Riparian Ecosystem Management Study (REMS):

Temperature, geometry, surface flow, and wetlands of selected headwaters streams Capitol Forest and the Willapa Hills, WA.

J. Janisch and W. Ehinger, Environmental Assessment Program, Washington Department of Ecology, Olympia, WA

INTRODUCTION
Though headwaters streams are often short, of moderate-to-high gradient, and with basins of only a few hectares, such streams (defined as Type 5 (seasonal, <2ft bfw)) or Type 4 (perennial, <2ft bfw); Washington Water Typing System), may disproportionably influence downstream water quality because of their high total mileage relative to main stem rivers. Thus, even though often unsuitable as fish habitat, management of headwaters basins can influence downstream fish populations via temperature, nutrient and detritus export, and sediment loading.

Although Clean Water Act (CWA) standards apply to both seasonal and non-fish bearing perennial streams,current data is inadequate to set long-term management policy for headwaters streams. This study, in co-operation with Washington DNR and the U.S. Forest Service, was designed to examine changes to biological populations, water temperature, and other variables occuring on such streams after logging. After a calibration period, three levels of riparian canopy retention were applied to headwaters channels. Using a BACI design, basins in which logging occured were then monitored for several years relative to unharvested reference streams (also headwaters). Monitoring began in 2003 (pre-harvest) and has continued to date, yielding at least three years of post logging data for each stream. Of the eight sets of streams (31 total, distributed across two regions) studied, Washington Dept. of Ecology staff collect data at six sets (21 streams total).

As a study co-operator, Washington Department of Ecology (ECY) primary objective was to quantify stream temperature, the most commonly violated water quality standard on forested lands. Several other system components were also studied. Here we describe the role of ECY staff in this project, outlining our approach.

Contact:

Jack Janisch
email: jaja461@ecy.wa.gov
phone: 360.407.6649

William Ehinger
email: wehi461@ecy.wa.gov
phone: 360.407.6416

Environmental Assessment Program, Washington Dept of Ecology
P.O. Box 47710, Mailstop 47600
Olympia, WA 98504-7710

Table 1: Distribution of research tasks by agency

ECY	DNR	USFS
WA Department of Ecology P.O. Box 47600 Olympia, WA 98504-7600	WA Dept. of Natural Resources P.O. Box 47001 Olympia, WA 98504-7001	USDS Forest Service Pacific Northwest Research Station 3625 93rd Avenue Southwest Olympia, WA 98512-9193
water temperature	region and stand selection	electroshocking
air temperature	buffer / treatment assignment	small-mammal inventory
channel CWD survey	harvest schedule	amphibian surveys
wetland survey	channel gradient survey	mollusk surveys
in-channel overstory photos	off channel overstory	litterfall
surface flow	off-channel understory	aquatic surface drift
GPS coordinates		flow volume
soil temperature		
relative humidity/weather		

QUESTIONS (ECY)

1. What is the effect of each buffer treatment on water temperature in headwaters streams?
2. Is this effect related to the presence of riparian wetlands, LWD, or the pattern of surface flow?

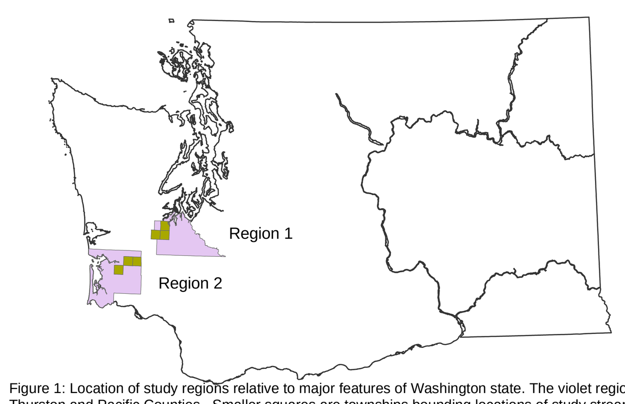


Figure 1: Location of study regions relative to major features of Washington state. The violet regions are Thurston and Pacific Counties. Smaller squares are townships bounding locations of study streams.

