

**Nutrient and Organic Matter Fate and Transport in the Klamath River:
June to September 2007**

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EXECUTIVE SUMMARY

The purpose of this study was to determine the fate and transport of nutrients and organic matter in the Klamath River in the vicinity of the Klamath Hydroelectric Project (Project). Existing field data and modeling results suggest that the short residence time through river reaches, coupled with distinct reach features, of the Klamath River in the vicinity of the Klamath Hydroelectric Project (Project) limits the processing of organic matter and retention or removal of nutrients by benthic algae or other processes (PacifiCorp 2006). The nutrient and organic matter fate and transport study assessed the differences or changes in concentrations of various constituents through two representative unimpounded river reaches in the Klamath River. The two reaches, located upstream and downstream of the Project reservoirs, are defined as follows:

1. Upper Reach: Klamath River from Keno dam to J.C. Boyle reservoir (River Mile [RM] 233.4 to 228.2)
2. Lower Reach: Klamath River from Iron Gate dam to Walker Bridge Road (RM 189.7 to RM 157.5)

Several sites bracketing these two reaches were sampled approximately monthly during the June-September 2007 period. During each sampling event, multiple samples per day were collected over a four-day period at each site. These sub-daily samples were composited for each day, resulting in one composite sample per day per site. Each of these daily composite samples were analyzed for ammonia (as N), nitrate + nitrite (as N), total Kjeldahl nitrogen (as N), total phosphorous (as P), orthophosphate (as P), dissolved organic carbon, chlorophyll-a, and pheophytin. In addition, total nitrogen was assessed based on the sum of total Kjeldahl nitrogen and nitrate + nitrite. At the time of sub-daily sampling, measurement of water temperature, dissolved oxygen, pH, and conductivity were taken with multi-probe instrumentation. At the sampling site below Iron Gate dam, in addition to the daily composite sample, the individual sub-daily samples were collected throughout the sampling season. This analysis of sub-daily samples provided additional information on the potential temporal (sub-daily) heterogeneity of nutrient releases to the river from Iron Gate reservoir.

Notable findings of the nutrient and organic matter fate and transport study include:

- Nutrient concentrations, with few exceptions did not differ considerably from the upstream end to the downstream end within the upper and lower reaches. Specifically,
 - There was little change in concentrations of total nitrogen and total phosphorous at the upstream and downstream points in both the upper reach and lower reach. Statistical comparison of the mean and variance of the paired data sets indicate there was no statistically significant difference ($p=0.05$) in total nitrogen and total phosphorous concentrations though the reaches.
 - Even though there was no statistically-significant change in total nitrogen and total phosphorus concentrations in the two study reaches, it appears that intermediate processes within the reaches account for some observed changes of inorganic or organic nutrient forms (e.g., sequestration of nutrients in algal biomass, denitrification, burial, desiccation, atmospheric deposition, conversion, senescence, reentrainment and erosion, etc.).
 - Changes in the concentrations of inorganic nitrogen forms (i.e., ammonia and nitrate+nitrite) were particularly evident in the upper reach. These data indicate that waters released from Keno dam were relatively high in ammonia and low in nitrate+nitrite during summer months. These data further indicate that these waters were subjected to nitrification during transit through the reach, leading to notably higher concentrations of nitrate+nitrite and lower concentrations of ammonia at the downstream end of the reach above J.C. Boyle reservoir. Meanwhile, as noted

above, total nitrogen concentrations were statistically the same at the upstream and downstream ends of the reach. Ammonia concentrations below Iron Gate dam are low (all below the reporting limit) and such transformations played a minor role in lower reach during the sampling periods.

- Changes in the concentrations of inorganic phosphorus also were evident in the upper reach, indicated by the increase in orthophosphate concentrations between Keno Dam to the site above J.C. Boyle reservoir. These data suggest that phosphorus bound in organic matter from upstream sources (dissolved and particulate) probably undergoes some level of conversion (e.g., oxidation) yielding the observed increase in orthophosphate. Datasonde data collected during the sampling periods suggest that dissolved oxygen concentrations are maintained at levels approximately 70 to 100 percent of saturation.
- Dissolved organic carbon (DOC) was used in the study as a measure for dissolved organic matter. There was little change in DOC concentrations between the upstream and downstream points in both the upper reach and lower reach. Statistical tests show that there is no statistically significant difference ($p=0.05$) in the mean and variance of the paired data sets. Similarly, volatile suspended solids (VSS), a measure of particulate organic matter, did not change appreciably from the upstream and downstream sites within each of the study reaches, although VSS data showed more scatter than DOC data.
- Tributary contributions of nutrients and organic matter in the upper reach are negligible. In the lower reach, data from the Shasta River and Beaver Creek indicate that concentrations of nutrients and organic matter in these tributaries are at times different and at times similar to the mainstem. Generally, Beaver Creek exhibits higher quality water than the mainstem Klamath River. However, overall flow contributions from these tributaries are minor.
- In addition to comparing nutrient and organic matter concentrations between the upstream and downstream ends of the lower reach, further within-reach changes in concentrations were assessed in the lower study reach by comparing the intermediate site at I-5 with Iron Gate Dam and Walker Bridge Road. As with the comparison of the upstream and downstream ends of the reach, few differences in nutrient and organic matter concentrations occurred in these sub-reaches.
- Sub-daily variability below Iron Gate Dam for nutrients was assessed. Sub-daily variability depended on the constituent and month. In general, sub-daily variability was present at some level for all constituents, but the degree of scatter varied considerably. For ammonia, concentrations were all below the reporting limit and although there was variability, this occurred over a small range. Nitrate+nitrite data illustrated little variability in June, July, and September. However, August data reflect potential sub-daily variability. Total Kjeldahl nitrogen illustrated sub-daily variability in several months, suggesting that a composite sample may be more representative than a single grab sample. PO₄, TP, and DOC showed little sub-daily variation.

1.0 STUDY SCOPE

1.1 PURPOSE

The purpose of this study was to determine the nutrient and organic matter fate and transport of the Klamath River in the vicinity of the Project by measuring various physical, chemical, and biological water quality constituents. Water samples were collected and sent to labs to quantify the chemical and biological parameters while physical measurements were collected using water quality probes. This report is largely a presentation of field data, a summary of field conditions, and key findings.

1.2 STUDY SCOPE

Existing field data and modeling results suggest that the short residence time and reach features (e.g., gradient, flow regime, velocity, depth, light, etc.) through the river reaches in the Project area limits the removal and/or retention of organic matter and nutrients, and that the relatively long residence time through the Project reservoirs enhances the removal and/or retention of organic matter and nutrients (PacifiCorp 2006). This study was specifically designed to investigate nutrient concentrations (nitrogen and phosphorus) and organic matter (as represented by organic carbon) during transit of flows through two unimpounded river reaches in the Klamath River just upstream and downstream of the Project reservoirs, defined as follows:

1. Upper Reach: Klamath River from Keno dam (monitoring site KR23335 at RM 233.4) to above J.C. Boyle reservoir (site KR22822 at RM 228.2)
2. Lower Reach: Klamath River from below Iron Gate dam (site KR18973 at RM 189.7) to Walker Bridge Road (site KR15750 at RM 157.5)

These sites bracket the two reaches and were sampled for multiple consecutive days at approximately monthly intervals during the June-September 2007 period. The multiple day sampling events included collection of three samples per day (and four below Iron Gate dam) over a four-day period at each site. The sub-daily samples were composited for each day, resulting in one composite sample per day per site. Each of these daily composite samples was analyzed for ammonia (NH₄), nitrate + nitrite (NO₃+NO₂), total Kjeldahl nitrogen (TKN), total phosphorous (TP), orthophosphate (PO₄), dissolved organic carbon (DOC), total suspended solids (TSS), volatile suspended solids (VSS), and chlorophyll-a and pheophytin. Measurement of water temperature, dissolved oxygen, pH, and conductivity were taken with multi-probe instrumentation. For the site below Iron Gate dam (monitoring site KR18973), in addition to the daily composite sample, the individual sub-daily samples were analyzed for the parameters listed above.

The original study sampling plan (see Appendix A) was modified in response to comments from the State Water Resources Control Board (SWRCB). Specifically, an additional site was added at Interstate 5 and sites for the tributaries at Beaver Creek and the Shasta River were included. Details of the SWRCB comments and responses to those comments are included in SWRCB (2007) and PacifiCorp (2007), respectfully.

1.3 REPORT ORGANIZATION

This report includes an executive summary: Section 1 describes the study methods; Section 2 presents the methods and data collected for the study; Section 3 is a discussion of results, including intra-reach sampling, tributary conditions, and sub-daily variability in nutrients below Iron Gate dam; Section 4 is a summary; and Section 5 provides references. There are nine appendices, including the study plan; study site descriptions, descriptions of analytical methods and quality assurance, standard operating procedures

for field work, physical water quality measurements, meteorological data, flow data, and the final data from laboratory water quality analyses.

2.0 STUDY METHODS

Study methods outlined herein include site selection, sampling period and frequency, parameters, and field methods.

2.1 SITE SELECTION

Geographically, sampling sites were selected for the two reaches to represent the top and bottom of each reach. The reach from Keno dam to above J.C. Boyle reservoir is approximately 5 miles long with little tributary inflow. The reach from Iron Gate dam to Walker Bridge Road is considerably longer (over 30 miles) and includes the Klamath River at Interstate 5 site and the Shasta River and Beaver Creek tributaries for the July through September sampling. Due to fires in the region during July, access to the lower river (below the Shasta River) was unavailable. Site locations, number, and approximate river mile are presented in Table 1. A more detailed description of each sampling site is provided in Appendix B. Site identifications were assigned to all sampling sites associated with four water quality sub-programs completed by PacifiCorp in 2007 (not described herein). Hence, sample sites described herein Table 1 are a subset of a larger group of sites.

Table 1. Sampling Locations, Identifications and Associated River Mile

Site ID	Site Name	Approx. River Mile
<i>Upper Reach Sites</i>		
KR23335	Klamath River Below Keno dam	233
KR22822	Klamath River Above J.C. Boyle	228
<i>Lower Reach Sites</i>		
KR18973	Klamath River Below Iron Gate dam	190
KR17600	Klamath River At I-5 Rest Area	178
KR15750	Klamath River At Walker Bridge Road	157
-	Klamath River Above Shasta River ¹	176
-	Mouth Of Shasta River ¹	0.6
-	Mouth of Beaver Creek ²	0.2

¹ Shasta River enters the Klamath River at approximately RM176.

² Beaver Creek enters the Klamath River at approximately RM162.

Each of the sampling sites identified above was investigated to identify requisite characteristics: representative of the mainstem river, well mixed, not impacted by external inflows (e.g., return flows) over the range of expected flows. In all cases safety was a consideration in selection of a sampling site. The program retained the flexibility to move sampling location for safety issues or to retain desired sampling conditions. Such a change occurred on one occasion: the July sampling at Klamath River near Walker Bridge Road was relocated to above the Shasta River due to wildfires in the area. No other sampling sites were moved during the 2007 study.

2.2 SAMPLING PERIOD AND FREQUENCY

Sampling occurred from June through September to capture seasonal water quality variability. Sampling was completed for four consecutive days for the periods June 18-21, July 16-19, August 13-16, and September 10-13, 2007. During the June sampling event, both grab and composite samples were collected at the upstream and downstream sites for the upper and lower reaches. The grab samples were collected three-times daily (morning, early afternoon, and late afternoon) and parallel sampling was used to create a composite of these three sampling times. These data provide insight into both potential sub-daily variability and to compare composite sample results to individual grab samples. This latter point was intended to ascertain if single grab samples was representative of river conditions or if composites would appropriately reflect water quality conditions on a given day.

For the rest of the sampling events (July-September), only the Iron Gate dam grab samples were retained to investigate potential sub-daily variations in water quality. Throughout the program an additional evening grab sample was taken at Iron Gate dam to yield a total of four grab samples for that site (although this sample was not included in the composite). In addition, grab sampling was conducted once during each study period in Shasta River and Beaver Creek to study the effects of the tributaries on the mainstem of the Klamath River (Table 2).

Table 2. Site Specific Grab and Composite Sampling for 2007

Site ID	Site Name	Grab/Composite Sampling ¹			
		June 18-21	July 16-19	August 13-16	Sept. 10-13
<i>Upper Reach Sites</i>					
KR23335	Klamath River Below Keno dam	G/C	C	C	C
KR22822	Klamath River Above J.C. Boyle	G/C	C	C	C
<i>Lower Reach Sites</i>					
KR18973	Klamath River Below Iron Gate dam	G/C	G/C	G/C	G/C
KR17600	Klamath River At I-5I-5 Rest Area	-	C	C	C
KR15750	Klamath River At Walker Bridge Road	G/C	-	C	C
-	Klamath River Above Shasta River	-	C	-	-
-	Mouth Of Shasta River ²	-	-	G	G
-	Mouth of Beaver Creek ³	-	-	G	G

¹ 'G' Indicates a grab sample was collected; 'C' Indicates a composite sample was collected; '-' Indicates no samples were collected at that site during that sampling period.

2.3 PARAMETERS

Water samples (grab and composite samples) were collected and analyzed for a range of parameters including,

- Ammonium as nitrogen, NH_4^+ (NH4),
- Nitrate plus nitrite as nitrogen, NO_3^- plus NO_2^- (NO3+NO2),
- Total Kjeldahl nitrogen as nitrogen (TKN),
- Total phosphorus as phosphorus (TP),
- Ortho-phosphate as phosphorus, PO_4^{3-} (PO4),
- Total organic carbon (TOC),

- Dissolved organic carbon (DOC),
- Total suspended solids (TSS),
- Volatile suspended solids (VSS),
- Chlorophyll-a, and
- Algae speciation, density, and biovolume (these data are presented in *Phytoplankton of the Klamath Hydroelectric Project (FERC 2082), 2007*).

Total suspended solids and volatile suspended solids were added and during the sampling program due to a limitation of the TOC method¹ available from the production lab (a replacement lab was not identified during this field program). Water samples were collected and delivered to CH2M HILL Applied Sciences Laboratory in Corvallis, OR for analysis of NH₄, NO₃+NO₂, TKN, TP, PO₄, TOC, DOC, TSS, and VSS. Water samples were collected and delivered to Aquatic Analysts in White Salmon, WA for analysis of chlorophyll-a, and algae speciation, density, and biovolume. Appendix C contains descriptions of analytical methods requirements and the data quality objectives for each analyte tested.

Although the focus of this study was to collect discrete water quality samples, these data were augmented with other information. Water quality probes were deployed to collect physical data (temperature, dissolved oxygen, pH, and specific conductance) and photosynthetically available radiation (PAR) measurements were completed. In addition, basic meteorological conditions were noted during time of collection (e.g., air temperature, relative humidity, wind speed), and are augmented with sampling period observations from local meteorological stations. Similarly, flow data from USGS gages during the field periods was examined.

2.4 SAMPLING DESCRIPTION

Samples were collected at the river locations three times per day, and were defined as “am1,” “am2,” or “pm1.” A fourth sample, designated “pm2,” was collected below Iron Gate dam. As noted above, certain grab samples were used to form a composite sample. Further quality assurance (QA) samples were collected. Each is briefly outlined below.

2.4.1 Grab Samples

Field crews collected the am1, am2, and pm1 samples daily at each site. A sample volume was collected in the churn sample splitter (churn) and all bottles were filled from a single churn. The pm2 sample was collected in two, four liter Nalgene containers collected in the evening by California Department of Fish and Game (CDFG) staff. These sample containers were refrigerated and processed in a churn sample splitter the following day, prior to the am2 sampling.

2.4.2 Composite Samples

Composite samples consisted of am1, am2, and pm1 sub-samples. Sub-samples were collected in 4 L sample containers at each sampling location. Upon completing the pm1 sampling, 2 L (2000 ml) was extracted from each 4L container (am1, am2, and pm1) and combined in the churn to create a composite sample. The sample bottles were then filled from the churn following standard operating procedures. June protocols were slightly different: bottles were filled with one-third of the total volume (330 ml) at each site visit (am1, am2, and pm1), and stored on ice in the interim.

¹ CH2M HILL Applied Sciences Laboratory in Corvallis, OR uses EPA Method 415.1 for total organic carbon (TOC). The method states in section 5.2 “[T]his procedure is applicable only to homogeneous samples which can be injected into the apparatus reproducibly by means of a microliter type syringe or pipette. The openings of the syringe or pipette limit the maximum size of particles which may be included in the sample.” The particulate matter in the Klamath River apparently is an interference, with larger material being excluded via the microliter type syringe or pipette. Thus, TOC values tend to be similar to DOC values. TOC values are not presented in this report.

2.4.3 QA Samples

An important element of the study was external quality assurance sampling to provide a mechanism to quantify uncertainty in field observations. Familiar measures of uncertainty include the accuracy of water quality probes where temperature, dissolved oxygen, pH and other parameters have specific $\pm \epsilon_i$ values, where ϵ_i represents level of precision for measured parameter i . For parameters such as temperature and dissolved oxygen, these bounds are readily determined by the manufacturer through a wide number of extensive statistical tests and physical experiments. Collecting whole water samples for processing in a laboratory setting comes with a similar, but different level of uncertainty quantitation, and external QA provides a means to apply this information in a meaningful and useful manner.

QA samples consisting of regular (production), duplicate, blank, spike, and filter blank samples were collected below Iron Gate dam in June. QA samples in June were collected at the am2 sampling. Due to sampling time constraints in the longer reach between Iron Gate dam and Walker Bridge Road, QA sampling was moved to the shorter upper reach below Keno dam for the remainder of the sampling periods. At the below Keno dam site, the QA samples were taken from a composite of am1, am2, and pm1 samples.

QA samples included blanks and filter blanks; spikes for TSS, VSS, NH₄, NO₃+NO₂, TKN, TP, and PO₄, and duplicates. Spikes and reference solutions were purchased from Environmental Resource Associates (ERA). Nutrient spikes included consisted of the Custom Inorganic Standard from ERA (Cat #092). A Hardness water reference solution from ERA was used for TSS and VSS (Hardness, WasteWatR, Cat #507). A more comprehensive discussion of methods is outlined in Appendix C.

2.4.4 Field Study Methods

A more comprehensive discussion of methods is outlined in the Standard Operation Procedures (SOP) in Appendix D. The following section highlights some procedural changes to the methods during the study.

2.5 SAMPLING DATA SUMMARY

The locations, number of samples, and constituents sampled under the 2007 study are summarized herein. A brief discussion of censored data is included to identify the final data set used in the study assessment, and to aid with data interpretation.

2.5.1 Sample Counts

There were a total of 176 samples (106 grabs plus 70 composites) collected during the four sampling periods (Table 3). Each grab and composite sample was analyzed for the constituents identified above (Table 4). The difference in number of samples analyzed for each constituent varies due to site location, sampling period, access, and other factors. There were fewer TSS and VSS samples because those tests were not added until August (to provide a surrogate for TOC). Data are presented in tabular form in Appendix E.

Table 3. Number of Individual Grab and Composite Samples Collected During Each Sampling Period Submitted for Laboratory Analysis.

	Grab/Composite Samples ^{1,2}			
	June 18-21	July 16-19	Aug. 13-16	Sept. 10-13
Klamath River below Keno dam	12/4	0/4	0/4	3/1
Klamath River above J.C. Boyle reservoir	12/4	0/4	0/4	3/1
Klamath River below Iron Gate dam	15/4	15/4	15/4	15/4
Klamath River at I-5 Rest Area	-/-	0/4	0/4	0/4
Klamath River above confluence with Shasta River ³	-/-	0/4	-/-	-/-
Klamath River at Walker Bridge Road	12/4	-/-	0/4	0/4
Shasta River near mouth	-/-	-/-	1/0	1/0
Beaver Creek near mouth	-/-	-/-	1/0	1/0
TOTAL	51/16	15/20	17/20	23/14

¹ Results are presented as: number of individual grab samples/number of composite samples.

² A '-' indicates that no samples were collected at that site during that sampling period.

³ Sampling occurred at Klamath River above Shasta River instead of at Walker Bridge Road on 7/16-7/19 due to fire closures downstream of the Shasta River.

Table 4. Total Number of Samples Analyzed for Each Constituent by Location.

	Number of Samples Analyzed for Each Constituent										
	NH4	NO2+NO3	TKN	TN ¹	TP	PO4	DOC	TSS	VSS	Chlor-a ²	Pheo ³
Klamath River below Keno	28	28	28	28	28	28	28	8	8	24	24
Klamath River ab. JCB	28	28	28	28	28	28	28	8	8	23	23
Klamath River below IGD	76	76	76	76	76	76	76	38	38	57	57
Klamath River at I-5	12	12	12	12	12	12	12	8	8	7	7
Klamath River at Walker	23	23	23	23	23	24	24	8	8	20	20
Klamath River above Shasta	4	4	4	4	4	4	4	0	0	4	4
Shasta River	2	2	2	2	2	2	2	2	2	1	1
Beaver Creek	2	2	2	2	2	2	2	2	2	1	1
Total	175	175	175	175	175	176	176	74	74	137	137

¹ TN was not directly sampled, but was calculated as $TN = NO_2 + N_3 + TKN$, where $TKN = NH_4 + \text{Organic N}$.

² 'Chlor-a' refers to Chlorophyll-a, a measure of algal biomass.

³ 'Pheo' refers to Pheophytin, a measure of density and biomass.

2.6 CENSORED DATA

When presenting data and interpreting results, it is important to consider those samples that were identified by the laboratory as below the method reporting limit (RL), i.e., censored data, and “non-detect” (ND). To aid the discussion of censored data, it is useful to define censored data, method detection limit, method reporting limit, and other associated terms.

Data sets with “less than” (<) observations are termed censored data. To identify when data are censored, one must define the method detection limit and/or method reporting limit. Method detection limit (MDL) is explicitly defined in Standard Methods (APHA 2005) as “the constituent concentration that, when processed through the complete method, produces a signal with a 99 percent probability that it is different than the blank” (p 1-3). The level of quantitation (LOQ) or the minimum quantitation level (MQL) is defined in Standard Methods as “the constituent concentration that produces a signal sufficiently greater than the blank that it can be detected within specified levels by good laboratories during routine operating conditions. Typically it is a concentration that produces a signal that is $10s$ above the reagent water blank signal” (p 1-3), where s is the standard deviation. The relationship among the MDL and the LOQ is approximately 1:2.5 (APHA 2005). Further, Standard Methods states that although the LOQ is useful within a laboratory, the practical quantitation limit (PQL) is higher than the LOQ and “is about five times the MDL and represents a practical and routinely achievable detection level with relatively good certainty that any reported value is reliable” (p 1-17). The MRL presented by most laboratories (although nomenclature may vary) is equivalent to the PQL.

The relationship between MDL and MRL may vary among parameters and among particular laboratories. Based on the data in Table 5, the ratio of MRL to MDL for various constituents in this study (based on CH2M HILL Applied Sciences Laboratory documentation) ranges from approximately 2.6 (for TP) to over 20 (for NH₄). Further, the MDL may change during a sampling season due to laboratory internal procedures.

Important to this discussion is that, whether external quality assurance is implemented in a program or not, laboratories consider MRL as the reproducible limit. That is, values that fall below the MRL, even if they are above the MDL, cannot be replicated. In most cases, values were above the MRL; however, certain samples had laboratory results below the MRL or below the MDL (i.e., “ND”). For the purpose of this report, data were not censored below the MRL. Rather, values between the MRL and the MDL were employed without modification in statistical analyses (however, in the final data set these values are appropriately (j) flagged, denoting values are below the reporting limit). Those values below the MDL (i.e., “ND”) were assigned the MDL value for the statistical and graphical analyses presented herein.

Table 5. Minimum Detection Limit and Reporting Limits.

Constituent	Method Reporting Limit (mg/l)^{a, b}	Minimum Detection Limit (mg/l or ug/L)^{a, b}
NH4	0.10	0.0046
NO3+NO2	0.01	0.0013
TKN	0.10	0.011
TN ^c	0.11	0.0123
TP	0.05	0.019
PO4 ^d	0.01	0.0031
DOC	0.50	0.057
TSS	2.00	0.95
VSS	2.00	0.38
Chlorophyll-a	n/a	0.10
Pheophytin	n/a	0.10

^a 'n/a' indicates that the reporting limit or minimum detection limit were not available/provided for that constituent.

^b Chlorophyll-a and pheophytin concentrations are in micro-grams per liter (ug/l); all other constituents are in milligrams per liter (mg/L).

^c TN is calculated as TKN + (NO3+NO2). The MRL and MDL were estimated as the sum of the MRL and MDL for TKN and (NO3+NO2).

^d The method detection limit for PO4 identified by CH2M HILL changed after August 15, from 0.0031 mg/l to 0.0018 mg/l.

3.0 DISCUSSION OF RESULTS

The principal objective of the fate and transport study was to assess changes in nutrient and organic matter conditions from the top to bottom of two selected reaches in the Project area. The two reaches assessed essentially bracket the Project area and provide an opportunity to compare both within reach (i.e., intra-reach) conditions as well as between reach (i.e., inter-reach) conditions. The study also provided an opportunity to assess potential sub-daily variability in water quality conditions.

Three approaches were used to complete the comparisons of intra-reach (top and bottom) samples, and investigate sub-daily variability. The first approach used the *Equality of Two Variances* (ETV) to assess if the variance of the two data sets was statistically similar (using a statistical probability level $p=0.05$). The second approach employed the *Two-Sample t-Test* (t-Test) to determine if the means of paired data were statistically similar ($p=0.05$). The third approach examined the number of data points that fell within the relative percent difference (RPD) criteria included in the external QA element of the sampling program.

For the statistical tests there are four possible outcomes:

- both tests pass indicating that there is no statistical difference in the variance (ETV) or mean (t-Test) (, i.e., $p_{variance} > 0.05$ and $p_{mean} > 0.05$),),
- both tests fail indicating that the variance (ETV) and mean (t-Test) are both statistical different (i.e., $p_{variance} \leq 0.05$ and $p_{mean} \leq 0.05$),),
- the variance test (ETV) passes and the mean test (t-Test) fails (i.e., $p_{variance} > 0.05$ and $p_{mean} \leq 0.05$),),
- the variance test (ETV) fails and the mean test (t-Test) passes (i.e., $p_{variance} \leq 0.05$ and $p_{mean} > 0.05$),).

Both the ETV and t-Test analyses were conducted using the statistical data analysis program Systat 11. Both tests assume that the data sets were normally distributed and independent. Not all of the field data sets were normally distributed (approximately 83 percent² of the data sets were normally distributed³), but the tests were run for all data sets, regardless of their distribution to provide, at a minimum, potential insight into the data.

The RPD assessment used a graphical analysis to determine the number of data points outside the RPD. Specifically, representative “error bars” are included in the data plots for each sample representing the RPD criteria:

- For data values greater than five times the MRL, RPD is less than or equal to 20 percent of the data value.
- For data values less than or equal to five times the MRL, RPD is plus or minus the reporting limit.
- For chlorophyll-a and pheophytin, the MDL was used in place of the MRL because no MRL was available.

The reporting limits used to calculate the RPD are listed in Table 5 in the previous section.

Presented herein are two main topics exploring the water quality data collected in 2007. These include:

² Approximately 83 percent of the data sets (258 out of 312) were normally distributed. The 312 data sets were composed of 228 composite samples and 84 grab samples. For both the composite and grab sample data sets, 27 data sets were not normally distributed based on statistical measures. Approximately 88 percent of the composite sample data sets and 68 percent of the grab sample data sets appeared normally distributed.

³ Each data set was evaluated using the Shapiro-Wilk normality test ($W \gg 0$ and $SW-p > 0.05$) and visually (histograms) to determine if the data set were normally distributed.

- Intra-reach comparisons of nutrient and organic matter conditions at the top and bottom of the upper reach and at the top, middle, and bottom of the lower reach. This assessment also includes an assessment of the relative contributing effect of the Shasta River and Beaver Creek tributaries.
- Sub-daily variability of nutrient and organic matter conditions, particularly below Iron Gate dam.

3.1 DATA

The data for the grab and composite samples obtained in this study are included in Appendix E. Other data appendices include datasonde data (Appendix F), meteorological observations (Appendix G), and flow observations (Appendix H).

3.2 INTRA-REACH AND TRIBUTARY SAMPLING

A principal element of this study was to assess intra-reach water quality conditions, i.e., differences between the top and bottom of each reach. For the Keno Dam to J.C. Boyle reach (upper reach), sampling sites were chosen to represent the upstream and downstream locations. For the Iron Gate Dam to Walker Road reach (lower reach) upstream, intermediate, and downstream locations were compared (Table 6) depending on availability of data.

Table 6. Top and Bottom of Each Reach and the Length of Each Reach.

Top of the Reach	Bottom of the Reach	Approximate River Mile Distance
<i>Upper Reach</i>		
Klamath River below Keno dam	Klamath River above J.C. Boyle reservoir	5
<i>Lower Reach</i>		
Klamath River below Iron Gate dam	Klamath River at I-5 Rest Area	12
Klamath River at I-5 Rest Area	Klamath River at Walker Bridge Road	22
Klamath River at Iron Gate dam	Klamath River at Walker Bridge Road	32
Klamath River at Iron Gate dam	Klamath River above Shasta River Confluence	14
Klamath River at I-5 Rest Area	Klamath River above Shasta River Confluence	2

Similarities and differences in constituent concentrations between the top and bottom of the reach varied depending on the reach and month of the year. Concentrations are compared herein (versus loads). For the Keno dam to J.C. Boyle reservoir reach, this comparison was equivalent to comparing loads because there are minimal accretions and depletions in this reach. For Iron Gate dam to Walker Bridge Road, there are tributary contributions. These accretions were on the order of 400 cfs (approximately 35 percent of the flow at Iron Gate dam) in June, on the order of 200 cfs (approximately 18 percent of flow at Iron Gate dam) in July, and on the order of 100 cfs (less than 10 percent of flow at Iron Gate dam) in August and September.

