SHASTA RIVER FIELD MONITORING REPORT

2001-2002

Sponsored by the
Shasta Valley Resource Conservations District
with funding from the

Klamath River Basin Fisheries Task Force,
United States Fish and Wildlife Service

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Table of Contents

Table of Tables

Table of Figures

Acknowledgements

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Our most sincere acknowledgements go to the landowners who provided access to the river for field surveys and data collection. We also would like to thank all those who attended and participated in public meetings and workshops. There are a few people whom we wish to specifically acknowledge for their support and participation.

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1 Introduction

1.1 Objective

The objective of the Shasta River field monitoring project was to complete the necessary fieldwork and develop the requisite data to implement a computer model to characterize and analyze the specific causes of elevated water temperature in relation to stream flow in the Shasta River. The flow and temperature model is a tool that can assist in habitat restoration efforts directed towards abatement of water temperatures deleterious to anadromous salmonids. This monitoring effort is part of a two-part project, wherein the monitoring effort was funded by the Klamath River Basin Fisheries Task Force, administered by the United States Fish and Wildlife Service through cooperative agreement 11333-1-J017 with Great Northern Corporation (Project # 2001-HP-03) while the computer modeling was funded separately through a grant from the California Department of Fish and Game.

1.2 Statement of Problem

The California Department of Fish and Game (DFG) has determined that the Shasta River (Figure 1-1) is the most important spawning nursery area for Chinook salmon in the Upper Klamath basin (DWR, 2001). Historically the Shasta supported fall and spring-run Chinook salmon, coho salmon and steelhead trout. According to annual spawning counts at the Shasta River weir, the 1931 fall run of over 80,000 Chinook salmon had dropped to 553 fish in 1990 (DFG, 1991). The Department of Water Resources (DWR) has identified physical barriers (dams, weirs), flow alterations due to water management practices, and water quality issues such as temperature and contaminant concentration as potential problems associated with the ability of salmon to spawn in this area. The DFG and the United States Fish and Wildlife Service (USFWS) have determined that flow and temperature are the critical water quality parameters for restoration of this system (DWR, 2001). Further, the North Coast Regional Water Quality Control Board has listed water temperature on the 303d list for the Shasta River.

Concern for fish habitat, water temperature and flow has prompted a number of studies in the Shasta River basin. The California Department of Fish and Game (DFG, 1995; DFG, 1996) and the United States Fish and Wildlife Service (USFWS, 1992) have carried out studies to assess the current fish habitat and associated needs. Flow and water temperature studies have been performed by the California Department of Water Resources (DWR, 1964; DWR, 1985). The Department of Civil and Environmental Engineering Modeling Group at the University of California, Davis (CEEMG) conducted a data inventory in 1997. In addition, Deas *et al.* (1996) conducted a woody riparian vegetation inventory. Preliminary modeling of flow and temperature was explored by the CEEMG (1998). These studies provide a basis for continuing work in the Shasta River basin.

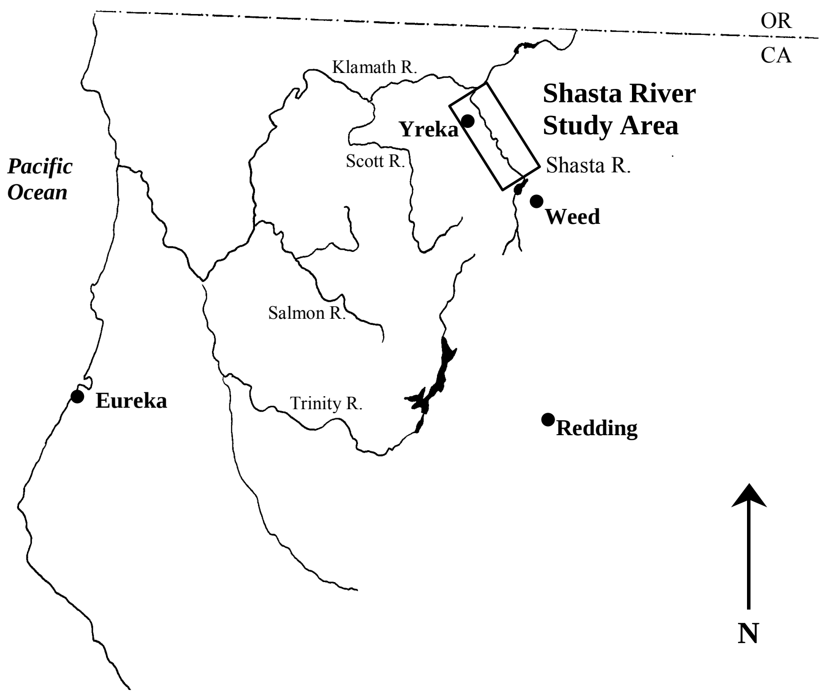


Figure 1-1 Location of the Shasta River

Water temperatures in sections of the 32-mile study reach of the Shasta River, which extends from four miles below Dwinnell Reservoir to the confluence with the Klamath River, are documented to exceed temperatures lethal for Chinook salmon, coo salmon, and steelhead trout (USFWS, 1992; Piper *et al*., 1983). The Shasta River basin is 800 square miles with a mean annual unimpaired runoff of approximately 162,300 acre-feet (DWR, 1985). The Shasta River receives inflow from tributaries, springs, and agricultural return flows while losing water to several dams and irrigation diversions and other losses.

For small streams, such as the Shasta River, riparian shading can play an important role in water temperature response through the direct reduction of incoming solar radiation. Thus, riparian restoration is a potentially beneficial measure to control stream temperature. The factors that make small streams sensitive to riparian shading include shallow depths, low flows, and the ability of the tree canopy to shade significant portions of the stream. Riparian revegetation is not the only viable alternative to control stream temperature. Flow also plays a vital role in the heating capacity of the system. Thus, two main options available to control stream temperatures in the Shasta River are (a) to manage flow and (b) manage riparian vegetation. Thus the field data required for the modeling project includes vegetation as well as geometric, flow, and temperature data.

1.3 Study Area

The Shasta River, located in central Siskiyou County, Northern California, originates in the Eddy Mountains and flows northeastward for roughly seventy miles before discharging into the Klamath River. The Shasta River flow is fed by glacial melting and mountain precipitation from Mount Shasta that is delivered to the river by underground flows and springs. The river is impounded by Dwinnell Dam at river mile 36.4. Due to minimal flows and difficulty in gaining access to the upper river, the study area extends from approximately river mile 32 to the confluence with the Klamath River.

Figure 1-2 depicts the Shasta River stream course from Dwinnell Dam to the Klamath River as derived from the National Hydrography Dataset. The upstream end of the study reach is referred to as Shasta above Parks (SRP). The Shasta River flowing downstream from SRP is joined by several small tributaries including Parks Creek, Willow Creek, Little Shasta River, and Yreka Creek and a large tributary, Big Springs, that is spring fed. Many of the system's smaller tributaries are dry in the summer. During the irrigation season from April to October there are several agricultural diversions along the river, the most substantial are those of the Grenada Irrigation District (GID) and the Shasta Water Users Association (SWA). Agricultural return flow varies along the system and enters the river in a variety of forms: as flow in defined channels, diffuse overland flow, and subsurface flow. The Shasta River is steep in the headwaters with an average slope from Dwinnell Reservoir (RM 36.4) to SRP (RM 31.8) of 0.8%, or about 40 feet per mile. Between SRP and where Interstate 5 crosses the river (RM 8.3) the average slope is 0.2%, or about 10 feet per mile. This allows the river to develop a complex set of meanders. For the last eight miles the river runs through a bedrock canyon with a steeper slope of 1.0%, or about 50 feet per mile. Figure 1-3 illustrates the profile of the river with elevations taken from 1:24,000-scale United States Geological Survey (USGS) maps.

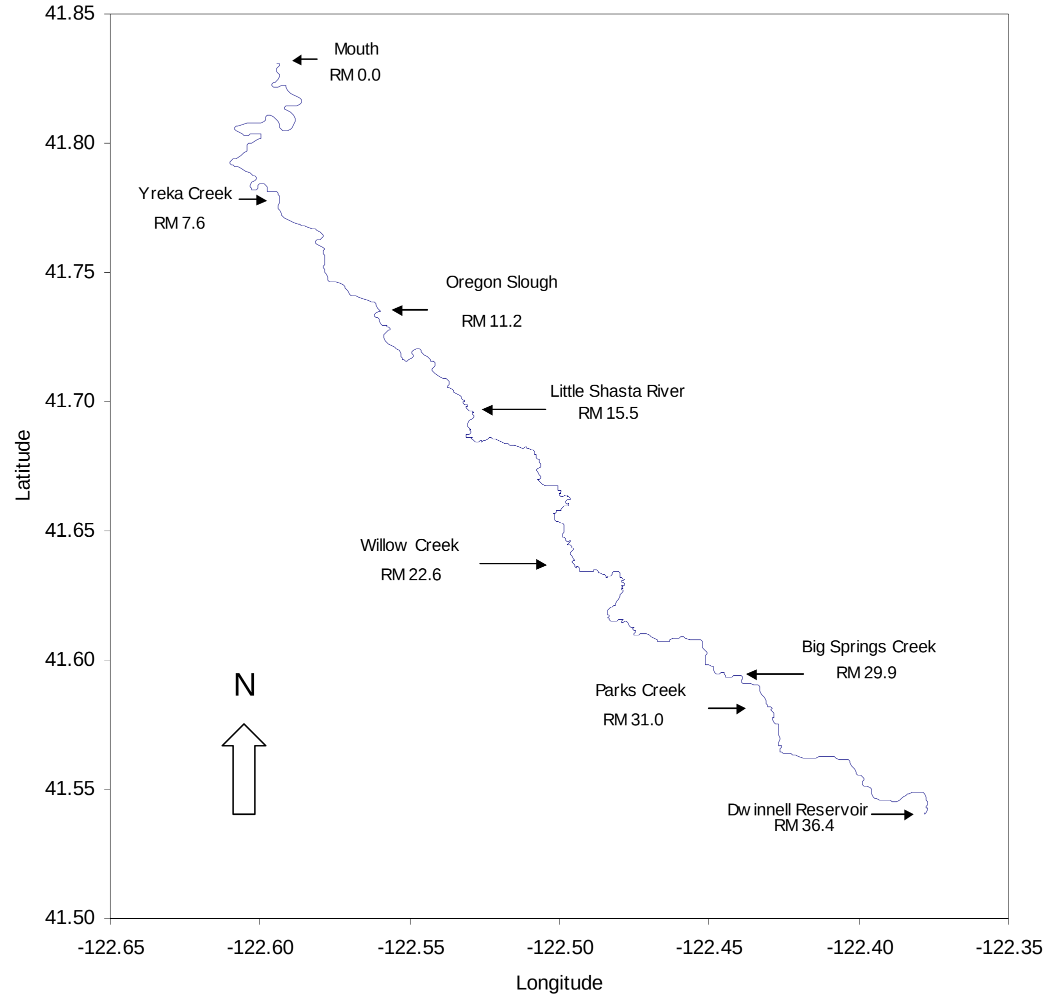


Figure 1-2 Shasta River as derived from the National Hydrography Dataset

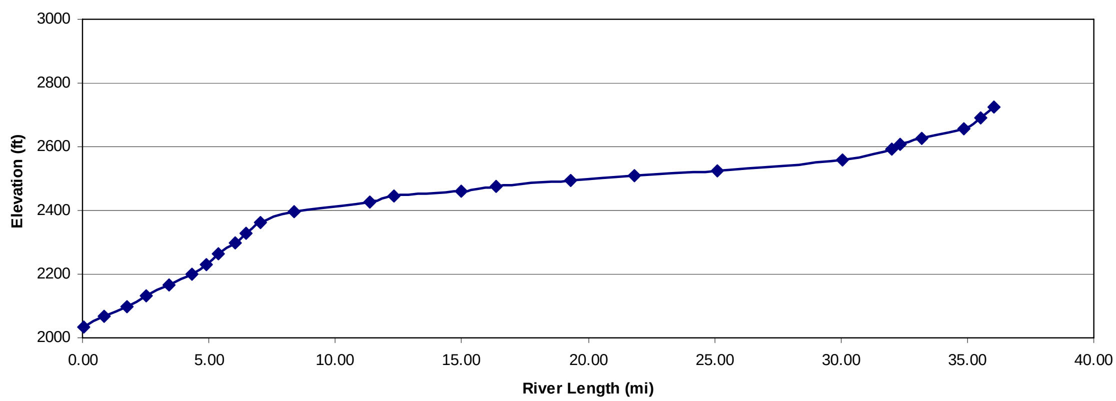


Figure 1-3 Shasta River longitudinal profile

2 Field Monitoring Programs

Required data for modeling flow and temperature include geometric descriptions of locations and cross-sections, riparian vegetation shading data, flow data, water temperature data, and climatic data. Climatic data for the Shasta River basin was available from Brazie Ranch weather station. To supplement the existing database more detailed cross-sectional geometry, riparian vegetation shading, flow, and water temperature field monitoring was conducted during the field seasons of 2001 and 2002. These programs are briefly introduced below. Although not a formal project component Watercourse Engineering, Inc. actively supported the DFG temperature monitoring program, therefore the details of that program are discussed herein. Additional monitoring programs identified by UC Davis (1998), specifically, geometric description, riparian vegetation shading characterization, and flow measurement were implemented.

Geometry: Stream cross-section geometry was available for a significant portion of the river study reach from previous DFG habitat surveys. However, additional fieldwork was carried out to further characterize the geometric stream channel representation of the river.

Riparian Vegetation Shading: Riparian vegetation field monitoring included measurement of baseline (no shade) and reduced (shaded) incoming solar radiation conditions throughout the Shasta River twice during the 2001 field season and a survey of tree height throughout the basin. The focus of this element of the project was to quantify the effect of riparian shading on water temperature and water temperature control potential for anadromous fisheries restoration. Findings are relevant to re-vegetation projects, water temperature monitoring, water temperature modeling studies, and other restoration activities on the Shasta River as well as neighboring reaches of the main stem Klamath River and tributaries (e.g., Scott River).

Flow: A flow study was proposed to characterize the nature of the Shasta River during late spring through fall. Subtask elements included review of existing data, reevaluation of past monitoring efforts, selection of appropriate locations, development of a flow monitoring protocol, and remote gauging of flow at fifteen-minute intervals during low flow periods (seasonally). Fifteen-minute flow monitoring sites were chosen by dividing the study reach into five approximately equal sections. The exact location of each monitoring site was governed by access (roads and land owner cooperation). Water temperature was monitored at all flow monitoring locations. These data proved invaluable in understanding the flow and thermal variability of the Shasta River and were necessary for modeling.

