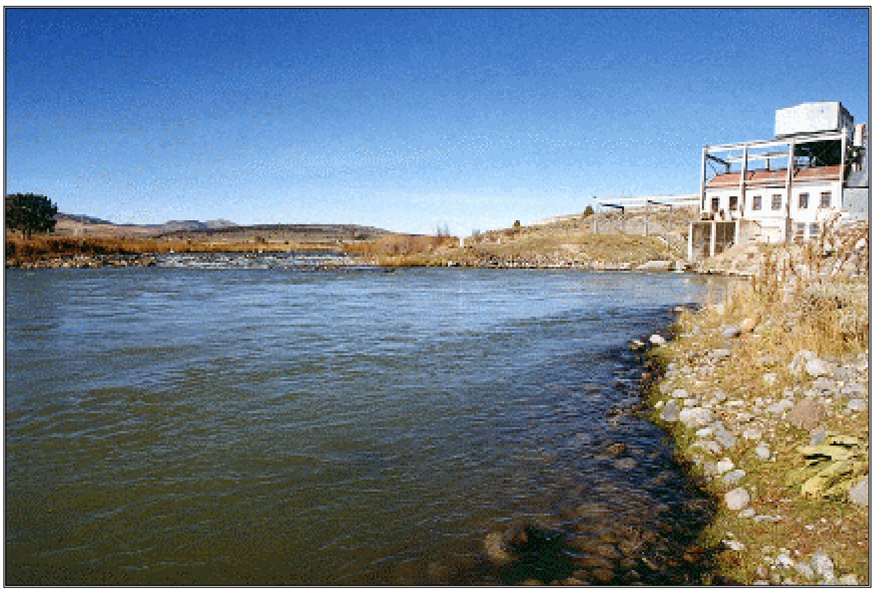
Bear River Hydroelectric Project (No. 20)
Grace-Cove Development

2006 Water Quality Summary



Prepared for:

PacifiCorp

Prepared by:

Ecosystems Research Institute

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EXECUTIVE SUMMARY

A water quality monitoring study was undertaken on the Bear River within PacifiCorp's Grace/Cove hydroelectric complex (Development) during July, August, and September 2006. This study was implemented to define water quality conditions at four separate locations within this reach of the Bear River. Continuous monitoring probes gathered data for a minimum of seven continuous days during the months of July, August and September at four locations on the Bear River including: above and below Grace Dam, at the mouth of Black Canyon, and below the Cove Hydroelectric Plant. Water quality grab samples were collected at the same time the probes were checked and were analyzed for nutrients and suspended solids.

Hydrology during each of the sampling periods was different. During July, the range of flows below Soda Dam was greater (180 cfs) than that recorded in August (148 cfs). Sampling during September occurred over a period in which the flows were drawn down dramatically over a short time period (537 cfs).

Some instantaneous water quality data demonstrated distinctive daily patterns over all months. Diel variations were recorded for temperature and dissolved oxygen. Specific conductance and turbidity did not consistently show this same pattern. To further explore this variation, the data were divided into two twelve-hour data sets; 7 PM to 7AM (night) and 7AM to 7PM (day). This distinction separates the warmer and cooler periods of each day, as well as periods of solar radiation and reduces variation within each group. ANOVAs were used to compare differences between sites. When differences were found, a Tukey test was used to evaluate pair-wise differences. In order to evaluate correlations between sites pair-wise linear regressions were calculated for each parameter.

Grab samples collected during this time were consistent with the water quality conditions recorded during the 2004 and 2005 instantaneous sampling efforts. Total phosphorous, which generally increased over the sampling period, was highest overall at GC04 (0.057 mg/L in August). With the exception of the first sampling date in July, both GC01 and GC02 exhibited the lowest overall concentrations. Orthophosphorus, the dissolved portion of phosphorus, was highest at GC03 (0.051 mg/L in August). Orthosphosphorus as a percentage of phosphorus was also greater at GC03.

The total inorganic nitrogen, which is made up of nitrate, nitrite and ammonia, did not display the same increasing concentration or increasing between sites pattern as phosphorous. Total inorganic nitrogen concentrations at GC01 and GC02 mirrored each other during the monitoring season, but doubled at GC03 and then increased that same amount again at GC04. These increases were due to increases in nitrate and are consistent with the water quality conditions recorded during the 2004 and 2005 instantaneous sampling efforts.

A comparison of each site and sampling event to the IDAPA water quality standards was undertaken utilizing the continuous data collected in this investigation. The instantaneous temperature requirement for the prescribed beneficial use of this section of the Bear River was exceeded at sites except GC03 during July, but at none of the sites in August and September. Average daily temperature was exceeded at every site except GC03 in July and August, but not in September. Instantaneous dissolved oxygen was lower than the standard only in July, August

and September (GC01, GC02 and GC04 in July; GC01 and GC02 in August; GC02 in September). Additionally, dissolved oxygen (expressed as a percent of atmosphere) was exceeded at all sites during July and all sites except GC03 during August and September. Exceedences of IDAPA water quality standards during the 2006 monitoring period were much less than those recorded in 2005. Given the poor water quality conditions recorded in the Bear at the control site (GC01), it is unlikely that the operations of the project contributed to recorded temperature exceedences of IDAPA standards at monitoring sites downstream where exceedences decrease relative to the control site. Monitoring results indicate that the project had little effect on violations of water temperature criteria as set forth in the IDAPA.

In the case of dissolved oxygen (mg/l), exceedences decrease with distance downstream during both July and August. During all three monitoring periods, dissolved oxygen (expressed as a percent of atmosphere) at sites GC02, GC03, and GC04's percent exceedence of IDAPA standards was greater than exceedences recorded at the control site (GC01) similar to the pattern seen in 2005. Physical characteristics of the Bear River vary considerably from the control site as you move downstream to the other monitoring locations. Site GC01 is located in a fairly turbulent reach of the river, whereas the latter monitoring locations are located in areas with fairly laminar flows. Increased photosynthesis in these laminar reaches drives up percent saturation. Dissolved oxygen data (expressed as percent of atmosphere) recorded at sites GC02, GC03, and GC04 is fairly representative of this relationship. As with temperature, it is unlikely that project operations significantly contributed to violations of dissolved oxygen criteria as set forth in the IDAPA.

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1.0 INTRODUCTION

The primary objective of the Water Quality Monitoring Plan (WQMP) is to accurately define the water quality conditions above, within and below the Grace/Cove hydroelectric complex (Development). The secondary objective is to evaluate the data and determine if the Development has contributed to violations of water quality criteria as set forth in the Idaho Water Quality Standards and Wastewater Treatment Requirements (IDAPA 58.01.02). This report will review the parameters, locations, and frequency of sampling conducted during July, August, and September 2006. This report includes data collected and conclusions of the study. In addition, quality assurance/quality control requirements will be reviewed and evaluated in terms of data fitness.

1.1 Bear River Historical Water Quality

The Bear River spans over 550 miles, draining a 470,000-acre watershed which encompasses parts of three states. The river's flow and irrigation diversions are under the control of the Bear River Compact and regulated by the Bear River Commission. Water quality within the river falls under the jurisdiction of the states of Idaho, Utah, and Wyoming.

Precipitation within the Bear River basin is distributed unevenly with regards to both time and area. Most of the water within the basin is derived from winter snowfall. Data obtained at the U. S. Weather Bureau stations at Preston, Grace, and Montpelier show that the average monthly precipitation ranges from a high of 1.93 inches in April to a low of 0.65 inches in July. The range in annual precipitation at these stations is from about 8.5 inches to about 23 inches. The 50 percent exceedence value for Preston, meaning half the time one could expect total precipitation to exceed this value, is 16 inches per year while Grace and Montpelier are close to 14 inches annually. Over 50 percent of the surface area of the Idaho Bear River basin receives between 10-20 inches of annual precipitation. The areal distribution of precipitation is influenced by elevation and ranges from 10 inches at low elevations to over 50 inches at higher altitudes. Average precipitation over the entire Idaho Bear River basin is 3.3 million acre-feet annually.

On the mainstem Bear River in Idaho, there are six gaging stations (not including the two on the inlet and outlet to Bear Lake). A historical review of these data indicates that for the last 30-year period, maximum flows (1.75 to 2.0 million ac-ft) occurred in 1993, 1994 and 1996. Between 1988 and 1995, as well as 2000 to 2004, flows throughout the basin were low (less than 0.50 million ac-ft per year). For this 30-year period of record, an average of 432,000 ac-ft of water entered the Middle Bear River from Wyoming and 850,000 ac-ft exited at the Utah border. The Idaho portion of the Bear River yielded an average of 517,000 ac-ft of water. Although a large portion is produced within the watershed, the majority of the water entering Utah in the summer is from Bear Lake storage captured from upper basin sources during runoff and released for downstream irrigation in Utah. The storage of 1.42 million ac-ft of water in Bear Lake, represents the majority of storage above Alexander Reservoir near Soda Springs. Irrigation water used for agriculture represents the single largest consumptive use in the basin. A total of 90 irrigation companies serve 177,800 acres of irrigated land in the Middle Bear River. Bear Lake County has the largest number of companies (47) and the largest amount of acreage (75,680 acres), followed by Caribou, Franklin, and Oneida counties. Last Chance Canal, located immediately above this project, withdraws a significant amount of Bear River water during the summer irrigation season. Land is irrigated on both the north and south sides of the river throughout the project area (Last Chance down to Cove).

The Idaho Bear River basin has four major subbasins, or hydrologic units, all within the state of Idaho. The hydologic unit that this project is located in is HUC#16010202 which extends from below Alexander Reservoir to the Idaho-Utah border. This subbasin has 18 tributaries, of which four are found on Idaho's 303(d) list. The remaining three subbasins are coldwater and salmonid spawning designated. Recreation contact is primary or secondary for these three streams. The Bear River in this subbasin has five reaches, all of which are on Idaho's 303(d) list, including the reach containing this project. Nutrients, sediment and flow alteration are the reasons given for the 303(d) listing of the river, reservoir and tributaries in this subbasin.

Water quality studies on the Bear River date back to the 1950s. The Idaho Bear River reach (that portion downstream of the Wyoming-Idaho border) has been the subject of water quality investigations starting as early as 1953 (Clyde 1953). The studies focused on suspended sediments and flow. Several studies have also been conducted on the current condition of and influences on water quality in the reach above Bear Lake, extending as far as Woodruff Reservoir in Wyoming down to the Idaho-Utah stateline. Of the studies on Bear River water quality in the project reach (Wyoming-Idaho stateline to the Utah-Idaho stateline), the most extensive was completed by ERI in 1998, and is described in detail later in this section. Prior to that discussion, a brief summary of historical water quality investigations on the Bear River system is provided.

Early water quality studies focused on sediments and salinity in the river. Clyde (1953) evaluated sedimentation patterns in the Bear River between Oneida and Cutler reservoirs. Between 1910 and 1950, the riverbed raised six feet due to the deposition of over 110 million tons of sediment. Heimer (1978) measured turbidity and suspended sediments at sites from below Bear Lake to the Utah-Idaho stateline. Based on his 1975 data, sediment loads in the river increased from 98 tons/month (3,000 kg/day) at Soda Springs to 351 tons/month (10,600 kg/day) near Preston, then decreased to 171 tons/month (5,180 kg/day) at the stateline. Waddell (1970), Haws and Hughes (1973), and Hill et al (1973) all summarized water quality data collected in the late 1960s and early 1970s. Most analyses were for major anions and cations only. Over this time period, total dissolved solids (TDS) averaged about 375 mg/liter at the Bear Lake outlet, with little change throughout the Idaho reach.

The first extensive water quality study of the Idaho portion of the Bear River was conducted in 1975 and 1976 (Perry 1978), with samples collected every two weeks at 15 stations. Perry concluded that total suspended solids (TSS) and TDS concentrations responded differently in the reaches above and below Oneida. From Bear Lake to above Oneida, TSS and TDS decreased at higher flows due to a dilution effect. However, below Oneida, solids increased during runoff. He attributed this to high sediment inputs from tributaries below Oneida. High nitrate concentrations in Black Canyon, possibly from Grace wastewater treatment plant (WWTP), and fecal coliform contamination in the river near Preston were also identified as water quality problems.

In the late 1970s, the emphasis shifted to nutrient contamination in the river, with most data collected below Oneida Reservoir by Utah State University Water Research Laboratory.

Barker et al. (1989) summarized nutrient data collected from Bear Lake outlet to the Idaho-Utah stateline during 1987 and 1988. Average TP concentrations increased from 0.06 mg/liter at Bear Lake outlet to 0.100 mg/liter at the Idaho-Utah stateline. Average orthophosphorus increased from 0.008 to 0.037 mg/liter over the same reach, although on most dates the concentrations were low and relatively constant from site to site. Nitrate concentrations ranged from 0.140 mg/liter at the outlet to 0.860 mg/liter at the stateline.

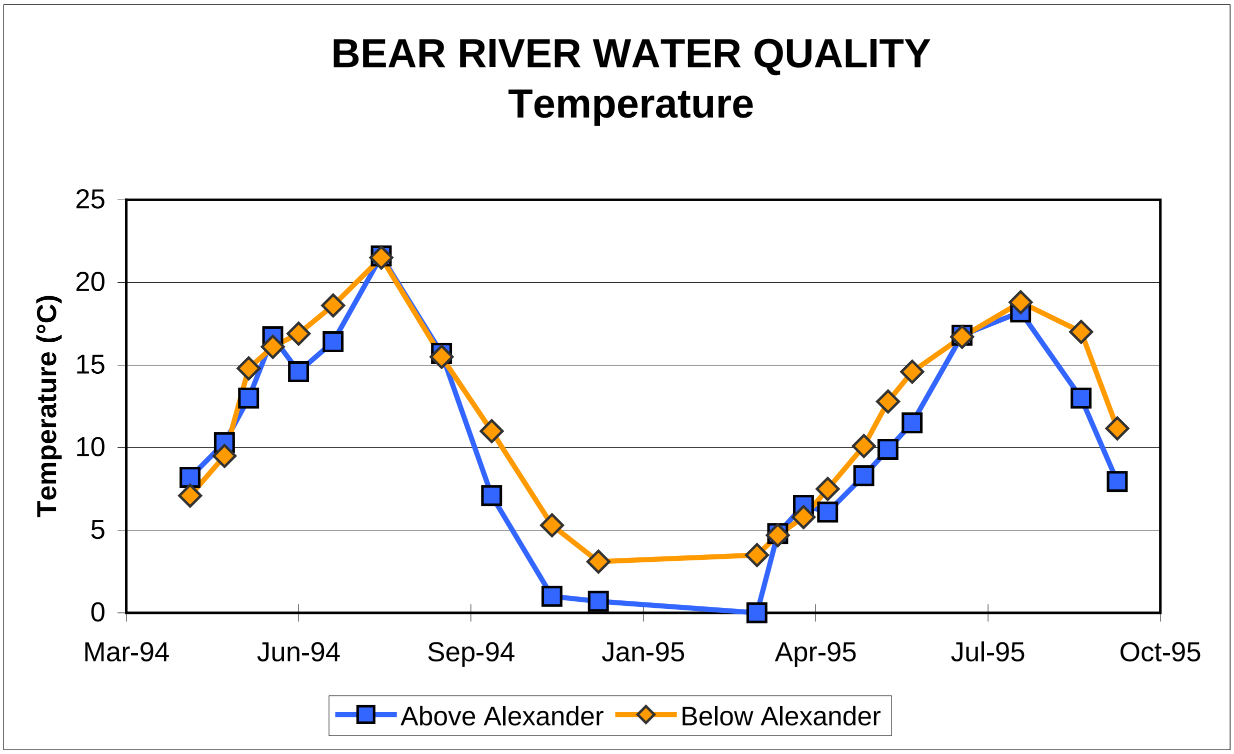
ERI (1998) conducted the most current and extensive water quality investigation on the mainstem Bear River. Twelve sites on the mainstem Bear River were sampled from April 1994 through September 1996 and in 1999-2000 including the inlet and outlet to Bear Lake as well as the outlet to Black Canyon below Grace, Idaho. In addition, several point sources, including the Soda Springs WWTP and the Clear Springs fish hatchery were also sampled. Several monitoring sites on the mainstem and tributaries were also monitored by PacifiCorp as part of their relicensing effort on three hydroelectric facilities in Idaho. Data from several of these sites are included in this review of available information. This study represents the basis for the summary and analysis of water quality conditions in the Middle Bear River watershed used to establish a Middle Bear River TMDL. (ERI 2004)

Temperatures within the Bear River at the study location have shown 20° to 22°C difference from the winter to the summer. In the data set from 1994 to 1995, the temperatures throughout the study area reflected the Bear River inflow to Alexander Reservoir. In this data set, the temperature criterion for the study section of the Bear River (Last Chance down to Cove) was exceeded in only 4 to 5 percent of the observations. These data for five stations in the Bear River can be seen in Figure 1-1.

Dissolved oxygen (Figure 1-2) was also measured at the same sites as temperature. The data reflect a grab sample measurement and not an electronic data collection. The number of exceedences of the coldwater concentrations at these sites was only 5 to 8 percent of the observations.

The concentrations of total suspended solids (TSS) were far more variable than for other parameters throughout the study reach. Alexander Reservoir, located downstream of the Bear Lake Marsh Outlet, receives Bear River water year round. TSS concentrations above Alexander Reservoir were similar to concentrations observed at the Bear Lake Marsh outlet, though there were more exceedences of the TSS criterion. Two out of the five runoff months exceeded the 60 mg/l criterion during the 1994-1996 study. There was only one base flow criterion exceedence, occurring during August. Highest concentrations occurred in June, July and August (73, 62, and 60 mg/L, respectively), with the lowest occurring in December, January and February (17, 8.8 and 7.0 mg/L, respectively). At the Bear River below Alexander Reservoir, the number of exceedences decreased to zero (Figure 1-3).

Total phosphorus and orthophosphorus are pollution indicators and the mainstem Bear River has historically recorded high levels of both (ERI 1998). During ERI’s 1994-1996 studies, the Bear River flowing into Alexander Reservoir exceeded the 0.050 mg/L criterion eleven of the twelve months. For nine of those exceedences, average concentrations were two to three times the allowable level. With extremely high levels of phosphorous entering Alexander Reservoir, it



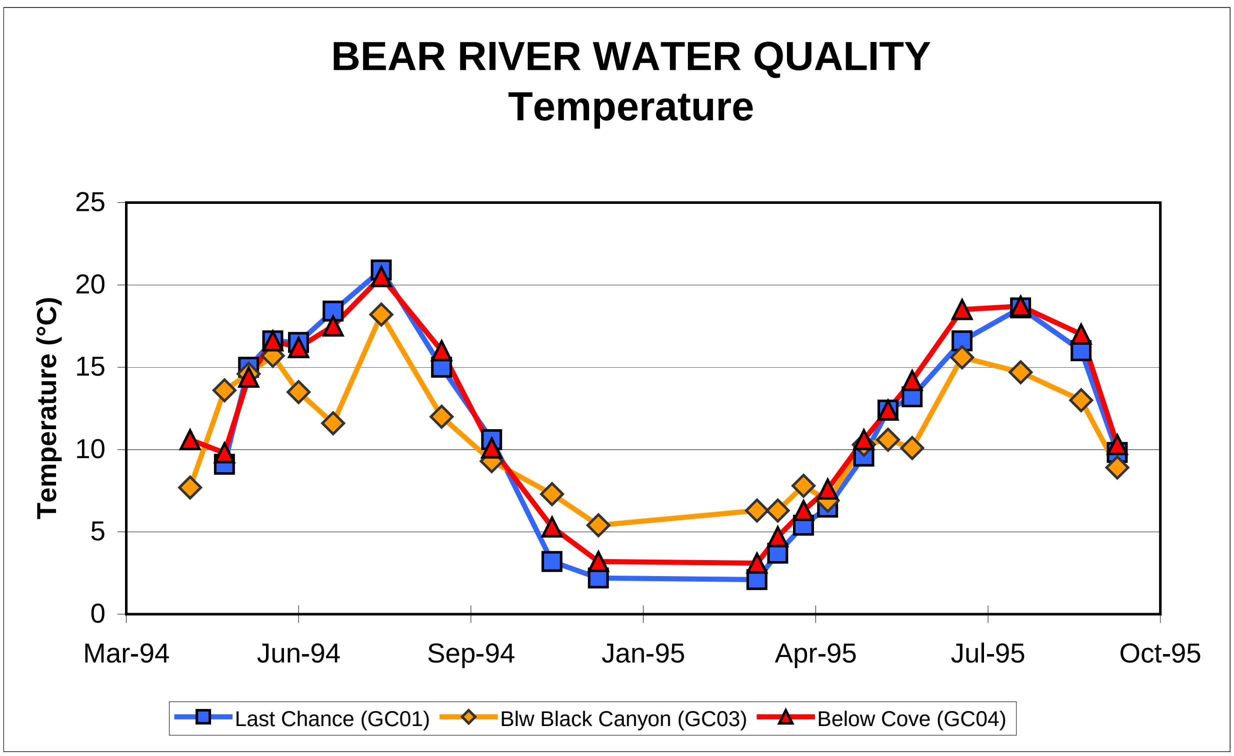
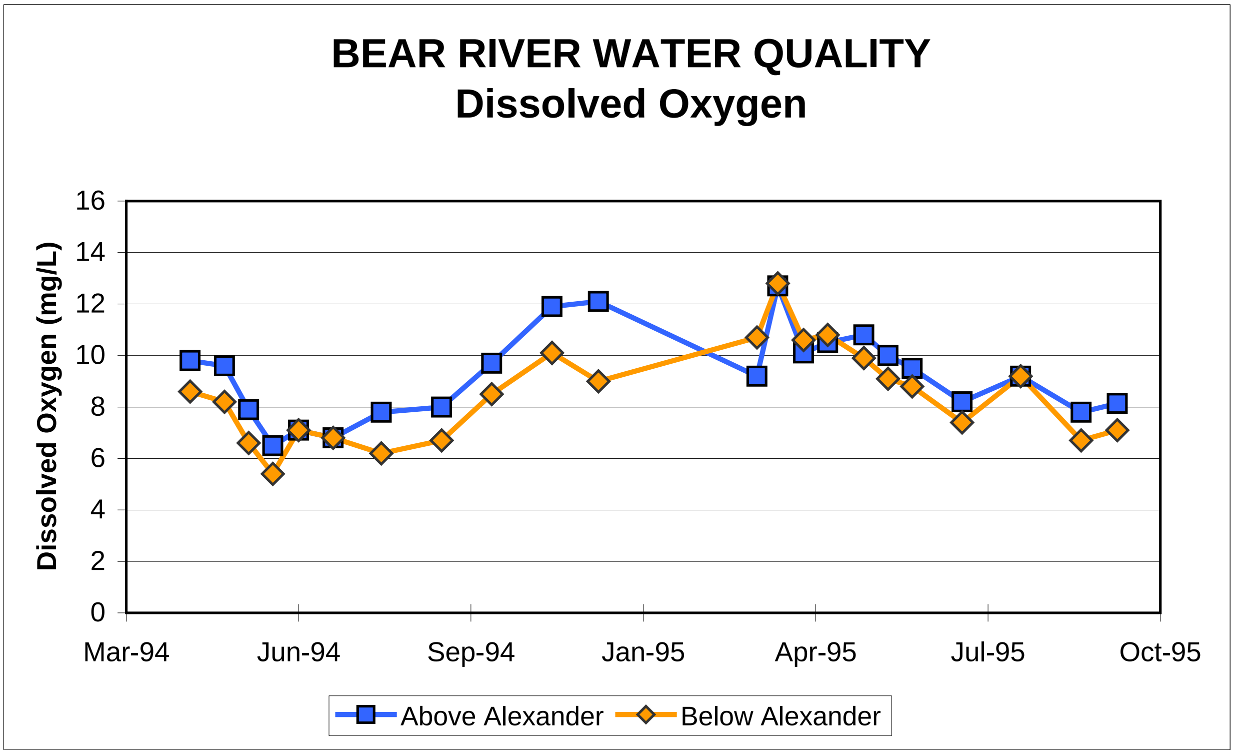


Figure 1-1. The water temperatures at five locations in the Bear River above Cove from 1994-1996.



