Interim Report

INVESTIGATION OF WATER QUALITY CONDITIONS

IN THE

SHASTA RIVER,

SISKIYOU COUNTY

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SHASTA RIVER STUDY

INTRODUCTION AND BACKGROUND

The Water Quality Control Plan for the North Coast Region (Basin Plan) (NCRWQCB 1989) identifies the designated beneficial uses of water within the Shasta Valley. These include: municipal, domestic, and agricultural supply, freshwater replenishment, cold freshwater habitat, warm freshwater habitat, wildlife habitat, fish migration, and spawning habitat. Numeric water quality objectives have been adopted by the Regional Water Quality Control Board (Regional Board) for some parameters. Narrative objectives have been adopted for other water quality parameters, nutrients, for example.

This office was contacted in writing by the California Department of Fish and Game (CDFG) with regards to observed water quality and fish survival problems in the Shasta River (CDFG 1985; 1987; 1988). At that time, Regional Board staff had already fostered concerns with respect to these issues. There was not a large amount of historical water quality data, anadromous spawning/escapement was declining, and existing water quality data indicated problems (U.S. Department of the Interior:USDI 1985; CDFG 1960's, misc. data). Recent reports of juvenile fish mortality have preserved a high level of concern in the area.

In mid 1985, CDFG stated in a memo (CDFG 1985) that: 1) the Shasta River is the most important spawning and nursery area for the King chinook salmon population of the upper Klamath River; 2) the Shasta River is warm and enriched with nutrients and organic materials, resulting in the occurrence of dissolved oxygen concentrations of less than five mg/L during the late spring and early summer period; 3) there have been documented instances of anadromous fish kills during the end of the out-migration period; 4) the existing (1985) Water Quality Control Plan does not fully describe the extent of water quality problems in the Shasta River; 5) there is concern that water quality problems in the Shasta River will interfere with maintenance and restoration of the fishery; 6) corrective actions are recommended to be sought for the water quality problems on the Shasta River.

Review of the 1985 U.S. Department of the Interior report (USDI 1985) revealed that: 1) water temperatures adverse to salmon and steelhead use of the lower Shasta River have been a problem since at least 1961. Water temperatures up to 85 F (29.4 C) were reported between 1961 and 1970. As of 1985, high water temperatures were still a problem along the lower Shasta; 2) the principal constraints to salmon and steelhead production in the Shasta sub-basin were (in order of importance): low flows and high summer water temperatures; unscreened water diversions; degraded spawning gravel; and possible hydroelectric projects. Relatively rapid in-stream flow reductions at the start of the irrigation season were seen as a possible contribution to juvenile fall chinook, coho, and steelhead losses by stranding them in pools and side channels.

A 1987 CDFG memo to this office (CDFG 1987) discussed the problem of depressed dissolved oxygen levels possibly resulting from high biological oxygen demand and high temperatures. It further stated that more information is needed on water quality problems to establish funding priorities and management strategies for efforts to improve the physical habitat on the Shasta River. Internal communications here, in the summer of 1987, discussed the feasibility of addressing these concerns with Regional Board staff studies.

Another memorandum from CDFG to the Regional Water Quality Control Board Executive Officer, in the spring of 1988 (CDFG 1988), stated that: 1) the Department had documented critical conditions due to low dissolved oxygen concentrations, high nutrient concentrations, and high temperatures, especially during poor water years; 2) a great deal of emphasis had been placed upon restoration of salmon and steelhead in the Klamath River system. Rehabilitation on the Shasta River would be critical to the success of current major efforts of various state and federal agencies to restore anadromous fish runs in the Klamath River; 3) CDF&G officially asked for cooperation from Regional Board staff in conducting a joint water quality monitoring program on the Shasta River to "identify potential solutions for these significant water quality problems."

In May of 1988, the North Coast Region Surveillance, Monitoring and Planning Unit (SMP) prepared a "Proposal for a Water Quality Investigation of the Lower Shasta River", with the stated objective "to determine the extent to which changes in water quality are affecting the beneficial uses of the Shasta River downstream of Dwinnell Reservoir, by distinguishing between the multiple actual/possible dissolved oxygen consumers in the system. The final result of this study will be a report detailing the findings and making recommendations regarding solution of the problem." Funding was subsequently made available to the Regional Board staff for a water quality study during FY '91-92 and FY '92-93.

In October of 1989, staff of the Regional Board SMP Unit attended a meeting of the Shasta Valley Resource Conservation District (RCD). At that meeting staff of the California Department of Water Resources (DWR) announced their intent to perform a three pronged study of the Shasta River: 1) water quality characterization; 2) water budget; and 3) land use. In March of 1990, DWR published the Shasta Valley Water Quality Literature Review (DWR 1990). Budgetary constraints have prevented further progress toward the completion of this study by DWR.

Staff of the Regional Board collected field data from selected stations in July and August of 1986. No data were collected in 1987. Again, in 1988, field data were collected on two occasions, in May and September, and one set of samples was submitted for laboratory analysis. In 1989, data were collected in April, June, and October. On three of these dates, samples were submitted for laboratory analysis. No sampling was performed in 1990.

In April, 1991, laboratory contract funds and staff resources were committed to an intensive two year study of the water quality conditions in the Shasta River. Frequent sampling episodes focused on daily changes in water quality parameters, mainly during the irrigation season, from April 1 through October 1. Sampling during this study period has typically included morning, midday, and evening field measurements of pH, temperature, specific conductance, and dissolved oxygen. Additional water samples were collected at various times throughout the day and submitted for laboratory analysis. Laboratory parameters typically included nutrients, general chemistry, and minerals. The results of these sampling efforts, through June 1992, are the subject of this report.

WATERSHED DESCRIPTION

The Shasta Valley is in central Siskiyou County (Figure 1). It is elliptical in shape with the major axis lying in a north-south direction. The valley is 36 miles long and 30 miles wide at its widest point. In 1964, California Department of Water Resources estimated that of the 507,000 acres within the Shasta Valley, 141,000 are irrigable lands (DWR 1964).

Glacial melting on Mount Shasta and mountain precipitation are the principal sources of recharge for the Shasta River. Much of this recharge reaches the river through underground flow (DWR 1961). The Shasta River originates in the higher elevations of the Eddy Mountains southwest of the Shasta Valley and flows northward to join with springs from underground flow from Mount Shasta which surface in the vicinity of Big Springs and elsewhere in the valley (Figure 1). The river continues north through the Shasta Valley to Yreka before entering a steep seven mile long canyon leading to the Klamath River. The Little Shasta River, a major tributary within the valley, originates in the Cascade Range near Goosenest and flows westward to join the Shasta River about two miles south of Montague. The Little Shasta River is heavily diverted for irrigation prior to its confluence with the Shasta River. Several minor tributaries originate in the mountains along the west side of the Shasta Valley. These streams are generally short and steep, and drain areas of impervious rock. Most of these tributaries are ephemeral (DWR 1990).

A single large storage reservoir, Lake Shastina (Dwinnell Reservoir), with a storage capacity of about 50,000 acre-feet, has been in operation on the Shasta River since 1928. Dwinnell Reservoir is filled with the flows of the Shasta River, Beaughton Creek, and a major ditch diversion from Parks Creek at the south west extreme of the valley. There is heavy agricultural usage of the waters of Beaughton Creek and the Shasta River above Dwinnell Reservoir. This reservoir supplies water through a 20-mile long canal to Little Shasta Valley and the northeastern portion of the Shasta Valley. Several other instream diversions are accomplished through in-stream control structures or pumps. Water diverted in this way is used through the remainder of the valley.

Groundwaters in the valley are heavily influenced by local geology, and are best described as bicarbonate in nature, with a dominant cation (DWR 1976). Waters derived from serpentine areas have been found to contain magnesium as the dominant cation with a high percent of silica. Waters derived from limestone were found to contain calcium as the dominant cation. Waters derived from volcanic formations were found to contain high salinity, sodium, silica, and boron (USGS 1960). Boron is a micronutrient, but in higher concentrations becomes toxic to plants. Most groundwater mineral problems within the Shasta Valley have been found to be quite localized, stemming from natural sources. Areas which have been found to contain poor quality ground water due to mineralized conditions include: 1) along Oregon Slough and the Little Shasta River; 2) in the vicinity of Montague; 3) between Grenada and Big Springs; 4) in the Willow Creek/Julian Creek drainages (DWR 1951, 1959, 1964, 1990). The Willow Creek and Julian Creek areas contain highly mineralized groundwater of deep origin which is high in boron, dissolved solids and sodium. Consequently, irrigation water derived from these sources (from pumped wells) can have the potential of adding a proportionately high load of dissolved solids through agricultural return flows. The Table Rock area contains springs which are high in boron, chloride and sodium (DWR 1959). These springs feed into both Oregon Slough and the Little Shasta River and are deemed to be largely responsible for high boron levels found in the lower Shasta River during low flow periods (DWR 1990).

