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Subject: FW: 2011 Water Quality Report
Date: Thursday, March 01, 2012 6:55:21 PM
Attachments: [DRAFT 2011 Annual WQ report.docx](#)

From: Frantz, Waikele M.
Sent: Thursday, March 01, 2012 6:55 PM
To: Pat Irle
Cc: Charlie McKinney
Subject: 2011 Water Quality Report

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To: Patricia Irle, Washington State Department of
Ecology
Charlie McKinney, Washington State Department of
Ecology

From: Waikele Hampton, Environmental Permit Coordinator
Public Utility District No. 1 of Chelan County (Chelan PUD)

Re: Rocky Reach Hydroelectric Project No. 2145
License Article 401 - Water Quality Annual Report

Ms. Irle and Mr. McKinney:

As per Section 5.7(8) of the 401 Water Quality Certification for Rocky Reach, Chelan PUD hereby submits the 2011 Water Quality Annual Report for your review.

Please review and submit your comments on or before 5:00 p.m., April 12, 2012 to me via email at waikele.frantz@chelanpud.org or via fax to (509) 661-8203.

Pursuant to the FERC Order Modifying and Approving Quality Assurance Project Plan, Chelan PUD will file the Final Water Quality Report with FERC by May 1, 2012.

All received comments will be appended to the final plan with a description of how each comment or recommendation was incorporated in the report, or, if the licensee does not adopt a recommendation, the filing with the FERC will include the licensee's reasons, based on project-specific information for not adopting such recommendation.

If you have any questions, please do not hesitate to contact me.

Thank you,
Waikel e Hampton
509-661-4627

ROCKY REACH ANNUAL WATER QUALITY MONITORING REPORT, 2011

DRAFT

**ROCKY REACH HYDROELECTRIC PROJECT
FERC Project No. 2145**

March 1, 2012



**Public Utility District No. 1 of Chelan County
Wenatchee, Washington**

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EXECUTIVE SUMMARY

The Public Utility District No. 1 of Chelan County (Chelan PUD) owns and operates the Rocky Reach Hydroelectric Project (Project) on the Columbia River. The Project is operated under the terms and conditions of Federal Energy Regulatory Commission (FERC) Hydroelectric Project License No. 2145.

The FERC issued a new license for the Rocky Reach Hydroelectric Project (FERC Project No.2145) on February 19, 2009. The new license incorporated the terms of the Rocky Reach Settlement Agreement, which included a comprehensive Water Quality Management Plan (WQMP), and the terms of the 401 Water Quality Certification (401 Certification) issued by the Washington Department of Ecology (WDOE) on April 4, 2006. The 401 Certification requires Chelan PUD to monitor total dissolved gas (TDG) and temperature in the Project forebay and tailrace annually; temperature in the upstream fishway and juvenile fish bypass system for one year; a one-time study of pH, dissolved oxygen (DO), and water temperature in shallow water areas of the Rocky Reach reservoir, including areas that contain dense growths of aquatic macrophytes; and a one-time study of Gas Bubble Trauma (GBT). The 401 Certification requires that a Quality Assurance Project Plan (QAPP) for these parameters be submitted for Ecology approval. A QAPP was submitted to Ecology and the final QAPP was filed with FERC on February 19, 2010, and approved on November 3, 2010. The QAPP provided the basic framework for all the water quality monitoring and reporting required in the Rocky Reach 401 Certification. In addition, Section 5.7(8) of the 401 Certification requires the submittal of an annual report of water quality monitoring results, along with a summary report by March 1 of each year to WDOE, while the FERC Order Modifying and Approving the QAPP requires the submittal of the same report by May 1 of each year.

The following report contains a summary of water quality monitoring conducted in 2011 and proposed actions to be implemented in 2012.

SECTION 1: INTRODUCTION

The Rocky Reach Hydroelectric Project (Project), owned and operated by Chelan County Public Utility District (Chelan PUD), is located on the Columbia River in Chelan County, Washington, approximately seven miles upstream of the city of Wenatchee, Washington (Figure 1). The Project utilizes the waters of the Columbia River, whose drainage basin extends over substantial portions of northern Washington, Idaho, Montana and into Canada. The Project reservoir (Lake Entiat) extends 43 miles to Douglas County PUD's Wells Dam. The Project consists primarily of an 8,235-acre reservoir; a 2,847-foot-long by 130-foot-high concrete gravity dam spanning the river, including a powerhouse and spillway; a juvenile fish bypass system, and hatchery facilities.

