California Regional Water Quality Control Board
North Coast Region

Shasta River Water Quality Conditions

2002 & 2003

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Draft for Public Review

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Introduction

Staff of the North Coast Regional Water Quality Control Board's (Regional Water Board) Total Maximum Daily Load (TMDL) Development Unit are scheduled to complete the technical analyses for the Shasta River dissolved oxygen and temperature TMDLs by December 2004. In support of these TMDL analyses, Regional Water Board staff and U.S. Geological Survey (USGS) completed water quality monitoring studies in the Shasta River watershed in 2002 and 2003. The studies conducted by USGS were completed under contract to the Regional Water Board. The objectives of the monitoring studies conducted in 2003 are outlined in the "Shasta River Dissolved Oxygen Monitoring Plan" (NCRWQCB, 2003a). Monitoring conducted by Regional Water Board staff was in accordance with the "Klamath River Basin TMDLs Quality Assurance Project Plan" (NCRWQCB, 2003b). Monitoring conducted by USGS was in accordance with the USGS "National Field Manual for Water-Quality Sampling" (Wilde and others, 1998) and the USGS "Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting" (Wagner and others, 2000). Results of the Shasta River 2002 and 2003 water quality monitoring studies conducted by Regional Water Board staff and USGS are presented in this document.

Monitoring Studies and Results

A number of water quality monitoring studies were conducted in 2002 and 2003 in the Shasta River watershed. The results of the monitoring studies are presented according to the following monitoring categories:

1) Grab sample analysis of physical parameters, nutrients, constituents that exert an oxygen demand, and chlorophyll a;
2) Continuous measurement of temperature, dissolved oxygen, pH, and specific conductance;
3) Instantaneous field measurement of temperature, dissolved oxygen, pH, specific conductance, and flow; and
4) Sediment oxygen demand.

Monitoring locations and site names are shown in **Table 1** and **Figure 1**. The monitoring categories conducted at each site are also identified in Table 1.

Grab Samples

Grab samples were collected for laboratory analysis of ammonia (NH_3 as N), nitrate-nitrite (NO_2/NO_3 as N), total Kjeldahl nitrogen (TKN), ortho-phosphate (Ortho-P), total phosphorus (Phosphorus), total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD), total organic carbon (TOC), chlorophyll a (Chl–a), and pheophytin a (Pheo-a). Grab samples were not analyzed for each water quality parameter at every sample event, in accordance with the monitoring objectives.

In 2002 USGS collected grab samples once per month in July, August, and September at the following Shasta River locations: Edgewood Road, Montague-Grenada Road, and near the mouth at the USGS gage (see Table 1 and Figure 1 for site location descriptions). 2002 analytical results are presented (along with 2003 results) in **Table 2**.

In 2003 water quality grab samples were collected to support various Shasta River studies, as outlined below.

Parcel Tracking

Parcel tracking studies were conducted in June, August, and October 2003 by Regional Water Board staff and USGS to provide a more direct investigation of changes in water quality with distance downstream. The June parcel tracking study was conducted over a two-day period, June 17-18. In August parcel tracking studies were conducted on two consecutive days, August 19 and 20. The October study was conducted on the 22nd. During each parcel tracking study grab samples were collected at the following Shasta River locations: Riverside Drive, 1.9 miles downstream of Big Springs Creek, Highway A12, Freeman Road, Montague-Grenada Road, Highway 3, Yreka-Ager Road, and near the mouth at the USGS Gage. Analytical results of the parcel tracking studies are presented in **Tables 2 and 3** and **Figures 2 to 8**.

Background Nutrients

The objective of the background nutrient sampling was to quantify nutrient levels in upper tributary locations and springs within various geologic regions of the Shasta River watershed. The following springs were sampled at least once during the summer 2003: Big Spring Spring and Big Spring Lake, Hidden Valley Spring, Bassey Spring, Soda Spring, Jim Spring, and Evan Spring. The following tributaries were sampled close to their source at least three times during the summer 2003: Beaughton Creek, Parks Creek, No Name Fork Shasta River, the Little Shasta River (at Ball Mountain Road and Martin's Dairy Campground), and upper Shasta River (at Old Stage Road). Analytical results of the background nutrient sampling are presented in **Table 4**.

Wastewater Treatment Plant Bracketing

The objective of the wastewater treatment plant bracketing sampling was to evaluate whether the City of Weed, City of Montague, and City of Yreka wastewater treatment disposal systems affect the water quality of Boles Creek, Oregon Slough, and Yreka Creek, respectively. Grab samples were collected from Boles Creek upstream and downstream of the Weed wastewater treatment disposal ponds once in June, July, and October. Grab samples were collected from Oregon Slough upstream and downstream of the Montague wastewater treatment disposal ponds once in June, July, and October. Grab samples were collected from Yreka Creek upstream, at, and downstream of the Yreka wastewater treatment disposal system once in June and July. Analytical results of the wastewater treatment plant bracketing are presented in **Table 5**.

Irrigation Return Flows

The objective of the irrigation return flow (tailwater) monitoring was to characterize the water quality of representative irrigation return flows. Irrigation return flows were sampled at a total of 16 locations during the summer of 2003. Due to property owner concerns, the locations of the irrigation return flow samples are not identified in this report. Analytical results of the irrigation return flow sampling are presented in **Table 6**.

Lake Shastina Profile

The objective of the Lake Shastina profile sampling was to evaluate differences in concentrations of nutrients and algae (chlorophyll a and pheophytin a) with depth. On September 10 and 11, 2003, samples were collected at two locations of Lake Shastina: Station "B" is located near the center of the reservoir; Station "C" is located near the dam. There is no Station "A". At each location samples were collect at three depths: at the surface, at mid-depth, and just off the bottom. Analytical results of the Lake Shastina sampling are presented in **Table 7**.

Bacteriological Sampling

The sample methodology for the Sediment Oxygen Demand study (discussed below) required prolonged contact with Shasta River water by Regional Water Board and USGS staff. To evaluate potential health risks to staff, bacteriological sampling was conducted at Montague-Grenada Road and Highway 3 on July 24, 2003. Analytical results of the bacteriological sampling are presented in **Table 8**.

Continuous Water Quality Monitors

Continuous water quality monitors are instruments capable of measuring temperature, dissolved oxygen, pH, and specific conductance at hourly or sub-hourly intervals for extended periods of time. Sondes are capable of measuring all four water quality parameters. Optic StowAways measure only water temperature.

Sondes

The objective of the sonde deployments was to characterize the spatial and temporal variation of temperature, dissolved oxygen, pH, and specific conductance in the Shasta River. In 2002 USGS measured temperature, dissolved oxygen, pH, and specific conductance with YSI 6920 sondes from June 25 through October at one-hour intervals at three Shasta River locations: Edgewood Road, Montague-Grenada Road, and near the mouth at the USGS gage.

In 2003 USGS measured temperature, dissolved oxygen, pH, and specific conductance at one-hour intervals with YSI 6920 sondes from May through September at four Shasta River locations: Edgewood Road, Montague-Grenada Road, Highway 3, and near the mouth at the USGS gage. Graphs of the USGS 2002 and 2003 sonde data are presented in **Figures 9 to 24**.

Appendix 1 presents USGS' methodology for correcting continuous dissolved oxygen data from USGS datasonde sensors, and discusses uncertainty associated with datasonde dissolved oxygen records.

In 2003 Regional Water Board staff measured temperature, dissolved oxygen, pH, and specific conductance at 15-minute intervals with YSI 6600 sondes for two to three-day periods at the following sites and months:

Location	June	July	August	September	October
Shasta River at Riverside Drive	X	X	X		X
Shasta River downstream of Big Springs Creek	X		X		
Shasta River at Highway A12	X	X	X	X	X
Shasta River at Freeman Road	X	X	X		
Shasta River at Montague-Grenada Road		X			X
Shasta River at Highway 3		X			X
Shasta River at Yreka Ager Road	X	X	X		X
Lake Shastina				X	
Little Shasta River near Mouth	X				
Big Springs Spring			X	X	
Big Springs Lake				X	
Hidden Valley Spring				X	
Bassey Spring				X	

Graphs of the Regional Water Board 2003 sonde data are presented in **Figures 25 to 31**. Graphs of diel (24-hour) dissolved oxygen fluctuations, as well as field measurements of dissolved oxygen, are presented in **Figures 32 to 38**. The 2003 sonde data from Little Shasta River near the mouth, Big Springs Spring, Big Springs Lake, Hidden Valley Spring, and Bassey Spring are presented in **Table 9**.

On September 10, 2003 temperature, dissolved oxygen, and pH were measured at one- and two-foot increments at two locations ("B" and "C") in Lake Shastina. Station "B" is located near the center of the reservoir. Station "C" is located near the dam. There is no Station "A". The results of these profile measurements are presented in **Figure 39**.

On September 10-11, 2003 sondes were deployed at Stations "B" and "C" in Lake Shastina at three depths: surface, mid-depth, and just off the bottom. Graphs of the Lake Shastina sonde deployments are presented in **Figures 40 to 43**.

Optic StowAways

In 2003 Regional Water Board staff measured water temperature at ½-hour intervals from June to October at the following 9 locations: Shasta River at Riverside Drive, Shasta River at Highway A12, Shasta River at Freeman Road, Shasta River at Yreka-Ager Road, Shasta River at Old Shasta River Road, Little Shasta River near mouth, Little Shasta River at Ball Mountain Road, Parks Creek near Stewart Springs Resort, and Boles Creek near Old Edgewood Drive. Graphs of the Regional Water Board 2003 Optic StowAway data are presented in **Figures 44 to 53**.

Field Measurements

Temperature, Dissolved Oxygen, pH, and Specific Conductance

Field measurement of temperature, dissolved oxygen, pH, and specific conductance was performed by Regional Water Board staff at grab sample and continuous water quality monitoring locations using YSI 600XL sondes. The field measurement of temperature, dissolved oxygen, pH, and specific conductance at the continuous water quality monitoring locations serve as a check to the continuous water quality monitor results. Field measurement results of temperature, dissolved oxygen, pH, and specific conductance are presented in **Tables 2 to 6** and field measurement results of dissolved oxygen are shown on **Figures 32 to 38**.

Winkler Dissolved Oxygen Titration

Field analysis of dissolved oxygen was conducted at the Regional Water Board continuous water quality monitoring locations using the Winkler Dissolved Oxygen test. The Winkler Dissolved Oxygen test is a modified Winkler dissolved oxygen titration, performed with a Hach digital titration kit. This field analysis was generally performed at least once at each Regional Water Board sonde deployment. The Winkler dissolved oxygen titration results serve as a check to the continuous water quality monitor results. The Winkler dissolved oxygen titration results are presented in **Figures 32 to 38**.

Flow

Flow was measured at the water quality monitoring locations during most sample events. Flow was measured using Marsh McBirney flow meters. Flow measurement results are presented in **Table 10**.

Sediment Oxygen Demand

USGS and Regional Water Board staff conducted a Sediment Oxygen Demand (SOD) study in the Shasta River from August 12-14, 2003. SOD is the rate of dissolved oxygen loss from a waterbody through its uptake and consumption by biotic and abiotic reactions in surficial sediments. SOD rates were measured and sediment characteristics classified in the Shasta River upstream and downstream of Montague-Grenada Road and at four locations near the Highway 3 bridge. Results of the SOD study are presented in **Table 11**. **Appendix 2** presents the methodolgy employed for measuring SOD rates in the Shasta River.

Acknowledgements

Staff of the Regional Water Board owe special thanks to the property owners who allowed access to private property necessary for conducting these water quality monitoring studies. We also thank the members of the Shasta River TMDL Technical Advisory Group for assistance in developing the 2003 monitoring plan. Finally, we wish to thank the California Department of Fish and Game for loaning six Optic StowAways used in these studies.

Literature Cited

North Coast Regional Water Quality Control Board (NCRWQCB), 2003a. Shasta River Dissolved Oxygen Monitoring Plan.

NCRWQCB, 2003b. Klamath River Basin TMDLs Quality Assurance Project Plan.

Wagner, J., H. Mattraw, G. Ritz, B. Smith, 2000. Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting. Water Resources Investigations Report 00-4252.

Wilde, F. D.; Radtke, D. B.; Gibs, Jacob; Iwatsubo, R. T. 1998. National Field Manual for the Collection of Water-Quality Data: Preparations for Water Sampling. Techniques of Water-Resource Investigation 09-A1

List of Tables

Table 1. Shasta River Water Quality Monitoring Locations and Activities

Site ID	Site Location	River Mile[1]	Grab Sampling	Sonde Location[2]	Temperature Location[3]	SOD Location[4]
Shanrmth	Shasta River near Mouth at USGS Gage	0.6	X	X		
Shaosrr	Shasta River at Old Shasta River Road	4.0			X	
Shaatyard	Shasta River at Yreka-Ager Road	10.4	X	X	X	
Shaathwy3	Shasta River at Highway 3	12.3	X	X		X
Shaatmgr	Shasta River at Montague-Grenada Road	14.7	X	X		X
Shaatfrln	Shasta River at Freeman Road	17.9	X	X	X	
Shaata12	Shasta River at Highway A12	21.9	X	X	X	
Shaatptrs	Shasta River 1.9 Miles Downstream of Big Springs Creek	27.9	X	X		
Shaathwr	Shasta River at Big Springs Road	33.7	X			
Shaatrvsd	Shasta River at Riverside Drive	35.7	X	X	X	
Lake Shastina (Dwinnell Reservoir) is located at river mile 36.4.						
All locations upstream of Shastina are determined using an assumed stream length along the floor of Shastina.						
LkshastB	Lake Shastina -- Station B		X	X		
LkshastC	Lake Shastina -- Station C		X	X		
Shaatedgrd	Shasta River at Edgewood Road	42.9	X	X		
Shaatosr	Shasta River at Old Stage Road	47.7	X			
Shannf	North N Fork Shasta River	47.5+0.1	X			
Lshanrmth	Little Shasta River Near Mouth	15.5+0.3	X	X	X	
Lshaatbmr	Little Shasta River at Ball Mountain Road	15.5+10.0	X			
Lshatmd	Little Shasta River at Martin's Dairy Campground	15.5+23.8	X			
Yreatagr	Yreka Creek at Anderson Grade Road	7.6+0.6	X			
Yreatact	Yreka Creek at Cutoff Trench	7.6+2.9	X			
Yreathwy3	Yreka Creek at Highway 3	7.6+3.4	X			
Yreatobrd	Yreka Creek at Oberlin Road	7.6+5.3	X			
Orslus	Oregon Slough Upstream of Montague Wastewater Treatment Ponds	11.2+1.6	X			
Orslds	Oregon Slough Downstream of Montague Wastewater Treatment Ponds	11.2+1.1	X			
Parus	Parks Creek Upper	30.4+17.0	X		X	
Beaatspr	Beaughton Creek Upper	43.7+5.8	X			
Bolds	Boles Creek Downstream of City of Weed Wastewater Treatment Ponds	44.8+1.8	X		X	
Bolus	Boles Creek Upstream of City of Weed Wastewater Treatment Ponds	44.8+2.3	X			
Bassp	Bassey Spring		X	X		
Sodsp	Soda Spring		X			
Evasp	Evans Spring		X			
Jimsp	Jim Spring		X			
Hvrsp	Hidden Valley Spring		X	X		
Bigsplk	Big Springs Lake		X	X		
Bigsp	Big Springs Spring		X	X		

[1] River Miles for tributary locations are identified as the Shasta River miles at the confluence + the miles upstream of the confluence

[2] Sonde Location = Continuous measurement of temperature, dissolved oxygen, pH, and specific conductance with sonde.

[3] Temperature Location = Continuous measurement of temperature with Optic StowAway.

[4] SOD Location = Sediment oxygen demand measurement location.

Table 2. Shasta River Water Quality Results from Field Measurement and Grab Sample Analysis, 2002 and 2003 -- By Location

			Field Parameter					Lab Analysis (mg/L)												
Location	Date	Time	Tw	pH	DO mg/l	DO sat (%)	Sp Cond	NH3 as N	NO3 as N	NO2 as N	NO2+NO3 as N	Ortho P	Phosphorus	TDS	TSS	TKN	BOD	Chl - a	Pheo-a	TOC
Shasta River @ Riverside Dr																				
	18-Jun-03	9:10	14.5	7.58	9.22	90.6	237	0.069		ND	ND	ND	ND	110	ND	0.53	ND	ND		2.9
	19-Aug-03	8:30	19.5	7.91	7.47	81.5	245	ND	ND	ND	ND	ND	0.078	170	30	ND	3.4	0.0210		3.8
	20-Aug-03	9:20	19.8	7.94	7.47	82.0	245	ND	ND	ND	ND	ND	0.086	190	ND	0.60	15.0	0.0210		3.8
	22-Oct-03	16:45	17.3	8.09	8.06	84.0	275	0.090			0.120	0.094	ND	170	ND	0.92	ND			2.7
Shasta River @ Big Springs Road																				
	18-Jun-03	17:30						ND			ND	0.110	0.170	200	ND	ND				4.0
Shasta River below Big Springs Creek (1.9 miles downstream)																				
	17-Jun-03	9:40	16.0	7.75	8.95	90.8	391	ND		ND	0.064	0.140	0.100	250	ND	ND	ND	ND		2.7
	19-Aug-03	10:30	16.1	7.73	8.81	89.5	395	0.081	0.190	ND	0.190	0.180	0.190	250	ND	ND	ND	0.0022		2.0
	20-Aug-03	10:00	15.3	7.65	8.09	80.5	418	ND	0.180	ND	0.180	0.130	0.160	310	ND	ND	ND	ND		1.8
Shasta River @ County Road A-12																				
	17-Jun-03	8:40	19.6	8.00	6.80	83.0	426	ND			ND	0.140	0.150			0.23		0.0017	4.6	3.7
	19-Aug-03	8:30	18.2	7.90	6.60	77.0	426	ND			ND	0.150	0.170			0.20		0.0010	3.7	4.1
	20-Aug-03	10:45	18.8	8.07	8.93	96.0	420	0.053	ND	ND	ND	0.140	0.170	270	ND	ND	ND	0.0018		2.2
	22-Oct-03	17:05	13.9	8.23	11.34	109.8	402	ND			0.230	0.170	0.170	260	ND	ND	ND			0.9
Shasta River @ Freeman Road																				
	17-Jun-03	12:45	21.0	7.99	9.35	105.2	464	ND		ND	ND	0.160	0.170	240	ND	0.61	ND	ND		3.8
	19-Aug-03	14:45	21.4	8.13	10.55	119.8	461	0.140	ND	ND	ND	0.140	0.170	280	ND	ND	ND	0.0011		2.9
	20-Aug-03	12:00	19.7	8.07	8.79	96.2	498	ND	ND	ND	ND	0.160	0.170	330	ND	ND	ND	0.0011		2.6
Shasta River @ Montague-Grenada Rd																				
	11-Jul-02	11:30	23.0	8.40	8.20	106.0	516	0.009			ND	0.160	0.190			0.33		0.0010	1.7	3.4
	15-Aug-02	9:25	19.0	7.90	7.20	86.0	503	ND			ND	0.150	0.160			0.22		0.0004	1.2	2.9
	18-Sep-02	16:15	19.0	8.30	11.00	130.0	522	ND			ND	0.160	0.160			0.18		0.0004	1.1	5.0
	9-Apr-03	18:20	15.0	8.30	9.60	105.0	454	ND			0.079	0.120	0.140			0.23	ND	0.0019	3.5	5.3
	17-Jun-03	11:50	21.0	8.30	8.70	109.0	479	ND			ND	0.140	0.170			0.33		0.0009	2.9	5.6
	19-Aug-03	11:20	21.0	8.20	8.90	110.0	490	ND			ND	0.170	0.190			0.30		0.0007	1.5	5.0
	20-Aug-03	13:30	21.9	8.22	9.94	113.6	551	ND	ND	ND	ND	0.260	0.310	340	ND	ND	ND	0.0016		5.0
	22-Oct-03	8:15	12.0	8.01	8.80	81.9	427	0.110			0.180	ND	0.160	260	ND	ND	ND			1.1
Shasta River @ Highway 3																				
	10-Apr-03	10:50	12.0	8.30	9.10	93.0	472	ND			0.072	0.120	0.140			0.21	ND	0.0034	4.0	4.8
	17-Jun-03	14:35	23.0	8.40	9.90	129.0	484	ND			ND	0.150	0.170			0.35		0.0007	2.1	4.5
	19-Aug-03	12:50	22.0	8.40	10.00	127.0	498	ND			ND	0.140	0.170			0.38		0.0009	1.6	5.7
	20-Aug-03	12:30	21.4	8.26	9.51	107.6	514	ND	ND	ND	ND	0.220	0.240	370	ND	0.86	ND	0.0016		5.0
	22-Oct-03	8:45	12.2	8.09	8.94	83.4	428	0.071			0.170	0.210	0.180	270	ND	ND	ND			1.1
Shasta River @ Yreka-Ager Rd																				
	17-Jun-03	17:00	24.6	8.16	9.28	111.3	503	0.097		ND	ND	0.150	0.130	280	ND	0.64		ND		1.3
	19-Aug-03	16:30	24.0	8.40	10.75	127.8	510	0.450	ND	ND	ND	0.140	0.170	310	ND	ND	3.5	0.0016		4.3
	20-Aug-03	13:30	22.9	8.35	10.33	120.4	517	ND	ND	ND	ND	0.170	0.190	370	ND	0.63	ND	0.0018		4.5
	22-Oct-03	7:45	12.6	8.05	8.77	82.6	436	0.095			0.150	0.190	0.660	270	ND	ND	ND			1.2
	22-Oct-03	14:00	13.5	8.44	11.98	115.1	433	0.140			0.140	0.200	0.130			ND				
	22-Oct-03	19:00	13.7	8.43	10.35	99.9	432	ND			0.140	0.170	0.140			ND				
Shasta River near Mouth @ USGS Gage																				
	10-Jul-02	16:45	30.0	8.60	7.10	98.0	590	0.030			0.016	0.290	0.350			0.52		0.0021	3.8	7.3
	14-Aug-02	13:40	25.0	8.40	9.40	124.0	642	0.010			ND	0.320	0.340			0.59		0.0016	2.5	7.9
	17-Sep-02	15:15	19.0	8.50	9.40	110.0	627	0.009			0.015	0.260	0.270			0.47		0.0017	3.4	10.6
	10-Apr-03	15:40	15.5	8.80	10.30	112.0	480	ND			0.051	0.100	0.120			0.22	ND	0.0028	3.5	4.5
	17-Jun-03	18:15	26.0	8.80	8.80	121.0	494	ND			ND	0.150	0.170			0.36		0.0004	1.1	5.1
	19-Aug-03	18:20	25.5	8.80	7.30	97.0	530	ND			ND	0.160	0.190			0.41		0.0009	2.7	6.7
	20-Aug-03	15:30						0.054	ND	ND	ND	0.160	0.180	350	ND	0.51	ND	0.0020		5.0
	22-Oct-03	18:15	14.4	8.62	9.84	96.3	438	ND			0.120	0.170	0.130	280	ND	ND	ND			1.3
	Reporting Limits (mg/L)							0.050	0.050	0.050	0.050	0.050	0.050	10	10	0.50		0.0005	0.0005	0.80

Notes: ND = Non-Detect (parameter is not present or present at concentrations below the laboratory reporting limit).
An empty cell = No sample for this parameter.

Table 3. Shasta River Water Quality Results from Field Measurement and Grab Sample Analysis, 2003 -- Parcel Tracking Study

			Field Parameter					Lab Analysis (mg/L)												
Date	Location	Time	Tw	pH	DO mg/l	DO Sat (%)	Sp Cond	NH3 as N	NO3 as N	NO2 as N	NO2+NO3 as N	Ortho P	Phosphorus	TDS	TSS	TKN	BOD	Chl - a	Pheo-a	TOC
17-Jun-03 / 18-Jun-03																				
	Riverside Drive	9:10	14.5	7.58	9.22	90.6	237	0.069		ND	ND	ND	ND	110	ND	0.53	ND	ND		2.9
	below Big Springs Crk	9:40	16.0	7.75	8.95	90.8	391	ND		ND	0.064	0.140	0.100	250	ND	ND	ND	ND		2.7
	County Road A-12	8:40	19.6	8.00	6.80	83.0	426	ND			ND	0.140	0.150			0.23		0.0017	4.6	3.7
	Freeman Road	12:45	21.0	7.99	9.35	105.2	464	ND		ND	ND	0.160	0.170	240	ND	0.61	ND	ND		3.8
	Montague-Grenada Rd	11:50	21.0	8.30	8.70	109.0	479	ND			ND	0.140	0.170			0.33		0.0009	2.9	5.6
	Highway 3	14:35	23.0	8.40	9.90	129.0	484	ND			ND	0.150	0.170			0.35		0.0007	2.1	4.5
	Yreka-Ager Road	17:00	24.6	8.16	9.28	111.3	503	0.097		ND	ND	0.150	0.130	280	ND	0.64		ND		1.3
	USGS Gage	18:15	26.0	8.80	8.80	121.0	494	ND			ND	0.150	0.170			0.36		0.0004	1.1	5.1
19-Aug-2003																				
	Riverside Drive	8:30	19.5	7.91	7.47	81.5	245	ND	ND	ND	ND	ND	0.078	170	30	ND	3.4	0.0210		3.8
	below Big Springs Crk	10:30	16.1	7.73	8.81	89.5	395	0.081	0.190	ND	0.190	0.180	0.190	250	ND	ND	ND	0.0022		2.0
	County Road A-12	8:30	18.2	7.90	6.60	77.0	426	ND			ND	0.150	0.170			0.20		0.0010	3.7	4.1
	Freeman Road	14:45	21.4	8.13	10.55	119.8	461	0.140	ND	ND	ND	0.140	0.170	280	ND	ND	ND	0.0011		2.9
	Montague-Grenada Rd	11:20	21.0	8.20	8.90	110.0	490	ND			ND	0.170	0.190			0.30		0.0007	1.5	5.0
	Highway 3	12:50	22.0	8.40	10.00	127.0	498	ND			ND	0.140	0.170			0.38		0.0009	1.6	5.7
	Yreka-Ager Road	16:30	24.0	8.40	10.75	127.8	510	0.450	ND	ND	ND	0.140	0.170	310	ND	ND	3.5	0.0016		4.3
	USGS Gage	18:20	25.5	8.80	7.30	97.0	530	ND			ND	0.160	0.190			0.41		0.0009	2.7	6.7
20-Aug-2003																				
	Riverside Drive	9:20	19.8	7.94	7.47	82.0	245	ND	ND	ND	ND	ND	0.086	190	ND	0.60	15.0	0.0210		3.8
	below Big Springs Crk	10:00	15.3	7.65	8.09	80.5	418	ND	0.180	ND	0.180	0.130	0.160	310	ND	ND	ND	ND		1.8
	County Road A-12	10:45	18.8	8.07	8.93	96.0	420	0.053	ND	ND	ND	0.140	0.170	270	ND	ND	ND	0.0018		2.2
	Freeman Road	12:00	19.7	8.07	8.79	96.2	498	ND	ND	ND	ND	0.160	0.170	330	ND	ND	ND	0.0011		2.6
	Montague-Grenada Rd	13:30	21.9	8.22	9.94	113.6	551	ND	ND	ND	ND	0.260	0.310	340	ND	ND	ND	0.0016		5.0
	Highway 3	12:30	21.4	8.26	9.51	107.6	514	ND	ND	ND	ND	0.220	0.240	370	ND	0.86	ND	0.0016		5.0
	Yreka-Ager Road	13:30	22.9	8.35	10.33	120.4	517	ND	ND	ND	ND	0.170	0.190	370	ND	0.63	ND	0.0018		4.5
	USGS Gage	15:30						0.054	ND	ND	ND	0.160	0.180	350	ND	0.51	ND	0.0020		5.0
22-Oct-2003																				
	Riverside Drive	16:45	17.3	8.09	8.06	84.0	275	0.090			0.120	0.094	ND	170	ND	0.92	ND			2.7
	County Road A-12	17:05	13.9	8.23	11.34	109.8	402	ND			0.230	0.170	0.170	260	ND	ND	ND			0.9
	Montague-Grenada Rd	8:15	12.0	8.01	8.80	81.9	427	0.110			0.180	ND	0.160	260	ND	ND	ND			1.1
	Highway 3	8:45	12.2	8.09	8.94	83.4	428	0.071			0.170	0.210	0.180	270	ND	ND	ND			1.1
	Yreka-Ager Road	19:00	13.7	8.43	10.35	99.9	432	ND			0.140	0.170	0.140			ND				
	USGS Gage	18:15	14.4	8.62	9.84	96.3	438	ND			0.120	0.170	0.130	280	ND	ND	ND			1.3
	Reporting Limits (mg/L)							0.050	0.050	0.050	0.050	0.050	0.050	10	10	0.50		0.0005	0.0005	0.80

Notes: ND = Non-Detect (parameter is not present or present at concentrations below the laboratory reporting limit).
An empty cell = No sample for this parameter.

Table 4. Shasta River Tributaries and Springs -- Water Quality Results from Field Measurement and Grab Sample Analysis, 2003.

				Field Parameters					Lab Analysis (mg/L)													
Watershed	Location	Date	Time	Tw	pH	DO mg/l	DO Sat (%)	Sp Cond	NH3 as N	NO3 as N	NO2 as N	NO2+NO3 as N	Ortho P	Phosphorus	TDS	TSS	TKN	BOD	Chl - a	Pheo-a	TOC
Little Shasta River Watershed (Springs)																					
	Bassey Spring	21-Aug-03	9:30	9.81	6.84	9.75	86.0	327	0.088	0.290	ND	0.290		ND			ND				
	Bassey Spring	17-Sep-03	10:00	9.19	7.13	10.08	87.7	303	0.071			0.240	0.066	0.460			ND				
	Soda Spring	17-Sep-03	10:15						0.340			ND	ND	0.350			6.50				
	Jim Spring	21-Aug-03	10:35	7.60	7.31	11.10	92.8	91	ND	0.260	ND	0.260		0.110			ND				
	Evan Spring	21-Aug-03	10:05	8.50	7.09	9.60	82.1	101	ND	0.210	ND	0.210		ND			ND				
Shasta River Watershed (Springs)																					
	Hidden Valley Spring	18-Jun-03	18:00						ND			0.220	0.120	0.088			ND				
	Hidden Valley Spring	23-Jul-03	10:50	13.01	7.26	4.42	41.8	290	ND			0.180	0.098	0.200			0.69				
	Hidden Valley Spring	16-Sep-03	16:30	12.5	7.5	2.8	26.4	268.0	ND			0.140	ND	0.070			ND				
	Big Springs Spring	16-Sep-03	17:30	11.3	7.0	9.6	87.7	381.0	ND			0.140	0.160	0.220			ND				
				Springs		Maximum value			0.340	0.290	ND	0.290	0.160	0.460			6.500				
						Minimum value			ND	0.210	ND	ND	ND	ND			ND				
Shasta River Watershed (Lake)																					
	Big Springs Lake	19-Aug-03	13:00	13.38	6.58	11.80	-	358	ND	0.170	ND	0.170	0.200	0.210	260	ND	ND	ND	ND		ND
	Big Springs Lake	16-Sep-03	17:45	12.8	6.9	12.2	115.0	353.0	ND			ND	0.150	0.330			ND				
Little Shasta River Watershed																					
	Little Shasta River at MDC	22-Jul-03	16:40	9.70	7.60	10.71	94.3	100	ND			0.063	ND	0.120			ND				
	Little Shasta River at BMR	19-Jun-03	16:00	16.30	8.16	9.15	93.3	94	ND			ND		ND			ND				
	Little Shasta River at BMR	21-Jul-03	11:05	17.40	8.16	9.01	94.1	108	ND			ND	ND	ND			ND				
	Little Shasta River at BMR	21-Aug-03	10:40	15.26	8.10	9.14	91.2	110	ND	ND	ND	ND		ND			ND				
	Little Shasta River at Mouth	17-Jun-03	14:30	27.07	8.27	10.96	138.4	845	ND		ND	ND	0.092	0.098	480	ND	0.95	ND			2.10
Upper Shasta River Watershed (Above Dwinnell Reservoir - SE)																					
	Beaughton Creek Upper	19-Jun-03	14:45	-	-	-	-	-	ND			0.089	0.160	0.150			ND				
	Beaughton Creek Upper	22-Jul-03	10:00	5.72	7.24	12.48	104.3	106	ND			0.083	0.190	0.400			ND				
	Beaughton Creek Upper	21-Oct-03	11:25	7.34	7.36	10.76	89.3	106	0.050			0.110	0.210	0.070			ND				
Upper Shasta River Watershed (Above Dwinnell Reservoir - SW)																					
	Shasta River at ER	11-Jul-02	13:30	28	8.9	7.5	108	238	0.009			0.012	0.070	0.100			0.32		0.0026	0.0042	4.40
	Shasta River at ER	15-Aug-02	11:30	22	8	9.9	127	219	<.015			<.013	0.050	0.070			0.23		0.0065	0.0047	3.90
	Shasta River at ER	19-Sep-02	8:15	11.5	7.7	10.4	106	201	<.015			<.013	0.060	0.080			0.16		0.0060	0.0086	4.10
	Shasta River at ER	09-Apr-03	13:25	13	8.7	11	116	199	<.015			0.018	0.030	0.040			0.08		0.0036	0.0022	3.10
	Shasta River at ER	22-Oct-03	15:45	16.28	8.99	11.12	113.3	179	ND			0.081	ND	0.084	130	ND	ND	ND			1.90
	Shasta River at OSR	19-Jun-03	15:50	-	-	-	-	-	ND			ND	ND	ND			ND				
	Shasta River at OSR	22-Jul-03	10:50	16.77	8.30	9.54	98.3	163	0.056			ND	ND	ND			ND				
	Shasta River at OSR	21-Aug-03	13:45	16.83	8.33	9.01	93.0	200	ND	ND	ND	ND		ND			ND				
	NNF Shasta River	19-Jun-03	16:00	-	-	-	-	-	ND			ND	ND	ND			ND				
	NNF Shasta River	22-Jul-03	11:10	19.95	8.10	8.40	92.4	202	ND			0.051	ND	ND			1.00				
	NNF Shasta River	21-Aug-03	13:30	17.15	8.09	8.75	90.9	186	ND	ND	ND	ND		ND			ND				
Parks Creek																					
	Parks Creek Upper	19-Jun-03	18:00	13.02	8.29	9.81	92.7	106	ND			ND		ND			ND				
	Parks Creek Upper	22-Jul-03	11:20	17.63	8.45	8.81	92.5	203	ND			0.061	ND	0.230			0.66				
	Parks Creek Upper	21-Aug-03	13:00	27.00	8.37	9.13	91.3	238	ND	0.098	ND	0.098		ND			ND				
	Parks Creek Upper	21-Oct-03	14:15	10.30	8.36	10.13	90.5	253	ND			0.110	ND	ND			ND				
					Reporting Limits (mg/L)				0.050	0.050	0.050	0.050	0.050	0.050	10	10	0.50		0.0005	0.0005	0.80

Location Notes:
Little Shasta River at MDC = Little Shasta River at Martin's Dairy Campground
Little Shasta River at BMR = Little Shasta River at Ball Mountain Road
Shasta River at ER = Shasta River at Edgewood Road
Shasta River at OSR = Shasta River at Old Stage Road
NNF Shasta River = North N Fork Shasta River

Notes: ND = Non-Detect (parameter is not present or present at concentrations below the laboratory reporting limit).
An empty cell = No sample for this parameter.

