Monitoring Recovery Trends in Key Spring Chinook Habitat: Annual Report 2010

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Annual Report (2010)

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A : 165. Produce Environmental Compliance Documentation

Provide proof of all EC and permits to BPA permit-NOAA

A. **Stream work permit-NOAA**
B. **Stream work permit-USFWS**

   On June 2, 2010 the USFWS sent Jennifer Stolz a memo concerning the permit for our instream work in the Grande Ronde, Catherine Creek, and the Minam River. The memo subject was: proposed CRITFC Accord Monitoring Project, Grande Ronde Subbasin, Union and Wallowa Counties, Oregon-Informal Consultation (FWS reference 13420-2010-I-0112). This memo provided the USFWS's concurrence on this project in accordance with the ESA of 1973.

   On June 8, 2010 we received a letter from William W. Stelle, Regional Administrator of NOAA in response to our May 24, 2010 permit request with the subject: Endangered Species Act Section 7 Informal Consultation and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Columbia River Inter-Tribal Fish Commission's (CRITFC's) proposal to conduct stream and riparian monitoring in the upper Grande Ronde River, Minam River, and Catherine Creek, Oregon. NOAA concurred that the proposed actions in our Accords habitat monitoring project are "not likely to adversely affect (NLAA) critical habitat or species listed as threatened or endangered under the Endangered Species Act (ESA)."

B : 191. Watershed Coordination - Coordinate with regional agencies, tribes, and landowners

Description: Coordination with other entities involved in M&E and data collection in the Grande Ronde and Upper Columbia under the ISEMP work. Agencies involved include NMFS, ODFW, CTUIR, Nez Perce Tribe, EPA, BOR, USGS. Coordination with the specified agencies in the Columbia is needed to initiate and sustain work. Provide peer review of monitoring plans of other agencies and tribes and seek peer review of CRITFC plans and progress. CRITFC participates in appropriate regional forums (e.g. PNAMP), and individually with other agencies to improve the comparability of results from tribal projects with similar efforts within the interior Columbia Basin. Share information, data, scientific literature, expertise in developing monitoring plans that have highly reliable methods and a spatially stratified and statistically sound sampling design. Host pre- and post-field-season workshops with habitat monitoring teams from member tribes and with the CHaMP group. These workshops will be used to standardize and refine sampling protocols, training material and methods, and sampling designs among our member tribes and associated partner agencies. This is essential as there are numerous BPA and NOAA projects doing similar work in other basins like the Upper Columbia, S.F. Salmon and the John Day. This project is akin to the others and will give us a better cross-sectional coverage to make inferences for the Columbia River (e.g., in evaluating whether habitat quality is adequate for salmonid survival to specific lifecycle stages).

Deliverable Specification: Coordination with the specified agencies in the Columbia is needed to initiate and sustain work. Provide peer review of monitoring plans of other agencies and tribes and seek peer review of CRITFC plans and progress. Participate in appropriate regional forums (e.g., PNAMP), and individually with other agencies, to improve the comparability of results from tribal projects with similar efforts within the interior Columbia Basin. Share information, data, scientific literature, expertise in developing monitoring plans that have highly reliable methods and a spatially stratified and statistically sound sampling design. Host pre- and post-field-season workshops with habitat monitoring teams from member tribes. These workshops will be used to standardize sampling protocols, training material and methods, and sampling designs among our member tribes.

A. Coordinate with regional agencies, tribes, and landowners

CRITFC coordinated with other entities involved in M&E and data collection in the Grande Ronde and Upper Columbia. Agencies involved will be NMFS, BPA, PNAMP, ODFW, Grande Ronde Watershed Council, Umatilla Tribe (CTUIR), and Nez Perce Tribe.

Land owner co-ordination is essential as we will need to have owner permission to collect data in some areas. This will also require co-ordination with the USFS as it will be essential for data sharing.

We also coordinated with BPA and NOAA when it became apparent that BPA would fund ODFW in addition to CRITFC for habitat monitoring in the Grande Ronde and Catherine Creek. NOAA is developing a procedure known as CHaMP (Columbia Habitat Monitoring Program), which is a Scientific Protocol for Salmonid Habitat Surveys. CRITFC staff reviewed three versions of CHaMP and provided written and verbal recommendations to the CHaMP development team for revisions. In addition, CRITFC attended a meeting of the ISRP on February 10, 2011 in which the CHaMP team presented an overview of their methodology. CRITFC was able to present written and verbal recommendations at this meeting for needed revisions to the monitoring protocol. See **Appendix A** for the CRITFC comments on CHaMP submitted to the ISEMP group and the ISRP.

In late 2008 CRITFC hosted all four member tribal habitat staff for a meeting to discuss plans for tribal M&E. At this meeting CRITFC presented its proposed habitat monitoring and spring Chinook productivity modeling plan. The tribal staff presented their intended monitoring plans.

CRITFC attended a coordination meeting in Mission, OR prior to the 2010 field season with representatives from CTUIR. CRITFC and CTUIR each gave PowerPoint presentations on its monitoring plans in the Grande Ronde. We agreed to share data coming from our Accord project. We discussed access issues, especially in the Meadow and McCoy Creek areas.

We had a meeting with CTUIR's subcontractor (Stillwater Sciences) in our Portland office in early 2011 and discussed opportunities to share in the overall plans for monitoring salmon habitat quality/quantity. Stillwater Sciences has developed a modeling framework called Ripple that

has many framework elements in common with those that we have proposed for modeling spring Chinook productivity on a life cycle basis.

CRITFC staff has supplied CTUIR staff with all water temperature and streamflow data collected in 2010. We also supplied CTUIR LiDAR data and aerial photos for project areas of special interest to the Tribe. CTUIR also supplied CRITFC with water temperature data collected from its monitoring sites.

We participated with two of the CTUIR research teams plus ODFW staff in an annual Chinook redd monitoring effort in the Upper Grande and Catherine Creek. We initiated a plan to GPS the redds that had been flagged by the end date of spawning. This work was completed with the extensive help of the CTUIR survey teams.

