Geologic controls on summer water temperature and flow in Luckiamute River tributaries and implications concerning habitat use by juvenile steelhead

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Introduction

The geology of the Luckiamute River watershed includes a formation of basalt along its southern boundary, sandstone and siltstone rock along its southwestern, west, and northern edges, and alluvium elsewhere. Intrusions of igneous rock occur among the sandstone and siltstone and are most extensive in the northwest corner of the watershed.

This terrain has a dense stream network due to tectonic uplift, high rock weathering rates, and abundant winter rainfall. Yet, the portion of the stream network with surface flow contracts considerably during the summer since rainfall is scarce from July through September. The main source of summer water to streams is groundwater resulting from deep infiltration during the wet season.

Studies elsewhere in Oregon suggest that groundwater flux to streams during the summer and the temperature of that water as it flows downstream through stream channels is dependent on geology, with highly fractured or porous formations producing the highest flows per unit drainage area and the coolest streams. A comparison of small watersheds in the mid-Coast Range of Oregon indicated that those underlain by highly-fractured marine basalt had summer base flow volumes that averaged 3 times greater than those underlain by bedded sandstone (Hicks 1990). Similarly, streams flowing through the central High Cascades in Oregon had unit summer flows that were 14 times greater than nearby streams flowing through the Western Cascades formation, which typically has lesser porous geology (Tague and Grant, 2004). Furthermore, streams draining the High Cascades averaged 5 degrees cooler than streams draining the Western Cascades.

Low flows combined with warm summer temperatures result in stream temperatures for portions of the Luckiamute watershed that sometime exceed the limits for juvenile steelhead trout survival and growth. The warmer stream segments in the watershed generally occur at greater distances from the headwaters. Data collected by the Oregon Department of Environmental Quality indicate that it is mainly the portion of the stream network within 15 miles of a drainage divide that is cool enough to sustain steelhead trout during the warmest part of the summer, assuming that fish will continue to occupy water that is 70 degrees or cooler (Figure 1). Streams that do not have adequate shade (shown as circles in Figure 1) are capable of approaching or exceeding 70 degrees even at closer distances to the headwaters.

