Partnership for the Umpqua Rivers

Your Watershed Council

Appendix A: Background Information

Supplemental Information For

Report

Water Temperature Variability on the Lower Umpqua River

December, 2010

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Conversion Tables

Conversion Tables

°C	°F
10.0	50.0
10.5	50.9
11.0	51.8
11.5	52.7
12.0	53.6
12.5	54.5
13.0	55.4
13.5	56.3
14.0	57.2
14.5	58.1
15.0	59.0
15.5	59.9
16.0	60.8
16.5	61.7
17.0	62.6
17.5	63.5
18.0	64.4
18.5	65.3
19.0	66.2
19.5	67.1
20.0	68.0
20.5	68.9
21.0	69.8
21.5	70.7
22.0	71.6
22.5	72.5
23.0	73.4
23.5	74.3
24.0	75.2
24.5	76.1
25.0	77.0
25.5	77.9
26.0	78.8
26.5	79.7
27.0	80.6
27.5	81.5
28.0	82.4
28.5	83.3
29.0	84.2
29.5	85.1
30.0	86.0

°F = (1.8 x °C) +32

°F	°C
50	10.0
51	10.6
52	11.1
53	11.7
54	12.2
55	12.8
56	13.3
57	13.9
58	14.4
59	15.0
60	15.6
61	16.1
62	16.7
63	17.2
64	17.8
65	18.3
66	18.9
67	19.4
68	20.0
69	20.6
70	21.1
71	21.7
72	22.2
73	22.8
74	23.3
75	23.9
76	24.4
77	25.0
78	25.6
79	26.1
80	26.7
81	27.2
82	27.8
83	28.3
84	28.9
85	29.4
86	30.0
87	30.6
88	31.1
89	31.7
90	32.2

°C = (°F-32) / 1.8

Miles	Kilometers
1	1.61
2	3.22
3	4.83
4	6.44
5	8.05
6	9.66
7	11.27
8	12.87
9	14.48

Miles	Kilometers
0.62	1
1.24	2
1.86	3
2.49	4
3.11	5
3.73	6
4.35	7
4.97	8
5.59	9

Acres	Hectares
1	0.40
2	0.81
3	1.21
4	1.62
5	2.02
6	2.43
7	2.83
8	3.24
9	3.64

Acres	Hectares
2.47	1
4.94	2
7.41	3
9.88	4
12.36	5
14.83	6
17.30	7
19.77	8
22.24	9

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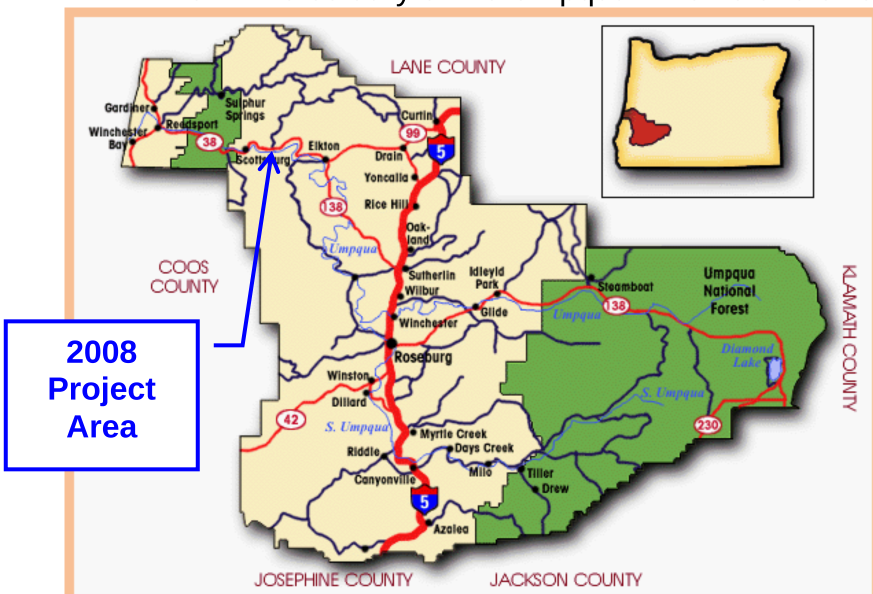
Geographic Setting

The greater Umpqua River Basin is located in Douglas County in southwestern Oregon and stretches from the Cascade Mountain crest to the Pacific Ocean at Reedsport, Oregon (See Map). The drainages of the North and South Umpqua Rivers together make up about 2/3 of the greater Basin drainage, and each river is about 105 mi long. The Lower Umpqua River flows in a northwesterly direction another 112 mi. to the ocean. Together, the three rivers form one of the longest coastal basins in Oregon with a drainage area of over 4,700 sq. mi.

The spawning sites for several important fish populations are in the North and South Umpqua Rivers and their tributaries, which combine to form the Lower Umpqua River northwest of Roseburg, Oregon. Major tributaries of the Lower Umpqua River include Calapooya, Elk, and Scholfield Creeks and the Smith River. The estuary of the Umpqua River is one of largest on the Oregon coast and has a tidal effect that extends upstream to Scottsburg, Oregon.



The Lower Umpqua is a low gradient system with an elevation gain of only 330 feet over 111 miles. Gage 14321000 at Elkton (RM 56.9) measures flow for 3683 sq miles of the watershed. For the 82 year record, average discharge is 7512 cfs with observed extremes of 265,000 cfs and 640 cfs. The summer drought period creates low flow conditions starting in April with minimum flows typically occurring in September (1,200 cfs). These conditions have produced a wide, low velocity, channel that is, for the most part, scoured to bedrock with minimal side channels and debris accumulations. As a result, maximum summer temperatures in the Lower Umpqua often exceed 80 °F with a minimum of identified thermal refugia sites.