The Federal Energy Regulatory Commission (FERC) issued a new license for the Rocky Reach Hydroelectric Project (FERC Project No.2145) on February 19, 2009. The new license incorporated the terms of the Rocky Reach Settlement Agreement, which included a comprehensive Water Quality Management Plan (WQMP), and the terms of the 401 Water Quality Certification (401 Certification) issued by the Washington Department of Ecology (WDOE) on April 4, 2006. The 401 Certification requires Chelan PUD to monitor total dissolved gas (TDG) and temperature in the Project forebay and tailrace annually; temperature in the upstream fishway and juvenile fish bypass system (JFBS) for one year; a one-time study of pH, dissolved oxygen (DO), and water temperature in shallow water areas (macrophyte beds) of the Rocky Reach reservoir, including areas that contain dense growths of aquatic macrophytes; and a one-time study of Gas Bubble Trauma (GBT). In addition, the 401 Certification requires Chelan PUD to compile hourly temperature data from the Wells Dam tailrace. The 401 Certification also requires that a Quality Assurance Project Plan (QAPP) for these parameters (does not include Wells Dam tailrace temperature) be submitted for Ecology approval. A QAPP was submitted to Ecology and the final QAPP (Appendix A) was filed with FERC on February 19, 2010 (approved on November 3, 2010). The QAPP provided the basic framework for all the water quality monitoring and reporting required in the Rocky Reach 401 Certification.

Section 5.7(8) of the 401 Certification requires the submittal of an annual report of water quality monitoring results, along with a summary report by March 1 of each year to WDOE. WDOE will use the monitoring results to track the Project's progress toward meeting and remaining in compliance with the state water quality standards. Additionally, the FERC Order Modifying and Approving the QAPP requires the submittal of the same report to the FERC by May 1 of each year.

The following report contains a summary of water quality monitoring conducted in 2011 and proposed actions to be implemented in 2012.



Figure 1-1. Location of Rocky Reach Hydroelectric Project on the Columbia River.

SECTION 2: MONITORING PROCEDURES

2.1 Forebay and Tailrace TDG and Temperature

Consistent with the 401 Certification, TDG and temperature were monitored in the Project forebay and tailrace on an hourly basis, April 1 - August 31 and April – October, respectively.

The forebay fixed monitoring station (FMS) is located on the upstream side of the dam (Figure 2), the standpipe affixed to the corner between the powerhouse and spillway, approximately mid-channel. Consistent with the 401 Water Quality Certification (Ecology, April 4, 2006), the tailrace fixed monitoring station is located approximately 0.38 mile downstream of the dam (Figure 2). The standpipe is affixed to the downstream side of a pier nose supporting the juvenile bypass system outfall pipe. This location is east of mid-channel, and is minimally impacted by powerhouse flows when the project is passing water over the spillway (Schneider and Wilhelms, 2005). This location was chosen because it was the most feasible location near the end of the aerated zone, which is the compliance point for the Mid-Columbia TDG TMDL.

Forebay and tailrace TDG and temperature data were collected using instruments that can immediately transmit the data to Chelan PUD headquarters, allowing for real-time data recording. A multi-parameter instrument (Minisonde) developed by Hydrolab, Inc., equipped with TDG and temperature sensors, was lowered down the standpipe at each site and submerged to depth of approximately 15 feet.

TDG and temperature measurements were recorded throughout the monitoring season at 15-minute intervals. These 15-minute intervals were averaged into hourly readings for use in compiling daily and 12-hour averages for TDG and daily averages and daily highs for temperature. All hourly data were forwarded to Chelan PUD headquarters building and then onto the US Army Corps of Engineers Reservoir Control Center (RCC) and posted at their site on the World Wide Web. Data transmitted to RCC was limited to that data collected between April 1 and September 6 (entire TDG monitoring season). The remainder of the temperature data (September 7 – October 31) is available upon request from Chelan PUD.

2.1.1 Alternative Spillway Operations

In 2011, high flow volumes and high levels of TDG in the Columbia River provided an opportunity for Chelan PUD to implement a test of spillway operations not previously tested under the high-flow conditions. The purpose was to evaluate the effectiveness of alternative operations using gates 2-12, to determine whether TDG levels could be reduced without adverse effects on fish passage. The testing utilized four spill configurations: standard, TDG Spill Pattern, Shallow Arc Spill, and Flattened Spill Pattern.

The standard spill configuration used at Rocky Reach uses gates 2-8 with a minimum discharge per spill bay of about 4 kcfs. The standard spill configuration was designed to create a crown-shaped pattern of turbulent flow below the spillway with decreasing velocities leading toward the fishway entrances. This spill pattern provides favorable guidance conditions for adult migrant salmon and steelhead. The same pattern is used for juvenile fish passage spill. During spill operations, whether for juvenile fish passage, TDG management, or for other purposes, the gates are operated via a computer automated system that follows the spill pattern. Gates 9-12 are used only in high flow conditions when gates 2-8 cannot pass enough water.

