Lower White River Nutrients and pH Study

Data Summary Report

DEPARTMENT OF ECOLOGY
State of Washington

July 2010

Publication No. 10-03-040

Publication and Contact Information

This report is available on the Department of Ecology's website at
www.ecy.wa.gov/biblio/1003040.html

Data for this project are available at Ecology's Environmental Information Management (EIM) website www.ecy.wa.gov/eim/index.htm. Search User Study ID, NMat0002.

The Activity Tracker Code for this study is 10-156.

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Cover photo: Lower White River at river mile 25, looking downstream.
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Lower White River Nutrients and pH Study

Data Summary Report

by

Nuri Mathieu

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Waterbody Number: WA-10-1030

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Abstract

The White River is a glacially-fed tributary that drains into the Puyallup River near Sumner, Washington. Past studies have documented pH levels in the Lower White River that failed to meet Washington State water quality standards.

The bypass reach of the Lower White River extends from a diversion in Buckley, Washington (that feeds into Lake Tapps) to the confluence with the Lake Tapps tailrace, just downstream of Auburn, Washington. Before 2004, most of the White River's flow was diverted to Lake Tapps and used for hydro-electric power generation by Puget Sound Energy (PSE). In January 2004, PSE ceased power generation, and most of the flow was returned to the Lower White River bypass reach. The change in streamflow may have affected pH levels within the bypass reach.

The goal of this 2009 monitoring study was to provide information about the Lower White River in its current state. The primary objective was to collect continuous pH measurements, algae samples, and water quality samples at key locations along the Lower White River.

The study found that pH levels met water quality standards during three 48- hour continuous monitoring deployments conducted in September and October of 2009.

Acknowledgements

The author of this report thanks the following people for their contribution to this study:

- Nancy Rapin, Water Quality Specialist, Muckleshoot Indian Tribe.
- Joel Massmann, Water Quality Engineer and Consultant, Keta Waters LLC.
- Char Naylor, Water Quality Program Manager, Puyallup Tribe of Indians.
- Washington State Department of Ecology staff:
  - Chuck Hoffman, Cindy James, Betsy Dickes, and Kim McKee, Water Quality Program.
  - Trevor Swanson and James Kardouni, Western Operations Section, Environmental Assessment Program.
  - Christopher Moore and Greg Pelletier, Statewide Operations Section, Environmental Assessment Program.
  - Joan LeTourneau, Cindy Cook, and Carol Norsen, Environmental Assessment Program.

Introduction

Overview

The White River, located in the Puget Sound basin in western Washington, originates from several glaciers on Mt. Rainier. The river flows westerly until emptying into the Puyallup River near Sumner, Washington.

In September and October of 1990, the Washington State Department of Ecology (Ecology) measured pH levels that did not meet (exceeded) Washington State water quality standards (WAC 173-201A) in the Lower White River at river mile (RM) 4.9, 6.3, and 8.0. These measurements were taken during a total maximum daily load (TMDL) study conducted in the Puyallup River watershed (Pelletier, 1993). Subsequent monitoring, conducted from 1996-2003, documented continued exceedances of pH standards in the Lower White River (Pelletier, 1993; Erickson, 1999; Ecology, 2009; Stuart, 2002; Ebbert, 2003).

Based on the pH exceedances, the White River was placed on Washington State's 303(d) list of impaired waterbodies. The federal Clean Water Act of 1972 requires the state to develop a water quality improvement report or TMDL and to implement activities in the plan to bring these water bodies back into compliance with standards.

Interested parties have completed additional data collection and analysis in support of a TMDL study; however, a TMDL report has not yet been finalized. Recent improvements in wastewater treatment will likely result in reduced nutrient loads.

This 2009 study provides information about the Lower White River and the effects of improved wastewater treatment.

Study area

The White River drains a 494-square-mile basin with a total length of 68 miles. Mud Mountain Dam, around RM 28, provides flood control for the river valley and affects flows in the river downstream.

A diversion at RM 24 removes a regulated amount of water, which is temporarily stored in Lake Tapps and then returned to the White River at about RM 4. Historically, the majority of the White River was diverted to Lake Tapps and used for hydro-electric power generation by Puget Sound Energy (PSE). The mainstem of the White River from the diversion to the return was referred to as the "bypass reach," which contained only a small residual of the flow upstream of the diversion.

The Muckleshoot Indian Tribe owns and governs reservation land along the Lower White River within the study area. The White River flows through Muckleshoot land between RMs 16 and 9. Surface waters that flow into the reservation boundaries are considered waters of the state

upstream of the boundary and tribal waters downstream of the boundary. The opposite applies to waters flowing out of tribal land.

In January 2004, PSE ceased hydropower operations, and the majority of flow was returned to the White River bypass reach, while diverting a much smaller amount of water to maintain water levels in Lake Tapps for recreation.

The Cascade Water Alliance recently purchased the water rights to the diversion from PSE. Cascade Water Alliance and the Puyallup and Muckleshoot Tribes reached an agreement outlining future management of the White River and Lake Tapps for protection of fishery resources, providing municipal water supply in the future, and continuing recreational use of Lake Tapps.

The study area for this project extends from The Lower White River at RM 25.1, just upstream of the Rainier School wastewater treatment plant (WWTP), to RM 4.9, downstream of the City of Auburn and about a mile upstream of the Lake Tapps return.

What causes high pH levels in the Lower White River?

Excess nutrients in the White River promote benthic algal growth (periphyton) on rocks, or other debris, in the streambed. These algae remove dissolved inorganic carbon from the water column to use in photosynthesis.

Carbon dioxide (CO_2) dissolves in water to form carbonic acid (H_2CO_3), which then disassociates into a hydrogen ion (H^+) and bicarbonate (HCO_3^-). The higher the proportion of dissolved CO_2 relative to bicarbonate and carbonate, the lower the pH level. During daylight hours, algae consume dissolved CO_2 in the water column for photosynthesis, causing the pH to increase.

In waters with excessive algal growth, inorganic carbon uptake can occur at a rate much faster than it is replenished by the atmosphere, resulting in high pH levels that can be harmful to aquatic life.

Why did Ecology conduct this study?

Since water year (WY) 2001, two major changes have occurred within the Lower White River.

1. The flow regime has changed dramatically now that PSE is no longer diverting large amounts of water for power generation.
2. The Buckley and Enumclaw WWTPs, the two major point sources within the area of concern, upgraded their nutrient-removal capabilities.

The goal of this 2009 monitoring study was to provide information about the Lower White River and the effects of improved wastewater treatment. The primary objective of the study was to collect diurnal pH (using Hydrolabs deployed for 48 hour periods) at key locations along the Lower White River.

Methods

Study design

The study design consists of three data collection components:

1. Continuous Hydrolab deployments at all sites.
   a. Measure pH, dissolved oxygen, conductivity, and temperature.
   b. Record data in 15-minute intervals.
   c. Deploy for 48 hours or more (per deployment).

2. Periphyton sampling at all sites.
   a. Scrub and rinse rocks for sample collection and analyze for chlorophyll-a and ash-free dry mass (AFDM).
   b. Measure surface area of rock.
   c. Estimate periphyton biomass at each site.

3. Nutrient sampling at only three sites (Table 1).
   a. Collect samples listed under Laboratory analysis in Table 2.
   b. Field staff will filter orthophosphate and dissolved organic carbon samples; lab staff will filter chlorophyll-a samples.

Sampling dates and locations

Field staff deployed Hydrolabs and collected nutrient and periphyton samples during three 2009 surveys:

- September 14-16. Deployments ranged from 49 to 59 hours, depending on site.
- October 5-7. Deployments ranged from 49 to 54 hours, depending on site.
- October 19-21. Deployments ranged from 47 to 51 hours, depending on site.

Each deployment captured a minimum of one diurnal peak in pH values on the middle day of the survey. A definitive peak in pH was not always captured on the first or last day of the survey due to the logistical constraints of deploying and retrieving equipment throughout the watershed. In most cases, the pH peak was captured on two consecutive days per deployment per site.

Conditional sampling was scheduled to continue from November 2009 to January 2010, provided the stream flow remained at, or returned to, baseflow. Heavy rains in late October 2009 caused flows to rise above 1000 cfs, and the flow did not return to below 1000 cfs for the remainder of the year.

Sampling occurred at six stations along the Lower White River (Table 1; Figure 1).

Table 1. Station names, descriptions, and coordinates.

Station Name	Location Description	Latitude °N	Longitude °W	Nutrients
10-WHT-25.1	Just upstream of Rainier School WWTP	47.16626	-121.99328	X
10-WHT-20.4	At 80th and 274th; downstream of Enumclaw and Buckley	47.18772	-122.06889	X
10-WHT-16.2	PSE power line access road; just upstream of Muckleshoot Reservation	47.22499	-122.11278	
10-WHT-8.5	Upstream end of Game Farm Park in Auburn	47.27487	-122.20855	
10-WHT-6.3	At A St./railroad tracks in Auburn	47.26657	-122.22900	X
10-WHT-4.9	At 8th St. in Sumner; downstream of Auburn	47.24997	-122.24408	

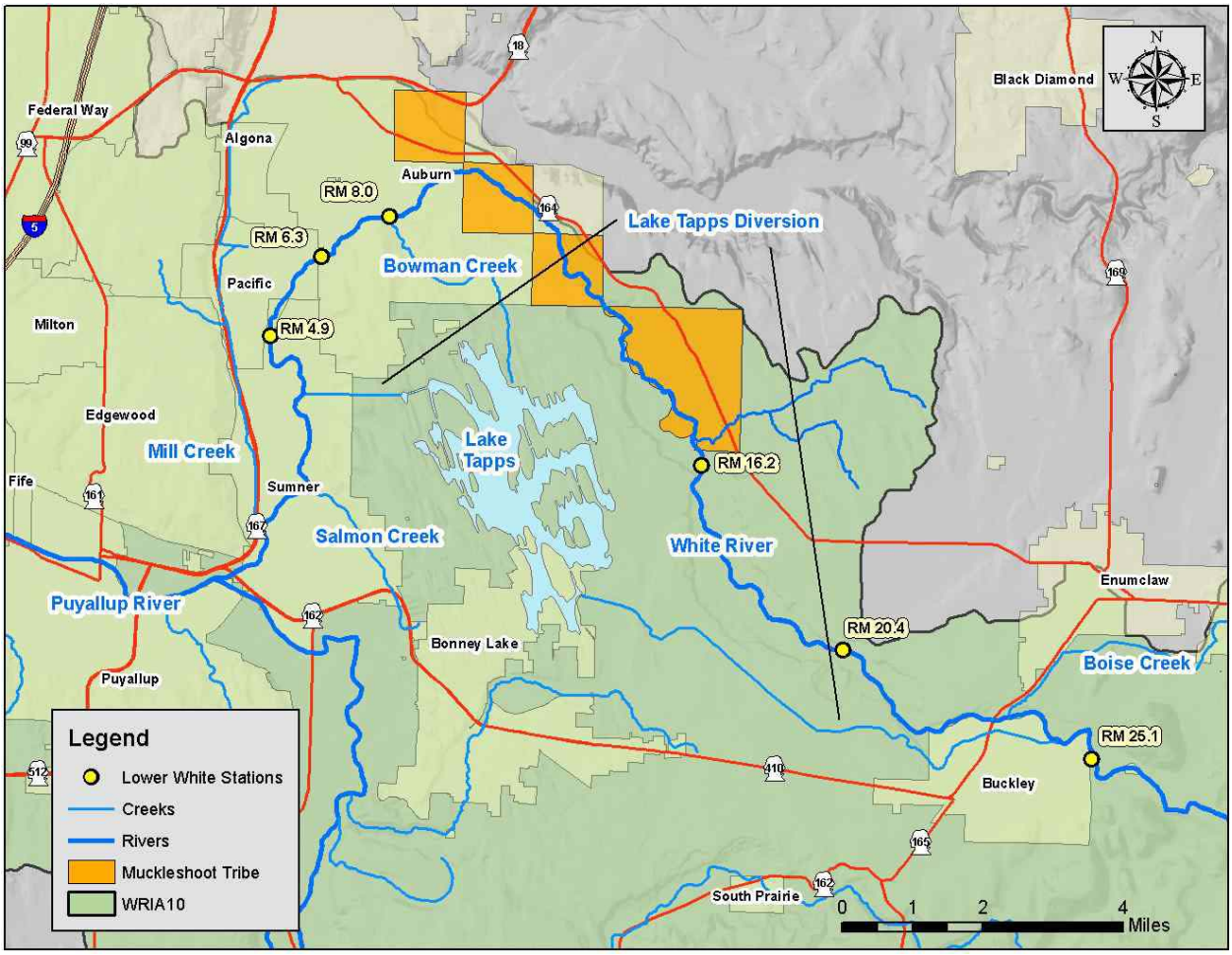

Figure 1. Map of Lower White River and sampling stations.

Sampling and measurement procedures

Field staff followed standard Ecology protocols for field measurements and sample collection, preservation, and shipping to the Manchester Environmental Laboratory (MEL) (Table 2).

Table 2. Sampling and measurement methods and protocols.

Parameter	Measurement/ Sample Type	Lab Method	Field Protocol Number
Alkalinity	Grab Sample	SM 2320	EAP015 (Joy, 2006)
Chloride	Grab Sample	EPA 300.0	EAP015 (Joy, 2006)
Chlorophyll-a – water	Grab Sample	SM 10200H(3)	EAP015 (Joy, 2006)
Chlorophyll-a – algae	Rock scrape	SM 10200H(3)	USGS – NWQAP (Moulton, 2002)
Ash-free Dry Weight	Rock scrape	SM 10300C	USGS – NWQAP (Moulton, 2002)
Dissolved Organic Carbon	Grab Sample	EPA 415.1	EAP015 (Joy, 2006)
Total Organic Carbon	Grab Sample	EPA 415.1	EAP015 (Joy, 2006)
Total Persulfate Nitrogen	Grab Sample	SM 4500-NO_3^-B	EAP015 (Joy, 2006)
Ammonia	Grab Sample	SM 4500-NH_3^-H	EAP015 (Joy, 2006)
Nitrate/Nitrite	Grab Sample	4500-NO_3^- I	EAP015 (Joy, 2006)
Orthophosphate	Grab Sample	SM 4500-P G	EAP015 (Joy, 2006)
Total Phosphorus	Grab Sample	EPA 200.8	EAP015 (Joy, 2006)
Total Suspended Solids	Grab Sample	SM 2540 D	EAP015 (Joy, 2006)
Turbidity	Grab Sample	SM 2130	EAP015 (Joy, 2006)
Dissolved Oxygen	Winkler	SM 4500 OC	EAP034 (Ward, 2007); EAP035 (Mathieu, 2006)
Temperature, pH, Dissolved Oxygen, Conductivity	Hydrolab sonde	n/a	EAP010 (Swanson, 2007)

Ecology's periphyton field sampling protocols are adapted from the revised USGS protocols (Moulton et al., 2002). Field staff collected periphyton biomass samples by scraping algal material from a measured surface area on representative rocks. Ecology collected three rocks from a transect across the river at each site and composited algae from each rock into samples for laboratory analysis of chlorophyll-a and ash-free dry weight. At all sites, a replicate sample (three additional rocks composited) was collected from a different transect and analyzed as a separate sample. Field staff selected sampling transects in areas representative of the dominant habitat type observed at each site.

Specific conductance is relatively low in the Lower White River with values typically below 100 µS/cm (Ecology, 2009). When possible, field staff deployed Hydrolab sondes with a Low-Ionic Strength Reference (LISREF) (Beckman© Red Label Lazaran™) pH reference electrode. The LISREF electrode is designed to reduce unstable potentials in the reference electrode junction caused by low-ionic strength waters. Field staff calibrated LISREF pH meters with conventional buffers and then checked probes against low-ionic strength buffers both before and after calibration.

Results

Data quality results

Overall, data collected for the project was found to be of acceptable quality and useable based on the study objectives. Some results were qualified or rejected based on failure to meet data quality objectives or other issues. A summary of data quality is provided below. More detailed data quality results are available in Appendix A.

Hydrolab deployments

Ecology evaluated the data quality of continuous Hydrolab data by collecting in-situ measurements and performing a post-deployment check using standards upon retrieval. A summary of Hydrolab data quality is included below:

- **In-situ check probe measurements**. Field staff used a calibrated Hydrolab sonde, or check probe, to collect multiple spot-check measurements at each of the six sites over the course of a deployment. For dissolved oxygen, in-situ checks were performed by collecting Winkler dissolved oxygen samples.
- **Evaluation of bias in check probe**. Ecology staff first evaluated the check probe for bias by performing a paired Wilcoxon Rank Sum test to determine if the measurements taken with the check probe were significantly higher or lower than the deployed probe measurements from each site. If a significant bias was observed, the check probe values were adjusted by the average bias; an example of this scenario is presented in Appendix A.
- **Post-deployments checks**. Upon retrieval, field staff checked each deployed probe with pH and conductivity standards and by performing the water-saturated, air-calibration method for dissolved oxygen. Some data were qualified or rejected based on comparison of post-check values to measurement quality objectives (MQOs). An example of a qualified dataset is presented in Appendix A.
- **Low-ionic strength pH reference probes**.
    - During all three deployment periods, the Hydrolab sondes with LISREF pH probes exhibited an abnormally long warm-up period. In each case, the sonde calibrated adequately for pH. After calibration, the LISREF probe was stored in pH electrolyte prior to deployment. Upon deployment, pH values started out high and then gradually dropped, regardless of the normal diurnal cycle, until finally "settling" and resuming the normal diurnal cycle observed in the deployed standard pH probes.
    - Ecology staff rejected the first 12 hours of pH data from the LISREF probes based on the abnormal settling period. The check sonde also had a LISREF probe and showed high pH values during check measurements taken earlier in each survey. Check probe pH data taken early in each survey were also rejected. Appendix A includes a detailed summary of how LISREF probe data were evaluated.
- **Continuous data bias corrections**. Once the check probe measurements had been corrected for bias and suspect data rejected, Ecology staff evaluated the continuous data for bias by

comparing it to both the check probe values measured in the field and the post-check values of the standards. If a bias was observed, the continuous values were adjusted by the average bias; an example of this scenario is presented in Appendix A.

