

Water quality trends in the Entiat River subbasin: Final annual report to BPA and NOAA Fisheries

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Work Element: E: 157. Collect/Generate/Validate Field and Lab Data: Measure, analyze and
interpret water quality trends in the Entiat River subbasin

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Abstract

The ISEMP program monitors the status and trend of water quality elements that may affect restoration project effectiveness in the Entiat subbasin. As part of this effort, the PNW Research Station (PNW) measures, analyzes and interprets temporal trends in natural stream water pH, dissolved oxygen, specific conductance and temperature. The Entiat River is currently on the Clean Water Act 303(d) list for pH exceedence, and there is insufficient information to determine the spatial and temporal extent or potential causes of this exceedence. In the late spring 2007, PNW deployed data-logging, multiparameter probes at four locations in the Entiat subbasin to measure water quality parameters, focusing on pH. Data collection was seasonally interrupted by river ice in early December. Daily average pH did not exceed the water quality standard of 8.5 at any of the measurements sites. However, instantaneous values did exceed this standard near the mouth of the Entiat River during late summer – fall period. This suggested that in the lowest portion of the river peaks in pH may be occurring because of photosynthesis caused by high rates of periphyton productivity in response to increased sunlight, temperature, and possible nutrient enrichment. Conversely, dissolved oxygen reached annual low levels during this same late summer - fall period, in part because of increased water temperatures and increased biochemical oxygen demand.

Introduction

The Integrated Status and Effectiveness Monitoring Project (ISEMP) seeks to design, implement, test, and evaluate status and trends and effectiveness monitoring programs for salmon and steelhead populations and habitat. ISEMP pilot projects are being developed in the following three interior Columbia River basins: John Day River, Salmon River, and Wenatchee and Entiat Rivers. The USDA Forest Service has stewardship responsibility for approximately 80% of the land in the Entiat River subbasin. The mission of the Aquatic and

Land Interactions Team at the USDA Forest Service, Pacific Northwest Research Station Laboratory (PNW) in Wenatchee is to increase understanding of the effects of natural processes and human activities on interactions between aquatic and terrestrial ecosystems, with emphasis on understanding the effects of land management on water quality and quantity, watershed processes, and associated biota in the interior Columbia River basin. Part of this mission is to identify limiting factors for recovery of listed species in the Entiat River subbasin and elsewhere, as well as to contribute to monitoring strategies for the Upper Columbia River Salmon Recovery Plan. Under BPA contract # 32338, as part of the ISEMP effort, PNW measures, analyzes and interprets temporal trends in the primary water quality parameters of interest to salmon recovery in the Entiat River subbasin. These include pH, dissolved oxygen, specific conductance, and temperature.

The Entiat River is currently on the Clean Water Act 303(d) list for pH exceedence, and there is insufficient information to determine the spatial and temporal extent or potential causes of this exceedence, which may have a confounding effect on understanding trends in salmon and steelhead production. The primary objective of this project is to better understand patterns of occurrence and spatial and temporal trends in stream water pH, dissolved oxygen, specific conductance and temperature in the Entiat River subbasin, with particular emphasis on pH, owing to reported exceedences of that Washington State water quality standard. This information will provide a basis for assessing the extent and timing of variation in pH and will inform mitigation strategies. Exceedence of pH standards may be limited to the downstream-most portion of the river near the confluence with the Columbia River. At this location relatively warm temperatures, phosphate-rich soils, and nutrient-rich sediments may promote algal and other periphyton activity that can raise pH levels.

Project area

The Entiat River subbasin is located on the eastern slope of the central Cascade Mountains in Washington State, roughly 55 km (34 mi) northwest of Wenatchee. The Entiat River is 85 km (53 mi) long, and its drainage area is approximately 1100 square kilometers (425 square miles). Wildfire, flooding, and historic land use in much of the lower subbasin have been primary disturbance processes. Land use has included flood and channel control projects and structures, grazing, roading, agriculture, timber harvesting, residential development, and recreation (CCCD, 2004).

The Entiat River provides water for agriculture, livestock, domestic use, and recreation. The river also supports the subbasin's ecosystem, by supplying water, sediment, woody debris, nutrients, and other materials to downriver reaches. The river provides critical habitat for three fish species listed under the Endangered Species Act, including endangered spring Chinook salmon (*Oncorhynchus tshawytscha*), endangered summer steelhead (*Oncorhynchus mykiss*), and threatened bull trout (*Salvelinus confluentus*). Salmon populations in the Entiat River have been in decline since European settlement, and an active restoration program, designed to assist in the recovery of listed salmonids, is underway. Restoration work, beginning at least as early as 1996, is primarily focused in the lower river, downstream of the Entiat National Fish Hatchery (RM 6.7) (CCCD, 2004; UCSRB, 2007).

Methods and materials

The current PNW study is measuring water quality and characterizing conditions at four locations in the Entiat River subbasin. We employ In-Situ, Troll 9500¹ data logging multiparameter probes equipped with optical dissolved oxygen sensors at four sites. Site suitability was determined during field reconnaissance based on a spatial distribution that effectively meets project objectives and achieves continuity with the existing stream gauging program. Probe deployment follows the USGS, NAWQA approach, in that a few points that integrate critical drainage areas are sampled intensively. One probe is deployed at each of the stream gauging sites listed in Table 1.

Table 1. Location of water quality probes in Entiat River basin.

River	Location	ID	RKM	Coordinates
Entiat	near Entiat ("Keystone") USGS gauge	12452990	2.4 km	47° 39' 48", 120° 14' 58"
Entiat	near Ardenvoir ("Stormy") USGS gauge	12452890	29 km	47° 49' 07", 120° 25' 19"
Entiat	N. Fk. Campground, WDOE ² /CCD ³ gauge	46A170	58 km	47° 59' 15", 120° 34' 47"
Mad	Mad River at Ardenvoir, USGS gauge	12452800	0.5 km	47° 44' 13", 120° 22' 03"

These probes are designed for field calibration. This is advantageous, because it allows for calibration at the ambient temperature, elevation, and barometric pressure at the measurement site, thereby improving accuracy. Furthermore, the meters remain on site, so interruption of data collection is minimized. Vented cables on these instruments measure real-time barometric pressure used to calculate dissolved oxygen values, thereby improving accuracy compared to fixed-pressure instruments. Probes, once calibrated, provide stable measurements that satisfy USEPA data quality standards and are capable of long-term data logging, minimizing the cost of field crews relative to routine water quality sampling.

The probes are secured in the channel inside protective, four-inch diameter pipe, perforated at the probe location to insure ample water circulation. Probes record water quality parameters (pH, temperature, dissolved oxygen, and conductivity) at 15-minute intervals, allowing us to characterize diel patterns. Probes and batteries are inspected and downloaded at one- to two-week intervals. Checks include calibration and any necessary adjustments. Inspection interval may be extended if instrument drift remains consistently within bounds. Sensor methodologies and manufacturer's stated accuracies are given in Table 2.

¹ The use of trade names in this paper is for the information and convenience of the reader. Such use does not constitute and official endorsement by the U.S. Department of Agriculture of any product to the exclusion of other that may be suitable.

² Washington State Department of Ecology

³ Cascadia Conservation District

Table 2. Sensor methodology and manufacturer's estimated accuracy

Variable	Methodology	Manufacturer's estimated accuracy
pH	Standard Methods 4500-H+, EPA 150.2	0.1 pH units
DO	ASTM #D888-05, Method C – Note: EPA has recommended to each of its Regions Interim Approval for the use of ASTM International D888-05 Standard Test Methods for Dissolved Oxygen in Water, Test Method C for use in measuring Dissolved Oxygen (DO) in wastewater 40 CFR part 136.5 (ATP Case No. N05-0046)	0.2 mg/L
Conductivity	Standard Methods 2510, EPA 120.1	0.5% or 2 μ S/cm
Temperature	EPA 170.1	0.1° C

A fifth probe, calibrated before and after use, is used for hand-held reference checks on field-deployed instrument readings when field instruments are downloaded. Data from reference and field-deployed instruments are compared. Deviations exceeding acceptable standards are flagged for further evaluation and explanation is provided in the database (see "Data handling" section below). Following initial calibration and deployment, sensors will be recalibrated whenever values differ by a predetermined amount from the reference probe (Table 3). Temperature sensors are not user calibrated. Temperature data exceeding the threshold value will be monitored closely and sensors replaced if appropriate. All calibrations are done according to manufacturer's specifications. We meet or exceed the instrument manufacturer's guidelines for calibration QA/QC.

The following procedure will be followed for each of these reference checks:

- a. Allow reference instrument to equilibrate to the stream environment for a minimum of five minutes.
- b. Record both field and reference instrument readings.
- c. Compare the field and reference water quality readings.
- d. If the difference between the field and reference readings is greater than the threshold deviations (Table 3), then the field sensor in question must be calibrated.
- e. Sensor calibration may also be required under the following conditions:
 - i) Consistent, repeated deviant trend in reference checks
 - ii) Environmental disturbance to instrument (e.g. covered in fine sediment, biofouling)
 - iii) Sensor parameters outside manufacturer recommended ranges

Table 3. Calibration threshold deviation from the reference instrument

Variable	Threshold deviation
pH	0.2 pH units
DO	1 mg/L
Conductivity	5 μ S/cm
Temperature	0.5° C

Field Instrument Calibration

Calibrations are performed on field instrument sensors when indicated by reference checks. The calibration procedures for the pH, conductivity, and optical dissolved oxygen (DO) sensors are described below.

pH Calibration

The pH sensors are calibrated with a 2-point calibration using pH 7 and 10 buffer solutions. This ensures that the pH sensors are accurate between pH 7 and 10, the expected range of pH variation for the Entiat River. The In-Situ⁴ software guides the calibration procedure. After each calibration the slope and offset (y-intercept) of the pH calibration curve are noted. If the slope and offset are outside the manufacturer's recommended range (slope: -54 to -62 mV/pH, offset: 390 to 450 mV), then the pH sensor requires maintenance or replacement.

