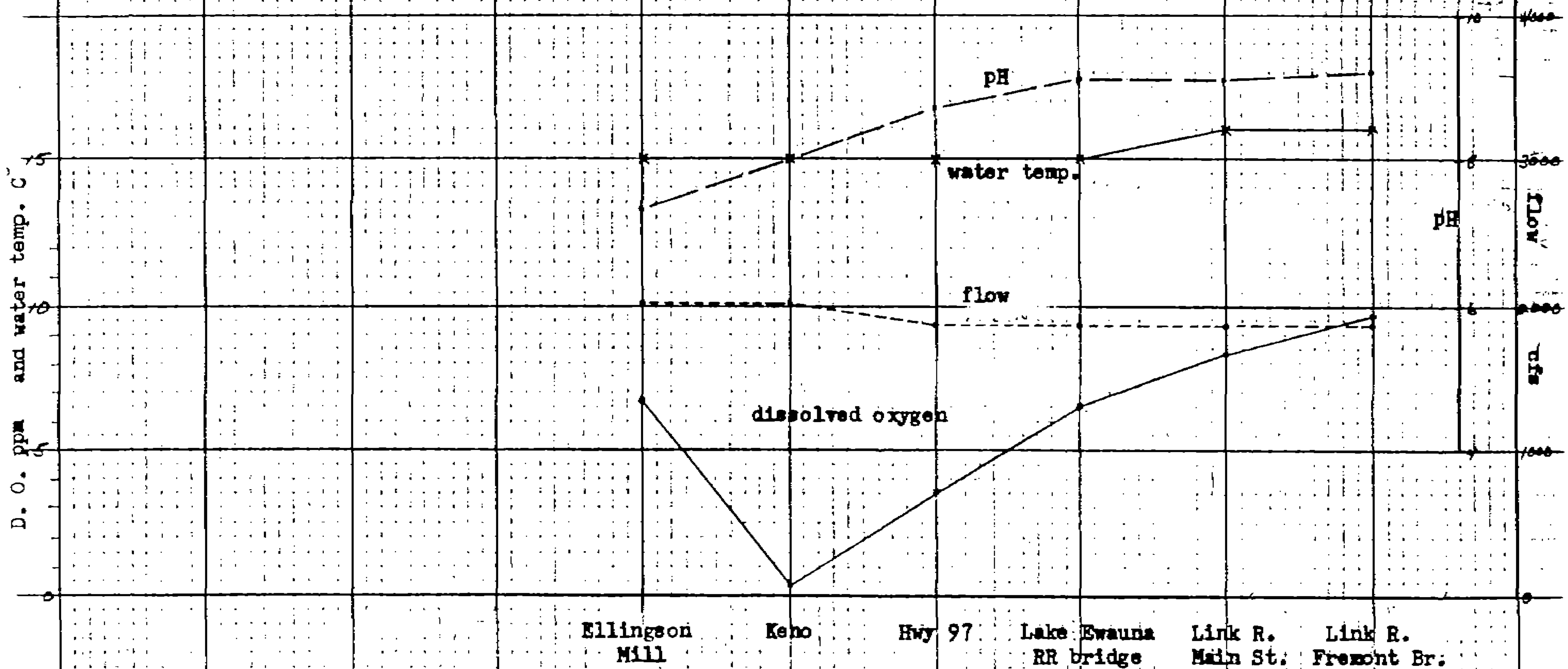


Figure 23. Dissolved oxygen concentrations found by Oregon State Sanitary Authority at Stations from Klamath Lake to J.C. Boyle powerhouse, 1959.

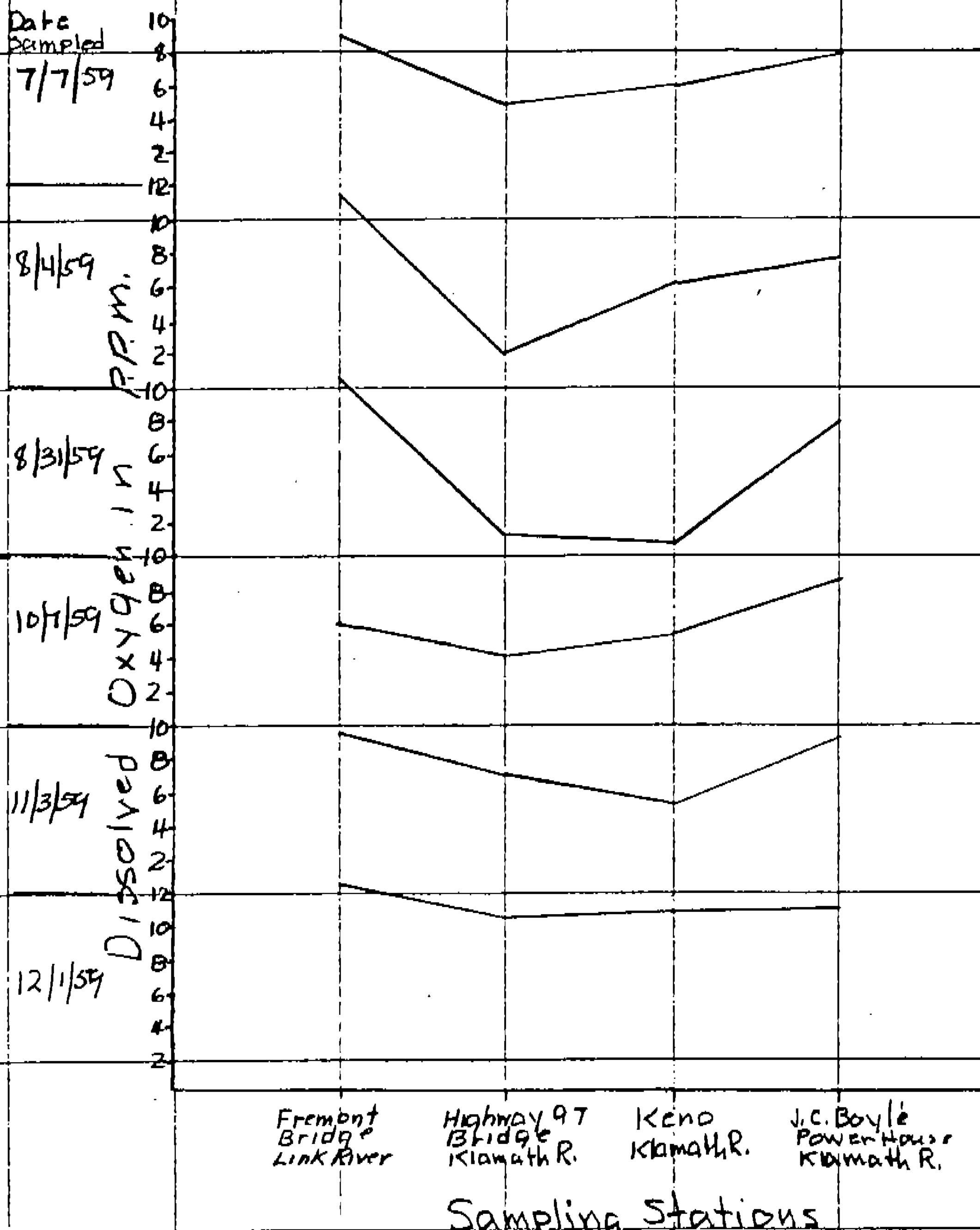


Figure 24. Water quality and flow measurements for Klamath River found by Oregon State Sanitary Authority, October 7, 1959.

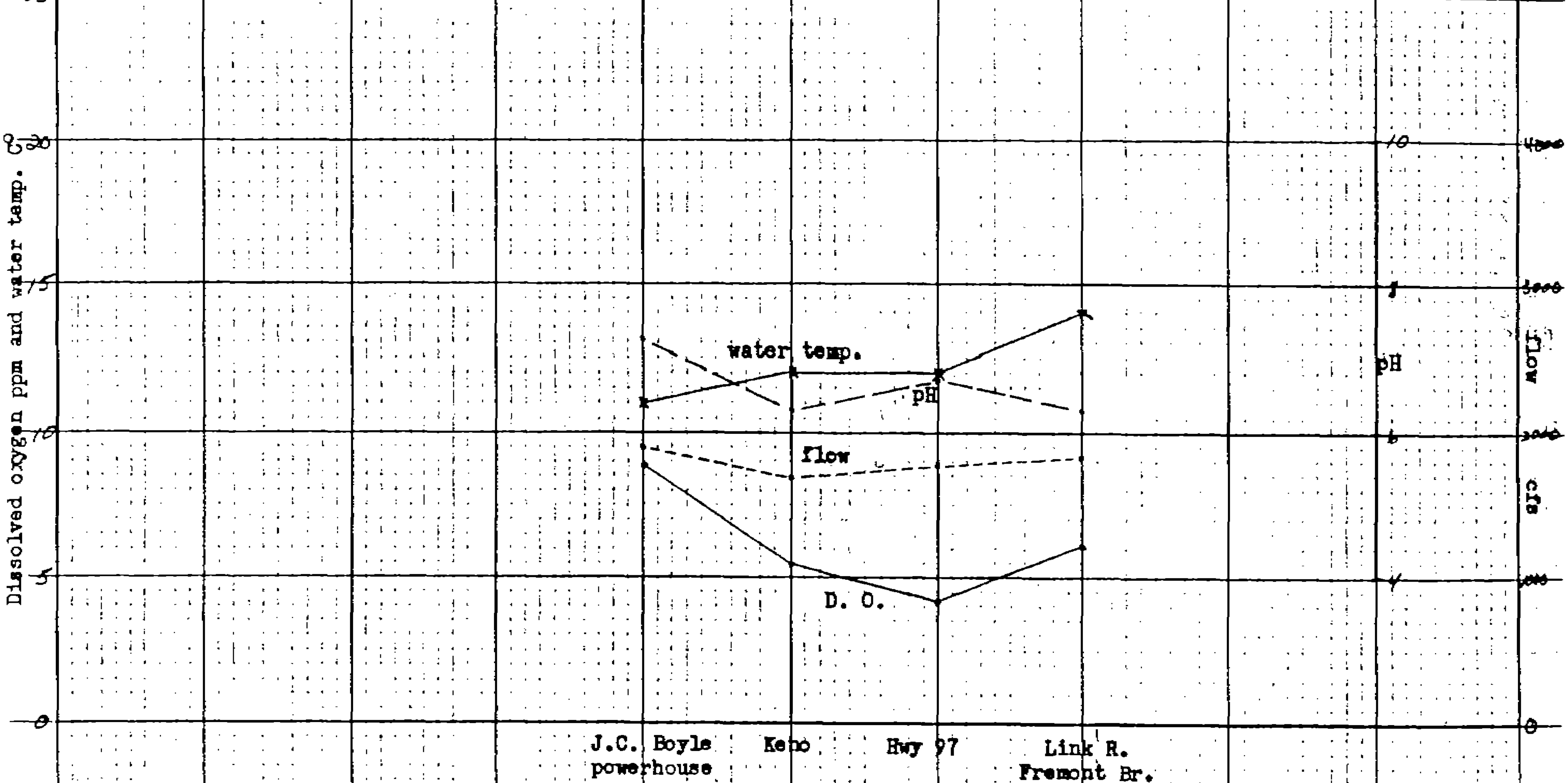


Figure 25. Dissolved oxygen concentrations found by Oregon State Sanitary Authority at stations from Klamath Lake to J.C.Boyle powerhouse, 1960.

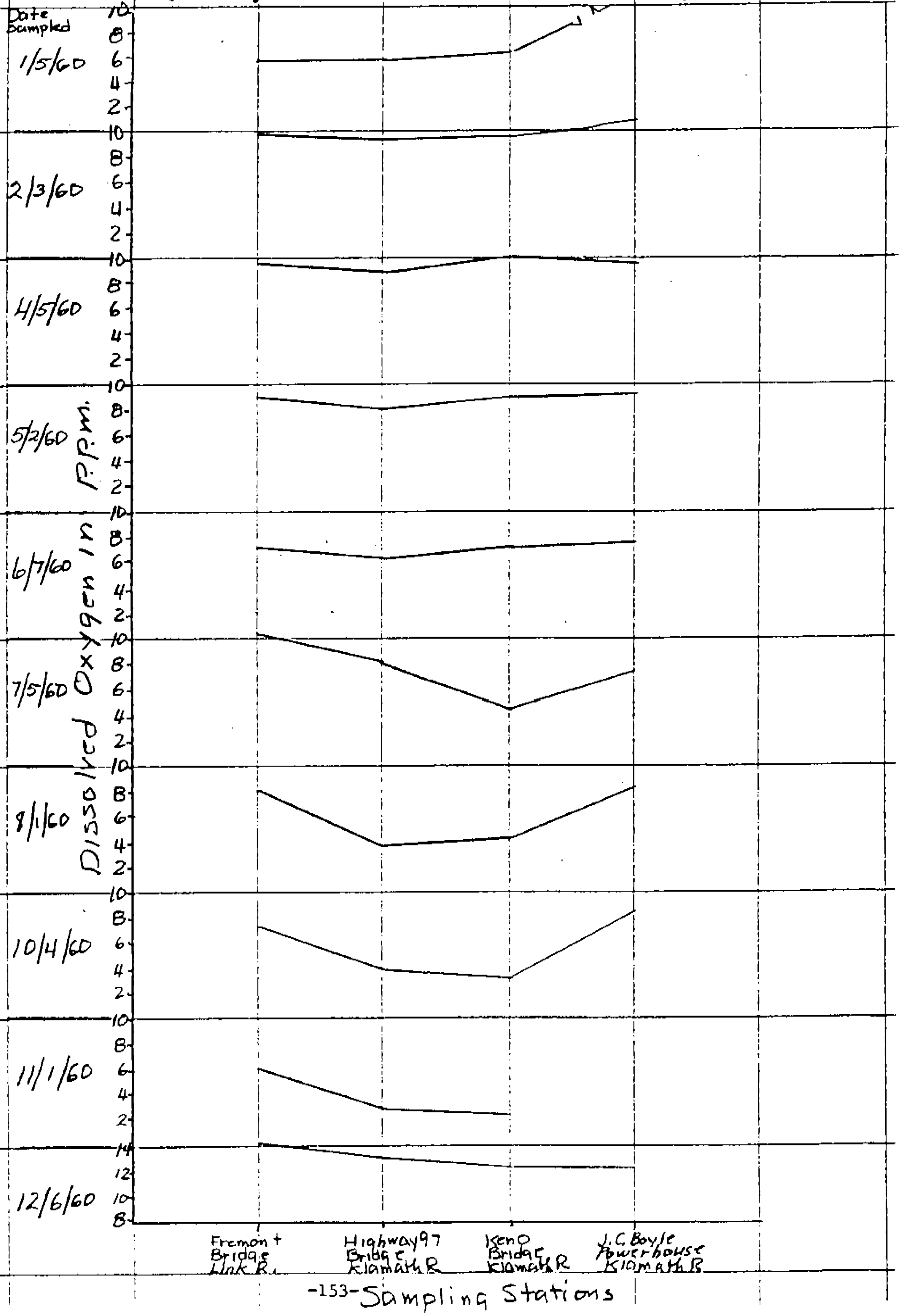


Figure 26. Water quality and flow measurements for Klamath River from Oregon State Sanitary Authority, October 4, 1960.