Table 3 summarizes the data quality results by site and parameter for each of the three Hydrolab deployments.

Table 3. Data quality results summary for continuous Hydrolab deployments.

Site	Deployment (2009)	Temp	SpCond	pH	Dissolved Oxygen
10-WHT-25.1	September 14-16	A	QPC[2]	A	A
10-WHT-20.4		A	A[2]	n/a	A
10-WHT-16.2		A	A[2]	A[1]	A[3]
10-WHT-8.5		A	QPC[2]	A	A
10-WHT-6.3		A	QPC[2]	A[1]	A
10-WHT-4.9		A	QPC[2]	A	QO[4]
10-WHT-25.1	October 5-7	n/a	A	A[1]	A
10-WHT-20.4		A	A	A	QO[4]
10-WHT-16.2		A	QPC[2]	A[1]	A
10-WHT-8.5		A	A[2]	QPC	QW
10-WHT-4.9		A	A	A	QO[4]
10-WHT-25.1	October 19-21	A	QPC[2]	A	A[5]
10-WHT-20.4		A	QPC[2]	A[1]	A
10-WHT-16.2		A	A	A[1]	QW[2]
10-WHT-8.5		A	A	QPC	REJ
10-WHT-6.3		A	A[2]	QPC	A
10-WHT-4.9		A	A	A	A

[1] pH data rejected during extended low-ionic settling period (first 12 hours).
[2] Continuous data adjusted based on bias correction.
[3] Post-calibration result was in *qualify* range; upgraded data quality to acceptable based on Winkler checks.
[4] Post-calibration result was in *reject* range; upgraded data quality to estimate (qualified) based on Winkler checks.
[5] Rejected data after dissolved oxygen probe failure at 10/20/09 12:45 pm.
A = acceptable data quality.
QPC = qualified based on post calibration; QW = qualified based on Winkler checks.
QO = qualified for other reason; REJ = data rejected.

Periphyton biomass

All periphyton samples were collected in duplicate. Overall, periphyton data were deemed of acceptable quality. Associated laboratory duplicates were within MEL's MQO acceptance range. All lab blanks were below the detection limit for their associated methods with the exception of one blank for ash-free dry weight, which was less than 1% of the lowest sample concentration observed.

Duplicate periphyton result values were averaged together to provide a more spatially representative estimate of biomass density at each site.

Water quality samples

A small set of water quality data were collected at three of the six sites. All data were found to be of acceptable quality and met the study data quality objectives. MEL performed duplicate analyses, analytical spikes, and blanks according to the MEL Quality Assurance Manual (MEL, 2006). All lab blanks were below the detection limits for their associated methods. All lab duplicates were within MEL's MQO acceptance range. Matrix spike and lab control sample recoveries were within an acceptable range.

The field replicates taken at site 10-WHT-25.1 on October 6, 2009 all met their respective precision data quality objectives (Table 6).

Study results

Hydrolab deployments

Appendix B contains plots of the corrected continuous Hydrolab deployment data for each site. Figures 2-4 compare pH levels at each site during the three deployments to the Washington State pH water quality criteria for the Lower White River.

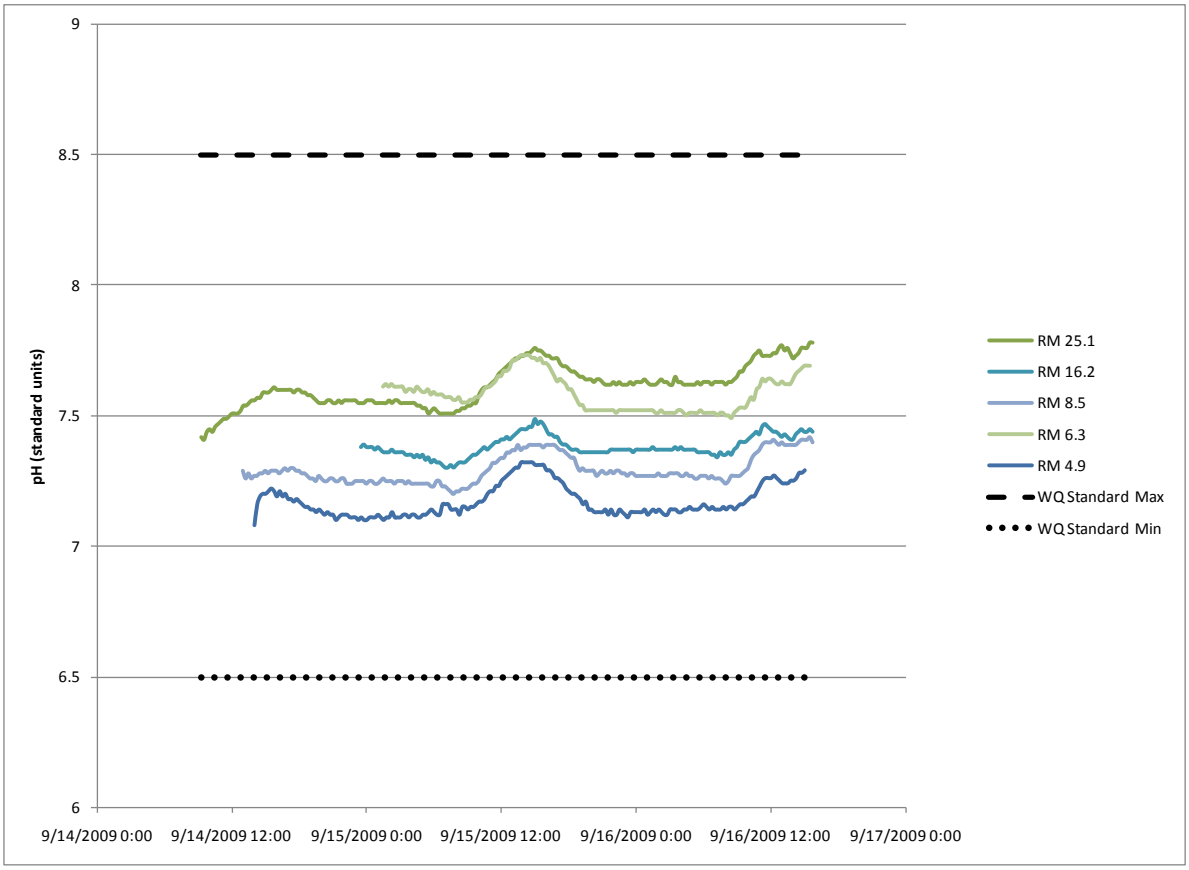

Figure 2. Continuous pH data comparison between deployment sites, September 14-16, 2009.

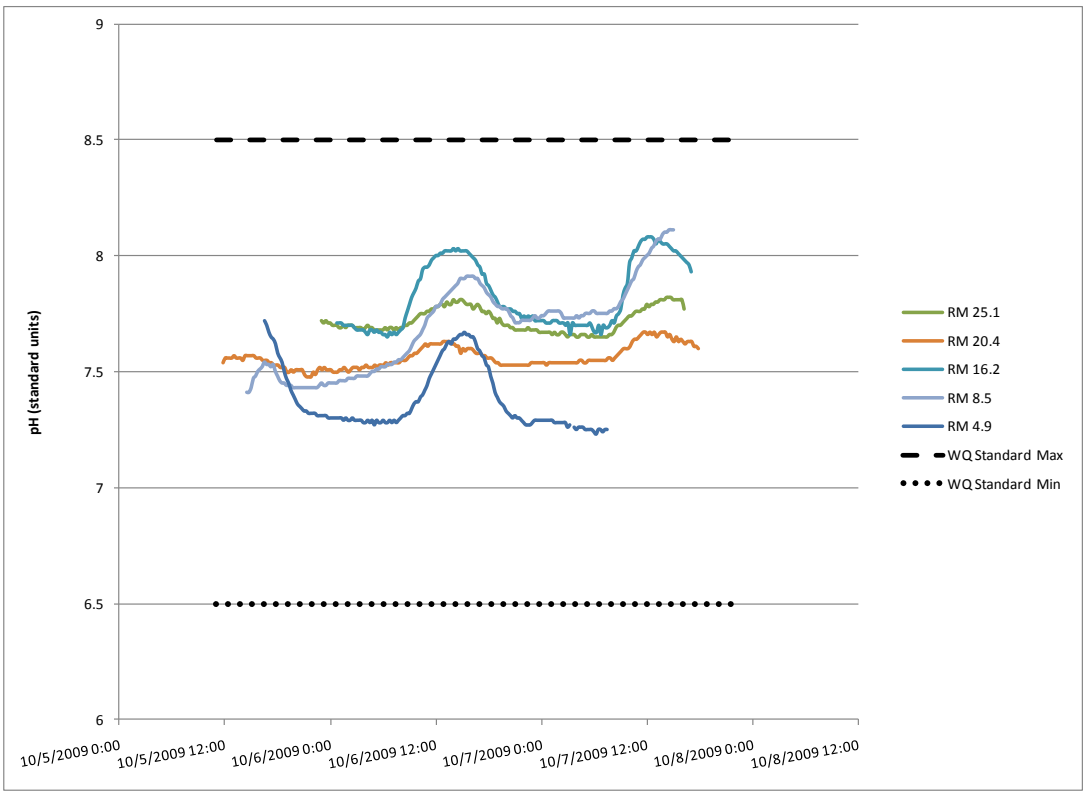

Figure 3. Continuous pH data comparison between deployment sites, October 5-7, 2009.

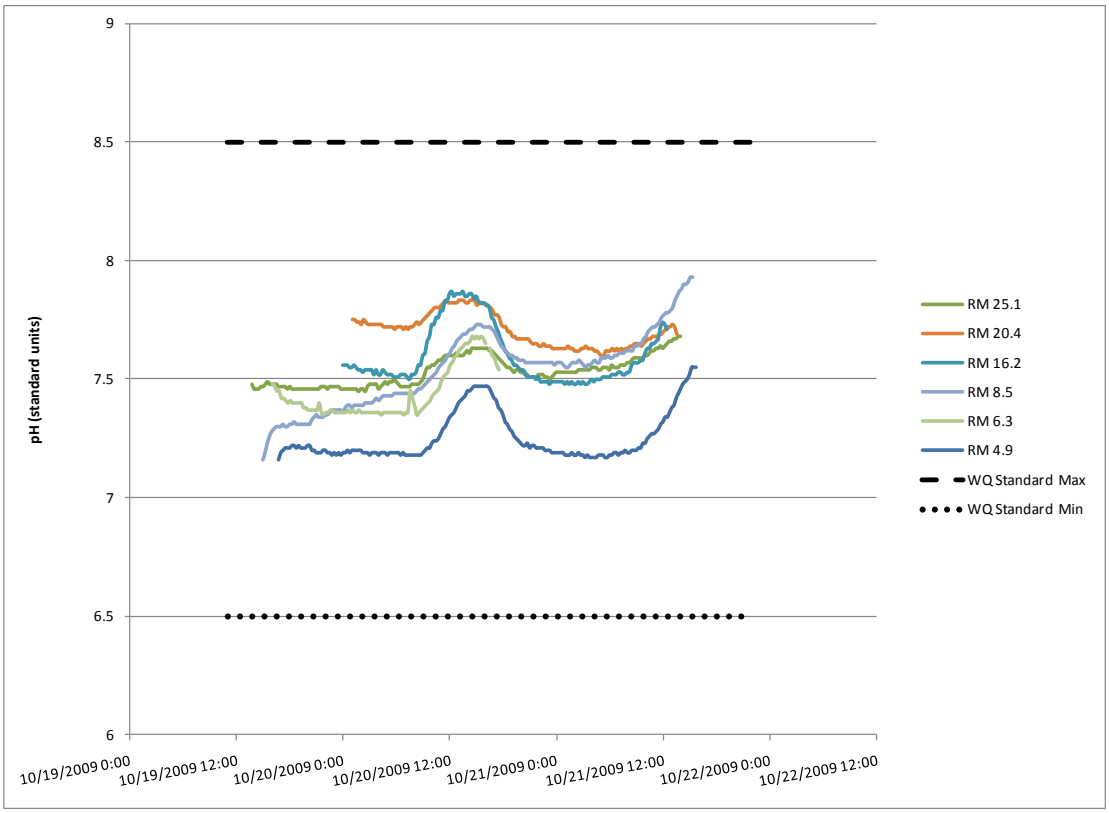

Figure 4. Continuous pH data comparison between deployment sites, October 19-21, 2009.

Streamflow

Streamflow data was obtained from three USGS continuous gages on the Lower White River at RM 6.3 (#12100496), RM 8.0 (#12100490), and RM 23.8 (#12097850)(USGS, 2010). Data from WY 2009 has been reviewed and approved by USGS; however, the WY 2010 data are provisional and still under review. Table 4 contains the average daily streamflow for each day of the sampling events.

Table 4. Average daily flow during Ecology sampling dates at three USGS stream gages.

Date (2009)	Flow (cfs)		
	#12100496 RM 6.3	#12100490 RM 8.0	#12097850 RM 23.8
Sept 14	631 [A]	734 [P]	660 [A]
Sept 15	606 [A]	696 [P]	613 [A]
Sept 16	572 [A]	648 [P]	594 [A]
Oct 5	386 [P]	412 [P]	NR
Oct 6	383 [P]	409 [P]	355 [P]
Oct 7	383 [P]	409 [P]	360 [P]
Oct 19	502 [P]	606 [P]	482 [P]
Oct 20	447 [P]	520 [P]	435 [P]
Oct 21	424 [P]	483 [P]	428 [P]

[A] Approved data.
[P] Provisional data.
NR= Not Reported

Figure 5 depicts the average daily streamflow at RM 6.3 from August 2009 to January 2010. Figure 6 depicts the average daily streamflow at RM 6.3 from September 8 to October 28, 2009. Figures 5 and 6 also highlight flows during the sampling dates in September and October.

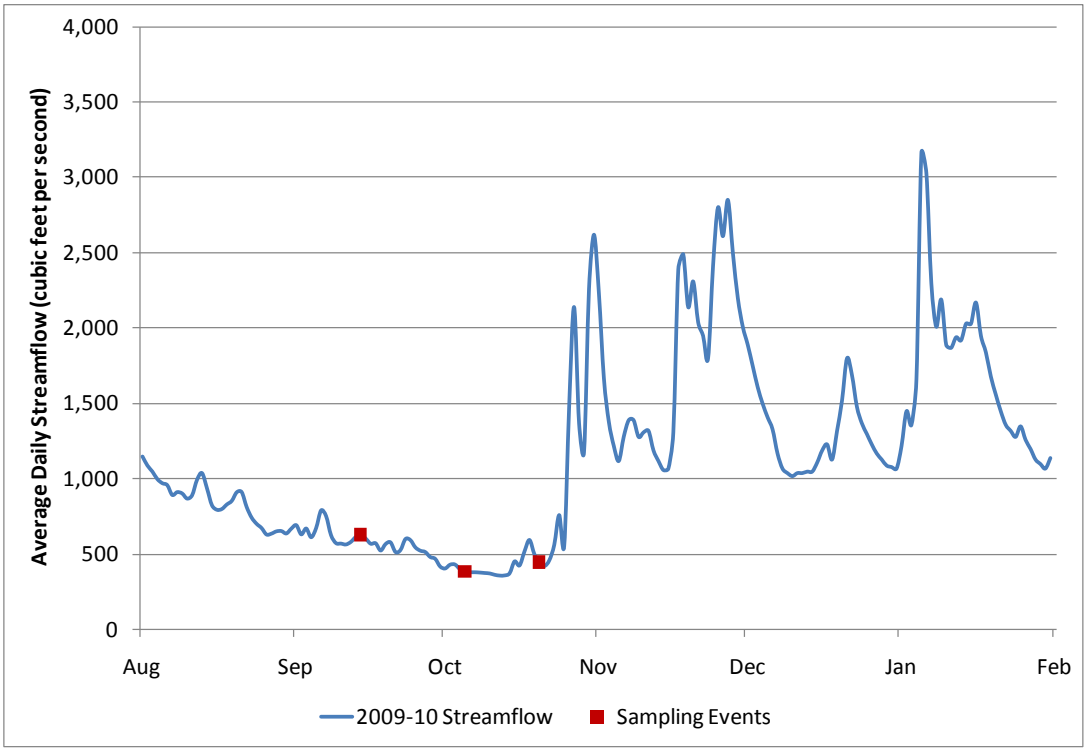

Figure 5. Average daily flow at USGS gage #12100496 (RM 6.3), August 1, 2009 to January 31, 2010.