ODFW provided CRITFC with the final redd count sightings documented with handheld GPS units. CRITFC participated in redd count surveys again in 2010 and noted redd locations with GPS devices.

CRITFC staff met with the Grande Ronde Model Watershed and private landowners at a meeting in La Grande to discuss issues with access to private lands.

We frequently stopped to visit with ODFW field staff housed both at La Grande Fish Research Office at EOU (Badgley Hall). We had several phone calls with the ODFW staff to discuss coordination on CHaMP monitoring protocol.

We have received water temperature and streamflow data from the USFS Regional Office in La Grande. These data in conjunction with USGS and OWRD data available online provide a good database from which to develop regional streamflow statistics.

We attended numerous PNAMP meetings held in Portland to discuss regional progress in monitoring. Several presentations of monitoring methods were made by USFS personnel representing AREMP and PIBO monitoring protocols; WDOE; USGS; ODFW.

Coordination with other agencies and organizations has involved acquiring spatial data and GIS layers as baseline information about the watersheds and for integration with future analyses. This section describes coordination beyond sharing of stream temperature and flow data. We have acquired spatial data with researchers from the Environmental Protection Agency (EPA) in Corvallis (Jim Wigington and Joe Ebersole) regarding testing of their hydrological landscape region (HLR) classification. The HLRs incorporate information on climate class, seasonality of runoff, aquifer and soil permeability, and topography. This watershed classification system is expected to explain spatial variation in several watershed processes we are measuring (e.g., sediment dynamics and stream flow), and will therefore be important to account for when making inferences about potential habitat improvement. To date we have acquired spatial data in the form of GIS shapefiles and have included this in our master project mapping depository.

We are coordinating with Oregon Department of Environmental Quality (ODEQ) to expand the range of metrics describing habitat quality for Chinook salmon. Often the measurement of a few, simplistic metrics (such as stream flow, water temperature, and sediment) cannot adequately describe habitat quality for an organism in a holistic manner, so more integrated metrics (such as biotic indices based on aquatic invertebrates) are required. Our collaboration with ODEQ involves coordination of monitoring efforts so that collection of aquatic invertebrates at monitoring sites yields data that can be used in the river invertebrate classification and prediction system (RIVPACS) (Wright 1994), a biotic index that is gathering momentum among researchers in the western U.S. We conferred with ODEQ concerning regional laboratories that would provide high quality analysis of macroinvertebrate samples. We also have received water quality data from ODEQ in the form of a database that can be queried to construct maps of spatial distribution of water quality parameters for various months. We are continuing discussions with ODEQ about this database so that we can fully understand the chemical analysis methods used, detection limits of the methods, and so that we can discriminate surface from groundwater samples.

The Oregon Department of Fish & Wildlife's (ODFW) aquatic habitat inventory (AHI) is a comprehensive habitat survey conducted in contiguous channel units and summarized at the reach scale throughout the state (Moore et al. 2008). Because of the spatially-extensive nature of the AHI survey in the upper Grande Ronde and Catherine Creek watersheds, it seems strategic to capitalize on this existing data set, especially since there may be a new round of similar data collection in portions of the study area beginning 2010 (Kim Jones, ODFW, pers. comm.). We have acquired spatial data and related attributes for AHI channel unit and reach-scale surveys, performed quality control procedures on the data set, and have conducted preliminary analyses to elucidate the inter-related nature of habitat variables and demonstrate a proof-of-concept regarding future modeling strategies (see Develop RM&E Methods and Designs section). We used the AHI to model stream channel width relative to basin area as a means of estimating appropriate reach lengths to monitor at all sample points.

We coordinated with EPA concerning GRTS sampling and incorporating our 2010 GRTS sample points into a broader spatial selection of points for 2011 sampling.

We acquired a land classification procedure performed by EPA that we will possibly use as a means of stratifying sampling reaches. Stratification may be performed as a post-sampling procedure.

We contacted ODFW office in LaGrande to propose developing a data sharing agreement that would be beneficial to both ODFW and CRITFC and protect the intellectual property and data collected by each group while affording proper authorship or citation of work done by the responsible agency. We are also in the process of developing such a data sharing arrangement with the CTUIR also.

B. Tribal coordination

We devoted considerable time in coordination with CRITFC member tribes that are seeking to develop sound RM&E plans. We anticipate that this project can serve as a model for other similar projects conducted by the CRITFC tribes in other areas. We will learn from these projects collectively, and share information about monitoring methods and study designs for different set objectives.

We have shared much of the data we collected in 2010 with the CTUIR monitoring team. These data included all water temperature and streamflow data. In return we have received CTUIR water temperature data.

C : 148. Install Flow Measuring Device - Install flow depth gauges at two channel cross-sections

A. Environmental compliance requirements complete

We obtained permits for installation of flow depth gauges in streams in the local area. The affected areas in the streams is extremely small and the installations are temporary in nature.

B. Deliverable: Install one stream gauging station each in the Upper Grande Ronde and Catherine Creek

We installed a streamflow depth gauge in Sheep Creek in the upper Grande Ronde on USFS land and also on the South Fork Catherine Creek on USFS land. These gauges were set to record flow depths every 30 minutes. The gauges operated from early June to approximately October 1, at which time we interrupted the gauge on the SF Catherine Creek due to its flashy nature and possibility that we could lose the expensive gauge. The gauge on Sheep Creek was allowed to collected data continuously through fall, winter, and spring. We installed a gauge on a branch of a conifer next to the Sheep Creek gauge in order to collect barometric pressure data that we could use to correct the readings of the in-stream gauge. For the SF Catherine Creek gauge, we applied air pressure data from a nearby climate station

D : 157. Collect/Generate/Validate Field and Lab Data – Collect water temperature and streamflow data

A. Environmental compliance requirements complete

See Section A165.

B. Calibrate and install water temperature monitoring devices

The Hobo Temp data loggers (U22-001-HOBO Pro v2 water temperature data logger) were calibrated in the CRITFC lab using procedures outlined in the CRITFC monitoring protocol using an Omega HH42 handheld thermistor thermometer as a NIST-traceable standard thermometer in an ice bath. Loggers were also re-calibrated after returning them from the field to detect drift in calibration. The longest period of time that a logger is deployed after its initial calibration is from June of one year to June of the succeeding year.