Agriculture is the major land use within the valley. However, local springtime flooding in typical years and a short growing season restrict the type of crops produced to pasture, alfalfa, small grains and a very limited selection of field crops (DWR 1990). Cattle production is a prominent feature of the valley landscape, with livestock frequently exercising unlimited access within the river channel. The lower river and tributaries from Yreka Creek down contain massive evidence of gravel spoils from early mining activities.

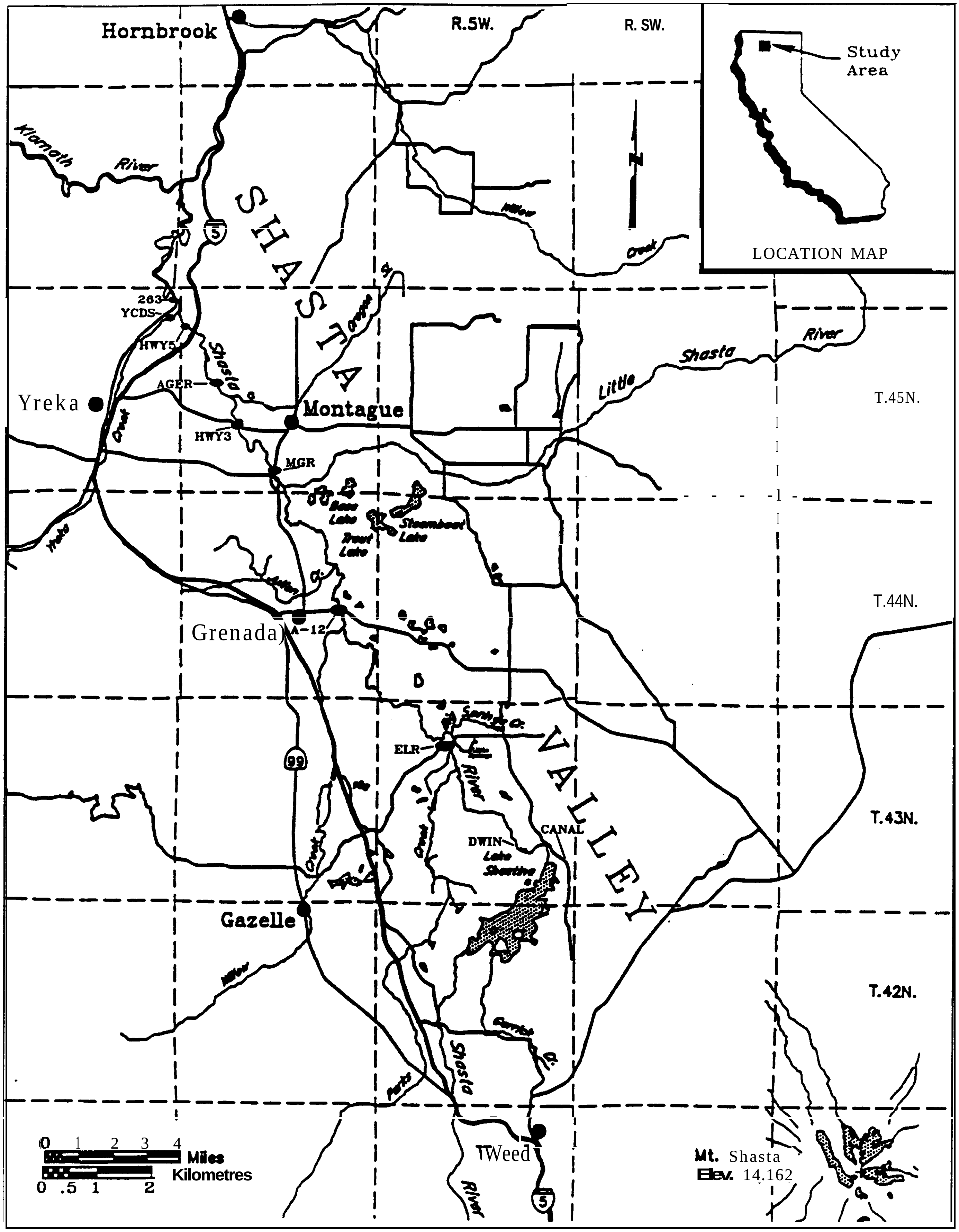

Figure 1. Study area map and location. (From DWR 1990)

METHODS AND MATERIALS

Station locations

The original proposal included the following six stations: (Figure 1)

1) DWIN - downstream of Dwinnell dam at Riverside Drive;
2) A-l 2 - Hwy99-97 Grenada cutoff river crossing;
3) MGR - Montague-Grenada Road river crossing;
4) HWY3 - Highway 3 river crossing;
5) 263 - old Highway 99 river crossing; and
8) CANAL - the canal below Dwinnell Dam at Big Springs Road.

The current study added the following stations:

7) ELR - East Louie Road river crossing (upstream of Big Spring Creek;
8) HWY5 - Anderson Grade Road river crossing upstream of Yreka creek, downstream of Highway 5;
9) AGER - Ager Road river crossing (area of diversion impoundment).

The respective stream mileage measurements for each station are presented in Table I, as measured from aerial photos contained in the publication: Klamath and **Shasta Rivers Environmental Atlas,** (DWR 1980). Aerial photo approximate scale is: 1 inch = 500 feet.

Table I. Mileage of Shasta River sample stations from confluence with Klamath River.

263-Highway 263:	7.25
HWY5-Anderson Grade:	8.00
AGER- Ager Road:	10.55
HWY3-Highway 3:	12.80
m-Montague/Grenada Road:	15.20
A-la-Highway 99/97 cutoff:	21.00
ELR-East Louie Road:	31.85
=-Riverside Drive:	37.75

Data Collection Period

Data discussed in this report were collected by various Regional Board staff during the period from July, 1986 through June, 1992. From April, 1991, through June 29, 1992, intensive sampling was performed. Scheduling of sample events covered early morning, mid-day, through late evening in order to best measure the fluctuations of pH and dissolved oxygen levels from biological activity, as well as to get an idea of daily temperature fluctuation at each of the various stations. Sampling was performed throughout the irrigation season, and to a lesser degree during the fall and winter.

Field Measurements

Water quality field measurements included: dissolved oxygen, pH, temperature, and specific conductance. Dissolved oxygen was measured with a Yellow Springs Instrument Co. (YSI) model 57 meter, air calibrated at the beginning and end of each sampling run. The Winkler method for measurement of dissolved oxygen was used for some of the earlier measurements of river dissolved oxygen, and for some preliminary Light Bottle/Dark Bottle tests for algal productivity. Comparisons yielded satisfactory replicate values for the model 57 YSI meter and Winkler analysis. Thereafter, the model 57 was used for all measurements. The YSI model 57 has a manufacturer's accuracy and precision rating of ± 0.8 mg/L for dissolved oxygen. Conductance and temperature were measured with a YSI model 3000 T-L C meter. The YSI model 3000 has a manufacturer's accuracy and precision rating of ± 8 micro-mhos for conductance and ± 1 C for temperature. The pH measurements were obtained with a Cole-Parmer Model 5941 l-00 meter, calibrated at the beginning and end of each sampling run, and checked periodically throughout the day, as temperatures varied. Cole Parmer model 5941 l-00 has a manufacturer's accuracy and precision rating of ± 0.2 pH.

Generally, a quality control sample was obtained at the beginning of each sampling run and retained for replicate analysis of conductance and pH at the end of the run. Replicate field measurements for QA/QC purposes are presented in Appendix 1. For thirty-six sets of field replicates during the period from April 1991 through June 1992, the manufacturer's specifications for accuracy were exceeded three times for conductivity, with the greatest difference being 14 micro-mhos(4.8% of the measured value of 293 micro-mhos). The manufacturer's specification for pH accuracy and precision were met in all replicate analysis. The greatest difference was 0.2 pH(2.6% of the measured value of 7.9 pH).

Analytical laboratories were subject to rigorous QA/QC procedures and performance evaluation protocol which are a standard component of our analytical services vendor contracts.

Laboratory Analysis

Table II. Matrix of stations and number of sampling events for each parameter. Shasta River for period from June 1986 through July 1992.

