Partnership for the Umpqua Rivers

Your Watershed Council

Appendix C: Work Notes

Supplemental Data For

Report

Water Temperature Variability on the Lower Umpqua River

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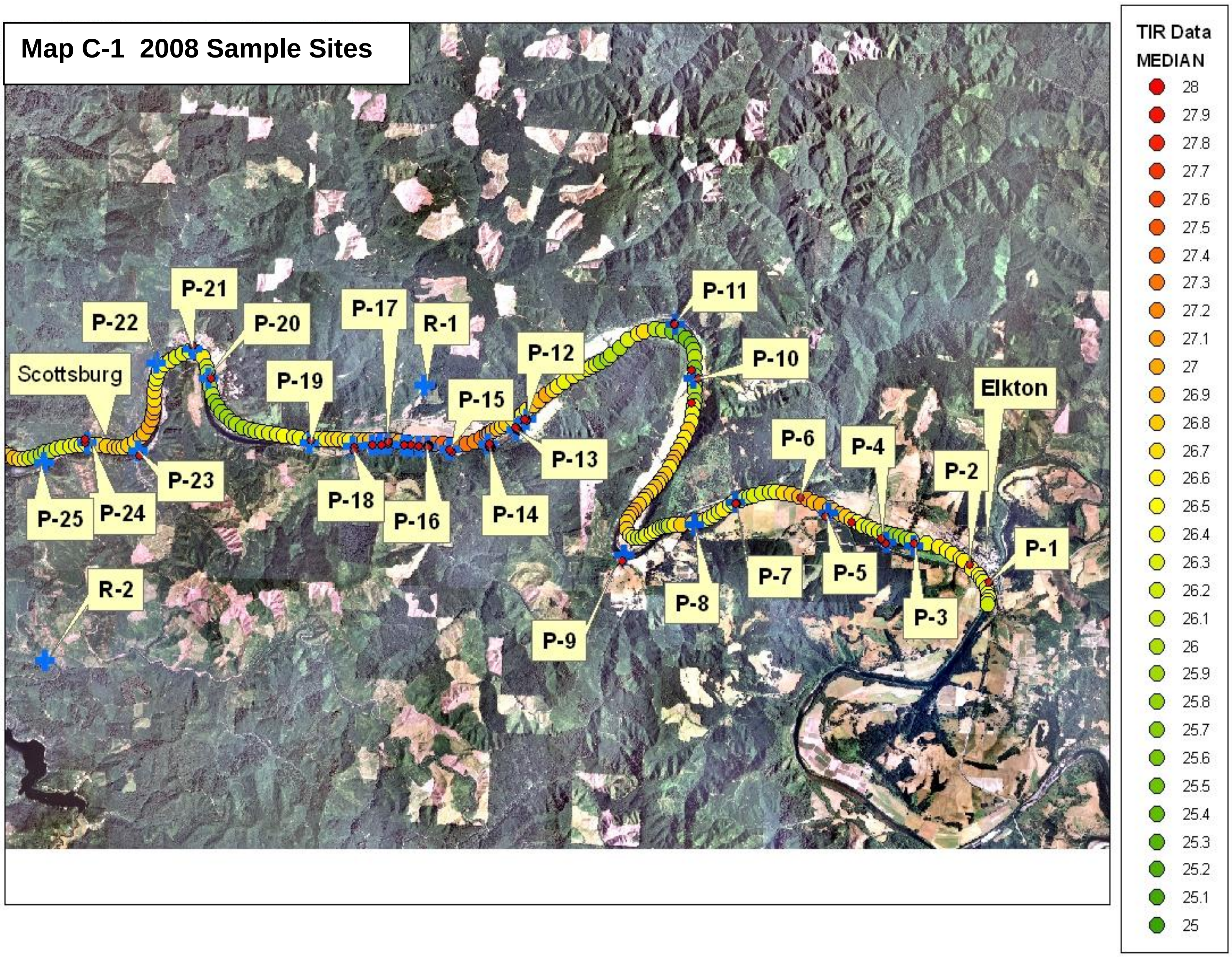
Appendix C. Work Notes

This document contains details on the field procedures and activities as well as the data analysis methodology

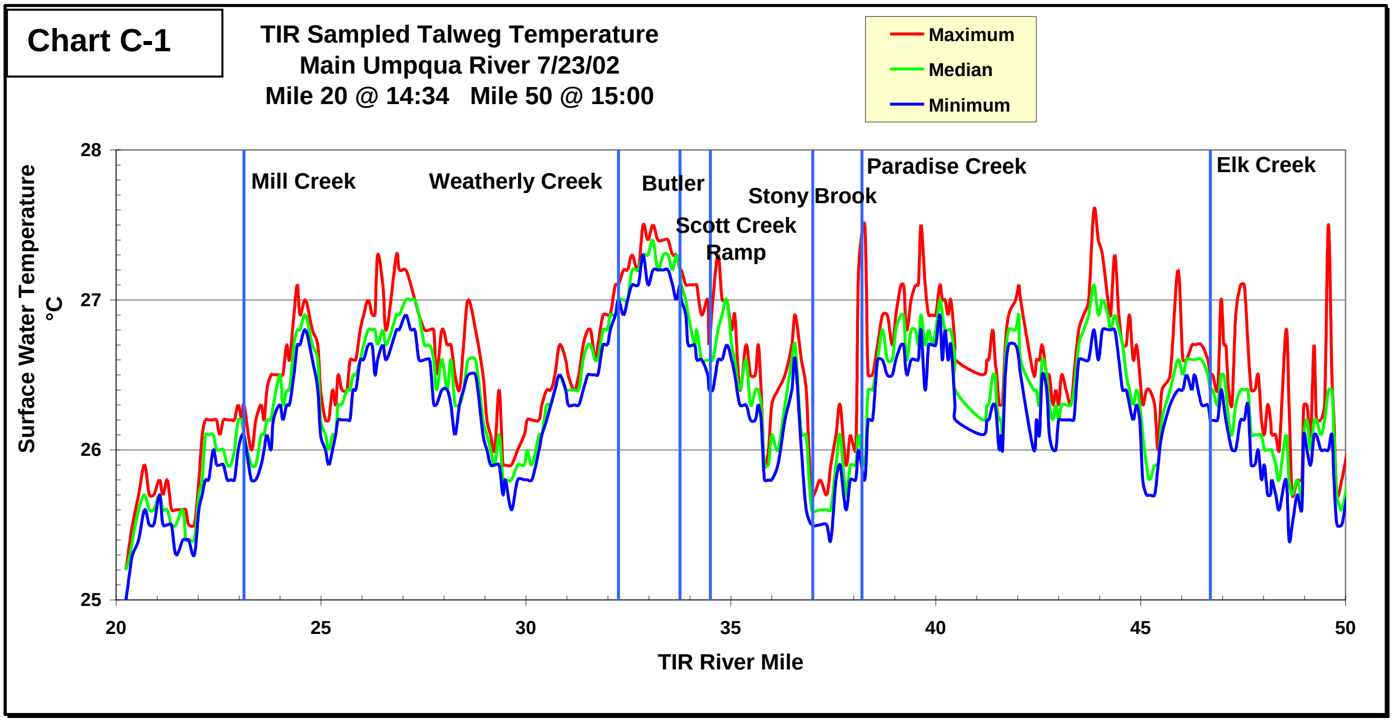
A primary objective of the 2008 Lower Umpqua Study was to sample the river temperature between Scottsburg and Elkton to identify potential thermal refugia. Emphasis was on sampling the variable temperature regions identified in the 2002 TIR median temperature profile.