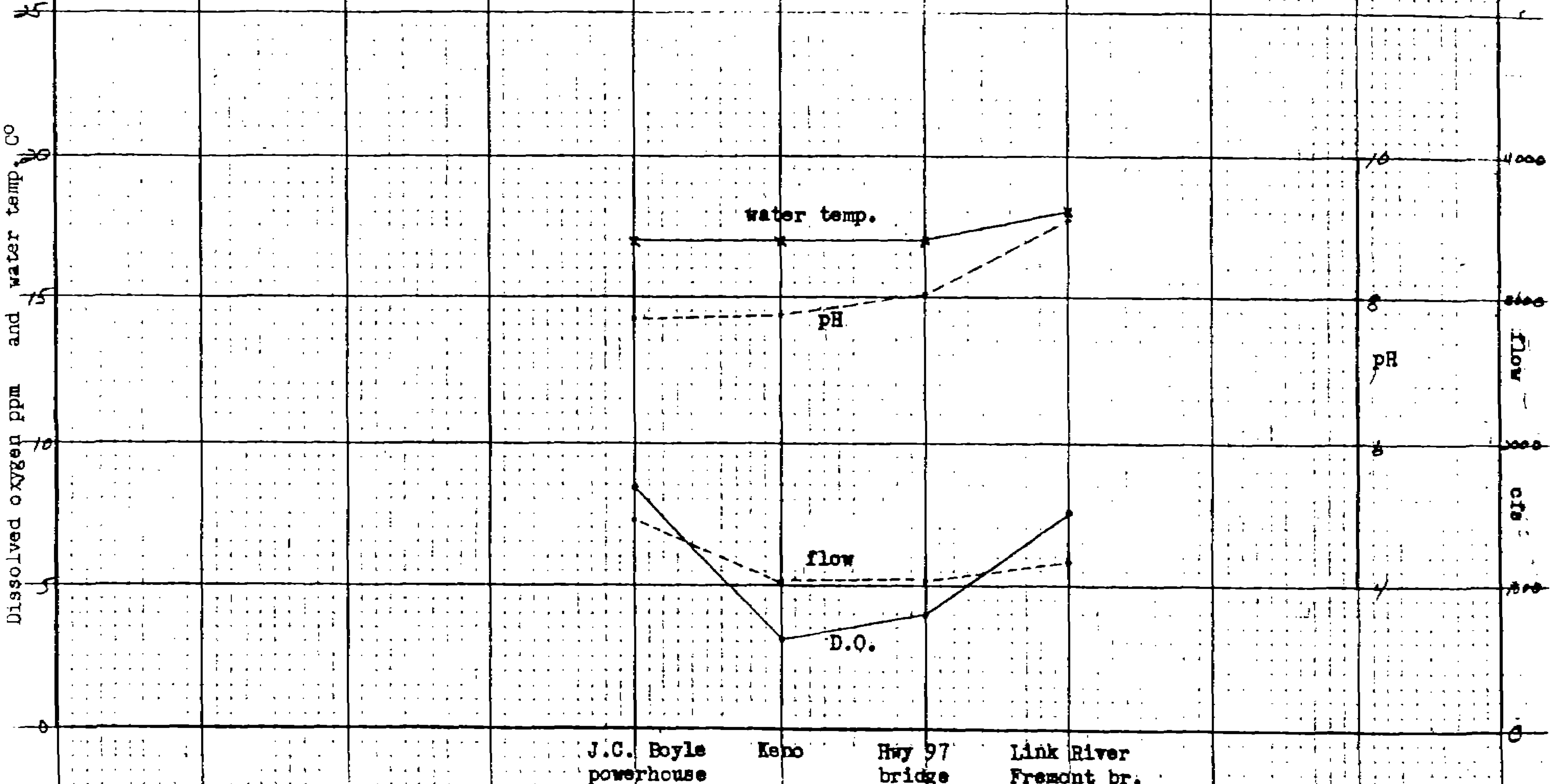


Figure 27. Dissolved oxygen concentrations taken by Oregon State Sanitary Authority at stations from Klamath Lake to J.C. Boyle powerhouse, 1961.

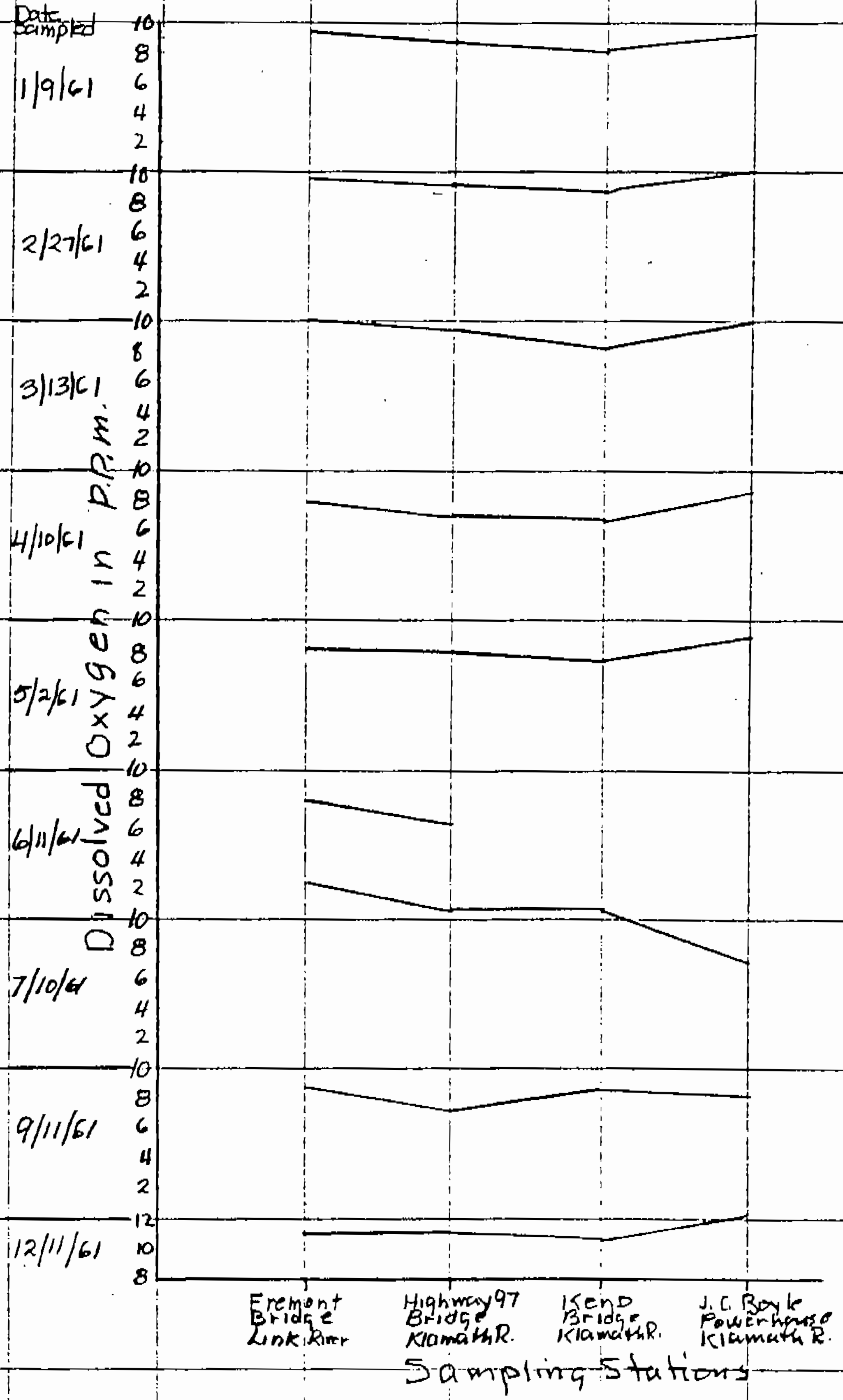


Figure 28. Water quality and flow measurements for Klamath River from Oregon State Sanitary Authority, September 11, 1961.

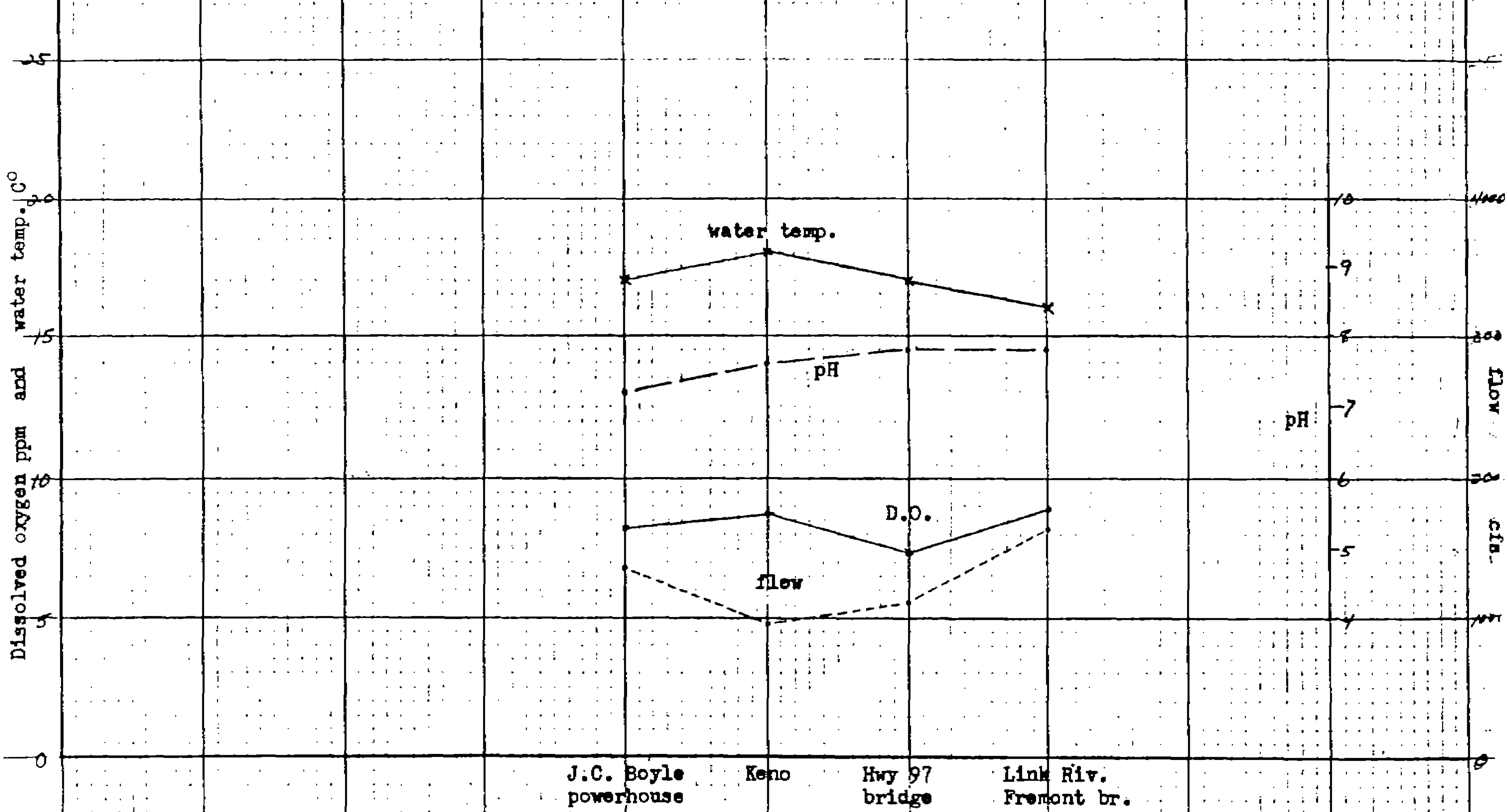


Figure 29. Dissolved oxygen concentrations found by Oregon State Sanitary Authority at stations from Klamath Lake to J.C. Boyle powerhouse, 1962 and1963.