Table 5. Wastewater Treatment Plant Bracketing -- Water Quality Results from Field Measurement and Grab Sample Analysis, 2003

			Field Parameters					Lab Analysis (mg/L)												
Location		Time	Tw	pH	DO mg/l	DO Sat (%)	Sp Cond	NH3 as N	NO3 as N	NO2 as N	NO2+NO3 as N	Ortho P	Phosphorus	TDS	TSS	TKN	BOD	Chl - a	Pheo-a	TOC
Weed Waste Water Treatment Facility - 6/18/2003																				
	Above	16:20	13.56	8.32	9.70	93.3	167	ND			0.460	0.082	0.160	150	ND	ND				ND
	Below	15:15	14.68	8.27	10.33	101.3	172	ND			0.360	0.100	0.076	150	ND	ND				ND
Weed Waste Water Treatment Facility - 7/22/2003																				
	Above	13:35	15.45	8.04	9.79	98.1	174	ND			0.530	0.094	0.120	150	ND	ND	9.2			ND
	Below	13:00	16.96	8.02	9.67	100.1	177	ND			0.530	0.110	0.100	180	ND	ND	ND			ND
Weed Waste Water Treatment Facility - 10/21/2003																				
	Above	13:40	11.54	7.96	10.04	92.3	168	ND			0.560	0.120	0.098	140	12	ND	ND			ND
	Below	12:50	11.87	7.98	10.20	94.5	173	ND			0.520	0.100	0.074	140	10	ND	ND			ND
Montague Waste Water Treament Facility - 6/18/2003																				
	Above (1)	13:00	21.47	8.22	12.39	141.4	541	0.220			0.140	0.220	0.270	340	18	0.78				1.8
	Below (1)	13:35	23.14	8.31	10.56	123.4	574	0.052			0.090	0.250	14.000	380	19	1.30				2.2
	Below (2)	11:49	22.23	7.85	11.65	134.3	692	0.260			0.210	0.250	0.260	430	ND	0.90				0.9
Montague Waste Water Treament Facility - 7/21/2003																				
	Above (2)	12:25	24.39	8.37	11.26	134.9	624	0.071			0.270	0.240	0.400	420	16	0.82	2.7			7.9
	Below (1)	12:10	23.27	8.34	13.68	161.2	590	0.071			0.130	0.220	0.220	400	14	0.97	ND			8.0
Montague Waste Water Treament Facility - 10/22/2003																				
	Above (2)	9:30	11.53	8.05	8.63	79.4	806	0.094			0.390	0.092	0.580	500	ND	ND	ND			3.0
	Below (1)	9:50	11.53	8.19	12.20	93.8	805	0.097			0.340	0.260	0.051	500	ND	ND	ND			2.9
Yreka Waste Water Treatment Facility - 6/19/2003																				
	Above (2)	11:20	16.07	8.01	10.91	110.9	502	ND			0.170		ND			ND				
	Above (1)	8:20	14.06	7.83	8.33	81.3	497	ND			0.620	ND	ND	270	ND	ND				0.2
	At	10:00	14.23	7.88	9.69	94.8	506	0.094			0.720	0.070	0.070	280	ND	ND				0.2
	Below	10:30	14.68	8.26	10.98	108.4	509	ND			0.870	0.150	0.150	280	ND	0.56				0.3
Yreka Waste Water Treatment Facility - 7/21/2003																				
	Above (2)	14:30	19.61	7.59	10.03	109.8	557			ND	0.098	ND	ND			ND				
	Above (1)	13:10	18.50	7.71	10.22	109.1	520	ND			0.860	ND	0.057	330	ND	ND	ND			ND
	At	15:10	19.25	7.80	9.43	102.7	535	0.200			1.000	0.150	0.130	340	ND	ND	ND			ND
	Below	15:40	22.70	8.26	8.67	100.9	542	0.180			1.600	0.170	0.210	360	10	ND	ND			1.2
				Reporting Limits (mg/L)				0.050	0.050	0.050	0.050	0.050	0.050	10	10	0.50		0.0005	0.0005	0.80

Location Notes:

Weed Wastewater Treatment Facility "Above" = Boles Creek approx. 200 meters downstream of bridge to the Weed Golf Club.
Weed Wastewater Treatment Facility "Below" = Boles Creek approx. 200 meters downstream "Above" location.
Montague Wastewater Treatment Facility "Above 1" = Oregon Slough at Ager Road.
Montague Wastewater Treatment Facility "Above 2" = Oregon Slough approximately 0.7 miles downstream of Ager Road.
Montague Wastewater Treatment Facility "Below 1" = Oregon Slough at Southern Pacific Railroad tressel.
Montague Wastewater Treatment Facility "Below 2" = Oregon Slough approximately 0.5 miles downstream of Southern Pacific Railroad tressel.
Yreka Wastewater Treatment Facility "Above 2" = Yreka Creek at Oberlin Road.
Yreka Wastewater Treatment Facility "Above 1" = Yreka Creek at Highway 3.
Yreka Wastewater Treatment Facility "At" = Yreka Creek at Cutoff Trench.
Yreka Wastewater Treatment Facility "Below" = Yreka Creek at Anderson Grade Road.

Notes: ND = Non-Detect (parameter is not present or present at concentrations below the laboratory reporting limit).
An empty cell = No sample for this parameter.

Table 6. Irrigation Return Flow (Tailwater) Water Quality Results from Field Measurement and Grab Sample Analysis, 2003

			Field Parameters					Lab Analysis (mg/L)											
Date	Sta ID	Time	Tw	pH	DO mg/l	DO Sat (%)	Sp Cond	NH3 as N	NO3 as N	NO2 as N	NO2+NO3 as N	Ortho P	Phosphorus	TDS	TSS	TKN	BOD	Chl - a	Pheo-a	TOC
19-Jun-2003																				
	Tail-Water 01	9:30						0.065			0.170	0.150	ND	470	11	0.80				5.2
	Tail-Water 02	11:00										ND		450	140					2.0
	Tail-Water 03	11:15						ND			0.083	ND	ND	400	ND	0.63				1.9
	Tail-Water 04	11:45						0.064			0.180	0.260	0.360	450	ND	1.30				2.4
	Tail-Water 05	12:00						ND			0.098	ND	ND	420	ND	ND				0.5
23-Jul-2003																				
	Tail-Water 06	9:00	21.7	8.05	6.68	76.0	740	0.074			0.061	ND	0.230	440	34	0.92	ND			2.6
	Tail-Water 07	9:40	19.6	8.13	9.57	104.7	761	0.051			0.520	0.068	0.074	470	ND	1.10	ND			2.6
17-Sept-2003 / 18-Sept-2003																				
	Tail-Water 08	8:45	8.6	7.84	9.42	81.0	450	0.061			ND	0.390	0.360	250	ND	0.57	ND			6.7
	Tail-Water 09	11:50						0.063			0.100	0.230	0.340	380	ND	2.30	4.3			20.0
	Tail-Water 10	13:15						0.110			0.077	0.290	0.094	350	ND	1.30	4.4			11.0
	Tail-Water 11	11:15	12.3	7.40	5.07	48.1	580	0.650			ND	0.790	0.880	450	24	3.90	7.0			20.0
	Tail-Water 12	12:00						ND			ND	0.230	0.280	340	ND	ND	ND			4.1
	Tail-Water 13	14:15						ND			ND	0.200	0.250	260	ND	0.81	2.0			5.5
26-Sept-2003 / 29-Sept-2003																				
	Tail-Water 14	16:15						0.094			ND	0.320	0.380	370	ND	2.10	2.4			18.0
	Tail-Water 15	11:15						0.058			ND	0.080	0.210	290	ND	ND	2.5			5.0
	Tail-Water 16	11:30						0.099			0.092	ND	0.420	730	ND	1.70	ND			21.0
					Maximum value			0.650			0.520	0.790	0.880	730	140	3.90	7.0			21.0
					Minimum value			ND			ND	ND	ND	250	ND	ND	ND			0.5
				Reporting Limits (mg/L)				0.050	0.050	0.050	0.050	0.050	0.050	10	10	0.50		0.0005	0.0005	0.80

Note:
Tailwater sample locations are not identified in this report, due to property owner concerns.

Notes: ND = Non-Detect (parameter is not present or present at concentrations below the laboratory reporting limit).
An empty cell = No sample for this parameter.

Table 7. Lake Shastina Water Quality Results from Field Measurement and Grab Sample Analysis, 2003

				Field Parameters					Lab Analysis												
	Depth (meters)	Date	Time	Tw	pH	DO mg/l	DO Sat (%)	Sp Cond	NH3 as N	NO3 as N	NO2 as N	NO2+NO3 as N	Ortho P	Phosphorus	TDS	TSS	TKN	BOD	Chl - a	Pheo-a	TOC
Lake Shastina Station "B"																					
	Surface	10-Sep-03	15:15	21.15	9.28	17.25	194.1	244	**0.093**			ND	ND	ND			**0.88**		**0.062**	**0.0095**	
	Surface	11-Sep-03	9:40	19.72	8.52	6.41	70.1	253	ND			ND	ND	ND			**0.67**				
	4 meters	10-Sep-03	16:00	19.79	8.56	5.89	64.6	254	ND			ND	ND	**0.072**			**0.84**		**0.038**	**0.0064**	
	4 meters	11-Sep-03	9:30	19.56	8.72	6.41	69.9	254	ND			ND	ND	ND			ND				
	8 meters	10-Sep-03	16:15	18.82	7.36	0.75	8.1	298	ND			ND	**0.08**	**0.16**			**0.54**				
	8 meters	11-Sep-03	9:15	18.95	7.49	0.31	3.3	281	ND			ND	ND	ND			ND				
Lake Shastina Station "C"																					
	Surface	10-Sep-03	17:05	26.22	9.43	21.35	250.0	244	ND			ND	ND	**0.59**			**1.2**		**0.081**	**0.0081**	
	Surface	11-Sep-03	10:10	19.84	8.61	7.23	79.3	252	ND			ND	**0.17**	ND			**1**				
	6 meters	10-Sep-03	16:55	19.49	8.29	3.13	34.1	257	ND			ND	ND	ND			ND		**0.012**	**0.0065**	
	6 meters	11-Sep-03	9:55	19.39	8.03	1.91	20.7	259	ND			ND	ND	ND			ND				
	13 meters	10-Sep-03	16:45	12.47	6.88	0.21	2.0	258	**1.6**			ND	ND	**0.18**			**2.5**				
	13 meters	11-Sep-03	9:50	12.43	6.88	0.13	1.2	259	**2.2**			ND	**0.37**	**0.059**			**2.4**				
					Reporting Limits (mg/L)				**0.050**	**0.050**	**0.050**	**0.050**	**0.050**	**0.050**	**10**	**10**	**0.50**		**0.0005**	**0.0005**	**0.80**

Location Notes:

There is no Station "A"

Station "B" is located near the center of the reservoir.

Station "C" is located near the dam.

Notes: ND = Non-Detect (parameter is not present or present at concentrations below the laboratory reporting limit).
An empty cell = No sample for this parameter.

Table 8. Shasta River Bacteriological Sample Results 2003

Site	**Total Coliform** (MPN/100 ml)	**Fecal Coliform** (MPN/100 ml)	**E. coli** (MPN/100 ml)	**Enterococcus** (MPN/100 ml)
Montague-Grenada Road	≥ 2,419.2	300	249.5	1091.0
Highway 3	≥ 2,419.2	500	285.1	165.2
CA DHS Threshold Level	10,000	400	235	61

Notes:
MPN = Most Probable Number
The California Department of Health Services (DHS) recommends posting fresh water beaches when single sample values exceed the levels identified in the fourth row of the table. California Department of Health Services. July 24, 2001. Draft Guidance for Fresh Water Beaches.
http://www.dhs.ca.gov/ps/ddwem/beaches/freshwater.htm
Total and fecal coliform, enterococcus, and e. coli are "indicator organisms" of microbiological contamination and are used by health authorities as surrogates for disease-causing organisms that are likely to be present in sewage, but are difficult to analyze for directly. Presence of these indicator organisms at both Shasta River sample locations at levels above the DHS thresholds indicates there may be disease-causing organisms present in the Shasta River.

Table 9. Shasta River Tributary and Springs -- Water Quality Results from Datasondes, 2003

		Temperature (Degrees C)			Specific Conductance (uS/cm)			Dissolved Oxygen (mg/L)			pH		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Little Shasta River near Mouth													
	06/16/03 - 06/20/03	15.72	27.92	20.80	707	843	775	4.03	11.37	6.98	7.96	8.46	8.18
	10/20/03 - 10/23/03	11.08	16.23	13.45	914	947	937	6.56	19.30	9.82	8.16	8.57	8.34
Big Springs Lake at Spring													
	08/18/03 - 08/22/03	11.26	11.27	11.26	386	399	393	9.69	12.03	10.66	6.31	6.45	6.37
	09/16/2003 - 09/18/03	11.28	11.31	11.29	296	351	301	9.84	11.21	10.39	6.27	6.58	6.30
Big Springs Lake at Lake Outlet													
	09/16/2003 - 09/18/03	10.49	12.86	11.65	338	356	344	8.16	13.09	10.63	6.43	6.65	6.57
Hidden Valley Spring													
	09/16/2003 - 09/18/03	12.34	12.49	12.36	268	288	273	1.34	8.38	3.19	7.14	7.20	7.17
Bassey Spring													
	09/16/2003 - 09/18/03	9.07	9.46	9.25	307	312	309	9.87	11.34	10.33	6.64	6.75	6.70

Table 10. Shasta River Flows (Cubic Feet Per Second) at Water Quality Monitoring Locations, 2002 and 2003

Shasta River Location	Date	Time	Flow
Near Mouth at USGS Gage	7/10/02	1645	20
	8/14/02	1340	16
	9/17/02	1515	19
	4/10/03	1540	209
	6/17/03	1815	103
	8/19/03	1820	62
Yreka-Ager Road	6/17/03	1630	74
	7/23/03	0830	62
	8/19/03	1630	61
Highway 3	4/10/03	1050	171
	6/17/03	1435	81
	8/19/03	1250	59
Montague-Grenada Road	7/11/02	1130	36
	8/15/02	0925	25
	9/18/02	1615	35
	4/09/03	1820	174
	6/17/03	1150	73
	8/19/03	1120	64
Freeman Road	6/17/03	1300	107
	7/23/03	1030	95
	8/19/03	1030	86
	8/20/03	1200	89
Highway A12	6/17/03	840	103
	8/19/03	0830	83
1.9 miles downstream of Big Springs Creek	6/17/03	0845	186
	8/19/03	1030	121
	8/20/03	1030	122
Riverside Drive	6/20/03	1130	3
	7/22/03	1400	10
	8/19/03	0830	9
Edgewood Road	7/11/02	1330	9
	8/15/02	1130	12
	9/19/02	0815	12
	4/09/03	1325	89

Table 11. Measured Sediment Oxygen Demand Rates and Sediment Characteristics at Shasta River Sites.

Sites[1]	Date	Replicate	Water Depth (meters)	Blank-Corrected SOD Rate at 20°C (SOD_{20}, $g/m^2/d$) [2]	Sediment Organic Content (%)	Sediment: Percent Finer than 63 microns (%)
Shasta River upstream of Montague- Grenada Road	Aug 12, 2003	1	0.9	2.0	2.3	5.7
		2	0.8	---	1.4	3.2
		3	0.7	1.0	1.7	3.3
Shasta River downstream of Montague- Grenada Road	Aug 12, 2003	1	0.7	1.6	4.8	5.0
		2	0.6	0.5	7.5	54.3
		3	0.5	1.0	4.1	2.4
Shasta River near Highway 3 – site A	Aug 13, 2003	1	0.9	1.5	2.6	2.1
		2	0.9	0.7	1.0	0.8
		3	0.8	0.1	1.5	1.6
Shasta River near Highway 3 – site B	Aug 13, 2003	1	0.9	1.3	1.4	3.3
		2	0.9	1.4	1.2	1.3
		3	0.8	1.7	1.5	2.9
Shasta River near Highway 3 – site C	Aug 14, 2003	1	0.7	2.1	0.9	0.7
		2	0.5	---	1.2	8.9
		3	0.4	2.3	0.8	2.3
Shasta River near Highway 3 – site D	Aug 14, 2003	1	0.6	1.8	6.5	29.9
		2	0.7	---	3.4	48.9
		3	0.7	2.3	6.3	44.4

Notes

1. Site Locations:
   Shasta River upstream of Montague- Grenada Road is located 100-200 meters upstream of the bridge.
   Shasta River downstream of Montague- Grenada Road is located approximately 400 meters downstream of bridge.
   Shasta River near Highway 3 – site A is located approximately 1 kilometer upstream of bridge; 200-300 meters upstream of pump house on right bank.
   Shasta River near Highway 3 – site B is located 50-100 meters upstream of site A, at bend in river.
   Shasta River near Highway 3 – site C is located 100-200 meters downstream of bridge.
   Shasta River near Highway 3 – site D is located 25-50 meters upstream of site C.

2. SOD_{20}, $g/m^2/d$ is sediment oxygen demand corrected for temperature of 20°C in grams per square meter per day.

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28. Continuous Sonde Data - Shasta River @ Freeman Road - Collected by NCRWQCB: 06/01/03 – 10/31/03
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30. Continuous Sonde Data - Shasta River @ Highway 3 - Collected by NCRWQCB: 06/01/03 – 10/31/03
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53. Continuous Temperature Data – Boles Creek- Collected by NCRWQCB: 06/01/03 - 10/31/03

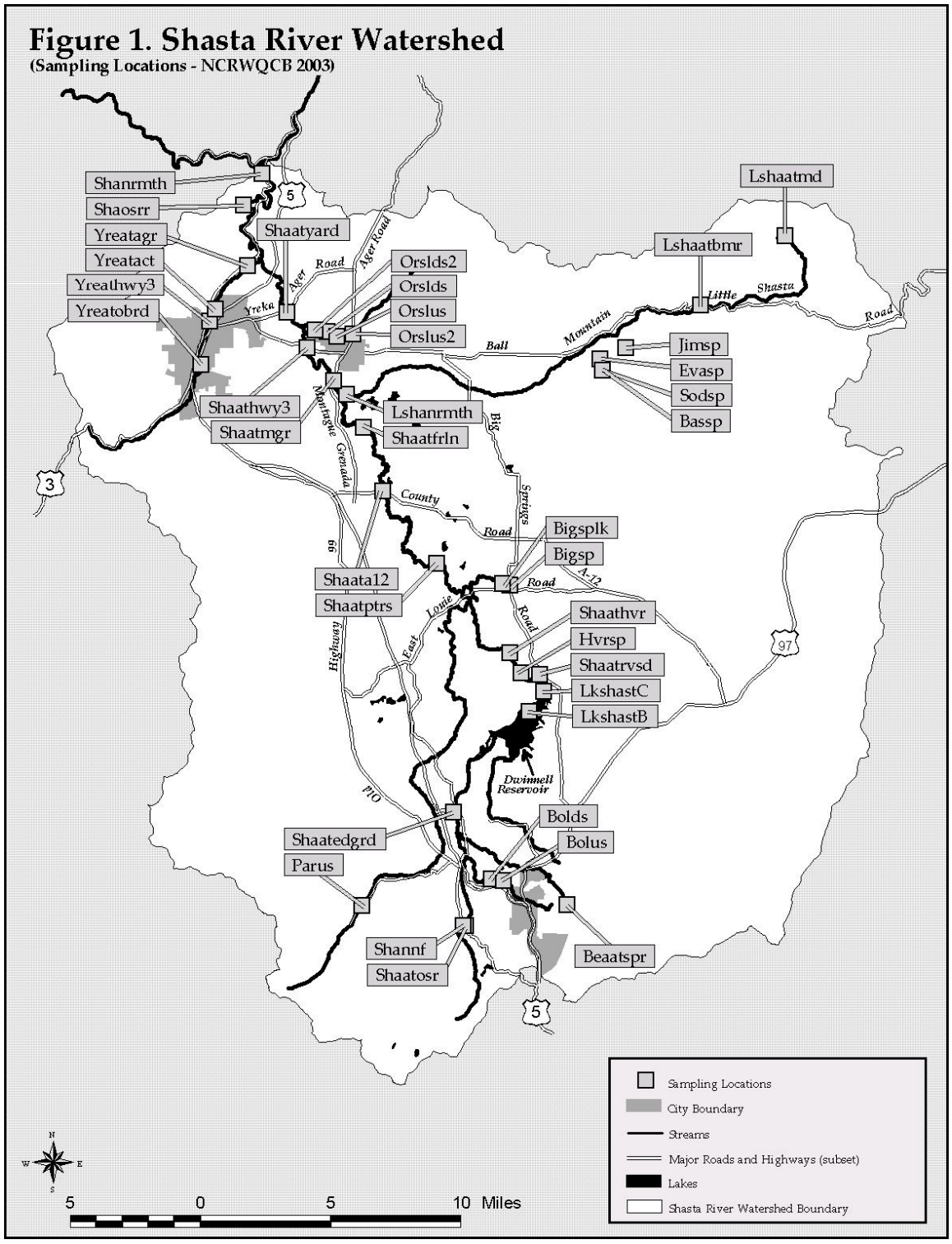
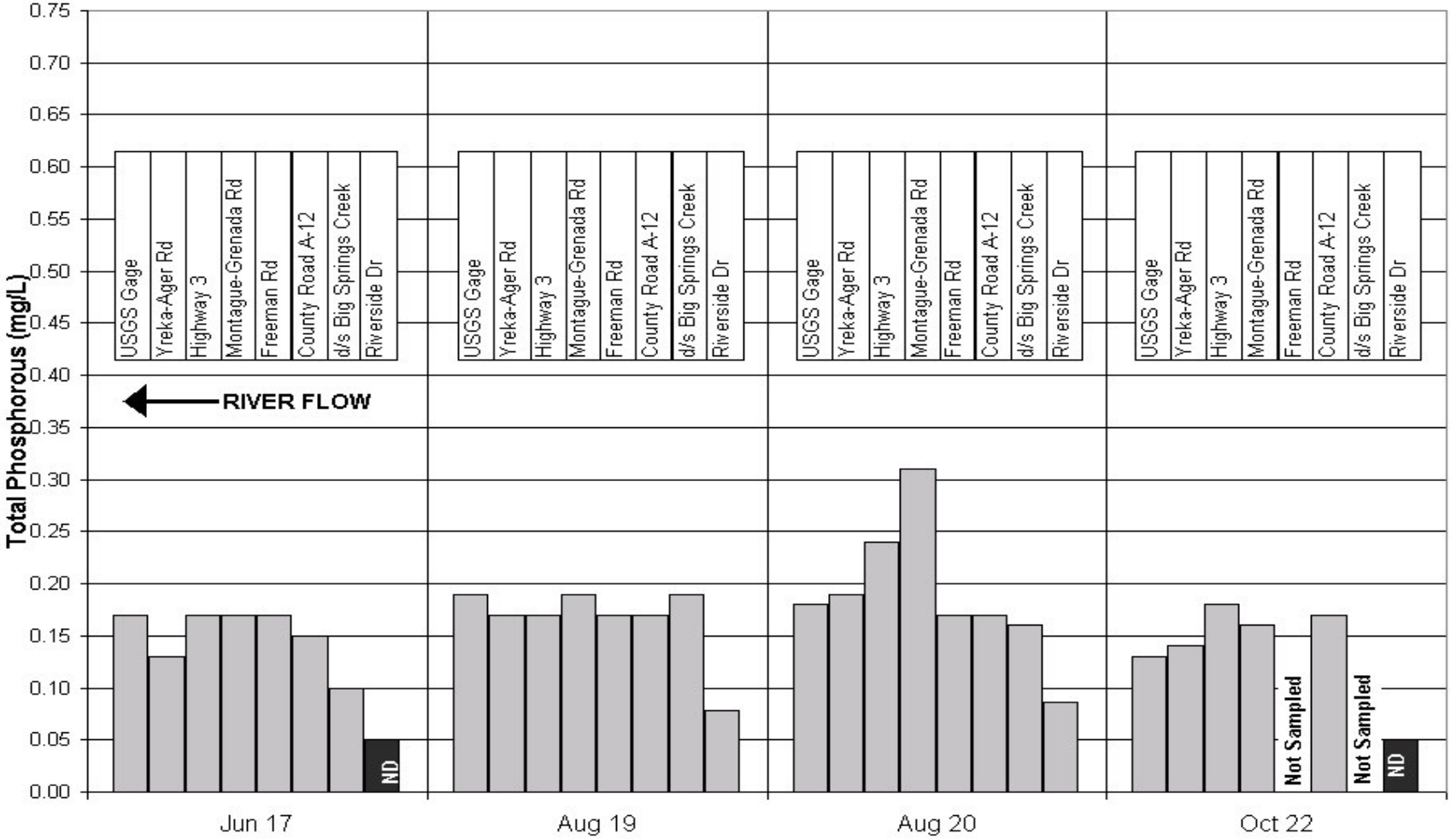
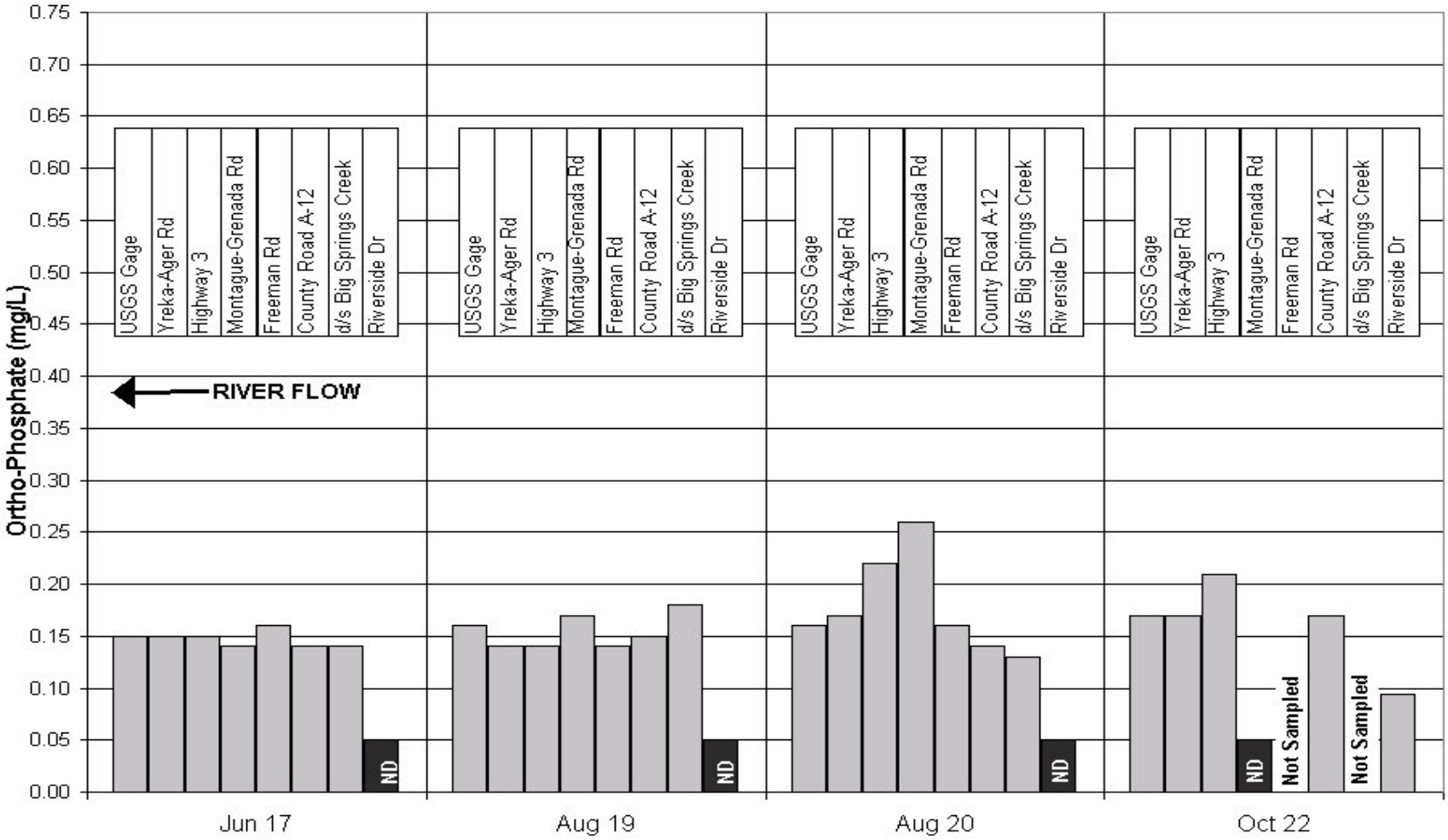


Figure 1. Shasta River Watershed
(Sampling Locations - NCRWQCB 2003)
Shanrmth
Shaosrr
Yreatagr
Yreatact
Yreathwy3
Yreatobrd
Shaatyard
Orslds2
Orslds
Orslus
Orslus2
Shaathwy3
Shaatmgr
Lshanrmth
Shaatfrln
Lshaatmd
Lshaatbmr
Jimsp
Evasp
Sodsp
Bassp
Bigsplk
Bigsp
Shaata12
Shaatptrs
Shaathvr
Hvrsp
Shaatrvsd
LkshastC
LkshastB
Bolds
Bolus
Shaatedgrd
Parus
Shannf
Shaatosr
Beaatspr
Dwinnell Reservoir
Ager Road
Yreka
Ball Mountain
Little Shasta Road
Montague Grenada
Big Springs
County Road
Louie
East Highway 96
A-12
Road
97
5
3
Sampling Locations
City Boundary
Streams
Major Roads and Highways (subset)
Lakes
Shasta River Watershed Boundary
5 0 5 10 Miles



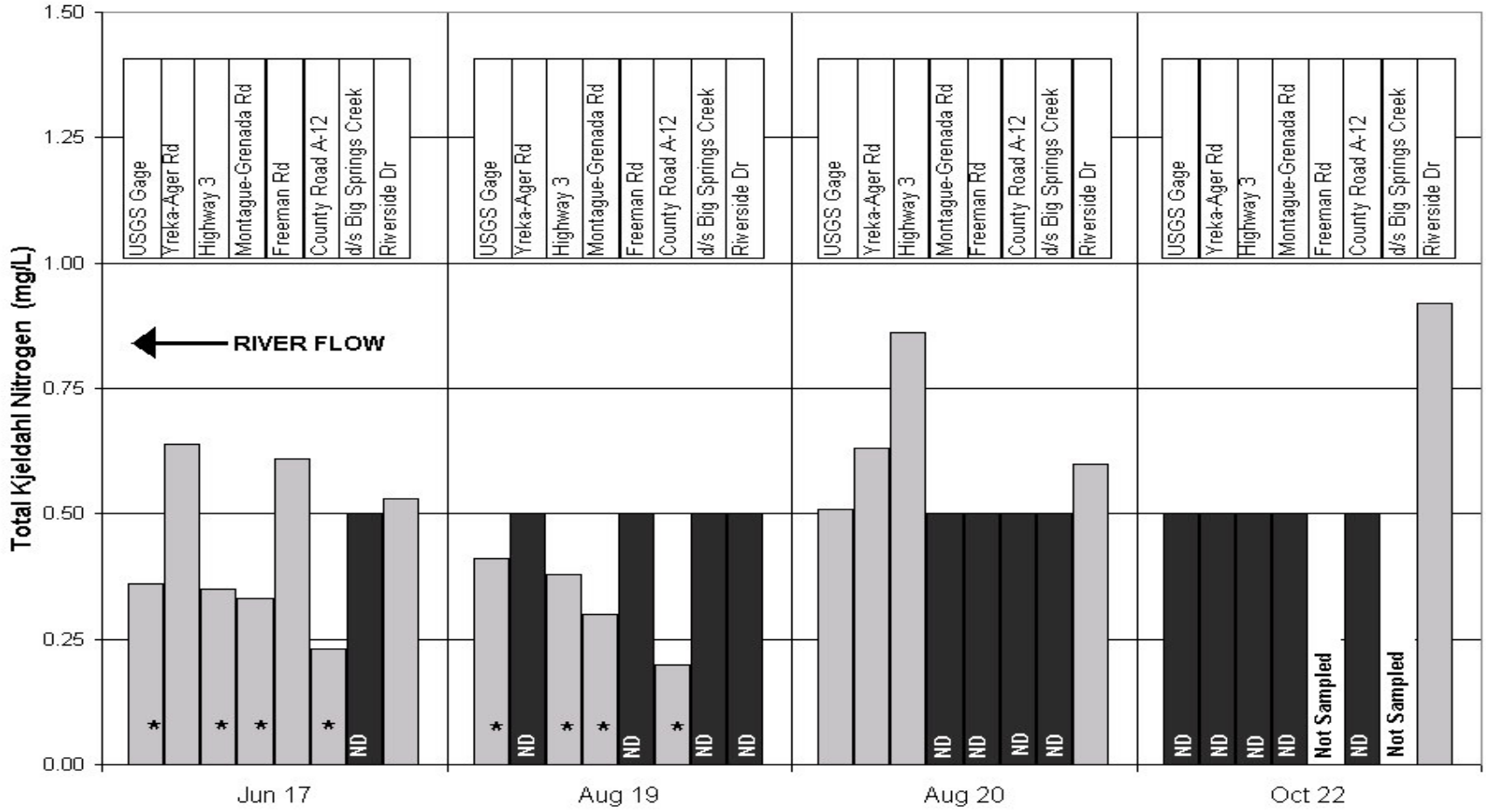
Notes: ND = Non-Detect (parameter is not present or present at concentrations below the laboratory reporting limit).