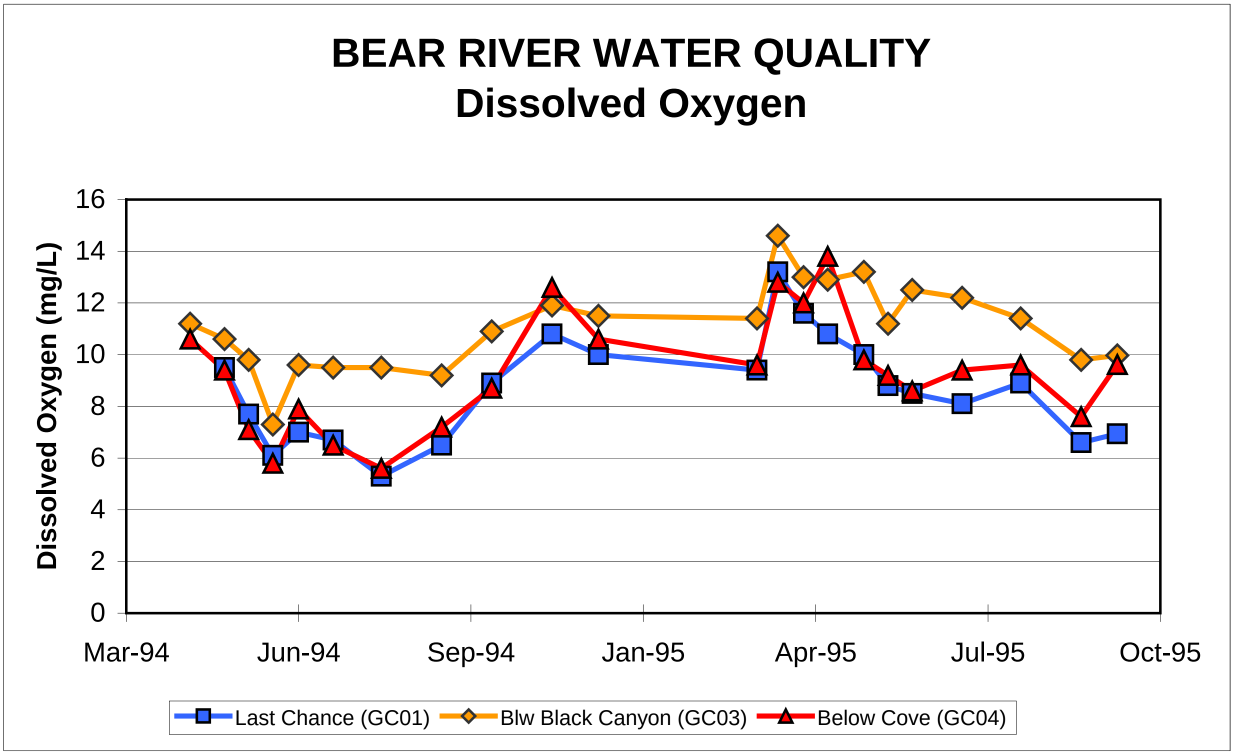
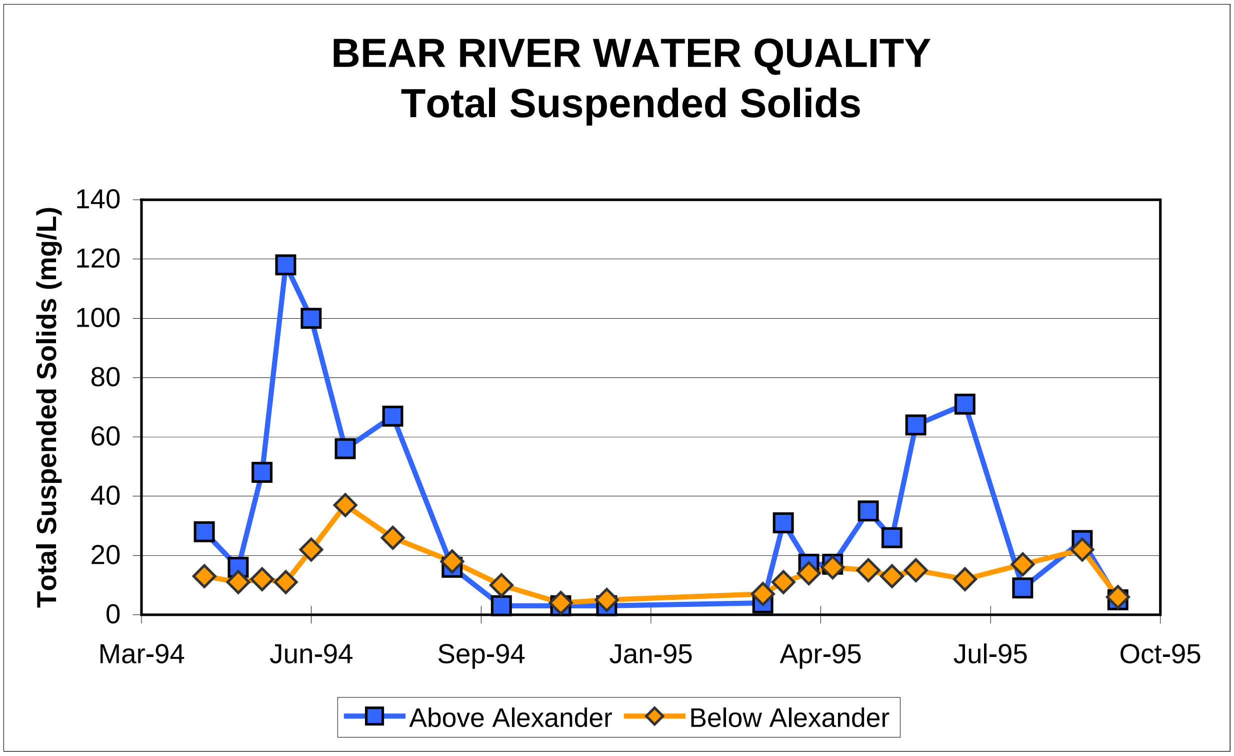


Figure 1-2. The dissolved oxygen concentrations at five locations in the Bear River above Cove from 1994-1996.



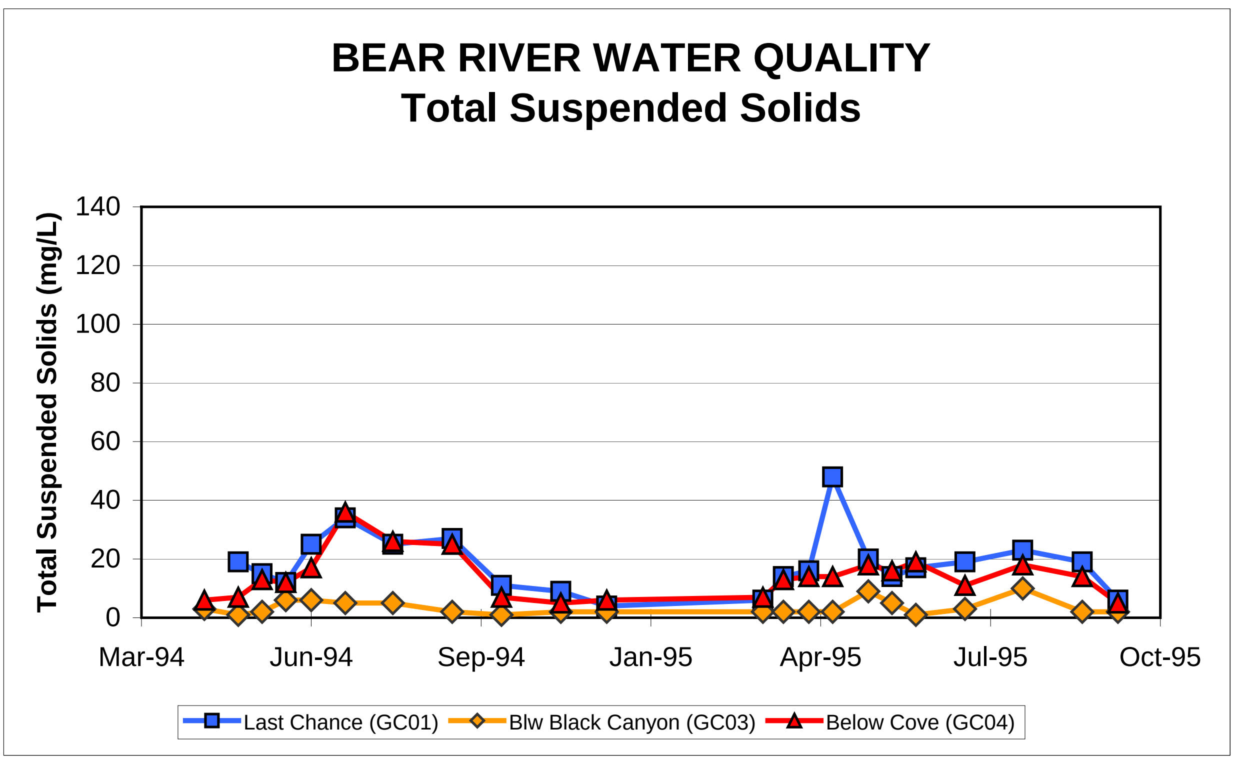
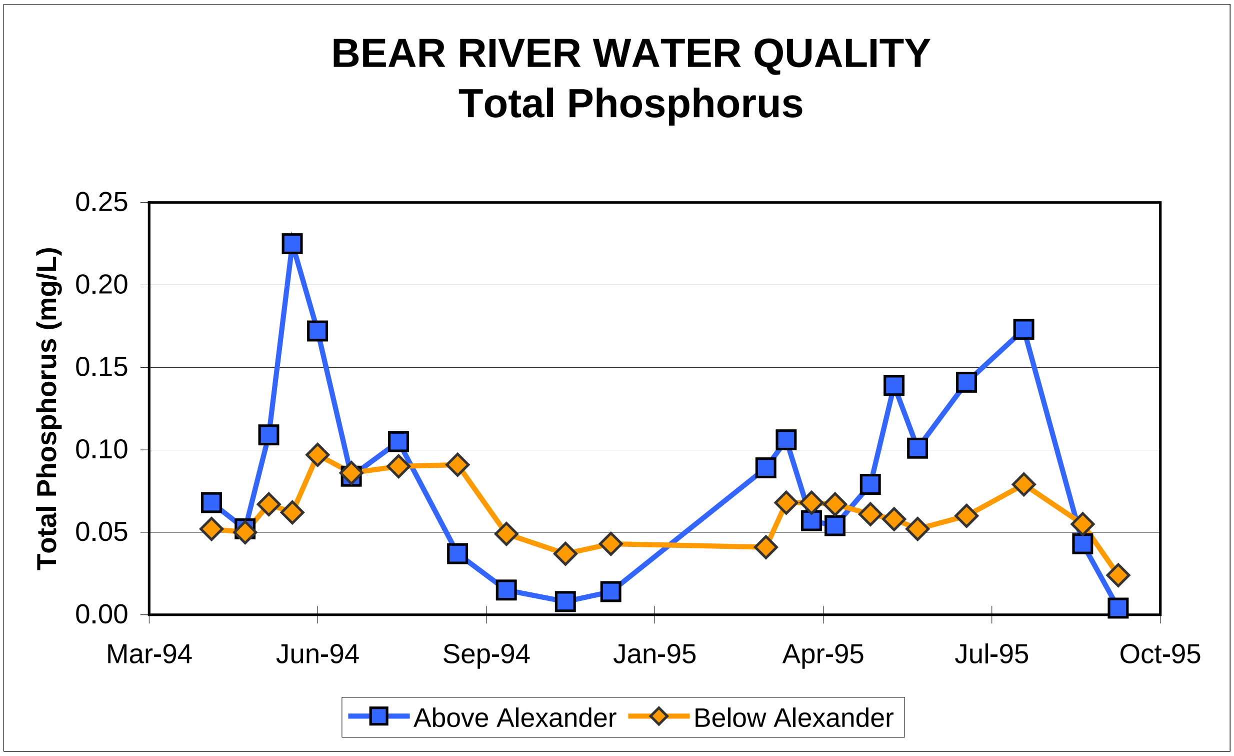


Figure 1-3. The total suspended solids concentrations at five locations in the Bear River above Cove from 1994-1996.



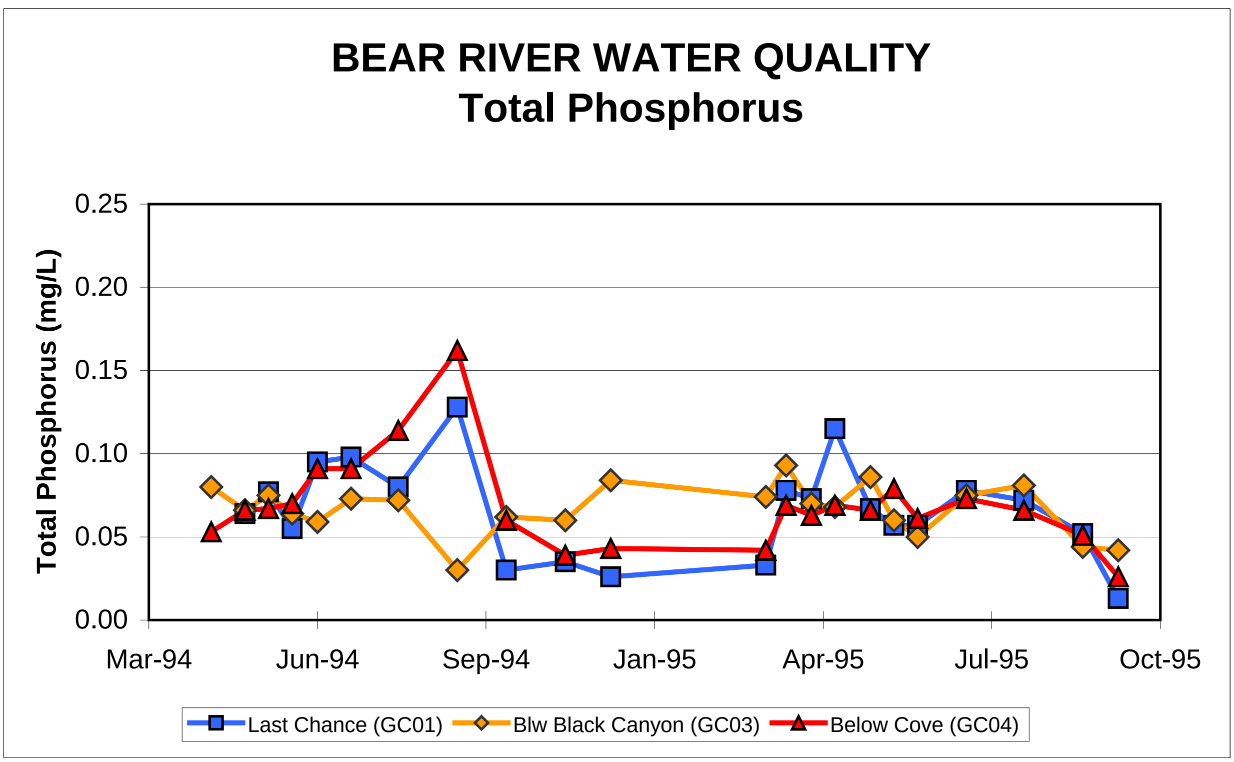
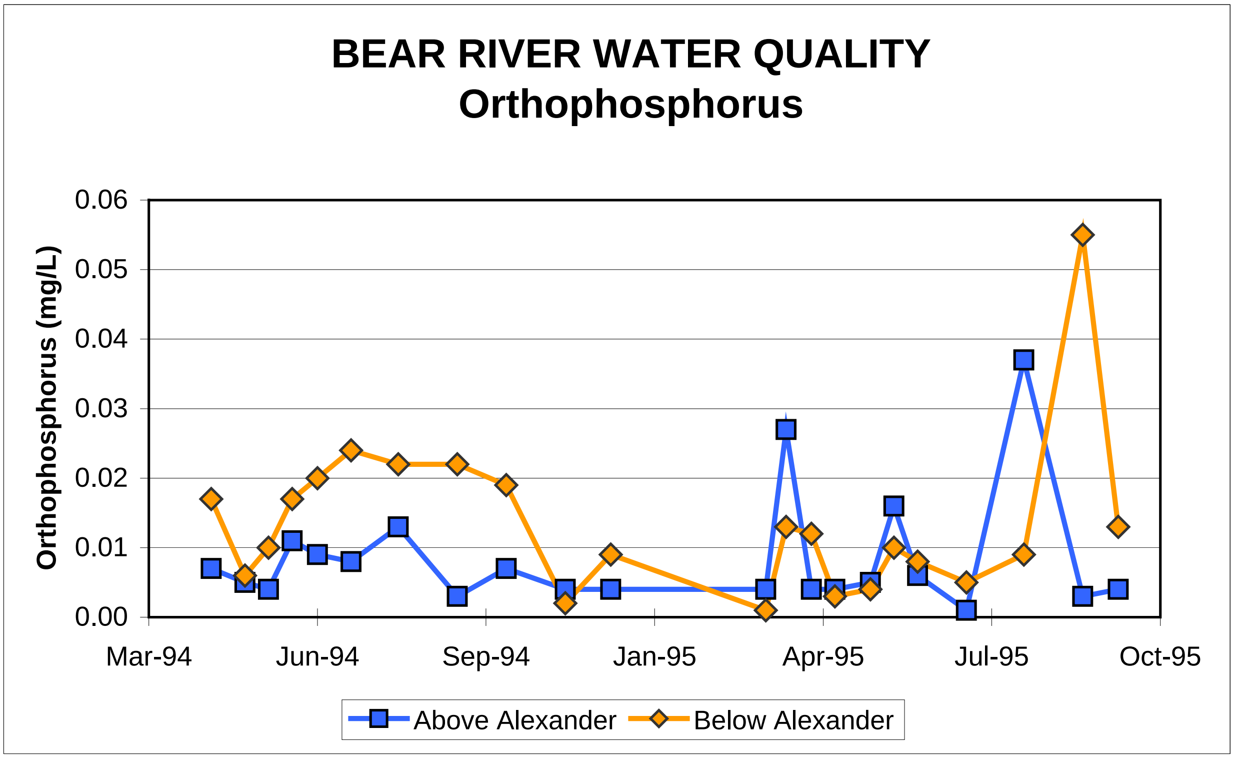


Figure 1-4. The total phosphorus concentrations at five locations in the Bear River above Cove from 1994-1996.