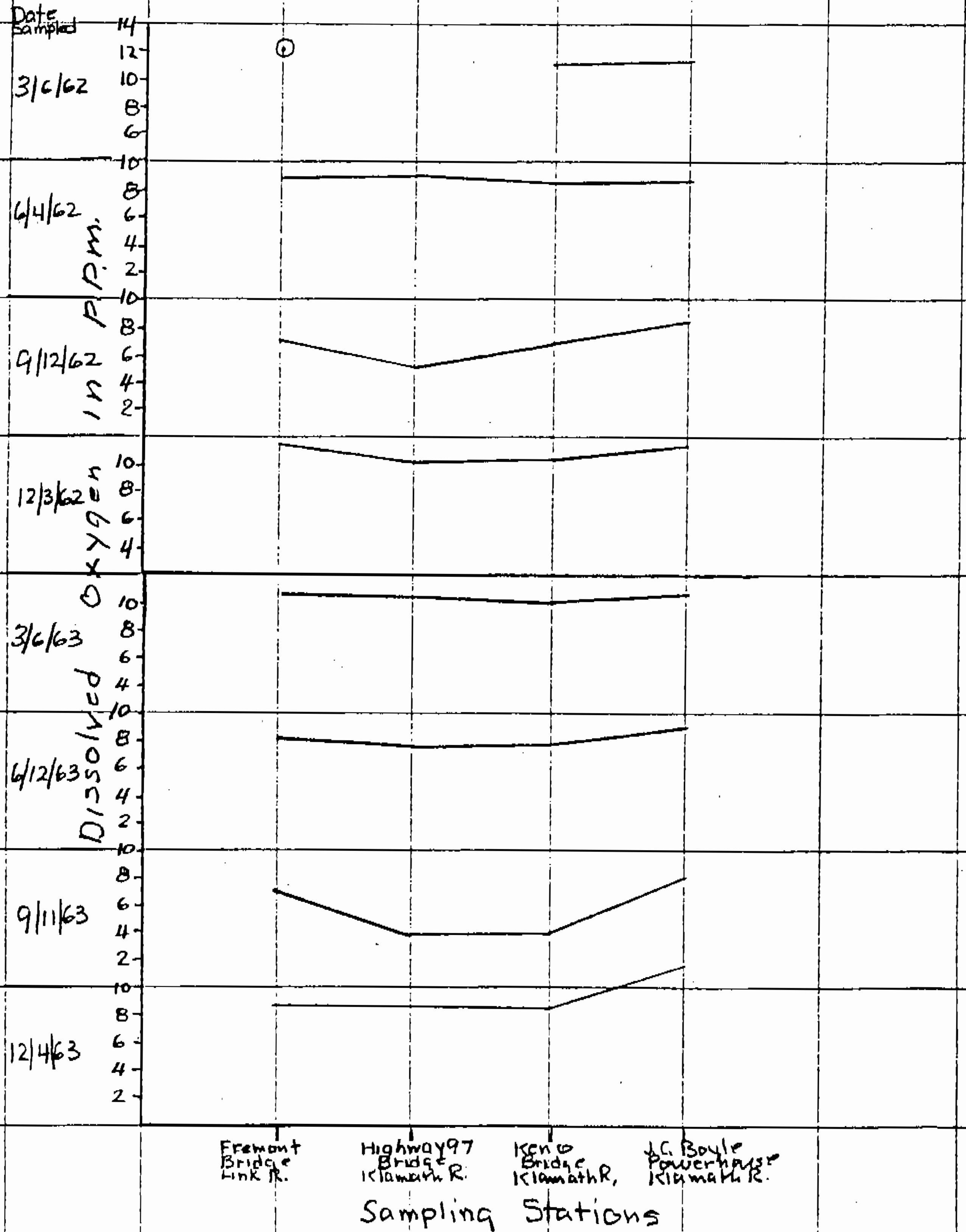


Figure 30. Water quality and flow measurements for Klamath River from Oregon State Sanitary Authority, September 12, 1962.

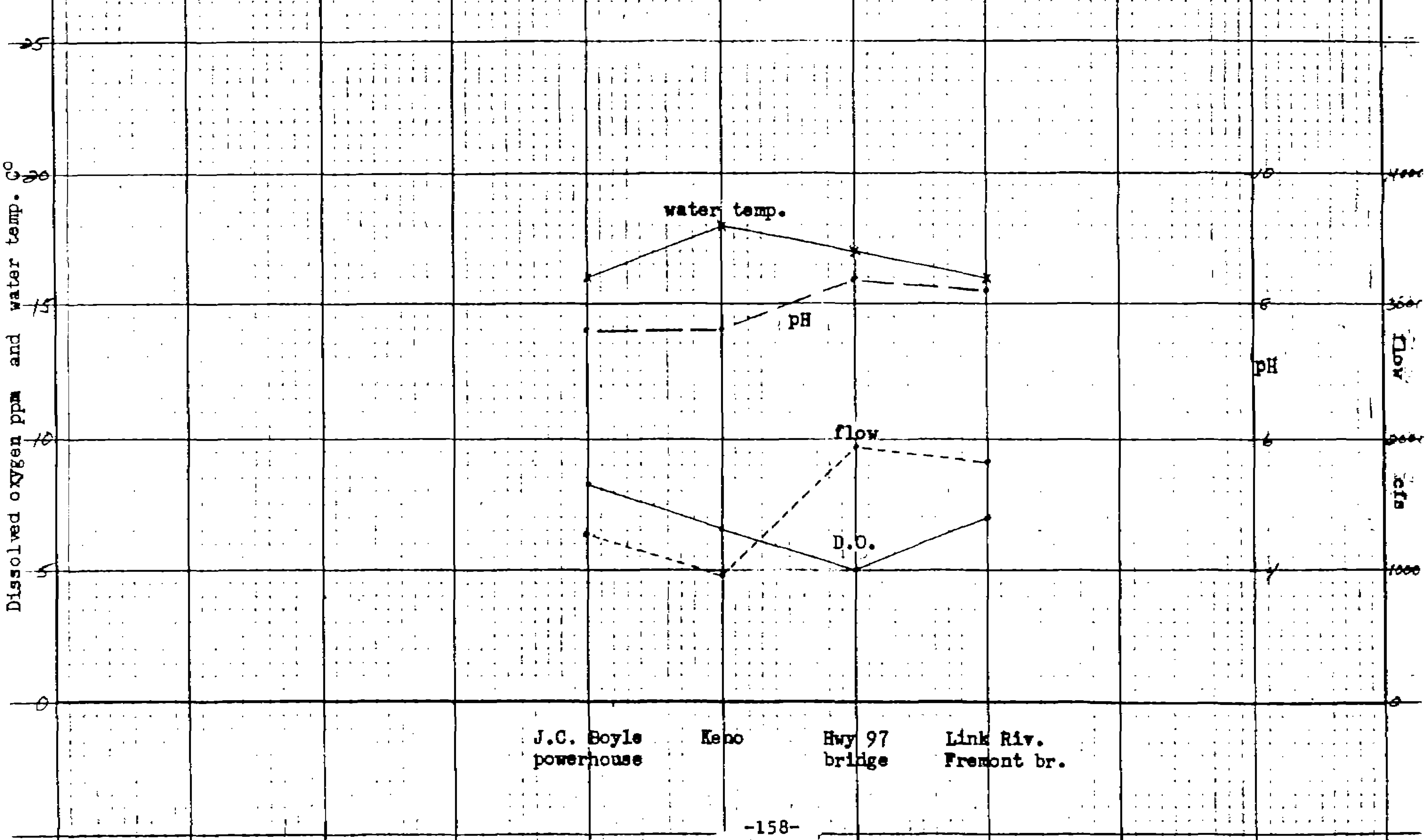


Figure 31. Water quality and flow measurements for Klamath River from Oregon State Sanitary Authority, September 11, 1963.

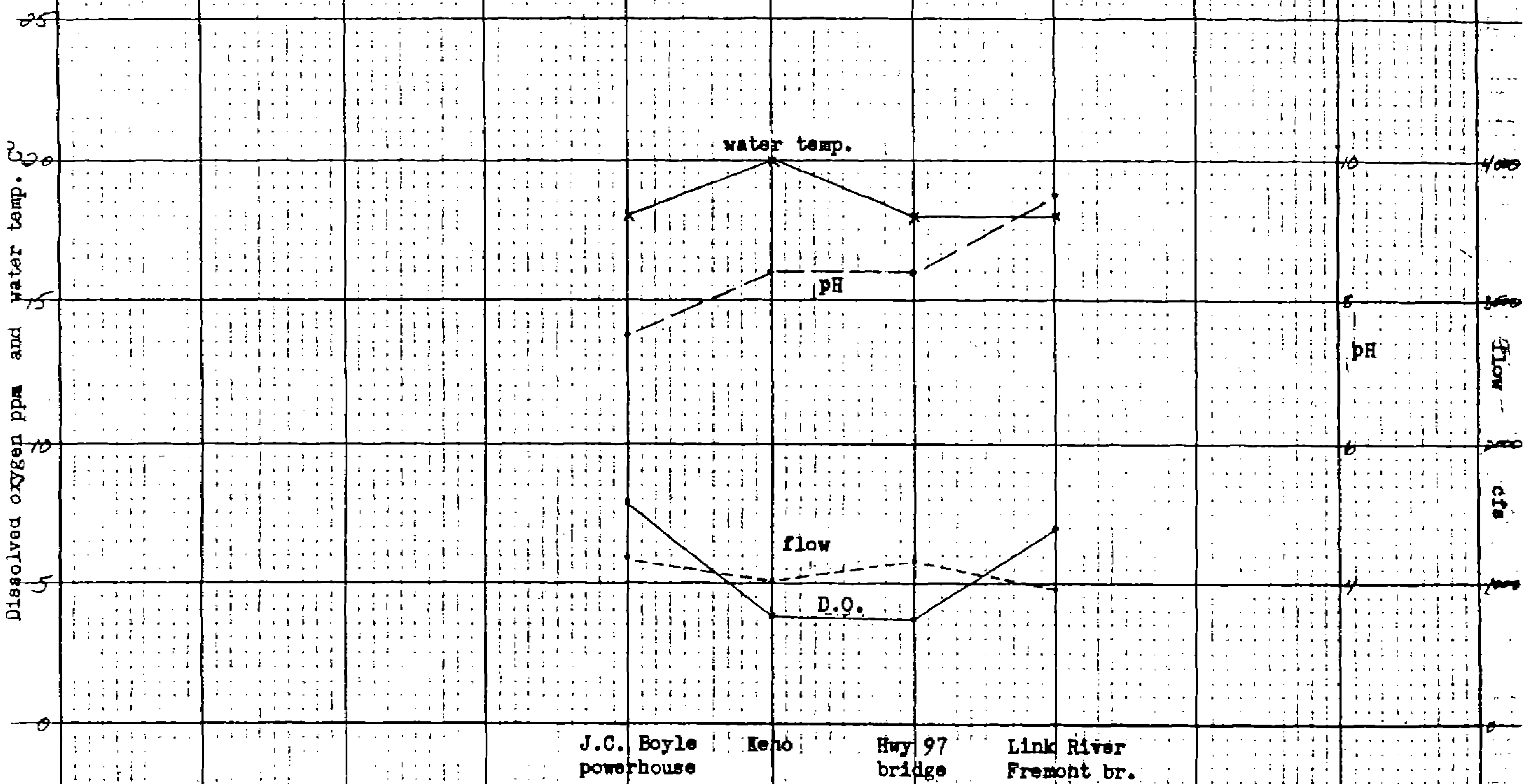
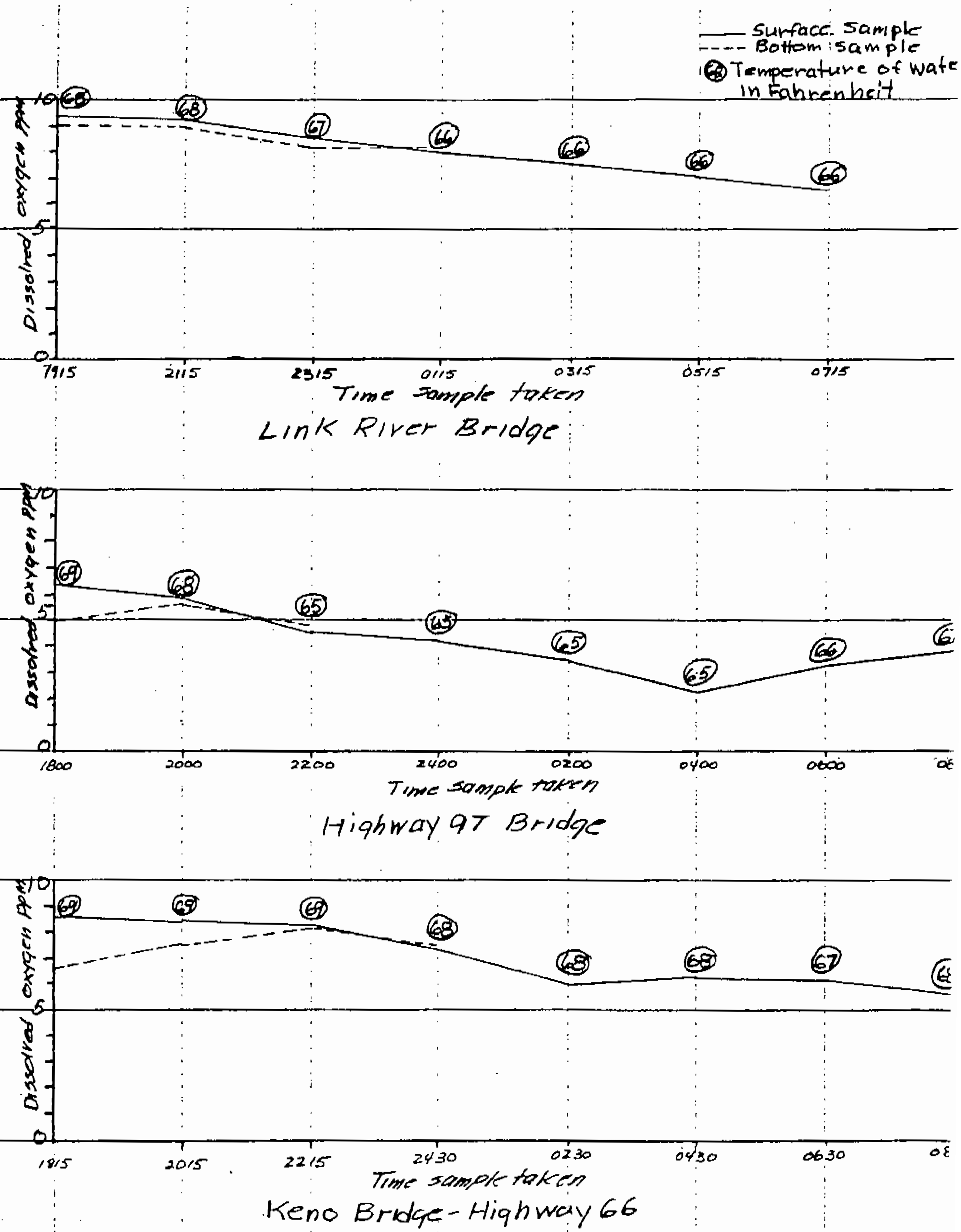


Figure 32. Dissolved oxygen samples taken during a 12 hour period on Klamath River, September 1-2, 1965.



