SHASTA RIVER FISHERIES WATER QUALITY PROJECT 1990 - 91

SHASTA VALLEY
RESOURCE CONSERVATION DISTRICT
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FUNDING PROVIDED BY:

THE KLAMATH RIVER BASIN FISHERIES TASK FORCE
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WRITTEN BY:

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ABSTRACT

A study to find limiting water quality factors to anadromous fisheries was conducted in the Shasta River, Klamath River drainage, Siskiyou County, California. Data was collected from April 1990 to February 1991. The study was done under a contract with the U. S. Fish and Wildlife Service as the administrative authority for the Klamath River Basin Conservation Area Restoration Program. Fifteen parameters were monitored; air and water temperatures, dissolved oxygen, BOD, pH, electrical conductivity, turbidity, hardness, alkalinity, nitrogen-nitrate, nitrogen-ammonia, un-ionized ammonia, orthophosphate, chlorophyll-a, and water flow. High water temperature was the only water quality parameter directly limiting anadromous fish.

INTRODUCTION

The anadromous fish stocks of the Shasta River have decreased in numbers since the 1940's. Poor water quality is thought to be a factor that has contributed to this decline. A proposal was submitted to conduct a limited water quality study with the purpose of relating water quality to anadromous fish. This proposal was accepted by the United States Fish and Wildlife Service (USFWS).

An Interagency Agreement between the Shasta Valley Resources Conservation District (SVRCD) and USFWS was formulated and initiated on May 16, 1990. The study was conducted by OUZEL Enterprises (OE) under contract to the SVRCD. Three agencies provided services to OE to help this study. They were: California Department of Fish and Game (DFG), California Department of Water Resources (DWR), and the North Coast Regional Water Quality Resources Control Board (NCRWQCB). Redding DFG provided laboratory and field equipment, facilities, and professional advice. DWR provided field equipment, professional advice, and background information. NCRWQCB critiqued laboratory procedures, and provided background information.

Data collections by several state agencies have been conducted in and in association with the Shasta River. DWR has collected water quality data at a river station near Yreka, and at some 45 other stations in the valley, for approximately 31 years (Bogener 1990). They have collected both physical and mineral water quality information from

wells and various surface water locations. NCRWQCB has established water quality objectives for the Shasta Valley for 20 parameters and have identified the beneficial uses of the valleys' water (1989). These uses are municipal and domestic supply freshwater replenishment, warm freshwater habitat, cold freshwater habitat, wildlife habitat, fish migrations, and spawning habitat. DFG has investigated several fish kills in the system and conducted a preliminary water quality study in 1989 (D. Maria, Personal Communication). The fish kills were attributed to low dissolved oxygen (DO) levels. The 1989 data suggested that there was a substantial diurnal range of DO's, pH was over 9 units in the afternoon and temperatures were high enough to be lethal to salmonids.

The purpose of this project was to obtain information on these and other water quality parameters that could affect anadromous fish; especially diurnal ranges of DO's (by collecting samples at various hours of the day), water temperature, and un-ionized ammonia levels. Originally it was also proposed to collect samples for organic pesticide/herbicide analysis. At a meeting in Redding in March 1990 personnel from NCRWQCB said they would be collecting and analyzing these parameters. That phase was removed from this project and more sampling stations were substituted.

Data collection started on April 4, 1990 and continued to January 23, 1991. Water samples were collected at seven stations from one-fourth mile below Dwinnell Dam to 500 feet upstream of the mouth at the Klamath River. On-site analyses were made on five parameters and the remaining ten were analyzed in a field laboratory or in DFG's Redding laboratory. An instream recording thermometer was used to collect daily maximum, minimum and average temperatures from mid-May to October. This year was a drought year and river flows were low.

Description of the Study Area

The study area was the Shasta River from below Dwinnell Dam to the DFG fish counting station near the mouth. From the dam downstream to Highway 263 bridge, where the river enters a canyon, the surrounding countryside is farmland, primarily irrigated pasture. The river in this 50 mile section is sinuous and sluggish. Much of the shoreline can be characterized as cattail marsh. The river bottom is usually of fine sediments and in the summer supports luxuriant growths of algae and other aquatic plants. There are many irrigation diversions, both gravity and pumped.

The major tributaries are Parks Creek, Big Springs Creek, Willow Creek, Little Shasta River and Yreka Creek. These, and other minor tributaries, are diverted for

irrigation. In the summer Big Springs Creek, and to a lesser extent Lake Shastina, contribute water to the Shasta River. Most other inflows are agricultural return waters that have been used a least once for irrigation. Yreka Creek, which runs through the City of Yreka, and Oregon Slough, near Montague, carry treated sewage effluent from these communities.

Below Highway 263 the river enters Shasta River Canyon. In this 12.3 mile stretch the gradient and water velocity increases. This leaves little room for the river to meander and the bottom composition is predominantly gravel and bedrock. Pasture land gives way to steep sided hills that descend abruptly to the waters' edge.

Shasta Valley weather is characterized by hot, dry summers and cool winters. Rainfall at Yreka, a community near the lower end of the river, averages 17.22 inches per annum. Temperatures vary from below zero -17.7°C (0°F) to over 43.3°C (110°F). The average high is 18.9°C (66°F) and the average low is 2.2°C (36°F). The elevation at Dwinnell Dam is 840 Meters (2,789 feet) and drops to 610 meters (2,001 feet) at the mouth. Historical river flows, measured at an USGS gauge near the mouth of the river, vary from 1.5 cubic feet per second (CFS) (Aug. 24, 1981 and Jul. 17, 1985) to 21,500 CFS (Dec. 22, 1964.).

The Shasta River host spawning runs of fall run chinook salmon, coho salmon and winter steelhead. Chinook Salmon usually begin to enter the river around mid-September and continue into late October. Spawning generally commences in early October and continues through early November. The salmon spawn throughout the Shasta River canyon and portions of the upper river where proper gradient, water velocity and bottom composition occur. They also spawn in Big Springs Creek. The eggs incubate during the winter and after the fry hatch they begin their downstream migration. This normally starts near the first of February and is usually complete by the end of March.

Steelhead primarily use tributary streams for spawning and rear only in the portions of those streams where water conditions are favorable through the summer, usually the headwaters. Steelhead enter the river from December through May. Spawning activities peak in March. The eggs have usually completed incubation and the fry have emerged by July. Fry remain in the system for another year and emigrate as smolts during the next spring runoff.

Coho salmon have a life history similar to steelhead except the adults, like chinook salmon, die after spawning.

Methods and Materials

Seven sites were chosen for water analysis and an eighth site to locate a temperature recorder. The sites were:

1. A culvert crossing at Riverside Drive, the first vehicle access below Dwinnell Dam;
2. Bridge crossing at Louie Road;
3. Bridge crossing at county road A-12;
4. Bridge Crossing on Montague - Grenada Road;
5. Bridge crossing on State Highway 3, near Montague;
6. First bridge crossing North of Yreka on State Highway 263;
7. Near mouth of Shasta River at California Department of Fish and Game's fish counting facility known as "Shasta Racks";
8. The Omniterm® Datapod 1 recording thermometer was located on the Val Verde Ranch 300 yards downstream of site four.

Water samples and flows were collected on a schedule shown in Appendix A. Air and water temperatures, DO, Electrical Conductivity (EC), and pH were measured on-site. One gallon plastic, acid-washed bottles were filled with

sample water taken sub-surface, or at the surface if depth was inadequate, and placed in ice chests chilled with reusable ice packs. Alkalinity, hardness, turbidity, nitrate, orthophosphate, ammonia, biological oxidation demand (BOD), chlorophyll-a, and un-ionized ammonia were determined either in a temporary laboratory located near Montague or at the DFG Water Quality laboratory in Redding.

Unless stated otherwise, the chemical analyses were performed using the procedures from STANDARD METHODS (1970).

Temperature

An Omniterm® Datapod 1 temperature recorder was used to collect daily maximum, minimum, and average temperatures. This unit was on loan from DFG Redding office.

Several glass thermometers were used during the study. All were either laboratory grade, mercury filled, single scaled or pocket type (Celsius). Air and water temperatures were taken. The pocket type was used for air readings and the laboratory type for water readings.

Dissolved Oxygen

The Winkler or iodometric method as approved by EPA was used. The chemicals were purchased from the HACH Company, the dry chemicals in capsule form and the wet in approved bottles. Samples were analyzed in the field using a kit similar to DWR's. It contained all the necessary chemicals and glassware.

pH

The pH's were measured using a Chemtrix Type 40 pH meter with a Markson general purpose electrode. The unit was calibrated at each station using standards for pH's 7.0 and 10.0 made from HACH buffer pillows.

Electrical Conductivity

Electrical conductivity was measured with a Beckman conductivity bridge on loan from DWR.

Alkalinity

Alkalinities were measured using a HACH test kit catalog no. 20637-00. Samples were titrated with sulfuric acid using a digital titrator.

Hardness

HACH test kit catalog no. 20636-00 was used, with a digital titrator using EDTA as the titrant.

Turbidity

Turbidities were measured at the DFG laboratory in Redding using a Hach Model 2100A turbidimeter. If the turbidities were not run within 48 hours of collection they were frozen for later analysis.

Biochemical Oxidation Demand

Samples were run at Montague. The incubation cabinet was an absorption type refrigerator controlled by a solid state, electronic thermo-regulator. Samples were nitrified

and run for five days using the procedure for natural waters.

Nitrates

For the period from April 4 to May 21 nitrate and ammonia samples were run on a Bausch and Lomb Spectronic mini 20 spectrophotometer borrowed from the Central Valley Regional Water Quality Control Board at Redding. From June 11th to the end of the project a HACH model DREL/2000 spectrophotometer was used for nitrate, phosphate and ammonia.

For the Mini 20 the procedure for nitrogen/nitrates described under catalog no. 33-09-06 was followed. Reproducible results were not obtained. (There was an apparent light leak. Passing a hand over the unit would cause the meter to move upscale a substantial amount.) HACH procedure #351 with a range of 0 to 0.4 mg/L NO_3^--N was used with the DREL/2000 Spectrophotometer. Reproducible results were also difficult to obtain. The standards supplied by HACH were reproducible but accuracy checks deviated at the third addition.

Orthophosphate

Orthophosphate (0 - 2.50 mg/L PO_4^{3-}) was measured using the HACH spectrophotometer (procedure #490). Only standard checks were performed.

Ammonia

For the Mini 20 the procedure for nitrogen/ammonia described under catalog no. 33-09-05 was followed. Again, reproducible results were not obtained. With the HACH unit the procedure followed was the Nessler Method (HACH Procedure #380) with a range of 0 to 2.50 mg/L NH_3^-N. Standard and accuracy checks were obtained.

Un-ionized Ammonia

Results were calculated using the tables in Morgan and Turner (1977).

Chlorophyll-a

The necessary equipment to run chlorophyll-a samples was not acquired until October. After collection, 100 ml. samples were preserved with approximately 0.4 ml. saturated $MgCO_3$ and frozen. A Turner Filter Fluorometer, Model 111, with blue lamp #110-853, T-5 Envelope, Lamp Adapter, primary filter (430 nm) and Secondary filter (>650 nm) was used to read the samples. The highest and lowest samples were sent to an EPA approved Laboratory (Neilson Research Corporation, Medford, Oregon) and results were converted to ug/L.

Water Flow

At sites one, three, four, and seven flow measurements were taken and rating curves developed. Equipment used was a direct reading Price Current meter on a top-setting rod.

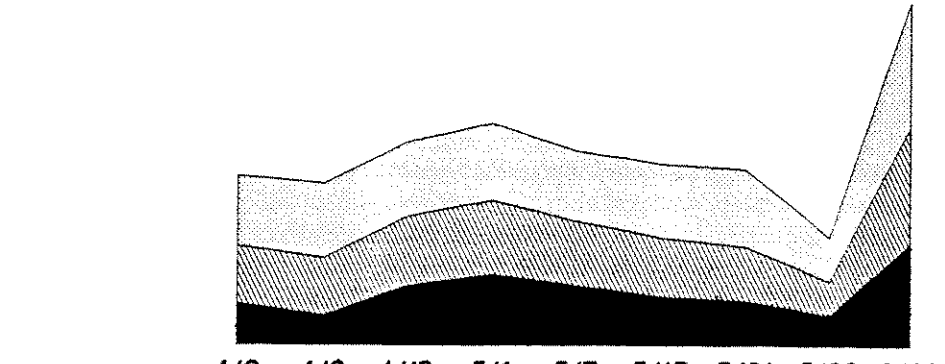
Results and Discussion

Tabulated results are located in Appendices B, C, D, and E.

Temperatures

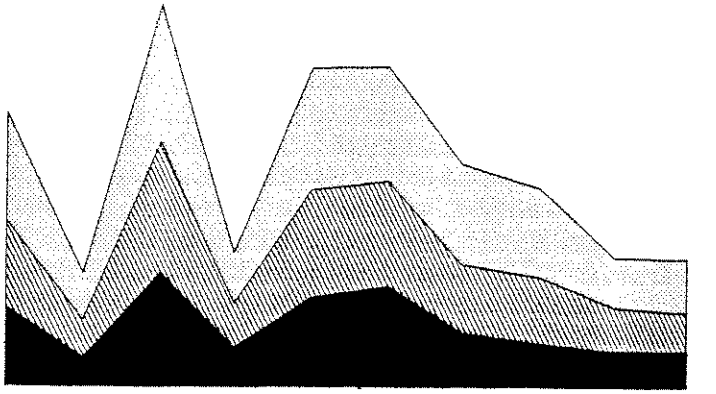
Air temperatures ranged from a low of 8°C (46.4°F) to 38.4°C (101.12°F), the lows occurring in April and June and the high in July (Figure 1, Appendix B).

Figure 1. Air Temperatures.
Field Samples.



	4/3	4/9	4/16	5/1	5/7	5/15	5/21	5/30	6/20
High	19	20	20	21	19	20	21	12	34
Average	15.6	15.6	16.7	20.1	17.4	16	14.7	9.3	31.9
Low	11	8	16	19	16	13	12	8	27.5

Spring 1990



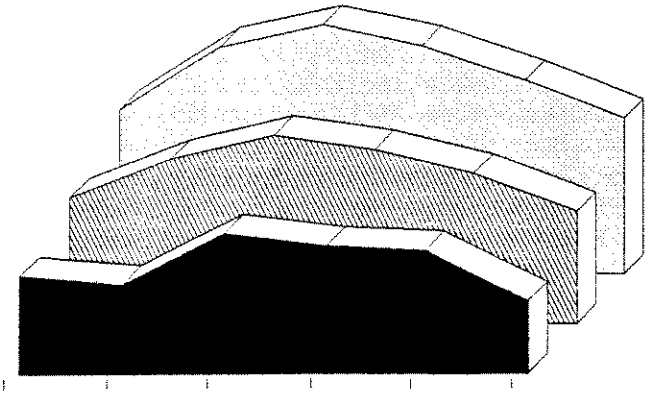
	6/27	6/28	7/13	7/27	8/9	8/22	9/13	9/27	10/13	1/23
High	30	13	38.4	14.3	34	32	28	25	14	15
Average	24.5	10.7	36.4	12.3	30.1	29.4	19.3	18.7	12.3	11
Low	22	8	32	11	25	28	15	12	10	10

Summer and Fall, 1990/91

Degrees Celsius.

The daily maximum, minimum, and average temperature data is illustrated and tabulated (Figure 2, Appendix E). During the 152 days of constantly recording temperatures 138 days were recorded that reached or exceeded 15.6°C (60°F), 90 days when it reached or exceeded 21.1°C (70°F), and 13

Figure 2. Temperature Recorder-1990.
Recorder Near Montague-Grenada Bridge.