Temperature: Watercourse Engineering, Inc. assisted the DFG in implementing the 2001 and 2002 temperature monitoring programs. Subtask elements included review of existing data, reevaluation of past monitoring efforts, development of monitoring protocol, selection of appropriate locations, and remote gauging of temperature at hourly intervals during low flow periods (seasonally). Hourly temperature monitoring sites were chosen based on previous DFG monitoring sites and additional locations where more data was desirable as indicated by preliminary modeling. The exact location of each monitoring site was governed by access (roads and land owner cooperation).

2.1 Summary of Field Monitoring for 2001 and 2002

The fieldwork for the Shasta River modeling project extended over a two-year period.

Field monitoring in 2001 extended from May to October. The field team was staffed by the DFG, Watercourse Engineering, Inc. and Great Northern Corporation. Several temperature and flow devices were placed in the field and downloaded on an average of two to three week intervals. Two four-day field sessions were devoted to riparian vegetation and geometric data collection during July and August 2001.

The 2002 field monitoring plan was formed based on an analysis of the 2001 data and results from the preliminary modeling effort. The field team was again staffed by the DFG, Watercourse engineering, Inc. and Great Northern Corporation. The 2002 field season extended from mid-March to mid-October in order to monitor a short period before and after irrigation season. The fieldwork included continuous temperature and flow monitoring at previously monitored sites in addition to sites at which the model indicated that more data was desirable.

2.2 Geometry

To characterize the geometry of the Shasta River for the modeling effort three types of data were required: a series data points specified by xy-coordinates in latitude and longitude depicting the course of the river, bed elevations, and cross-sectional shape. The characterization of the cross-sectional shape required field data collection. A river mile index was developed to effectively locate data collection sites on the river. Sites at approximately equal intervals were selected at which to collect cross-sectional data.

2.2.1 River Mile Index

To describe the location of various data collection sites on the river a river mile index was developed. The National Hydrography Dataset (NHD) was used to produce a digital base map of the Shasta River. Latitude and Longitude for line segments along the Shasta River were extracted from the NHD and densified by Cindy Moore at the Information Center for the Environment, University of California, Davis.

The NHD is a seamless set of digital spatial data maintained by the United States Geological Survey (USGS). The NHD is based on the USGS 1:100,000-scale Digital Line Graph (DLG) hydrography data and integrated with reach-related information from the EPA Reach File Version 3 (RF3). Thus, while NHD was initially based on 1:100,000-scale data, it is designed to incorporate higher-resolution data. The NHD came online in the spring of 2001. The USGS has built tools in ArcView to allow users to update the NHD with 1:24,000 datasets. The USGS is working with several state partners and the United States Forest Service to create the higher resolution data. As the work is verified and comes online it is classified as “high resolution” data. The data used for this study is classified as “medium” resolution data. The USGS is also working to link topographic, flow, and velocity data to the spatial data.

In processing the dataset nine duplicate points were identified and removed. One digitizing error was located. This point was also removed. No other changes were made to the NHD dataset.

To compute river miles the geographic coordinates in decimal degrees were converted to radians by multiplying the number of degrees by Π/180 = 0.017453293 radians/degree. Assuming a spherical earth with radius, *R*, river mile distance was calculated using the Haversine Formula (Sinnott, 1984) found in Equations (1) through (3).

$$a = \left(\sin\left(\frac{dlat}{2}\right)\right)^2 + \cos(lat1) * \cos(lat2) * \left(\sin\left(\frac{dlon}{2}\right)\right)^2 \qquad (1)$$

$$c = 2 * \arcsin(\min(1, sqrt(a))) \qquad (2)$$

$$d = R * c \qquad (3)$$

Where:

Two points in spherical coordinates (longitude and latitude) are defined as (*lon1*, *lat1*) and (l*on2*,*lat2*).

dlat = difference in latitude (*lat2-lat1* in radians)
dlon = difference in longitude (*lon2-lon1* in radians)
c = the great circle distance (radians)
d = the great circle distance in the same units as *R* (here it is miles)
R = radius of the earth = 3956 miles (min = 3937, max = 3976)

Using the Haversine formula distances were calculated between NHD coordinates. Major features on the Shasta were located in the NHD coordinate system and the River Mile Index (RMI) was calculated (Table 2-1). The sites listed in Table 2-1 can be located on the map in

Figure 2-1.

Table 2-1 River mile index

Location	River Mile
Mouth	0.0
USGS Gage	0.5
HWY 263	7.1
Yreka Creek	7.6
Anderson Grade	7.9
Interstate 5	8.3
Yreka-Ager Road	10.3
Oregon Slough (R bank)	11.2
HWY 3	12.3
Montague-Grenada Road (DWR Weir)	14.7
River Ranch Road	15.4
Little Shasta River	15.5
SWU Association	16.8
Freeman Lane	17.9
HWY A-12	21.9
Willow Creek	22.6
Grenada Irrigation District Pumps	26.9
Big Springs Creek	29.9
Louie Road	30.1
Parks Creek	31.0
Shasta above Parks	31.8
Riverside Drive	35.6
Dwinnell Reservoir	36.4

The study reach from river mile (RM) 31.8 to the Mouth was broken into five study segments in order to quickly reference and discuss each part of the system. Table 2-2 is a table of statistics for each reach including the number of NHD coordinates, length, and number of coordinates per mile. Note that there are more coordinates per mile in the meandering portions of the river, study segments 3 and 4. This is necessary to accurately represent the small-scale meanders in the system.

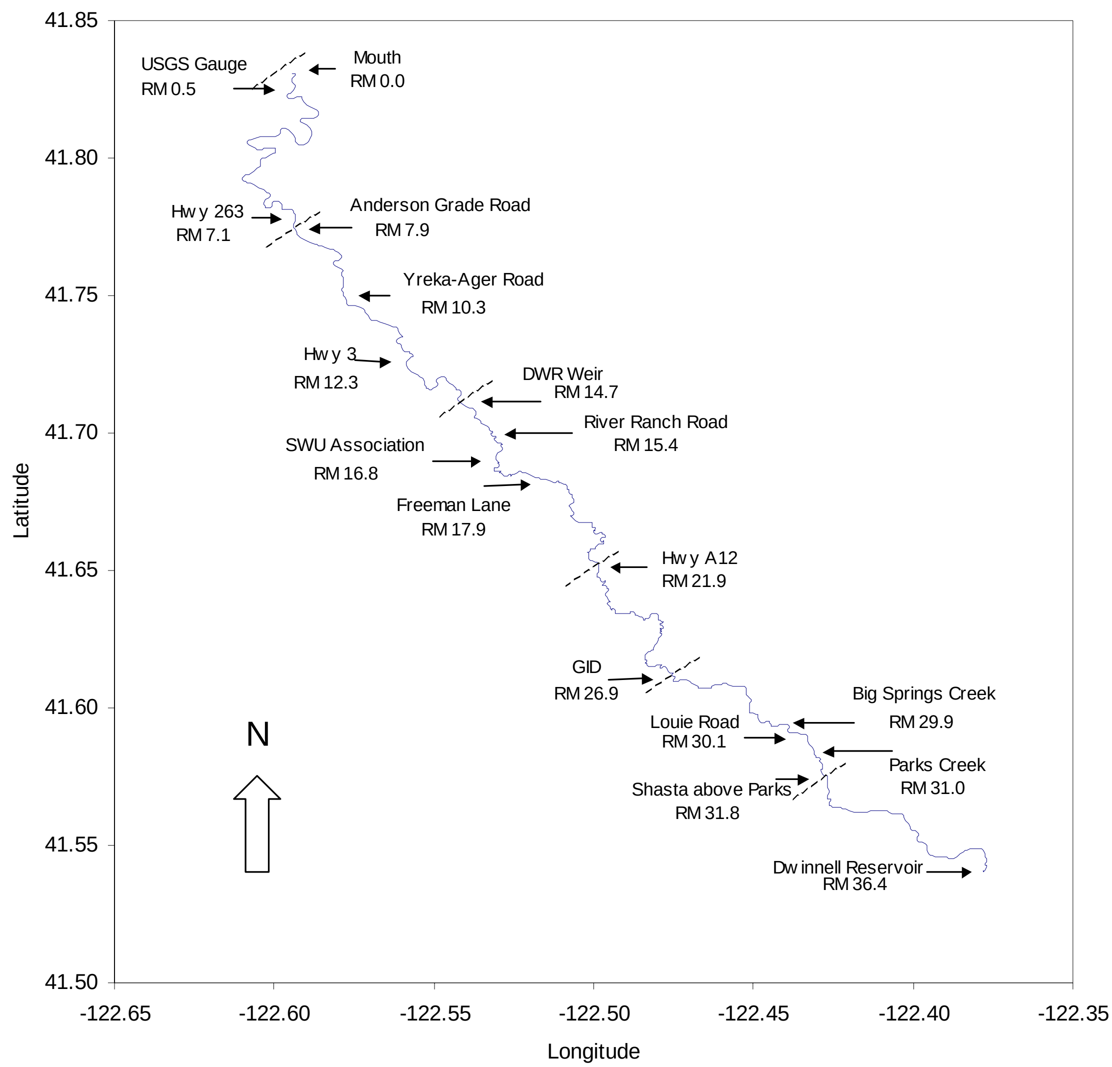


Figure 2-1 Shasta River site locations and associated river miles

Table 2-2 River segments statistics for Shasta River RMI

Study Segments	No. of NHD Coordinates	Segment Length (mi)	No. of Cords. Per Mile
1 Mouth to Anderson Grade	269	7.9	34
2 Anderson Grade to DWR Weir	253	6.9	37
3 DWR Weir to A12	333	7.2	46
4 A12 to GID	267	5.0	53
5 GID to Shasta above Parks	188	4.8	39
TOTAL	1310	31.8	

2.2.2 Cross-sectional Data

In order to properly represent the geometric features of the stream it was necessary to gather information about the cross-sectional shape of the Shasta River at various locations. Ten equally spaced sample locations were chosen in each of the five reaches. Access was not available for 7 of the 50 sites. Of the remaining 43, only 25 sites were visited and measured due to time constraints and difficult access. At each site key parameters associated with the shape of the cross-section including bankfull width, water surface width, water depth, and bank height were measured. Bankfull width was defined as the width of the stream when it is about to inundate the active floodplain. This parameter was often difficult to assess. Determining factors of bankfull width included: break in slope, change in vegetation, and change in substrate. The required equipment included a staff and a 100 ft tape measure. In addition, pictures were taken of each site. The sites accessed and their associated river miles are listed in Table 2-3.

Table 2-3 Cross-section sampling sites

Reach No.	River Mile	Reach No.	River Mile
1.4	2.36	3.3	16.17
1.5	3.14	3.4	16.89
1.6	3.93	3.5	17.61
1.8	5.50	3.6	18.33
1.9	6.28	4.1	21.95
1.10	7.07	4.2	22.45
2.1	7.85	4.7	24.97
2.2	8.54	4.9	25.98
2.3	9.22	4.10	26.48
2.4	9.91	5.1	26.98
2.5	10.60	5.3	27.95
3.1	14.72	5.10	31.38
3.2	15.44		

The analysis of the cross-section data is found in Table 2-4. Depth is defined as depth from the top of the bank to the lowest measured point of the cross-section. Note that one sampling point (RM 17.61) was not used in calculating the statistics for Reach 3, as it was found not to be representative of the reach. Cross-sectional data for individual sites can be found in Appendix A. Protocols for gathering geometric information can be found in Appendix E.

Table 2-4 Cross-section statistics

Reach No.	River Mile	No. Cross-Sections per Reach	Avg. Depth (ft)	Avg. Top Width (ft)
1	0.0-7.85	6	4.4	36
2	7.85-14.72	5	4.8	40
3	14.72-21.95	5	5.4	33
4	21.95-26.98	5	5.5	35
5	26.98-31.83	3	5.2	31

2.3 Riparian Vegetation Study

Field measurements were carried out to quantify vegetation height and transmittance, key factors in characterizing the effect of riparian vegetation on stream temperature.

2.3.1 Vegetation Height

Vegetation height was measured at 25 sites along the Shasta River. At each site species, height, and location (right or left bank) were recorded for trees and bulrush present. If the height of the trees/bulrush was less than 25 feet then a staff (25 ft in length) was used to directly measure the height. When this was not possible, a Brunton compass and 100-foot tape was used to calculate the vegetation height. The Brunton measures vertical angles to accuracies better than 1 degree. Figure 2-2 depicts how to calculate the tree height using a Brunton:

1) Measure the distance between the observer and the tree (X).

2) Site the top of the tree and measure the vertical angle with the Brunton (A). The angle can be read as a percent or in degrees.

3) Height of tree (H_T) = (distance to tree) x (% grade/100 or tangent of the angle) + height of the observer (H_O)

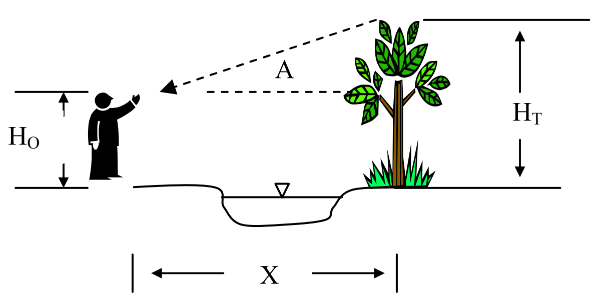


Figure 2-2 Diagram depicting the variables for calculating H_T, the height of a tree using a Brunton compass

A full protocol for gathering vegetation data can be found in Appendix E. Table 2-5 includes a list of riparian tree species native to the Shasta Valley.