Appendix B contains specific field data and Appendix A contains background information. Map C-1 shows the location of most of the sampled sites.

Map C-1 2008 Sample Sites



Groundwater Influence?



Based on the profile in Chart C-1 it appears that something significant may be affecting the bulk river surface temperature in the thalweg region. The Watershed Sciences report noted this variability and indicated that it was a valid representation of the longitudinal temperature distribution but could not provide an explanation for it. Since tributary inflow contribution does not appear to provide an explanation, another possibility is ground water contribution. Previous field work has shown that groundwater in the lower elevation regions of Umpqua Basin is approximately 54°F which is also the mean annual temperature of the area (See Appendix A / Groundwater). Upwelling groundwater could deliver cold water to the river bottom interface river much like lava tubes deliver molten lava up to floor of the ocean where it is rapidly cooled.

For example, on Chart C-1 in the Weatherly Ck region between RM 29.7 and RM 33.5 there is a 1.6 °C (2.9 °F) drop in surface temperature. The rate of decrease is fairly constant over the interval suggesting that, if inflow is responsible, it is not present at the end points but is distributed uniformly between the end points.

A simple mixing formula was used to estimate the quantity of groundwater inflow would be needed to cause the observed effect:

$$T1Q1+T2Q2=T3(Q1+Q2)$$

Where:

T1	Initial river temperature	27.4 °C
T2	Groundwater temperature	12.2 °C
T3	Temperature after mixing	25.8 °C
Q1	Nominal river flow (CFS)	1050 CFS
Q2	Required Groundwater inflow	

Solving for Q2 yields a groundwater inflow of 124 CFS which represents a flow contribution of over 10% or a longitudinal contribution of 32.4 cfs /mile.

Since the temperature gradient at the river bottom interface would be very steep, the cooling effect would probably not reach the surface where it would be detected by the TIR instruments See Appendix A / Radiation Basics. However, water upwelling at the rate calculated should be detectable by a temperature probe immediately at the water-river bed interface.

To test for this inflow, a direct measurement approached was used to sample the temperature of the river bottom to try to detect any emergent cold water. Note: This result could probably be tested by careful discharge measurements to determine the amount of flow gained in this reach. However, resources were not available to make the necessary measurements and a positive result would not help locate the source.

Observed Phase Shifts in the Diurnal Temperature Pattern

Review of the time-series data indicated that phase differences in the sinusoidal diurnal pattern. Based on a very limited amount of data it appeared that the data from the small streams and the edge of the river tended to be synchronized with the local environment while data from the thalweg region of the river may exhibit a delayed response. Based on only two sample points it appeared that the amount of phase lag in the thalweg was not constant which implies that the river does not reach its daily maximum and minimum values simultaneously at all points on the river. Consequently, a synoptic view as provided by the Watershed Sciences TIR report would show variability associated with the phase shift pattern.

It is helpful to recall that, for a point on a land surface, the diurnal minimum typically occurs at the end of the night-time cooling period just before the morning sun restarts the heating process. The maximum heating <u>rate</u> typically occurs during mid-day period of maximum solar exposure as denoted by the maximum slope of the heating curve and the maximum daily temperature value typically occurs in late afternoon before cooling starts when the net heat flux affecting the water goes negative.

As previously mentioned, good time-series data from the thalweg of large rivers are scarce. The following examples represent the extent of current knowledge of diurnal phase relationships on the Main Umpqua.

Scott Creek Ramp & Stony Brook 2008

Photo A-1 Scott Ck data logger deployment

Photo A-1 shows the data logger deployment near the Scott Ck Ramp (Site P-12). This unit and the Stony Brook (P-11) river unit both have good exposure to the thalweg zone of the river and they provided the best information of the time-series response of the longitudinal thalweg profile.

The data logger at P-12 was deployed later in the season and consequently the data record in Chart A-2 is abbreviated. However, for the period of record, it is apparent that a consistent phase shift in data exists between the two sites. It is also worth noting that the response and amplitude of the two sites is similar suggesting a similar response to similar conditions as would be expected in the thalweg zone.

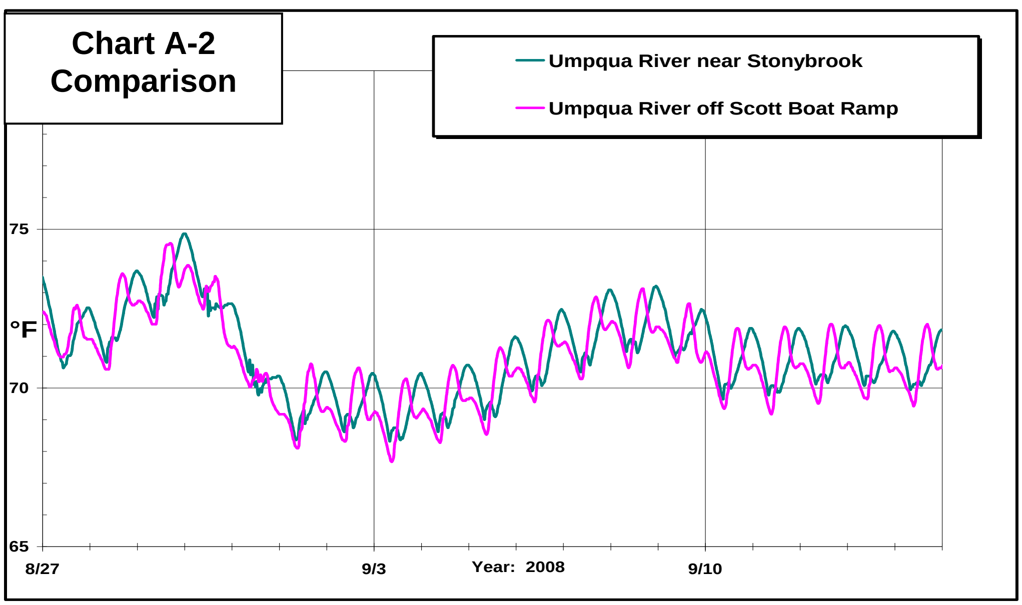


Chart C-3 shows detail for a representative day. The magenta line denotes the time at 3:00 PM, a typical time to sample the high daily temperatures. Note that on 9/13 the 3:00PM value for Scott Creek is noticeably closer to its daily maximum than that at Stony Brook.

