A Department of Ecology Report

DEPARTMENT OF ECOLOGY
State of Washington

Puyallup and White Rivers Dissolved Oxygen and Temperature Data Summary Report

Abstract

The Washington State Department of Ecology conducted continuous (every 30 minutes) monitoring for dissolved oxygen and temperature at two sites on the lower Puyallup River and one site on the lower White River. The monitoring period was August 14 – October 9, 2006.

Dissolved oxygen levels from both Puyallup River sites were sometimes lower than, or almost lower than, the recently adopted Washington State criteria for dissolved oxygen.

Stream temperature results from one Puyallup River site (river mile 11.8) and the White River site were sometimes higher than Washington State temperature criteria. The monitoring period did not include the highest seven-day average of the daily maximum peak temperatures for 2006.

By William J. Ward

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- Randal Walton was a field staff member who collected and analyzed most of the dissolved oxygen field grab samples among other tasks.
- Betsy Dickes was a field staff member who downloaded the continuous data from the sondes among other tasks.
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- Cindy Cook and Joan LeTourneau prepared the final document.

Introduction

The Washington Department State of Ecology (Ecology) monitored continuous dissolved oxygen (DO) and temperature at two sites on the lower Puyallup River and one site on the lower White River in 2006 (Figure 1). The Puyallup River sites were at river mile (RM) 2.9 and 11.8, and the White River site was at RM 1.8. Conductivity was also monitored at Puyallup River RM 2.9 site.

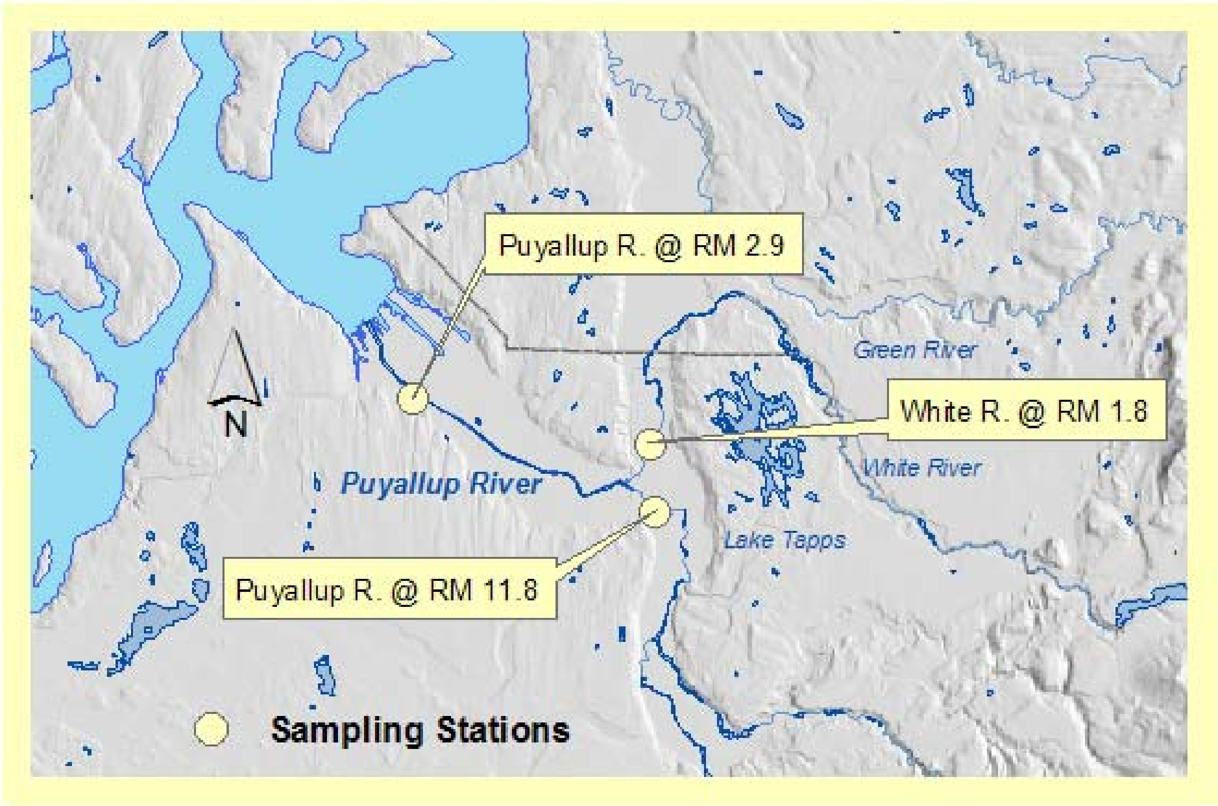

Figure 1. Sampling Sites.

The 2006 monitoring was conducted by Ecology's Environmental Assessment Program at the request of Ecology's Southwest Region Water Quality Program.

This study is an outgrowth of the *1993 Puyallup River Total Maximum Daily Load for Biochemical Oxygen Demand, Ammonia, and Residual Chlorine* study under which Ecology agreed to expand its water quality monitoring in the basin using continuous instrumentation with partial funding from interested parties.

The purpose of this study and previous post Total Maximum Daily Load (TMDL) studies were to:

1. Assess spatial and temporal changes in water quality.
2. Determine if designated uses are supported by existing instream water quality.
3. Provide site-specific water quality information in support of Ecology's water quality-based permitting of dischargers.

Background

The United States Geological Survey (USGS) recorded continuous DO levels near 8 mg/L at the White River at RM 1.8 in August and September (Ebbert, 2002) when the streamflows were dominated by releases from Lake Tapps. The 2001 study also recorded DO levels near 9 mg/L at the Puyallup River at RM 1.8 during the same time period.

This 2006 study and a 2004 Ecology study were conducted after Puget Sound Energy ceased White River diversions through Lake Tapps for power generation.

The 2004 Ecology study found that DO levels at the Puyallup River RM 11.8 site and the White River site were lower than the 8 mg/L DO criterion (Zentner, 2005). The 2004 study also found that temperature at the White River site was higher than the 18°C state water temperature criterion during most of August.

In December 2006, new Washington State Water Quality Standards for surface waters went into effect. The revised standards set new criteria based on aquatic life uses. The new, more restrictive DO criteria daily minimum was raised from 8 to 9.5 mg/L at both of the lower Puyallup River sites and remained unchanged on the lower White River (Table 1). The new stream temperature criterion was also revised from a daily maximum to a highest 7-day average of the daily maximums (7-DAD Max). In addition, the numeric temperature threshold became more restrictive at all three monitored sites (Table 1).

Methods

The field study measurements, sampling protocols, and sonde and minisonde calibration methods are described in detail in Ecology's *Stream Sampling Protocols for the Environmental Monitoring and Trends Section* (Ward, 2001) and in the *Quality Assurance Project Plan: Puyallup and White Rivers – Temperature and Dissolved Oxygen Monitoring* (Bell-McKinnon, 2006).

A Solinst, Inc. Model 3001 LTDO Level Logger® (sonde) was used to monitor oxygen and temperature on the White River at RM 1.8 and on the Puyallup River at RM 11.8. A Hydrolab® Minisonde 5 (minisonde) was also used to monitor oxygen, temperature, and conductivity on the Puyallup River at RM 2.9. The sondes and minisonde utilize a new optic DO electrode technology to measure the amount of oxygen in water. The sondes and minisonde were calibrated according to the manufacturer's specifications and programmed to record results at 30-minute intervals. In addition, a long-line thermistor and a calibrated hand-held conductivity meter were used to obtain instantaneous measurements.

The White River at RM 1.8 sonde and the Puyallup River at RM 2.9 minisonde were deployed in the same protective housings used in the 2001 USGS study (20-foot-long plastic pipe sections). The Puyallup River at RM 11.8 sonde was deployed in a similarly designed three-inch galvanized pipe because of a higher vandalism potential.