Conductivity Calibration

The conductivity sensors are calibrated with a 1-point calibration using 147 μ S/cm conductivity standard. Conductivity varies with temperature and therefore it can be difficult to know what the standard conductivity reading should be at a given temperature. To account for this, the pre- and post-calibration conductivity readings are compared to allow for a quick determination of the condition and accuracy of the conductivity sensor. After each calibration the cell constant (K_{cell}) for the conductivity sensor is noted. If the K_{cell} is outside the manufacturer recommended range (0.33 to 0.39), then the conductivity sensor requires maintenance or replacement.

DO Calibration

The DO sensors are calibrated with a 2-point calibration in 100% and 0% oxygen environments. The 100% saturation is obtained by bubbling air through deionized water. The 0% saturation is obtained by using a solution of sodium sulfite. DO sensors incorporate barometric pressure into the calculation of percent oxygen saturation. Therefore it is important to calibrate DO sensors at the same elevation (and hence barometric pressure) as the field site. The In-Situ⁵ DO sensor incorporates real-time barometric pressure at each site into the dissolved oxygen calculation. Hence the reference DO sensor is calibrated in the field at the median elevation site (Ardenvoir). Subsequent to this field calibration, the reference DO sensor is checked in a 100% oxygen-saturated environment before and after

⁴ See Footnote 1.

⁵ See Footnote 1.

each reference check day. If the reference DO sensor readings deviate from 100% saturation by more than 10%, then the DO sensor is field recalibrated as described above.

Reference Instrument Calibration

The reference instrument is calibrated before and after every day of reference checks. A 2-point (pH 7 and 10) calibration is performed on the reference pH sensor in the lab before each field day. At the end of the field day, the pH sensor reading in pH 7 buffer solution is checked. The complete 2-point calibration is unnecessary at the end of the day. If the end-of-the-day pH sensor reading deviates from the standard by more than 0.2 pH units (the pH sensor threshold deviation), the reference instrument pH readings for that day are not used. The conductivity sensor is calibrated in the lab before and after each field day with a 1-point calibration in a 147 $\mu\text{S}/\text{cm}$ conductivity standard. Conductivity varies with temperature; hence the pre-calibration and post-calibration conductivities readings are compared to determine the sensor accuracy. If the pre- and post-calibration conductivities deviate by more than 5 $\mu\text{S}/\text{cm}$, the reference conductivity readings for that day are not used.

Data handling

Time series of all data are examined for unusual patterns and values. Data corrected for normal instrument drift, identified through reference checks and field calibrations are considered valid, first-quality data (see Carroll et al., 2006). Data of uncertain quality may occur as a result of ice effects or other factors. These data are identifiable by extreme outliers, erratic fluctuations, or extreme variability relative to surrounding data. These uncertain data are treated as missing, and are not included in reporting or analyses. Nevertheless, all data, regardless of designations or adjustments, are permanently recorded in the database.

Field notes are kept for each sampling event. Notes are entered in a field notebook and include: date and time, sampling personnel, general sampling location, hand-held GPS latitude/longitude coordinates of probe locations, and appropriate results from field measurements.

Data time series are examined to determine short- and long-term temporal trends and timing and longevity of water quality exceedences. Spatial variation is analyzed by comparing results across the array of instrumented sites. Data are stored on computers at the PNW, Wenatchee Laboratory. Following QA/QC procedures, these data are provided to the BPA-ISEMP database.

Value of these data sets will increase as the length of record increases. A minimum of one year will be needed to provide a preliminary assessment of seasonal trends. Conclusions will become more robust as sampling continues. Extraordinary conditions of flow or sediment loading may require additional sampling. River ice in the winter may temporarily interrupt data collection to avoid damage to the probes.

Summary of results

Less than one full year of data were collected during the 2007 funding year, therefore results should be treated as preliminary. Daily and monthly averages are presented in Tables 4 – 8 and in the attached data file. Trends in pH were of particular concern because of a water quality listing for the Entiat River. Daily average pH did not exceed the water quality standard of 8.5 at any of the measurements sites (Figure 1). However, at the Keystone USGS gage, daily peaks exceeded the 8.5 level on several occasions in the afternoon during the late summer - fall period (Figure 2). This suggested that in the lowest portion of the river peaks in pH may be occurring because of photosynthesis caused by high rates of periphyton productivity in response to increased sunlight, temperature, and possible nutrient enrichment. The Mad River may be a significant contributor to these high pH values. Average values in the Mad are near 8 for the late summer - fall period. Conversely, dissolved oxygen at the Keystone site reached annual low levels during this same late summer - fall period, in part because of increased water temperatures and increased biochemical oxygen demand (Figure 2). In general, dissolved oxygen concentration tends to be near saturation in the Entiat River.

Table 4. Monthly averages of water quality parameters in the Entiat subbasin for 2007

<u>North Fork Campground</u>				
Month	Temp	pH	DO	Cond
April	3.77 ^e	7.25 ^e	11.76 ^e	22.81 ^e
May	4.38	7.25	11.63	19.64
June	5.77	7.18 ^h	11.27	17.84
July	9.14	7.41 ^k	10.31	23.08
August	10.14	7.58	10.02	29.45
September	7.97	7.65	10.20	31.59
October	3.77	7.43	11.55	28.16
November	2.10 ^e	7.45 ^e	12.00 ^e	25.64 ^e
December	---	---	---	---

<u>Entiat near Ardenvoir USGS Gage</u>				
Month	Temp	pH	DO	Cond
April	---	---	---	---
May	7.07 ^f	7.38 ^f	10.81 ^f	20.76 ^f
June	8.45 ^k	7.19 ^k	10.90 ^k	21.08 ^k
July	12.75	7.24	10.13	27.72
August	14.30	7.59	9.56	37.74
September	12.00	7.56	10.03	41.30
October	6.50	7.34	11.17	34.85
November	2.45	7.34	12.29	30.54
December	0.01 ^b	7.29 ^b	12.48 ^b	28.58 ^b

<u>Mad River USGS Gage</u>				
Month	Temp	pH	DO	Cond
April	---	---	---	---
May	8.45 ^a	7.56 ^a	11.24 ^a	29.03 ^a
June	9.19	7.55 ^g	10.98	35.31
July	15.39	8.08 ^d	9.50	71.30
August	14.62	8.06	9.64	89.15
September	11.58	8.15	10.32	91.21
October	6.16	8.04	11.60	78.11
November	2.36	7.96	12.60	72.83
December	-0.28 ^b	7.90 ^b	13.26 ^b	63.55 ^b

<u>Entiat near Entiat USGS Gage</u>				
Month	Temp	pH	DO	Cond
April	8.36 ^c	8.40 ^c	11.78 ^c	44.69 ^c
May	8.17 ⁱ	7.33 ^j	12.17 ^j	31.82 ^j
June	9.94	7.31 ⁱ	11.62	29.19
July	15.46	7.61	10.29	43.39
August	16.89	7.96	9.86	76.25
September	14.12	8.12	9.89	89.36
October	8.01	7.99	11.51	74.80
November	3.48	7.83	12.72	63.68
December	0.47 ^b	7.86 ^b	13.41 ^b	57.88 ^b

Superscripts denote incomplete monthly records. The superscript letters represent the total days of data as follows:

a - 3 days (d), b - 4d, c - 5d, d - 13d, e - 14d, f - 16d, g - 21d, h - 22d, i - 24d, j - 25d, k - 26d, l - 27d.

Table 5. North Fork site daily averages of water quality parameters for 2007. Discharge is from the North Fork Campground gauge.