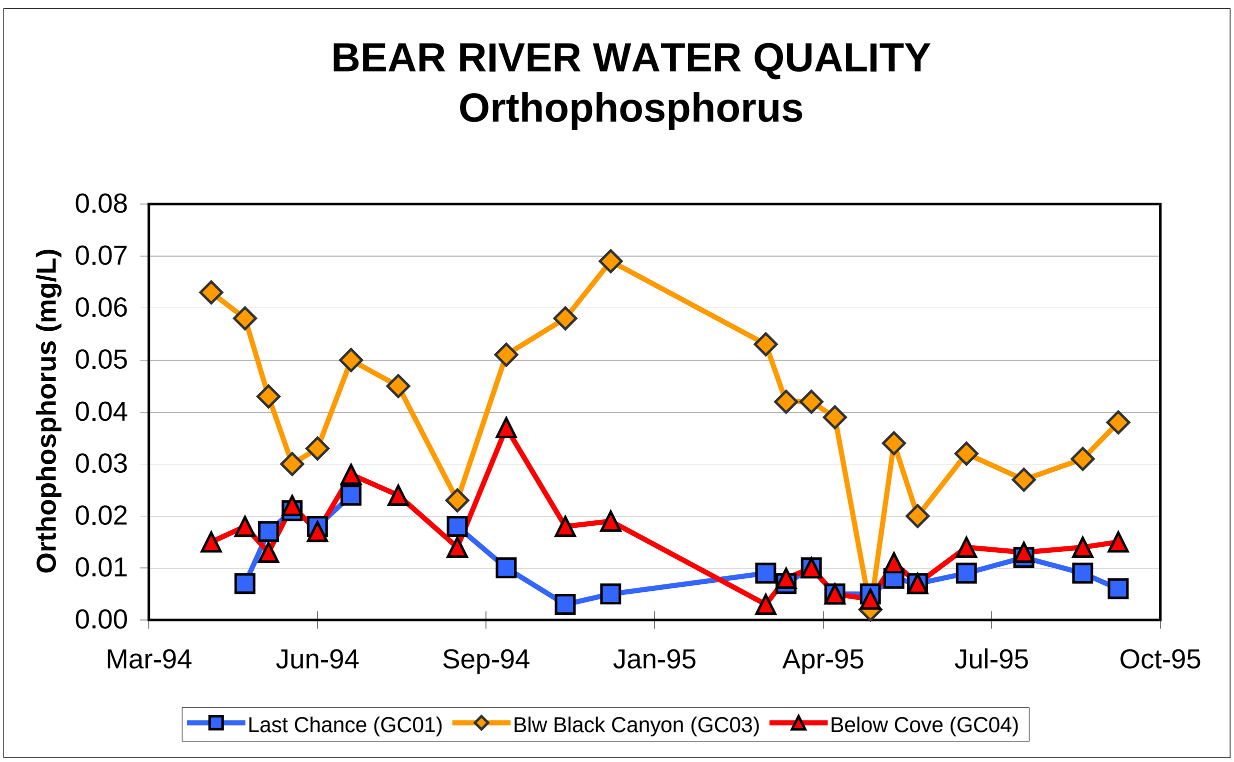
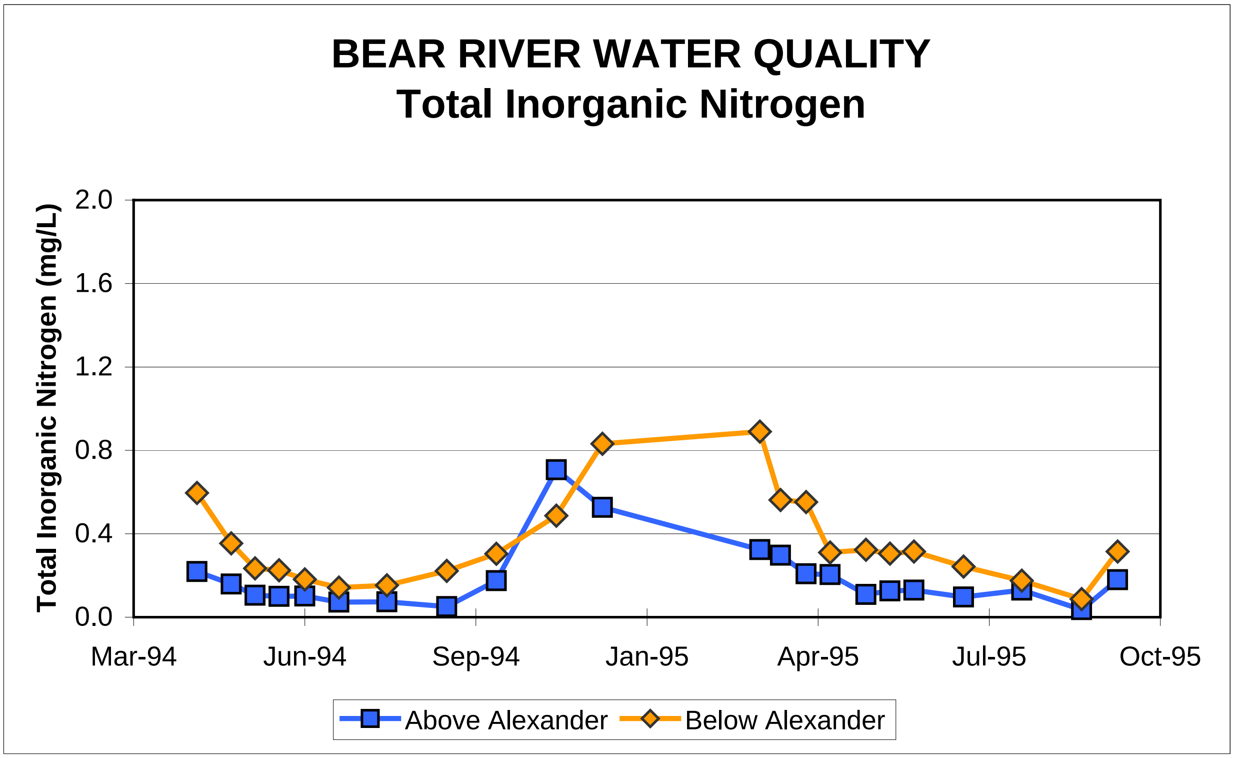


Figure 1-5. The orthophosphorus concentrations at five locations in the Bear River above Cove from 1994-1996.



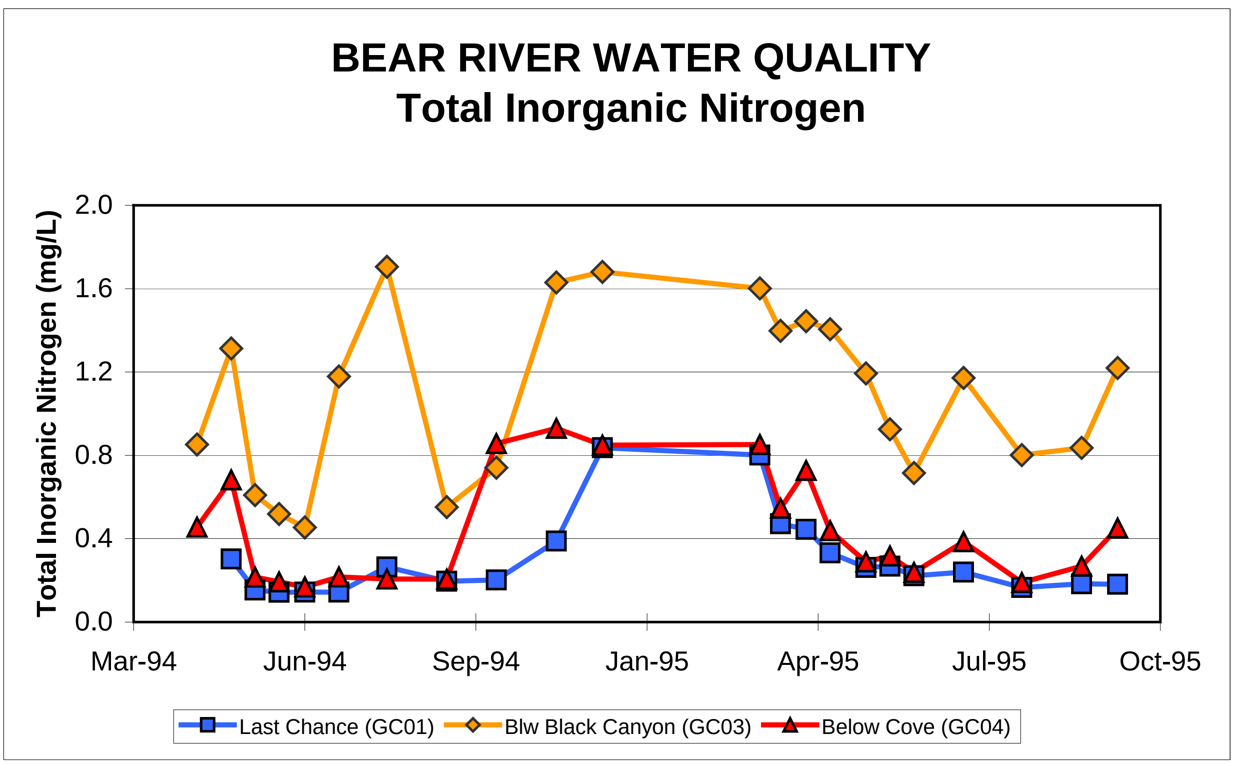


Figure 1-6. The total inorganic nitrogen concentrations at five locations in the Bear River above Cove from 1994-1996.

is not unexpected that the reservoir is also acting as a nutrient source for the soluble fraction of both phosphorous (ortho-phosphate) and nitrogen (nitrate, nitrite and ammonia). Historical data indicates that both these nutrients are leaving the reservoir in higher concentrations than are entering (Figures 1-4, 1-5 and 1-6). Although the overall effect is to remove vast amounts of nitrogen and phosphorous, the transformation below the reservoir has resulted in a clear (sediment removed) nutrient enriched ecosystem. This results in an abundance of rooted macrophytes and attached algae in the downstream reaches of the Bear River. This area is within the study location of this project (Last Chance to Cove). In addition, an inspection of Figures 1-4 through 1-6 also shows that Black Canyon outflows contain significant concentrations of orthophosphorus and total inorganic nitrogen. The source of these nutrients is undocumented but surface irrigation is suspected to be a large part of the cause. In total, the subject reach of the Bear River that is reflective of a highly productive, riverine system with high densities of primary producers.

2.0 MONITORING LOCATIONS

The Grace WQMP include sampling at four locations. These sites were continuously monitoring with YSI probes during three periods in 2006. In addition to the continuous monitoring, water quality samples (grab) were collected. These locations can be seen in Figures 2-1 and 2-2 and are described below.

GC01: Located below the outfall of the Last Chance Hydroelectric Plant and above the influence of the Grace forebay. This site represents the upstream control which will define water quality conditions entering the Development.

GC02: Located below the Grace Diversion Dam at the head of Black Canyon. This site will define the water quality conditions at the head of the bypass reach and will also define water quality conditions of Grace Diversion Dam water releases.

GC03: Located at the exit of the Bear River from Black Canyon. This site will define the water quality conditions resulting from the combination of the Grace Diversion Dam flow releases and the inflowing springs or point sources accruing within Black Canyon.

GC04: Located below the outfall of the Cove Hydroelectric Plant. This site represents the water quality conditions leaving the Grace/Cove Hydroelectric complex and represents the cumulative effects of the Development and land uses between the upper forebay of the Grace Diversion Dam and the outfall of the Cove plant.

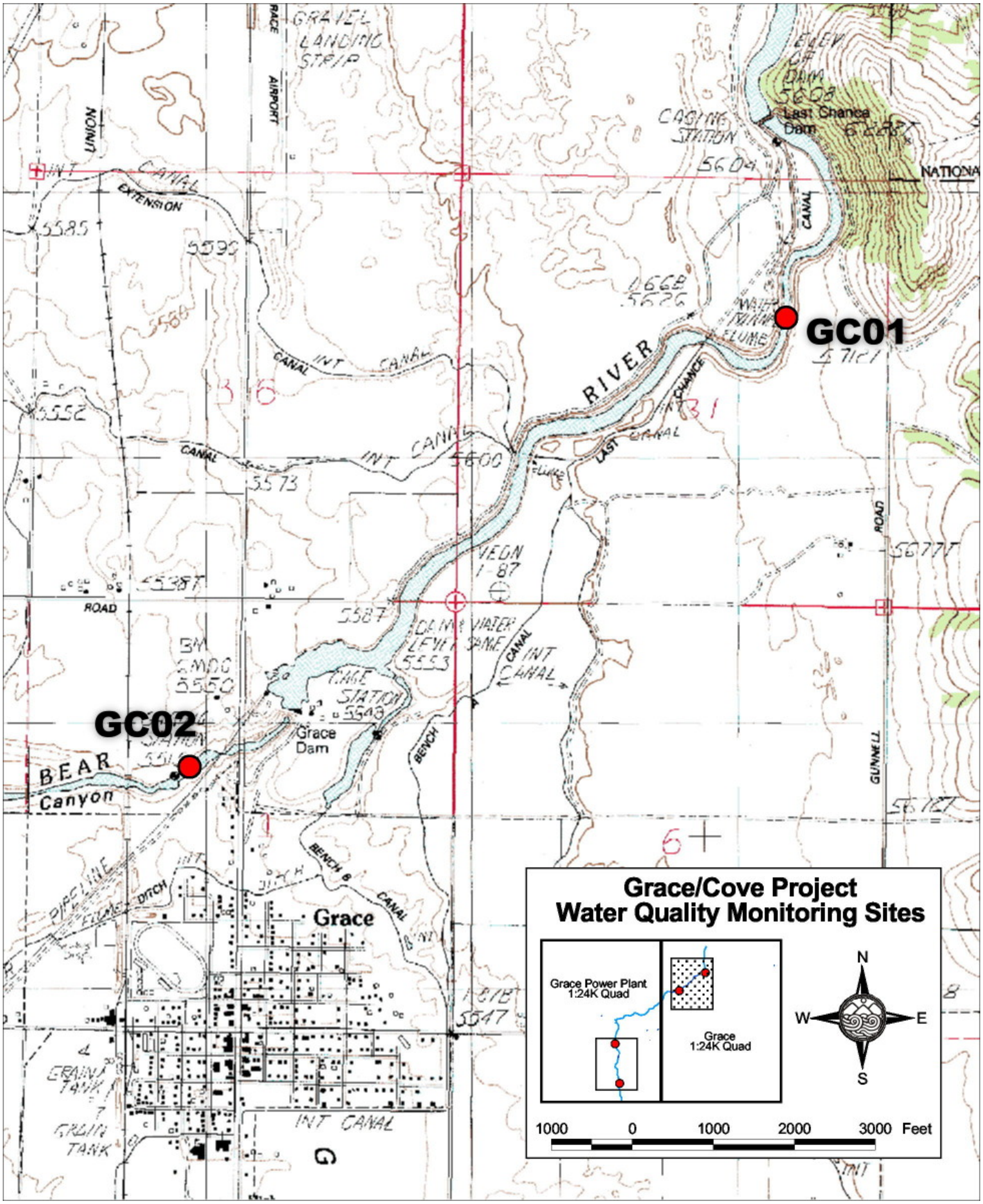


Figure 2-1. The location of the uppermost monitoring sites for the Grace/Cove WQMP.

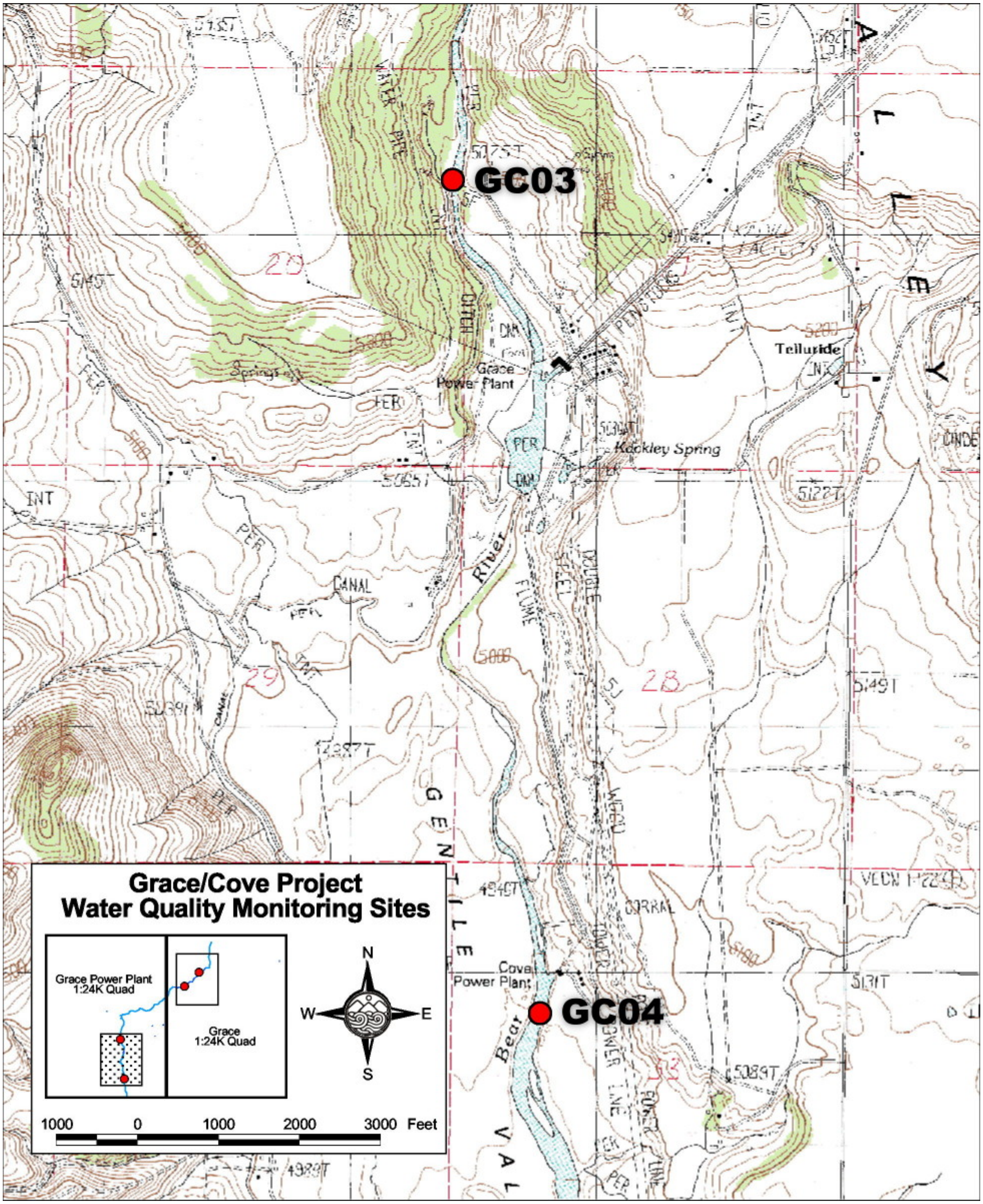


Figure 2-2. The location of the lowermost monitoring sites for the Grace/Cove WQMP.

2.1 Monitoring Frequency

Continuous monitoring probes (YSI Model 6920) collected dissolved oxygen, temperature, turbidity and specific conductance measurements at 15-minute intervals (reported hourly) over continuous periods from July 12 through July 19, August 9 through August 16 and September 6 through September 13, 2006. The Grace-Cove WQMP requires a minimum of continuous 7-day periods of hourly data for each month between July and September.

In addition to the continuous electronic data, water quality “grab” samples were also collected. Samples were returned to ERI’s laboratory for analysis. Parameters analyzed are described in the following section. Samples were taken twice during each of the continuous periods.

Flows in the Bear River immediately below the Grace Diversion Dam were monitored hourly and reported as average daily flows. This location corresponds to the continuous water quality station, GC02.

2.2 Monitoring Parameters

As noted above, two separate data sets were collected as part of the Grace-Cove WQMP. The parameters are defined below.

2.2.1 Continuously Monitoring Probes

YSI Model 6920 probes were installed by ERI at each of the four sites and were programmed to collect data at a 15-minute timestep over three 7-day periods. Parameters included:

1) specific conductance (µmhos/cm);

2) temperature (°C);

3) dissolved oxygen (mg O_2/L and % saturation); and,

4) turbidity (NTU).

2.2.2 Instantaneous Sampling

Grab samples were collected twice during each of the three continuous monitoring 7-day periods. Samples were analyzed by ERI’s EPA and state of Utah certified laboratory. Water quality parameters included:

1) total phosphorus (mg P/L);

2) orthophosphorus (mg P/L);

3) ammonia (mg N/L);

4) nitrate (mg N/L);

5) nitrite (mg N/L);

6) total suspended solids (mg/L); and,

7) turbidity (NTU).

3.0 MONITORING RESULTS

As noted in the previous sections, water quality data were instantaneously collected at four sites in the Bear River above, within and below the Grace-Cove Development. The collection and analysis of the data is intended to allow the major objectives of the program to be addressed. Those objectives are:

1) Characterize water quality conditions in the Grace bypass reach; and,

2) Help determine the Development’s contribution, if any, to violations of water quality criteria as set forth in the Idaho Water Quality Standards and Wastewater Treatment Requirements, IDAPA 53.01.02 (Water Quality Standards).

3.1 Continuous Monitoring

3.1.1 Site Hydrology

Inspection of the flow data collected for below Grace Dam and below Soda Dam (Figure 3-1) demonstrates the hydrology during each of the sampling episodes.

The first sampling period (July 12 through July 19) is characterized by flows ranging from 615 to 795 cubic feet per second (cfs) below Soda Dam (reflected in sites GC01 and GC04). Flows during this week decreased during the first half, then began increasing again by the end of the week. Flow below Grace Dam (GC02) ranged from 78 cfs to 122 cfs, and exhibited the same decreasing, then increasing pattern. Flow at GC03 is not gaged, but reflects those flows at GC02 plus the ungaged discharge from multiple springs in Black Canyon (Figure 3-1). Differences between the two stations reflect the conditions at the sites as a result of the diversion of water through the Grace powerplant (sites GC01 vs. GC02) and the subsequent mixing of bypass flows with groundwater discharge from Black Canyon.

The second sampling episode occurred between August 9 and August 16. Flows increased steadily over this time period, from 724 cfs to 871 cfs below Soda Dam. Flows below Grace Dam ranged from 73 cfs to 93 cfs.

The last sampling event occurred between September 6 and September 13 and included the lowest flows of the study period (Figure 3-1). A steep drop from 710 cfs to 173 cfs occurred below Soda Dam during the first five days of the sampling event, increasing to 500 cfs by the end of the event. Grace Dam remained fairly constant at about 85 cfs during the sampling period.