STATION	FIELD	NUTRIENT	MINERAL
CANAL	39	10	5
DWIN	52	19	9
ELR	44	15	8
A-12	53	16	7
MGR	54	16	7
HWY3	57	20	8
AGER	6	3	3
HwY5	33	12	7
263	11	7	1

Water samples were analyzed at contract laboratories for macro-nutrients (total nitrate, total Kjeldahl nitrogen (TKN), total ammonia as N, total phosphorous), mineral series (alkalinity, bicarbonate, free carbon dioxide, total carbon dioxide, carbonate, chloride, conductivity, hydroxide, sulfate, filterable residue, pH, hardness, silica, calcium, iron, magnesium, sodium, boron, potassium), turbidity, and trace metals analysis for arsenic, aluminum, and copper. Table II is a matrix of stations and sample analyses showing the number of times each parameter was measured from June 1986 through July 1992.

The contract lab which performed the ammonia analysis from July of 1990 through June of 1991 reported down to a detection limit of 0.01 mg/L. However the laboratory which analyzed the samples from July of 1991 through June of 1992 reported only down to a minimum detection limit of 0.2 mg/L. This is significant, in that under some temperature and pH conditions, it would be impossible to determine compliance with the USEPA criteria for ammonia, since sample results were below detection. For example, for a sample with pH of 8.75 at a temperature of 25 C, the U.S. EPA national ambient water quality criteria for total ammonia to protect aquatic life (continuous concentration, 4-day average) is not to exceed 0.15 mg/L total ammonia as NH,. This is equal to an analytical result of 0.123 mg/L ammonia as nitrogen (NH, x 0.822 = ammonia as N).

RESULTS

Study results are presented by general groupings of temperature, dissolved oxygen, nutrients, conductance, and general minerals. Discussion of the interrelationships is included with the results and summarized in the conclusion section.

Temperature

Temperature is an important water quality parameter with respect to its relationship to biological communities. There is currently no numeric objective for temperature in the Shasta River. 13.3° C is generally recognized as the optimum temperature for maintenance of most life stages for salmonid populations. 19.7° C is considered to be the temperature at which chronic stress effects occur (DF&G 1993).

During the period of this study, from June of 1986 through July of 1992, 316 temperature measurements were recorded by staff of the Regional Water Quality Control Board. Of these measurements, temperatures were 13.4° or higher 81.66% of the time, exceeding 19.6° C 37.72% of the time (Figure 2).

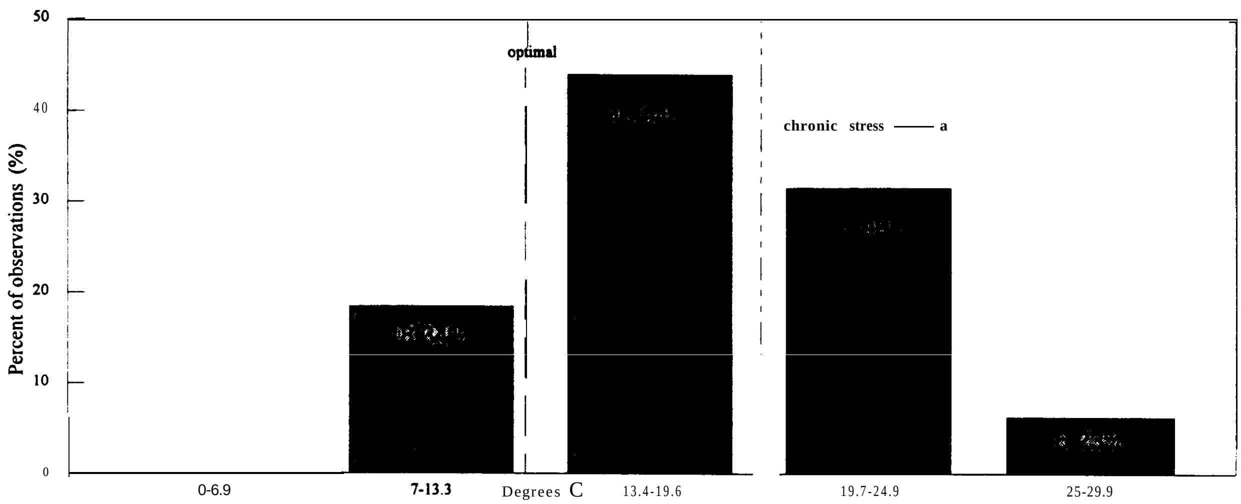

Figure 2. Temperature: distribution of 289 measurements at selected stations on the Shasta River, April 1 through October 1, for the period from July, 1986 through June, 1992.

During the irrigation season, usually from April to the beginning of October, median values for temperature ranged from 16.6° C at ELR near the Dwinnell Reservoir to 20.9° C at HWY5 30 miles downstream. Maximum temperatures during the study period varied from 21 .0° C at AGER to 29.1 ° C at MGR. Water temperatures generally increased from ELR (River Mile 31.85) to HWY5 (RM 8.00), then decreased below HWY5 to 263 (Figure 3). The median showed a drop of nearly 2° C between DWIN and ELR, thereafter increasing steadily to a total rise of about 2° C at HWY3. Between HWY3 and HWY5, there was an increase in median temperatures of more than 3° C. Finally, the median values dropped more than 3° C between HWY5 and 263 (Figure 3).

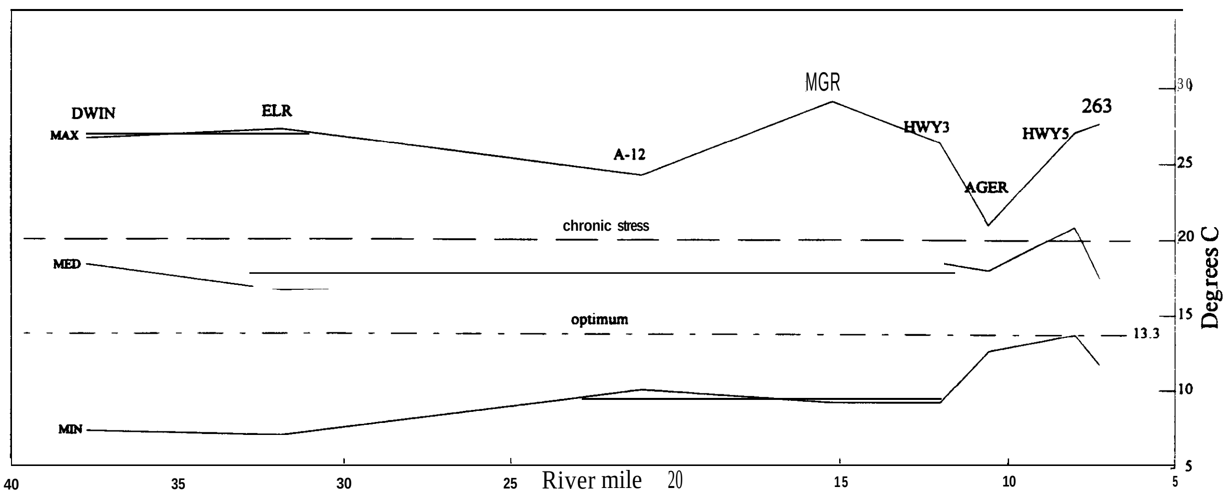

Figure 3. **Temperature minimum (MIN), median (MED) and maximum (MAX) by station. Shasta River, April 1 through October 1, for the period from July, 1986 through June, 1992.**

Dissolved oxygen (DO,)

The Basin Plan (NCRWQCB, 1989) objective for DO, in the Shasta River is a minimum of 7.0 mg/L with a median of 9.0 mg/L. DO, levels of 5 mg/L or less are generally considered to be immediately threatening to the survival of most fish species. Of a total of 296 DO, measurements taken at all stations, 3.4% were less than 5 mg/L 15.2% were less than 7 mg/L (Figure 4). Median DO, values ranged from 8.6 mg/L at DWIN to 10.4 mg/L at both ELR and 263. Dissolved oxygen medians gradually decreased downstream from ELR to HWY3, then decreased markedly between HWY3 and AGER by 2.3

Table III. Percent of time D.O. was <7 mg/L & < 5 mg/L at selected stations:

Station	<7mg/L	<5 mg/L
A-12	3.9%	0
HWY3	**19.6%**	**7.1%**
HWY5	**16.1%**	**3.4%**

mg/L, finally increasing over 3 mg/L between AGER and HWY5.