Date	Temperature (C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μ S/cm)	Discharge (cfs)
4/17/07	4.2	7.03	11.55	23.66	350
4/18/07	3.3	7.18	11.81	23.08	342
4/19/07	3.1	7.24	11.86	22.96	335
4/20/07	3.3	7.26	11.80	23.14	326
4/21/07	3.5	7.28	11.75	23.30	322
4/22/07	4.0	7.29	11.66	23.68	319
4/23/07	4.0	7.28	11.72	23.52	333
4/24/07	4.3	7.28	11.70	23.15	373
4/25/07	3.9	7.29	11.77	22.69	403
4/26/07	3.8	7.28	11.84	22.54	412
4/27/07	3.7	7.28	11.85	22.46	417
4/28/07	4.2	7.27	11.71	22.27	467
4/29/07	3.9	7.27	11.77	21.59	516
4/30/07	3.7	7.26	11.80	21.35	529
5/1/07	3.9	7.26	11.69	21.52	533
5/2/07	4.0	7.25	11.59	21.60	543
5/3/07	3.7	7.28	11.73	21.36	549
5/4/07	3.4	7.29	11.80	21.31	538
5/5/07	3.7	7.28	11.84	21.71	520
5/6/07	4.2	7.27	11.75	22.08	522
5/7/07	4.6	7.24	11.64	21.60	599
5/8/07	4.2	7.20	11.67	20.04	730
5/9/07	3.9	7.16	11.79	19.16	866
5/10/07	3.9	7.19	11.81	19.83	884
5/11/07	4.2	7.19	11.75	19.40	866
5/12/07	4.3	7.20	11.67	17.95	895
5/13/07	4.3	7.21	11.77	---	1012
5/14/07	4.2	7.22	11.86	---	1015
5/15/07	3.7	7.21	12.00	19.70	1052
5/16/07	4.6	7.14	11.55	18.78	1129
5/17/07	4.4	7.23	11.59	18.21	1191
5/18/07	4.4	7.25	11.59	18.42	1164
5/19/07	4.5	7.26	11.59	18.70	1123
5/20/07	3.9	7.29	11.66	18.74	1061
5/21/07	4.2	7.32	11.60	19.27	991
5/22/07	4.5	7.32	11.59	19.91	925
5/23/07	4.6	7.33	11.56	20.02	897
5/24/07	4.9	7.32	11.43	19.94	902
5/25/07	4.8	7.31	11.50	19.37	936
5/26/07	5.1	7.30	11.40	19.11	972
5/27/07	5.0	7.30	11.39	18.55	1034
5/28/07	4.7	7.30	11.54	18.41	1047
5/29/07	5.1	7.29	11.49	18.66	1039
5/30/07	5.3	7.26	11.41	18.37	1088

5/31/07	5.3	7.20	11.40	17.76	1166
6/1/07	5.4	6.93	11.35	13.19	1246
6/2/07	5.4	7.00	11.36	7.01	1350
6/3/07	5.3	6.94	11.42	6.58	1469
6/4/07	4.9	6.86	11.54	6.19	1574
6/5/07	4.6	7.11	11.53	7.27	1464
6/6/07	4.2	7.12	11.60	12.44	1204
6/7/07	5.3	7.17	11.37	18.91	1027
6/8/07	5.4	7.29	11.31	19.33	947
6/9/07	5.1	7.30	11.34	18.97	943
6/10/07	5.6	7.26	11.23	18.88	957
6/11/07	5.0	7.29	11.42	18.64	938
6/12/07	5.2	7.26	11.43	19.03	886
6/13/07	5.8	7.21	11.28	19.46	853
6/14/07	5.6	7.20	11.33	19.58	837
6/15/07	5.1	7.19	11.42	19.36	827
6/16/07	5.6	7.20	11.32	20.09	789
6/17/07	6.2	7.22	11.19	20.73	765
6/18/07	6.2	7.24	11.13	20.71	764
6/19/07	6.3	---	11.12	20.70	766
6/20/07	6.8	---	11.02	20.69	801
6/21/07	6.7	---	11.11	19.94	873
6/22/07	6.3	---	11.19	19.70	880
6/23/07	5.9	---	11.36	19.84	831
6/24/07	5.4	---	11.47	20.08	769
6/25/07	5.8	---	11.30	20.92	701
6/26/07	6.4	---	11.18	21.90	663
6/27/07	6.9	7.24	10.97	21.78	660
6/28/07	7.0	7.30	10.85	21.44	677
6/29/07	7.0	7.35	10.90	21.05	707
6/30/07	6.5	7.35	11.07	20.81	703
7/1/07	7.2	7.33	10.88	21.33	686
7/2/07	7.7	7.30	10.70	21.59	687
7/3/07	7.9	7.28	10.71	21.41	709
7/4/07	8.5	7.29	10.57	21.16	759
7/5/07	8.9	---	10.42	20.63	840
7/6/07	8.4	---	10.52	19.95	879
7/7/07	7.7	---	10.69	20.41	787
7/8/07	8.3	---	10.54	21.59	705
7/9/07	8.4	---	10.53	21.74	676
7/10/07	9.0	7.51	10.40	22.25	649
7/11/07	9.5	7.46	10.23	22.49	659
7/12/07	9.3	7.44	10.27	21.84	675
7/13/07	9.2	7.42	10.31	21.70	675
7/14/07	9.8	7.45	10.16	22.03	660
7/15/07	9.8	7.44	10.15	21.92	643
7/16/07	9.1	7.46	10.28	22.25	565
7/17/07	9.1	7.48	10.24	23.33	484
7/18/07	8.8	7.45	10.31	23.43	484

7/19/07	8.9	7.42	10.33	22.93	478
7/20/07	7.9	7.41	10.55	23.15	411
7/21/07	8.4	7.41	10.48	24.24	359
7/22/07	9.5	7.38	10.25	24.83	371
7/23/07	10.4	7.36	10.02	24.34	402
7/24/07	9.9	7.39	10.10	23.75	395
7/25/07	10.0	7.40	10.08	24.90	343
7/26/07	10.5	7.42	9.96	25.78	318
7/27/07	10.4	7.42	9.98	25.74	304
7/28/07	10.7	7.42	9.90	26.22	287
7/29/07	10.7	7.44	9.89	26.28	279
7/30/07	9.7	7.45	10.12	25.83	258
7/31/07	9.6	7.45	10.18	26.42	222
8/1/07	10.4	7.46	10.01	27.61	197
8/2/07	11.0	7.46	9.83	28.11	194
8/3/07	10.7	7.48	9.90	27.65	190
8/4/07	10.2	7.51	10.02	27.50	171
8/5/07	10.5	7.50	9.93	28.15	155
8/6/07	10.8	7.51	9.83	28.80	160
8/7/07	10.6	7.54	9.87	28.37	145
8/8/07	10.6	7.54	9.92	28.19	135
8/9/07	9.6	7.57	10.14	27.53	130
8/10/07	9.5	7.57	10.18	27.98	120
8/11/07	9.6	7.58	10.15	28.49	112
8/12/07	9.8	7.61	10.10	28.93	107
8/13/07	9.9	7.60	10.12	29.15	102
8/14/07	10.6	7.59	9.95	30.22	98
8/15/07	11.0	7.58	9.83	30.53	99
8/16/07	11.5	7.58	9.66	30.52	102
8/17/07	10.5	7.59	9.93	29.19	104
8/18/07	10.0	7.62	10.02	29.12	96
8/19/07	9.9	7.62	10.02	29.54	94
8/20/07	8.9	7.62	10.31	28.96	90
8/21/07	9.5	7.61	10.21	29.60	88
8/22/07	9.6	7.61	10.15	29.80	86
8/23/07	10.2	7.60	10.01	30.39	82
8/24/07	10.4	7.59	9.93	30.68	80
8/25/07	10.1	7.60	9.98	30.51	78
8/26/07	10.0	7.64	10.03	30.60	77
8/27/07	8.6	7.64	10.38	29.59	74
8/28/07	9.0	7.63	10.31	30.55	70
8/29/07	10.0	7.63	10.07	31.91	67
8/30/07	10.7	7.62	9.87	32.59	68
8/31/07	10.4	7.65	9.95	32.12	70
9/1/07	9.9	7.63	10.08	31.67	67
9/2/07	9.9	7.64	10.07	32.30	64
9/3/07	10.5	7.66	9.92	33.35	62
9/4/07	11.0	7.64	9.77	32.77	61
9/5/07	10.6	7.64	9.88	32.07	60

9/6/07	10.4	7.65	9.95	32.02	59
9/7/07	8.6	7.67	10.38	30.59	57
9/8/07	7.8	7.67	10.61	30.20	54
9/9/07	7.6	7.66	10.67	30.51	52
9/10/07	8.2	7.66	10.52	31.40	50
9/11/07	9.1	7.66	10.24	32.53	49
9/12/07	9.4	7.66	10.11	32.67	49
9/13/07	9.3	7.66	10.11	32.26	48
9/14/07	9.2	7.67	10.10	32.11	47
9/15/07	9.3	7.67	9.59	32.32	46
9/16/07	8.4	7.70	9.55	31.56	45
9/17/07	7.6	7.69	9.56	31.00	44
9/18/07	7.0	7.71	9.82	30.74	42
9/19/07	7.1	7.71	9.77	31.05	42
9/20/07	6.5	7.71	9.85	30.83	40
9/21/07	6.4	7.71	9.99	31.02	39
9/22/07	7.4	7.72	9.68	32.13	38
9/23/07	5.8	7.71	10.19	30.95	37
9/24/07	5.5	7.71	10.51	30.73	36
9/25/07	6.3	7.70	10.77	31.62	35
9/26/07	6.5	7.60	10.86	31.92	
9/27/07	6.9	7.52	10.68	32.41	
9/28/07	7.2	7.52	10.49	32.61	
9/29/07	4.7	7.49	11.22	30.35	
9/30/07	5.0	7.46	11.09	29.99	
10/1/07	5.0	7.44	11.15	30.09	
10/2/07	5.4	7.44	11.02	30.12	
10/3/07	4.9	7.45	11.16	29.27	
10/4/07	4.0	7.45	11.37	29.56	
10/5/07	3.5	7.43	11.53	29.18	
10/6/07	3.9	7.43	11.54	29.78	
10/7/07	5.5	7.42	11.09	31.14	
10/8/07	4.9	7.41	11.25	29.21	
10/9/07	5.9	7.40	10.94	30.21	
10/10/07	6.4	7.41	10.78	30.97	
10/11/07	5.2	7.43	11.18	29.80	
10/12/07	5.3	7.43	11.09	29.90	
10/13/07	4.4	7.42	11.31	29.40	
10/14/07	4.2	7.43	11.39	29.40	
10/15/07	5.0	7.42	11.12	30.16	
10/16/07	5.3	7.45	10.91	30.37	
10/17/07	4.0	7.46	11.35	29.21	
10/18/07	2.4	7.43	11.67	27.52	
10/19/07	2.7	7.43	11.63	26.87	
10/20/07	2.9	7.46	11.70	27.61	
10/21/07	2.8	7.45	11.97	27.96	
10/22/07	4.5	7.45	11.55	29.14	
10/23/07	4.0	7.41	11.61	28.21	
10/24/07	4.1	7.42	11.51	27.08	