	May	Jun	Jul	Aug	Sep	Oct
High	19.5	27	29.5	27	23	18.5
Average	14.97	19.5	22.34	20.53	17.75	13.25
Low	11.5	10.5	16.5	15	14.5	8.5

Degrees Celsius.

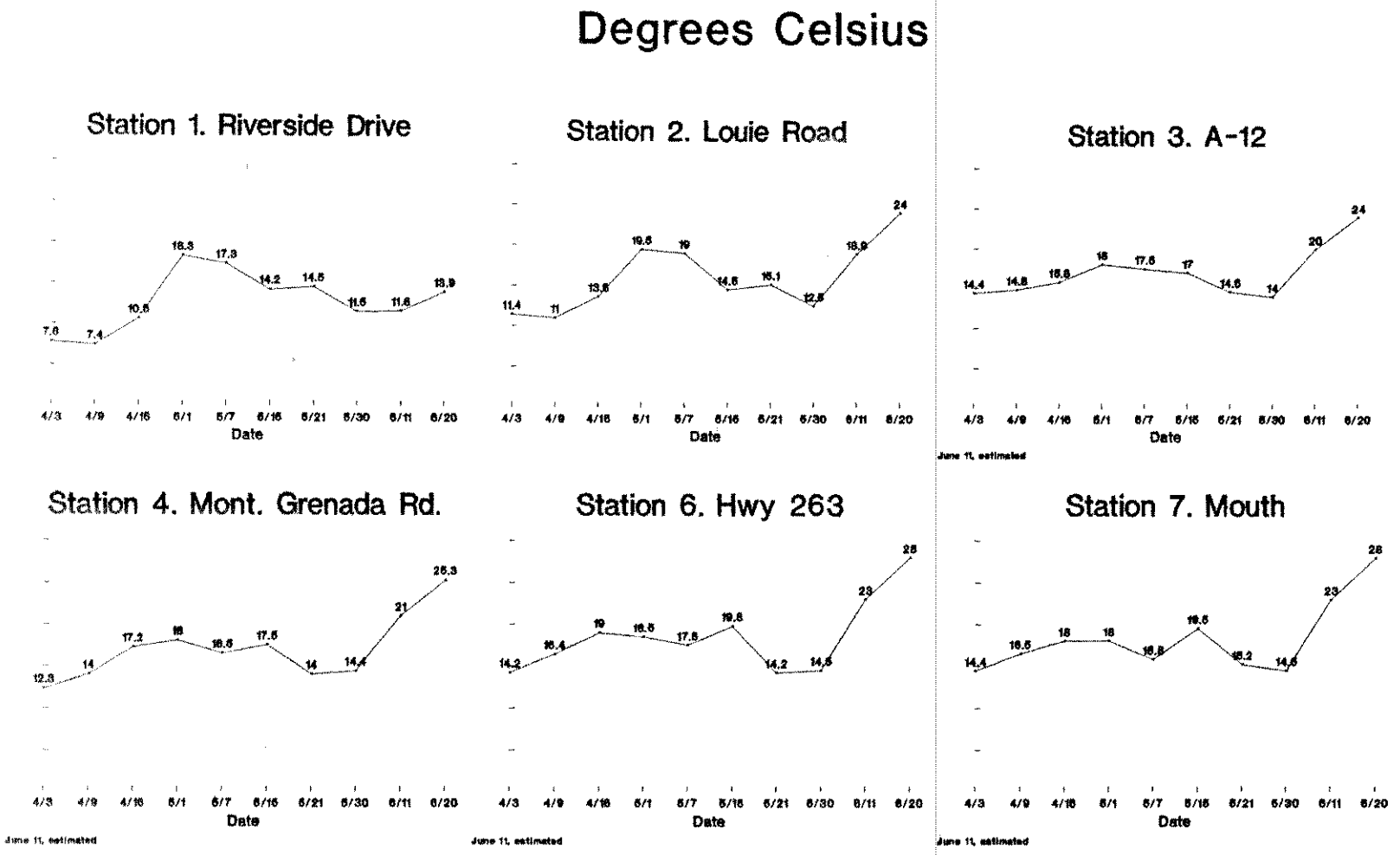
days when it reached or exceeded 26.7°C (80°F). On July 14th the water temperature was 29.5°C (85.1°F). Only 18 days were in the preferred 10 - 15.6° (50 - 60°F) range. Five in May, one in June and 18 in the latter part of October.

Grab samples taken at the seven stations showed that the location of the datapod suggested an average temperature for the entire system (Figures 3, 4, Appendix B). Usually the water was cooler at station one and warmest at stations sixth and seven. One sample taken at station seven was 32.0°C (89.6°F, July 13 at 1610 hours.)

Of the fifteen water quality parameters measured during this study only high water temperature was lethal to salmonids. In the literature there is abundant information on maximum, minimum, and optimum temperatures for various life stages, species, and under different conditions for anadromous salmonids (McKee, Moyle). Chinook salmon tolerate, for the short term, temperatures as low as 0.6°C (33°F) and as high as 25°C (77°F) but do well between 10 - 13.9°C (50 - 57°F)(Piper). The lethal high temperature is harder to ascertain. Most of the studies on high temperatures are done under controlled, laboratory conditions. Outside laboratory situations, other factors such as DO, physical stress, and acclimation become relevant. Long term exposure to sub-lethal high temperatures can result in death through stress, disease, or parasitic infections.

In general salmonids prefer water temperatures between 5 to 20°C (41 to 68°F) but some can live at higher temperatures. Steelhead fingerlings have been recovered in

Figure 3. Water Temperatures, Spring 1990

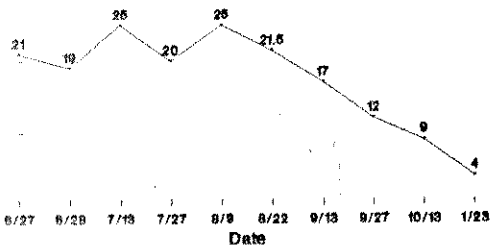


Six stations selected.

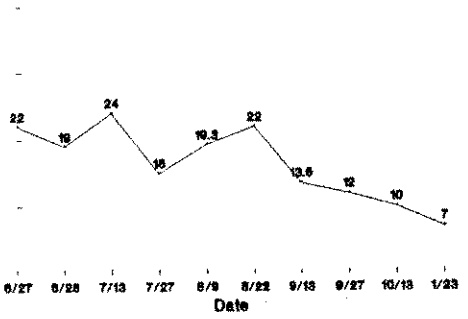
Figure 4. Water Temperatures, Summer/Fall 1990-91

Degrees Celsius

Station 1. Riverside Drive

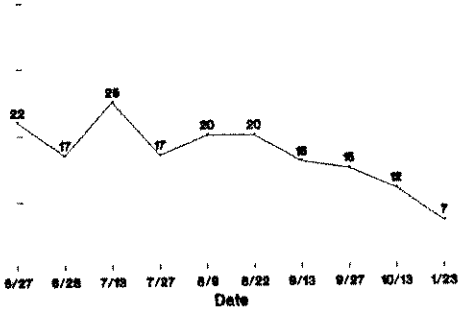


Station 2. Louie Road

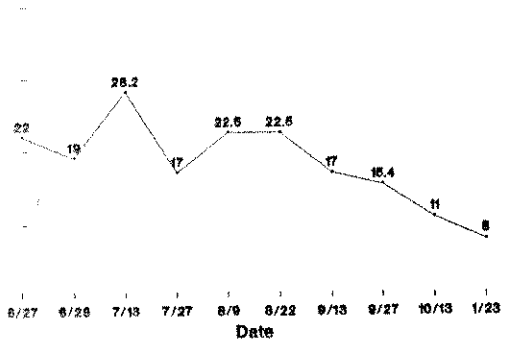


June 27,28 estimated

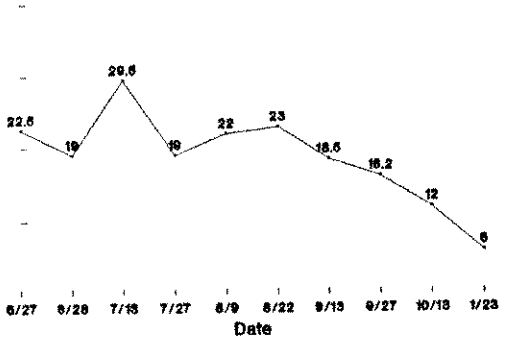
Station 3. A-12



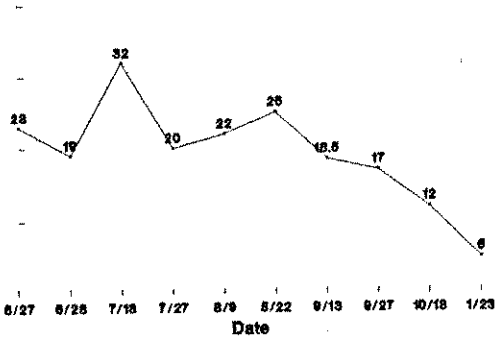
Station 4. Mont. Grenada Road



Station 6. Hwy 263



Station 7. Mouth



Six stations selected.

waters with temperatures as high as 30°C (86°F) with saturated DO conditions (Moyle). As temperatures increase salmonids become lethargic and are highly subject to disease organisms. In hatchery situations many managers claim high losses begin to occur when temperatures rise above 16°C (60°F) (A Nevison, Personal Communication).

The following temperatures for chinook salmon and steelhead were determined by the USFWS (Piper).

	Range	Optimum	Spawning
Chinook	0.56 - 25.0°C	10.0 - 13.9°C	7.2 - 12.8°C
Steelhead	0.56 - 25.6°C	10.0 - 15.6°C	10.0 - 12.8°C

Dissolved Oxygen

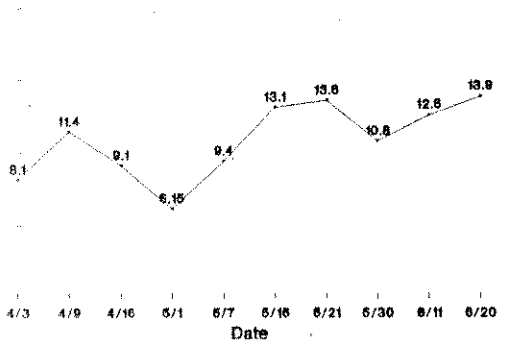
Dissolved oxygen values ranged from a low of 4.6 mg/L to a high of 19.2 mg/L (Figures 5, 6, and Appendix B). The lowest DO's occurred at stations two and three on May 1. At no other time did the measured DO drop below five mg/L. Collection times ranged from 0430 to 2030.

Five mg/L is considered by fisheries workers to be the safe minimum for salmonids (Ellis, Piper). The high levels (supersaturation) observed were believed to be caused by photosynthetic activity and has no adverse effect on salmonids. In less sluggish streams supersaturation is reduced by aeration.

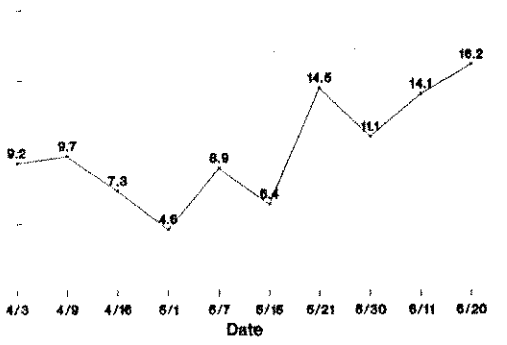
Figure 5. Dissolved Oxygen, Spring 1990.

Milligrams per Liter

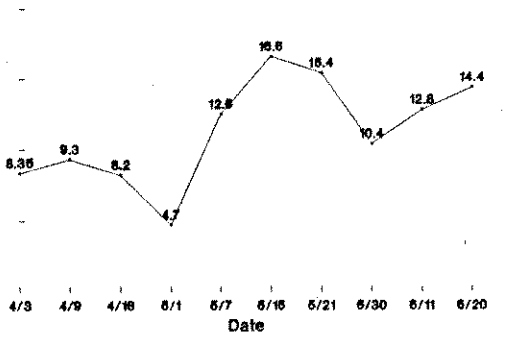
Station 1. Riverside Drive.



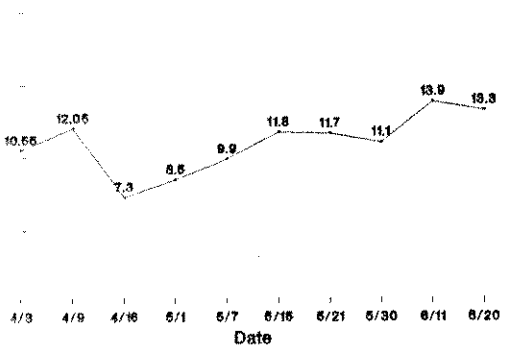
Station 2. Louie Road.



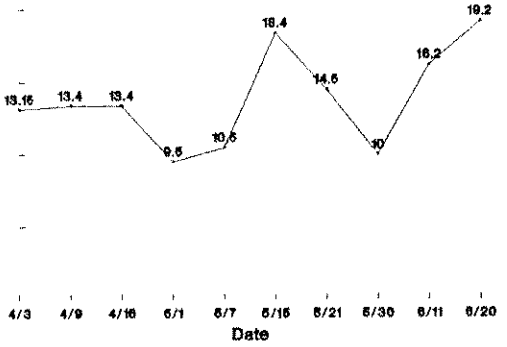
Station 3. A-12



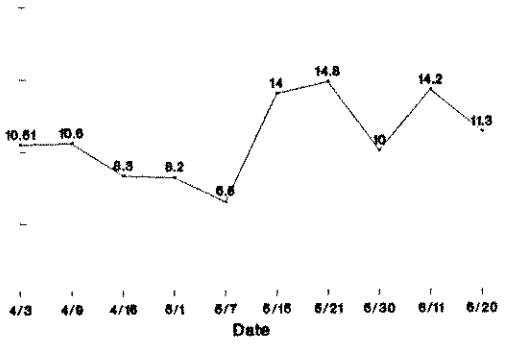
Station 4. Mont. Grenada Rd.



Station 6. Hwy 263



Station 7. Mouth.

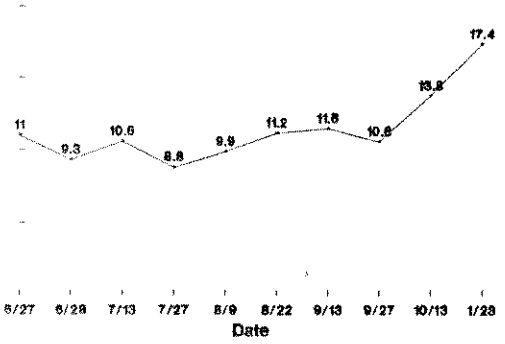


Six stations selected.

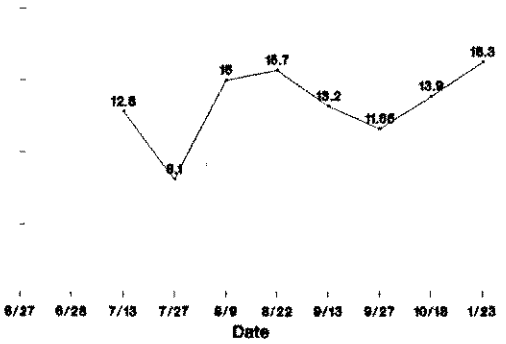
Figure 6. Dissolved Oxygen, Summer, Fall 90/91.