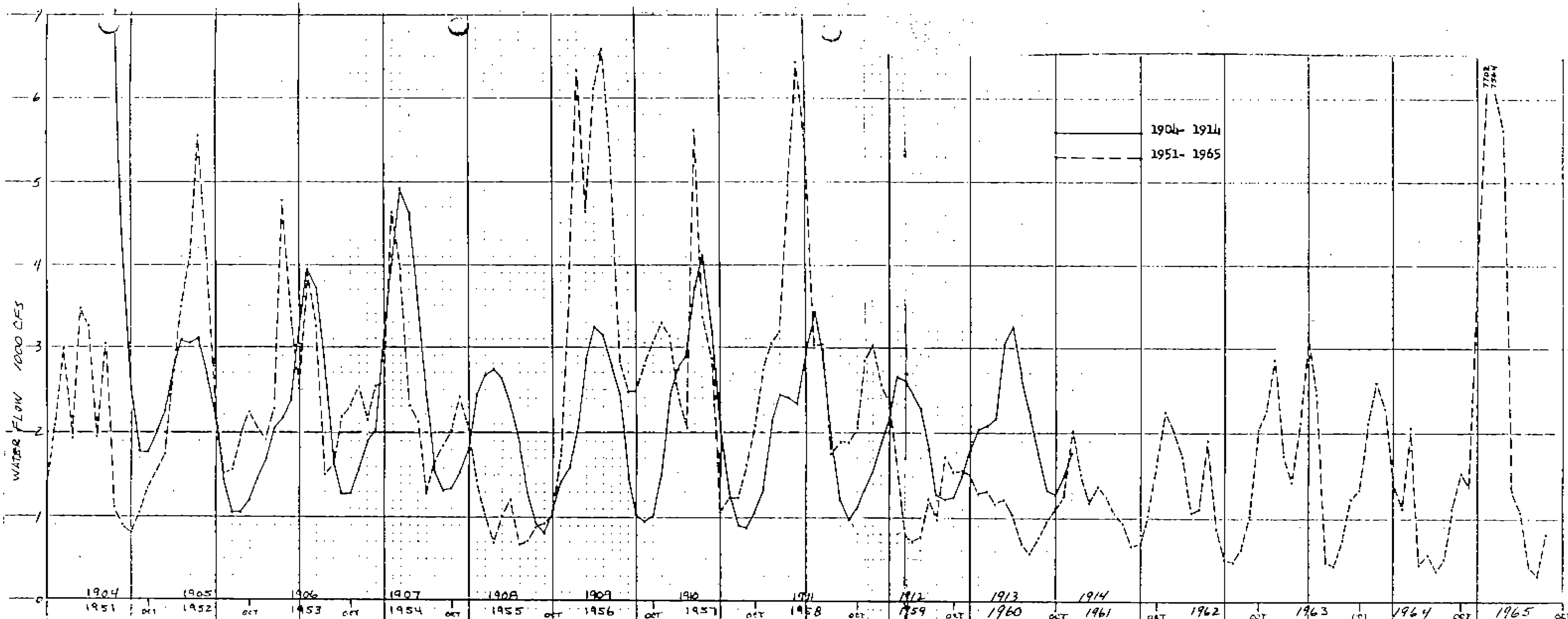


Figure 33. Monthly mean flows in Klamath River near Keno for water years 1904-1914 and 1951-1965 (from USGS).

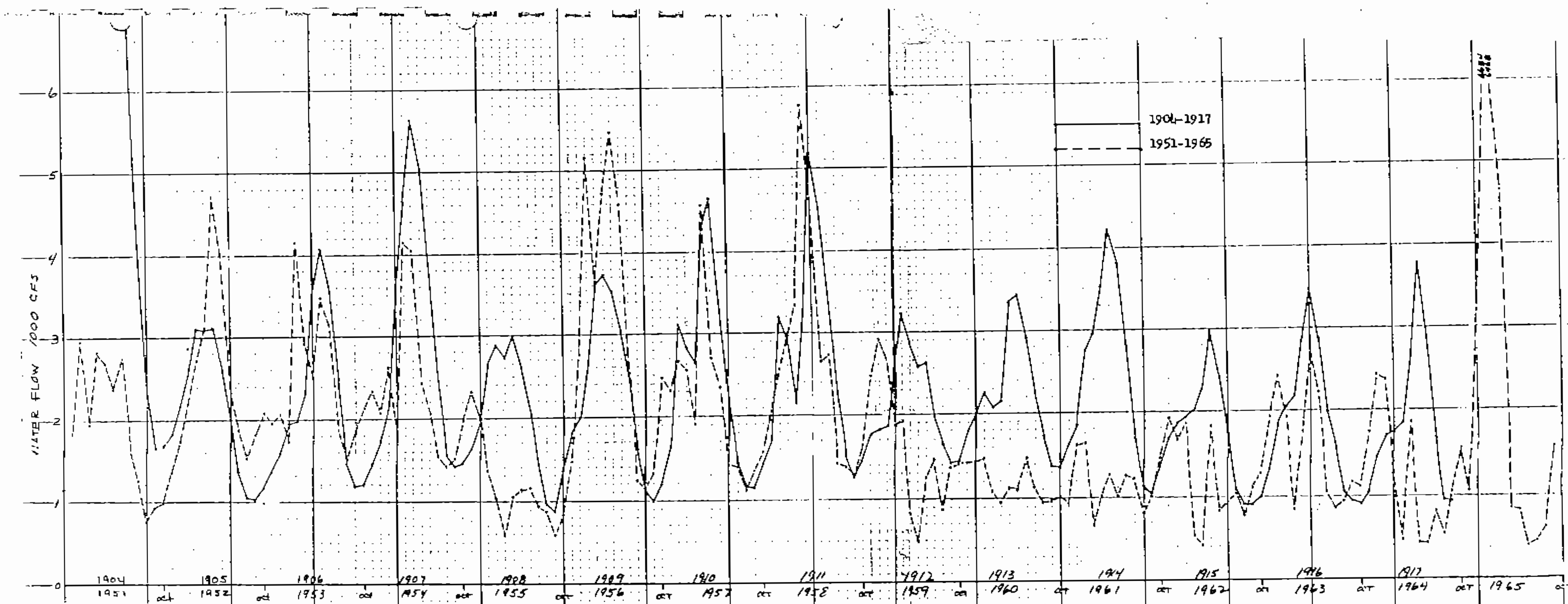


Figure 34. Monthly mean flows in Link River at Klamath Falls for water years 1904-1917 and 1951-1965 (from USGS).

Figure 35. Dissolved oxygen concentrations found on Sevenmile Creek, 1965.

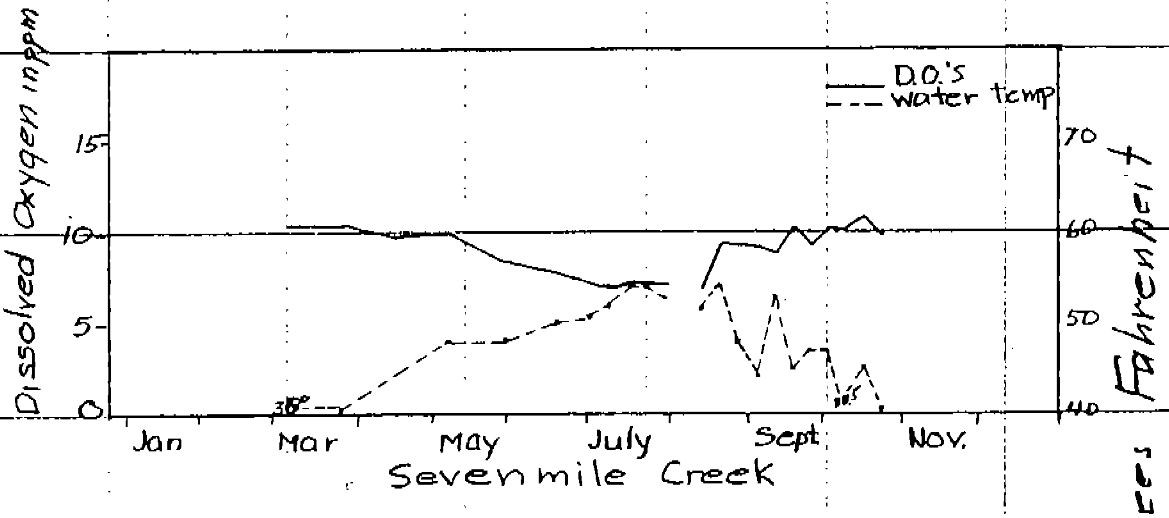


Figure 36. Dissolved oxygen concentrations found at two stations on Wood River, 1965.

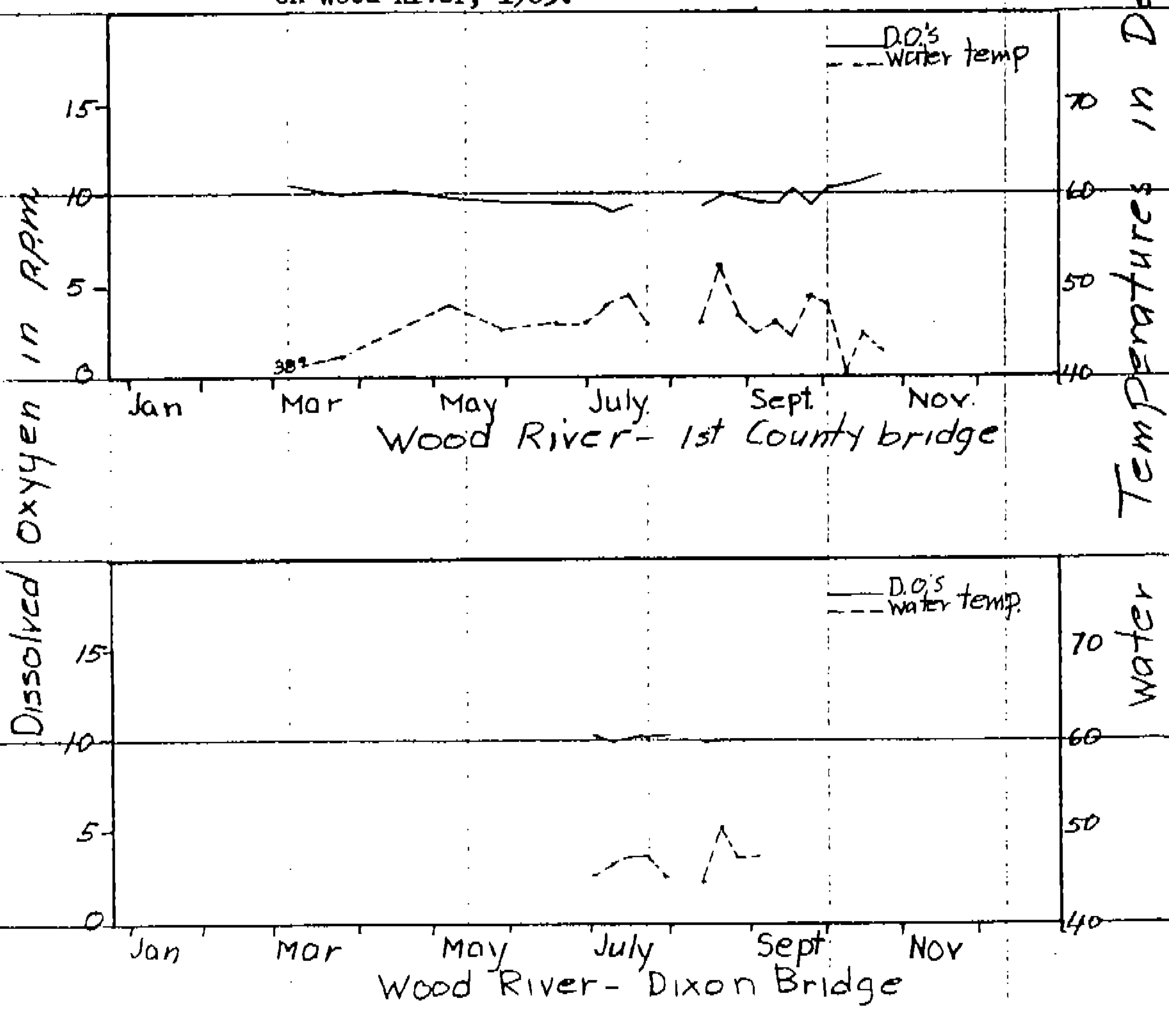


Figure 37. Dissolved oxygen concentrations and water temperatures found at four stations on Williamson River, 1965.