10/25/07	2.7	7.40	11.96	24.82
10/26/07	1.1	7.41	12.44	23.89
10/27/07	0.9	7.42	12.48	23.85
10/28/07	1.5	7.42	12.31	24.31
10/29/07	2.2	7.43	12.05	24.95
10/30/07	1.2	7.43	12.35	24.50
10/31/07	0.8	7.44	12.53	24.43
11/1/07	1.1	7.44	12.38	24.81
11/2/07	0.5	7.44	12.65	24.67
11/3/07	2.2	7.45	12.06	25.96
11/4/07	3.8	7.46	11.49	27.22
11/5/07	1.6	7.45	12.17	25.64
11/6/07	1.1	7.45	12.32	25.28
11/7/07	2.6	7.45	11.93	26.59
11/8/07	3.9	7.42	11.41	27.33
11/9/07	4.2	7.45	11.32	27.34
11/10/07	3.2	7.47	11.57	25.70
11/11/07	1.8	7.48	12.09	25.24
11/12/07	0.7	7.45	12.12	23.81
11/13/07	0.6	7.48	12.54	23.74
11/14/07	-0.1	7.49	13.00	23.80

Table 6. Ardenvoir site daily averages of water quality parameters for 2007. Discharge is from the Ardenvoir gauge.

Date	Temperature (C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μ S/cm)	Discharge (cfs)
5/16/07	8.1	7.56	9.95	21.57	1791
5/17/07	6.8	7.50	10.51	20.21	1975
5/18/07	6.5	7.47	10.86	19.99	1955
5/19/07	6.5	7.49	11.03	20.16	1835
5/20/07	5.8	7.55	11.19	20.08	1675
5/21/07	6.4	7.56	11.14	20.91	1512
5/22/07	6.7	7.23	11.16	21.54	1333
5/23/07	6.9	7.25	10.99	21.83	1250
5/24/07	7.3	7.26	10.73	22.06	1218
5/25/07	7.2	7.22	10.71	21.44	1294
5/26/07	7.6	7.22	10.57	21.31	1352
5/27/07	7.7	7.25	10.45	20.81	1505
5/28/07	6.9	7.26	10.79	20.09	1542
5/29/07	7.4	7.33	10.89	20.46	1533
5/30/07	7.8	7.54	11.03	20.21	1605
5/31/07	7.8	7.40	11.03	19.45	1821
6/1/07	7.8	7.18	10.98	19.03	2064
6/2/07	7.9	7.06	10.93	18.62	2340
6/3/07	7.9	7.20	10.88	17.90	2786
6/4/07	7.2	6.96	10.98	17.03	3197
6/5/07	6.7	6.51	11.04	17.11	2961
6/6/07	5.5	6.21	11.41	17.47	2312
6/7/07	8.7	7.52	10.54	20.95	1499
6/8/07	8.1	7.53	10.53	20.69	1363
6/9/07	---	---	---	---	1291
6/10/07	---	---	---	---	1310
6/11/07	---	---	---	---	1269
6/12/07	---	---	---	---	1177
6/13/07	9.2	7.19	10.65	21.69	1107
6/14/07	8.0	7.38	11.01	20.93	1072
6/15/07	7.5	7.47	11.07	20.70	1051
6/16/07	8.0	7.36	10.98	21.37	984
6/17/07	8.9	7.22	10.73	22.37	924
6/18/07	9.0	7.14	10.82	22.49	909
6/19/07	8.9	7.18	10.97	22.41	907
6/20/07	9.6	7.25	10.81	22.45	938
6/21/07	9.8	7.16	10.79	21.71	1040
6/22/07	9.2	7.20	10.94	21.09	1071
6/23/07	8.6	7.30	11.08	21.08	1012
6/24/07	8.2	7.41	11.16	21.38	912
6/25/07	8.2	7.43	11.22	22.13	808
6/26/07	9.0	7.32	11.02	23.22	738
6/27/07	9.0	7.30	10.88	23.34	718
6/28/07	9.6	7.16	10.63	23.87	727

6/29/07	9.9	7.17	10.58	23.81	750
6/30/07	9.2	7.17	10.80	23.21	742
7/1/07	9.9	7.18	10.58	24.03	721
7/2/07	10.8	7.18	10.30	24.79	711
7/3/07	11.0	7.18	10.18	24.93	721
7/4/07	11.7	7.15	10.12	24.82	761
7/5/07	12.3	7.15	10.05	24.43	842
7/6/07	12.1	7.13	10.13	23.45	917
7/7/07	10.9	7.15	10.35	23.48	828
7/8/07	11.5	7.18	10.13	24.92	710
7/9/07	11.8	7.19	10.06	25.33	664
7/10/07	12.1	7.17	10.14	25.71	623
7/11/07	13.0	7.23	10.20	26.13	615
7/12/07	12.7	7.24	10.27	25.74	624
7/13/07	12.4	7.24	10.41	25.41	618
7/14/07	13.0	7.26	10.31	25.66	601
7/15/07	13.9	7.27	10.08	26.31	583
7/16/07	12.7	7.28	10.30	26.23	524
7/17/07	12.6	7.24	10.25	27.48	452
7/18/07	12.3	7.21	10.26	28.03	441
7/19/07	12.7	7.23	10.30	28.07	438
7/20/07	11.5	7.23	10.50	27.78	396
7/21/07	11.7	7.23	10.49	28.98	359
7/22/07	13.1	7.23	10.23	30.56	343
7/23/07	14.1	7.22	9.99	30.51	359
7/24/07	14.3	7.24	9.90	30.03	360
7/25/07	14.0	7.22	9.95	30.56	327
7/26/07	14.6	7.29	9.74	31.91	305
7/27/07	14.6	7.37	9.75	32.27	293
7/28/07	14.9	7.36	9.67	32.80	282
7/29/07	15.1	7.36	9.58	33.22	274
7/30/07	14.3	7.36	9.78	32.82	263
7/31/07	13.9	7.44	9.91	33.05	246
8/1/07	14.5	7.53	9.81	34.29	229
8/2/07	15.4	7.56	9.48	35.56	221
8/3/07	15.4	7.58	9.36	35.66	218
8/4/07	14.8	7.57	9.29	35.29	212
8/5/07	15.0	7.57	9.06	35.95	204
8/6/07	15.3	7.58	8.79	36.38	204
8/7/07	15.1	7.60	8.72	36.57	197
8/8/07	14.9	7.60	8.69	36.35	192
8/9/07	14.2	7.58	8.78	35.92	187
8/10/07	13.8	7.57	9.59	35.79	178
8/11/07	13.9	7.59	9.81	36.54	169
8/12/07	13.1	7.59	9.89	36.27	162
8/13/07	13.6	7.58	9.93	36.98	158
8/14/07	14.7	7.59	9.57	38.51	151
8/15/07	15.3	7.62	9.39	39.42	148
8/16/07	15.5	7.61	9.25	39.42	148

8/17/07	15.1	7.61	9.36	38.72	149
8/18/07	14.2	7.61	9.71	37.62	145
8/19/07	13.6	7.61	9.78	37.37	143
8/20/07	12.1	7.60	10.12	36.26	144
8/21/07	12.8	7.59	10.10	37.23	141
8/22/07	13.7	7.60	9.81	38.39	138
8/23/07	14.3	7.59	9.68	39.18	132
8/24/07	14.6	7.60	9.62	39.76	127
8/25/07	14.7	7.62	9.62	40.16	124
8/26/07	14.1	7.64	9.76	39.60	121
8/27/07	13.1	7.61	10.06	38.67	119
8/28/07	13.1	7.60	10.11	38.93	116
8/29/07	14.0	7.61	9.88	40.30	113
8/30/07	14.8	7.58	9.66	41.49	111
8/31/07	14.7	7.60	9.70	41.39	110
9/1/07	14.0	7.59	9.89	40.40	109
9/2/07	14.3	7.59	9.83	40.87	107
9/3/07	15.1	7.61	9.66	41.95	104
9/4/07	15.2	7.60	9.53	42.30	101
9/5/07	15.0	7.61	9.59	42.27	100
9/6/07	14.9	7.63	9.61	42.36	99
9/7/07	13.5	7.62	10.09	41.11	97
9/8/07	12.3	7.60	10.49	39.93	95
9/9/07	11.9	7.59	10.55	39.78	93
9/10/07	12.4	7.59	10.40	40.50	90
9/11/07	13.3	7.57	10.18	41.83	89
9/12/07	13.8	7.56	9.72	42.77	87
9/13/07	13.6	7.55	9.77	42.60	86
9/14/07	13.3	7.56	9.82	42.34	85
9/15/07	13.5	7.55	9.71	42.73	84
9/16/07	12.4	7.57	9.83	41.85	83
9/17/07	11.8	7.55	9.83	41.17	83
9/18/07	11.2	7.56	10.00	40.75	84
9/19/07	10.9	7.55	10.10	40.50	84
9/20/07	10.2	7.55	10.12	39.95	84
9/21/07	10.0	7.54	10.08	40.34	81
9/22/07	10.5	7.57	9.87	41.15	79
9/23/07	9.8	7.54	10.11	40.67	78
9/24/07	9.8	7.54	10.11	41.06	77
9/25/07	10.2	7.54	10.04	41.69	77
9/26/07	10.3	7.48	10.03	42.00	76
9/27/07	10.4	7.47	10.32	42.35	76
9/28/07	10.3	7.49	10.04	42.58	75
9/29/07	8.2	7.48	10.75	40.18	75
9/30/07	8.0	7.46	10.72	38.97	80
10/1/07	8.2	7.46	10.83	37.10	88
10/2/07	8.5	7.45	10.74	37.54	90
10/3/07	7.6	7.44	10.90	34.18	110
10/4/07	7.1	7.37	10.82	35.63	91