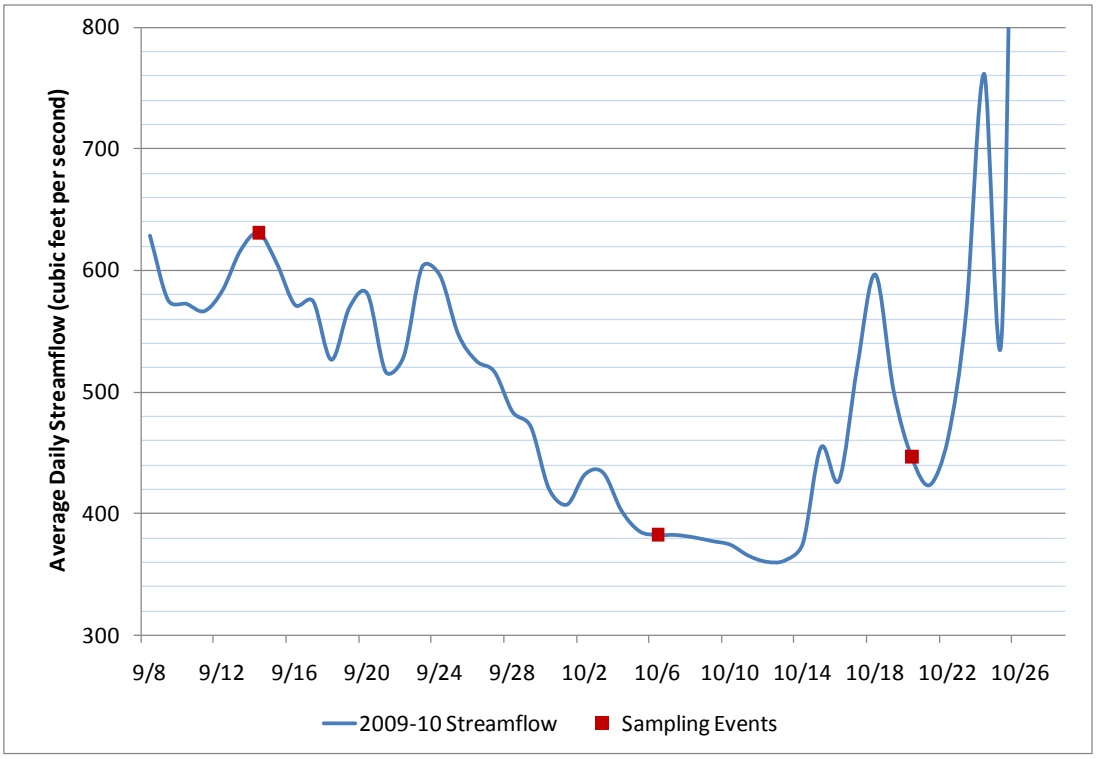

Figure 6. Average daily flow at USGS gage #12100496 (RM 6.3), September 8 to October 28, 2009.

Periphyton biomass

Table 5 contains periphyton biomass density results from the 2009 study. Ecology measured the mass of chlorophyll-a and the ash-free dry weight (AFDW) of each periphyton sample. Chlorophyll-a and AFDW are two commonly used surrogate parameters used to estimate overall periphyton biomass. Figures 7 and 8 plot chlorophyll-a and AFDW densities in the Lower White River during the September and October 2009 sampling events.

Table 5. Periphyton biomass density for six sites on the White River, fall 2009.

Site ID	September 15		October 6		October 20		Average	
	Chlorophyll-a (mg/m^2)	AFDW (mg/m^2)	Chlorophyll-a (mg/m^2)	AFDW (mg/m^2)	Chlorophyll-a (mg/m^2)	AFDW (mg/m^2)	Chlorophyll-a (mg/m^2)	AFDW (mg/m^2)
10-WHT-25.1	44.17	9429	8.83	1605	17.80	3515	23.60	4850
10-WHT-20.4	6.13	1801	2.11	789	11.37	4112	6.54	2234
10-WHT-16.2	50.95	6620	20.38	3908	31.00	6747	34.11	5758
10-WHT-8.5	25.15	4169	18.50	3456	46.13	7242	29.93	4956
10-WHT-6.3	53.22	6783	57.67	6164	78.84	11247	63.24	8065
10-WHT-4.9	89.65	11907	67.29	7285	89.00	6922	81.98	8704

AFDW= Ash-free dry weight (volatile organic matter).

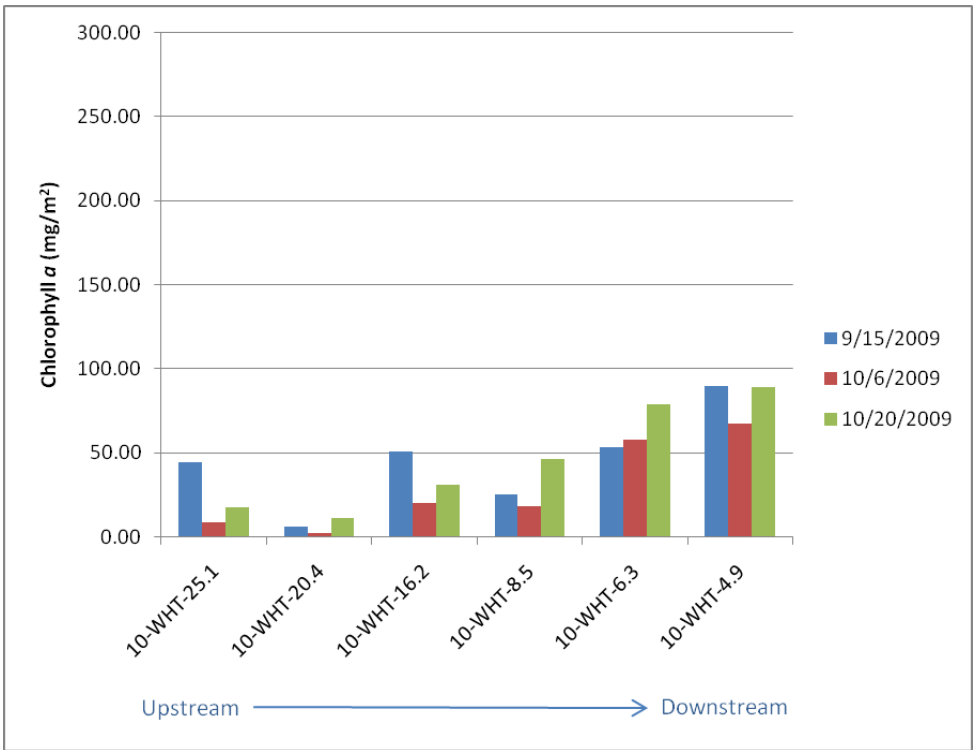

Figure 7. 2009 periphyton biomass densities (chlorophyll-a mass per area) on the Lower White River.

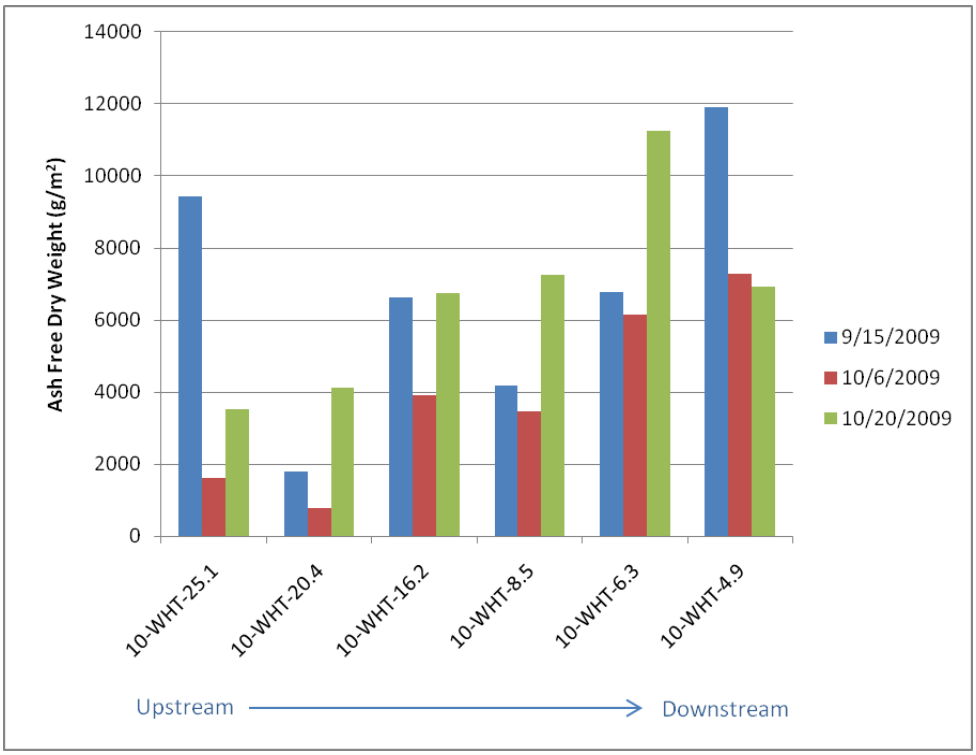

Figure 8. 2009 periphyton biomass densities (ash-free dry-weight mass per area) on the Lower White River.

Water quality samples

Table 6 contains water quality sampling results. Table 7 contains parameter names and methods for Table 6.

Table 6. Water quality sampling results for three sites on the Lower White River, fall 2009.

Site Name	Date	Time	ALK (mg/L)	NH3 (mg/L)	CL (mg/L)	Chl-a (µg/L)	DOC (mg/L)	N02-N03 (mg/L)	OP (mg/L)	TOC (mg/L)	TPN (mg/L)	TP (mg/L)	TSS (mg/L)	TURB (NTU)
10-WHT-25.1	Sept 15	15:00:00	16.9	0.010	1.72	1.1	1	0.051	0.0149	1	0.054	0.1490	165	100
10-WHT-20.4		15:50:00	18.3	0.101	1.93	1.2	1	0.073	0.0275	1	0.173	0.1810	221	110
10-WHT-6.3		18:50:00	21.8	0.098	2.03	1.7	1	0.110	0.0286	1	0.217	0.1670	136	95
10-WHT-25.1	Oct 6	17:05:00	26.0	0.062	2.31	0.7	1	0.109	0.0227	1	0.202	0.0448	22	12
10-WHT-25.1[r]		17:05:00	26.0	0.061	2.30	0.7	1	0.110	0.0228	1	0.207	0.0464	26	14
10-WHT-20.4		15:15:00	28.8	0.217	2.56	1.1	1	0.146	0.0436	1	0.436	0.0840	73	14
10-WHT-6.3		18:30:00	30.9	0.239	2.59	2.1	1	0.203	0.0474	1	0.531	0.0801	43	16
10-WHT-25.1	Oct 20	12:50:00	23.6	0.039	2.30	1.7	1	0.104	0.0240	1	0.120	0.0714	48	28
10-WHT-20.4		11:28:00	25.6	0.122	2.43	2.0	1	0.141	0.0336	1	0.262	0.0961	64	30
10-WHT-6.3		15:20:00	27.1	0.156	2.49	2.4	1	0.198	0.0412	1	0.359	0.0975	43	24

= Analyte was not detected at or above the reported result (i.e., under reporting limit).

= Analyte was positively identified. The associated numerical result is an estimate.
(These TSS samples contained fast settling sand that may have interfered with the analysis).

[r] replicate samples.

Table 7. Parameter names and methods for abbreviations used in Table 6.

Abbreviation	Parameter Name	Method
ALK	Alkalinity	SM2320B
NH3	Ammonia	SM4500-NH3H
CL	Chloride	EPA300.0
Chl-a	Chlorophyll-a	SM10200H3
DOC	Dissolved Organic Carbon	SM5310B
NO2-NO3	Nitrite-Nitrate	SM4500-NO3I
OP	Orthophosphate	SM4500-PG
TOC	Total Organic Carbon	SM5310B
TPN	Total Persulfate Nitrogen	SM4500NB
TP	Total Phosphorus	SM4500PF
TSS	Total Suspended Solids	SM2540D
TURB	Turbidity	SM2130

Discussion

Streamflow conditions

As noted previously, diversions at RM 24 for power generation ceased in January 2004. Much smaller diversions will continue in the future under an agreement with Cascade Water Alliance (CWA, 2010). However, critical low flows that might be expected in the by-pass reach during the fall in future years will likely be similar to critical low flows that have been historically observed above the diversion at RM 24. The historic data collected from USGS gage 120985000 located at RM 27.5 may provide reasonable estimates for the critical flows that can be expected in the by-pass reach of the White River in future years.

Comparison of streamflows observed during the 2009 data collection with historical statistics for flows measured at USGS gage 12098500 are included in Figures 9-10. The flows at this location represent the maximum flows that would be available to dilute nutrient loads from the Enumclaw and Buckley WWTPs if no diversions were allowed. The flow statistics shown in Figures 9-10 are based on data collected between 1928 and 2003. Measurements at this gage were discontinued on September 30, 2003.

Flows at RM 6.3 during the September 15-20, 2009 sampling events were near the 50th percentile and between the 25th and 50th percentile compared to historical flows at RM 27.5. Flows at RM 6.3 during the October 6, 2009 sampling event were near the 10th percentile of historical flows at RM 27.5 and likely representative of early October historical low-flow conditions upstream of the diversion. The average daily flow between September 15 and October 20 was 473 cfs. This is approximately 60% (173 cfs) above the 300 cfs critical flow (calculated from data at RM 27.5) used in the draft TMDL analysis.

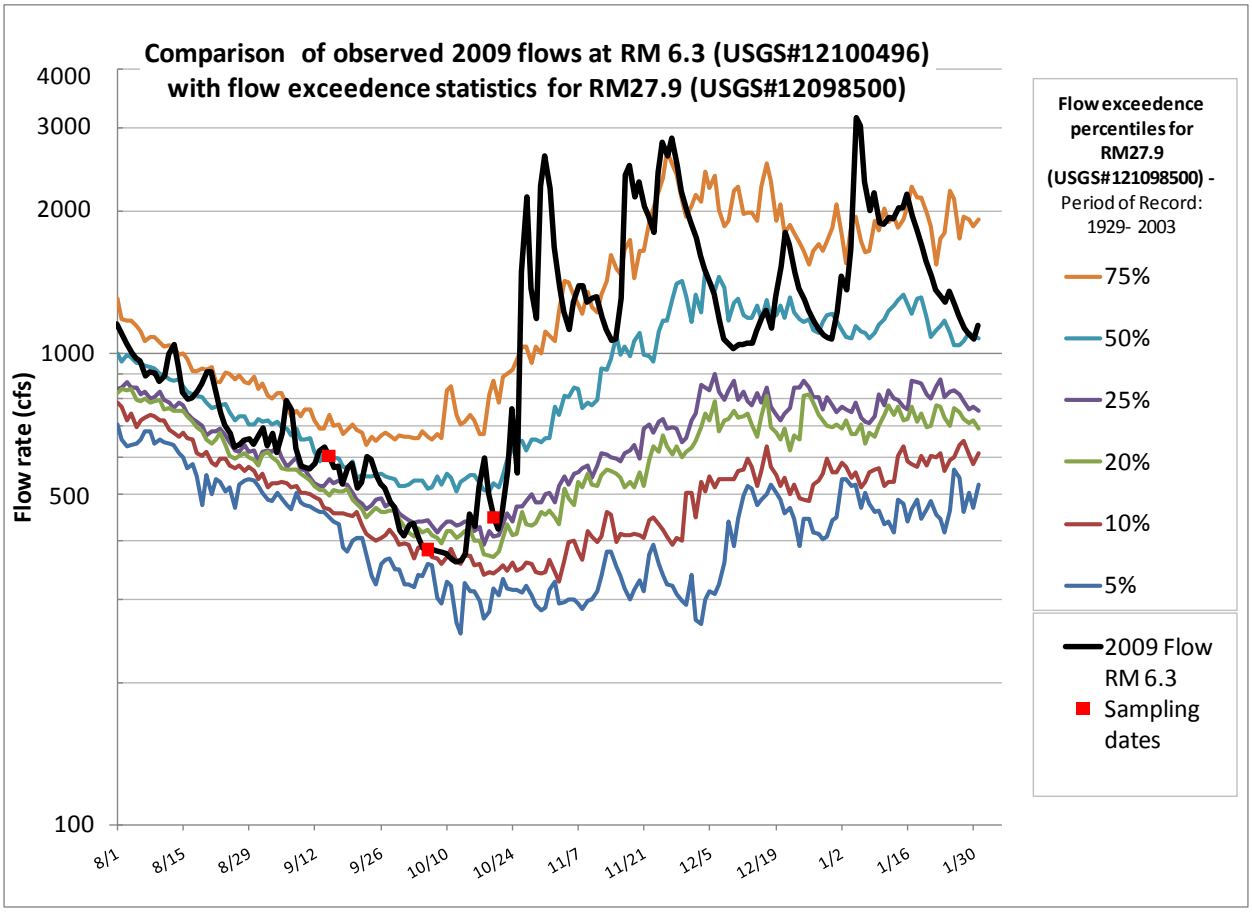

Figure 9. Comparison of streamflow at RM 6.3 on the Lower White River between August 2009 and January 2010 with exceedance statistics calculated from data collected at RM 27.5 (USGS gage 12098500).