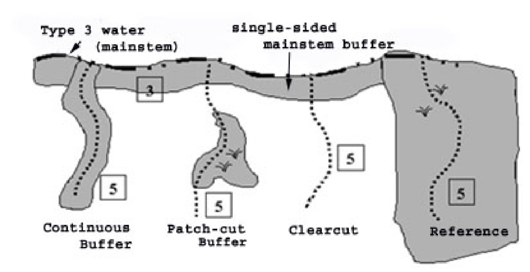


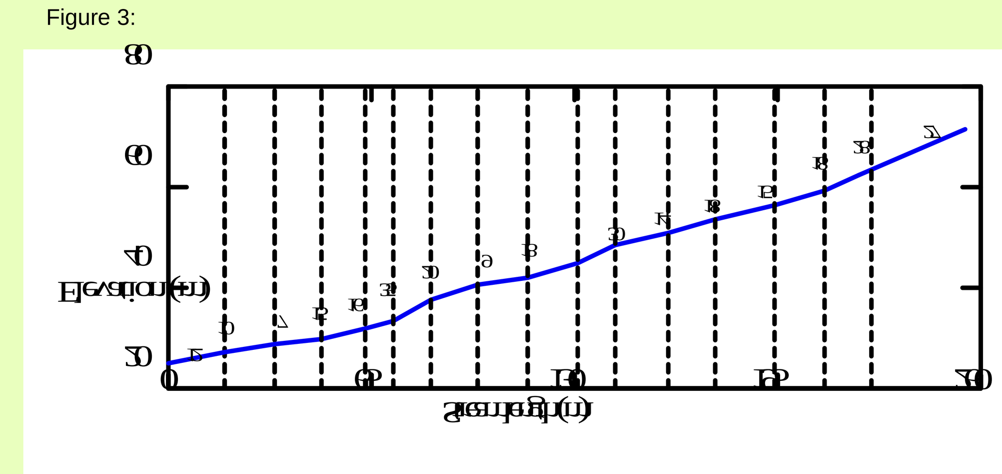
Figure 2: Idealized conceptual graphic of four headwaters (Type 5) waters confluent with a downstream fish-bearing water. Shaded regions indicate unharvested areas.

STUDY REGION
Study sites are distributed across two regions (Figure. 1): 1) Capitol Forest, and 2) Willapa Hills. Region 1 is centered approximately 10 km southwest of Olympia, WA, Thurston County. This region is a 37,000 ha parcel of public land administered by Washington Department of Natural Resources. Principle coniferous species are Douglas fir (Pseudotsuga menziesii), western hemlock (Tsuga heterophylla), and western red cedar (Thuja plicata). Region 2 is centered near Menlo, WA, approximately 10 km inland from the Pacific Ocean coast, Pacific County (Figure 1). This region is a checkerboard of state public and private forest lands. Principle coniferous species are T. heterophylla, sitka spruce (Picea sitkatensis), and T. plicata. Both regions are dominated by moderate to steep gradient slopes principally used for timber production, from which old growth was harvested approximately 60-80 years previous to our study. The forest canopy in both regions is coniferous with hardwoods (mostly red alder, Alnus rubra) invading riparian areas. The climate is winter wet, summer dry, with little rainfall May-September.

HARVEST TREATMENTS
Within each region are four study sites, referred to here as stands. Within each stand are 3-5, study streams, each of which received one of the following harvest treatments): a) unharvested reference, b) fixed-width buffer, c) partial buffer, d) no buffer (clearcut) (Fig. 2).

LONGITUDINAL PROFILE OF EACH STREAM
DNR staff applied a stream survey protocal to each stream, sub-dividing it based on change in gradient (>5% change), channel confinement (as ratio of deepest bfd / estimated 100 y flood plain width), substrate (as dominated by forest floor, pea gravel, etc), and other criteria. Percent gradient (vertical change) was then plotted against segment length. The vertical profile of a headwaters stream in our study (Figure 3) illustrates our methods and results. Intersection of the stream (blue) with the Y axis (0,24) indicates the confluence with the downstream water (fish-bearing or Type 3 (T3) based on state water typing rules) at the elevation indicated on the DEM. Change in elevation shown is thus relative to this point. Dashed vertical lines mark segment breaks, based on survey data. Numbers clustered around the stream profile are percent gradient for each segment.