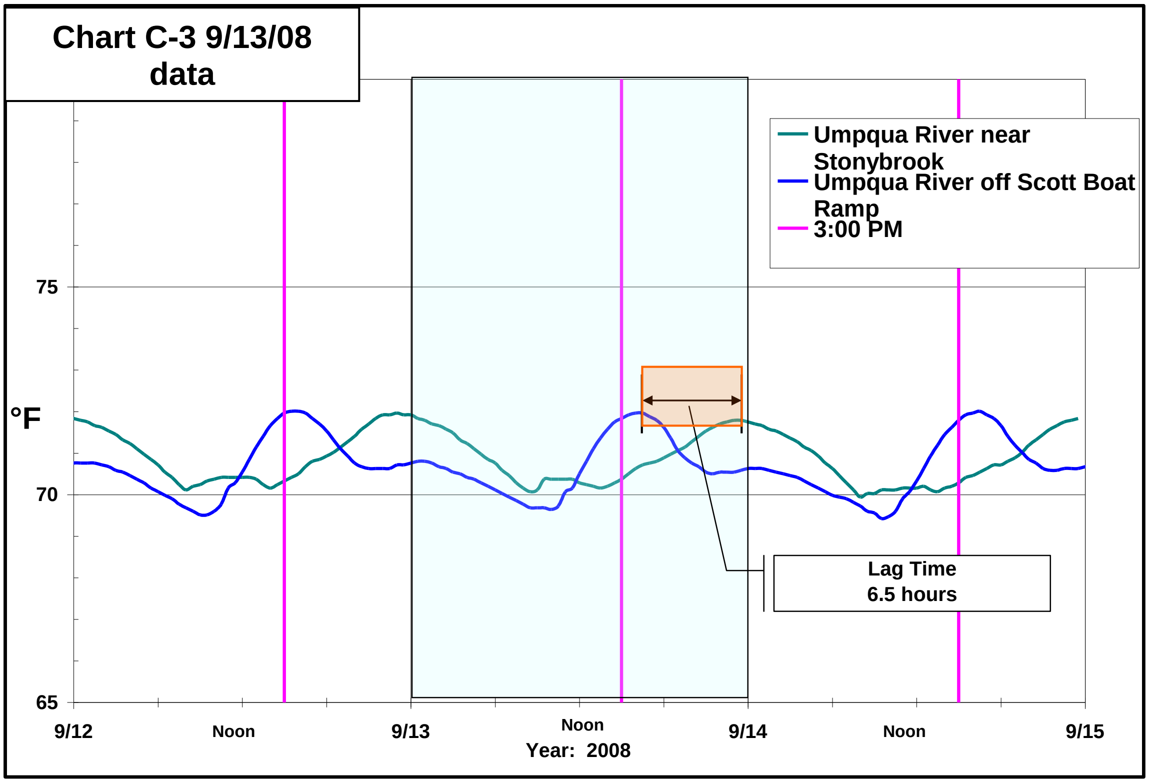


Table (9/13) shows that at 3:00 PM the Scott Ramp logger recorded 94% of its maximum value while the Stony Brook unit had reached only 17% of its maximum value.

9/13/2008	Ump @Scott Ramp	Ump @ Stony Brook
max	71.96	71.79
3:00:00 PM	71.83	70.37
min	69.73	70.07
ΔT °F	2.23	1.72
% ΔT	94.17%	17.44%
Dev from Max	0.13	1.42
Difference	0	-1.29

The corresponding temperature difference between the sites at this date and time is 1.29 °F. Examination of the 2002 TIR Median Temperature data in Chart C-1 shows the Stony Brook site about 1°C cooler which is close to the difference detected by the data loggers. [Note: On 7/23/02 TIR flight, Scott Ck was sampled at 2:46 PM and Stony Brook was sampled at 2:48 PM.]

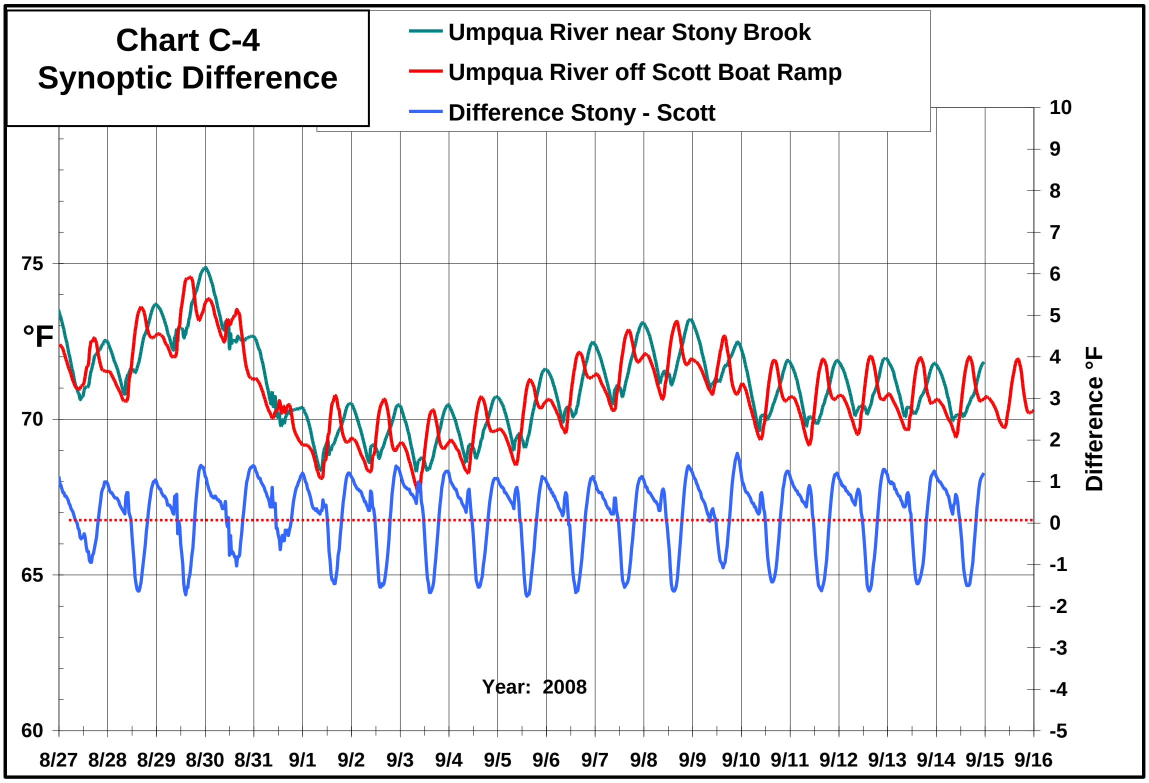
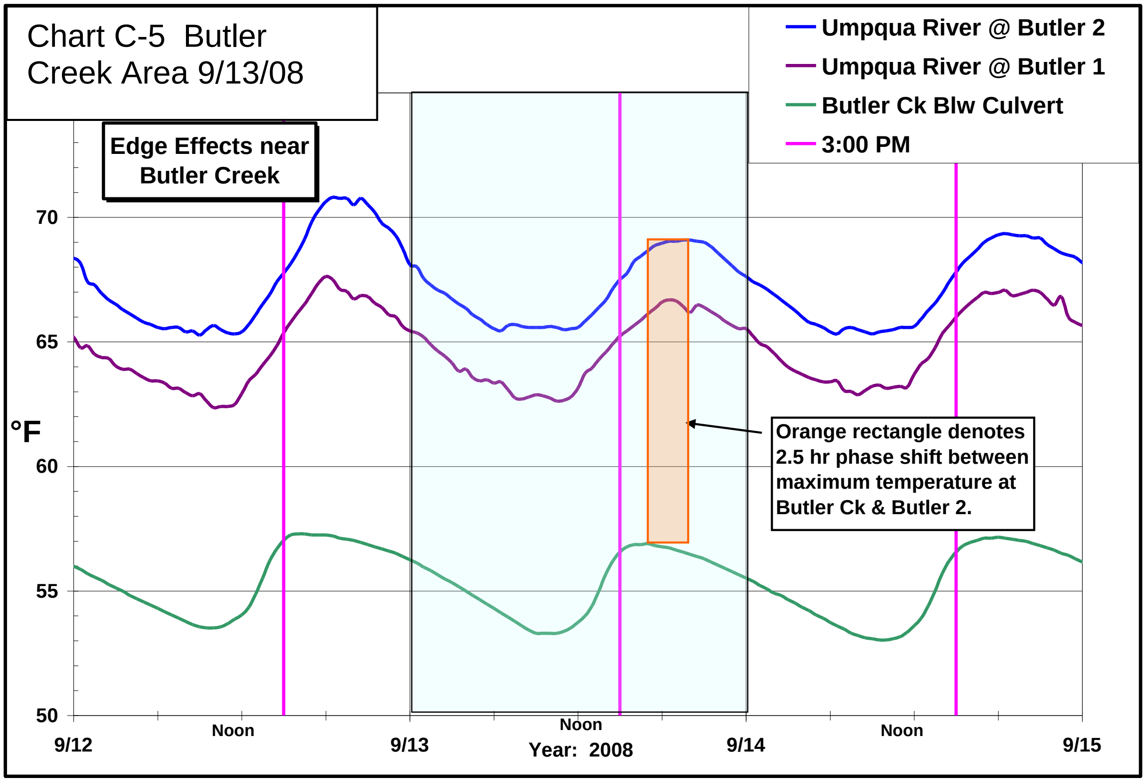