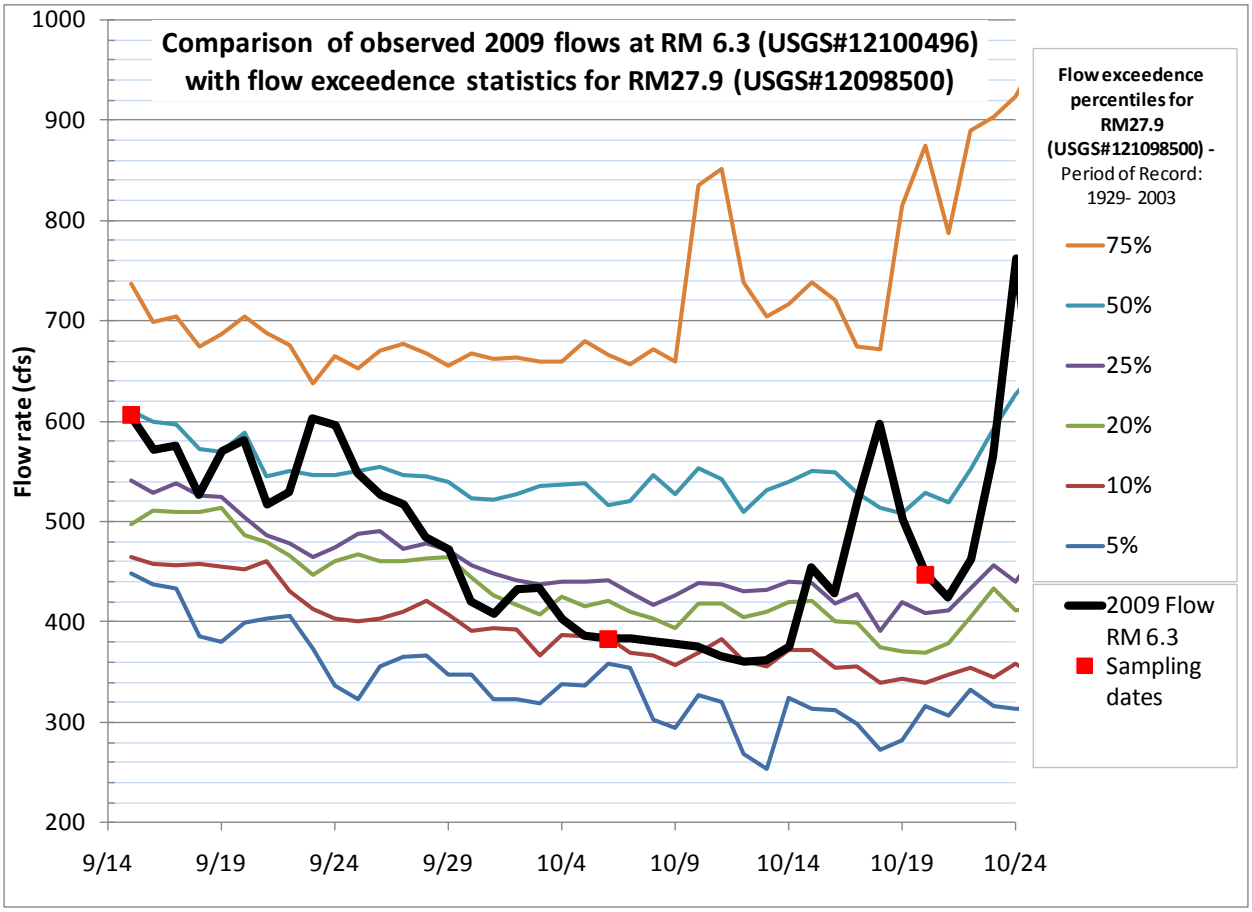

Figure 10. Comparison of streamflow at RM 6.3 on the Lower White River between September 14 to October 24, 2009 to exceedance statistics calculated from data collected at RM 27.5 (USGS gage 12098500).

Continuous pH measurements

Observed pH measurements during the three 48 deployments conducted in September and October 2009 met (did not exceed) the state water quality standards. Due to high flow conditions, continuous pH data collection ceased after the October 19-21 deployment. The highest observed pH values and lowest streamflows of the three 48-hour deployments occurred on October 5-7. This may or may not represent the most critical period for pH during 2009. Flows continued to drop gradually during the following week; however, without additional data it is impossible to know whether pH values met or exceeded state standards during that or any other unmonitored period during 2009. Due to high flows from November through January, monitoring events were not conducted during later months; in years with critical low-flow conditions, algal biomass continues to grow during these later months.

Table 8 summarizes peak pH values during the September and October monitoring events. These peaks ranged from 7.78 to 8.11 across all sites.

Table 8. Peak pH observations and diurnal swing at peak pH during the 2009 study.

Date	Peak pH (s.u.)	Diurnal swing at peak pH (s.u.)	Location of peak pH
September 16	7.78	0.15	RM 25.2
October 7	8.11	0.40	RM 8.5
October 21	7.93	0.38	RM 8.5

Limitations in comparability to previous studies

A data comparison of the 2000-01 data collection effort (Stuart, 2002) and the 2009 data collection effort was outside the scope of this study. However, the differences in flow conditions and study methods are briefly summarized below to provide context for future comparisons of the two studies.

Flow regimes

Comparison of streamflows during the 2000-01 data collection (Stuart, 2002) and the 2009 data collection illustrates the large difference between the two studies in the flow conditions at RM 6.3 below the diversion (Figure 11). Baseflow in 2009 occurred during October only and was approximately 200 cfs greater than baseflow in 2000-2001, which began in October 2000 and continued through January 2001.

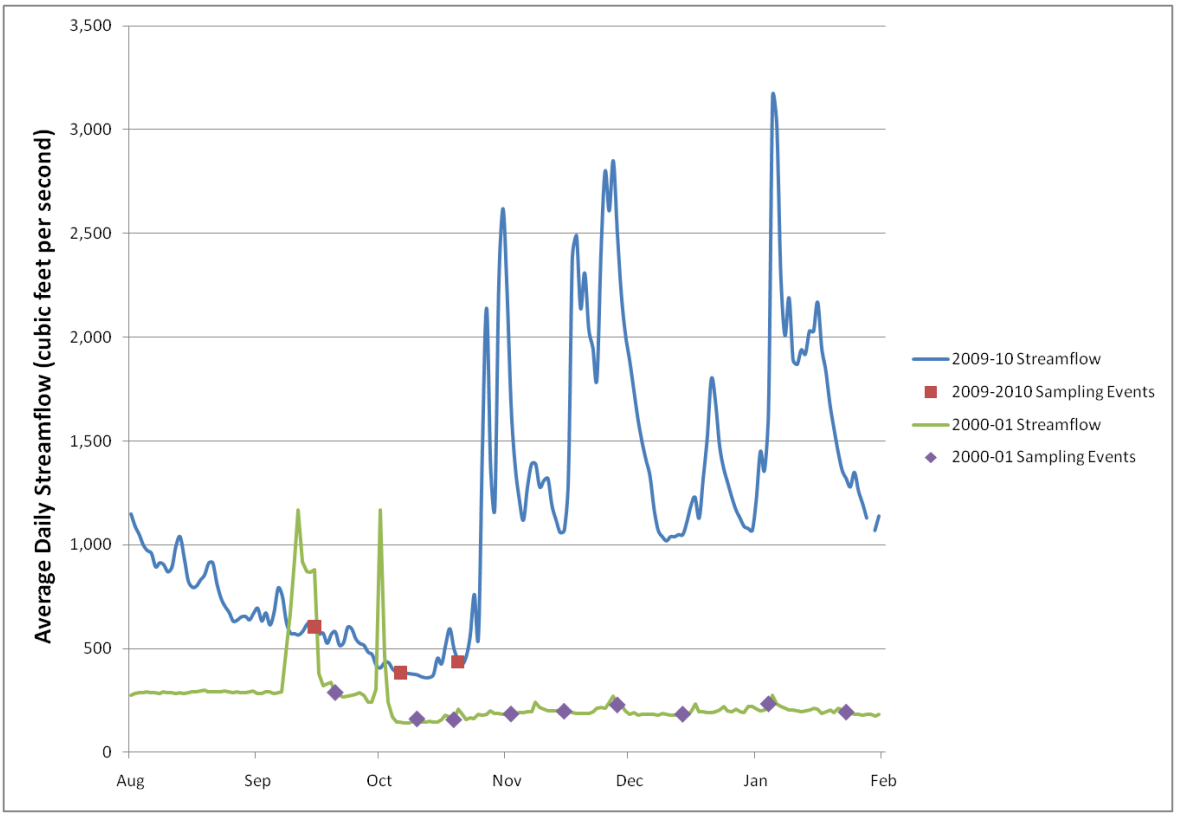

Figure 11. Comparison of streamflow at RM 6.3 on the Lower White River between August 2009 to January 2010 and August 2000 to January 2001.

Periphyton methods

Several differences exist between the periphyton sample collection methods used in the Stuart study and Ecology 2009 study:

- The Stuart study collected (Stuart, 2002):
  - Three rocks from within a one-meter circular ring at three locations for each site for a total of nine rocks scraped from each site.
  - Rocks from within the same habitat unit (e.g., riffle) at a site.
  - Rocks from depths of 0.2 to 0.6 meters (≈ 0.65 to 2 feet).
  - Rock surface area measurements by:
    - Measuring the three dimensions of the rock.
    - Calculating the surface area of the stone as a three-dimensional ellipsoid using a numerical integration algorithm available in the Maple 6 mathematics package. Half of the total surface area was assumed to be covered by periphyton.

- The Ecology 2009 study collected:
  - Three rocks from a transect across the stream at two transects for each site for a total of six rocks scraped from each site.
  - Rocks from either riffle or run habitat, or both, at a given site depending on the site and the location along the transect.
  - Rocks from depths ranging from 0.2 to 2 feet (≈ 0.05 to 0.6 meters).
  - Rock surface area measurements by:
    - Wrapping the exposed surface area of the rock (i.e., the portion of the rock not embedded in bottom sediments) in aluminum foil.
    - Flattening the piece of foil using relief cuts.
    - Scanning an image of the foil and calculating the surface area using image processing software.

Water quality analytical methods

Table 9 provides a comparison of analytical methods used in the two studies.

Table 9. Comparison of parameters and methods used for the Ecology 2009 study and the Stuart 2000-2001 study.

Parameter	Ecology Study Analytical Method	Parameter	Stuart Study Analytical Method
Alkalinity	SM2320B	Alkalinity	SM2320B
Ammonia	SM4500NH3H	Ammonium	SM4500NH_3F[1]
Ash-free Dry Weight	SM10300C	Ash-free Dry Weight	SM10300C.5
Chloride	EPA300.0	Not sampled	n/a
Chlorophyll-a	SM10200H3	Chlorophyll-a	SM10300C.6
Dissolved Organic Carbon	SM5310B	Not sampled	n/a
Nitrite-Nitrate	SM4500NO3I	Nitrate	SM4500NO_3F
Orthophosphate/SRP	SM4500PG	Orthophosphate/SRP	SM4500PE[1]
Total Organic Carbon	SM5310B	Not sampled	n/a
Total Persulfate Nitrogen	SM4500NB	Not sampled	n/a
Total Phosphorus	SM4500PF	Total Phosphorus	SM4500PE/4500PB[1]
Total Suspended Solids	SM2540D	Total Suspended Solids	SM2540D
Turbidity	SM2130	Not sampled	n/a

[1] Performed following the protocols developed by the Lake Tahoe research group of the University of California-Davis (Hunter et al., 1993). These protocols are slight modifications of Standard Methods (APHA, 2005) designed for very low nutrient concentrations.

Pink salmon run of 2009

The year 2009 had the largest pink salmon run on record for the Puyallup River, with over 540,000 pink salmon counted at Mud Mountain Dam (USACE, 2010). In total, more than 550,000 salmon were counted during the 2009 run. Over 99% of the salmon were counted between August and October 2009.

During the two previous odd-year pink salmon runs, the pink counts were less than 10% (2005) and 25% (2007) of the 2009 count. During the 2000-01 Stuart study, an even non-pink year, the fish count was just under 25,000 total salmon.

During the 2009 data collection, Ecology field staff observed vast numbers of dying and dead salmon in the Lower White River at all sites. An estimate of nutrient loading from salmon carcasses was not feasible; however, the decomposition of such a large number of salmon may have increased nutrient loads significantly during the 2009 study period.

Conclusions and Recommendations

Conclusions

The results of this data summary report support the following conclusions:

- pH levels met Washington State water quality standards during three 48-hour continuous monitoring deployments conducted by Ecology in September and October of 2009.
- Streamflow in the White River during the Ecology study was fairly representative of average streamflow conditions based on historical data above the diversion canal.
- A comparison of the datasets collected for the 2000-01 Stuart study and the 2009 Ecology study is complicated by differences in flow conditions, study methods, and salmon counts.
- Nutrient water concentrations, pH levels, and periphyton biomass may have been impacted by the large run of pink salmon that occurred during the 2009 study.

Recommendations

Additional monitoring is recommended during a dry low-flow year in the current flow regime. The monitoring should include the following:

- Measuring periphyton biomass, continuous pH, and nutrient water quality concentrations at a minimum of three sites: 10-WHT-25.1, 10-WHT-20.4, and 10-WHT-6.3.
- Additional monitoring of nutrient water quality parameters at the Buckley and Enumclaw Waste Water Treatment Plants during data collection.
- Flow permitting, extending the monitoring period into November to January.
- Collecting data during an even-year (non-pink) salmon run.

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Appendices

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Appendix A. Detailed Data Quality Results

Check probe bias corrections

Tables 10 and 11 depict an example of a check probe bias correction for temperature and the associated statistical test result.

Table 10. Example of check probe bias correction for temperature, September 14-17, 2009.

Site	Date	Time	Temp Deployed	Temp Check Probe	Difference	Temp Check Probe Corrected
10-WHT-25.1	Sept 14	9:15:00	14.03	13.8	-0.23	13.93
10-WHT-20.4		10:00:00	14.7	14.57	-0.13	14.70
10-WHT-16.2		11:30:00	15.37	15.27	-0.1	15.40
10-WHT-8.5		13:00:00	15.89	15.79	-0.1	15.92
10-WHT-6.3		13:30:00	16.13	15.98	-0.15	16.11
10-WHT-4.9		14:00:00	16.36	16.09	-0.27	16.22
10-WHT-25.1	Sept 15	9:45:00	12.58	12.36	-0.22	12.49
10-WHT-20.4		11:45:00	13.84	13.69	-0.15	13.82
10-WHT-16.2		14:00:00	15.55	15.46	-0.09	15.59
10-WHT-8.5		17:45:00	17.07	17	-0.07	17.13
10-WHT-6.3		18:45:00	17.12	17.11	-0.01	17.24
10-WHT-4.9		19:30:00	17.11	16.95	-0.16	17.08
10-WHT-4.9	Sept 16	15:00:00	15.64	15.51	-0.13	15.64
10-WHT-6.3		15:30:00	15.82	15.74	-0.08	15.87
10-WHT-8.5		16:00:00	15.71	15.62	-0.09	15.75
10-WHT-20.4		17:30:00	14.23	14.14	-0.09	14.27
10-WHT-16.2		18:00:00	14.55	14.47	-0.08	14.60
10-WHT-25.1	Sept 17	9:52:00	12.45	12.22	-0.23	12.35
				Average =	-0.13	

Table 11. Results of Wilcoxon Signed Rank Test for example in Table 1.

		N	Mean Rank	Sum of Ranks
Negative Ranks	a	18	9.5	171
Positive Ranks	b	0	0	0
Ties	c	0		
a =	Temp Check Probe < Temp Deployed			
b =	Temp Check Probe > Temp Deployed			
c =	Temp Check Probe = Temp Deployed			
Test Statistics				
	Values			
Z =	-3.728			
2-tailed p value[1] =	0.000			

Hydrolab post-deployment checks

Table 12. Example of post-deployment check results for specific conductance probes, September 14-16, 2009.