Figure 3:



METHODOLOGY OVERVIEW FOR SELECTED ECY TASKS

STEP1: WHAT IS THE LOCATION IN SPACE OF STUDY STREAMS?
Because headwaters streams are often short, few of the state's 30 m digital elevation model (30 m DEM) grid cells may be intersected. As a consequence, stream position derived from the DEM via hydomodels thus may be unreliable because small basins are not well defined. To independently assess the position of our study streams in x,y space, we collected GPS coordinates at each segment boundary defined by the gradient survey (described above, Fig. 3). These points, showing the estimated location of each stream along its length, can then be compared to the length, position, and geometry of study streams derived via hydromodeling. In the example shown (Figure 4), location of a study stream derived from the DEM (blue) is shown relative to two sets of GPS points mapping the stream. Both sets of points show the actual stream to be shorter and somewhat different in position and geometry than the modeled stream. Point Set 1 (green, 2005) resulted from coordinating GPS data collection with Trimble satellite constellation forcasting software. Set 2 (yellow, 2003) ignored satellite constellation. Set 1 generally shows less scatter and better tracking of segment length and direction.

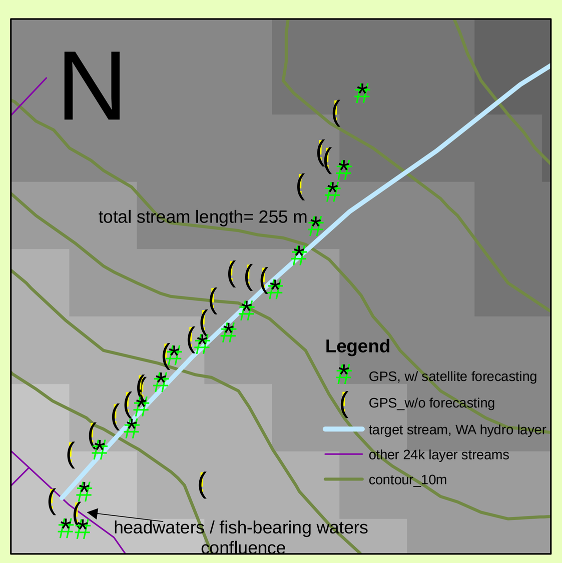


Figure 4: DEM, stream location derived from DEM, and GPS points

STEP 2: WHAT IS THE DIRECTIONAL GEOMETRY (X,Y) OF EACH STREAM?
Because the length of each stream segment was available from the gradient survey (described above) we built on this data to assess X,Y geometry of each stream channel. We established lat/long of the headwaters/fish bearing confluence for each stream via GPS, then assessed directional bearing of each segment (taken at segment marker flags) by compass. These data were then combined via an ARCMap length/direction tool and converted to a shapefile (Figure 5). We then overlayed our GPS coordinates to assess fit, giving two independent methods of estimating stream location and geometry. Though we use Magellan Meridian GPS units, less accurate than high-end Trible systems, much of our 2005 data shows estimated percent error (EPE) <8m or WAAS correction.