Figure 2. Total Phosphorus Grab Sample Data – Shasta River at Various Locations (Summer 2003) – Collected by NCRWQCB & USGS



Notes: ND = Non-Detect (parameter is not present or present at concentrations below the laboratory reporting limit).

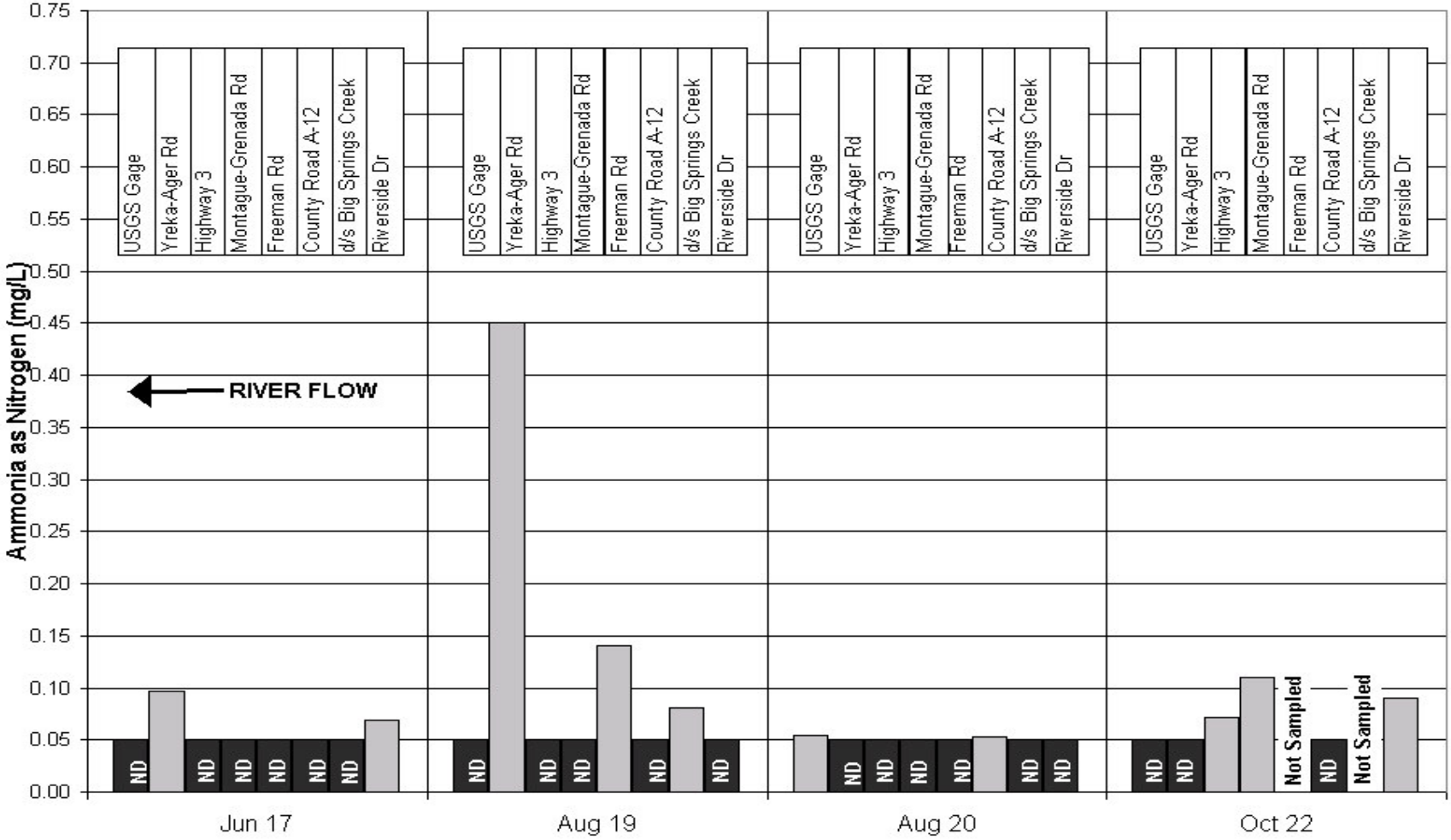
Figure 3. Ortho-Phosphate Grab Sample Data – Shasta River at Various Locations (Summer 2003) – Collected by NCRWQCB & USGS



Notes: ND = Non-Detect (parameter is not present or present at concentrations below the laboratory reporting limit).

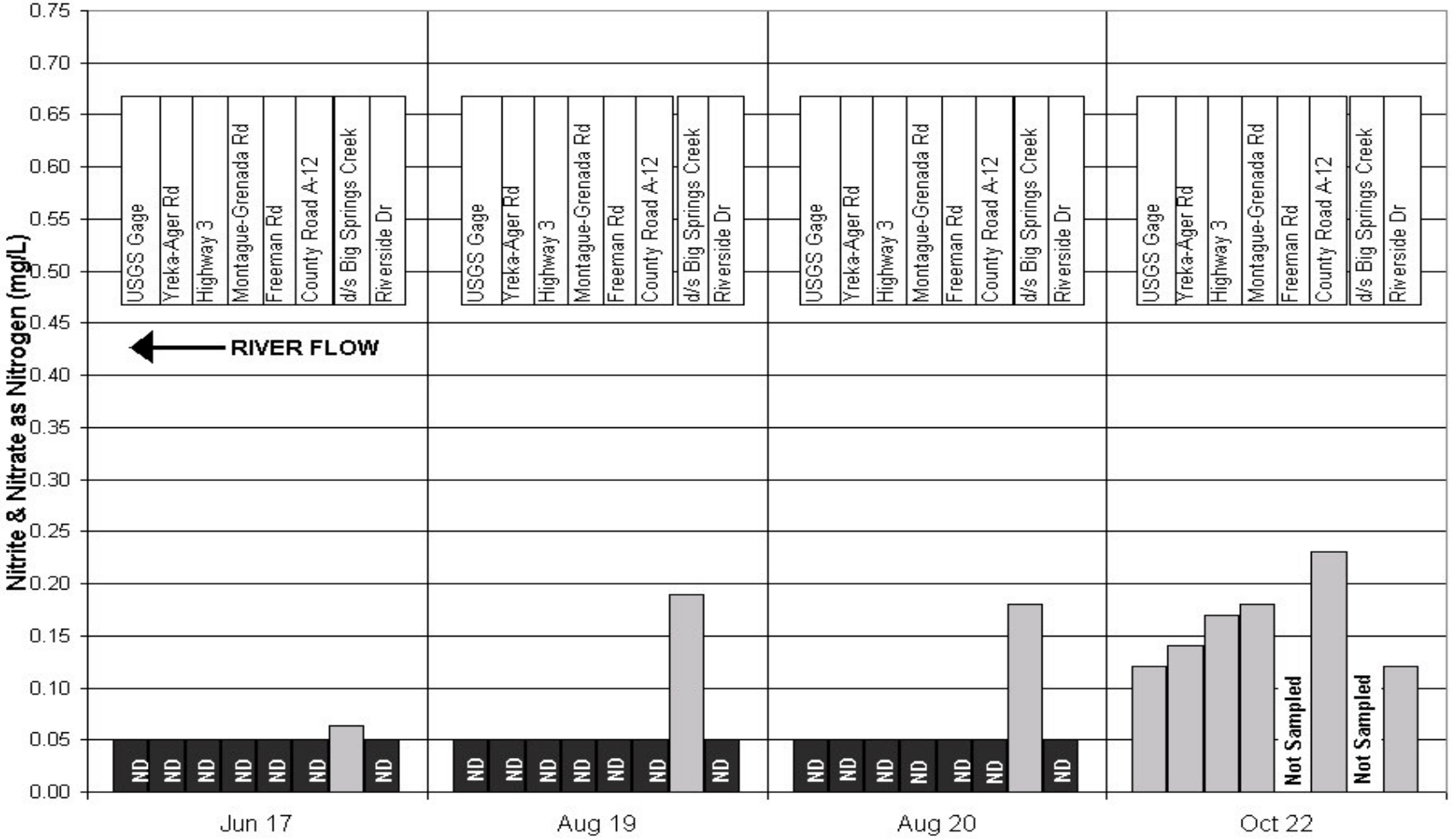
* = Sites sampled by USGS – Values reported using a laboratory analytical method with a lower reporting limit.

Figure 4. Total Kjeldahl Nitrogen Grab Sample Data – Shasta River at Various Locations (Summer 2003) – Collected by NCRWQCB & USGS



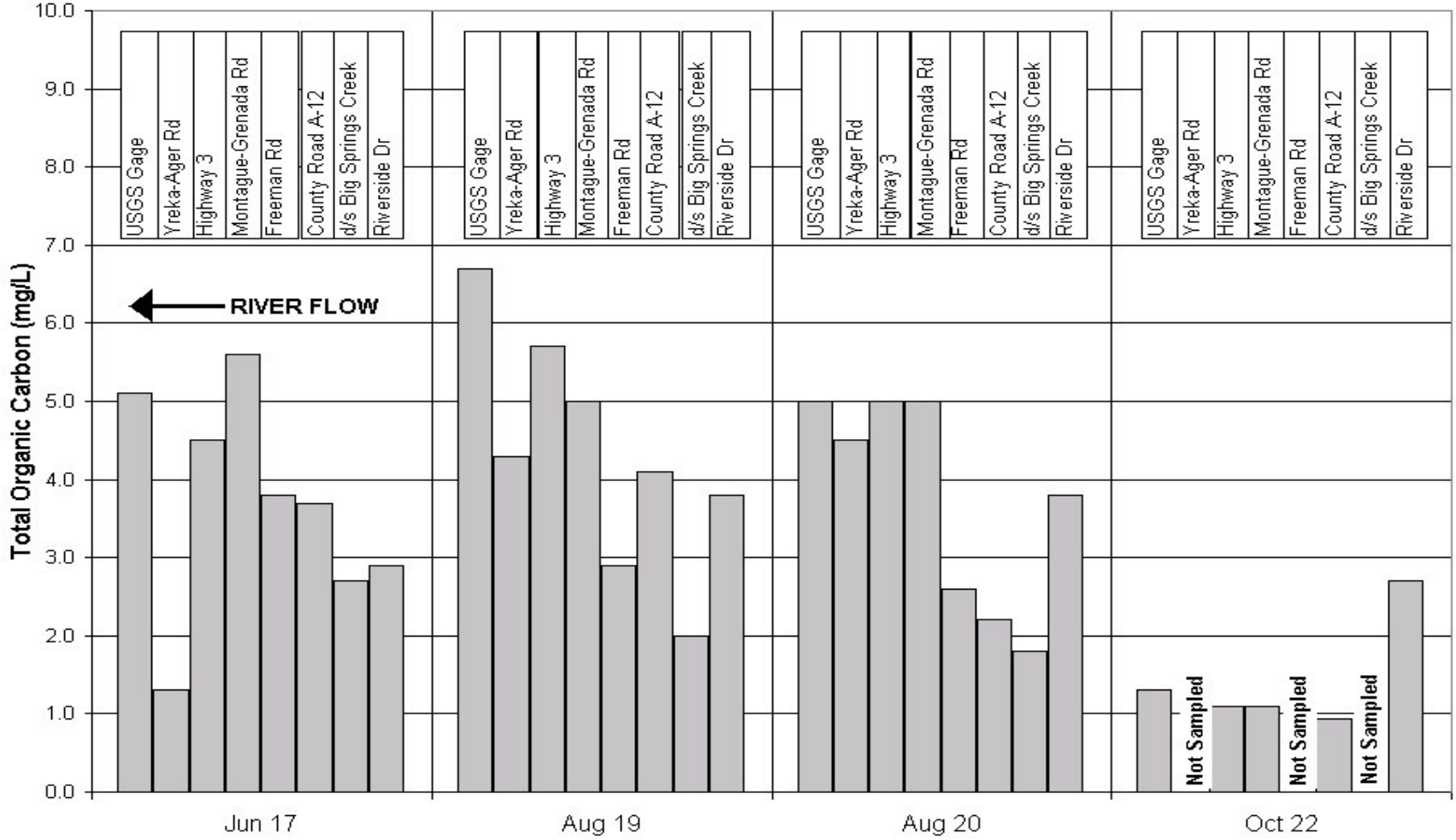
Notes: ND = Non-Detect (parameter is not present or present at concentrations below the laboratory reporting limit).

Figure 5. Ammonia Grab Sample Data – Shasta River at Various Locations (Summer 2003) – Collected by NCRWQCB & USGS



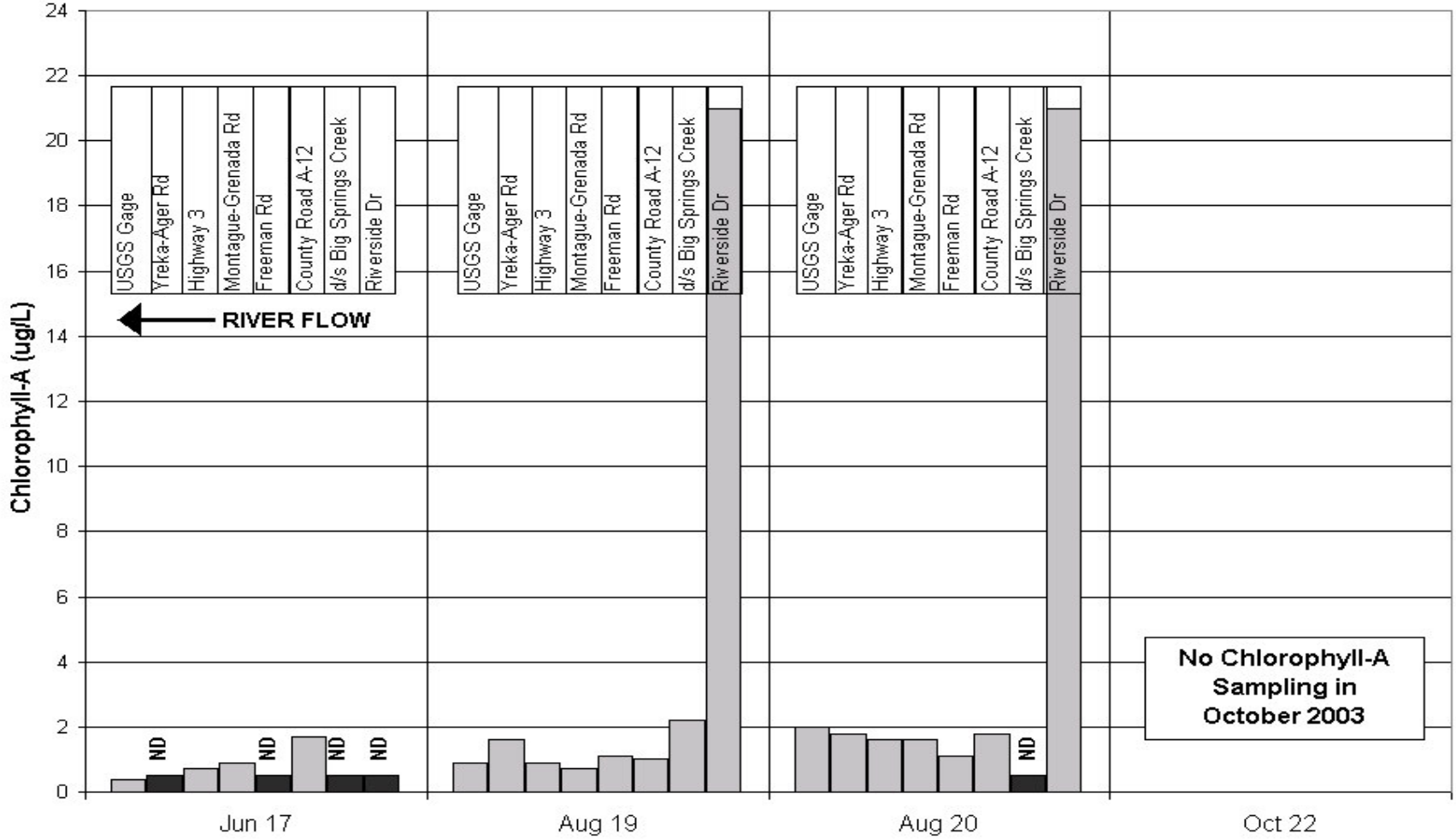
Notes: ND = Non-Detect (parameter is not present or present at concentrations below the laboratory reporting limit).

Figure 6. Nitrite + Nitrate Grab Sample Data – Shasta River at Various Locations (Summer 2003) – Collected by NCRWQCB & USGS



Notes: ND = Non-Detect (parameter is not present or present at concentrations below the laboratory reporting limit).

Figure 7. Total Organic Carbon Grab Sample Data – Shasta River at Various Locations (Summer 2003) – Collected by NCRWQCB & USGS



Notes: ND = Non-Detect (parameter is not present or present at concentrations below the laboratory reporting limit).

Figure 8. Chlorophyll-A Grab Sample Data – Shasta River at Various Locations (Summer 2003) – Collected by NCRWQCB & USGS.

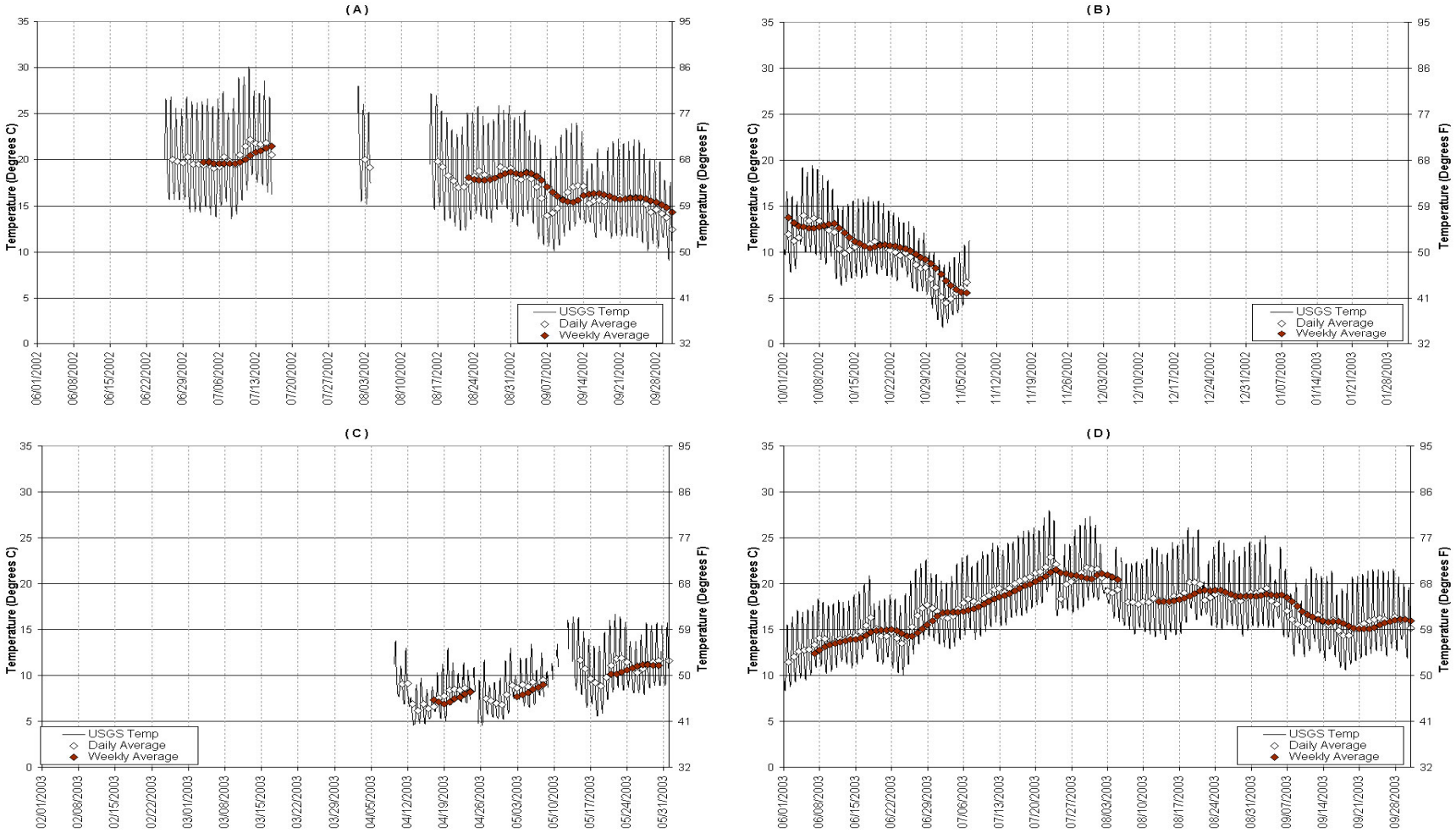


Figure 9. Continuous Temperature Data - Shasta River @ Edgewood Road - Collected by USGS: (A) 06/01/02 - 09/30/02, (B) 10/01/02 – 01/31/03, (C) 02/01/03 – 05/31/03, (D) 06/01/03 – 09/30/03.

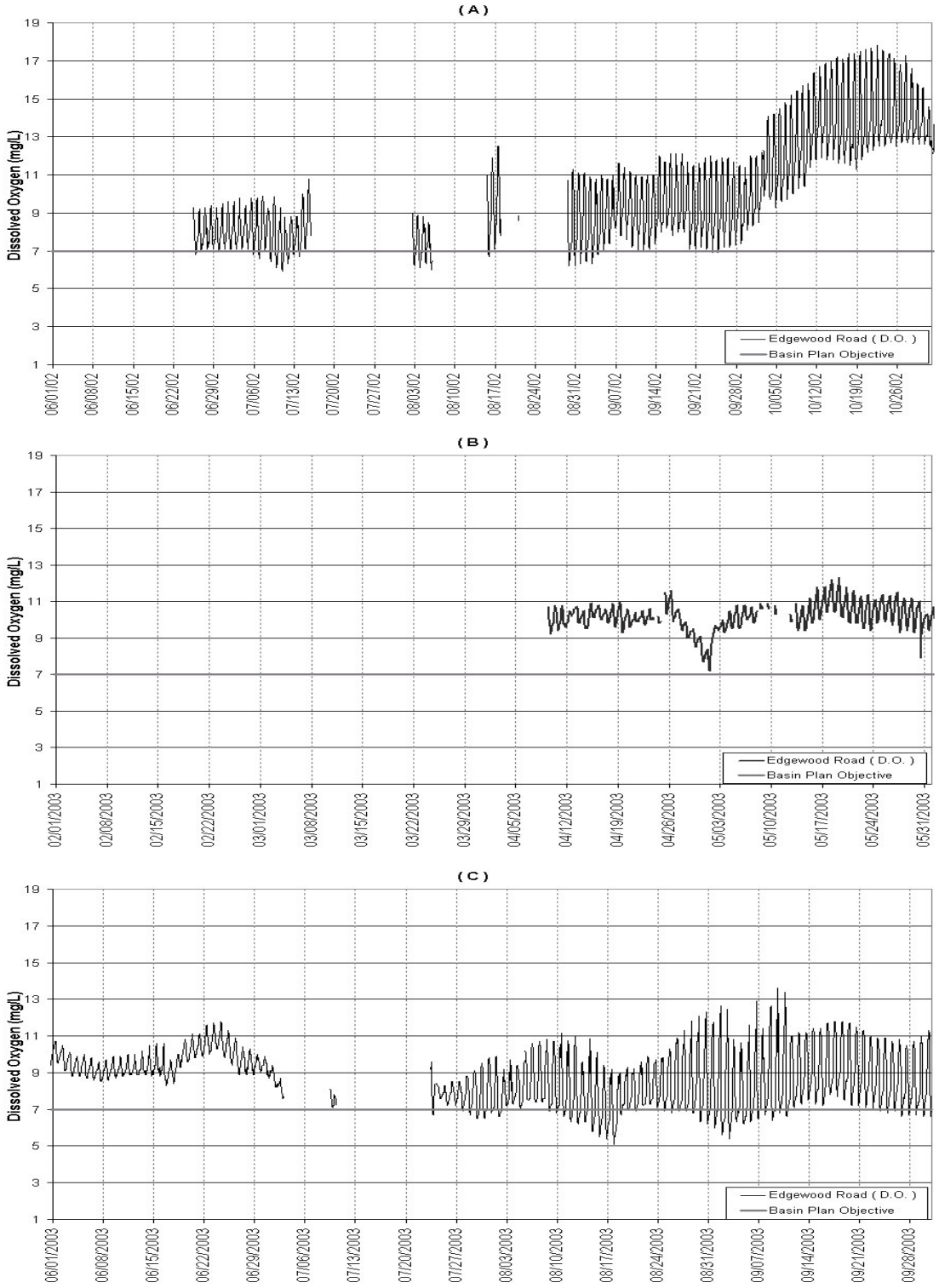


Figure 10. Continuous Dissolved Oxygen Data - Shasta River @ Edgewood Road - Collected by USGS: (A) 06/01/02 - 10/31/02, (B) 02/01/03 – 05/31/03, (C) 06/01/03 – 09/30/03.

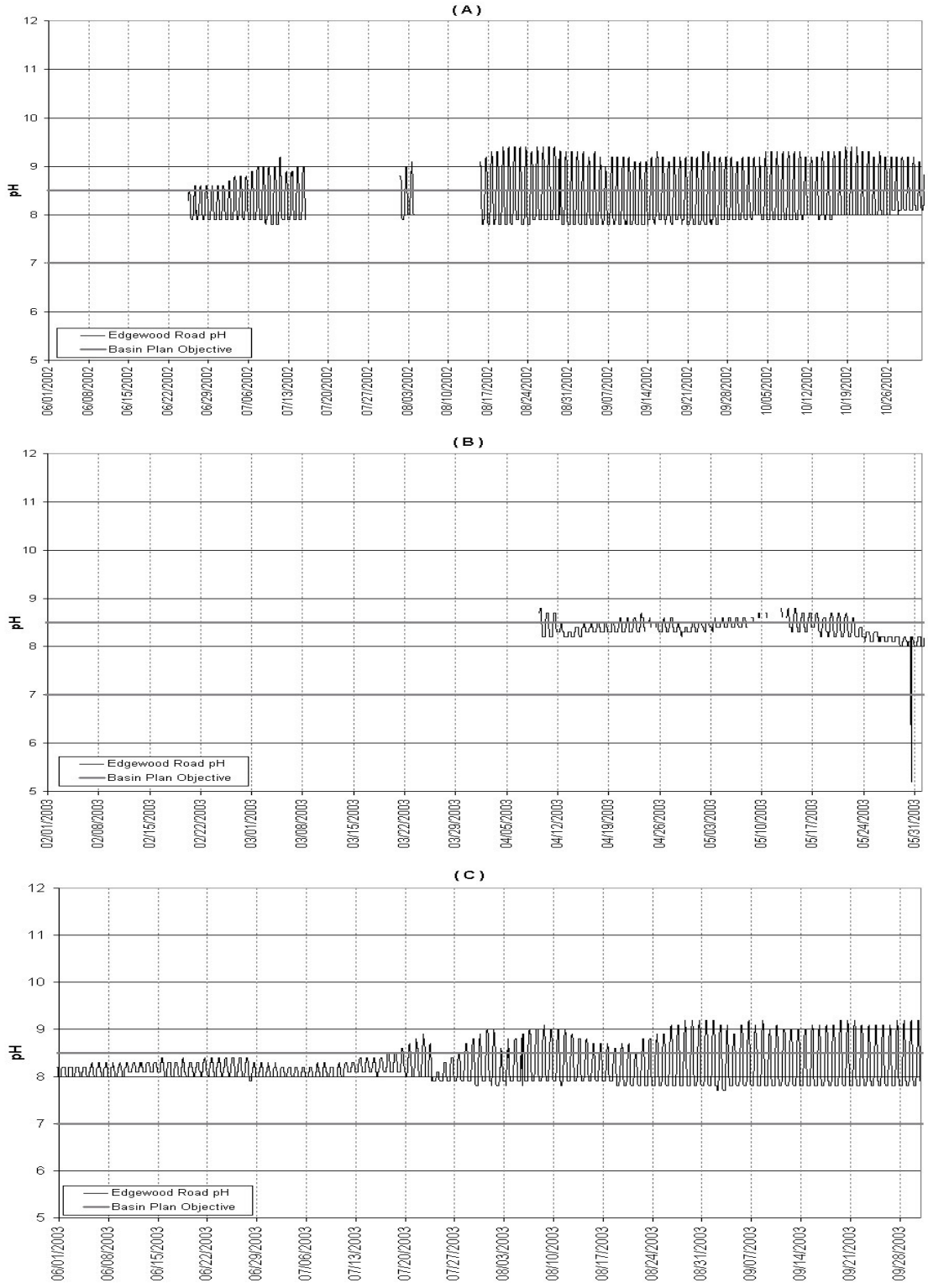


Figure 11. Continuous pH Data - Shasta River @ Edgewood Road - Collected by USGS: (A) 06/01/02 - 10/31/02, (B) 02/01/03 – 05/31/03, (C) 06/01/03 – 09/30/03.