Site	Reference standard value	Hydrolab post-check value	Difference	Reference standard value	Hydrolab post-check value	Difference	Conclusion
10-WHT-20.4	0	0	0.00	100	95.6	-4.60%	Accept
10-WHT-25.1	0	1.3	-1.30	100	108.6	7.92%	***Qualify***
10-WHT-4.9	0	0.7	-0.70	100	111.8	10.55%	***Qualify***
10-WHT-16.2	0	0	0.00	100	97.7	-2.35%	Accept
10-WHT-6.3	0	0	0.00	100	92.6	-7.99%	***Qualify***
10-WHT-8.5	0	0	0.00	100	110.1	9.17%	***Qualify***

pH data from low-Ionic strength reference probes

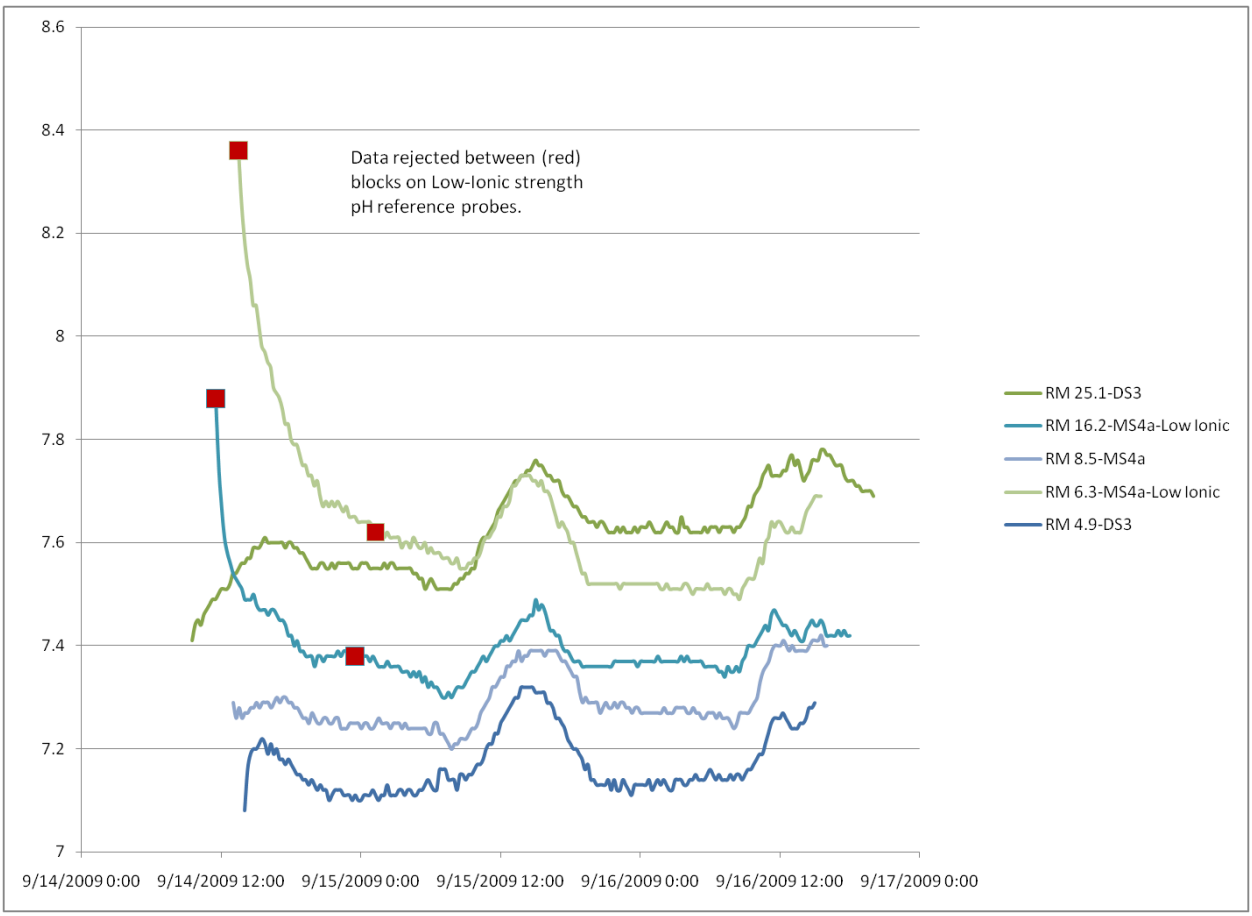

Figure 12. Rejected continuous pH data on Low-Ionic Strength Reference (LISREF) probes, September 14-16, 2009.

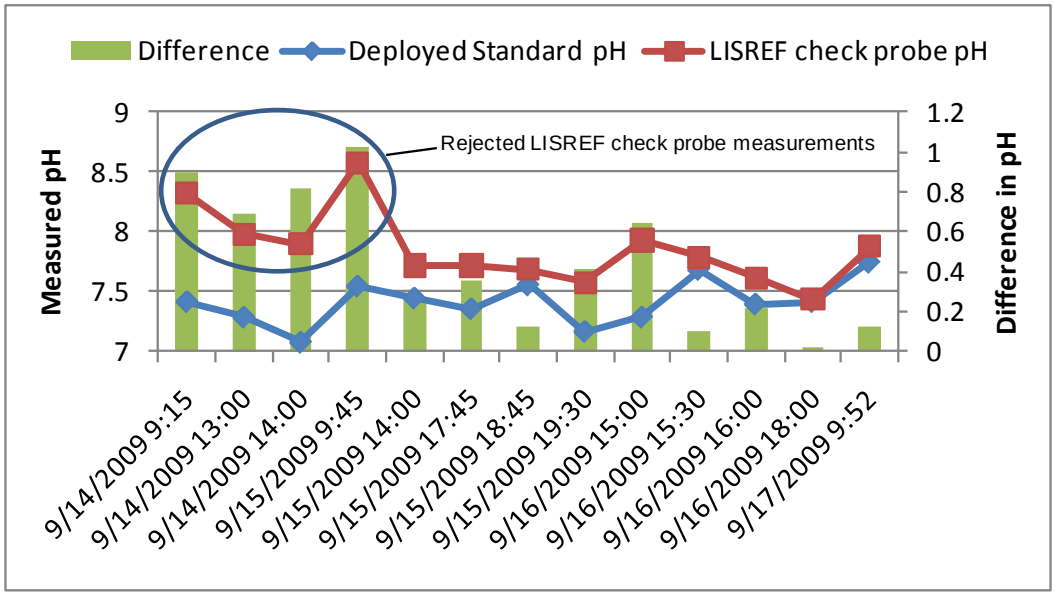

Figure 13. Rejected check probe pH measurements taken with Low-Ionic Strength Reference (LISREF) probe, September 14-16, 2009.

Continuous data bias corrections

Table 13. Continuous specific conductance data correction, September 14-16, 2009 (site 10-WHT-8.5).

Site	Date and Time	SpCond Deployed	SpCond Check Probe (or standard)	Difference	Percent Difference	SpCond Deployed Corrected	Percent Difference Corrected
10-WHT-8.5	Sept 14 13:00	72.5	68.1	-4.4	6.07%	67.4	1.00%
10-WHT-8.5	Sept 15 17:45	71.2	67.2	-4.0	5.62%	66.2	1.49%
10-WHT-8.5	Sept 16 16:00	76.9	71.4	-5.5	7.15%	71.5	0.16%
Post-Cal	Sept 17	110.1	100	-10.1	9.17%		
			Average =	-6.0	7.00%		0.88%
Rating for accuracy of data correction =				Good			

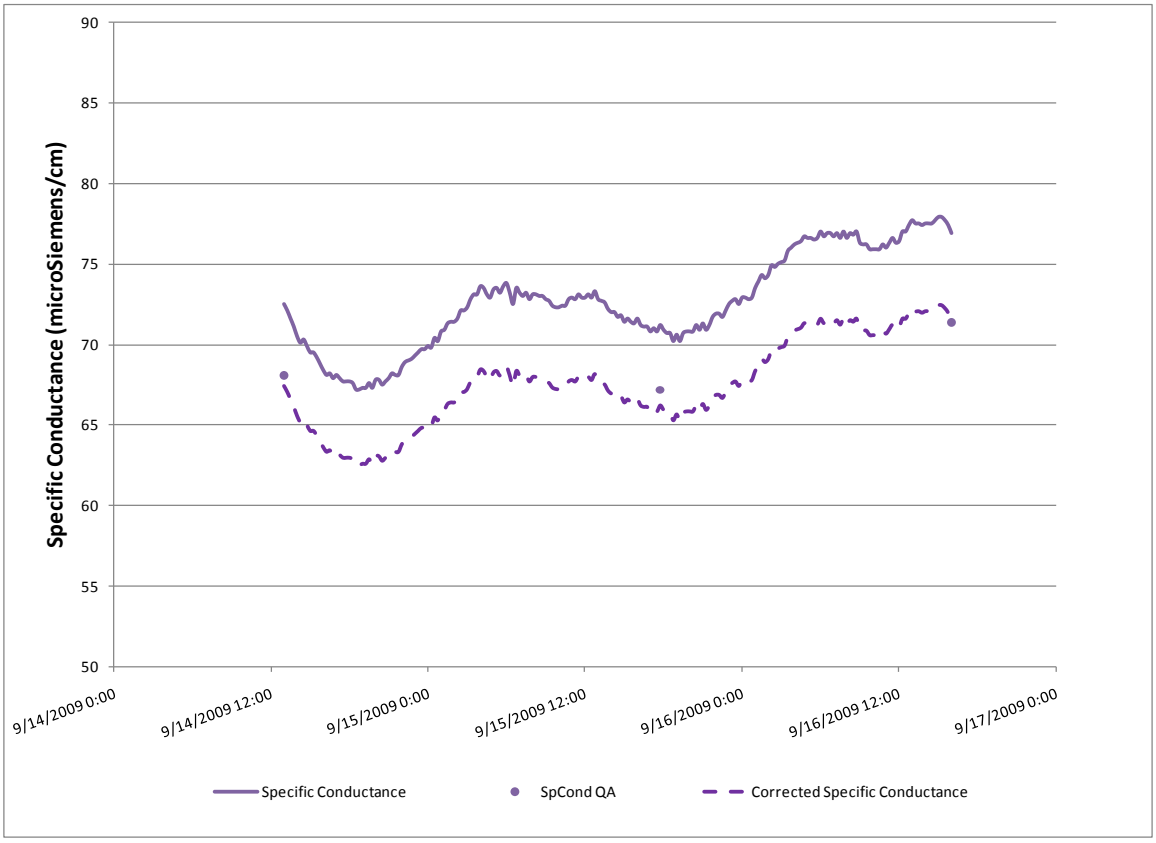

Figure 14. Plot of specific conductance data correction, September 14-16, 2009 (site 10-WHT-8.5).

Appendix B. Hydrolab Deployment Results

Figures 16 through 31 contain plots of continuous pH, temperature, dissolved oxygen, and conductivity data for the Lower White River. Data were collected during three 48-hour deployments in September and October 2009.

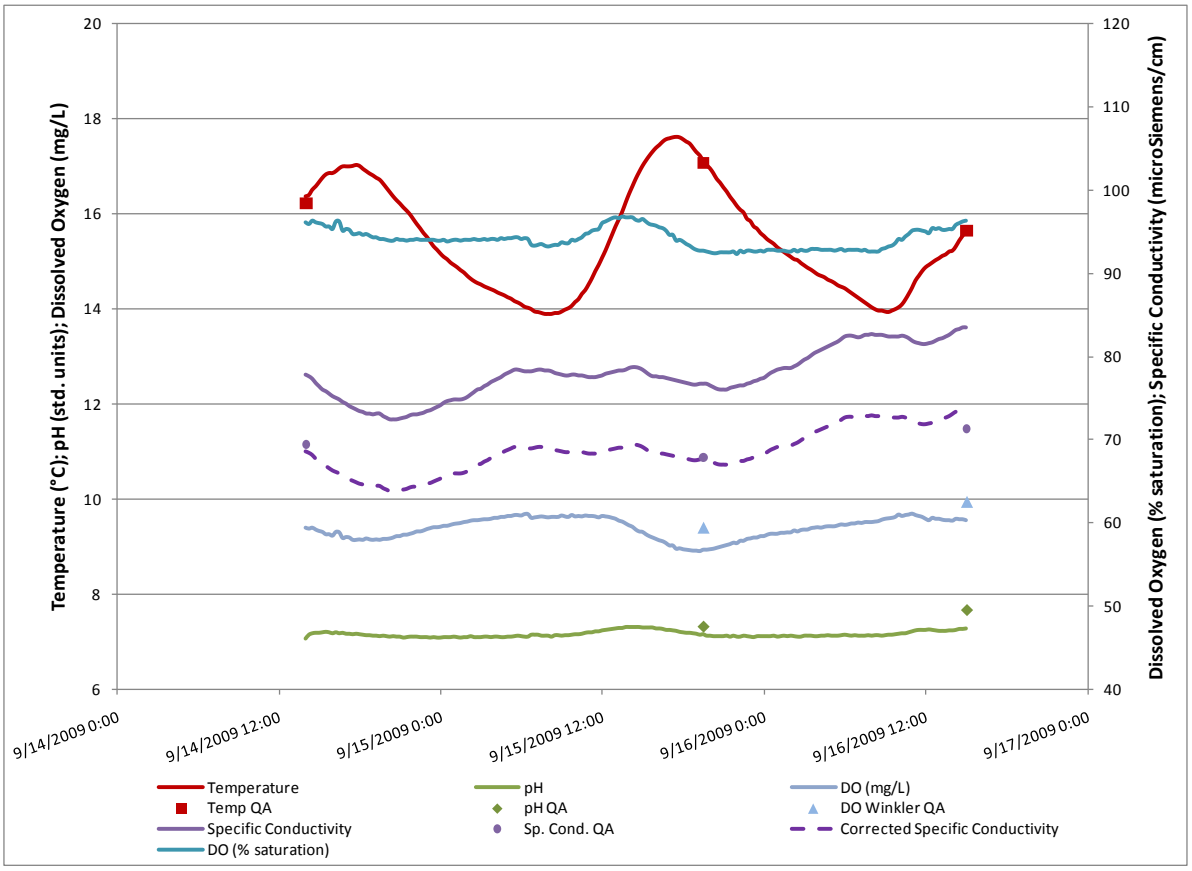

Figure 15. Continuous data for the Lower White River at RM 4.9, September 14-16, 2009.

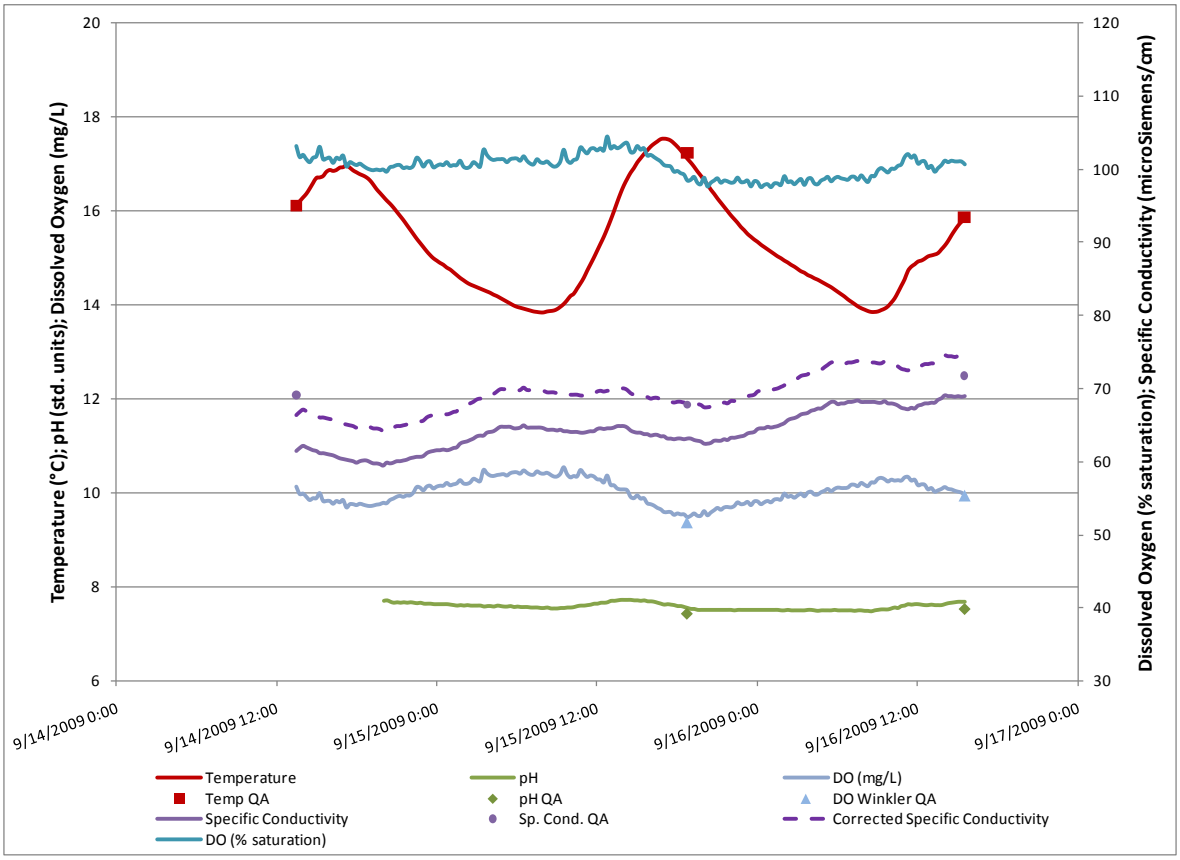

Figure 16. Continuous data for the Lower White River at RM 6.3, September 14-16, 2009.