Milligrams per Liter

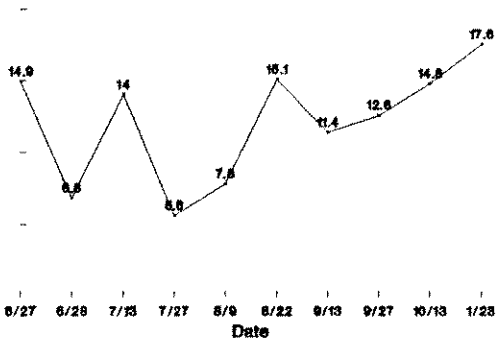
Station 1. Riverside Drive.



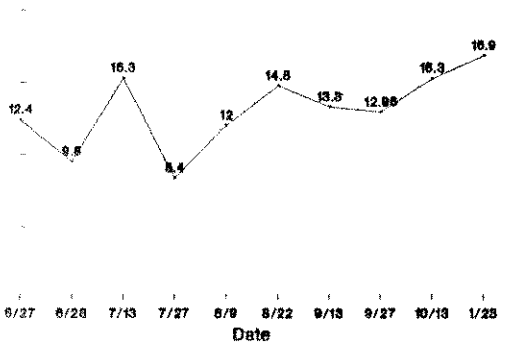
Station 2. Louie Road.



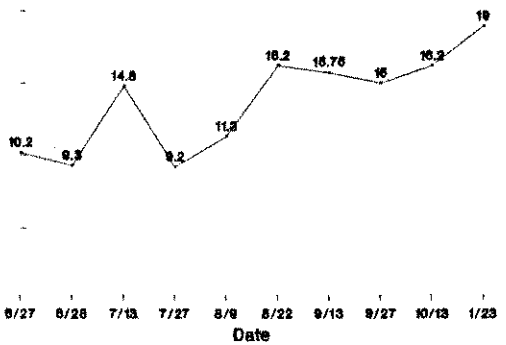
Station 5. Hwy 3.



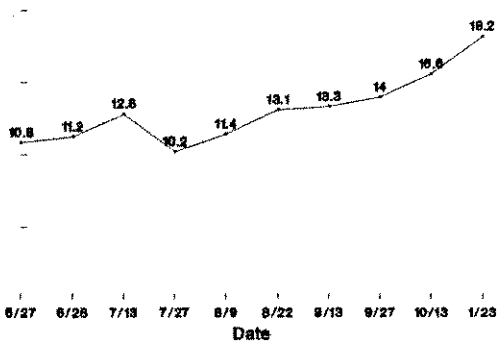
Station 4. Mont. Grenada Road.



Station 6. Hwy 263.



Station 7. Mouth.



Six Stations Selected

pH

Hydrogen ion concentrations ranged from 7.2 to 9.0 and were within the normal ranges for anadromous fish life (Figures 7, 8, and Appendix B). The pH of most natural waters varies from four to nine units (Ellis). Past studies suggested ninety percent of waters with good fresh water fish faunas had a pH of 6.7 to 8.2 units (Ellis).

The hydrogen-ion concentration in water is important to fishlife. Generally salmonids can withstand a range of 5.0 to 9.5 pH units. However most fish prefer the range of 6.5 to 9.0 pH units (Piper). As waters become more alkaline, toxic substances such as un-ionized ammonia are released and can cause death. Further discussion of this is included under ammonia.

Electrical Conductivity

In general EC increased from stations one to seven (Figures 9, 10, and Appendix C). A small anomaly exists at station three, as EC was often less that at stations two and four. This probably reflects inflows from tributary creeks. All EC levels were within the range suitable for all current beneficial uses (Bogener).

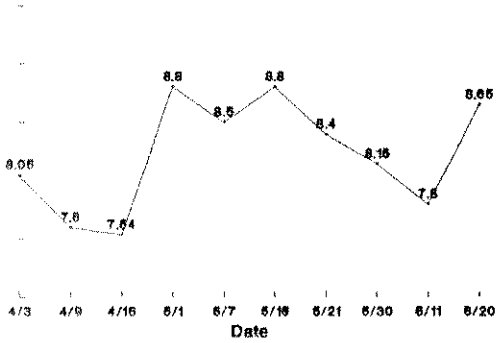
Alkalinity

Alkalinities ranged from 127 to 355 mg/l as $CaCO_3$. The lowest alkalinities were measured at station one. They

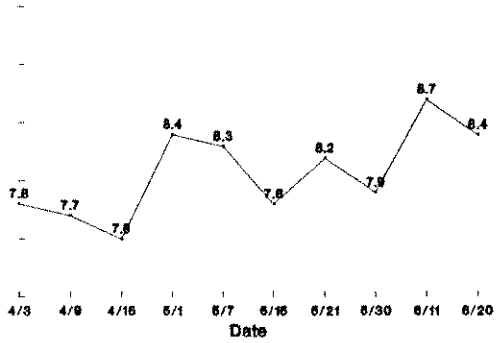
Figure 7. Hydrogen-ion (pH) Values. Spring 1990.

pH Units

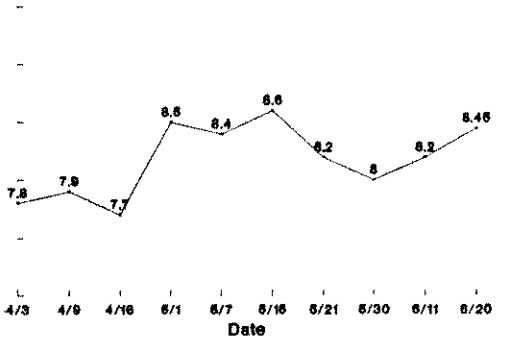
Station 1. Riverside Drive.



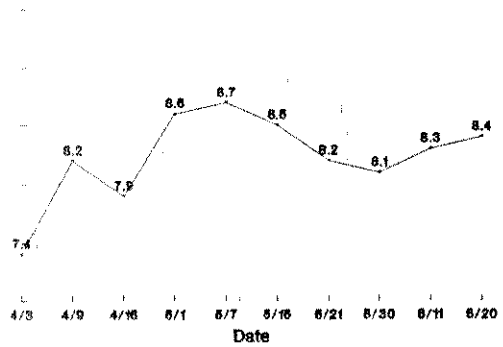
Station 2. Louie Road.



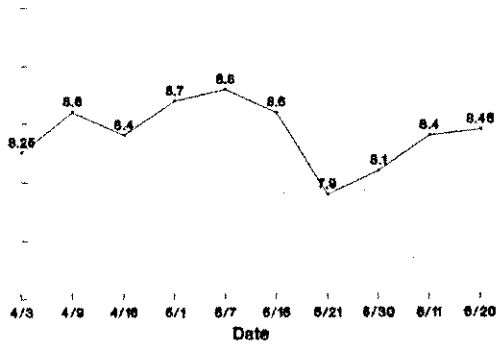
Station 3. A-12.



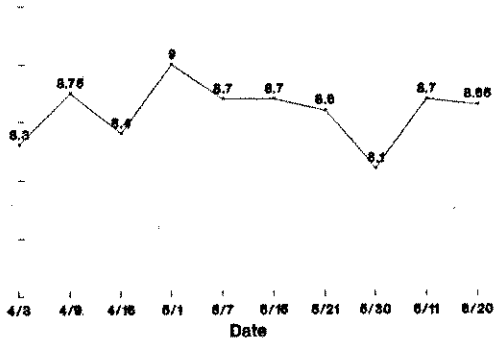
Station 4. Mont. Grenada Road.



Station 6. Hwy 263.



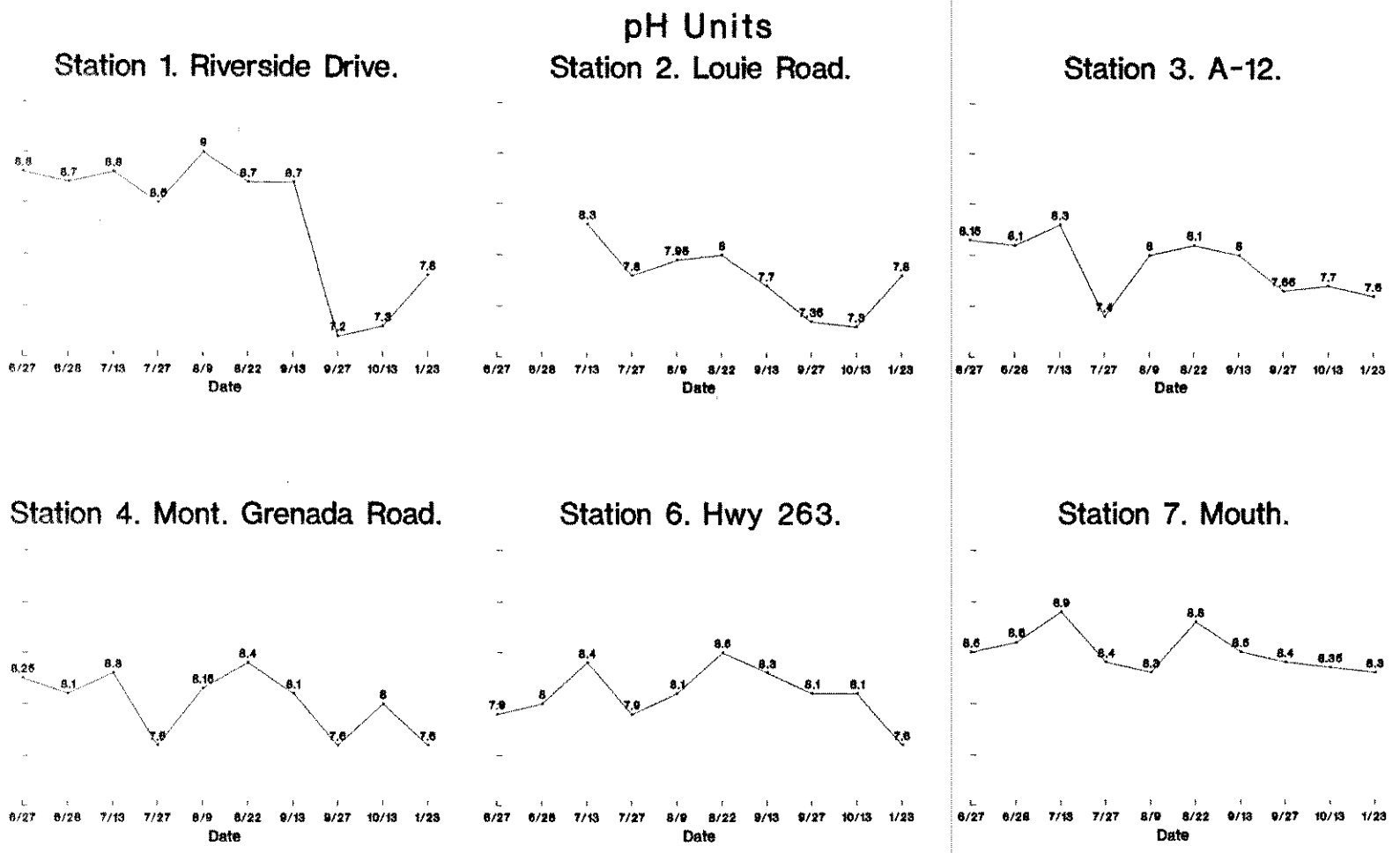
Station 7. Mouth.



Six Stations Selected

Figure 8. Hydrogen-ion (pH) Values.

Summer, Fall 1990-91.

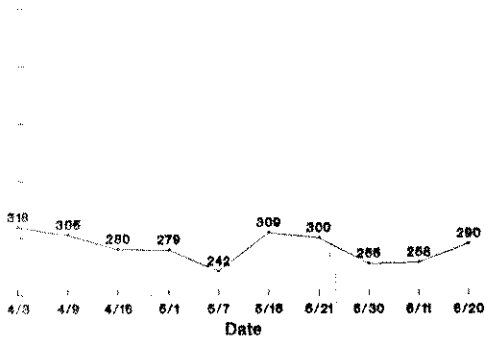


Six Stations Selected

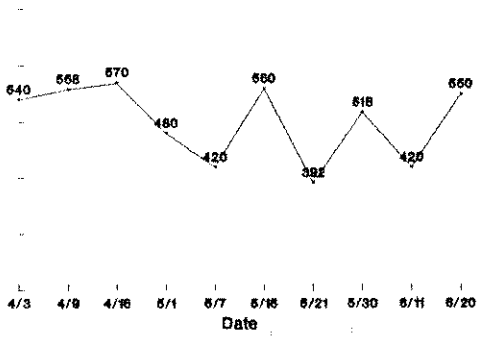
Figure 9. Electrical Conductivity, Spring 1990.

MicroMhos

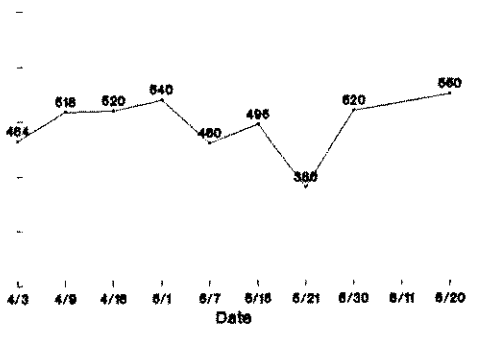
Station 1. Riverside Drive.



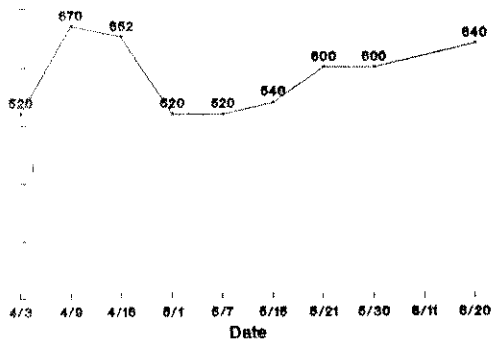
Station 2. Louie Road.



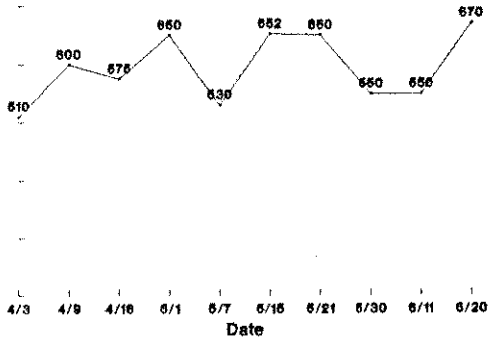
Station 3. A-12.



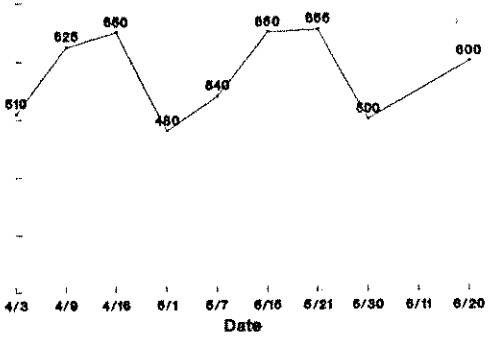
Station 4. Mont. Grenada Road.



Station 6. Hwy 263.



Station 7. Mouth.

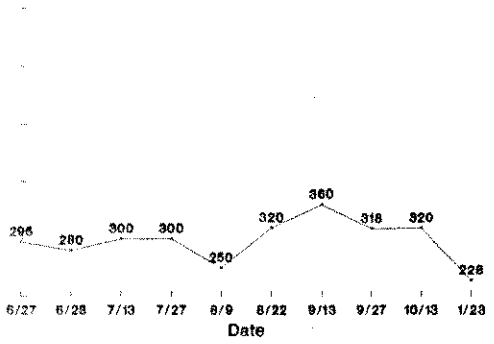


Six stations selected.