Table 2-5 Tree species found along the Shasta River

Common Name	Scientific Name	Other Names
White Alder	*Alnus rhombifolia*	Sierra Alder, Western Alder, California Alder
Oregon Ash	*Fraxinus latifolia*	Water Ash, Black Ash
Black Cottonwood	*Populus trichocarpa*	Western Balsam Poplar, California Poplar
Red Birch	*Betula fontanalis*	Water Birch
Oregon White Oak	*Quercus garryana*	
Red Willow	*Salix laevigata*	Smooth Willow, Polished Willow
Arroyo Willow	*Salix lasiolepsis var. bracelinea*	White Willow
Pacific Willow	*Salix lasiandra*	Wester Black Willow, Yellow Willow, Waxy Willow
Sandbar Willow	*Salix hindsiana*	Hind's Willow, Valley Willow

In this report the trees will be referred to by the common name given in Table 2-5. During the surveying all willows not identified as Sandbar Willows were classified as Arroyo Willow due to the difficulty in distinguishing between the Red, Arroyo and Pacific Willows. Trees under ten feet in height were considered saplings, and not included in the statistical analysis of tree heights found in Table 2-6. This eliminated four trees from the sampling dataset. Red Birch and Sandbar Willow were found to have similar height ranges and averages. Thirty-four of the sixty-eight trees measured were either Sandbar Willow or Red Birch, with an average height of twenty-two feet. Twenty-three out of sixty-eight were Arroyo Willow, with an average height of thirty-eight feet. The remaining eleven trees were White Alder, Oregon Ash, Oregon White Oak, and Black Cottonwood. Bulrush (*Scirpus*) was found throughout the system where the stream was protected from grazing. Bulrush ranged in height from 7-10 feet, the average being 9 feet.

Table 2-6 Vegetation height statistics

Sample Size	Species	Range of Height (ft)	Average Height (ft)
3	White Alder	21-35	27
4	Oregon Ash	17-37	27
2	Black Cottonwood	32-45	39
7	Red Birch	16-36	24
2	Oregon White oak	55-73	64
23	Arroyo Willow	20-54	38
27	Sandbar Willow	13-35	22

2.3.2 Vegetative Transmittance

The vegetative transmittance (Tr) is the percent of solar radiation passing through a particular type of barrier along the stream. It is calculated using Equation (4). Possible barriers include trees, stream banks, or other shade-rendering vegetation including bulrush. If Tr = 0.2 then 20% of the solar radiation is passing through the effective barrier. Transmittance may vary throughout a year for a particular type of vegetative barrier. For example, in the summer when the trees are in full bloom, the percent of solar radiation that penetrates the canopy is much less than in the winter when the trees are without leaves. This modeling project is concerned with summer temperatures of the Shasta River; therefore transmittance measurements were taken during the summer months.

$$T_r = \frac{Q_v}{Q_s} \qquad (4)$$

Where:

T_r = transmittance
Q_v = solar radiation under the tree canopy or effective barrier (W/m^2)
Q_s = unimpeded solar radiation (W/m^2)

Instrumentation: To determine the transmittance it is necessary to measure direct solar radiation and solar radiation underneath the effective barrier. Two devices were used to make these measurements. The LI200 was used to measure direct (unimpeded) solar radiation. SOLRAD was used to measure solar radiation underneath the tree canopy or other effective barrier.

SOLRAD is the Solar Radiation Measurement System produced by Kipp & Zonen, Inc. It consists of two main components, the CM 3 thermopile-type pyranometer and the CC

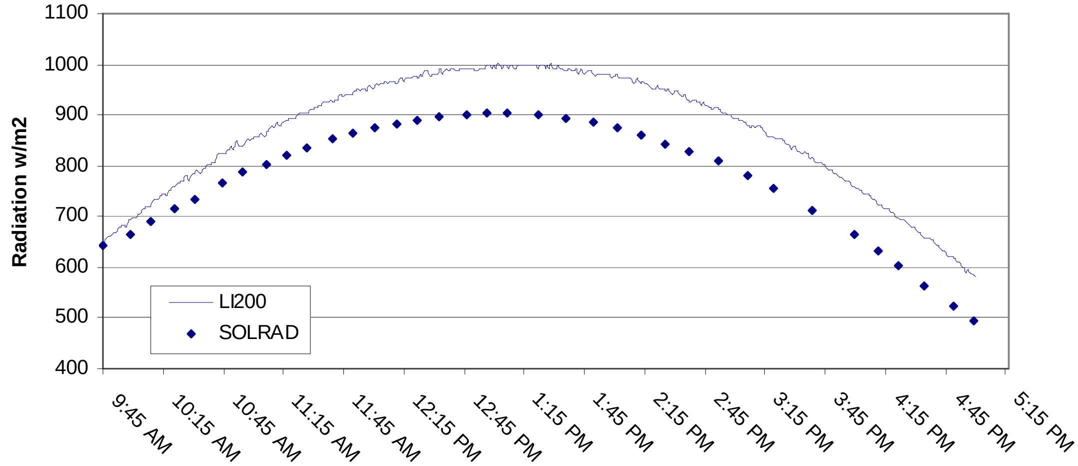
20 hand-held data logger. The pyranometer can be used in temperatures ranging from – 40 to 80 °C. It measures within the spectral range from 305 to 2800 nm. The sensitivity is 10-35 $\mu V/Wm^{-2}$. The accuracy under normal conditions is ± 10%. The data logger runs on a DC-standard 9 volt battery. The logger allows the user to choose actual or integrated values, set the sensor type, set the integration method, read stored totals, set the calibration type, and set the internal clock. (Kipp & Zonen Manual, 1992)

Whereas SOLRAD was designed to measure unobstructed or shaded conditions, the LI200 pyranometer was designed to measure only unobstructed solar radiation. The LI200, a product of LI-COR, Inc., has a maximum absolute error under natural daylight conditions of ± 5%. Since the sensitivity of the LI200 is 80 micro-amps per 1000 W/m2, an adapter was needed to amplify the signal to the HOBO logger, a product of Onset. The amplifier used was a UTA 200 made by EME Systems. It is specifically designed to be an interface between the LI200 and the HOBO loggers. Table 2-7 includes detailed specifications of SOLRAD and the LI200.

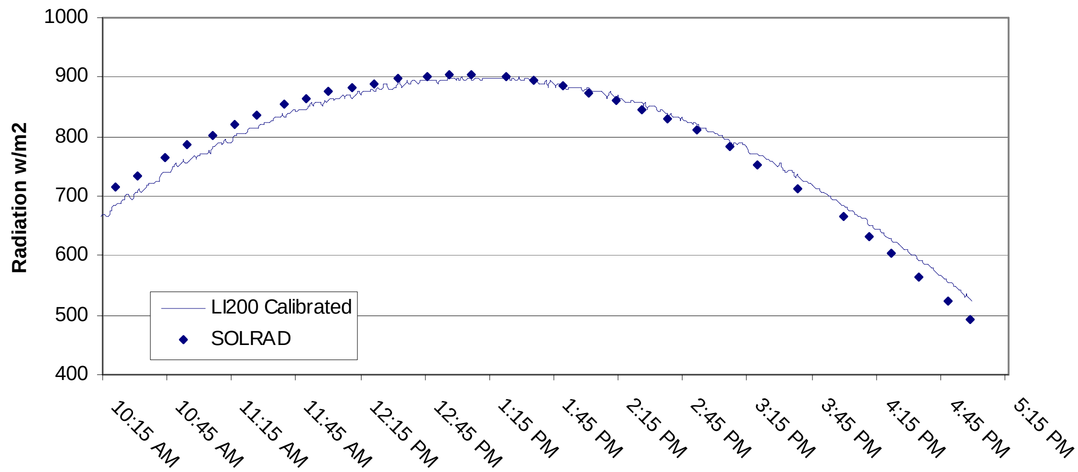
Table 2-7 Specifications of the solar radiation measurement devices

Specifications	**SOLRAD**	**LI200**
Response Time	(95%) 18 s	10 s
Sensitivity	10-35 V/Wm^{-2}	90 A/1000 Wm^{-2}
Linearity	± 2.5% (<1000 W/m2)	± 1% (<3000 W/m2)
Stability	<± 1% change/year	<± 2% change/year
Operating Temperature	-40 to +80 °C	-40 to +60°C
Tilt Response	<± 2%	No error.
Temperature Dependence	6% (-10 to 40°C)	0.15% per °C max.

SOLRAD and the LI200 were tested and calibrated so that they could be used together in the establishment of a transmittance value. For calibration purposes the instruments were each deployed in full sunlight for a 7.5-hour period. The two solar curves were compared and a calibration factor assigned. Figure 2-3 shows the solar curves before and after calibration. Note that the solar curves show a constant relationship after about 11:45am. There was some morning fog until about 10:00am, which may have contributed to the varied relationship between the two curves in the morning hours. The data after 10:00am was compiled and averaged to yield a calibration factor for the LI200 of 0.9 (i.e. the data from the LI200 is multiplied by 0.9 to compare it to data from SOLRAD).



(a)



(b)

Figure 2-3 Calibration of LI200 and SOLRAD (a) before (b) after calibration

<u>Field Procedure and Data:</u> Transmittance measurements were made at two locations along the Shasta River. Measurements were taken downstream of the DWR Weir at Mr. Meamber's property (RM 14.7) and on Mr. Fiock's property (RM 10.6). At each location the LI200 was deployed in direct sunlight and SOLRAD was moved between three tripods located under various effective barriers including trees, cut banks, and bulrush.

The LI200 logged solar radiation continuously at 1-minute intervals. Three values were recorded with SOLRAD: the starting value, the ending value, and an integrated value over the five-minute monitoring period at each station. With a five-minute integrating period each station was visited once every 20 minutes. The deployments varied in time from half of a day to a full day depending on the weather. If through the course of the day the SOLRAD station became exposed to full sunlight, then the tripod was moved to a new site and the transfer noted. A copy of the protocols for use of each device is included in Appendix E.

Figure 2-4 SOLRAD deployment in the Shasta River below DWR weir

Figure 2-5 is a sample graph of the solar radiation data on the Shasta River at the Fiock's property. Direct solar radiation as measured by the LI200 and calibrated for use with the SOLRAD data is the continuous line. The interruptions in the LI200 trace are due to the passing of clouds at various times of day. The squares are SOLRAD measurements taken under an Arroyo Willow and the triangles are SOLRAD measurements taken under a Sandbar Willow. Note that the relationship between unimpeded solar radiation and solar radiation under the canopy is not a direct relationship throughout the day. However, for the purposes of this study a single number was used to represent transmittance for a particular barrier. In the graph in Figure 2-5 the average transmittance is 0.1, or 10%.

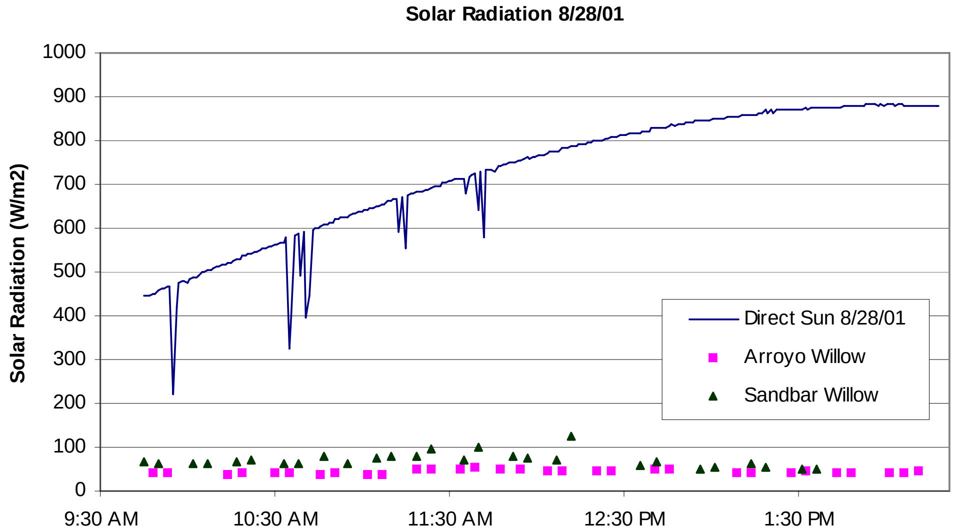


Figure 2-5 Sample transmittance data

Table 2-8 contains the averaged transmittance data for all deployments and stations. Each type of barrier was given a grade of good, fair or bad. "Good" meant full foliage, "bad" was poor cover, and "fair" was in between. Good foliage had values of transmittance that ranged from 6 to 14%. Fair foliage had values that ranged from 19 to 38%. The lower 2/3 of bulrush had values akin to good foliage, whereas the top 1/3 had values akin to fair foliage.

Table 2-8 Average transmittance values for various barriers

Type of Barrier	Grade (good/medium/bad)	Average Transmittance for deployment period (%)
Cut bank	Good	11
Arroyo Willow	Good	6
Sandbar Willow	Good	10
Arroyo Willow	Fair	21
Arroyo Willow	Fair-Good	19
Arroyo & Sandbar Willow	Fair	38
Arroyo & Sandbar Willow	Good	14
Birch	Good	7
Bulrush	Top 1/3 of plant	30
Bulrush	Lower 2/3 of plant	4
Bulrush	Lower 2/3 of plant	8
Bulrush	Lower 2/3 of plant	7

2.4 Flow Study

There are two full-time flow gages on the Shasta River: the USGS gage No. 11517500 (RM 0.5) and the DWR gage at the water master weir (RM 14.7). Data for both stations is available at the California Data Exchange Center (CDEC) under the station ID's SRY and SRM, respectively. In 2001 and 2002 this data was supplemented by continuous monitoring at five and six additional sites, respectively. These additional sites were monitored by measuring the water level with a pressure transducer and constructing a rating curve (or water level-flow relationship) for each site to convert water levels to flow rates.

Equipment used for flow measurement included remote logging pressure transducers, associated hardware and software, staff gauges, a flow meter consisting of a velocity measuring device and staff, a tape measure, and field log sheets and notebook. Field logs were used to record observations, field conditions, and any other items of note. Flow data sheets were used to record depths, widths, and velocity measurements for flow calculations.

The pressure transducers used were Global Water Instrumentation, Inc. water level loggers (WL15). Two types of WL15's were available: pressure transducers with a 25-foot flexible cable and pressure transducers mounted on vertical, non-flexible cable approximately 3 feet in length (weir stick style). The 25-foot cable WL15's have a range of 0-3 feet, whereas the weir stick type units have a range of 0-2 feet. The WL15 pressure transducer/data logger system has an accuracy of 0.2% of the full scale over a range of temperatures (-50°C to +50°C), or 0.1% of full scale at a constant temperature. Each pressure transducer was placed in a temporary stilling well secured to a T-posts driven into the riverbed. Values were logged every 15 minutes and downloaded approximately semi-monthly. Figure 2-6 is a picture of the deployment of the cable-style pressure transducer.

Figure 2-6 Pressure transducer deployment for the cable unit style

Each time the loggers were downloaded the section was rated using a Flo-Mate Portable Flowmeter Model 2000 from Marsh-McBirney, Inc. The portable flow meter measures stream velocity at an accuracy of ± 2% of the reading. It can measure within a range from –0.5 to +20 ft/s (-0.15 to 6 m/s). To rate each section the width of the river was divided into sections with each section being no more than 10% of the total width. The flow meter, mounted to a staff, was used to take velocity measurements in the middle of each section at a depth of 60% of the total height of the water column as measured from the water surface. The velocities were averaged over 30 second intervals and then applied to the whole section. The flows in each section were added to achieve a flow for the site.