10/5/07	7.3	7.35	10.84	36.75	87
10/6/07	7.3	7.38	10.93	37.14	84
10/7/07	8.6	7.38	10.59	38.68	83
10/8/07	8.0	7.38	10.79	36.81	95
10/9/07	8.6	7.36	10.62	37.34	90
10/10/07	9.2	7.34	10.37	38.18	88
10/11/07	8.1	7.36	10.78	36.95	90
10/12/07	8.3	7.34	10.71	37.39	88
10/13/07	7.5	7.30	10.86	36.71	87
10/14/07	7.3	7.32	10.94	36.76	85
10/15/07	7.6	7.31	10.79	37.18	85
10/16/07	8.0	7.32	10.58	37.52	85
10/17/07	6.8	7.36	10.91	36.30	85
10/18/07	5.3	7.33	11.16	34.82	87
10/19/07	5.7	7.33	11.19	34.24	93
10/20/07	5.3	7.33	11.35	33.19	95
10/21/07	4.9	7.32	11.65	33.61	90
10/22/07	6.4	7.33	11.39	35.18	91
10/23/07	7.3	7.30	11.10	35.10	103
10/24/07	6.8	7.31	11.13	33.99	107
10/25/07	5.5	7.30	11.51	31.81	111.30
10/26/07	3.9	7.24	12.03	30.14	105.49
10/27/07	3.1	7.26	12.25	29.70	104.72
10/28/07	3.4	7.26	12.17	30.00	105.38
10/29/07	3.7	7.29	12.01	30.33	103.90
10/30/07	3.6	7.29	12.03	30.30	101.80
10/31/07	2.5	7.29	12.37	29.67	98.88
11/1/07	2.7	7.30	12.30	29.92	99.02
11/2/07	2.2	7.29	12.47	29.79	94.42
11/3/07	3.1	7.30	12.25	30.66	96.80
11/4/07	6.0	7.33	11.29	33.35	96.47
11/5/07	4.3	7.32	11.75	31.65	96.02
11/6/07	3.1	7.33	12.10	30.86	93.96
11/7/07	3.5	7.33	12.03	31.31	92.92
11/8/07	5.0	7.33	11.56	32.60	95.77
11/9/07	6.1	7.33	11.20	32.99	101.54
11/10/07	5.7	7.33	11.21	32.11	105.42
11/11/07	3.8	7.34	11.83	30.17	100.36
11/12/07	3.6	7.34	11.82	30.38	102.59
11/13/07	2.9	7.34	12.23	28.96	102.33
11/14/07	1.8	7.35	12.60	28.89	95.28
11/15/07	2.7	7.35	12.24	29.77	100.13
11/16/07	3.0	7.34	12.11	29.14	106.95
11/17/07	2.7	7.34	12.17	28.65	106.97
11/18/07	2.6	7.34	12.21	28.82	105.13
11/19/07	2.8	7.36	12.27	29.60	99.94
11/20/07	1.9	7.35	12.56	29.48	94.46
11/21/07	0.9	7.36	12.82	29.92	85.16
11/22/07	0.3	7.29	12.76	32.02	78.85

11/23/07	0.0	7.29	12.55	39.36	71.98
11/24/07	0.5	7.37	12.87	30.08	86.06
11/25/07	0.5	7.36	12.89	29.78	83.69
11/26/07	0.5	7.37	12.86	29.87	83.33
11/27/07	0.2	7.36	12.85	29.56	85.71
11/28/07	0.0	7.29	13.02	29.76	89.26
11/29/07	0.4	7.36	12.99	28.30	94.02
11/30/07	0.5	7.36	12.97	28.32	92.88
12/1/07	0.2	7.36	12.81	28.14	90.66
12/2/07	-0.1	7.31	12.41	29.93	82.45
12/3/07	-0.1	7.24	11.97	31.46	83.63
12/4/07	0.0	7.25	12.75	24.78	128.82

Table 7. Mad River site daily averages of water quality parameters for 2007. Discharge is from the Mad River gauge.

Date	Temperature (C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μ S/cm)	Discharge (cfs)
5/29/07	9.0	7.58	11.11	30.38	411
5/30/07	8.1	7.55	11.35	28.94	410
5/31/07	8.2	7.55	11.26	27.79	438
6/1/07	8.4	7.54	11.21	26.51	472
6/2/07	8.5	7.50	11.17	25.55	502
6/3/07	8.8	7.47	11.11	24.45	542
6/4/07	8.2	7.45	11.26	23.00	585
6/5/07	7.4	7.51	11.42	23.42	512
6/6/07	6.3	7.56	11.69	25.24	404
6/7/07	7.5	7.55	11.43	28.69	340
6/8/07	8.2	7.56	11.24	30.90	310
6/9/07	7.9	7.55	11.27	31.87	296
6/10/07	8.6	7.55	11.08	32.55	286
6/11/07	7.9	7.59	11.32	32.18	273
6/12/07	7.9	7.59	11.36	33.11	257
6/13/07	9.3	7.58	10.98	35.10	245
6/14/07	8.7	7.59	11.13	34.95	234
6/15/07	8.5	7.61	11.19	35.26	227
6/16/07	8.5	7.62	11.13	36.05	215
6/17/07	9.1	7.61	11.01	37.36	203
6/18/07	9.6	7.58	10.87	38.41	194
6/19/07	9.8	7.60	10.82	39.07	188
6/20/07	10.9	7.53	10.52	40.24	184
6/21/07	11.5	7.49	10.40	40.06	184
6/22/07	10.8	---	10.6	39.1	182
6/23/07	10.0	---	10.8	38.9	173
6/24/07	9.7	---	10.8	39.7	166
6/25/07	9.3	---	11.0	40.4	155
6/26/07	9.9	---	10.86	42.60	146
6/27/07	10.6	---	10.60	44.62	138
6/28/07	11.2	---	10.41	46.15	134
6/29/07	11.6	---	10.33	47.01	129
6/30/07	11.0	---	10.54	46.87	124
7/1/07	11.7	---	10.32	48.81	118
7/2/07	12.9	---	10.05	51.19	113
7/3/07	13.4	---	9.97	52.67	107
7/4/07	14.4	---	9.75	54.84	103
7/5/07	15.7	---	9.44	57.43	99
7/6/07	16.3	---	9.29	59.05	94
7/7/07	15.0	---	9.57	58.49	89
7/8/07	14.9	---	9.59	59.61	85
7/9/07	15.0	---	9.60	61.07	81
7/10/07	15.0	---	9.62	63.72	77
7/11/07	16.0	---	9.40	67.75	73

7/12/07	15.9	---	9.41	70.35	70
7/13/07	15.4	---	9.50	71.67	69
7/14/07	16.5	---	9.30	74.19	66
7/15/07	17.4	---	9.10	76.68	64
7/16/07	16.3	---	9.31	76.04	63
7/17/07	15.6	---	9.40	75.97	61
7/18/07	15.2	---	9.44	75.95	65
7/19/07	15.3	8.08	9.50	75.49	63
7/20/07	14.1	8.05	9.72	74.87	61
7/21/07	14.0	8.04	9.78	74.68	60
7/22/07	15.5	8.03	9.50	78.31	58
7/23/07	16.7	8.06	9.23	81.44	56
7/24/07	16.6	8.09	9.25	81.98	53
7/25/07	15.8	8.08	9.40	81.55	52
7/26/07	16.3	8.08	9.30	83.19	49
7/27/07	16.3	8.10	9.30	83.97	47
7/28/07	16.6	8.10	9.23	85.14	46
7/29/07	16.6	8.12	9.24	85.92	45
7/30/07	15.4	8.12	9.50	84.19	45
7/31/07	15.2	8.07	9.55	84.21	43
8/1/07	15.7	8.04	9.46	85.70	42
8/2/07	16.4	8.05	9.28	87.64	40
8/3/07	16.4	8.07	9.29	88.40	39
8/4/07	15.5	8.06	9.47	87.00	39
8/5/07	15.9	8.04	9.36	87.99	39
8/6/07	16.2	8.03	9.30	88.06	40
8/7/07	16.2	8.03	9.30	88.94	38
8/8/07	15.5	7.98	9.46	88.21	38
8/9/07	14.4	7.98	9.63	86.40	37
8/10/07	14.2	7.99	9.75	86.46	36
8/11/07	13.9	8.00	9.81	86.14	35
8/12/07	14.1	8.03	9.78	86.93	35
8/13/07	14.0	8.00	9.82	86.79	36
8/14/07	14.9	8.01	9.58	89.31	34
8/15/07	15.7	8.03	9.42	91.49	33
8/16/07	15.7	8.01	9.35	92.21	33
8/17/07	15.0	8.02	9.53	91.43	32
8/18/07	14.3	8.06	9.68	90.10	32
8/19/07	13.9	8.04	9.75	89.48	33
8/20/07	12.5	8.02	10.09	85.80	35
8/21/07	12.8	8.01	10.05	85.93	35
8/22/07	14.1	8.02	9.73	89.03	33
8/23/07	14.4	8.02	9.66	90.56	31
8/24/07	14.3	8.09	9.68	91.11	30
8/25/07	14.9	8.17	9.54	93.04	29
8/26/07	14.1	8.20	9.76	91.74	29
8/27/07	12.4	8.16	10.13	88.52	29
8/28/07	12.8	8.16	10.09	89.34	28
8/29/07	13.7	8.16	9.86	91.58	28