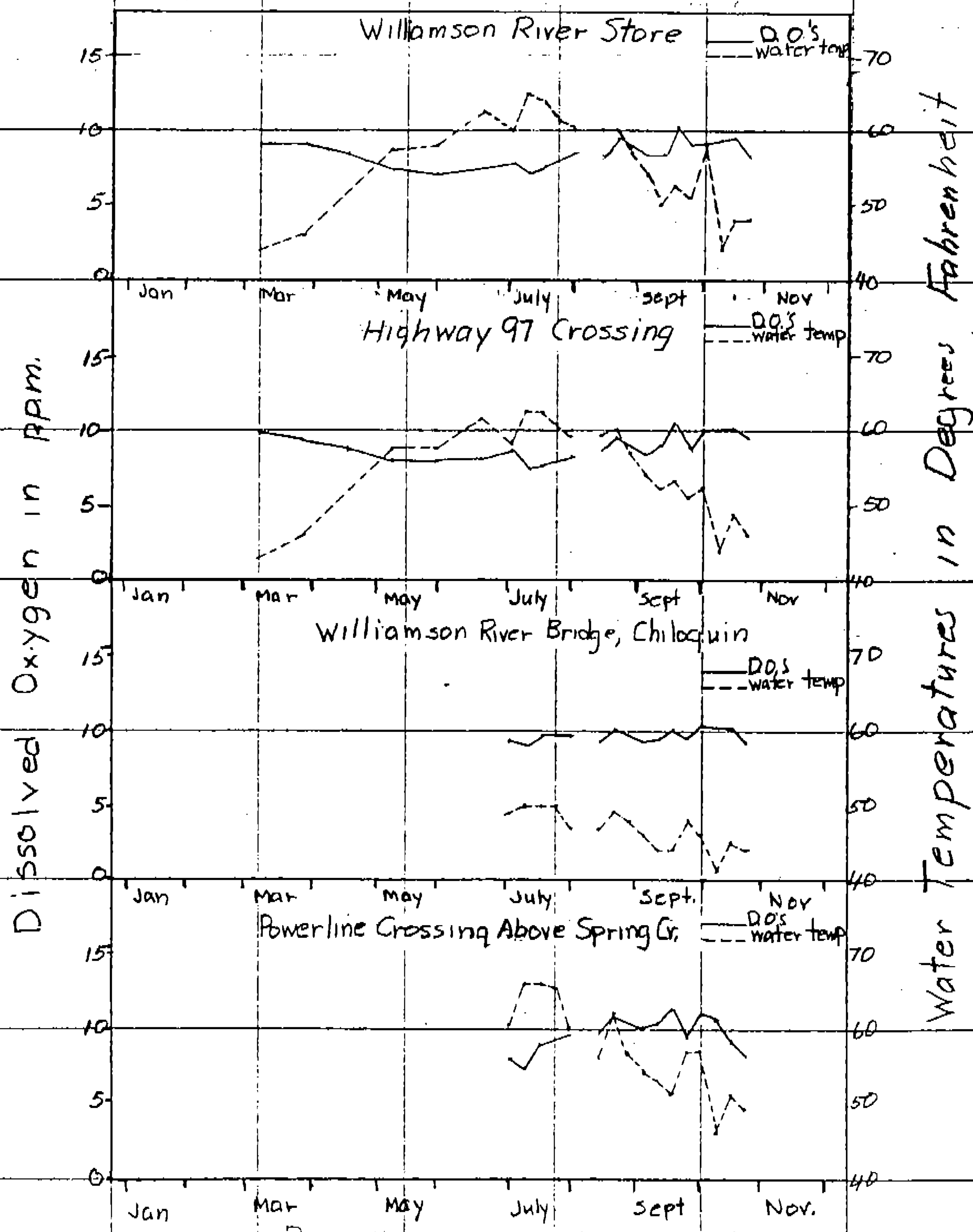
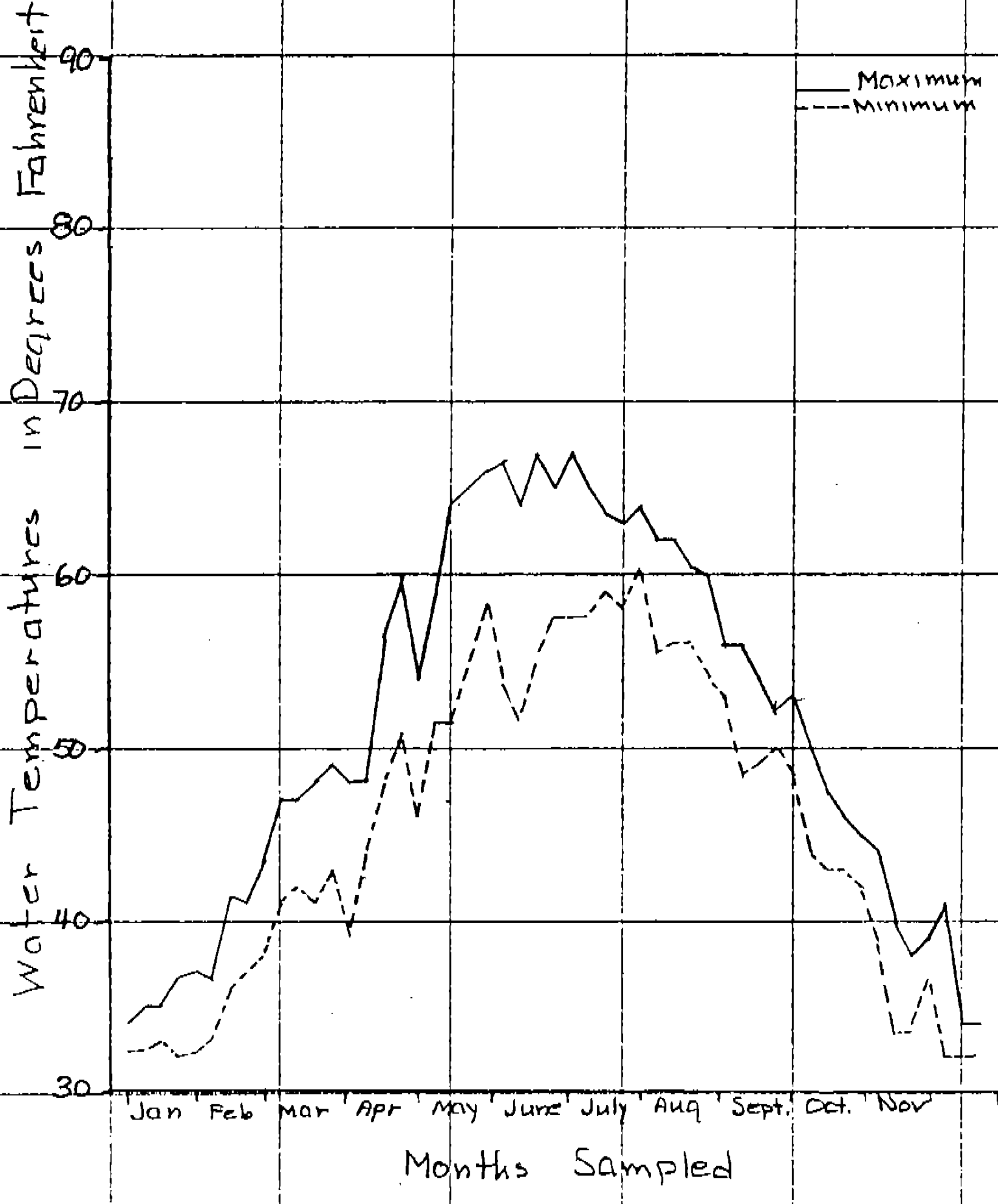


Figure 38. Weekly maximum and minimum water temperatures for Williamson River at Highway 97 beginning January 4, 1965.



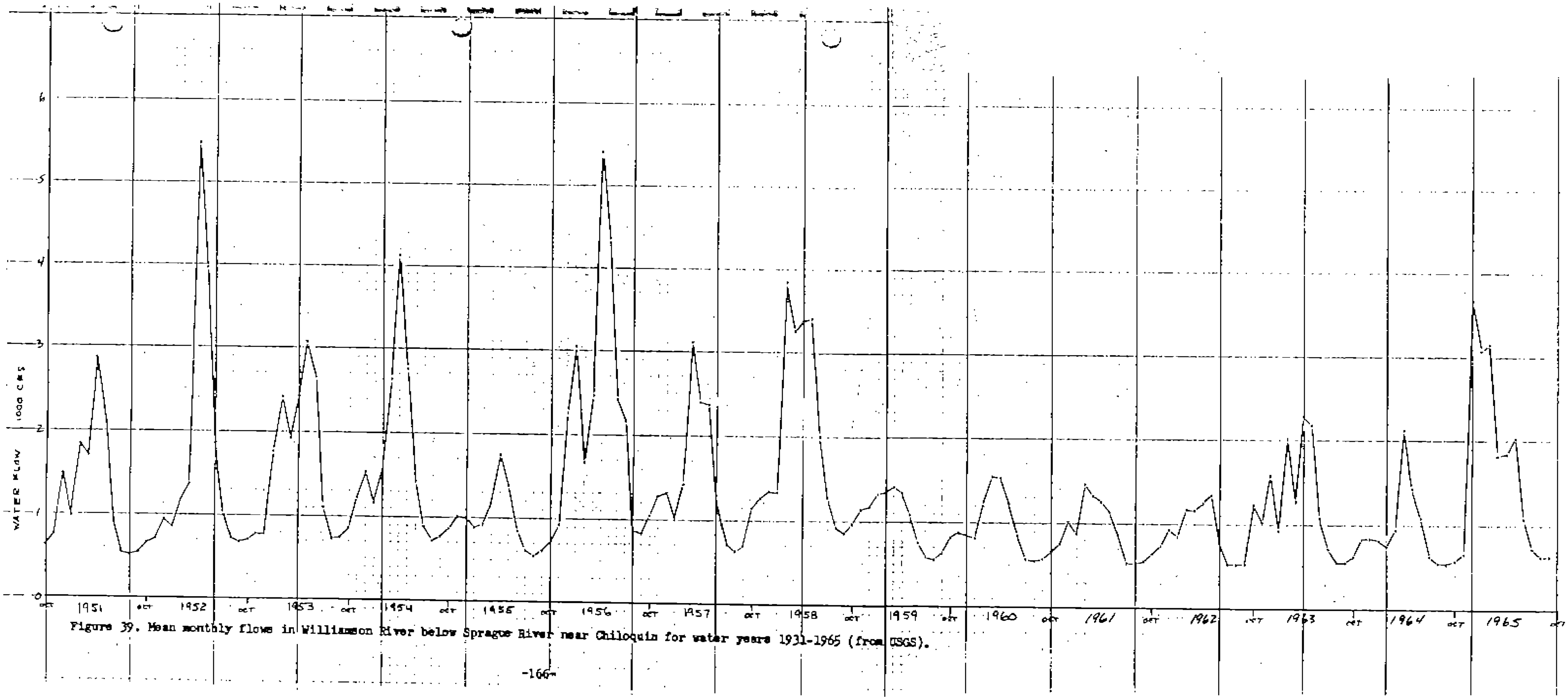


Figure 39. Mean monthly flows in Williamson River below Sprague River near Chiloquin for water years 1931-1965 (from USGS).

Figure 40. Dissolved oxygen concentrations found at four stations on Sprague River, 1965.

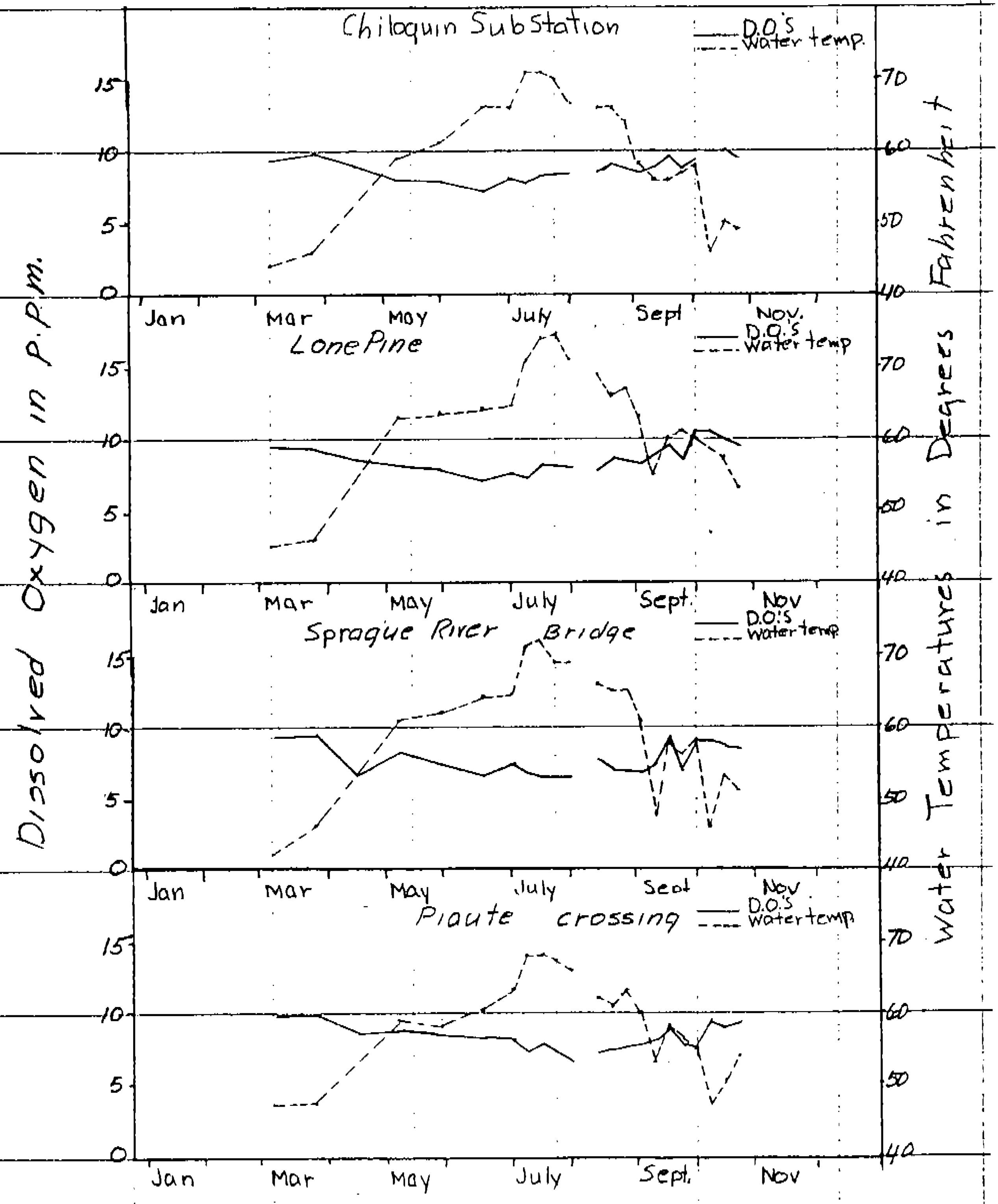


Figure 41. Weekly maximum and minimum water temperatures for Sprague River near Chiloquin beginning February 17, 1965.