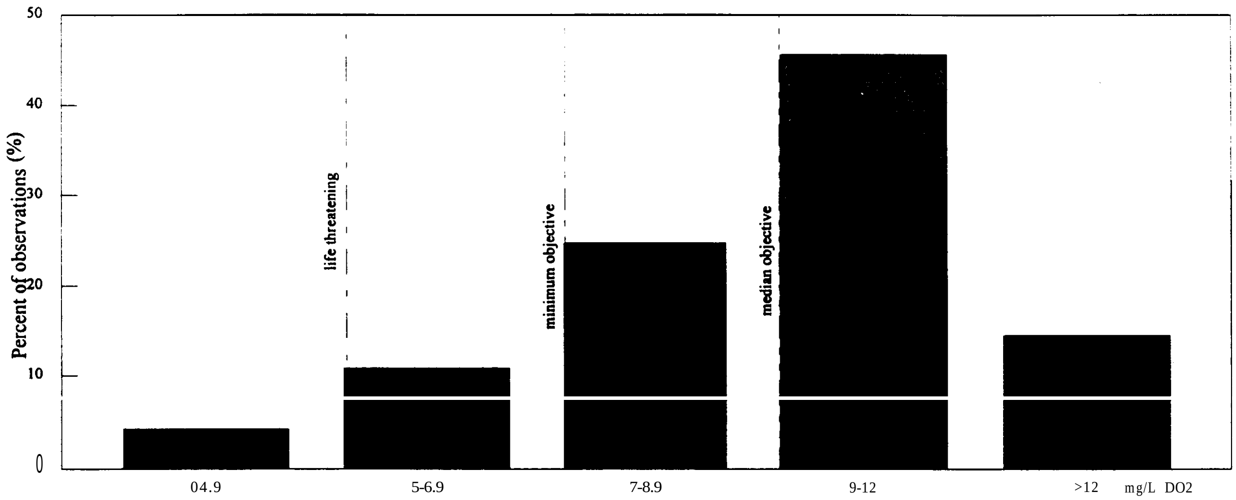

Figure 4. Dissolved oxygen: distribution of measurements at selected stations on the Shasta River, April 1 through October 1, for the period from July, 1986 through June, 1992.

Of additional interest was the observation of wide swings in DO, levels at a given station (Figure 5). Round the clock measurements of DO, levels indicated a high rate of photosynthetic productivity during sunny periods, and a high rate of oxygen demand during dark periods (Figure 6). Preliminary work done with light bottle/dark bottle analysis of aqueous samples showed no measurably significant effect on DO, levels from suspended algae (algae in the water column). On the other hand, preliminary tests with samples of the filamentous algae found in abundance on the river bottom, particularly at stations where wide DO, swings were measured, yielded extremely high levels of photosynthetic production (high DO,) with very low levels of respiration (Figure 7). It is likely that sediment loads of nutrient rich detritus may contribute significantly to biological oxygen demand in certain sections of the river. This is further supported by the observations of lowest DO, values at HWY3 and AGER Road, both low-velocity, deep-pool impoundments of the type which tend to collect organic debris and display very little mechanical aeration.

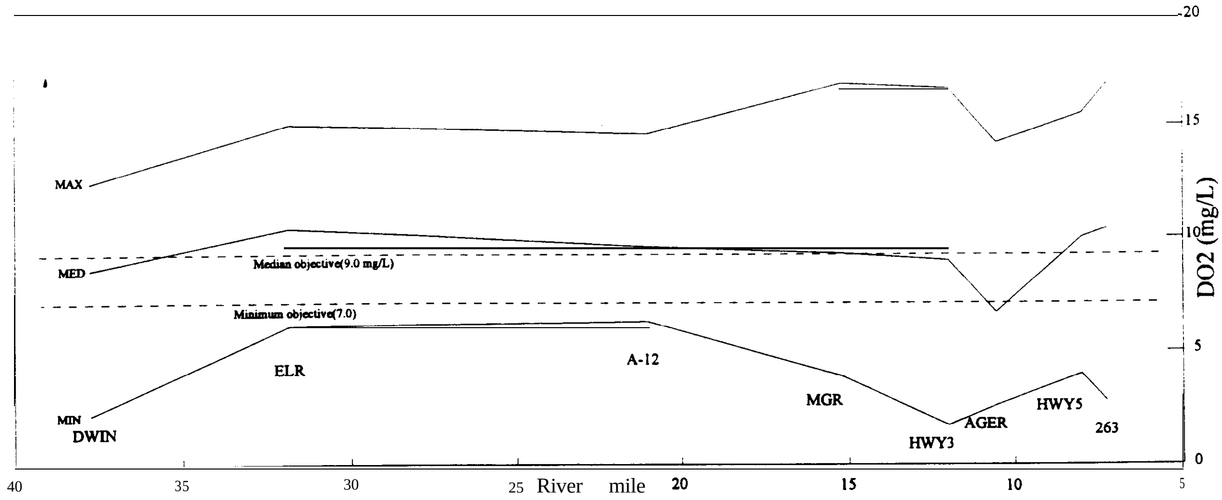

Figure 5. **Dissolved oxygen minimum (MIN), median (MED) and maximum (MAX) by station. Shasta River, April 1 through October 1, for the period from July, 1986 through June, 1992.**

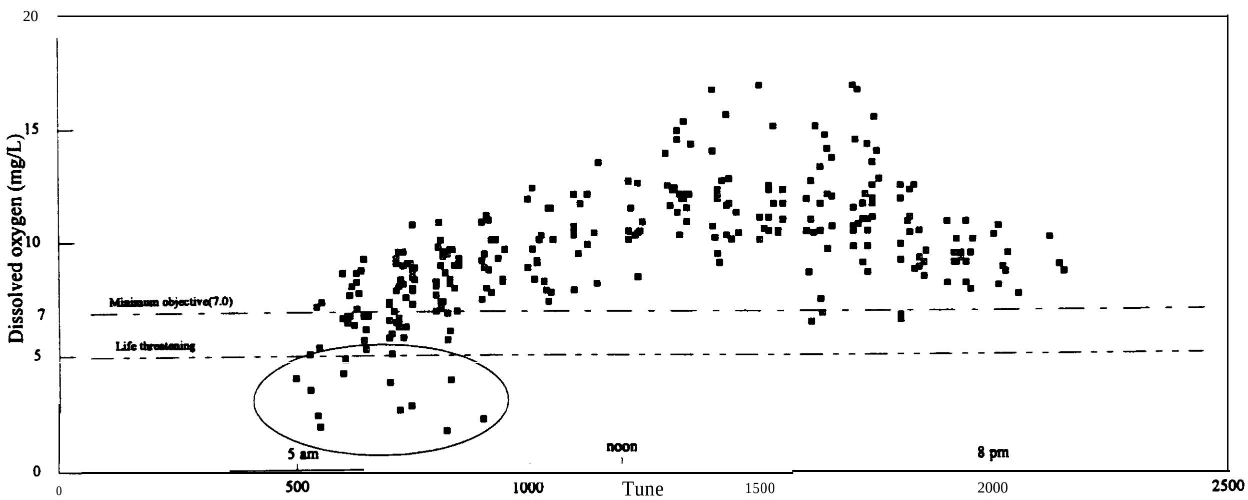

Figure 6. **Dissolved oxygen by time for selected stations. Shasta River, for period from July,1986 through June, 1992.**

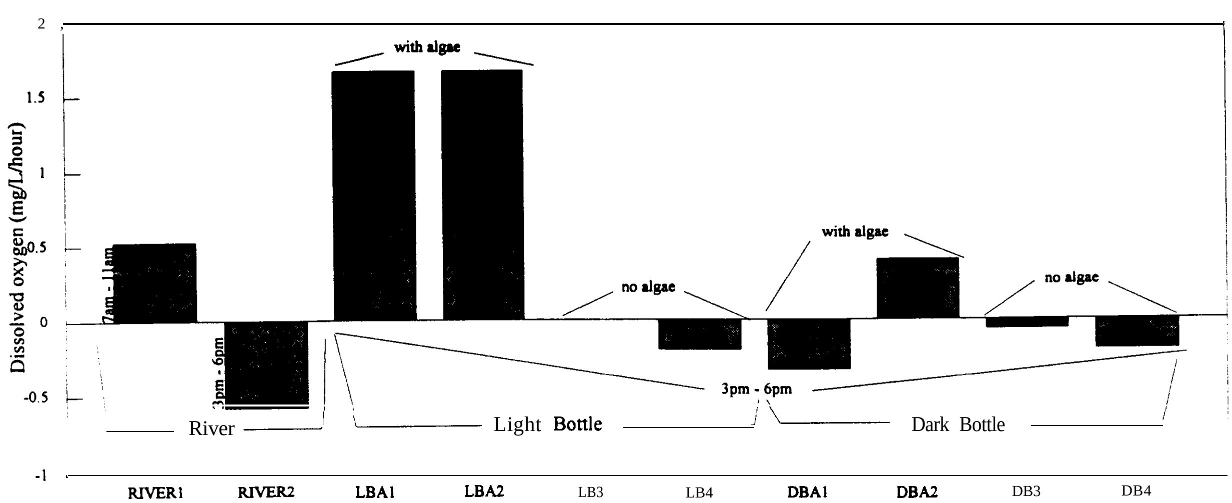

Figure 7. **Dissolved oxygen productivity and demand in river and light bottle/dark bottle. Shasta River, September 16.1992.**

Nutrients - Biostimulatory Substances

Nitrogen and phosphorous compounds are primary plant nutrients. When either of these are the limiting nutrient, any increase will stimulate plant growth in aquatic systems, hence, they are referred to as biostimulatory substances. The Basin Plan contains a narrative objective for biostimulatory substances: “Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses. " Nuisance growth related problems exist with respect to at least one beneficial use: irrigation. Casual observation of the constant cleaning required at diversion pumps such as those at MGR to keep aquatic plant growth out of the pump intake is testimony to this.