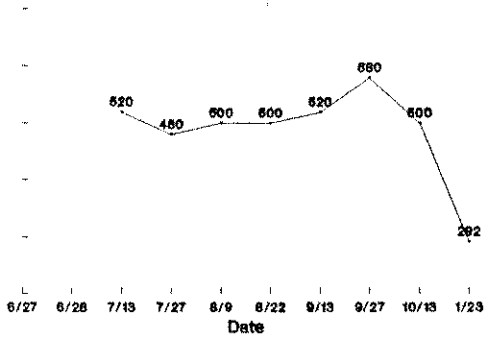
Figure 10. Electrical Conductivity, Summer/Fall 1990-91

MicroMhos

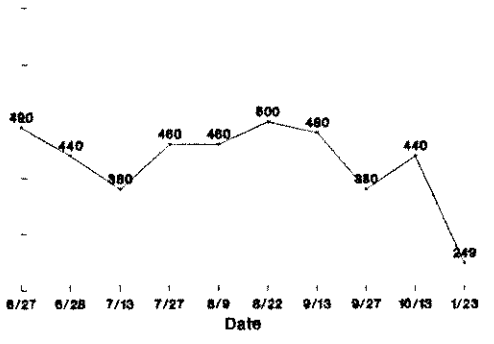
Station 1. Riverside Drive.



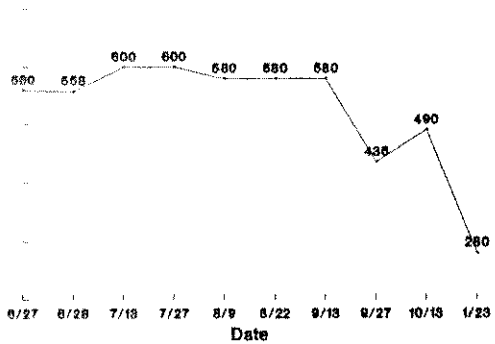
Station 2. Louie Road.



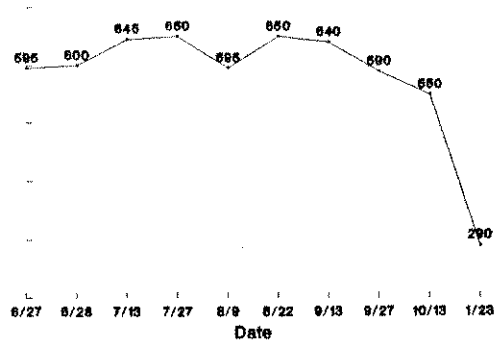
Station 3. A-12.



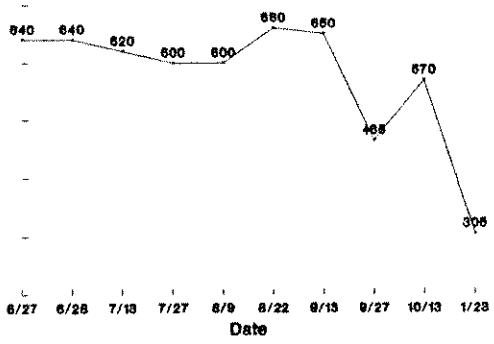
Station 4. Mont. Grenada Road.



Station 6. Hwy 263.



Station 7. Mouth.



Six stations selected.

increased downstream at all stations except station three where it was less than station two (Figures 11, 12 and Appendix C). This was probably due to the high CO_2 content of Big Springs Creek temporarily lowering the alkalinity of the river. The Shasta River rises in the Trinity Divide mountains, an area of low alkalinities, and steadily gains alkalinity as it accretes from waters of volcanic origin (Wilson).

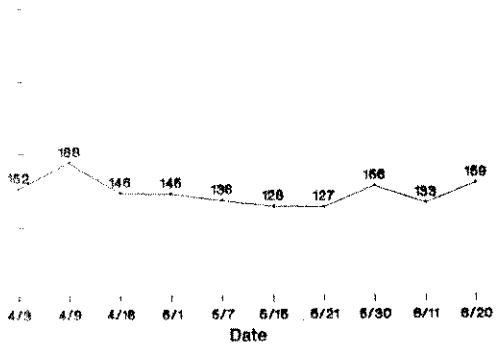
Alkalinity and hardness imply similar things about water quality, but they represent different types of measurements. Alkalinity refers to an ability to neutralize acid and is a direct counterpart of acidity. Hardness represents the concentration of calcium and magnesium cations also expressed as $CaCO_3$ - equivalent concentrations.

Alkalinity of a water refers to an ability to accept hydrogen ions (or to neutralize acid) and is a direct counterpart of acidity. Because alkalinity of many surface waters is primarily a function of carbonate, bicarbonate, and hydroxide content, it is taken as an indication of the concentration of these constituents. At low levels of alkalinity there is little buffering capacity to forestall acidification of the water. Most natural waters have an alkalinity of from 5 to 200 mg/l as $CACO_3$ (Leitritz). Extreme highs or lows are not especially detrimental to fish, although high alkalinities can be more beneficial to

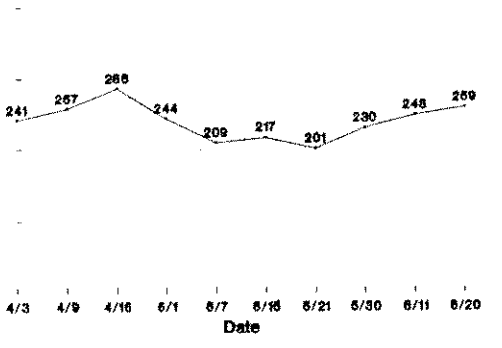
Figure 11. Alkalinity, Spring 1990.

Milligrams per Liter as CaCO3

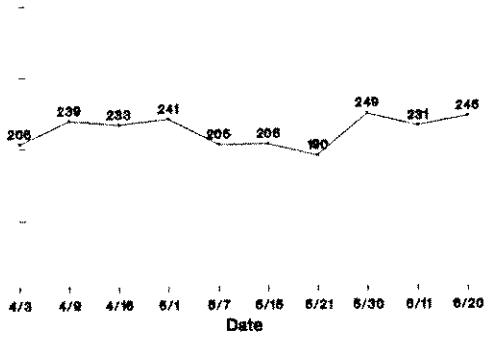
Station 1. Riverside Drive.



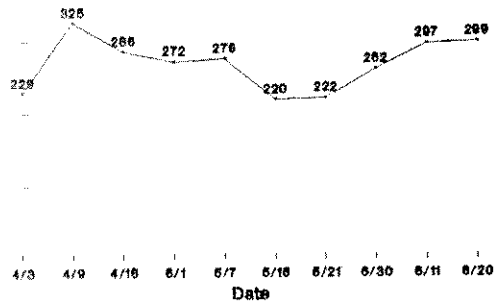
Station 2. Louie Road.



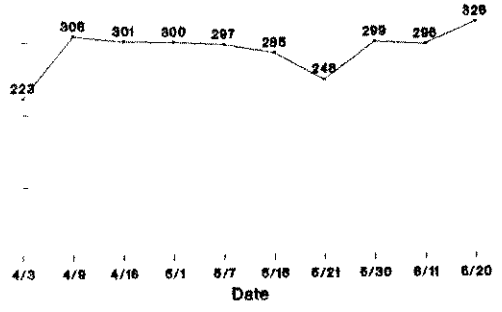
Station 3. A-12



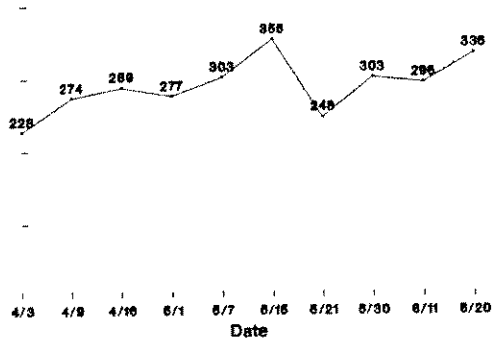
Station 4. Mont. Grenada Road.



Station 6. Hwy 263



Station 7. Mouth

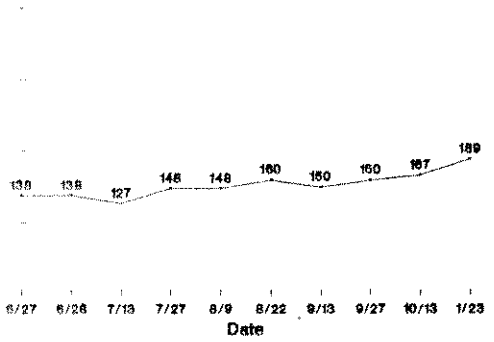


Six stations selected.

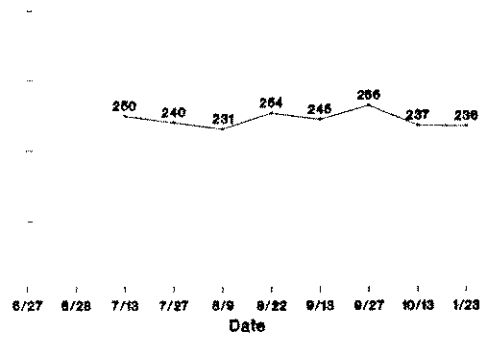
Figure 12. Alkalinity, Summer/Fall 1990-91.

Milligrams per Liter as CaCO3

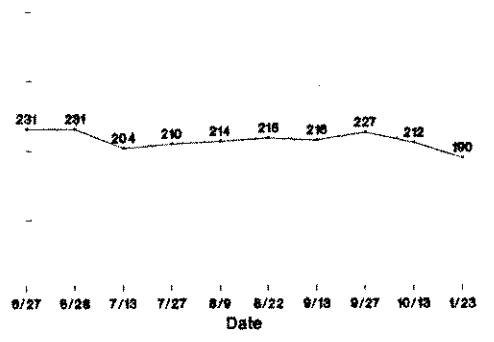
Station 1. Riverside Drive.



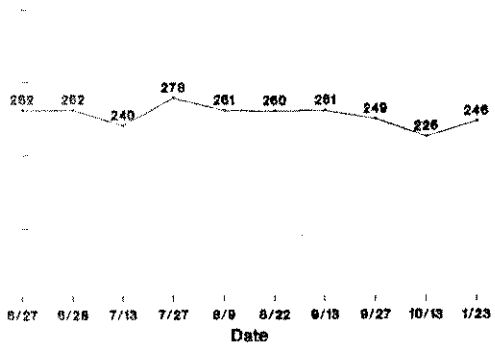
Station 2. Louie road.



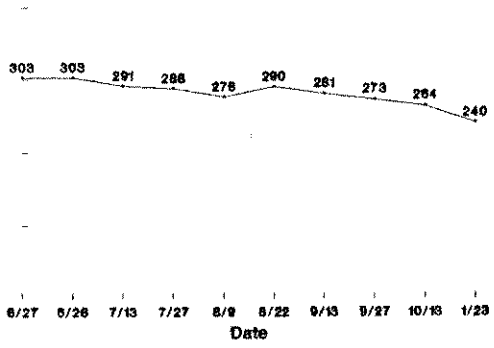
Station 3. A-12



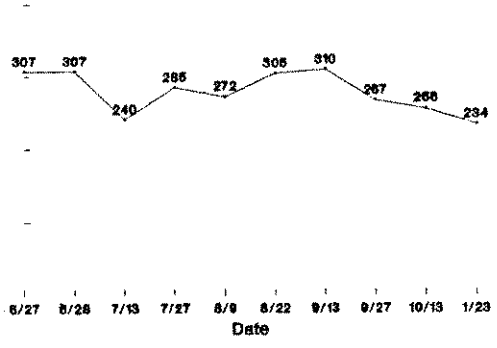
Station 4. Mont. Grenada Road.



Station 6. Hwy 263.



Station 7. Mouth.



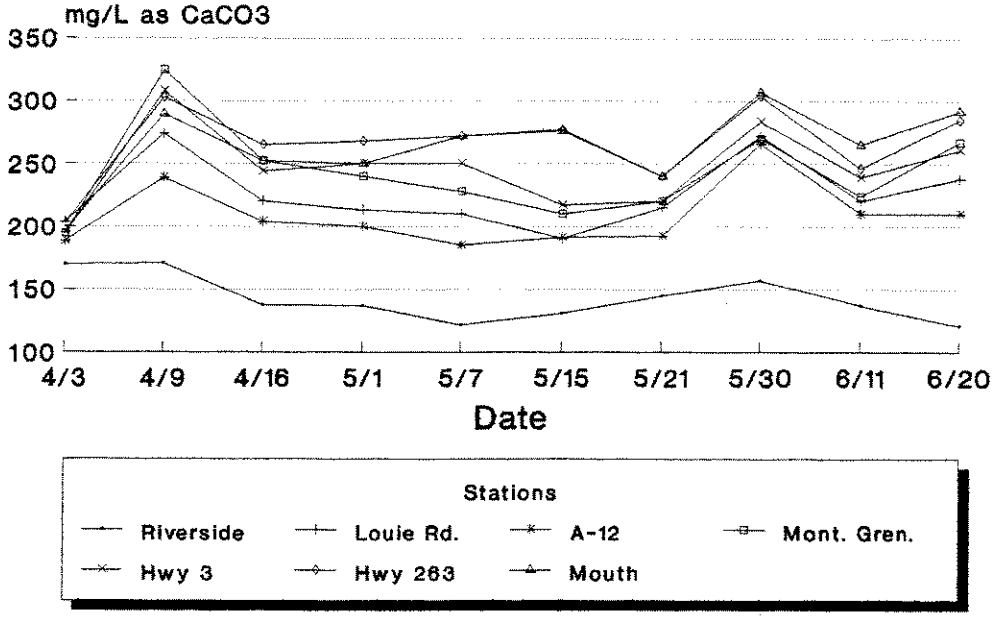
Six stations selected.

fish. Fish grow well over a wide range of alkalinities but values of 120 to 400 mg/l are optimum (Piper).

Hardness

Hardness values ranged from 121 to 325 mg/l as $CaCO_3$ during this study (Figures 13, 14 and Appendix C). Hardness represents the concentration of calcium (Ca^{++}) and magnesium

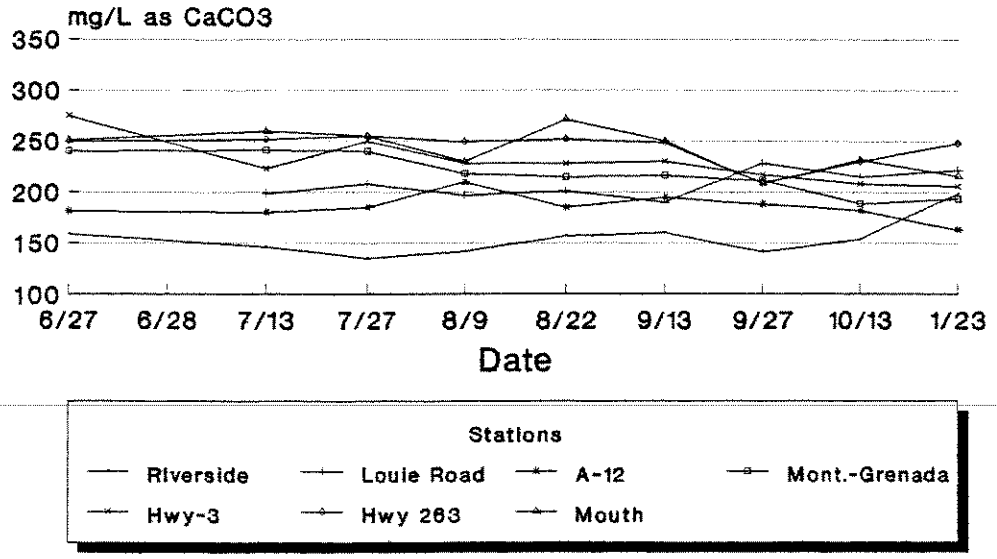
Figure 13. Hardness, Spring 1990



Seven Stations Sampled

(Mg^{++}) cations. Fish do well over a broad range of values but do best between 120 and 400 mg/L (Piper).