3.2.1 Intra-Reach Comparison: EVT and t-Test

The statistical tests of the data for the various study locations indicate that there was mostly little or no statistically-significant variation in mean or variance between the upper stream and downstream end of reaches (and for that matter, intermediate locations). There were exceptions, and in some cases important differences occurred within a reach. A summary of p-values inter-reach composite samples using the EVT and t-Test are presented in Table 7, with **bold** values indicating statistical differences.

Table 7. Summary of p-Values of the Inter-Reach Composite Sample Comparison (statistical differences in **bold**).

	Composite and Grab Sample Comparison ($p_{\text{variance}}/p_{\text{mean}}$)					
	Upper Reach	Lower Reach				
Constituent	Keno to JCB	IGD to I-5 Rest Area	I-5 Rest Area to Walker	IGD to Walker	IGD to Above Shasta	I-5 Rest Area to Above Shasta
NH ₄	0.000/0.000	0.057/ 0.045	0.049 /0.825	0.496/0.316	0.451/0.974	0.952/0.129
NO ₂ +NO ₃	0.000/0.000	0.317/0.785	0.692/0.098	0.463/0.050	0.879/0.936	0.419/0.712
TKN	0.000/0.000	0.671/0.785	0.495/0.890	0.268/0.907	0.817/0.250	0.143/0.538
TN	0.579/0.857	0.982/0.813	0.666/0.502	0.602/0.613	0.428/0.207	0.070/0.477
TP	0.641/0.739	0.906/0.687	0.750/0.735	0.764/0.774	0.201/0.439	0.244/0.109
PO ₄	0.453/ 0.016	0.733/0.633	0.984/0.953	0.478/0.636	0.721/0.802	0.743/0.743
DOC	0.988/0.941	0.661/0.745	0.967/0.732	0.515/0.810	0.035 /0.386	0.182/0.273
TSS	0.228/0.542	0.206/0.345	0.138/0.577	0.815/0.559	-/-	-/-
VSS	0.017 /0.165	0.239/0.677	0.336/0.725	0.823/0.943	-/-	-/-
Chl_a ¹	0.197/0.080	0.598/0.758	0.108/0.366	0.742/0.749	0.238/0.293	0.511/0.658
Pheo ¹	0.345/0.802	0.011 /0.123	0.497/0.821	0.005 /0.176	0.828/0.521	0.009 /0.320

¹ 'Chl_a' refers to Chlorophyll-A and 'Pheo' refers to Pheophytin.

Systematically through the system (upper and lower reaches) there was no statistical difference within each reach for total nitrogen (calculated as NO₂+NO₃ and TKN) and total phosphorus (including intermediate locations in the lower reach). The clear exception was inorganic and soluble nitrogen species in the upper reach. Review of field data indicate that NH₄ was largely absent at Keno Dam in June, but otherwise present at concentrations between approximately 0.8 mg/l and 1.5 mg/l in July, August, and September. NO₂+NO₃ was largely absent below Keno Dam throughout the study period. Conversely, field data for the Klamath River above J.C. Boyle Reservoir indicate that NH₄ concentrations were all under 0.4 mg/l, while NO₂+NO₃ values ranged from 0.2 mg/l to nearly 1.5 mg/l. TKN showed a systematic reduction through the upper reach with upstream values between approximately 1.5 mg/l and 4.0 mg/l, while the downstream values were between approximately 1.5 mg/l and 2.0 mg/l. These data suggest that ammonia (both as NH₄ and that fraction of NH₄ in TKN) was undergoing nitrification in this reach. An important observation was that inorganic forms of nitrogen change considerably in this reach, but that total nitrogen (calculated as NO₂+NO₃ and TKN) was not statistically different.

In the upper reach, the mean of PO₄ was statistically different (mean) between the upstream and downstream locations, illustrating a consistent increase in concentration through this reach. It is likely that oxidation of organic matter (from TP) was contributing to PO₄: a finding supported by the fact that TP was not statistically different through the reach. VSS was also statistically different (variance) in the upper river. The reason is unknown at this time, but the large organic inputs from upstream may be a contributor.

In the lower reach there were statistical differences in NH₄ (mean and variance), DOC (variance), and pheophytin (variance). The NH₄ concentrations in the lower reach showed statistical differences in two data sets. In all cases these were very low concentrations – all data in the lower reach were below the reporting limit – and thus the significance of statistical differences are questionable. Statistical differences in DOC were limited to the July period for the reach between IGD and the Shasta River. This was a small sample set (n=4) because the sampling location was temporarily relocated due to the

occurrence of wildfires in the area. Further, rain occurred during this period, which could have contributed to some variability in downstream water quality (e.g., tributary contribution). Finally, pheophytin showed considerable scatter throughout the study period in several locations. Such variability in pheophytin was not explored herein.

These data are further explored in the following section under the RPD assessment, wherein graphical analyses of the data augment the statistical analyses of the data.

3.2.2 Intra-Reach Comparison: RPD Assessment

The RPD assessment used the QA criteria into the analysis to provide further insight into the data. Specifically, by using RPD data a quantitative measure of data quality is introduced to the analysis which the statistical tests of mean and variance did not. Comparing intra-reach conditions in the RPD assessment included graphing concentrations at the top and bottom of the reach as paired data (top of reach, bottom of reach) for each constituent. The x-axis represents the concentration at the top of the reach and the y-axis represents the concentration at the bottom of the reach or, in the case of the lower reach, an intermediate location. A 1:1 line was included in each graph denoting a line of equivalent concentration, i.e., a point that falls on the 1:1 line has the same concentration at the upstream and downstream location. Finally, dashed lines are added to the graphs to represent one RPD above and below the one-to-one line. These RPD limits are intended to form an envelope, providing a visual template to investigate the information while considering inherent uncertainty in the data, i.e., the envelope (region between the two dashed lines) captures those points that are within \pm RPD and are theoretically indifferent from the one-to-one line given the level of quantification in this study. Additional details on the RPD graphs are included in Appendix I.

Reach findings are discussed below, with the lower reach broken into several categories:

- Upper Reach - Below Keno Dam to Above J.C. Boyle Reservoir
- Lower Reach 1a - Below Iron Gate Dam to I-5 Rest Area;
- Lower Reach 2a - At I-5 Rest Area to at Walker Bridge Road;
- Lower Reach 3a - Below Iron Gate Dam to at Walker Bridge Road;
- Lower Reach 2b - At I-5 Rest Area to Above Shasta River Confluence; and
- Lower Reach 3b - Below Iron Gate dam to Above Shasta River Confluence.

Lower Reach 1a, 2a, and 3a, refer to the standard sampling program sampling sites, while reach 2b, and 3b represent the July sampling period when access to the Walker Bridge Road site was unavailable and the downstream most site was placed at the Klamath River above the Shasta River.

3.2.2.1 Upper Reach (Below Keno Dam to Above J.C. Boyle Reservoir)

The relationships between the concentration at the top and bottom of the upper reach varied by constituent, but results are consistent with the statistical analysis above (Table 7). The graphical results are presented in Figure 1 and discussed by constituent in the following sections.

Phosphorous

TP concentrations fell within ± 1 RPD of the one-to-one line indicating similar concentrations at the top and bottom of the reach. These data appeared uniformly distributed around the one-to-one line.

Concentrations of PO₄ tended to be slightly higher downstream (above J.C. Boyle reservoir) than upstream, and were distributed along the upper RPD line.

Nitrogen

TN concentrations fell within ± 1 RPD of the one-to-one line suggesting similar concentrations at the top and bottom of the reach. These data appeared uniformly distributed around the one-to-one line. NH₄ and NO₃+NO₂ concentrations showed noteworthy differences. In June, NH₄ and NO₃+NO₂ were largely non-detect at Keno. However, for July, August, and September, NH₄ concentrations ranged from approximately 0.8 mg/l to 1.5 mg/l at Keno and NO₃+NO₂ concentrations were non-detect. During these same three months, concentrations of NH₄ ranged from 0.2 mg/l to 0.4 mg/l above J.C. Boyle, while NO₃+NO₂ concentrations ranged from 1.0 mg/l to 1.4 mg/l. TKN concentrations tended to be higher at the top of the reach (below Keno dam). These data suggest a notable conversion of NH₄ to NO₃+NO₂ via nitrification in this reach, while TN, as noted above, was unchanged or conserved.

DOC, TSS and VSS

DOC and VSS concentrations all fell within ± 1 RPD of the one-to-one line indicating similar concentrations at the top and bottom of the reach. These data appeared uniformly distributed around the one-to-one line. TSS, while uniformly distributed around the one-to-one line, did not all fall within ± 1 RPD.

Chlorophyll-a and Pheophytin

Chlorophyll-a concentrations tended to be higher at the top of the reach (below Keno dam). For chlorophyll-a, about half of the data points were below the lower RPD line. Pheophytin values were scattered, indicating that the concentrations at the top and bottom of the reach varied.

3.2.2.2 Lower Reach 1a (Below Iron Gate Dam to I-5 Rest Area)

Lower reach 1a extended from Iron Gate dam to the I-5 rest area, approximately 12 miles below Iron Gate Dam. The results are described briefly and presented in Figure 2.

Phosphorous

TP and PO₄ concentrations fell within ± 1 RPD of the one-to-one line indicating similar concentrations at the top and bottom of the reach. These data appeared uniformly distributed around the one-to-one line.

Nitrogen

TN, TKN, NH₄, and NO₃+NO₂ concentrations generally fell within ± 1 RPD of the one-to-one line indicating similar concentrations at the top and bottom of the reach. These data appeared uniformly distributed around the one-to-one line. TN, TKN, and NO₃+NO₂ concentrations showed some scatter outside the one-to-one line, but did not suggest systematic increases or decreases upstream to downstream, with one exception. That exception was NO₃+NO₂ in September for which concentrations at I-5 were lower than at Iron Gate dam, with the data distributed along the lower RPD line.

DOC, TSS and VSS

DOC concentrations all fell within ± 1 RPD of the one-to-one line indicating similar concentrations at the top and bottom of the reach. These data are clustered around the one-to-one line. TSS and VSS in August were all within ± 1 RPD; however, in September the data appear to be slightly higher at I-5 than below Iron Gate dam (distributed along the upper RPD line).

Chlorophyll-a and Pheophytin

Chlorophyll-a concentrations were uniformly distributed around the one-to-one line, and generally fell within ± 1 RPD (at low concentrations some values were outside the ± 1 RPD envelope). Pheophytin

concentrations tended to be scattered, but suggest that concentrations tended to be higher upstream (below Iron Gate dam), particularly at lower concentrations.

3.2.2.3 Lower Reach 2a (At I-5 Rest Area to at Walker Bridge Road)

Lower Reach 2a continued downstream from I-5 to Walker Bridge Road, approximately 21 miles downstream. There were only 8 samples to compare (August and September) and results are presented in Figure 3.

Phosphorous

TP and PO₄ concentrations fell within ± 1 RPD of the one-to-one line indicating similar concentrations at the top and bottom of the reach. These data were uniformly distributed around the one-to-one line.

Nitrogen

TN, TKN, and NH₄ were generally within ± 1 RPD of the one-to-one line. There is one data point from a sample taken in September that fell outside the lower RPD line. Otherwise, the data shows that concentrations do not differ at the bottom of the reach compared to the top. NO₃+NO₂ concentrations are systematically lower at the bottom of the reach than at the top of the reach for August and September.

DOC, TSS and VSS

DOC concentrations all fell within ± 1 RPD of the one-to-one line indicating similar concentrations at the top and bottom of the reach. These data were distributed around the one-to-one line. TSS and VSS were all within ± 1 RPD with the exception of VSS for one point from a sample taken in September. The VSS data from September sampling appeared to be slightly higher at I-5 than Walker Bridge Road.

Chlorophyll-a and Pheophytin

Chlorophyll-a concentrations were distributed around the one-to-one line, and generally fell within ± 1 RPD (at low concentrations one value was outside the ± 1 RPD envelope). Pheophytin concentrations tended to be low in August, and widely scattered in September.

3.2.2.4 Lower Reach 3a (Below Iron Gate Dam to at Walker Bridge Road)

Lower reach 3a extends from Iron Gate dam to Walker Bridge Road, a distance of 33 miles. The results are described briefly and presented in Figure 4.

Phosphorous

TP and PO₄ concentrations fell within ± 1 RPD of the one-to-one line indicating similar concentrations at the top and bottom of the reach. These data appeared uniformly distributed around the one-to-one line.

Nitrogen

TN, TKN, and NH₄ are generally within ± 1 RPD of the one-to-one line. In September, there was one data point that falls outside the lower RPD line, but there did not appear to be a strong trend that concentrations are higher or lower at the bottom of the reach than at the top. NO₃+NO₂ concentrations were similar top and bottom in June, suggesting a tendency for lower downstream concentration (but were mixed) in August, and systematically lower at the bottom of the reach than at the top of the reach for September (July data were not collected due to fires).

DOC, TSS and VSS

DOC concentrations all fell within ± 1 RPD of the one-to-one line indicating similar concentrations at the top and bottom of the reach. These data appeared clustered around the one-to-one line. TSS and VSS were all within ± 1 RPD.

Chlorophyll-a and Pheophytin

Chlorophyll-a concentrations were distributed around the one-to-one line, and generally fell within ± 1 RPD. Pheophytin concentrations tended to be low in August, and although widely scattered in September, suggest that values were higher below Iron Gate dam than at Walker Bridge Road.

3.2.2.5 Lower Reach 2b (At I-5 Rest Area to Above Shasta River Confluence)

The above Shasta River confluence site was only sampled in July (four samples) due to fires in the study area. For completeness, these results are presented herein in Figure 5. Briefly, all parameters were within ± 1 RPD except a single TKN observation (and TN value), a single chlorophyll-a observation, and all pheophytin observations.

3.2.2.6 Lower Reach 3b (Below Iron Gate dam to Above Shasta River Confluence)

The above Shasta River confluence site was only sampled in July (four samples) due to fires in the study area. For completeness, these results are presented herein in Figure 6. Briefly, all parameters were within ± 1 RPD except a single TKN observation (and TN value), a single chlorophyll-a observation, and two pheophytin observations.

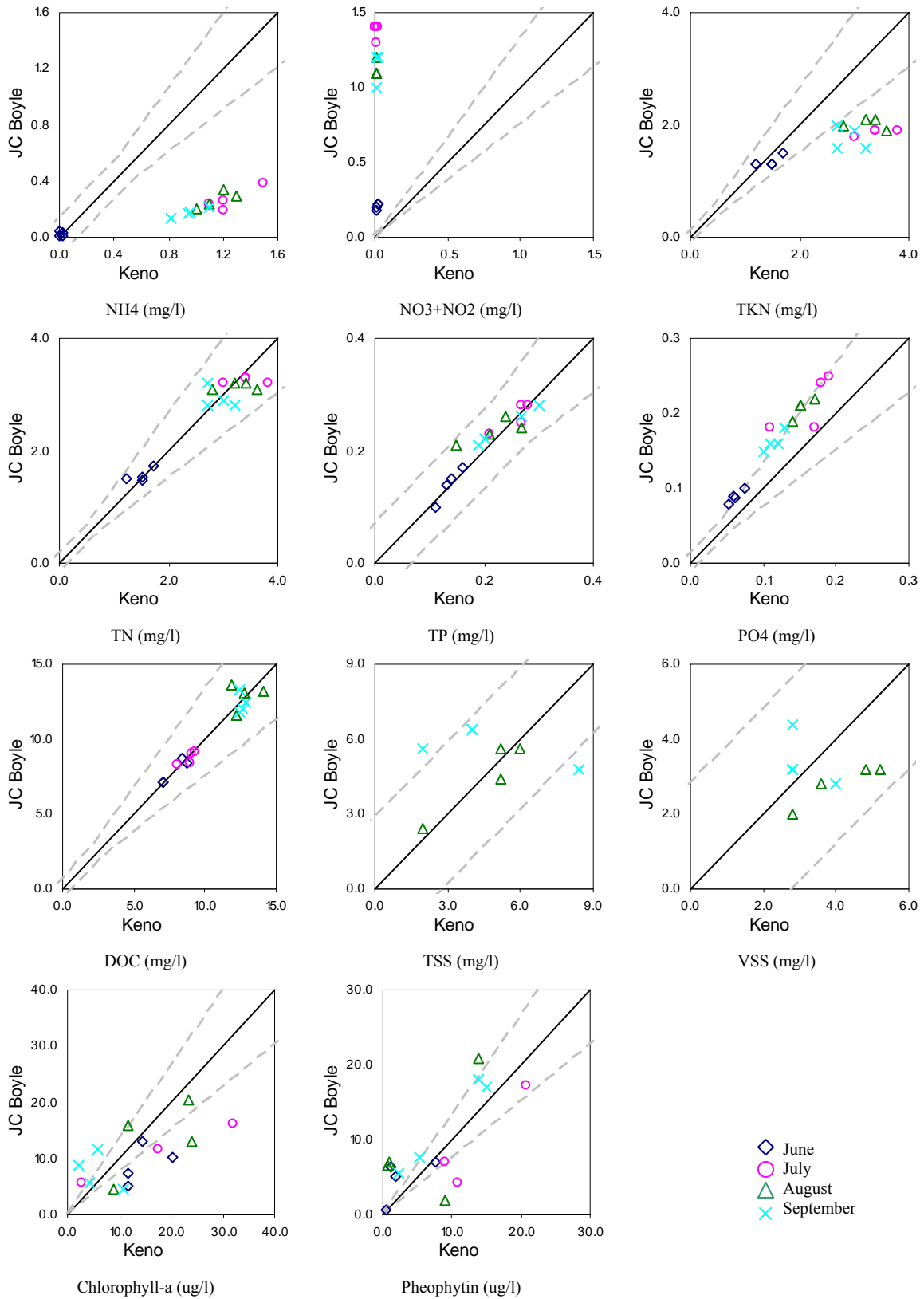


Figure 1. Inter-reach concentrations in the upper reach (below Keno dam to above J.C. Boyle reservoir) for each constituent.

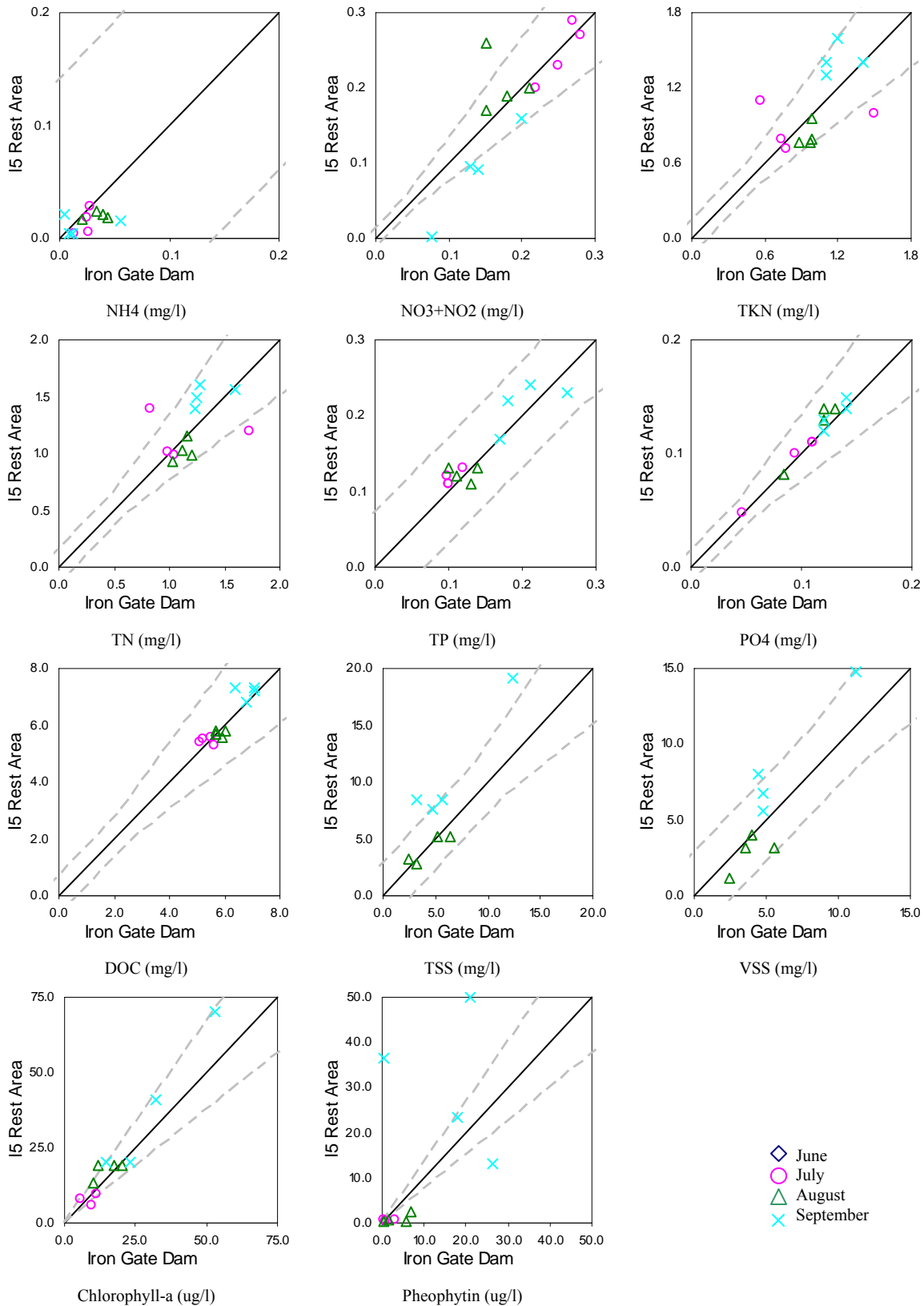


Figure 2. Inter-reach concentrations in the lower reach 1a (below Iron Gate dam to at I-5 Rest Area) for each constituent.

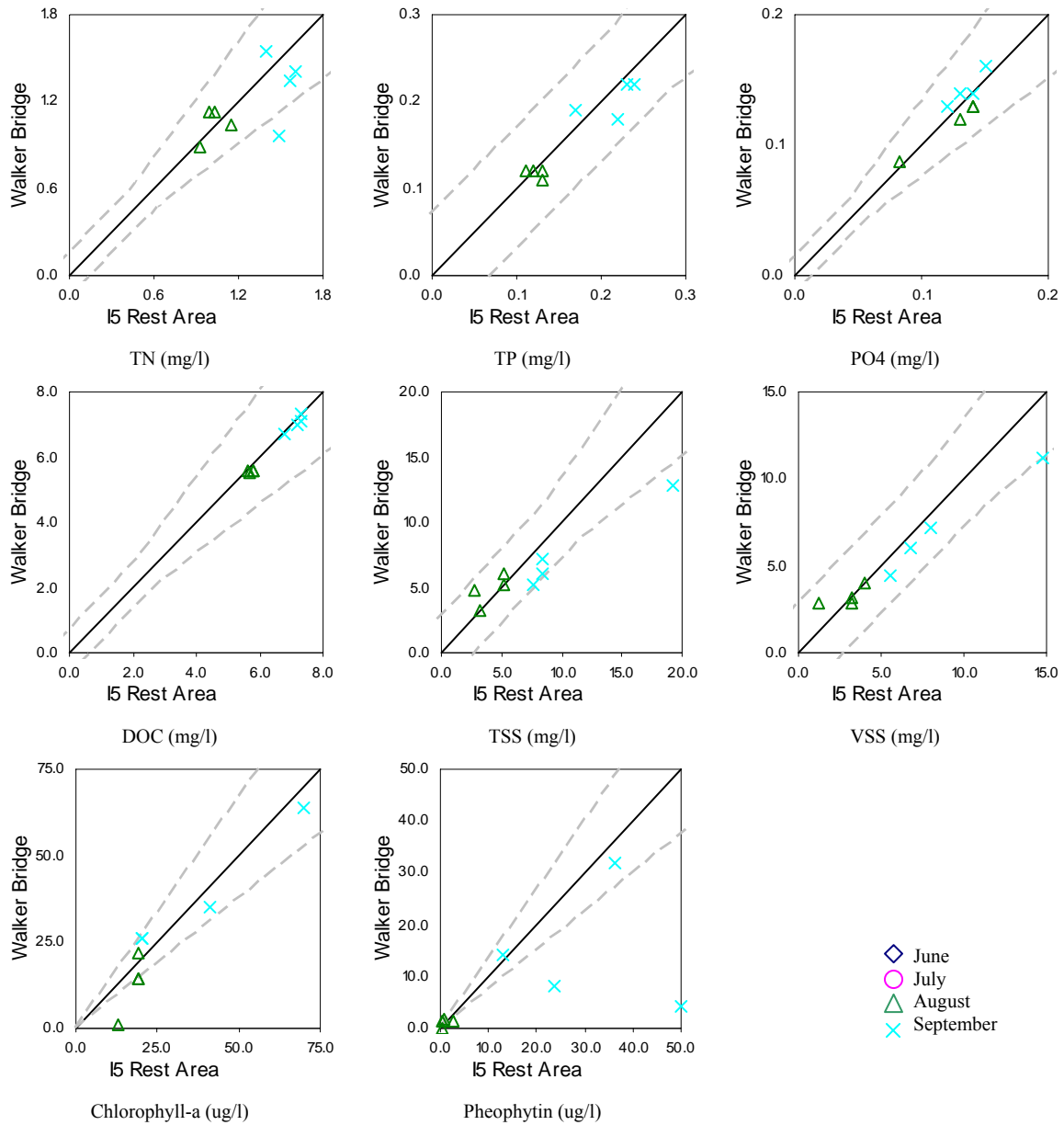


Figure 3. Inter-reach concentrations in the lower reach 2a (at I-5 Rest Area to at Walker Bridge Road) for each constituent.

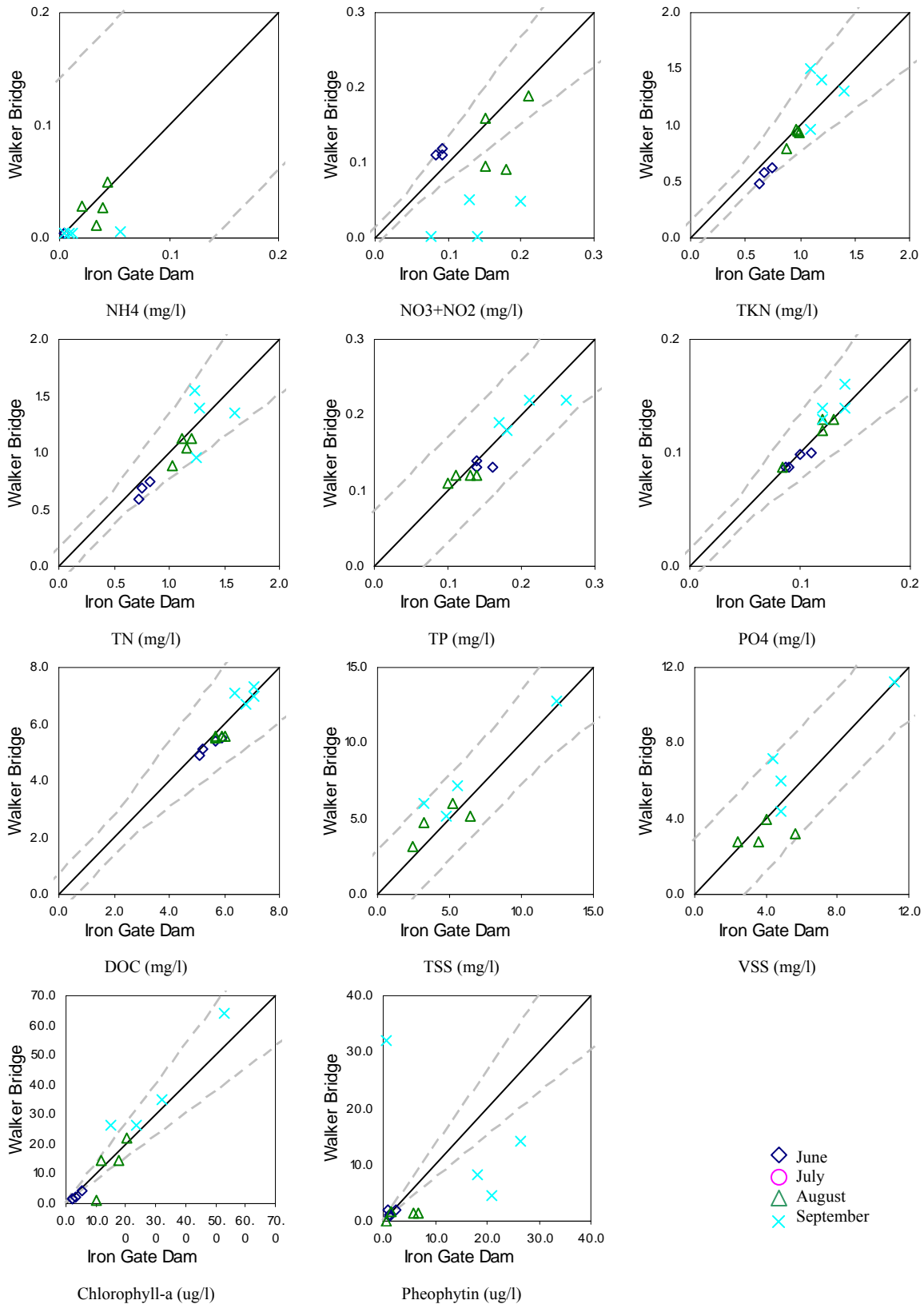


Figure 4. Inter-reach concentrations in the lower reach 3a (below Iron Gate dam to at Walker Bridge Road) for each constituent.