We installed water temperature loggers at approximately 70 sites between the upper Grande Ronde and Catherine Creek. Sites were selected using a GRTS procedure.

C. Water temperature field data collection

Water temperature data were downloaded from the Hobo loggers in late September using the optical data shuttle. Data were then transferred to a field laptop computer after readings from a day's worth of logger retrievals were uploaded to the shuttle. Each logger serial number was compared with the serial number recorded for the device that was installed at each site upon collection of data from the logger.

D. Collect FLIR data and produce water temperature model via subcontract

A subcontract with Watershed Sciences, Inc. was implemented. In August 2010 Watershed Sciences collected FLIR data from a helicopter that flew over the entire stream network for the upper GR and Catherine Creek. These data were then processed by Watershed Sciences. At the same time as the FLIR data collection, color video images were recorded of the same stream miles. Images were mosaiced together to form a continuous streamzone band incorporating the riparian buffer with the stream channel. As of March 2011, Watershed Sciences is working to complete the water temperature modeling component. A delay in acquiring all needed water temperature and streamflow data from field data loggers from outside sources resulted in not completing the temperature modeling. This work will be complete in approximately May 2011, at which point Watershed Sciences will train CRITFC staff in the use of the model and the LiDAR and FLIR data.

E. Streamflow data

Approximately 70 stream sites were selected by Watershed Sciences to provide ideal locations for monitoring streamflows that would facilitate building a water temperature model. Streamflow monitoring locations were selected upstream of the mouths of major tributaries to represent the cubic meters/sec of streamflow and water temperature of this flow entering a mainstem. A temperature logger was also place upstream of these tributary mouths on the mainstem and streamflow was also measured at the same location so that mixing temperatures below the confluence could be calculated by a mass balance. The streamflows were measured within a few days on each side of the FLIR flight to correspond with the water surface temperatures measured with FLIR. The water temperatures for the exact time of the FLIR flight were extracted from the water temperature records from the logger locations.

F. Conduct sediment infiltration study with gravel-filled buckets in spawning

We were unable to complete the infiltration study because of time constraints. The field season of 2010 was heavily committed to gathering streamflow and water temperature records from 70 sites throughout the study areas. Consequently, it was not possible to implant gravel-filled buckets into spawning gravels in September after spawning was completed by Chinook.

G. Collect macroinvertebrate samples

We collected benthic macroinvertebrate samples from each of 20 sampling reaches (16 in the UGR and Catherine Creek, and 4 from the Minam River). Benthic samples were made with a 0.92 ft^2Hess sampler with 500 um mesh. A sample was a composite from 8 separate Hess samples taken from riffle habitats. The sampler was placed near the center of a 9-cell matrix (3 x 3) that comprised the entire riffle area. The first cell to be sampled was selected by random number table. If the first cell was 3, for example, the succeeding cells that were selected were offset by 4, so the cells selected were 3, 7, 2, 6, 1, 5, 9, 4, 8. If there are 9 riffles in the study reach, then only 1 cell is sampled per riffle. If there were fewer than 9 riffles, then two cells would be selected in some reaches. If there are more than 9 riffles, then some riffles would not have any cells sampled.

The 8 composited samples collected in a plastic bucket with 500-um mesh were transferred to 500-ml wide-mouth sample jars. Samples were preserved in 100% isopropyl alcohol in 2010. However, because isopropyl alcohol tends to make macroinvertebrates somewhat brittle, and because samples with large amounts of organic matter tend to dilute the alcohol, we replaced the isopropyl with ethanol on returning to the laboratory. For the 2011 field season we will use strictly 100% ethanol.

H. Snorkel sample to estimate fish densities by reach-preliminary

CRITFC field staff snorkeled each of the 20 sample sites, placing special attention on pools, glides, and alcoves or side channels. In wide channels snorkelers recorded fish species, numbers of individuals by species, and size classes for individuals on estimated sampling lanes. Sample lane widths were estimated as the distance on each side of a snorkeler that plastic fish of various sizes could be observed. These plastic models were also used to calibrate each snorkeler's estimates of length class. Counts of numbers by size class were made of all salmonid species, but for non-salmonids, only presence/absence and general level of abundance (rare, common, very abundant) were noted.

I. Map habitat units

Channel units (habitat types) were identified according to the CRITFC sampling protocol. Habitat units identified were riffle, pool, run, sheet, rapid, cascade, falls, dry channel, other. Pools were classified as plunge, scour, backwater, dammed, trench, and step. Channel units were measured for width and depth. Channel units and associated data were recorded in sequence from downstream to upstream. The entire reach length could then be summed as the total of lengths of all individual

channel units. The overall channel slope was shot with an engineering level or in steep channels using the inclination function on the rangefinder.

J. Data entry

CRITFC field staff worked with CRITFC database managers to develop a database entry form that corresponds with our field data entry sheets. This database is programmed using SQL and allows summaries to be made of data.

A habitat data entry form was developed for consistent entry of data from the field forms into a Sequel database. The user manual (HabitatEntryForms 1.2, User Manual, February 17, 2011) is provided in **Appendix B.**

K. Data summaries

E : 156. Develop RM&E Methods and Designs - Review and develop monitoring protocols and statistical designs

A. Field manual for fine sediment, water temperature streamflow monitoring, climate

The CRITFC Accords monitoring protocol document was created and uploaded to PISCES. This document is:

Stream Habitat Monitoring Protocol for the Upper Grande Ronde River and Catherine Creek. Version 1.0. A component of Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators, June 2010. Casey Justice, Seth White, and Dale McCullough.

In addition, we worked on additional components to the CRITFC monitoring protocol that we intend to explore in future field seasons. Among these new components is intragravel dissolved oxygen (IGDO). We also need to develop our procedures for conducting the infiltration study in the 2011 field season. Needed here is an assessment of the initial particle size composition that should be used to measure infiltration of framework material by fine particles. In addition, we need to work on development of a bucket design that may allow vertical and horizontal movement of fines into the bucket and also facilitate extraction of the bucket and sediment sample without loss of fines.