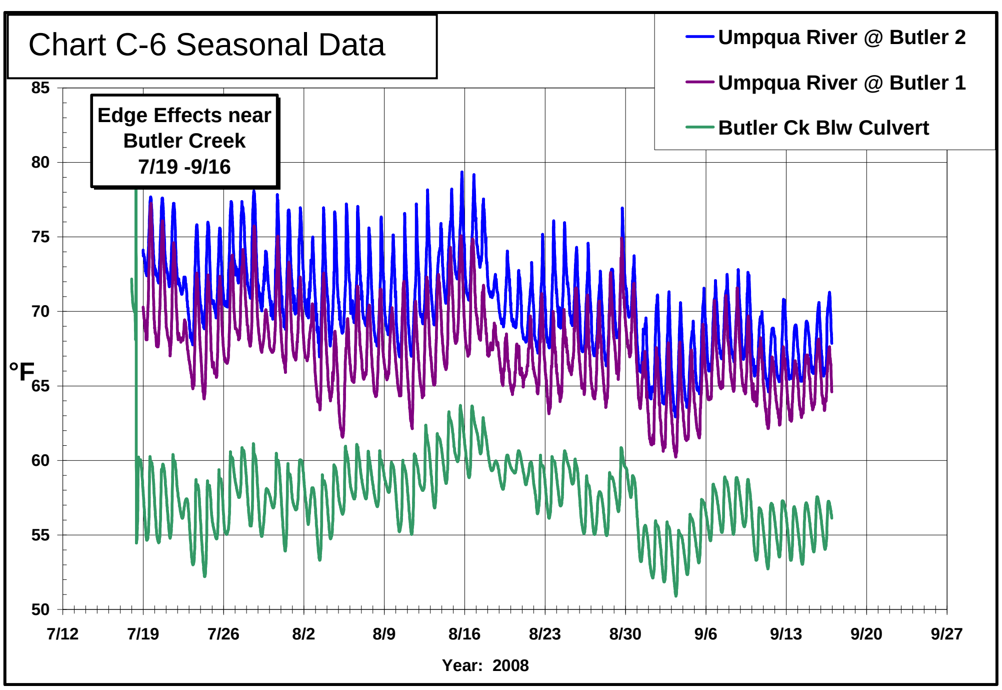
Chart C-4 indicates that the phase pattern remained constant for the limited period of record and the wave pattern appears to have a period of 24-hours. It appears that the wave moves about 2.8 miles in 6.5 hours giving it a phase velocity of 0.43 mph and an effective wavelength of about 10 miles. These results suggest that the assumption that the extreme values of the thalweg diurnal temperature pattern occur simultaneously at all points on the river is not valid and synoptic views of the profiles show differences between locations that are a function of the time-of-day and not an indication of localized heating or cooling.

Butler Creek 2008

Chart C-5 shows that the 9/13/08 the response for Butler Creek appears to be following the expected pattern for a small shaded stream with heating beginning at 10:30 AM and reaching the daily maximum at 5:00 PM but the response of the data loggers in the river is different. For “Butler 2” the 9/13/08 warming segment appears to be starting at about 12:00 and a maximum reached at 7:30 PM, 2.5 hours later than the Butler Creek data. Chart C-6 shows that the phase shift persists over the two month sample period.



The higher temperature for the two river units is consistent with the edge effects observed in the TIR data at other locations. The exact cause of the phase shift is beyond the scope of this analysis. Factors such as antecedent temperature, thermal mass, aspect, topography and riparian shading may be contributing factors.

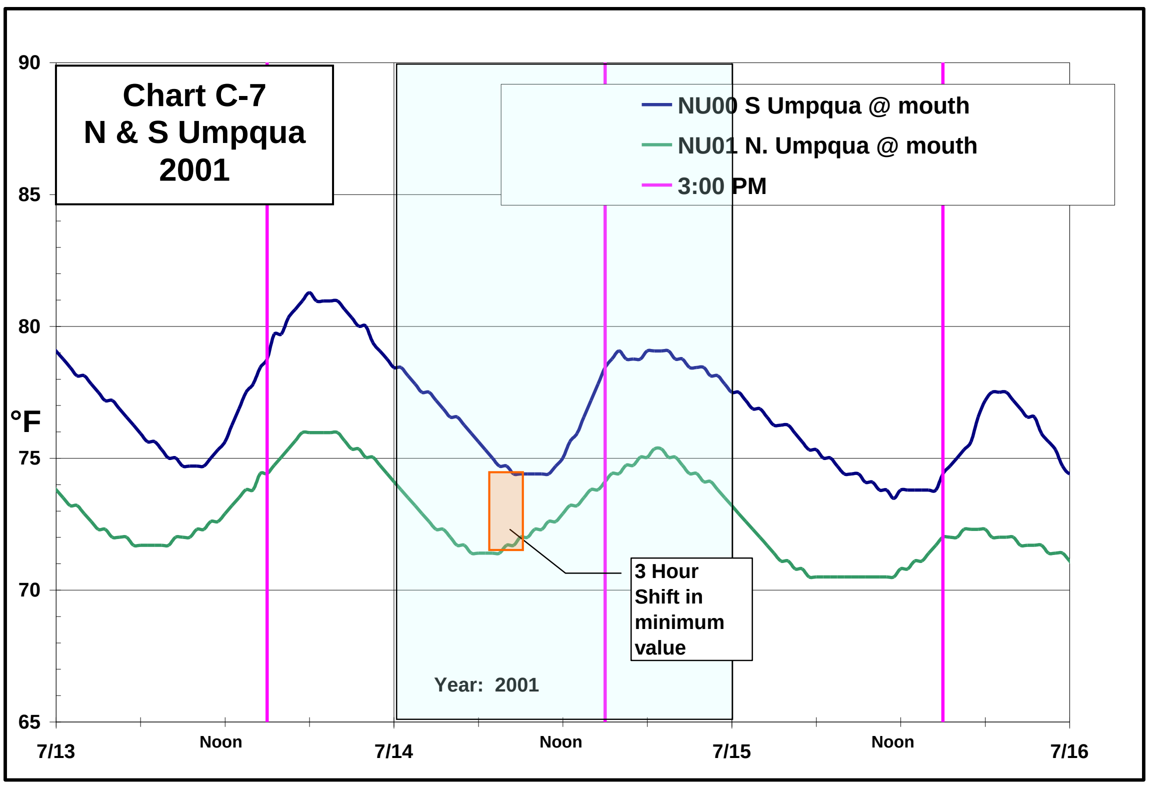


9/13/2008	Butler Creek	Ump @ Butler 1	Ump @ Butler 2
max	56.9	66.69	69.09
3:00:00 PM	56.56	65.23	67.5
min	53.3	62.66	65.44
ΔT °F	3.6	4.03	3.65
% ΔT	90.56%	63.77%	56.44%
Dev from Max	0.34	1.46	1.59
Difference	0	-1.12	-1.25

The 9/13 chart indicates that the 3 PM values represent significantly different points on the respective diurnal curves. Note: Butler 1 and Butler 2 were in a backwater area associated with the confluence of Butler Creek. The data is consistent with the notion that small streams tend to be very responsive to local conditions while points nearer the thalweg tend to show a phase shift that may be maximum in the thalweg.