Table 1. Summary of the new dissolved oxygen and temperature criteria at monitored sites.

Monitoring Site	Designated Use Criteria	Dissolved Oxygen		Temperature	
		New (1-day minimum)	Old (shall exceed)	New (Highest 7-DAD Max)	Old (shall not exceed)
Puyallup River at RM 2.9	Core Summer Salmonid Habitat	9.5 mg/L	8 mg/L	16°C	18°C
Puyallup River at RM 11.8	Core Summer Salmonid Habitat (June 15 - Sept. 15)	9.5 mg/L	8 mg/L	16°C	18°C
	Spawning and Incubation (Sept. 15 - July 1)			13°C	NA
White River at RM 1.8	Salmonid Spawning, Rearing, and Migration	8 mg/L	8 mg/L	17.5°C	18°C

The sondes and minisonde were retrieved, inspected, cleaned, downloaded, and redeployed every 3-4 days following strict protocols. Prior to retrieval, a minimum of two sequential DO field grab samples were collected, and a long-line thermistor was used to measure stream temperature. In addition, conductivity grab samples were collected and then measured using a separate calibrated meter at the Puyallup RM 2.9 monitoring site. A minimum of two sequential DO field grab samples were also collected just after the redeployment of a sonde or minisonde. All DO samples were fixed before leaving a monitoring site and analyzed either later that sampling day or the morning of the following day.

Field notes and photographs were taken to document any conditions that might have had an effect on the continuous monitoring results. The interior of the protective housings were also brushed and then flushed with water to prevent potential sediment buildup prior to sonde and minisonde redeployment. This step was usually done while the data from a sonde or minisonde was downloaded.

The design of the sampler used to collect the DO grab samples was based on the stainless steel version documented in Standard Methods (APHA, 2005). The sampler was constructed from a plastic container, tubes, and PVC pipe extension pole sections. The sampler design enabled sample collection to be at the location of sonde or minisonde DO sensor (typically several feet down a cut stream bank and several feet from shore).

Quality Assurance

The study began on August 14, 2006. The late start date meant that the sondes and minisonde were not deployed during the hottest period of the summer when the stream temperature seasonal 7-DAD Max period likely occurred and when low stream DO levels may have also occurred. The data analysis did not include data after October 9, 2006 because monitoring results after that date had many data gaps and severe data validation problems resulting from consecutive storm events.

Field quality control measurements, grab sample results, pre- and post-calibration check results, and field notes were used to identify and eliminate anomalous data. These measurements and results were also used in conjunction with provisionary USGS flow data for the data analysis. All finalized data sets have several expected one-hour data gaps that occurred when the sonde or minisonde was removed for data download and cleaning.

The pre- and post-study calibration check results for the sondes and minisonde DO sensors indicated that they remained within acceptable calibration limits during the entire deployment period (within 0.2 mg/L of the Winkler grab sample results collected from a test water bath). Paired DO grab samples (collected sequentially) were also collected before sonde or minisonde removal and after their redeployment. This was done so the results could be used to verify the accuracy of the continuous DO data records and to determine if a data correction factor for that data was warranted.

The expected difference between several sets of DO grab sample pairs exceeded the typical maximum of 0.3 mg/L based on Ecology's long-term ambient monitoring results (Ecology, 2008). The cause of the variability between the DO grab sample pairs was not completely identified or eliminated but considered to be a combination of field equipment problems, sampling problems, laboratory errors, and inexperienced field staff. Based on this assumption, the sequential DO grab sample sets having a difference of more than 0.3 mg/L were omitted for the data evaluation.

The mean difference between the average of the grab sample pair results and the continuous DO data was not consistent enough to establish a correction factor for the sondes and minisonde. All uncorrected DO data have at least a fair accuracy rating (± 0.8 mg/L) based on USGS guidelines (Wagner et al., 2006).

Results

All result remarks below are based on the continuous DO and temperature data summary tables (Appendix A, Tables A-1 through A-3) and data plots (Appendix B, Tables B-1 and B-2).

Puyallup River at RM 2.9

The minisonde recorded 30-minute DO, temperature, and conductivity data beginning August 15, 2006. The initial 23 days of results were affected by siltation problems, bad calibrations, and battery life issues based on a review of the data and field notes. This analysis uses the remaining data set from September 8 to October 9, 2006.

Dissolved Oxygen

Many of the daily minimum recorded values were very close to but just above the new minimum DO criterion of 9.5 mg/L. The measured DO saturation values ranged from 90 to 100%.

Temperature

The maximum daily stream temperature for the period monitored in September was 15.5°C at 7 PM on the 15th. Most daily maximum peak temperatures occurred near midnight which may result from solar impacts to a stream segment with little riparian vegetation located upstream of the site.

Conductivity

Conductivity was monitored at this lower river site to determine if the results were affected by increases in salinity during any of the monitoring period. Increases in salinity could occur during a low-flow/high-tide period. Based on a review of the results, none of the finalized data were affected by salinity. If any results were affected, they would be subject to less stringent DO criteria.

Puyallup River at RM 11.8

The sonde recorded usable 30-minute DO and temperature data from August 14 to October 9, 2006.

Dissolved Oxygen

The new minimum DO criterion of 9.5 mg/L was not met on two days, and there were two other instances when the results were at the minimum criterion. The estimated DO saturation values when the criterion was not met ranged from 88 to 92%. The DO saturation values ranged from 95-100% during the remainder of the study period.

Temperature

The stream temperature exceeded the 7-DAD Max water quality temperature criterion of 13°C during the last week of September. The maximum daily temperature for the monitored period was 16.6°C at 8 PM on August 14. Most daily maximum peak temperatures occurred between 7 and 9 PM.

White River at RM 1.8

The sonde recorded usable 30-minute DO and temperature data from August 14 to October 9, 2006.

Dissolved Oxygen

All recorded results were above the 8 mg/L daily minimum water quality criterion. The estimated DO saturation values were near 100%.

Temperature

The stream temperature exceeded the 7-DAD Max water quality temperature criterion at the beginning of the period monitored. The maximum daily temperature was 19.2°C on August 14 at 6:30 PM; this was well above the 17.5°C 7-DAD Max water quality criterion. Most daily maximum peak temperatures occurred between 6 and 8 PM.

Discussion

Temporal changes in DO can be observed in the plots of the available 2001, 2004, and 2006 continuous temperature and DO data for the White River at RM 1.8 site (Appendix B, Figure B-3). The 2001 data were collected when Puget Sound Energy diverted water through Lake Tapps for power generation. The 2004 and 2006 data were collected when very little water was diverted (Appendix C).

The DO level plots indicate the DO levels were noticeably lower in 2001 when compared to the other two years even though the water temperatures for all three years look similar. The measured or estimated DO percent saturation levels for the sites also indicate that most of the time the levels were at or near 100%.

Pre- and post-DO calibration results for the sondes and minisonde were within the manufacturer's specifications of 0.2 mg/L. This indicates that the new optic probes remained calibrated throughout the nearly three-month deployment period (no calibration drift) and the new technology can be used for deployment periods beyond the typical 3-4 days attainable from older membrane-Clarks Cell probes.

Site visits were conducted every 3-4 days during the study to flush sediment off the probes to minimize the effect of accumulating sediment on probe accuracy. The schedule proved successful at the upper river sites, and the field observations indicated that the schedule frequency could easily be reduced to once per week or even less often. The challenge was that the Puyallup River RM 2.9 minisonde easily became inundated by sediment, probably due to a lower stream velocity at high tide (Figure 2).