Figure 14. Hardness
Summer/Fall 1990-91



Seven Stations Sampled

Turbidity

Turbidities ranged from 0.4 to 7.6 Nephelometric turbidity units (NTU), (Appendix C). These values are low for natural waters. Salmonids can tolerate turbidity up to 100,000 mg/L for a short time with little adverse affect (Piper). There were few storm events during the period samples were collected. During storm events turbidities would be higher.

Water considered muddy usually contains less than 2000 mg/L (Piper). It is usually not harmful to fish, except

indirectly, as silt can cause smothering of eggs and benthic organisms and reduces light penetration.

Biochemical Oxidation Demand

BOD values ranged from 0.1 to 10 mg/l (Appendix B). BOD is not normally a water quality parameter measured when considering fishlife; it is more often used when dealing with polluted, high oxygen demand waters. However, DFG requested these tests be conducted, especially for station one. BOD can indicate what could occur in a system during the diurnal period and substitute for a 24 hour sampling regime for DO. In general results are not conclusive, except that often the highest BOD's were at station one and the lowest at stations six and seven.

There were periodic failures with the test, primarily from thermistor deficiencies in the controller.

Nitrates.

Nitrate values varied from <0.01 to 0.28 mg/L NH_3^-N with the highest occurring during the winter period at station six (Appendix D). (A value of 0.45 mg/L was measured during the spring using the mini spec 20.)

There was little change in nitrogen concentrations from station one to station seven. Concentrations were low, bordering upon the lower sensitivity limits of the test equipment. However, in the winter sample nitrogen

concentrations were higher and there was some change between stations.

Orthophosphate

Orthophosphate values ranged from 0.01 to 2.01 mg/L PO_4^{3-} (Appendix D).

Orthophosphate levels varied from station to station with the highest at stations six and seven. These values probably reflect the effect of the two sewage effluent inputs to the system. Phosphates apparently are not limiting factors, but this study was not sufficient in scope to verify this opinion.

The nutrients, nitrogen and phosphorus, affect fishlife indirectly by causing an increase in algae and other aquatic plant life. Such plant life decreases the amount of spawning areas, can cause diurnal swings of DO, increases pH that can result in increased amounts of ammonia. Aquatic plants can increase protective habitat for young fish and also reduce water velocities.

Ammonia

The highest calculated ammonia value was 0.17 mg/L on April 9th at Station 7 (Appendix D). However this was using the mini spec 20 equipment, which has been described as suspect. Using the HACH equipment the highest level found was 0.04 mg/L.

The toxicity of ammonia to fish is directly related to the amount of ammonia or undissociated ammonium hydroxide. This is a function of pH and temperature. The combined reversible equations are as follows:

$$NH_3 + H_2O \rightleftharpoons NH_4OH \rightleftharpoons NH_4^+ + OH^-$$

$$\left(\frac{NH_4^+}{NH_4OH}\right) = \frac{1.8X10^{-5}}{OH^{-5}}$$

The dissociation constant for ammonium hydroxide is 1.8 x 10^{-5} at 25^0C and the ratio of ammonium ions to NH_4OH is a function of pH. At pH 6 this ratio is 1800 to 1, at 7 it's 180 to 1 and at 8 it's 18 to 1 (McKee and Wolf 1963).

The calculated ammonia LC50's for trout listed in the literature range from 0.2 mg/L to as high as 0.6 mg/L (McKee and Wold 1963). Factors that cause these differences include different strains of fish, concentrations of free carbon dioxide in the water, alkalinity, hardness, and other water quality factors. The LC50 for minnows is reported to be between 5 and 7 mg/L of ammonia (LeClerc 1960).

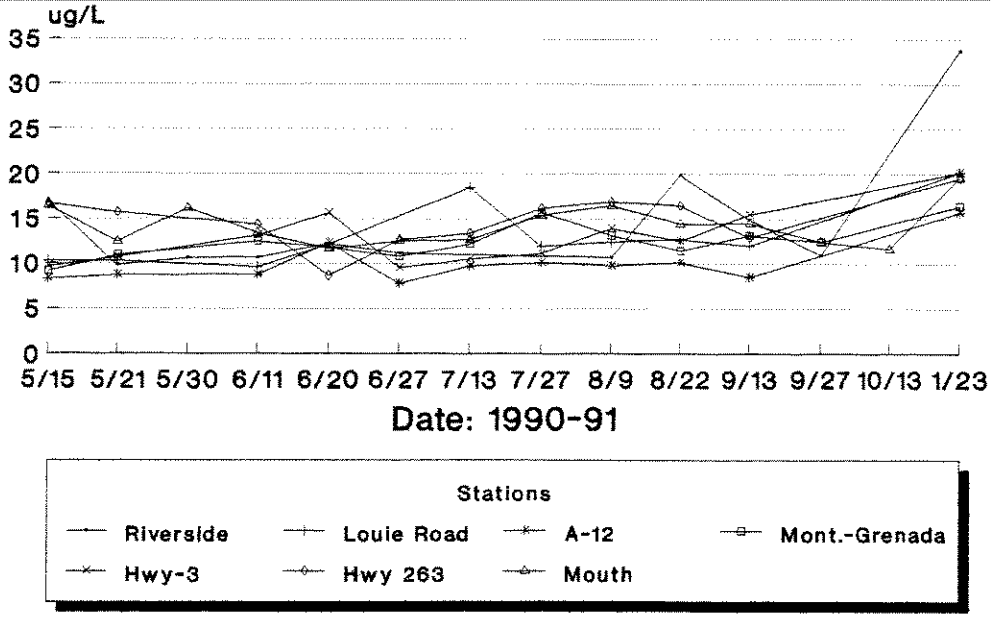
Toxic levels of ammonia were not found in the Shasta River. Fisheries workers have suggested that toxic levels of ammonia as a possible cause for previous fish kills. Data

collected during this study did not substantiate this premise.

Chlorophyll-a

The chlorophyll-a concentrations were so low that conclusions are difficult to draw (Figure 15, Appendix D). These data possibly reflect the length of time between

Figure 15. Chlorophyll-a.



Seven Stations Sampled

sample collection and testing. It was difficult getting the equipment together to be able to run the collected samples.

Chlorophyll measurements can be significant in research dealing with pollution; as chlorophyll levels can be a

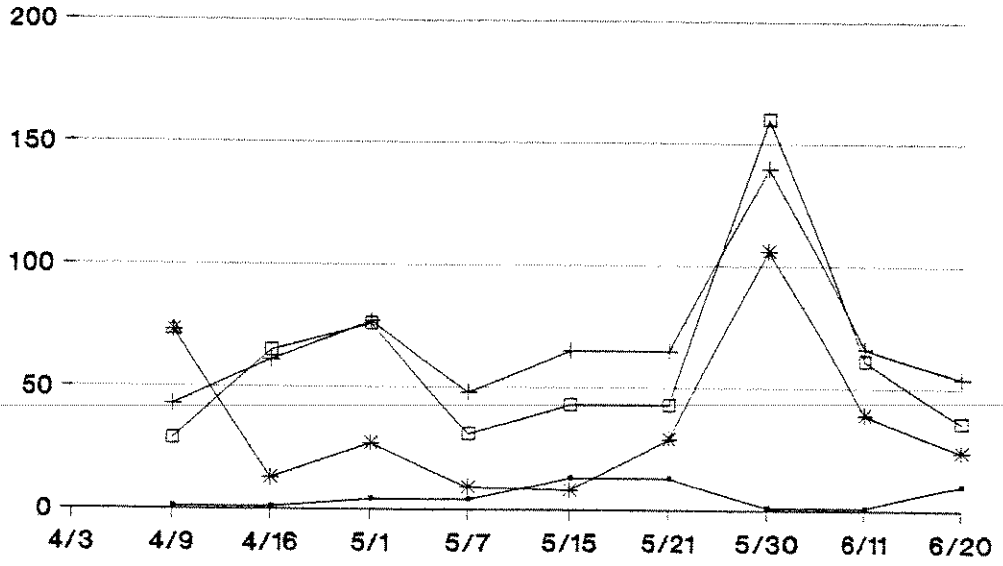
direct measure of algae abundance. The algae serve as an indicator of the nutrients and chemicals in a system.

WATER FLOW.

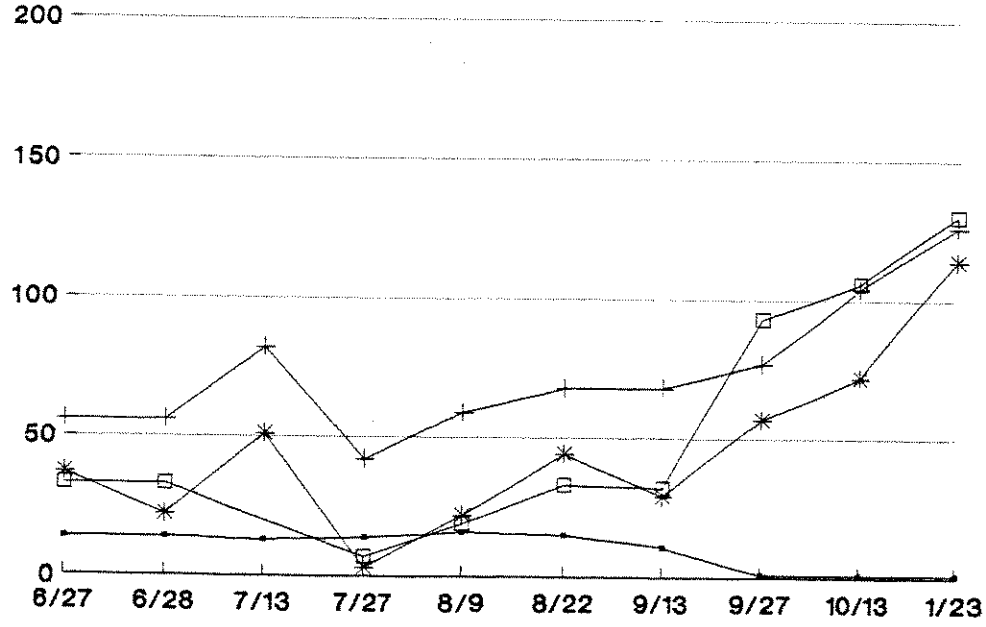
Water flow ranged from less than one CFS to an estimated 160 CFS during this study (Figures 16, 17, and Appendix C).

The flow at station one is normally low as it is made up of leakage water from the dam or irrigation ditch. Water was bypassed into the river during the summer season. Flows at station one ranged from less than one CFS to about 14 CFS. During DFG's 1989 data collection flows at station one were never greater than one CFS (D. Maria, Personal Communication). At station two they were fairly constant at about 45 CFS and at three 70 CFS. During the irrigation season, April 1 to October 15, flows were reduced at station four and gradually increased until station seven was similar in flow to station three.

Figure 16. Estimated River Flow.
Cubic Feet per Second



Spring, 1990



Summer - Fall 1990-91.

Stations

Riverside — A-12 — Mont.-Gren. — Mouth

SUMMARY AND CONCLUSIONS

High water temperature was the only water quality parameter measured that is considered harmful to salmonids. It is the period from mid-September until cool fall water temperatures occur that is critical to chinook salmon. Cooling of the river waters during this study to tolerable temperatures did not occur until the end of the first week in October.

Steelhead in Shasta River are subject to high spring, summer and fall water temperatures. The few coho salmon using the river face the same high temperature problems as the steelhead. Neither steelhead nor salmon find over-summer conditions favorable in the Shasta River. It is only in the headwaters of the larger tributaries, and portions of Big Springs Creek, where steelhead and coho juveniles can survive.

The causes of the high temperatures are varied. Some possibilities are:

1. During the period when water temperatures are a problem for salmonids, nearly all the water in the Shasta River is sun heated, irrigation return water that has been used at least once. Big Springs Creek is the

exception but there is no indication that its inflow cools the river.

2. The river is oriented North to South in a flat valley with little shade from vegetation or land forms.

3. The river is sluggish and tea colored. Both of these conditions exacerbates the effects of insolation.

4. Cool-water flows are reduced because of water diversions.

There are several ways to reduce river temperatures. Some are more practical than others.

1. Release adequate cool water from Dwinnell Dam, and other basin impoundments, into the river.

2. Reduce diversions from tributary streams and allow free-flow to the river.

3. If the waters are removed for irrigation, re-route flows away from the river, re-use, or cool the return waters.

4. Create new cool-water sources such as pumping from wells or re-routing waters from other watersheds.

5. Vigorously promote the growth of large shade trees and shrubs that will overhang and shade the river.

6. Protect shade-producing riparian vegetation from grazing.

7. Create and maintain deep pools for thermal stratification.

8. Decrease water transit time.

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SUMMARY OF EXPENDITURES

Personnel Costs	$ 16,379
Travel	1,662
Non-Expendable Equipment	1,734
Expendable Equipment/Supplies	1,815
Operations & Maintenance	638
Overhead	2,242
Total	$ 24,470

Non-Expendable Equipment:

HACH Model DREL/2000, Kit #45250-01 — $1,470

Accessory for Turner Fluorometer for Chlorophyll-a measurements.

Cat. No.	Description
110-853	Lamp
110-856	Lamp Adapter
110-922	Filter (5-60)
110-921	Filter (2-64)

Cost — 264

Total Non-Expendable Equipment — $ 1,734

APPENDIX A

SHASTA RIVER WATER QUALITY STUDY.
Sample Collection Schedule

Date	Air Temperature	Weather	Time
4-3-90	11.3 - 19.2C	Clear and Calm	0915-1220
4-9-90	8.3-19.9C	Clear and Calm	0845-1415
4-16-90	16-20.5C	Overcast and Calm	0845-1218
5-1-90	19.0-20.7	Clear with lt. winds	1640-1850
5-7-90	15.8-19.4	Clear and Calm	1200-1540
5-15-90	13.0-20.0C	Clear and Calm	1010-1440
5-21-90	12.5-21.0C	Brkn O'cast, lt. rain	1350-1715
5-30-90	8.0-11.5	Stormy, Int. rain	0505-0728
6-11-90	13.0-31.0C	Prtly cloudy, lt wind	0832-1250
6-20-90	27.5-34.0	Clear and Calm	1352-1700
6-27-90	22.0-30.0C	Clear with lt. winds	1800-2040
6-28-90	8.0-13.0	Clear and Calm	0436-0645
7-13-90	32.0-37.5C	Clear and Calm	1350-1610
7-27-90	11.0-14.0	Clear and Calm	0445-0716
8-9-90	25.0-34.0	Clear and Calm	0916-1200
8-22-90	28.0-32.0C	Clear and Calm	1231-1500
9-13-90	15.0-28.0C	Clear and Calm	0945-1200
9-27-90	11.5-25.0C	Clear and Calm	0845-1145
10-13-90	10.0-14.0C	O'cast and clearing	0922-1147
1-23-91	10.0-15.0C	Clear and Calm	1200-1420

APPENDIX B
SHASTA RIVER WATER QUALITY STUDY 1990-91
Selected Water Quality Parameters
NA = Not Available