Confluence of S Umpqua and N Umpqua 7/14/2001 (Ref Chart C-7)

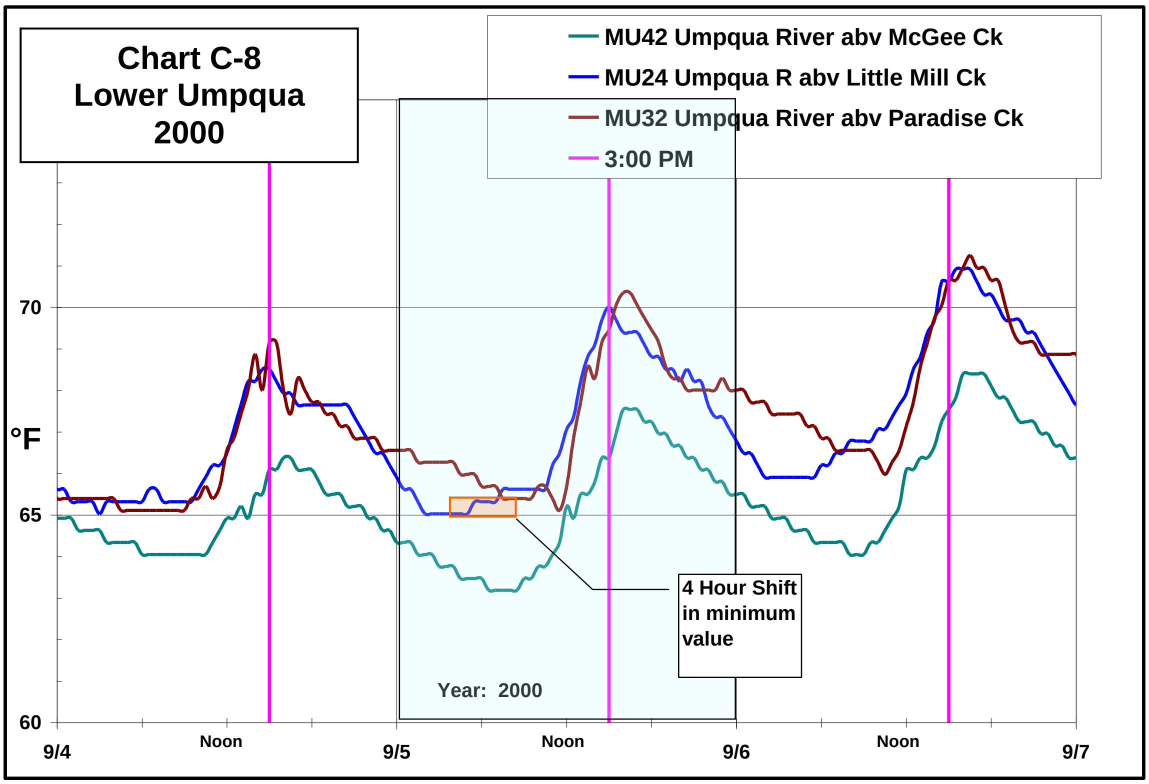
Both loggers were located on the edge of the river. The logger for the North Umpqua may have had better circulation and is more representative of thalweg conditions. Note larger shift in the minimum than the maximum value.



7/14/2001	N Ump	S ump
max	75.35	79.07
3:00:00 PM	74.11	78.44
min	71.4	74
ΔT °F	3.95	5.07
% ΔT	68.61%	87.57%
Dev from Max	1.24	0.63
Difference	0.61 °F	

Lower Umpqua Sampling at edge of river 9/5/2000 data

All of the loggers were located on the edge of the river. The McGee site may have had the best circulation.



9/5/2000	Ump abv Mill Ck	Ump abv Paradise	Ump abv McGee
max	70.01	70.35	67.54
3:00:00 PM	70.01	69.46	66.38
min	65.03	65.11	63.19
ΔT °F	4.98	5.24	4.35
% ΔT	100.00%	83.02%	73.33%
Dev from Max	0	0.89	1.16
Difference	0	-0.89	-1.16

17 & 18 08 work

Objective: Conduct a coarse sample survey to identify any potential areas with cold-water upwelling.

Methodology:

A drift boat was used to transverse the river through the project region. The project was divided into a two-day period because a portion of the river was not safely navigable (Sawyer Rapids). Since the measurements would not be taken in a synoptic manner, data loggers, set at a 5-minute interval, were deployed in the river at each end of the work area to record the diurnal response of the river. For general information, data loggers were also deployed at the mouths of several tributaries and a Sonde sampler was used to record other water quality parameters. Appendix B: Field Work contains the data for each site.

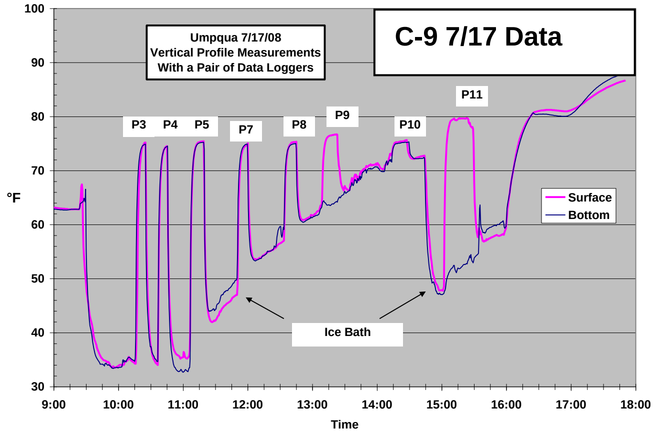
Two general approaches were taken to measure the river water temperature. A pair of Onset Tidbit data loggers was set at thirty second sampling interval to measure the surface and bottom temperature at selected locations. One logger was tied to a weight to measure the bottom and the other was tied to a float to record the surface temperature. Each measurement was taken over a period of about 8 minutes to allow the instrument to fully adjust to the prevailing condition. Upon extraction from the river the units were placed into an ice bath to provide a definite pulse on the thermograph. Concurrently, at some of the locations the bottom and surface temperature was recorded using the PUR NIST thermometer to provide confirmation of the data logger information. At each sample location the sample time was noted and GPS waypoints were established.