The high suspended sediment levels in the Puyallup River may have been the primary cause of most of the (1) data quality problems for the study, (2) variability between the DO grab sample pairs, and (3) variability between the DO grab sample pair averages and the continuous monitoring results. Other factors that may also have caused some of the grab sample and monitoring results variability include sampling and laboratory errors, and inexperienced field staff.

Although the reason for the DO grab sample pair variability was not completely identified, more project oversight might have helped identify and eliminate it. The inconsistent variability within these samples (1) made it more difficult to evaluate sonde and minisonde accuracy and (2) prevented the development of a data correction factor (if one was warranted).

Figure 2. Photo of silted minisonde probes from the Puyallup River at RM 2.9 site.

Conclusions

The recently approved Washington State dissolved oxygen (DO) criteria are more stringent on the lower Puyallup River than when the 1993 Puyallup River TMDL study was done (old criterion = 8 mg/L, new criterion = 9.5 mg/L). The data indicate that the oxygen levels in the Puyallup River at RM 2.9 site were very near the new minimum criterion (without any August data), and the levels in the Puyallup River at RM 11.8 site occasionally exceeded it. The mostly 95-100% DO saturation levels at these sites indicate that stream water temperature is keeping the DO levels near the new minimum criterion.

Recent continuous DO study data at the White River RM 1.8 monitoring site indicate that the Puget Sound Energy operation change to cease water diversions through Lake Tapps has likely improved the lowest daily DO levels in the river by at least 1 mg/L. The 2001 USGS study found minimum DO levels near 8 mg/L when some water was diverted though Lake Tapps. This study and the 2004 Ecology study found minimum levels ranging from 9-9.5 mg/L when no water was being diverted through the lake.

The limited continuous temperature data (which does not include the seasonal 7-DAD Max) indicates that the criterion is sometimes not being met in the Puyallup River at RM 11.8 and in the White River at RM 1.8 monitoring sites. The finding for the White River site was also documented in the 2004 study.

The Puyallup River RM 2.9 site is a high maintenance site for conducting continuous monitoring. The minisonde probes were sometimes fouled and isolated by silt making some of the affected data unusable. The probe fouling was primarily due to a combination of the high stream suspended solid content, the slack water and sometimes eddy effect created by high tides during low-flow periods, and the nearly flat stream channel.

Recommendations

Further negative impacts to the Puyallup River RM 2.9 DO levels should be prevented because the DO levels are already very close to the new, more restrictive, minimum Washington State water quality criteria. A reduction in stream temperatures during late summer on the lower Puyallup River would have the greatest impact on increasing the stream DO levels.

A study evaluating potential heat sources to the White River stream temperature should be considered. The study focus should address riparian shade relationships, direct discharges, diversions through Lake Tapps, and any other potentially significant heat source that might be managed (altered) to reduce stream temperatures.

Efforts should be explored to reduce the Puyallup and White River stream temperatures because Washington State water quality criteria are not being met at all times.

White River diversions through Lake Tapps should be minimized to avoid lowering DO levels below the new state daily minimum water quality criterion at White River RM 1.8 and at Puyallup River RM 2.9.

A study of the effects of diverting the White River through Lake Tapps on the White River DO levels should be considered.

The lower Puyallup River RM 2.9 monitoring site should be abandoned because of the high silt problems. A location further upstream and possibly on the north side of the river should be considered.

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Appendix A. Sonde and Minisonde Data Summary Tables

Table A-1. Data Summary for the Puyallup River at RM 2.9.

Date	Dissolved Oxygen (mg/L)		Dissolved Oxygen (% Saturation)		Temperature (°C)			Conductivity (uhmos/cm)	
	Min.	Max.	Min.	Max.	Min.	Max.	7-DAD Max	Min.	Max.
9/8/06	9.8	10.5	94.6	99.6	13.4	14.6		73	84
9/9/06	9.6	10.2	93.3	98.8	13.3	15.1		76	82
9/10/06	9.8	10.4	93.4	100.1	12.4	14.4		81	87
9/11/06	9.7	10.5	93.4	100.3	12.4	14.5	14.5	76	89
9/12/06	9.7	10.5	93.8	100.4	12.6	14.7	14.2	78	87
9/13/06	9.6	10.4	93.8	97.7	13.2	15.1	13.9	81	87
9/14/06	10.0	10.5	92.8	96.8	11.8	13.2	13.7	84	93
9/15/06	10.0	10.7	90.9	98.4	11.3	12.5	13.6	93	101
9/16/06	10.1	10.8	92.3	99.3	11.3	12.7	13.4	100	105
9/17/06	10.0	10.7	92.6	98.9	12.0	13.0	13.1	100	108
9/18/06	9.9	10.3	91.5	96	12.5	13.7	12.9	102	108
9/19/06	9.8	10.5	92.5	97.6	12.4	13.8	12.8	91	103
9/20/06	10.1	10.7	93.5	96.6	11.6	12.8	12.8	91	98
9/21/06	10.2	10.8	92.6	96.7	11.0	11.7	12.9	83	98
9/22/06	10.5	11.0	93.5	99.9	10.0	12.0	13.0	87	93
9/23/06	10.3	10.9	93.3	100.8	10.5	12.8	13.0	92	102
9/24/06	9.9	10.8	92.2	100.8	11.2	13.6	13.3	96	102
9/25/06	9.7	10.6	91.6	100.6	12.1	14.1	13.7	82	101
9/26/06	9.6	10.5	91.9	100.2	12.3	14.3	14.0	93	99
9/27/06	9.7	10.5	92.2	100	12.5	14.3	14.2	92	97
9/28/06	9.6	10.4	93	99.8	12.5	14.6	14.1	88	94
9/29/06	9.7	10.5	93.1	99.2	12.1	14.5	13.9	86	92
9/30/06	9.8	10.6	92.4	98.8	11.6	13.8	13.6	88	93
10/1/06	10.0	10.7	92.5	99.3	11.7	13.1	13.3	91	99
10/2/06	10.1	11.0	92	100.2	10.7	12.4	13.1	92	99
10/3/06	10.2	11.0	93.1	100.1	11.3	12.3	13.0	92	97
10/4/06	10.3	10.9	92.9	100.2	11.2	12.5	12.9	93	104
10/5/06	10.1	10.8	92.7	100.7	12.0	13.2	12.8	100	111
10/6/06	9.7	10.6	91.7	97.6	12.2	13.5	12.8	93	104
10/7/06	9.9	11.0	91.4	102	11.6	13.0		87	100
10/8/06	9.4	10.9	86.3	100.4	11.6	12.7		88	105
10/9/06	10.2	10.6	92.8	96.1	10.9	12.2		91	96

Table A-2. Data Summary for the Puyallup River at RM 11.8.