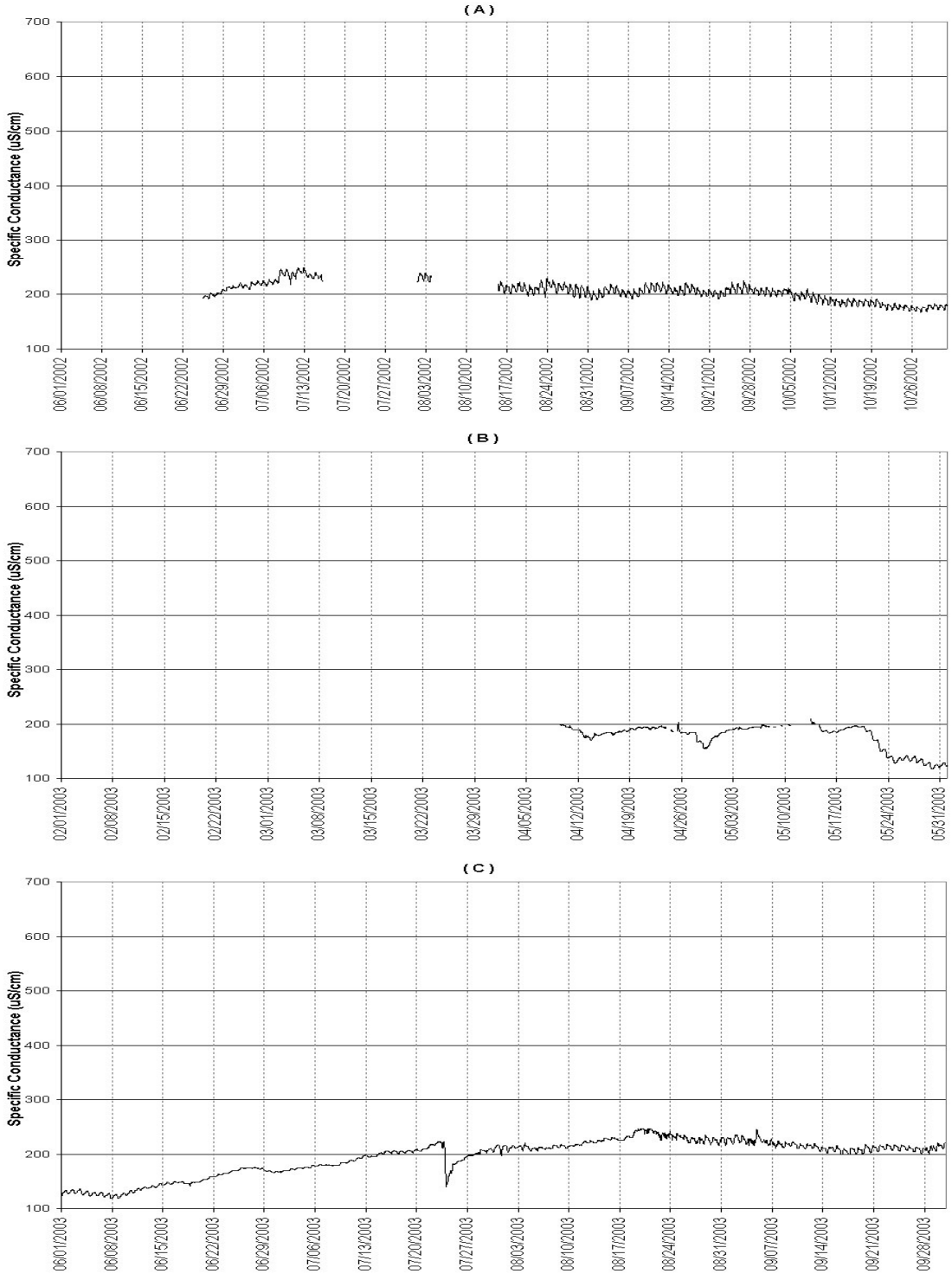


Figure 12. Continuous Specific Conductance Data - Shasta River @ Edgewood Road - Collected by USGS: (A) 06/01/02 - 10/31/02, (B) 02/01/03 – 05/31/03, (C) 06/01/03 – 09/30/03.

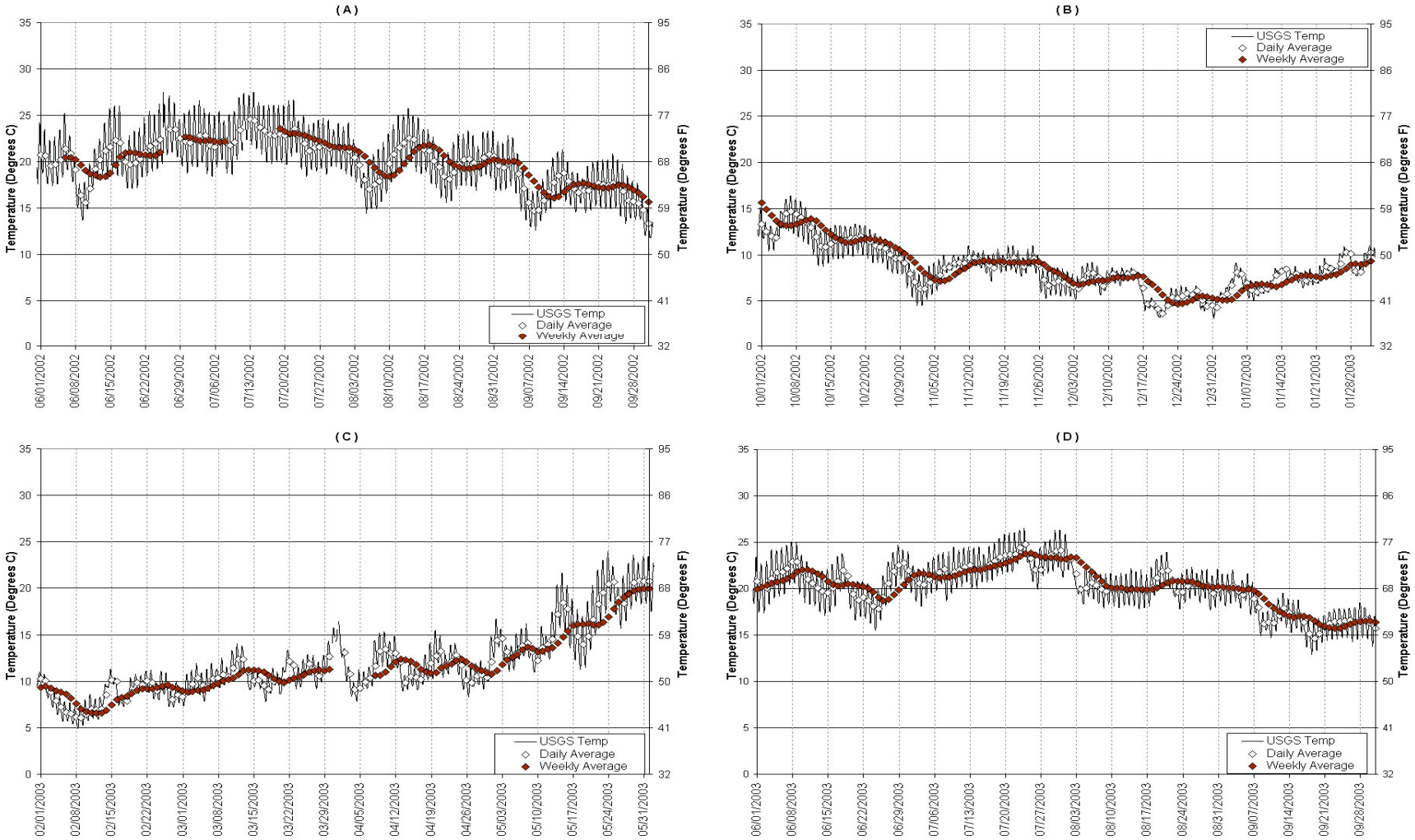


Figure 13. Continuous Temperature Data - Shasta River @ Montague-Grenada Road - Collected by USGS: (A) 06/01/02 - 09/30/02, (B) 10/01/02 – 01/31/03, (C) 02/01/03 – 05/31/03, (D) 06/01/03 – 09/30/03.

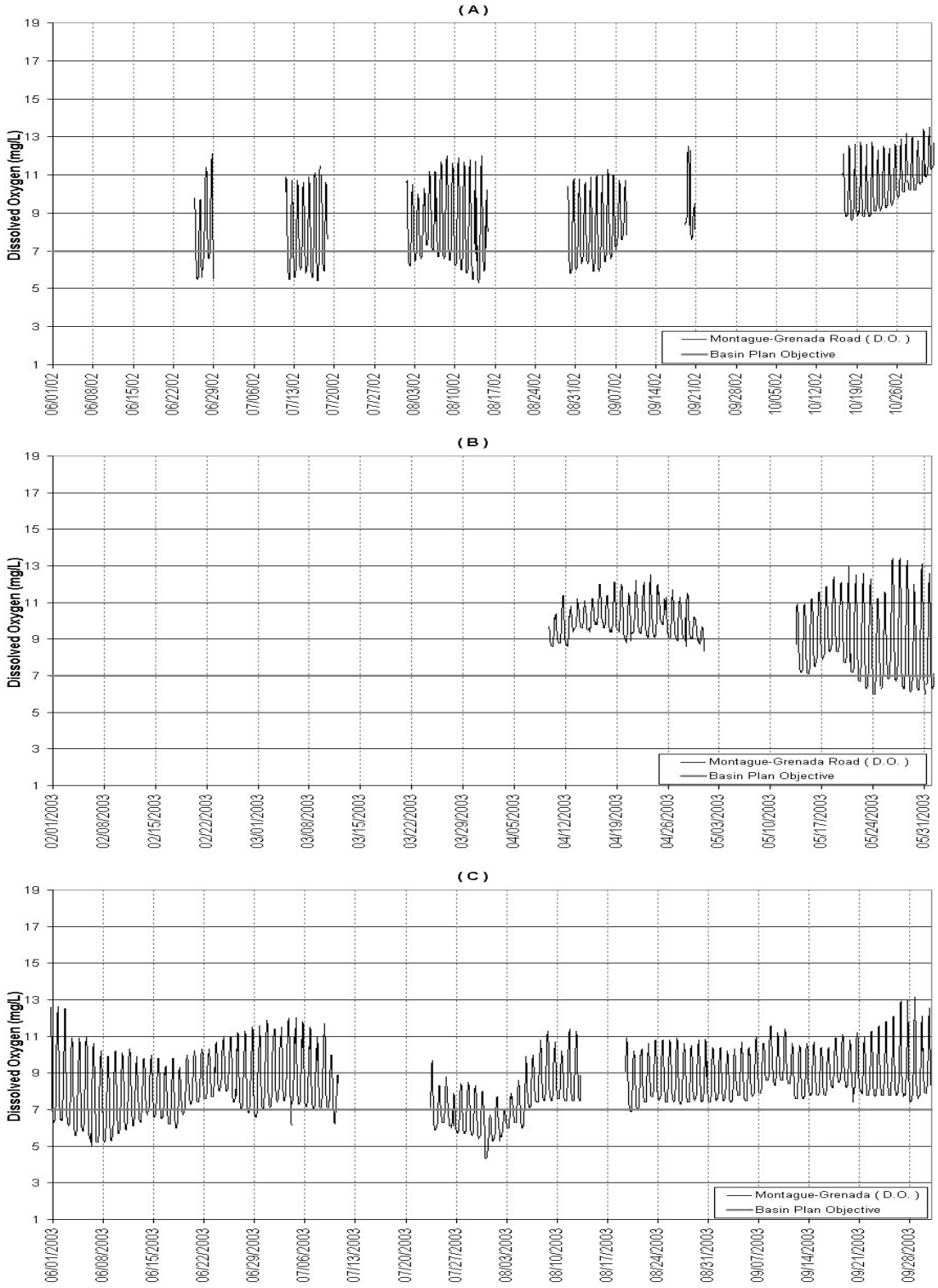


Figure 14. Continuous Dissolved Oxygen Data - Shasta River @ Montague-Grenada Road - Collected by USGS: (A) 06/01/02 - 10/31/02, (B) 02/01/03 – 05/31/03, (C) 06/01/03 – 09/30/03.

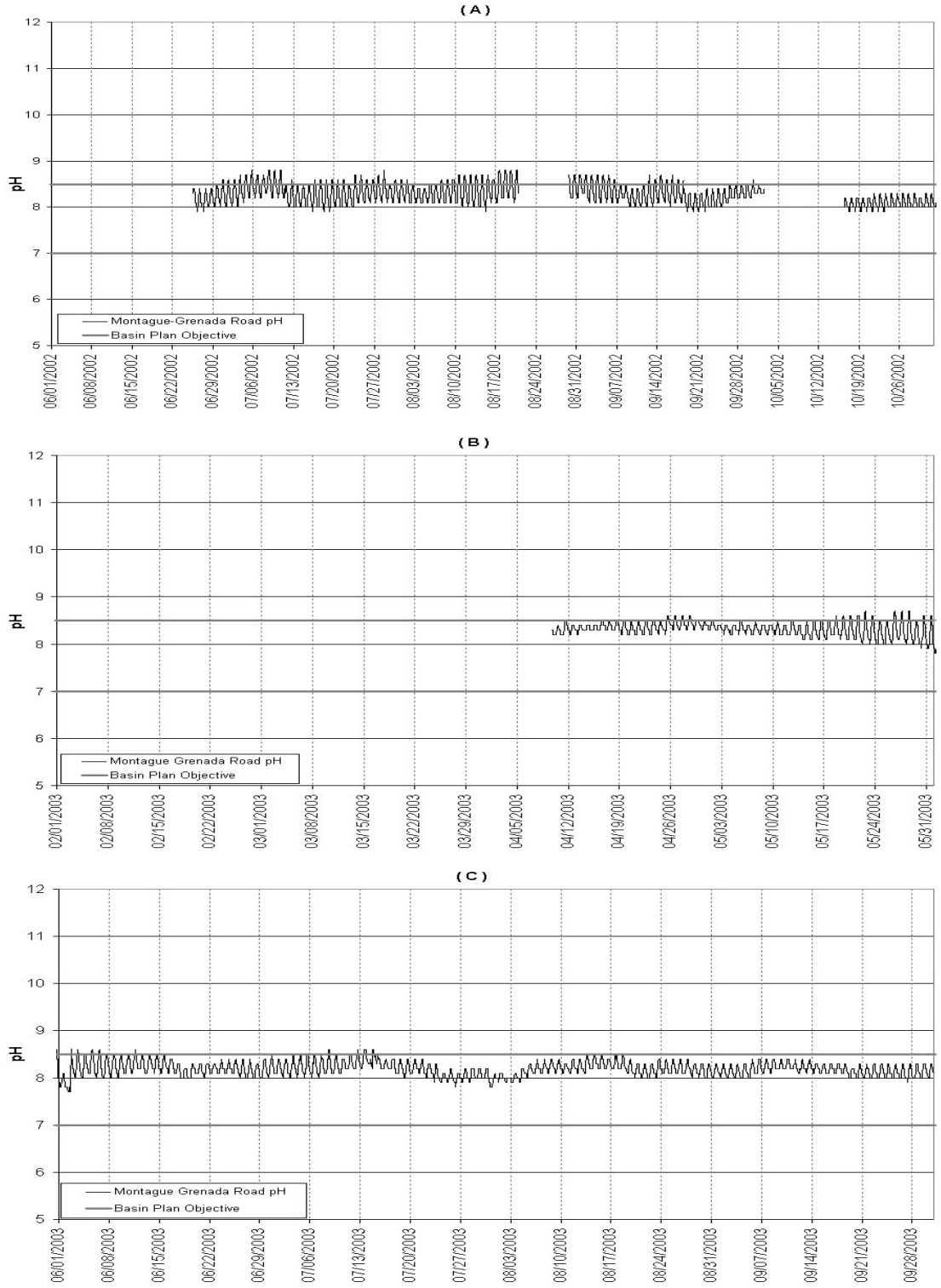


Figure 15. Continuous pH Data - Shasta River @ Montague-Grenada Road - Collected by USGS: (A) 06/01/02 - 10/31/02, (B) 02/01/03 – 05/31/03, (C) 06/01/03 – 09/30/03.

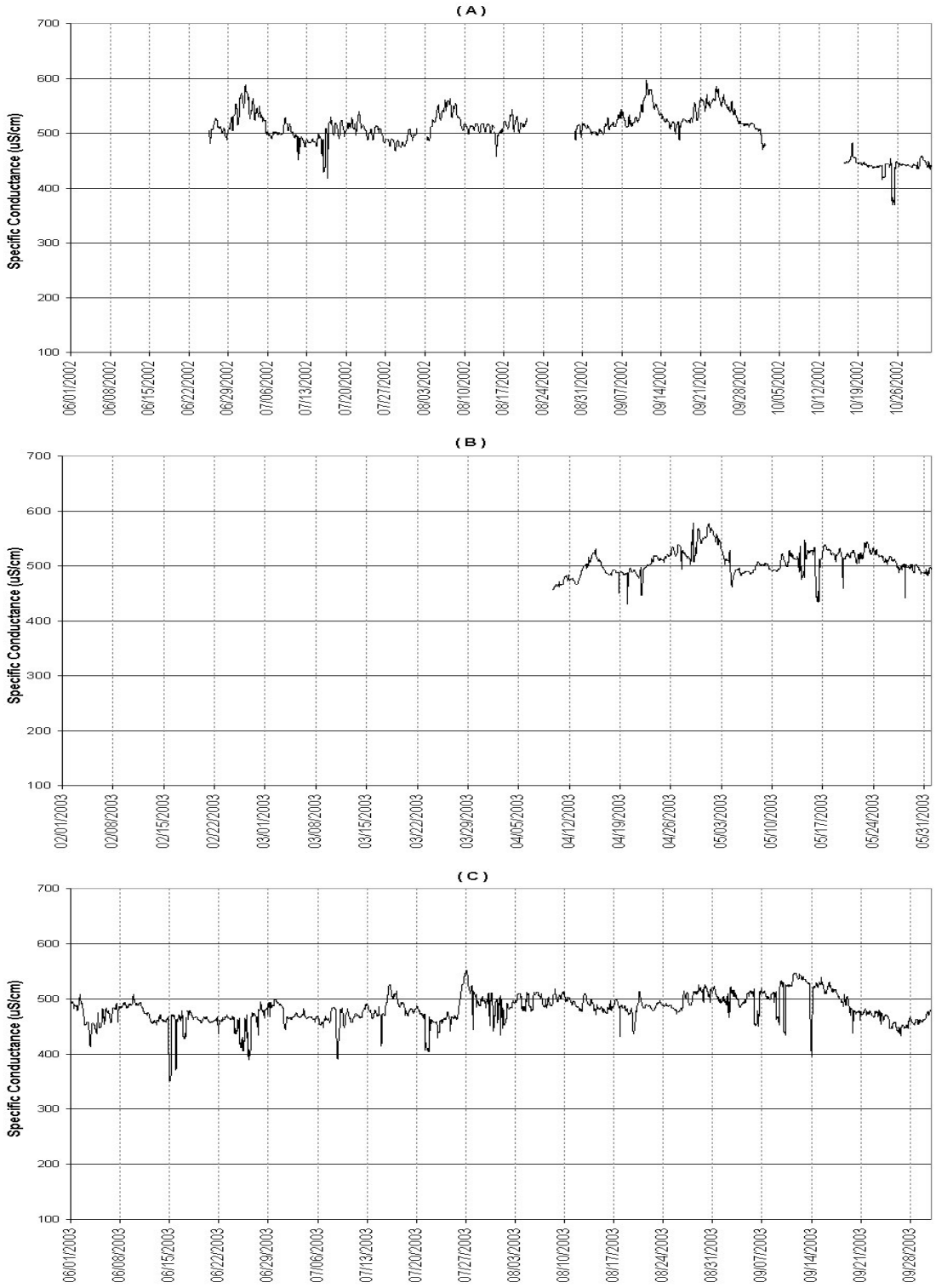


Figure 16. Continuous Conductance Data - Shasta River @ Montague-Grenada Road - Collected by USGS: (A) 06/01/02 - 10/31/02, (B) 02/01/03 – 05/31/03, (C) 06/01/03 – 09/30/03.

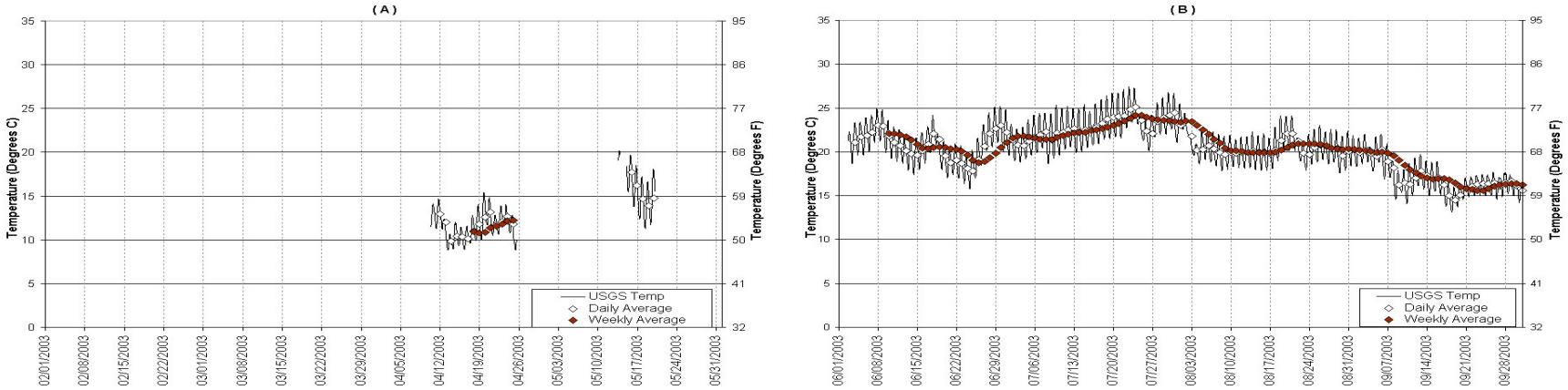


Figure 17. Continuous Temperature Data - Shasta River @ Highway 3 - Collected by USGS: (A) 02/01/03 – 05/31/03, (B) 06/01/03 – 09/30/03.

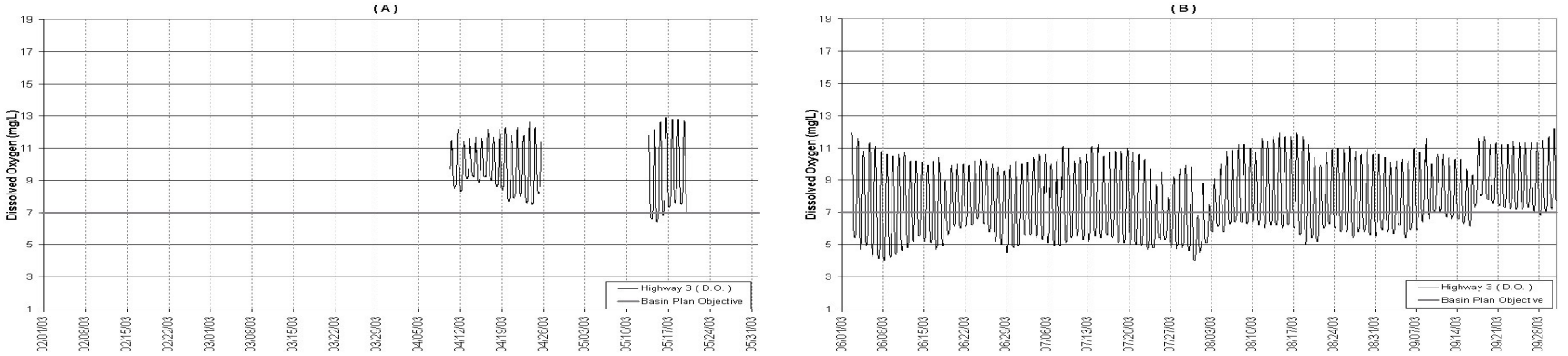


Figure 18. Continuous Dissolved Oxygen Data - Shasta River @ Highway 3 - Collected by USGS: (A) 02/01/03 – 05/31/03, (B) 06/01/03 – 09/30/03.

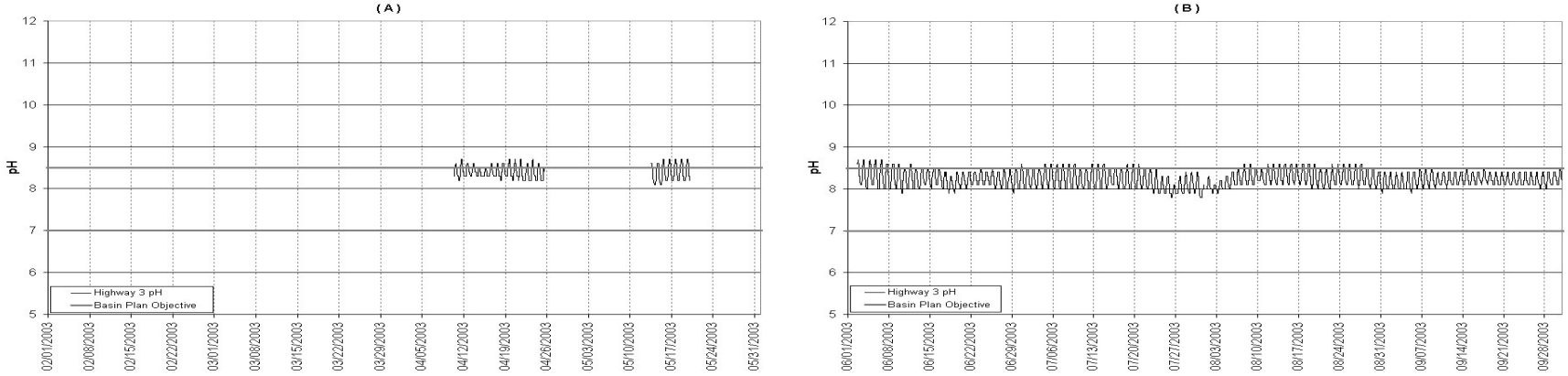


Figure 19. Continuous pH Data - Shasta River @ Highway 3 - Collected by USGS: (A) 02/01/03 – 05/31/03, (B) 06/01/03 – 09/30/03.

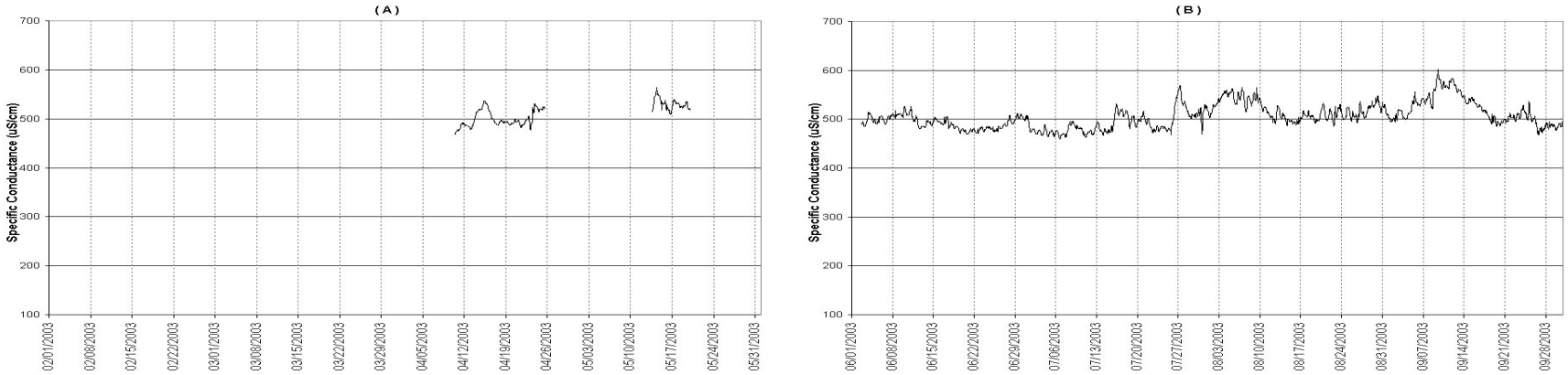


Figure 20. Continuous Conductance Data - Shasta River @ Highway 3 - Collected by USGS: (A) 02/01/03 – 05/31/03, (B) 06/01/03 – 09/30/03

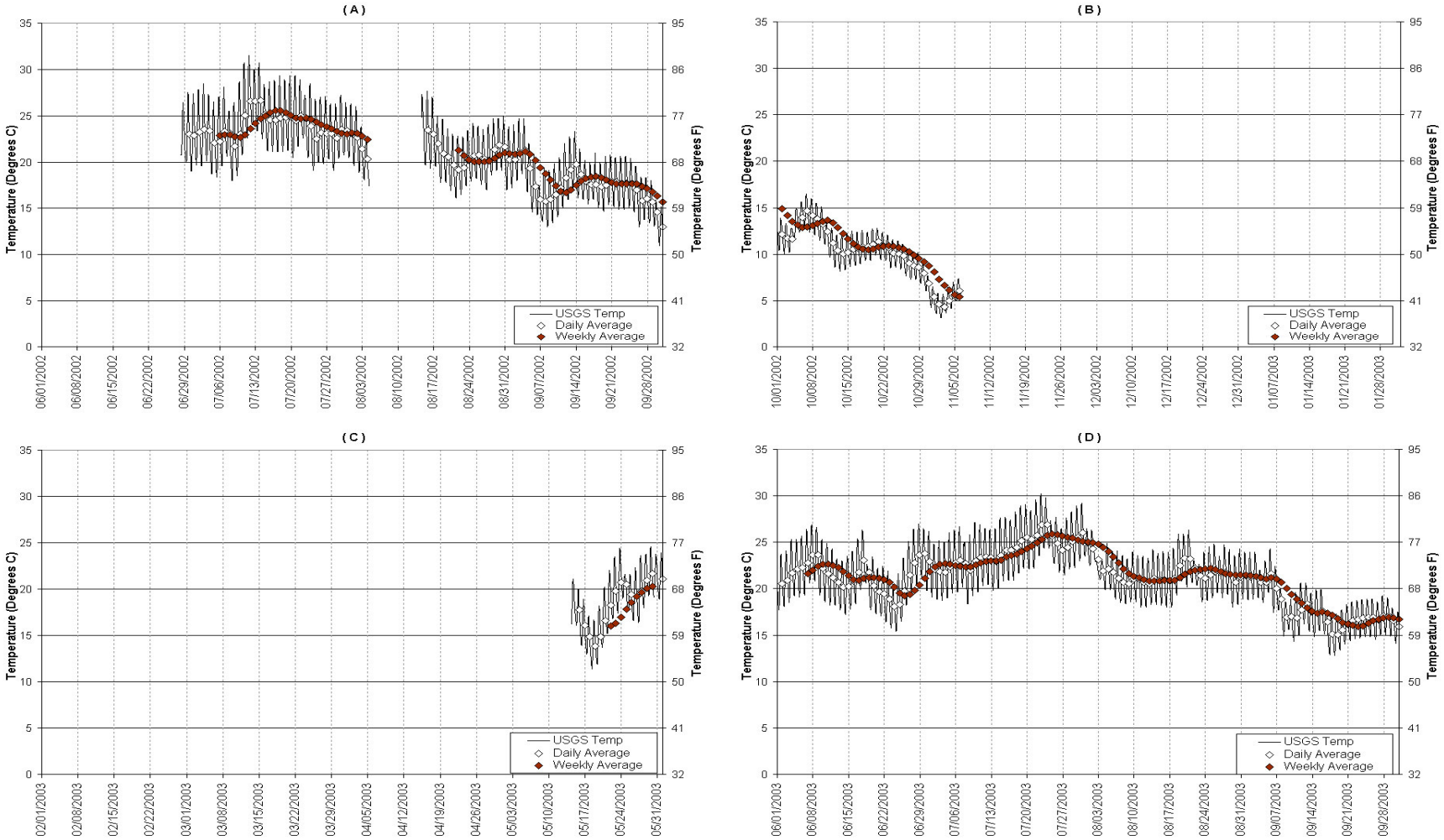


Figure 21. Continuous Temperature Data - Shasta River Near Mouth @ USGS Gage - Collected by USGS: (A) 06/01/02 - 09/30/02, (B) 10/01/02 – 01/31/03, (C) 02/01/03 – 05/31/03, (D) 06/01/03 – 09/30/03.