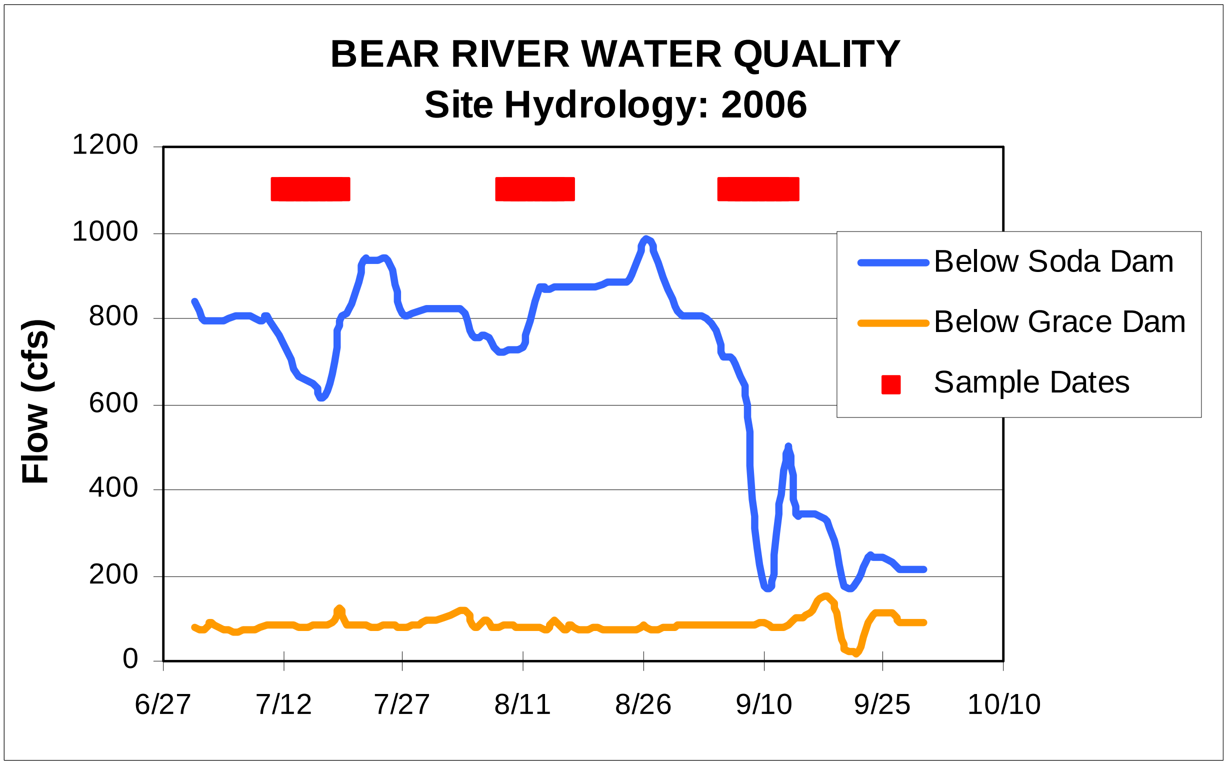


Figure 3-1. Flows recorded in the Bear River during the 2006 monitoring period.

3.1.2 Site Water Quality

3.1.2.1 July 2006 Water Quality

The water quality data collected continuously at the four stations are plotted in Figures 3-2 through 3-6. Temperature and dissolved oxygen demonstrated a distinctive daily pattern. A summary of water quality attributes at each site during the sample period in July (July 12-19) is provided in Table 3-1. The table contains the number of observations, average, minimum and maximum values and variance statistics for each parameter.

At each station, for each day of measurement, maximum water temperatures (21.3-24.0°C) were reached between 4:00 p.m. and 8:00 p.m. Minimum temperatures (14.9-20.1 °C) occurred between 6:00 and 7:00 a.m. Dissolved oxygen expressed as mg/l (Figure 3-3) and percent saturation (Figure 3-4) followed similar diel patterns. Specific conductance and turbidity did not have a consistent diel pattern for all sites. Turbidity levels varied between sites with GC02 and GC04 recording the greatest number of peak events (Figure 3-5). Large mats of periphytic algae were common throughout the study area and often lodged onto the probes, causing artificially high turbidity readings. The probes were visited at least once every 48 hours and any debris was cleaned at each visit.

To characterize diel variation a one-way ANOVA was conducted for each parameter. The data were blocked by time of day so that observations within each hour (i.e. 6 p.m.) were compared to observations at every other hour. The analysis assumes that each hourly block includes at least 28 replicates (4 observations/hr over 7 days). The results of the one-way ANOVA for each site and each parameter are shown in Table 3-2. The ANOVAs indicate that for temperature and dissolved oxygen (percent saturation and concentration) there are significant differences between times of day (p-value<0.001) at all four sites. With the exception of GC03, there is also a significant difference in conductance at all four sites. Significant differences in turbidity occurred at only GC01 and GC03.

In order to partition the daily variation confirmed by the ANOVAS, the data were divided into two 12-hour data sets; 7 PM to 7 AM (night) and 7 AM to 7 PM (day) This distinction separates the warmer and cooler periods of each day, as well as the solar input availability, and reduces variation within each group. Two additional analyses were completed to detect statistically significant differences between sites for the monitored parameters. Tukey tests were completed to determine which pairs of sites were different for each parameter. In addition, paired linear regressions were run between sites to determine the degree of similarity.

The Tukey analysis tested for differences among all possible pairs of sites for each parameter (Table 3-3). The meaningful comparisons are those relative to the control site (GC01). The temperature at GC01 was significantly different ($p<0.05$) from all sites at both day and night. With the exception of GC02, percent saturation of dissolved oxygen was also significantly different from GC01 for daytime and nighttime at the downstream sites. Daytime dissolved oxygen concentration was significantly different from GC01 at all sites except GC02, but

Table 3-1. The descriptive statistics of the instantaneous data collected on the Bear River in July 2006.

Date	N	Range	Minimum	Maximum	Mean	Standard Error	Standard Deviation	Variance
Temperature (°C)								
GC01	672	3.89	19.32	23.21	20.86	0.04	1.11	1.22
GC02	672	3.07	20.09	23.16	21.42	0.03	0.76	0.57
GC03	672	6.39	14.91	21.30	18.12	0.06	1.61	2.59
GC04	672	6.80	17.19	23.99	19.85	0.07	1.83	3.36
Specific Conductance (μmho/cm)								
GC01	672	0.021	0.633	0.654	0.643	0.0002	0.005	0.0000
GC02	672	0.027	0.623	0.650	0.634	0.0003	0.007	0.0000
GC03	672	0.196	0.227	0.423	0.294	0.0022	0.057	0.0032
GC04	672	0.052	0.650	0.702	0.668	0.0004	0.009	0.0001
Dissolved Oxygen (%)								
GC01	672	53.30	58.20	111.50	79.04	0.63	16.46	270.92
GC02	672	98.10	20.90	119.00	85.87	0.69	17.93	321.41
GC03	672	49.90	68.90	118.80	90.31	0.55	14.37	206.54
GC04	672	86.60	60.80	147.40	86.45	0.84	21.78	474.45
Dissolved Oxygen (mg/L)								
GC01	672	4.26	5.29	9.55	7.03	0.05	1.31	1.72
GC02	672	8.51	1.87	10.38	7.57	0.06	1.52	2.31
GC03	672	4.50	6.45	10.95	8.51	0.05	1.26	1.58
GC04	672	6.99	5.68	12.67	7.82	0.07	1.73	3.00
Turbidity (NTU)								
GC01	672	27.80	7.10	34.90	15.10	0.14	3.52	12.39
GC02	672	878.90	5.40	884.30	11.52	1.40	36.25	1313.74
GC03	672	10.50	1.40	11.90	3.05	0.05	1.20	1.44
GC04	672	121.20	2.10	123.30	6.98	0.23	6.04	36.54

Table 3-2. The ANOVA for determining if there is a significant difference between the parameter values over time of day. This analysis is assuming each hour (e.g. 6:00 p.m.) has seven replicates over the study in July 2006.

		Sum of Squares	df	Mean Square	F	Sig.
TEMPERATURE						
GC01	Between Groups	750.531	23	32.632	305.126	0
	Within Groups	69.301	648	0.107		
	Total	819.832	671			
GC02	Between Groups	106.28	23	4.621	10.777	0
	Within Groups	277.839	648	0.429		
	Total	384.119	671			
GC03	Between Groups	133.986	23	5.825	2.351	0
	Within Groups	1605.517	648	2.478		
	Total	1739.503	671			
GC04	Between Groups	2087.129	23	90.745	355.026	0
	Within Groups	165.629	648	0.256		
	Total	2252.758	671			
SPECIFIC CONDUCTANCE						
GC01	Between Groups	0.001355	23	5.892E-05	2.283	0.001
	Within Groups	0.01673	648	2.581E-05		
	Total	0.01808	671			
GC02	Between Groups	0.003512	23	0.0001527	3.942	0
	Within Groups	0.0251	648	3.873E-05		
	Total	0.02861	671			
GC03	Between Groups	0.02413	23	0.001049	0.318	0.999
	Within Groups	2.14	648	0.003303		
	Total	2.164	671			
GC04	Between Groups	0.03611	23	0.00157	42.739	0
	Within Groups	0.0238	648	3.674E-05		
	Total	0.05992	671			
DISSOLVED OXYGEN (%)						
GC01	Between Groups	169082.812	23	7351.427	375.013	0
	Within Groups	12702.825	648	19.603		
	Total	181785.637	671			
GC02	Between Groups	148238.419	23	6445.149	61.938	0
	Within Groups	67429.465	648	104.058		
	Total	215667.884	671			
GC03	Between Groups	8909.764	23	387.381	1.936	0.006
	Within Groups	129677.601	648	200.12		
	Total	138587.365	671			

		Sum of Squares	df	Mean Square	F	Sig.
GC04	Between Groups	276006.238	23	12000.271	183.621	0
	Within Groups	42349.154	648	65.354		
	Total	318355.391	671			
DISSOLVED OXYGEN (mg/L)						
GC01	Between Groups	1069.245	23	46.489	342.582	0
	Within Groups	87.935	648	0.136		
	Total	1157.179	671			
GC02	Between Groups	1079.406	23	46.931	64.576	0
	Within Groups	470.934	648	0.727		
	Total	1550.34	671			
GC03	Between Groups	61.046	23	2.654	1.725	0.019
	Within Groups	996.83	648	1.538		
	Total	1057.876	671			
GC04	Between Groups	1738.681	23	75.595	178.914	0
	Within Groups	273.793	648	0.423		
	Total	2012.474	671			
TURBIDITY (NTU)						
GC01	Between Groups	1476.444	23	64.193	6.085	0
	Within Groups	6835.633	648	10.549		
	Total	8312.077	671			
GC02	Between Groups	29353.117	23	1276.222	0.97	0.502
	Within Groups	852169.17	648	1315.076		
	Total	881522.286	671			
GC03	Between Groups	70.349	23	3.059	2.207	0.001
	Within Groups	898.13	648	1.386		
	Total	968.478	671			
GC04	Between Groups	771.246	23	33.532	0.915	0.578
	Within Groups	23746.412	648	36.646		
	Total	24517.657	671			

Table 3-3. The results of the TUKEY tests to determine significant differences (p-value, 0.05) between means for different sample locations. The analysis has been grouped for the hours of 7 PM to 7 AM (night) and 7 AM to 7 PM (day) for hourly data collected in July of 2006.

	Mean Difference	Std. Error	Sig. Level	95% Confidence Interval	
				Lower	Upper
NIGHTTIME (7 PM - 7 AM)					
Temperature					
GC01 vs GC02	-0.7052	0.08848	0	-0.9325	-0.4779
GC01 vs GC03	2.3961	0.08848	0	2.1688	2.6234
GC01 vs GC04	1.6122	0.08848	0	1.3849	1.8395
GC02 vs GC03	3.1013	0.08848	0	2.874	3.3286
GC02 vs GC04	2.3174	0.08848	0	2.0901	2.5447
GC03 vs GC04	0.7839	0.08848	0	0.5566	1.0112
Specific Conductance					
GC01 vs GC02	0.007729	0.002071	0.001	0.002409	0.01305
GC01 vs GC03	0.3524	0.002071	0	0.347	0.3577
GC01 vs GC04	-0.02889	0.002071	0	-0.03421	-0.02357
GC02 vs GC03	0.3446	0.002071	0	0.3393	0.35
GC02 vs GC04	-0.036619	0.002071	0	-0.041939	-0.031299
GC03 vs GC04	0.3813	0.002071	0	0.3759	0.3866
Dissolved Oxygen (%)					
GC01 vs GC02	-1.033	1.0027	0.732	-3.609	1.5429
GC01 vs GC03	-14.6833	1.0027	0	-17.2593	-12.1074
GC01 vs GC04	4.3705	1.0027	0	1.7946	6.9465
GC02 vs GC03	-13.6503	1.0027	0	-16.2263	-11.0743
GC02 vs GC04	5.4036	1.0027	0	2.8276	7.9795
GC03 vs GC04	-19.0539	1.0027	0	-21.6298	-16.4779
Dissolved Oxygen (mg/L)					
GC01 vs GC02	-0.016696	0.08383	0.997	-0.2321	0.1987
GC01 vs GC03	-1.7306	0.08383	0	-1.9459	-1.5152
GC01 vs GC04	0.179	0.08383	0.142	-0.036396	0.3943
GC02 vs GC03	-1.7139	0.08383	0	-1.9292	-1.4985
GC02 vs GC04	0.1957	0.08383	0.09	-0.019699	0.411
GC03 vs GC04	-1.9095	0.08383	0	-2.1249	-1.6942
Turbidity					
GC01 vs GC02	4.239	0.7988	0	2.1869	6.291
GC01 vs GC03	12.2631	0.7988	0	10.211	14.3151
GC01 vs GC04	8.0009	0.7988	0	5.9488	10.0529
GC02 vs GC03	8.0241	0.7988	0	5.9721	10.0762
GC02 vs GC04	3.7619	0.7988	0	1.7099	5.814
GC03 vs GC04	4.2622	0.7988	0	2.2102	6.3142

	Mean Difference	Std. Error	Sig. Level	95% Confidence Interval Lower	95% Confidence Interval Upper
DAYTIME (7 AM - 7 PM)					
Temperature					
GC01 vs GC02	-0.2778	0.05009	0	-0.4065	-0.1491
GC01 vs GC03	2.9835	0.05009	0	2.8548	3.1121
GC01 vs GC04	1.1182	0.05009	0	0.9895	1.2468
GC02 vs GC03	3.2612	0.05009	0	3.1325	3.3899
GC02 vs GC04	1.3959	0.05009	0	1.2672	1.5246
GC03 vs GC04	1.8653	0.05009	0	1.7366	1.994
Specific Conductance					
GC01 vs GC02	0.03798	0.001406	0	0.03437	0.04159
GC01 vs GC03	-0.018271	0.001406	0	-0.021882	-0.01466
GC01 vs GC04	0.05117	0.001406	0	0.04756	0.05478
GC02 vs GC03	-0.056247	0.001406	0	-0.059858	-0.052636
GC02 vs GC04	0.0132	0.001406	0	0.009585	0.01681
GC03 vs GC04	-0.069443	0.001406	0	-0.073055	-0.065832
Dissolved Oxygen (%)					
GC01 vs GC02	-1.7286	0.71	0.071	-3.5525	0.09534
GC01 vs GC03	-10.2182	0.71	0	-12.0421	-8.3942
GC01 vs GC04	-38.2598	0.71	0	-40.0837	-36.4359
GC02 vs GC03	-8.4896	0.71	0	-10.3135	-6.6657
GC02 vs GC04	-36.5313	0.71	0	-38.3552	-34.7073
GC03 vs GC04	28.0417	0.71	0	26.2178	29.8656
Dissolved Oxygen (mg/L)					
GC01 vs GC02	-0.1336	0.06154	0.131	-0.2917	0.02446
GC01 vs GC03	-1.4209	0.06154	0	-1.579	-1.2628
GC01 vs GC04	-3.7411	0.06154	0	-3.8992	-3.583
GC02 vs GC03	-1.2873	0.06154	0	-1.4453	-1.1292
GC02 vs GC04	-3.6075	0.06154	0	-3.7656	-3.4494
GC03 vs GC04	2.3202	0.06154	0	2.1622	2.4783
Turbidity					
GC01 vs GC02	-8.1461	3.9193	0.16	-18.215	1.9228
GC01 vs GC03	12.4068	3.9193	0.008	2.3379	22.4757
GC01 vs GC04	8.6399	3.9193	0.122	-1.429	18.7088
GC02 vs GC03	20.553	3.9193	0	10.4841	30.6219
GC02 vs GC04	16.786	3.9193	0	6.7171	26.8549
GC03 vs GC04	3.767	3.9193	0.772	-6.3019	13.8359

Table 3-4. The results of the paired linear regressions between the four sample sites on the Bear River during July 2006.

	N	R2	Sig. Level
TEMPERATURE			
GC01 vs GC02	671	0.307	0
GC01 vs GC03	671	0.041	0
GC01 vs GC04	671	0.812	0
GC02 vs GC03	671	0.043	0
GC02 vs GC04	671	0.304	0
GC03 vs GC04	671	0.033	0
CONDUCTIVITY			
GC01 vs GC02	671	0.161	0
GC01 vs GC03	671	0.101	0
GC01 vs GC04	671	0.181	0
GC02 vs GC03	671	0.346	0
GC02 vs GC04	671	0	0.658
GC03 vs GC04	671	0.11	0
DISSOLVED OXYGEN (%)			
GC01 vs GC02	671	0.431	0
GC01 vs GC03	671	0	0.9
GC01 vs GC04	671	0.374	0
GC02 vs GC03	671	0.01	0.009
GC02 vs GC04	671	0.717	0
GC03 vs GC04	671	0.019	0
DISSOLVED OXYGEN (MG/L)			
GC01 vs GC02	671	0.42	0
GC01 vs GC03	671	0	0.815
GC01 vs GC04	671	0.297	0
GC02 vs GC03	671	0.008	0.018
GC02 vs GC04	671	0.676	0
GC03 vs GC04	671	0.017	0.001
TURBIDITY (NTU)			
GC01 vs GC02	671	0.002	0.247
GC01 vs GC03	671	0.018	0
GC01 vs GC04	671	0.044	0
GC02 vs GC03	671	0	0.696
GC02 vs GC04	671	0	0.606
GC03 vs GC04	671	0	0.62

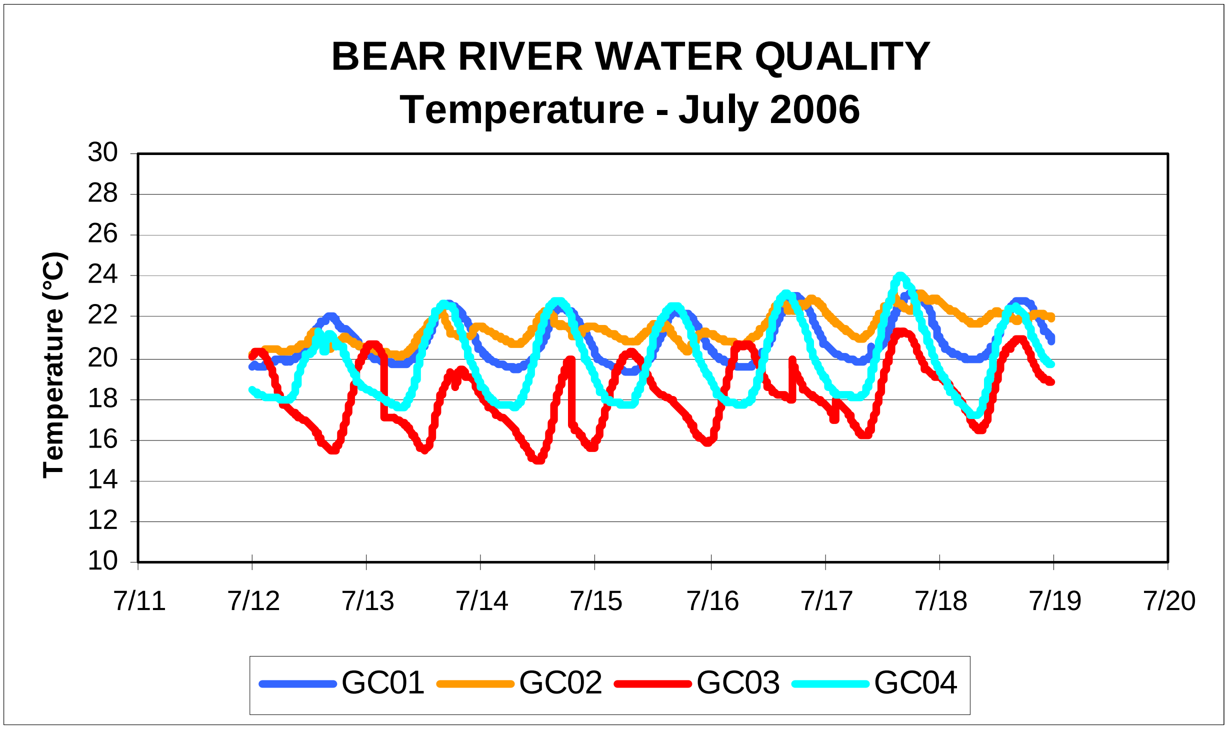


Figure 3-2. Temperature at four monitoring stations during July 2006.