The TDG Spill Pattern was intended to utilize all of the available spillgates in an effort to avoid higher flows (shallow gate openings) through individual gates. These shallow gate openings of 2-3 feet may result in spill that is more surface oriented.

The Shallow Arc Spill configuration was designed to spread spill volumes more evenly across the spillway while maintaining the majority of flow in the center of the river.

The Flattened Spill Pattern was intended to more evenly distribute the spill flow across the entire width of the spillway. Basically, the same number of gates are open the same amount but redistributed to promote more surface mixing and less concentration of deep spill at one location.

The study was conducted from early June to the end of July while river flows were high. The testing schedule established that each configuration was to be run for 24 hours at a time (midnight to midnight, until the end of June; and 0700 -0700 until the end of the study). Upon the completion of one scenario, another would begin.

A study plan for 2012 is being prepared to further implement and evaluate the alternative spillway operations used during 2011.

2.2 Fishway and Juvenile Fish Bypass Temperature

As per the QAPP, Chelan PUD will install temperature loggers at two locations in the upstream fishway (exit and near the bottom of the ladder) and two locations (entrance and sampling facility) in the JFBS. Although the 401 Certification and QAPP do not specify a schedule for installation of the temperature loggers, Chelan PUD is expecting to install the loggers in the upstream fishway during winter 2012/2013, and in the juvenile sampling facility during spring 2012. Loggers will be installed in the juvenile fish bypass system entrance after further evaluation of temperature data that is collected using a velocity meter is completed to determine if a logger in the gateway entrance (as specified in the QAPP) is needed.

2.3 Wells Dam Tailrace Temperature

Hourly water temperature from April 7 – September 15 was retrieved from the Columbia River DART page at <http://www.cbr.washington.edu/dart/>.

2.4 GBT

No GBT study was conducted in 2011. Refer to the schedule of 2012 planned activities in Section 5 of this document.

2.5 Macrophyte Bed DO, pH, and Temperature

No water quality study was conducted in macrophyte beds in 2011. Refer to the schedule of 2012 planned activities in Section 5 of this document.



Figure 2. Location of forebay and tailrace FMSs, and JFBS SC entrance.

2.6 Data Evaluation and Completeness (QA/QC)

2.6.1 Data Completeness

TDG

Refer to the 2011 Annual Gas Abatement Report (Appendix B) for further information about TDG.

Temperature

A comparison was made to determine what percentage of all possible data (hourly readings) was collected throughout the monitoring season (Table 2-1). Prior to the start of fish spill season, software and hardware upgrades were completed at each fixed monitoring station (FMS) to help increase the FMS system reliability. Throughout the 2011 monitoring season (April 1 – October 31), nearly 100% of all possible data were collected at the forebay and tailrace FMS.

No data was collected in the fishway or at the JFBS.

Table 2-1. Overview of temperature data set during the 2011 monitoring period (April 1 – October 31).

Location	Available data collection hours	Number of omitted/ lost hourly readings	Percent data completeness (%)
FB FMS	5,136	3	99.94
TR FMS	5,136	264	94.86
Total	10,272	269	97.38

Gas Bubble Trauma

No study was conducted in 2011.

Macrophyte Bed DO, pH, and Temperature

No studies were conducted in 2011.

2.6.2 Calibration and Maintenance

Forebay and Tailrace TDG and Temperature

Section 5.7.3 of the 401 Certification requires Chelan PUD to maintain a TDG monitoring program that is at least as stringent as the QA/QC calibration and monitoring procedures and protocols developed by the USGS monitoring methodology for the Columbia River.

Chelan PUD has developed its QA/QC protocols following established protocols by other resource agencies conducting similar monitoring programs, such as the USGS, U.S. Army Corps of Engineers, and other mid-Columbia River Dam operators, as well as HydroLab Corporation's recommendations. These QA/QC protocols are included in Chelan PUD's approved QAPP (Appendix A).

Chelan PUD entered into a Professional Services Agreement with Columbia Basin Environmental to perform monthly calibrations and equipment maintenance on the forebay and tailrace TDG/temperature instruments. Quality Assurance/Quality Control measures were accomplished through training in instrument maintenance, operation, and factory prescribed calibration methods. A detailed log was maintained for all work done on the monitoring equipment, including monthly maintenance, calibration, exchange of instruments, and any other pertinent information. Redundant measurements with a mobile

instrument to verify the accuracy of the in-situ instruments were conducted during the monthly calibrations. Calibration reports are included as Appendix C.

For all field-deployed equipment, a pre-and post-calibrated protocol was conducted in accordance with the manufacturer's recommendations to document instrument bias and performance at representative temperatures. The accuracy of the field thermometers was maintained by a two-point comparison between the field equipment and a certified reference thermometer. This comparison was made prior to and after logger deployment, and at a minimum of annually for real-time equipment.