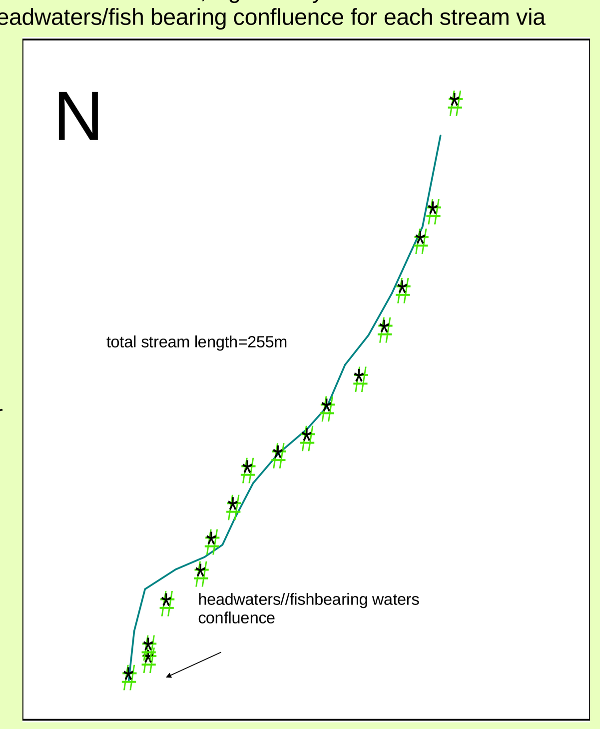


Figure 5: GPS points and stream drawn via length/bearing tool

STEP 3: MONITOR WATER AND AIR TEMPERATURE
Prior (2003) to forest harvest approximately 200 temperature data loggers (30 minute interval, contious recording) were installed at 21 headwaters (T5) streams. On each T5, paired air and water temperature (AT and WT) data loggers were installed a) high, near the headwall (first apperance of surface flow), and b) low, between the confluence and buffer boundary of the fishbearing water (FBW) (i.e., forested buffers are retained around FBWs), (Figure 6). Low monitoring sites are located above weirs. To assess the influence of weir impoundment on water temperature, an additional WT logger was installed just below each weir. In those stands were weirs were not built temperature stations were installed near the T3 buffer boundary. Additional temperature stations were installed where there was reasonable expectation that temperature might be influenced. For example, on streams where surface flow was not continuous between the upper and lower stations, additional stations were installed where water reemerged. The confluence of each fish-bearing /headwater stream was also bracketed with a temperature monitoring station. This network of sensors remained in place thru harvest (2003-2005) and we are now collecting post-harvest data.

Temperature data logger

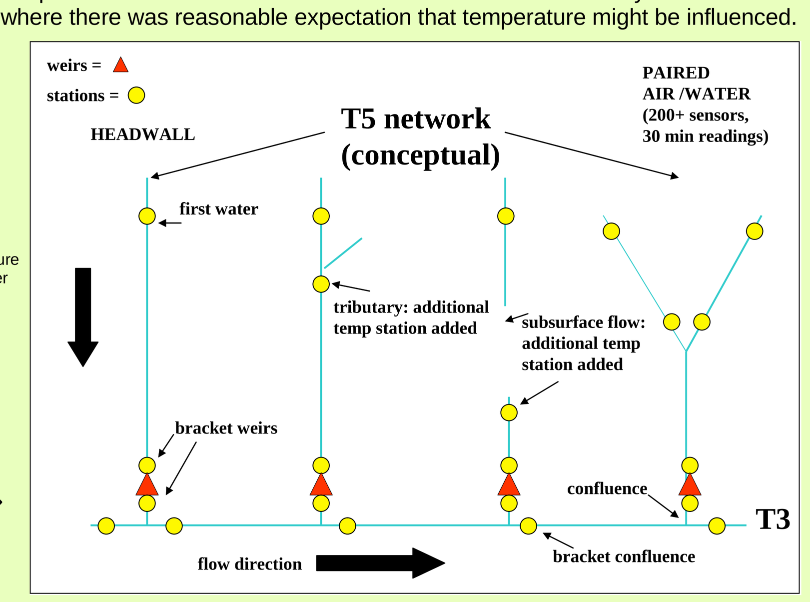


Figure 6: Location of temperature monitoring stations in an idealized stream network

STEP 4: WETLAND LOCATION IN HEADWATERS STUDY STREAMS
In this preliminary survey of headwaters wetlands, we simplified the Washington wetlands identification and delineation methods but still assessed the wetland triad (hydrology, soils, vegetation). Beginning at the confluence, the full length of each stream was walked and each candidate site showing either OB/FAQ wetland vegetation or mucky/grabby soils was evaluated against wetland criteria. As our study streams are often <1m BFW, minimum size criteria were not used so as not to exclude steep-walled channel (common) or force inclusion of broad sites having mostly upland character (also common). Sites meeting wetland definitions were then described (e.g., hydrology, soils, vegetation), measured (maximum length and width), and GPS coordinates of midpoint taken. Wetland shape relative to measurements and the channel was also carefully drawn so that shapefiles could be constructed (Figure 7) and their area calculated. Finally each site assessed was photographed (Figure 8).