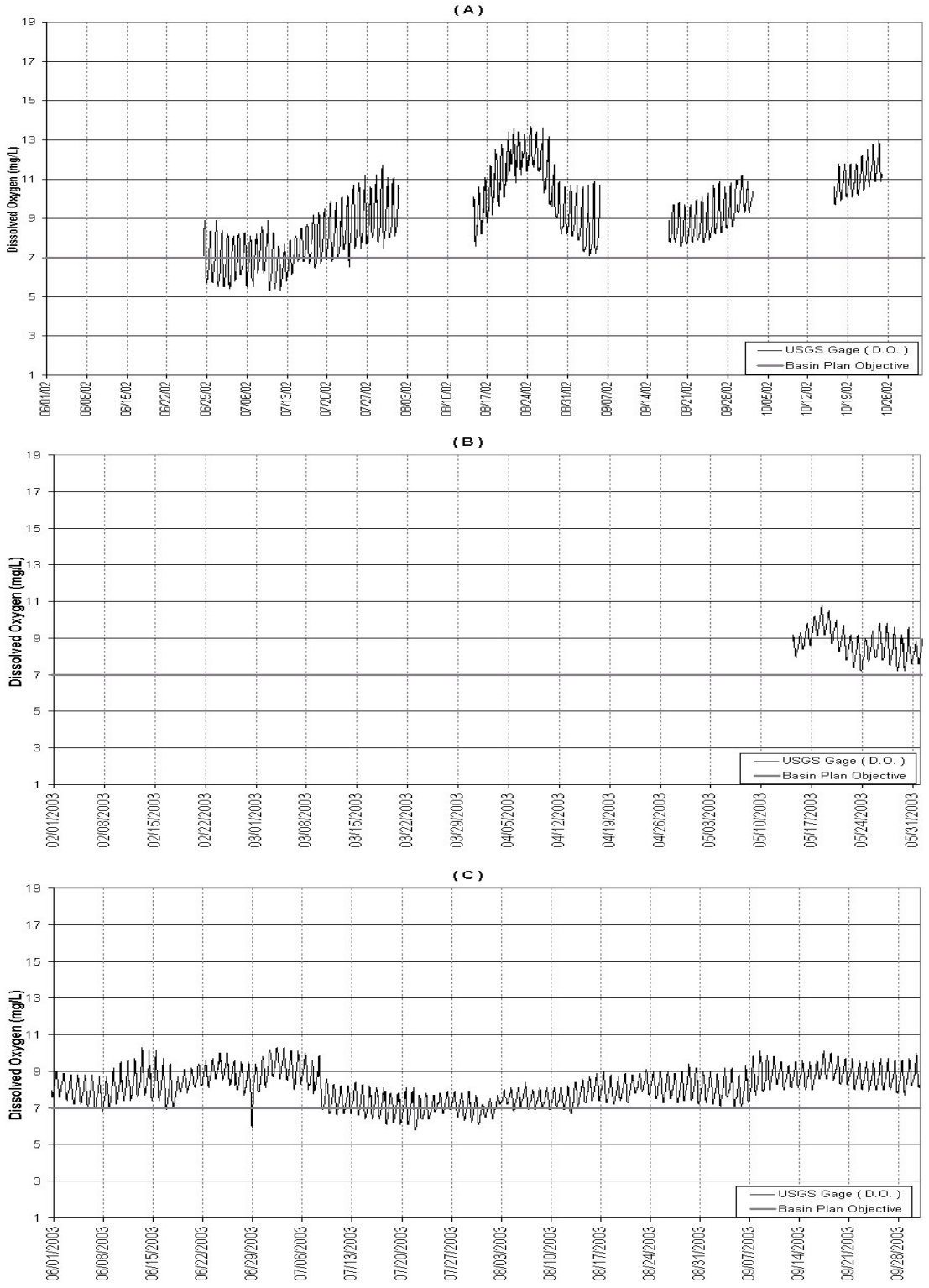


Figure 22. Continuous Dissolved Oxygen Data - Shasta River Near Mouth @ USGS Gage - Collected by USGS: (A) 06/01/02 - 10/31/02, (B) 02/01/03 – 05/31/03, (C) 06/01/03 – 09/30/03.

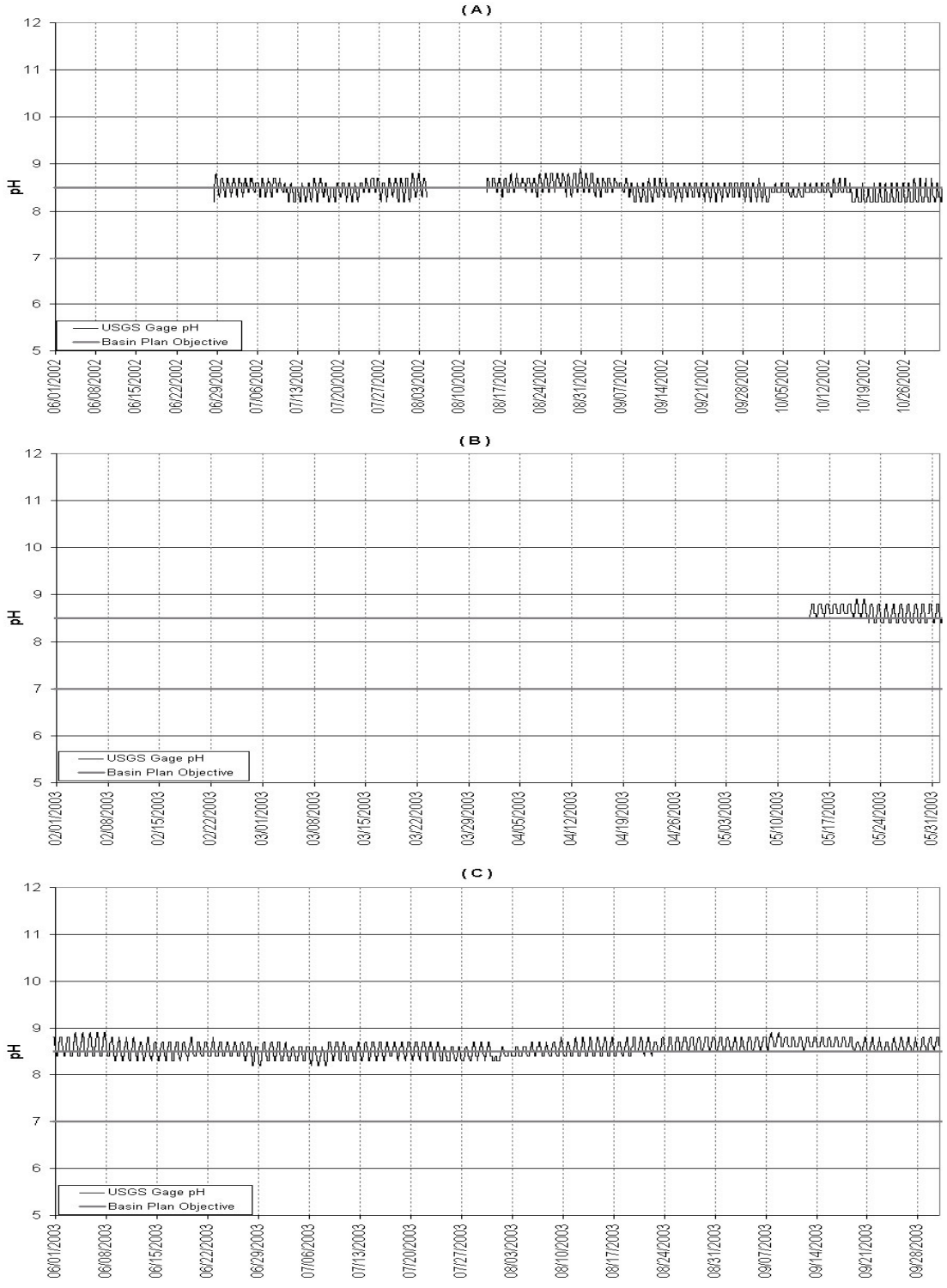


Figure 23. Continuous pH Data - Shasta River Near Mouth @ USGS Gage - Collected by USGS: (A) 06/01/02 - 10/31/02, (B) 02/01/03 – 05/31/03, (C) 06/01/03 – 09/30/03.

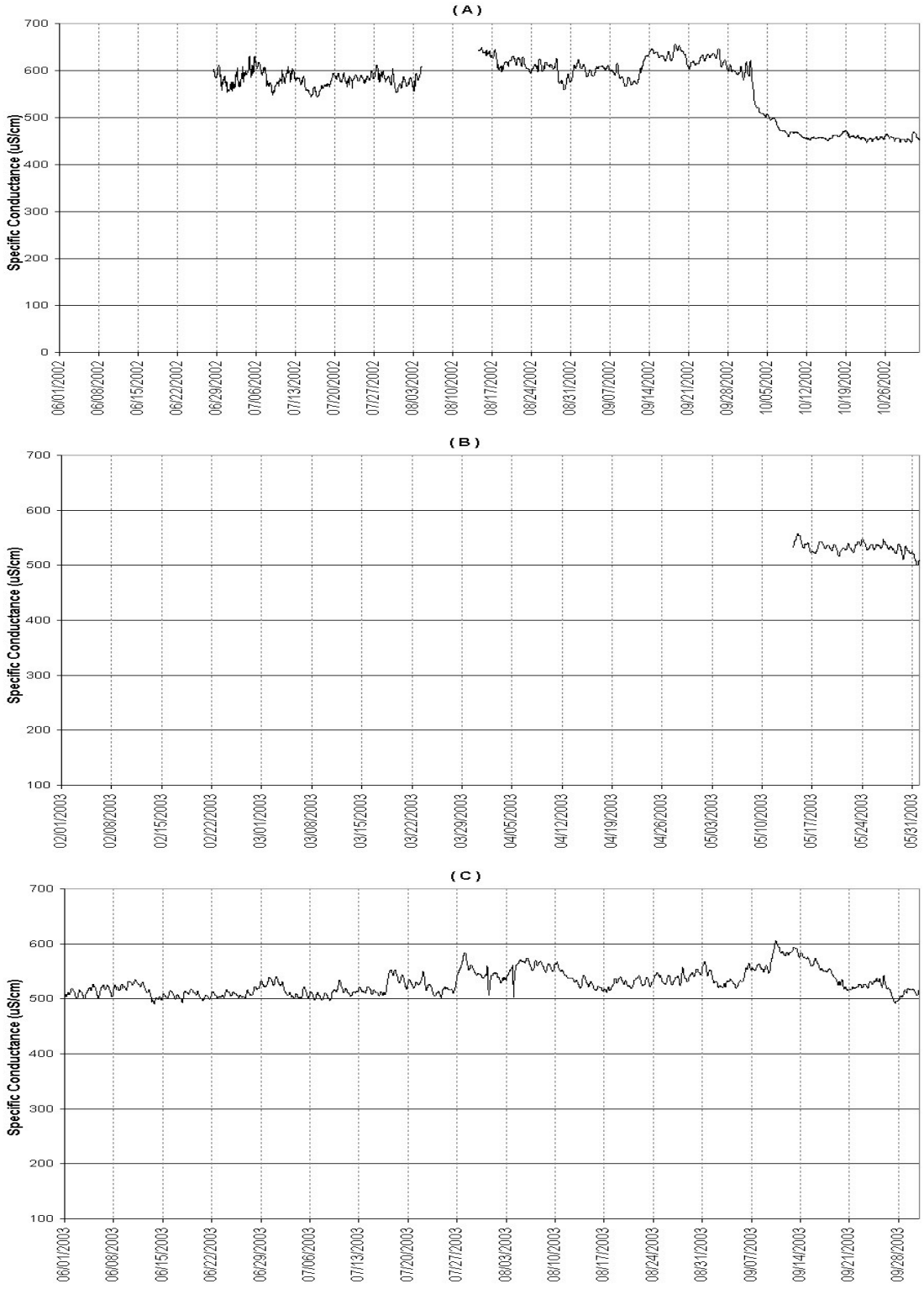


Figure 24. Continuous Conductance Data - Shasta River Near Mouth @ USGS Gage - Collected by USGS: (A) 06/01/02 - 10/31/02, (B) 02/01/03 – 05/31/03, (C) 06/01/03 – 09/30/03.

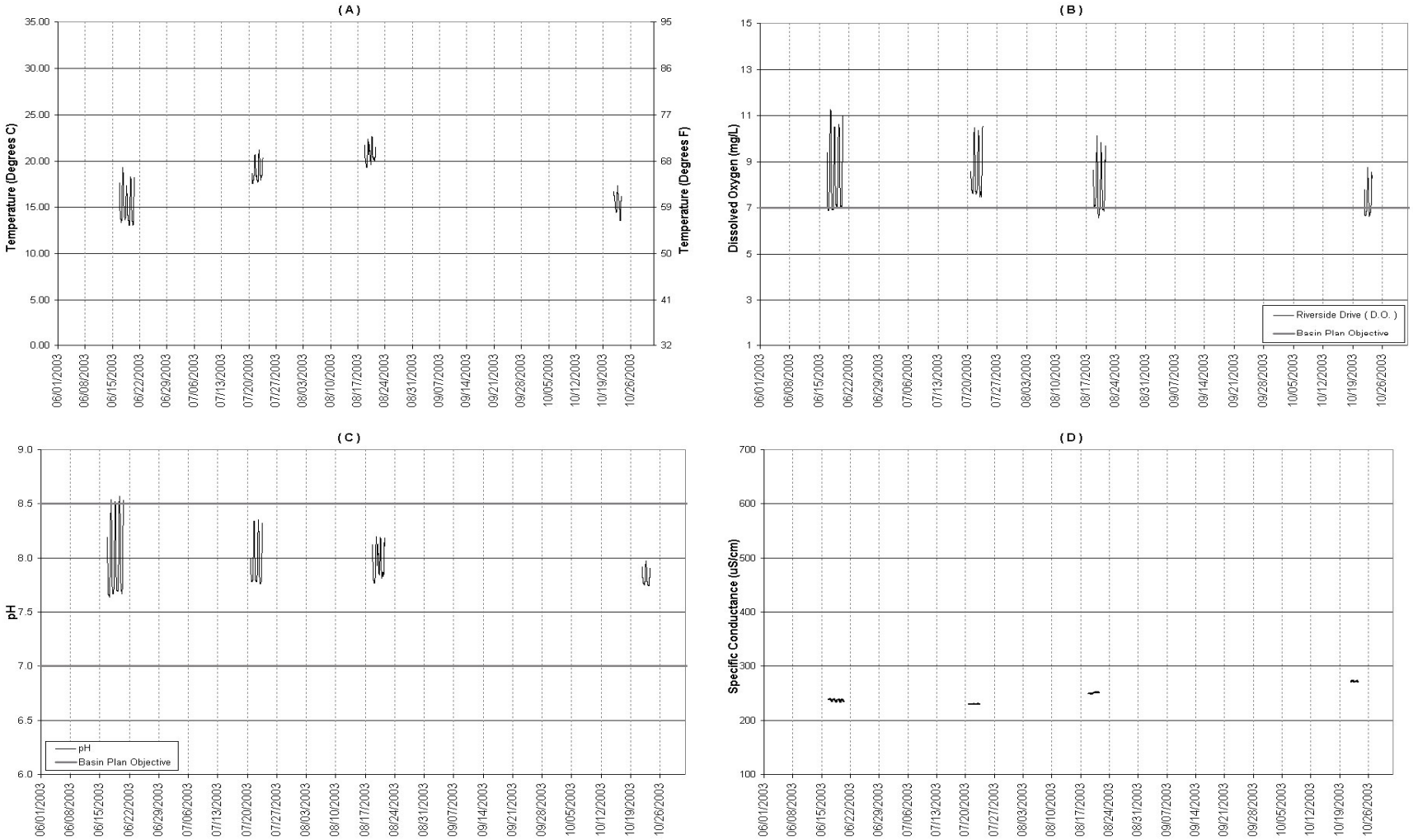


Figure 25. Continuous Sonde Data - Shasta River @ Riverside Drive - Collected by NCRWQCB: 06/01/03 – 10/31/03 (A) Temperature, (B) Dissolved Oxygen, (C) pH, (D) Specific Conductance.

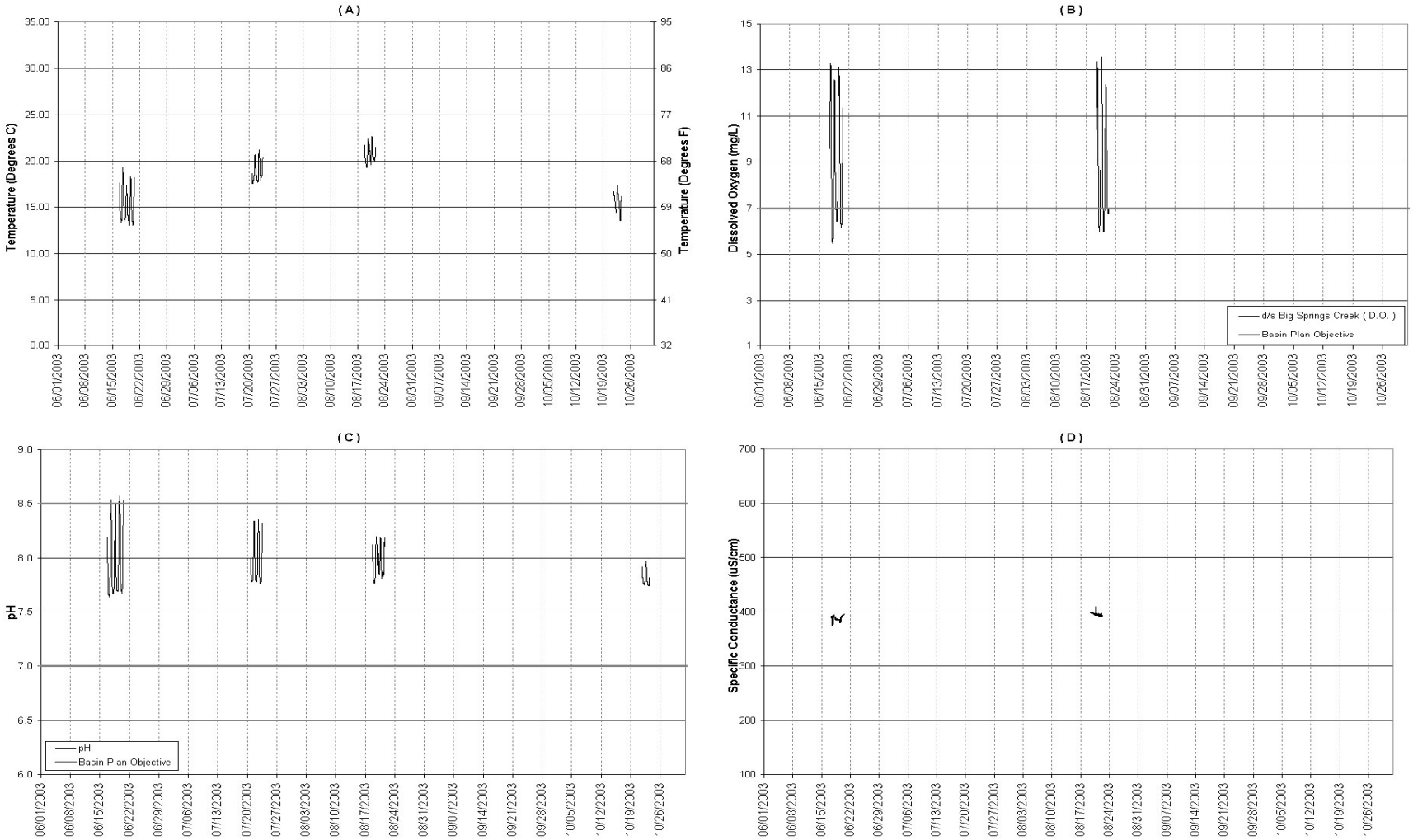


Figure 26. Continuous Sonde Data - Shasta River d/s Big Springs Creek - Collected by NCRWQCB: 06/01/03 – 10/31/03 (A) Temperature, (B) Dissolved Oxygen, (C) pH, (D) Specific Conductance.

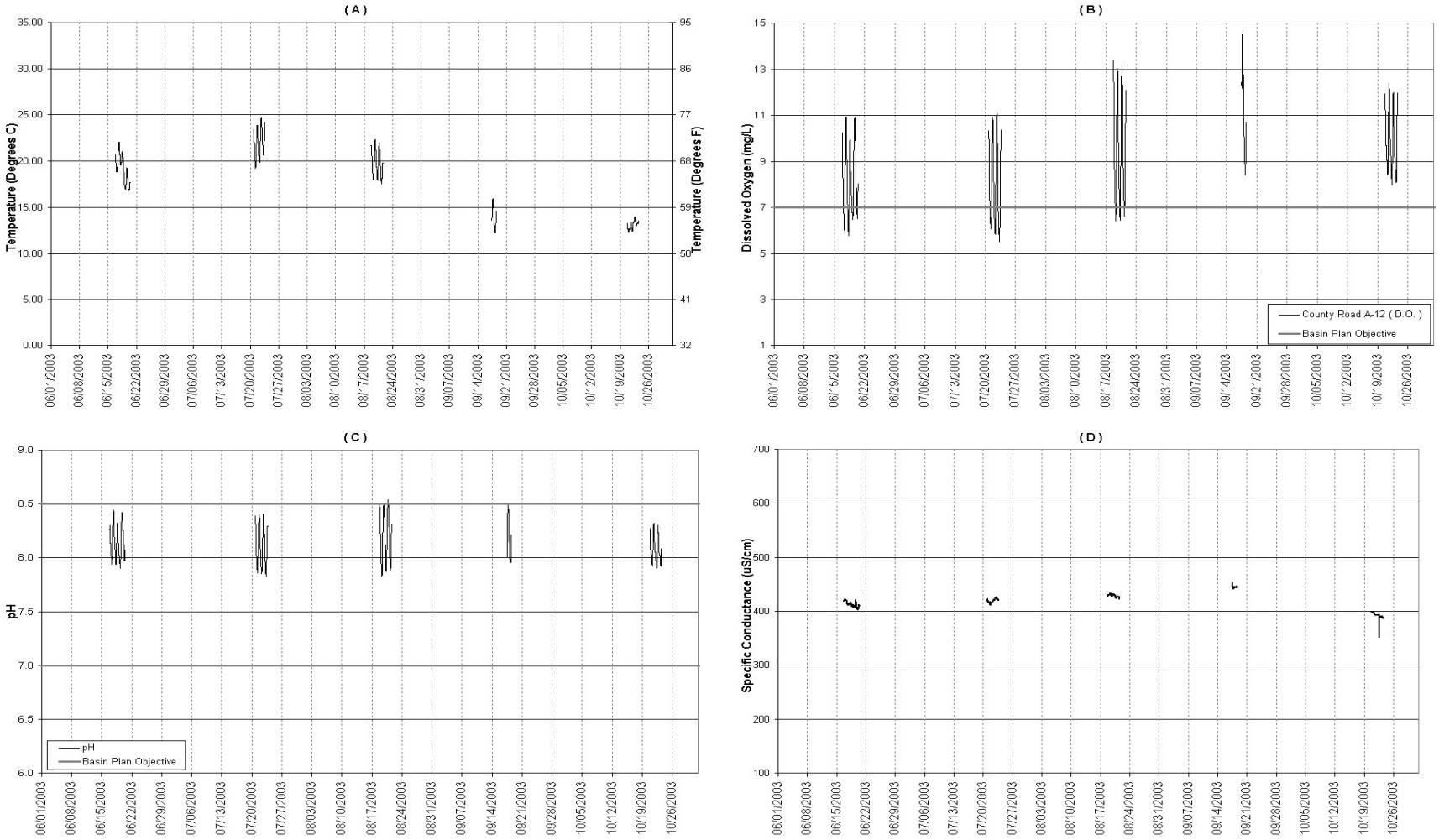


Figure 27. Continuous Sonde Data - Shasta River @ County Road A-12 - Collected by NCRWQCB: 06/01/03 – 10/31/03 (A) Temperature, (B) Dissolved Oxygen, (C) pH, (D) Specific Conductance.

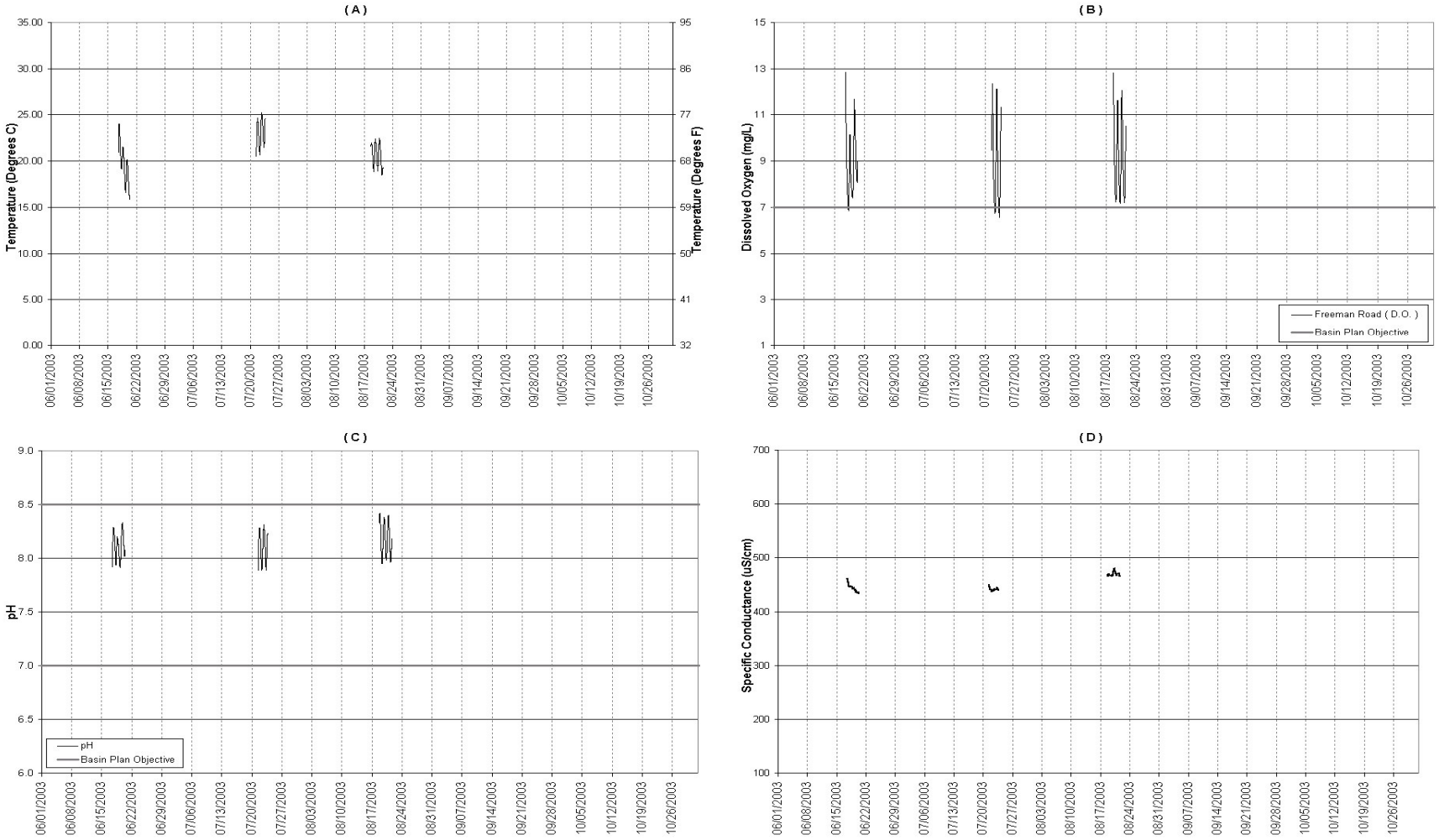


Figure 28. Continuous Sonde Data - Shasta River @ Freeman Road - Collected by NCRWQCB: 06/01/03 – 10/31/03 (A) Temperature, (B) Dissolved Oxygen, (C) pH, (D) Specific Conductance.

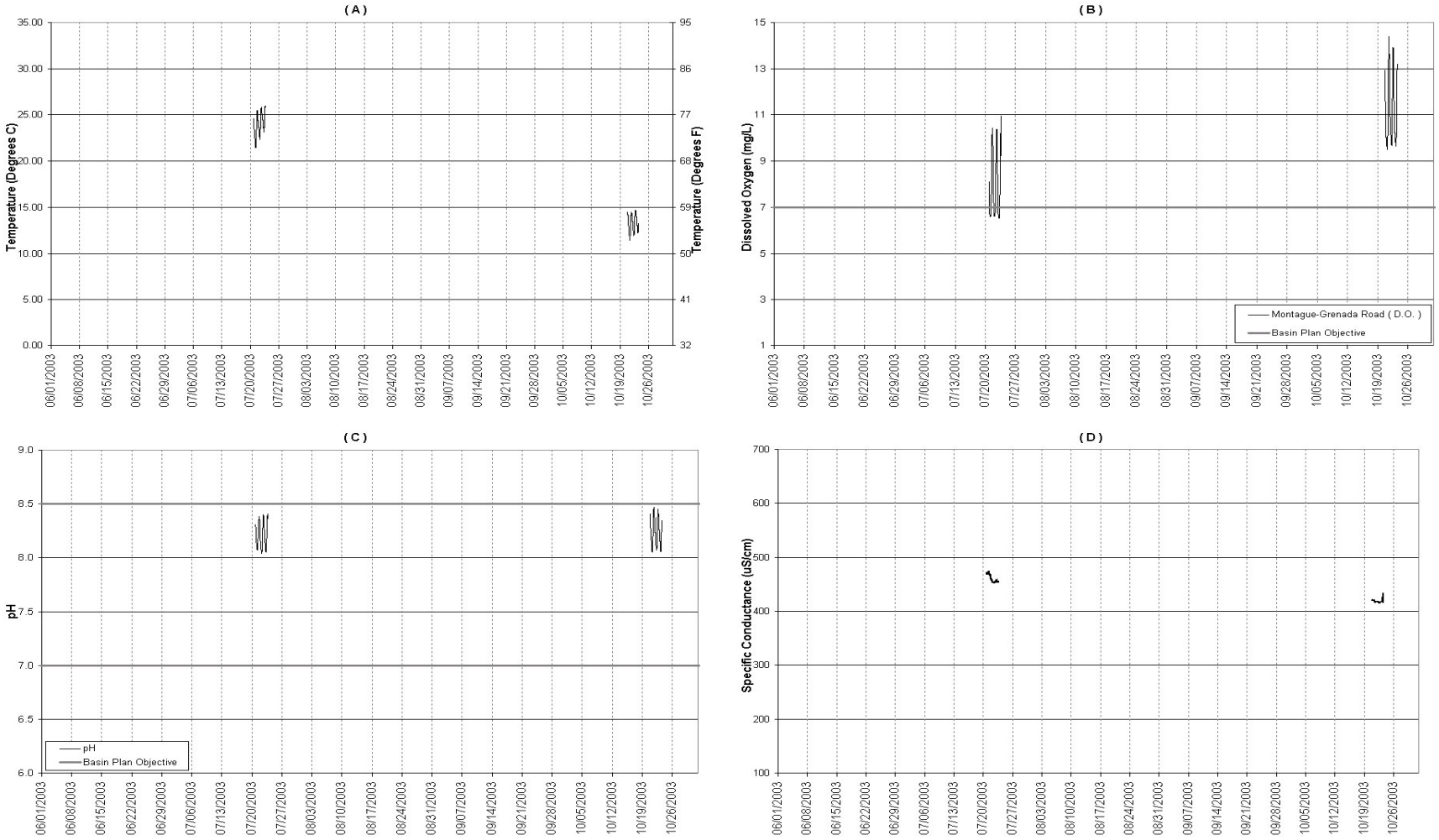


Figure 29. Continuous Sonde Data - Shasta River @ Montague-Grenada Road - Collected by NCRWQCB: 06/01/03 – 10/31/03 (A) Temperature, (B) Dissolved Oxygen, (C) pH, (D) Specific Conductance.