Fishway and juvenile fish bypass system

At this time, instruments have not been installed in the fishway or JFBS. Therefore, there is no data to report for those locations.

GBT

No studies were conducted during 2011.

DO/pH

No studies were conducted during 2011.

SECTION 3: RESULTS

3.1 TDG

Refer to the 2011 Gas Abatement Annual Report (Appendix B) for further information about TDG.

3.1.1 Alternative Spillway Operations

Chelan PUD is currently analyzing the data gathered during the spill gate testing conducted in 2011. This data will be valuable in the development of a plan to investigate alternative spillway operations (as per Section 5.4(1)(b)(6) of the 401 Certification) in 2012. Data from 2011 and any data collected during the 2012 monitoring season will be included and discussed in the 2012 Annual Gas Abatement Report.

3.2 Temperature

3.2.1 Forebay, Tailrace, and Wells Dam tailrace

Hourly temperature from the forebay and tailrace FMSs and Wells Dam tailrace, was averaged and the daily averages are presented in Appendix D. The summary values (min, max) for all hourly TDG measurements taken from each location during the 2011 fish spill season are presented in Table 3-1 below.

Table 3-1. Minimum and maximum daily average and daily high temperatures at Wells Dam tailrace and Rocky Reach forebay and tailrace FMS, April 1 – October 31, 2011.

Location	Minimum Temp (°C)	Maximum Temp (°C)
Wells Dam Tailrace Daily Average (April 7 – Sept 15)	4.7	19.0
Rocky Reach Forebay Daily Average	4.6	19.2
Rocky Reach Forebay Daily High	4.7	19.5
Rocky Reach Tailrace Daily Average	4.3	19.1
Rocky Reach Tailrace Daily High	4.4	19.1

Daily averages from the Rocky Reach forebay and tailrace FMSs were averaged into monthly averages to determine the average change in temperature from the forebay to tailrace. Additionally, daily average temperature data from the Wells Dam tailrace was averaged into monthly averages to determine the average change in temperature from the Wells Dam tailrace to the Rocky Reach forebay. This summary can be found in Table 3-2 below.

Table 3-2. Average monthly temperatures (°C) in the Wells Dam tailrace, Rocky Reach forebay and tailrace, April 1 – October 31, 2011.

	Wells Dam Tailrace Average Monthly Temperature	RR FB Average Monthly Temperature (based on daily averages)	Change in Temperature (Wells TR to Rocky Reach FB)	RRTR Average Monthly Temperature (based on daily averages)	Change in Temperature (Rocky Reach FB to TR)
April	6.12 (begins April 7)	5.96	-0.16	5.62	-0.25
May	9.08	9.14	0.06	9.62	-0.07
June	12.28	12.2	-0.08	12.16	-0.04
July	15.14	15.12	-0.02	15.05	-0.07
August	17.89	18.07	0.18	17.99	-0.09
September	18.62 (ends Sept 15)	18.56	0.20	18.47	-0.09
October		16.72		16.65	-0.07
Average	13.24	13.68	0.09 (April 7 – Sept 15)	13.95	-0.10

3.2.2 Upstream Fishway

At this time, instruments have not been installed in the upstream fishway or in the JFBS. Therefore, there is no data to report for those locations.

3.3 GBT

No studies were conducted in 2011.

3.4 Dissolved Oxygen and pH

No studies were conducted in 2011.

SECTION 4: DISCUSSION

4.1 TDG

Refer to the 2011 Annual Gas Abatement Report (Appendix B) for further information about TDG.

4.1.1 Alternative Spillway Operations

Chelan PUD is currently analyzing the data gathered during the spill gate testing conducted in 2011. This data will be instrumental in the development of a plan to investigate alternative spillway operations (as per Section 5.4(1)(b)(6) of the 401 Certification) in 2012. Data from 2011 and any data collected during the 2012 monitoring season will be included and discussed in the 2012 Annual Gas Abatement Report.

4.2 Temperature

Water temperatures were monitored at three locations in 2011; the Wells Dam tailrace and Rocky Reach forebay and tailrace. Based on the daily average temperature water traveling from the Wells tailrace to Rocky Reach forebay generally increased in temperature an average of 0.09°C (range: decrease 0.16°C to an increase of 0.2°C), while water traveling from the Rocky Reach forebay to Rocky Reach tailrace generally decreased in temperature by 0.10°C (range: decrease of 0.25°C to a decrease of 0.04°C).

As per Section 5.5(1)(c) of the 401 Certification, this data will be used to run the CE-QUAL-W2 model in Year 5 of the License to evaluate the Project compliance with numeric temperature criteria.

4.3 GBT

No studies were conducted in 2011.

4.4 Macrophyte Bed DO, pH, and Temperature

No studies were conducted in 2011.