Date	Dissolved Oxygen (mg/L)		Temperature (°C)		
	Min.	Max.	Min.	Max.	7-DAD Max
8/14/06	9.8	11.1	13.1	16.6	
8/15/06	9.9	11.3	12.0	15.7	
8/16/06	9.1	10.9	12.0	14.6	
8/17/06	9.6	11.6	10.9	14.3	15.6
8/18/06	10.0	11.3	12.0	15.7	15.4
8/19/06	9.9	11.2	12.2	16.2	15.2
8/20/06	9.8	11.3	12.0	16.3	15.1
8/21/06	9.3	11.1	12.2	15.2	15.0
8/22/06	9.9	11.2	11.3	14.2	15.0
8/23/06	10.3	11.3	11.1	13.5	15.0
8/24/06	10.4	11.3	11.5	14.1	15.0
8/25/06	9.8	11.4	11.0	15.8	15.1
8/26/06	9.8	11.2	12.4	16.1	15.2
8/27/06	9.7	11.1	12.2	16.3	15.1
8/28/06	9.7	11.1	12.1	15.9	15.2
8/29/06	10.1	11.2	11.5	14.7	15.2
8/30/06	10.5	11.4	10.6	12.7	15.2
8/31/06	9.9	11.7	10.1	14.9	15.1
9/1/06	9.5	11.2	11.4	16.1	15.1
9/2/06	9.7	11.0	12.2	15.9	15.1
9/3/06	9.9	11.0	12.4	15.5	15.5
9/4/06	10.0	11.2	12.2	15.7	15.4
9/5/06	10.1	11.5	11.2	15.1	15.2
9/6/06	9.5	11.4	11.1	15.0	14.9
9/7/06	10.0	11.5	11.3	14.7	14.8
9/8/06	10.3	11.5	11.0	14.3	14.7
9/9/06	10.3	11.1	12.3	14.1	14.7
9/10/06	10.2	11.6	10.8	15.0	14.5
9/11/06	10.1	11.5	11.0	14.5	14.1
9/12/06	10.0	11.4	11.2	14.9	13.9
9/13/06	10.4	11.1	11.9	14.0	13.8
9/14/06	10.8	11.3	10.9	11.8	13.5
9/15/06	10.5	11.7	9.9	13.0	13.4
9/16/06	10.5	11.8	9.8	13.2	13.2
9/17/06	10.6	11.7	10.5	13.0	12.8
9/18/06	10.4	11.2	11.5	14.0	12.7
9/19/06	10.4	11.2	11.4	13.1	12.6
9/20/06	10.5	11.5	10.8	11.9	12.7
9/21/06	10.8	11.8	10.0	11.1	12.9
9/22/06	10.8	12.0	9.2	12.3	13.0
9/23/06	10.2	12.1	9.1	13.4	13.2
9/24/06	10.1	11.7	9.8	14.4	13.6
9/25/06	9.8	11.3	10.8	14.7	14.1
9/26/06	10.0	11.3	10.9	14.6	14.4
9/27/06	10.1	11.4	11.0	14.9	14.3
9/28/06	10.1	11.3	11.4	14.7	14.2
9/29/06	10.3	11.4	11.1	13.9	13.8
9/30/06	10.5	11.5	10.3	13.2	13.3

Table A-2 (cont.). Data Summary for the Puyallup River at RM 11.8.

Date	Dissolved Oxygen (mg/L)		Temperature (°C)		
	Min.	Max.	Min.	Max.	7-DAD Max
10/3/06	10.5	12.1	9.0	11.3	12.6
10/4/06	10.6	12.2	9.1	11.9	12.4
10/5/06	10.5	11.8	9.8	13.3	12.3
10/6/06	10.6	11.8	10.0	12.8	12.0
10/7/06	10.9	11.8	10.1	12.4	
10/8/06	11.0	12.1	9.6	11.8	
10/9/06	11.3	12.0	9.2	10.9	

Table A-3. Data Summary for the White River at RM 1.8.

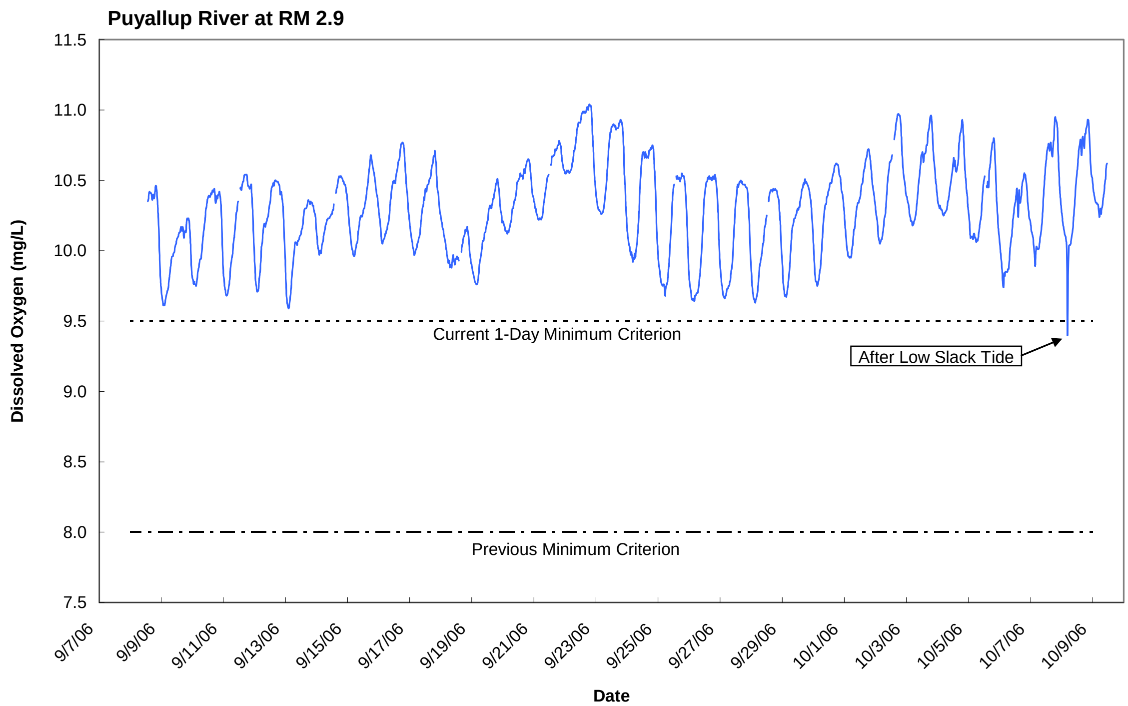
Date	Dissolved Oxygen (mg/L)		Temperature (°C)		
	Min.	Max.	Min.	Max.	7-DAD Max
8/14/06	9.3	10.5	14.9	19.2	
8/15/06	9.4	10.5	14.9	17.1	
8/16/06	9.8	10.7	13.6	16.8	
8/17/06	9.9	11.1	13.0	16.6	18.0
8/18/06	9.5	11.0	13.4	18.3	17.8
8/19/06	9.3	10.5	14.3	19.0	17.7
8/20/06	9.3	10.4	14.4	19.1	17.5
8/21/06	9.5	10.5	14.6	18.0	17.3
8/22/06	9.8	10.6	13.8	16.4	17.3
8/23/06	10.1	10.8	12.6	14.9	17.2
8/24/06	10.1	10.8	12.8	15.6	17.2
8/25/06	9.6	10.9	12.9	17.9	17.3
8/26/06	9.4	10.7	13.9	18.5	17.3
8/27/06	9.3	10.6	14.2	18.7	17.3
8/28/06	9.3	10.5	14.4	18.9	17.4
8/29/06	9.5	10.4	14.0	16.7	17.2
8/30/06	10.2	11.0	12.3	15.0	17.1
8/31/06	10.0	11.3	11.2	15.7	16.9
9/1/06	9.6	11.2	12.2	17.0	16.8
9/2/06	9.5	11.0	13.0	17.7	17.0
9/3/06	9.5	10.8	13.9	17.5	17.3
9/4/06	9.5	10.6	13.6	17.8	17.5
9/5/06	9.6	10.6	13.9	17.8	17.4
9/6/06	9.6	10.7	13.5	17.5	17.1
9/7/06	9.7	10.7	13.2	16.9	16.9
9/8/06	9.8	10.8	12.8	16.4	16.7
9/9/06	9.9	10.5	13.7	16.0	16.6
9/10/06	10.0	10.9	12.5	16.0	16.3
9/11/06	9.9	11.0	12.3	16.3	15.8
9/12/06	9.7	11.0	12.7	17.0	15.4
9/13/06	9.9	10.7	13.5	15.4	15.1
9/14/06	10.3	10.9	11.9	13.4	14.7
9/15/06	10.5	11.2	10.9	13.5	14.5
9/16/06	10.4	11.3	10.9	14.1	14.1
9/17/06	10.3	11.2	11.3	13.4	13.7
9/18/06	10.1	11.0	12.4	14.4	13.5
9/19/06	10.1	10.9	12.5	14.0	13.5
9/20/06	10.5	11.1	11.7	12.8	13.5
9/21/06	10.7	11.1	11.3	12.1	13.7
9/22/06	10.6	11.6	10.2	13.3	13.9
9/23/06	10.3	11.5	10.8	14.3	14.2
9/24/06	10.0	11.4	11.3	15.1	14.6
9/25/06	9.9	11.2	12.2	15.9	15.2
9/26/06	9.9	11.3	12.4	15.7	15.5
9/27/06	9.9	11.2	12.7	16.0	15.5
9/28/06	9.8	11.2	12.9	16.1	15.3
9/29/06	9.9	11.2	12.7	15.5	15.0
9/30/06	10.1	11.3	12.3	14.1	14.7

Table A-3 (cont.). Data Summary for the White River at RM 1.8.