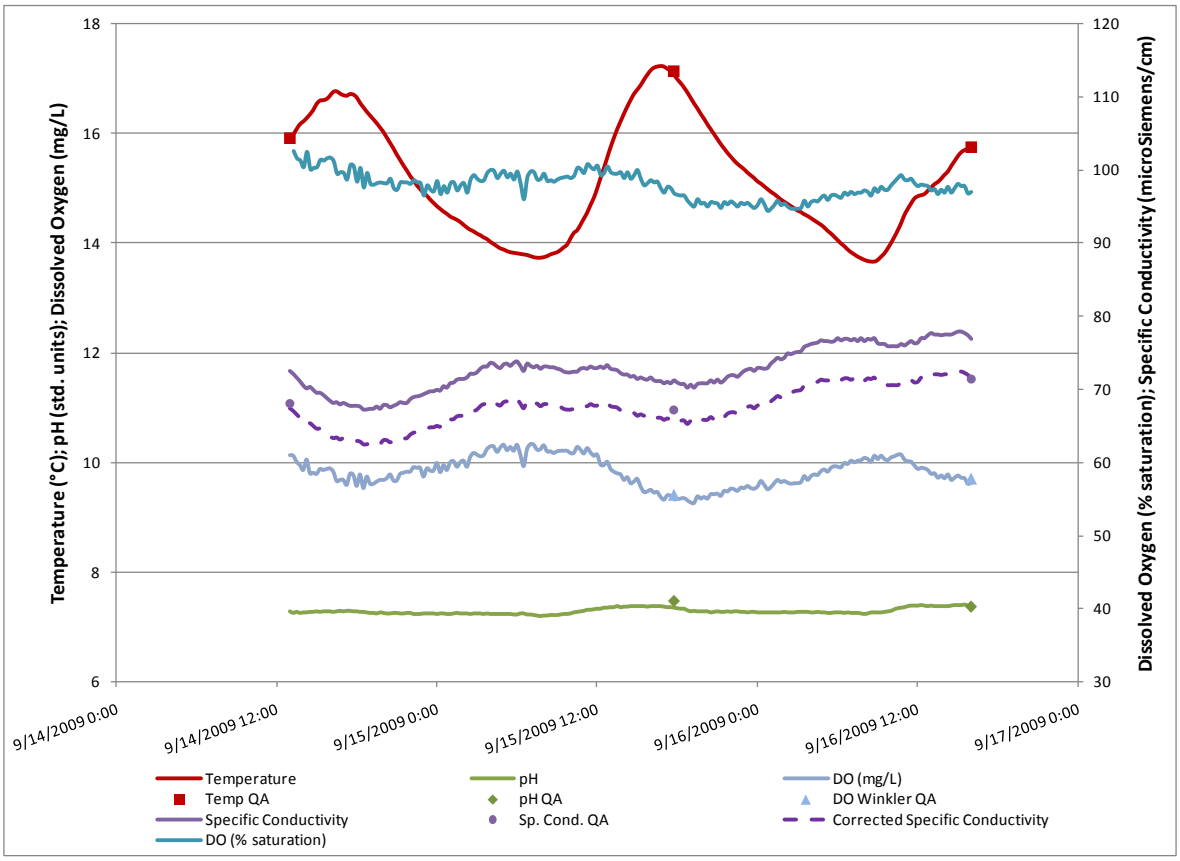

Figure 17. Continuous data for the Lower White River at RM 8.5, September 14-16, 2009.

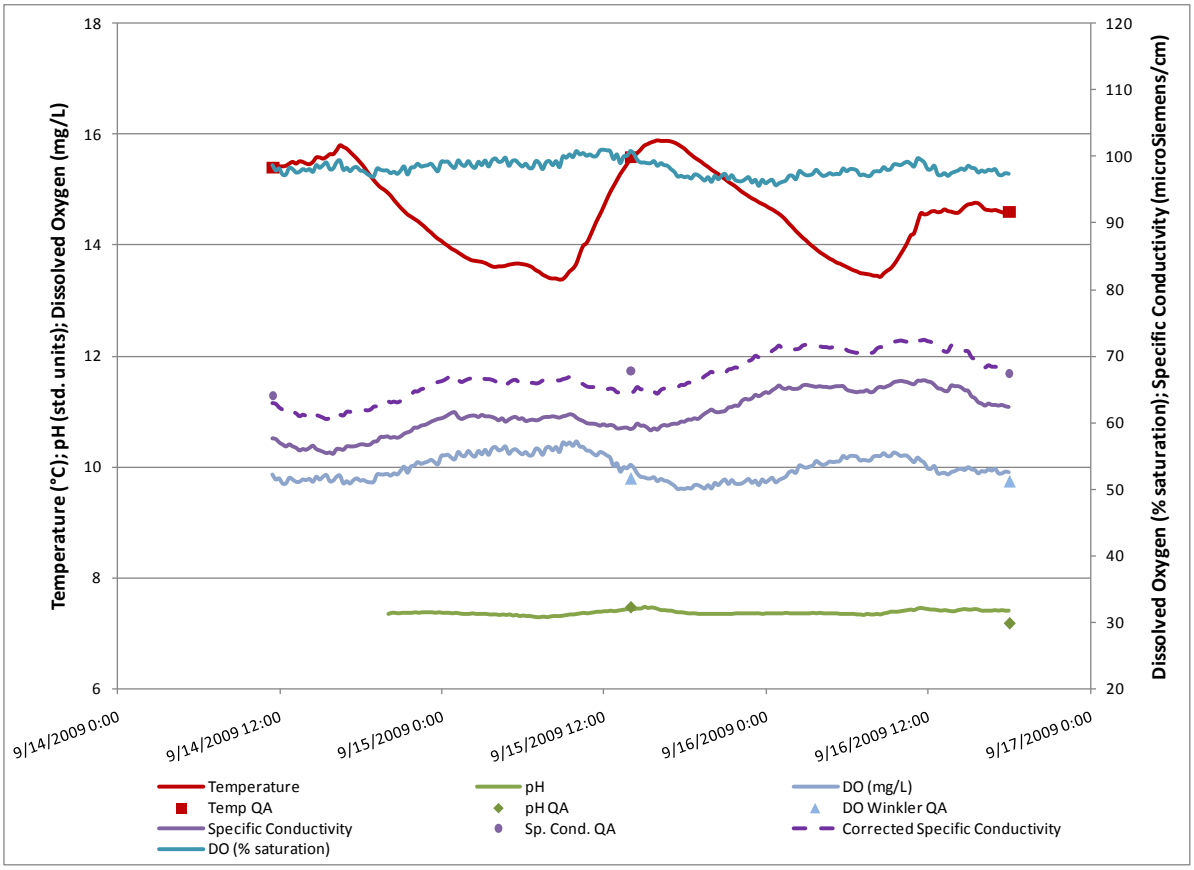

Figure 18. Continuous data for the Lower White River at RM 16.2, September 14-16, 2009.

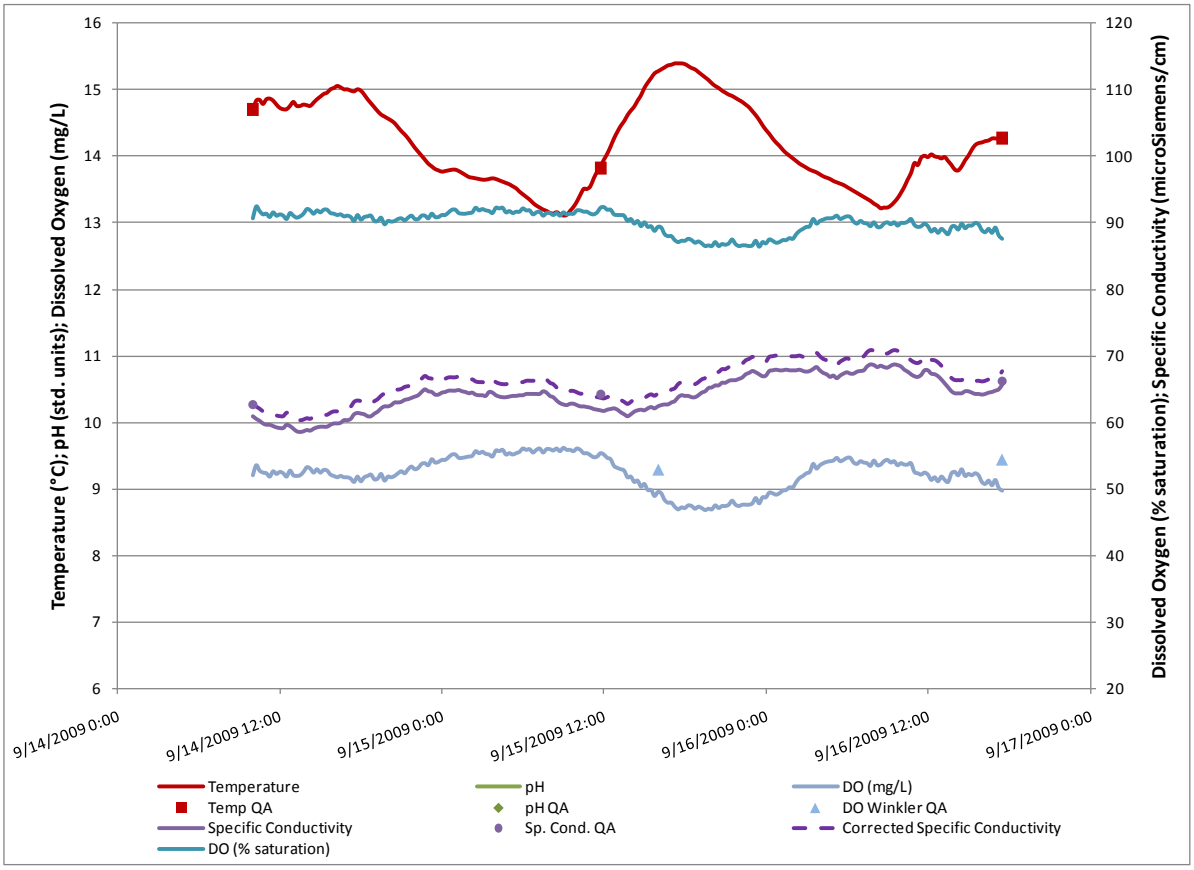

Figure 19. Continuous data for the Lower White River at RM 20.4, September 14-16, 2009.

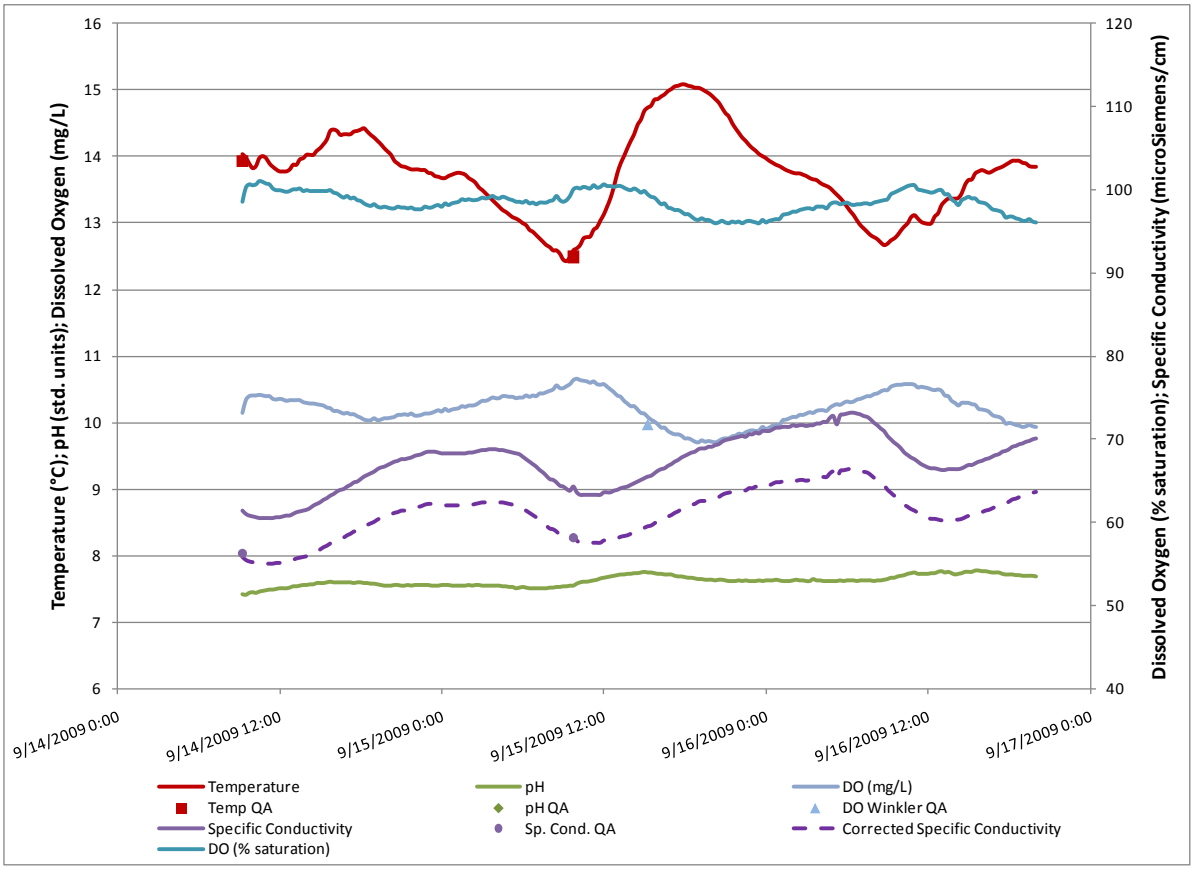

Figure 20. Continuous data for the Lower White River at RM 25.1, September 14-16, 2009.

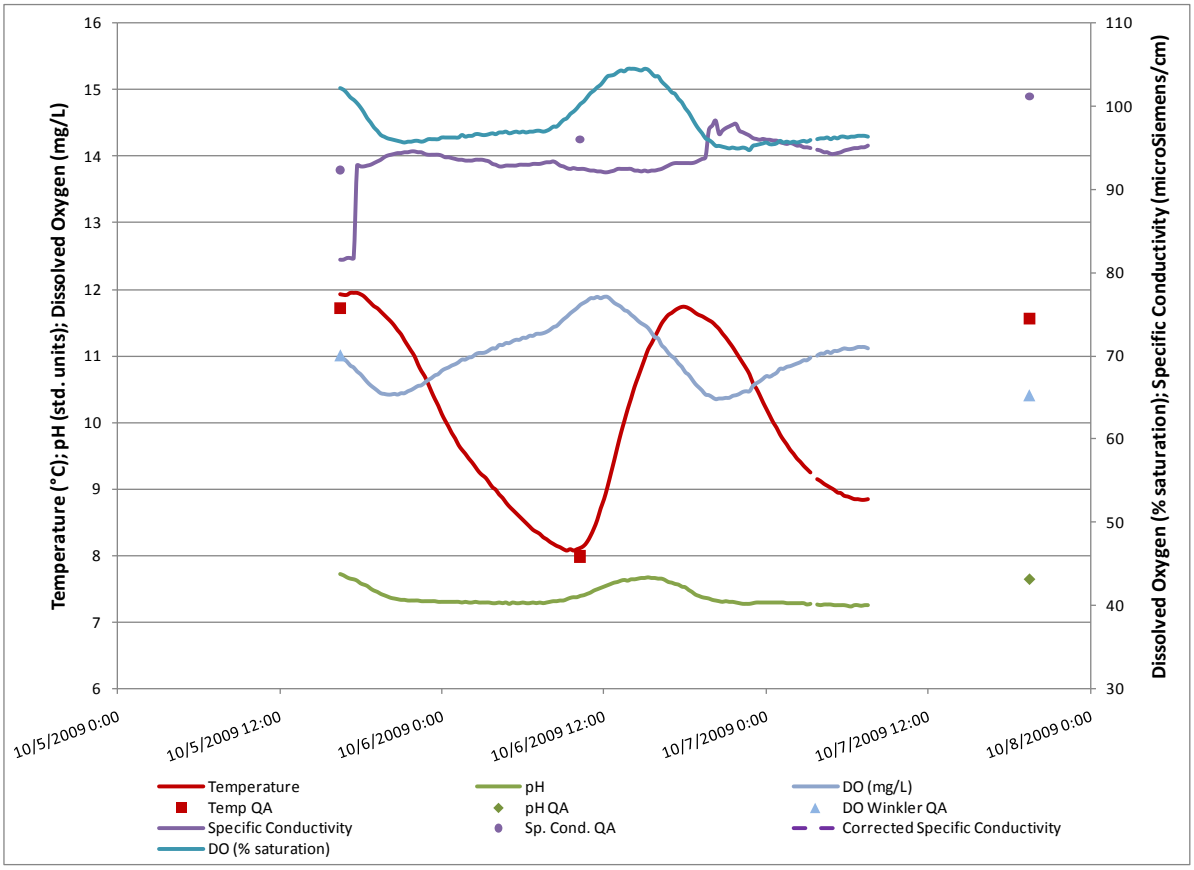

Figure 21. Continuous data for the Lower White River at RM 4.9, October 5-7, 2009.