SECTION 5: PROPOSED 2012 ACTION PLAN

5.1 TDG

Chelan PUD plans to continue the TDG monitoring program conducted in 2011.

As per Section 5.4(1)(b)(6) of the 401 Certification, Chelan PUD is drafting a plan to further investigate alternative spillway operations using any of gates 2-12, as was begun in 2011, to determine, whether TDG levels can be reduced without adverse effects on fish passage. A draft of the plan will be complete and ready for review by May 1, 2012, with the goal of having a final plan in place prior to high flows. Implementation of the plan is dependent on high flow conditions and approval of the HCP CC. Results of the testing conducting in 2011 and any testing conducted in 2012 will be included and discussed in the 2012 Annual Gas Abatement Report.

5.2 Temperature

5.2.1 Forebay and Tailrace

Chelan PUD plans to continue the forebay and tailrace temperature monitoring program conducted in 2011.

5.2.2 Fishway and juvenile fish bypass system

As per the QAPP, Chelan PUD will install temperature loggers at two locations in the upstream fishway (exit and near the bottom of the ladder) and two locations (entrance and sampling facility) in the JFBS. Although the 401 Certification and QAPP do not specify a schedule for installation of the temperature loggers, Chelan PUD is expecting to install the loggers in the upstream fishway during winter 2012/2013 and in the juvenile sampling facility during spring 2012. Loggers will be installed in the juvenile fish bypass system entrance after further evaluation of temperature data that is collected using a velocity meter is completed to determine if a logger in the gateway entrance (as specified in the QAPP) is needed.

5.3 GBT

Chelan PUD plans to develop a study plan for reservoir GBT during the winter of 2012/2013. Dependent on appropriate TDG conditions, implementation would begin spring of 2013, subsequent to review and approval by WDOE.

5.4 Dissolved Oxygen/pH

Chelan PUD recently submitted to WDOE an update to the February 2010 QAPP to provide specific details regarding sampling design, equipment updates, and other information specific to the assessment of water quality in shallow water areas of the Rocky Reach reservoir, including areas with macrophyte beds.

The proposed schedule for implementation of the macrophyte bed study is as follows:

5/1/2012	Ecology and RRFF comments/edits to Chelan PUD
6/1/2012	Final QAPP/Study Design to WDOE and RRFF
7/1/2012	Ecology Approval of QAPP
7/1-8/1/2012	Equipment preparation, calibration, data forms and maps
8/6-10/2012	First sample week
8/20-24/2012	Second sample week
9/3-7/2012	Third sample week
9/17-21/2012	Fourth sample week

SECTION 6: PROPOSED CHANGES TO QAPP

Chelan PUD does not propose any changes to the QAPP at this time.

APPENDIX A: FINAL QUALITY ASSURANCE PROJECT PLAN

The final Quality Assurance Project Plan can be found at the following link:

http://www.chelanpud.org/departments/licensingCompliance/rr_implementation/ResourceDocuments/33937.pdf

APPENDIX B: 2011 ANNUAL GAS ABATEMENT REPORT

The 2011 Annual Gas Abatement Report can be found at the following link:

http://www.chelanpud.org/departments/licensingCompliance/rr_implementation/ResourceDocuments/38065.pdf