Thermal Environment

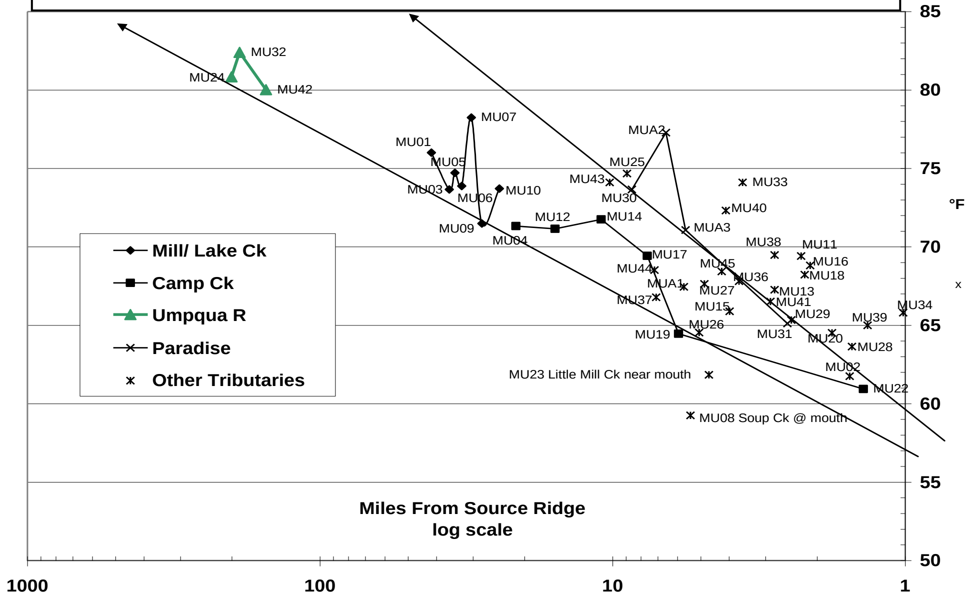
Previous Studies

The Umpqua Temperature Stream Temperature characterization Project (1998-2001) used one hundred data loggers over a period of four years to obtain synoptic summer season temperature data, for each of the major watersheds in the lower basin. In the summer of 2002, Oregon DEQ contracted with Watershed Sciences, LLC of Corvallis to conduct airborne thermal infrared (TIR) remote sensing surveys in the Umpqua Basin.

Thermal response of streams in a lower coastal basin.

Chart A1[1] shows the distribution of the maximum daily temperature values of several sites on August 8,2000 as a function of each site's distance from its respective source point. Note that the streams consistently become warmer at they become larger with the large river showing water temperatures in the 80°F

Chart A1 8/8/00 Maximum Temperature as a Function of Distance From Source



range. For the small streams the immediate temperatures seems to be influenced more by its local environment than by the contributing upstream flow. The pattern of increasing temperature is thought to be primarily the result of larger width-to-depth ratios channels and proportionally reduced local groundwater contribution. For small streams, the effect of the upstream contribution appears to be minor.

Variability of water temperature in the river

The diurnal solar input drives changes in the surface temperature [See Appendix A / Radiation Basics]. Various components such as air, soil and water have different thermal properties and consequently respond to the incoming flux at a different rate however, they tend to vary around a daily mean. Stream temperatures respond at different rates with the temperature of shallow water responding faster to a change in solar input than deep water. Likewise, aspect and topographic relief can affect the net amount of solar radiation received by the river. It is apparent that a wide range of data is needed to characterize the spatial and temporal variability of the river system.

Temperature measurement in large rivers is more difficult than measurement small streams due to the obvious difficulty of accessing all parts of the river body.

In a small stream it is usually an easy matter to test the variability of the cross-section and select an appropriate monitoring point. Typically, the relatively small water mass is thermally well mixed and responsive to local thermal processes.

Temperature data loggers are a useful tool since they typically provide time-series data at 30 minute intervals for the summer season. However, in the larger rivers, placement of data loggers becomes problematic. Units placed along the edge of the river are subject to theft or vandalism or exposure to the air interface as the river recedes during the summer season. Data logger placement in the main portion of the river presents problems with access and retrieval. Consequently, comprehensive time-series river temperature data is usually limited to the relatively few sites along the banks that provide suitable access to deep water. As a result, the time-series data from the large rivers is biased to edge effects with limited data from the thalweg region of the river.

The 2002 TIR Aerial Survey by Watershed Sciences provides a wealth of information about the surface temperature of the river at a particular moment in time[2]. The associated GRID files enable detailed temperature determination at the square meter level. While the spatial information is extensive, the data is essentially limited to one point in time.

Grab samples can be taken by wading and from a boat. By carefully recording location and time of measurement, a hint of the thermal characteristics can be achieved. However, the data variability in the river is great and careful consideration of location and time differences must be made when evaluating grab-sample data.

The TIR data and other studies show that the temperature variability in the rivers is particularly high along the edges with more consistent temperature along the central thalweg region. Shallow water and protruding rocks typically produce warmer zones along the edge while cold-water contributions can produce typically small cool zone.