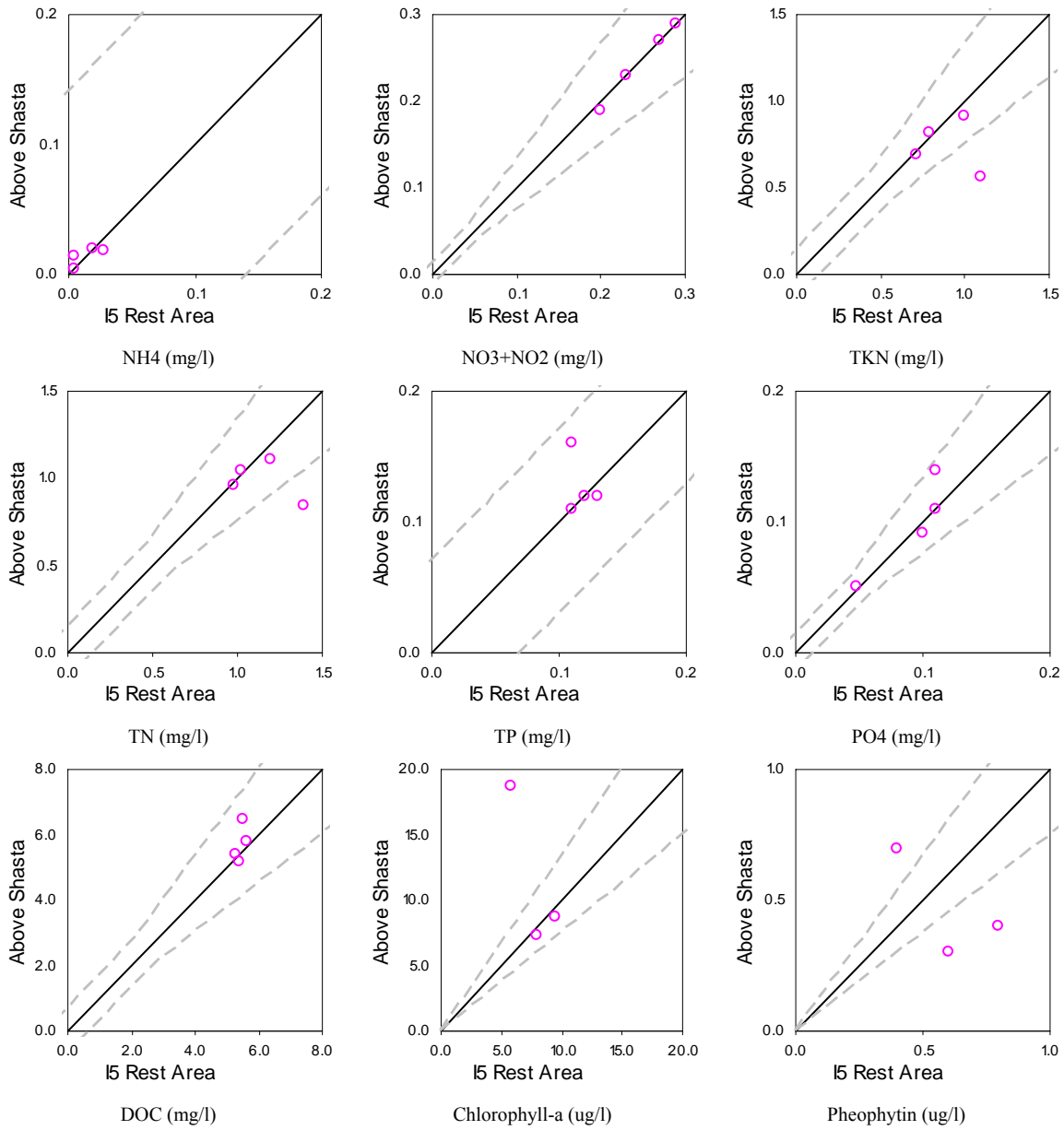


Figure 5. Inter-reach concentrations in the lower reach 2b (at I-5 Rest Area to above Shasta River) for each constituent (July data only).

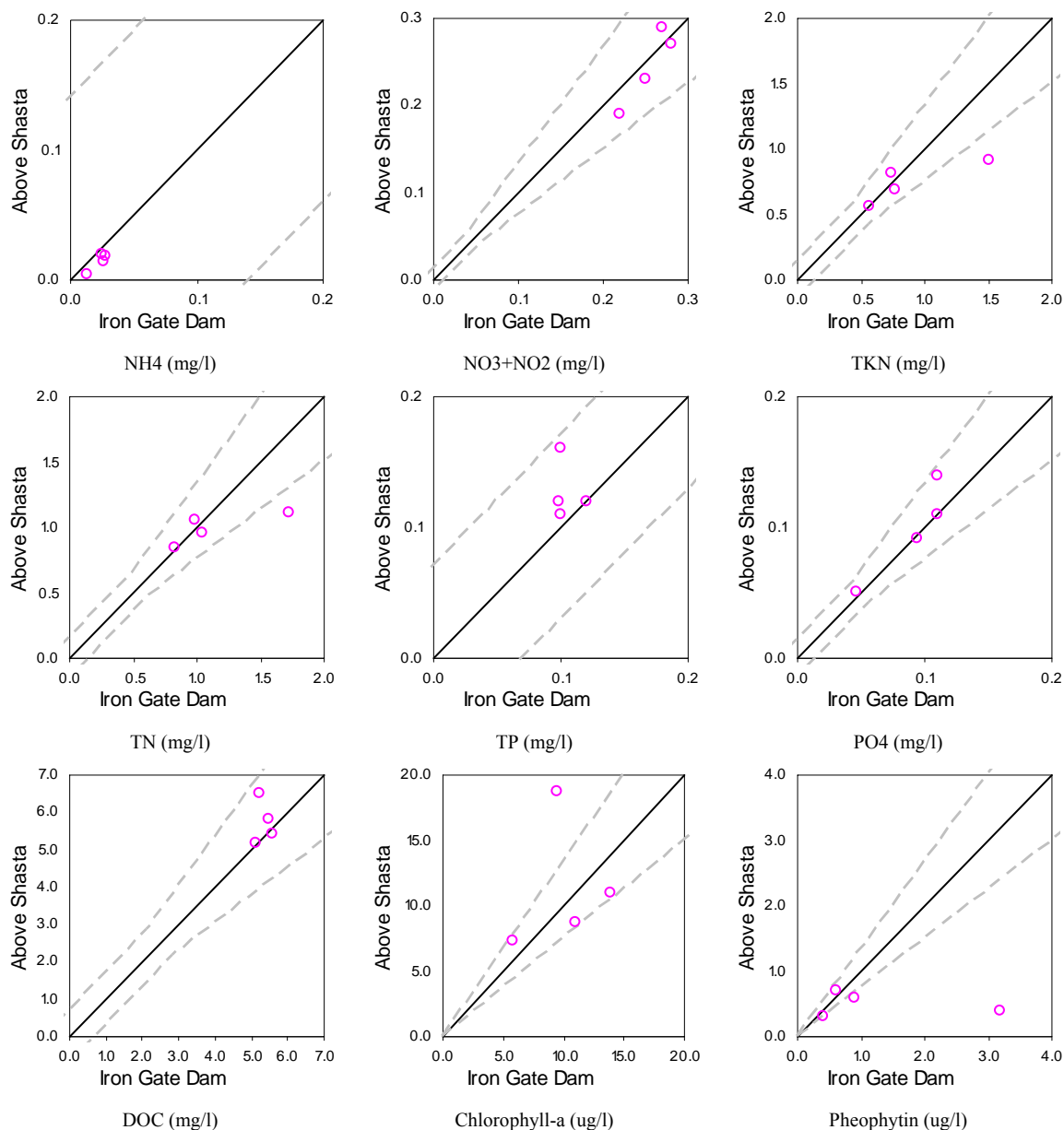


Figure 6. Inter-reach concentrations in the lower reach 3b (at Iron Gate dam to above Shasta River) for each constituent (July data only).

3.2.3 Tributary Conditions: Lower Reach

In August and September, one grab sample was taken in the Shasta River (confluence at RM 176 and Beaver Creek (confluence at RM 162), upstream of their confluences with the Klamath River. These water quality conditions were compared with composite samples in the lower reach to determine similarities and/or differences between mainstem and tributary conditions. Flow in the Shasta on the August 14 sampling date was 22 cfs and on the September 12 sampling date was 44 cfs. Not flow data were available for Beaver Creek, but is typically on par with impaired flows at the Shasta River.

Constituent concentrations for tributaries and mainstem sampling locations in the lower reach are presented in Table 8 and Table 9 for August 14 and September 12, respectively. Beaver Creek

experienced notably lower concentrations compared to the mainstem, while the Shasta River exhibited water quality conditions that were more akin to the mainstem

Table 8. Constituent Concentrations of All Sites (Composite) and Tributaries for August 14, 2007.

	Constituent Concentration (mg/l or ug/l) ¹				
	Below IGD	At I-5 Rest Area	Shasta River	Beaver Creek	At Walker Bridge
River Mile	190	178	176	162	157
Sampling Time ²	n/a	n/a	8:45	12:15	n/a
NH4	0.040(j)	0.021(j)	0.0046 ³ (j)	0.0046 ³ (j)	0.027(j)
NO3+NO2	0.150	0.260	0.0013 ³ (j)	0.041	0.160
TKN	0.97	0.77	0.52	0.13	0.97
TN	1.1	1.0	0.52	0.17	1.1
TP	0.110	0.120	0.110	0.019(j)	0.120
PO4	0.120	0.140	0.150	0.0031 ³ (j)	0.130
DOC	5.9	5.6	5.7	1.1	5.6
TSS	3.2	2.8	0.95 ³ (j)	0.95 ³ (j)	4.8
VSS	2.4	1.2(j)	0.95 ³ (j)	0.95 ³ (j)	2.8
Chlorophyll-a	10.2	13.1	2.9	2.0	1.0
Pheophytin	0.50	0.20	8.5	0.50	0.10

¹ Chlorophyll-a and pheophytin are in micro-grams per liter (ug/l), all other constituents in milligrams per liter (mg/l).

² At below IGD, I-5 Rest Area, and Walker Bridge, composite samples were used for comparison, sample time was not applicable.

³ these values were non-detect, MDL presented herein

(j) – below method reporting limit

In general values were carried to three significant digits (e.g., 0.xxx for constituents with concentrations typically less than 1.0, and x.xx for constituents with concentrations that generally exceeded 1.0) only for consistency, and does not represent accuracy to the thousandths of a mg/l (or appropriate unit).

Table 9. Constituent Concentrations of All Sites (Composite) and Tributaries for September 12, 2007.

	Constituent Concentration (mg/l) ¹				
	Below IGD	At I-5 Rest Area	Shasta River	Beaver Creek	At Walker Bridge
River Mile	190	178	176	162	157
Sampling Time ²	n/a	n/a	12:35	9:25	n/a
NH4	0.056(j)	0.015(j)	0.0046 ³ (j)	0.041(j)	0.0046 ³ (j)
NO3+NO2	0.200	0.160	0.011	0.0013 ³ (j)	0.048
TKN	1.4	1.4	0.31	0.71	1.3
TN	1.6	1.6	0.32	0.71	1.3
TP	0.180	0.220	0.019(j)	0.160	0.180
PO4	0.120	0.130	0.170	0.160	0.140
DOC	6.8	6.8	1.3	6.6	6.7
TSS	4.8	7.6	1.6(j)	2.8	5.2
VSS	4.8	5.6	1.6(j)	1.2(j)	4.4
Chlorophyll-a	23.4	20.4	0.5	2.9	26.3
Pheophytin	26.4	13	0.5	0.1	14.1

¹ Chlorophyll-a and pheophytin are in micro-grams per liter (ug/l), all other constituents in milligrams per liter (mg/l).

² At below IGD, I-5 Rest Area, and Walker Bridge, composite samples were used for comparison, sample time was not applicable.

³ These results were non-detect, MDL presented herein

(j) – below method reporting limit

In general values were carried to three significant digits (e.g., 0.xxx for constituents with concentrations typically less than 1.0, and x.xx for constituents with concentrations that generally exceeded 1.0) only for consistency, and does not represent accuracy to the thousandths of a mg/l (or appropriate unit).

3.3 SUB-DAILY VARIABILITY

As discussed previously, sub-daily grab samples (am1, am2, pm1, and pm2) were collected below Iron Gate dam in June, July, August, and September, as well as composite samples. The retention of individual sub-daily grab samples provided an opportunity to assess potential sub-daily variability in nutrient concentrations below the dam.

Two metrics were developed to quantitatively assess sub-daily variability. Both metrics used a 50 percent change in mean daily concentration as the basis for comparison. This magnitude change in concentration was selected as 2.5 times the RPD (± 20 percent) and thus would indicate changes well beyond analytical uncertainty. The first metric compared the maximum daily range ($C_{\max} - C_{\min}$) for a specific constituent for each of the four days to 50 percent of the mean daily concentration for the constituent over the four days. The second metric compared the standard deviation for the constituent over the four days to 50 percent of the mean daily concentration for the constituent over the four days. By the nature of the data, the standard deviation is less than the maximum daily range, thus the two metrics together provide two levels of sensitivity.

Differing amounts of sub-daily variation were apparent below Iron Gate dam, depending on parameter and month sampled (Table 10). For several of the constituents the maximum concentration range was at

least 50 percent of the daily average concentration for the month of August. The standard deviation for each month was notably smaller and generally less than 50 percent of the daily mean.

Table 10. Summary of the Sub-daily Concentration Analysis for Below Iron Gate dam.

Constituent	Sub-Daily Variability Comparison Below Iron Gate Dam ^{1,2,3}			
	June	July	August	September
NH4	●, ■	○, ■	○, ■	○, □
NO3+NO2	●, ■	●, ■	○, ■	○, ■
TKN	○, ■	●, ■	○, ■	○, ■
TN	○, ■	●, ■	●, ■	○, ■
TP	○, ■	●, ■	●, ■	●, ■
PO4	●, ■	○, ■	○, ■	●, ■
DOC	●, ■	○, ■	●, ■	●, ■

¹ '○' indicates that the maximum daily range is greater than or equal to 50% of the average concentration and '●' indicates that the maximum daily range is less than 50% of the average concentration.

² '□' indicates that the standard deviation is greater than or equal to 50% of the average concentration and '■' indicates that the standard deviation is less than 50% of the average concentration.

³ '-' indicate constituents that were not sampled for at that site or the results were unavailable.

Sub-daily variability in the constituent concentrations listed above depended on the constituent and month. In general, sub-daily variability was present at some level for all constituents, but the degree of scatter varied considerably. For NH4, concentrations were all below the reporting limit and although there was variability, this occurred over a small range. NO3+NO2 there was little variability in June, July, and September. However, August data reflect potential sub-daily variability. TKN illustrated sub-daily variability in several months, suggesting that a composite sample may be more representative than a single grab sample. PO4, TP, and DOC showed little sub-daily variation. The nutrient data for all sampling periods is depicted graphically in Figure 7 through Figure 13.

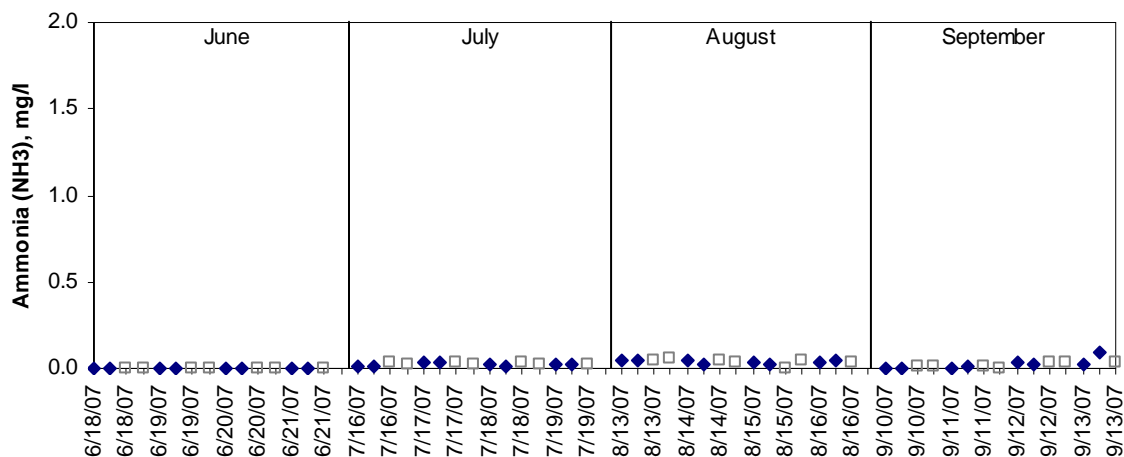


Figure 7. Sub-daily NH4 concentrations below Iron Gate dam (filled diamonds are morning samples and open squares are afternoon samples).

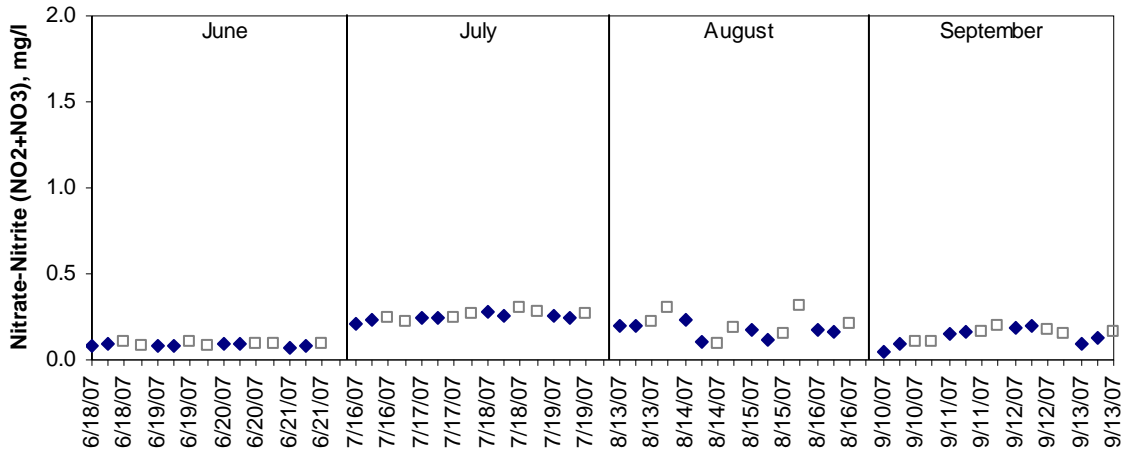


Figure 8. Sub-daily NO₃+NO₂ concentrations below Iron Gate dam (filled diamonds are morning samples and open squares are afternoon samples).

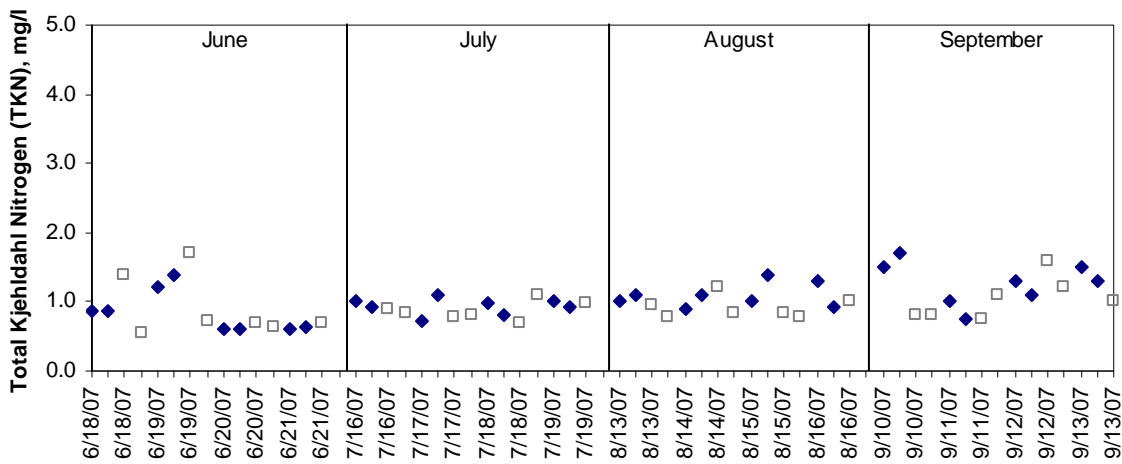


Figure 9. Sub-daily TKN concentrations below Iron Gate dam (filled diamonds are morning samples and open squares are afternoon samples).

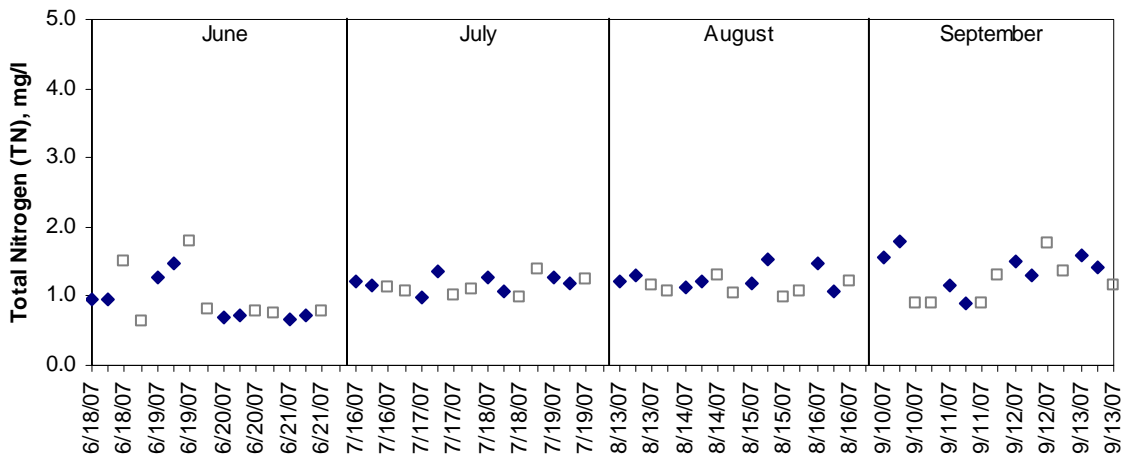


Figure 10. Sub-daily TN concentrations below Iron Gate dam (filled diamonds are morning samples and open squares are afternoon samples).

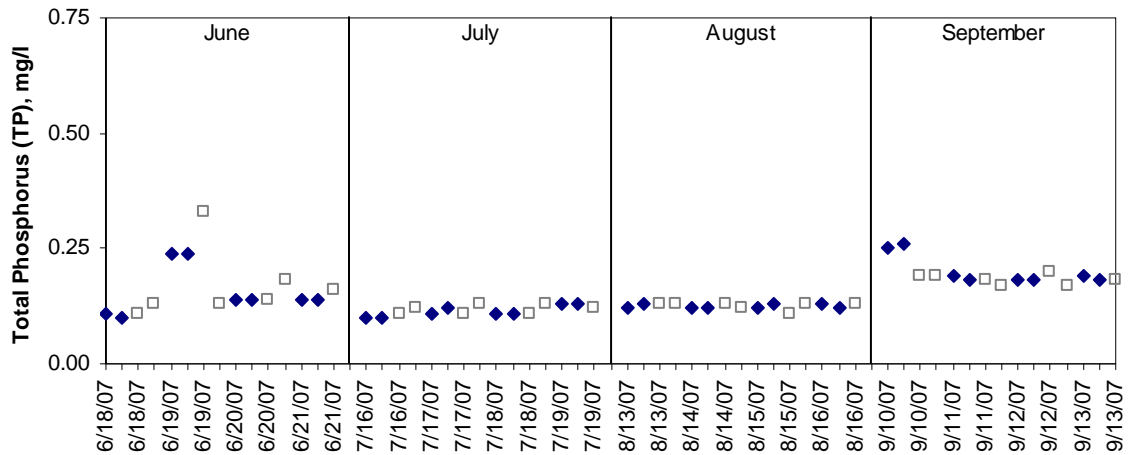


Figure 11. Sub-daily TP concentrations below Iron Gate dam (filled diamonds are morning samples and open squares are afternoon samples).

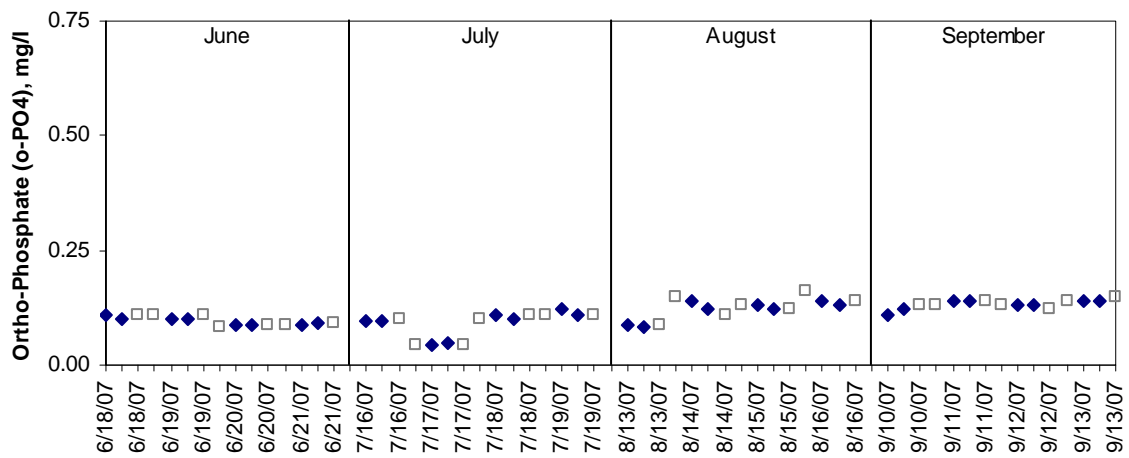


Figure 12. Sub-daily PO4 concentrations below Iron Gate dam (filled diamonds are morning samples and open squares are afternoon samples).

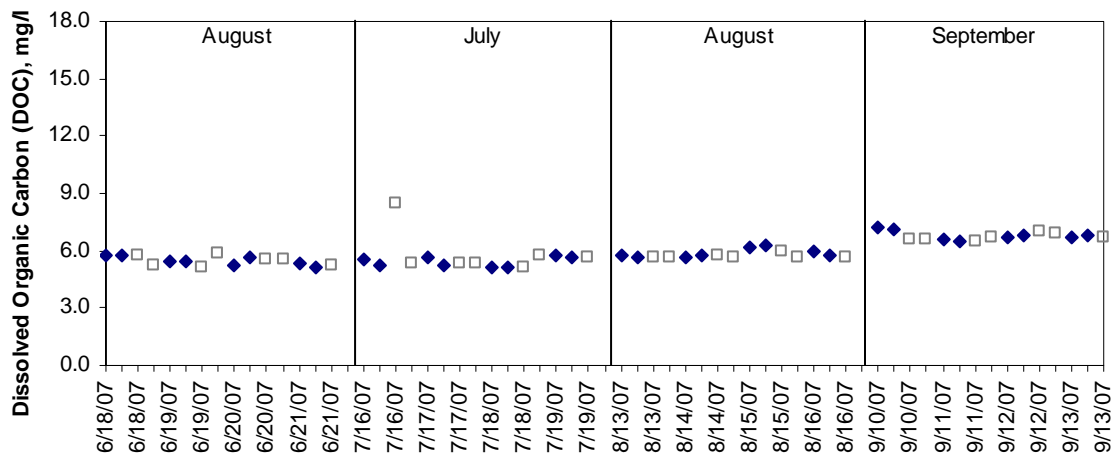


Figure 13. Sub-daily DOC concentrations below Iron Gate dam (filled diamonds are morning samples and open squares are afternoon samples).

3.3.1 Composite vs. Grab Sampling

The sub-daily grab and composite sampling also provided an opportunity to examine the implications of grab sampling versus a composite sample. Although results varied, findings suggest that at certain locations and/or at certain times of year where there is potential for variability in some constituents. In such cases, a composite sample may prove to be representative of overall daily conditions. Two examples comparing composite and grab samples for NO₂+NO₃ and PO₄ below Iron Gate dam in September are shown in Figure 14 and Figure 15, respectively. Thus, the use of composite samples in this study provided a more robust approach to assessing the fate of nutrients in the studied river reaches.