APPENDIX C: CALIBRATION REPORTS

Site	InstrID	Date	Time	BP mmHg	Temperature (°C)			TDG Pressure (mmHg)				Deviation from STD TDG %Saturation			
				STD	STD	Probe	Diff	100%	113%	126%	139%	100%	113%	126%	139%
RIGW	37606	03/28/11	10:55	748.7	4.50	4.5	0.0	748	848	948	1049	0.1	0.1	0.1	0.0
RIGW	32546	04/25/11	14:40	709.8	12.00	11.9	0.1	710	810	910	1010	0.0	0.0	0.0	0.0
RIGW	32546	05/25/11	13:05	741.1	10.50	10.3	0.2	741	841	941	1041	0.0	0.0	0.0	0.0
RIGW	32546	06/30/11	15:10	746.9	14.30	14.2	0.1	747	847	947	1047	0.0	0.0	0.0	0.0
RIGW	32546	07/27/11	12:15	746.3	17.10	17.0	0.1	747	847	947	1047	-0.1	-0.1	-0.1	-0.1
RIGW	32546	08/24/11	10:20	745.1	19.10	19.0	0.1	745	845	945	1045	0.0	0.0	0.0	0.0
RIGW	32548	09/28/11	14:15	754.7	18.70	18.5	0.2	755	854	954	1055	0.0	0.1	0.1	0.0
RIS	60047	03/28/11	13:30	747.2	5.00	5.1	-0.1	745	844	942	1041	0.3	0.4	0.7	0.8
RIS	37606	04/26/11	12:30	745.9	8.00	7.9	0.1	746	845	945	1045	0.0	0.1	0.1	0.1
RIS	37606	05/25/11	14:10	740.3				741	841	941	1041	-0.1	-0.1	-0.1	-0.1
RIS	37606	06/30/11	13:40	745.4	14.80	14.6	0.2	745	844	944	1045	0.1	0.2	0.2	0.1
RIS	37606	07/27/11	13:30	744.8	17.20	17.1	0.1	744	844	944	1044	0.1	0.1	0.1	0.1
RIS	37606	08/24/11	11:40	743.2	18.80	18.6	0.2	743	843	943	1043	0.0	0.0	0.0	0.0
RIS	37606	09/28/11	13:25	754.0	18.80	18.5	0.3	754	854	954	1055	0.0	0.0	0.0	-0.1
RRDW	38865	03/28/11	11:00	748.8	4.60	4.5	0.1	748	848	948	1048	0.1	0.1	0.1	0.1
RRDW	38865	04/26/11	9:45	744.4	7.40	7.3	0.1	744	844	944	1045	0.1	0.1	0.1	-0.1
RRDW	38865	05/25/11	13:15	739.3	10.60	10.5	0.1	739	839	939	1039	0.0	0.0	0.0	0.0
RRDW	38865	06/30/11	12:05	744.3	14.50	14.3	0.2	744	844	944	1044	0.0	0.0	0.0	0.0
RRDW	38865	07/27/11	14:30	743.5	17.00	16.8	0.2	743	843	943	1043	0.1	0.1	0.1	0.1
RRDW	38865	08/24/11	13:30	741.3	19.00	19.0	0.0	741	840	940	1041	0.0	0.2	0.2	0.0
RRDW	38865	09/28/11	11:50	754.2	17.90	17.7	0.2	752	852	952	1053	0.3	0.3	0.3	0.2
RRH	60048	03/28/11	14:00	747.0	6.20	6.3	-0.1	744	842	942	1041	0.4	0.7	0.7	0.8
RRH	37607	04/25/11	14:20	709.8	11.40	11.4	0.0	710	810	911	1011	0.0	0.0	-0.2	-0.2
RRH	37607	05/25/11	15:35	737.4	10.80	10.7	0.1	737	837	937	1038	0.1	0.1	0.1	-0.1
RRH	37607	06/30/11	11:20	742.5	14.60	14.5	0.1	745	844	944	1044	-0.3	-0.2	-0.2	-0.2
RRH	37607	07/27/11	15:05	741.6	17.80	17.7	0.1	742	842	942	1042	-0.1	-0.1	-0.1	-0.1
RRH	37607	08/24/11	14:05	739.0	19.70	19.5	0.2	739	839	939	1040	0.0	0.0	0.0	-0.1
RRH	37607	09/28/11	12:20	751.8	18.30	18.2	0.1	750	850	950	1051	0.2	0.2	0.2	0.1

APPENDIX D: DAILY AVERAGE TEMPERATURES

Date	Wells Tailrace Daily Average	Rocky Reach Forebay Daily Average	Rocky Reach Forebay Daily High	Rocky Reach Tailrace Daily Average
4/1/11		4.63	4.72	4.37
4/2/11		4.57	4.70	4.29
4/3/11		4.56	4.66	4.31
4/4/11		4.57	4.68	4.33
4/5/11		4.70	4.78	4.42
4/6/11		4.80	4.97	4.54
4/7/11	4.68	4.97	5.12	4.71
4/8/11	4.8	5.00	5.15	4.73
4/9/11	5	5.13	5.29	4.87
4/10/11	5.22	5.28	5.40	5.02
4/11/11	5.42	5.47	5.63	5.18
4/12/11	5.56	5.68	5.83	5.40
4/13/11	5.66	5.85	5.96	5.58
4/14/11	5.67	5.86	5.96	5.58
4/15/11	5.76	5.92	5.99	5.64
4/16/11	5.97	5.99	6.19	5.72
4/17/11	6.21	6.26	6.43	5.97
4/18/11	6.21	6.44	6.59	6.17
4/19/11	6.25	6.54	6.63	6.27
4/20/11	6.34	6.57	6.65	6.30
4/21/11	6.32	6.66	6.79	6.39
4/22/11	6.44	6.68	6.78	6.41
4/23/11	6.64	6.80	6.98	6.53
4/24/11	6.77	6.96	7.16	6.69
4/25/11	6.85	7.08	7.17	6.81
4/26/11	6.9	7.09	7.22	6.91
4/27/11	6.99	7.11	7.21	7.04
4/28/11	7.07	7.17	7.26	7.07
4/29/11	6.95	7.28	7.43	
4/30/11	7.14	7.29	7.42	
5/1/11	7.43	7.33	7.55	
5/2/11	7.41	7.60	7.73	
5/3/11	7.43	7.62	7.81	
5/4/11	7.6	7.67	7.83	
5/5/11	7.85	7.91	8.09	
5/6/11	7.93	8.07	8.19	
5/7/11	8.01	8.20	8.31	
5/8/11	8.15	8.25	8.40	
5/9/11	8.32	8.40	8.63	