8/30/07	14.4	8.13	9.64	93.55	27
8/31/07	14.8	8.16	9.59	94.82	27
9/1/07	13.7	8.11	9.82	93.15	26
9/2/07	13.9	8.12	9.79	93.51	26
9/3/07	15.1	8.13	9.52	96.37	25
9/4/07	15.2	8.09	9.45	97.13	25
9/5/07	15.1	8.10	9.52	97.31	25
9/6/07	15.0	8.10	9.57	97.33	25
9/7/07	13.3	8.11	9.98	94.04	24
9/8/07	11.9	8.08	10.35	91.26	24
9/9/07	11.1	8.06	10.50	89.63	24
9/10/07	11.5	8.06	10.40	90.44	24
9/11/07	12.5	8.10	10.09	92.72	23
9/12/07	13.6	8.16	9.79	95.46	22
9/13/07	12.8	8.15	10.03	94.10	22
9/14/07	12.4	8.16	10.11	93.27	22
9/15/07	12.8	8.18	10.01	94.26	22
9/16/07	12.5	8.24	10.08	93.83	22
9/17/07	11.5	8.17	10.29	92.16	23
9/18/07	10.9	8.21	10.50	90.24	23
9/19/07	10.4	8.18	10.62	89.32	23
9/20/07	9.6	8.18	10.75	87.48	23
9/21/07	9.3	8.16	10.80	87.16	23
9/22/07	10.1	8.20	10.57	88.79	
9/23/07	8.6	8.15	10.98	85.97	
9/24/07	8.8	8.14	11.04	86.16	
9/25/07	10.0	8.16	10.68	88.52	
9/26/07	9.8	8.16	10.75	88.46	
9/27/07	10.4	8.24	10.58	89.87	
9/28/07	10.1	8.21	10.52	89.65	
9/29/07	7.7	8.20	11.25	84.40	
9/30/07	7.9	8.14	11.11	84.17	
10/1/07	8.0	8.14	11.15	81.88	
10/2/07	8.3	8.14	11.05	81.10	
10/3/07	7.3	8.09	11.25	73.32	
10/4/07	6.7	8.14	11.44	76.06	
10/5/07	6.2	8.12	11.59	77.85	
10/6/07	6.8	8.15	11.49	79.72	
10/7/07	8.4	8.17	11.03	83.45	
10/8/07	8.1	8.16	11.10	81.18	
10/9/07	8.2	8.14	11.01	81.91	
10/10/07	9.0	8.15	10.78	84.92	
10/11/07	7.9	8.18	11.19	82.82	
10/12/07	8.4	8.18	11.03	84.15	
10/13/07	6.9	8.13	11.41	81.57	
10/14/07	6.7	8.15	11.48	81.43	
10/15/07	7.3	8.15	11.20	83.33	
10/16/07	7.8	8.17	10.98	84.39	
10/17/07	6.0	8.05	11.53	79.72	

10/18/07	4.8	7.90	11.86	76.63
10/19/07	5.1	7.91	11.73	76.93
10/20/07	4.8	7.91	11.91	75.40
10/21/07	4.8	7.92	12.14	72.39
10/22/07	6.5	7.91	11.65	80.13
10/23/07	6.6	7.83	11.54	73.85
10/24/07	6.8	7.86	11.37	74.35
10/25/07	5.4	7.88	11.83	73.67
10/26/07	3.2	7.90	12.49	71.34
10/27/07	2.5	7.92	12.66	72.36
10/28/07	3.0	7.92	12.47	73.26
10/29/07	3.9	7.94	12.13	74.76
10/30/07	3.2	7.94	12.37	73.89
10/31/07	2.5	7.96	12.64	73.79
11/1/07	2.8	7.96	12.50	74.45
11/2/07	2.1	7.94	12.80	73.12
11/3/07	4.0	7.96	12.09	77.69
11/4/07	6.7	7.97	11.12	82.18
11/5/07	3.9	7.95	12.06	76.15
11/6/07	2.9	7.97	12.36	74.89
11/7/07	4.1	7.97	11.96	77.02
11/8/07	5.7	7.95	11.44	80.06
11/9/07	6.2	7.97	11.27	79.77
11/10/07	5.3	7.96	11.46	77.35
11/11/07	3.5	7.97	12.10	73.39
11/12/07	4.0	7.98	11.91	74.94
11/13/07	2.9	7.95	12.39	70.51
11/14/07	1.7	7.97	12.88	72.43
11/15/07	2.5	7.97	12.48	73.05
11/16/07	3.3	7.95	12.23	72.18
11/17/07	3.0	7.94	12.34	68.36
11/18/07	2.9	7.94	12.41	66.84
11/19/07	2.7	7.95	12.53	71.32
11/20/07	1.7	7.95	12.98	71.54
11/21/07	0.3	7.96	13.48	72.65
11/22/07	-0.3	7.98	13.64	78.03
11/23/07	-0.3	7.99	13.61	78.98
11/24/07	-0.3	7.95	13.47	69.51
11/25/07	-0.1	7.95	13.49	68.39
11/26/07	0.0	7.96	13.44	68.97
11/27/07	-0.2	7.95	13.42	67.49
11/28/07	-0.3	7.93	13.53	65.64
11/29/07	0.1	7.93	13.41	63.44
11/30/07	0.3	7.93	13.31	64.49
12/1/07	-0.2	7.94	13.27	64.62
12/2/07	-0.3	7.94	13.21	69.32
12/3/07	-0.3	7.88	13.26	62.39
12/4/07	-0.3	7.84	13.30	57.86

Table 8. Keystone site daily averages of water quality parameters for 2007. Discharge is from the Keystone gauge.

Date	Temperature (C)	pH	Dissolved Oxygen (mg/L)	Conductivity (μS/cm)	Discharge (cfs)
4/25/07	8.8	8.61	11.86	46.51	868
4/26/07	7.4	8.13	11.94	44.25	899
4/27/07	7.7	8.19	11.81	43.30	912
4/28/07	9.3	8.17	11.53	---	972
4/29/07	8.6	8.91	11.78	---	1057
4/30/07	---	---	---	---	---
5/1/07	7.9	7.56	12.10	40.77	1138
5/2/07	7.7	7.63	12.29	40.35	1166
5/3/07	7.2	7.72	12.59	39.08	1186
5/4/07	7.4	7.70	12.57	39.16	1169
5/5/07	7.0	7.73	12.81	38.90	1138
5/6/07	7.7	7.75	12.66	39.74	1119
5/7/07	9.4	7.61	12.10	40.28	1194
5/8/07	9.1	7.30	11.95	35.69	1452
5/9/07	8.1		12.11	31.27	1716
5/10/07	6.9		12.42	27.98	1824
5/11/07	---	---	---	---	1809
5/12/07	---	---	---	---	1846
5/13/07	---	---	---	---	2031
5/14/07	---	---	---	---	2055
5/15/07	9.7	7.27	11.62	30.75	2011
5/16/07	8.3	7.22	12.05	28.79	2227
5/17/07	8.1	7.24	12.13	27.10	2451
5/18/07	7.7	7.29	12.23	27.11	2465
5/19/07	7.7	7.3	12.3	27.2	2356
5/20/07	6.9	7.3	12.4	27.3	2169
5/21/07	7.5	7.3	12.3	29.7	2008
5/22/07	7.9	7.3	12.2	30.4	1732
5/23/07	8.2	7.2	12.15	31.09	1634
5/24/07	8.6	7.2	11.97	31.34	1610
5/25/07	8.5	7.2	12.07	30.10	1672
5/26/07	8.9	7.2	11.91	29.40	1746
5/27/07	9.2	7.1	11.80	28.27	1896
5/28/07	8.1	7.1	12.17	26.89	1990
5/29/07	8.6	7.1	12.09	27.31	1937
5/30/07	9.2	7.1	11.91	27.22	2000
5/31/07	9.3	7.0	11.83	26.00	2298
6/1/07	9.3	6.9	11.74	25.47	2493
6/2/07	9.4	6.8	11.64	25.64	2744
6/3/07	9.4	6.7	11.47	26.38	3067
6/4/07	8.8	6.7	11.48	26.35	3448
6/5/07	8.0	6.7	11.75	24.75	3334
6/6/07	6.8	6.7	12.30	23.17	2613
6/7/07	9.7	---	11.69	27.00	1879
6/8/07	9.3	---	11.77	27.66	1628
6/9/07	8.6	---	11.91	27.78	1563