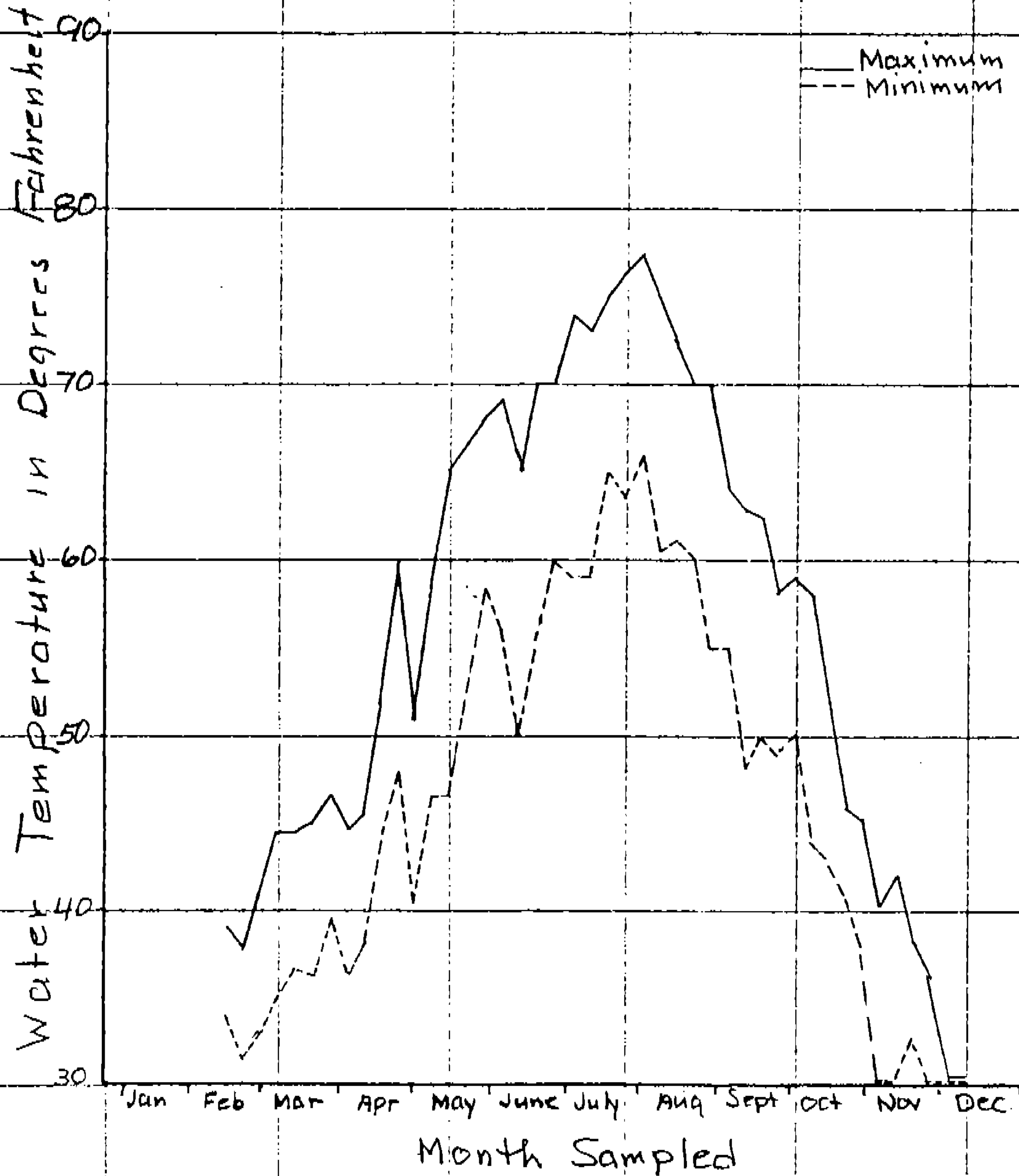
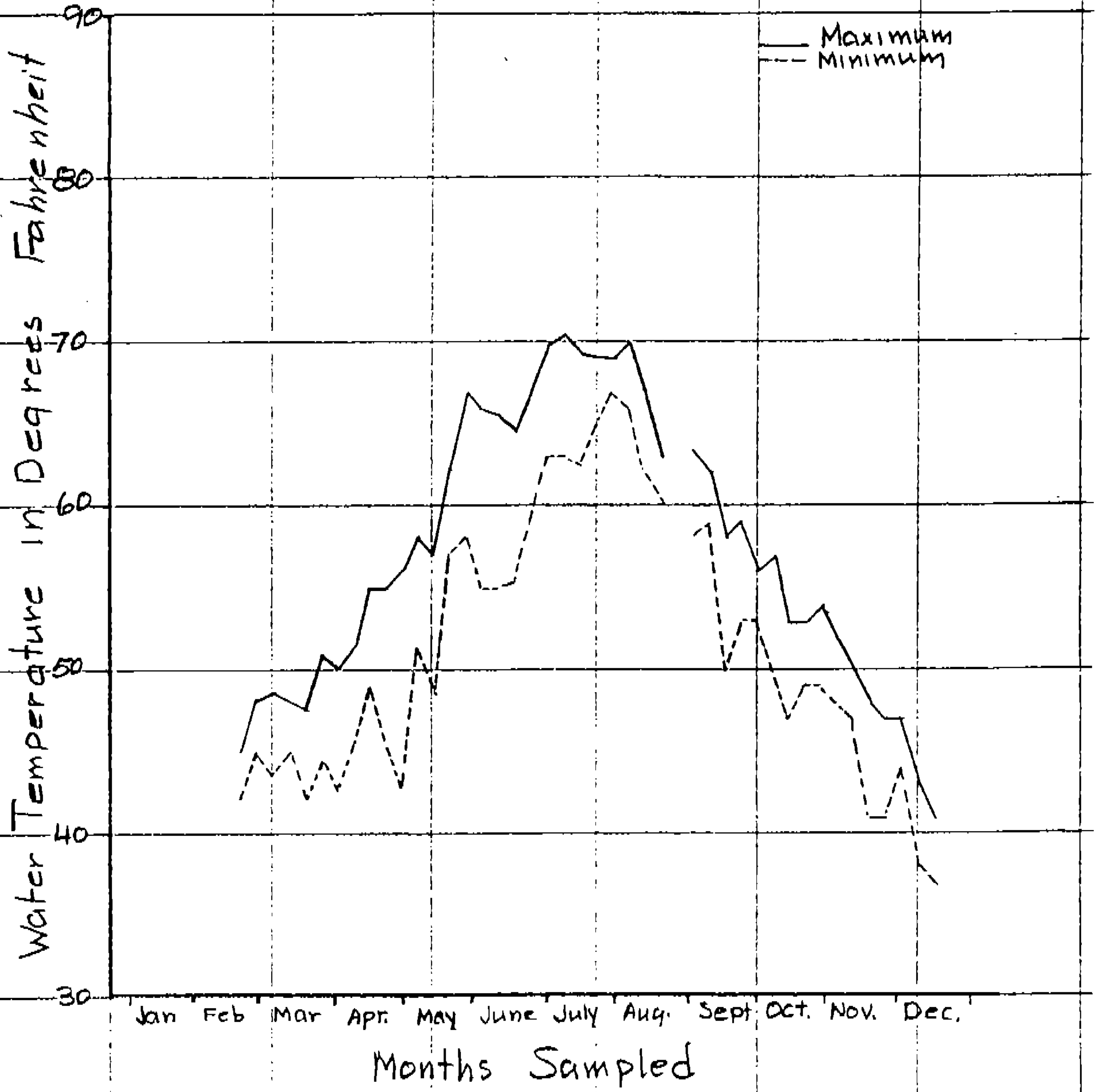


Figure 42. Weekly maximum and minimum water temperatures for Sprague River near Beatty beginning February 24, 1965.



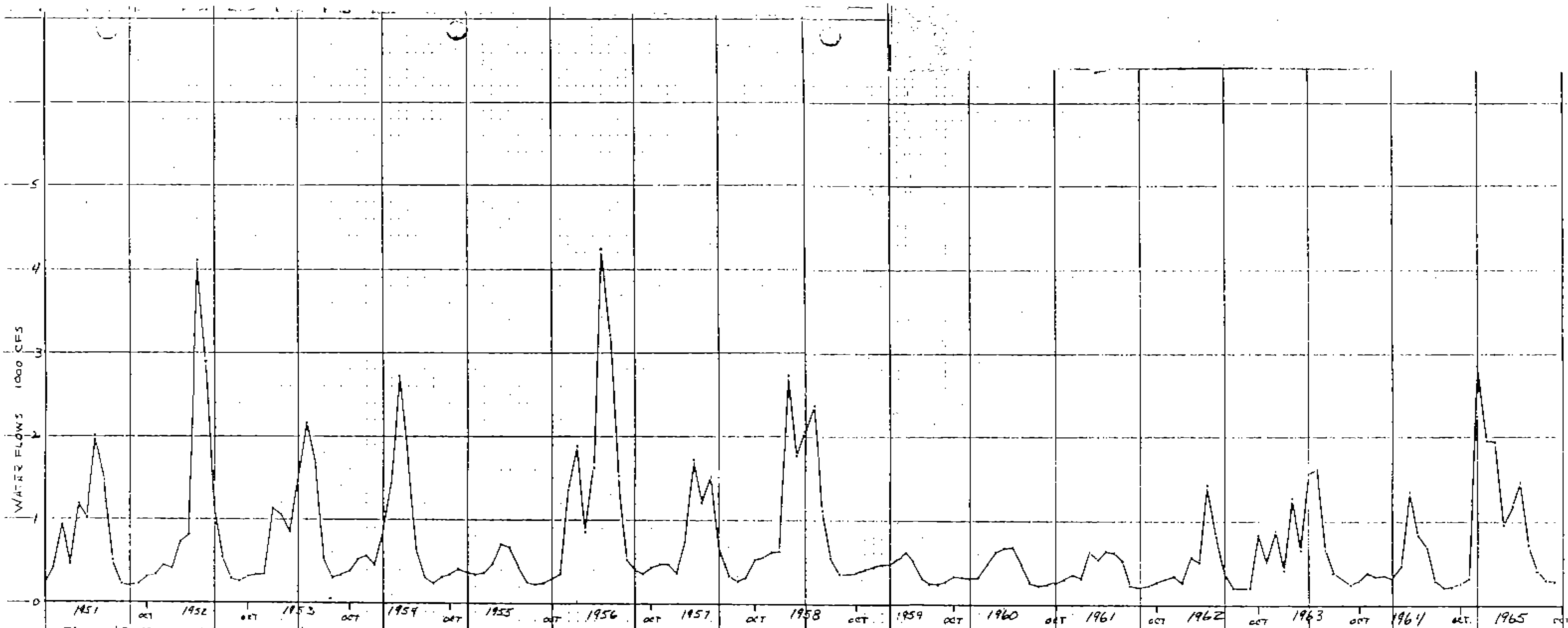


Figure 43. Mean monthly flows in Sprague River near Chiloquin for water years 1951-1965 (from USGS).