Date	Station	Time	Air Temp C	Water Temp. C	Dissolved Oxygen mg/L	pH Units	DO Sat. mg/L	BOD mg/L
** 04/03/90								
04/03/90	Riversde	0915	11.3	7.8	8.10	8.05	69	NA
04/03/90	Louie Rd	1006	13.8	11.4	9.20	7.80	85	NA
04/03/90	A-12	1040	14.0	14.4	8.35	7.80	83	NA
04/03/90	Mont-Gre	1110	17.0	12.3	10.55	7.40	92	NA
04/03/90	Hwy-3	1128	15.5	12.0	11.45	7.80	108	NA
04/03/90	Hwy-263	1200	19.4	14.2	13.15	8.25	130	NA
04/03/90	Mouth	1220	18.2	14.4	10.51	8.30	103	NA
** 04/09/90								
04/09/90	Riversde	0845	8.3	7.4	11.40	7.60	95	NA
04/09/90	Louie Rd	1010	12.3	11.0	9.70	7.70	89	NA
04/09/90	A-12	1115	15.0	14.8	9.30	7.90	86	NA
04/09/90	Mont-Gre	1205	17.6	14.0	12.05	8.20	121	NA
04/09/90	Hwy-3	1300	17.9	14.2	13.40	8.35	132	5.5
04/09/90	Hwy-263	1340	18.0	16.4	13.40	8.60	138	NA
04/09/90	Mouth	1415	19.9	16.5	10.60	8.75	110	NA
** 04/16/90								
04/16/90	Riversde	0845	16.0	10.6	9.10	7.54	42	NA
04/16/90	Louie Rd	0915	19.0	13.6	7.30	7.50	37	NA
04/16/90	A-12	1010	18.2	15.8	8.20	7.70	42	NA
04/16/90	Mont-Gre	1030	18.0	17.2	7.30	7.90	38	NA
04/16/90	Hwy-3	1140	20.3	15.6	8.30	7.80	43	NA
04/16/90	Hwy-263	1250	20.5	19.0	13.40	8.40	73	NA
04/16/90	Mouth	1218	20.5	18.0	8.30	8.40	45	NA
** 05/01/90								
05/01/90	Riversde	1620	20.7	18.3	6.15	8.80	66	NA
05/01/90	Louie Rd	1545	20.7	19.5	4.60	8.40	52	NA
05/01/90	A-12	1700	20.3	18.0	4.70	8.50	51	0.1
05/01/90	Mont-Gre	1745	20.5	18.0	8.50	8.60	92	3.2
05/01/90	Hwy-3	1815	19.5	18.5	6.20	8.70	68	0.3
05/01/90	Hwy-263	1835	19.5	18.5	9.50	8.70	105	NA
05/01/90	Mouth	1850	19.0	18.0	8.20	9.00	89	NA
** 05/07/90								
05/07/90	Riversde	1540	19.4	17.3	9.40	8.50	99	5.6

APPENDIX B
SHASTA RIVER WATER QUALITY STUDY 1990-91
Selected Water Quality Parameters
NA = Not Available

Date	Station	Time	Air Temp C	Water Temp. C	Dissolved Oxygen mg/L	pH Units	DO Sat. mg/L	BOD mg/L
05/07/90	Louie Rd	1505	15.8	19.0	8.90	8.30	98	1.1
05/07/90	A-12	1421	18.0	17.5	12.50	8.40	135	4.3
05/07/90	Mont-Gre	1340	16.5	16.5	9.90	8.70	105	NA
05/07/90	Hwy-3	1320	15.5	15.5	10.40	8.35	108	NA
05/07/90	Hwy-263	1245	18.8	17.5	10.50	8.80	113	7.3
05/07/90	Mouth	1200	18.4	15.8	6.50	8.70	67	2.2
** 05/15/90								
05/15/90	Riversde	1010	14.2	14.2	13.10	8.80	130	2.6
05/15/90	Louie Rd	1104	14.5	14.5	6.40	7.80	65	2.2
05/15/90	A-12	1205	13.0	17.0	16.60	8.60	174	2.0
05/15/90	Mont-Gre	1258	15.9	17.5	11.80	8.50	127	1.7
05/15/90	Hwy-3	1338	18.0	17.0	16.70	8.60	175	2.0
05/15/90	Hwy-263	1410	17.0	19.8	18.40	8.60	207	0.3
05/15/90	Mouth	1440	20.0	19.5	14.00	8.70	158	1.1
** 05/21/90								
05/21/90	Riversde	1715	12.5	14.5	13.60	8.40	139	7.3
05/21/90	Louie Rd	1620	14.5	15.1	14.50	8.20	148	3.5
05/21/90	A-12	1550	14.5	14.6	15.40	8.20	157	2.3
05/21/90	Mont-Gre	1520	14.9	14.0	11.70	8.20	117	1.3
05/21/90	Hwy-3	1500	13.0	13.6	13.50	8.10	135	3.9
05/21/90	Hwy-263	1430	14.0	14.2	14.50	7.90	145	3.6
05/21/90	Mouth	1350	21.0	15.2	14.80	8.60	151	3.2
** 05/30/90								
05/30/90	Riversde	0505	11.5	11.5	10.80	8.15	104	3.5
05/30/90	Louie Rd	0535	11.5	12.5	11.10	7.90	109	NA
05/30/90	A-12	0606	8.5	14.0	10.40	8.00	104	NA
05/30/90	Mont-Gre	0630	8.5	14.4	11.10	8.10	111	NA
05/30/90	Hwy-3	0651	8.0	14.5	10.80	8.10	111	NA
05/30/90	Hwy-263	0711	8.0	14.5	10.00	8.10	102	NA
05/30/90	Mouth	0728	8.7	14.5	10.00	8.10	102	3.6
** 06/11/90								
06/11/90	Riversde	0832	13	11.6	12.6	7.80	119	2.1
06/11/90	Louie Rd	0915	14	18.9	14.1	8.10	155	2.2
06/11/90	A-12	1020	23	NA	12.8	8.2	NA	1.9

APPENDIX B
SHASTA RIVER WATER QUALITY STUDY 1990-91
Selected Water Quality Parameters
NA = Not Available

Date	Station	Time	Air Temp C	Water Temp. C	Dissolved Oxygen mg/L	pH Units	DO Sat. mg/L	BOD mg/L
06/11/90	Mont-Gre	1104	NA	NA	13.9	8.3	NA	--
06/11/90	Hwy-3	1200	NA	NA	14.2	8.35	NA	2.3
06/11/90	Hwy-263	1230	NA	NA	16.2	8.4	NA	1.6
06/11/90	Mouth	1250	NA	NA	14.2	8.7	NA	1.9
** 06/20/90								
06/20/90	Riversde	1352	27.5	21.0	13.9	8.65	138	3.9
06/20/90	Louie Rd	1430	31	24	16.2	8.4	197	----
06/20/90	A-12	1515	31	24	14.4	8.45	176	----
06/20/90	Mont-Gre	1542	33	25.3	13.3	8.4	165	----
06/20/90	Hwy-3	1608	34	25	15.2	8.5	189	----
06/20/90	Hwy-263	1641	34	28	19.2	8.45	252	2.9
06/20/90	Mouth	1700	33	28	11.3	8.65	148	----
** 06/27/90								
06/27/90	Riversde	1800	30	21	11.0	8.8	127	7.8
06/27/90	A-12	1845	26	22	13.9	8.15	163	3.9
06/27/90	Mont-Gre	1915	24	22	12.4	8.25	146	2.4
06/27/90	Hwy-3	1941	23	24	14.9	8.3	182	3.5
06/27/90	Hwy-263	2007	22.5	22.5	10.2	7.90	122	1.8
06/27/90	Mouth	2040	22	23	10.8	8.5	129	1.8
** 06/28/90								
06/28/90	Riversde	0550	8	19	9.3	8.7	103	NA
06/28/90	A-12	0520	13	17	10.1	8.10	107	NA
06/28/90	Mont-Gre	0500	11	19	9.5	8.10	105	NA
06/28/90	Hwy-3	0436	10	19	6.8	8.0	75	NA
06/28/90	Hwy-263	0630	11	19	9.3	8.0	103	NA
06/28/90	Mouth	0645	11	19	11.2	8.6	124	NA
** 07/13/90								
07/13/90	Riversde	1350	37.5	25.0	10.60	8.80	131	NA
07/13/90	Louie Rd	1415	37.5	24.0	12.80	8.30	156	NA
07/13/90	A-12	1446	37.5	25.0	14.40	8.30	170	NA
07/13/90	Mont-Gre	1510	38.0	28.0	15.30	8.30	200	NA
07/13/90	Hwy-3	1530	37.0	28.0	14.00	8.30	183	NA
07/13/90	Hwy-263	1550	34.0	29.5	14.80	8.40	200	NA
07/13/90	Mouth	1610	32.0	32.0	12.80	8.90	179	NA

APPENDIX B
SHASTA RIVER WATER QUALITY STUDY 1990-91
Selected Water Quality Parameters
NA = Not Available

Date	Station	Time	Air Temp C	Water Temp. C	Dissolved Oxygen mg/L	pH Units	DO Sat. mg/L	BOD mg/L
** 07/27/90								
07/27/90	Riversde	0445	13.0	20.0	8.80	8.50	99	10.
07/27/90	Louie Rd	0511	12.0	15.0	8.10	7.8	82	NA
07/27/90	A-12	0542	12.0	17.0	10.2	7.40	108	3.60
07/27/90	Mont-Gre	0604	11.0	17.0	8.4	7.6	89	NA
07/27/90	Hwy-3	0636	11.0	20.0	5.6	7.8	63	NA
07/27/90	Hwy-263	0658	13.0	19.0	9.2	7.9	102	3.0
07/27/90	Mouth	0716	14.0	20.0	10.2	8.4	115	NA
** 08/09/90								
08/09/90	Riversde	1200	34.0	25.0	9.90	9.0	123	3.9
08/09/90	Louie Rd	1133	34.0	19.3	15.0	7.95	165	1.7
08/09/90	A-12	1100	32.0	20.0	12.1	8.0	136	1.1
08/09/90	Mont-Gre	1030	29.0	22.0	12.0	8.15	140	1.1
08/09/90	Hwy-3	1015	29.0	22.0	7.8	7.85	89	3.1
08/09/90	Hwy-263	0947	28.0	22.0	11.3	8.1	132	3.2
08/09/90	Mouth	0916	25.0	22.0	11.4	8.3	133	0.8
** 08/22/90								
08/22/90	Riversde	1231	28	21.5	11.2	8.7	131	4.60
08/22/90	Louie Rd	1300	29	22	15.7	8.0	184	6.55
08/22/90	A-12	1328	29	20	12.9	8.1	145	3.6
08/22/90	Mont-Gre	1352	29	22	14.8	8.4	173	2.4
08/22/90	Hwy-3	1410	29	20.8	15.1	8.3	173	3.4
08/22/90	Hwy-263	1433	30	23	16.2	8.5	193	2.3
08/22/90	Mouth	1500	32	25	13.1	8.8	162	1.4
** 09/13/90								
09/13/90	Riversde	0940	17	17	11.50	8.7	122	2.5
09/13/90	Louie Rd	1002	17	13.5	13.2	7.7	131	1.45
09/13/90	A-12	1029	17	16	13.3	8.0	138	1.5
09/13/90	Mont-Gre	1040	15	17	13.3	8.1	141	0.45
09/13/90	Hwy-3	1107	20	16	11.4	8.2	118	2.0
09/13/90	Hwy-263	1130	21	18.5	15.75	8.3	174	1.0
09/13/90	Mouth	1200	28	18.5	13.3	8.5	147	0.7

APPENDIX B
SHASTA RIVER WATER QUALITY STUDY 1990-91
Selected Water Quality Parameters
NA = Not Available

Date	Station	Time	Air Temp C	Water Temp. C	Dissolved Oxygen mg/L	pH Units	DO Sat. mg/L	BOD mg/L
** 09/27/90								
09/27/90	Riversde	0845	11.5	12.0	10.6	7.2	100	1.9
09/27/90	Louie Rd	0917	15.0	12.0	11.65	7.35	110	3.6
09/27/90	A-12	1001	14.0	15.0	12.60	7.65	128	1.4
09/27/90	Mont-Gre	1023	19.0	15.0	12.95	7.60	131	1.3
09/27/90	Hwy-3	1051	23.0	15.5	12.6	8.0	130	1.7
09/27/90	Hwy-263	1121	23.0	16.2	15.0	8.1	155	1.45
09/27/90	Mouth	1145	25.0	17.0	14.0	8.40	148	0.4
** 10/13/90								
10/13/90	Riversde	0922	10.0	9.0	13.8	7.3	122	NA
10/13/90	Louie Rd	0947	11.0	10.0	13.9	7.3	126	NA
10/13/90	A-12	1023	12.0	12.0	13.0	7.7	123	NA
10/13/90	Mont-Gre	1046	12.0	11.0	15.3	8.0	141	NA
10/13/90	Hwy-3	1106	13.0	11.0	14.8	8.0	134	NA
10/13/90	Hwy-263	1125	14.0	12.0	16.2	8.1	153	NA
10/13/90	Mouth	1147	14.0	12.0	15.6	8.35	148	NA
** 01/23/91								
01/23/91	Riversde	1200	10.0	4.0	17.4	7.8	135	NA
01/23/91	Louie Rd	1123	13.0	7.0	16.3	7.8	137	NA
01/23/91	A-12	1243	10.0	7.0	16.5	7.6	139	NA
01/23/91	Mont-Gre	1308	11.0	8.0	16.9	7.6	145	NA
01/23/91	Hwy-3	1327	14.0	7.0	17.6	7.5	148	NA
01/23/91	Hwy-263	1350	15.0	6.0	19.0	7.6	156	NA
01/23/91	Mouth	1420	14.0	5.0	18.2	8.3	145	NA

APPENDIX C
SHASTA RIVER WATER QUALITY STUDY 1990-91
Selected Water Quality Parameter and Flow
NA = Not Available

Date	Station	Time	Hardness Mg/l as CaCO3	Alkalinity Mg/l as CaCO3	Turbidity NTU	Elect. Cond. (EC) umhos	Flow CFS (est)
** 04/03/90							
04/03/90	Riversde	0915	170	152	0.7	318	NA
04/03/90	Louie Rd	1006	204	241	1.1	540	NA
04/03/90	A-12	1040	188	206	1.6	464	NA
04/03/90	Mont-Gre	1110	194	229	2.1	520	NA
04/03/90	Hwy-3	1128	194	219	2.0	522	NA
04/03/90	Hwy-263	1200	203	223	1.9	510	NA
04/03/90	Mouth	1220	197	228	1.5	510	NA
** 04/09/90							
04/09/90	Riversde	0845	171	188	0.7	305	1.03
04/09/90	Louie Rd	1010	274	257	2.3	558	42.63
04/09/90	A-12	1115	239	239	1.6	518	73.32
04/09/90	Mont-Gre	1205	325	325	2.0	670	29.25
04/09/90	Hwy-3	1300	308	342	2.2	660	-----
04/09/90	Hwy-263	1340	303	308	1.5	600	-----
04/09/90	Mouth	1415	290	274	1.0	625	72.96
** 04/16/90							
04/16/90	Riversde	0845	138	146	0.8	280	1.00
04/16/90	Louie Rd	0915	220	286	1.1	570	NA
04/16/90	A-12	1010	204	233	1.9	520	61.00
04/16/90	Mont-Gre	1030	252	286	1.6	652	13.38
04/16/90	Hwy-3	1140	244	297	1.4	670	------
04/16/90	Hwy-263	1250	265	301	0.9	575	------
04/16/90	Mouth	1218	252	289	0.6	650	64.50
** 05/01/90							
05/01/90	Riversde	1620	137	145	1.0	279	3.61
05/01/90	Louie Rd	1545	213	244	1.4	480	45.93
05/01/90	A-12	1700	200	241	2.2	540	76.68
05/01/90	Mont-Gre	1745	240	272	2.2	520	26.68
05/01/90	Hwy-3	1815	250	275	1.2	625	------
05/01/90	Hwy-263	1835	268	300	1.0	650	------
05/01/90	Mouth	1850	250	277	0.5	480	75.51