6/10/07	9.4	---	11.70	27.96	1567
6/11/07	8.8	---	11.93	27.35	1537
6/12/07	8.7	---	12.04	27.82	1447
6/13/07	10.0	7.5	11.70	29.28	1364
6/14/07	9.6	7.5	11.79	29.08	1329
6/15/07	9.0	7.44	11.90	28.91	1303
6/16/07	9.3	7.48	11.84	29.73	1243
6/17/07	10.5	7.51	11.54	31.35	1172
6/18/07	10.9	7.52	11.44	31.59	1149
6/19/07	10.6	7.52	11.50	31.13	1142
6/20/07	11.5	7.51	11.26	31.36	1156
6/21/07	11.8	7.46	11.24	30.03	1242
6/22/07	11.1	7.42	11.40	28.78	1285
6/23/07	10.4	7.43	11.56	28.71	1238
6/24/07	10.2	7.45	11.60	29.59	1143
6/25/07	9.9	7.46	11.76	30.79	1035
6/26/07	10.8	7.49	11.56	32.87	943
6/27/07	11.2	7.51	11.34	33.94	909
6/28/07	11.6	7.51	11.20	34.20	905
6/29/07	11.9	7.51	11.14	33.82	923
6/30/07	11.5	7.52	11.35	33.07	923
7/1/07	12.1	7.53	11.17	34.16	891
7/2/07	13.2	7.53	10.90	35.18	870
7/3/07	13.6	7.54	10.84	35.07	871
7/4/07	14.1	7.54	10.69	34.77	903
7/5/07	14.9	7.54	10.47	33.90	979
7/6/07	14.9	7.51	10.42	31.96	1065
7/7/07	13.7	7.54	10.73	31.90	984
7/8/07	14.1	7.57	10.66	34.57	850
7/9/07	14.5	7.58	10.56	36.26	795
7/10/07	14.8	7.57	10.54	37.40	740
7/11/07	15.6	7.56	10.33	38.45	721
7/12/07	15.4	7.56	10.34	37.86	728
7/13/07	14.7	7.51	10.48	37.11	721
7/14/07	15.5	7.55	10.34	38.18	706
7/15/07	16.7	7.56	10.03	39.50	685
7/16/07	15.7	7.57	10.24	39.78	637
7/17/07	15.0	7.56	10.28	41.88	560
7/18/07	15.1	7.50	10.12	44.09	537
7/19/07	15.2	7.58	10.28	44.26	539
7/20/07	14.3	7.63	10.50	44.60	491
7/21/07	14.2	7.66	10.59	46.90	451
7/22/07	16.0	7.67	10.22	50.90	423
7/23/07	17.2	7.66	9.90	51.41	432
7/24/07	17.3	7.68	9.84	50.31	431
7/25/07	16.9	7.66	9.93	51.17	401
7/26/07	17.5	7.69	9.80	54.11	376
7/27/07	17.6	7.71	9.69	55.76	357
7/28/07	17.8	7.72	9.71	57.26	343
7/29/07	18.1	7.71	9.66	58.57	332

7/30/07	17.0	7.74	9.87	58.23	321
7/31/07	16.9	7.80	9.97	59.46	301
8/1/07	17.5	7.83	9.88	64.37	278
8/2/07	18.3	7.88	9.64	67.77	265
8/3/07	18.2	7.90	9.65	68.59	260
8/4/07	17.5	7.91	9.81	67.74	259
8/5/07	18.0	7.92	9.67	70.17	250
8/6/07	18.0	7.92	9.63	70.90	246
8/7/07	18.1	7.98	9.64	71.28	237
8/8/07	17.5	7.92	9.78	68.93	233
8/9/07	16.7	7.89	9.98	68.69	227
8/10/07	16.5	7.90	10.10	69.29	219
8/11/07	16.4	7.92	10.11	70.93	211
8/12/07	16.2	7.94	10.16	73.65	204
8/13/07	16.0	7.91	10.29	74.61	199
8/14/07	17.4	7.95	9.95	77.97	188
8/15/07	18.1	8.03	9.77	79.84	180
8/16/07	18.2	7.97	9.64	80.57	179
8/17/07	17.6	7.96	9.84	79.37	178
8/18/07	16.7	7.98	9.99	77.10	180
8/19/07	16.0	7.99	10.12	77.02	179
8/20/07	14.3	7.93	10.53	74.75	186
8/21/07	14.7	7.93	10.53	76.05	184
8/22/07	15.9	7.96	9.99	79.20	177
8/23/07	17.0	7.96	9.94	82.13	171
8/24/07	17.1	8.01	9.87	82.78	164
8/25/07	17.4	8.03	9.66	83.64	159
8/26/07	16.4	8.03	9.69	82.62	156
8/27/07	15.2	7.97	10.29	81.00	153
8/28/07	15.5	7.99	9.76	82.81	146
8/29/07	16.4	7.98	9.22	85.22	144
8/30/07	17.2	8.00	9.41	87.25	142
8/31/07	17.4	8.13	9.24	87.49	140
9/1/07	16.3	8.10	9.54	85.35	142
9/2/07	16.5	8.13	9.58	85.87	142
9/3/07	17.7	8.16	9.33	89.39	134
9/4/07	18.0	8.12	9.13	91.23	129
9/5/07	17.7	8.12	8.64	91.28	129
9/6/07	17.4	8.13	9.32	91.27	128
9/7/07	15.8	8.12	9.71	87.97	128
9/8/07	14.7	8.11	9.98	86.42	130
9/9/07	14.1	8.13	10.16	85.97	127
9/10/07	14.4	8.15	10.10	87.20	123
9/11/07	15.3	8.15	9.64	89.65	118
9/12/07	16.4	8.17	9.43	93.11	115
9/13/07	15.8	8.16	9.63	91.90	117
9/14/07	15.3	8.14	9.70	91.18	117
9/15/07	15.6	8.16	9.58	92.18	115
9/16/07	14.6	8.21	9.81	90.66	114
9/17/07	14.1	8.11	9.87	90.43	111

9/18/07	12.9	8.15	10.19	87.79	111
9/19/07	13.1	8.07	10.17	88.62	112
9/20/07	12.0	8.07	10.29	86.73	114
9/21/07	12.0	8.01	9.13	87.33	114
9/22/07	12.2	8.17	10.36	89.10	112
9/23/07	11.2	8.02	10.58	88.15	111
9/24/07	11.5	8.03	10.57	89.33	109
9/25/07	12.5	8.06	10.31	92.17	105
9/26/07	12.3	8.10	10.33	92.15	105
9/27/07	12.4	8.22	10.22	92.42	105
9/28/07	12.0	8.14	10.05	92.04	105
9/29/07	9.8	8.16	10.86	87.38	107
9/30/07	9.8	7.95	10.53	86.56	115
10/1/07	9.9	8.06	10.91	83.06	134
10/2/07	10.2	8.04	10.77	81.83	137
10/3/07	9.4	8.00	11.04	73.78	186
10/4/07	8.8	8.02	11.22	73.82	153.99
10/5/07	8.7	8.00	11.23	78.84	141.13
10/6/07	9.1	8.08	11.22	81.41	132.66
10/7/07	10.9	8.17	10.74	85.94	130.00
10/8/07	10.3	8.13	10.87	82.77	139.13
10/9/07	10.0	8.04	10.88	78.27	145.28
10/10/07	10.7	7.94	10.55	82.98	135.53
10/11/07	9.6	8.11	11.00	80.21	137.34
10/12/07	10.1	8.08	10.90	81.33	136.16
10/13/07	9.2	8.04	11.11	81.03	135.00
10/14/07	8.9	8.09	11.21	81.17	130.16
10/15/07	9.2	8.09	10.99	82.24	130.09
10/16/07	9.5	8.01	10.77	82.93	130.19
10/17/07	7.8	7.96	11.31	78.94	131.90
10/18/07	6.5	7.83	11.52	75.82	135.41
10/19/07	7.1	7.97	11.63	76.11	142.73
10/20/07	6.6	7.99	11.94	72.10	152.94
10/21/07	6.2	7.88	12.17	73.14	142.17
10/22/07	7.8	7.96	11.79	77.24	139.84
10/23/07	8.5	7.94	11.60	74.94	160.02
10/24/07	8.4	8.00	11.59	71.53	167.60
10/25/07	7.1	7.92	11.98	63.34	175.13
10/26/07	5.2	7.91	12.55	59.79	168.18
10/27/07	4.3	7.90	12.75	59.81	161.30
10/28/07	4.6	7.91	12.65	60.58	160.48
10/29/07	5.1	7.92	12.45	61.47	159.19
10/30/07	4.8	7.91	12.61	61.35	156.39
10/31/07	3.9	7.90	12.88	61.05	151.03
11/1/07	4.2	7.90	12.66	62.57	150.16
11/2/07	3.5	7.89	12.95	61.60	146.60
11/3/07	4.5	7.90	12.51	69.18	143.15
11/4/07	7.2	7.88	11.54	74.00	147.59
11/5/07	5.6	7.86	12.09	68.97	148.47
11/6/07	4.5	7.80	12.42	66.62	143.88