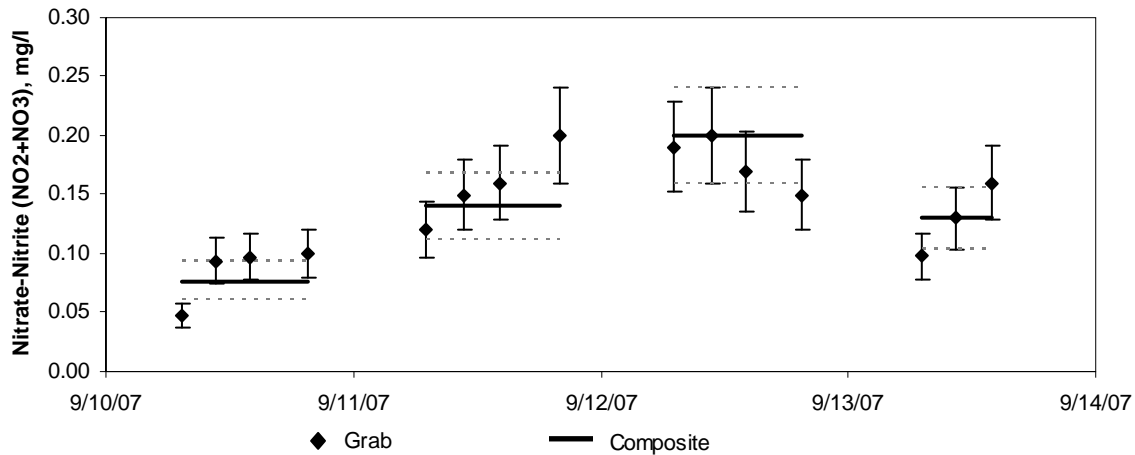


Figure 14. NO₂+NO₃ concentrations for Klamath River below Iron Gate dam: September 2007.

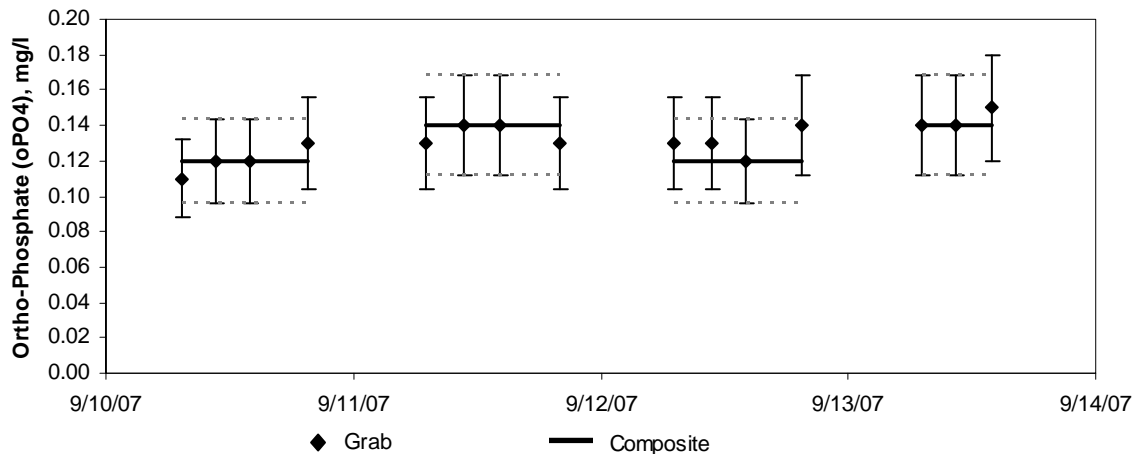


Figure 15. PO₄ concentrations for Klamath River below Iron Gate dam: September 2007.

4.0 SUMMARY

The purpose of this study was to determine the fate and transport of nutrients and organic matter in the Klamath River in the vicinity of the Klamath Hydroelectric Project (Project). Existing field data and modeling results suggest that the short residence time through river reaches, coupled with distinct reach features, of the Klamath River in the vicinity of the Klamath Hydroelectric Project (Project) limits the processing of organic matter and retention or removal of nutrients by benthic algae or other processes

(PacifiCorp 2006). The nutrient and organic matter fate and transport study assessed the differences or changes in concentrations of various constituents through two representative unimpounded river reaches in the Klamath River. The two reaches, located upstream and downstream of the Project reservoirs, are defined as follows:

1. Upper Reach: Klamath River from Keno dam to J.C. Boyle reservoir (River Mile [RM] 233.4 to 228.2)
2. Lower Reach: Klamath River from Iron Gate dam to Walker Bridge Road (RM 189.7 to RM 157.5)

Several sites bracketing these two reaches were sampled approximately monthly during the June-September 2007 period. During each sampling event, multiple samples per day were collected over a four-day period at each site. These sub-daily samples were composited for each day, resulting in one composite sample per day per site. Each of these daily composite samples were analyzed for ammonia (as N), nitrate + nitrite (as N), total Kjeldahl nitrogen (as N), total phosphorous (as P), orthophosphate (as P), dissolved organic carbon, chlorophyll-a, and pheophytin. In addition, total nitrogen was assessed based on the sum of total Kjeldahl nitrogen and nitrate + nitrite. At the time of sub-daily sampling, measurement of water temperature, dissolved oxygen, pH, and conductivity were taken with multi-probe instrumentation. At the sampling site below Iron Gate dam, in addition to the daily composite sample, the individual sub-daily samples were collected throughout the sampling season. This analysis of sub-daily samples provided additional information on the potential temporal (sub-daily) heterogeneity of nutrient releases to the river from Iron Gate reservoir.

Notable findings of the nutrient and organic matter fate and transport study include:

- Nutrient concentrations, with few exceptions did not differ considerably from the upstream end to the downstream end within the upper and lower reaches. Specifically,
 - There was little change in concentrations of total nitrogen and total phosphorous at the upstream and downstream points in both the upper reach and lower reach. Statistical comparison of the mean and variance of the paired data sets indicate there was no statistically significant difference ($p=0.05$) in total nitrogen and total phosphorous concentrations though the reaches.
 - Even though there was no statistically-significant change in total nitrogen and total phosphorus concentrations in the two study reaches, it appears that intermediate processes within the reaches account for some observed changes of inorganic or organic nutrient forms (e.g., sequestration of nutrients in algal biomass, denitrification, burial, desiccation, atmospheric deposition, conversion, senescence, reentrainment and erosion, etc.).
 - Changes in the concentrations of inorganic nitrogen forms (i.e., ammonia and nitrate+nitrite) were particularly evident in the upper reach. These data indicate that waters released from Keno dam were relatively high in ammonia and low in nitrate+nitrite during summer months. These data further indicate that these waters were subjected to nitrification during transit through the reach,, leading to notably higher concentrations of nitrate+nitrite and lower concentrations of ammonia at the downstream end of the reach above J.C. Boyle reservoir. Meanwhile, as noted above, total nitrogen concentrations were statistically the same at the upstream and downstream ends of the reach.
 - Changes in the concentrations of inorganic phosphorus also were evident in the upper reach, indicated by the increase in orthophosphate concentrations between Keno Dam to the site above J.C. Boyle reservoir. These data suggest that phosphorus bound in organic matter from upstream sources (dissolved and particulate) probably undergoes some level of conversion (e.g., oxidation) yielding the observed increase in orthophosphate. Datasonde data collected during the sampling

periods suggest that dissolved oxygen concentrations are maintained at levels approximately 70 to 100 percent of saturation.

- Dissolved organic carbon (DOC) was used in the study as a measure for dissolved organic matter. There was little change in DOC concentrations between the upstream and downstream points in both the upper reach and lower reach. Statistical tests show that there is no statistically significant difference ($p=0.05$) in the mean and variance of the paired data sets. Similarly, volatile suspended solids (VSS), a measure of particulate organic matter, did not change appreciably from the upstream and downstream sites within each of the study reaches, although VSS data showed more scatter than DOC data.
- Tributary contributions of nutrients and organic matter in the upper reach are negligible. In the lower reach, data from the Shasta River and Beaver Creek indicate that concentrations of nutrients and organic matter in these tributaries are at times different and at times similar to the mainstem. Generally, Beaver Creek exhibits higher quality water than the mainstem Klamath River. However, overall flow contributions from these tributaries are minor.
- In addition to comparing nutrient and organic matter concentrations between the upstream and downstream ends of the lower reach, further within-reach changes in concentrations were assessed in the lower study reach by comparing the intermediate site at I-5 with Iron Gate Dam and Walker Bridge Road. As with the comparison of the upstream and downstream ends of the reach, few differences in nutrient and organic matter concentrations occurred in these sub-reaches.
- Sub-daily variability below Iron Gate Dam for nutrients was assessed. Sub-daily variability depended on the constituent and month. In general, sub-daily variability was present at some level for all constituents, but the degree of scatter varied considerably. For ammonia, concentrations were all below the reporting limit and although there was variability, this occurred over a small range. Nitrate+nitrite data illustrated little variability in June, July, and September. However, August data reflect potential sub-daily variability. Total Kjeldahl nitrogen illustrated sub-daily variability in several months, suggesting that a composite sample may be more representative than a single grab sample. PO₄, TP, and DOC showed little sub-daily variation.

5.0 REFERENCES

- American Public Health Assoc., American Water Works Assoc., and Water Environment Federation (APHA). 2005. Standard Methods for the examination of water and wastewater, 21st Edition. Editors: A.D. Eaton, L.S. Clesceri, E.W. Rice, A.E. Greenberg, M.H. Franson. Washington D.C.
- PacifiCorp. 2007. "Responses to State Water Resources Control Board Comments on PacifiCorp's 2007 Water Quality Studies. Transmittal from C. Scott to L.F. Grober, State Water Resources Control Board. August 7, 2007. 5 pp.
- PacifiCorp. 2006. Causes and Effects of Nutrient Conditions in the Upper Klamath River. Klamath Hydroelectric Project (FERC Project No. 2082). PacifiCorp, Portland, Oregon. November 2006. 77 pp.
- State Water Resources Control Board (SWRCB). 2007. "Comments on PacifiCorp's 2007 Water Quality Studies. Transmittal from L.F. Grober to C. Scott, PacifiCorp. July 3, 2007. 3 pp.

APPENDIX A: STUDY PLAN FOR 2007 NUTRIENT AND ORGANIC MATTER FATE
AND TRANSPORT STUDY

Study Plan: Field Study Of Nutrient And Organic Matter Fate And Transport In Representative Reaches In The Klamath River System

PacifiCorp Energy
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Portland, OR 97232

May 11, 2007

PURPOSE

Asarian and Kann (2006) claim that river reaches, such as that which occurs below Iron Gate dam on the Klamath River, provide significant instream retention or removal of nutrients. This study will perform focused sampling of nutrients in river reaches upstream and downstream of the Project reservoirs to more clearly resolve the question of nutrient and organic matter processing and retention in the river.

APPROACH

Existing field data and modeling results suggest that the short residence time through the river reaches in the project area limits the processing of organic matter and sequestering of nutrients by benthic algae, and that the relatively long residence time through the reservoir reaches in the project area enhances the processing of organic matter and sequestering of nutrients (PacifiCorp 2006). This study will be specifically designed to determine the effect on nutrient concentrations of passage through two representative unimpounded river reaches in the Klamath River just upstream and downstream of the Project reservoirs, defined as follows:

1. Klamath River from Keno dam (monitoring site KR23335) to J.C. Boyle reservoir (KR22822)
2. Klamath River from Iron Gate dam (monitoring site KR18973) to Walker Bridge Road (KR15750)

The four sites bracketing the two reaches as listed above will be sampled approximately monthly during the June-September 2007 period. During each sampling event, multiple samples per day will be collected over a three or four-day period at each site. Samples at these sites will be taken offshore in the current just beneath the surface. The sub-daily samples will be composited for each day, resulting in one composite sample per day per site. Each of these daily composite samples will be analyzed for ammonia, nitrate + nitrite (as N), total Kjeldahl nitrogen (TKN), total phosphorous, orthophosphate, total organic carbon (TOC), dissolved organic carbon (DOC), and chlorophyll-a.

At the time of sub-daily sampling, measurement of water temperature, dissolved oxygen, pH, and conductivity will be taken with multi-probe instrumentation. For the site below Iron Gate dam (monitoring site KR18973), in addition to the daily composite sample, the individual sub-daily samples will be analyzed for the parameters listed above. This analysis of sub-daily samples will provide additional information on the temporal (sub-daily) heterogeneity of nutrients in waters released to the river from Iron Gate reservoir.

SCHEDULE

Planning and implementation: May-June 2007. Field sampling period: June-September 2007.

REFERENCES

Asarian, E. and J. Kann. 2006. Klamath River Nitrogen Loading and Retention Dynamics 1996-2004. Report prepared for the Yurok Tribe Environmental Program. July 2006.

APPENDIX B: STUDY SITE DESCRIPTIONS

Klamath River Below Keno Dam



Klamath River below Keno dam, looking downstream from river left (September 13, 2007).

Sampling site was from the bedrock at river left below the fish ladder, in well mixed location (Figure 33). Water depth was approximately 2-3 feet at this location. The river was highly aerated from Keno dam, with appreciable foam along the river banks, by rocks in the river, and below the radial gates of the dam. A large number of birds (herons, egrets, pelicans, cormorants) were observed each month.

Klamath River Above J.C. Boyle Reservoir



Klamath River above J.C. Boyle reservoir, looking upstream from river left (September 10, 2007).

Sampling site was river left at the mouth of the canyon, well above the reservoir influence. Water depth was approximately 2 feet at this location and was fast flowing and well-mixed. Access to the river was through the Sportsmen's club. The sampling site had few plants and large boulders (Figure 34).

Klamath River Below Iron Gate Dam



Klamath River below Iron Gate dam, looking downstream from river right (August 14, 2007).

Sampling site was at the boat ramp on river right, downstream from the bridge and across the river from the Iron Gate Fish Hatchery (Figure). The river had a steady flow adjacent to the shore due to releases from Iron Gate dam and reservoir, allowing for well-mixed sampling in approximately 2 feet of water.

Klamath River at I-5 Rest Area



Klamath River at I-5 Rest Area, looking straight across from river left (July 16, 2007).

From July to September, an intermediate site between Iron Gate dam and Walker Bridge Road was selected and composite samples were collected daily. Sampling site was river left, beyond a rock wall by the picnic area in the first section of the rest area (Figure). Apart from the rock wall area, the entire length of the river at the rest area is fenced and inaccessible. Water depth was approximately 2 feet at this location and was fast-flowing and well-mixed.

Klamath River at Walker Bridge Road



Klamath River at Walker Bridge Road Bridge, looking straight across from river left (September 12, 2007).

In previous years, sampling was completed on river right, and attempts were made to sample here during the first sample of the first day in June. Access was difficult due to tall weeds and deep, slow river conditions. The growth of riparian vegetation, steep bank, and deep channel presented a challenge to the samplers. Sampling conditions on river right were deemed “fair.” River left, under the bridge) provided better access and a more representative sampling site (Figure). Parking and access were considerably easier and the river flowed up against the bank on river left, providing a deep, well-mixed sampling location. In July, Highway 96 at Highway 263 was closed due to a wildfire, restricting access to Walker Bridge Road. Hence, no samples were collected at Walker Bridge Road during this sampling period. Instead, an alternate site (Klamath River above Shasta) was selected.

Klamath River Above Shasta River Confluence



Klamath River above Shasta River confluence, looking downstream from river left (July 18, 2007).

The sampling site for Klamath River above Shasta River was accessed in two ways: driving down the USGS access road, which had a chained entryway located less than a mile on the right (west) side of Hwy 263, or hiking down a gravel path about 0.25 miles on Hwy 263. Either route ended at approximately the same location (near the Shasta River fish weir). The path to the river led to the sampling site at an abandoned bridge abutment (Figure). Water depth was approximately 3 feet at this location and was fast-moving and well-mixed.

Shasta River



Shasta River, looking downstream from river right (August 14, 2007).

In August and September, a grab sample was taken once at Shasta River approximately one-half a mile upstream of the confluence with the Klamath River (at river mile (RM) 176) (Figure). The site was located off highway 263, just upstream of USGS gage (Station 11517500). The site was accessible by parking off the side of the road and hiking down a gravel path, or by driving down an access road. At the sampling site the water about 2 feet deep and well-mixed. The site was shaded by large trees on both sides of the bank.

Beaver Creek



Beaver Creek, looking upstream from river right (sampling site was on river left) (August 14, 2007).

In August and September, a grab sample was taken once at Beaver Creek about 750 feet upstream of the confluence with the Klamath River (at RM 162). The site was accessible by driving onto Beaver Creek Road off Highway 96, and parking at the second turnout (approximately a tenth of a mile from the junction). There a path leads down to Beaver Creek (Figure). Water depth at the site was relatively shallow, less than 2 feet. Just upstream of the sampling location, the creek split into two channels, with the bulk of the flow coming down the west channel (where the sampling occurred). The two branches of the creek joined together downstream of the sampling site before entering the Klamath River.

APPENDIX C: ANALYTICAL METHODS REQUIREMENTS, DATA QUALITY
OBJECTIVES, AND SUMMARY OF EXTERNAL QUALITY ASSURANCE

Descriptions of Analytical Methods Requirements and Data Quality Objectives

Introduction

The Klamath River 2007 (KR2007) field work included external quality assurance samples. These studies were scheduled to occur between June and September 2007. The water samples were analyzed for ammonia (NH₄), nitrate-nitrite (NO₃+NO₂), total Kjeldahl nitrogen (TKN), total phosphorus (TP), orthophosphate (PO₄), total organic carbon (TOC), dissolved organic carbon (DOC), total suspended solids (TSS), volatile suspended solids (VSS), and alkalinity (Alk). To ensure the reliability of the data, the project incorporated external quality assurance samples (QA samples) with the production samples, or non-QA samples, at a target rate of 10 percent for spike and duplicates and 5 percent for blanks per sampling session during the entire sampling period, as per the Quality Assurance Project Plan (QAPP) adopted by Watercourse, E&S Environmental and PacificCorp.

Table 11. Sampling Sites of KRWQ 2007.

Site Number	Site ID	Site Name	Approximate River Mile
1	KR25479	Upper Klamath Lake lower end near Fremont Bridge	255
2	KR25312	Klamath River below Link dam	253
3	KR23360	Keno reservoir lower end near log boom	234
4	KR23335	Klamath River below Keno dam	233
5	KR22822	Klamath River above J.C. Boyle	228
6	KR22478	J.C. Boyle reservoir lower end near log boom	225
7	KR22460	Klamath River below J.C. Boyle dam	225.5
8	KR22040	Klamath River above J.C. Boyle Powerhouse	220.4
9	KR22020	Klamath River below J.C. Boyle Powerhouse	220.2
10	KR20642	Klamath River above Shovel Creek	207
11	-	Copco reservoir in Mallard Cove	-
12	-	Copco reservoir in Copco Cove	-
13	-	Copco reservoir in Cove near Residences	-
14	KR19874	Copco reservoir near dam near deep point	199
15	KR19645	Klamath River below Copco	196
16	KR19019	Iron Gate reservoir lower end near dam	190
17	KR18973	Klamath River below Iron Gate dam	189.7
18	KR17600	Klamath River at I-5 rest area	178
19	KR15750	Klamath River at Walker Bridge Road	158
20	KR12850	Klamath River at Seiad Valley	129
21	KR15900	Klamath River at Orleans	159
22	KR04250	Klamath River at Weitchpec	43
23	KR00600	Klamath River at Turwar	6
24	-	Shasta River near mouth	-
25	-	Beaver Creek near mouth	-

Quality Assurance Review

The laboratory results for the external QA samples were generally acceptable and provide invaluable insight into data quality and potential uncertainty associated with the data set. QA samples exceeding the adopted acceptance criteria were submitted for reanalysis. Reanalysis results which confirmed the original results for the QA samples could indicate a manufacture error in QA spikes or an error produced by field personnel while preparing and incorporating the QA sampling into the production samples. Due to these possible errors, the QAPP guidelines accept the original results of a QA sample as reliable when the laboratory is able to confirm the original result with reanalysis. If the laboratory is unable to confirm the original results for a QA sample, the guidelines assert the need to submit the whole sample batch of production and QA samples for reanalysis. The CH2M HILL laboratory was unable to automatically check confirmation of original results, thus increasing the processing time of reanalyzing entire sampling batches past the acceptable time frame – much of this was due to unanticipated seasonal workload at the CH2M HILL lab. Therefore no entire batch reanalysis was performed for this project. If QA results were not confirmed, the entire batch of production samples was marked as qualified for the constituent in question and no further action was taken.

Quality Assurance Criteria

There were several criteria, or QA assessment values, used for determining the acceptability of sample results. The blank sample concentrations had to be less than ten percent of the lowest samples concentration reported in its batch or less than or equal to twice the reporting limit. For a duplicate sample, if the results were greater than or equal to five times the reporting limit, the Relative Percent Difference (RPD) should be less than 20 percent (Equation [1] below). If the results are less than five times the reporting limit, the values of the duplicate sample and the regular sample can vary plus or minus the reporting limit. For a spike sample, if the sample result does not exceed the spike concentration by five times or more, the recovery should fall between approximately 80 percent and 120 percent (Equations [2] and [3] below). If the sample result does exceed the spike concentration by five times or more, there are no criteria to determine the acceptability of the result. Also, all spike concentrations were sufficiently large enough such that all sample results for 2007 did not exceed the spike concentration by five times or more.

Reanalysis ideally would be done within the recommended hold times for each constituent. Due to lab turn around time and data QA processing time, any reanalyzed were at or just beyond the identified hold times.

$$RPD = \frac{[Regular] - [Duplicate]}{[M]} \times 100 \quad (1)$$

$$\text{Recovery for Added Spike} = \frac{[Spike] - [M]}{[Spike Material Added]} \times 100 \quad (2)$$

$$\text{Recovery for Reference Solution} = \frac{[Spike]}{[Reference Solution]} \times 100 \quad (3)$$

where:

M	= Mean of Regular and Duplicate Concentrations.
Regular	= Concentration of regular sample
Duplicate	= Concentration of duplicate sample
Spike	= Concentration of either spiked sample or reference solution

As reanalysis of samples during a project can become cost prohibitive, it was the practice for Watercourse to allow for samples to be approximately acceptable. Approximately acceptable samples are those samples whose QA assessment values are just outside of the acceptable limits. The extent to which the acceptable limits are stretched is dependent on several things, including the performance of the specified constituent's QA assessment in the course of the current study, type of QA sample involved, constituent in question, condition of the sample (e.g., level of particulate matter), familiarity with the laboratory, and the adherence to the SOP during the sample collection.

Laboratory Methods

Laboratory methods used by CH2M HILL and Aquatic Analysts are presented below.

Table 12. Grab sample analyses, methods, and processing laboratory.

Analysis	Method	Laboratory
Alkalinity	EPA310.1	CH2M HILL
DOC	EPA415.1	CH2M HILL
NH4	EPA350.3	CH2M HILL
NO3+NO2	EPA353.2	CH2M HILL
PO4	EPA365.1	CH2M HILL
TKN	EPA351.2	CH2M HILL
TOC	EPA415.1	CH2M HILL
TP	EPA365.1	CH2M HILL
TSS	EPA160.2	CH2M HILL
VSS	EPA160.4	CH2M HILL
Chlor-a, lab	SM10200 H	Aquatic Analysts
algae spec., density, BV	SM10200 F	Aquatic Analysts

QA Sample Summary

Out of a total of 336 QA samples, 35 samples fell outside the aforementioned QA limits (approximately 11 percent). Accepting RPD limits up to approximately 30 percent (versus 20 percent) reduced the non-conforming sample number to 21 (approximately 6 percent).

Blanks

There were a total of 120 QA blank samples. Of those samples, eight had QA assessment results outside of the acceptable QA limits. Of these eight samples, seven were reanalyzed and all seven original results were confirmed.

Regulars / Duplicates

There were 120 sets of regular and duplicate samples. Of these samples, nine sets had RPD values above acceptable limits. Of those nine, five sets were reanalyzed, but none of the original results were confirmed.

Spikes

There were 86 QA spike samples analyzed during 2007. Of these samples, four had recoveries outside of acceptable limits. Of those four, one was reanalyzed and the original result was not confirmed.

Laboratory QC Reports

All laboratory QC reports were acceptable.

Constituent Summary

Ammonia

There were a total of 48 QA samples for ammonia. Of those samples, none had QA assessment values outside of acceptable limits. No ammonia samples were reanalyzed.

Nitrate - Nitrite

There were a total of 48 QA samples for nitrate-nitrite. Of those samples, six had QA assessment values outside of acceptable limits. Three samples were reanalyzed and none of the original results were confirmed.

Total Kjeldahl Nitrogen (TKN)

There were a total of 48 QA samples for TKN. Of those samples, six had QA assessment values outside of acceptable limits. Three samples were reanalyzed and two of the original results were confirmed.

Total Phosphorus (TP)

There were a total of 48 QA samples for total phosphorus. Of those samples, four had QA assessment values outside of acceptable limits. Three samples were reanalyzed and two original results were confirmed.

Ortho-Phosphate (PO₄)

There were a total of 46 QA samples for analyzed for orthophosphate. Of those samples, two had QA assessment values outside of acceptable limits. Both of those samples were reanalyzed and one of the original results was confirmed.

Total Organic Carbon (TOC)

There were a total of 24 QA duplicate samples analyzed for TOC. Of those samples, none had QA assessment values outside of acceptable limits. Collection of TOC was discontinued after the week of July 18, 2007.

Dissolved Organic Carbon (DOC)

Initially, it was attempted to include DOC in the formal QA spike process by placing unfiltered reference solution in the sample vials to produce a spike QA sample. This idea was discontinued after one trial as to cost prohibitive. Although there were not full sets of QA samples for DOC without the spike samples (and this excluding DOC from the formal QA process), the following is a summary of the existing QA samples for DOC.

There were 32 QA duplicate samples analyzed for DOC. Of those samples, two had QA assessment values outside of acceptable limits. Both samples were reanalyzed and both original results were confirmed.

Total Suspended Solids (TSS)

Initially, TSS was included in the formal QA process by analyzing the whole set of QA samples for TSS. However, seven of the eight TSS spike samples had recoveries outside acceptable limits. Therefore, all TSS spike samples were disregarded and TSS only has a partial QA set associated with it. Therefore, TSS was no longer included in the formal QA process for spikes. The QA summary for the available QA TSS samples is included below for informal consideration (see below for additional discussion).

There were 16 QA duplicate samples analyzed for TSS. Of those samples, one had QA assessment values outside of acceptable limits. However, TSS is not able to be reanalyzed due to its short hold time.

Volatile Suspended Solids (VSS)

Although VSS cannot be included in the formal QA spike process as there was no spike sample available for VSS, existing QA samples for VSS are included. There were 16 QA duplicate samples for VSS in 2007. None of the VSS samples had QA assessment values outside of acceptable limits.

Quality Assurance Notes on the Klamath River 2007 Project

During the QA assessment process for the Klamath River 2007 project, there were a few issues pertaining to the QA samples that were discovered or occurred. These issues are discussed below.

Hold Time Expired Prior to Receiving Data Analysis

Two of the initial sample sets analyzed by the laboratory were not analyzed and reported in a timely manner and the hold times for NH₄ and NO₃+NO₂ had elapsed before the data was received, thus making it inappropriate to ask for reanalysis when the QA assessment values for the regular / duplicate NH₄ samples for and the blank NO₃+NO₂ sample fell outside of the acceptable limits.

Hold Time Expired Prior to Completion of QA Assessment

One set of samples did not have the QA assessment values calculated prior to the hold times elapsing for the constituents. Therefore, when the QA assessment values for regular / duplicate TP samples and the blank TKN sample fell outside of the acceptable limits, reanalysis was not viable.

No Spike / Reference Solution Added to Sample Bottle

During the sampling season, spike solutions or reference solutions were not added to sample bottles on two occasions. Results for these samples are obviously not true spike QA samples. Therefore these samples were not included in the QA analyses.

TSS and VSS Short Hold Time / TSS Low Recovery

TSS and VSS samples have a short hold time and reanalysis is not possible. The inability to reanalyze these samples made it difficult to investigate a TSS spike recovery issue. Of the 12 TSS QA spike samples of the Klamath River 2007 project, 11 had recoveries outside of acceptable limits. TSS spike recovery values were often less than 10 percent. The cause of this low recovery was thoroughly investigated. According to the makers of the TSS spike, the most common cause of low TSS spike recovery is when the sample is not adequately shaken prior to decanting the sample into smaller volumes. However, according to the SOP at CH2M HILL, TSS samples are “vigorously” shaken prior to decanting the appropriate sample volume for the analysis. Interviews with field personnel and laboratory personal on standard operating procedures and processes did not yield additional insight. The low TSS recovery issue is therefore unresolved and the spike samples for TSS are not included in the QA assessment.

Incorrect QA Type Assignments – Unresolved

On July 18, 2007 for the upper river samples it appeared that there was something amiss with the QA type assignment. The blank sample values were high enough to be spike values. The spike values were low enough to be a regular sample. The duplicate sample values were low enough to be blank values, and the production sample (for the second site) appeared to be the duplicate of the regular sample at the QA site. From discussions with the sampling crew, there were no indications in the field book or field notes that would indicate that the incorrect bottles were used during the sample collection. From discussion with the laboratory, there was no indication that the wrong labels were attached to the sample water during analysis. Laboratory values were retained in the sample set, but all samples collected on July 18, 2007 for the study are therefore considered qualified data.

Original Value Below Laboratory Reporting Limit

One NO₃+NO₂ regular / duplicate sample set was not able to be reanalyzed because both of the sample values for NO₃+NO₂ were below the reporting limit of the laboratory. CH2M HILL will not reanalyze samples whose original values were below their reporting limits.