APPENDIX C
SHASTA RIVER WATER QUALITY STUDY 1990-91
Selected Water Quality Parameter and Flow
NA = Not Available

Date	Station	Time	Hardness Mg/l as CaCO3	Alkalinity Mg/l as CaCO3	Turbidity NTU	Elect. Cond. (EC) umhos	Flow CFS (est)
** 05/07/90							
05/07/90	Riversde	1540	122	136	0.9	242	3.50
05/07/90	Louie Rd	1505	210	209	1.4	420	19.47
05/07/90	A-12	1421	185	205	1.5	460	47.97
05/07/90	Mont-Gre	1340	228	276	1.8	520	9.30
05/07/90	Hwy-3	1320	250	275	1.5	520	------
05/07/90	Hwy-263	1245	272	297	0.9	530	------
05/07/90	Mouth	1200	272	303	0.4	540	30.75
** 05/15/90							
05/15/90	Riversde	1010	131	128	1.3	309	12.66
05/15/90	Louie Rd	1104	190	217	1.1	560	29.28
05/15/90	A-12	1205	191	206	1.2	495	64.97
05/15/90	Mont-Gre	1258	210	220	1.7	540	8.20
05/15/90	Hwy-3	1338	217	232	1.6	540	------
05/15/90	Hwy-263	1410	277	285	1.2	652	------
05/15/90	Mouth	1440	276	355	0.6	650	43.35
** 05/21/90							
05/21/90	Riversde	1715	145	127	1.9	300	12.60
05/21/90	Louie Rd	1620	215	201	1.0	392	29.00
05/21/90	A-12	1550	192	190	1.5	380	65.00
05/21/90	Mont-Gre	1520	220	222	2.6	600	28.80
05/21/90	Hwy-3	1500	220	220	1.9	600	------
05/21/90	Hwy-263	1430	240	248	2.7	650	------
05/21/90	Mouth	1350	240	248	1.0	655	43.00
** 05/30/90							
05/30/90	Riversde	0505	157	156	NA	255	1.40
05/30/90	Louie Rd	0535	272	230	NA	518	NA
05/30/90	A-12	0606	266	249	NA	520	140
05/30/90	Mont-Gre	0630	270	262	NA	600	105.80
05/30/90	Hwy-3	0651	284	290	NA	550	------
05/30/90	Hwy-263	0711	304	299	NA	550	------
05/30/90	Mouth	0728	307	303	NA	500	160

APPENDIX C
SHASTA RIVER WATER QUALITY STUDY 1990-91
Selected Water Quality Parameter and Flow
NA = Not Available

Date	Station	Time	Hardness Mg/l as CaCO3	Alkalinity Mg/l as CaCO3	Turbidity NTU	Elect. Cond. (EC) umhos	Flow CFS (est)
** 06/11/90							
06/11/90	Riversde	0832	137	133	NA	258	0.55
06/11/90	Louie Rd	0915	220	248	NA	420	NA
06/11/90	A-12	1020	210	231	NA	NA	65.5
06/11/90	Mont-Gre	1104	224	297	NA	NA	39.0
06/11/90	Hwy-3	1200	239	268	NA	NA	------
06/11/90	Hwy-263	1230	246	296	NA	NA	------
06/11/90	Mouth	1250	265	296	NA	NA	61.4
** 06/20/90							
06/20/90	Riversde	1352	121	159	1.1	290	10.4
06/20/90	Louie Rd	1430	238	259	NA	550	NA
06/20/90	A-12	1515	210	245	NA	550	54.2
06/20/90	Mont-Gre	1542	267	299	NA	640	23.7
06/20/90	Hwy-3	1608	261	314	NA	670	------
06/20/90	Hwy-263	1641	285	326	NA	670	------
06/20/90	Mouth	1700	292	336	NA	600	35.6
** 06/27/90							
06/27/90	Riversde	1800	159	138	NA	295	13.86
06/27/90	A-12	1845	181	231	NA	490	56.4
06/27/90	Mont-Gre	1915	240	262	NA	560	36.50
06/27/90	Hwy-3	1941	275	270	NA	570	------
06/27/90	Hwy-263	2007	250	303	NA	595	------
06/27/90	Mouth	2040	251	307	NA	640	32.50
** 06/28/90							
06/28/90	Riversde	0550	157	135	NA	280	13.86
06/28/90	A-12	0520	181	138	NA	440	56.4
06/28/90	Mont-Gre	0500	240	262	NA	558	22.26
06/28/90	Hwy-3	0436	275	270	NA	420	------
06/28/90	Hwy-263	0630	250	303	NA	600	------
06/28/90	Mouth	0645	251	135	NA	640	32.50
** 07/13/90							
07/13/90	Riversde	1350	146	127	NA	300	13.4
07/13/90	Louie Rd	1415	199	250	NA	392	NA

APPENDIX C
SHASTA RIVER WATER QUALITY STUDY 1990-91
Selected Water Quality Parameter and Flow
NA = Not Available

Date	Station	Time	Hardness Mg/l as CaCO3	Alkalinity Mg/l as CaCO3	Turbidity NTU	Elect. Cond. (EC) umhos	Flow CFS (est)
07/13/90	A-12	1446	180	204	NA	380	82.3
07/13/90	Mont-Gre	1510	241	240	NA	600	51.0
07/13/90	Hwy-3	1530	223	258	NA	600	------
07/13/90	Hwy-263	1550	252	291	NA	650	------
07/13/90	Mouth	1610	260	240	NA	655	NA
** 07/27/90							
07/27/90	Riversde	0445	135	148	3.8	300	14.3
07/27/90	Louie Rd	0511	208	240	1.4	480	NA
07/27/90	A-12	0542	185	210	NA	460	41.7
07/27/90	Mont-Gre	0604	240	278	3.4	600	3.1
07/27/90	Hwy-3	0636	250	268	0.6	600	------
07/27/90	Hwy-263	0658	255	288	1.0	650	------
07/27/90	Mouth	0716	255	285	0.5	600	6.6
** 08/09/90							
08/09/90	Riversde	1200	142	148	6.6	250	15.6
08/09/90	Louie Rd	1133	197	231	2.6	500	NA
08/09/90	A-12	1100	210	214	5.2	460	58.7
08/09/90	Mont-Gre	1030	218	261	7.2	580	21.6
08/09/90	Hwy-3	1015	228	265	7.2	450	------
08/09/90	Hwy-263	0947	249	276	5.9	595	------
08/09/90	Mouth	0916	230	272	6.6	600	18.8
** 08/22/90							
08/22/90	Riversde	1231	157	160	4.1	320	15.1
08/22/90	Louie Rd	1300	201	254	3.2	500	NA
08/22/90	A-12	1328	185	218	3.2	500	67.8
08/22/90	Mont-Gre	1352	215	260	3.5	580	44.0
08/22/90	Hwy-3	1410	228	282	3.3	500	------
08/22/90	Hwy-263	1433	252	290	3.3	650	------
08/22/90	Mouth	1500	271	305	2.8	660	32.5
** 09/13/90							
09/13/90	Riversde	0940	160	150	1.9	360	11.3
09/13/90	Louie Rd	1002	190	245	0.8	520	NA
09/13/90	A-12	1029	195	216	1.5	480	67.8

APPENDIX C
SHASTA RIVER WATER QUALITY STUDY 1990-91
Selected Water Quality Parameter and Flow
NA = Not Available

Date	Station	Time	Hardness Mg/l as CaCO3	Alkalinity Mg/l as CaCO3	Turbidity NTU	Elect. Cond. (EC) umhos	Flow CFS (est)
09/13/90	Mont-Gre	1040	216	261	4.2	580	28.8
09/13/90	Hwy-3	1107	230	283	3.5	650	------
09/13/90	Hwy-263	1130	248	281	3.8	640	------
09/13/90	Mouth	1200	250	310	3.7	650	31.95
** 09/27/90							
09/27/90	Riversde	0845	141	160	1.0	318	<1.0
09/27/90	Louie Rd	0917	228	265	NA	580	NA
09/27/90	A-12	1001	188	227	NA	380	76.85
09/27/90	Mont-Gre	1023	211	249	7.6	435	57.0
09/27/90	Hwy-3	1051	217	260	NA	560	------
09/27/90	Hwy-263	1121	209	273	NA	590	------
09/27/90	Mouth	1145	209	267	7.2	465	93.3
** 10/13/90							
10/13/90	Riversde	0922	154	167	NA	320	<1.0
10/13/90	Louie Rd	0947	215	237	NA	500	NA
10/13/90	A-12	1023	182	212	NA	440	104
10/13/90	Mont-Gre	1046	189	225	NA	490	72.4
10/13/90	Hwy-3	1106	208	233	NA	510	------
10/13/90	Hwy-263	1125	230	264	NA	550	------
10/13/90	Mouth	1147	232	256	2.8	570	105.6
** 01/23/91							
01/23/91	Riversde	1200	199	189	2.5	228	<1.0
01/23/91	Louie Rd	1123	222	236	3.3	292	NA
01/23/91	A-12	1243	163	190	2.1	249	126
01/23/91	Mont-Gre	1308	194	246	2.8	280	114.0
01/23/91	Hwy-3	1327	206	215	4.6	282	------
01/23/91	Hwy-263	1350	248	240	3.9	290	------
01/23/91	Mouth	1420	216	234	3.2	305	>130

APPENDIX D
SHASTA RIVER WATER QUALITY STUDY 1990-91
Nutrients
NA = Not Available

Date	Station	Time	Nitrates MgN(NO3)/l	Ammonia MgN(NO3)/l	Un-Ion. Ammonia Percent	Phosp'te Mg/l as PO/4\3-	Chloro-A ug/l
** 04/03/90							
04/03/90	Riversde	0915	NA	NA	NA	NA	NA
04/03/90	Louie Rd	1006	NA	NA	NA	NA	NA
04/03/90	A-12	1040	NA	NA	NA	NA	NA
04/03/90	Mont-Gre	1110	NA	NA	NA	NA	NA
04/03/90	Hwy-3	1128	NA	NA	NA	NA	NA
04/03/90	Hwy-263	1200	NA	NA	NA	NA	NA
04/03/90	Mouth	1220	NA	NA	NA	NA	NA
** 04/09/90							
04/09/90	Riversde	0845	<0.01	0.15	<0.01	NA	NA
04/09/90	Louie Rd	1010	0.20	<0.01	<0.01	NA	NA
04/09/90	A-12	1115	0.20	1.68	0.04	NA	NA
04/09/90	Mont-Gre	1205	0.20	<0.01	<0.01	NA	NA
04/09/90	Hwy-3	1300	<0.01	<0.01	<0.01	NA	NA
04/09/90	Hwy-263	1340	0.19	1.88	0.21	NA	NA
04/09/90	Mouth	1415	<0.01	1.13	0.17	NA	NA
** 04/16/90							
04/16/90	Riversde	0845	<0.01	<0.01	0.04	NA	NA
04/16/90	Louie Rd	0915	<0.01	<0.01	<0.01	NA	NA
04/16/90	A-12	1010	<0.01	<0.01	<0.01	NA	NA
04/16/90	Mont-Gre	1030	<0.01	2.75	0.07	NA	NA
04/16/90	Hwy-3	1140	<0.01	<0.01	<0.01	NA	NA
04/16/90	Hwy-263	1250	<0.01	<0.01	<0.01	NA	NA
04/16/90	Mouth	1218	<0.01	<0.01	<0.01	NA	NA
** 05/01/90							
05/01/90	Riversde	1620	0.27	<0.01	<0.01	NA	NA
05/01/90	Louie Rd	1545	<0.01	<0.01	<0.01	NA	NA
05/01/90	A-12	1700	<0.01	<0.01	<0.01	NA	NA
05/01/90	Mont-Gre	1745	<0.01	<0.01	<0.01	NA	NA
05/01/90	Hwy-3	1815	<0.01	<0.01	<0.01	NA	NA
05/01/90	Hwy-263	1835	<0.01	<0.01	<0.01	NA	NA
05/01/90	Mouth	1850	<0.01	<0.01	<0.01	NA	NA
** 05/07/90							
05/07/90	Riversde	1540	0.45	0.93	0.09	NA	NA

APPENDIX D
SHASTA RIVER WATER QUALITY STUDY 1990-91
Nutrients
NA = Not Available

Date	Station	Time	Nitrates MgN(NO3)/l	Ammonia MgN(NO3)/l	Un-Ion. Ammonia Percent	Phosp'te Mg/l as PO/4\3-	Chloro-A ug/l
05/07/90	Louie Rd	1505	<0.01	0.38	0.03	NA	NA
05/07/90	A-12	1421	<0.01	<0.01	<0.01	NA	NA
05/07/90	Mont-Gre	1340	<0.01	<0.01	<0.01	NA	NA
05/07/90	Hwy-3	1320	<0.01	<0.01	<0.01	NA	NA
05/07/90	Hwy-263	1245	<0.01	<0.01	<0.01	NA	NA
05/07/90	Mouth	1200	0.05	<0.01	<0.01	NA	NA
** 05/15/90							
05/15/90	Riversde	1010	<0.01	<0.01	<0.01	NA	16.9
05/15/90	Louie Rd	1104	<0.01	0.58	<0.01	NA	10.3
05/15/90	A-12	1205	<0.01	0.30	0.03	NA	8.3
05/15/90	Mont-Gre	1258	0.30	0.02	<0.01	NA	9.1
05/15/90	Hwy-3	1338	0.01	<0.01	<0.01	NA	9.6
05/15/90	Hwy-263	1410	0.05	0.38	0.05	NA	16.7
05/15/90	Mouth	1440	<0.01	0.38	0.06	NA	16.4
** 05/21/90							
05/21/90	Riversde	1715	<0.01	0.13	<0.01	NA	9.8
05/21/90	Louie Rd	1620	<0.01	0.56	<0.01	NA	10.3
05/21/90	A-12	1550	<0.01	<0.01	<0.01	NA	8.7
05/21/90	Mont-Gre	1520	<0.01	<0.01	<0.01	NA	10.9
05/21/90	Hwy-3	1500	<0.01	0.20	<0.01	NA	10.7
05/21/90	Hwy-263	1430	<0.01	<0.01	<0.01	NA	15.7
05/21/90	Mouth	1350	<0.01	<0.01	<0.01	NA	12.4
** 05/30/90							
05/30/90	Riversde	0505	<0.01	NA	NA	NA	10.6
05/30/90	Louie Rd	0535	NA	NA	NA	NA	NA
05/30/90	A-12	0606	NA	NA	NA	NA	NA
05/30/90	Mont-Gre	0630	NA	NA	NA	NA	NA
05/30/90	Hwy-3	0651	NA	NA	NA	NA	NA
05/30/90	Hwy-263	0711	NA	NA	NA	NA	NA
05/30/90	Mouth	0728	NA	NA	NA	NA	16.2
** 06/11/90							
06/11/90	Riversde	0832	<0.01	<0.01	<0.01	NA	10.7
06/11/90	Louie Rd	0915	<0.01	<0.01	<0.01	NA	9.6
06/11/90	A-12	1020	<0.01	<0.01	<0.01	NA	8.8