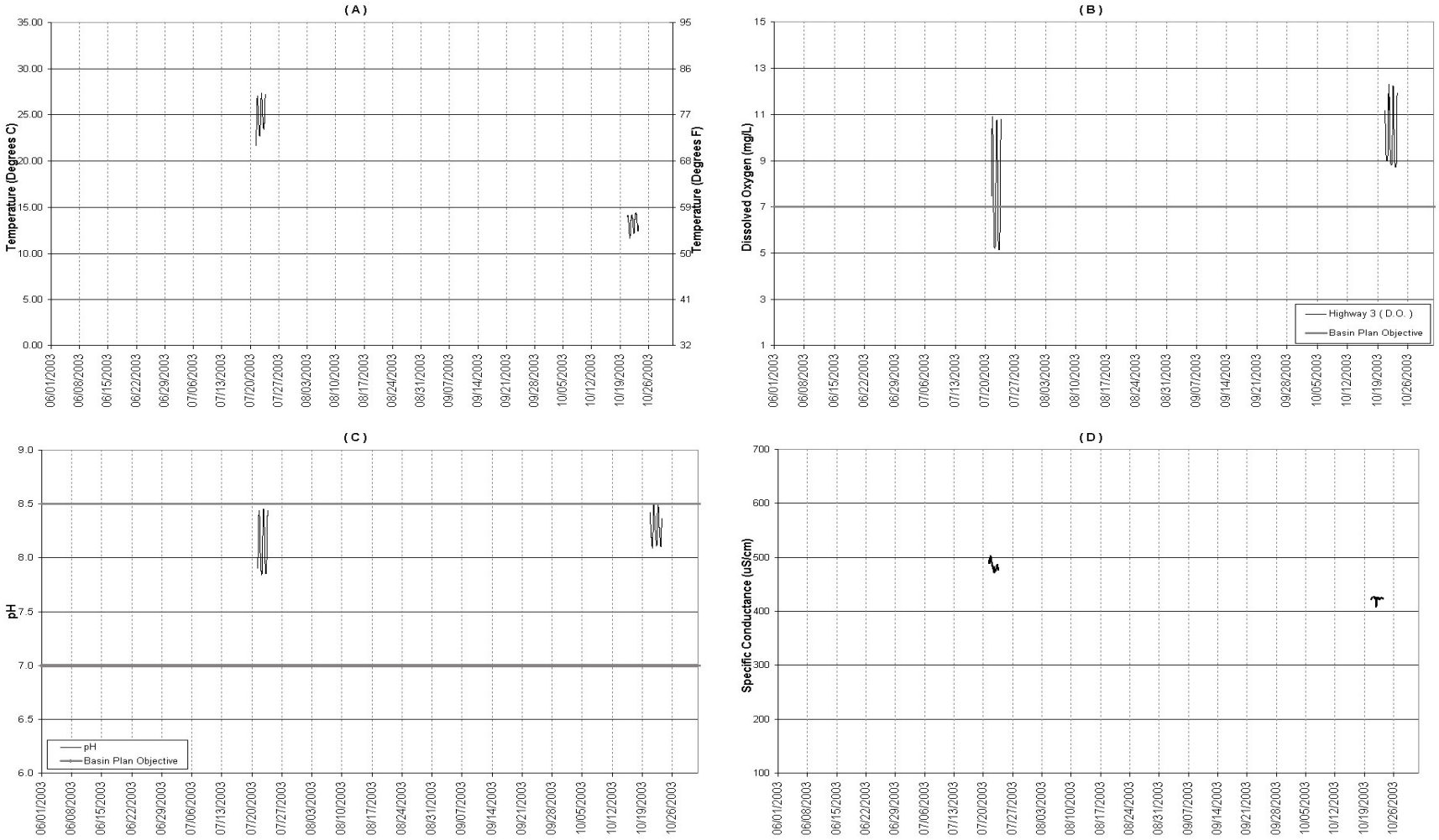


Figure 30. Continuous Sonde Data - Shasta River @ Highway 3 - Collected by NCRWQCB: 06/01/03 – 10/31/03 (A) Temperature, (B) Dissolved Oxygen, (C) pH, (D) Specific Conductance.

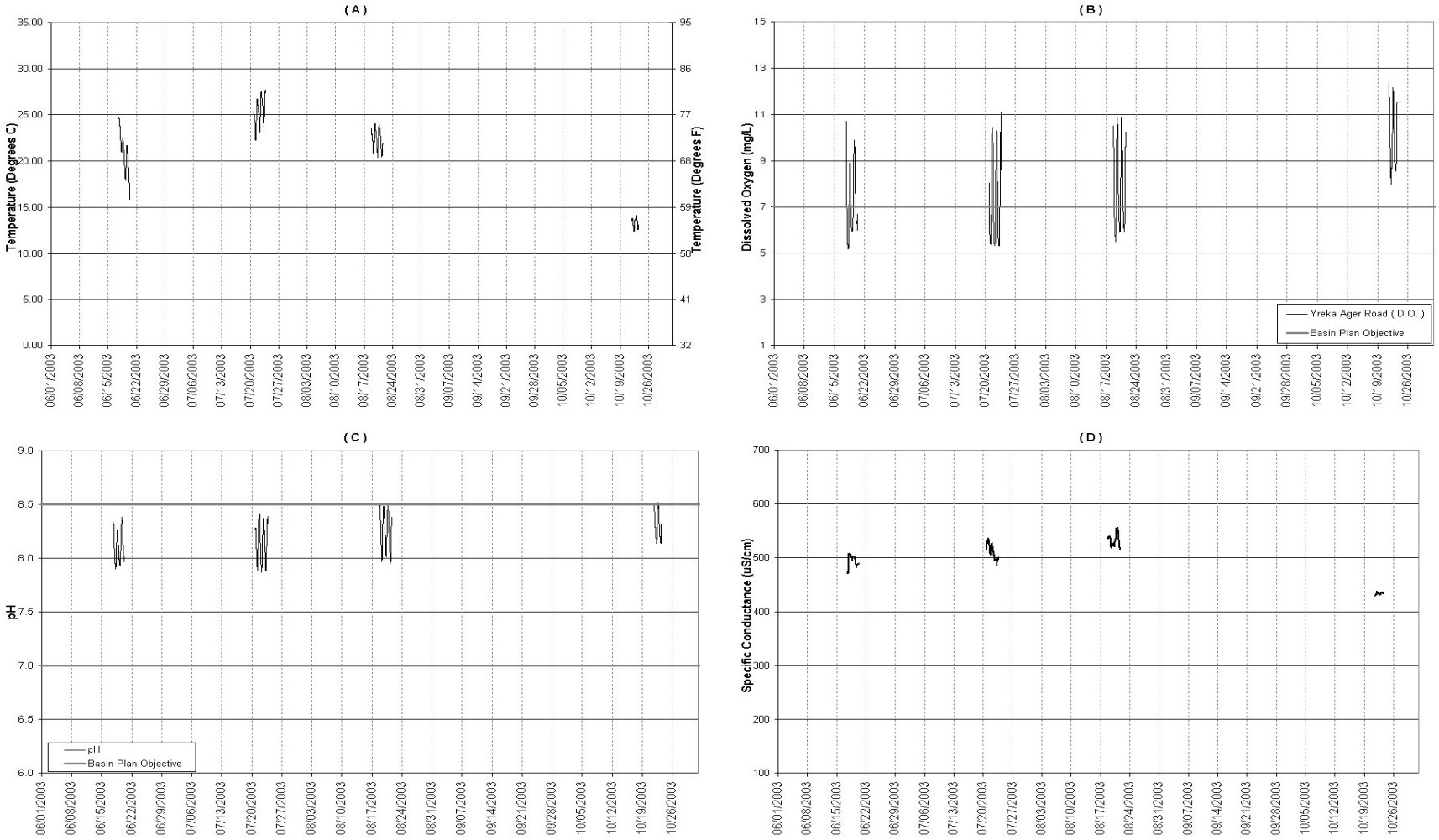


Figure 31. Continuous Sonde Data - Shasta River @ Yreka-Ager Road - Collected by NCRWQCB: 06/01/03 – 10/31/03 (A) Temperature, (B) Dissolved Oxygen, (C) pH, (D) Specific Conductance.

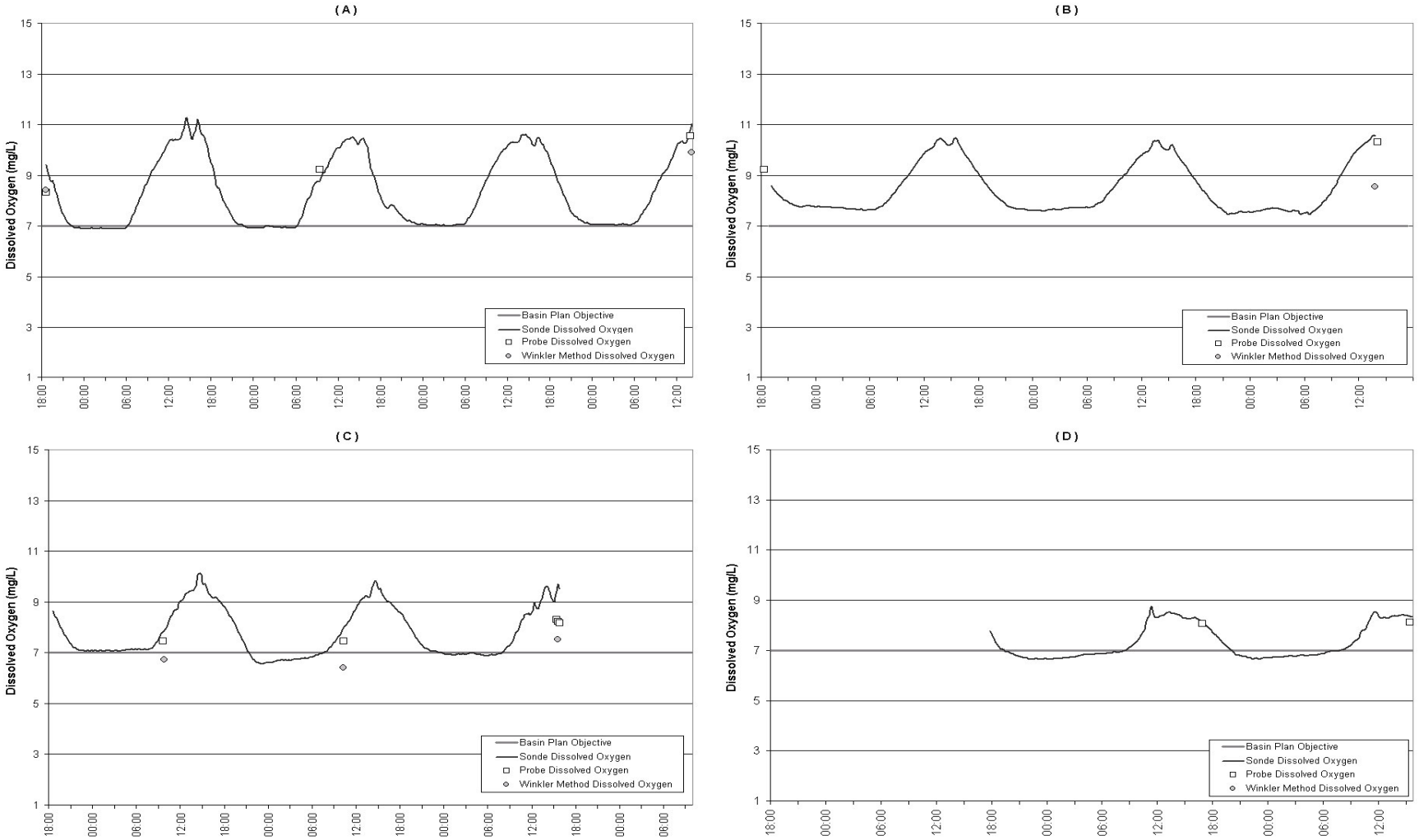


Figure 32. Continuous Dissolved Oxygen Data - Shasta River @ Riverside Drive - Collected by NCRWQCB: (A) 06/16/03 – 06/20/03, (B) 07/20/03 – 07/23/03, (C) 08/18/03 – 08/22/03, (D) 10/20/03 – 10/23/03.

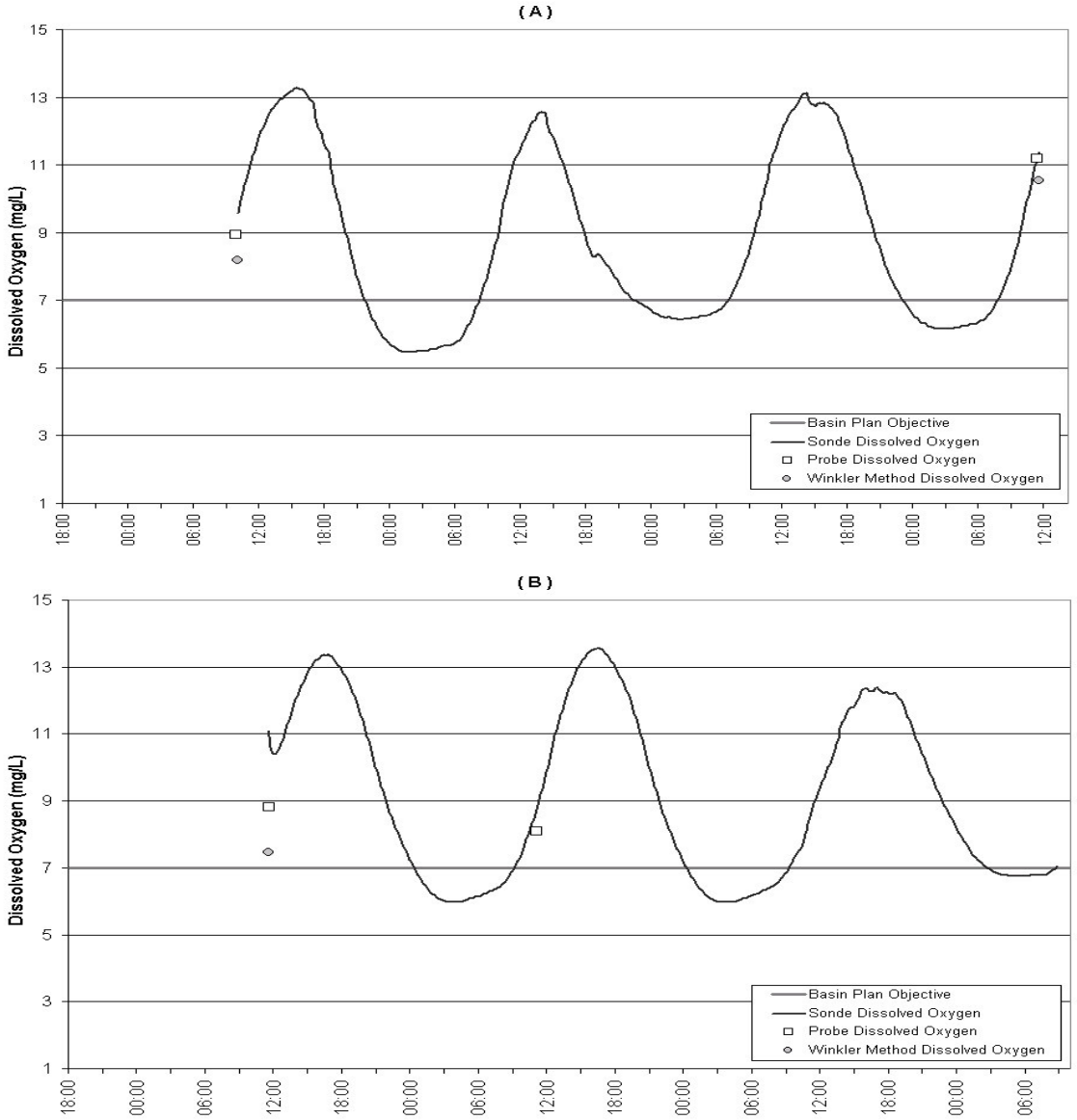


Figure 33. Continuous Dissolved Oxygen Data - Shasta River d/s Big Springs Creek - Collected by NCRWQCB: (A) 06/16/03 – 06/20/03, (B) 08/18/03 – 08/22/03.

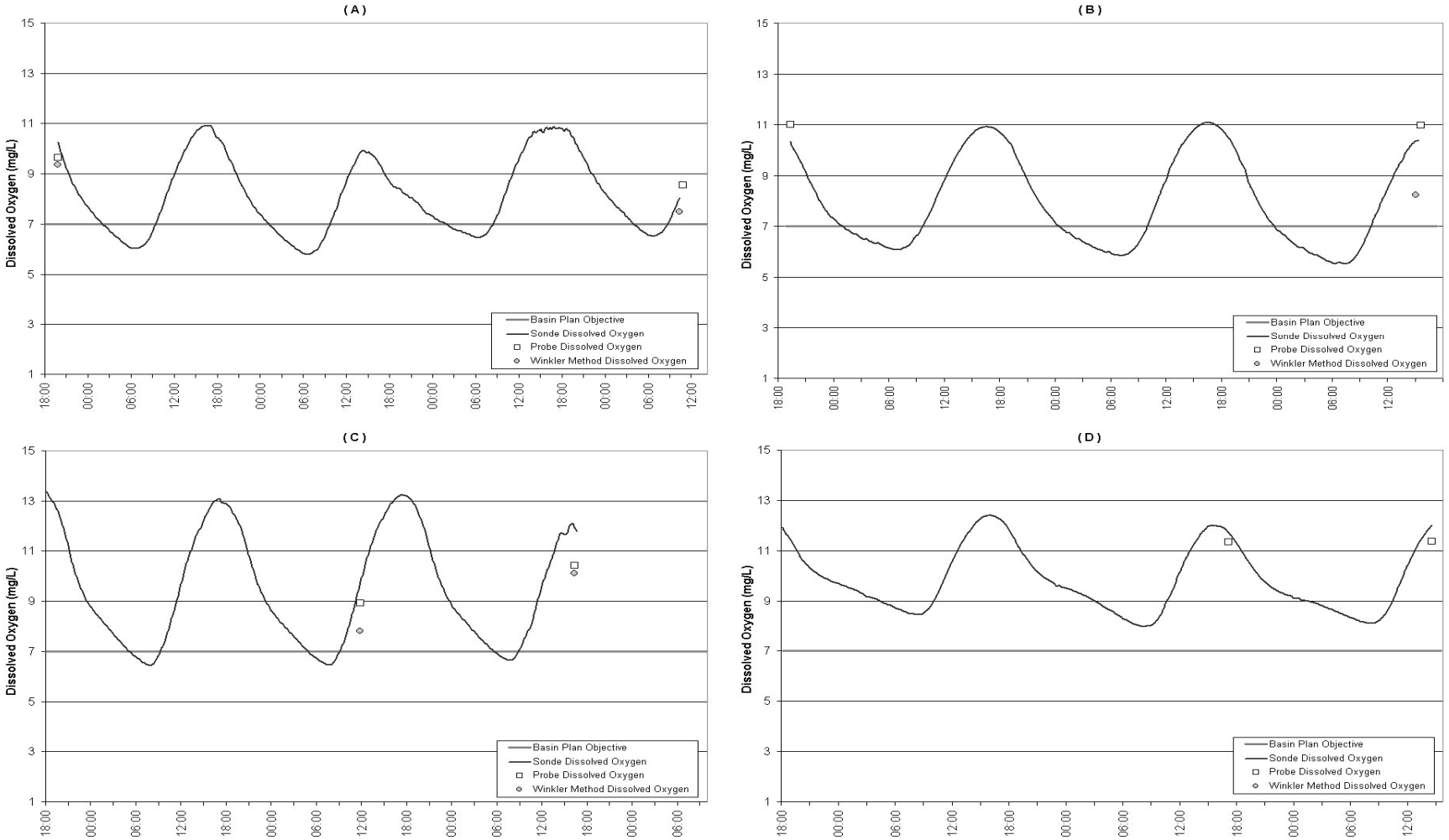


Figure 34. Continuous Dissolved Oxygen Data - Shasta River @ County Road A-12 - Collected by NCRWQCB: (A) 06/16/03 – 06/20/03, (B) 07/20/03 – 07/23/03, (C) 08/18/03 – 08/22/03, (D) 10/20/03 – 10/23/03.

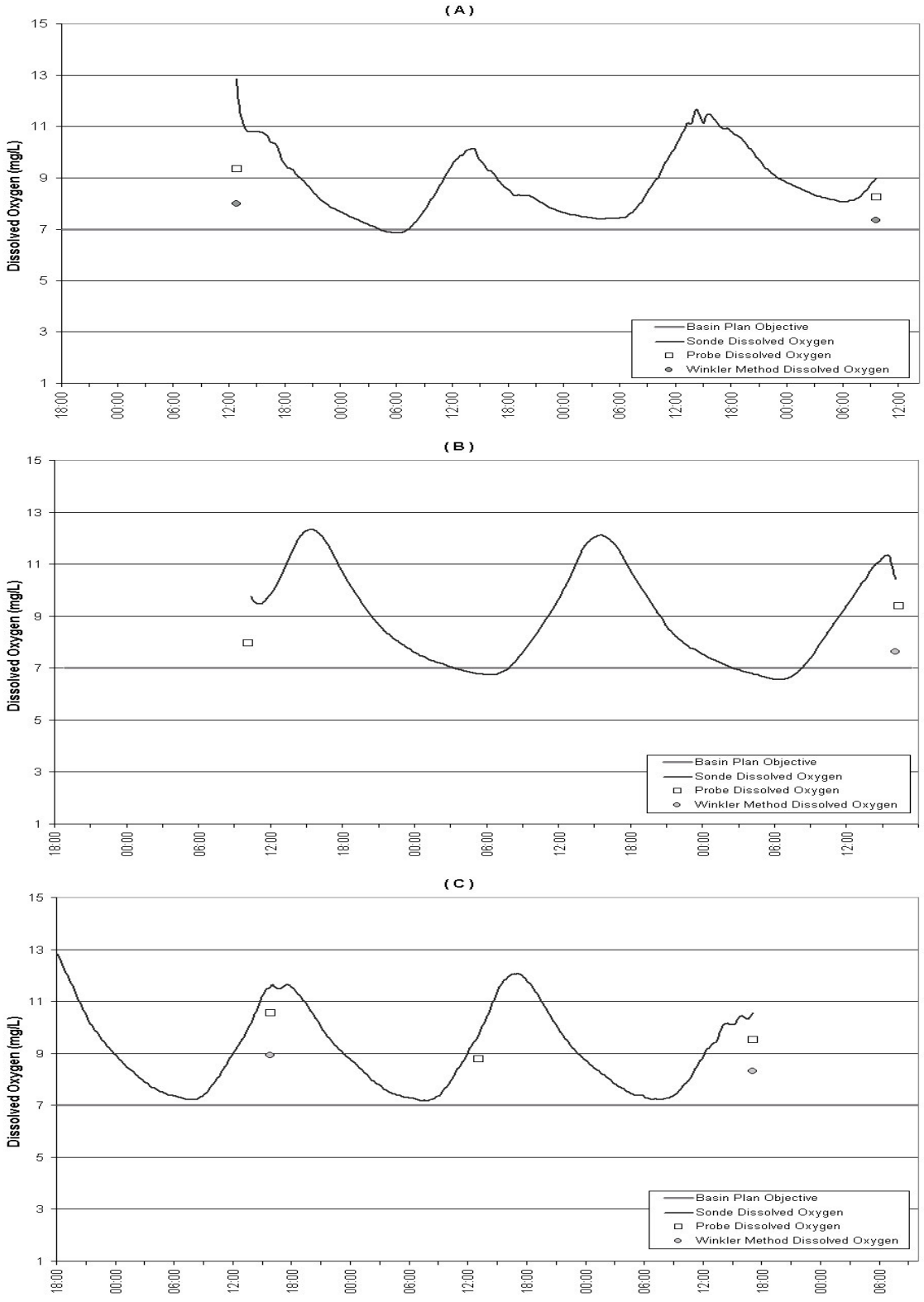


Figure 35. Continuous Dissolved Oxygen Data - Shasta River @ Freeman Road - Collected by NCRWQCB: (A) 06/16/03 – 06/20/03, (B) 07/20/03 – 07/23/03, (C) 08/18/03 – 08/22/03.

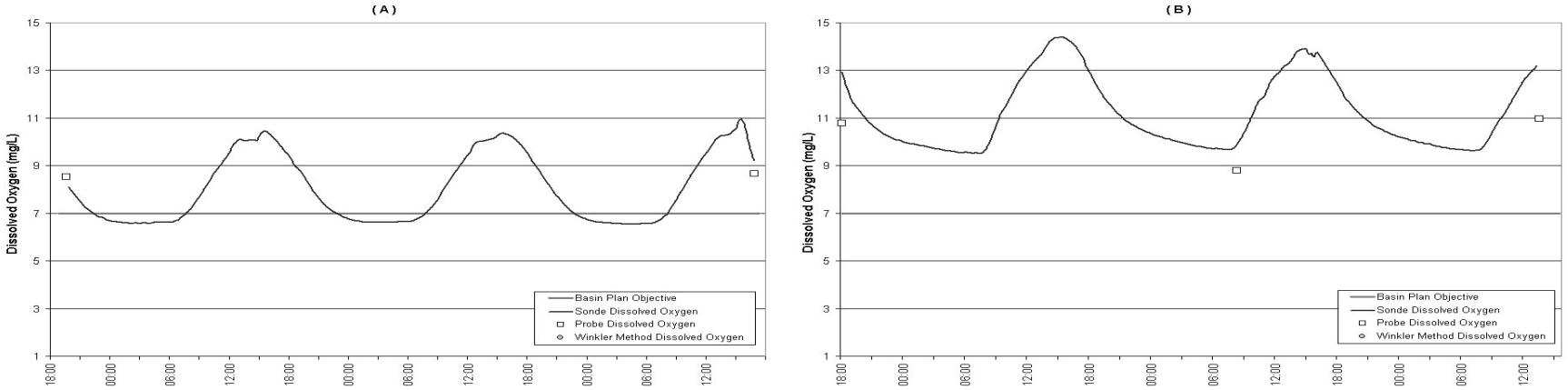


Figure 36. Continuous Dissolved Oxygen Data - Shasta River @ Montague-Grenada Road - Collected by NCRWQCB: (A) 07/20/03 – 07/23/03, (B) 10/20/03 – 10/23/03.

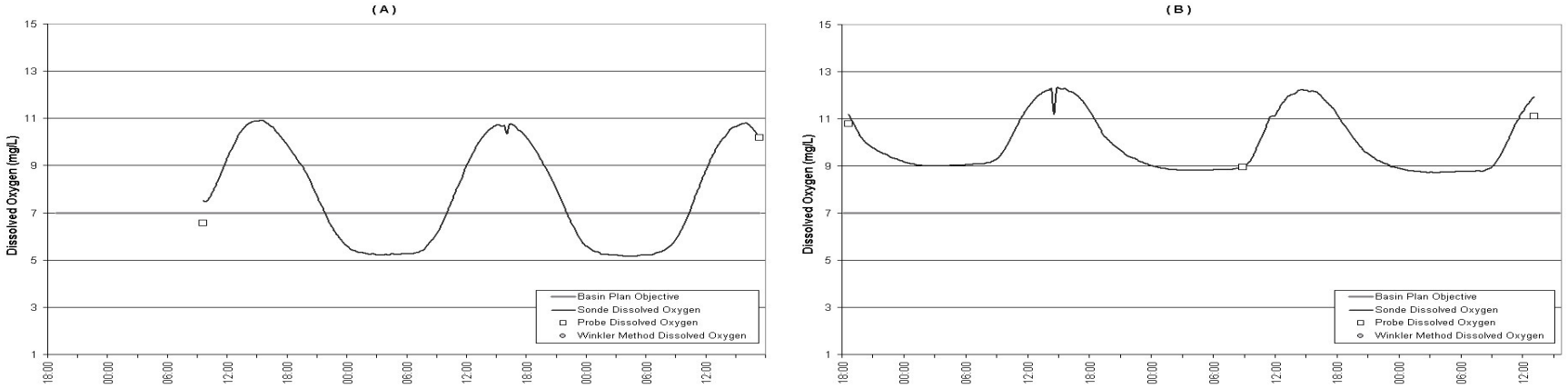


Figure 37. Continuous Dissolved Oxygen Data - Shasta River @ Highway 3 - Collected by NCRWQCB: (A) 07/20/03 – 07/23/03, (B) 10/20/03 – 10/23/03.

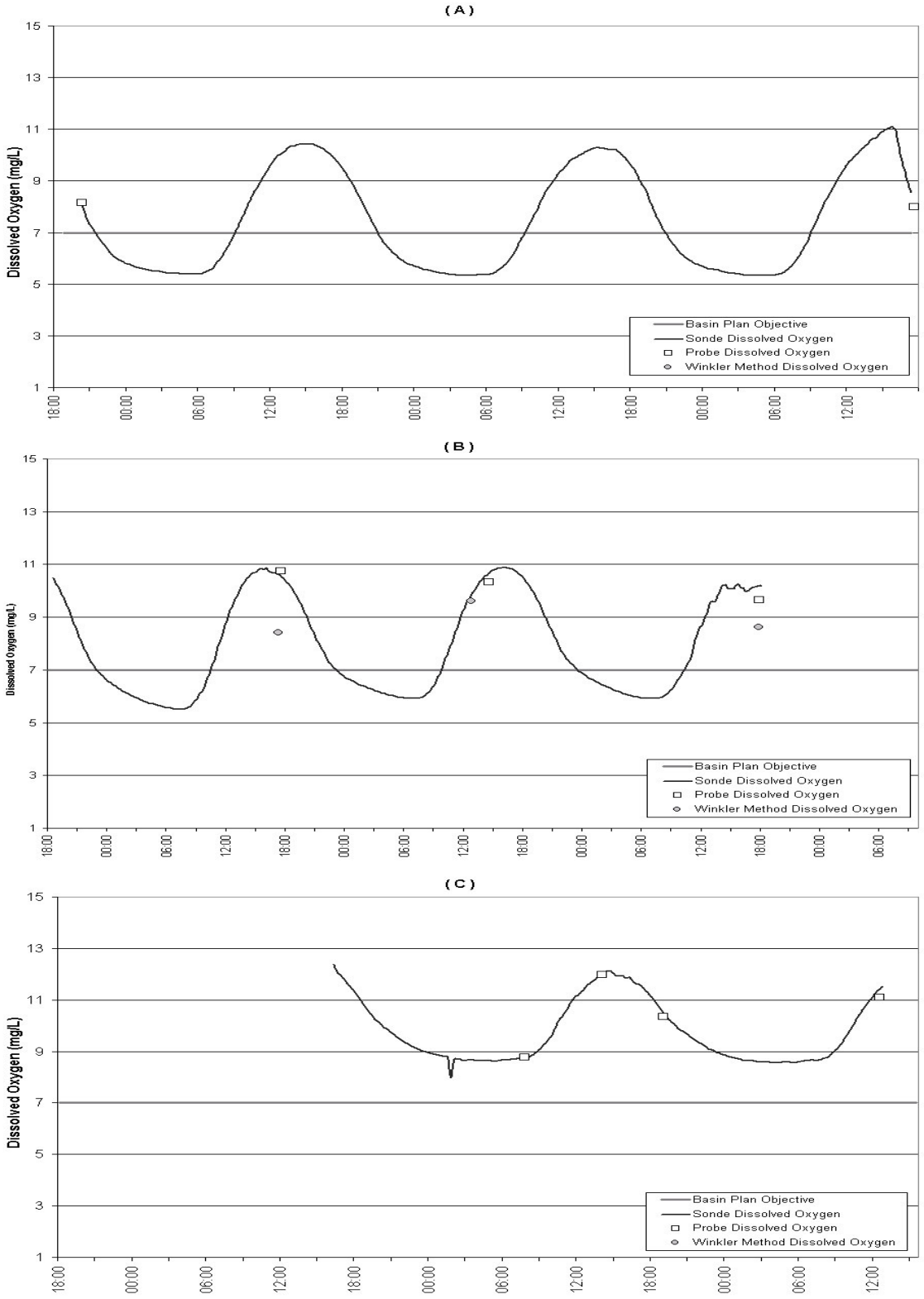


Figure 38. Continuous Dissolved Oxygen Data - Shasta River @ Yreka-Ager Road - Collected by NCRWQCB: (A) 07/20/03 – 07/23/03, (B) 08/18/03 – 08/22/03, (C) 10/20/03 – 10/23/03.