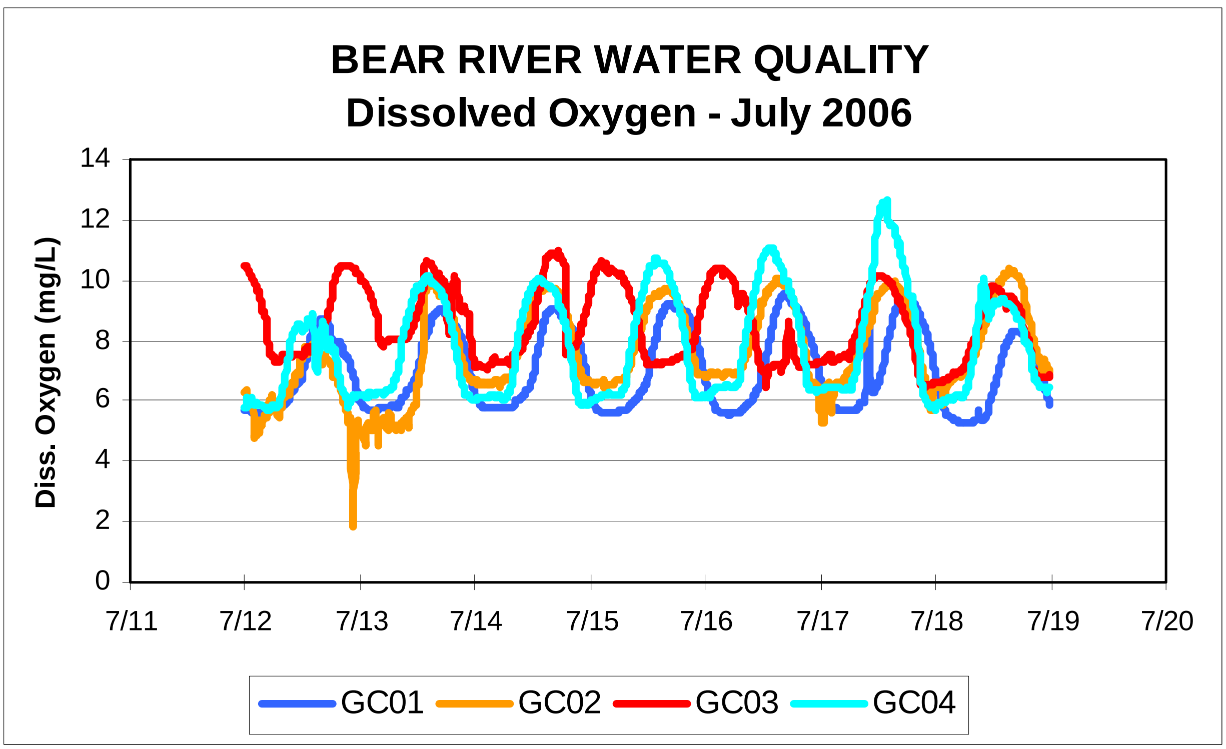


Figure 3-3. Dissolved oxygen at four monitoring stations during July 2006.

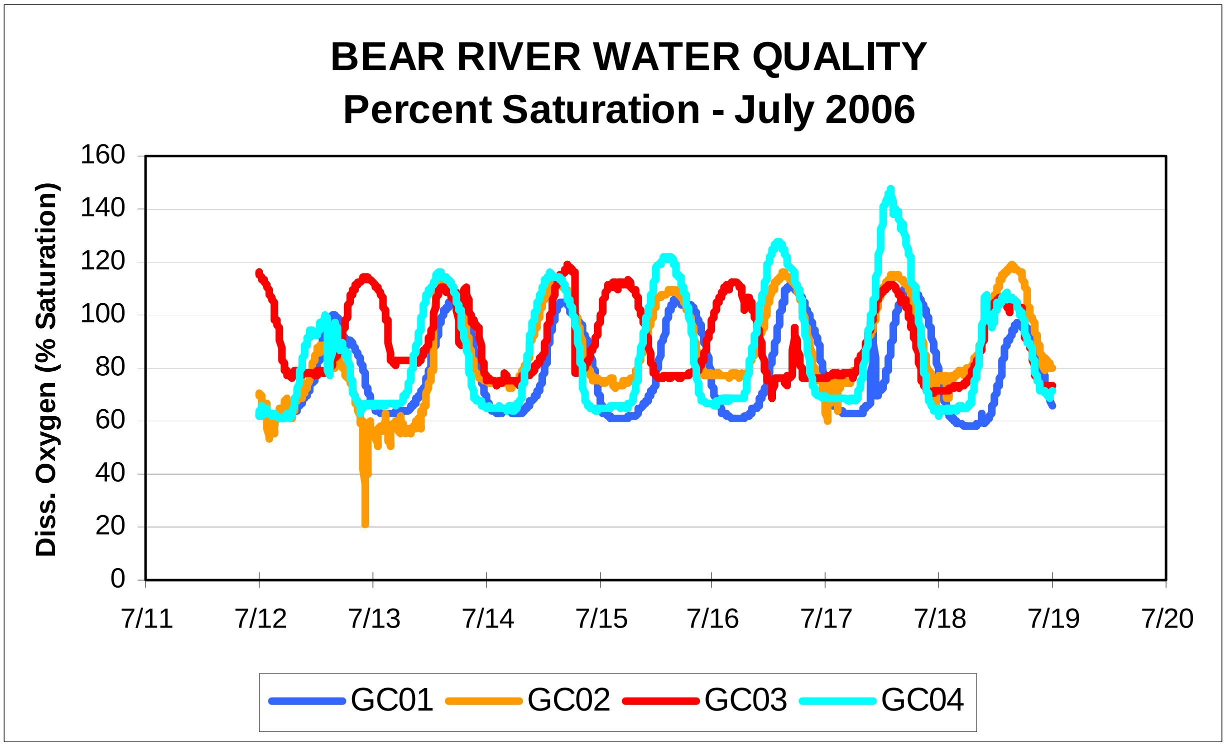


Figure 3-4. Percent saturation of dissolved oxygen at four monitoring stations during July 2006.

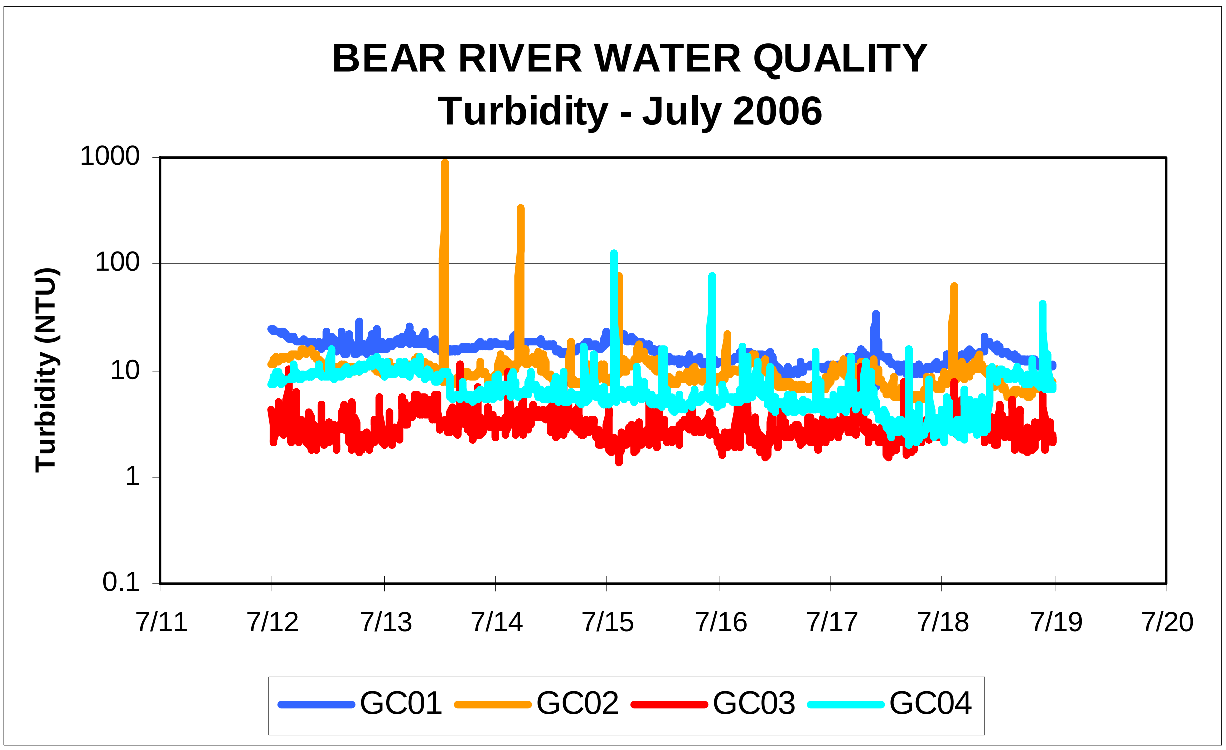


Figure 3-5. Turbidity at four monitoring stations during July 2006.

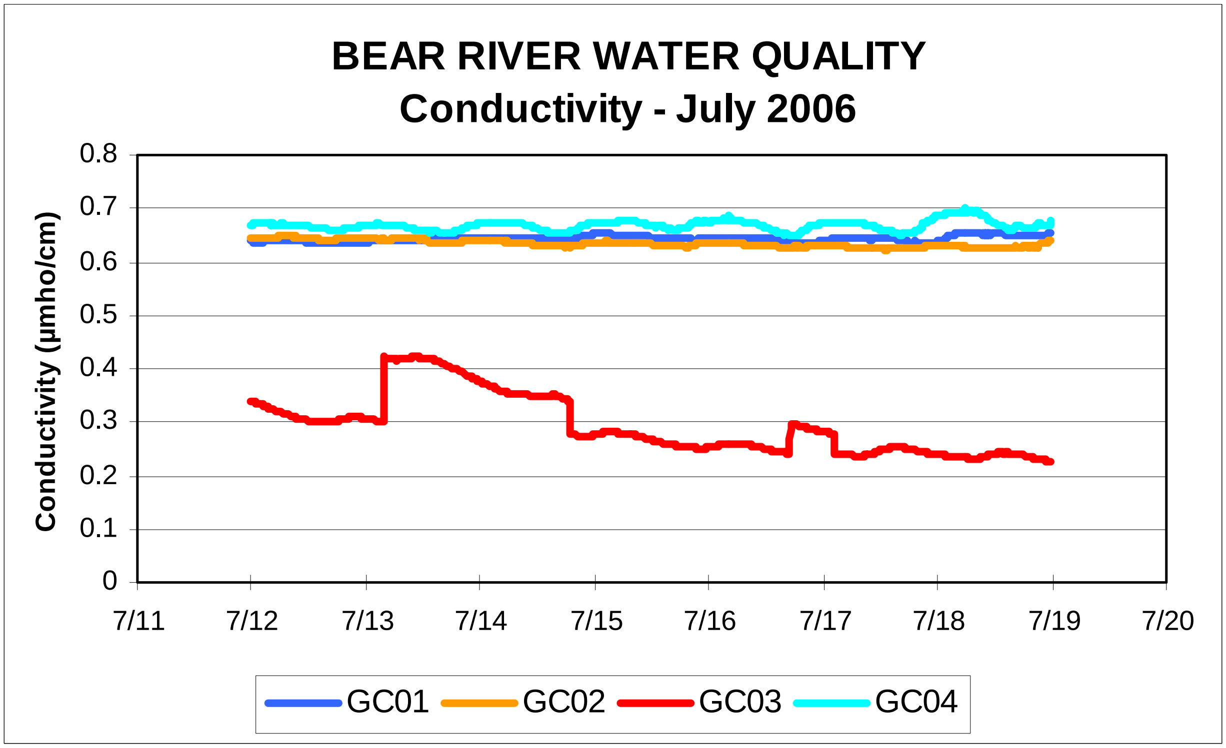


Figure 3-6. Specific conductance at four monitoring stations during July 2006.

concentrations at GC03 were the only significant difference during the nighttime. Interestingly, turbidity showed significant differences from GC01 at all sites, but only during the nighttime.

By comparing the differences between adjacent sample sites (GC01 vs GC02; GC02 vs. GC03; GC03 vs.GC04) we can evaluate the systematic change in water quality parameters as water moves through the hydroelectric complex. In the case of temperature, significant differences occurred at all adjacent sample sites at all hours ($p<0.05$). There was no significant difference between GC01 and GC02 for dissolved oxygen (concentration and saturation), but significant differences at all hours occurred between GC02 and GC03, as well as GC03 and GC04. Turbidity during the nighttime was significantly different at all adjacent sites. During the daytime, however, the only pair with significant differences was GC02 and GC03.

Pair-wise linear regressions were used to determine if the same pattern of changes were occurring at each site for each parameter. In other words, can the parameter values at any site predict the values of another site. The regressions for the entire July data set (n=671) are shown in Table 3-4. The table includes the coefficient of determination (r2) and the significance level of the regression relationship. Because of the large sample size, a large proportion of the regressions are significant. However, inspection of the r2 value indicates what proportion of the variability at a site can be explained by the second site. For example, the variability in temperature at site GC01 can explain only 31 percent of the variability in temperature at GC02 ($p< 0.05$), but can explain 81 percent of the temperature variability at GC04 ($p < 0.05$). The second highest coefficient of determination was found between GC02 and GC04 for dissolved oxygen percent saturation. The regression indicates that 72 percent of the variability in percent saturation at GC04 can be explained by percent saturation at GC02.

3.1.2.2 August 2004 Water Quality

The water quality data collected continuously at the four stations are plotted in Figures 3-7 through 3-11. Temperature and dissolved oxygen demonstrated a distinctive daily pattern. A summary of water quality attributes at each site during the sample period in August (August 9-15) is provided in Table 3-5. The table contains the number of observations, average, minimum and maximum values and variance statistics for each parameter.

Maximum water temperatures recorded at each station ranged from 19.7°C to 21.9°C, with the greatest range in temperature occurring at GC03. Minimum temperatures ranged from 13.7°C to 19.1°C (Figure 3-7). Dissolved oxygen expressed as mg/l (Figure 3-8) and percent saturation (Figure 3-9) exhibited similar diel patterns with the greatest range occurring in GC04. Specific conductance and turbidity did not have a consistent diel pattern for all sites. Turbidity levels varied between sites with GC02 recording the greatest number of peak events (similar to August). Though GC03 had overall lower turbidity readings during August, it experienced more variability than GC01 and GC04 (Figure 3-10). Large mats of periphytic algae were common throughout the study area and often lodged onto the probes, causing artificially high turbidity readings. The probes were visited at least once every 48 hours and any debris was cleaned at each visit.

Table 3-5. The descriptive statistics of the instantaneous data collected on the Bear River in August 2006.

Date	N	Range	Min-imum	Max-imum	Mean	Standard Error	Standard Deviation	Variance
Temperature (°C)								
GC01	672	3.39	18.52	21.91	19.86	0.04	0.93	0.86
GC02	672	2.32	19.14	21.46	19.93	0.02	0.44	0.20
GC03	672	6.05	13.68	19.73	16.77	0.06	1.50	2.24
GC04	672	3.47	17.6	21.07	18.90	0.03	0.87	0.76
Specific Conductance (μmho/cm)								
GC01	672	0.016	0.708	0.724	0.71	0.00	0.00	0.00
GC02	672	0.024	0.662	0.686	0.68	0.00	0.01	0.00
GC03	672	0.044	0.713	0.757	0.73	0.00	0.01	0.00
GC04	672	0.15	0.615	0.765	0.66	0.00	0.03	0.00
Dissolved Oxygen (%)								
GC01	672	50.9	60.8	111.7	77.59	0.57	14.88	221.52
GC02	672	62.7	47.3	110	81.94	0.51	13.24	175.33
GC03	672	51.8	76.8	128.6	95.99	0.66	17.10	292.49
GC04	672	69.2	80.7	149.9	120.41	0.64	16.60	275.52
Dissolved Oxygen (mg/L)								
GC01	672	4.19	5.61	9.8	7.04	0.05	1.21	1.47
GC02	672	5.49	4.34	9.83	7.44	0.04	1.15	1.33
GC03	672	5.13	7.31	12.44	9.29	0.06	1.56	2.42
GC04	672	5.9	7.66	13.56	11.15	0.05	1.38	1.91
Turbidity (NTU)								
GC01	672	56.4	10.1	66.5	17.34	0.17	4.39	19.26
GC02	672	1436.5	8.1	1444.6	21.47	2.77	71.75	5148.14
GC03	672	461.9	1.2	463.1	8.79	1.08	27.96	781.61
GC04	672	26.2	3.9	30.1	10.71	0.13	3.30	10.90

Table 3-6. The ANOVA for determining if there is a significant difference between the parameter values over time of day. This analysis is assuming each hour (e.g. 6:00 p.m.) has seven replicates over the study in August 2006.

		Sum of Squares	df	Mean Square	F	Sig.
TEMPERATURE						
GC01	Between Groups	514.869	23	22.386	244.325	0
	Within Groups	59.371	648	0.09162		
	Total	574.24	671			
GC02	Between Groups	53.262	23	2.316	18.867	0
	Within Groups	79.534	648	0.123		
	Total	132.796	671			
GC03	Between Groups	1356.812	23	58.992	258.879	0
	Within Groups	147.662	648	0.228		
	Total	1504.474	671			
GC04	Between Groups	406.938	23	17.693	109.532	0
	Within Groups	104.673	648	0.162		
	Total	511.611	671			
SPECIFIC CONDUCTANCE						
GC01	Between Groups	0.0008211	23	3.57E-05	4.526	0
	Within Groups	0.005112	648	7.888E-06		
	Total	0.005933	671			
GC02	Between Groups	0.001777	23	7.725E-05	2.716	0
	Within Groups	0.01843	648	2.845E-05		
	Total	0.02021	671			
GC03	Between Groups	0.04465	23	0.001941	44.824	0
	Within Groups	0.02807	648	4.331E-05		
	Total	0.07272	671			
GC04	Between Groups	0.03115	23	0.001354	1.666	0.027
	Within Groups	0.527	648	0.0008128		
	Total	0.558	671			
DISSOLVED OXYGEN (%)						
GC01	Between Groups	135046.094	23	5871.569	279.93	0
	Within Groups	13591.863	648	20.975		
	Total	148637.957	671			
GC02	Between Groups	103014.352	23	4478.885	198.341	0
	Within Groups	14632.965	648	22.582		
	Total	117647.317	671			

		Sum of Squares	df	Mean Square	F	Sig.
GC03	Between Groups	188138.134	23	8179.919	652.522	0
	Within Groups	8123.236	648	12.536		
	Total	196261.37	671			
GC04	Between Groups	114126.65	23	4962.028	45.447	0
	Within Groups	70750.342	648	109.183		
	Total	184876.992	671			
DISSOLVED OXYGEN (mg/L)						
GC01	Between Groups	896.751	23	38.989	273.617	0
	Within Groups	92.337	648	0.142		
	Total	989.087	671			
GC02	Between Groups	791.435	23	34.41	215.175	0
	Within Groups	103.627	648	0.16		
	Total	895.062	671			
GC03	Between Groups	1542.991	23	67.087	539.392	0
	Within Groups	80.595	648	0.124		
	Total	1623.586	671			
GC04	Between Groups	740.041	23	32.176	38.298	0
	Within Groups	544.417	648	0.84		
	Total	1284.458	671			
TURBIDITY (NTU)						
GC01	Between Groups	2986.179	23	129.834	8.469	0
	Within Groups	9934.001	648	15.33		
	Total	12920.18	671			
GC02	Between Groups	287399.62	23	12495.636	2.557	0
	Within Groups	3166998.965	648	4887.344		
	Total	3454398.585	671			
GC03	Between Groups	24397.065	23	1060.742	1.375	0.114
	Within Groups	500063.538	648	771.703		
	Total	524460.603	671			
GC04	Between Groups	786.539	23	34.197	3.396	0
	Within Groups	6524.593	648	10.069		
	Total	7311.132	671			

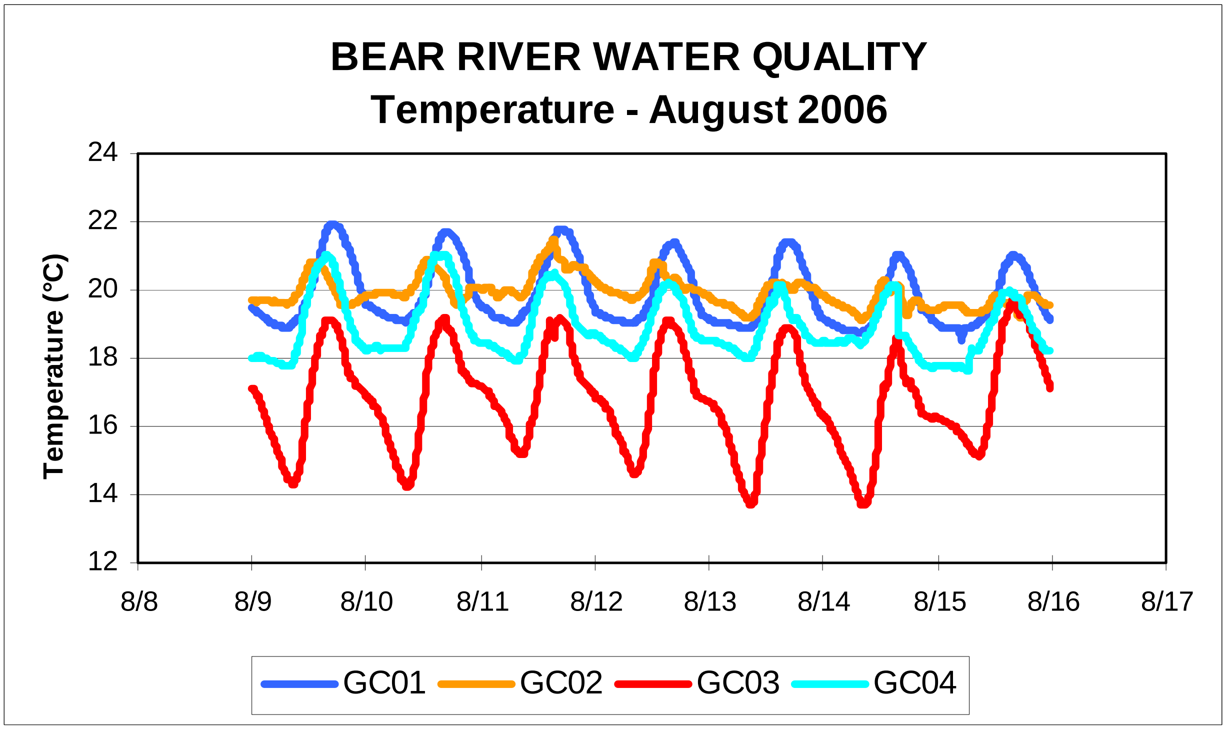


Figure 3-7. Temperature at four monitoring stations during August 2006.