Phosphorus

Phosphorus is a primary plant nutrient which occurs naturally in some groundwater aquifers. Another main source of phosphorus is animal waste and fertilizer products associated with agricultural practices. Phosphorus was found to be present in sufficient concentrations for plant growth in nearly all samples from the river. The lowest phosphorus concentrations were in samples taken from the DWIN and CANAL stations just below Dwinnell Reservoir. There is a general trend of increasing phosphorus with movement downstream, with the largest increase downstream of HWY3. Concentrations at HWY5 station were slightly higher (Figure 8).

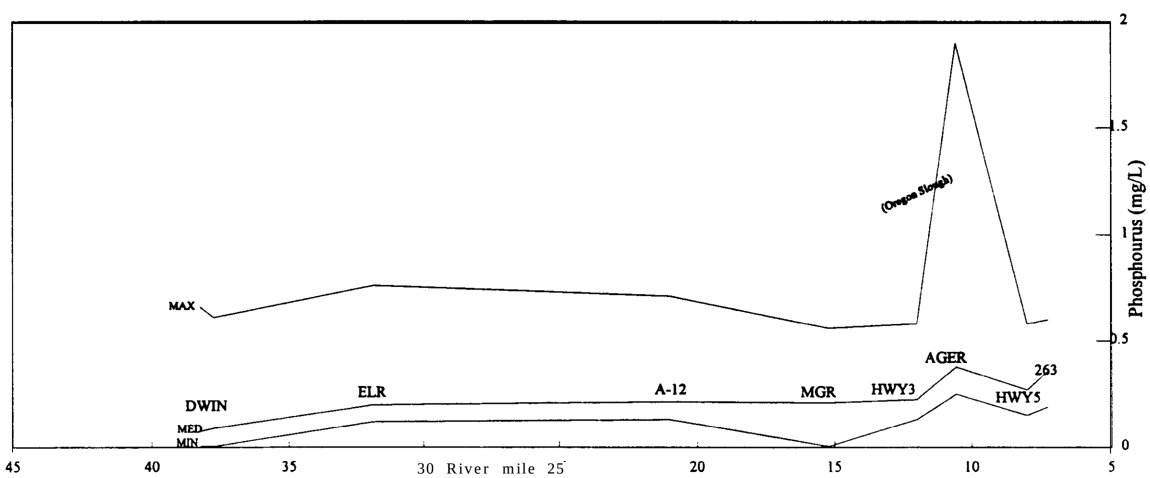

Figure 8. Phosphorus: minimum (MIN), median (MED) and maximum (MAX) by station. Shasta River, April 1 through October 1, for the period from July, 1986 through June, 1992.

Phosphorus concentrations ranged from non-detect (less than 0.010 mg/L on four samples (once at stations MGR and DWIN, twice at CANAL) to 0.760 mg/L at ELR and 1.9 mg/L at AGER. Median concentrations ranged from 0.085 at DWIN, 0.115 mg/L at CANAL, and 0.27 at HWY%.

Ammonia

In water, ammonia is measured as total ammonia-nitrogen (NH,-N) and exists in equilibrium with the hydrolyzed form, ammonium hydroxide. U.S. EPA criteria for ammonia are based on the occurrence of un-ionized ammonia as a function of total ammonia, temperature, and pH (Appendix 2). For a given concentration of total ammonia in water, as either temperature or pH increases, the concentration of un-ionized ammonia also increases. Un-ionized ammonia is the fraction of total ammonia which is toxic to aquatic organisms. Total ammonia-nitrogen (NH,-N) is formed by chemical and bacterial decomposition or breakdown of plant and animal matter, principally protein-bearing materials. Ammonia is relatively quickly oxidized to other forms of nitrogen: nitrite then nitrate. High levels of NH,-N in surface waters normally indicate a relatively recent source, either from discharge of NH,, or from high decomposition rates in the absence of oxygen. Additionally, high levels of NH,-N in surface water can lower dissolved oxygen levels during the oxidation process. Ammonia concentrations were generally low, most frequently below analytical detection limits (Figure 9).

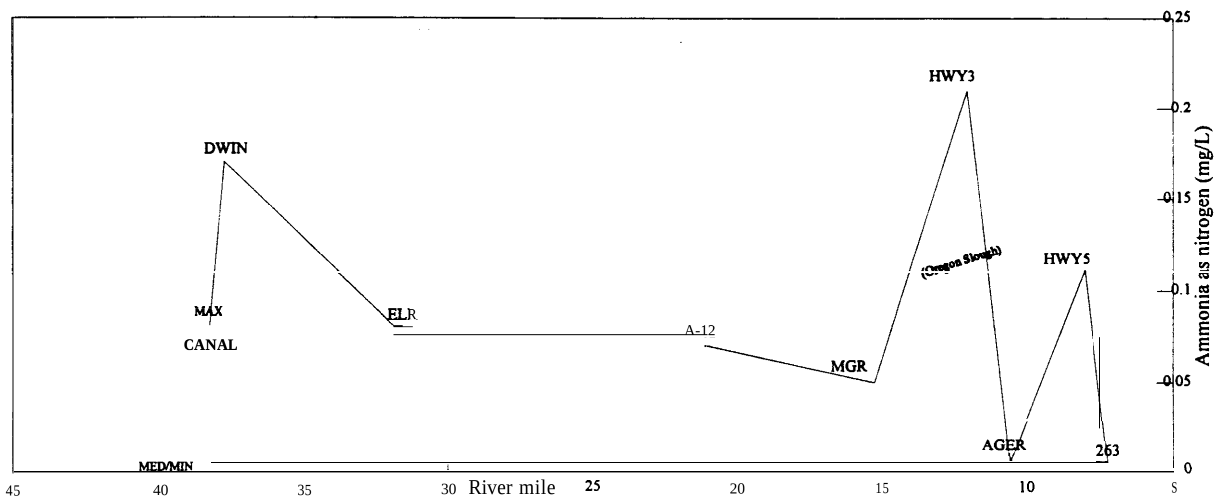

Figure 9. Ammonia as nitrogen: minimum (MIN), median (MED) and maximum (MAX) by station. Shasta River, April 1 through October 1, for the period from July, 1986 through June, 1992.

Nitrate (NO,)

In surface water, ammonia oxidizes, first to nitrite (NO,), then quickly to nitrate (NO,). NO, is readily used by algae and vascular plants as a primary nutrient, and is often the limiting nutrient in stream and river systems. High concentrations of NO, can promote growth of algae and aquatic plants. Large amounts of aquatic plant growth can cause wide swings in dissolved oxygen levels by increasing dissolved oxygen through photosynthetic activity during daylight hours, while conversely decreasing dissolved oxygen levels at night through respiration. Decomposition of dead and dying plant matter exacerbates the decreasing oxygen, with adverse impacts on aquatic life.

The median concentrations of NO, observed during the study period ranged from non-detect (less than 0.05 mg/L at HWY5, AGER, HWY3, MGR and CANAL, to 0.100 mg/L at 263 (Figure 10).