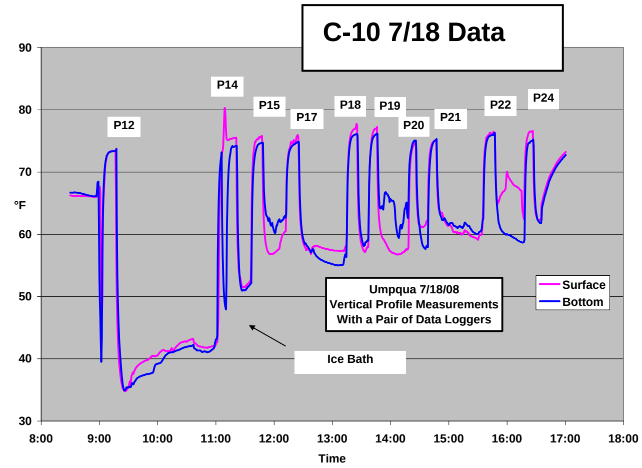
The objective of the redundant sampling was to help assure accurate data. The temperature response curve from the data loggers provided assurance that thermal equilibrium conditions had been reached.

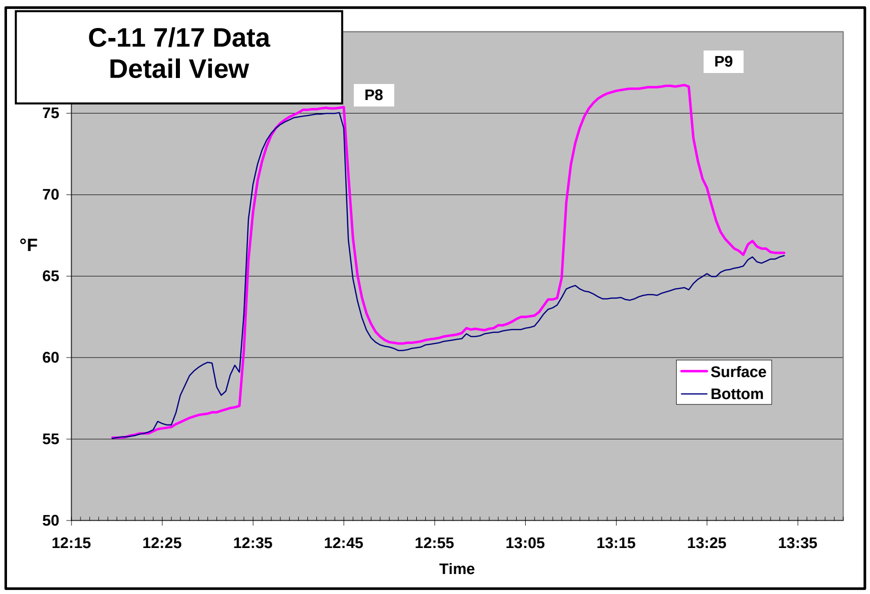
On 7/17/2008 Sites P-3, P-4, P-5 P-7 P-8, P-9, P-10 and P-11 were sampled. On 7/18/2008 Sites P-12, P-14, P-15 P-17 P-18, P-19, P-20 and P-21 P-22, P-23, P-24 and P-25 were sampled.

Charts C-9 & C-10 show the raw data of the data logger sampling. The maximum values represent the measured river temperature and the minimum values show the temperature of the iced water in the storage bucket. Nominally, the data loggers were immersed at least ten minutes during each sampling cycle. Chart C-11 shows a detailed view of a typical temperature response curve for the Tidbit data logger. Note that a “bottom” reading was not taken at site “F” due to shallow water.

Note: In areas with high current there was a tendency for the surface data logger unit to be exposed to the air interface resulting in a higher recorded temperature.