Representative 2007 Seasonal Temperature Pattern

{Data provided by Hydrologist Denise Dannman.}

Chart A2 Typical 2008 Seasonal Pattern for Air and Water

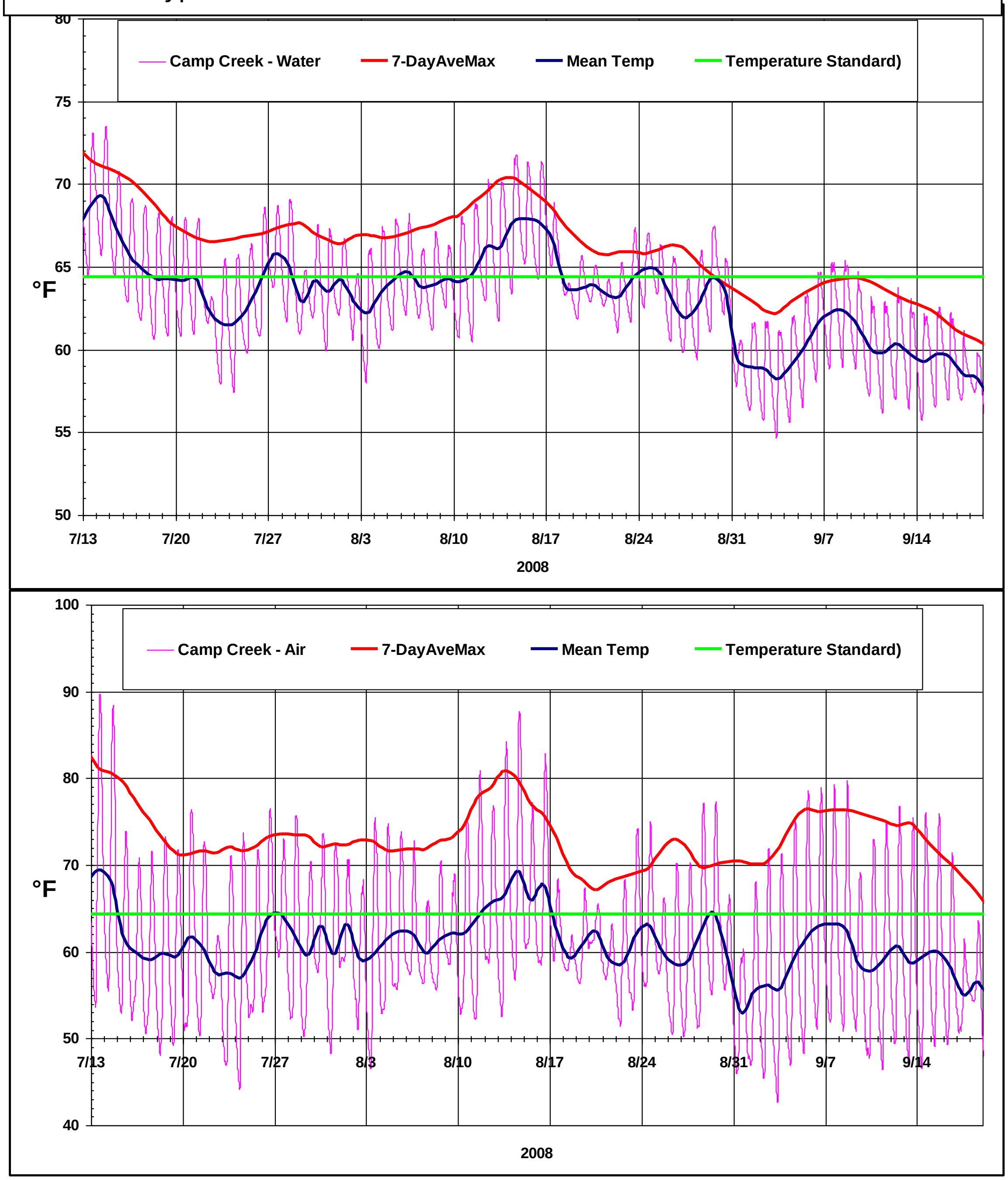


Chart A2 shows typical seasonal pattern for streams in the Umpqua Basin. This site is at the mouth of Camp Creek in the Mill Creek drainage (Project site R2). Note that the mean values for both charts are very similar indicating a similar response for the local thermal environment.

TIR Data

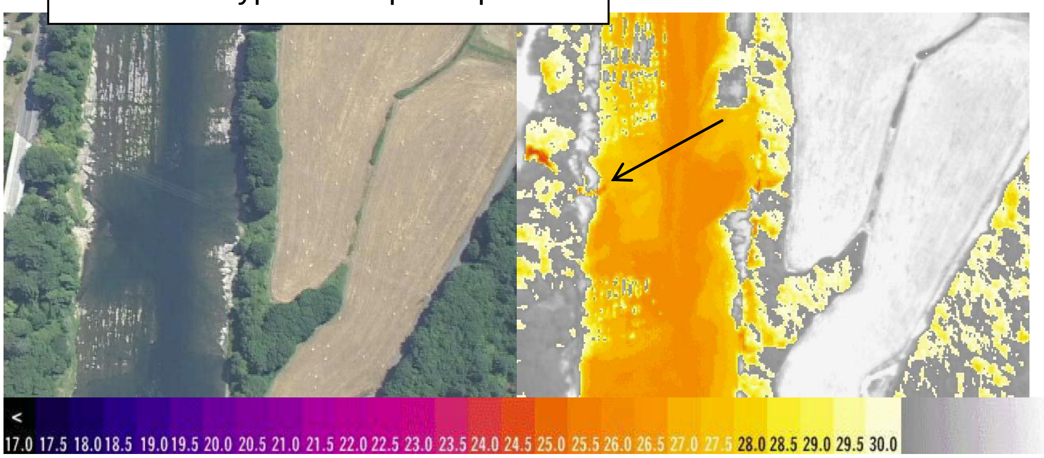
A full report of the 2002 TIR flight is available at:

Aerial Surveys in the Umpqua River Basin May 2, 2003

http://www.deq.state.or.us/wq/tmdls/docs/umpquabasin/tir/umpqua.pdf

In the summer of 2002, Oregon DEQ contracted with Watershed Sciences, LLC of Corvallis to conduct airborne thermal infrared (TIR) remote sensing surveys in the Umpqua Basin. An extensive set of images with an area of approximately 1200 by 1400 feet were taken along the river route at approximately 700 foot intervals. A software application was provided to conveniently view these images along with the locations superimposed on a color orthophoto of the project area using ESRI GIS version 3.2. Photo A1 shows a typical photo set from the Watershed Sciences data file. [Note the small thermal influence of Paradise Creek as indicated by the arrow.]