The draft protocol for measuring IGDO is provided in **Appendix C:** Intragravel dissolved oxygen, hydraulic conductivity, and vertical hydraulic gradient (head).

B. Training in use of field equipment

CRITFC staff received training in use of the Trimble Geo-XT handheld GPS device from Electronic Data Solutions.

A CRITFC staff member with prior experience using the YSI Professional Plus full featured multiparameter water quality meter (DO, conductivity, water temperature, ORP) trained the remaining staff in its use and calibration.

Weekly field sampling trips involved securing assistance from field crew members who worked intermittently or as a one-time event. This required that

C. Test tool for streambed substrate characterization

Streambed surface sediment particle size characterization was advanced by development of a 9-cell grid frame device with an underwater viewing scope with a fine cross hair to precisely identify particles on the bed surface. Grid spacing was set to exceed the d10 particle size. That is, the grid spacing is larger than 90% of all bed surface particle diameters encountered in most of the study sites.

In 2010 we had the underwater viewing tube modified to improve the visibility of the cross-hairs so that particles could be more easily pinpointed under all viewing conditions. High light levels made it difficult to see a red cross-hair, but a bolder, black cross-hair was much better.

This method was designed to make it less subjective in identifying particles normally selected using the Wolman pebble count method. This method is prone to bias against small and large particles in the way that an observer paces the streambed and is able to feel for a particle that may be wedged between two cobbles. Although it is obvious that the subjectivity is much reduced with this new method, we have not employed it yet on a consistent basis because, (1) there is resistance against deviating from the Wolman method, even considering its known weaknesses, (2) we should conduct a test of the Wolman method against our new method, which could be done using a computerized simulation, (3) this method requires transporting of the grid frame and the viewing scope, which adds to field equipment needed.

D. Develop modified McNeil sampler

We had a new McNeil sampler constructed that has the same diameter inner core, but does not have the large diameter work basin with an inner collar that allows collection of sediment from core excavation. This new sampler is basically just a straight stainless steel tube the diameter of the inner core used in the larger, conventional McNeil sampler. It is lighter to transport, but has the disadvantage of not permitting collection of sediment inside the large working housing and it is also more difficult to reach deep into the tube to extract sediment, given the more confined work space. We used this sampler in the Minam River wilderness where we had to backpack all equipment in.

E. GIS analysis of sediment particle size distribution

See report describing GIS sediment analysis in **Appendix D.** Evaluation of Surface Sediment Particle Composition using a GIS-Simulation of a Stream Reach. Dale McCullough, David Graves, Saang-Yoon Hyun.

F. Sampling design

Two related tasks are currently under development: 1. a life-cycle model of spring chinook in the Grande-Ronde basin (Upper Grande-Ronde, Catherine and Mineham creeks) and 2. a spawner to smolt model. The purpose of the life-cycle model is to predict long-term potential production from habitat conditions. The purpose of the spawner to smolt model is to provide the empirical basis for the calibration of the life-cycle model in the spawner to smolt stages.

Spawner to smolt model (SSM)

Development of the SSM is currently using data from the Catherine Creek area. Spawner numbers are taken from the NOAA SPS (Spawner Population Summary) database (https://www.webapps.nwfsc.noaa.gov/). These data span the perio 1980-2009. Egg, Parr, early migrant, late migrant, and smolts at Lower Granite dam come from ODFW's "Investigations into the early life history of nuturally produced spring chinook salmon and summer steelhead in the Grande Ronde river subbasin" project (BPA contract 00046139). We have developed an Excell spreadsheet model that predicts the abundances of eggs, parr on Sept 1, parr migrating downstream mid fall, parr migrating downstream late winter, and smolts at Lower Granite dam. We are using environmental indices as forcing variables and estimating the scaling relationship between environemental factors and productivities, capacities and migration rates. The environmental indices currently included are flow and temperature. The framework used to integrate flow and temperature is the same that will be used to integrate other environemental factors such as bank full width and percent fine sediment.

Life cycle model

A life cycle model is currently under development in conjunction with the SSM, but it's final design characteristics are dependent on the final outcome of the SSM. The life cycle model is a natural extension of the SSM. It extends prediction beyond smolts to complete the entire life history. The life cycle model differs from the SSM in two important ways, yet still has the same underlying mechanisms. The first way it differs is that it does not statistically estimate relationships. Those are already established by the SSM from spawners to smolts at Lower Granite dam. The life stage survivals beyond Lower Granite dam are assumed to be known from historical patterns. The ocean portions is assumed to be known as well, and the fishery mortality will also follow historical patterns. The second difference between the life cycle model is that it will predict the number of brood year spawners returning of each age class. As a result the model will predict the entire life cycle, whereas the SSM uses emprical spawner numbers as the basis for predicting smolts. The life cycle model will use predicted spawners to predict smolts and all subsequent life stages.

G. Riparian and stream restoration monitoring and analysis

We conducted a literature review of riparian classification studies that have been done in the Grande Ronde basin or NE Oregon in general. Kovalchik (1987) and Kovalchik et al. (1988a, 1988b) pioneered the development of riparian community classification based on geomorphic indicators.

This work was initiated in north-central Oregon, but was later extended to NE Oregon by Crowe (see Crowe and Clausnitzer 1997, Crowe et al. 2004, and Powell et al. 2007) and Wells (see Wells 2006, and Powell et al. 2007). We are planning to enlist regional experts to conduct a riparian classification mapping for our CRITFC habitat project in order to map potential natural riparian vegetation by reach.

Riparian metrics for PNV analysis were explored and are provided in **Appendix E:** Riparian metrics for potential natural vegetation mapping in the Grande Ronde River.