Concentration Sub-set Analysis

Two 'total' constituent concentrations were sampled: total phosphorus and total suspended solids. Total phosphorus (TP) is, in theory, composed of orthophosphate (PO₄) and organic phosphorus. As such, the concentration of PO₄ should be less than or equal to TP. Likewise, volatile suspended solids (VSS) is a sub-set of total suspended solids (TSS) and should be less than or equal to TSS. TP and PO₄ samples were collected at all sites in all months. TSS and VSS samples were only collected in August and September.

Due to uncertainty in laboratory results (e.g., RPD criteria), these subsets (PO₄ and VSS) can exceed the total concentrations. In almost all cases TP concentrations exceeded PO₄ concentrations and TSS values were higher than VSS. Where discrepancies occurred they were minor: when incorporating potential variability in the sample based on the RPD, discrepancies could be explained in all but one case for TP and PO₄ (September 12, 2007 at the Shasta River).

Elevated Concentrations for Selected Constituents: June

On June 19, the am1 and am2 samples illustrated high TKN and TP values (approximately 50 to 100 percent above samples from prior to and after the sampling time). Tracking these samples downstream over the next few days failed to show these elevated concentrations appearing at the Walker Bridge Road site. There are several elevated values in the first few days of sampling at both Iron Gate dam and Walker bridge road in June that, after discussions with the field crew and laboratory are unresolved.

APPENDIX D: STANDARD OPERATION PROCEDURES

Standard Operating Procedures (SOP)

Presented below is a generic Watercourse SOP used in the Klamath Basin. There may be elements included herein that were not addressed in the Fate and Transport Study.

Standard Operating Procedure for Water Quality Grab Sampling

Prior to leaving the office

- Gather sampling equipment.
- Inspect all sampling equipment for damage, dirt, etc.
- Pack a cell phone and telephone number directory.
- Check equipment batteries, replace if expired and carry extras.
- Verify that the multi-probe unit and turbidimeter have been recently calibrated by checking the calibration log.
- Pack field notebook, extra paper, SOP, QAPP, Chain Of Custody (COC) sheets, and shipping addresses (should be in QAPP or SOP).
- Check bottles needed for sampling.
- Affix labels to appropriate bottles or pack appropriate labels.
- Prepare Blank samples and reference solution bottles (if applicable).
- Get Ice (Blue Ice or crushed ice).

At the sampling site

- Fill in the labels on the bottles.
- Collect all necessary samples—see the appropriate QAPP for a constituent/bottle list for the project.
- Filter and preserve samples as needed.
- Store samples in a cooler on ice and cover with ice.
- Fill out field notebook and field log (field log and field notebook are the same for Reclamation) and COC sheet(s).

After sampling

- Package coolers for shipping (fill out shipping label, affix cooler seal). Place COC in plastic bag in cooler before sealing.
- Ship the samples at the end of each day of sampling.
- Post-calibration of equipment.
- Clean and store field equipment.
- Copy pages from field notebook and store in a secure location in the office after sampling session.

- Copy field notebook, field log and COC and send to appropriate parties.

Grab Sampling

The sample bottle or churn splitter is used to collect a water grab sample. Care is exercised not to disturb sediment while sampling. Avoid surface debris when collecting samples. The sample bottle and/or churn splitter is rinsed with environmental water three times. If bottles are pre-preserved, rinsing with environmental water is not appropriate. Prior to collecting the sample and water is run through the pour spout of the churn splitter during each rinse. Do not disturb the location where sample is to be taken with discarded rinse water. The preferred method of collecting whole (unfiltered) samples is to dip the sample bottle with the mouth pointed up-stream in the current. Filtered and Quality Assurance (QA) samples must be collected in a churn splitter. If used, the churn splitter is cleaned at each site after sample collection by 1) carefully inspecting and removing any foreign material, 2) rinsing the exterior, and 3) rinsing the interior three times with de-Ionized (DI) water. Allow DI water to run through the pour spout during each rinse.

See Table 12 for a list of constituents, appropriate bottles, filtration, and sample preservation information.

Table 13. Grab Sample List.

Constituents	Bottle	Filtered	Preservation
Nutrients: NH ₄ , NO ₃ +NO ₂ , TKN, TP	1,000 ml HDPE	No	4°C, H ₂ SO ₄
PO ₄	500 ml HDPE	No	4°C
Alkalinity	1,000 ml HDPE	No	4°C
DOC	40 ml Amber (2)	No	4°C, H ₂ SO ₄
TSS	1,000 ml HDPE	No	4°C
VSS	1,000 ml HDPE	No	4°C
Chlorophyll a/Phaeophytin	250 ml Dark HDPE	No	4°C, Mg
Total Dissolved Solids (TDS)	250 ml HDPE	Yes	4°C
Algae Speciation	250 ml HDPE	N	4°C, Lugols

Van Dorn Sampler

The Van Dorn sampler is used to collect samples from a site where it is not possible to directly fill the sample bottles or churn splitter, such as reservoir sampling from a bridge. Rinse the Van Dorn sampler with environmental water three times prior to the collection of sample water. The Van Dorn sampler is lowered, the trigger mechanism activated, and then the sampler is raised to the surface. The water is then poured from the Van Dorn sampler into the churn splitter. The Van Dorn sampler is cleaned at each site after sample collection by 1) carefully inspecting and removing any foreign material; 2) rinsing the exterior; and 3) rinsing the interior three times with DI water.

Samples may also be collected using a battery operated 12v DC submersible pump (Ben Meadows Model DC60, ABS body, stainless steel propellers and chemically inert seals). The pump fitted with 30 m of 3/8-inch ID Tygon tubing is lowered to the desired sampling depth and run until 5 tube volumes have been pumped. The sample bottles are then filled sequentially as the pump continues to operate. For QA samples (regular, duplicate, and spikes) the pump is used to fill the churn splitter. Sample bottles are filled from the churn splitter as described below. The pump is rinsed with distilled water between sample

locations. At the end of the sampling period the pump and tubing are rinsed with distilled water followed by a dilute chlorine bleach solution.

Churn Splitter

The churn splitter allows different sub-sample volumes to be obtained from the composite sample while still maintaining the same basic chemical and physical properties of the original sample. The volume of the churn splitter limits the volume of sample that can be divided. Suspended inorganic sediments coarser than 62 micrometers (um) cannot be split. Samples may be taken from a plastic (Nalgene™) churn splitter for analysis of all other dissolved and suspended inorganic constituents.

Sub-samples totaling 10 liters may be withdrawn from the 14-liter churn. The 4 liters remaining in the 14-liter churn should not be used for unfiltered sub-samples because they will not be representative. However, the sample water remaining in the churn splitter may be used for filtered sub-samples for the determination of dissolved constituents.

The procedure for cleaning and use of the churn splitter is as follows:

- A. Clean the churn splitter between sampling events. After removing any foreign material from the churn splitter with a nylon brush, soap & water, the churn splitter is rinsed three times with DI water.
- B. Pour about 200 ml of dilute (i.e. 6 percent) nitric acid into the churn splitter (if sampling for low level metals constituents). Wet all inside surfaces of churn splitter with the acid. Acid is run through the pour spout. Dispose of dilute acid down a drain with a good flow of tap water.
- C. Rinse the churn splitter with DI water three times. Drain DI water from the spout during each rinse. The churn splitter is now ready for field use.
- D. The churn splitter is rinsed with environmental water three times in the field at each sample site prior to sample water collection. Drain environmental water through pour spout during each rinse.
- E. Fill out the labels on all sub-sample containers. Set aside the filtered sample bottles (at the QA site there are multiple bottles to be filtered) that will contain filtered environmental water. These samples will be filtered from the remaining environmental water in the churn splitter after the other unfiltered samples have been collected. The remaining bottles (unfiltered sample bottles) are rinsed three times with environmental water after the churn splitter has been rinsed and filled. Only rinse the bottles that will contain water collected at the current site. The churn splitter is rinsed three times with DI water after each site.
- F. If QA samples are not collected at a site, then approximately 6 liters of environmental water is required at each site. Fill the churn splitter so as to have enough water for all samples. The last 4 liters of sample in churn cannot be used for non-filtered samples. It is important to sufficiently fill the churn splitter to have adequate water supply for all samples.
- G. For QA samples, the churn splitter may have to be filled more than once to collect all the required samples. Duplicate and triplicate (spike or reference) samples are collected at the QA site. Three sample bottles (regular, duplicate, and spike) are filled from the same churn splitter volume for most of the constituents. All three bottles for these constituents must be collected from the same churn splitter volume. Triplicate (spike) samples are collected for mercury, trace metals, Mg & Ca, orthophosphate, and nutrients. The field sampler adds a spike solution to a known volume of

environmental water for these constituents. For some of the constituents, only two sample bottles (regular and duplicate samples) of environmental water are filled from the same churn splitter of water and the third is filled with a reference solution. A third bottle of environmental water is not collected for total alkalinity, BOD, or TDS triplicate (spike/reference) samples. A reference solution of known concentration is poured into the spike/reference bottle by the sampler for this constituent. Specific preparation of QA samples is discussed in the “Sample Quality Control and Quality Assurance” section of this SOP.

- H. It is sometimes necessary to composite water into the churn splitter from a sampling device. A Van Dorn sampler can be used for this. Where a Van Dorn sampler cannot be used, a sample bottle is used over and over to fill the churn splitter. Swirl the water in sample bottle prior to pouring into the churn splitter in order to minimize the amount of suspended material lost in transferring from the bottle to the churn splitter. As stated in the Grab Sampling section above, it is preferred to collect unfiltered environmental water directly into a sample bottle. QA samples (regular, duplicate, and triplicate) must be dispensed from a single churn splitter volume.
- I. Churn the sample at a uniform rate of about 9 inches per second (in/s). The churning disc should touch the bottom of the tank on every stroke and the stroke length should be as long as possible without breaking the water surface. If the churning rate is significantly greater than 9 in/s or if the churning disc breaks the water surface, excessive air is introduced into the sample and may change the dissolved gases, bicarbonate, pH, and other characteristics of the sample. On the other hand, inadequate stirring may result in non-representative sub-samples.
- J. After churning the sample in the splitter for at least 10 strokes to assure uniform dispersion of the suspended material, begin the withdrawal of sub-samples. As sub-samples are withdrawn and the volume of sample in the churn decreases, maintain the churning rate of about 9 in/s. If a break in churning is necessary, the stirring rate must be reestablished (i.e., 10 strokes) before withdrawals are continued.
- K. While operating the churn, withdraw an adequate volume of sample water to field rinse bottles for unfiltered sub samples. Rinse each bottle three times with sample water.
- L. Withdraw sub-samples for unfiltered samples first. The first sub-sample withdrawn should be the largest sub-sample required (usually 1 liter of sample).
- M. After all the required unfiltered sub-samples have been withdrawn, the environmental water remaining in the churn may be filtered for sub-samples required for dissolved constituents. Remember to field rinse bottles three times with filtered sample water prior to filling. Procedures for filtering and preserving samples are described later.
- N. After all filtered sub-samples have been withdrawn, empty the churn splitter and clean the mixing tank, lid, and churning disc three times with DI water. Allow the DI water to run through the pour spout during each rinse.

Filtering Water Samples

Water samples are filtered using a peristaltic pump and 0.45um inline filter. The inlet tube to the pump is rinsed with environmental water then placed in the churn splitter. An inline filter is attached to the exit tube of the pump. Approximately 500-ml of environmental water is pumped through filter before any sample water is collected. This water should not be used to rinse sample bottles. Rinse all filtered sample bottles three times with the filtered environmental water. Continue filtering until all filtered samples have

been collected. After using the pump at a sample site, discard the inline filter and pump about a 500-ml of DI water through the tubing. Rinse the outside of the inlet and outlet tubing with DI water.

If the peristaltic pump fails or is unusable for any reason, samples can be filtered with a filter syringe. The filter syringe is used as follows: Disassemble a clean 100-ml (or appropriate size) filter syringe. Rinse the inside of syringe with environmental water three times. Place a new 0.45um (or appropriate size) disc style filter on the end of the syringe. Fill the filter syringe with environmental water. Push 10-15 ml of environmental water through the filter before any sample water is collected. Filter approximately half of the water in the syringe into the sample bottle and rinse. Shake sample bottle and discard water. Rinse the sample bottle three times with the filtered environmental water. Fill the sample bottle with filtered water using the syringe-filter procedure. Refill the syringe if more sample water is needed and the filter has not clogged. If filter is clogged, attach a new filter, rinse as stated above and continue.

Water Sample Preservation

Physical preservation techniques are used for all samples and include cooling and keeping the samples out of the sunlight. Some of the water samples are also preserved with acid to prevent degradation of constituents before they are analyzed. Specific requirements for the field preservation of the samples are listed in the Grab Sample List of the SOP. All samples will be preserved immediately at the collection site.

Metals

Preserve metals in water for a 6 month hold time with nitric acid. Mercury has a hold time of only 28 days. 1 ml of 70 percent nitric acid is used for each 250 ml of sample water. The sample is also chilled to 4°C in the field.

Nutrients

The 1,000 ml nutrient suite bottle requires 2 ml of H₂SO₄ and has a hold time of 28 days. The sample is also chilled to 4°C in the field.

- Other Samples
- No acid preservation is used for orthophosphate, BOD, total alkalinity, and TDS. Total alkalinity and TDS samples have a 14-day hold time. Orthophosphate samples have a 48-hour hold time. BOD samples have a 48-hour hold time. Hydrogen Sulfide (Sulfide) samples are preserved with NaOH and have a 7-day hold time. The samples are also chilled to 4°C in the field.

If in doubt about any sample, it is best to keep it chilled and out of the sunlight.

Dispensing Acid from Ampule for preserving samples

Rubber, latex or vinyl gloves and safety glasses are worn to prevent acid from contacting hands or eyes while preserving samples. If acid is present in the neck of the ampule, gently tap until all of the acid is in the body of the ampule. Place the provided ampule “breaker” over the ampule, point away from face, and apply steady pressure until the ampule snaps at the pre-scored line. Hold the ampule upside down over the sample bottle between the thumb and index finger of one hand. With the other index finger, lightly tap the bottom of the ampule until all of the acid is dispensed. Properly discard the empty acid ampules.

Site samples will be preserved using acid from re-closable plastic vials. Gloves and safety glasses are also worn during the use of the re-closable vials to protect hands and eyes from acid. Vials should also be properly discarded once empty.

Sample Handling and Transportation

Sample handling and transportation vary depending upon the analysis requested, sample preservation requirements, and the distance to the laboratory. However, once preserved, some samples will remain stable for long periods of time. All samples for KBAO projects will be shipped overnight delivery on the day they are collected.

All water samples will be shipped in a cooler or ice chest. This provides protection, insulation, and containment in case of breakage or spillage. When shipping samples that require chilling, pack adequate quantities of frozen blue ice or crushed ice with the samples. Seal the ice chests securely with duct or packing tape to ensure they do not accidentally open.

Sample Quality Control and Quality Assurance

Objective

Quality control of samples during collection, transportation and processing is an integral part of a sampling program. Quality control procedures are implemented to assess potential sampling and analytical bias.

Techniques

Production Samples

A production sample is a sample taken at a site where no QA samples are collected. A production sample has the abbreviation of "P."

Regular Samples

A regular sample is the production sample at the QA site and has associated QA samples. A regular sample has the abbreviation of "R."

Duplicate Samples

A split sample is a portion or sub-sample of a total sample. The duplicate sample has an identical water matrix as the regular sample. This sample is used to determine analytical precision within a laboratory. A duplicate sample has the abbreviation of "D."

Triplicate Samples (Field Spikes and Reference Solutions)

These are reference solutions used to fill the sample bottles or chemical solutions (spikes) that are added to specified volumes of environmental water. A graduated cylinder is used to measure the volume of environmental water used for the "spiked" samples. All of the triplicate sulfide nutrient and trace metal samples are "spiked". Rinse the graduated cylinder three times with sample water. Using the graduated cylinder, measure out the appropriate volume of sample water (total triplicate sample volume – volume of spike = volume of environmental water). Pour approximately half of the sample water from the graduated cylinder into the sample bottle. Add the "spike" solution to the sample bottle. DO NOT add the spike to the graduated cylinder. Rinse the inside of the "spike" container with sample water from the graduated cylinder and add to the sample bottle. Pour the remaining half of the sample water from the graduated cylinder into the sample bottle. A reference solution is used for the total alkalinity BOD and TDS triplicate sample. In this case the triplicate (reference solution) is not mixed with environmental water, instead the reference solution is used to fill the entire sample bottle. A triplicate sample has the abbreviation of "S."

Blanks

A blank sample is used to test laboratory analysis and ensure the bottles are not contaminated. Blank sample bottles are rinsed three times with DI water. The sample bottles are then filled with DI water and

corresponding preservatives are added. The blank should be prepared in the lab/office to avoid field contamination and carried in the field while sampling. A blank sample has the abbreviation of “B.”

Rinseate Blanks

A rinseate blank tests the field crew techniques and sampling equipment for contamination. After the sampling equipment has been cleaned with DI water at the last sampling site, the rinseate blank is collected. Rinseate blanks are prepared by pouring DI water into the sample collection equipment (Van Dorn, etc). Wet all internal surfaces. The rinseate water is then collected into the churn splitter. The sample bottles are rinsed three times with the rinseate water before sample collection. Fill the sample bottles with rinseate water. Filter rinseate water for filtered constituents using a peristaltic pump and filter. Preservation is added to samples requiring it. A rinseate blank has the abbreviation of “RB.”

Standards

Standards or reference materials are used for equipment that requires calibration. Use of reference standards is an integral component of quality control. Both field and laboratory equipment must be periodically calibrated to assure the instruments accuracy. Laboratories should calibrate equipment as required by the analysis method. The field equipment, such as the Hydrolab H20 unit and the Hach 2100P turbidity meter require regular calibration. The Hydrolab H20 unit will be calibrated as described in the KBAO Hydrolab calibration SOP. Staff will calibrate the YSI 600 in the office and/or field as per manufacturer specifications. The manufacturer’s instructions for calibrating the turbidimeter will be followed.

Sample Identification

A unique sample identification (ID) number is used for samples collected at different sites. The same number is used for all sample bottles collected at a given site on a given day. A letter prefix associated to the specific sampling project precedes the sample ID number. For example, a letter prefix of KRWQ identifies the sample as part of the Klamath River Water Quality Monitoring Program. These sample identification numbers are pre-selected by the KBAO and/or other sampling agency.

Field Notebooks

A bound field notebook is used to document collection of a sample, sample ID number, field observations, and other pertinent information necessary to reconstruct the sample collection processes. All entries are made in permanent waterproof ink. Any corrections made to the field notebooks are lined out, initialed, and dated. The person who collected the sample signs the field notebook. Field personnel will carry the field notebook during sampling. Past physical measurements and observations can be compared to current conditions. The field crew will make copies of the field notebook once they have returned to the office. Making copies will minimize the amount of data lost in the event the field notebook gets lost or damaged.

Field notebooks include:

- Sample Identification Information (including Field ID)
- Field Measurements (Water temp., pH, DO, etc.)
- Equipment Information (serial number, model number, manufacturer, etc.)
- Sample Types (P, R, D, S, B, RB)
- Sample Collection (what analysis/constituents requested, etc.)
- Sample Preservation Information
- Date and Time of Collection
- Weather Conditions
- Comments

Field notebooks provide a convenient system for tracking the monitoring and analysis requests for each site in a particular project. Further, the field ID provides the cross-reference to laboratory results and sampling locations. The field crew keeps the field notebooks on file when the program is complete.

Chain of Custody

A COC accompanies all samples to record possession and transportation of samples. Field identification number, sample type, requested analysis, date of collection, and time of collection as well as other information is recorded on the COC. COC's are completed with permanent ink. Any corrections made to the COC's are lined out, initialed, and dated. All samples are kept in a secured area accessible only to authorized personnel during sample collection and transport. Upon completion of the field collection of the samples, the COC sheet accompanies the samples to the lab. COC sheets are also legally binding and act as a work order for the laboratory. It is critical that the field identification numbers are properly recorded on the field notebook and COC forms. Sample collectors, individuals transferring samples, and those receiving samples, all sign the COC. The COC forms are in triplicate and field personnel should remove only the field copy (pink sheet).

Calibration Log

A bound calibration logbook is used to store calibration information for equipment requiring calibration. Calibration information for the Hydrolab H20 unit and Hach 2100P turbidimeter will be recorded in a bound calibration logbook. When instruments are calibrated in the field, all appropriate calibration information is recorded in the field notebook and may not be included in a calibration log, particularly if rented or borrowed instruments are used.

Ringed Field Binder

A ringed binder is used to store information pertinent to a sampling project. The binder can be used to store a copy of the SOP, QAPP, level one clean-bottle certificates, acid purity certificates, certificates for in-line filters, COC sheets, copy of field notebook, and other pertinent information.

Security Shipping Seals

When shipping samples a security seal is attached across the lid and side of the ice chests. The seal is signed and dated by the sampling personnel. The seal is attached so that it must be broken when the container is opened.

Equipment and Supplies

- Field notebook
- Field datasheets
- Clipboard
- Chain of Custody form
- Zip-lock bag for COC form
- “Sharpie” felt tip pens
- Ball point pens
- Van Dorn sampler with rope and messenger
- Churn splitter
- Peristaltic pump and in-line filters
- Prepared bottles and labels
- Extra sample bottles
- Extra bottle labels
- Sulfuric and/or nitric acid ampules
- Waste container for broken acid ampules
- Rubber, latex, or vinyl gloves
- Safety glasses
- Spikes
- Graduated cylinder
- 10 gallons (or appropriate quantity) DI water
- Squeeze bottle for DI water
- Water quality sonde unit, spare battery and cables
- Turbidity meter
- Ice chests
- Ice packs (Blue ice)
- Packing tape
- UPS overnight shipping forms
- Rope
- Waders (Waders may be knee, hip, or chest)
- Cell phone and telephone numbers
- Knife/scissors
- Maps
- Paper towels
- Camera and film
- GPS unit

- Extra batteries
- Tools
- Syringe filters (back-up filters)
- Drinking water / food
- Leather gloves
- Sunglasses
- Hat
- Sun block

Laboratory and Other Contacts

CH2M HILL Applied Sciences Laboratory

2300 NW Walnut Blvd
Corvallis, Oregon 97339
(541) 768-3111
Contact: Kathy McKinley

Aquatic Analysts

232 Acme Rd.
White Salmon, WA 98672
(509) 493-8222
Contact: Jim Sweet

Watercourse Engineering, Inc.

424 2nd Street, Suite B
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(530) 750-3072
Contact: Mike Deas

APPENDIX E: 2007 NUTRIENT AND ORGANIC MATTER FATE AND TRANSPORT
STUDY DATA

FIELD CONSTITUENT DATA

The concentration results for all of the constituents of interest for each sample are presented in Table 13 through Table 20.

Table 14. Constituent Concentrations for All Grab and Composite Samples at the Klamath River Below Keno dam Site.

Date	Time	Type ²	Constituent Concentrations ¹									
			NH4	NO2+NO3	TKN	TP	PO4	DOC	TSS	VSS	Chlor-a ³	Pheo ⁴
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
		MRL	0.10	0.01	0.10	0.05	0.01	0.50	2.00	2.00	n/a	0.10
		MDL	0.0046	0.0013	0.011	0.019	0.0031 ⁵	0.057	0.95	0.95	n/a	0.10
06/18/07	7:10	C	ND	0.0130	1.5	0.110	0.059	7.0	-	-	20.4	1.9
06/19/07	6:55	C	ND	0.0160	1.2	0.130	0.052	7.1	-	-	11.7	1.2
06/20/07	6:50	C	ND	0.0180	1.5	0.140	0.075	8.7	-	-	14.6	0.4
06/21/07	7:00	C	ND	0.0190	1.7	0.160	0.061	8.4	-	-	11.7	7.6
07/16/07	7:00	C	1.200	0.0130	3.8	0.280	0.190	9.1	-	-	17.5	10.8
07/17/07	15:00	C	1.200	0.0190	3.4	0.270	0.170	9.0	-	-	17.5	25.4
07/18/07	6:50	C	1.100	0.0096(j)	3.4	0.210	0.110	8.1	-	-	2.9	20.7
07/19/07	6:50	C	1.500	0.0047(j)	3.0	0.270	0.180	9.3	-	-	32.1	9.1
08/13/07	7:15	C	1.300	0.0130	3.6	0.240	0.140	11.9	2.0	2.8	24.1	0.9
08/14/07	7:00	C	1.200	0.0079(j)	3.4	0.270	0.170	12.8	6.0	4.8	11.7	8.9
08/15/07	6:50	C	1.100	0.0097(j)	3.2	0.150	0.150	14.1	5.2	5.2	23.4	0.7
08/16/07	6:50	C	1.000	0.0110	2.8	0.210	0.150	12.2	5.2	3.6	8.8	13.9
09/10/07	7:45	C	1.100	0.0083(j)	3.2	0.300	0.130	12.4	8.4	4.0	-	-
09/11/07	7:25	C	0.960	0.0190	2.7	0.270	0.110	12.7	4.0	2.8	-	-
09/12/07	7:30	C	0.950	0.0210	2.7	0.190	0.100	12.4	4.0	2.8	-	-
09/13/07	7:20	C	0.820	0.0110	3.0	0.200	0.120	12.9	2.0	2.8	-	-
06/18/07	7:10	G	ND	0.0100	1.4	0.092	0.059	6.8	-	-	16.1	11.8
06/18/07	11:10	G	ND	0.0130	1.5	0.100	0.068	7.1	-	-	17.5	1.4
06/18/07	15:05	G	ND	0.0160	1.9	0.140	0.075	7.3	-	-	13.4	0.1
06/19/07	6:55	G	ND	0.0140	1.9	0.170	0.048	6.8	-	-	13.1	7.8
06/19/07	11:15	G	ND	0.0150	1.2	0.140	0.046	6.8	-	-	14.6	1.7
06/19/07	14:55	G	ND	0.0180	1.2	0.140	0.050	7.0	-	-	13.2	1.5
06/20/07	6:50	G	0.028(j)	0.0150	2.2	0.180	0.049	7.6	-	-	20.4	7.0
06/20/07	11:00	G	ND	0.0180	1.6	0.150	0.052	8.5	-	-	17.5	5.7
06/20/07	15:00	G	ND	0.0180	1.6	0.150	0.055	8.7	-	-	14.6	0.9
06/21/07	7:00	G	ND	0.0170	2.2	0.220	0.057	8.2	-	-	1.0	2.0
06/21/07	10:45	G	ND	0.0220	1.6	0.160	0.066	9.0	-	-	12.4	2.2
06/21/07	14:30	G	ND	0.0210	1.6	0.180	0.068	8.4	-	-	11.0	2.1

¹ A '-' indicates no samples were analyzed for that constituent at that site, date, and time. A 'ND' indicates that the samples were analyzed, but the concentrations were below the reporting limit.

² 'G' indicates a grab sample was collected; 'C' indicates a composite sample was collected.

³ 'Chlor-a' refers to Chlorophyll-a, a measure of algal biomass.

⁴ 'Pheo' refers to Pheophytin, a measure of density and biomass.

⁵ The method detection limit for PO4 identified by CH2MHill changed after August 15, from 0.0031 mg/l to 0.0018 mg/l.

Table 15. Constituent Concentrations for All Grab and Composite Samples at the Klamath River above J.C. Boyle reservoir.

Date	Time	Type ²	Constituent Concentrations ¹									
			NH4	NO2+NO3	TKN	TP	PO4	DOC	TSS	VSS	Chlor-a ³	Pheo ⁴
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
		MRL	0.10	0.01	0.10	0.05	0.01	0.50	2.00	2.00	n/a	0.10
		MDL	0.0046	0.0013	0.011	0.019	0.0031 ⁵	0.057	0.95	0.95	n/a	0.10
06/18/07	8:15	C	0.045(j)	0.180	1.3	0.10	0.089	7.1	-	-	10.2	5.2
06/19/07	7:55	C	ND	0.200	1.3	0.14	0.079	7.1	-	-	7.3	6.4
06/20/07	8:00	C	0.035(j)	0.220	1.3	0.15	0.100	8.4	-	-	13.1	0.7
06/21/07	8:00	C	ND	0.220	1.5	0.17	0.088	8.7	-	-	5.1	7.1
07/16/07	8:00	C	0.190	1.300	1.9	0.28	0.250	9.0	-	-	11.7	4.2
07/17/07	15:45	C	0.260	1.400	1.9	0.25	0.180	8.4	-	-	-	-
07/18/07	7:25	C	1.100	0.014	3.4	0.24	0.110	8.1	-	-	5.8	17.3
07/19/07	7:28	C	0.390	1.400	1.8	0.28	0.240	9.1	-	-	16.1	7.1
08/13/07	8:10	C	0.290	1.200	1.9	0.26	0.190	13.6	2.4	2.0	13.1	7.0
08/14/07	7:55	C	0.340	1.100	2.1	0.24	0.220	13.1	5.6	3.2	16.0	2.0
08/15/07	7:50	C	0.240	1.100	2.1	0.21	0.210	13.2	5.6	3.2	20.4	6.6
08/16/07	7:55	C	0.200	1.100	2.0	0.23	0.210	11.6	4.4	2.8	4.4	20.9
09/10/07	8:30	C	0.210	1.200	1.6	0.28	0.180	13.3	4.8	2.8	-	-
09/11/07	8:10	C	0.180	1.200	1.6	0.26	0.160	12.0	6.4	3.2	-	-
09/12/07	8:20	C	0.170	1.200	2.0	0.21	0.150	11.8	6.4	4.4	-	-
09/13/07	8:00	C	0.140	1.000	1.9	0.22	0.160	12.4	5.6	3.2	-	-
06/18/07	8:15	G	ND	0.180	1.4	0.11	0.094	6.7	-	-	8.0	0.3
06/18/07	12:10	G	ND	0.180	1.4	0.11	0.098	6.7	-	-	16.1	0.3
06/18/07	16:00	G	ND	0.190	1.4	0.12	0.098	7.3	-	-	7.3	6.9
06/19/07	7:55	G	ND	0.210	1.2	0.15	0.093	6.8	-	-	11.0	3.0
06/19/07	12:15	G	ND	0.200	1.4	0.15	0.081	7.1	-	-	7.4	6.9
06/19/07	15:50	G	ND	0.200	1.2	0.15	0.084	6.8	-	-	5.8	3.6
06/20/07	8:00	G	0.027(j)	0.220	1.3	0.15	0.074	7.6	-	-	14.6	3.9
06/20/07	12:25	G	ND	0.220	1.3	0.16	0.085	8.1	-	-	6.5	6.6
06/20/07	16:00	G	ND	0.230	1.2	0.15	0.089	8.3	-	-	10.2	0.5
06/21/07	8:00	G	ND	0.220	1.5	0.17	0.082	8.1	-	-	9.5	4.2
06/21/07	11:40	G	ND	0.220	1.5	0.19	0.088	8.2	-	-	5.0	6.3
06/21/07	15:30	G	ND	0.230	1.4	0.17	0.097	8.6	-	-	5.8	7.0

¹ A '-' indicates no samples were analyzed for that constituent at that site, date, and time. A 'ND' indicates that the samples were analyzed, but the concentrations were below the reporting limit.