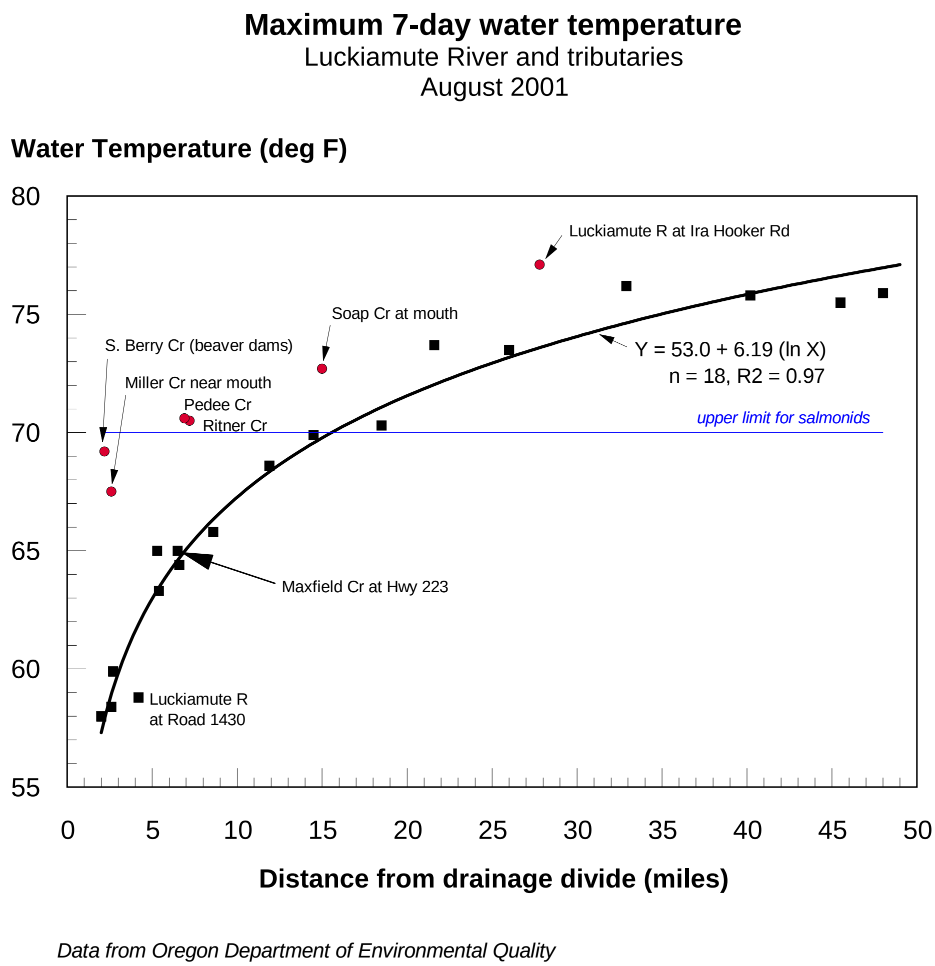

Figure 1. Relationship between maximum 7-day stream temperature and distance from drainage divide for streams in the Luckiamute River watershed. Stream segments with adequate upstream shading are shown as black squares and those with sparse shading are shown as red circles.

Fish are able to use marginally warm streams by congregating in localized zones of cooler water during the warmest part of the day. Cool water can occur at discrete points where groundwater enters (springs), become stratified at the bottom of deep pools, and occur where subsurface water flowing through gravel deposits is intercepted by the stream channel. These cool water zones would be expected to be more common in porous rock types and where the rock breaks down into persistent gravel- and cobble-sized material, thereby forming a deep gravel layer in the channel.

Purpose of study

I propose to examine a subset of perennial fish-bearing streams in the upper Luckiamute watershed in order to evaluate flow and water temperature differences between those that flow through marine basalt geology and those that flow through nearby sandstone geology. My hypothesis is that the streams in the marine basalt will have higher unit flows, lower overall water temperature, and greater frequency of cool water refugia during the warmest portion of the summer when compared to the streams in sandstone geology. These differences in water characteristics between the two geologic formations may be great enough to influence the distribution and carrying capacity of coolwater communities of fishes that use these stream systems.

Study design

I propose that the study focus on six streams in the upper Luckiamute River watershed, equally divided between basalt and sandstone geology. Study segments would be one-half mile long and located in each subbasin such that the downstream end is 3.5 miles from the drainage divide. At this distance from the drainage divide, summer flow could be assured even during a droughty summer and the study segments would be on forest land (and therefore, shaded). By picking a common position (3.0 to 3.5 miles from drainage divide) for evaluating water characteristics in each subbasin, the effects of stream warming in a downstream direction can be isolated from geology effects.

Candidate streams include five in the sandstone geology and three in the basalt geology (Figure 2). Three of the five streams in the sandstone geology would be chosen at random for inclusion in the study and all three of the basalt streams would be used. The candidate stream segments are all located on private forest land and landowner approval will be needed prior to any field work.

Each stream segment would be evaluated during a single afternoon in late July or early August, a time when air temperatures are typically the highest and summer flows are low. Only on cloudless days for which the air temperature is expected to exceed 85 deg F will measurement be made. A digital thermometer will be used to construct a longitudinal profile of stream temperature starting at the downstream end and moving towards the upstream end. Streams in this area typically reach a maximum temperature in the late afternoon on warm days but the variation around that maximum is rarely greater than 0.5 deg F over a four-hour period centered on the maximum (Figure 3). Consequently, a longitudinal profile of the stream temperature made over the one-half mile and within this