In the process of conducting riparian classification and PNV mapping, we are planning to first emphasize the following environmental variables as a means of defining riparian mapping units:

valley width
bankfull width
elevation
slope and valley gradient
soil maps
aspect
geomorphology (landform-scale)
temperature
precipitation
topographic position index
soil moisture

With these predictor variables and prior experience in classifying the riparian community types in the Grande Ronde River area of NE Oregon, we would like to be able to map the zonation of potential natural vegetation throughout the extent of the spring Chinook spawning and rearing zone. CRITFC has a GIS database with these characteristics listed above and with others too that may be needed. We can supply a zonation of the riparian system according to a variety of streamside geomorphic and/or climatic classes. If the potential riparian communities can be assigned to the various streamside zones, it would meet our objective of being able to more accurately model the solar radiation inputs to the stream system. The modeled solar input for the current condition is computed from LiDAR data, which indicates the vegetation height, canopy density, canopy gap, and compass orientation of the channel. Potential natural riparian vegetation would provide a good estimate of the type of riparian vegetation (deciduous, coniferous, shrub), the maximum height of the vegetation, and the mean canopy density. If we know the percentage of the riparian zone occupied by deciduous vs. coniferous, it may be possible to estimate winter-time temperatures.

If potential riparian vegetation cannot be fully estimated using available information (i.e., GIS data and prior published riparian classification work), it may be necessary to conduct some field work to make inferences. Also, some field work may be needed to perform validation of office-based classification work.

We would like for a subcontractor to evaluate the existing riparian classification work done for the Grande Ronde and Catherine Creek and the available potential natural vegetation mapping to estimate the extent of work (office plus field) that may be needed to conduct this mapping of riparian vegetation throughout the extent of use of the Grande Ronde and Catherine Creek by spring Chinook. This work could begin in June 2011 if we find the person with the appropriate experience.

There are three priorities for mapping potential natural riparian vegetation throughout the streamside zone used by spawning and rearing spring Chinook in the Upper Grande Ronde and Catherine Creek. These are ordered from highest to lowest. We would like to develop a map that accomplishes all three priorities, if possible, for a reasonable cost and amount of time spent in the field. The resolution of mapping can be adjusted to provide the basic information needs and possibly avoid detailed floristic composition if necessary.

1) Identify potential riparian natural vegetation zones (i.e., historic vegetation that existed prior to human impact and with natural levels of wildlife impact and natural disturbance). This would differentiate coniferous vs. deciduous for tree communities; general % of each major type (coniferous and deciduous); canopy density; average canopy height; multistory composition and canopy cover by tree, shrub, grasses, forbs and cover by each general type. The use of these data would be in a water temperature model (Heat Source) that calculates potential solar radiation loading to stream reaches. It needs canopy height and density information. Canopy width might be important in some settings too where the riparian vegetation is a narrow strip.

2) Identify potential natural vegetation communities according to their primary taxa. This is a general community type that would specify to some extent the community diversity. It would also make use of the canopy height and density information from priority 1. The use of these data would be in modeling the potential terrestrial macroinvertebrate inputs to the stream and litter inputs. It is expected that terrestrial macroinvertebrates are delivered to the stream as drifting organisms that can be consumed by salmonids. We will be collecting information on terrestrial macroinvertebrate taxa and drift biomass flux by size category. Riparian canopies that are more diverse and denser are expected to provide substrates for higher terrestrial invertebrate production. Also, the diversity of riparian vegetation can be linked to the biomass and diversity of coniferous vs. deciduous litterfall. This allows drawing a linkage between sources of benthic macroinvertebrate food (periphyton vs. detritus) and the benthic macroinvertebrate composition. The conifer needle litter contributes organic matter inputs that are more slowly decomposed than deciduous leaf inputs. Differential leaf decomposition rates provide detrital resources of varying longevities in the stream system. This increases the stability and continuity of detrital material and the macroinvertebrate taxa based on a detritus-based food web.

3) Another use of riparian community classification would be in estimating the natural levels of streambank stabilization that are present. Certain types of riparian vegetation have dense

and/or deep roots. The percentage cover by various species with significant root structure would be useful information to relate to potential and current levels of streambank stability.

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H. Deliverable: monitoring plan for temperature, sediment and flow measures on the Grande Ronde

The monitoring protocol was developed and revised. The current version is listed below. This document has been posted to PISCES and has been distributed to the CHaMP group, ODFW, and CTUIR. This protocol is similar in most ways to the CHaMP protocol. The CRITFC monitoring protocol is posted to PISCES.

Casey Justice, Seth White, and Dale McCullough. 2010. Stream Habitat Monitoring Protocol for the Upper Grande Ronde River and Catherine Creek. Version 1.0. A component of Monitoring

Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators, June 2010.

F : 160. Create/Manage/Maintain Database - Develop and manage fish habitat condition database

A. Continue database development and implementation

A complete report of the database development is given in **Appendix F.**

Notes on how the CTUIR water temperature data were collected are provided in **Appendix G.**

G : 162. Analyze/Interpret Data - Summarize preliminary findings

A. GIS Analysis

A robust stream classification is an integral component of this project as it provides a basis for comparing units for analysis, facilitates understanding of ecological processes that vary under different watershed conditions, and creates common ground for administering management activities and communicating findings.

Progress on the development of our stream classification framework is described in **Appendix H:** Conceptual Framework, Methods, and Field Test of a Stream Classification in the Grande Ronde River Basin. Seth White, Dale McCullough, Casey Justice, Denise Kelsey.

B. Analysis of temperature, sediment, flow, riparian canopy

Watershed Sciences, Inc. was the subcontractor that collected the FLIR remote sensing data on stream water temperatures throughout the spring Chinook distribution extent. At the same time they collected color video images of the entire stream system within the extent, including a 250-m buffer on each side of the river. These images were stitched together and orthorectified so that the images can be used as an accurate spatial scale for making measurements of features observed. These images can also be used as a base map for making additional field notes of locations of habitat features. The report summarizing the FLIR data collection is available in **Appendix I:**

Watershed Sciences, Inc. 2010. Airborne thermal infrared remote sensing. Upper Grande Ronde River Basin, Oregon. Remote sensing Aug 7-12, 2010, report date December 31, 2010. 84 p.