11/7/07	4.9	7.75	12.19	70.14	142.33
11/8/07	6.1	7.80	11.72	72.98	142.90
11/9/07	7.3	7.89	11.42	72.25	156.09
11/10/07	7.0	7.88	11.42	68.79	161.84
11/11/07	5.0	7.83	12.10	59.84	165.33
11/12/07	5.1	7.80	11.86	62.31	157.95
11/13/07	4.3	7.89	12.39	59.17	170.80
11/14/07	3.0	7.74	12.90	58.54	153.77
11/15/07	3.7	7.65	12.66	61.54	151.02
11/16/07	4.4	7.76	12.48	59.85	165.07
11/17/07	3.7	7.82	12.70	56.41	171.88
11/18/07	3.7	7.82	12.74	56.49	173.72
11/19/07	3.9	7.78	12.72	59.11	160.58
11/20/07	3.5	7.79	12.97	60.92	151.10
11/21/07	1.8	7.81	13.40	61.12	132.26
11/22/07	0.5	7.82	13.69	62.75	115.99
11/23/07	0.5	7.82	13.56	71.62	101.28
11/24/07	1.0	7.88	13.47	69.07	122.67
11/25/07	1.1	7.83	13.42	61.54	129.78
11/26/07	1.3	7.84	13.32	63.29	123.19
11/27/07	0.6	7.87	13.54	61.71	123.09
11/28/07	0.3	7.87	13.81	60.91	128.32
11/29/07	0.8	7.85	13.64	57.98	141.05
11/30/07	1.3	7.85	13.42	59.00	137.56
12/1/07	0.8	7.86	13.34	58.19	136.03
12/2/07	0.0	7.90	13.51	57.10	132.00
12/3/07	0.2	7.83	13.26	58.83	143.36
12/4/07	0.9	7.86	13.52	57.42	172.64

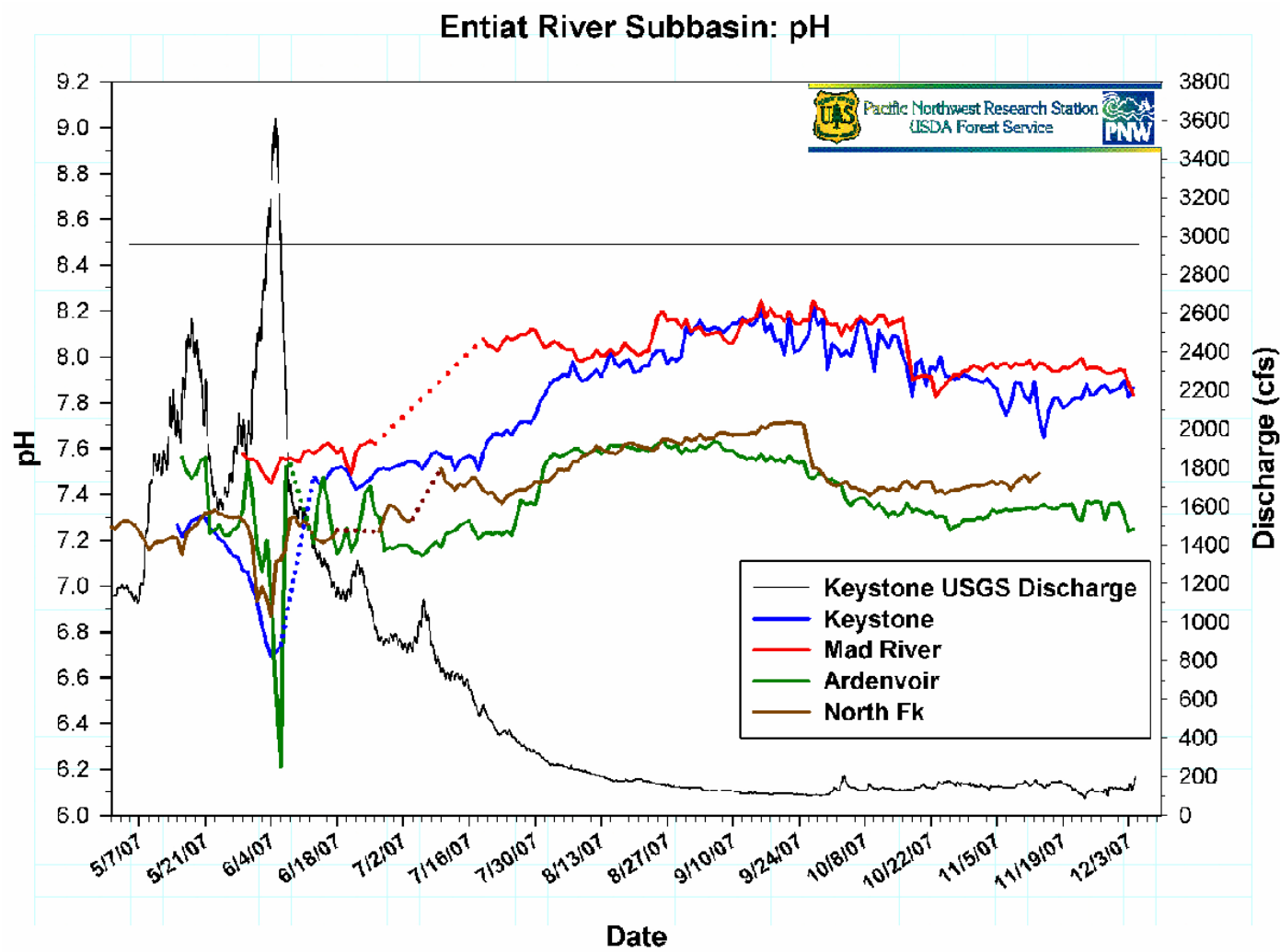


Figure 1. Daily mean pH values at the four monitored sites with associated discharge at the USGS, Keystone gauge. Dotted lines indicate uncertain data.

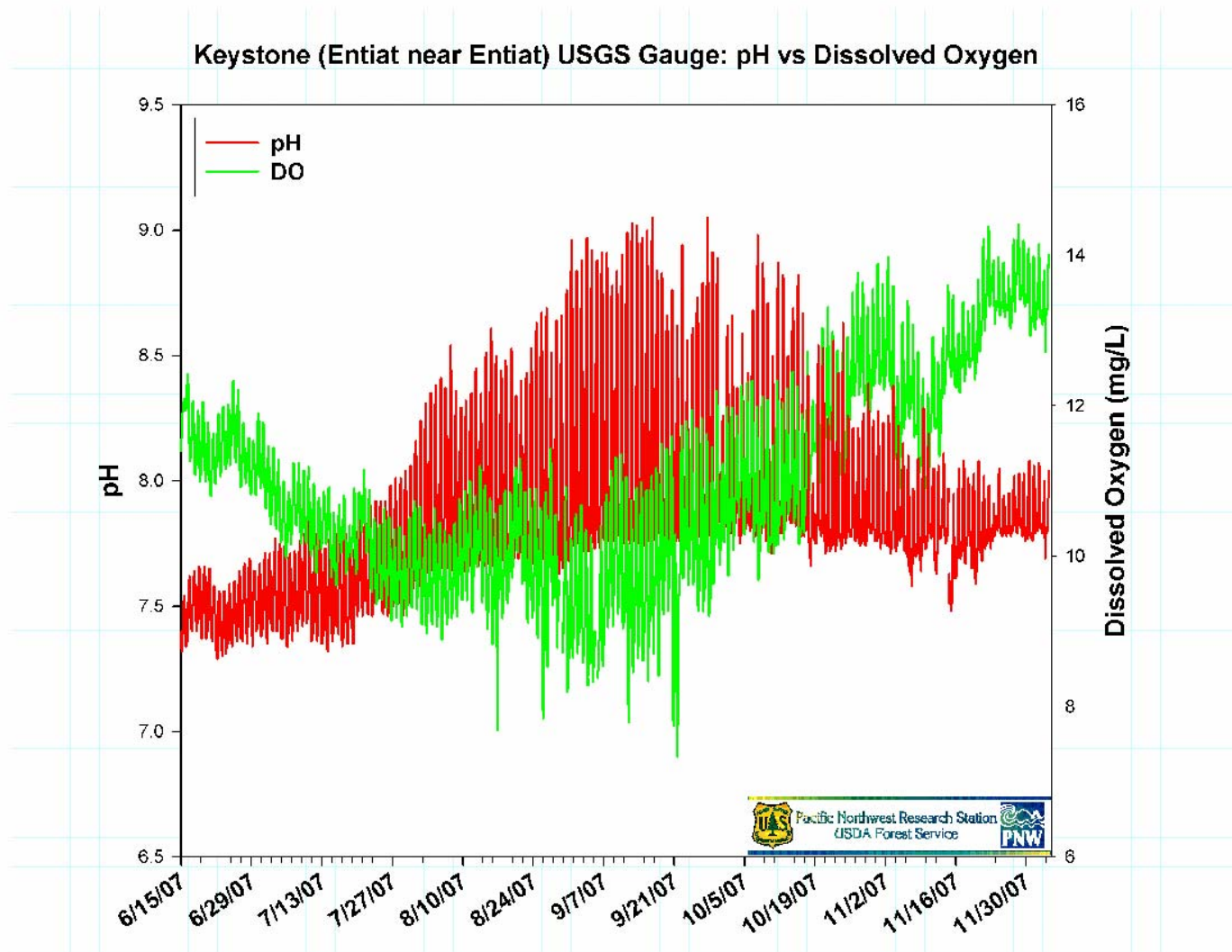


Figure 2. Daily peak pH values at the Keystone gauge with associated dissolved oxygen levels

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