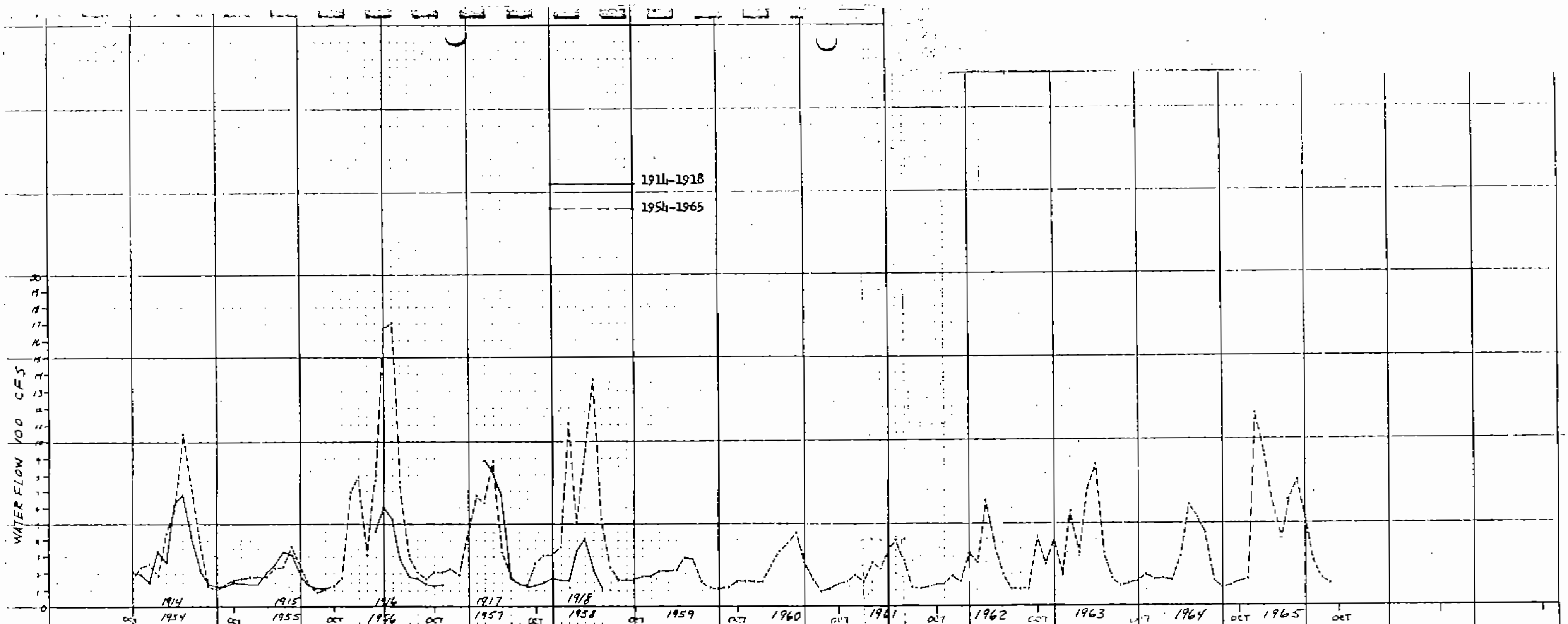


Figure 44. Mean monthly flows in Sprague River near Beatty for water years 1914-18 and 1954-65 (from USGS).

Figure 45. Dissolved oxygen concentrations and water temperatures found at two stations on South Fork Sprague River, 1965.

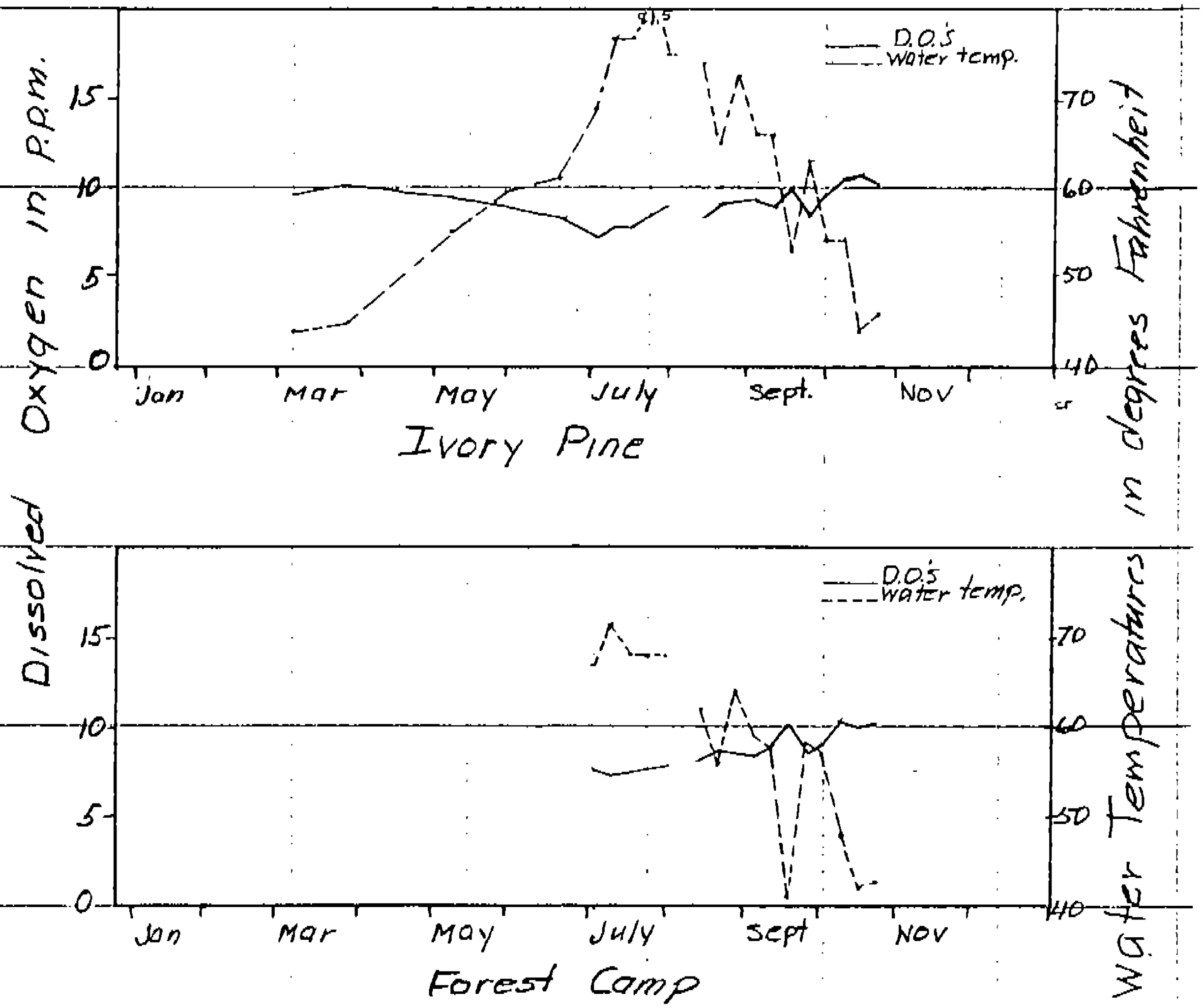


Figure 46. Dissolved oxygen concentrations and water temperatures found on Sycan River, 1965.

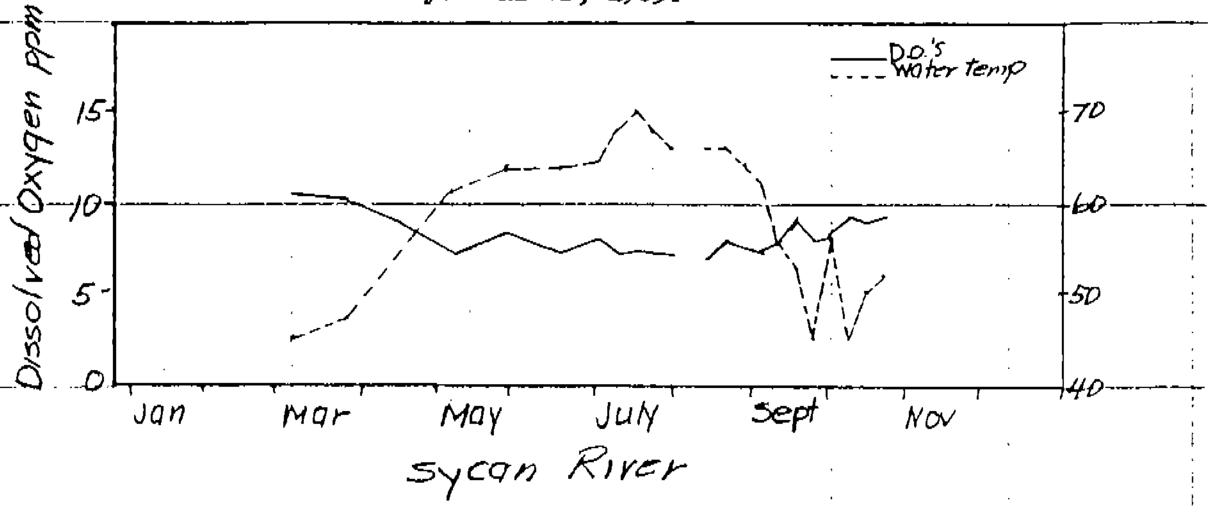
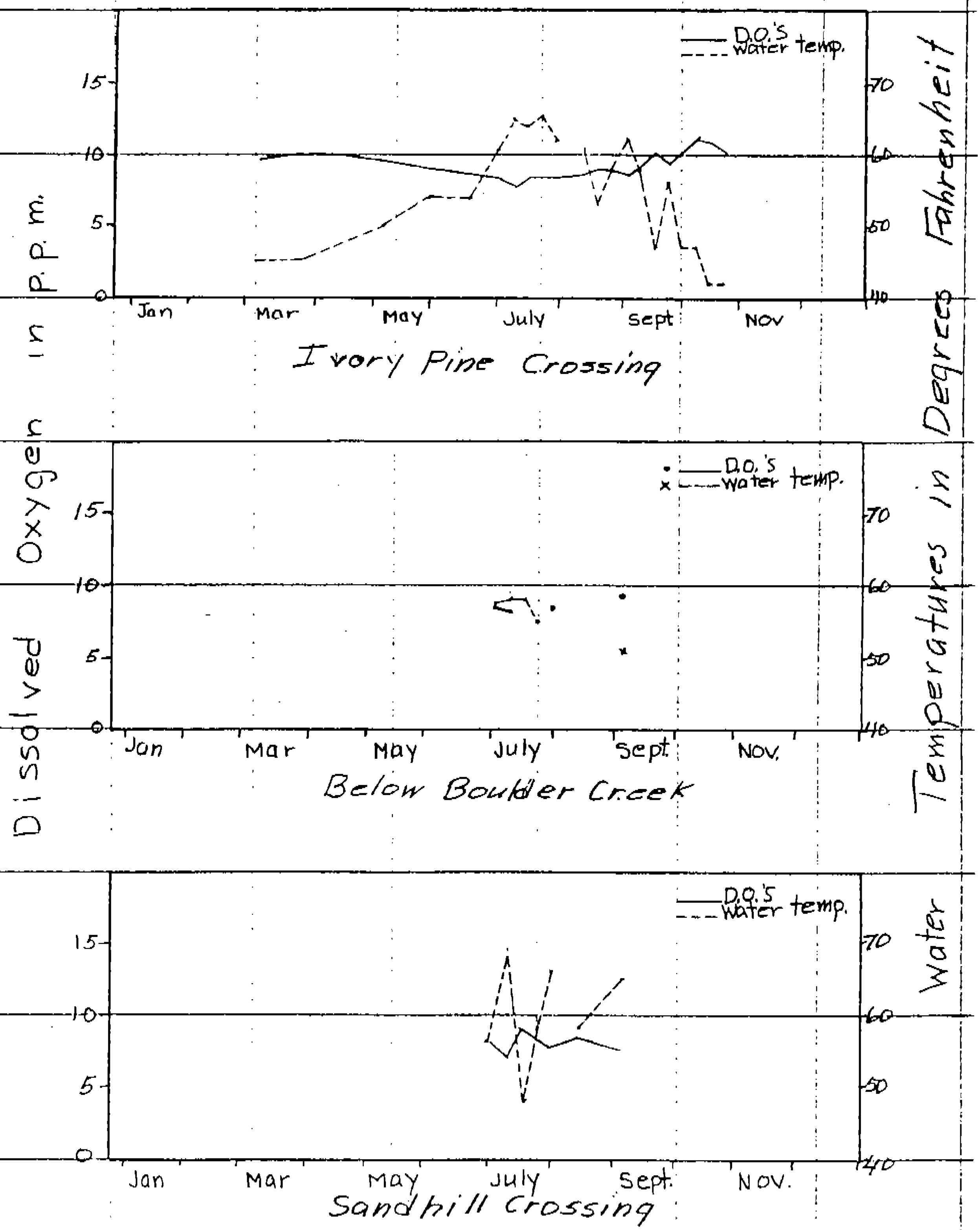


Figure 47. Dissolved oxygen concentrations and water temperatures found at three stations on North Fork Sprague River, 1965.



APPENDIX

Cost Estimates of Plan A and B

REG. PROF. ENGINEER
State of Washington
State of Idaho
Province of B. C.

MILO C. BELL
Consulting Engineer
BOX 23
MUKILTEO, WASHINGTON 98275

September 24th, 1965

Dr. J. A. R. Hamilton
Pacific Power & Light Company
Public Service Building
Portland, Oregon

Dear Dr. Hamilton:

You have asked for an estimate of costs of fish facilities for the Klamath River power projects, at and above Iron Gate.

In order to furnish such figures, I have made the following assumptions: the fishway pools would have one foot difference in elevation and would be 8 x 10 x 6 feet deep; all structures are to be built of concrete. I have assumed that travelling water screens with a velocity of approach of one foot per second would be used. For the sake of uniformity, it is assumed that each screen would have a 25-foot effective depth and would be 10 feet wide. The faces would be flush and the fish would be led to a common major by-pass.

In each project it is assumed that there would be an auxiliary water supply of 100 second feet available at the fishway entrances. Thus, when comparing costs only per pool, you will note that the addition of the auxiliary water supply, plus the needed regulated pools for varying tail water and head water levels, increases the cost of the low head dam fishways, although a basic cost per pool of $4,000.00 was used.

In considering hauling, only the addition of a trap from the existing Iron Gate fishways was considered. If the small migrants are to be handled from the Copco I pool, there could be an increased cost brought about by the necessary handling facilities to elevate the migrants to hauling trucks. No cost has been placed on a pipe line, if such an installation were to be used.