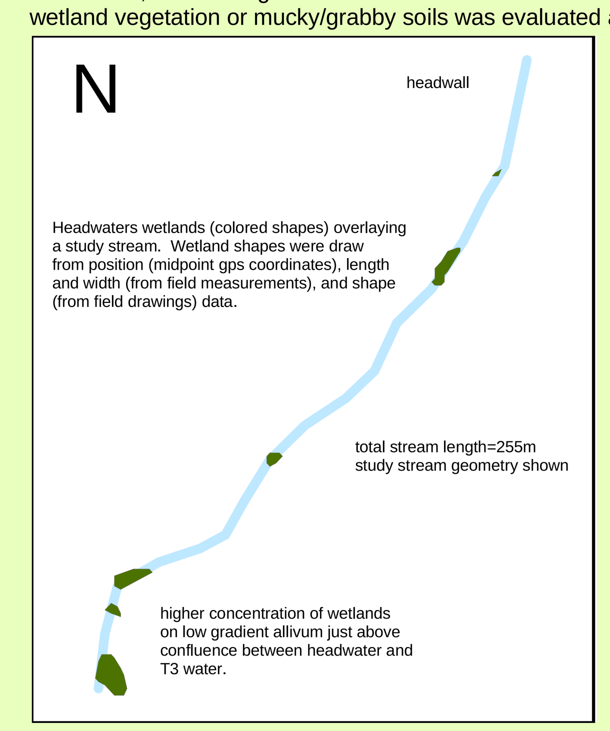


Figure 7: Position, shape and relative area of wetlands identified on a study stream.

Figure 8: Candidate site being assessed

STEP 5: IN CHANNEL AND RIPARIAN CWD LOADS
To assess CWD loads we adapted WA Timber, Fish, and Wildlife methods for larger streams and rivers. We used a hybrid method, treating the stream as a transect of with determined by bank full width (BFW). Because there was uncertainty in how much stream length to survey to provide a good estimate, we surveyed all streams for their entire length. All logs, stumps, snags, and rootballs >10 cm intersecting the BF zone were thus assessed for decomp class, species, orientation, and type, as well as volume measurements (Fig. 9). We measured the full length of all pieces and tied our measurements to gradient segment so that volume could be evaluated against gradient. Our resultant data allows calculation of volume as a total as well as by zone --BF zone and riparian zone (e.g., stream banks). The CWD survey is repeated post-harvest.

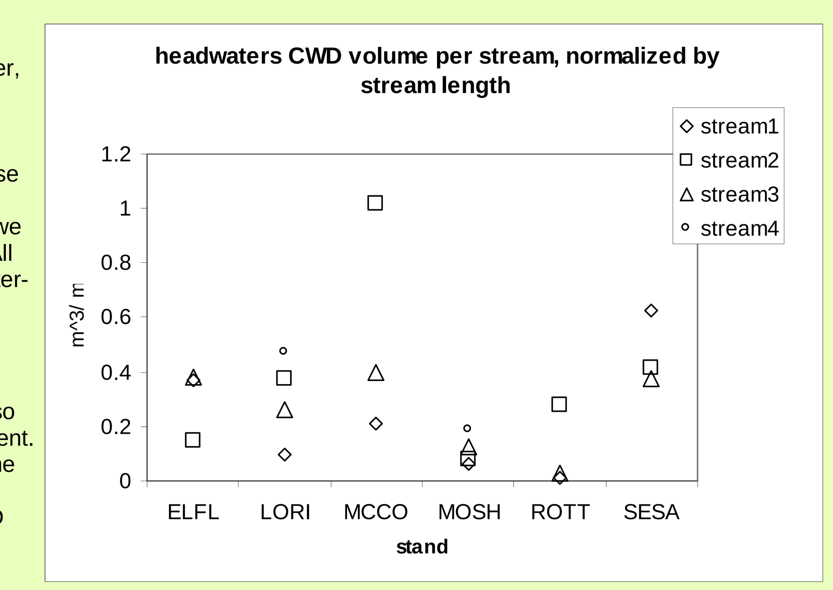


Figure9: Preliminary estimate of CWD loads in 21 headwaters streams (3-4 streams / stand). Data collected 2003.