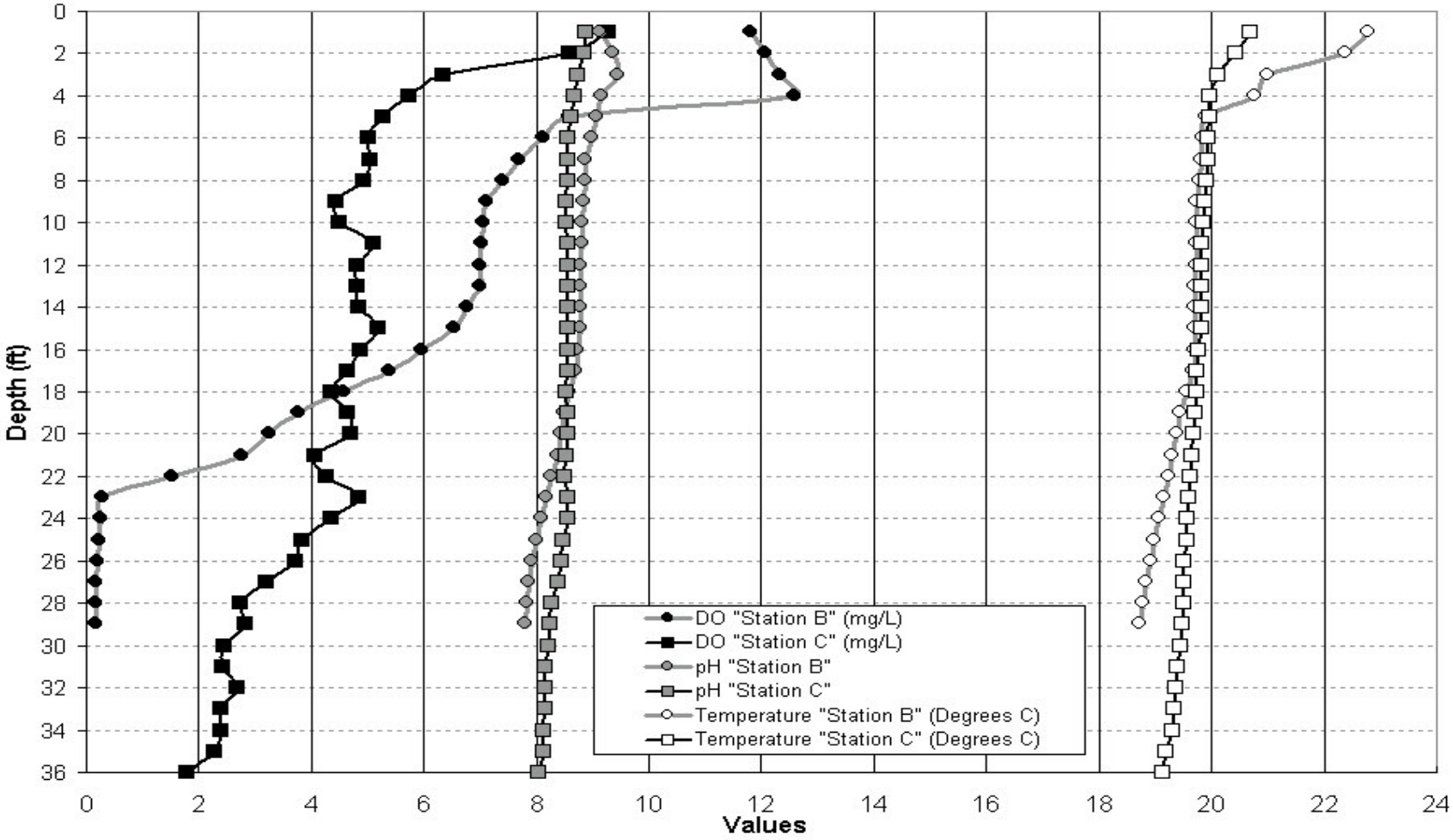


Figure 39. Temperature, Dissolved Oxygen, pH Profile Data – Lake Shastina - Collected by NCRWQCB: 09/10/03.

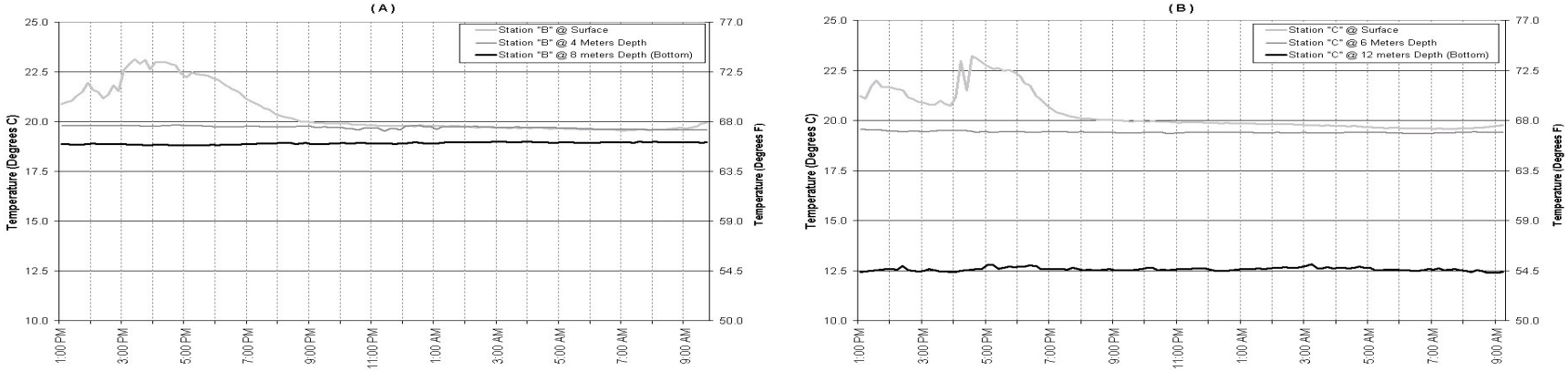


Figure 40. Continuous Temperature Data – Lake Shastina - Collected by NCRWQCB: A) Station "B" 09/10/03, (B) Station "C" 09/10/03.

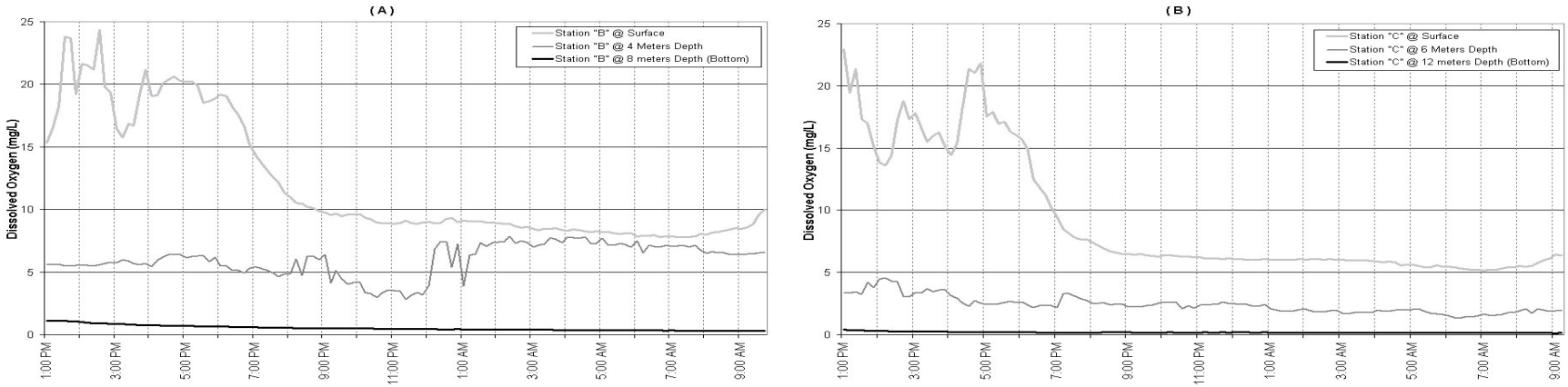


Figure 41. Continuous Dissolved Oxygen Data – Lake Shastina - Collected by NCRWQCB: : A) Station "B" 09/10/03, (B) Station "C" 09/10/03.

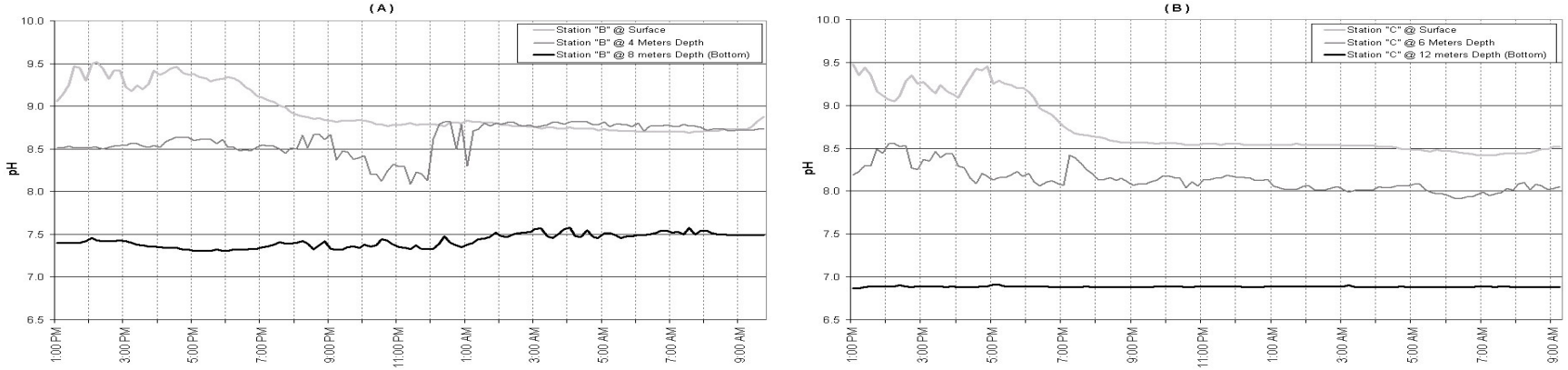


Figure 42. Continuous pH Data – Lake Shastina - Collected by NCRWQCB: A) Station "B" 09/10/03, (B) Station "C" 09/10/03.

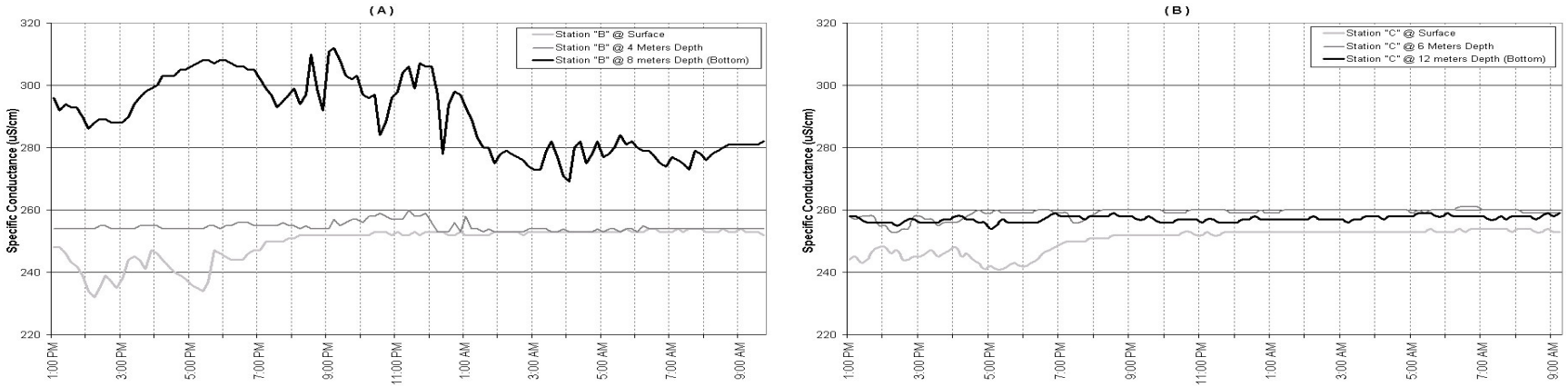


Figure 43. Continuous Specific Conductance Data – Lake Shastina - Collected by NCRWQCB: A) Station "B" 09/10/03, (B) Station "C" 09/10/03.

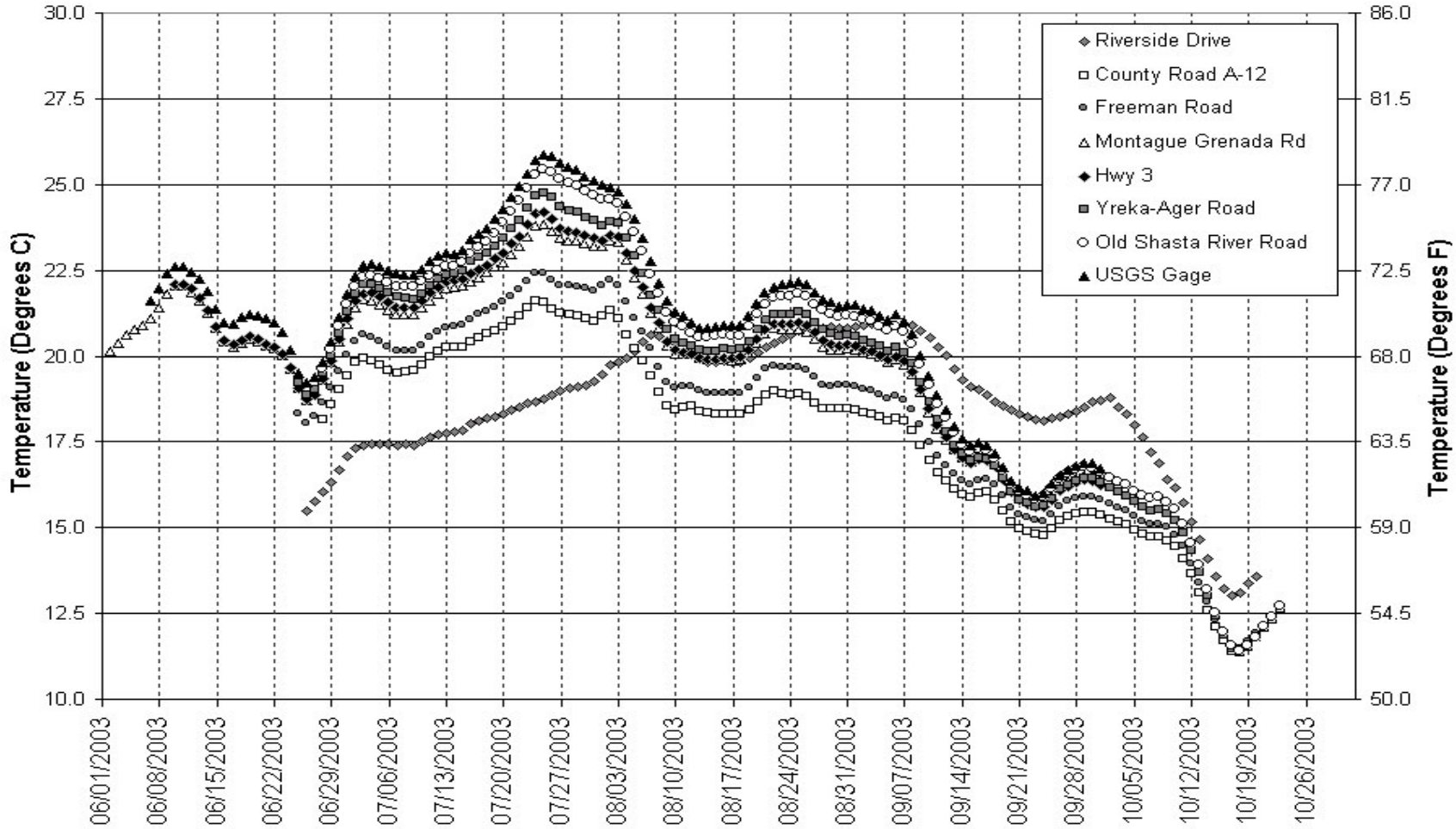


Figure 44. Weekly Average Temperature – Shasta River @ Various Locations - Collected by NCRWQCB & USGS: 06/01/03 – 10/31/03.

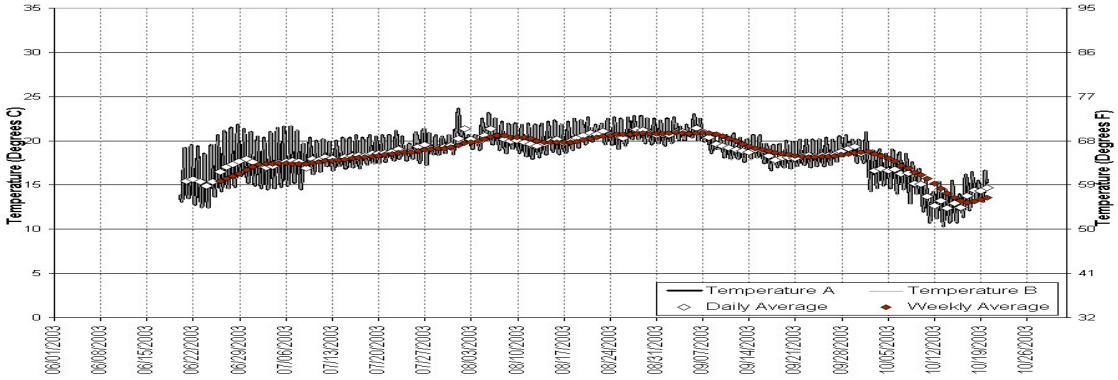


Figure 45. Continuous Temperature Data - Shasta River @ Riverside Drive - Collected by NCRWQCB: 06/01/03 - 10/31/03. (For quality control purposes, two optic StowAway sensors (A and B) were deployed at this site).

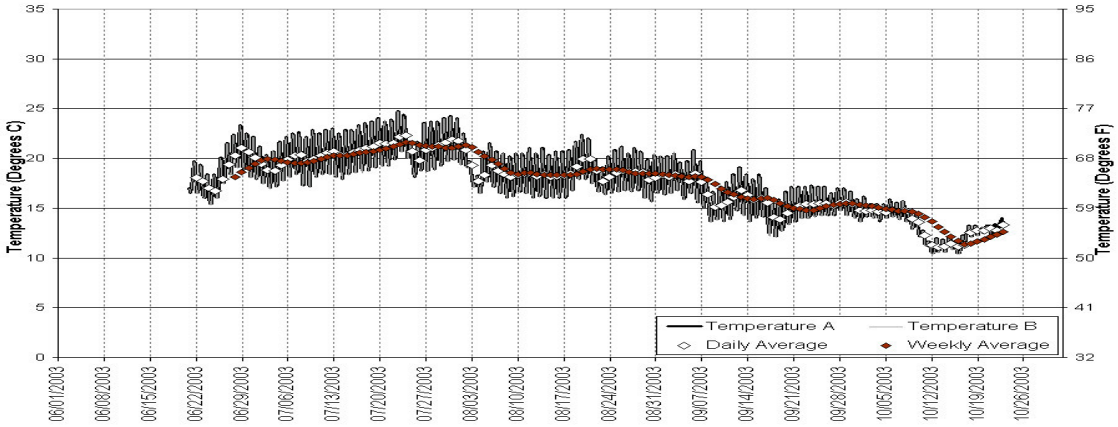


Figure 46. Continuous Temperature Data - Shasta River @ County Road A-12 - Collected by NCRWQCB: 06/01/03 - 10/31/03. (For quality control purposes, two optic StowAway sensors (A and B) were deployed at this site).

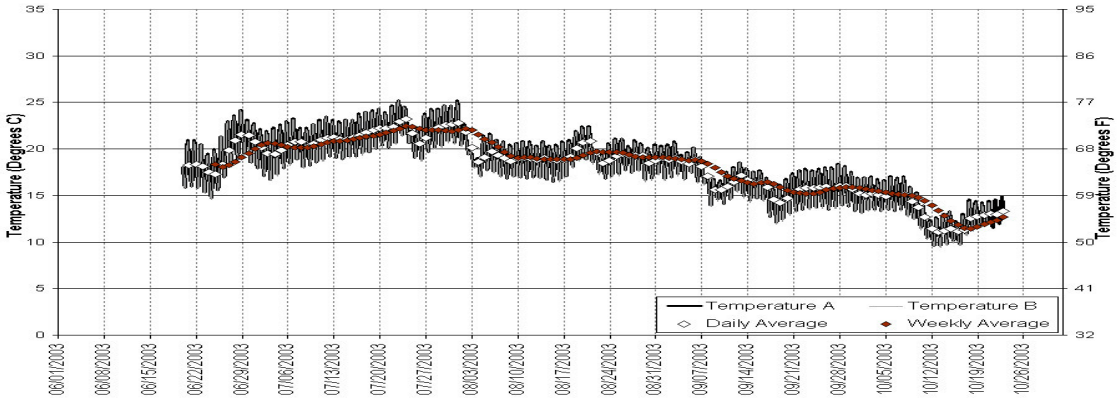


Figure 47. Continuous Temperature Data - Shasta River @ Freeman Road - Collected by NCRWQCB: 06/01/03 - 10/31/03. (For quality control purposes, two optic StowAway sensors (A and B) were deployed at this site).

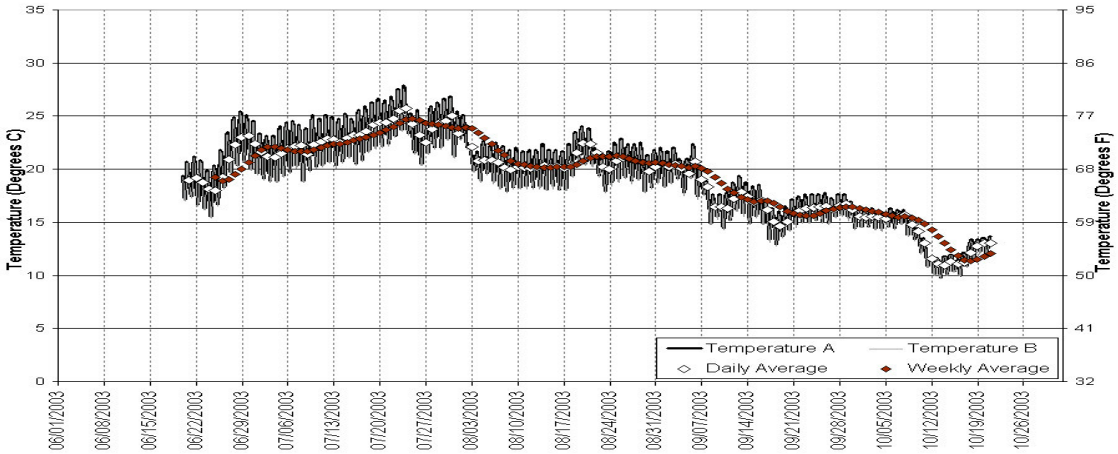


Figure 48. Continuous Temperature Data - Shasta River @ Yreka-Ager Road - Collected by NCRWQCB: 06/01/03 - 10/31/03. (For quality control purposes, two optic StowAway sensors (A and B) were deployed at this site).

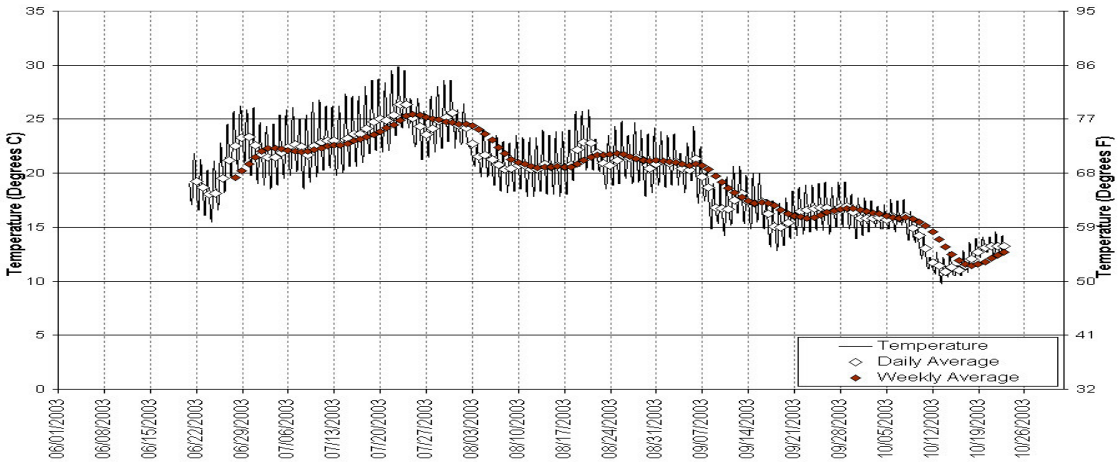


Figure 49. Continuous Temperature Data - Shasta River @ Old Shasta River Road - Collected by NCRWQCB: 06/01/03 - 10/31/03.

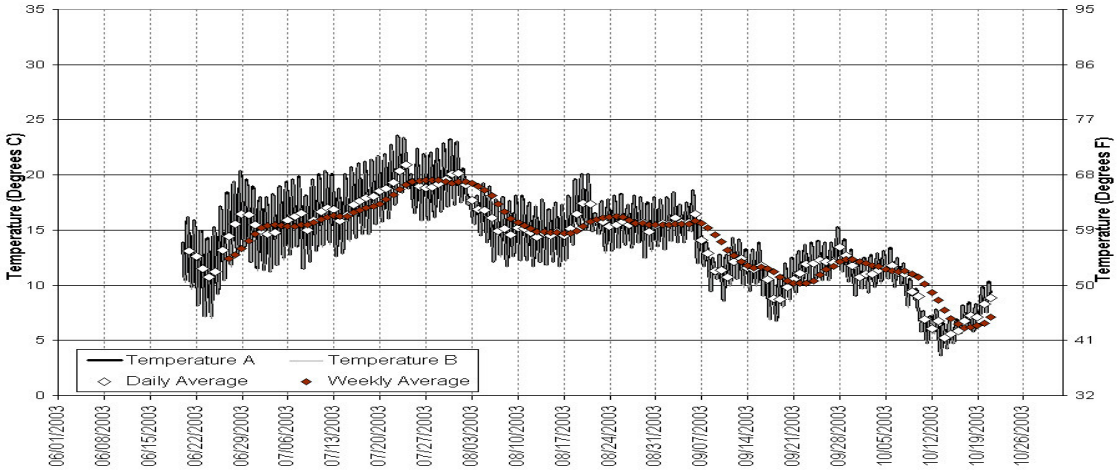


Figure 50. Continuous Temperature Data – Little Shasta River @ Ball Mountain Road - Collected by NCRWQCB: 06/01/03 - 10/31/03. (For quality control purposes, two optic StowAway sensors (A and B) were deployed at this site).

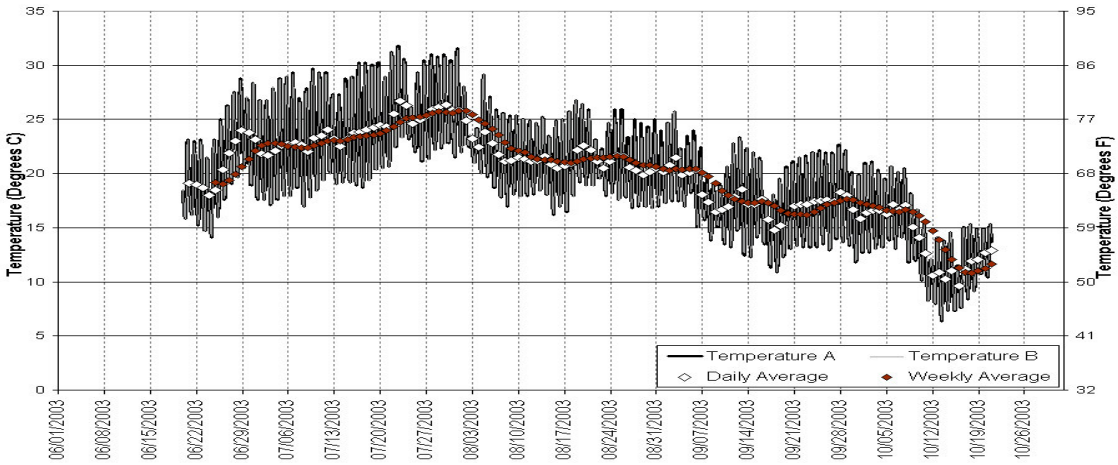


Figure 51. Continuous Temperature Data – Little Shasta River near Mouth - Collected by NCRWQCB: 06/01/03 - 10/31/03. (For quality control purposes, two optic StowAway sensors (A and B) were deployed at this site).

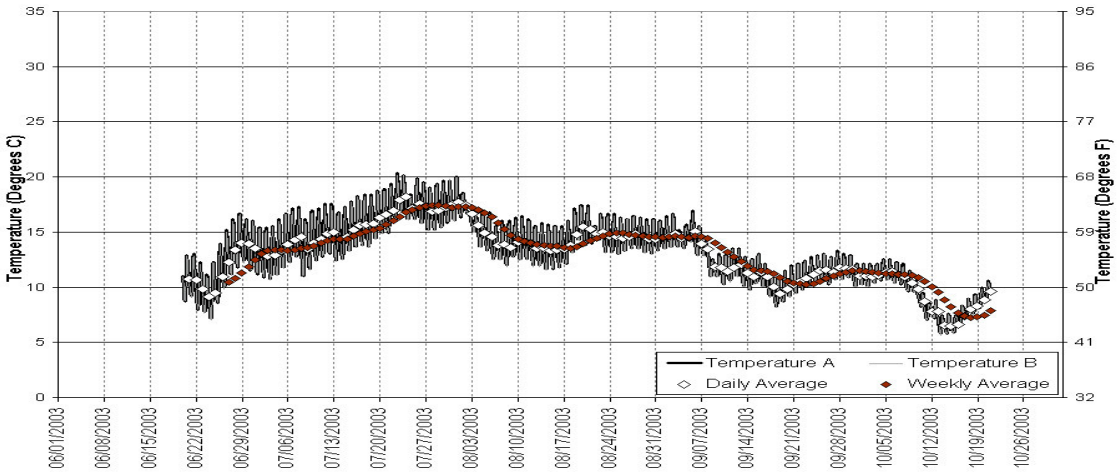


Figure 52. Continuous Temperature Data – Upper Parks Creek - Collected by NCRWQCB: 06/01/03 - 10/31/03. (For quality control purposes, two optic StowAway sensors (A and B) were deployed at this site).

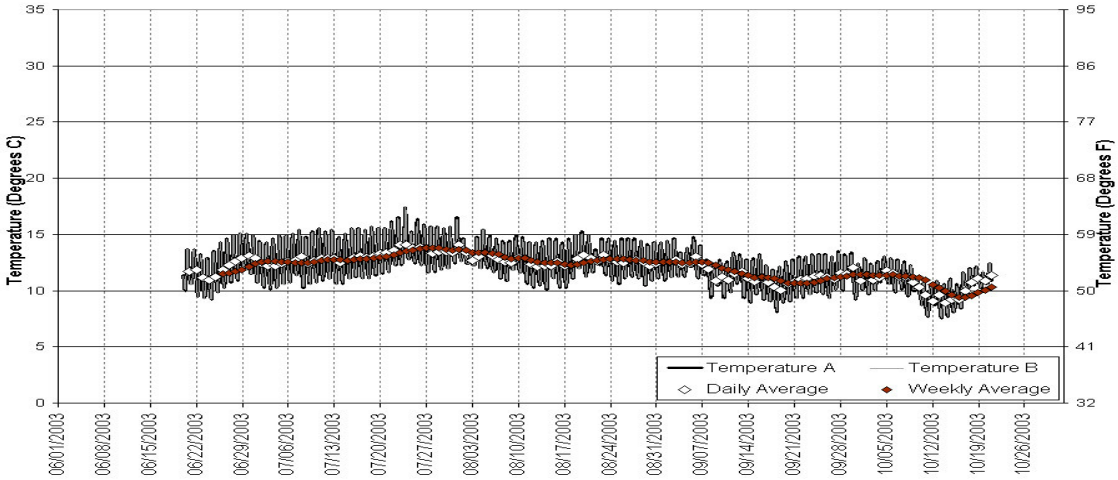


Figure 53. Continuous Temperature Data – Boles Creek - Collected by NCRWQCB: 06/01/03 - 10/31/03. (For quality control purposes, two optic StowAway sensors (A and B) were deployed at this site).

Appendix 1: Methodology for Correcting Continuous Dissolved Oxygen Data from USGS Datasonde Sensors and Associated Data Uncertainty

NOTE: This appendix is excerpted from a USGS report by Flint and co-workers (2004), which, as of May 5, 2004, is in draft and is subject to revision.

The continuous field measurement of dissolved oxygen is difficult and requires frequent site visits for probe maintenance and cleaning due to biofouling and recalibration for sensor drift. Data are thus corrected to maintain the best accuracy according to field calibrations. In order to illustrate reliability of USGS dissolved oxygen data collection and data accuracy, the following discussion describes the theory of dissolved oxygen measurements and inherent errors associated with the measurements. USGS protocols for probe deployment and maintenance, data processing, and reporting are briefly described with information excerpted from Wagner and others (2000). This publication and several other publications are available for more details on USGS protocols (Radke and others, 1998; Wilde and Radke, 1998). Additional discussion regarding supersaturated dissolved oxygen conditions comes from studies in Oregon lakes and rivers (Doyle and Caldwell, 1996; Kelly, 1997; Rounds and others, 1998; Wood and Rounds, 1998). Examples of data collected on the Shasta River for 2002 and 2003 are used to illustrate data uncertainty in the Lower Klamath River Basin.