5/10/11	8.37	8.69	8.87	
5/11/11	8.51	8.71	8.82	8.60
5/12/11	8.55	8.70	8.77	8.63
5/13/11	8.73	8.77	8.87	8.71
5/14/11	8.9	8.94	8.96	8.85
5/15/11	8.68	8.96	9.02	8.89
5/16/11	8.64	8.67	8.86	8.60
5/17/11	8.86	8.67	8.85	8.58
5/18/11	9.25	9.07	9.24	8.99
5/19/11	9.55	9.46	9.67	9.40
5/20/11	9.85	9.80	9.98	9.73
5/21/11	9.98	10.01	10.09	9.97
5/22/11	10.05	10.08	10.16	10.02
5/23/11	10.12	10.16	10.27	10.11
5/24/11	10.27	10.29	10.44	10.23
5/25/11	10.32	10.39	10.43	10.33
5/26/11	10.24	10.36	10.45	10.29
5/27/11	10.23	10.29	10.37	10.24
5/28/11	10.29	10.29	10.33	10.25
5/29/11	10.49	10.48	10.65	10.43
5/30/11	10.67	10.64	10.83	10.59
5/31/11	10.76	10.75	10.84	10.70
6/1/11	10.9	10.84	11.00	10.79
6/2/11	11.18	11.09	11.30	11.04
6/3/11	11.36	11.39	11.61	11.33
6/4/11	11.54	11.61	11.81	11.55
6/5/11	11.64	11.69	11.85	11.65
6/6/11	11.57	11.76	11.94	11.73
6/7/11	11.53	11.77	11.94	11.74
6/8/11	11.3	11.62	11.76	11.58
6/9/11	11.14	11.38	11.49	11.32
6/10/11	11.22	11.41	11.48	11.36
6/11/11	12.96	11.41	11.57	11.38
6/12/11		11.68	11.86	11.65
6/13/11		11.95	12.15	11.91
6/14/11	12.3	12.16	12.33	12.13
6/15/11	12.18	12.23	12.36	12.21
6/16/11	12.06	12.11	12.25	12.09
6/17/11	12.23	12.09	12.25	12.05
6/18/11	12.33	12.26	12.37	12.24
6/19/11	12.49	12.33	12.50	12.33

6/20/11	12.78	12.63	12.88	12.60
6/21/11	12.92	12.89	13.09	12.85
6/22/11	13	12.98	13.08	12.95
6/23/11	13.1	12.97	13.07	12.95
6/24/11	13.01	13.03	13.13	12.98
6/25/11	13.04	13.00	13.07	12.93
6/26/11	12.88	13.03	13.07	12.95
6/27/11	13.01	12.93	12.97	12.88
6/28/11	13.21	12.99	13.09	12.96
6/29/11	13.49	13.29	13.49	13.26
6/30/11	13.44	13.47	13.53	13.44
7/1/11	13.31	13.46	13.58	13.43
7/2/11	13.16	13.52	13.65	13.46
7/3/11	13.45	13.43	13.55	13.38
7/4/11	13.9	13.68	13.95	13.62
7/5/11	14.12	14.09	14.23	14.02
7/6/11	13.91	14.22	14.28	14.20
7/7/11	14.26	14.14	14.31	14.10
7/8/11	14.4	14.36	14.50	14.32
7/9/11	14.43	14.44	14.51	14.37
7/10/11	14.15	14.49	14.54	14.44
7/11/11	14.26	14.24	14.35	14.19
7/12/11	14.67	14.34	14.47	14.27
7/13/11	14.99	14.75	14.97	14.68
7/14/11	15.03	15.02	15.12	14.97
7/15/11	15.08	15.10	15.16	15.04
7/16/11	15.13	15.13	15.16	15.08
7/17/11	15.15	15.19	15.24	15.13
7/18/11	15.46	15.26	15.39	15.22
7/19/11	15.54	15.52	15.64	15.45
7/20/11	15.61	15.61	15.67	15.50
7/21/11	15.77	15.66	15.76	15.58
7/22/11	15.78	15.69	15.74	15.60
7/23/11	16.11	15.83	15.98	15.73
7/24/11	16.23	16.15	16.28	16.05
7/25/11	16.15	16.29	16.39	16.19
7/26/11	16.12	16.13	16.23	16.04
7/27/11	16.5	16.20	16.36	16.11
7/28/11	16.52	16.49	16.70	16.40
7/29/11	16.61	16.68	16.89	16.60
7/30/11	16.75	16.77	16.99	16.68