Photo A1 Typical TIR photo pair

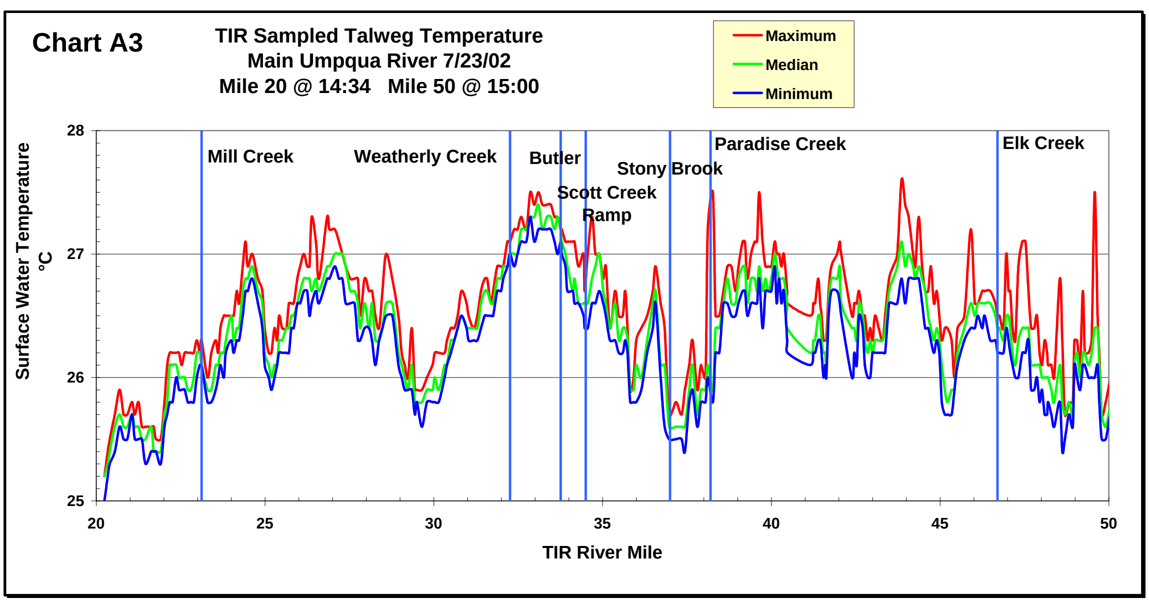


In general, the TIR data confirmed that the water surface temperature of the river edges were typically warmer and more variable while the surface water temperature of the central thalweg was fairly uniform and cooler. Exceptions occurred at the mouth of some of the tributaries that showed a small cool zone associated with the inflow from the tributary (See sample photos on following pages).

In addition to supplying image pairs for over 17,000 sites, Watershed Sciences also specifically sampled the thalweg portion of the channel for selected sites as shown in Photo A2 that was excerpted from the Watershed Sciences document. The radiant temperature (pixel value) was queried from each “X” point and the maximum, median, and minimum value was generated for each sample.

Photo A2 – TIR/color video image pair showing how temperatures are sampled from the TIR images. The black X’s on the TIR image show typical sampling locations near the center of the stream channel.

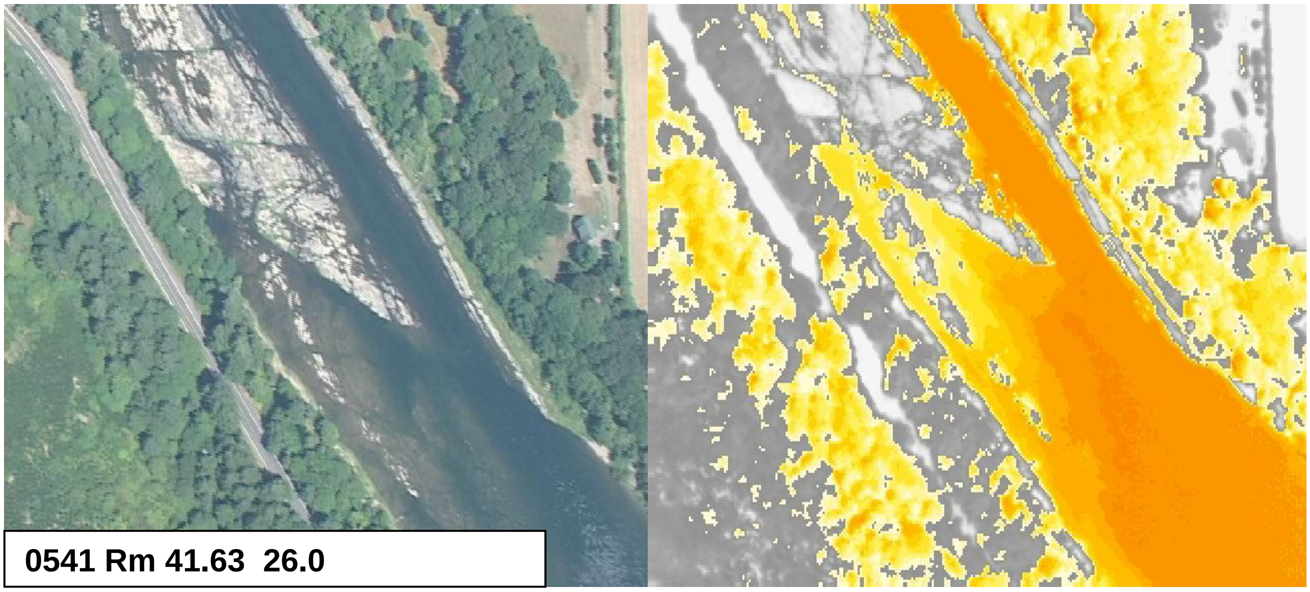
Chart A3 shows the maximum, minimum, and median sampled values for the project area. Of particular interest was the approximately 1.5 °C (2.7 °F) temperature drop observed between RM 30 and RM 335. The discussion in the Watershed Sciences report indicated that this type of fluctuation was real and not a result of instrument noise or calibration drift. However, it went on to indicate that there was no obvious explanation for the pattern (See Watershed Sciences report page 10).