Each pressure transducer underwent pre and post season testing to ensure that each unit was operating within manufacturer specifications. Testing included deploying the pressure transducers in a container with a staff gage. Over the course of the test the water level was changed several times and the staff gage readings recorded. The data was then compared to the logged file from the pressure transducer. Full field protocol for monitoring flow in the Shasta River can be found in Appendix E.

2.4.1 Flow Study 2001

In 2001 six additional sites were chosen for continuous flow monitoring. These locations are found in Table 2-9.

Table 2-9 Locations of pressure transducers during the 2001 field season

Location	River Mile
Anderson-Grade Road	7.9
Montague-Grenada Road (DWR Weir)	14.7
Highway A12	21.9
Shasta River below the Grenada Irrigation District Pumps (GID)	26.9
Parks Creek	31.0
Shasta River above Parks Creek	31.8

The flow and stage measurements for each site were converted to rating curves in order to relate the pressure transducer water depth measurements to flows. Figure 2-7 is a sample graph of the 2001 rating curve for the pressure transducer at Anderson Grade. The rating curves for each site were developed in a similar format.

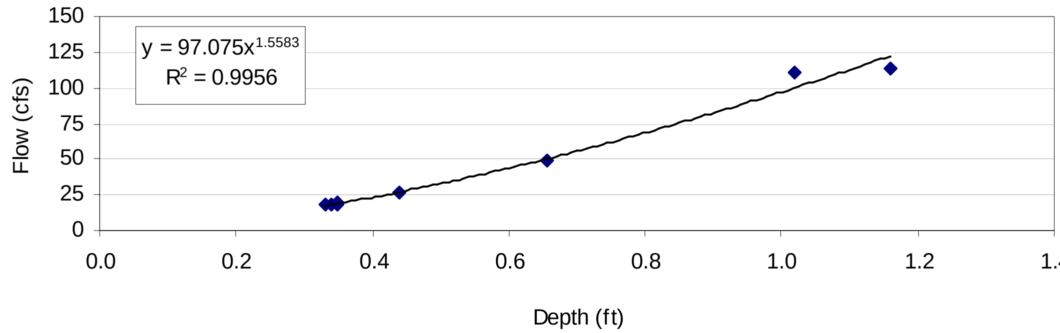


Figure 2-7 Sample pressure transducer rating curve for Anderson Grade (2001)

Table 2-10 contains the equations for each rating curve. This table also contains the number of data points used to create the curves, the R^2 value associated with each curve, and the difference in elevation between the pressure transducer and staff gage. Since the staff gage and the pressure transducer were at different elevations, the change in elevation between them was needed to adjust the pressure transducer data so that it could be used with the rating curve that was related to heights measured from the staff gage. The value found in Table 2-10 was added to the measured pressure transducer value before using the rating curve to calculate flow. There is more than one value at the DWR weir because the pressure transducer at this site was removed for repairs and not replaced at the same elevation, thus the relationship between pressure transducer height and staff gage was altered. After the 15-minute interval pressure transducer heights were converted to flows using the rating curves, the data was averaged up to an hourly flow dataset. Appendix B contains monthly graphs of hourly-averaged flow for each site.

Table 2-10 Pressure transducer site rating curves for 2001

Location	Rating Curve	R^2 value	Number of Points	Change in Elevation* (ft)
Anderson-Grade Road	$y=97.075x^{1.7377}$	0.9956	7	-0.737
DWR Weir	$y=49.661x^{1.6241}$	0.9424	9	0.345, 0.235, -0.478
A12	$y=99.978x^{1.3848}$	0.9261	8	-1.117
GID	$y=23.447x^{1.609}$	0.9681	4	1.065
Parks Creek	$y=20.371x^{1.4061}$	0.924	9	-0.153
Shasta above Parks	$y=11.635x^{1.7377}$	0.6703	6	0.233

*Difference in elevation between the staff gage and pressure transducer

The only site where temporarily flow measurements were duplicated with a permanent station was at the DWR weir. Data was available from two sources at this site, the DWR Weir and the pressure transducer. Figure 2-8 is a comparison between the two types of flow measurements at the DWR weir. Comparison of the calculated flow data for the two sites verifies the reliability of the temporary flow measurement method.

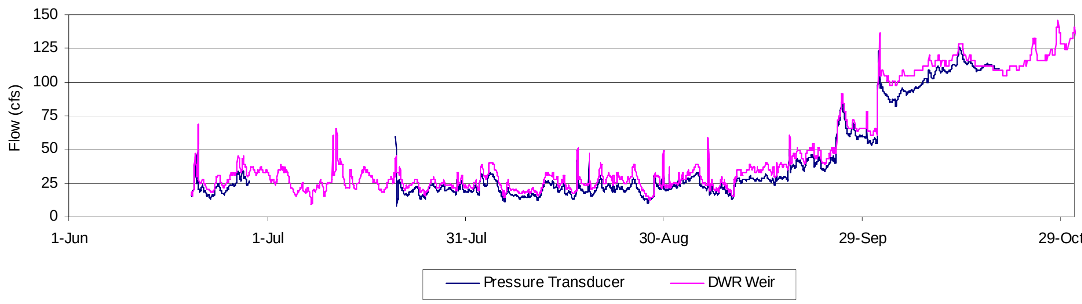


Figure 2-8 Comparison of flow measured with the permanent station and the temporary pressure transducer at DWR Weir from June to October 2001

2.4.2 Graphs of Weekly Flow Statistics (2001)

Weekly statistics were calculated from the hourly flow data. Statistics include: the average hourly value, the minimum single hourly value, and the maximum single hourly value for a given week. The statistics are calculated based on Julian weeks (JW). The 2001 field season spanned JW 25 – 46. See Appendix D for a table of Julian weeks and dates. Figure 2-9 through Figure 2-16 are graphs of these weekly flow statistics by site. The sites are ordered downstream to upstream. Note that the y-axis scale for Shasta River Above Parks Creek and Parks Creek is 50 cfs, whereas the scale for all other sites is 200 cfs. Tables of the 2001 weekly flow statistics are located in Appendix B.

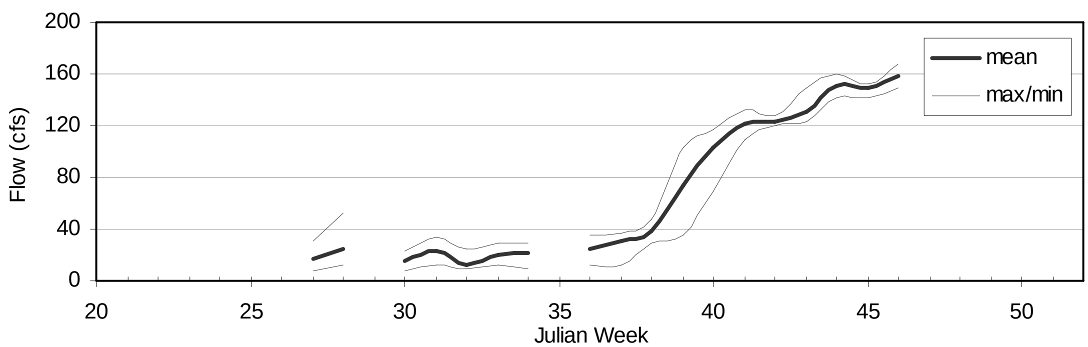


Figure 2-9 Shasta River at the Mouth weekly mean, maximum, and minimum flow (2001)

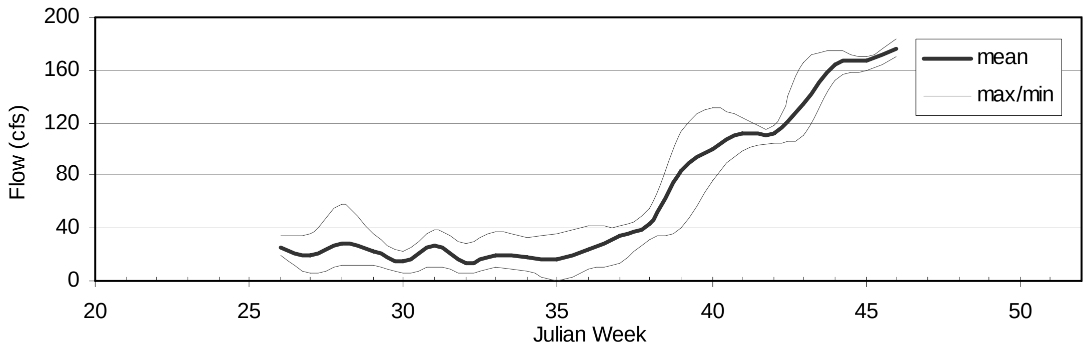


Figure 2-10 Shasta River at Anderson Grade Road weekly mean, maximum, and minimum flow (2001)

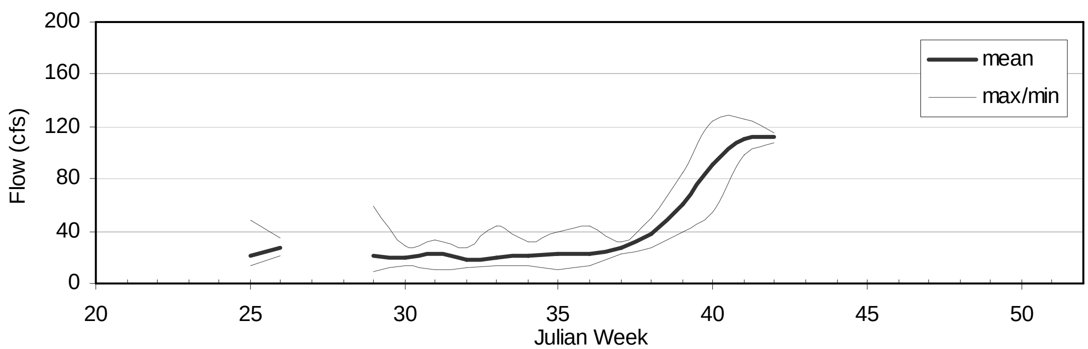


Figure 2-11 Shasta River at DWR Weir pressure transducer weekly mean, maximum, and minimum flow (2001)

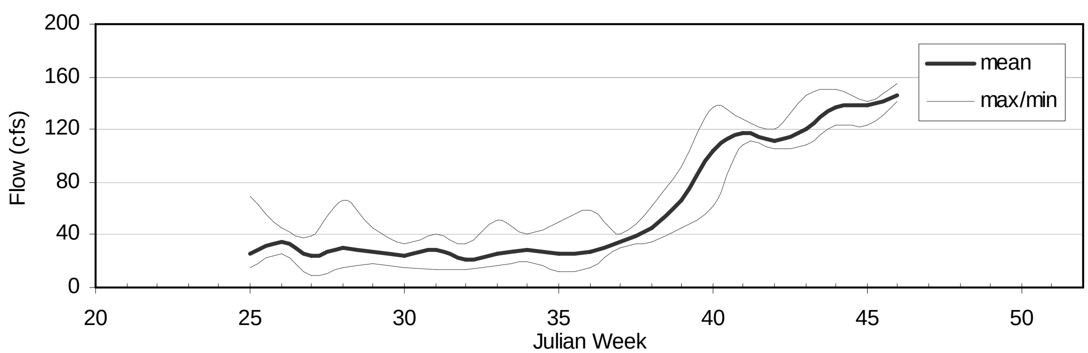


Figure 2-12 DWR Weir permanent station weekly mean, maximum, and minimum flow (2001)

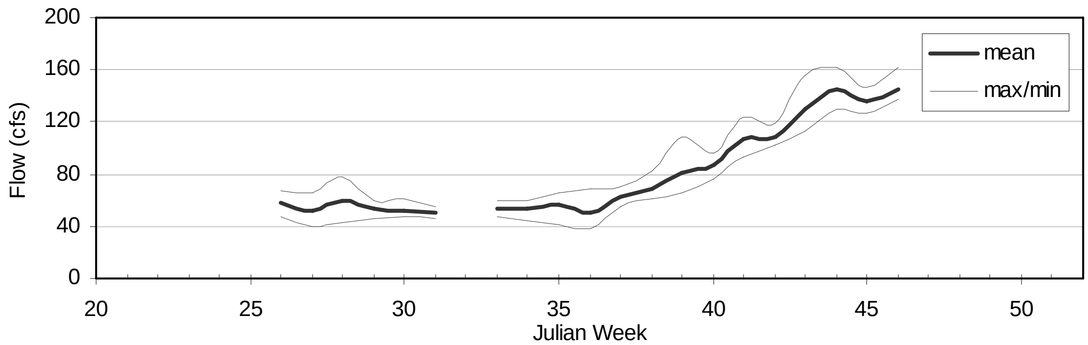


Figure 2-13 Shasta River at Highway A12 weekly mean, maximum, and minimum flow (2001)

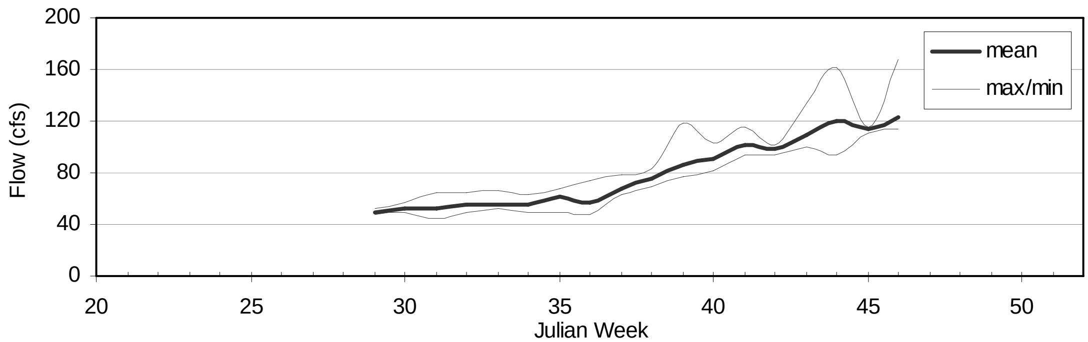


Figure 2-14 Shasta River below the Grenada Irrigation District Pumps weekly mean, maximum, and minimum flow (2001)