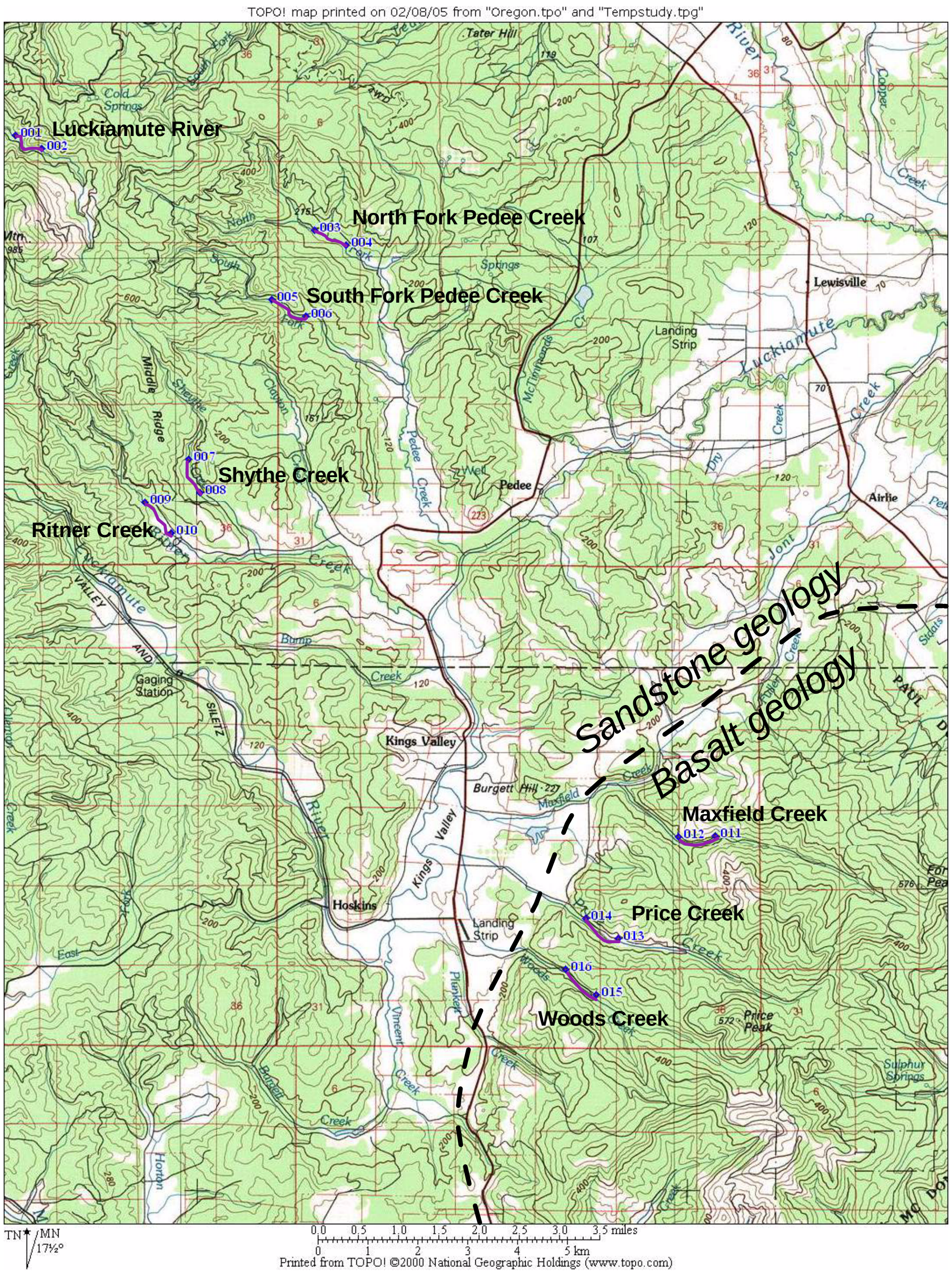

Figure 2. Candidate study sites 3.0 to 3.5 miles from the drainage divide in the upper Luckiamute River watershed.