Sediment data were subjected to a QA/QC process to ensure data quality. Data were then given a preliminary analysis, which is presented in **Appendix J:** Analysis of Sediment Size in Catherine Creek, Minam River, and Upper Grande Ronde River. Casey Justice, Dale McCullough, Seth White.

Temperature data were subjected to a QA/QC process to ensure data quality. Data were then given a preliminary analysis, which is presented in **Appendix K:** Summary of Stream Temperature in the Upper Grande Ronde River and Catherine Creek during Summer 2010. Casey Justice, Dale McCullough, Seth White.

C. Hydrological analysis

Approximately 70 sites in the Upper Grande Ronde River and Catherine Creek were monitored for streamflows to provide essential input data for the Heat Source temperature modeling. We also collected continuous flow data at two temporary stream gauging stations. These data were summarized in a report: Summary of 2010 Stream Flow and Hydrologic Data Resources in the Grande Ronde River basin, which is provided in **Appendix L.**

Deliverable: GIS analysis on existing data layers

An updated compilation of all GIS layers developed for the monitoring project's geodatabse is provided in **Appendix M:** List of files in the Grande Ronde Geodatabase

H : 161. Disseminate Raw/Summary Data and Results -Present findings and procedures in professional meetings

A. Presentation in AFS, JNAMBS, and/or JASA

White, S. 2010. Historical roots of the fish zonation concept and its application as an index of river health in central European rivers. Paper presented at North American Benthological Society Meeting.

Abstract: Although the concept of predictable change in fish communities along river profiles is frequently credited to Huet (1959), to the best of our knowledge the idea was first conceived by the Czech scientist Antonín Frič in 1871, who later produced a map of fish zonation of the Czech lands. Frič's idea has important implications for the present: First, quantifying deviations from expected fish community types can provide an index of river health sensitive to multiple stressors. Second, Frič's map is an historical record of fish distribution that can guide determination of reference conditions. We sampled young-of-year fish assemblages in over 230 sites across the Czech Republic and calculated a multivariate index describing deviation from expected fish zonation by river type. Our index was sensitive to land use occurring upstream in the watershed; especially the interrelated effects of reservoirs, urban areas, and agriculture. Next, we used Frič's map to evaluate determination of reference conditions, especially pertaining to diadromous fishes. We discuss implications for the Water Framework Directive, which requires water bodies to be at good or better ecological status by 2015.

Justice, C., S. White, and D.A. McCullough. 2011. Conceptual framework for assessing status and trends in habitat conditions and modeling biotic response for spring Chinook salmon in the upper Grande Ronde River basin. Paper presented at Oregon American Fisheries Society meeting, Bend, Oregon.

Abstract: The Columbia River Inter-Tribal Fish Commission initiated a monitoring program in the Upper Grande Ronde River, Catherine Creek, and Minam River basins in 2009 designed to assess current status and trends in key limiting habitat factors for ESA-listed spring Chinook salmon populations. This presentation outlines our conceptual framework and specific approaches for achieving this objective, and presents initial results from the first non-pilot year of this study (2010). We selected a probabilistic sample of 20 reaches distributed throughout the basins and measured a suite of stream habitat characteristics in each sample reach including channel morphology, surface and sub-surface substrate composition, water quality, discharge, and biotic community (benthic invertebrates and fish abundance). In addition, stream temperature and discharge data were collected at approximately 85 sites during June through September. Temperature and discharge data will be combined with remote sensing data including LIDAR and FLIR to develop a basin-wide Heat Source water temperature model. Habitat characteristics measured in the field will be used as input data for a life cycle model, which will link biotic responses of spring Chinook salmon with changes in key fish habitat variables. Analyses demonstrating the link between sub-surface substrate composition and potential embryo survival rates will be presented to demonstrate the above concepts. These tools will allow us to evaluate restoration potential for imperiled salmon populations in the upper Grande Ronde basin and identify and prioritize restoration actions that will be most effective for population recovery.e of, spawner-recruit data. A previous study of 25 populations from Oregon to Alaska demonstrated that watershed size is a good predictor of unfished equilibrium population size. Here this relationship is further developed by evaluating a series of Bayesian hierarchical models of increasing complexity. The model that performed best included a temporal random walk to account for patterns in the spawner-recruit residuals and life history-specific distributions for the productivity parameter.

B. FSBI Fish and Climate Change conference

Sharma, R., N. Mantua, and R.C. Francis. 2010. Relating spatial and temporal scales of climate and ocean cycles on Pacific Northwest Chinook survival and maturation.

Abstract: Pacific Northwest Chinook, *Oncorhynchus tshawytscha*, have exhibited a high degree of variability in survival and timing of maturation over the past three decades. This variability is summarized for twenty two different Pacific Northwest stocks and analyzed using multivariate data analysis techniques. Results indicate that survival is grouped into eight distinct regional clusters: northern BC and Alaska, Georgia Straits, lower Fraser River and west coast of Vancouver Island, Puget Sound and Hood Canal, lower Columbia Tules, Columbia Brights and Cowlitz, Oregon and Washington coasts, and the Klamath River. Age at maturation did not exhibit regional patterns. Environmental data indicate that Pacific Northwest salmon survival is only weakly correlated with ocean conditions, while age at maturation appears to have no linkage to ocean conditions.

Maturation does appear to be positively correlated with ocean conditions in good ocean condition years, but not in other years. Further analysis for each of the eight regions indicates that local ocean conditions following the outmigration of smolts from freshwater to marine areas has a significant effect on survival for the majority (six of eight) of the stocks analyzed. Analyses of the data indicate that Pacific Northwest Chinook survival covaries on a spatial scale of 400-600 kms. Lagged time series models are presented that tie large-scale tropical Pacific conditions, intermediate-basin scale northeastern Pacific conditions, and local conditions to survival of Pacific Northwest stocks.

C. Post data to the internet

Data collected in our monitoring work have not yet been posted to the internet. Data dissemination agreements have not yet been finalized. The data are being maintained in the CRITFC databases and are stored on CRITFC servers.