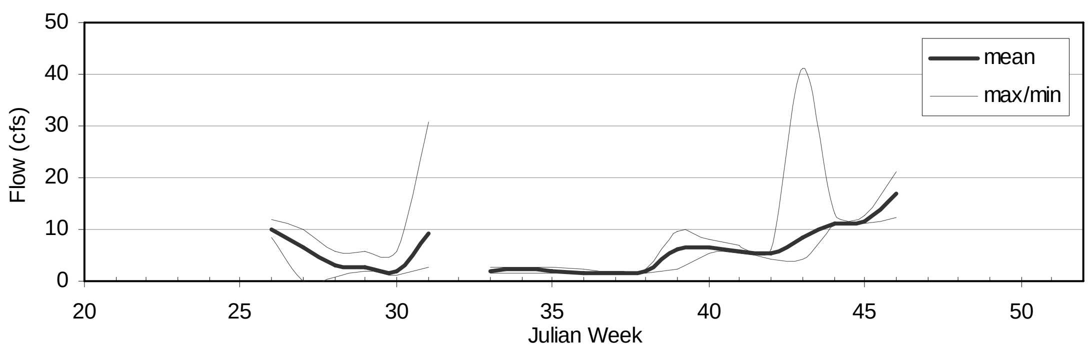


Figure 2-15 Parks Creek weekly mean, maximum, and minimum flow (2001)

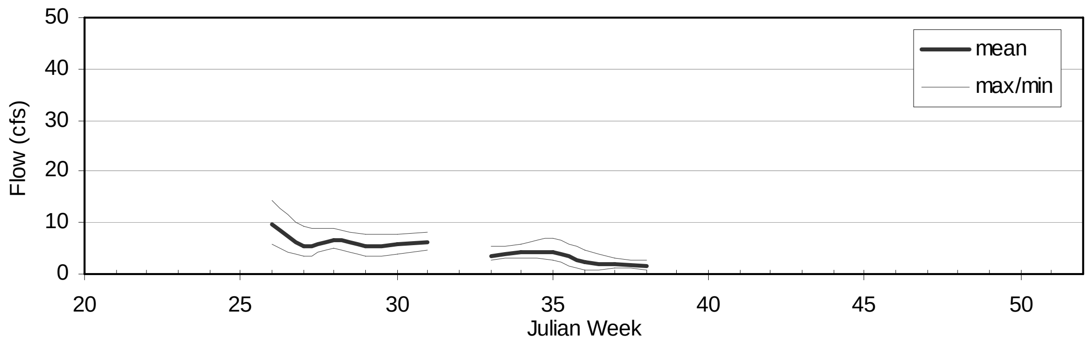


Figure 2-16 Shasta River Above Parks Creek weekly mean, maximum, and minimum flow (2001)

2.4.3 Flow Study 2002

In 2002 flow was continuously monitored at the five additional sites listed in Table 2-11. It was originally planned to monitor flow at Shasta above Parks Creek and Parks Creek; however, due to access issues this was not possible. Data was available for the upper river section for model comparison at Louie Road (RM 30.1) through an agreement with a local landowner. However, the data is not part of this study. The temporary setup at the DWR weir site was removed from the flow monitoring sites because field data from 2001 indicated that the measurements of the pressure transducer and the weir were similar.

Table 2-11 Locations of pressure transducers during the 2002 field season

Location	River Mile
Anderson-Grade Road	7.9
Yreka-Ager Road	10.3
Freeman Lane	17.9
A12	21.9
GID	26.9

Table 2-12 contains the rating curves that were developed for each of the 2002 monitoring sites. This table also contains the applicable dates of the rating curve, the number of data points used to create the curves, and the R^2 value associated with each curve.

There are two reasons why a particular site might have more than one rating curve. First, if the staff gage was moved or displaced during the field season this would cause the relationship between the staff gage and the flow to change. On 5/21/02 at GID the cable type pressure transducer had to be replaced with a weir stick type unit due to sedimentation build up in the PVC casing. This sedimentation was affecting the pressure transducer readings. In the course of replacing the unit the staff gage was moved, hence the need for a second rating curve at GID. The third rating curve at GID, along with the second rating curves at Freeman Lane and A12, were needed due to a shift adjustment that occurred between mid-July and the beginning of August. To form the rating curve several measurements of flow and associated stage are recorded during a field season. According to the USGS website during the course of a field season "(s)ome measurements (can) indicate a change in the rating, often due to a change in the bed, (aquatic vegetation,) or riparian vegetation. Such changes are called shifts; they may indicate a short- or long-term change in the rating for the gage. In normal usage, the measured shifts (or corrections) are applied mathematically to a defined rating."

Table 2-12 Pressure transducer site rating curves for 2002

Location	Applicable Dates	Rating Curve	R^2 value	No. of Points
Anderson Grade Road	3/19/02 to 10/18/02	$y=32.785x^{2.7392}$	0.9933	14
Yreka-Ager Road	5/7/02 to 10/18/02	$y=8.572x^{3.6865}$	0.9358	12
Freeman Lane	5/7/02 to 7/18/02	$y=47.567x^{1.2743}$	0.8862	6
	8/7/02 to 10/15/02	$y=71.583x^{1.3463}$	0.9945	5
A12	3/19/02 to 7/15/02	$y=89.682x^{1.2508}$	0.7156	8
	8/5/02 to 10/15/02	$y=74.094x^{1.262}$	0.9586	6
GID	3/18/02 to 4/19/02	$y=59.208x^{1.1153}$	0.9136	3
	5/21/02 to 7/23/02	$y=17.75x^{3.0295}$	0.7552	5
	8/21/02 to 10/15/02	$y=45.429x^{1.5967}$	0.9824	6

Table 2-13 contains the dates of deployment, serial number of unit deployed, and average elevation change between the staff gage and the pressure transducer for each site. (See Section 2.4.1 for an explanation of the average elevation change.) Often when a malfunctioning unit is exchanged it is impossible to deploy the new unit in the exact location of the old unit. This causes a change in the relationship between the base of the staff gage and the sensor on the pressure transducer. For this reason, some of the sites found in Table 2-13 have multiple values for the average change in elevation between the pressure transducer and the staff gage.

Table 2-13 Pressure transducer deployment dates and change in elevation values for 2002

Location	Dates of Deployment	Serial Number of Unit	Avg. Change in Elevation (ft)
Anderson Grade Road	3/19/02 to 6/13/02	13839	0.388
	6/13/02 to 10/18/02	13840	-0.230
Yreka-Ager Road	5/7/02 to 10/18/02	13838	-0.755
Freeman Lane	5/7/02 to 10/15/02	13837	-0.339
A12	3/19/02 to 10/15/02	13836	-0.550
GID	3/19/02 to 5/21/02	13840	-1.418
	5/21/02 to 6/3/02	14274	-0.242
	6/19/02 to 9/21/02	14273	-0.242
	9/21/02 to 10/15/02	20466	-0.242

The data 15-minute pressure transducer data was averaged to hourly data, adjusted with the appropriate change in elevation, and converted to flows using the appropriate rating curves. Where a site contained multiple rating curves due to a shift adjustment a linear interpolation was used to scale the data when transitioning from one rating curve to another. At GID no linear interpolation was necessary due to the gaps in data between rating curves. Appendix B contains monthly graphs of hourly-averaged flow for each site. Note that there are gaps in the data. These gaps were due to errors in downloading and malfunctioning units.

2.4.4 Graphs of Weekly Flow Statistics (2002)

Weekly statistics were calculated from the 2002 hourly flow data. Statistics include: the average hourly value, the minimum single hourly value, and the maximum single hourly value for a given week. The statistics are calculated based on Julian weeks (JW). The 2002 field season spanned JW 11 – 43. See Appendix D for a table of Julian weeks and dates. Figure 2-17 through Figure 2-23 are graphs of these weekly flow statistics by site. The sites are ordered downstream to upstream. Note that the y-axis scale is 400 cfs for all graphs. Tables of the 2002 weekly flow statistics are located in Appendix B.

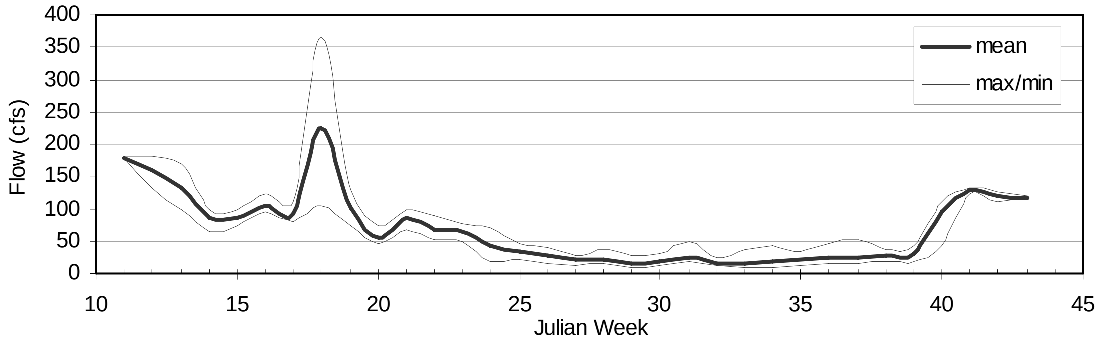


Figure 2-17 Shasta River at the Mouth weekly mean, maximum, and minimum flow (2002)

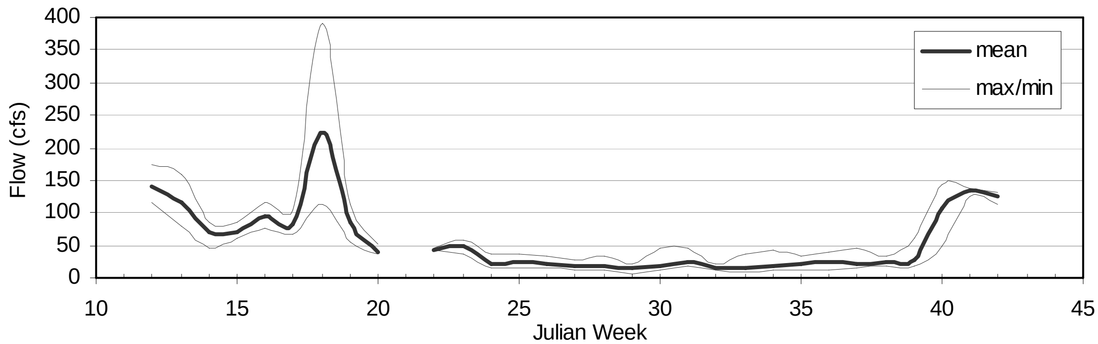


Figure 2-18 Shasta River at Anderson Grade Road weekly mean, maximum, and minimum flow (2002)

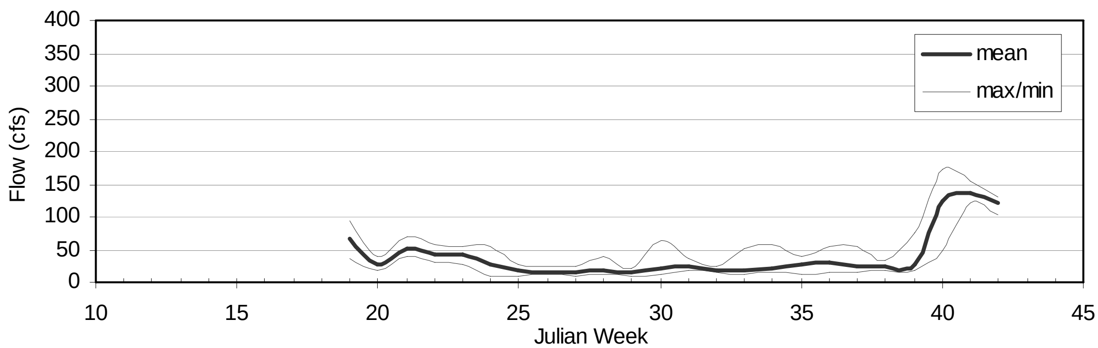


Figure 2-19 Shasta River at Yreka-Ager Road weekly mean, maximum, and minimum flow (2002)

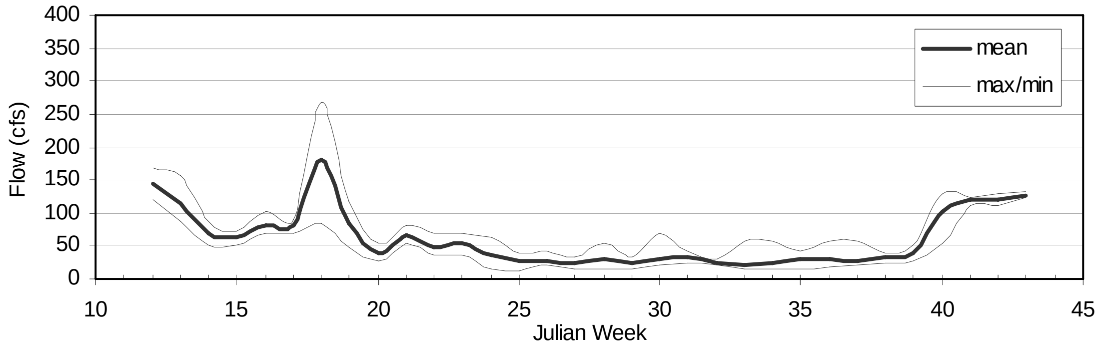


Figure 2-20 Shasta River at DWR Weir weekly mean, maximum, and minimum flow (2002)

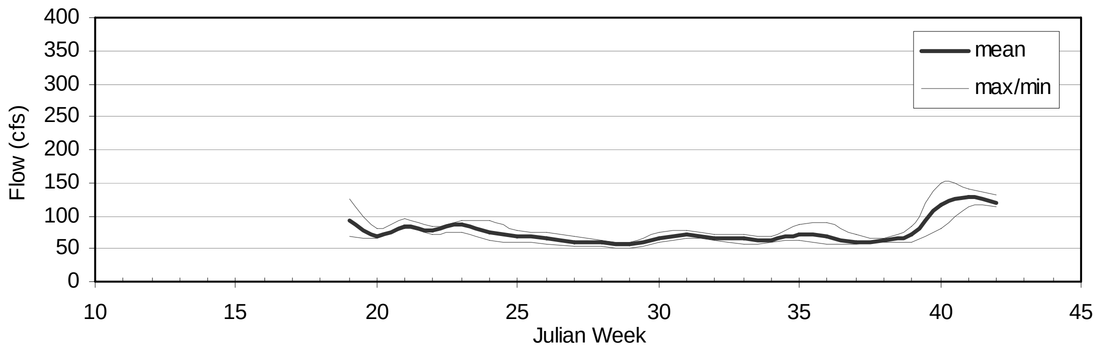


Figure 2-21 Shasta River at Freeman Lane weekly mean, maximum, and minimum flow (2002)