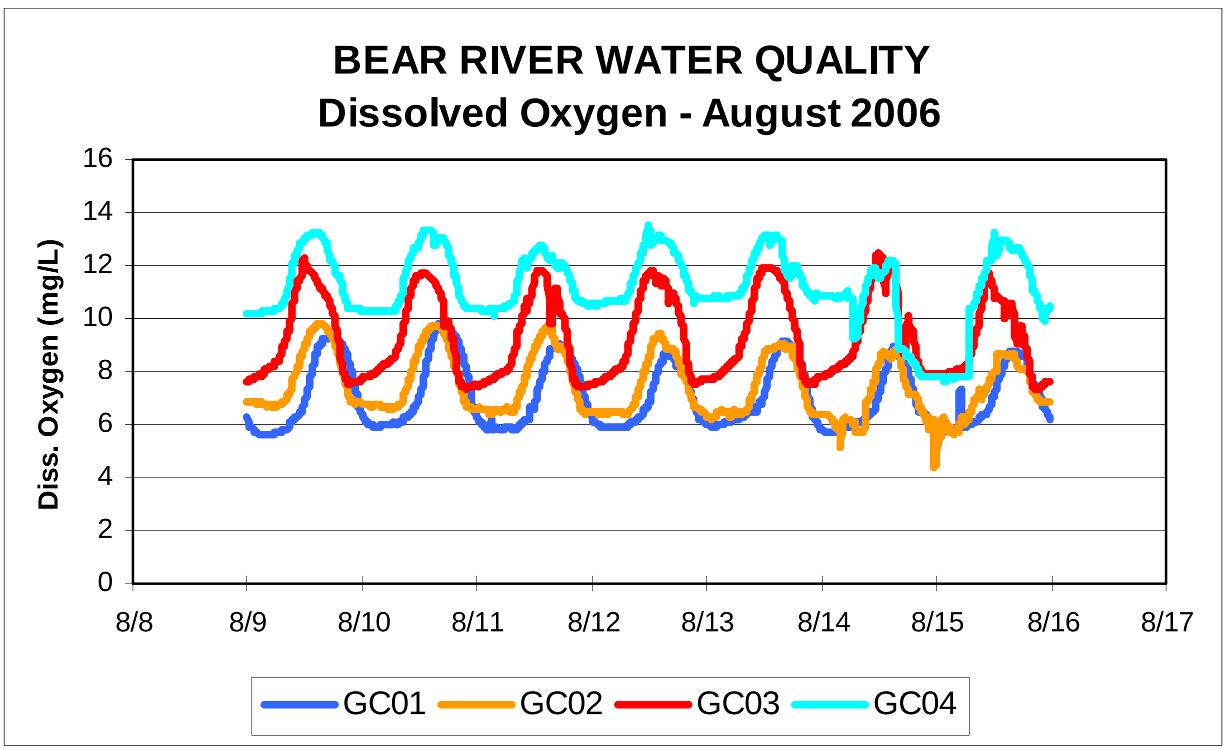


Figure 3-8. Dissolved oxygen at four monitoring stations during August 2006.

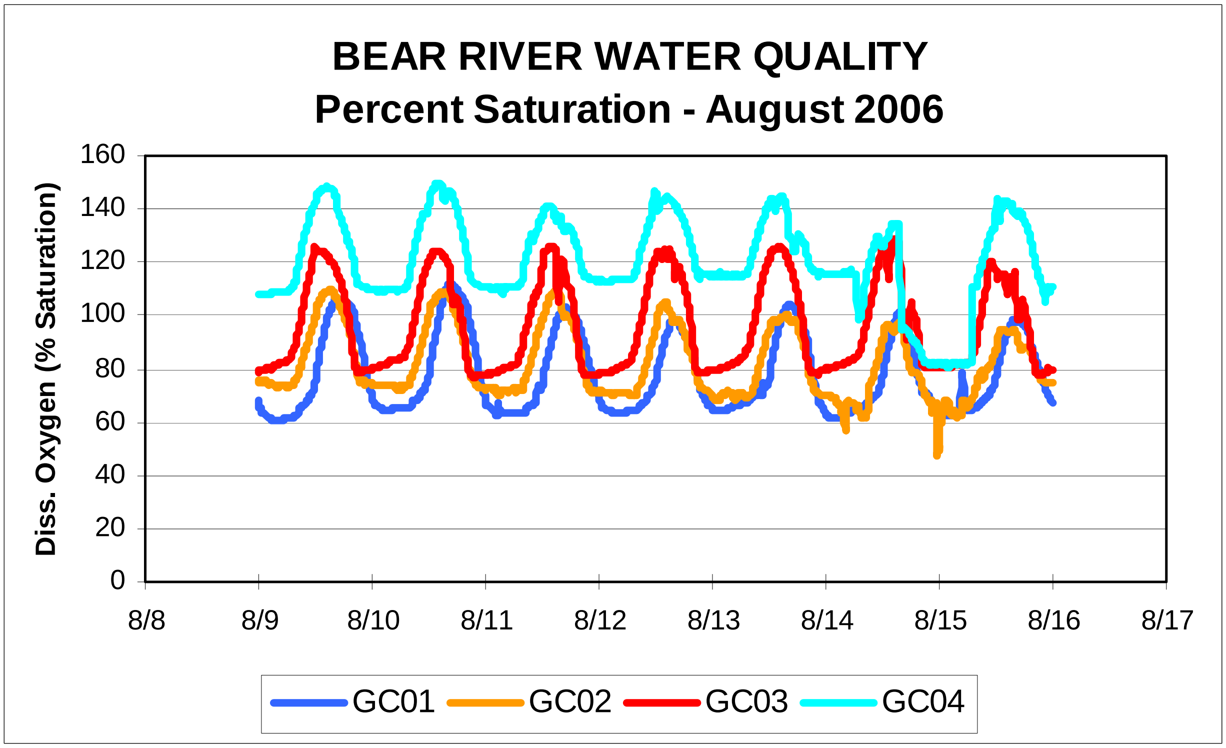


Figure 3-9. Percent saturation of dissolved oxygen at four monitoring stations during August 2006.

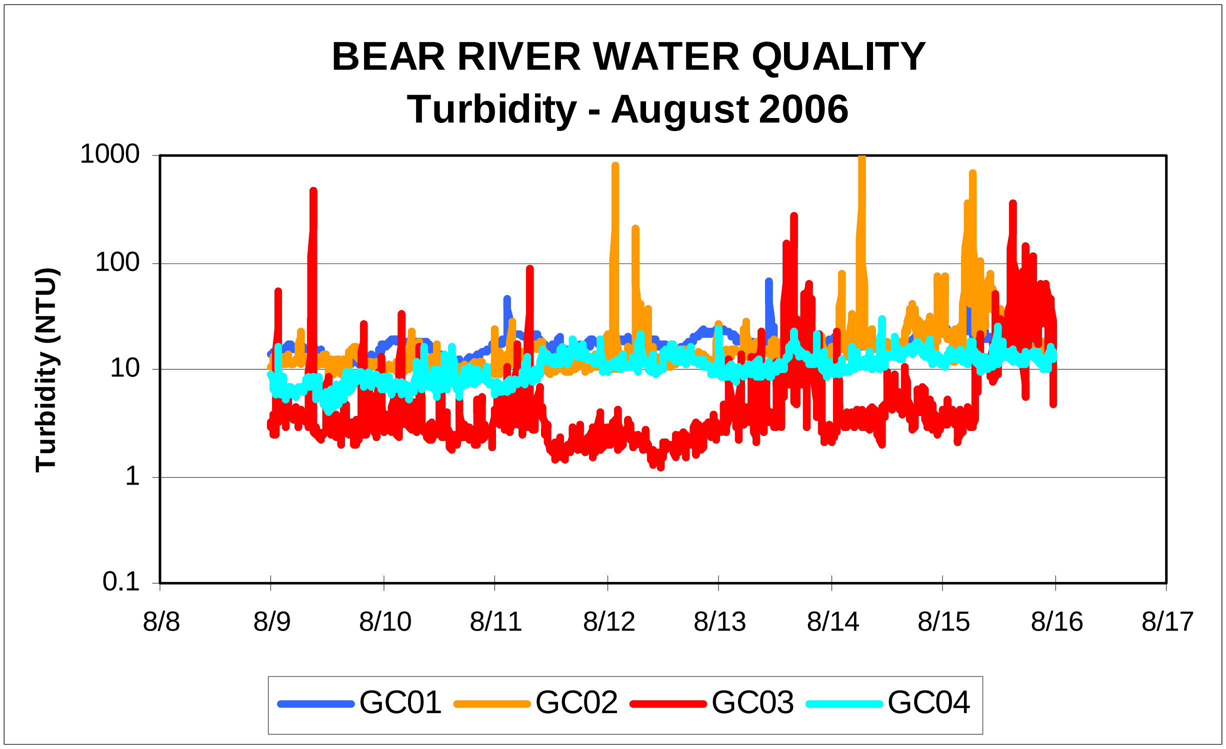


Figure 3-10. Turbidity at four monitoring stations during August 2006.

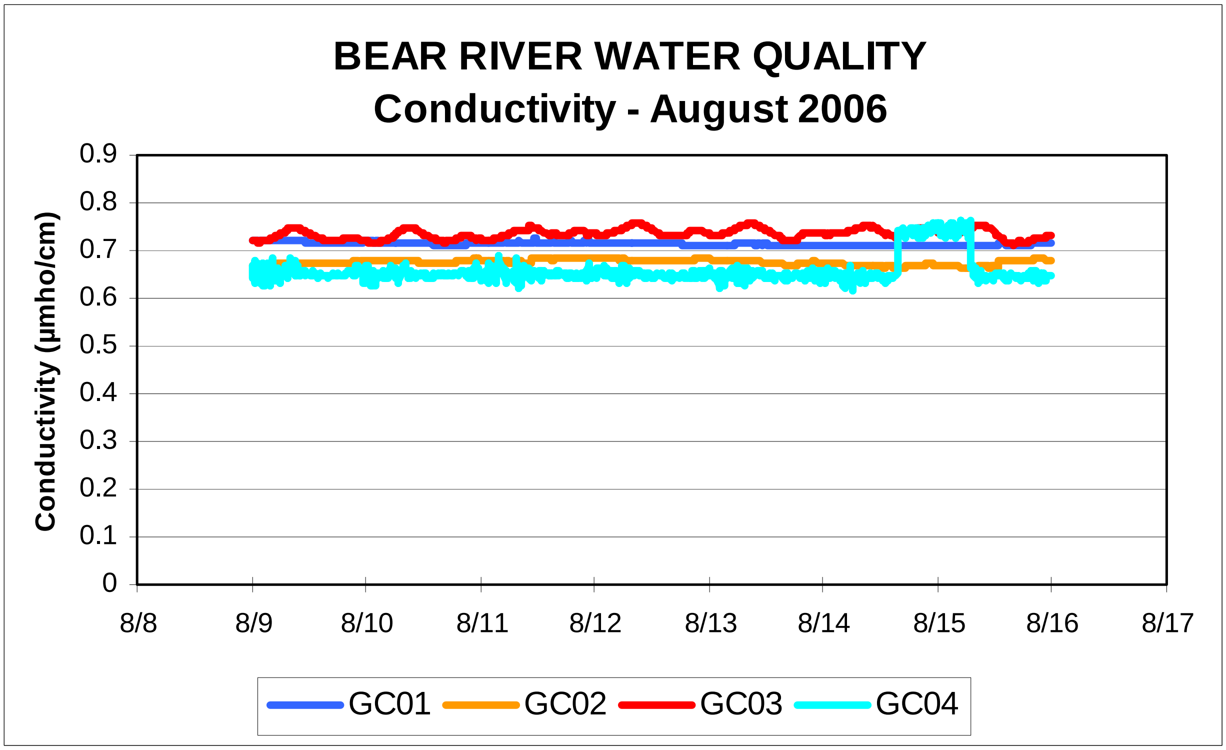


Figure 3-11. Specific conductance at four monitoring stations during August 2006.

To characterize diel variation a one-way ANOVA was conducted for each parameter. The data were blocked by time of day so that observations within each hour (i.e. 6 p.m.) were compared to observations at every other hour. The analysis assumes that each hourly block includes at least 28 replicates (4 observations/hr over 7 days). The results of the one-way ANOVA for each site and each parameter are shown in Table 3-6. The ANOVAs indicate that for temperature and dissolved oxygen (percent saturation and concentration) there are significant differences between times of day (p-value<0.001) at all four sites, just as seen in the July sampling set. Conductance between times of day significantly differed at all sites except GC04. Significant differences in turbidity between times of day occurred at all sites except GC03.

In order to partition the daily variation confirmed by the ANOVAS, the data were divided into two 12-hour data sets; 7 PM to 7 AM (night) and 7 AM to 7 PM (day) This distinction separates the warmer and cooler periods of each day, as well as the solar input availability, and reduces variation within each group. Two additional analyses were completed to detect statistically significant differences between sites for the monitored parameters. Tukey tests were completed to determine which pairs of sites were different for each parameter. In addition, paired linear regressions were run between sites to determine the degree of similarity.

The Tukey analysis tested for differences among all possible pairs of sites for each parameter (Table 3-7). The meaningful comparisons are those relative to the control site (GC01). The temperature at GC01 was significantly different (p<0.05) from all sites during the nighttime, but was not significantly different from GC02 during the day. Dissolved oxygen (both percent saturation and concentration) was not significantly different from GC02 during the night, but was during the day. Dissolved oxygen was significantly different when compared to GC03 and GC04 for both night and day. for all other sites. With the exception of GC02, percent saturation of dissolved oxygen was also significantly different from GC01 for daytime and nighttime at the downstream sites. Daytime dissolved oxygen concentration was significantly different from GC01 at all sites except GC02, but concentrations at GC03 were the only significant difference during the nighttime. There were no significant differences in turbidity during August.

By comparing the differences between adjacent sample sites (GC01 vs GC02; GC02 vs. GC03; GC03 vs.GC04) we can evaluate the systematic change in water quality parameters as water moves through the hydroelectric complex. With the exception of GC01 and GC02 during the daytime hours, there were significant differences in temperature at all adjacent sample sites (p<0.05). Specific conductance also had significant differences between all adjacent sample sites for all hours. There was no significant difference between GC01 and GC02 for dissolved oxygen (concentration and saturation), but significant differences at all hours occurred between GC02 and GC03, as well as GC03 and GC04. Only GC02 and GC03 showed significant differences in turbidity (night).

Pair-wise linear regressions were used to determine if the same pattern of changes were occurring at each site for each parameter. The regressions for the entire August data set (n=671) are shown in Table 3-8. The table includes the coefficient of determination (r2) and the significance level of the regression relationship. Because of the large sample size, a large proportion of the regressions are significant. However, inspection of the r2 value indicates what proportion of the variability at a site can be explained by the second site. For example, as seen in

Table 3-7. The results of the TUKEY tests to determine significant differences (p-value, 0.05) between means for different sample locations. The analysis has been grouped for the hours of 7 PM to 7 AM (night) and 7 AM to 7 PM (day) for hourly data collected in August of 2006.

	Mean Difference	Std. Error	Sig. Level	95% Confidence Interval	
				Lower	Upper
NIGHTTIME (7 PM - 7 AM)					
Temperature					
GC01 vs GC02	-0.2778	0.05009	0	-0.4065	-0.1491
GC01 vs GC03	2.9835	0.05009	0	2.8548	3.1121
GC01 vs GC04	1.1182	0.05009	0	0.9895	1.2468
GC02 vs GC03	3.2612	0.05009	0	3.1325	3.3899
GC02 vs GC04	1.3959	0.05009	0	1.2672	1.5246
GC03 vs GC04	1.8653	0.05009	0	1.7366	1.994
Specific Conductance					
GC01 vs GC02	0.03798	0.001406	0	0.03437	0.04159
GC01 vs GC03	-0.018271	0.001406	0	-0.021882	-0.01466
GC01 vs GC04	0.05117	0.001406	0	0.04756	0.05478
GC02 vs GC03	-0.056247	0.001406	0	-0.059858	-0.052636
GC02 vs GC04	0.0132	0.001406	0	0.009585	0.01681
GC03 vs GC04	-0.069443	0.001406	0	-0.073055	-0.065832
Dissolved Oxygen (%)					
GC01 vs GC02	-1.7286	0.71	0.071	-3.5525	0.09534
GC01 vs GC03	-10.2182	0.71	0	-12.0421	-8.3942
GC01 vs GC04	-38.2598	0.71	0	-40.0837	-36.4359
GC02 vs GC03	-8.4896	0.71	0	-10.3135	-6.6657
GC02 vs GC04	-36.5313	0.71	0	-38.3552	-34.7073
GC03 vs GC04	28.0417	0.71	0	26.2178	29.8656
Dissolved Oxygen (mg/L)					
GC01 vs GC02	-0.1336	0.06154	0.131	-0.2917	0.02446
GC01 vs GC03	-1.4209	0.06154	0	-1.579	-1.2628
GC01 vs GC04	-3.7411	0.06154	0	-3.8992	-3.583
GC02 vs GC03	-1.2873	0.06154	0	-1.4453	-1.1292
GC02 vs GC04	-3.6075	0.06154	0	-3.7656	-3.4494
GC03 vs GC04	2.3202	0.06154	0	2.1622	2.4783
Turbidity					
GC01 vs GC02	-8.1461	3.9193	0.16	-18.215	1.9228
GC01 vs GC03	12.4068	3.9193	0.008	2.3379	22.4757
GC01 vs GC04	8.6399	3.9193	0.122	-1.429	18.7088
GC02 vs GC03	20.553	3.9193	0	10.4841	30.6219
GC02 vs GC04	16.786	3.9193	0	6.7171	26.8549
GC03 vs GC04	3.767	3.9193	0.772	-6.3019	13.8359

	Mean Difference	Std. Error	Sig. Level	95% Confidence Interval Lower	Upper
DAYTIME (7 AM - 7 PM)					
Temperature					
GC01 vs GC02	0.144	0.09139	0.393	-0.0908	0.3788
GC01 vs GC03	3.2058	0.09139	0	2.971	3.4406
GC01 vs GC04	0.8048	0.09139	0	0.57	1.0396
GC02 vs GC03	3.0618	0.09139	0	2.8271	3.2966
GC02 vs GC04	0.6608	0.09139	0	0.426	0.8956
GC03 vs GC04	2.401	0.09139	0	2.1662	2.6358
Specific Conductance					
GC01 vs GC02	0.03966	0.0009148	0	0.03731	0.04201
GC01 vs GC03	-0.022054	0.0009148	0	-0.024404	-0.019703
GC01 vs GC04	0.06203	0.0009148	0	0.05968	0.06438
GC02 vs GC03	-0.061714	0.0009148	0	-0.064064	-0.059364
GC02 vs GC04	0.02237	0.0009148	0	0.02002	0.02472
GC03 vs GC04	-0.084086	0.0009148	0	-0.086436	-0.081736
Dissolved Oxygen (%)					
GC01 vs GC02	-6.9679	1.0225	0	-9.5947	-4.341
GC01 vs GC03	-26.5765	1.0225	0	-29.2033	-23.9497
GC01 vs GC04	-47.3902	1.0225	0	-50.017	-44.7634
GC02 vs GC03	-19.6086	1.0225	0	-22.2355	-16.9818
GC02 vs GC04	-40.4223	1.0225	0	-43.0491	-37.7955
GC03 vs GC04	20.8137	1.0225	0	18.1869	23.4405
Dissolved Oxygen (mg/L)					
GC01 vs GC02	-0.6696	0.0839	0	-0.8851	-0.454
GC01 vs GC03	-3.0843	0.0839	0	-3.2999	-2.8688
GC01 vs GC04	-4.4881	0.0839	0	-4.7036	-4.2726
GC02 vs GC03	-2.4148	0.0839	0	-2.6303	-2.1993
GC02 vs GC04	-3.8185	0.0839	0	-4.0341	-3.603
GC03 vs GC04	1.4038	0.0839	0	1.1882	1.6193
Turbidity					
GC01 vs GC02	-0.1229	1.5126	1	-4.0089	3.7631
GC01 vs GC03	4.6872	1.5126	0.01	0.8012	8.5732
GC01 vs GC04	4.6092	1.5126	0.012	0.7232	8.4952
GC02 vs GC03	4.8101	1.5126	0.008	0.9241	8.6961
GC02 vs GC04	4.7321	1.5126	0.01	0.8461	8.6181
GC03 vs GC04	0.07798	1.5126	1	-3.808	3.964

Table 3-8. The results of the paired linear regressions between the four sample sites on the Bear River during August 2006.

	N	R2	Sig. Level
TEMPERATURE			
GC01 vs GC02	671	0.271	0
GC01 vs GC03	671	0.772	0
GC01 vs GC04	671	0.688	0
GC02 vs GC03	671	0.256	0
GC02 vs GC04	671	0.401	0
GC03 vs GC04	671	0.542	0
CONDUCTIVITY			
GC01 vs GC02	671	0.116	0
GC01 vs GC03	671	0.001	0.458
GC01 vs GC04	671	0.047	0
GC02 vs GC03	671	0.009	0.013
GC02 vs GC04	671	0.176	0
GC03 vs GC04	671	0.025	0
DISSOLVED OXYGEN (%)			
GC01 vs GC02	671	0.646	0
GC01 vs GC03	671	0.335	0
GC01 vs GC04	671	0.331	0
GC02 vs GC03	671	0.751	0
GC02 vs GC04	671	0.677	0
GC03 vs GC04	671	0.609	0
DISSOLVED OXYGEN (MG/L)			
GC01 vs GC02	671	0.657	0
GC01 vs GC03	671	0.21	0
GC01 vs GC04	671	0.266	0
GC02 vs GC03	671	0.623	0
GC02 vs GC04	671	0.609	0
GC03 vs GC04	671	0.527	0
TURBIDITY (NTU)			
GC01 vs GC02	671	0.007	0.03
GC01 vs GC03	671	0.001	0.372
GC01 vs GC04	671	0.024	0
GC02 vs GC03	671	0	0.778
GC02 vs GC04	671	0.006	0.04
GC03 vs GC04	671	0.009	0.016

the July sampling set, the variability in temperature at site GC01 can explain only 27 percent of the variability in temperature at GC02 ($p < 0.05$), but can explain 69 percent of the temperature variability at GC04. The highest coefficient of determination was found between GC01 and GC03 for temperature ($r2=0.77$).