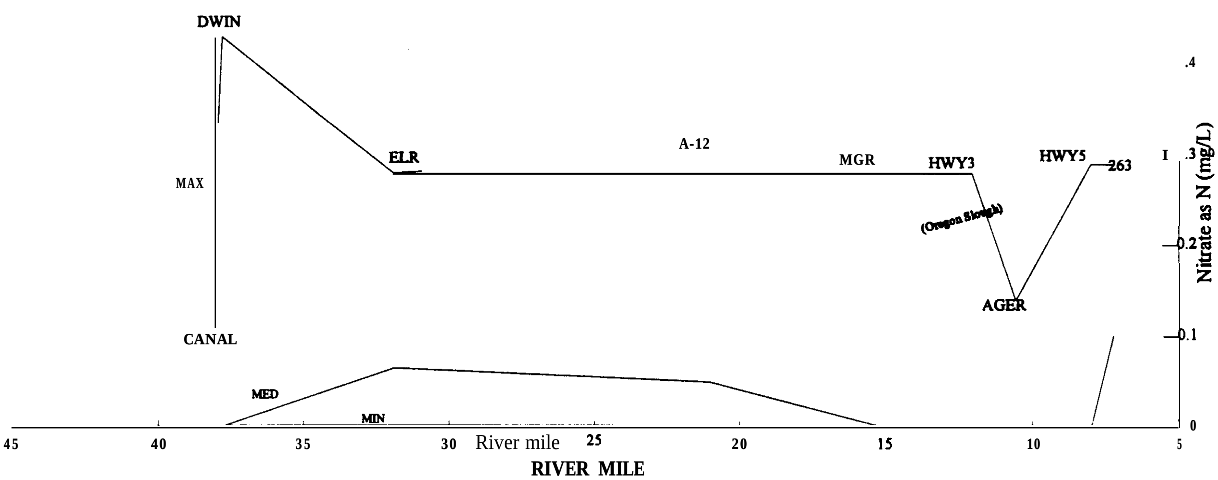

Figure 10. Nitrate as nitrogen: minimum (MIN), median (MED) and maximum (MAX) by station. Shasta River, April 1 through October 1, for the period from July, 1986 through June, 1992.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is the sum of organic nitrogen (from plant and animal matter) plus ammonia. In the Shasta River, the major component of TKN was organic nitrogen. TKN values varied, with the median upstream concentration at DWIN being the same value as the median downstream-most concentration at 263 (Figure 11). However, there are significant freshwater springs which enter the river below Dwinnell Reservoir. Springs of the type found in this area do not commonly have measurable levels of TKN or nitrate. Consequently, TKN values decrease from a median of 0.48 mg/L at DWIN to a median- of 0.28 at A-l 2, where significant spring flows are noted. After this, TKN values increased to a median of 0.37 mg/L at MGR, 0.46 mg/L at HWY3, and 0.64 mg/L at AGER, thereafter decreasing to a median of 0.56 mg/L at HWY5 and 0.48 mg/L at 263. Significant mass loading of TKN occurs below A-l 2, possibly from the Little Shasta River or other return flows.

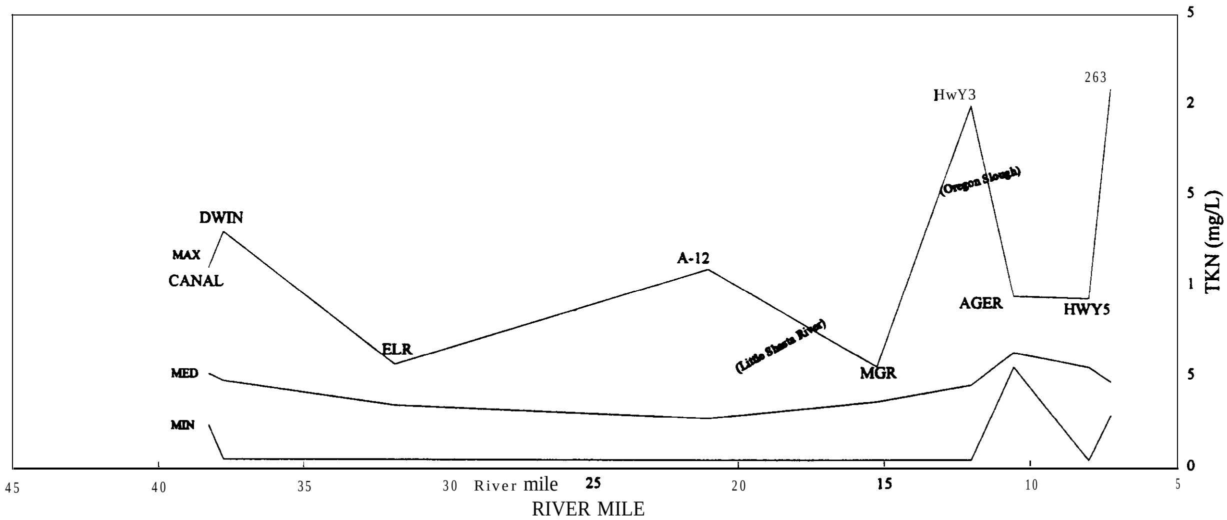

Figure 11. Total Kjeldahl Nitrogen: minimum (MIN), median (MED) and maximum (MAX) by station. Shasta River, April 1 through October 1, for the period from July, 1986 through June, 1992.

Conductance

Specific conductance (SC) is a measure of the electrical conductance by water at 25° C, and is a function of the concentration of dissolved solids in solution. The higher the concentration of dissolved solids in solution, the higher the SC of the water. The Basin Plan objective for specific conductance in the Shasta River is a maximum not exceeding 800 micro-mhos, and a median not exceeding 600 micro-mhos.

There was one measurement where the Basin Plan objective for a maximum conductance was not met. Also, the Basin Plan objective of a maximum median value of 600 micro-mhos specific conductance was exceeded slightly more than 50% of the time at stations MGR and HWY3, and was exceeded at HWY5 always during the irrigation season. It is believed that the major sources of dissolved solids in the Shasta River are mineralized spring water and surface runoff of irrigation water. During the irrigation season CANAL water below Dwinnell had a range of 270 micro-mhos to 357 micro-mhos, while SC values at HWY5 ranged from 508 micro-mhos to 771 micro-mhos. The SC at CANAL was relatively constant, while SC in the river varied considerably in response to inputs, and dilution from lower conductivity sources. Specific conductance displayed a general increase from upstream to downstream, with some dilution from unknown sources occurring below AGER Road (Figure 12). Big Spring Creek at the bridge(BSB) was observed to have a much lower SC than the river at ELR. On one date, SC was 275 micro-mhos at CANAL, 394 micro-mhos at DWIN, 590 micro-mhos at ELR, and 341 micro-mhos at BSB. On a second date, SC was 279 micro-mhos at CANAL, 288 micro-mhos at DWIN, 573 micro-mhos at ELR, and 352 micro-mhos at BSB. SC is most probably increased from return flows in the area of Hole in the Ground, Hidden Valley, and Parks Creek, as well as possibly some springs with high SC. Inversely, SC is decreased by flows from Big Spring Creek and other freshwater **flows downstream of** ELR.

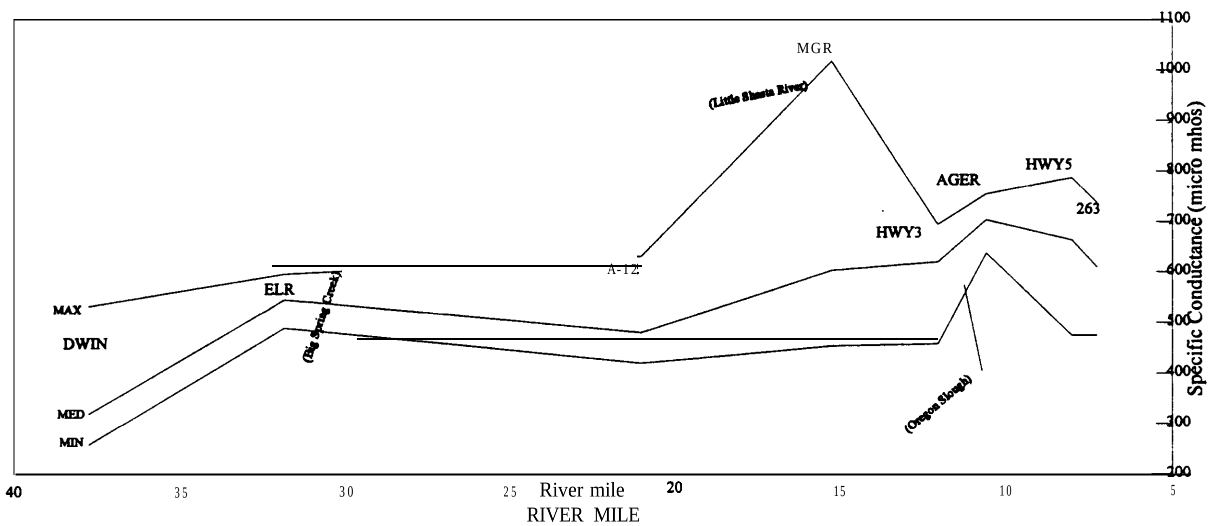

Figure 12. Specific conductance: minimum (MIN), median (MED) and maximum (MAX) by station. Shasta River, April 1 through October 1, for the period from July, 1986 through June, 1992.

Alkalinity/pH

Alkalinity of water refers to an ability to accept hydrogen ions, to neutralize acid, and is a direct counterpart to acidity. High alkalinity has the effect of buffering or resisting pH change, and consequently reducing effects on pH from biological sources. Buffering is a function of the presence in water of a weak, or slightly ionized, acid (mainly calcium and magnesium carbonates, and HCO_3^- formed from CO, and water), together with the salt of a weak acid, typically bicarbonates, carbonates, chlorides, nitrates, and sulfates of calcium, magnesium, and iron normally found in streams of this type. CO, enters the water through decomposition, plant and algal respiration, and from the atmosphere. Alkalinity was moderate to high, ranging from 128 mg/L to 474 mg/L with a median value of 239 mg/L (Figure 13).