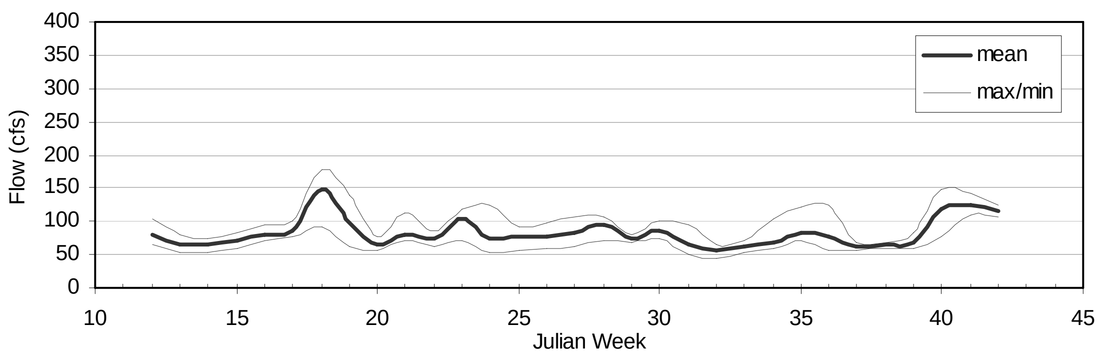


Figure 2-22 Shasta River at Highway A12 weekly mean, maximum, and minimum flow (2002)

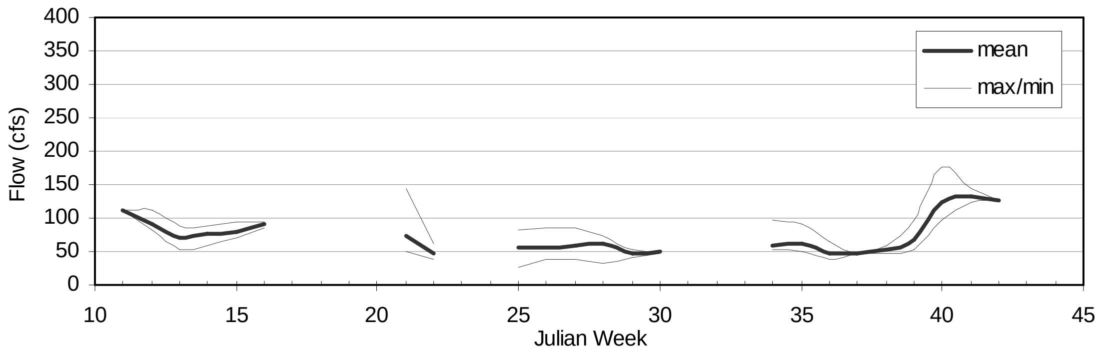


Figure 2-23 Shasta River below the Grenada Irrigation District Pumps weekly mean, maximum, and minimum flow (2002)

2.4.5 Complications with WL15's

At the start of the 2001 field season five 25 foot cable-type Global Water WL15 pressure transducers were purchased by Watercourse Engineering, Inc. to record water level for the flow study on the Shasta River. (The California Department of Fish and Game (DFG) purchased 4 weir-stick type WL15 pressure transducers with 3 foot cables. These units provided invaluable flexibility in maintaining the monitoring level when problems arose with some of the cable-style units.) Watercourse Engineering, Inc. tested each unit acquired from Global Water prior to field deployment. All units were deemed fully functional. During the course of the 2001 field season several maintenance issues arose with the WL15's. Issues included: spontaneous negative depth readings, and data not downloading to the laptop even after battery replacement. In addition, all the units were recalled by Global Water during the early fall of 2001 for an "update." This recall caused a disruption in the field season and extra personnel hours to switch out the units one by one to send back to the manufacturer.

Prior to the 2002 field season all units were again recalled for another "update" by Global Water. It was assumed that these updates would eliminate the issues experienced during the 2001 field season. Again, after the units were returned to Watercourse Engineering, Inc. all units were tested prior to field deployment and found to be fully functional. Unfortunately, during the 2002 field season there were again issues with units malfunctioning. These issues included: problems with data download after battery replacement, variable or "craggy" signal output even with fresh batteries, and negative depth readings. These issues occurred with both the cable-type and weir-stick style units. During a conversation with a Global Water technician in July 2002, Watercourse Engineering, Inc. was told that the weir stick style units were believed to have a faulty design that would be discontinued. Global Water noted that the epoxy used to secure the units inside a black PVC pipe potentially caused damage to the unit sensor while curing. Later in July 2002 Global Water discontinued its manufacture of the WL15's in PVC casing (weir stick model). An agreement was finally reached with Global Water to send two spare units that would be on hand if problems in the Shasta River flow study continued. Fortunately, with a well-developed deployment and downloading protocol, as well as having field equipment and personnel support of DFG, Watercourse Engineering, Inc. was able to minimize the loss of data due to these issues.

Global Water WL15's were originally chosen for this project due to their affordability, ease of use, self-contained data logger, and flexibility in deployment. However, the experience of using these instruments during the 2001and 2002 field seasons suggests that these instruments may be less reliable than desired. In response to this concern other methods of measuring eater level were explored.

2.4.6 Water level logger testing: Solinst Levelogger

Due to complications with the WL15 pressure transducer, noted in Section 2.4.5, an additional method to record water level was explored. At the end of the 2002 field season Watercourse Engineering, Inc. researched a water level logger by Solinst and purchased one unit to test the reliability. The Solinst levelogger differs from a pressure transducer in that it is incased (not exposed to the atmosphere). Therefore it needs to be corrected for barometric pressure because it measures the water level and the atmospheric pressure. Thus a barologger, a product by Solinst for use with the levelogger that measures barometric pressure, was also purchased. The levelogger is also equipped with a water temperature sensor and logger.

The levelogger/barologger pair was tested in-house and a field protocol developed. See Appendix E for the Solinst levelogger/barologger protocol. To compare measurement capability of the levelogger to the WL15 the Solinst units were deployed beside a WL15 on the Shasta River at Freeman Lane during the last two weeks of the field season from October 4^{th} to October 18^{th}, 2002. From October 4^{th} to October 6^{th}, 2002 the WL15 and the Solinst levelogger recorded similar trends with the flow values being within ± 5% of each other. After October 6^{th}, 2002 to the end of the study period the two units recorded opposite trends but maintained almost identical daily mean flows. These test results are inconclusive and further testing is recommended.

2.5 Water Temperature Study

The water temperature study was managed by the Department of Fish and Game (DFG) with assistance from Watercourse Engineering, Inc. Onset Hobo and Stowaway loggers were placed at ten sites along the Shasta River. A few of the sites differed from 2001 to 2002 due to access issues and additional desired locations for more detailed information. At several sites duplicate loggers were deployed to confirm that the original logger was functioning properly.

During the 2001 field season Watercourse Engineering, Inc. discovered that the DFG was monitoring with four types of Onset loggers. Each type of logger had a different accuracy. Table 2-14 contains a list of the logger type, temperature range, and associated accuracy. Watercourse suggested the use of the WTA08 –5+37 and XTI –05+37 for monitoring in the Shasta River due to the higher accuracy level. The temperature devices logged hourly data and were downloaded approximately monthly during the both field seasons. Monthly plots of hourly temperature data for each site can be found in Appendix C.

Table 2-14 Onset logger models, temperature ranges, and accuracies

Model	Temperature Range	Accuracy
WTA08	-39+75 °C	+/- 0.5 °C
WTA08	-5+37 °C	+/- 0.2 °C
STEB08	-5+37 °C	+/- 0.7 °C
XTI	-5+37 °C	+/- 0.33 °C

2.5.1 Water Temperature Study 2001

It was found at the end of the 2001 field season that there was no established protocol for deployment and downloading of the temperature devices. Analysis of the temperature data yielded discrepancies of up to 4°C between several of the duplicate loggers, and up to 7°C at one logger site. Preliminary water temperature data was obtained from the DWR 2001 monitoring program and used to discern the properly functioning units. A comparison of the two data sets for these sites found that several of the duplicate temperature devices did not yield reliable data due to either the device itself, or the deployment method. Fortunately reliable data was available for all sites except Hwy 263 and Yreka-Ager Road. Table 2-15 contains a list of the temperature logger sites, associated river mile, and serial number of the reliable logger. In cases where the data from both loggers were reliable, an average was taken. It was assumed that the difference in readings between the two loggers was within the error of the instrument. Upon completing this analysis of the 2001 data a protocol was developed for the DFG to be implemented starting with the 2002 field season (See Appendix E).

Table 2-15 Shasta River temperature logger locations (2001)

Location	RM	Serial Number
Mouth of Shasta	0.5	331932
Hwy 263	7.1	Not used
Anderson Grade	7.9	155044
Yreka-Ager Rd	10.3	Not used
Hwy A-3	12.3	103555
DWR Weir	14.7	155048
Hwy A-12	21.9	877
GID	26.9	331942
Parks Creek	31.0	Average of 331936 and 103557
Shasta above Parks Creek	31.8	Average of 332048 and 126375

2.5.2 Graphs of Weekly Temperature Statistics (2001)

Weekly statistics were calculated from the 2001 hourly water temperature data. Statistics include: the average hourly value, the minimum single hourly value, and the maximum single hourly value for a given week. The statistics are calculated based on Julian weeks (JW). The 2001 field data spanned JW 1 – 51. See Appendix D for a table of Julian weeks and dates. Figure 2-24 through Figure 2-31 are graphs of these weekly water temperature statistics by site. The sites are ordered downstream to upstream. Tables of the 2001 weekly water temperature statistics are located in Appendix C.

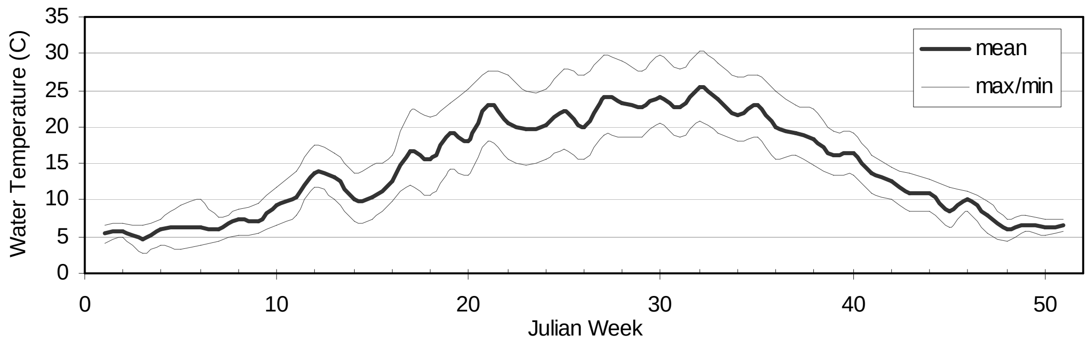


Figure 2-24 Shasta River at the Mouth weekly mean, maximum, and minimum water temperature (2001)

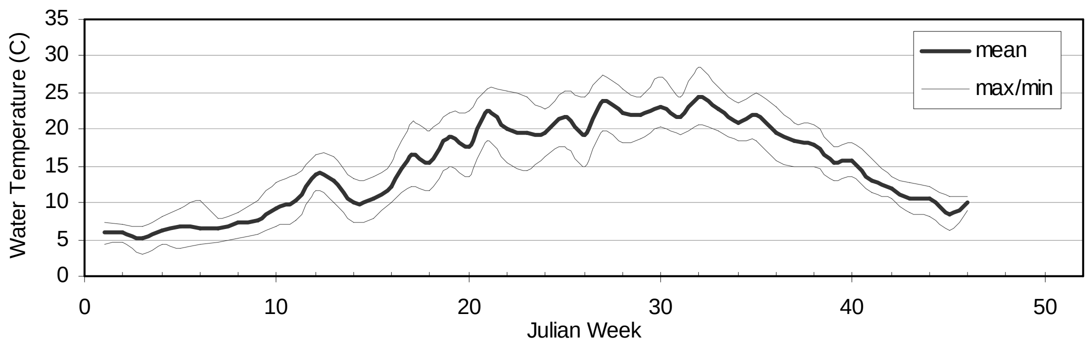


Figure 2-25 Shasta River at Anderson Grade Road weekly mean, maximum, and minimum water temperature (2001)

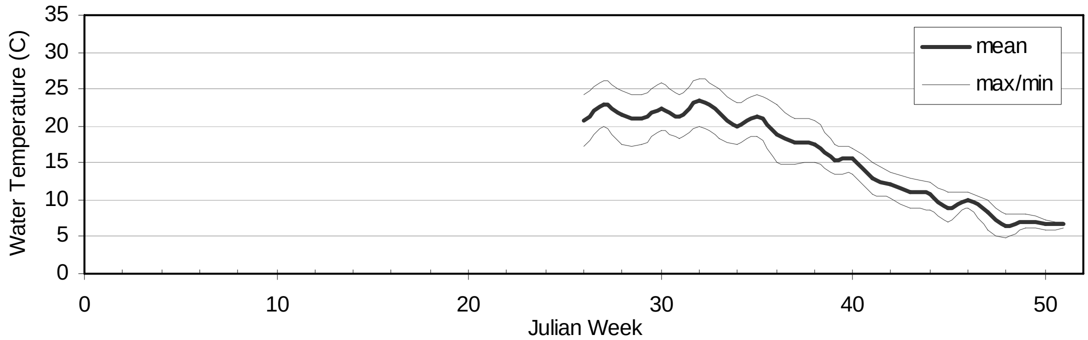


Figure 2-26 Shasta River at Highway 3 weekly mean, maximum, and minimum water temperature (2001)

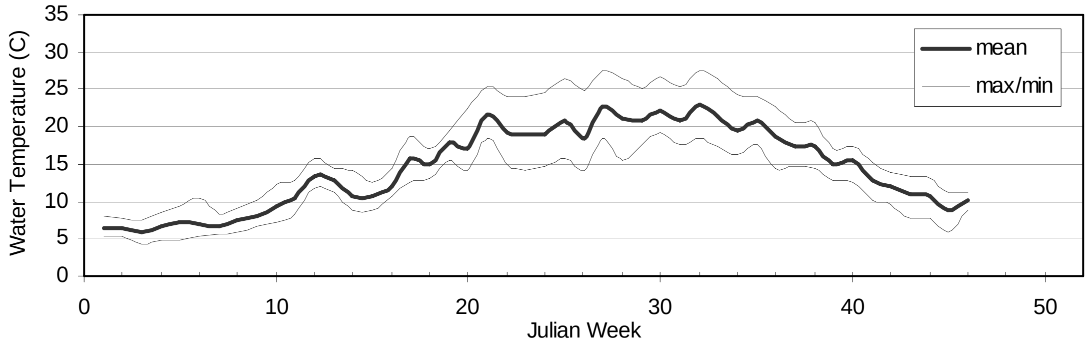


Figure 2-27 Shasta River at DWR Weir weekly mean, maximum, and minimum water temperature (2001)