Date	Dissolved Oxygen (mg/L)		Temperature (°C)		
	Min.	Max.	Min.	Max.	7-DAD Max
10/1/06	10.3	11.4	11.7	13.6	14.4
10/2/06	10.3	11.5	10.9	13.9	14.2
10/3/06	10.5	11.6	12.4	13.5	14.0
10/4/06	10.5	11.6	12.3	14.0	14.0
10/5/06	10.3	11.5	12.9	14.9	14.0
10/6/06	10.3	11.3	13.2	14.0	13.9
10/7/06	10.5	11.7	12.7	14.1	
10/8/06	10.5	11.7	12.7	13.6	
10/9/06	10.6	11.1	11.8	13.2	

Appendix B. Sonde and Minisonde Result Plots

Figure B-1. Plots of continuous dissolved oxygen data and the minimum water quality criteria.



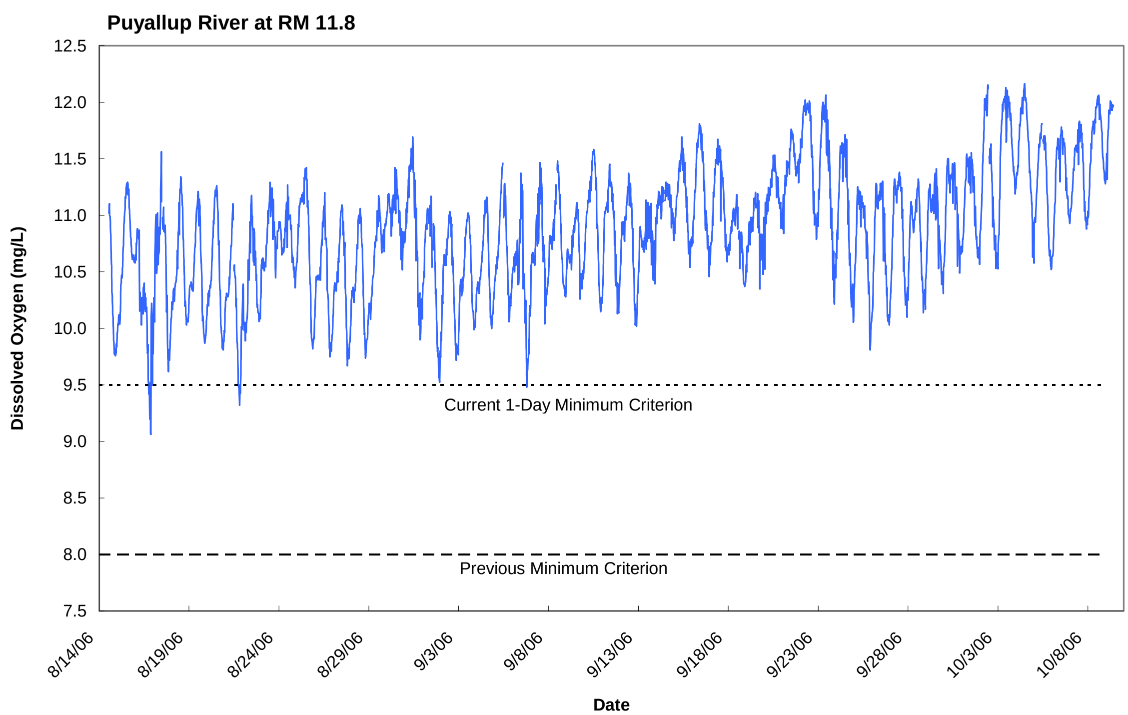


Figure B-1 (cont.). Plots of continuous dissolved oxygen data and the minimum water quality criteria.

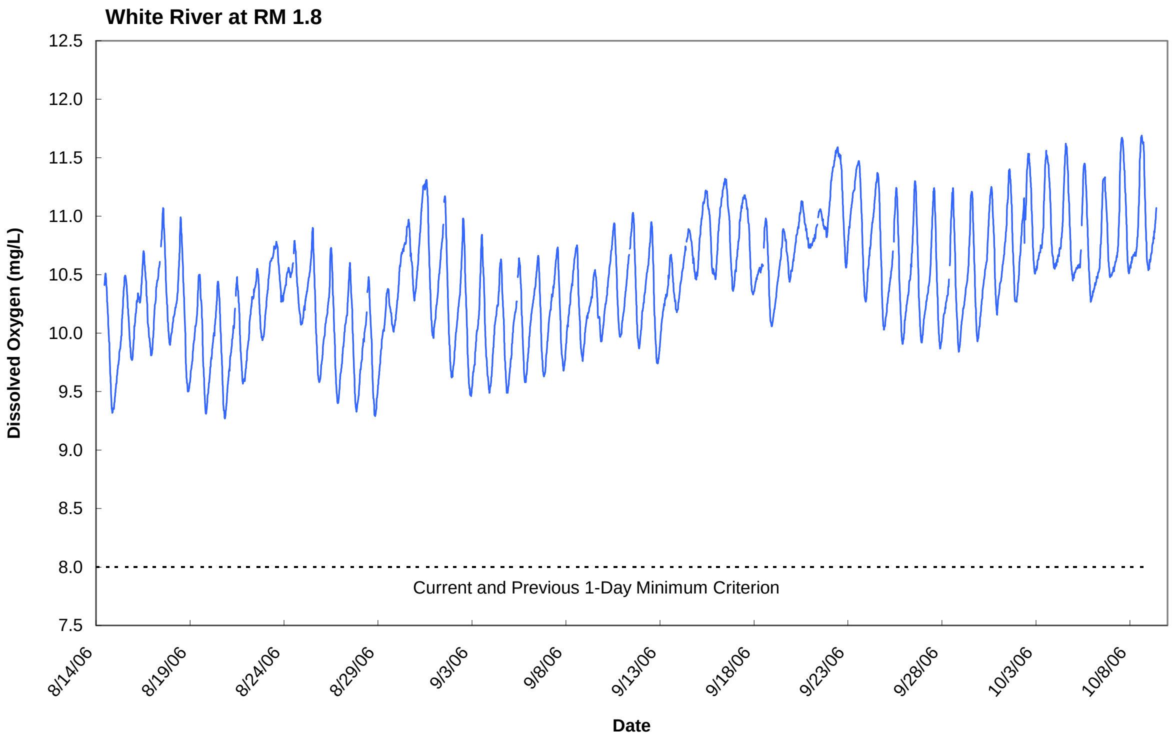
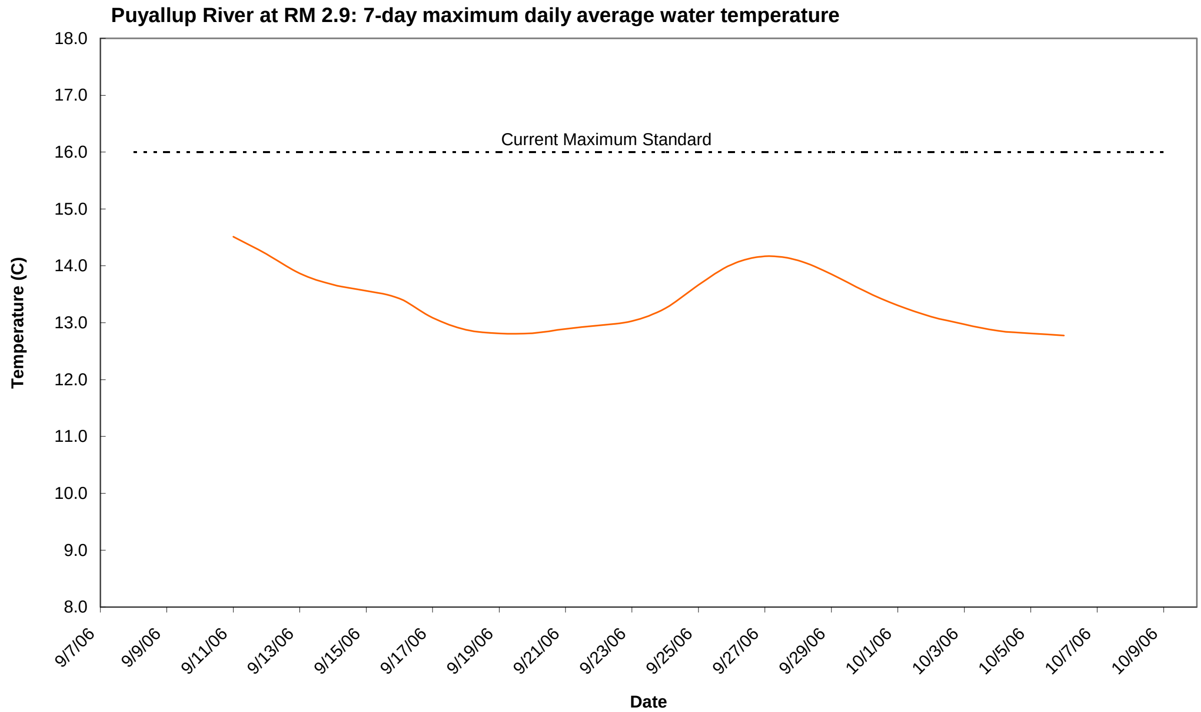