3.1.2.3 September 2006 Water Quality

The water quality data collected continuously at the four stations are plotted in Figures 3-12 through 3-16. Temperature and dissolved oxygen demonstrated a distinctive daily pattern. A summary of water quality attributes at each site during the sample period in September (September 6-12) is provided in Table 3-9. The table contains the number of observations, average, minimum and maximum values and variance statistics for each parameter.

Maximum water temperatures recorded at each station ranged from 17.7°C to 18.7°C, with the greatest range in temperature occurring at GC03, just as seen in the August sampling. Minimum temperatures ranged from 12.6°C to 15.9°C. Dissolved oxygen expressed as mg/l (Figure 3-13) and percent saturation (Figure 3-14) exhibited similar diel patterns with the greatest range occurring in GC03. Specific conductance and turbidity did not have a consistent diel pattern for all sites. Turbidity levels varied between sites with fewer peak events recorded. Turbidity at GC01 was greater overall, though an increase in turbidity occurred at GC02 during the last half of the period.

To characterize diel variation a one-way ANOVA was conducted for each parameter. The data were blocked by time of day so that observations within each hour (i.e. 6 p.m.) were compared to observations at every other hour. The analysis assumes that each hourly block includes at least 28 replicates (4 observations/hr over 7 days). The results of the one-way ANOVA for each site and each parameter are shown in Table 3-10. The ANOVAs indicate there are significant differences between times of day ($p\text{-value} < 0.001$) at all four sites for temperature, conductivity, and dissolved oxygen (percent saturation and concentration). Significant differences in turbidity between times of day occurred at only sites GC03 and GC04. The Cove Dam was decommissioned during 2006 and from September 6 through September 18, the dam was actively being demolished, with the potential to affect measurements at GC04.

In order to partition the daily variation confirmed by the ANOVAS, the data were divided into two 12-hour data sets; 7 PM to 7 AM (night) and 7 AM to 7 PM (day) This distinction separates the warmer and cooler periods of each day, as well as the solar input availability, and reduces variation within each group. Two additional analyses were completed to detect statistically significant differences between sites for the monitored parameters. Tukey tests were completed to determine which pairs of sites were different for each parameter. In addition, paired linear regressions were run between sites to determine the degree of similarity.

The Tukey analysis tested for differences among all possible pairs of sites for each parameter (Table 3-11). The meaningful comparisons are those relative to the control site (GC01). The temperature at GC01 was significantly different ($p < 0.05$) from all sites during the

Table 3-9. The descriptive statistics of the instantaneous data collected on the Bear River in September 2006.

Date	N	Range	Min-imum	Max-imum	Mean	Standard Error	Standard Deviation	Variance
Temperature (°C)								
GC01	672	3.36	15.33	18.69	16.77	0.03	0.81	0.65
GC02	672	2.06	15.86	17.92	16.76	0.02	0.56	0.31
GC03	672	5.04	12.61	17.65	15.26	0.05	1.22	1.48
GC04	668	3.8	14.71	18.51	16.23	0.04	1.00	0.99
Specific Conductance (μmho/cm)								
GC01	672	0.014	0.702	0.716	0.71	0.00	0.00	0.00
GC02	672	0.012	0.692	0.704	0.70	0.00	0.00	0.00
GC03	672	0.043	0.687	0.73	0.71	0.00	0.01	0.00
GC04	667	0.074	0.692	0.766	0.72	0.00	0.01	0.00
Dissolved Oxygen (%)								
GC01	672	43.3	70.2	113.5	84.58	0.52	13.58	184.55
GC02	672	52.4	52	104.4	79.94	0.43	11.23	126.13
GC03	672	67.1	54.3	121.4	86.19	0.66	17.09	291.97
GC04	668	55.6	66.4	122	81.13	0.50	12.88	165.80
Dissolved Oxygen (mg/L)								
GC01	672	3.76	6.92	10.68	8.18	0.05	1.18	1.39
GC02	672	4.84	5.06	9.9	7.74	0.04	1.01	1.02
GC03	672	6.52	5.37	11.89	8.62	0.06	1.66	2.76
GC04	668	5.17	6.5	11.67	7.94	0.04	1.14	1.31
Turbidity (NTU)								
GC01	672	145.3	9.2	154.5	14.56	0.23	5.87	34.45
GC02	672	87.5	6.4	93.9	17.50	0.49	12.76	162.84
GC03	672	13.9	0.8	14.7	2.14	0.04	1.05	1.10
GC04	667	17.1	3.3	20.4	6.19	0.07	1.75	3.08

Table 3-10. The ANOVA for determining if there is a significant difference between the parameter values over time of day. This analysis is assuming each hour (e.g. 6:00 p.m.) has seven replicates over the study in September 2006.

		Sum of Squares	df	Mean Square	F	Sig.
TEMPERATURE						
GC01	Between Groups	367.679	23	15.986	148.516	0
	Within Groups	69.75	648	0.108		
	Total	437.429	671			
GC02	Between Groups	170.82	23	7.427	122.265	0
	Within Groups	39.362	648	0.06074		
	Total	210.182	671			
GC03	Between Groups	847.237	23	36.836	163.813	0
	Within Groups	145.715	648	0.225		
	Total	992.952	671			
GC04	Between Groups	382.192	23	16.617	38.148	0
	Within Groups	280.526	644	0.436		
	Total	662.718	667			
SPECIFIC CONDUCTANCE						
GC01	Between Groups	0.001665	23	7.241E-05	14.599	0
	Within Groups	0.003214	648	4.96E-06		
	Total	0.00488	671			
GC02	Between Groups	0.001609	23	6.996E-05	15.924	0
	Within Groups	0.002847	648	4.393E-06		
	Total	0.004456	671			
GC03	Between Groups	0.03812	23	0.001657	34.795	0
	Within Groups	0.03086	648	4.763E-05		
	Total	0.06898	671			
GC04	Between Groups	0.009108	23	0.000396	2.212	0.001
	Within Groups	0.115	643	0.000179		
	Total	0.124	666			
DISSOLVED OXYGEN (%)						
GC01	Between Groups	116648.877	23	5071.69	457.41	0
	Within Groups	7184.929	648	11.088		
	Total	123833.806	671			
GC02	Between Groups	75282.943	23	3273.171	226.802	0
	Within Groups	9351.851	648	14.432		
	Total	84634.794	671			

		Sum of Squares	df	Mean Square	F	Sig.
GC03	Between Groups	183806.383	23	7991.582	427.752	0
	Within Groups	12106.423	648	18.683		
	Total	195912.806	671			
GC04	Between Groups	42029.653	23	1827.376	17.166	0
	Within Groups	68556.855	644	106.455		
	Total	110586.508	667			
DISSOLVED OXYGEN (mg/L)						
GC01	Between Groups	873.604	23	37.983	435.63	0
	Within Groups	56.499	648	0.08719		
	Total	930.103	671			
GC02	Between Groups	594.283	23	25.838	190.877	0
	Within Groups	87.718	648	0.135		
	Total	682.001	671			
GC03	Between Groups	1737.552	23	75.546	426.407	0
	Within Groups	114.805	648	0.177		
	Total	1852.357	671			
GC04	Between Groups	285.763	23	12.424	13.629	0
	Within Groups	587.064	644	0.912		
	Total	872.827	667			
TURBIDITY (NTU)						
GC01	Between Groups	636.807	23	27.687	0.798	0.736
	Within Groups	22478.954	648	34.69		
	Total	23115.761	671			
GC02	Between Groups	3379.693	23	146.943	0.899	0.6
	Within Groups	105884.832	648	163.403		
	Total	109264.525	671			
GC03	Between Groups	53.285	23	2.317	2.201	0.001
	Within Groups	682.007	648	1.052		
	Total	735.292	671			
GC04	Between Groups	184.941	23	8.041	2.774	0
	Within Groups	1864.033	643	2.899		
	Total	2048.973	666			

Table 3-11. The results of the TUKEY tests to determine significant differences (p-value, 0.05) between means for different sample locations. The analysis has been grouped for the hours of 7 PM to 7 AM (night) and 7 AM to 7 PM (day) for hourly data collected in September of 2006.

	Mean Difference	Std. Error	Sig. Level	95% Confidence Interval	
				Lower	Upper
NIGHTTIME (7 PM - 7 AM)					
Temperature					
GC01 vs GC02	0.2884	0.05082	0	0.1579	0.419
GC01 vs GC03	1.5057	0.05082	0	1.3752	1.6363
GC01 vs GC04	0.8698	0.05082	0	0.7393	1.0004
GC02 vs GC03	1.2173	0.05082	0	1.0867	1.3478
GC02 vs GC04	0.5814	0.05082	0	0.4508	0.7119
GC03 vs GC04	0.6359	0.05082	0	0.5053	0.7664
Specific Conductance					
GC01 vs GC02	0.008923	0.0006511	0	0.00725	0.0106
GC01 vs GC03	0.001298	0.0006511	0.191	-0.000375	0.00297
GC01 vs GC04	-0.018045	0.0006511	0	-0.019717	-0.016372
GC02 vs GC03	-0.007625	0.0006511	0	-0.0092976	-0.0059524
GC02 vs GC04	-0.026967	0.0006511	0	-0.02864	-0.025295
GC03 vs GC04	0.01934	0.0006511	0	0.01767	0.02101
Dissolved Oxygen (%)					
GC01 vs GC02	9.9503	0.6305	0	8.3305	11.5701
GC01 vs GC03	10.2304	0.6305	0	8.6105	11.8502
GC01 vs GC04	7.2039	0.6305	0	5.5841	8.8237
GC02 vs GC03	0.2801	0.6305	0.971	-1.3398	1.8999
GC02 vs GC04	-2.7464	0.6305	0	-4.3662	-1.1266
GC03 vs GC04	3.0265	0.6305	0	1.4067	4.6463
Dissolved Oxygen (mg/L)					
GC01 vs GC02	0.9051	0.05743	0	0.7576	1.0527
GC01 vs GC03	0.7423	0.05743	0	0.5947	0.8898
GC01 vs GC04	0.5482	0.05743	0	0.4007	0.6958
GC02 vs GC03	-0.1629	0.05743	0.024	-0.3104	-0.015319
GC02 vs GC04	-0.3569	0.05743	0	-0.5044	-0.2093
GC03 vs GC04	0.194	0.05743	0.004	0.04648	0.3416
Turbidity					
GC01 vs GC02	-2.8732	0.511	0	-4.1859	-1.5605
GC01 vs GC03	12.3438	0.511	0	11.0311	13.6564
GC01 vs GC04	8.3134	0.511	0	7.0007	9.6261
GC02 vs GC03	15.217	0.511	0	13.9043	16.5296
GC02 vs GC04	11.1866	0.511	0	9.8739	12.4993
GC03 vs GC04	4.0304	0.511	0	2.7177	5.343

	Mean Difference	Std. Error	Sig. Level	95% Confidence Interval	
				Lower	Upper
DAYTIME (7 AM - 7 PM)					
Temperature					
GC01 vs GC02	-0.2684	0.08304	0.007	-0.4817	-0.055048
GC01 vs GC03	1.5094	0.08304	0	1.2961	1.7228
GC01 vs GC04	0.2139	0.08336	0.05	-0.00025203	0.428
GC02 vs GC03	1.7778	0.08304	0	1.5645	1.9911
GC02 vs GC04	0.4823	0.08336	0	0.2681	0.6964
GC03 vs GC04	1.2955	0.08336	0	1.0814	1.5097
Specific Conductance					
GC01 vs GC02	0.01097	0.0006707	0	0.009247	0.01269
GC01 vs GC03	0.003542	0.0006707	0	0.001819	0.005265
GC01 vs GC04	-0.013603	0.0006732	0	-0.015332	-0.011873
GC02 vs GC03	-0.0074286	0.0006707	0	-0.0091515	-0.0057056
GC02 vs GC04	-0.024573	0.0006732	0	-0.026302	-0.022844
GC03 vs GC04	0.01714	0.0006732	0	0.01542	0.01887
Dissolved Oxygen (%)					
GC01 vs GC02	-0.653	1.0388	0.923	-3.3216	2.0157
GC01 vs GC03	-13.4482	1.0388	0	-16.1169	-10.7796
GC01 vs GC04	-0.3305	1.0427	0.989	-3.0092	2.3482
GC02 vs GC03	-12.7952	1.0388	0	-15.4639	-10.1266
GC02 vs GC04	0.3225	1.0427	0.99	-2.3562	3.0012
GC03 vs GC04	-13.1177	1.0427	0	-15.7964	-10.439
Dissolved Oxygen (mg/L)					
GC01 vs GC02	-0.025179	0.09262	0.993	-0.2631	0.2128
GC01 vs GC03	-1.6244	0.09262	0	-1.8624	-1.3865
GC01 vs GC04	-0.070355	0.09297	0.874	-0.3092	0.1685
GC02 vs GC03	-1.5993	0.09262	0	-1.8372	-1.3613
GC02 vs GC04	-0.045177	0.09297	0.962	-0.284	0.1937
GC03 vs GC04	-1.5541	0.09297	0	-1.7929	-1.3152
Turbidity					
GC01 vs GC02	-3.0137	0.5835	0	-4.5127	-1.5147
GC01 vs GC03	12.4979	0.5835	0	10.9989	13.9969
GC01 vs GC04	8.4301	0.5857	0	6.9254	9.9348
GC02 vs GC03	15.5116	0.5835	0	14.0126	17.0106
GC02 vs GC04	11.4438	0.5857	0	9.9391	12.9485
GC03 vs GC04	4.0678	0.5857	0	2.5631	5.5725

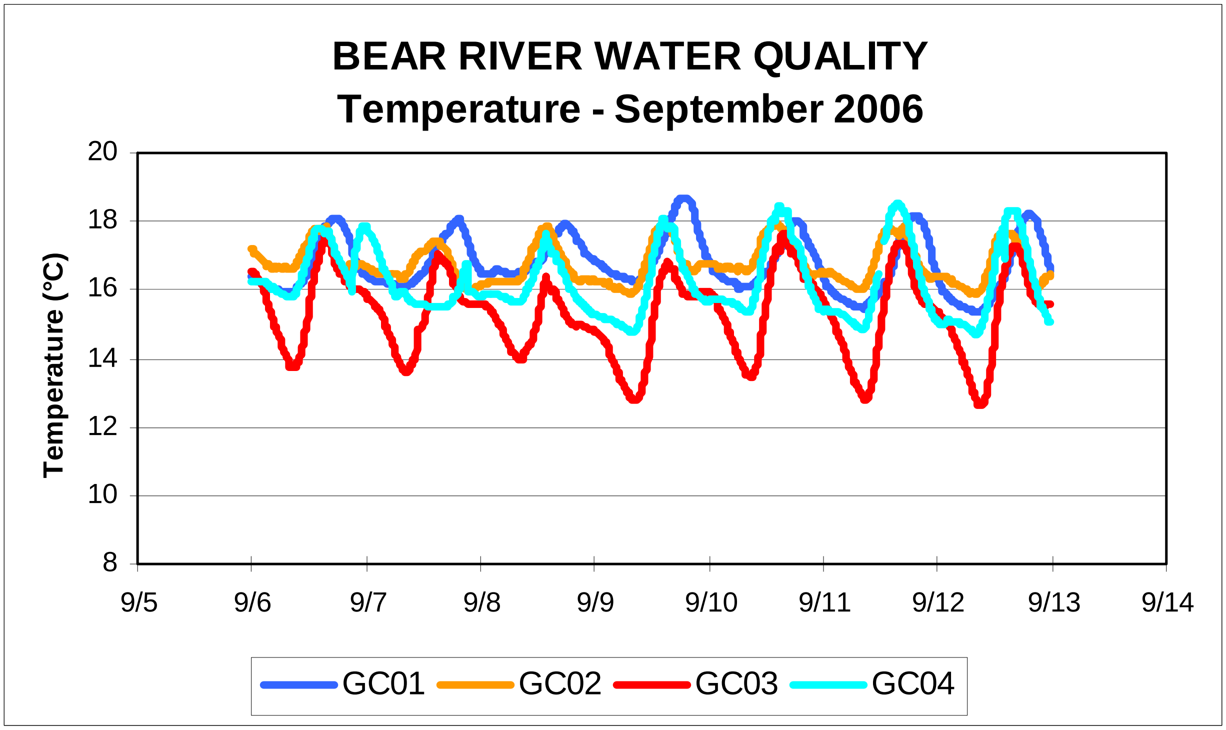


Figure 3-12. Temperature at four monitoring stations during September 2006.

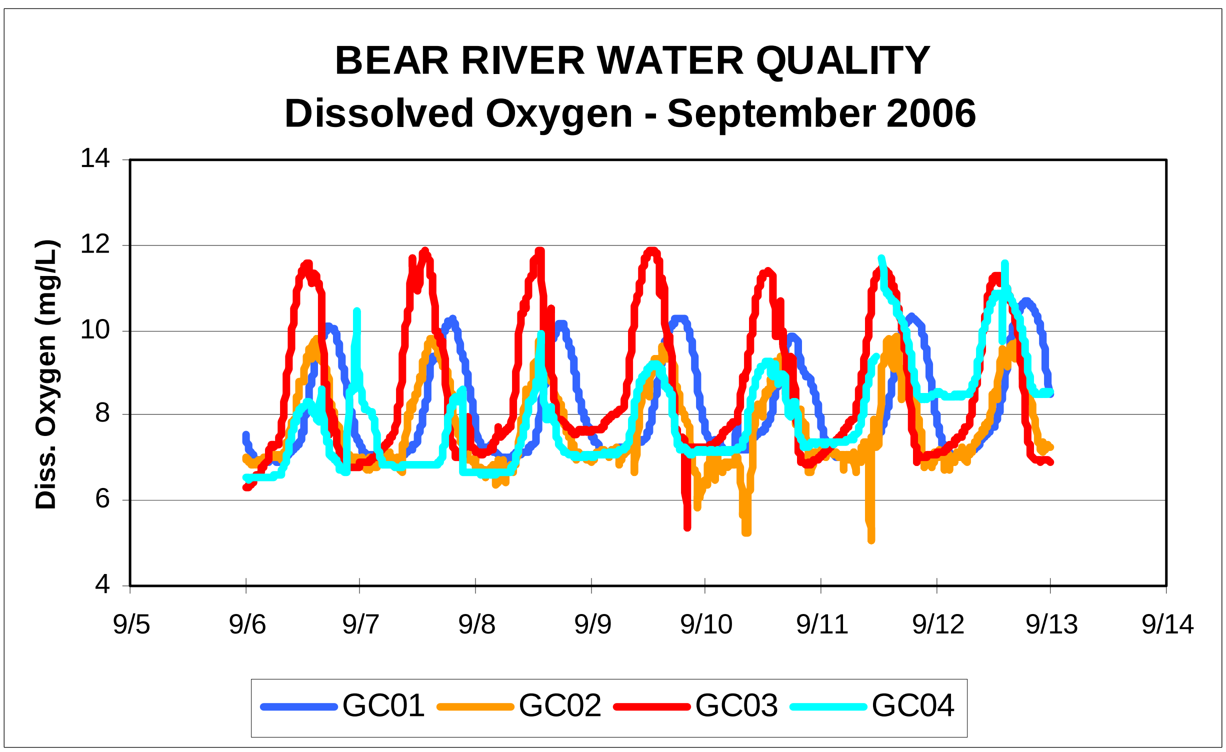


Figure 3-13. Dissolved oxygen at four monitoring stations during September 2006.

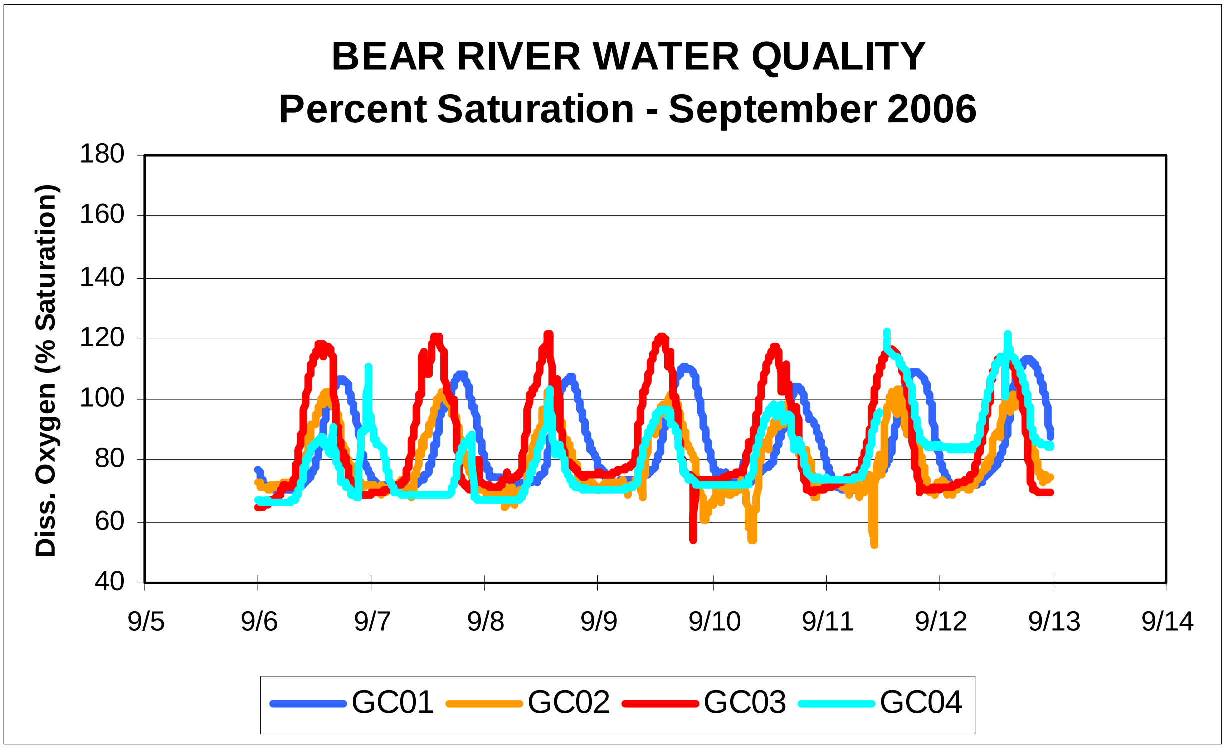


Figure 3-14. Percent saturation of dissolved oxygen at four monitoring stations during September 2006.