² 'G' indicates a grab sample was collected; 'C' indicates a composite sample was collected.

³ 'Chlor-a' refers to Chlorophyll-a, a measure of algal biomass.

⁴ 'Pheo' refers to Pheophytin, a measure of density and biomass.

⁵ The method detection limit for PO4 identified by CH2MHill changed after August 15, from 0.0031 mg/l to 0.0018 mg/l.

Table 16. Constituent Concentrations for all grab and composite samples at the Klamath River below Iron Gate dam.

Date	Time	Type ²	Constituent Concentrations ¹									
			NH4	NO2+NO3	TKN	TP	PO4	DOC	TSS	VSS	Chlor-a ³	Pheo ⁴
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
		MRL	0.10	0.01	0.10	0.05	0.01	0.50	2.00	2.00	n/a	0.10
		MDL	0.0046	0.0013	0.011	0.019	0.0031 ⁵	0.057	0.95	0.95	n/a	0.10
06/18/07	6:45	C	ND	0.098	0.75	0.130	0.100	5.9	-	-	5.1	1.1
06/19/07	6:35	C	ND	0.091	0.63	0.140	0.110	5.1	-	-	3.4	1.2
06/20/07	6:30	C	ND	0.092	0.74	0.140	0.087	5.7	-	-	2.0	2.4
06/21/07	6:30	C	ND	0.084	0.67	0.160	0.090	5.2	-	-	2.0	1.0
07/16/07	6:40	C	ND	0.220	1.5	0.098	0.094	5.6	-	-	9.5	0.4
07/17/07	6:40	C	0.025(j)	0.25	0.74	0.10	0.046	5.1	-	-	13.9	0.9
07/18/07	13:50	C	ND	0.280	0.77	0.100	0.110	5.2	-	-	11.0	0.6
07/19/07	6:35	C	0.028(j)	0.270	0.56	0.120	0.110	5.5	-	-	5.8	3.2
08/13/07	6:50	C	0.044(j)	0.210	0.99	0.130	0.084	5.7	2.4	3.6	17.5	5.7
08/14/07	6:35	C	0.040(j)	0.150	0.97	0.110	0.120	5.9	3.2	2.4	10.2	0.5
08/15/07	6:30	C	ND	0.150	0.88	0.100	0.120	6.0	6.4	5.6	11.7	6.8
08/16/07	6:30	C	0.034(j)	0.180	0.98	0.140	0.130	5.7	5.2	4.0	20.4	1.5
09/10/07	7:18	C	ND	0.077	1.2	0.210	0.120	7.1	12.4	11.2	-	-
09/11/07	7:05	C	ND	0.140	1.1	0.260	0.140	6.4	3.2	4.4	-	-
09/12/07	7:08	C	0.056(j)	0.200	1.4	0.180	0.120	6.8	4.8	4.8	-	-
09/13/07	7:05	C	ND	0.130	1.1	0.170	0.140	7.1	5.6	4.8	-	-
06/18/07	6:45	G	ND	0.087	0.88	0.110	0.110	5.8	-	-	5.1	0.7
06/18/07	10:30	G	ND	0.100	1.4	0.110	0.110	5.8	-	-	4.4	2.8
06/18/07	14:30	G	ND	0.087	0.55	0.130	0.110	5.2	-	-	1.5	2.1
06/18/07	20:35	G	ND	0.094	0.87	0.100	0.100	5.8	-	-	5.8	0.2
06/19/07	6:35	G	ND	0.078	1.2	0.240	0.100	5.4	-	-	3.9	1.0
06/19/07	10:30	G	ND	0.100	1.7	0.330	0.110	5.1	-	-	2.0	4.9
06/19/07	13:45	G	ND	0.080	0.72	0.130	0.084	5.9	-	-	3.9	1.0
06/19/07	20:30	G	ND	0.087	1.4	0.240	0.100	5.4	-	-	3.4	1.3
06/20/07	6:30	G	ND	0.092	0.61	0.140	0.088	5.2	-	-	2.4	2.0
06/20/07	11:15	G	ND	0.098	0.68	0.140	0.089	5.5	-	-	4.4	1.3
06/20/07	14:55	G	ND	0.091	0.65	0.180	0.089	5.5	-	-	2.0	0.2
06/20/07	20:30	G	ND	0.091	0.62	0.140	0.088	5.7	-	-	3.7	1.9
06/21/07	6:30	G	ND	0.074	0.60	0.140	0.089	5.3	-	-	13.1	3.2
06/21/07	10:40	G	ND	0.090	0.68	0.160	0.092	5.2	-	-	1.5	1.5
06/21/07	14:30	G	ND	0.083	0.65	0.140	0.090	5.1	-	-	1.0	1.9
07/16/07	6:40	G	ND	0.210	1.0	0.100	0.094	5.5	-	-	10.2	1.0
07/16/07	10:25	G	ND	0.230	0.92	0.100	0.095	5.2	-	-	10.2	1.0
07/16/07	13:45	G	0.031(j)	0.240	0.90	0.110	0.099	8.5	-	-	13.1	0.2
07/16/07	20:12	G	ND	0.220	0.85	0.120	0.043	5.3	-	-	14.6	0.4
07/17/07	6:40	G	0.030(j)	0.250	0.73	0.110	0.042	5.7	-	-	13.1	0.6
07/17/07	10:35	G	0.036(j)	0.250	1.1	0.120	0.047	5.2	-	-	15.3	1.0

Nutrient and Organic Matter Fate and Transport in the Klamath River: 2007

Date	Time	Type ²	Constituent Concentrations ¹									
			NH4	NO2+NO3	TKN	TP	PO4	DOC	TSS	VSS	Chlor-a ³	Pheo ⁴
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
07/17/07	14:20	G	0.033(j)	0.250	0.77	0.110	0.042	5.3	-	-	13.2	0.4
07/17/07	20:20	G	ND	0.270	0.82	0.130	0.100	5.3	-	-	11.7	0.3
07/18/07	6:45	G	ND	0.280	0.98	0.110	0.110	5.1	-	-	10.2	1.0
07/18/07	10:30	G	ND	0.260	0.81	0.110	0.100	5.1	-	-	11.7	0.3
07/18/07	13:50	G	0.040(j)	0.300	0.69	0.110	0.110	5.1	-	-	18.2	0.6
07/18/07	20:10	G	ND	0.280	1.1	0.130	0.110	5.8	-	-	13.1	1.0
07/19/07	6:35	G	ND	0.260	1.0	0.130	0.120	5.8	-	-	10.2	0.9
07/19/07	10:30	G	ND	0.250	0.93	0.130	0.110	5.7	-	-	9.5	0.8
07/19/07	14:30	G	ND	0.270	0.98	0.120	0.110	5.6	-	-	8.8	1.9
08/13/07	6:50	G	0.041(j)	0.200	1.0	0.120	0.087	5.8	3.2	4.0	20.4	8.8
08/13/07	10:20	G	0.041(j)	0.200	1.1	0.130	0.084	5.7	4.8	4.4	17.5	10.0
08/13/07	14:20	G	0.046(j)	0.220	0.95	0.130	0.088	5.7	4.0	3.6	24.4	0.6
08/13/07	20:15	G	0.059(j)	0.300	0.77	0.130	0.150	5.7	2.4	2.0	12.4	1.3
08/14/07	6:45	G	0.048(j)	0.230	0.89	0.120	0.140	5.7	3.2	2.0	17.5	4.8
08/14/07	10:30	G	ND	0.100	1.1	0.120	0.120	5.8	4.0	4.4	20.4	4.4
08/14/07	14:15	G	0.047(j)	0.097	1.2	0.130	0.110	5.8	8.0	7.6	32.1	21.1
08/14/07	20:30	G	0.039(j)	0.190	0.84	0.120	0.130	5.7	5.2	4.4	14.6	4.3
08/15/07	6:30	G	0.039(j)	0.180	1.0	0.120	0.130	6.2	4.0	2.8	19.0	1.6
08/15/07	10:25	G	0.028(j)	0.120	1.40	0.130	0.120	6.3	7.2	6.0	29.2	19.2
08/15/07	14:15	G	ND	0.150	0.84	0.110	0.120	6.0	7.2	6.0	17.5	15.1
08/15/07	20:00	G	0.048(j)	0.310	0.77	0.130	0.160	5.6	2.4	1.6 (j)	13.1	0.6
08/16/07	6:35	G	0.039(j)	0.180	1.3	0.130	0.140	6.0	4.8	4.4	19.0	1.6
08/16/07	10:20	G	0.042(j)	0.160	0.92	0.120	0.130	5.8	4.0	4.0	17.5	0.1
08/16/07	14:10	G	0.030(j)	0.210	1.0	0.130	0.140	5.7	4.8	4.4	19.0	2.1
09/10/07	7:18	G	ND	0.048	1.5	0.250	0.110	7.2	12.8	10.8	-	-
09/10/07	10:43	G	ND	0.094	1.7	0.260	0.120	7.1	10.4	9.2	-	-
09/10/07	13:55	G	ND	0.097	0.96	0.190	0.120	7.1	8.0	5.2	-	-
09/11/07	7:05	G	ND	0.100	0.80	0.190	0.130	6.6	8.4	9.6	-	-
09/11/07	10:40	G	ND	0.120	1.3	0.230	0.130	6.5	7.2	5.2	-	-
09/11/07	14:10	G	ND	0.150	1.0	0.190	0.140	6.6	4.8	5.2	-	-
09/11/07	19:30	G	ND	0.160	0.75	0.180	0.140	6.5	2.0	4.0	-	-
09/11/07	20:00	G	ND	0.200	1.1	0.170	0.130	6.7	4.4	5.2	-	-
09/12/07	7:10	G	0.030(j)	0.190	1.3	0.180	0.130	6.7	5.2	3.2	-	-
09/12/07	10:40	G	ND	0.200	1.1	0.180	0.130	6.8	6.8	7.6	-	-
09/12/07	14:05	G	0.030(j)	0.170	1.6	0.200	0.120	7.0	8.4	6.4	-	-
09/12/07	19:30	G	0.039(j)	0.150	1.2	0.170	0.140	6.9	3.6	4.0	-	-
09/13/07	7:05	G	0.028(j)	0.098	1.5	0.190	0.140	6.7	6.8	8.4	-	-
09/13/07	10:25	G	0.095(j)	0.130	1.3	0.180	0.140	6.8	6.8	6.0	-	-
09/13/07	13:55	G	0.036(j)	0.160	1.0	0.180	0.150	6.7	6.0	5.2	-	-

¹ A '-' indicates no samples were analyzed for that constituent at that site, date, and time. A 'ND' indicates that the samples were analyzed, but the concentrations were below the reporting limit.

² 'G' indicates a grab sample was collected; 'C' indicates a composite sample was collected.

Date	Time	Type ²	Constituent Concentrations ¹									
			NH4	NO2+NO3	TKN	TP	PO4	DOC	TSS	VSS	Chlor-a ³	Pheo ⁴
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l

³ 'Chlor-a' refers to Chlorophyll-a, a measure of algal biomass.

⁴ 'Pheo' refers to Pheophytin, a measure of density and biomass.

⁵ The method detection limit for PO4 identified by CH2MHill changed after August 15, from 0.0031 mg/l to 0.0018 mg/l.

Table 17. Constituent Concentrations for All Grab and Composite Samples at the Klamath River at the I-5 Rest Area.

Date	Time	Type ²	Constituent Concentrations ¹									
			NH4	NO2+NO3	TKN	TP	PO4	DOC	TSS	VSS	Chlor-a ³	Pheo ⁴
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
		MRL	0.10	0.01	0.10	0.05	0.01	0.50	2.00	2.00	n/a	0.10
		MDL	0.0046	0.0013	0.011	0.019	0.0031 ⁵	0.057	0.95	0.95	n/a	0.10
07/16/07	7:30	C	ND	0.200	1.0	0.120	0.100	5.3	-	-	5.8	0.6
07/17/07	7:30	C	ND	0.230	0.79	0.110	0.048	5.4	-	-	-	-
07/18/07	14:45	C	ND	0.270	0.71	0.110	0.110	5.5	-	-	9.5	0.4
07/19/07	7:20	C	0.028	0.290	1.1	0.130	0.110	5.6	-	-	8.0	0.8
08/13/07	7:46	C	ND	0.200	0.79	0.110	0.082	5.7	3.2	3.2	19.0	0.3
08/14/07	7:05	C	ND	0.260	0.77	0.120	0.140	5.6	2.8	1.2	13.1	0.2
08/15/07	7:10	C	ND	0.170	0.76	0.130	0.130	5.8	5.2	3.2	19.0	2.5
08/16/07	7:10	C	ND	0.190	0.96	0.130	0.140	5.8	5.2	4.0	19.0	0.8
09/10/07	8:01	C	ND	ND	1.6	0.240	0.120	7.3	19.2	14.8	-	-
09/11/07	7:55	C	ND	0.091	1.4	0.230	0.140	7.3	8.4	8.0	-	-
09/12/07	7:45	C	ND	0.160	1.4	0.220	0.130	6.8	7.6	5.6	-	-
09/13/07	7:45	C	ND	0.095	1.3	0.170	0.150	7.2	8.4	6.8	-	-

¹ A '-' indicates no samples were analyzed for that constituent at that site, date, and time. A 'ND' indicates that the samples were analyzed, but the concentrations were below the reporting limit.

² 'G' indicates a grab sample was collected; 'C' indicates a composite sample was collected.

³ 'Chlor-a' refers to Chlorophyll-a, a measure of algal biomass.

⁴ 'Pheo' refers to Pheophytin, a measure of density and biomass.

⁵ The method detection limit for PO4 identified by CH2MHill changed after August 15, from 0.0031 mg/l to 0.0018 mg/l.

Table 18. Constituent Concentrations for All Grab and Composite Samples at the Klamath River at Walker Bridge Road.

Date	Time	Type ²	Constituent Concentrations ¹									
			NH4	NO2+NO3	TKN	TP	PO4	DOC	TSS	VSS	Chlor-a ³	Pheo ⁴
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
		MRL	0.10	0.01	0.10	0.05	0.01	0.50	2.00	2.00	n/a	0.10
		MDL	0.0046	0.0013	0.011	0.019	0.0031 ⁵	0.057	0.95	0.95	n/a	0.10
06/18/07	8:30	C	-	-	-	-	0.099	5.5	-	-	4.4	0.8
06/19/07	8:05	C	ND	0.110	0.48	0.130	0.100	4.9	-	-	2.2	1.0
06/20/07	8:00	C	ND	0.120	0.63	0.140	0.087	5.4	-	-	1.5	1.9
06/21/07	7:45	C	ND	0.110	0.58	0.130	0.088	5.1	-	-	1.5	2.0
08/13/07	8:32	C	0.050(j)	0.190	0.94	0.120	0.087	5.5	3.2	2.8	14.6	1.3
08/14/07	7:50	C	0.027(j)	0.160	0.97	0.120	0.130	5.6	4.8	2.8	1.0	0.1
08/15/07	8:00	C	0.029(j)	0.095	0.79	0.110	0.120	5.6	5.2	3.2	14.6	1.3
08/16/07	8:00	C	ND	0.091	0.95	0.120	0.130	5.6	6.0	4.0	21.9	1.7
09/10/07	9:00	C	ND	ND	1.4	0.220	0.130	7.3	12.8	11.2	-	-
09/11/07	8:45	C	ND	ND	0.96	0.220	0.140	7.1	6.0	7.2	-	-
09/12/07	8:34	C	ND	0.048	1.3	0.180	0.140	6.7	5.2	4.4	-	-
09/13/07	15:35	C	ND	0.051	1.5	0.190	0.160	7.0	7.2	6.0	-	-
06/18/07	8:30	G	ND	0.120	0.87	0.100	0.100	5.0	-	-	5.1	0.9
06/18/07	12:45	G	ND	0.098	1.1	0.095	0.110	5.6	-	-	4.4	0.2
06/18/07	16:00	G	ND	0.098	1.2	0.089	0.098	5.6	-	-	4.4	0.3
06/19/07	8:05	G	ND	0.120	0.58	0.280	0.110	5.0	-	-	2.2	2.1
06/19/07	12:15	G	ND	0.110	1.6	0.440	0.120	5.1	-	-	1.0	2.7
06/19/07	15:25	G	ND	0.110	1.0	0.440	0.100	4.9	-	-	2.9	0.9
06/20/07	8:00	G	ND	0.120	0.59	0.140	0.094	5.2	-	-	5.8	1.9
06/20/07	13:05	G	ND	0.110	0.58	0.130	0.098	5.0	-	-	2.4	1.4
06/20/07	16:20	G	ND	0.120	0.57	0.120	0.120	5.5	-	-	3.4	0.8
06/21/07	7:45	G	ND	0.100	0.64	0.150	0.091	5.2	-	-	2.4	2.1
06/21/07	12:20	G	ND	0.110	0.59	0.160	0.095	5.1	-	-	2.4	0.4
06/21/07	15:45	G	ND	0.100	0.62	0.140	0.088	5.1	-	-	1.5	1.5

¹ A '-' indicates no samples were analyzed for that constituent at that site, date, and time. A 'ND' indicates that the samples were analyzed, but the concentrations were below the reporting limit.

² 'G' indicates a grab sample was collected; 'C' indicates a composite sample was collected.

³ 'Chlor-a' refers to Chlorophyll-a, a measure of algal biomass.

⁴ 'Pheo' refers to Pheophytin, a measure of density and biomass.

⁵ The method detection limit for PO4 identified by CH2MHill changed after August 15, from 0.0031 mg/l to 0.0018 mg/l.

Table 19. Constituent Concentrations for All Grab and Composite Samples at the Klamath River above Shasta River Confluence.

Date	Time	Type ²	Constituent Concentrations ¹									
			NH4	NO2+NO3	TKN	TP	PO4	DOC	TSS	VSS	Chlor-a ³	Pheo ⁴
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
		MRL	0.10	0.01	0.10	0.05	0.01	0.50	2.00	2.00	n/a	0.10
		MDL	0.0046	0.0013	0.011	0.019	0.0031 ⁵	0.057	0.95	0.95	n/a	0.10
07/16/07	8:30	C	ND	0.190	0.92	0.120	0.092	5.4	-	-	18.8	0.3
07/17/07	8:20	C	ND	0.230	0.82	0.110	0.051	5.2	-	-	11.0	0.6
07/18/07	15:30	C	ND	0.270	0.69	0.160	0.140	6.5	-	-	8.8	0.7
07/19/07	7:45	C	ND	0.290	0.56	0.120	0.110	5.8	-	-	7.3	0.4

¹ A '-' indicates no samples were analyzed for that constituent at that site, date, and time. A 'ND' indicates that the samples were analyzed, but the concentrations were below the reporting limit.

² 'G' indicates a grab sample was collected; 'C' indicates a composite sample was collected.

³ 'Chlor-a' refers to Chlorophyll-a, a measure of algal biomass.

⁴ 'Pheo' refers to Pheophytin, a measure of density and biomass.

⁵ The method detection limit for PO4 identified by CH2MHill changed after August 15, from 0.0031 mg/l to 0.0018 mg/l.

Table 20. Constituent Concentrations for All Grab Samples in Shasta River.

Date	Time	Type ²	Constituent Concentrations ¹									
			NH4	NO2+NO3	TKN	TP	PO4	DOC	TSS	VSS	Chlor-a ³	Pheo ⁴
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
		MRL	0.10	0.01	0.10	0.05	0.01	0.50	2.00	2.00	n/a	0.10
		MDL	0.0046	0.0013	0.011	0.019	0.0031 ⁵	0.057	0.95	0.95	n/a	0.10
08/14/07	8:45	G	ND	ND	0.52	0.110	0.150	5.7	ND	ND	2.9	8.5
09/12/07	12:35	G	ND	0.011	0.31	0.011	0.170	1.3	1.6(j)	1.6(j)	-	-

¹ A '-' indicates no samples were analyzed for that constituent at that site, date, and time. A 'ND' indicates that the samples were analyzed, but the concentrations were below the reporting limit.

² 'G' indicates a grab sample was collected; 'C' indicates a composite sample was collected.

³ 'Chlor-a' refers to Chlorophyll-a, a measure of algal biomass.

⁴ 'Pheo' refers to Pheophytin, a measure of density and biomass.

⁵ The method detection limit for PO4 identified by CH2MHill changed after August 15, from 0.0031 mg/l to 0.0018 mg/l.

Table 21. Constituent Concentrations for All Grab Samples in Beaver Creek.

Date	Time	Type ²	Constituent Concentrations ¹									
			NH4 mg/l	NO2+NO3 mg/l	TKN mg/l	TP mg/l	PO4 mg/l	DOC mg/l	TSS mg/l	VSS mg/l	Chlor-a ³ mg/l	Pheo ⁴ mg/l
		MRL	0.10	0.01	0.10	0.05	0.01	0.50	2.00	2.00	n/a	0.10
		MDL	0.0046	0.0013	0.011	0.019	0.0031 ⁵	0.057	0.95	0.95	n/a	0.10
08/14/07	12:15	G	ND	0.041	0.13	0.013(j)	ND	1.1	ND	ND	2.0	0.5
09/12/07	9:25	G	0.041(j)	ND	0.71	0.160	0.160	6.6	2.8	1.2(j)	-	-

¹ A '-' indicates no samples were analyzed for that constituent at that site, date, and time. A 'ND' indicates that the samples were analyzed, but the concentrations were below the reporting limit.

² 'G' indicates a grab sample was collected; 'C' indicates a composite sample was collected.

³ 'Chlor-a' refers to Chlorophyll-a, a measure of algal biomass.

⁴ 'Pheo' refers to Pheophytin, a measure of density and biomass.

⁵ The method detection limit for PO4 identified by CH2MHill changed after August 15, from 0.0031 mg/l to 0.0018 mg/l.

APPENDIX F: YSI 600 XLM DATASONDE DATA

Physical and Datasonde Data

Water quality probes were used to measure water temperature, specific conductance, dissolved oxygen, and pH. Water quality measurements in June were measured using handheld multi-parameter probes (Model: YSI 556). From July to September, datasondes (Model: YSI 600 XLM) were deployed in the field for continuous data-logging during the four day sampling events. Discrete physical measurements were taken in June using a handheld datasonde and the results are reported in Table 21. These data are considered raw data without QA. Data sondes were rented for these applications and different sondes were used at different locations and times.

Table 22. June Spot Measurements of Water Temperature, Dissolved Oxygen, Specific Conductivity, and pH Measured by Handheld Datasondes.

Date	Time	Site Name	Tw (°C)	DO (mg/L)	Specific Conductivity (µS/cm)	pH
06/18/07	11:10	Klamath River below Keno dam	19.44	8.65	129	8.64
06/18/07	15:05	Klamath River below Keno dam	20.22	8.85	137	8.65
06/18/07	08:15	Klamath River above J.C. Boyle reservoir	19.1	7.46	123	7.77
06/18/07	12:10	Klamath River above J.C. Boyle reservoir	20.74	8.03	122	8.12
06/18/07	16:00	Klamath River above J.C. Boyle reservoir	21.38	8.11	130	8.31
06/18/07	06:45	Klamath River below Iron Gate dam	19.38	14.24	171	8.1
06/18/07	10:30	Klamath River below Iron Gate dam	19.31	14.54	172	7.8
06/18/07	14:30	Klamath River below Iron Gate dam	19.7	17.57	172	8.17
06/18/07	08:30	Klamath River at Walker Bridge Road	17.91	17.61	193	8.18
06/18/07	12:45	Klamath River at Walker Bridge Road	19.58	10.13	191	8.18
06/18/07	16:00	Klamath River at Walker Bridge Road	20.8	9.74	191	8.4
06/19/07	06:55	Klamath River below Keno dam	19.83	9.11	136	8.66
06/19/07	11:15	Klamath River below Keno dam	19.84	9.45	120	8.71
06/19/07	14:55	Klamath River below Keno dam	20.49	8	121	8.71
06/19/07	07:55	Klamath River above J.C. Boyle reservoir	19.27	8.33	124	7.78
06/19/07	12:15	Klamath River above J.C. Boyle reservoir	21.35	7.95	122	8.23
06/19/07	15:50	Klamath River above J.C. Boyle reservoir	21.9	7.25	130	8.28
06/19/07	06:35	Klamath River below Iron Gate dam	19.61	8.11	171	7.83
06/19/07	10:30	Klamath River below Iron Gate dam	19.61	8.52	171	7.97
06/19/07	13:45	Klamath River below Iron Gate dam	19.55	8.78	170	7.97
06/19/07	08:05	Klamath River at Walker Bridge Road	19.41	8.66	190	7.95
06/19/07	12:15	Klamath River at Walker Bridge Road	19.91	9.61	191	8.13
06/19/07	15:25	Klamath River at Walker Bridge Road	21.25	9.79	190	8.34
06/20/07	06:50	Klamath River below Keno dam	20.44	9.22	169	8.34
06/20/07	11:00	Klamath River below Keno dam	20.5	9.4	178	8.68
06/20/07	15:00	Klamath River below Keno dam	21.12	9.43	168	8.76
06/20/07	08:00	Klamath River above J.C. Boyle reservoir	19.75	8.01	172	7.56
06/20/07	12:25	Klamath River above J.C. Boyle reservoir	21.7	8.31	170	8.39
06/20/07	16:00	Klamath River above J.C. Boyle reservoir	22.16	8.11	166	8.21

Date	Time	Site Name	Tw (°C)	DO (mg/L)	Specific Conductivity (µS/cm)	pH
06/20/07	06:30	Klamath River below Iron Gate dam	19.54	8.44	148	8.08
06/20/07	11:15	Klamath River below Iron Gate dam	19.83	6.79	147	8.34
06/20/07	14:55	Klamath River below Iron Gate dam	19.79	6.54	147	8.26
06/20/07	08:00	Klamath River at Walker Bridge Road	19.9	7.49	164	8.06
06/20/07	13:05	Klamath River at Walker Bridge Road	20.29	7.85	163	8.27
06/20/07	16:20	Klamath River at Walker Bridge Road	21.38	8.16	163	8.42
06/21/07	07:00	Klamath River below Keno dam	20.69	8.99	177	8.63
06/21/07	10:45	Klamath River below Keno dam	20.7	9.14	185	8.79
06/21/07	14:30	Klamath River below Keno dam	21.56	9.6	182	8.73
06/21/07	08:00	Klamath River above J.C. Boyle reservoir	20.01	7.84	181	7.61
06/21/07	11:40	Klamath River above J.C. Boyle reservoir	21.79	8.18	176	8.12
06/21/07	15:30	Klamath River above J.C. Boyle reservoir	22.45	8.32	179	8.16
06/21/07	06:30	Klamath River below Iron Gate dam	19.73	5.89	145	7.87
06/21/07	10:40	Klamath River below Iron Gate dam	19.96	6.42	147	8.37
06/21/07	14:30	Klamath River below Iron Gate dam	19.88	6.15	146	8.13
06/21/07	07:45	Klamath River at Walker Bridge Road	19.76	6.69	164	8.09
06/21/07	12:20	Klamath River at Walker Bridge Road	19.67	7.58	160	8.25
06/21/07	15:45	Klamath River at Walker Bridge Road	20.82	7.23	161	8.42

Continuous (15-minute intervals) physical measurements were taken for approximately three days in July, August, and September (Table D-2 and Figure D-1 through Figure D-4).

Table 23. Continuous Data Logging Intervals for July, August, and September at All Sites.