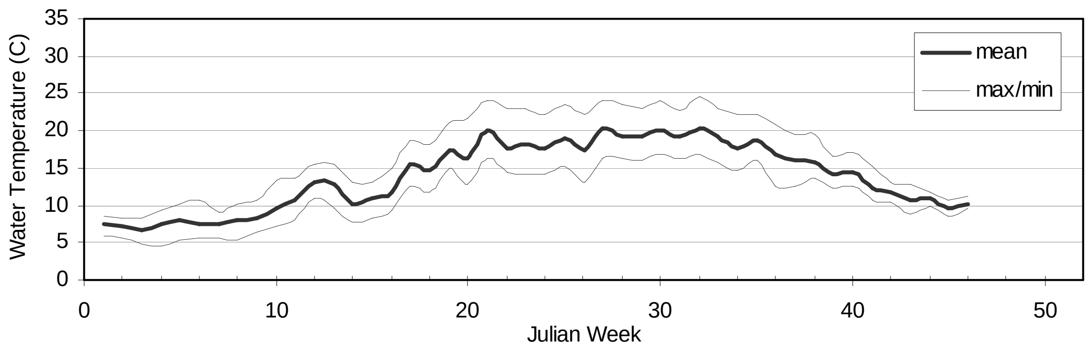


Figure 2-28 Shasta River at Highway A12 weekly mean, maximum, and minimum water temperature (2001)

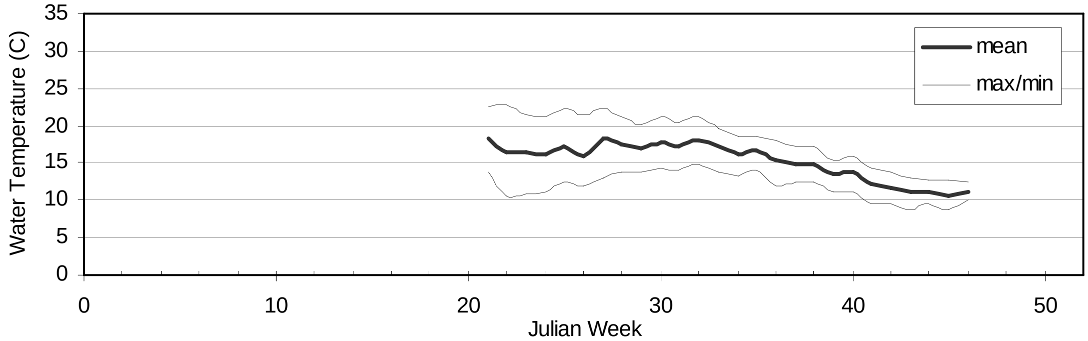


Figure 2-29 Shasta River below the Grenada Irrigation District Pumps weekly mean, maximum, and minimum water temperature (2001)

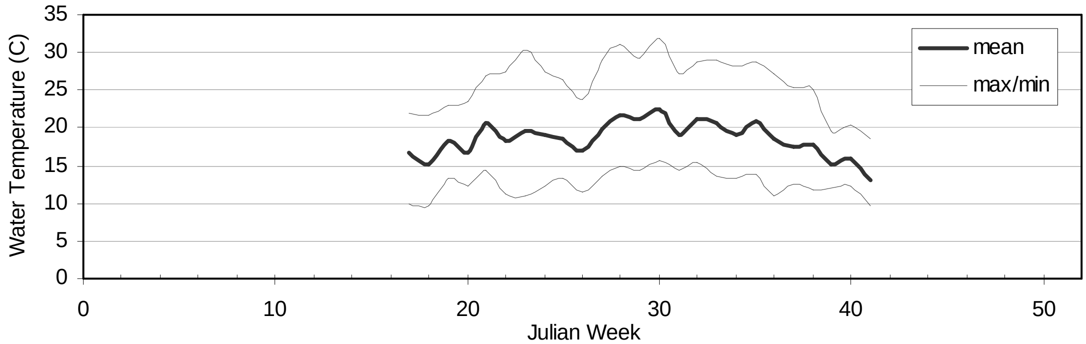


Figure 2-30 Parks Creek weekly mean, maximum, and minimum water temperature (2001)

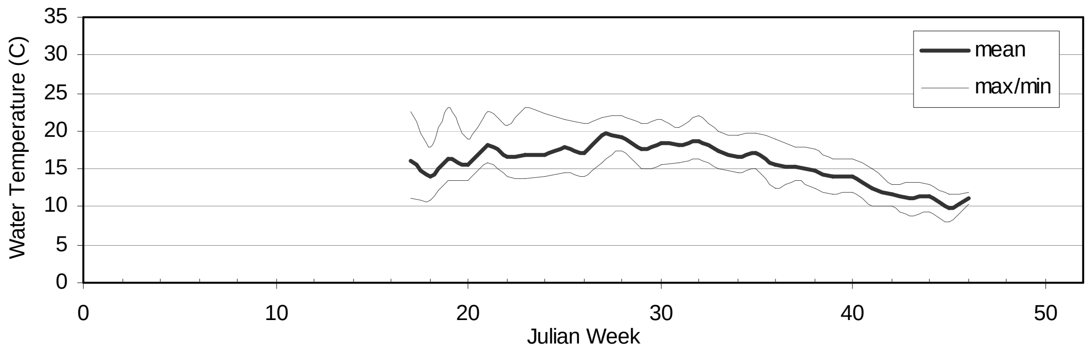


Figure 2-31 Shasta River above Parks Creek weekly mean, maximum, and minimum water temperature (2001)

2.5.3 Water Temperature Study 2002

In 2002 water temperature was continuously monitored at the ten sites listed in Table 2-16. Note that Shasta above Parks and Parks Creek were not monitored in 2002 due to an access issue. In addition, two sites were added to the 2001 list: River Ranch Road and Freeman Lane. These sites were added because preliminary modeling indicated that increased resolution would provide additional insight in the reach between DWR Weir and A12. The 2002 temperature monitoring protocol can be found in Appendix E.

Following the newly developed protocol all thermistors were subject to pre- and post-season testing. The DFG tested their loggers according to the protocol outlined by Onset Corporation (the temperature logger manufacturer). Crushed ice made from distilled water was placed in insulated container. The ice was crushed to maintain as consistent and uniform a temperature as possible. The container was then filled with distilled water to just below the level of the ice and stirred. The loggers were submerged in the ice bath and the container was placed the in a refrigerator to minimize temperature gradients. The thermistors logged for four days. The ice melted slowly, so the actual temperature approached approximately 0°C. The logged values were then compared to see if they were within the accuracy set by Onset Corporation. Six of the eighteen loggers failed the testing, were returned to the manufacturer and were replaced by new units.

Because some of the DFG loggers did not pass the pre-season testing and new loggers would not be available in time for deployment, Watercourse Engineering, Inc. lent six loggers to the DFG at the beginning of the 2002 field season. The Watercourse loggers were tested in a room temperature water bath over an 18-hour period. Logged values were compared against one another to insure that all loggers were recording values within the manufacturer specifications. The Watercourse loggers were switched out on 5/7/02 when new DFG loggers became available and had passed pre-season testing.

Table 2-16 shows the location, serial number, and period of deployment for all water temperature loggers. The final dataset was derived from more than one thermistor at six of the logging sites. Four of these sites used two units due to the switch out in May of the Watercourse temperature loggers. At Yreka-Ager Road unit 295560 was used for the second half of the field season due to an error in deployment of unit 392303 in August. At Highway A12 unit 5542 was stolen during the month of June and unit 243406 was deployed to replace the stolen unit.

Table 2-16 Shasta River temperature logger locations (2002)

Location	RM	Serial Number	Dates of Deployment
Mouth of Shasta	0.5	154918	03/19/02 - 10/23/02
Hwy 263	7.1	136012	03/19/02 - 05/07/02
		71765	05/07/02 - 10/23/02
Anderson Grade	7.9	136019	03/19/02 - 05/07/02
		134	05/07/02 - 10/18/02
Yreka-Ager Rd	10.3	392303	03/18/02 - 08/07/02
		295560	08/07/02 - 10/18/02
Hwy A-3	12.3	103555	03/19/02 - 10/23/02
DWR Weir	14.7	155048	03/19/02 - 05/07/02
		130	05/07/02 - 10/23/02
River Ranch Road	15.4	88096	03/19/02 - 05/07/02
		137	05/07/02 - 10/23/02
Freeman Lane	17.9	127	05/7/02 - 10/15/02
Hwy A-12	21.9	5542	03/19/02 - 06/08/02
		243406	07/01/02 - 10/15/02
GID	26.9	877	03/19/02 - 10/15/02

2.5.4 Graphs of Weekly Temperature Statistics (2002)

Weekly statistics were calculated from the 2002 hourly water temperature data. Statistics include: the average hourly value, the minimum single hourly value, and the maximum single hourly value for a given week. The statistics are calculated based on Julian weeks (JW). The 2002 field data spanned JW 12 – 43. See Appendix D for a table of Julian weeks and dates. Figure 2-32 through Figure 2-41 are graphs of these weekly water temperature statistics by site. The sites are ordered downstream to upstream. Tables of the 2002 weekly water temperature statistics are located in Appendix C.

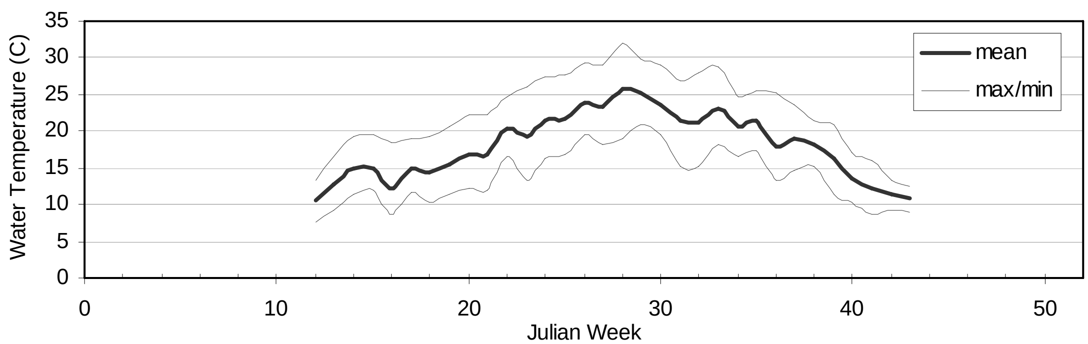


Figure 2-32 Shasta River at the Mouth weekly mean, maximum, and minimum water temperature (2002)

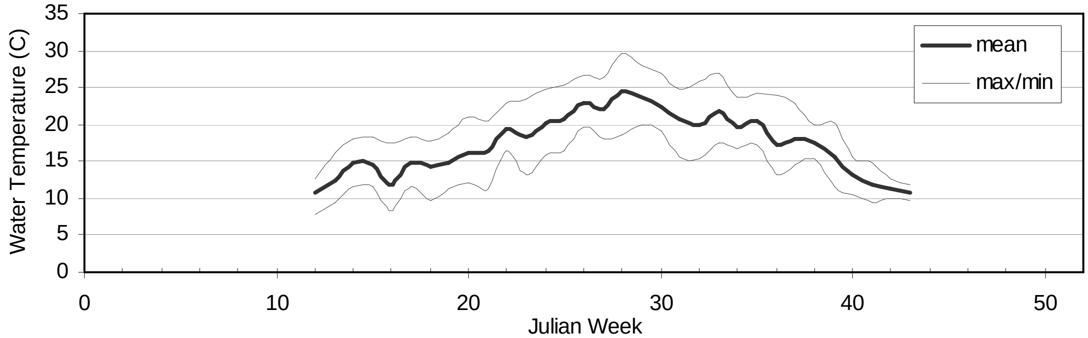


Figure 2-33 Shasta River at Highway 263 weekly mean, maximum, and minimum water temperature (2002)

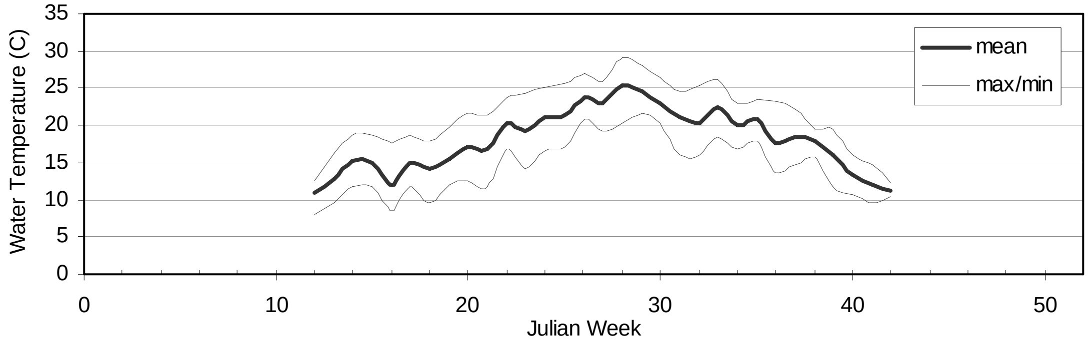


Figure 2-34 Shasta River at Anderson Grade Road weekly mean, maximum, and minimum water temperature (2002)

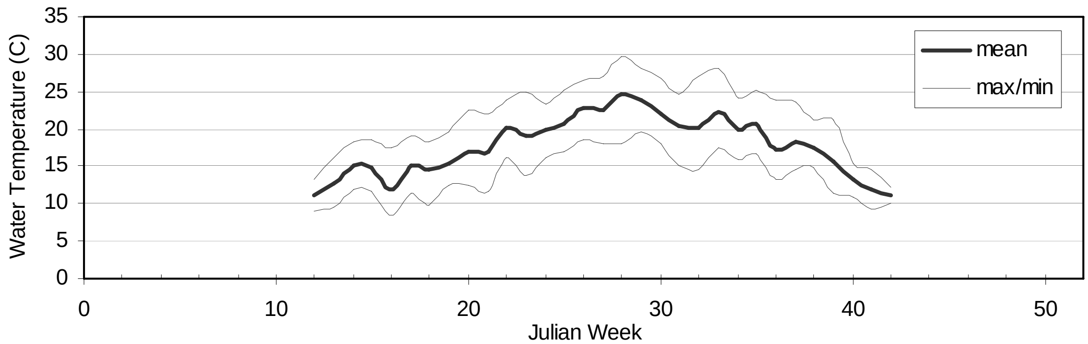


Figure 2-35 Shasta River at Yreka-Ager Road weekly mean, maximum, and minimum water temperature (2002)