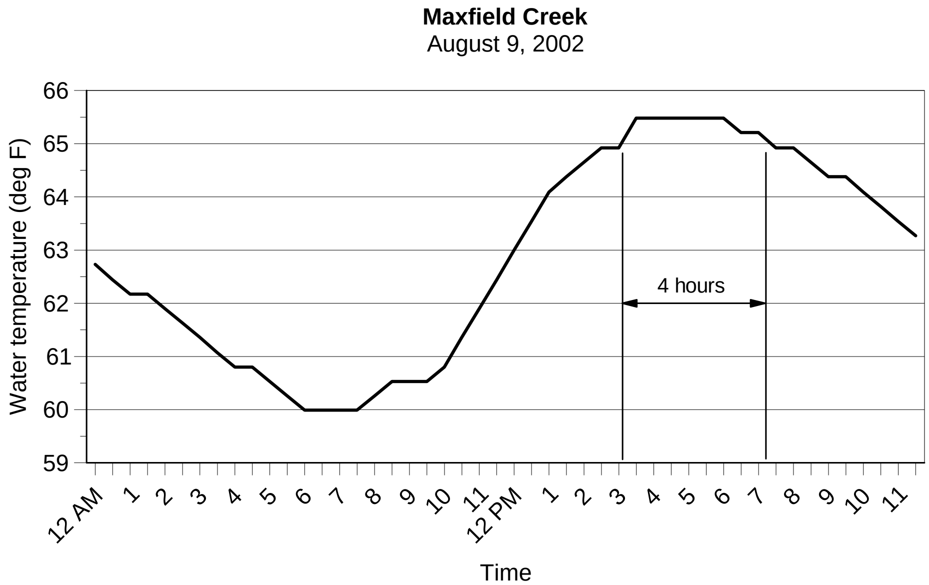

Figure 3. Typical change in stream temperature during a warm day in early August.

time window will show the spatial variability of temperature with reasonable accuracy.

I propose that temperature measurements be made at intervals of 50 feet along the stream thalweg and at selected intermediate points where discrete zones of cool water might be expected. These zones would include the bottom of deep pools, tributary junctions, seeps and springs, and the downstream end of prominent gravel bars where subsurface flow comes to the surface. Therefore, each stream segment would have a minimum of 53 temperature measurements. In addition, a recording temperature gauge will be set up at the downstream end of the stream segment for the duration of the measurements and its record used to check for temperature "drift" during the course of the manual measurements. For two of the sites, recording gauges will be installed to measure water temperature throughout the course of measurements at all six sites. These records will be used to help adjust for differences in air temperature among sampling days.

Other measurements and observations made at each site will include:

1. Wetted channel width at 100-foot intervals.
2. Flow at both the upstream and downstream ends of the stream segment.
3. Spherical canopy density at 100-foot intervals.
4. Substrate description at 100-foot intervals (% fines, gravel, cobble, boulder, bedrock).
5. Description of riparian vegetation at 100-foot intervals.

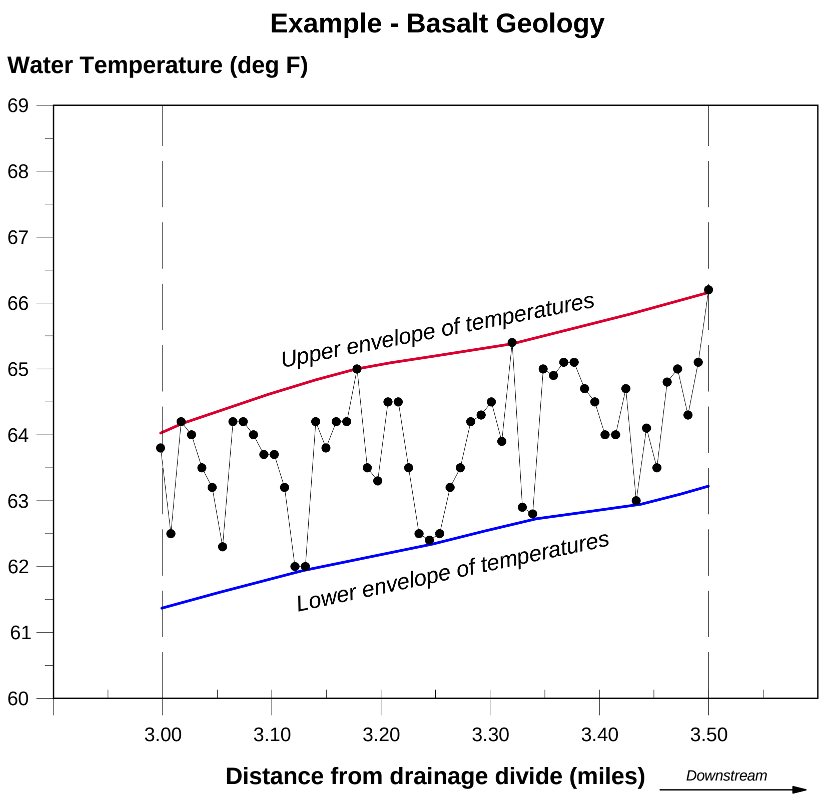

Figure 4. Example of expected variability in water temperature in a stream segment flowing through basalt geology.