Theory and Measurement of Dissolved Oxygen

The DO concentration in surface water is related primarily to atmospheric reaeration and photosynthetic activity of aquatic plants (*Radtke and others, 1998*). The range of observed DO in surface waters typically is from 2 to 10 milligrams per liter (mg/L) at 20 °C. The value for 100-percent saturation of DO decreases with increased temperature and salinity, and increases with increased atmospheric pressure. Occasions of excess oxygen (supersaturation) often are related to extreme photosynthetic production of oxygen by aquatic plants as a result of nutrient (nitrogen and phosphorus) enrichment, sunlight, and low-flow conditions. Occasions of saturated oxygen commonly are related to cascading flow conditions, both natural and artificial. DO may be depleted by inorganic oxidation reactions or by biological and chemical processes that consume dissolved, suspended, or precipitated organic matter (*Hem, 1989*).

The most commonly used technique for measuring DO concentrations with continuous water-quality sensors is the amperometric method, which measures DO with a temperature-compensated polarographic membrane-type sensor. While polarographic membrane-type sensors generally provide accurate results, they commonly are sensitive to temperature and water velocity and are prone to fouling. Because the permeability of the membrane and solubility of oxygen in water change as functions of temperature, barometric pressure, and salinity, it is critical that the DO sensors be calibrated. DO

sensors are prone to inaccuracies from algal fouling, sedimentation, low velocity, and very high velocities. They also experience drift in the electronics, and can experience leakage of the membrane. A complete discussion of DO calibration, measurement, and limitations can be found in *Radtke and others (1998).*

USGS Protocols for Collecting, Processing, and Reporting Continuous Dissolved Oxygen Data

Lower Klamath River Basin studies implemented YSI 6920 Data Sonde meters with dissolved oxygen sensors. Implementation of the meters during the 2002 and 2003 field seasons followed standard USGS protocols for the collection of continuous dissolved oxygen data, calibration of meters, and correction and reporting of data (Wilde and Radtke, 1998).

Collecting field measurements of dissolved oxygen

Maintenance frequency of DO sensors generally is governed by the fouling rate, and this rate varies by sensor type, hydrologic environment, and season. In addition to fouling problems, physical disruptions (such as pump failure, recording equipment malfunction, sedimentation, electrical disruption, debris, or vandalism) or battery failure also may require additional site visits.

During a site visit the sensor inspection is done to provide an ending point for the interval of water quality record since the last service visit, a beginning point for the next interval of water-quality record, and verification that the sensor is working properly. This is accomplished by recording the initial sensor readings, servicing the sensors, recording the cleaned sensor readings, performing a calibration check of sensors by using the 100% oxygen saturated standard, and if the readings of the DO sensor are outside the range of acceptable differences, +/- 0.3 mg/L, recalibrating the sensor. The difference between the initial sensor reading and the cleaned sensor reading is the sensor error as a result of fouling; the difference between the calibration-check reading and calibrated-sensor reading, if necessary, is a result of drift.

Data-processing procedures

Corrections to data should not be made unless the causes of errors can be validated or explained by information or observations in the field notes or by comparison to information from adjacent stations. The initial data evaluation checks the success of the transfer of raw field data (instrument readings) to the office data base and provides the opportunity for initial checks to evaluate and correct erroneous data. The application of corrections and shifts allows data to be adjusted to compensate for errors that occurred during the service interval as a result of environmental or instrumentation effects. The sequence for determining the type and degree of measurement error in the field for DO

generally is for fouling, then drift. If the deviation between actual value and sensor reading exceed the criterion for water-quality data shifts, a correction is required. The correction is a linear interpolation over the time between sensor inspections. The allowable limit of +/- 0.3 mg/L is a minimal requirement.

Identification of electronic drift or loss of sensor sensitivity should be distinguished from fouling drift, if at all possible. The degree of fouling is determined from the difference between sensor measurements before and after the sensors are cleaned and is assumed to occur linearly with time between sensor checks. A calibration drift is an electronic drift in the equipment from the last time it was calibrated and is determined by the difference between readings of a cleaned sensor in standards or buffers and a calibrated sensor. If, after checking, the deviation from calibrations is within the calibration criteria of the sensor, then no sensor drift is present. Drift is assumed to occur at a constant rate across the service interval. If the sensor readings exceed the shift criteria of 0.3 mg/L, then the correction is a linear interpolation over the time between calibration checks.

Systematic adoption of a standardized final data evaluation process, including maximum allowable limits and publication criteria are used by USGS District offices, which have established quality-control limits for shifting data. These commonly are referred to as "maximum allowable limits." If the recorded values differ from the field-measured values by more than the maximum allowable limits, the data are not published. For DO, the maximum allowable limit is 2.0 mg/L. This is considered a minimum standard for quality, and Districts are encouraged to establish stricter requirements. Even with the establishment of maximum allowable limits, professional judgment by the hydrographer still is needed in record processing.

Uncertainty in Dissolved Oxygen Data Collection and Processing

Although DO probes are designed to operate linearly, biofouling with time is most likely not a linear function. To the best of our knowledge, few studies have been conducted to measure rates of biofouling and/or instrument drift, and it is not clear exactly how a biofilm affects recorded DO levels, though it likely varies according to numerous factors, including photo-intensity, time of day, temperature, etc. Given these uncertainties, it is USGS' practice to apply a time-prorated linear data correction to DO data records that exhibit biofouling and instrument drift and report the recorded levels of DO with a qualitative rating of the data. The USGS is one of the only agencies that correct DO data.

Dissolved oxygen data on the Shasta River, 2002-2003

Dissolved oxygen concentrations were measured at three locations in the Shasta River from June through November of 2002, and at four locations from April through September of 2003 (Table 1). To illustrate the methods of data processing, the following data and calculations are included: (1) data following the initial data evaluation, which

checks the success of the transfer of raw field data (instrument readings) to the office database and provides the opportunity for initial checks to evaluate and correct erroneous data, (2) computed data following corrections and shifts, and (3) dissolved oxygen at saturation calculated from measured water temperature and atmospheric pressure (average values on the basis of measurements during site visits) (Figures 1 through 4). Occasional corrections for biofouling and drift are evident, more often as decreases in the computed data, although occasionally as increases. There are generally large diurnal fluctuations in the data in mid to late summer, especially at the upper 3 sites where the water is shallower and more slowly moving.

For purposes of example, the site at Edgewood (Figure 4) has site visits noted on the figure. At that site, the instrument was deployed in 2002 at the bottom of an approximately 50-m long riffle. In 2003 the monitor was relocated to above the riffle. Corrections were made following site visits for biofouling in 2002, and for biofouling and drift in 2003 according to Table 2. Calibrations were performed monthly in 2002, and at every site visit in 2003. Corresponding corrections and shifts to the data can be seen as linear prorated changes.

Although the measured DO values commonly exceed the solubility of DO, indicating supersaturated conditions, only three times did the entire diurnal cycle remain supersaturated through 24-hour periods: at Yreka in August (possibly a periphyton bloom/die off) and October of 2002, and at Edgewood in October 2002. The record at Edgewood in October of 2002 is of particular interest, as the diurnal fluctuations in DO exceeded saturated conditions on a 24-hour basis for nearly a month. Comparison of this occurrence with other sites where DO has been studied indicates that supersaturated conditions for extended periods of time do occur occasionally. Studies in Oregon on the Tualatin River and in Upper Klamath Lake (Rounds and others, 1999; Wood and Rounds, 1998; *http://oregon.usgs.gov/projs_dir/or207/klake_data_2002. html*), indicate it is not unusual at all for this to occur, particularly in a system with little turbulence, few waterfalls or riffles, and an abundance of algae. These conditions are prevalent in the Shasta River which has an abundance of rooted aquatic plants in addition to a substantial population of attached algae. As long as conditions are favorable for the continued growth of the algae and aquatic plants, they can easily produce sufficient dissolved oxygen via photosynthesis to offset any consumptive processes and any losses to the atmosphere. Studies show that supersaturation is an annual occurrence in many systems in Oregon. For example, the Tualatin River has a record of continuous DO data since 1991 (Doyle and Caldwell, 1996; *http://oregon.usgs.gov/cgi-bin/grapher/graph_setup.pl? site_id=14207200*). At that site, supersaturated conditions occurred annually for 24-hour periods extending from 1 to 6 weeks. In 1992, supersaturated conditions persisted for a month at a time for several periods, and as high as 250 percent saturation, even though that river has a TMDL meant to protect it from low dissolved oxygen conditions. Locations in Upper Klamath Lake exceed 100% saturation values for 24-hour periods for extended periods of time from May until October, 2002, probably for over 60% of the 5-month time period (*http://oregon.usgs.gov/projs_dir/or207/klake_data_2002.html*).

There are many uncertainties associated with DO data and with the Shasta River data in particular. At the beginning of the 2002 field season, field crews unfamiliar with the collection of continuous DO data were trained in the USGS procedures, following Wagner and others (2000). In 2002, YSI 6920 Multi-parameter Water Quality Loggers with probes for DO, pH, and specific conductance/water temperature were rented from the USGS Hydrologic Instrumentation Facility. Numerous battery failures and other problems occurred with the probes, in addition to the expected biofouling. Drift was not corrected for in 2002, and field calibrations were done, whenever it was noted as necessary, to replace the DO sensor (approximately monthly). In 2003, new instruments were obtained and more frequent field visits were made (Table 2). In addition to corrections for biofouling, drift corrections were made and DO sensors were replaced as needed following inspections and calibrations in 2003 (approximately every two weeks).

Uncertainties in DO data collected continuously in the field can be exemplified by the data collected in the Shasta River in 2002 and 2003. USGS field protocols were followed more rigorously in 2003 than in 2002, with more frequent site visits, field calibrations, and sensor replacements, thus providing more certainty in the data in between visits. In addition, both biofouling and drift corrections were made in 2003. Data occurring as a result of obvious probe failure, membrane leakage or battery failure were removed in the intial data review, but more frequent site visits and probe inspections in 2002 could have provided more confidence in data collected between site visits and field calibrations. In general, uncertainties governed by probe behavior due to biofouling and drift are consistently corrected for deviations from field calibrated values by greater than 0.3 mg/L and by no more than 2.0 mg/L, with the exception of 8/18/03 and 9/30/03 at Edgewood when they were corrected by -2.2 and -2.4 mg/L, respectively. Uncertainties in the linear prorated corrections between calibrations, therefore, introduce no more error than the correction factor for that time period as noted in Table 2. Very careful inspection of the entire dataset, including the dependent data collected coincidentally of water temperature, pH, and specific conductance, as well as discharge, although not necessarily at the identical location, as well as specific consideration of individual site characteristics, weather conditions, nutrients, and presence of algal and macrophyte populations, would assist in the interpretation of the adequacy and uncertainty of the DO data at these sites.

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Table 1. USGS 2002 - 2003 continuous monitoring stations on the Shasta River basin.

[ID, USGS station identification number; sq. mi., square miles; latitude and longitude in decimal degrees; R., River]

Abbreviation	Name[1]	ID	Latitude	Longitude	Drainage area (sq. mi)	Location	Measurement Dates 2002	Measurement Dates 2003
YREKA	Shasta R. near Yreka	11517500	41.8229	-122.5956	793	Shasta R. just upstream of confluence with Klamath R.	6/29/02 - 11/6/02	5/14/03 - 9/30/03
HWY3	Shasta R at Hwy 3 near Montague	11510715	41.7268	-122.5584	676	Shasta R. at Hwy 3		4/10/03 - 9/30/03
MONTAGUE	Shasta R. near Montague	11517000	41.7092	-122.5369	673	1 mi below Little Shasta R.	6/26/02 - 11/6/02	4/11/03 - 9/30/03
EDGE	Shasta R. near Edgewood	11516750	41.4714	-122.4397	70	0.8 mi downstream from Beaughton Creek	6/26/02 - 11/6/02	4/11/03 - 9/30/03

Note: The station names are reported by the Regional Water Board as follows:
Shasta R. near Yreka = Shasta River Near Mouth at USGS Gage
Shasta R at Hwy 3 near Montague = Shasta River at Highway 3
Shasta R. near Montague = Shasta River at Montague-Grenada Road
Shasta R. near Edgewood = Shasta River at Edgewood Road

Table 2. Corrections and shifts made to dissolved oxygen data at Edgewood site on the Shasta River during 2002-2003.

Date of site visit	Correction due to biofouling	Correction due to drift	Total correction	Comment
6/25/2002				Sonde deployed
8/2/2002	0.0		0.0	7/16/02 - 8/1/02 battery failure, 8/2/02 faulty probe
8/15/2002	-0.9		-0.9	
8/29/2002	0.0		0.0	8/4/02 - 8/15/02 battery failure, 8/18/02 - 8/29/02 faulty probe
9/19/2002	0.4		0.4	
9/30/2002	-1.5		-1.5	
10/2/2002	0.0		0.0	
10/16/2002	0.0		0.0	
11/6/2002	0.7		0.7	Sonde removed for season
4/9/2003			0.0	Sonde deployed
5/13/2003			0.0	4/24/03 and 5/9/03 - 5/12/03 battery failure, new Sonde deployed
5/30/2003	0.0	-0.9	-0.9	
6/16/2003	0.0	0.5	0.5	
6/27/2003	0.0	0.0	0.0	
7/3/2003	0.0	2.0	2.0	
7/9/2003	0.0	0.0	0.0	hole found in membrane, drift correction applied to 6/27/03 - 7/3/03
7/23/2003	0.0	0.0	0.0	7/10/03 probe failure, 7/23/03 hole found in membrane, no data 7/9/03 - 7/22/03
8/5/2003	0.0	-0.5	-0.5	
8/18/2003	-2.0	-0.2	-2.2	
9/11/2003	0.0	-1.8	-1.8	
9/30/2003	-0.2	-2.2	-2.4	Sonde removed for season

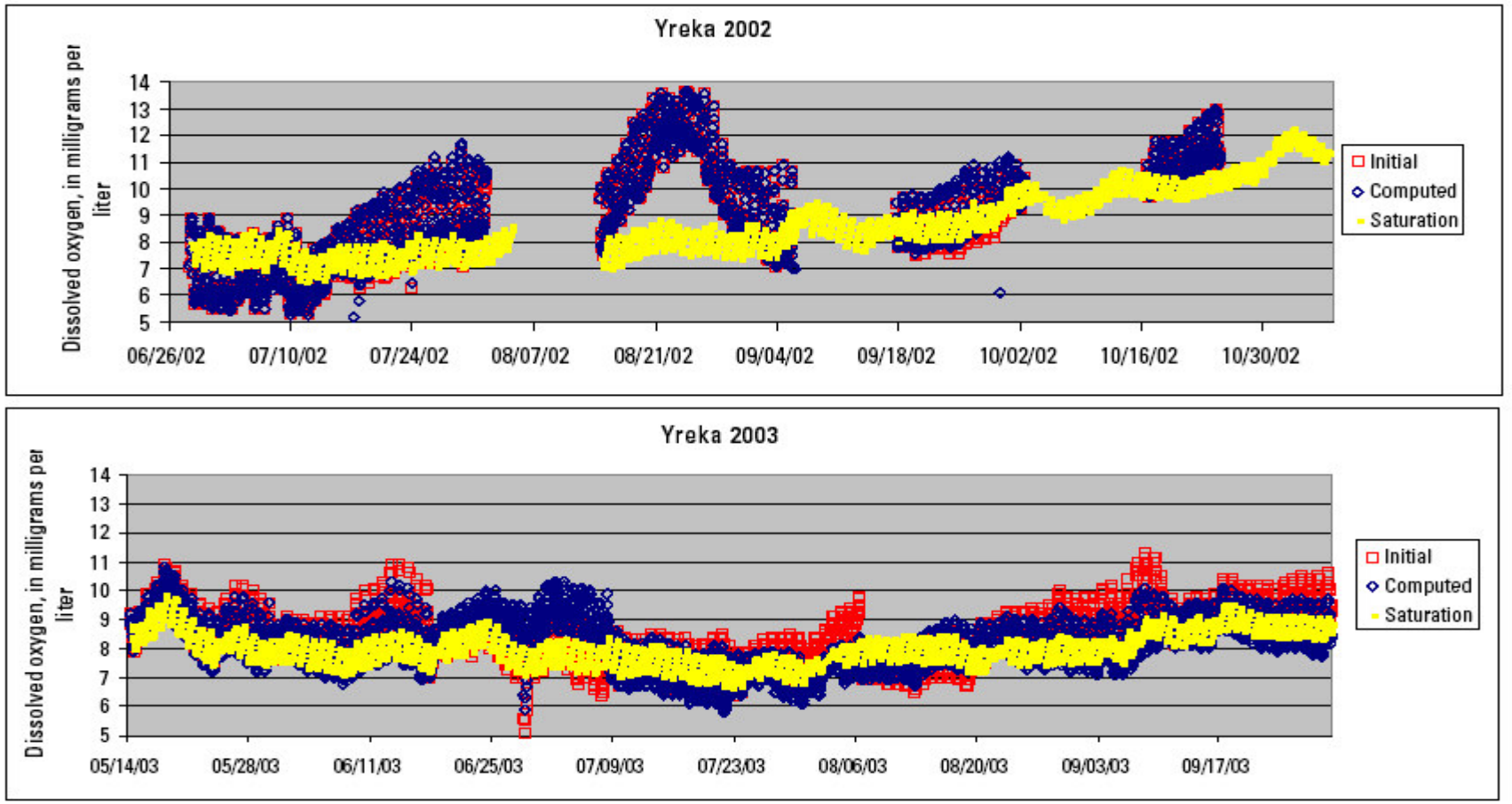

Figure 1. Measured continuous data of dissolved oxygen with initial edited record, computed record, and saturated values for 2002 and 2003 for the USGS site on the Shasta River at Yreka. The Regional Water Board refers to this station as "Shasta River Near Mouth at USGS Gage".

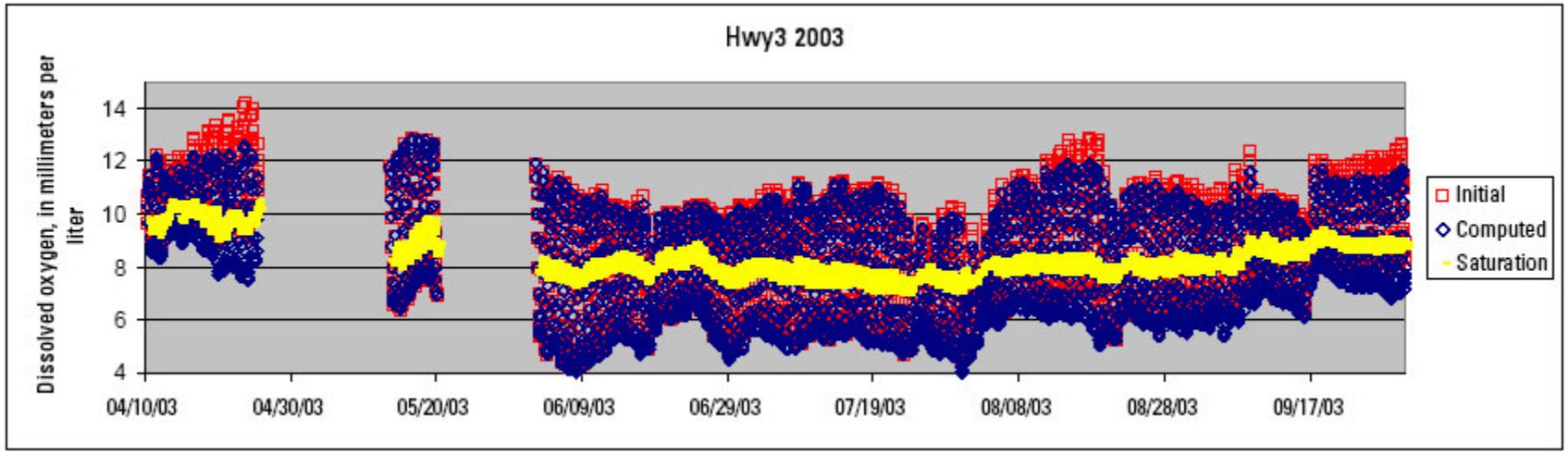

Figure 2. Measured continuous data of dissolved oxygen with initial edited record, computed record, and saturated values for 2003 for the USGS site on the Shasta River at Hwy 3. The Regional Water Board refers to this station as "Shasta River at Highway 3".

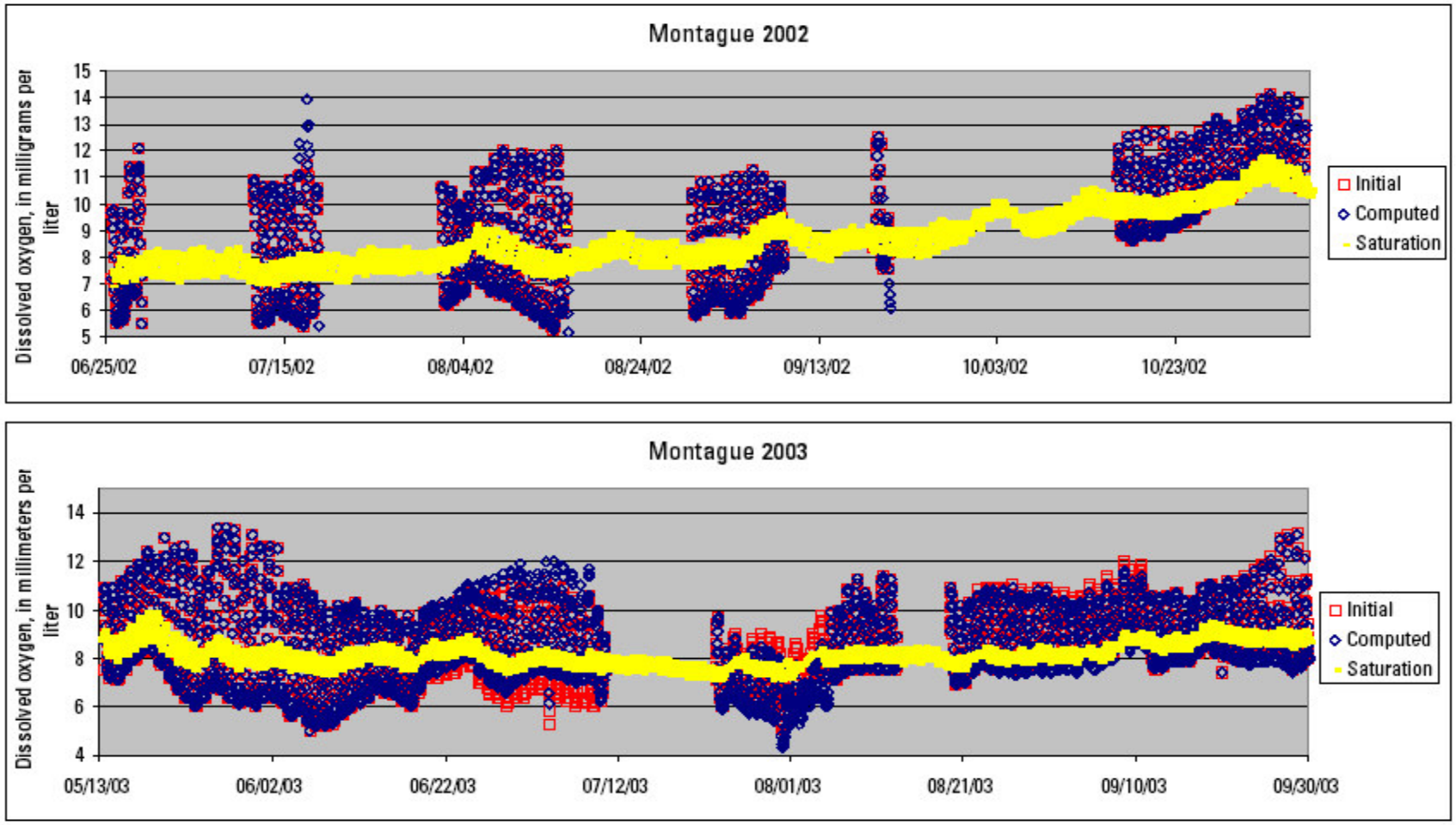

Figure 3. Measured continuous data of dissolved oxygen with initial edited record, computed record, and saturated values for 2002 and 2003 for the USGS site on the Shasta River at Montague. The Regional Water Board refers to this station as "Shasta River at Montague-Grenada Road".

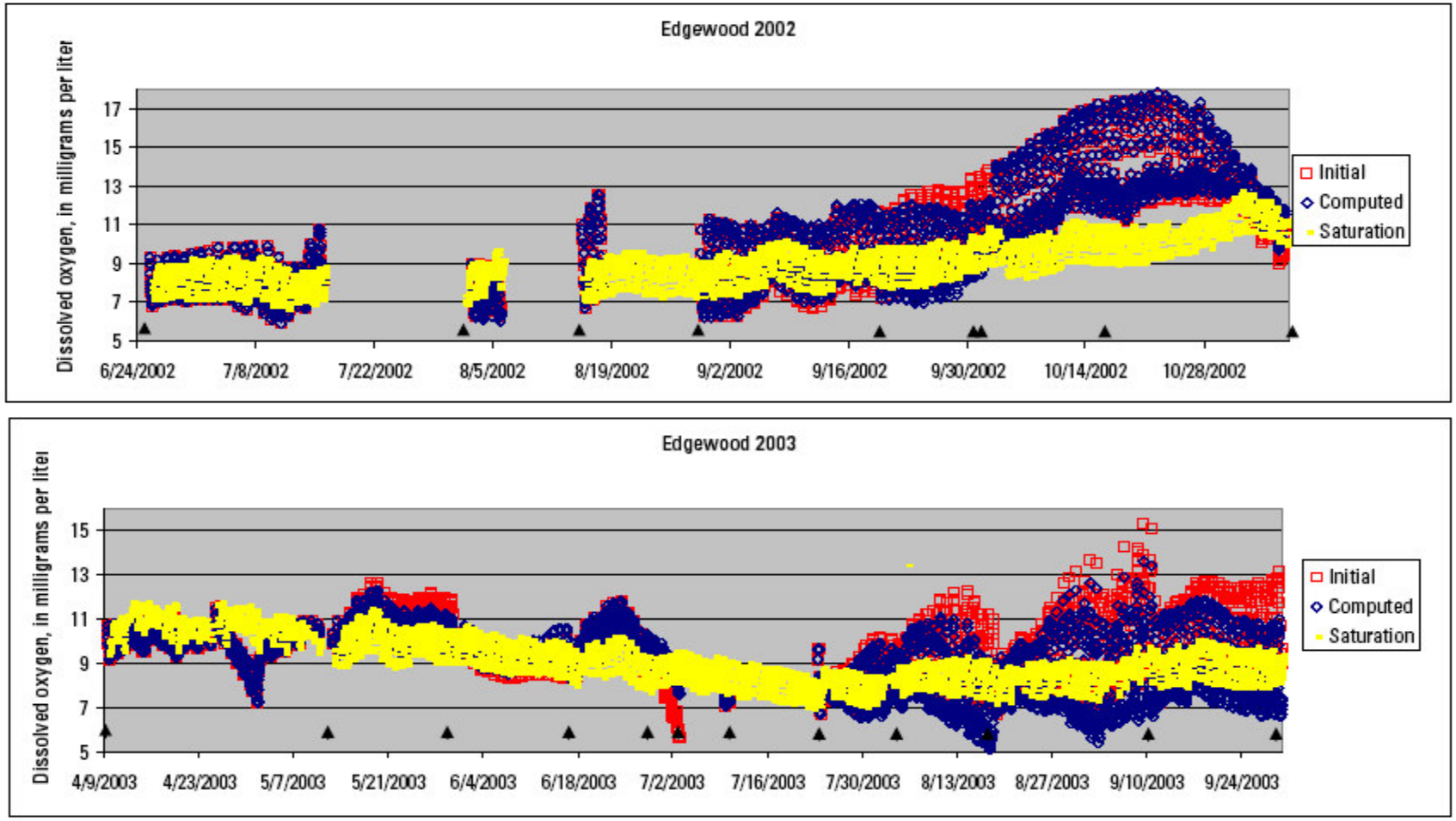

Figure 4. Measured continuous data of dissolved oxygen with initial edited record, computed record, and saturated values for 2002 and 2003 for the USGS site on the Shasta River at Edgewood. The Regional Water Board refers to this station as "Shasta River at Edgewood Road". Filled triangles identify dates of site inspections by USGS.

Appendix 2: Sediment Oxygen Demand Study on the Shasta River – Methodology

This section of the document is excerpted from a USGS report by Flint and co-workers (2004).

Background

Sediment oxygen demand (SOD) is the rate of dissolved oxygen loss from a waterbody through its uptake and consumption by biotic or abiotic reactions in surficial sediments. In most systems, such oxygen consumption is dominated by microbially mediated decomposition processes. In other words, organic materials in the waterbody's sediments rot and decompose; that process requires oxygen to proceed, and the oxygen is supplied from the overlying water. In streams with an abundance of sedimentary organic material, from soil erosion or an accumulation of plant and algal detritus, SOD can be an important part of the stream's dissolved oxygen budget. Observations of sediment accumulation and low dissolved oxygen levels indicate that some reaches of the Shasta River may have a significant SOD; as a result, this investigation was initiated to measure that rate.

The rate of SOD was measured at six sites in two reaches of the Shasta River (**Table 10**). These sites were chosen because they are located in a reach of the Shasta River that is known to have dissolved oxygen problems and to accumulate some amount of fine sediment and plant detritus. Other considerations for site selection included access, type of stream substrate, and the amount of macrophyte (aquatic plant) growth.

Procedure

Sediment oxygen demand rates were measured with *in-situ* chambers, as previously described by Murphy and Hicks (1986), Caldwell and Doyle (1995), Rounds and Doyle (1997), and Doyle and Rounds (2003). These chambers allow a known volume of water to be isolated above a known area of stream sediment. The dissolved oxygen concentration in that isolated water then is monitored over the course of at least two hours. Measurements typically are performed with three such chambers at each site to assess the variability of the site's SOD. In addition, a fourth chamber with a sealed bottom to exclude interaction with stream sediments is used to assess the level of oxygen loss due to biochemical oxygen demand (BOD) in the water column. The measured oxygen loss rate in each of the three SOD chambers, once corrected for the effects of BOD as measured in the fourth chamber, is a direct measurement of the site's SOD rate. Final SOD rates are corrected to 20° C (SOD_{20}) and reported as a loss rate in grams of oxygen per square meter per day ($g/m^2/d$). Details of the procedures were documented previously by Rounds and Doyle (1997). An estimate of the SOD rate at any temperature is then given by:

$$SOD_T = SOD_{20} \times 1.065^{(T-20)}$$

where SOD_T is the SOD rate at temperature T (°C).

To measure SOD rates with this type of *in-situ* chamber, (1) the stream must be deep enough to submerge the chamber (> 0.4 meters), (2) the sediments must be fine enough to allow the chamber's cutting edge to seat and seal to the stream bottom, and (3) the stream's dissolved oxygen concentration must be high enough (> 4 mg/L, approx.) to provide a measurable loss rate and a stable aerobic environment for the sediment's microbial community.

In the reaches where the SOD rate was measured, the Shasta River has a productive population of attached algae and an abundance of rooted aquatic plants (macrophytes). Both the algae and the macrophytes produce dissolved oxygen through photosynthesis. In order to measure only the effects of SOD (and BOD), it was important to exclude these oxygen producers from the SOD measuring chambers, either through prudent site selection or by physical removal of these plants prior to chamber deployment.

At the two sites near Montague-Grenada Road, macrophytes were less abundant, allowing suitable sites for chamber deployment to be found without removing any plant material. At all sites near Highway 3, however, macrophytes were abundant and had to be removed from the site of each chamber deployment prior to SOD measurement. The tops of the plants were removed by cutting them off near their base, taking care not to disturb the plants' roots or the site's sediments. In this manner, the plant's production of dissolved oxygen was eliminated without disturbing the sediments or any respiration processes in the plant's roots. Such measures may introduce additional uncertainty into the subsequent SOD measurement, but it was the only way to collect such a measurement in areas dominated by macrophytes.

At each SOD measuring site, samples also were collected to roughly characterize the organic content and particle size of the stream sediments. Samples were analyzed for percent organic content (loss on ignition: Fishman and Friedman, 1989) and for the size fraction finer than 63 microns (Guy, 1969) by the USGS Cascades Volcano Observatory sediment laboratory.

Results are presented in **Table 10**.

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