Attached hereto are sheets indicating the price per element as used, and a listing of costs for each project. As we both recognize, there can be many variations in individual projects which would affect costs.

Sincerely yours,

Milo Bell

Encls

Cost per fishway pool, 8 x 10 x 6 feet	$4,000.00
Exit pool regulating facilities	$5,000.00
Entrance pool regulating facilities	$5,000.00
Gravity auxiliary water supply	$17,000.00 - 20,000.00
Screens, in place	$50.00 per second foot
Screen structure	$80.00 per second foot
Regulating dam for screens	$80.00 per second foot

The above estimates are based upon figures taken from recently bid fishways with moderately difficult conditions of installation. Cofferdams are allowed for all new installations to the extent of $10,000.00 per project.

Fish screen estimates are based upon installations similar to that proposed for the Imnaha, with prices up-dated.

The above estimates are subject to considerable variation: for example, prices could be changed materially if a major dam were being constructed. The fishway prices above indicated are from projects in which the fishways are required to withstand all move-in and move-out costs and added prices for small quantities.

The hauling facilities are based upon a Buckley trap principle, with a water supply connected to an existing system, with a total cost of $94,000.00; a special roadway to include special drains at $10,000.00; a connection into the existing fishway system at $15,000.00; miscellaneous equipment such as housing for trucks and so forth at $10,000.00 and two tank trucks at $25,000.00 each. This gives a cost of $179,000.00. In my judgment, based upon the brief visit I made to Iron Gate, this estimate is too low and would be nearer to $250,000.00 for the above outlined equipment.

REG. PROF. ENGINEER
State of Washington
State of Idaho
Province of B. C.

MILO C. BELL
Consulting Engineer
BOX 23
MUKILTEO, WASHINGTON 98275

March 3rd, 1966

Dr. J. A. R. Hamilton
Pacific Power & Light Company
Public Service Building
Portland, Oregon 97204

Dear Dr. Hamilton:

In discussing with you the cost changes for the projects outlined in the letter which I submitted on September 24th, 1965, the structural estimates furnished are approximately twelve percent below the present price level. Since that date there has been approximately a six percent national rise in construction costs, and recent bidding on fishway construction indicates that the Pacific coast construction costs have risen at an even greater rate than the national average. I have not been advised of any increase in screen prices which would reflect an increase in steel costs. However, basic structure costs have increased. I would suggest, therefore, that the following be added to the project costs as submitted:

Iron Gate	$67,000.00
Copco I	81,000.00
Screens in Copco I pool	149,000.00
Warm Springs	46,000.00
Salt Caves	85,000.00
Bear Springs	53,000.00
Big Bend	66,000.00
Keno	68,000.00
Upper Klamath	16,000.00
Hauling from Iron Gate	30,000.00
	$661,000.00

Regarding trucking costs, the following appears to be reasonable. I have asked for additional prices for an actual fish-hauling operation which has not yet been made available. Tentatively, I would suggest using the following:

*Based on one truck in operation for 18,000 miles travel, six months per year:

60¢ per mile (includes one driver, insurance, depreciation etc.)	$10,800.00
Extra operators, 1½ man-years	7,500.00
Extra stand-by truck (includes insurance, depreciation etc.)	3,200.00
	$21,500.00
20 percent administration cost	4,000.00
	$25,500.00

*Two trucks available @ $27,500.00 each (new price based on present estimate up $2,500.00 from previous estimate) $55,000.00

For fishway and screen structure operation costs, the following have been used, based on 50 year life structures.

Operations	0.5 percent
Interest	2.5 percent
Taxes	0.25 percent
Amortization	2.0 percent
Replacement	0.5 percent
Administration & insurance	0.25 percent
	6.0 percent per year

For travelling screens and hauling structures, the following percentages have been used:

Operations	1.0 percent
Interest	2.5 percent
Taxes	0.25 percent
Amortization	2.00 percent
Replacement	2.00 percent
Administration & insurance	0.25 percent
	8.0 percent per year

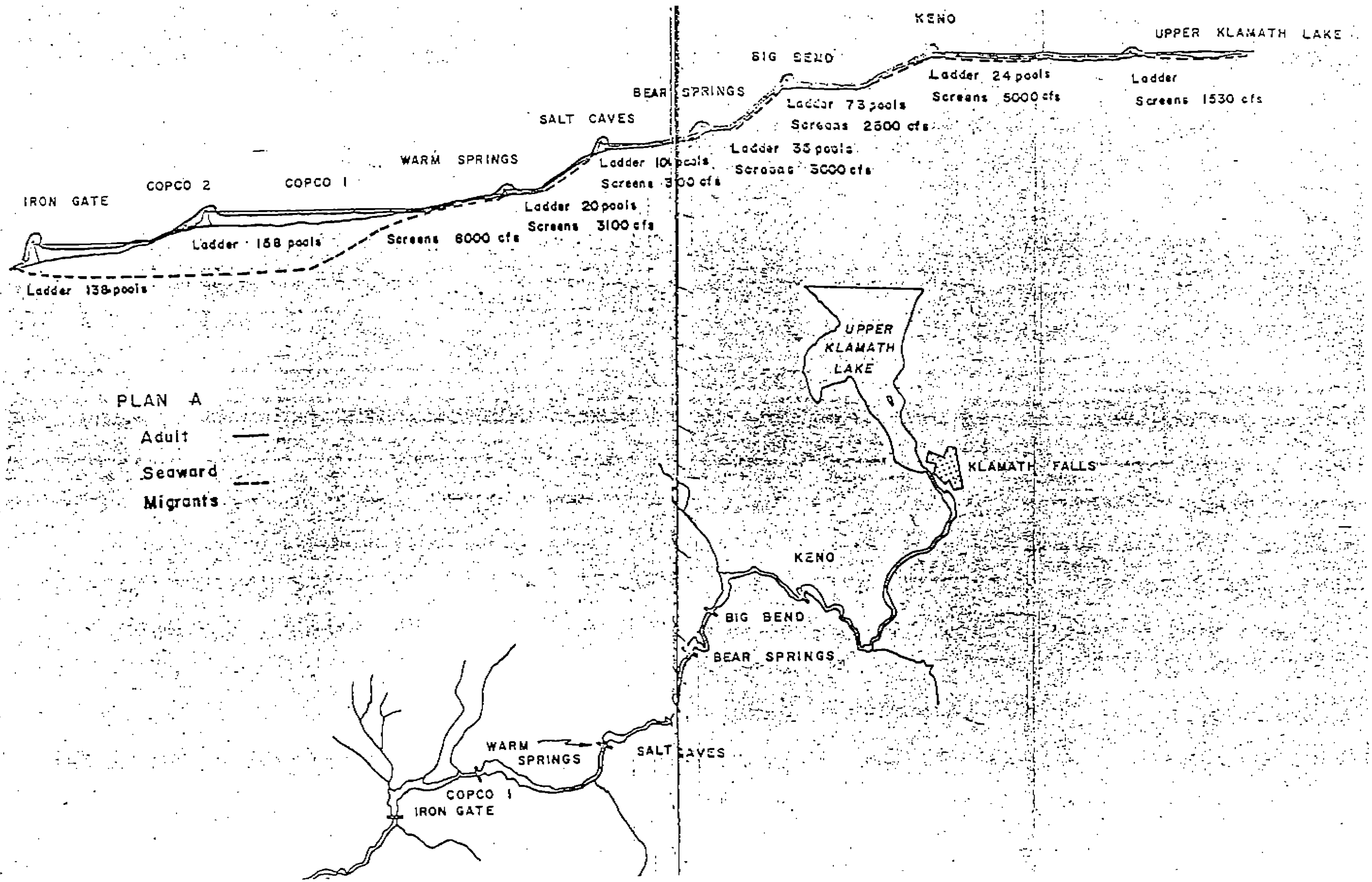
For combined screens and their needed structures, use 7.0 percent per year.

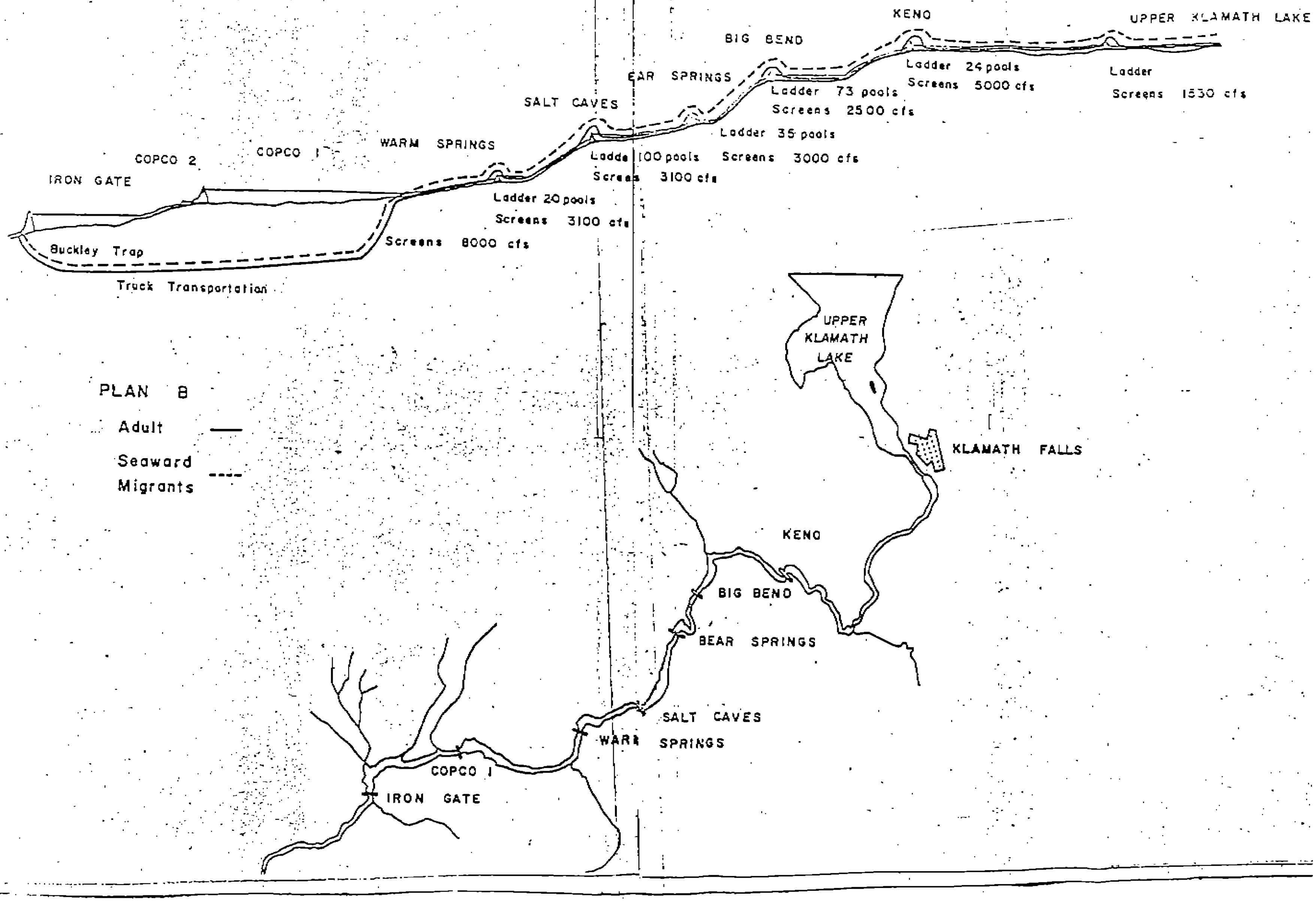
Annual cost, based on estimated costs
as of March 1, 1966

	Fishways	Screens
Iron Gate	$37,000.00	
Copco I	45,000.00	
Copco I (screen structure)	8,500.00	$127,000.00
Warm Springs	7,800.00	30,500.00
Salt Caves	30,000.00	30,500.00
Bear Springs	12,000.00	29,000.00
Big Bend	22,000.00	24,500.00
Keno	9,000.00	50,000.00
Upper Klamath		15,000.00
Hauling from Iron Gate (see trucking costs)		

Yours very truly,

[signature]


KENO
UPPER KLAMATH LAKE
BIG BEND
BEAR SPRINGS
SALT CAVES
WARM SPRINGS
COPCO 1
COPCO 2
IRON GATE
Ladder 24 pools
Screens 5000 cfs
Ladder
Screens 1530 cfs
Ladder 73 pools
Screens 2600 cfs
Ladder 35 pools
Screens 3000 cfs
Ladder 10 pools
Screens 3100 cfs
Ladder 20 pools
Screens 3100 cfs
Ladder 158 pools
Screens 6000 cfs
Ladder 138 pools
PLAN A
Adult
Seaward Migrants
UPPER KLAMATH LAKE
KLAMATH FALLS
KENO
BIG BEND
BEAR SPRINGS
WARM SPRINGS
SALT CAVES
COPCO 1
IRON GATE



UPPER KLAMATH LAKE
KENO
BIG BEND
EAR SPRINGS
SALT CAVES
WARM SPRINGS
COPCO 1
COPCO 2
IRON GATE
Ladder 24 pools
Screens 5000 cfs
Ladder
Screens 1530 cfs
Ladder 73 pools
Screens 2500 cfs
Ladder 35 pools
Screens 3000 cfs
Ladde 100 pools
Scree 3100 cfs
Ladder 20 pools
Screens 3100 cfs
Screens 8000 cfs
Buckley Trap
Truck Transportation
PLAN B
Adult
Seaward
Migrants
UPPER
KLAMATH
LAKE
KLAMATH FALLS
KENO
BIG BEND
BEAR SPRINGS
SALT CAVES
WARM SPRINGS
COPCO 1
IRON GATE