7/31/11	16.88	16.93	17.19	16.84
8/1/11	17.05	17.00	17.22	16.92
8/2/11	17.17	17.17	17.38	17.08
8/3/11	17.12	17.24	17.44	17.15
8/4/11	16.96	17.35	17.53	17.27
8/5/11	17.34	17.31	17.45	17.23
8/6/11	17.46	17.53	17.88	17.45
8/7/11	17.55	17.87	18.01	17.78
8/8/11	17.6	17.84	18.02	17.76
8/9/11	17.62	17.95	18.05	17.87
8/10/11	17.62	17.91	18.07	17.82
8/11/11	17.71	17.92	18.02	17.84
8/12/11	17.76	17.98	18.15	17.87
8/13/11	17.9	18.05	18.22	17.94
8/14/11	17.88	18.08	18.24	17.97
8/15/11	17.89	18.14	18.24	18.00
8/16/11	17.82	18.07	18.15	17.98
8/17/11	17.77	18.09	18.24	17.99
8/18/11	17.66	17.98	18.11	17.90
8/19/11	17.81	17.94	18.06	17.85
8/20/11	18.05	17.96	18.17	17.88
8/21/11	18	18.23	18.46	18.16
8/22/11	17.98	18.37	18.44	18.29
8/23/11	18.03	18.18	18.28	18.11
8/24/11	18.33	18.30	18.42	18.21
8/25/11	18.51	18.49	18.72	18.41
8/26/11	18.54	18.78	18.96	18.70
8/27/11	18.62	18.90	19.00	18.81
8/28/11	18.76	18.85	18.94	18.78
8/29/11	18.73	18.97	19.07	18.90
8/30/11	18.71	19.03	19.06	18.95
8/31/11	18.54	18.88	19.00	18.81
9/1/11	18.43	18.69	18.83	18.62
9/2/11	18.5	18.59	18.65	18.53
9/3/11	18.49	18.54	18.73	18.45
9/4/11	18.49	18.62	18.91	18.47
9/5/11	18.5	18.86	19.42	18.62
9/6/11	18.48	18.75	18.86	18.67
9/7/11	18.44	18.73	18.85	18.66
9/8/11	18.41	18.74	18.78	18.65
9/9/11	18.44	18.75	19.08	18.65

9/10/11	18.54	18.83	19.18	18.72
9/11/11	18.86	18.87	19.46	18.75
9/12/11	18.98	18.88	19.07	18.78
9/13/11	19	18.97	19.15	18.88
9/14/11	18.9	19.16	19.26	19.08
9/15/11	18.78	19.17	19.23	19.08
9/16/11		19.00	19.14	18.93
9/17/11		18.70	18.86	18.63
9/18/11		18.40	18.49	18.34
9/19/11		18.36	18.46	18.28
9/20/11		18.26	18.34	18.20
9/21/11		18.24	18.30	18.17
9/22/11		18.27	18.31	18.20
9/23/11		18.30	18.39	18.23
9/24/11		18.36	18.49	18.28
9/25/11		18.36	18.46	18.29
9/26/11		18.25	18.30	18.19
9/27/11		18.22	18.35	18.14
9/28/11		18.05	18.19	17.98
9/29/11		17.93	18.00	17.86
9/30/11		17.85	17.96	17.79
10/1/11		17.94	17.98	17.86
10/2/11		17.99	18.12	17.89
10/3/11		17.95	17.99	17.88
10/4/11		17.76	17.87	17.69
10/5/11		17.65	17.69	17.56
10/6/11		17.59	17.67	17.50
10/7/11		17.49	17.52	17.41
10/8/11		17.38	17.43	17.33
10/9/11		17.33	17.37	17.27
10/10/11		17.37	17.41	17.30
10/11/11		17.32	17.40	17.23
10/12/11		17.22	17.28	17.16
10/13/11		16.95	17.10	16.89
10/14/11		16.79	16.82	16.73
10/15/11		16.85	16.94	16.76
10/16/11		16.85	16.94	16.78
10/17/11		16.77	16.83	16.69
10/18/11		16.71	16.77	16.62
10/19/11		16.65	16.80	16.58
10/20/11		16.64	16.74	16.58

10/21/11		16.66	16.73	16.59
10/22/11		16.55	16.71	16.48
10/23/11		16.46	16.51	16.40
10/24/11		16.25	16.38	16.20
10/25/11		15.98	16.10	15.91
10/26/11		15.71	15.86	15.63
10/27/11		15.43	15.51	15.36
10/28/11		15.34	15.42	15.27
10/29/11		15.10	15.20	15.02
10/30/11		14.92	15.02	14.84
10/31/11		14.66	14.80	14.60