Month	Start		Finish	
	Date	Time	Date	Time
July	July 16, 2007	15:30	July 19, 2007	14:15
August	August 13, 2007	11:15	August 16, 2007	13:30
September	September 10, 2007	10:30	September 13, 2007	13:45

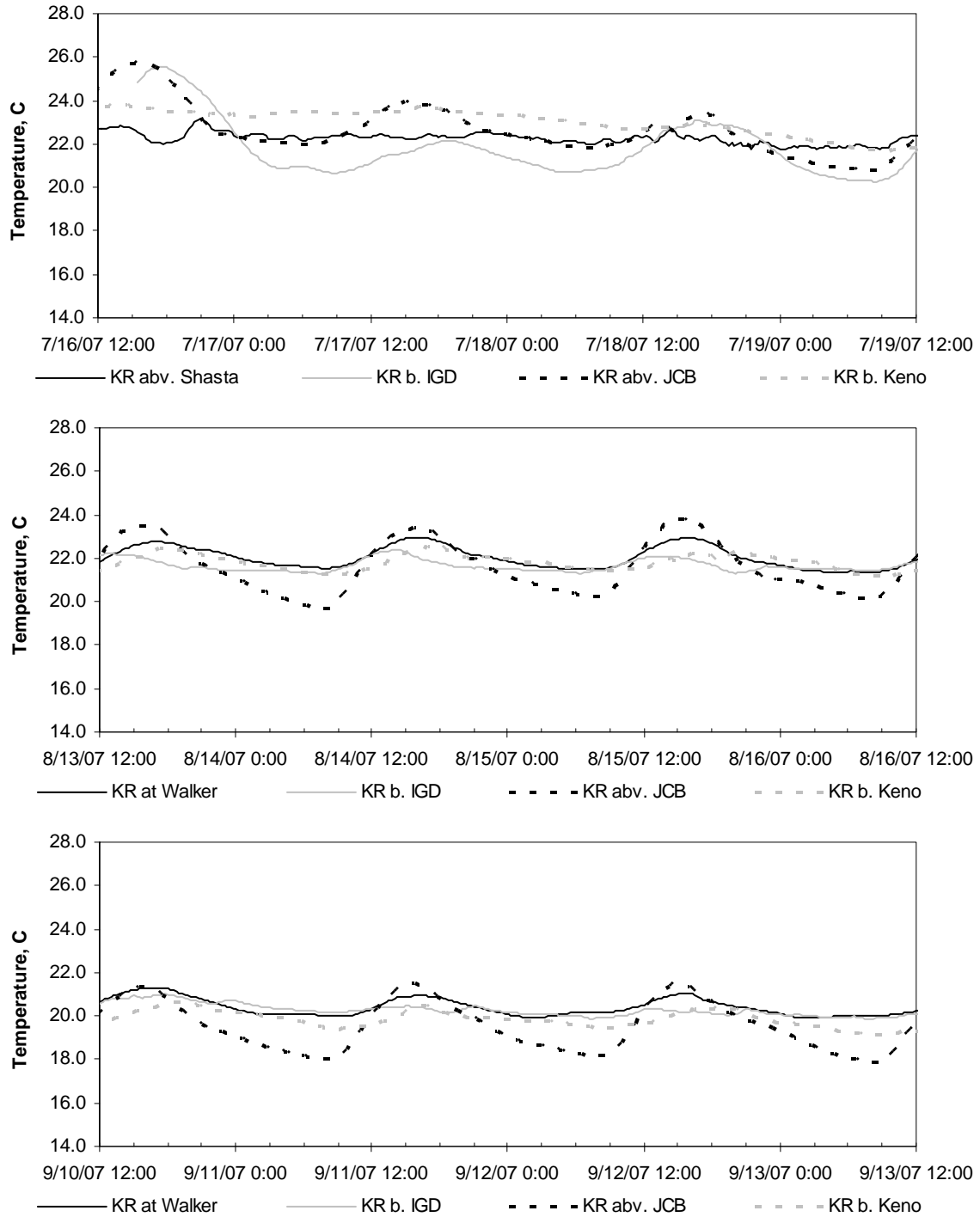


Figure 16. Datasonde water temperature data from (top) July, (middle) August, and (bottom) September 2007 sampling program.

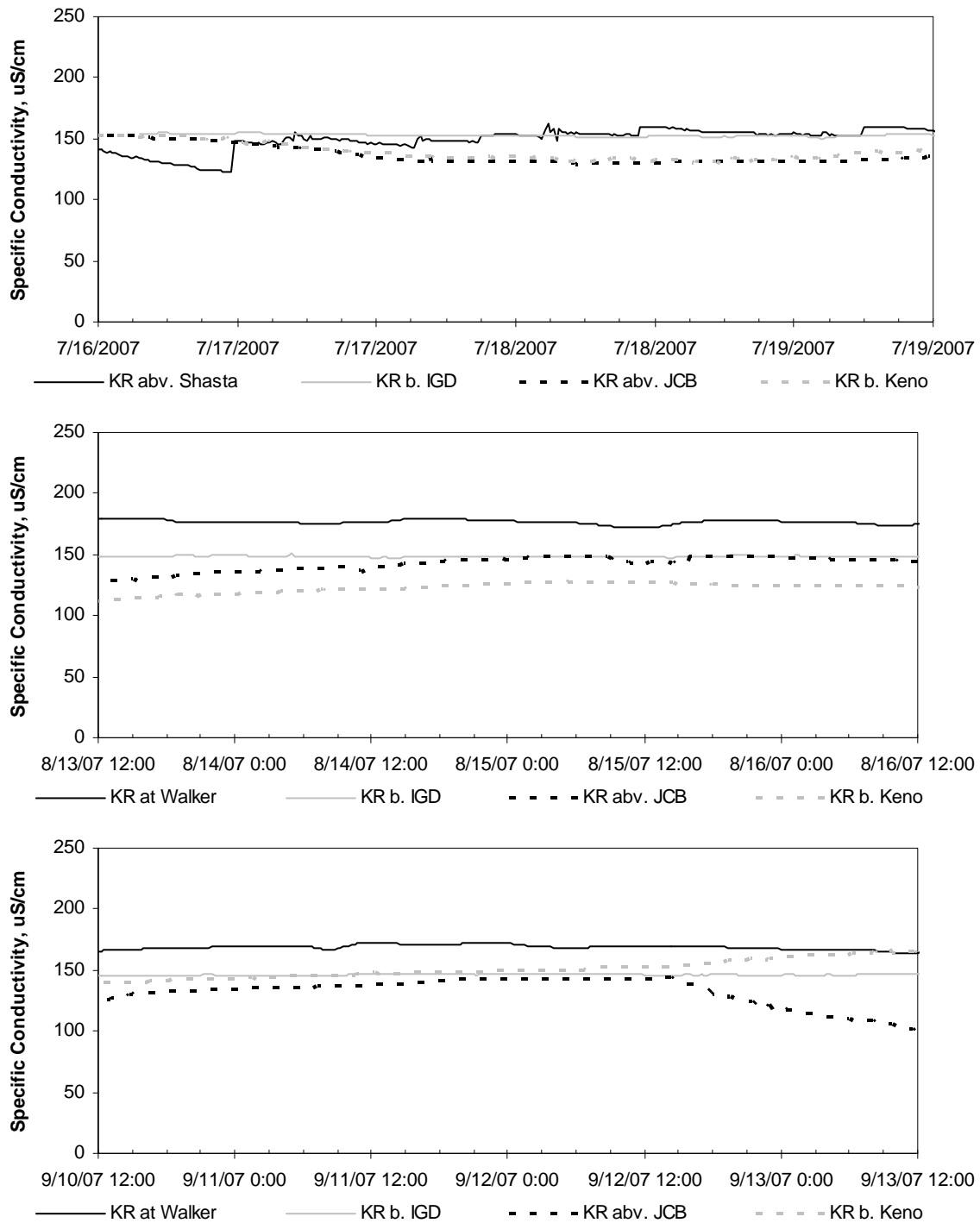


Figure 17. Datasonde specific conductance data from (top) July, (middle) August, and (bottom) September 2007 sampling program.

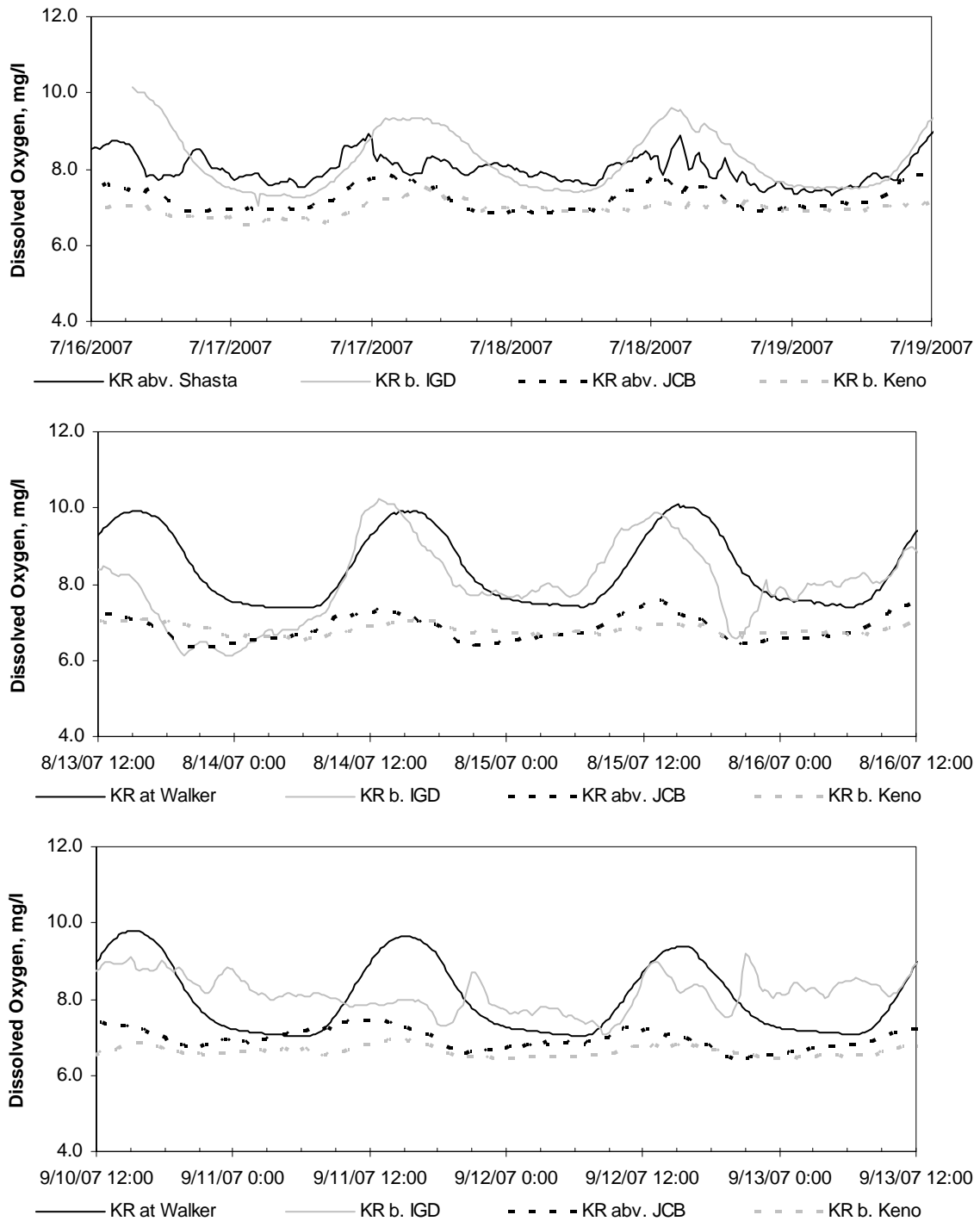


Figure 18. Datasonde dissolved oxygen data from (top) July, (middle) August, and (bottom) September 2007 sampling program.

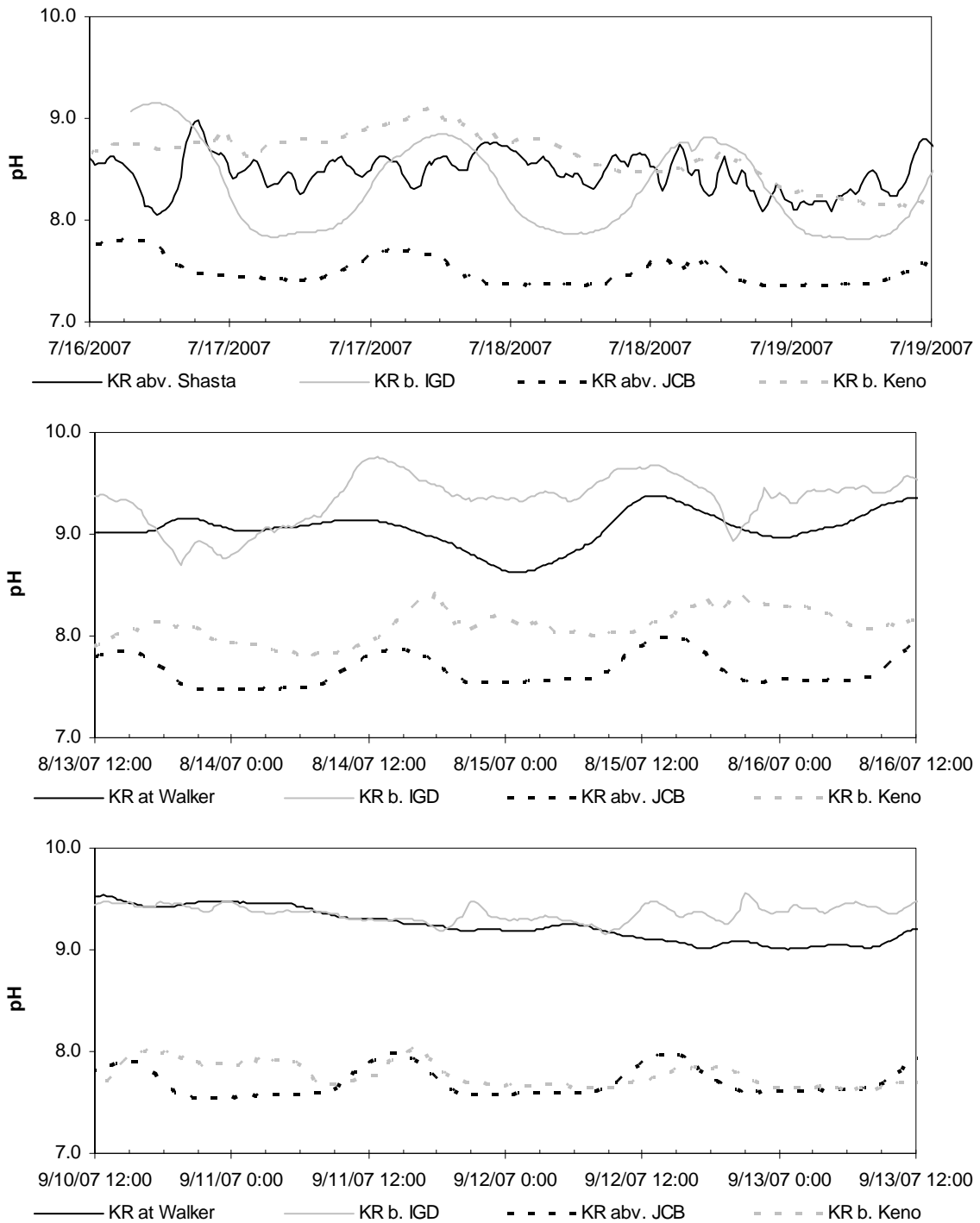


Figure 19. Datasonde pH data from (top) July, (middle) August, and (bottom) September 2007 sampling program.

APPENDIX G: METEOROLOGICAL DATA

Meteorological Data – Local Stations

Air temperature, wind speed, relative humidity, dew point temperature, and wet bulb temperature were measured at the site using a handheld meteorological station (Kestrel 4000, Serial #551131 and Serial #89184) in order to document local conditions. Time-permitting, weather data were collected at each site and at each of the three sampling time points.

Complete hourly meteorological data sets were obtained from regional stations for the upper and lower reaches during the sampling periods. In the upper reach, air temperature, relative humidity, wind speed, and solar radiation data were downloaded from the Klamath Falls Oregon AgriMet Station KFLO (latitude 42°09'53", longitude 121°45'18", elevation 4100'), which is part of an automated data collection platform managed by the U.S. Bureau of Reclamation. The KFLO weather station is approximately 12 miles east-southeast from the study reach.

For the lower reach, similar meteorological data were obtained from Brazie Ranch station operated by the California Department of Forestry (latitude 41.6870°N, longitude 122.6000°W, elevation 3020' ft). Data collected from the KFLO station are meant to represent conditions at the upper river. Brazie Ranch Station is located approximately 15 miles south of the study reach, near Yreka. Although not located along the Klamath River, these data are useful in characterizing general conditions in the lower river reach. All data from these two sites are provisional.

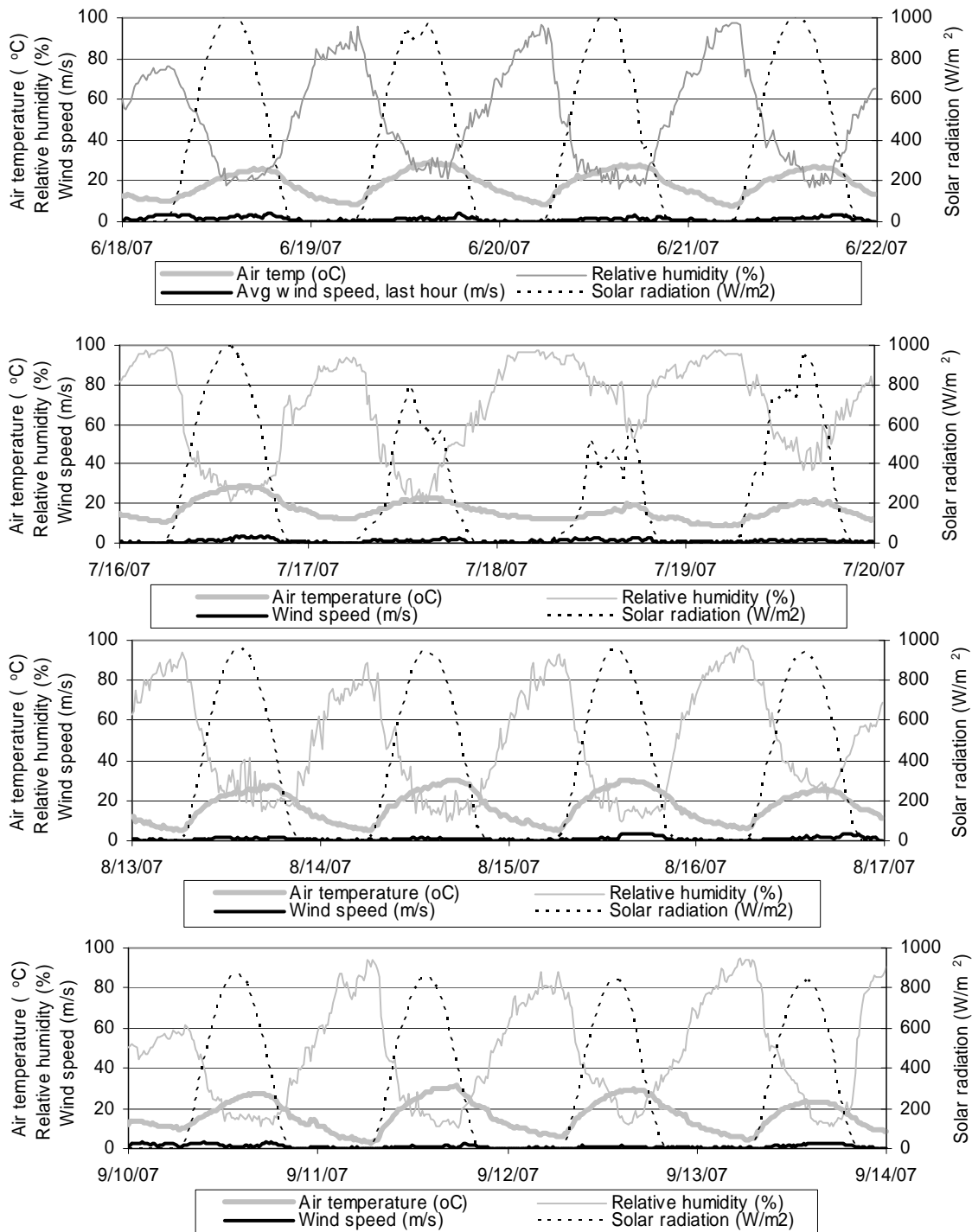


Figure 20. Air temperature, relative humidity, average wind speed, and global solar radiation at the upper river (Klamath Falls, Oregon AgriMet Station for (top) June, (upper middle) July, (lower middle) August, and (bottom) September. (Data obtained from <http://www.usbr.gov/pn/agrimet/hourlydata.html>.)

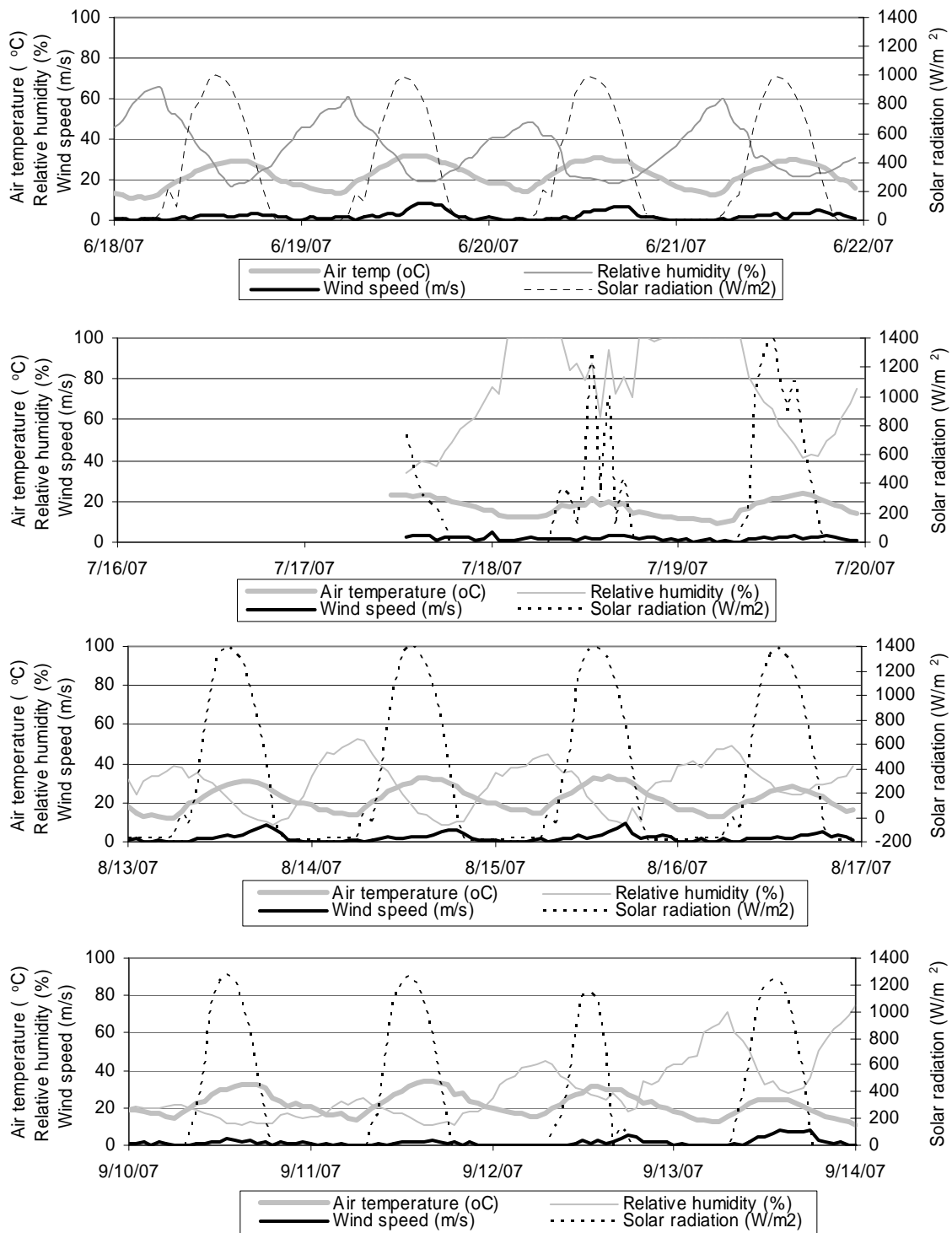


Figure 21. Air temperature, relative humidity, wind speed, and solar radiation at the lower river (Brazie Ranch Station) for (top) June, (upper middle) July, (lower middle) August, and (bottom) September. (Data obtained from http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=BZR).

Meteorological Data – Field Observations

Point measurements for wind speed, air temperature, relative humidity, dew point temperature, and wet bulb temperature were collected using a handheld meteorological station (Kestrel 4000). There are considerable challenges employing a handheld station, including: different elevations and aspects, inconsistent site location, highly variable local conditions, user differences, instantaneous readings versus averaged reading, and other factors. These data are collected to provide general insight to local conditions, but show considerable variation (even at a single site) and only generally track the more distant meteorological stations identified above.

Table 24. Handheld Met Station data. Data in June were instantaneous readings. Data in July were averaged over 20 s for wind, and at least 5 min for air temperature, relative humidity, dew point, and wet bulb.