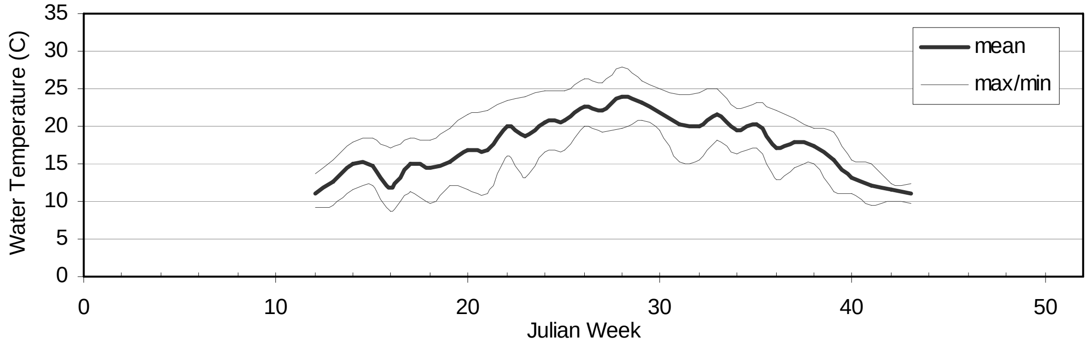


Figure 2-36 Shasta River at Highway 3 weekly mean, maximum, and minimum water temperature (2002)

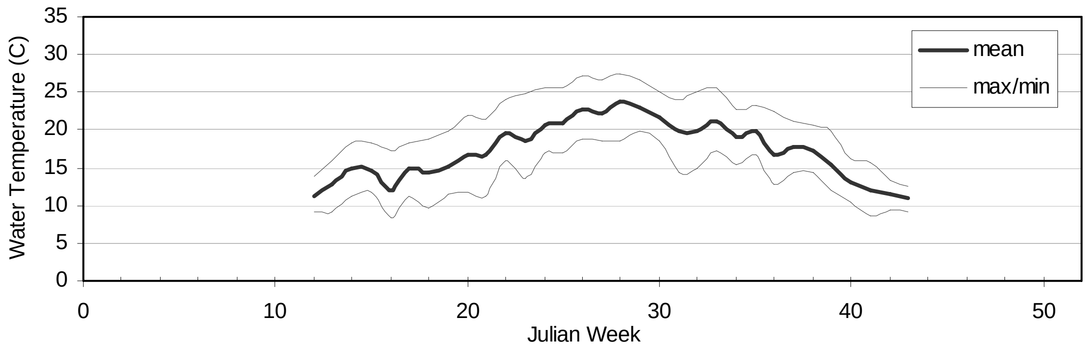


Figure 2-37 Shasta River at DWR Weir weekly mean, maximum, and minimum water temperature (2002)

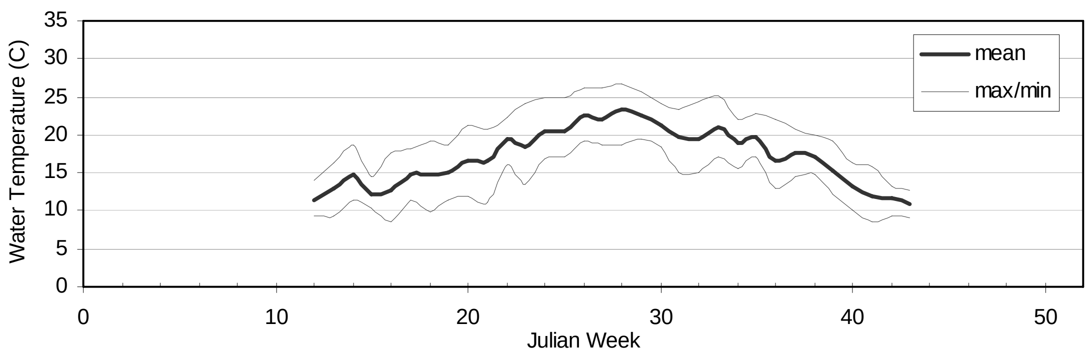


Figure 2-38 Shasta River at River Ranch Road weekly mean, maximum, and minimum water temperature (2002)

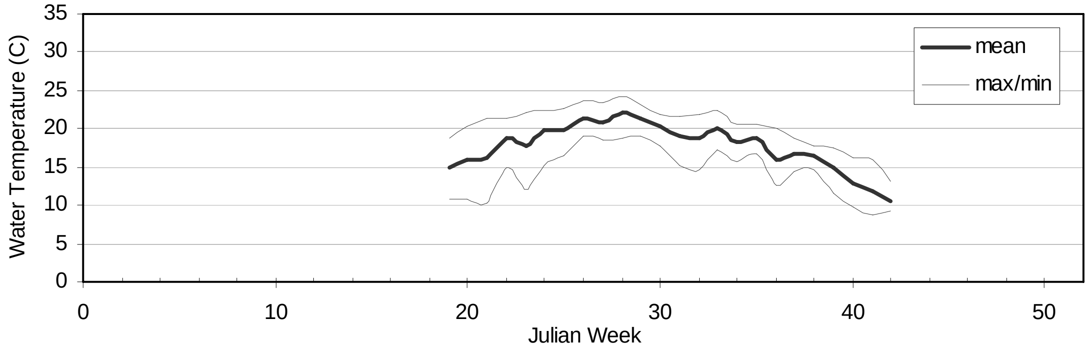


Figure 2-39 Shasta River at Freeman Lane weekly mean, maximum, and minimum water temperature (2002)

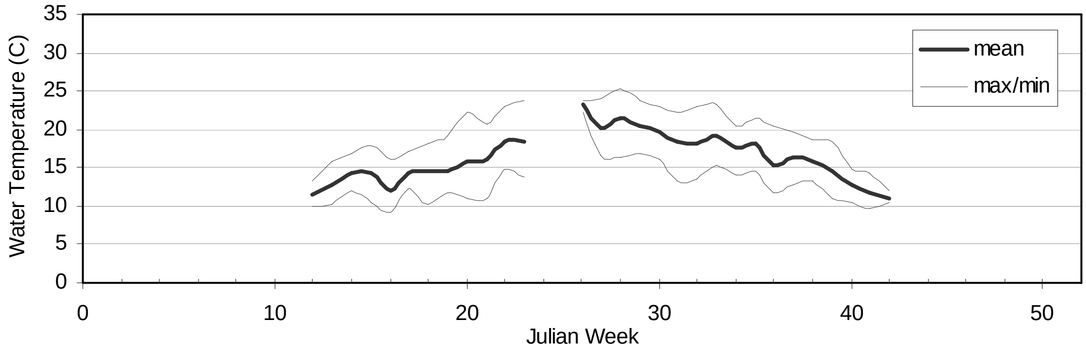


Figure 2-40 Shasta River at Highway A12 weekly mean, maximum, and minimum water temperature (2002)

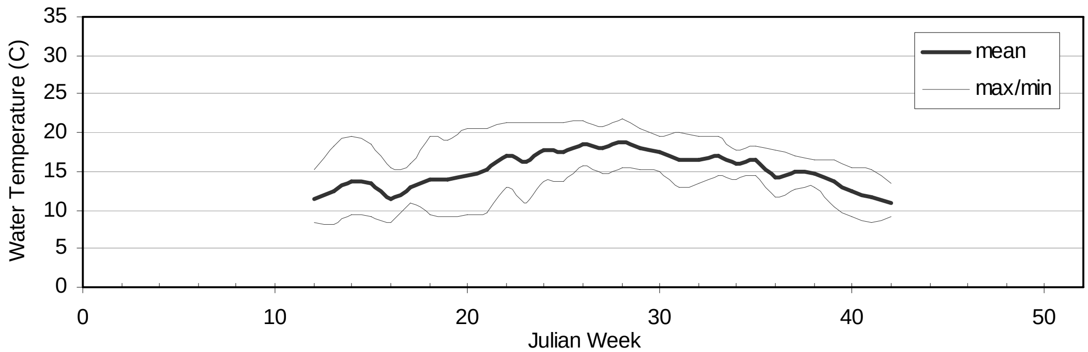


Figure 2-41 Shasta River below the Grenada Irrigation District Pumps weekly mean, maximum, and minimum water temperature (2002)

3 Findings and Recommendations

As with all field projects, much is discovered in the process of data gathering. In addition a better understanding of and insight into the dynamics of the Shasta River can be gained from analyzing the data obtained during the 2001 and 2002 field seasons. This section highlights some of the project findings and recommendations for future work.

3.1 Geometry

1. Stream cross-sectional geometry can be estimated for a significant portion of the river study reach from previous DFG habitat surveys. However, difficulty in correlating some of the habitat survey information made necessary additional fieldwork (measurement of cross sections) to further characterize the geometric stream channel representation of the river. Recommendation: Attempt to better correlate habitat survey information and establish a method whereby all available cross-sectional data can be referenced to a single atlas of the river. In absence of habitat work, collect additional cross sectional information to support modeling.

2. The twenty-five of the fifty desired cross-sections that were obtained through fieldwork provided a good basis for modeling of the Shasta River. Access issues prevented the collection of all of the desired cross-sections. Recommendation: Seek funding for detailed set of aerial photos of such a quality as to accurately measure river width. This would provide cross-sections for areas of the river that are difficult to access can be verified by cross-sections already measured on the ground.

3. Data points for the Shasta River were derived from the National Hydrography Dataset medium-resolution data. This set of data points provided the best available basis for the river modeling grid and river mile index. Recommendation: The United States Geological Survey is in the process of updating portions of the National Hydrography Dataset from medium resolution to high-resolution data. When the high-resolution data becomes available acquire the dataset and use it to construct a new river grid and river mile index. Compare to the data from this report to detemrine if the high-resolution data makes a significant difference in the reference system.

3.2 Riparian Vegetation

1. The Shasta River is vegetated in large part by two types of willows: the Arroyo and Sandbar. Bulrush was the third vegetation component that was assessed and found to potentially play a shading role on this relatively small river system. This lack of diversity made characterization of riparian vegetation somewhat easier than in streams with more diverse vegetation communities. No attempt was made in this study to map the predominate populations along the riverbanks. Recommendation: Prepare a more detailed vegetation study by mapping the predominate species along the right and left river banks.

2. Characterization of riparian vegetation transmittance using solar pyranometers proved effective. The average transmittance value for the types of shade-rendering vegetation in the Shasta River was found to be approximately 10% for woody riparian vegetation species and approximately 6% for the lower 2/3 of the bulrush. This study only addressed the role of that vegetation plays in obstructing direct solar radiation. Vegetation could potentially play other roles that could affect the water temperature. Recommendation: Research "insulation" during the night from vegetation; explore microclimate effects of riparian vegetation. This would involve placing meteorological stations in various riparian areas adjacent to the river, as well as control points in unshaded areas to compare effects of vegetation on the heat released from the river during the day and at night.

3.3 Flow

1. The use of remote logging pressure transducers coupled with semi-monthly discharge and water level measurements was a successful method to characterize sub-daily flow throughout the study reach. Flows less than 2 cfs to over 200 cfs were monitored. Recommendation: Continue to monitor the flow at 5-6 stations using the method established in this report. Recommended stations at which to monitor the flow include: Shasta above Parks, Parks Creek, GID, Highway A12, Freeman Lane, and Anderson Grade Road. Recall that flow is already continuously monitored at the DWR weir and the mouth.

2. Adopting protocols and deployment methods was necessary to accommodate changing field conditions. The WL15 by Global Water, Inc., although accurate and affordable, is not always reliable. Recommendation: Continue to explore different instrumentation, techniques and protocols. Specifically, conduct further testing on the Solinst levelogger. Continue to use the WL15 for water level logging until a different measurement and logging system proves as accurate and more reliable. At the end of the 2002 field season Global Water, Inc. was contacted about some of the reliability issues. At this time Global Water, Inc. suggested changing the batteries once a month as an additional precautionary measure when using a 15-minute recording interval. They stated that once the 9V battery falls to 7.5V or below the units start to log erroneous measurements.

3. Flow Characterization Findings and Recommendations

    - The reach from Shasta above Parks GID typically increases flow moving downstream. This is likely due to the large influx of water at Big Springs.

    - The reach from GID to Freeman Lane has no discernable trend in gaining or losing water before, during, or after irrigation season.

    - The reach from Freeman Lane to DWR Weir typically loses flow moving downstream during the irrigation season.

- The reach from DWR Weir to the Mouth has no discernable trend in gaining or losing water before, during, or after irrigation season.

Thoroughness was limited in certain river reaches. However, sufficient flow data was collected to greatly improve the understanding of the river by hydrology. Nonetheless improved characterization of flow and spring influences above GID would be useful. Recommendation: Seek cooperation of local landowners and organizations to establish more monitoring sites in the region above GID.

3.4 Water Temperature

1. Deployment of remote logging thermistors is an effective means of collecting water temperature data. Water temperature monitoring is a useful way to characterize the thermal regime. Recommendation: Continue using the water temperature monitoring protocols developed in this study.

2. Access for water temperature monitoring was limited, but the results were useful. Generally, water temperatures were found to increase moving downstream, with the exception of temperatures at GID. Presumably, GID has lower temperatures due to the influx of cooler water in the Big Springs region. Recommendation: Maintain the current monitoring sites (Shasta above Parks, Parks Creek, GID, Highway A12, Freeman Lane, River Ranch Road, DWR weir, Yreka-Ager Road, Highway 3, Anderson Grade, Highway 263, and the mouth) and seek to work with local landowners and organizations to expand monitoring especially in those areas where water flows into or is diverted from the river. Such areas needing further resolution include upstream and downstream of Big Springs.

3. To maintain a robust temperature monitoring program requires adequate funding. Recommendation: Seek long-term funding for the support of the temperature monitoring program.

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4.1.1.1 Appendix A
Channel Geometry

4.1.1.2 Appendix B
Flow Data and Statistics

4.1.1.3 Appendix C
Water Temperature Data and Statistics

4.1.1.4 Appendix D
Julian Week Table

4.1.1.5 Appendix E
Field Protocols