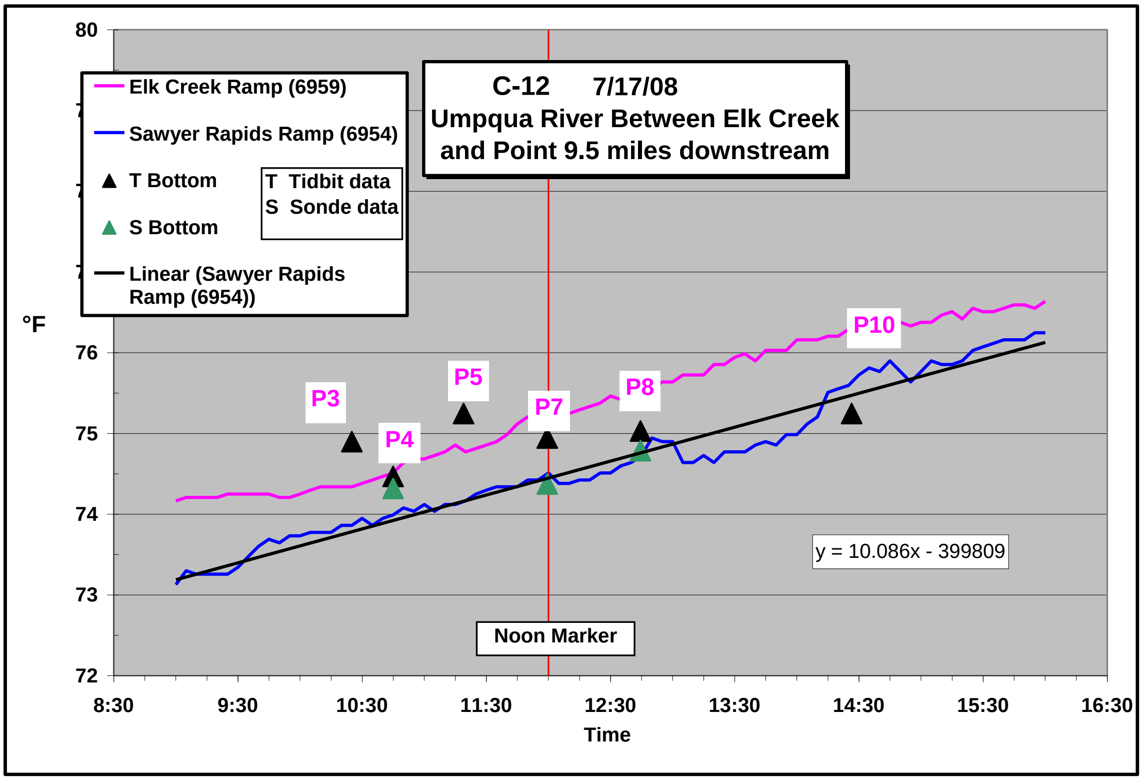




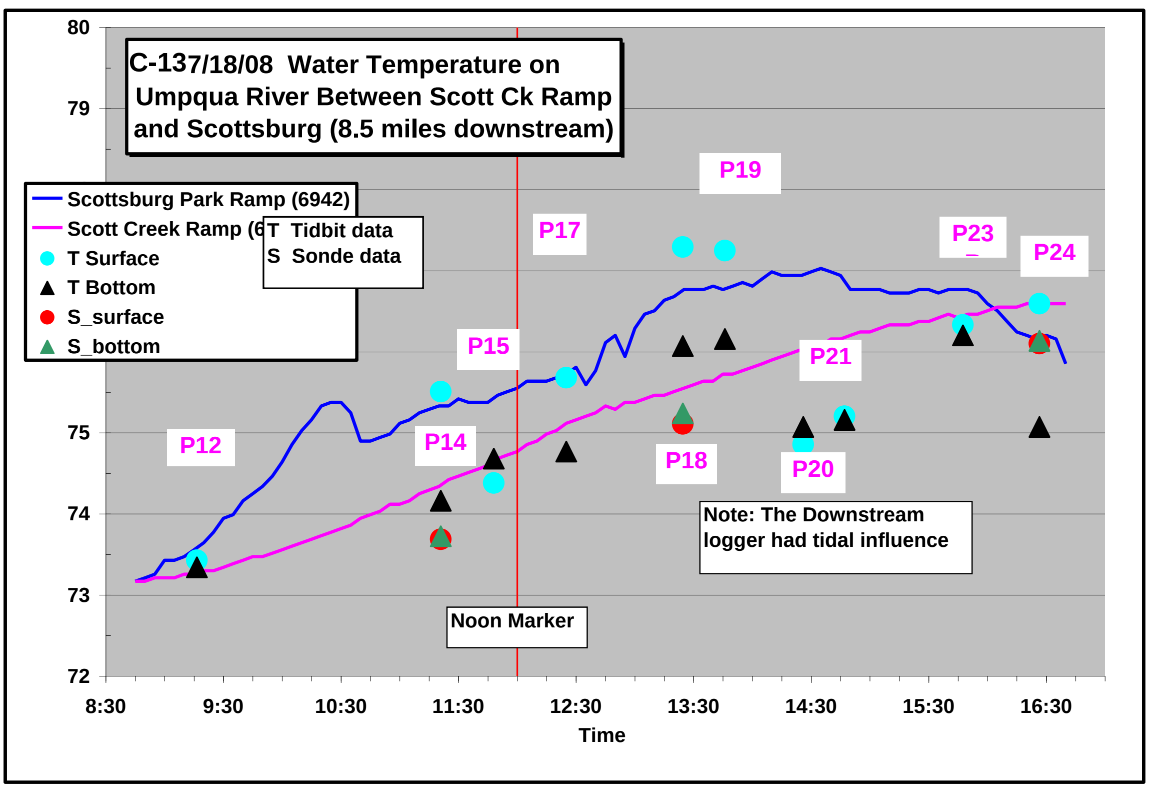


For the 7-17 work period the upstream 5-minute logger was deployed near the Elkton boat ramp and the downstream logger was deployed near the boat ramp located between sites P10 and P11.

Charts C-12 & C-13 show the processed data with the two river reference temperature curves.



C-12 7/17/08
Umpqua River Between Elk Creek and Point 9.5 miles downstream
Elk Creek Ramp (6959)
Sawyer Rapids Ramp (6954)
T Bottom
S Bottom
Linear (Sawyer Rapids Ramp (6954))
T Tidbit data
S Sonde data
°F
Time
Noon Marker
y = 10.086x - 399809
P3
P4
P5
P7
P8
P10



C-137/18/08 Water Temperature on Umpqua River Between Scott Ck Ramp and Scottsburg (8.5 miles downstream)
Scottsburg Park Ramp (6942)
T Surface
T Bottom
S_surface
S_bottom
T Tidbit data
S Sonde data
Time
Noon Marker
Note: The Downstream logger had tidal influence
P12
P14
P15
P17
P18
P19
P20
P21
P23
P24

It is apparent that there is more scatter in this data collection, in particular with the surface tidbit data. It is suspected that the floating device did not adequately submerge the sensing device in high current causing erroneously high temperature values. [Note: As an afterthought, mounting the surface unit on an insulated shaft that is fastened to the boat at a fixed depth (i.e. six inches) would have been a better arrangement. The unit would be synchronized with the bottom unit and data pairs could be matched to the peaks of the bottom data.]

For the 7-18 work period the upstream 5-minute logger was deployed near the Scott Ck boat ramp and the downstream logger was deployed near the Scottsburg boat ramp located at site P-25.

Data Normalization

The data from the reference river loggers in Charts C-12 & C-13 indicate that significant diurnal heating occurred during the sampling period which introduces a bias into the point-sample results. To correct for this effect, a data normalization procedure was used by calculating the heating rate for each day from the river reference data and then applying it systematically to sample results to approximate conditions at 12:00 noon on 7/17/008. The noon value was selected since it is typically near the daily mean, thereby having less error between “hot” and “cold” days.

7_17 heat rate	11.448 degF/day

Site	Initial Value	D from Noon	Adjusted to Noon
P-3	74.90	0.0660	75.65
P-4	74.47	0.0521	75.06
P-5	75.25	0.0285	75.57
P-7	74.94	0.0003	74.95
P-8	75.03	-0.0309	74.68
P-9			
P-10	75.25	-0.1017	74.08
P-11	75.63	-0.1410	74.02

Chart 7_17 shows a sample calculation for the 7/17/ data. Since the noon temperature of the river on 7/18 was 0.35°F cooler, all of the 7/18 adjusted noon values were increased by that amount to conform to the 7/17 conditions.

Since some of the surface data appears to be questionable and the main objective of this trial was to measure the temperature at the bottom of the river, selected bottom values were plotted longitudinally along with the 2002 TIR thalweg sampled data as shown in Chart C-14.

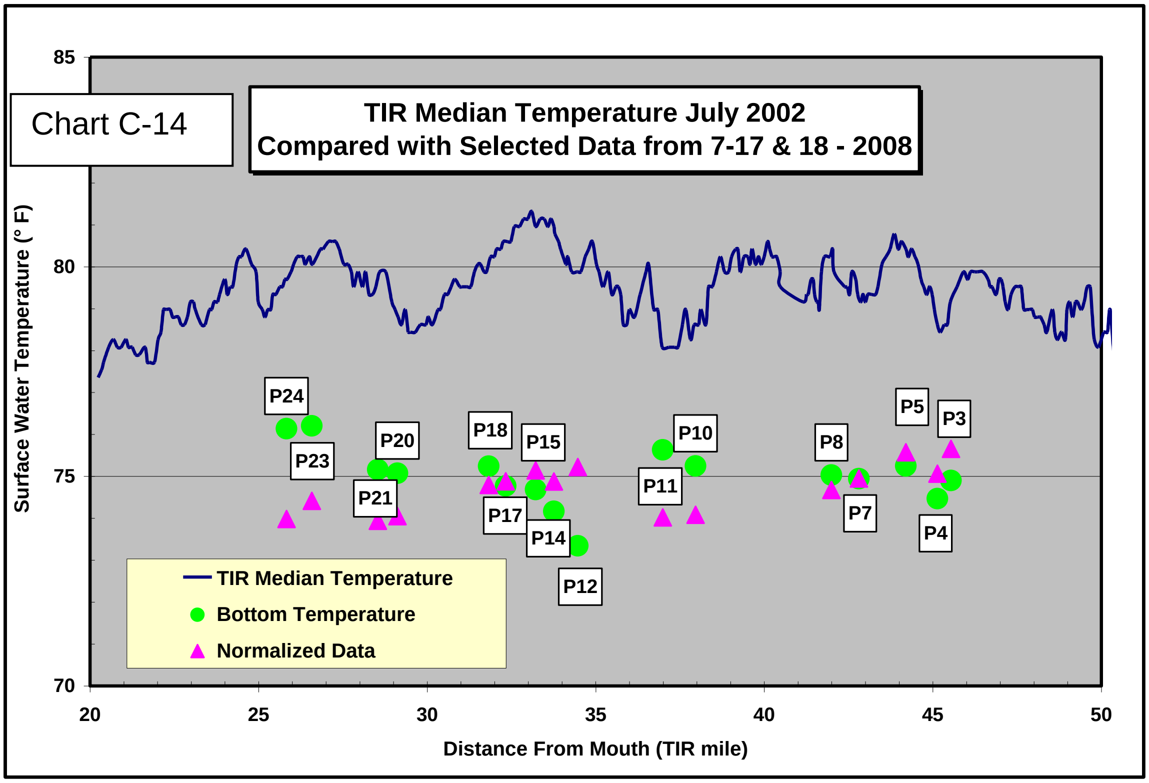


Chart C-14 compares the sampling results with the 2002 TIR profile. The temperature offset between the TIR data and the project results simply represents the relative seasonal condition and isn't significant. However, if the variability between sites is the result of physical conditions a similar pattern should be expected.