D. Present findings and procedures in routine professional meetings

See coordination with other agencies discussion

E. Deliverable: presentation in AFS/JASA/FSBI

See Section B of this work element.

I : 183. Produce Journal Article - Produce journal publications on fish/habitat relationships

A. Produce draft journal article on fish habitat relationships

McCullough. 2011. The Diversity of Response to Full Protection of the Beneficial Use under the US's Clean Water Act. Re-submitted after peer review. March 2011.

Abstract: The Clean Water Act of the United States is the pre-eminent federal law addressing the goal to restore and maintain the chemical, physical, and biological integrity of US waters. Full protection of the coldwater fish resources requires technically sound application of best available science on water temperature effects and a tight linkage from the goals in federal law, to State standards, monitoring, enforcement, and application of best management practices to restore ecological function of fish habitat. A survey of the 50 States comprising the United States reveals that 46 states support either native salmonids or introduced salmonids that have become self-sustaining in streams. Although this distribution may not be extensive in some of the States, the problem of devising water quality criteria that support salmonids is one that is widespread. In addition, the current EPA Gold Book guidance for development of protective standards, dating from 1973, still recommends the use of MWAT (maximum weekly average temperature) as a means of assigning protective chronic temperature standards to coldwater

fisheries. MWAT, applied according to EPA guidance, is typically used in conjunction with an acute upper limit. From its inception, evidence was available to show that MWAT was inadequate in protecting against chronic thermal impairment. In the US, each State has been permitted independently to develop protective temperature criteria that purport to provide full protection of designated uses (*e.g.*, coldwater fish use) and apply the best available science. A review of the 50 States' water temperature standards indicates a wide variety of quantitative criteria and levels of protection. Few states employ EPA recommendations to use MWAT, but inadequate standards are nonetheless common, as is lack of monitoring and listing of water temperature impairments. The divergence of temperature standards found in State statutes to protect fish species having highly similar biological requirements is indicative of the failure of States to provide consistent levels of protection and of the EPA to ensure State application of the best science through its standards approval process.

McCullough. 2010. Are Coldwater Fish Populations of the United States Actually Being Protected in Water Quality Standards? Freshwater Reviews 3:147-199.

Abstract: Governmental water quality agencies as a whole are faced with identifying water quality goals linked to a level of biotic protection, applying the best available science in development of water quality standards and associated management principles, implementing water quality laws so that there is consistency with goals, development of guidance documents for applying science to law, monitoring, and enforcement. Deviations in this path from goals to standards to enforcement are common across countries as well as among states within the United States and result in numerous means to fail in protecting aquatic biota. The Clean Water Act is the key US law for water quality protection. Its goal is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" and to fully protect the most sensitive beneficial uses. The US Environmental Protection Agency (EPA) Gold Book guidance for development of protective water temperature standards, dating from 1973, still recommends the use of MWAT (maximum weekly average temperature) as an index for assigning protective chronic temperature standards to coldwater fisheries. MWAT, applied according to EPA guidance, is typically used in conjunction with an acute upper limit. Unfortunately, MWAT is a criterion that is not protective, as can be shown by reference to several case studies on salmonids. Use of MWAT at a basin scale can result in considerable reduction in available salmonid rearing area and can in many cases be little better than recommending upper incipient lethal as a standard. Although MWAT is not used by many US states in standards, it is problematic in that it is cited as the official EPA model for a protective standard. The conceptual use of MWAT highlights some critical problems in application of the Clean Water Act and its associated federal regulations for protection of coldwater fishes, such as the concepts of full protection, protection of the most sensitive species, restoration of water quality, and support of species' viability at a basin scale. A recent review of the 50 states' water temperature standards indicates a wide variety of quantitative criteria and levels of protection applied to species having highly similar thermal requirements. Full implementation of the CWA in support of salmonids' thermal requirements has been spotty, with some states taking criteria development,

monitoring, listing, and TMDL development seriously and others virtually ignoring the problem. In addition, Section 316 of the CWA poses conflicts with basic goals of the CWA by giving deference to the thermoelectric power industry to discharge heated effluent under a process where variances granted supersede water quality-based limits. This is exacerbated by EPA 316 guidance permitting evaluation of biological trends amidst shifting or uncertain baselines in a limited set of RIS (representative important species) rather than application of best available science to protect the most sensitive species as well as to protect the entire aquatic community that is reflective of high quality habitat conditions. Designing water temperature standards to be fully protective and supportive of species viability (abundance, productivity, spatial structure, and diversity) benefits from application of concepts of optimum growth and survival temperatures distributed at a basin scale with reference to the natural thermal potential along a river continuum. Some notable successes in standards development found in the US Pacific Northwest can be offered as future national models.

Liermann, M.C ., R . Sharma, C.K . Parken. 2010. Using accessible watershed size to predict management parameters for Chinook salmon, *Oncorhynchus tshawytscha*, populations with little or no spawner-recruit data: a Bayesian hierarchical modelling approach. Fisheries Management and Ecology 17:40–51.

Abstract: Escapement goals for Chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), populations tend to be highly uncertain due to variability in, and in some cases complete absence of, spawner-recruit data. A previous study of 25 populations from Oregon to Alaska demonstrated that watershed size is a good predictor of unfished equilibrium population size. Here this relationship is further developed by evaluating a series of Bayesian hierarchical models of increasing complexity. The model that performed best included a temporal random walk to account for patterns in the spawner-recruit residuals and life history-specific distributions for the productivity parameter.

Liermann, M.C . and R . Sharma. 2010. Using hierarchical models to estimate effects of ocean anomalies on Pacific Northwest Chinook, *Oncorhynchus tshawytscha*, recruitment.

The high variability in survival over the past three decades of north-west Pacific Chinook salmon *Oncorhynchus tshawytscha* is summarized for 24 stocks and analysed using hierarchical Bayesian models. Results from a simple model indicate that recruitment anomalies appear to be correlated in time and space. A simple model with a covariate based on basin-scale effects (Pacific Decadal Oscillation and El Ni˜no Southern Oscillation) and local-scale effects (sea surface temperature, SST anomaly) was introduced to explain this variability. The model still exhibited residual patterns that were removed when a random-walk component was added to the model. The analysis indicates that recruitment is negatively related to SST anomaly for all stocks and the effect of basin-scale variables is negligible. The effect of climate over the next century is expected to result in estimated recruitment declining by an average of 13% for *O. tshawytscha* stocks coastwide.