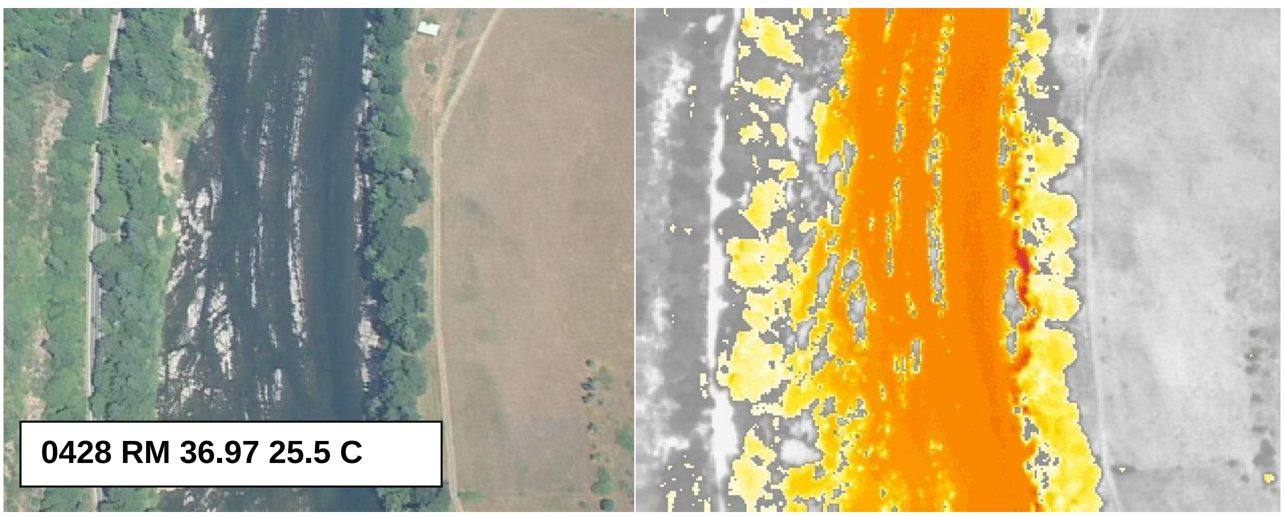


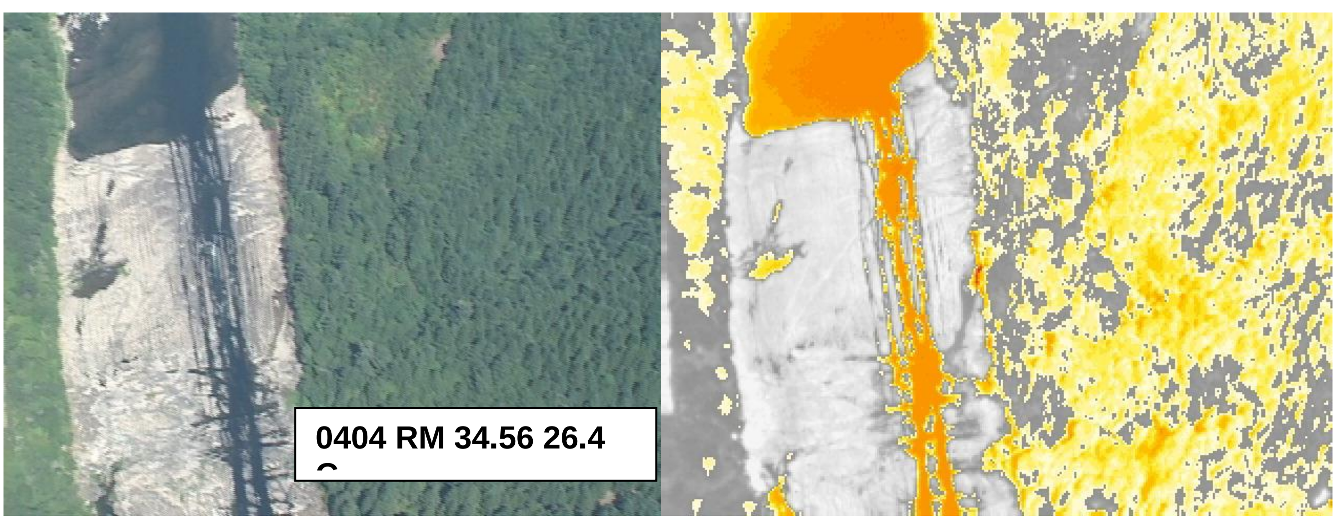
Note that the flight time through the project area was less than 26 minutes and adjustments for diurnal heating were not made in this case since typical thalweg heating rates are about 0.3°C/hr. Also, note that the River Miles indicated in Chart A3 is based on the TIR flight data and is offset somewhat from the River Miles that appear on the USGS quad maps.

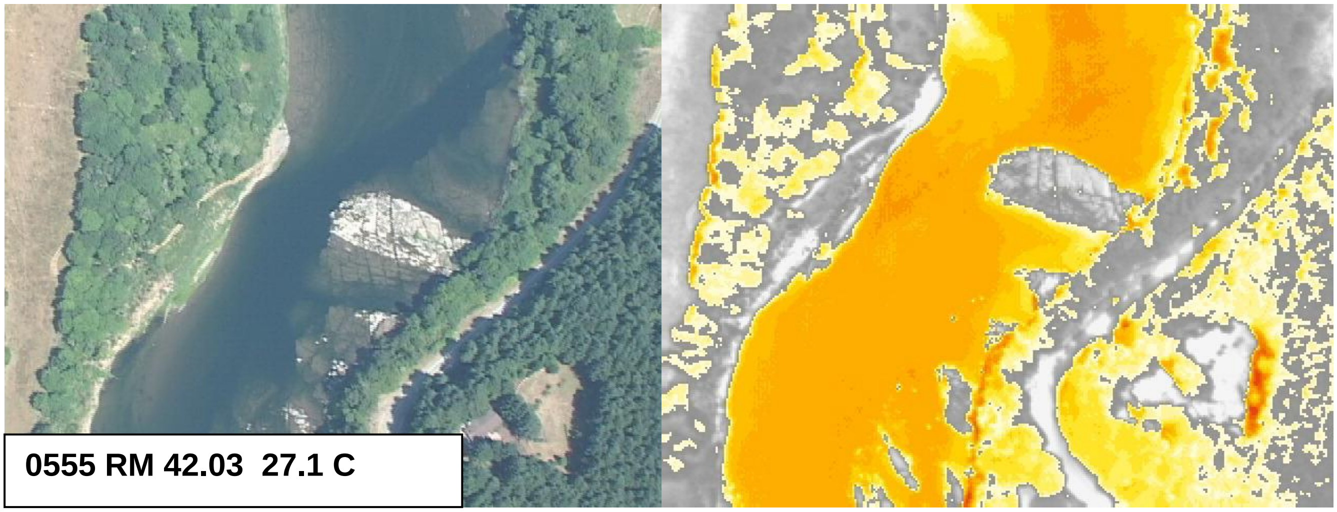
Another product of the TIR project was the associated Grid Files that enabled the extraction of the observed temperature value at the pixel level and a direct comparison with the 2008 data.