While there are some implicit assumptions (such as constant heat rate between sites) it is thought that the uncorrected data is seriously distorted due to diurnal heating and that the "normalized" data better describes the relative thermal condition of the sites.

Table: Range of variability within project zone.

Data °F	Minimum	Maximum	Difference
TIR	**78.1**	**81.3**	**3.2**
Selected Data	**73.3**	**76.2**	**2.9**
Normalized Selected Data	**73.9**	**75.2**	**1.3**

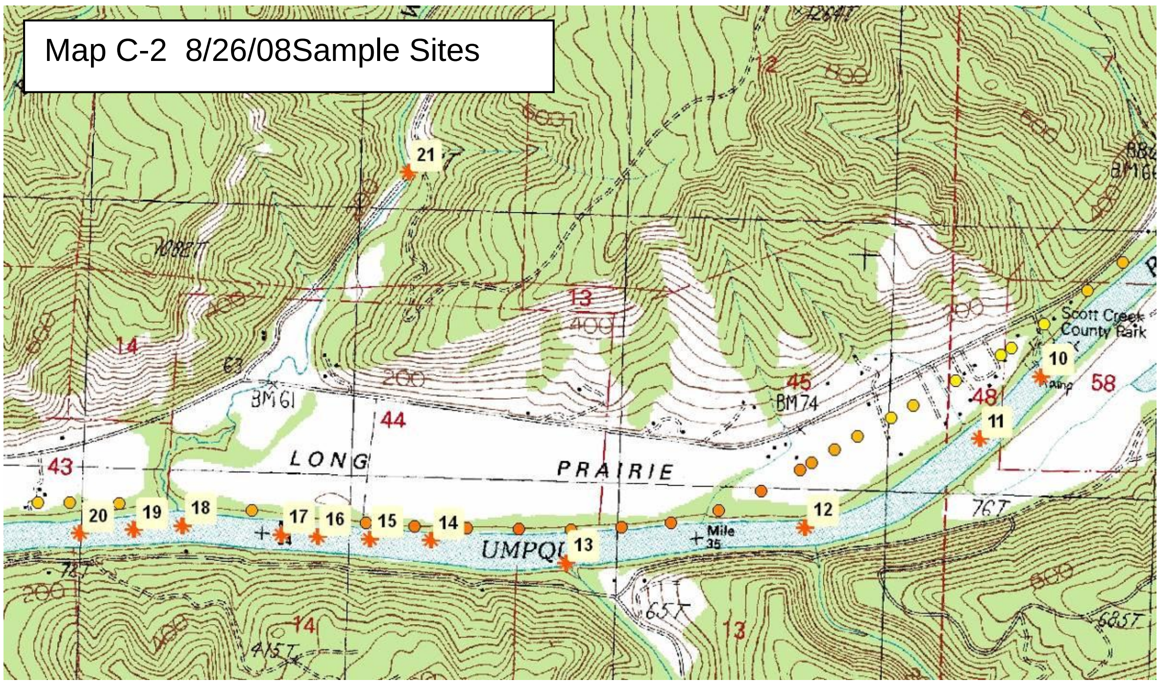
The variability in the 7/17 & 7/18 2008 data does not allow for a decisive comparison with the detailed pattern of the TIR data. However, it may be worth noting that the range of the extreme values in the normalized data is noticeably less suggesting a relatively homogenous temperature distribution.

In terms of the project objective, the most important observation is that none of the measured sites show any indication of upwelling water from the river bottom that would account for the observed TIR cooling / warming pattern.

8-26 Work.

On 8-26 the main focus was to sample the temperature of the river bottom more intensely with particular emphasis on the region adjacent to Weatherly Creek. It was noted that there appears to be a significant alluvial terrace in this area that may be intercepting flow from Weatherly Creek and reintroducing it directly into the river bottom as groundwater inflow.

On 8/26/08 a longitudinal profile was sampled as shown on Map C-2. Some of the sample points for the 8/26 work correspond with Map C-1 as shown in the Cross Reference Table.



Sample Point Cross Reference	
Map C-2	Map C-1
10	P-12
11	P-13
12	P-14
13	P-15
21	R-1

Chart C-15 shows the time series plot of the sample data along with diurnal data from a data logger at the Scott Ck Boat Ramp. The chart also shows the result of the normalization procedure that was used also for the 7/17&7/18 samples.

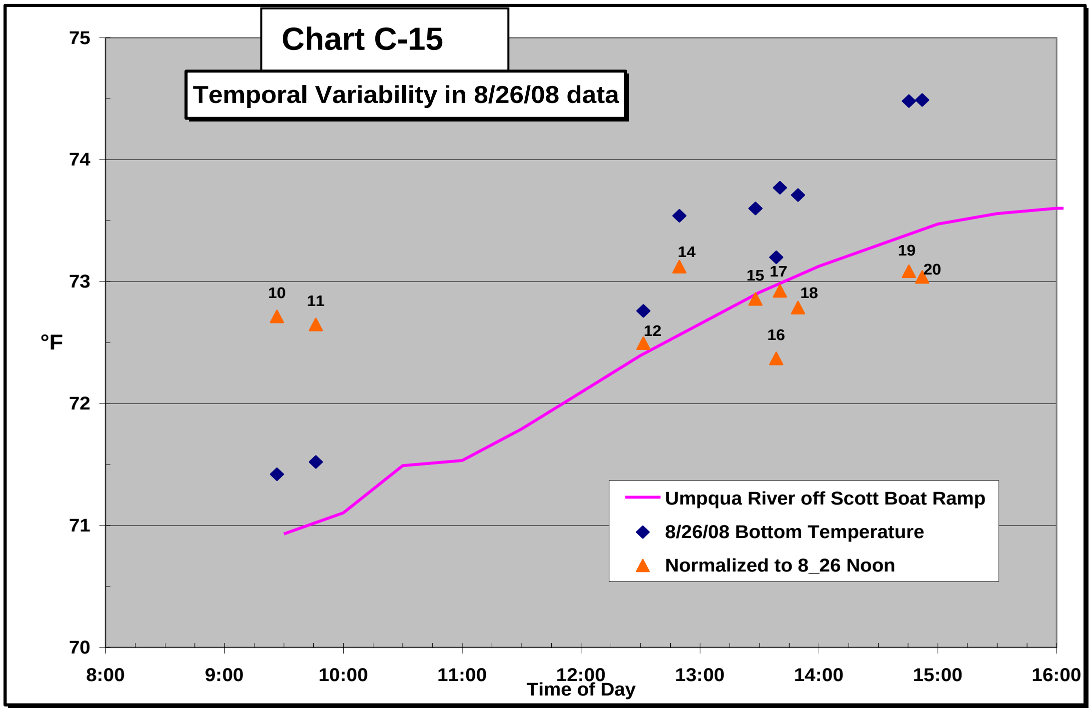


Chart C-16 shows the data plotted against the river distance.
The results of this work are similar to those of 7/17 & 7/18. The normalized data pattern is not distinctly different from the TIR data and no indication of coldwater upwelling was observed. If coldwater upwelling was the cause of the observed TIR variability, a relatively large inflow would be expected to be found in the study area. That no cold-water upwelling was detected suggests that coldwater inflow may not be the cause of the variability in the TIR data profile within this project area.