Legend
Percent surface flow
no channel/alluvium
0
10
20
30
40
50
60
70
80
90
100

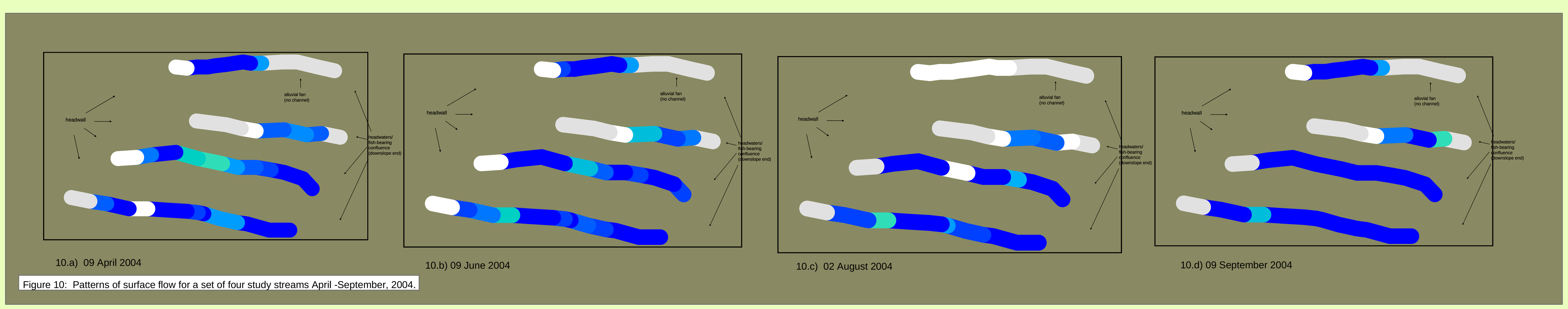


Figure 10: Patterns of surface flow for a set of four study streams April -September, 2004.

HOW DO HEADWATERS SURFACE FLOW PATTERNS CHANGE OVER TIME?

Because the Pacific NW climate is seasonally (June-September) hot and dry, surface runoff during this period is much reduced. Thus streams which derive volume primarily from surface flow rather than ground water sources may experience drying and wetup patterns which track rain events. To asses wheather such patterns could be detected we walked the full length of each stream, rating surface flow via a simple, rapid method we devised. Building on our earlier stream gradient survey, which subdivided each stream into segments (see above) we rated percent surface flow for each stream segment as ((estimated length of flow per stream segment/segment length)*100) to nearest 10%. We repeated the surveys several times for each stream May-Sept.

Combining our rating of surface flow for each stream segment with segment node coordinates and bearing, we then created a series of shapefiles showing surface flow for each segment at points in time across the annual thermal peak. Each panel in the series above shows a set of four streams at one of our research sites in the Willapa Hills, WA, on a particular day. Stream geometry and relative position are field derived via methods described above.

Though our methodology is somewhat crude, variation in flow over time is clearly visible. Patterns of drying and wetup suggest several points, including a relationship between surface flow and gradient (though our analysis is just beginning). Because our study streams respond rapidly to rain events, tracking flow over time may help identify the contributions of both groundwater and surface runoff in maintaining headwaters surface flow. Third, by overlaying flow patterns with our wetlands shapefiles we can asess whether wetlands are perennially flowing refugia or dry seasonally. Fourth, flow patterns can be combined with segment-level substrate ratings (collected earlier by DNR) to assess relationships between segments experiencing drying / wetup and substrate categories.

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FUTURE WORK
continue temperature and surface flow monitoring thru 2006
analyze wetlands, flow, CWD
integrate low elevation color photographs/photogrammetry
develop website for public release of data sets
coauthor peer reviewed and agency articles/reports