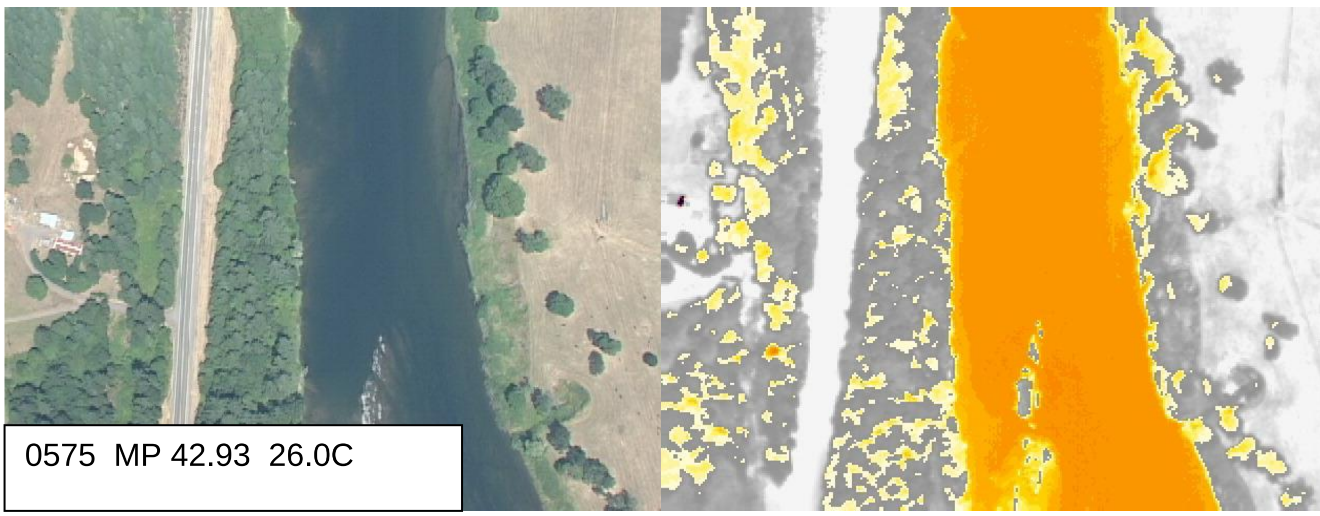
The following photos are examples of the TIR data from the project area.


0541 Rm 41.63 26.0

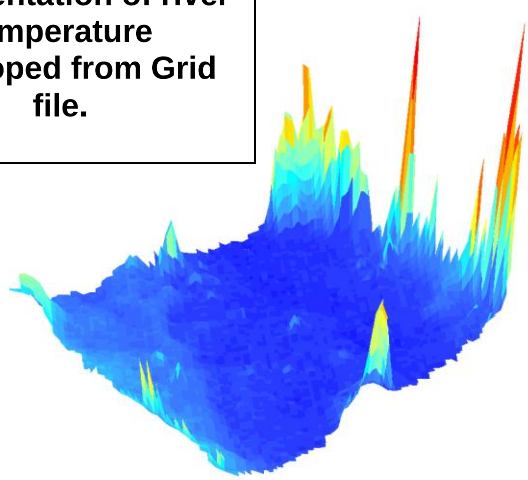

0428 RM 36.97 25.5 C


0404 RM 34.56 26.4





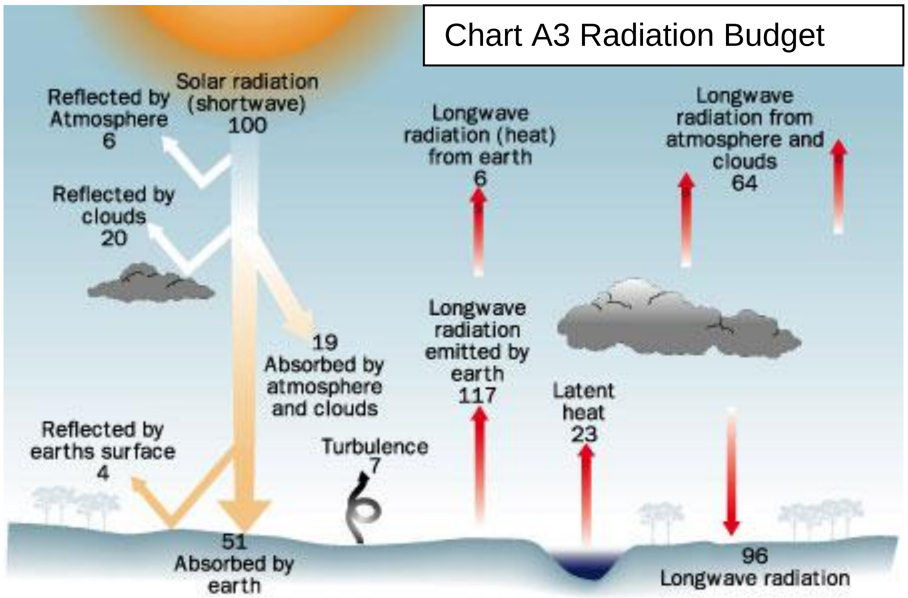
3-Dimensional representation of river temperature developed from Grid file.



Radiant Heating Basics

Essentially all of the energy originates from the sun and about 50% of the solar energy that reaches the atmosphere is absorbed by the earth. Because of the greenhouse effect, another 96% of the initial amount reaches the earth as longwave radiation. The solar energy is distributed during the daylight hours while the longwave radiation is distributed over the 24-hour period. The observed ambient temperature represents the net energy from these two sources. [See Chart A2 in the Thermal Environment section.]