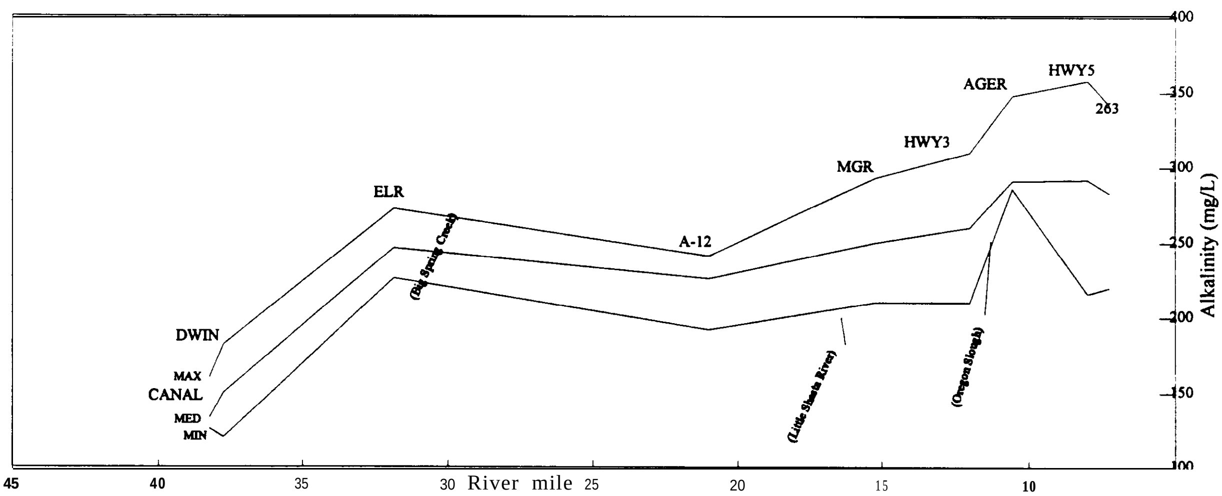

Figure 13. Alkalinity: minimum (MIN), median (MED) and maximum (MAX) by station. Shasta River, April 1 through October 1, for the period from July, 1986 through June, 1992.

Alkalinity was lowest immediately below Dwinnell Reservoir at DWIN and CANAL, where it never exceeded 182 mg/L. Levels increased sharply at ELR, thereafter showing a general trend of increasing alkalinities downstream (though some dilutional effects were measured in slightly lower alkalinity levels at A-l 2) (Figure 13).

The river also had a high pH, ranging from pH 7.2 to pH 9.6, with a median value of pH 8.2 (Figure 14). Basin Plan objectives for pH in the Shasta River are 6.5 to 8.5. All stations exceeded the maximum objective of pH 8.5 occasionally. The general trend in pH was decreasing from the canal below Dwinnell Reservoir and in the river at DWIN, where the Basin Plan maximum pH of 8.5 was exceeded more than 50% of the time, then increasing again from HWY3 downstream. The Basin Plan maximum pH was exceeded in 50% of the measurements at station 263.

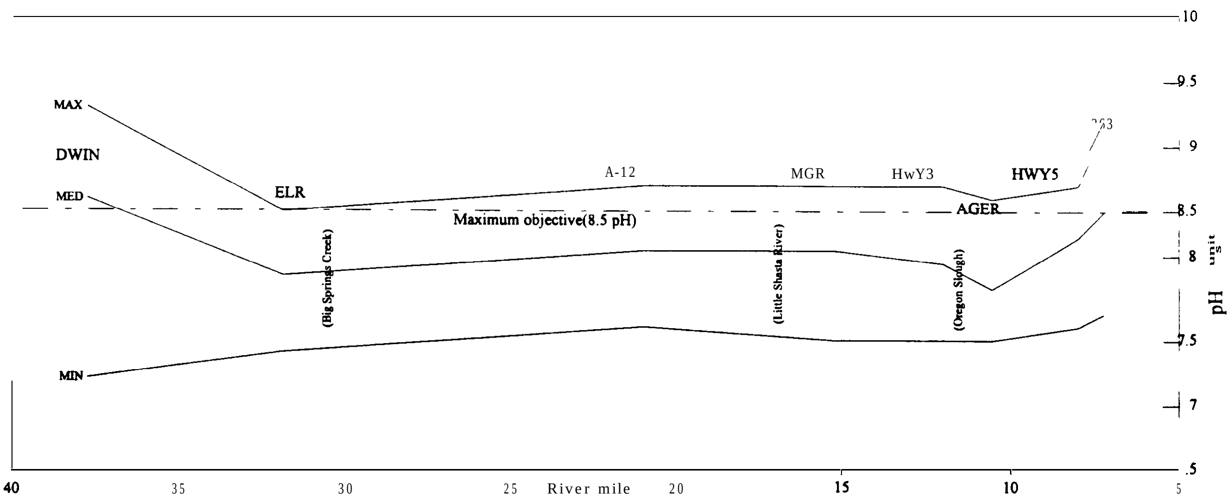

Figure 14. **pH: minimum (MIN), median (MED) and maximum (MAX) by station. Shasta River, April 1 through October 1, for the period from July, 1986 through June, 1992.**

There was a trend of daily fluctuations in pH with the lowest values being attained in the early morning (Figure 15). As the day progressed toward noon, pH values increased, until several hours later when there was an observable drop in pH values. Those relationships are caused by increased photosynthesis during the day, removing CO_2 from the water and allowing the pH to rise. The reverse occurs at night, with plant respiration and decomposition releasing CO_2 to the water and driving pH downward.

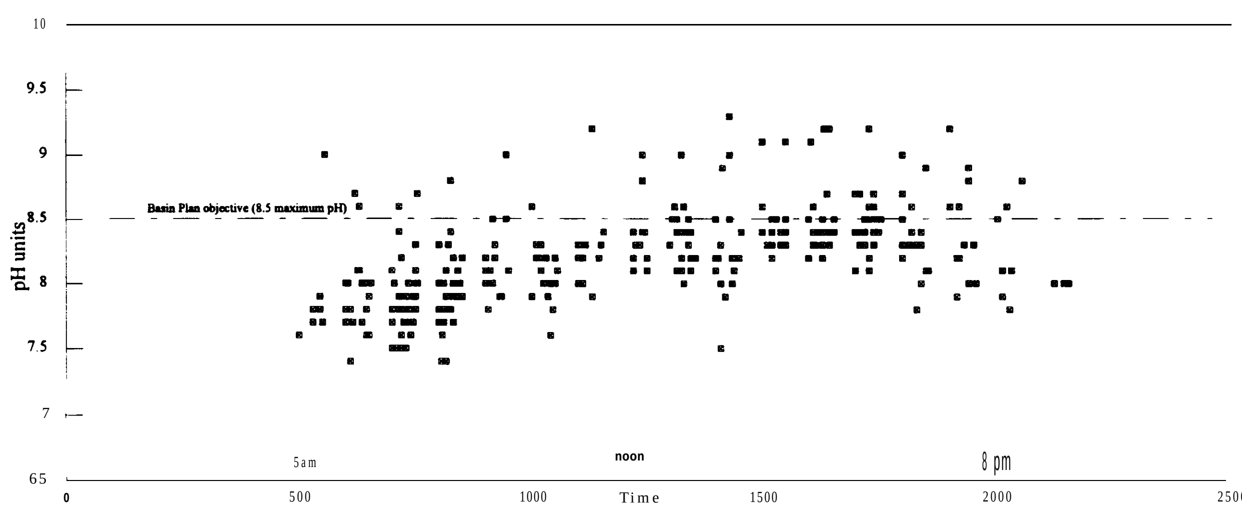

Figure 15. **pH by time for selected stations. Shasta River, for period from July,1986 through June, 1992.**

Minerals

Arsenic was not found in detectable concentrations in DWIN or CANAL. Arsenic was found to occur at ELR in all but one sample, in every sample from downstream of ELR, and in one sample from Big Spring Creek. Concentrations ranged from 0.007 mg/L at 263 to 0.020 mg/L at ELR. Arsenic was higher than 90% of measures in 196 other streams (CVRWQCB, 1990). The Water Quality Control Plan for Inland Surface Waters of California (ISWP)(SWRCB 1991) objective for arsenic is not to exceed 0.190 mg/L for a 4-day average, and not to exceed 0.360 mg/L over a 1 -hour average. Sodium and chloride levels were seen to increase going downstream. Sulfate levels were highly variable (Figure 16). **(This will be related to p. 18 discussion regarding CO3- > SO4 shift in a future report.)**