Date	Time	Site Name	Wind (m/s)	Air Temp (°C)	Relative Humidity (%)	Dewpoint (°C)	Wet Bulb (°C)
6/18/07	11:10	Klamath River below Keno dam	1.3	20.6	45.9	7.3	12.5
6/18/07	15:05	Klamath River below Keno dam	1.1	24.7	35.5	4.3	13.4
6/19/07	6:55	Klamath River below Keno dam	<1	15.2	55	5	8.9
6/19/07	11:15	Klamath River below Keno dam	<1	25.2	43	12.1	16.8
6/19/07	14:55	Klamath River below Keno dam	2	27.4	23.4	5	14.2
6/20/07	6:50	Klamath River below Keno dam	0	14.6	60.5	5.9	9.7
6/20/07	11:00	Klamath River below Keno dam	0.6	25.1	27.3	4.8	14.8
6/20/07	15:00	Klamath River below Keno dam	0.6	27.6	18.6	1.9	15.8
6/21/07	7:00	Klamath River below Keno dam	0.3	13.1	58.8	3.7	9.6
6/21/07	10:45	Klamath River below Keno dam	0.6	28.3	29.5	8.8	17
6/21/07	14:30	Klamath River below Keno dam	1.8	32.6	17.2	4.5	18.5
7/16/2007	7:00	Klamath River below Keno dam		27.5	38.6	12	18.4
7/16/2007	11:00	Klamath River below Keno dam	0.6	27.3	38.9	11.9	18.2
7/16/2007	15:00	Klamath River below Keno dam	0.8	27.4	38.5	11.9	18.2
7/17/2007	7:00	Klamath River below Keno dam	0.1	15.1	66.5	9.5	12.1
7/17/2007	11:00	Klamath River below Keno dam	0.3	23	37.6	7.3	14.2
7/17/2007	14:50	Klamath River below Keno dam	0.5	24.3	24.9	6.2	16.2
7/18/2007	6:50	Klamath River below Keno dam	0.4	15.1	74.2	10.4	12.2
7/18/2007	11:15	Klamath River below Keno dam	0.6	18.2	69	12.1	14.3
7/18/2007	14:50	Klamath River below Keno dam	0.5	20.2	66.2	13.7	16.1
7/19/2007	6:50	Klamath River below Keno dam	1	10.4	73.9	5.9	8
7/19/2007	10:55	Klamath River below Keno dam	0.8	20.8	48.5	9.3	14
7/19/2007	14:50	Klamath River below Keno dam	1	23.5	38.8	8.6	15
8/13/2007	7:15	Klamath River below Keno dam	0.4	10	69	4.2	6.9
8/13/2007	11:15	Klamath River below Keno dam	0.6	24.3	34.1	7.4	15
8/13/2007	15:05	Klamath River below Keno dam	2.2	27.2	20	2.1	15.4
8/14/2007	7:00	Klamath River below Keno dam	0.4	7.7	59.2	2.3	6.4
8/14/2007	11:15	Klamath River below Keno dam	0.5	22.2	31.2	5.6	12.8
8/14/2007	14:52	Klamath River below Keno dam	1	30.5	16.4	2.9	17.4

Date	Time	Site Name	Wind (m/s)	Air Temp (°C)	Relative Humidity (%)	Dewpoint (°C)	Wet Bulb (°C)
8/15/2007	7:00	Klamath River below Keno dam	0.3	12.8	63.6	6	9.2
8/15/2007	11:00	Klamath River below Keno dam	1	24.5	23.8	2.4	14
8/15/2007	15:00	Klamath River below Keno dam	1	34.5	25.3	11.2	20.7
8/16/2007	6:50	Klamath River below Keno dam	0.4	13.7	61.8	6.4	9.7
8/16/2007	11:00	Klamath River below Keno dam	3.1	21	37	5.7	13
8/16/2007	14:50	Klamath River below Keno dam	2.8	26.2	22.6	3.3	15.3
9/10/2007	7:30	Klamath River below Keno dam	0.6	8.5	60.6	1.2	5.2
9/10/2007	11:10	Klamath River below Keno dam	1.5	24.8	27.2	4.2	14.4
9/10/2007	14:30	Klamath River below Keno dam	0.4	28	21	3.5	16
9/11/2007	7:27	Klamath River below Keno dam	0.3	13.2	43.6	1.1	7.8
9/11/2007	10:37	Klamath River below Keno dam	1.4	22.9	32.7	5.6	13.8
9/11/2007	14:30	Klamath River below Keno dam	1	28.6	24.6	6.3	16.7
9/12/2007	7:30	Klamath River below Keno dam	0	10.8	58.5	6.9	7
9/12/2007	11:05	Klamath River below Keno dam	0.4	24.2	33.8	10.1	14.6
9/12/2007	14:10	Klamath River below Keno dam	0.8	26.5	28.9	10.4	16.5
9/13/2007	7:20	Klamath River below Keno dam	0	15.4	44.8	3.4	9.5
9/13/2007	11:00	Klamath River below Keno dam	1.8	20.4	45.3	8.1	13.4
9/13/2007	13:43	Klamath River below Keno dam	2.5	24.5	25.6	3.4	14.2
6/18/07	8:15	Klamath River above J.C. Boyle reservoir	<1	14.6	60.3	10.1	6.8
6/18/07	12:10	Klamath River above J.C. Boyle reservoir	1.3	24.5	21	0.7	11.4
6/18/07	16:00	Klamath River above J.C. Boyle reservoir	1	26.5	27.8	7	15
6/19/07	7:55	Klamath River above J.C. Boyle reservoir	<1	15.4	60	7.3	10.6
6/19/07	12:15	Klamath River above J.C. Boyle reservoir	1.5	26.1	31	9.8	16.4
6/19/07	15:50	Klamath River above J.C. Boyle reservoir	3.3	28.5	20.8	4.4	14.5
6/20/07	8:00	Klamath River above J.C. Boyle reservoir	0.3	16.4	57.2	5.1	12.1
6/20/07	12:25	Klamath River above J.C. Boyle reservoir	1.2	28.28	23.8	6.7	17.3
6/20/07	16:00	Klamath River above J.C. Boyle reservoir		31.2	22.8	5.3	17.8
6/21/07	8:00	Klamath River above J.C. Boyle reservoir	0.6	15.9	58.6	8.2	11.8
6/21/07	11:40	Klamath River above J.C. Boyle reservoir	2.1	28	25.4	6.5	16.4
6/21/07	15:30	Klamath River above J.C. Boyle reservoir	2	32.3	17.4	4.1	18.3
7/16/2007	8:00	Klamath River above J.C. Boyle reservoir	0.7	27.4	38.7	11.9	18.4
7/16/2007	11:30	Klamath River above J.C. Boyle reservoir	1.2	27.3	38.9	11.9	18.3
7/16/2007	15:55	Klamath River above J.C. Boyle reservoir	1.2	27.4	38.4	11.8	18.2
7/17/2007	7:30	Klamath River above J.C. Boyle reservoir	0	17.2	61.3	9.1	12.3
7/17/2007	12:00	Klamath River above J.C. Boyle reservoir	0.4	25	35.8	9.7	16.2
7/17/2007	15:45	Klamath River above J.C. Boyle reservoir	0.3	26.2	36.7	10.6	17
7/18/2007	7:25	Klamath River above J.C. Boyle reservoir	0.9	16.3	65.8	9.9	12.5
7/18/2007	11:50	Klamath River above J.C. Boyle reservoir	1.9	20.3	62.9	12.6	15
7/18/2007	15:45	Klamath River above J.C. Boyle reservoir	0.7	20.6	59.9	12.5	15.5

Date	Time	Site Name	Wind (m/s)	Air Temp (°C)	Relative Humidity (%)	Dewpoint (°C)	Wet Bulb (°C)
7/19/2007	7:28	Klamath River above J.C. Boyle reservoir	0.9	10.8	76.1	6.5	8.3
7/19/2007	11:35	Klamath River above J.C. Boyle reservoir	0.7	25.4	39.3	10.4	16.5
7/19/2007	15:50	Klamath River above J.C. Boyle reservoir	1.2	23.5	41	9.4	15.3
8/13/2007	8:20	Klamath River above J.C. Boyle reservoir	0.3	12.4	55.9	3.9	8.3
8/13/2007	12:15	Klamath River above J.C. Boyle reservoir	0.3	24.3	27.3	4.8	15.8
8/13/2007	16:15	Klamath River above J.C. Boyle reservoir	2.3	29	18	2.2	16.5
8/14/2007	8:00	Klamath River above J.C. Boyle reservoir	0.4	10.4	51.7	1	6.2
8/14/2007	15:56	Klamath River above J.C. Boyle reservoir	0.4	28.7	32.8	10.8	18.2
8/15/2007	8:00	Klamath River above J.C. Boyle reservoir	0.3	13.7	61	6.2	9.7
8/15/2007	11:50	Klamath River above J.C. Boyle reservoir	1	22.1	31.2	4.3	13.2
8/15/2007	15:50	Klamath River above J.C. Boyle reservoir	1.6	31.4	16.2	2.6	17.7
8/16/2007	7:55	Klamath River above J.C. Boyle reservoir	0.3	12.7	54	3.7	8.3
8/16/2007	11:35	Klamath River above J.C. Boyle reservoir	0.8	23.6	39.6	8.8	15
8/16/2007	16:00	Klamath River above J.C. Boyle reservoir	1.5	26.7	26.2	5.7	15.7
9/10/2007	8:30	Klamath River above J.C. Boyle reservoir	0	11.7	49.4	1.4	7
9/10/2007	12:05	Klamath River above J.C. Boyle reservoir	0.7	21.1	29	2.2	12.3
9/10/2007	15:35	Klamath River above J.C. Boyle reservoir	1.1	25.7	29.8	6.4	15.5
9/11/2007	8:08	Klamath River above J.C. Boyle reservoir	0.5	10.4	40.8	-2.3	5.2
9/11/2007	11:35	Klamath River above J.C. Boyle reservoir	0.5	20.4	24.3	-0.6	11.4
9/11/2007	15:45	Klamath River above J.C. Boyle reservoir	1.1	31	33.9	13	19.8
9/12/2007	8:20	Klamath River above J.C. Boyle reservoir	<1	8.6	50.6	-0.7	4.9
9/12/2007	12:00	Klamath River above J.C. Boyle reservoir	0.5	26.5	27.5	7.8	16.8
9/13/2007	9:36	Klamath River above J.C. Boyle reservoir	0.4	8.3	57.4	0.7	5.4
9/13/2007	11:45	Klamath River above J.C. Boyle reservoir	2	20.6	40.9	6.8	13.1
9/13/2007	15:24	Klamath River above J.C. Boyle reservoir	1.3	24.5	28.5	4.9	14.5
6/18/07	6:45	Klamath River below Iron Gate dam	0.4	17.8	54.6	8.1	12.9
6/18/07	10:30	Klamath River below Iron Gate dam	1.2	24.3	33.6	6.9	15.6
6/18/07	14:30	Klamath River below Iron Gate dam	2.1	29.8	24.3	6.3	17.6
6/19/07	6:35	Klamath River below Iron Gate dam	0.4	15.83	56.6	7.3	11.7
6/19/07	10:30	Klamath River below Iron Gate dam	1.7	24.7	31.1	6.6	13.4
6/19/07	13:45	Klamath River below Iron Gate dam	0.8	32.7	22.6	9.5	20.2
6/20/07	6:30	Klamath River below Iron Gate dam	<1	13	62.6	5.6	8.8
6/20/07	14:55	Klamath River below Iron Gate dam	1	36.4	13	2.7	16.5
6/21/07	6:30	Klamath River below Iron Gate dam	<1	15.1	58.9	6.8	10.3
6/21/07	10:40	Klamath River below Iron Gate dam	1.2	24.5	34.9	7.7	14.4
6/21/07	14:30	Klamath River below Iron Gate dam	<1	30.7	17	2.6	14.8
7/16/2007	6:40	Klamath River below Iron Gate dam	0.7	26	39.7	11.2	16.8
7/16/2007	10:30	Klamath River below Iron Gate dam	0	28.6	44	14.8	19.2
7/16/2007	13:45	Klamath River below Iron Gate dam	1	33.9	20.4	8	17.5

Date	Time	Site Name	Wind (m/s)	Air Temp (°C)	Relative Humidity (%)	Dewpoint (°C)	Wet Bulb (°C)
7/17/2007	6:40	Klamath River below Iron Gate dam	1.1	17.3	56.2	8.7	12.3
7/17/2007	10:35	Klamath River below Iron Gate dam	0.5	25	35	8.5	15.1
7/17/2007	14:25	Klamath River below Iron Gate dam	2.8	24.3	36.4	7.9	14.3
7/18/2007	6:35	Klamath River below Iron Gate dam	0.4	16.7	84.4	14.1	15
7/18/2007	10:30	Klamath River below Iron Gate dam	0.6	24.1	51.1	13.8	17.6
7/18/2007	13:50	Klamath River below Iron Gate dam	0.9	24.2	45	11.6	16.2
7/19/2007	6:35	Klamath River below Iron Gate dam	0.5	14.6	80.3	11.6	13
7/19/2007	10:30	Klamath River below Iron Gate dam	0.4	21.9	50.5	11.1	15.1
7/19/2007	14:15	Klamath River below Iron Gate dam	0.3	29.9	28.1	10.7	18.5
8/13/2007	6:50	Klamath River below Iron Gate dam	0.6	16.9	43.1	4.1	10
8/13/2007	10:20	Klamath River below Iron Gate dam	0.8	25.5	28.7	6.1	14.2
8/13/2007	14:20	Klamath River below Iron Gate dam	0.9	35	14	3.5	16.6
8/14/2007	6:35	Klamath River below Iron Gate dam	1	14.3	40.5	1.1	7.9
8/14/2007	10:30	Klamath River below Iron Gate dam	0	29.2	27	8.3	16.4
8/14/2007	14:20	Klamath River below Iron Gate dam	0.6	35.9	11.5	1.4	16.6
8/15/2007	6:30	Klamath River below Iron Gate dam	1	14.8	40.8	2.5	8.7
8/15/2007	10:25	Klamath River below Iron Gate dam	0.7	29.8	26	8.1	16.4
8/16/2007	6:35	Klamath River below Iron Gate dam	0.6	14.6	48.9	4	9
8/16/2007	10:20	Klamath River below Iron Gate dam	0.8	28.3	25.5	6.7	15.4
8/16/2007	14:10	Klamath River below Iron Gate dam	0.2	32.5	18.9	5.8	16.5
9/10/2007	7:09	Klamath River below Iron Gate dam	0.4	11.4	42.1	-0.7	5.6
9/10/2007	10:39	Klamath River below Iron Gate dam	0.8	26.2	18.7	0.5	12.6
9/10/2007	13:50	Klamath River below Iron Gate dam	0.7	33.3	13	1	15.3
9/11/2007	7:05	Klamath River below Iron Gate dam	<1	12.8	33.9	-2.5	6
9/11/2007	10:40	Klamath River below Iron Gate dam	<1	21.7	29.8	3.1	11.8
9/11/2007	14:10	Klamath River below Iron Gate dam	<1	33.7	15.7	2.4	16.1
9/12/2007	7:08	Klamath River below Iron Gate dam	0.1	17	40.5	3.5	9.8
9/12/2007	10:25	Klamath River below Iron Gate dam	0.6	25.2	32.2	7.3	14.6
9/12/2007	14:02	Klamath River below Iron Gate dam	0.4	31.4	25.8	9.3	17.5
9/13/2007	7:05	Klamath River below Iron Gate dam	<1	12.7	53.9	3.3	7.5
9/13/2007	10:30	Klamath River below Iron Gate dam	<1	25	37.4	9	14.8
9/13/2007	14:00	Klamath River below Iron Gate dam	<=1	29	19.8	3.9	14.6
7/16/2007	7:30	Klamath River at I-5 Rest Area	0.2	26	39.7	11.2	16.8
7/16/2007	11:15	Klamath River at I-5 Rest Area	0	27.9	38.5	12.6	17.7
7/16/2007	14:35	Klamath River at I-5 Rest Area	1.5	33.7	27.4	12.1	19.3
7/17/2007	7:30	Klamath River at I-5 Rest Area	0.7	19.3	41	5.7	11.6
7/17/2007	11:30	Klamath River at I-5 Rest Area	0.2	24	35.2	7.8	14.4
7/17/2007	15:40	Klamath River at I-5 Rest Area	0.9	22.5	38.7	7.9	14
7/18/2007	7:30	Klamath River at I-5 Rest Area	0.5	19.5	74.4	14.7	16.3

Date	Time	Site Name	Wind (m/s)	Air Temp (°C)	Relative Humidity (%)	Dewpoint (°C)	Wet Bulb (°C)
7/18/2007	11:25	Klamath River at I-5 Rest Area	0.2	23.5	57.2	14.6	17.7
7/18/2007	14:45	Klamath River at I-5 Rest Area	0.5	22.6	74.6	18	19.4
7/19/2007	7:20	Klamath River at I-5 Rest Area	0.1	14.9	76.4	10.8	12.5
7/19/2007	11:10	Klamath River at I-5 Rest Area	0.7	21.6	47.5	10	14.5
7/19/2007	15:20	Klamath River at I-5 Rest Area	0	29.7	30.8	11.4	18.2
8/13/2007	7:46	Klamath River at I-5 Rest Area	0.6	14.8	53.7	5.4	9.7
8/13/2007	11:03	Klamath River at I-5 Rest Area	0.5	24.6	33.4	7.4	14.4
8/13/2007	15:25	Klamath River at I-5 Rest Area	0.8	29.8	17.6	2.7	14.6
8/14/2007	7:06	Klamath River at I-5 Rest Area	0	15.9	51.6	5.9	10.4
8/14/2007	11:08	Klamath River at I-5 Rest Area	0	27.9	23.9	5.5	14.9
8/14/2007	15:08	Klamath River at I-5 Rest Area	0.6	33.8	17.4	5.8	17.1
8/15/2007	7:10	Klamath River at I-5 Rest Area	0	14.5	57.7	6.5	10.1
8/15/2007	11:05	Klamath River at I-5 Rest Area	0	27.4	26.3	6.3	14.8
8/15/2007	15:00	Klamath River at I-5 Rest Area	0.8	31.6	12.8	0.9	14.3
8/16/2007	7:10	Klamath River at I-5 Rest Area	0	14.4	51	4.4	9.1
8/16/2007	11:00	Klamath River at I-5 Rest Area	0.4	26.5	25.3	5.1	14.2
8/16/2007	15:00	Klamath River at I-5 Rest Area	1.2	30.1	20.6	5.1	15.4
9/10/2007	8:01	Klamath River at I-5 Rest Area	0.4	15.1	38.1	1	8.1
9/10/2007	11:18	Klamath River at I-5 Rest Area	0.8	26.7	22.5	3.5	13.7
9/10/2007	14:58	Klamath River at I-5 Rest Area	0.7	32.1	22.6	8.1	17.2
9/11/2007	7:55	Klamath River at I-5 Rest Area	<1	11.6	50	2	7
9/11/2007	11:10	Klamath River at I-5 Rest Area		25.2	24.6	4	13.3
9/11/2007	15:05	Klamath River at I-5 Rest Area		32.4	34	18.4	20.5
9/12/2007	7:45	Klamath River at I-5 Rest Area	0.5	17.1	45.7	5.3	9.5
9/12/2007	11:15	Klamath River at I-5 Rest Area	1	24.3	39.4	9.7	15.4
9/12/2007	15:00	Klamath River at I-5 Rest Area	0	31.7	26.5	10.3	18.1
9/13/2007	7:45	Klamath River at I-5 Rest Area	0	15.1	61	8	11.4
9/13/2007	11:35	Klamath River at I-5 Rest Area		25.3	54	16	19
9/13/2007	14:40	Klamath River at I-5 Rest Area	<1	29.6	27.5	5.9	15.3
6/18/07	8:30	Klamath River at Walker Bridge Road	0	21	38.9	5.28	12.22
6/18/07	12:45	Klamath River at Walker Bridge Road	0.4	25.8	36.4	8.4	16.4
6/18/07	16:00	Klamath River at Walker Bridge Road	0.8	28.6	34.3	10.7	18.2
6/19/07	8:05	Klamath River at Walker Bridge Road	0.3	19.3	54.1	9.4	13.5
6/19/07	12:15	Klamath River at Walker Bridge Road	0.5	30.3	30.6	10	18.7
6/19/07	15:25	Klamath River at Walker Bridge Road	1	30.56	33.6	12.06	19.56
6/20/07	8:00	Klamath River at Walker Bridge Road	<1	17.1	51.4	7.2	11.6
6/20/07	13:05	Klamath River at Walker Bridge Road	<1	28.7	24.5	6.6	15.6
6/20/07	16:20	Klamath River at Walker Bridge Road	<1	29.4	24.5	7.3	16.2
6/21/07	7:45	Klamath River at Walker Bridge Road	<1	15.3	60	8.1	11.2

Date	Time	Site Name	Wind (m/s)	Air Temp (°C)	Relative Humidity (%)	Dewpoint (°C)	Wet Bulb (°C)
6/21/07	12:20	Klamath River at Walker Bridge Road	0	27.8	33.7	9.6	16.6
6/21/07	15:45	Klamath River at Walker Bridge Road	1.8	28.3	27.4	7.8	16.1
8/13/2007	8:32	Klamath River at Walker Bridge Road	0.7	18.3	38.4	3.6	10.2
8/13/2007	11:50	Klamath River at Walker Bridge Road	0.5	31.7	22.2	7.6	17
8/13/2007	16:26	Klamath River at Walker Bridge Road	1.1	34.1	15.4	4.2	16.6
8/14/2007	7:50	Klamath River at Walker Bridge Road	0.6	17.8	53.6	7.6	11.6
8/14/2007	11:45	Klamath River at Walker Bridge Road	0	26.9	38.5	11.5	17.1
8/14/2007	16:10	Klamath River at Walker Bridge Road	0.4	32.2	20.9	7.5	17.1
8/15/2007	8:00	Klamath River at Walker Bridge Road	0	17.4	51	6.6	11.3
8/15/2007	11:50	Klamath River at Walker Bridge Road	0.6	27.5	31.6	9.2	16.3
8/15/2007	16:00	Klamath River at Walker Bridge Road	1	30.7	22	6.6	16.3
8/16/2007	8:00	Klamath River at Walker Bridge Road	0	15.3	58.5	7.2	10.8
8/16/2007	11:45	Klamath River at Walker Bridge Road	0.5	26	37.9	10.5	16.3
8/16/2007	16:00	Klamath River at Walker Bridge Road	2.8	26.7	29.8	7.6	15.3
9/10/2007	9:00	Klamath River at Walker Bridge Road	0	16	40.5	2.6	9.1
9/10/2007	12:08	Klamath River at Walker Bridge Road	1	28.7	24.2	6	15.4
9/10/2007	15:57	Klamath River at Walker Bridge Road	1.3	34.1	16.7	5.3	17
9/11/2007	8:45	Klamath River at Walker Bridge Road	<1	15.7	49	4.9	10
9/11/2007	11:55	Klamath River at Walker Bridge Road	<1	27.5	31.9	9.8	17
9/11/2007	15:45	Klamath River at Walker Bridge Road	<1	33.4	20.1	6.5	16.9
9/12/2007	8:34	Klamath River at Walker Bridge Road	0.3	17.1	55.6	8.2	12
9/12/2007	11:55	Klamath River at Walker Bridge Road	0	25.2	39	10.3	15.9
9/12/2007	16:15	Klamath River at Walker Bridge Road	0.7	29.5	36.3	12.7	18.6
9/13/2007	8:30	Klamath River at Walker Bridge Road	<1	13.4	72.5	9.6	11.8
9/13/2007	12:15	Klamath River at Walker Bridge Road	<1	22.8	41.4	9.1	14.6
9/13/2007	15:35	Klamath River at Walker Bridge Road	2.5	23.8	44	11.5	16.3
7/16/2007	8:30	Klamath River above Shasta	0.1	21.6	65.7	15.6	17.6
7/16/2007	11:40	Klamath River above Shasta	0.5	27.2	38.2	12.5	18
7/16/2007	15:05	Klamath River above Shasta	0.5	31.2	34.1	13.3	19.2
7/17/2007	8:20	Klamath River above Shasta	0	18.7	44.1	6.1	11.6
7/17/2007	12:15	Klamath River above Shasta	0.9	22.6	36	6.8	13.4
7/17/2007	16:10	Klamath River above Shasta	0.9	21.7	46.7	9.7	14.4
7/18/2007	8:17	Klamath River above Shasta	0.3	20.3	71.6	15.1	16.8
7/18/2007	12:00 PM	Klamath River above Shasta	0.3	21.2	61.1	13.4	16.2
7/18/2007	15:30	Klamath River above Shasta	0	20.6	95.3	19.8	20.1
7/19/2007	7:45	Klamath River above Shasta	0	15.9	72.4	10.9	12.8
7/19/2007	11:35	Klamath River above Shasta	0	22.8	47.4	11	15.5
7/19/2007	16:00	Klamath River above Shasta	0.5	26.6	35.3	10	16.3
8/13/2007	16:30	Klamath River below Keno dam boat	2	27	29.1	7.5	16.2

Date	Time	Site Name	Wind (m/s)	Air Temp (°C)	Relative Humidity (%)	Dewpoint (°C)	Wet Bulb (°C)
		dock					
8/14/2007	8:45	Shasta River	0	19.3	49	8.2	12.8
8/14/2007	12:15	Beaver Creek	0	30.8	22.2	6.7	16.4
9/12/2007	9:25	Shasta River	0.4	17.9	57.8	9.4	12.9
9/12/2007	12:35	Beaver Creek	0	24.4	42.8	11	16

APPENDIX H: PROVISIONAL FLOW DATA FROM U.S. GEOLOGICAL SURVEY
(USGS) NATIONAL WATER INFORMATION SYSTEM (NWIS)

Flow Data

Provisional flow data within the study area were obtained from U.S. Geological Survey (USGS) National Water Information System (NWIS) database for Klamath River near Keno Station (USGS Gage No. 11509500), Klamath River below Iron Gate dam station (11516530), Klamath River near Seiad Valley (11520500), and Shasta River near Yreka (11517500).

Flow data in the project area are presented in Table 24 to Table 26 summarize average, minimum, and maximum daily stream flows at Keno station (USGS 11509500), Iron Gate dam station (USGS 11516530), and Seiad Valley station (USGS 11520500) from June to September. These included average, minimum, and maximum stream flows and document local conditions near the sites during the sampling periods.

Table 25. Average, Minimum and Maximum Stream Flows at Keno (11509500). Data Obtained from <http://waterdata.usgs.gov/nwis/rt>.

Date	Average (ft³/s)	Minimum (ft³/s)	Maximum (ft³/s)
6/18/07	1,194	1,190	1,200
6/19/07	1,191	1,190	1,200
6/20/07	1,172	1,140	1,200
6/21/07	1,146	1,140	1,150
7/16/07	701	698	702
7/17/07	700	698	702
7/18/07	706	698	733
7/19/07	710	698	724
8/13/07	711	707	715
8/14/07	830	680	909
8/15/07	770	693	914
8/16/07	707	698	715
9/10/07	718	693	960
9/11/07	700	671	711
9/12/07	699	693	707
9/13/07	703	698	711

Table 26. Average, minimum and maximum stream flows at Iron Gate dam (11516530). Data obtained from <http://waterdata.usgs.gov/nwis/rt>.

Date	Average (ft³/s)	Minimum (ft³/s)	Maximum (ft³/s)
6/18/07	1,542	1,540	1,550
6/19/07	1,541	1,530	1,560
6/20/07	1,542	1,520	1,570
6/21/07	1,538	1,520	1,550
7/16/07	1,026	1,020	1,030
7/17/07	1,029	1,020	1,050
7/18/07	1,030	1,010	1,050
7/19/07	1,032	1,020	1,040
8/13/07	1,020	1,020	1,030
8/14/07	1,020	1,010	1,030
8/15/07	1,020	1,010	1,020
8/16/07	1,020	1,020	1,020
9/10/07	1,028	1,020	1,040
9/11/07	1,028	1,020	1,040
9/12/07	1,029	1,020	1,040
9/13/07	1,028	1,020	1,040

Table 27. Average, minimum and maximum stream flows at Seiad Valley (11520500). Data obtained from <http://cdec.water.ca.gov/selectQuery.html>.

Date	Average (ft³/s)	Maximum (ft³/s)	Minimum (ft³/s)
6/18/2007	2,006	1,980	2,020
6/19/2007	1,937	1,721	2,020
6/20/2007	1,964	1,950	1,980
6/21/2007	1,947	1,920	1,960
7/16/2007	1,207	1,200	1,210
7/17/2007	1,212	1,200	1,250
7/18/2007	1,290	1,250	1,320
7/19/2007	1,359	1,290	1,420
8/13/2007	1,128	1,120	1,140
8/14/2007	1,120	1,110	1,120
8/15/2007	1,110	1,100	1,120
8/16/2007	1,117	1,100	1,120
9/10/2007	1,124	1,110	1,140
9/11/2007	1,136	1,120	1,140
9/12/2007	1,126	1,120	1,140
9/13/2007	1,120	1,110	1,130

APPENDIX I: RPD ASSESSMENT

RPD Assessment: Discussion

The RPD represented in the figures (dashed line) is measured perpendicular to the one-to-one line (Figure 22(a) and (b)). Recall that the RPD represents a quantification of uncertainty within the data set for each data point given the external QA program in place. The ‘envelope’ (region between the two dashed lines) captures those points that are within \pm RPD and are theoretically indifferent from the one-to-one line given the level of quantification in this study. However, this strict interpretation does not incorporate the uncertainty of each data point, thus it is an approximate representation. For example, in Figure 22(b), the horizontal error bars correspond to the RPD associated with the upstream concentration (horizontal axis), whereas the vertical error bars correspond to the RPD associated with the downstream concentration (vertical axis) – and the magnitude of the uncertainty based on the RPD at each location is not necessarily equal. The actual value of the sample could be any combination within these ranges (rectangle) – in other words, all points within the error bars are equally likely to be the ‘actual’ value.

For example, the measured value of the plotted triangle symbol (green) on Figure 22(b) is (1.28, 1.60). The RPD values are (0.26, 0.32). So, while the measured value was reported as a single upstream and downstream pairing, given uncertainty, the actual values could be any combination of pairs where the upstream concentration is between 1.02 (measured upstream minus one RPD) and 1.53 (measured upstream plus one RPD) and the downstream concentration is between 1.28 (measured downstream minus one RPD) and 1.92 (measured downstream plus one RPD). In other words, (1.02, 1.28) is the same as (and just as likely to occur as) (1.53, 1.92), (1.15, 1.40), and (1.28, 1.60). In the case of the triangle symbol (green), the data point falls within one RPD of the one-to-one line, meaning the majority of the equally likely points fall within the envelope. The opposite case is the square symbol (pink), where the data point falls just outside the envelope, meaning the majority of the possible points fall outside of the envelope. This means that measured value outside the envelope still have the potential to have points that could fall within the envelope (see the diamond symbol [blue]). More equally likely points fall within the envelope when the measured value is closer to the one-to-one line (such as the cross symbol [cyan]). Conversely, less points fall within the envelope when the measured point is further from the one-to-one line (such as the solid circle [grey]).

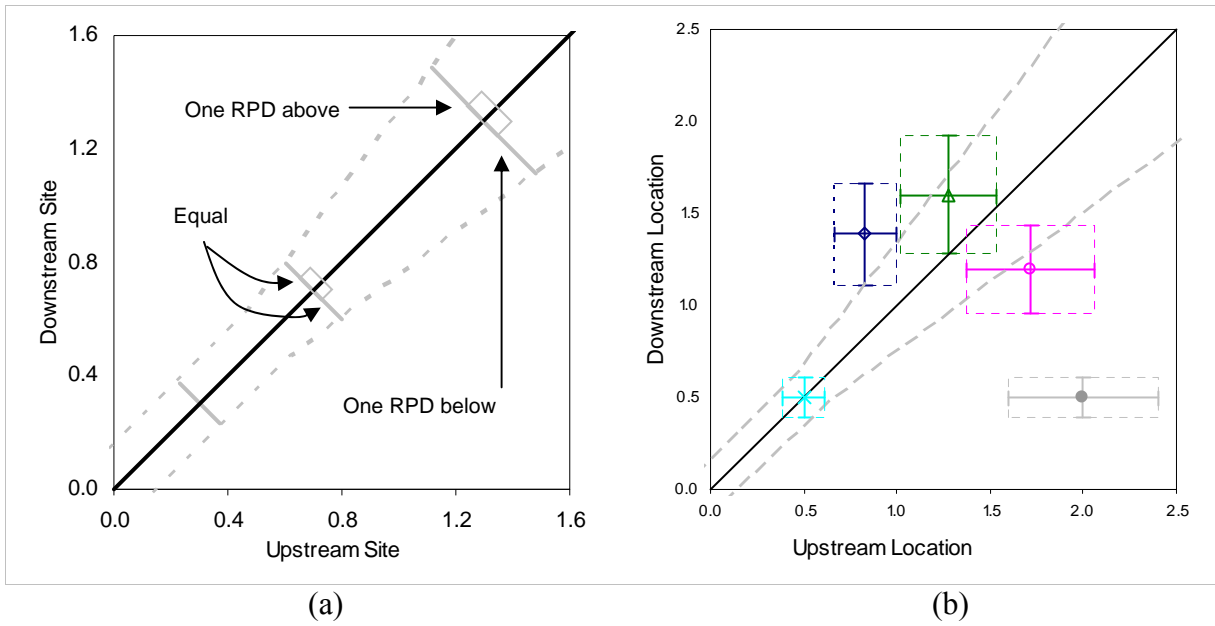


Figure 22. Example plot of one-to-one line and the one-RPD above/below line for a sample constituent.