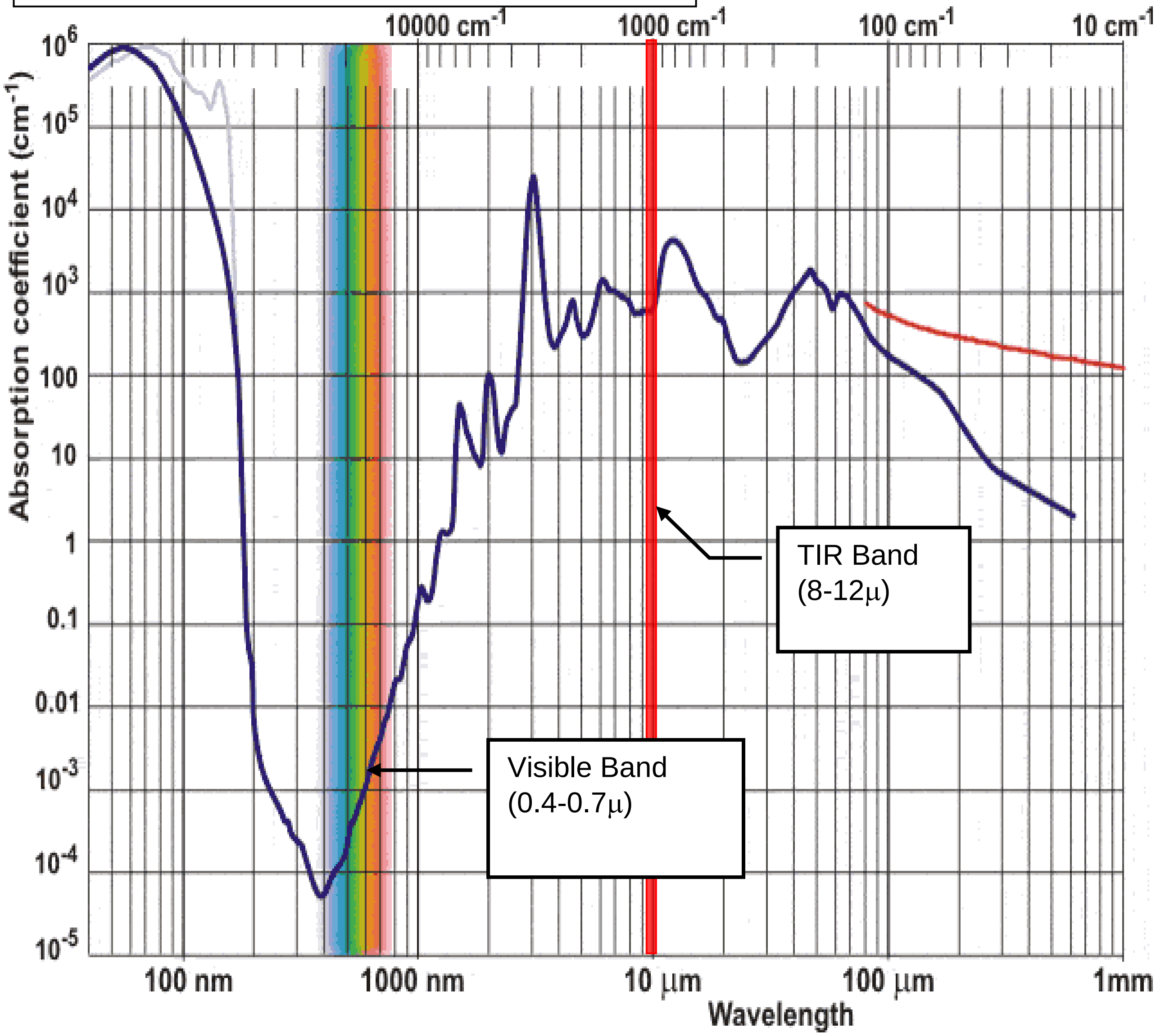
Chart A3 Radiation Budget



The thermal absorption capability of water varies greatly with wavelength as shown in Chart A4. Note that the absorption coefficient varies by a factor of about 1,000,000 between the visible band and the 10 micron infrared band. The implication is that water is nearly transparent to solar energy and, in shallow water most of the solar radiant energy passes through the water and is absorbed on the bed of the river or stream where part of it is converted to heat. Conversely, longwave energy from the atmosphere and the local environment is mostly absorbed be the surface of the water. In flowing water there is active mixing and the resultant water temperature is typically fairly uniform with depth.

Another implication is that a coldwater source on the bottom of a river would not be detectable by TIR if the cold water was not reaching the surface. The sampling strategy for this project was directed toward the detection of these coldwater sources.

Chart A4 **Absorption coefficients for water**



Source of chart http://www.lsbu.ac.uk/water/vibrat.html

Fish Utilization

Umpqua TMDL Data[3]

The Umpqua Basin is a key anadromous fishery in Oregon and it follows that the 111 miles of the Lower Umpqua are an integral part of the migration route for these fish. Table1 shows that several key species have migration periods that coincide with the low flow period on the Lower Umpqua. It is amazing that these fish are able to survive under these severe conditions.

Table A1 Umpqua Fish Use from Umpqua TMDL

Key species of interest to this TMDL include the Steelhead Trout *(Onchorhyncus mykiss)*, the Chinook Salmon *(Oncorhynchus tshawytscha)*, Coho Salmon *(Onchorhyncus kisutch)* and the Coastal Cutthroat Trout *(Onchorhynchus clarki clarki)* Life stages periodicities for these key species are listed in Table 1.1.

It is important to note that the table below covers the entire Umpqua Basin, and fish use is different in the different subbasins.

Table 1.1 **Umpqua Basin Fish Use (Source: Oregon Department of Fish and Wildlife, 2005)**

Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Winter Steelhead	Adult migration	■	■	■	■	■							
	Adult Spawning	■	■	■	■	■	■						
	Adult Holding	■	■	■	■	■				■	■	■	■
	Eggs to Fry	■	■	■	■	■	■	■					
	Juvenile Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juvenile migration	■	■	■	■	■	■						
Summer Steelhead	Adult migration			■	■	■	■	■	■	■	■	■	
	Adult Spawning	■	■	■	■						■	■	■
	Adult Holding			■	■	■	■	■	■	■	■		
	Eggs to Fry	■	■	■							■	■	■
	Juvenile Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juvenile migration	■	■	■	■	■	■	■					
Fall Chinook Salmon	Adult migration							■	■	■	■	■	■
	Adult Spawning	■					■	■	■	■	■	■	■
	Adult Holding							■	■	■	■	■	■
	Eggs to Fry	■	■	■	■					■	■	■	■
	Juvenile Rearing		■	■	■	■	■	■	■	■	■		
	Juvenile migration		■	■	■	■	■	■	■	■	■		
Spring Chinook Salmon	Adult migration	■	■	■	■	■	■	■					
	Adult Spawning	■								■	■	■	■
	Adult Holding	■	■	■	■	■	■	■	■	■	■	■	■
	Eggs to Fry	■	■	■						■	■	■	■
	Juvenile Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juvenile migration	■	■	■	■	■	■	■	■	■	■		
Coho Salmon	Adult migration	■							■	■	■	■	■
	Adult Spawning	■									■	■	■
	Adult Holding	■							■	■	■	■	■
	Emergence	■	■	■	■	■					■	■	■
	Juvenile Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juvenile migration		■	■	■	■	■						
Searun Cutthroat Trout	Adult migration	■	■	■	■	■	■	■	■	■	■	■	■
	Adult Spawning	■	■	■	■	■	■	■	■	■	■	■	■
	Adult Holding		■	■	■	■	■	■	■	■	■		
	Emergence	■	■	■	■	■					■	■	■
	Juvenile Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juvenile migration	■	■	■	■	■	■	■	■	■			

Additional Fish Use Information from ODFW Roseburg

Data provided by Holly Truemper, ODFW Roseburg:

- Chum Salmon (few): optimum 7.2-15.6°C *
- Pink Salmon (few): lethal limits are 0, 25.6°C *
- Sockeye Salmon (few): prefer 10-15°C, but this is based primarily on lakes *
- Speckled Dace: in Oregon 32-68°F but in California have tolerated up to 90°F **
- Longnose Dace: prefer 55-70°F **
- Pacific Lamprey: spawn, egg: Mar-May, rearing: year round, range 52-64°F, observed to 77°F **
- Brook Lamprey: 52-64°F **
- Northern Squawfish (Umpqua pikeminnow): for pikeminnow in Lake Wash 68-73°F**, observed throughout Umpqua tribs into August in 2008 ***
- Redside shiner: typically 55-68°F, observed up to 75°F**
- Largescale sucker:
- Threespine stickleback: <23-24°C for long term survival, hatch @ 18-20°C *
- Umpqua Chub: spawn, egg, fry: June-Aug, juv and adult rearing: year round, 17-26°C range (Markle)***
- American Shad: in freshwater from 14-20°C *
- White Sturgeon: eggs hatch 12.7°C, spawn 8-14°C*
- Green Sturgeon: eggs hatch 12.7°C, spawn 8-14°C *
- Sculpin: typically <20-22°C *
- Warmwater species: smallmouth bass, largemouth bass, bluegill, brown bullhead, yellow bullhead, black crappie, green sunfish, striped bass ***

* From Fishes of California by P.B. Moyle
** From Fishes of Washington by Wydoski and Whitney
*** From Roseburg ODFW information

Management Issues

- There may be a tendency to put emphasis on the management and preservation of cold water refugia sites that are typically located in the upper headwaters of the tributary streams with a corresponding lack of emphasis for the lower system. Detailed information on fish use in the Lower Umpqua River is limited and, because of the obviously severe environment, it is tempting to “write off” this portion of the basin. However, it should be obvious that the Lower Umpqua is a vital link to the anadromous fish life cycle and should receive full consideration.
- The purpose of this study is to learn more about the thermal processes and conditions in the Lower Umpqua. Meaningful temperature data is difficult to difficult to obtain in a large river because of the inherent temporal and spatial and temporal variability. At any day at given point the river temperature changes with the diurnal solar pattern. The daily pattern also changes throughout the summer season, with some days being warmer or cooler

than others. The temperature can also vary across the river due to local influences such as shallow water at the edges or tributary inflow. Temperature data loggers that are deployed to sample at 30 minute intervals are effective in identifying the temporal variability. However, it is usually difficult to deploy and retrieve the units in the deeper, central thalweg portion of the channel. Consequently, there is a paucity of continuous temperature data for the thalweg environment. It is recommended that an effort is made to learn more about the thermal response of this important component of the river system.

Ground-water Notes

Previous field work has shown that groundwater in the lower elevation regions of Umpqua Basin is typically in the range of 54°F which is also the mean annual temperature of the area. 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. Also, like lava in the ocean, the water surface temperature would not necessarily indicate the thermal conditions on the bottom. The TIR photos detect only surface temperature since water is opaque to the infra-red radiation associated with these temperatures. [See the Radiant Heating section] Consequently, it is possible that there may be areas on the river bottom with water temperature in the range of 13°C (55.4°F) that were not detected by the TIR photos. An objective of this project was to try to confirm the existence of these upwelling areas.

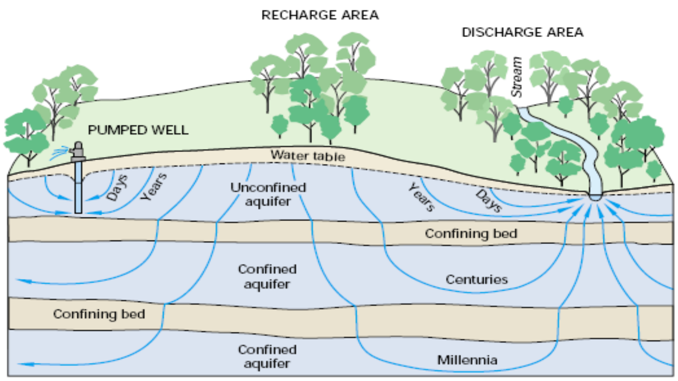


Figure 3. Ground-water flow paths vary greatly in length, depth, and traveltime from points of recharge to points of discharge in the ground-water system.

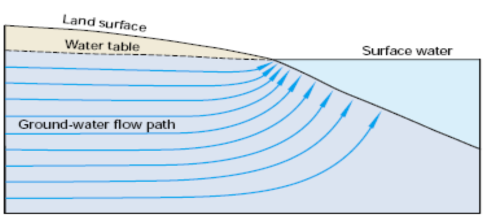


Figure 4. Ground-water seepage into surface water usually is greatest near shore. In flow diagrams such as that shown here, the quantity of discharge is equal between any two flow lines; therefore, the closer flow lines indicate greater discharge per unit of bottom area.

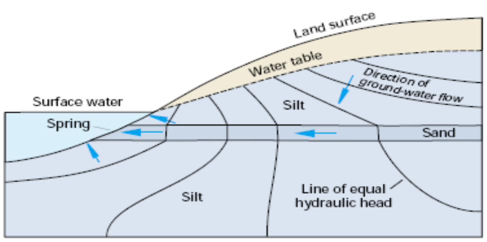


Figure 5. Subaqueous springs can result from preferred paths of ground-water flow through highly permeable sediments.

References

1. Smith, K., *Lower Umpqua Watershed Temperature Study -Summer 2000*. 2000, Umpqua Basin Watershed Council.
2. *Aerial Surveys in the Umpqua River Basin*. 2003, Watershed Sciences, LLC: Corvallis.
3. DEQ, *Umpqua River Basin TMDL / Water Quality Management Plan*. 2006.

Useful Links

Some useful links:
Aerial Surveys in the Umpqua River Basin May 2, 2003
http://www.deq.state.or.us/wq/tmdls/docs/umpquabasin/tir/umpqua.pdf

An interesting method to measure continuous profile of the river bottom.
http://pubs.usgs.gov/sir/2006/5136/pdf/sir20065136.pdf

Videos of the presentations of the recent AFS thermal refugia conference.
http://www.ruraltech.org/video/2008/WDAFS/index.asp