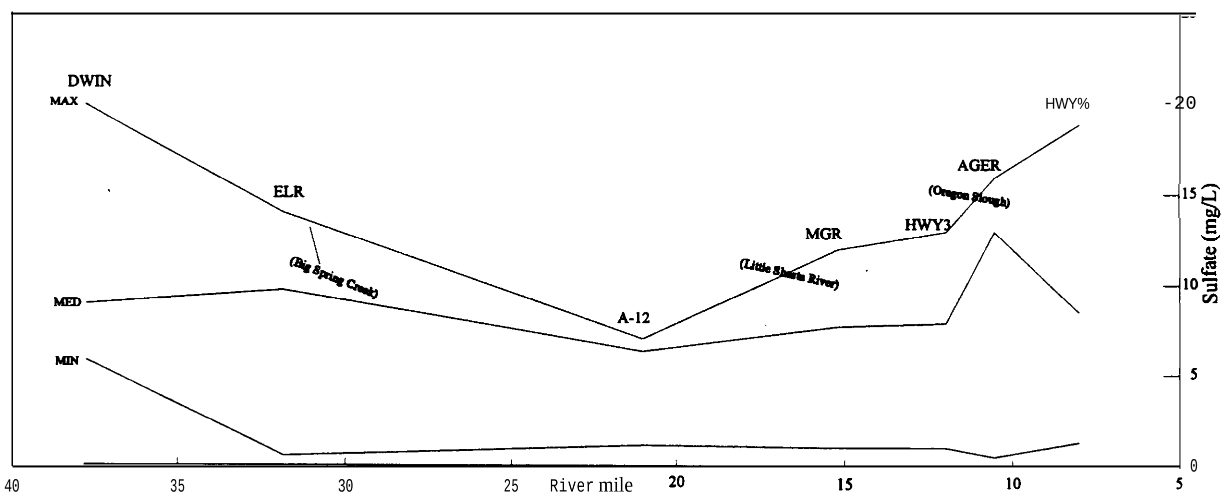

Figure 16. Sulfate: minimum (MIN), median (MED) and maximum (MAX) by station. Shasta River, April 1 through October 1, for the period from July, 1986 through June, 1992.

Note on Yreka Creek: During sampling on the Shasta River, Yreka Creek was often sampled as a major tributary. Substantial loading of ammonia, boron, chloride, iron, phosphorus, and potassium were found to occur downstream of the Yreka Publicly Owned Treatment Works (POTW), when compared to samples from adjacent to and upstream of the POTW. Staff of the Regional Board's Northern District are working with the Yreka POTW on this issue.

DISCUSSION

The Shasta River below Dwinnell Reservoir receives water from creeks, springs, agricultural returns, and a small discharge from Dwinnell Reservoir. The water from Dwinnell Reservoir had elevated levels of nitrogen and phosphorus compounds, as shown in chemical analysis of samples from the canal and the river immediately downstream of the dam. Proceeding downstream to East Louie Road and then to Highway A-l 2, there was a decrease in total nitrogen concentrations. This is most probably due to the high volume of spring water inflows and relatively low volume of agricultural return water in this section. Proceeding downstream from A-l 2 to Montague-Grenada Road, Highway 3, and Ager Road, there was an upward trend in both nitrogen concentrations and flow volume. This was believed to be from agricultural return water bearing organic matter. After peaking out at Ager Road, concentrations of nitrogen dropped slightly, such that the median concentration at Highway 263 was roughly equivalent to that at the Canal station, i.e., water from Dwinnell Reservoir. While the concentrations were equivalent, the volume of flow was significantly higher at the downstream station, thus the actual amount of nitrogen was higher. This was indicative of loading of nitrogen from the Shasta Valley.

Phosphorous loading was also observed, although this was not as dramatic. As a relationship to these changes in water chemistry, there was an obvious variability in the growth and composition of aquatic vegetation masses. Increases in nutrients result in increases in plant mass. In the upper study section, currents are somewhat swift, clarity is high, and gravel bottoms are generally visible, with a variety of rooted and attached vegetation growing near the banks. In the lower reaches, currents were often indiscernible, clarity low, and deep pools characterized by thick, muddy bottom deposits predominated. Thick mats of attached filamentous algae, macrophytes, and duckweed were typical in late spring through early winter, particularly in the slack water section in the vicinity of Highway 3 and Ager Road. The pools appear to have been formed by in-stream diversions which blocked the flow, allowing suspended matter to become deposited and allowing luxuriant growths of aquatic vegetation to become established. While lush aquatic vegetation was also observed in the vicinity of the Montague-Grenada Road bridge, the duckweed and surface matting did not occur.

Decomposition of organic matter in sediment exerts a high oxygen demand. This was masked during daylight when dissolved oxygen levels were driven up by plant photosynthesis in the presence of high sunlight plus high nutrient conditions. However, as soon as sunlight became faint, there was an almost instantaneous sag in dissolved oxygen, frequently below Basin Plan objectives. In addition to loading of nitrogen into the system, temperatures increase downstream from East Louie Road. During the irrigation season, it was not uncommon to observe large amounts of agricultural return water flowing unrestrained off the fields into the river.

Initial studies detected significant nutrient loading in Yreka Creek in close proximity downstream of the Yreka POTW. This condition is being addressed by Regional Board Northern District staff.

CONCLUSIONS

As stated in the introductory section of this report, in 1985 the U.S. Department of the Interior reported threats to the recovery of anadromous fish populations in the Shasta River due to low flows and high summer water temperatures; unscreened water diversions; degraded spawning gravel; and possible hydroelectric projects. Relatively rapid in-stream flow reductions at the start of the irrigation season were seen as a possible contribution to juvenile fall chinook, coho, and steelhead losses by stranding them in pools and side channels. Additional 1985 information from California Department of Fish and Game reported observations of depressed levels of dissolved oxygen, high temperatures, and mortality of large numbers of young of the year. During the period covered in this report, field observations confirmed the occurrence of a majority of the above water quality conditions. Hydroelectric projects were not considered. Also during the period of this report, staff of CDFG observed at least one instance of an estimated several hundred dead juvenile fish in the vicinity of a screened diversion (May/June, 1992).

Generally, water quality was determined by inflow upstream of ELR and remained stable until the area downstream of Highway A-l 2. Water temperature, nutrients, dissolved solids, and alkalinity increased, and night time dissolved oxygen decreased in that area of the lower river. Those changes in the presence of increasing stream flow rate suggest significant loading to the river downstream of Highway A-l 2.

Organic nitrogen is the largest component of nitrogen in the system. Organic nitrogen is not elemental nitrogen or nitrate fertilizer, but rather is the result of biological processes. The possible inputs of organic nitrogen include algae, aquatic macrophytes, and plant and animal wastes washed into the river. Based on the light bottle/dark bottle studies done to date, the organic nitrogen appears to be mostly dissolved, indicating the source is decomposition of the above noted inputs.

Nutrient loading of Yreka Creek, a tributary downstream of Highway 5, was documented from the Yreka POTW. That situation is being addressed by the Northern District personnel.

Dissolved oxygen and pH exhibited daily fluctuations in response to benthic algal and aquatic macrophyte production. Plant respiration did not fully account for the nighttime lows in dissolved oxygen. It appears that sediment oxygen demand plays a large part in that relationship.

The Basin Plan minimum dissolved oxygen objective of 7.0 mg/L was not attained in 15% of the measurements. The median objective of 9.0 mg/L (50% of the measurements must equal or exceed) was attained in 61% of the measurements.

Arsenic was measured downstream of Dwinnell Reservoir in virtually all samples, well below the ISWP objectives for the protection of aquatic life, but exceeding the ISWP objective of 5 μg/L for surface waters used as drinking water sources. This was not unexpected with the history of volcanism in the area.

RECOMMENDATIONS

Focus springtime sampling on:

1) sediment oxygen, pH, and nutrient relationships;

2) continue light bottle/dark bottle experiments to provide supporting information for the sediment interactions;

3) nutrient, temperature, dissolved solids, and pH in the area downstream of Highway A-l 2, possibly doing up- and downstream sampling of agricultural tailwater runoff; and

4) perform at least one set of total vs. dissolved nutrients samples.

Present the interim report and recommendations to the Shasta Valley CRMP group, Dept. of Fish and Game, and interested agencies and parties with continued involvement at the local level by water quality staff to push for improvements.

We recommend looking at discharge rates, water column and bottom sediment oxygen demand relationships, aquatic vegetation biomass and productivity (particularly for attached vegetation), and fish population estimates, to pin down effects from agricultural return water nutrient levels and subsequent biological effects on water quality. Focusing assessment activities on ponded diversion areas and irrigation returns will provide information on these specific situations, and provide useful information to the agricultural community with regard to causes and solutions.

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