APPENDIX D
SHASTA RIVER WATER QUALITY STUDY 1990-91
Nutrients
NA = Not Available

Date	Station	Time	Nitrates MgN(NO3)/l	Ammonia MgN(NO3)/l	Un-Ion. Ammonia Percent	Phosp'te Mg/l as PO/4\3-	Chloro-A ug/l
06/11/90	Mont-Gre	1104	<0.01	<0.01	<0.01	NA	12.5
06/11/90	Hwy-3	1200	<0.01	<0.01	<0.01	NA	13.1
06/11/90	Hwy-263	1230	<0.01	<0.01	<0.01	NA	14.3
06/11/90	Mouth	1250	<0.01	<0.01	<0.01	NA	13.4
** 06/20/90							
06/20/90	Riversde	1352	<0.01	<0.01	<0.01	0.15	12.2
06/20/90	Louie Rd	1430	<0.01	0.12	0.01	0.58	12.1
06/20/90	A-12	1515	<0.01	0.11	0.01	0.56	12.3
06/20/90	Mont-Gre	1542	<0.01	0.18	0.02	0.70	11.8
06/20/90	Hwy-3	1608	0.01	0.23	0.04	0.59	15.6
06/20/90	Hwy-263	1641	0.02	0.18	0.03	1.11	8.6
06/20/90	Mouth	1700	<0.01	0.15	0.04	1.16	11.6
** 06/27/90							
06/27/90	Riversde	1800	<0.01	<0.01	<0.01	0.02	11.1
06/27/90	A-12	1845	<0.01	0.01	<0.01	0.33	7.8
06/27/90	Mont-Gre	1915	<0.01	<0.01	<0.01	0.35	10.8
06/27/90	Hwy-3	1941	0.01	0.01	<0.01	0.51	9.5
06/27/90	Hwy-263	2007	<0.01	<0.01	<0.01	1.26	12.6
06/27/90	Mouth	2040	<0.01	<0.01	<0.01	1.13	12.5
** 06/28/90							
06/28/90	Riversde	0550	<0.01	<0.01	<0.01	0.02	11.1
06/28/90	A-12	0520	<0.01	0.01	<0.01	0.33	7.8
06/28/90	Mont-Gre	0500	<0.01	<0.01	NA	0.35	10.8
06/28/90	Hwy-3	0436	0.01	<0.01	NA	0.51	9.5
06/28/90	Hwy-263	0630	<0.01	<0.01	NA	1.26	12.6
06/28/90	Mouth	0645	<0.01	<0.01	NA	1.13	12.5
** 07/13/90							
07/13/90	Riversde	1350	<0.01	<0.01	<0.01	0.17	NA
07/13/90	Louie Rd	1415	<0.01	0.02	<0.01	0.65	18.5
07/13/90	A-12	1446	<0.01	0.02	<0.01	0.56	9.7
07/13/90	Mont-Gre	1510	<0.01	<0.01	<0.01	0.63	12.1
07/13/90	Hwy-3	1530	<0.01	<0.01	<0.01	0.56	10.5
07/13/90	Hwy-263	1550	<0.01	<0.01	<0.01	1.74	13.3
07/13/90	Mouth	1610	<0.01	0.02	<0.01	1.70	12.6

APPENDIX D
SHASTA RIVER WATER QUALITY STUDY 1990-91
Nutrients
NA = Not Available

Date	Station	Time	Nitrates MgN(NO3)/l	Ammonia MgN(NO3)/l	Un-Ion. Ammonia Percent	Phosp'te Mg/l as PO/4\3-	Chloro-A ug/l
** 07/27/90							
07/27/90	Riversde	0445	0.03	0.15	0.02	0.10	NA
07/27/90	Louie Rd	0511	0.13	0.19	<0.01	0.70	11.9
07/27/90	A-12	0542	0.04	0.06	<0.01	0.60	10.1
07/27/90	Mont-Gre	0604	0.01	0.14	<0.01	0.67	15.7
07/27/90	Hwy-3	0636	0.03	0.15	<0.01	0.76	11.1
07/27/90	Hwy-263	0658	0.12	0.11	<0.01	2.01	16.2
07/27/90	Mouth	0716	0.04	0.14	0.01	1.74	15.4
** 08/09/90							
08/09/90	Riversde	1200	<0.01	0.07	0.03	0.21	20.7
08/09/90	Louie Rd	1133	0.02	0.07	<0.01	0.75	12.4
08/09/90	A-12	1100	<0.01	<0.01	<0.01	0.63	9.8
08/09/90	Mont-Gre	1030	<0.01	0.04	<0.01	0.74	13.1
08/09/90	Hwy-3	1015	0.04	0.19	<0.01	0.80	13.9
08/09/90	Hwy-263	0947	0.10	0.10	<0.01	1.68	16.9
08/09/90	Mouth	0916	<0.01	0.03	<0.01	1.22	16.5
** 08/22/90							
08/22/90	Riversde	1231	<0.01	0.01	0.03	0.01	19.9
08/22/90	Louie Rd	1300	0.03	0.14	<0.01	0.62	12.7
08/22/90	A-12	1328	0.01	0.07	<0.01	0.58	10.1
08/22/90	Mont-Gre	1352	0.01	0.13	0.01	0.62	11.4
08/22/90	Hwy-3	1410	0.01	0.16	0.01	0.68	12.5
08/22/90	Hwy-263	1433	0.03	0.18	0.02	1.24	16.5
08/22/90	Mouth	1500	0.02	0.13	0.03	1.19	14.4
** 09/13/90							
09/13/90	Riversde	0940	<0.01	0.14	0.02	0.30	14.9
09/13/90	Louie Rd	1002	0.05	0.08	<0.01	0.64	12.0
09/13/90	A-12	1029	<0.01	0.07	<0.01	0.51	8.5
09/13/90	Mont-Gre	1040	0.01	0.13	<0.01	0.54	13.1
09/13/90	Hwy-3	1107	0.02	0.20	<0.01	0.60	15.5
09/13/90	Hwy-263	1130	0.02	0.13	<0.01	0.86	12.9
09/13/90	Mouth	1200	0.01	0.10	0.01	0.81	14.5

APPENDIX D
SHASTA RIVER WATER QUALITY STUDY 1990-91
Nutrients
NA = Not Available

Date	Station	Time	Nitrates MgN(NO3)/l	Ammonia MgN(NO3)/l	Un-Ion. Ammonia Percent	Phosp'te Mg/l as PO/4\3-	Chloro-A ug/l
** 09/27/90							
09/27/90	Riversde	0845	0.10	0.14	<0.01	0.55	10.9
09/27/90	Louie Rd	0917	0.04	0.21	<0.01	0.72	NA
09/27/90	A-12	1001	0.02	0.07	<0.01	0.82	NA
09/27/90	Mont-Gre	1023	0.01	0.07	<0.01	0.63	11.6
09/27/90	Hwy-3	1051	0.02	0.12	<0.01	0.53	NA
09/27/90	Hwy-263	1121	0.01	0.09	<0.01	0.77	NA
09/27/90	Mouth	1145	0.01	0.09	<0.01	0.84	12.4
** 10/13/90							
10/13/90	Riversde	0922	0.02	0.17	<0.01	0.40	NA
10/13/90	Louie Rd	0947	0.02	0.18	<0.01	0.65	NA
10/13/90	A-12	1023	0.05	0.16	<0.01	0.57	NA
10/13/90	Mont-Gre	1046	0.05	0.13	<0.01	0.60	NA
10/13/90	Hwy-3	1106	<0.01	0.17	<0.01	0.58	NA
10/13/90	Hwy-263	1125	0.02	0.18	<0.01	0.69	NA
10/13/90	Mouth	1147	<0.01	0.28	<0.01	0.70	11.6
** 01/23/91							
01/23/91	Riversde	1200	0.01	0.13	<0.01	0.35	33.7
01/23/91	Louie Rd	1123	0.19	0.13	<0.01	0.32	20.2
01/23/91	A-12	1243	0.25	0.08	<0.01	0.67	15.7
01/23/91	Mont-Gre	1308	0.17	0.09	<0.01	0.67	16.4
01/23/91	Hwy-3	1327	0.28	0.13	<0.01	0.67	20.2
01/23/91	Hwy-263	1350	0.28	0.15	<0.01	0.80	19.5
01/23/91	Mouth	1420	0.23	0.09	<0.01	0.66	19.5

APPENDIX E

Water Temperatures at Montague-Grenada Bridge
Shasta River, 1990

Date	Minimum	Maximum	Average
	(Degrees Celcius)		
05/16/90	15.0	18.5	16.5
05/17/90	15.5	19.0	17.0
05/18/90	15.0	19.5	17.0
05/19/90	14.5	18.5	16.0
05/20/90	13.0	16.0	14.0
05/21/90	13.0	14.5	13.5
05/22/90	13.0	15.5	14.0
05/23/90	12.0	14.0	13.0
05/24/90	12.0	16.0	14.0
05/25/90	12.5	17.0	15.0
05/26/90	14.5	17.5	16.0
05/27/90	13.5	16.5	15.0
05/28/90	13.5	15.0	14.0
05/29/90	13.5	16.5	15.5
05/30/90	14.0	17.5	15.5
05/31/90	11.5	15.0	13.5
Range	11.5	19.5	

Date	Minimum	Maximum	Average
	(Degrees Centigrade)		
06/01/90	10.5	13.0	11.5
06/02/90	11.0	16.0	14.0
06/03/90	14.0	18.5	16.5
06/04/90	15.0	19.0	16.5
06/05/90	15.5	20.5	17.5
06/06/90	16.0	19.5	17.5
06/07/90	16.0	20.0	18.0
06/08/90	16.5	21.0	18.5
06/09/90	17.5	22.5	20.0
06/10/90	17.5	22.0	19.0
06/11/90	16.0	21.5	18.0
06/12/90	16.0	21.5	18.0
06/13/90	15.0	21.5	17.5
06/14/90	15.5	20.5	17.5
06/15/90	16.5	21.5	18.5
06/16/90	17.5	22.0	19.0
06/17/90	17.5	22.5	19.0
06/18/90	17.0	23.0	19.5
06/19/90	17.5	23.0	20.0
06/20/90	18.5	25.0	21.5
06/21/90	20.5	26.5	23.0
06/22/90	21.5	27.0	23.5
06/23/90	18.5	26.0	22.0
06/24/90	18.5	26.0	22.0
06/25/90	18.0	24.5	21.0
06/26/90	18.5	24.5	21.0
06/27/90	18.0	24.0	20.5
06/28/90	18.8	25.0	21.0
06/29/90	18.5	25.5	21.5
06/30/90	18.5	25.5	21.5
Range	10.5	27.0	

Water Temperatures at Montague-Grenada Bridge
Shasta River, 1990

Date	Minimum	Maximum	Average
	(Degrees Celsius)		
07/01/90	19.0	26.5	22.0
07/02/90	17.5	26.5	21.5
07/03/90	16.5	23.5	19.5
07/04/90	17.5	25.0	20.5
07/05/90	16.5	22.5	19.5
07/06/90	16.5	20.5	18.0
07/07/90	17.5	23.5	19.5
07/08/90	18.5	24.5	21.0
07/09/90	20.0	26.0	22.5
07/10/90	21.0	26.5	23.0
07/11/90	21.0	27.0	23.5
07/12/90	21.0	27.0	23.5
07/13/90	21.5	28.0	25.0
07/14/90	22.5	29.5	25.5
07/15/90	22.0	29.0	25.0
07/16/90	22.0	27.5	24.5
07/17/90	22.0	27.5	24.5
07/18/90	20.0	23.0	21.5
07/19/90	20.0	26.5	22.0
07/20/90	20.5	24.0	22.0
07/21/90	21.5	26.0	23.5
07/22/90	22.5	27.0	24.5
07/23/90	21.5	27.0	24.0
07/24/90	19.5	25.5	22.0
07/25/90	18.0	24.5	21.0
07/26/90	17.5	25.0	20.5
07/27/90	18.5	25.5	21.5
07/28/90	19.0	26.5	22.5
07/29/90	20.0	27.0	23.0
07/30/90	20.5	27.5	23.5
07/31/90	19.5	26.5	22.5
Range	16.5	29.5	

Date	Minimum	Maximum	Average
	(Degrees Celsius)		
08/01/90	19.5	25.5	22.0
08/02/90	19.0	26.0	22.0
08/03/90	18.5	26.0	21.5
08/04/90	19.5	26.5	22.5
08/05/90	20.0	26.5	23.0
08/06/90	20.5	26.5	23.0
08/07/90	21.0	26.5	23.5
08/08/90	22.0	26.5	23.5
08/09/90	20.5	26.5	23.0
08/10/90	19.0	26.5	22.5
08/11/90	20.0	27.0	23.5
08/12/90	19.0	26.5	22.5
08/13/90	19.5	25.5	22.5
08/14/90	19.0	26.5	22.5
08/15/90	19.0	25.0	22.0
08/16/90	18.5	24.0	20.5
08/17/90	18.5	21.5	19.5
08/18/90	17.5	21.0	19.0
08/19/90	16.5	20.5	18.0
08/20/90	16.5	21.5	18.5
08/21/90	17.0	21.5	18.5
08/22/90	17.5	22.0	19.5
08/23/90	17.5	23.0	19.5
08/24/90	17.0	23.0	19.5
08/25/90	17.5	22.0	19.0
08/26/90	16.5	20.5	18.0
08/28/90	15.0	18.0	16.0
08/29/90	15.5	21.5	18.5
08/30/90	15.5	20.5	18.0
08/31/90	16.5	22.0	18.5
08/27/90	15.0	18.0	16.5
Range	15.0	27.0	

Water Temperatures at Montague-Grenada Bridge
Shasta River, 1990

Date	Minimum	Maximum	Average
	(Degrees Celsius)		
09/01/90	16.5	22.0	18.5
09/02/90	16.5	22.0	19.0
09/03/90	17.0	22.5	19.0
09/04/90	17.5	22.5	19.5
09/05/90	16.0	23.0	19.0
09/06/90	16.0	21.5	18.0
09/07/90	16.0	21.5	18.0
09/08/90	15.5	22.0	18.5
09/09/90	16.0	22.0	18.5
09/10/90	16.5	22.5	19.0
09/11/90	16.5	22.5	19.0
09/12/90	16.0	22.5	19.0
09/13/90	16.5	22.0	18.5
09/14/90	16.0	20.5	17.5
09/15/90	15.5	21.0	17.5
09/16/90	15.5	18.5	16.5
09/17/90	15.0	19.5	17.0
09/18/90	15.0	19.0	16.5
09/19/90	15.5	19.5	17.0
09/20/90	14.5	19.0	16.5
09/21/90	15.0	19.0	17.0
09/22/90	15.0	18.5	16.5
09/23/90	15.0	19.0	16.5
09/24/90	15.0	19.0	17.0
09/25/90	15.5	20.5	18.0
09/26/90	17.0	21.5	18.5
09/27/90	15.5	18.5	17.0
09/28/90	15.0	18.0	16.5
09/29/90	15.0	17.5	16.5
09/30/90	16.0	18.5	17.0
Range	14.5	23.0	

Date	Minimum	Maximum	Average
	(Degrees Celsius)		
10/01/90	15.5	18.5	17.0
10/02/90	15.5	18.0	16.5
10/03/90	14.5	17.5	16.0
10/04/90	13.5	16.5	14.5
10/05/90	13.5	16.5	15.0
10/06/90	14.0	16.5	15.5
10/07/90	11.5	15.5	14.0
10/08/90	10.5	14.5	13.0
10/09/90	10.5	13.5	12.0
10/10/90	10.5	13.0	12.0
10/11/90	11.0	13.5	12.5
10/12/90	10.5	13.5	12.0
10/13/90	10.5	13.5	12.0
10/14/90	10.5	13.5	12.5
10/15/90	11.0	14.0	12.5
10/16/90	11.0	14.5	13.0
10/17/90	12.0	15.5	14.0
10/18/90	10.0	15.0	13.0
10/19/90	10.0	13.5	12.0
10/20/90	11.0	12.5	11.5
10/21/90	9.5	13.0	11.5
10/22/90	9.5	13.0	11.0
10/23/90	11.0	14.5	12.5
10/24/90	8.5	14.5	12.5
Range	8.5	18.5	