Figure B-2. Plots of continuous temperature data and the maximum water quality criteria.



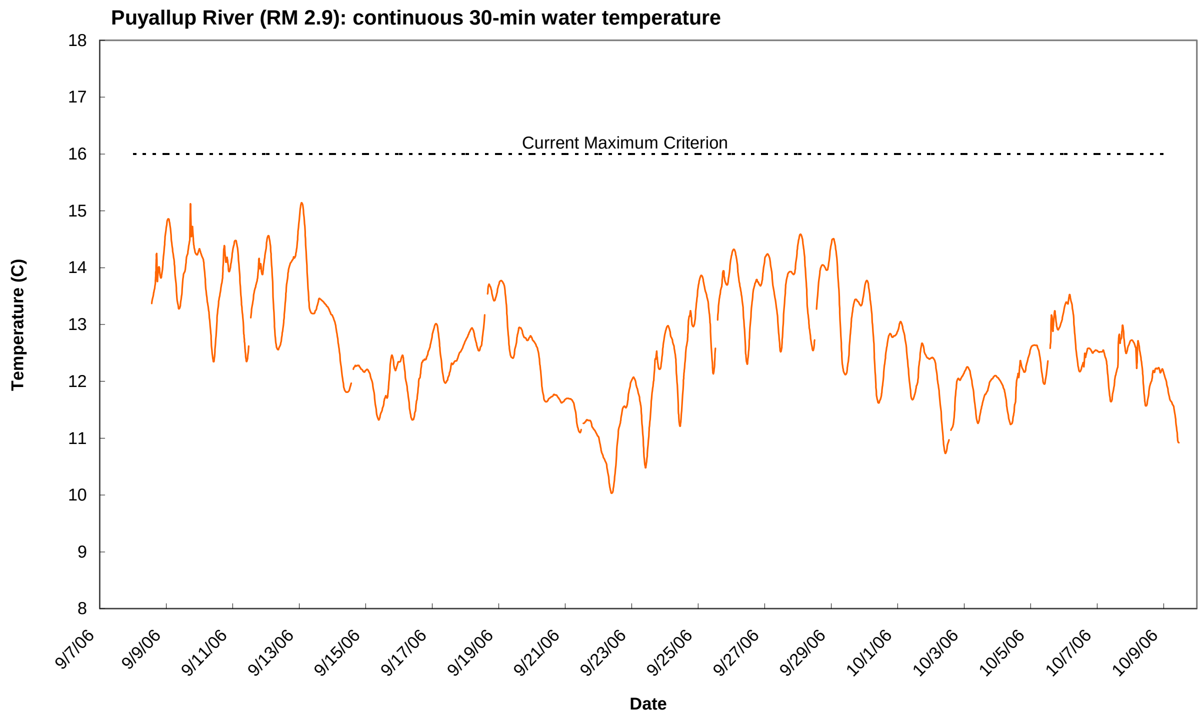
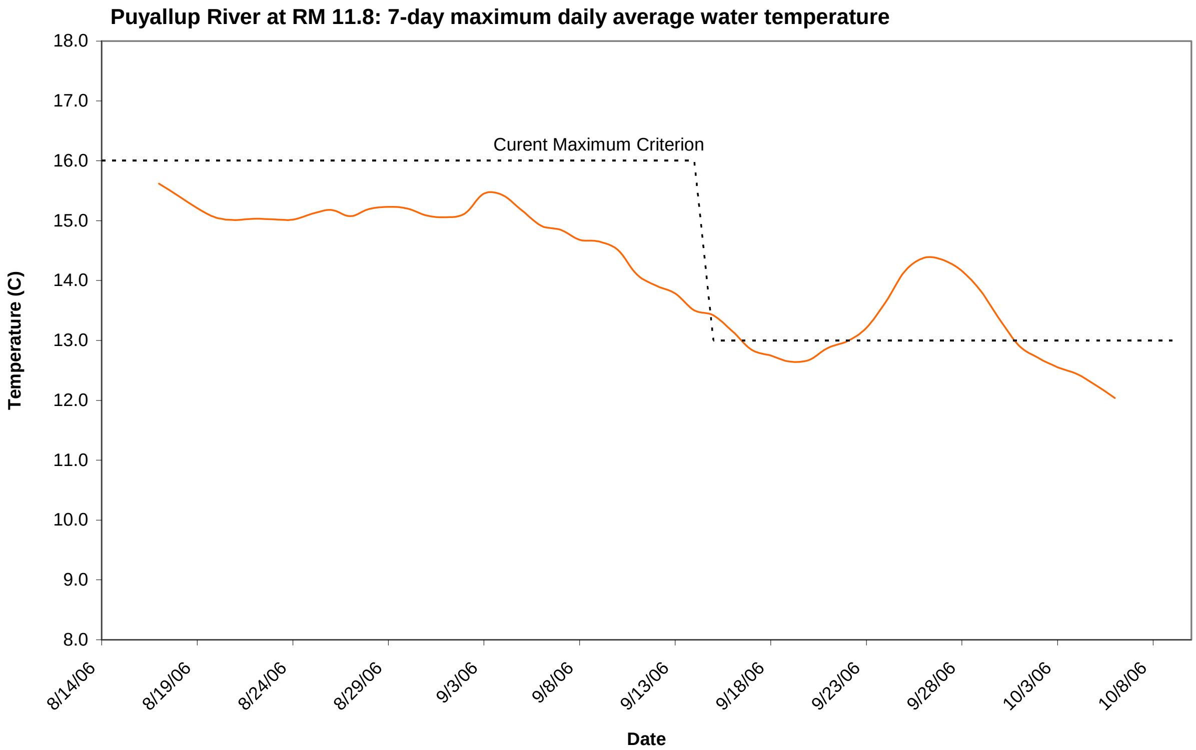


Figure B-2 (cont.). Plots of continuous temperature data and the maximum water quality criteria.