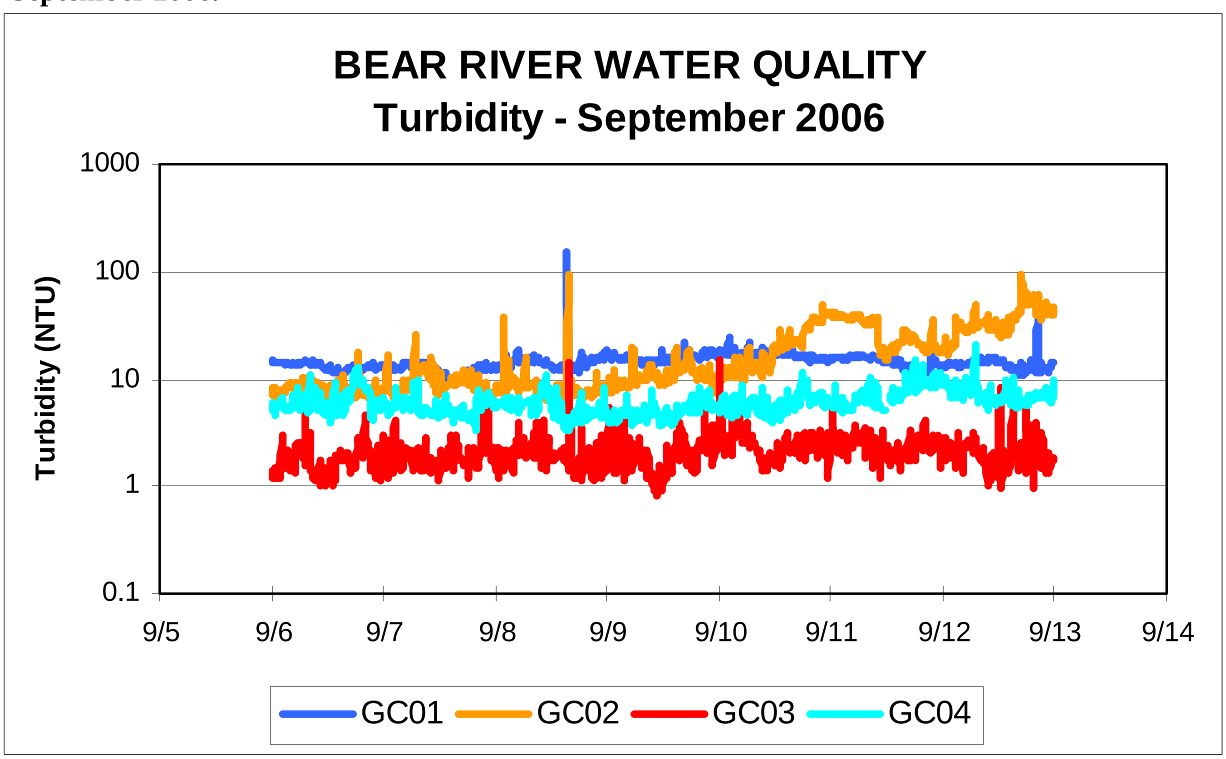


Figure 3-15. Turbidity at four monitoring stations during September 2006.

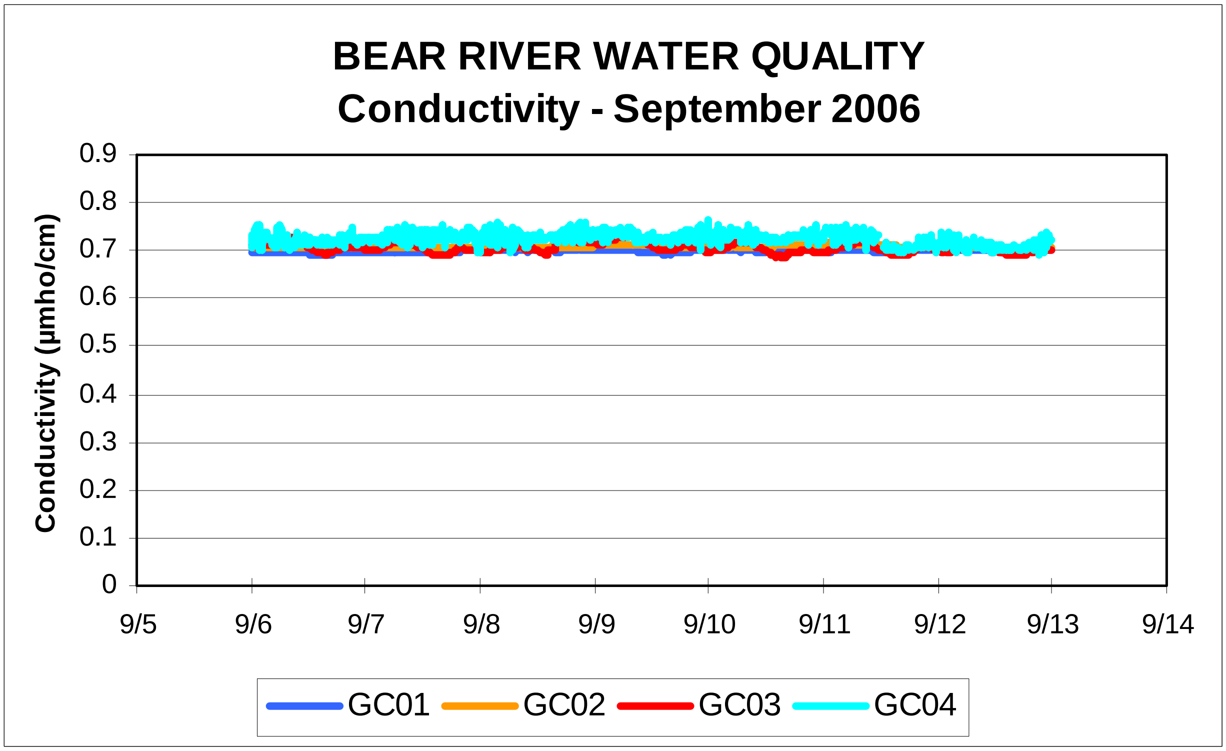


Figure 3-16. Specific conductance at four monitoring stations during September 2006.

nighttime, but was not significantly different from GC02 or GC04 during the day. Dissolved oxygen (percent saturation and concentration) was not significantly different from GC02 and GC03 during the daytime hours, but was significantly different among all sites during the night. Turbidity at all sites showed significant differences.

By comparing the differences between adjacent sample sites (GC01 vs GC02; GC02 vs. GC03; GC03 vs.GC04) we can evaluate the systematic change in water quality parameters as water moves through the hydroelectric complex. As seen in August, with the exception of GC01 and GC02 during the daytime hours, there were significant differences in temperature at all adjacent sample sites ($p<0.05$). Specific conductance also had significant differences between all adjacent sample sites for all hours. There was no significant difference between GC02 and GC03 and GC03 and GC04 for dissolved oxygen (concentration) during the nighttime, but significant differences did occur at both of those adjacent sites during the day. Significant differences occurred in turbidity at all adjacent sites during both the day and night.

Pair-wise linear regressions were used to determine if the same pattern of changes were occurring at each site for each parameter. The regressions for the entire September data set (n=666 to 671) are shown in Table 3-12. The table includes the coefficient of determination (r2) and the significance level of the regression relationship. Because of the large sample size, a large proportion of the regressions are significant. However, inspection of the r2 value indicates what proportion of the variability at a site can be explained by the second site. For example, the variability in temperature at site GC01 can explain only 12 percent of the variability in temperature at GC02 ($p< 0.05$), but can explain 50 percent of the temperature variability at GC03. The highest coefficient of determination was found between GC02 and GC04 for temperature (r2=0.65).

3.2 Instantaneous Data

Grab samples were collected twice during each of the continuous monitoring months and analyzed by ERI's laboratory. The results of the instantaneous data collections can be seen in Table 3-13.

Total phosphorous which generally increased over the sampling period, was highest overall at GC04 (0.057 mg/L in August). With the exception of the first sampling date in July, both GC01 and GC02 exhibited the lowest overall concentrations. Orthophosphorus, the dissolved portion of phosphorus, was highest at GC03 (0.051 mg/L in August). Orthosphosphorus as a percentage of phosphorus was also greater at GC03.

The total inorganic nitrogen, which is made up of nitrate, nitrite and ammonia, did not display the same increasing concentration or increasing between sites pattern as phosphorous. Total inorganic nitrogen concentrations at GC01 and GC02 mirrored each other during the monitoring season, but doubled at GC03 and then increased that same amount again at GC04. These increases were due to increases in nitrate and are consistent with the water quality conditions recorded during the 2004 and 2005 instantaneous sampling efforts.

Table 3-12. The results of the paired linear regressions between the four sample sites on the Bear River during September 2006.

	N	R2	Sig. Level
TEMPERATURE			
GC01 vs GC02	671	0.115	0
GC01 vs GC03	671	0.499	0
GC01 vs GC04	667	0.237	0
GC02 vs GC03	671	0.42	0
GC02 vs GC04	667	0.649	0
GC03 vs GC04	667	0.541	0
CONDUCTIVITY			
GC01 vs GC02	671	0.008	0.017
GC01 vs GC03	671	0.072	0
GC01 vs GC04	667	0.013	0.003
GC02 vs GC03	671	0.018	0
GC02 vs GC04	667	0	0.627
GC03 vs GC04	666	0.081	0
DISSOLVED OXYGEN (%)			
GC01 vs GC02	671	0.289	0
GC01 vs GC03	671	0.012	0.005
GC01 vs GC04	667	0.094	0
GC02 vs GC03	671	0.612	0
GC02 vs GC04	667	0.345	0
GC03 vs GC04	667	0.324	0
DISSOLVED OXYGEN (MG/L)			
GC01 vs GC02	671	0.306	0
GC01 vs GC03	671	0	0.582
GC01 vs GC04	667	0.082	0
GC02 vs GC03	671	0.487	0
GC02 vs GC04	667	0.28	0
GC03 vs GC04	667	0.271	0
TURBIDITY (NTU)			
GC01 vs GC02	671	0	0.951
GC01 vs GC03	671	0.004	0.111
GC01 vs GC04	666	0.006	0.049
GC02 vs GC03	671	0.006	0.039
GC02 vs GC04	666	0.075	0
GC03 vs GC04	666	0.004	0.091

Table 3-13. The water quality data collected as grab samples within the Bear River during 2006.

Date	Site	Log#	NH3 (mg/L)	NO2 (mg/L)	NO3+NO2 (mg/L)	TIN (mg/L)	OP (mg/L)	TP (mg/L)	TSS (mg/L)	TURB (NTU)
07/10/06	GC01	60873	0.180	0.018	0.113	0.293	0.005	0.053	21.1	8.5
	GC02	60874	0.057	0.018	0.164	0.220	0.010	0.042	10.3	5.7
	GC03	60875	0.038	0.006	1.079	1.117	0.019	0.048	9.9	1.4
	GC04	60876	0.038	0.012	0.569	0.607	0.016	0.053	12.2	4.6
07/28/06	GC01	60955	0.036	0.014	0.176	0.212	0.015	0.040	12.7	8.5
	GC02	60956	0.036	0.010	0.138	0.174	0.012	0.042	15.9	8
	GC03	60957	0.033	0.006	1.155	1.189	0.028	0.043	4.8	1.5
	GC04	60958	0.033	0.009	0.528	0.561	0.043	0.048	11.1	6
08/08/06	GC01	61027	0.033	0.012	0.127	0.161	0.008	0.038	14.4	10
	GC02	61028	0.036	0.010	0.143	0.179	0.017	0.041	9.7	7.9
	GC03	61029	0.036	0.005	1.026	1.062	0.051	0.051	3.5	1.3
	GC04	61030	0.036	0.007	0.518	0.554	0.018	0.049	9.2	5.8
08/23/06	GC01	61072	0.037	0.003	0.067	0.103	0.004	0.038	8.7	7.2
	GC02	61073	0.038	0.006	0.106	0.144	0.007	0.040	9.6	7.1
	GC03	61074	0.038	0.005	0.968	1.006	0.022	0.041	3.2	1.4
	GC04	61075	0.042	0.007	0.376	0.418	0.011	0.057	16.0	7.5
09/06/06	GC01	61169	0.036	0.007	0.098	0.134	0.007	0.035	14.2	10
	GC02	61170	0.037	0.005	0.114	0.151	0.008	0.033	8.3	6.2
	GC03	61171	0.036	0.006	0.788	0.824	0.037	0.038	5.9	1.9
	GC04	61172	0.037	0.006	0.425	0.462	0.015	0.045	10.5	6.9
09/20/06	GC01	61206	0.037	0.010	0.289	0.326	0.012	0.024	5.5	4.5
	GC02	61207	0.036	0.007	0.198	0.234	0.011	0.027	7.5	3.8
	GC03	61208	0.036	0.008	1.363	1.399	0.032	0.038	2.3	<1
	GC04	61209	0.231	0.019	1.593	1.824	0.038	0.053	7.9	3.2

3.3 Water Quality Compliance

The second objective of this investigation was to help determine the Development's contribution, if any, to violations of water quality criteria as set forth in the Idaho Water Quality Standards and Wastewater Treatment Requirements, IDAPA 53.01.02 (Water Quality Standards). A comparison of each site and sample event to the IDAPA Water Quality Standards was undertaken utilizing the hourly data collected in this investigation. The results of that analysis can be seen in Table 3-14.

With the exception of GC03, the instantaneous temperature requirement (temperature must be lower than 22°C) for the prescribed beneficial use of this section of the Bear River was exceeded at all sites during July. Daily average temperature (temperature must be lower than 19°C) was exceeded at all sites (except GC03) during July and August.

Exceedences of IDAPA water quality standards during the 2006 monitoring period were much less than those recorded in 2005. Given the poor water quality conditions recorded in the Bear at the control site (GC01), it is unlikely that the operations of the project contributed to recorded temperature exceedences of IDAPA standards at monitoring sites downstream where exceedences decrease relative to the control site. Monitoring results indicate that the project had little effect on violations of water temperature criteria as set forth in the IDAPA.

The second water quality standard parameter is dissolved oxygen. Again with the exception of GC03, the instantaneous concentration was lower than the required standard of 6 mg/L in July and August at all sites. Percent exceedences were less in August. The additional associated parameter of dissolved oxygen (expressed as a percent of atmosphere) exceeded water quality standards (must be less than 110%) at all sites during the month of July and at all sites during all months (with the exception again of GC03) during August and September.

In the case of dissolved oxygen (mg/l), exceedences decrease with distance downstream during both July and August. During all three monitoring periods, dissolved oxygen (expressed as a percent of atmosphere) at sites GC02, GC03, and GC04's percent exceedence of IDAPA standards was greater than exceedences recorded at the control site (GC01) similar to the pattern seen in 2005. Physical characteristics of the Bear River vary considerably from the control site as you move downstream to the other monitoring locations. Site GC01 is located in a fairly turbulent reach of the river, whereas the latter monitoring locations are located in areas with fairly laminar flows. Increased photosynthesis in these laminar reaches drives up percent saturation. Dissolved oxygen data (expressed as percent of atmosphere) recorded at sites GC02, GC03, and GC04 is fairly representative of this relationship. As with temperature, it is unlikely that project operations significantly contributed to violations of dissolved oxygen criteria as set forth in the IDAPA.

4.0 QUALITY CONTROL

This section will evaluate the quality assurance of sampling, sample handling, field techniques, field analyses, and data treatment. The procedures for calibration, maintenance, and downloading of the YSI Model 6920, used for the continuous monitoring task of this Development, will also be included in this section.

Specific data quality objectives for accuracy and precision of sampling are for measurements to fall within a 95 percent confidence interval around the true value. The confidence interval for each parameter is based on prior knowledge of the measurement system and is generated from the EPA publication "Estimation of Generic Acceptance Limits for Quality Control Purposes for Use in a Water Pollution Laboratory" (May 1991).

4.1 Continuously Monitoring Probes

Four YSI Model 6920 monitoring probes were installed at each of the stations. A backup probe was available in the case any problems were encountered with the equipment. Custom steel boxes were built in order to house, conceal and protect each probe. The probes were calibrated for each parameter according to the manufacturer's specifications (YSI 2001) before being placed in the field. Data were downloaded at the end of each continuous 7-day monitoring period using a laptop computer and the software EcoWatch for Windows. Each time the monitoring field crew was at the site, a grab sample was also taken. The probe was placed in a known calibration standard to record turbidity drift. This *in situ* measurement was compared to the standard and percent error was determined. The probe was then cleaned and calibrated in the field were run prior to and after the continuous 7-day sampling period. The QA/QC data is provided in Table 4-3. The program determined that no data was disqualified as per Table 4-2 for any site or time.

Table 3-14. The frequency of exceedences of relevant IDAPA 53.01.02 Water Quality Standards for the Bear River within the study site.

	Instant. Temp. (>22 C)		Daily Average Temp. (>19 C)		Instant. DO (< 6 mg/L)		DO, % of Atmosp. (>110%)	
	% Exceed	**N**	**% Exceed**	**N**	**% Exceed**	**N**	**% Exceed**	**N**
July								
GC01	22%	672	100%	7	36%	672	1%	672
GC02	26%	672	100%	7	15%	672	14%	672
GC03	0%	672	0%	7	0%	672	13%	672
GC04	18%	672	100%	7	8%	672	19%	672
August								
GC01	0%	672	100%	7	25%	672	1%	672
GC02	0%	672	100%	7	5%	672	0%	672
GC03	0%	672	0%	7	0%	672	28%	672
GC04	0%	672	100%	7	0%	672	80%	672
September								
GC01	0%	672	0%	7	0%	672	3%	672
GC02	0%	672	0%	7	1%	672	0%	672
GC03	0%	672	0%	7	0%	672	16%	672
GC04	0%	668	0%	7	0%	668	5%	668

Table 4-1. Rating continuous water quality records (Source: USGS, 2000. WRIR 00-4252, Table 9).

Measured physical property	RATINGS			
	Excellent	**Good**	**Fair**	**Poor**
Water temperature	≤ ± 0.2°C	> ± 0.2 to 0.5°C	> ± 0.5 to 0.8°C	> ± 0.8°C
Specific Conductance	≤ ± 3 %	> ± 3 to 10 %	> ± 10 to 15 %	> ± 15 %
Dissolved oxygen	≤ ± 0.3 mg/L	> ± 0.3 to 0.5 mg/L	> ± 0.3 to 1.0 mg/L	> ± 1.0 mg/L
pH	≤ ± 0.2 unit	> ± 0.2 to 0.5 units	> ± 0.5 to 0.8 units	> ± 0.8 units
Turbidity	≤ ± 5 %	> ± 5 to 10 %	> ± 10 to 15 %	> ± 15%

Table 4-2. Rejection criteria for continuous water-quality monitoring sensors.

Constituent	Manufacturer's Specifications[a]	Maximum Allowable Limits (USGS)[b]
Water temperature	> ± 0.15°C	> ± 2.0°C
Specific Conductance	> ± 0.5 %	> ± 30 %
Dissolved oxygen	> ± 0.2 mg/L or ± 2%, whichever is greater	> ± 2.0 mg/L or ± 20%, whichever is greater
pH	> ± 0.2 units	> ± 2.0 units
Turbidity	> ± 5% or 2 NTU whichever is greater	> ± 30%

[a] YSI Incorporated. 6-Series Environmental Monitoring Systems Operations Manual
[b] USGS, 2000. WRIR 00-4252, Table 8.

Table 4-3. Turbidity calibration data and percent error for continuous monitoring turbidity measurements taken during the summer of 2006. Ratings for turbidity were categorized as excellent, with the exception of the September dataset for station GC01 and GC02, which was categorized as good.

	Standard: 40 NTU		Standard: 80 NTU		Avg % Error
	Turbidity	%Error	Turbidity	%Error	
July 27, 2006					
GC01	38.5	3.8%	78.9	1.4%	2.6%
GC02	38.1	4.8%	79.1	1.1%	2.9%
GC03	39	2.5%	78	2.5%	2.5%
GC04	39.4	1.5%	79.1	1.1%	1.3%
August 22, 2006					
GC01	40.5	1.3%	79.7	0.4%	0.8%
GC02	39.6	1.0%	80.4	0.5%	0.8%
GC03	40.4	1.0%	81.2	1.5%	1.3%
GC04	40.1	0.3%	82.2	2.8%	1.5%
September 20, 2006					
GC01	43.5	8.8%	84.2	5.3%	7.0%
GC02	36.5	8.8%	76.3	4.6%	6.7%
GC03	40.5	1.3%	81.4	1.8%	1.5%
GC04	41.6	4.0%	82.1	2.6%	3.3%

5.0 REFERENCES

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