Data analysis

The water temperature profiles will be plotted in a manner shown in Figures 3 and 4. An upper envelope of stream temperatures will be established for each reach using the warmest spots along the stream segment and then the deviation of the temperature measurements from this upper envelope will be determined. Figure 3 illustrates the wide departures from the upper envelope that I expect to observe in the basalt streams and Figure 4 illustrates the narrow departures that I expect to observe in the sandstone streams. The temperature departure from the upper envelope will be expressed as a standard deviation for each site and comparisons among sites will be made using geology, shade, and flow as possible explanatory factors. The same analysis will be done using the average temperature for each reach.

Products

I will prepare a report of the field study results and a data dictionary of all information gathered. I will leave metal tags on trees at the ending and beginning points of each stream segment and note their GPS coordinates in case that further field studies are conducted at these sites.

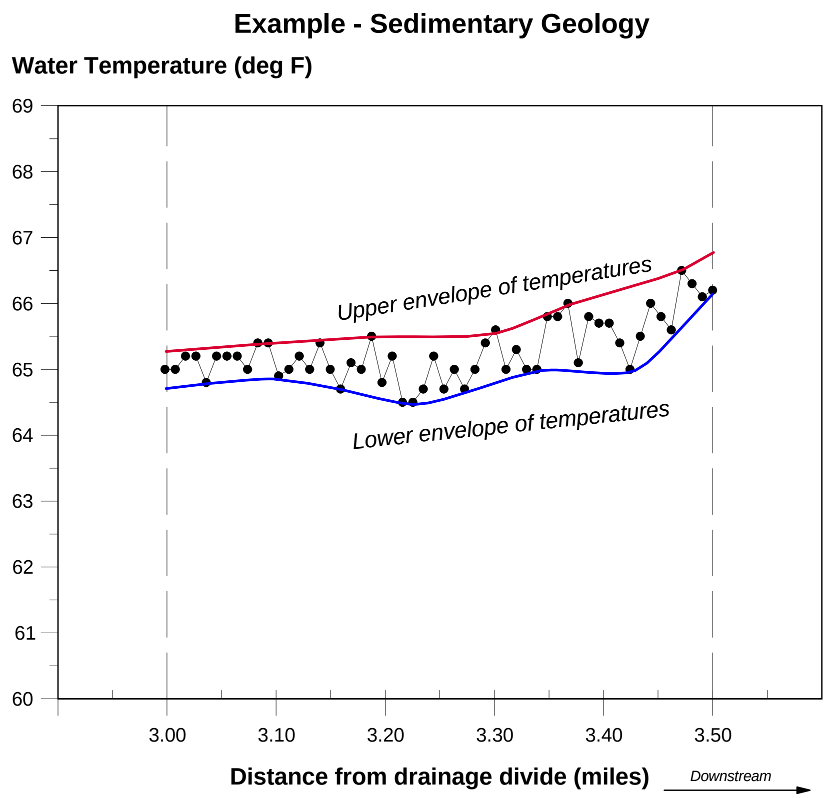

Figure 5. Example of expected variability in water temperature in a stream segment flowing through sandstone geology.

Equipment

3 recording temperature gauges
digital thermometer
cloth measuring tape (for measuring distance along stream)
flow meter, stop watch, plastic, and bucket (for flow)
spherical canopy densitometer (for shade)

Budget

Task		Cost
Site selection and obtaining landowner permission - early summer	14 hrs @ $17/hr	$238
Site measurements in late July or early August	6 sites @ 14 hrs/site @ $17/hr	$1428
Data analysis and report preparation	42 hours @ $17/hr	$714
Car mileage for field work	700 miles @ $0.37/mile	$260
Misc. field equipment		$140
Total		$2780

References

Hicks, B.J. 1990. The influence of geology and timber harvest on channel morphology and salmonid populations in coastal Oregon streams. Ph.D. thesis, Oregon State University, Corvallis.

Tague, C. and G. Grant. 2004. Hydrogeologic controls on stream temperatures in headwater catchments in relation to forest management activities, Willamette River basin. Progress Report 1, Oregon Headwaters Research Consortium. http://www.cascadewebdev.com/clients/headwaters/site/data/uploaded_images/pdfs/OHRC_Progress_Report1.pdf