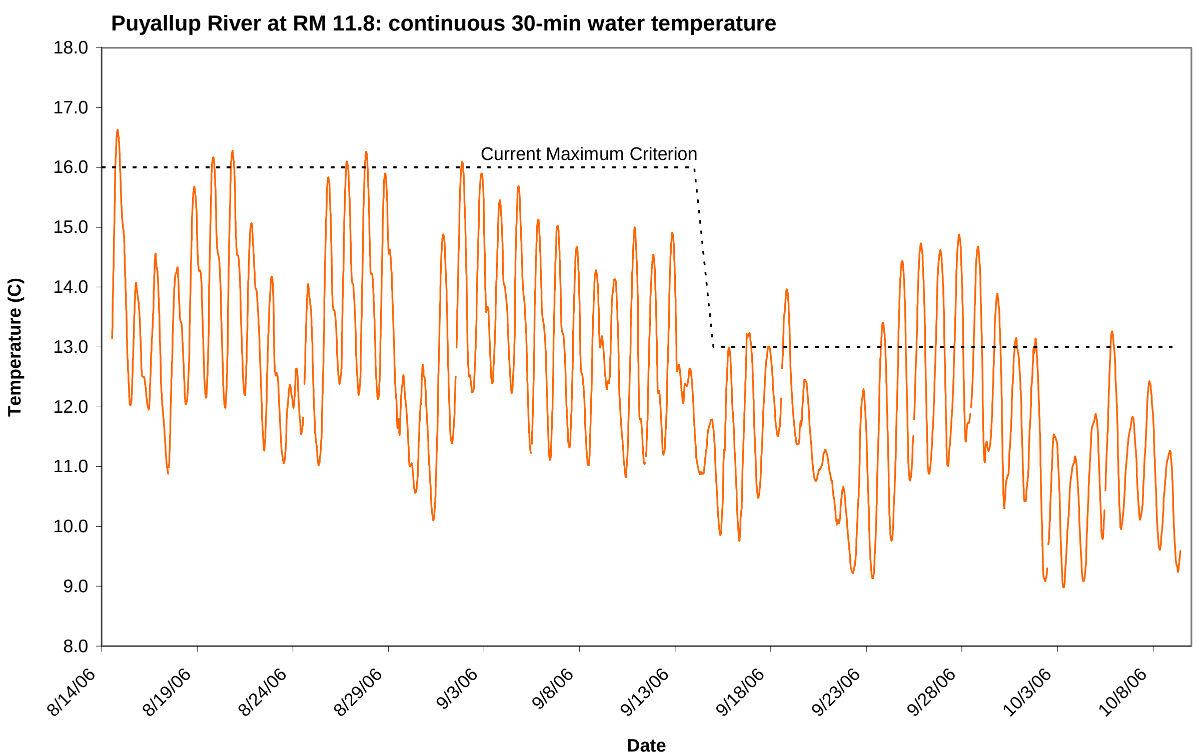
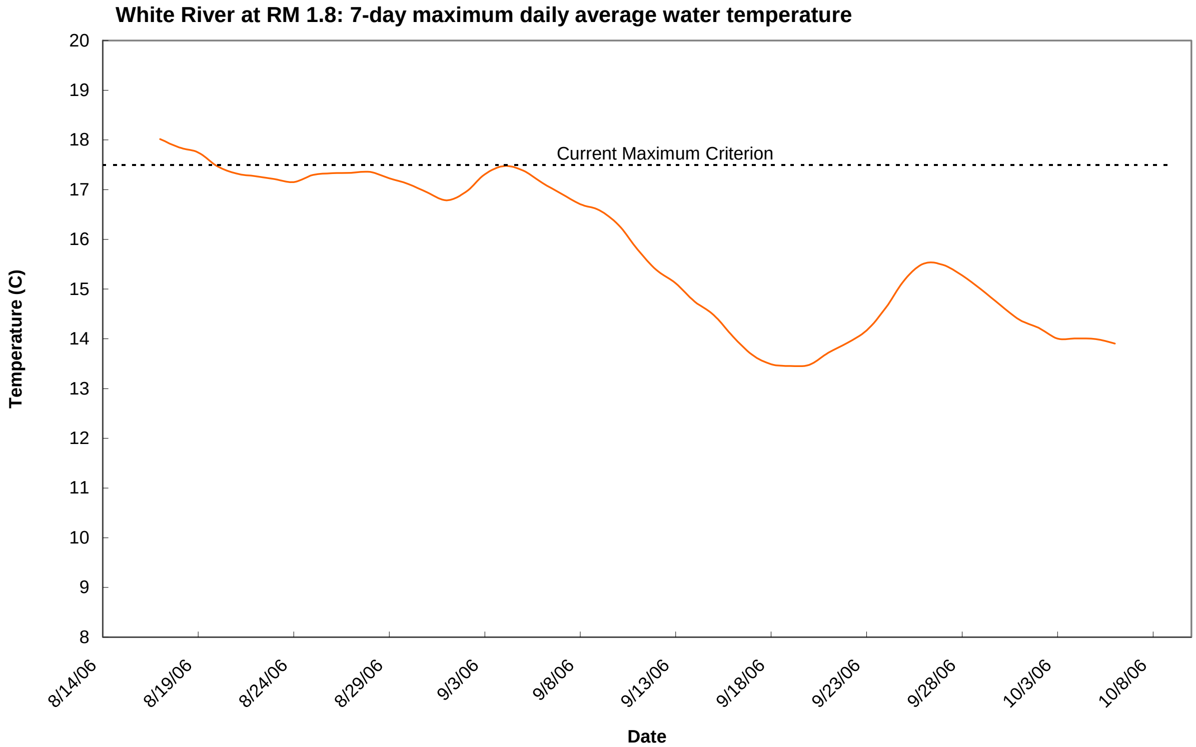


Figure B-2 (cont.). Plots of continuous temperature data and the maximum water quality criteria.