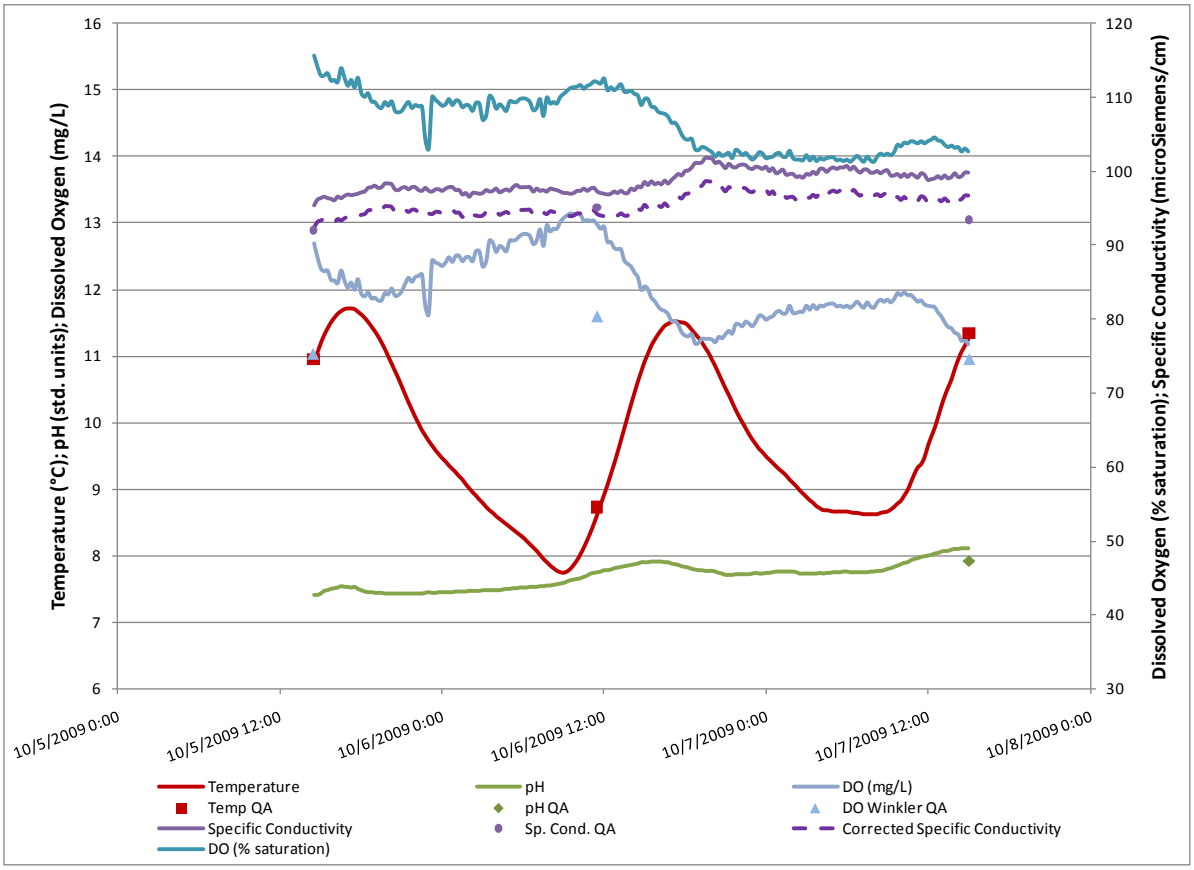

Figure 22. Continuous data for the Lower White River at RM 8.5, October 5-7, 2009.

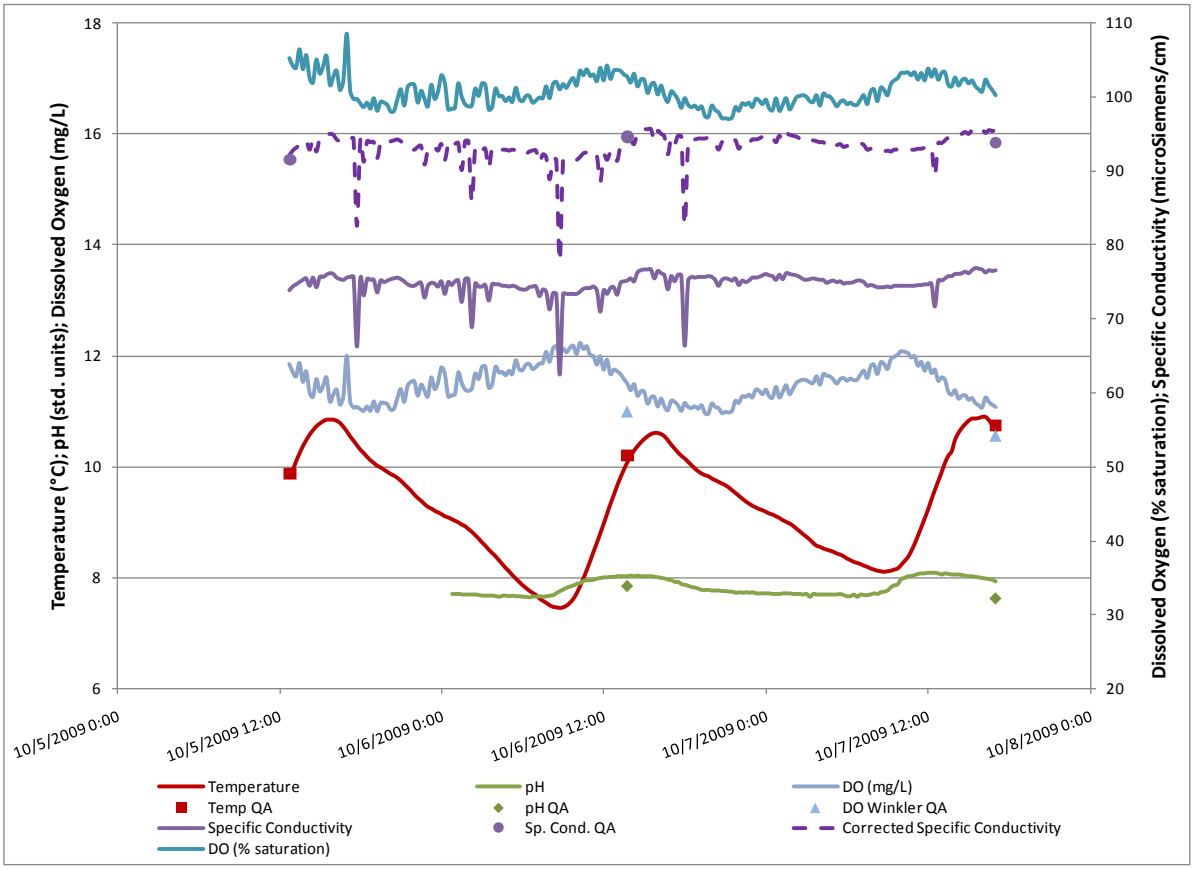

Figure 23. Continuous data for the Lower White River at RM 16.2, October 5-7, 2009.

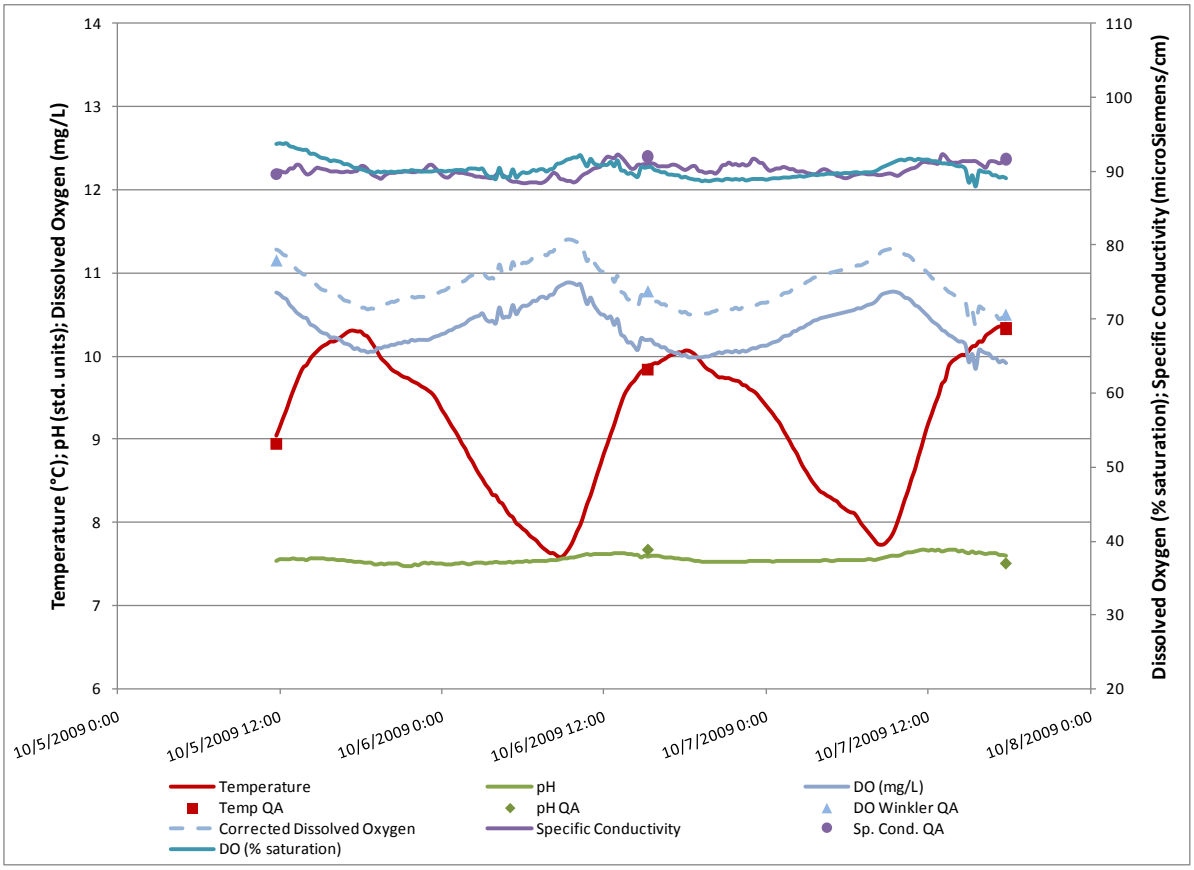

Figure 24. Continuous data for the Lower White River at RM 20.4, October 5-7, 2009.

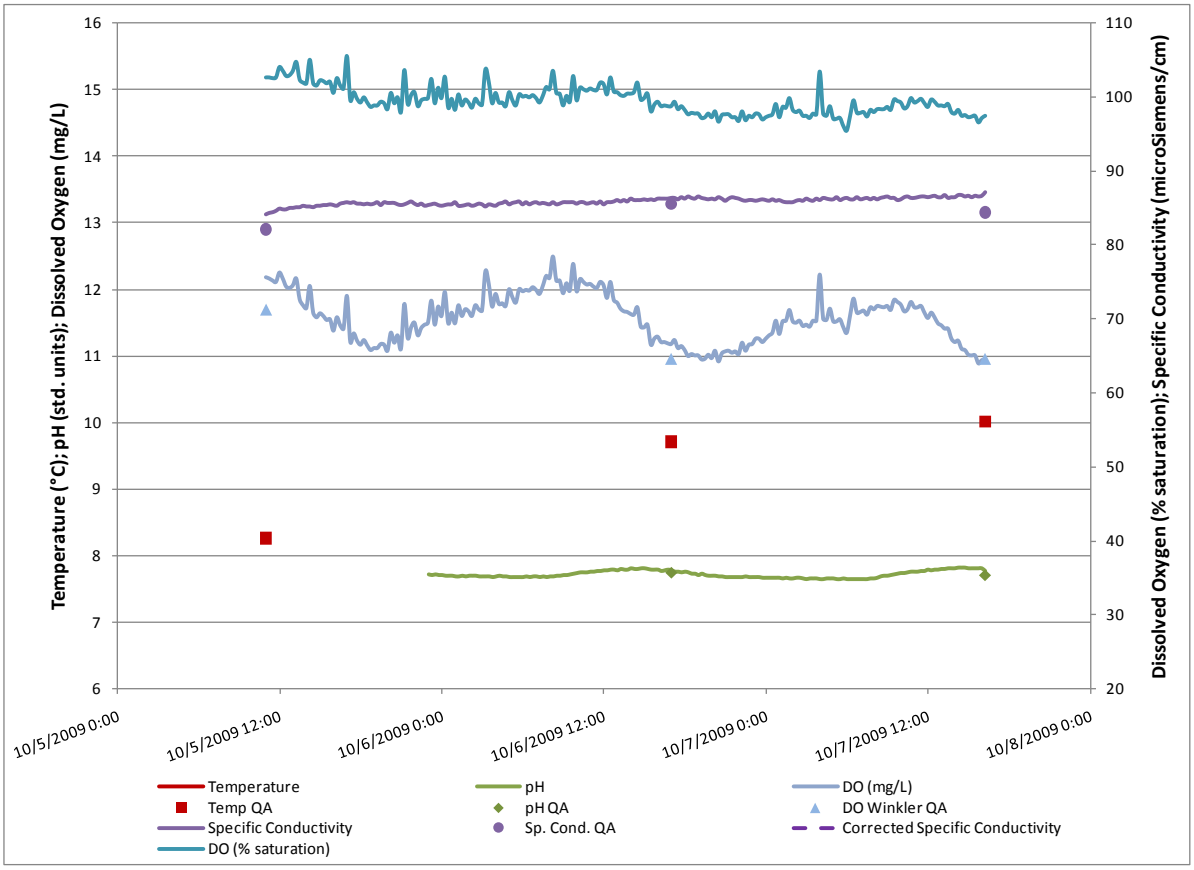

Figure 25. Continuous data for the Lower White River at RM 25.1, October 5-7, 2009.

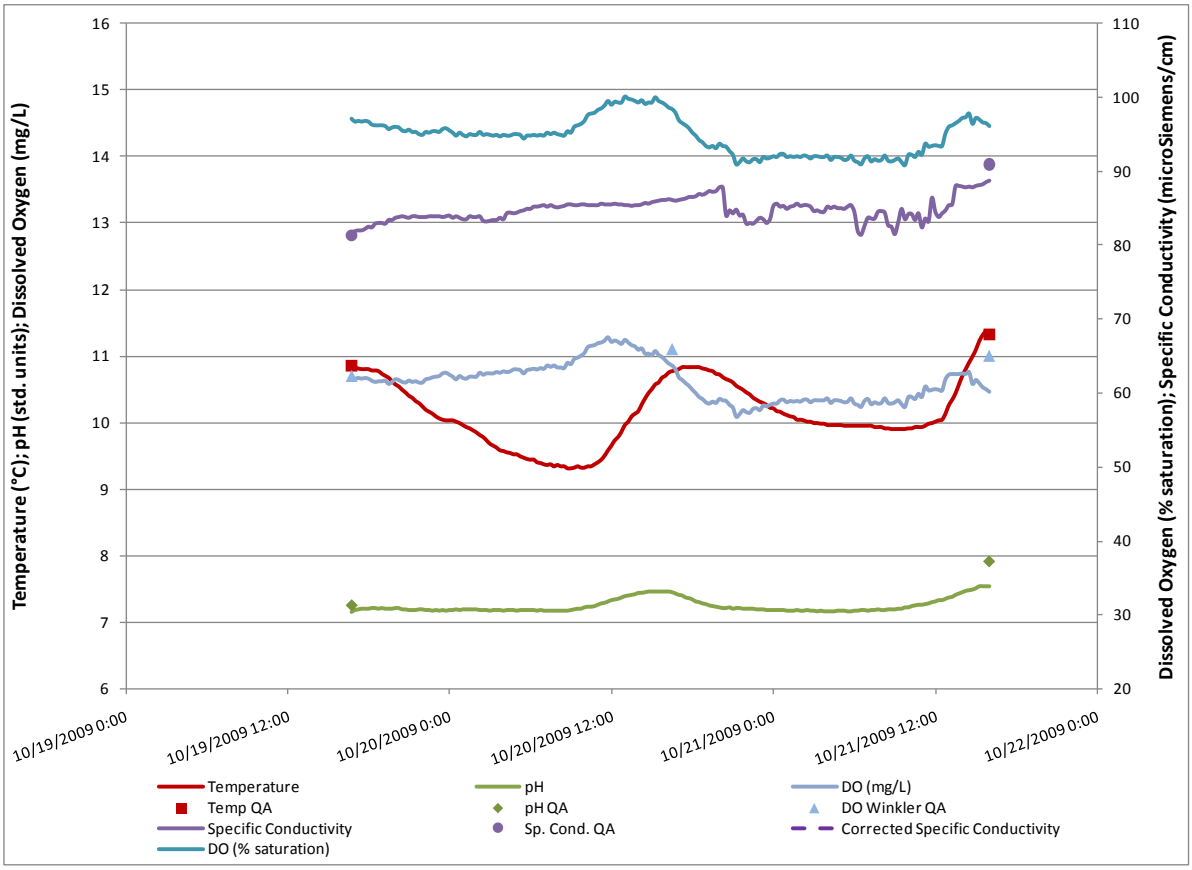

Figure 26. Continuous data for the Lower White River at RM 4.9, October 19-21, 2009.

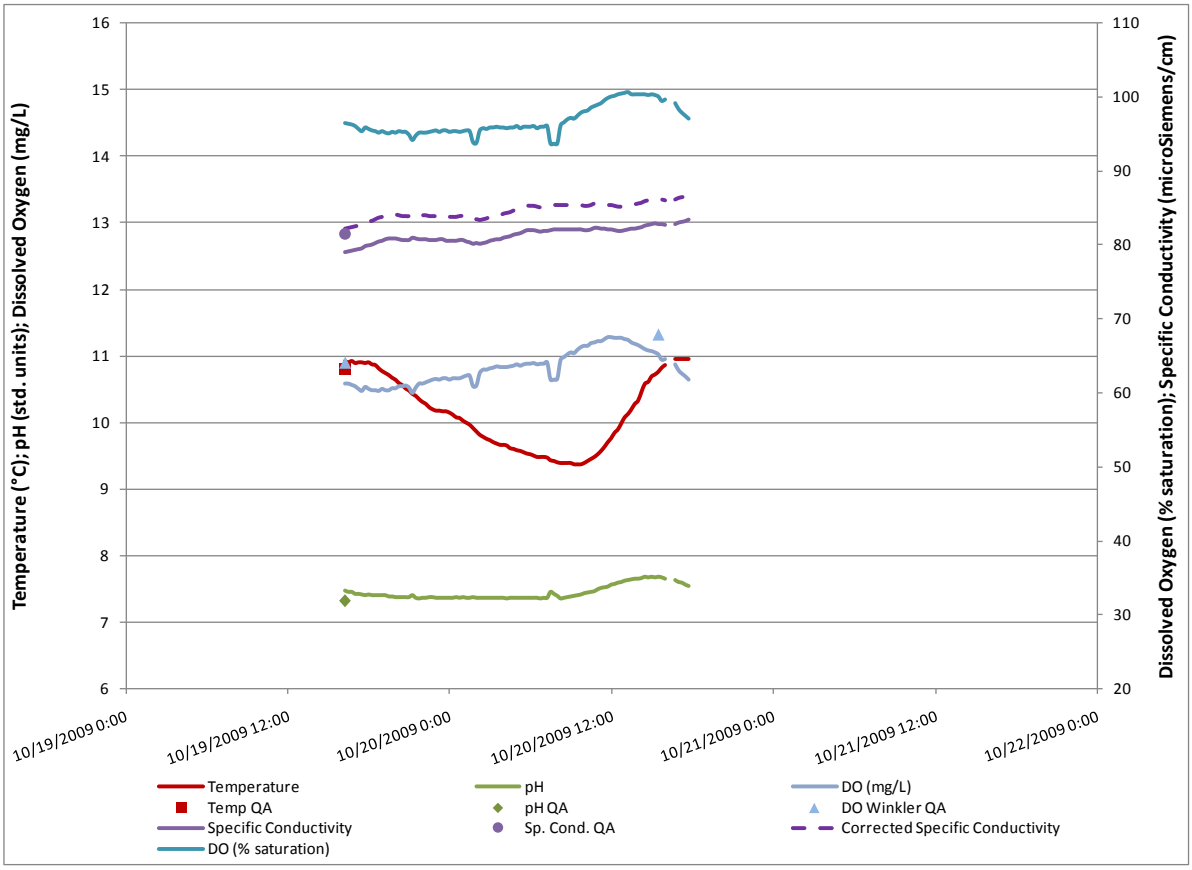

Figure 27. Continuous data for the Lower White River at RM 6.3, October 19-21, 2009.

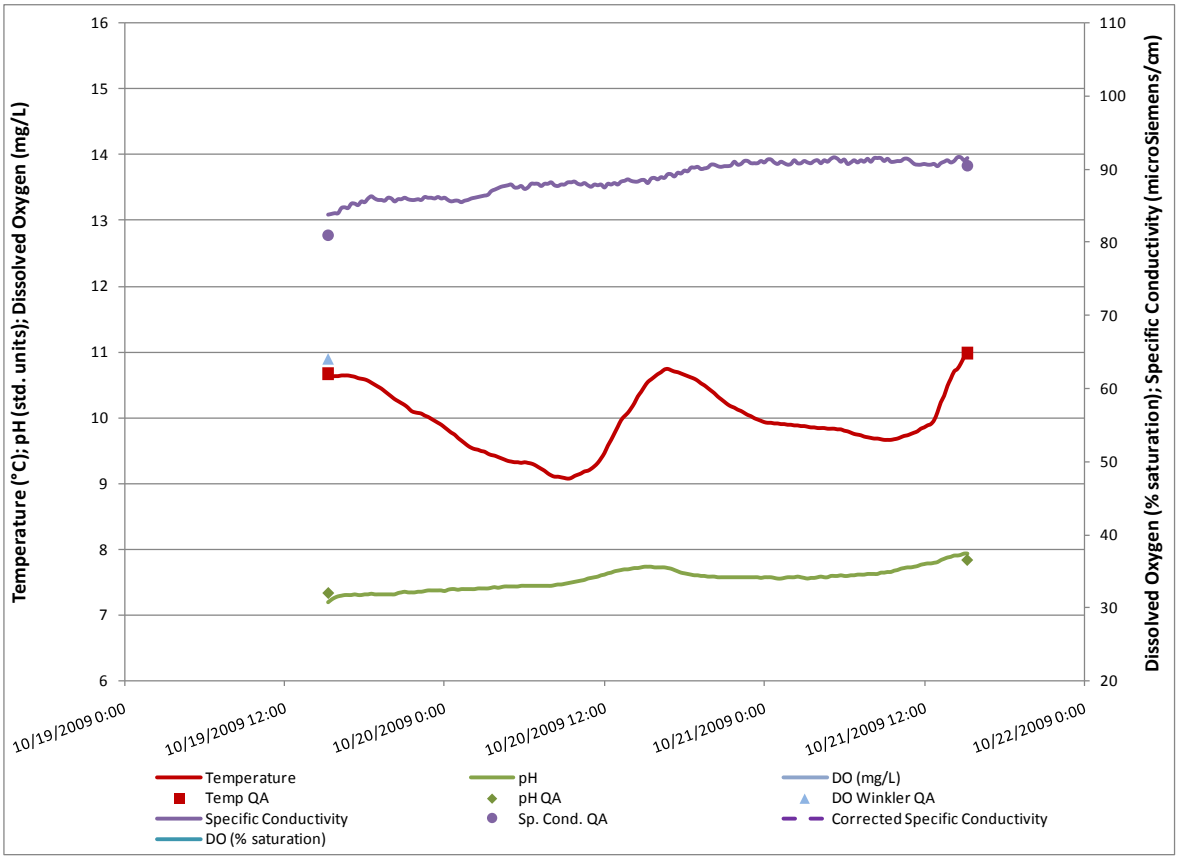

Figure 28. Continuous data for the Lower White River at RM 8.5, October 19-21, 2009.

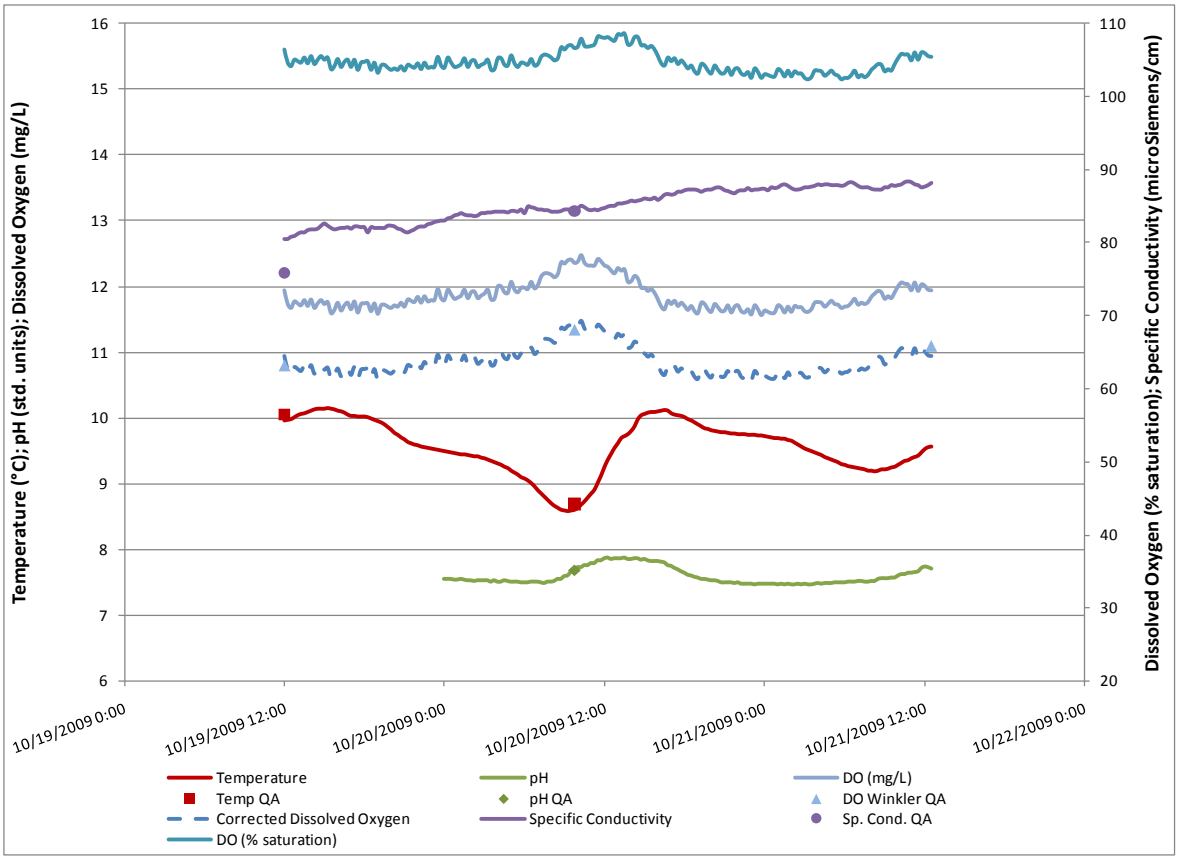

Figure 29. Continuous data for the Lower White River at RM 16.2, October 19-21, 2009.

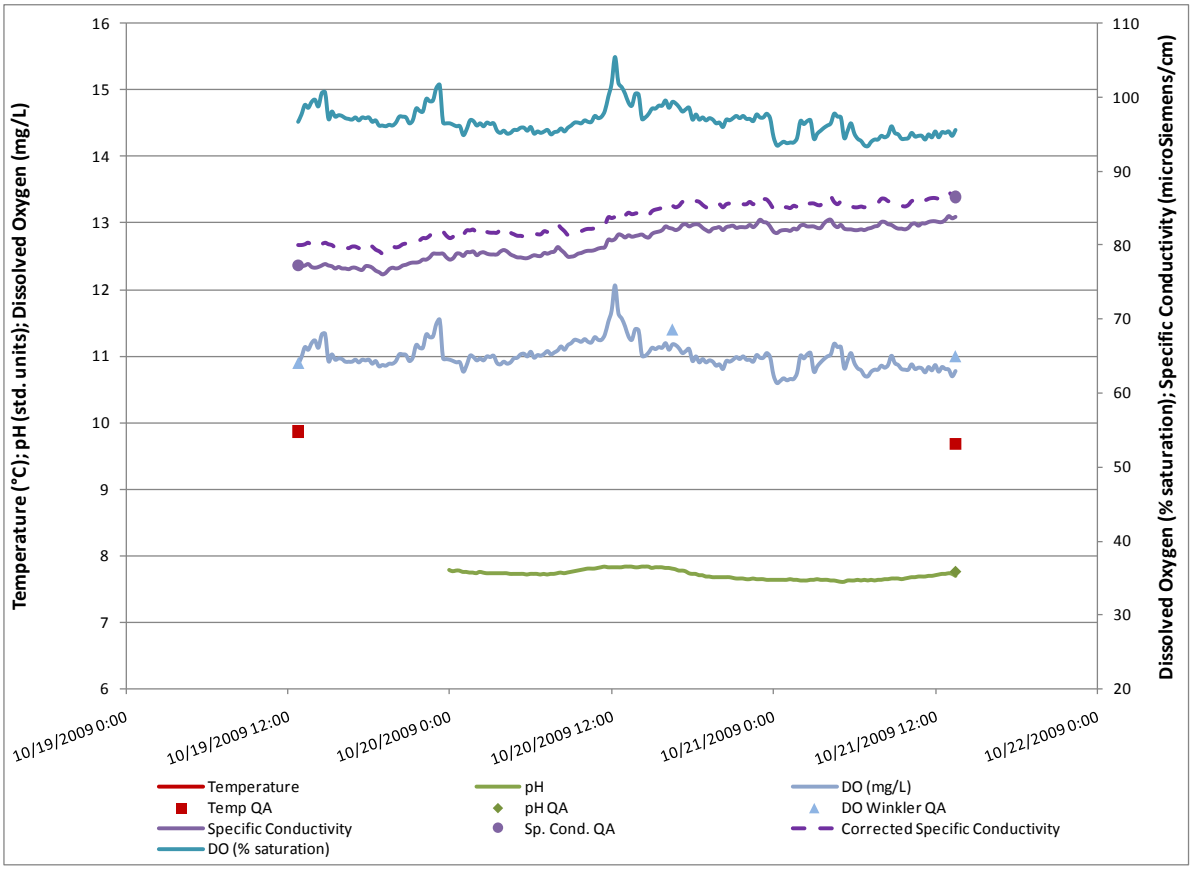

Figure 30. Continuous data for the Lower White River at RM 20.4, October 19-21, 2009.

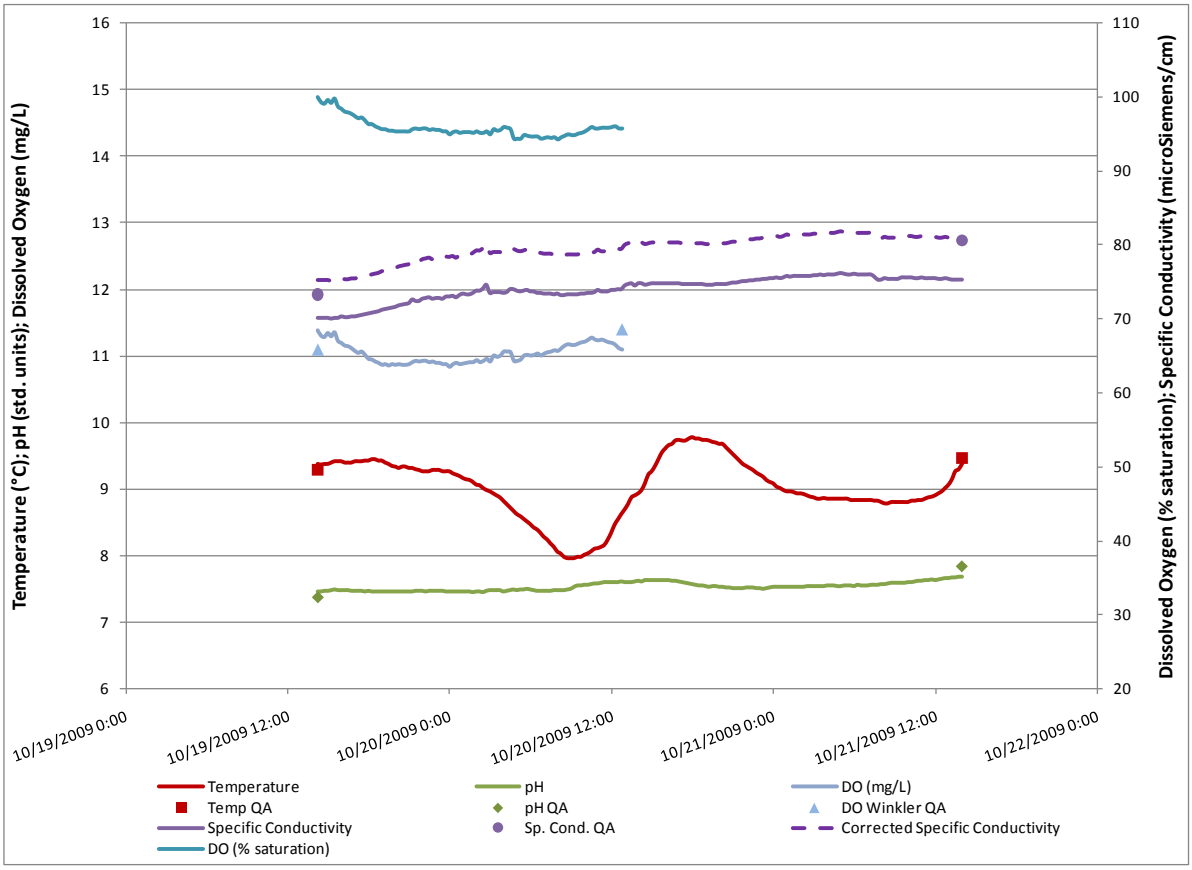

Figure 31. Continuous data for the Lower White River at RM 25.1, October 19-21, 2009.

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Appendix C. Glossary, Acronyms, and Abbreviations

Glossary

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Diel: Of, or pertaining to, a 24-hour period.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Diurnal: Daytime only, as opposed to nocturnal or crepuscular.

Grab sample: A discrete sample from a single point in the water column or sediment surface.

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

Periphyton: Microscopic plants and animals that are firmly attached to solid surfaces under water such as rocks, logs, pilings, and other structures.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Point source: Source of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Salmonid: Any fish that belong to the family *Salmonidae*. Basically, any species of salmon, trout, or char. www.fws.gov/le/ImpExp/FactSheetSalmonids.htm

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

Total Maximum Daily Load (TMDL): Water cleanup plan. A distribution of a substance in a waterbody designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Water year: October 1 through September 30. For example, WY07 is October 1, 2006 through September 30, 2007.

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

BMP	Best management practices
DO	(See Glossary above)
EAP	Environmental Assessment Program
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System software
LISREF	Low-Ionic Strength Reference
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
n/a	Not applicable
PSE	Puget Sound Energy
QA	Quality assurance
RM	River mile
RPD	Relative percent difference

RSD	Relative standard deviation
SM	Standard method
SOP	Standard operating procedures
SRM	Standard reference materials
TMDL	(See Glossary above)
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WRIA	Water Resources Inventory Area
WWTP	Wastewater treatment plant
WY	(See Glossary above)

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
dw	dry weight
ft	feet
g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams.
m	meter
mg	milligrams
mg/Kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mL	milliliters
mm	millimeters
NTU	nephelometric turbidity units
s.u.	standard units
µg/L	micrograms per liter (parts per billion)
umhos/cm	micromhos per centimeter
µS/cm	microsiemens per centimeter, a unit of conductivity
ww	wet weight