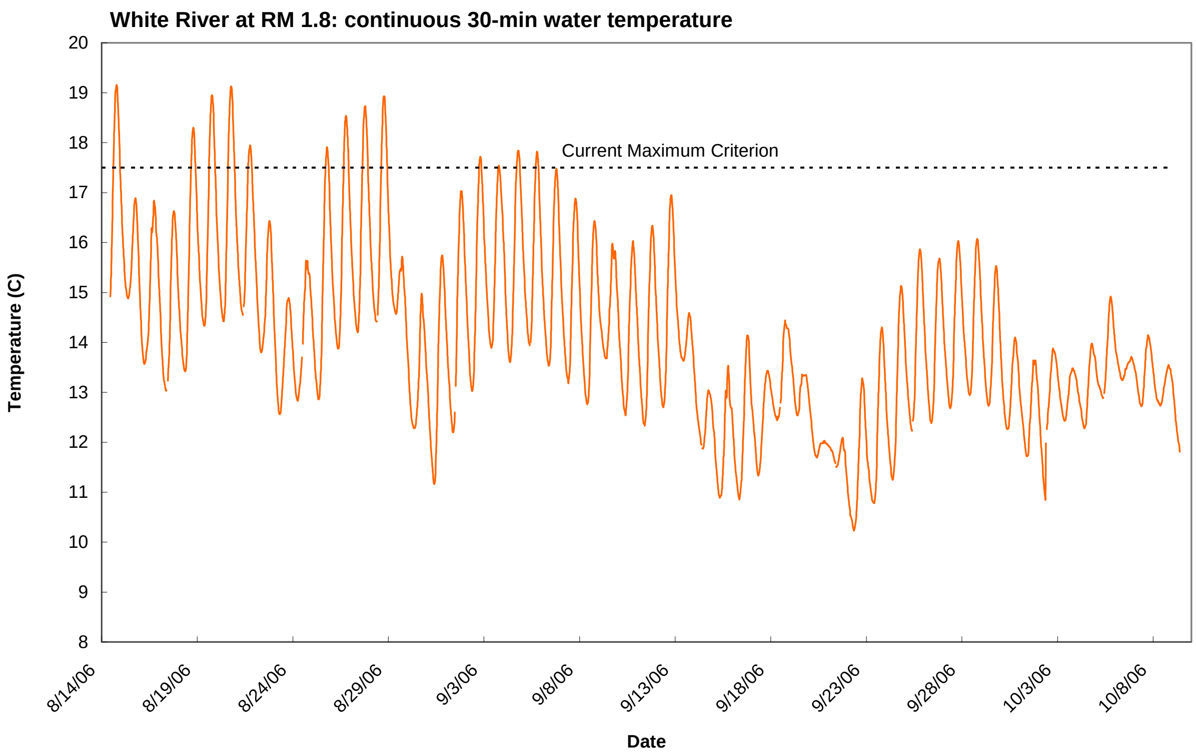
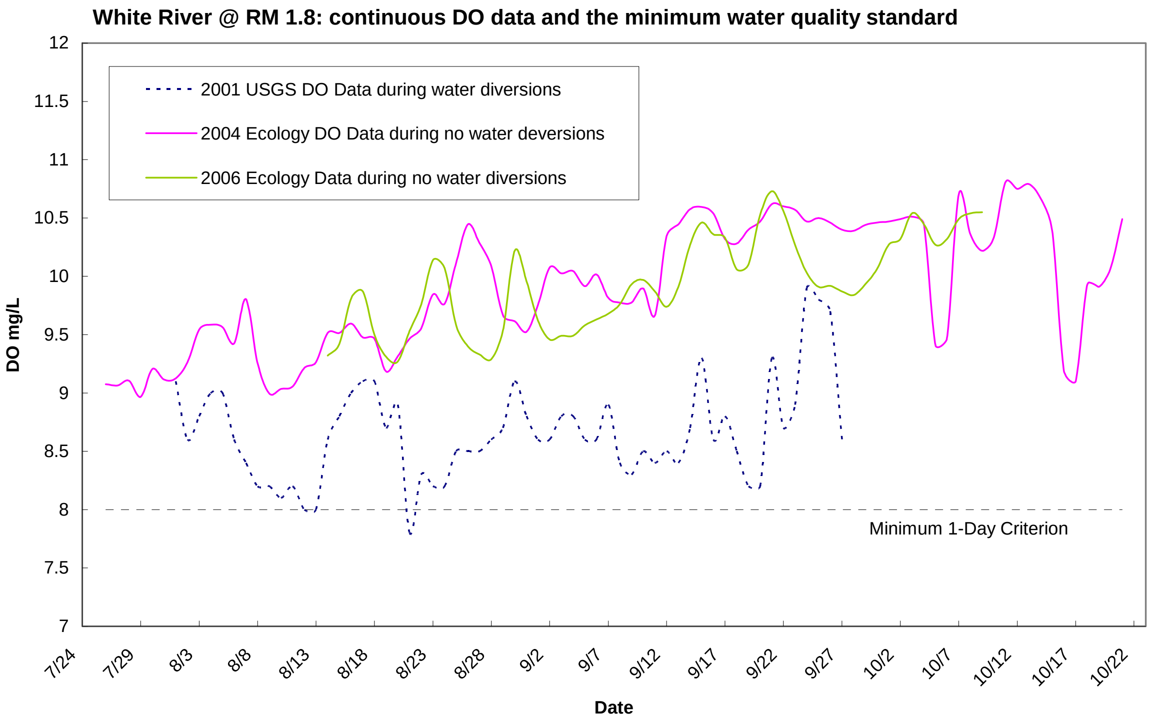
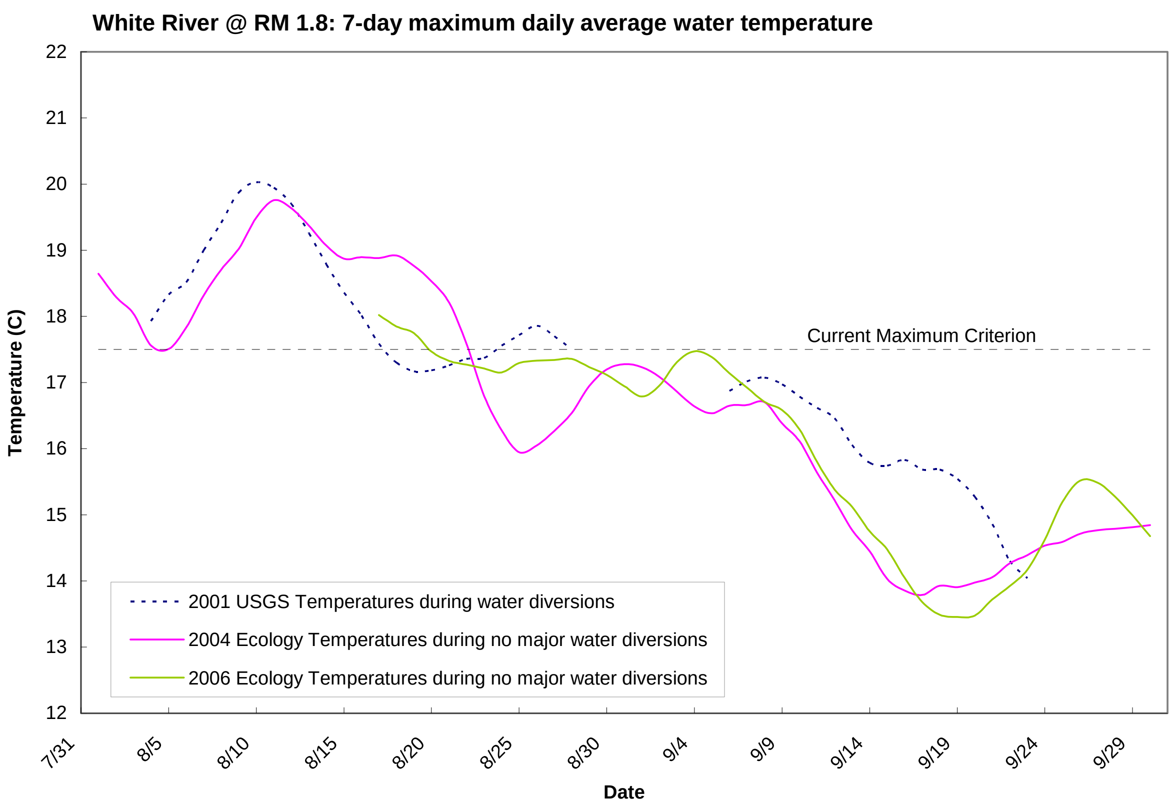


Figure B-3. Plots of 2001, 2004, and 2006 continuous dissolved oxygen and temperature data.





Appendix C. USGS Average Daily Flow Plots for Summers 2001, 2004, and 2006

Figure C-1. USGS average daily flow plots for summers 2001, 2004, and 2006.