B. Deliverable: draft paper on monitoring in the Grande Ronde basin

Our individual documents in this annual report concerning various monitoring elements, such as water temperature, sediment, and flow analysis are preliminary work toward our draft of a synthesis monitoring document.

J : 119. Manage and Administer Projects – Project Administration

A. Accrual-submit September 2010 estimate to BPA

The accrual estimates were submitted to BPA.

B. Submit draft 2011 SOW/budget to COTR

A new draft 2011 SOW and line item budget were developed and uploaded to PISCES.

C. Funding package—conduct internal review (e.g., supervisor or interagency)

The SOW was reviewed internally at CRITFC and approved.

D. Submit Final 2011 SOW/budget/property

The final SOW and budget were submitted to BPA. The updated property list was uploaded to PISCES.

E. Submit cost share data to BPA

There is no cost share available with this project. This conclusions was transmitted to BPA upon their request.

F. Obtain bids for potential subcontracts prior to 2011

Subcontractors for 2011 will be:

ABR, Inc., Alaska Biological Research, Inc., P.O. Box 80410, Fairbanks AK, 99708

ABR will process our benthic and drift macroinvertebrate samples.

The ABR proposal for macroinvertebrate sample processing and analysis is provided in **Appendix N.**

ABA. Aquatic Biology Associates, Inc., 3490 NW Deer Run Street, Corvallis, OR 97330

ABA will conduct quality assurance on the benthic and drift samples by validating the macroinvertebrate analysis done by ABR.

Watershed Sciences, Inc. will be completing work on the Heat Source temperature model that they are constructing from the LiDAR, FLIR, collected by them and water temperature data collected by CRITFC, CTUIR, USFS, and Grande Ronde Model Watershed.

We are in the process of enlisting the help of ABR, Inc. to do riparian classification work. We have located at ABR, Inc. in Fairbanks, Alaska an expert in the vegetation of the Grande Ronde region. Getting a scientifically-based riparian classification of potential natural vegetation will be a significant improvement in our ability to model potential water temperature regimes in the Upper Grande Ronde and Catherine Creek. We also have identified the other primary expert in local riparian flora in NE Oregon who is also an expert in riparian classification based on a geomorphic/climatic framework. We hope to enlist both these regional experts to develop a riparian classification that would provide a meaningful estimate of potential natural vegetation.

K : 132. Produce (Annual) Progress Report - Annual Report

April 1, 2010 to March 31, 2011

Appendix A

CRITFC comments on CHaMP

COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION
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04 February 2011

Review Comments on:

Bouwes, N., J. Moberg, B. Bouwes, S. Bennett, C. Beasley, C.E. Jordan, P. Nelle, M. Polino, S. Rentmeester, B. Semmens, C. Volk, M.B. Ward, and J. White. 2011. Scientific protocol for salmonid habitat surveys within the Columbia Habitat Monitoring Program. Prepared by the Integrated Status and Effectiveness Monitoring Program and published by Terraqua, Inc., Wauconda, WA. 118 pages.

Authors: Casey Justice, Seth White

Summary

By and large the Columbia Habitat Monitoring Protocol (CHaMP) closely resembles the monitoring procedures proposed by the Columbia River Inter-Tribal Fish Commission (CRITFC) in 2009 and implemented in 2010 (Justice et al. 2010) (see attached). Both protocols draw from the best available methods from a number of different stream habitat monitoring programs in the Pacific Northwest region including Integrated Status and Effectiveness Monitoring Program (ISEMP), PACFISH/INFISH Biological Opinion (PIBO) Effectiveness Monitoring Program, Environmental Protection Agency's Environmental Monitoring and Assessment Program (EPA-EMAP), Aquatic and Riparian Effectiveness Monitoring Program (AREMP), and the Oregon Department of Fish and Wildlife's Aquatic Inventories Project (ODFW-AIP). We agree with CHaMP's focus on process-based habitat assessment and its emphasis on channel-unit scale measurements that are more relevant to fish biology. While we fully understand the importance of coordinating regional monitoring strategies and appreciate the hard work that has been invested in developing a standardized monitoring protocol, we have some concerns with certain aspects of the protocol that we feel might limit its ability to adequately and efficiently characterize fish habitat. We hope that these issues can be addressed during the developmental phase of the CHaMP protocol.

Comments, Questions, and Concerns:

Comments are grouped into three categories based on their relative importance including:

Very Important – These comments pertain to issues that we feel should be addressed before implementation of CHaMP in 2011 and relate to broad-scale issues such as survey design and classification and potential problems with some survey methods or proposed habitat metrics.

Moderately Important – These comments pertain to issues that we feel should be addressed before implementation of CHaMP in 2011, but that are generally small-scale in scope and should be easy to fix.

Minor Importance – These comments pertain to issues that may not require modification before implementation of CHaMP in 2011, are generally small-scale in scope, but should be considered in an effort to improve the utility of CHaMP.

Very Important Comments:

1. Seth – Insert comments about classification system. The authors recommend using a regional-scale classification system developed by Beechie and others to stratify river networks into relatively homogeneous segments or reach types as described in Montgomery and Buffington (1997) (p. 13). These reach types can then be used to produce a stratified random sample using the Generalized Random Tessellation Survey (GRTS) design, thereby reducing the overall amount of variation in basin-scale estimates of habitat conditions. Although we are familiar with Beechie's recent classification system, we have already developed a similar classification system that we feel better describes the variation in reach types within the upper Grande Ronde River, Catherine Creek, Minam River, and Wenaha River basins (White et al. 2010) (see attached), and would prefer to use this system to select our sample sites. Is it necessary to use the Beechie classification system within the CHaMP protocol?

2. The CHaMP protocol recommends evaluating subsurface fine sediment in randomly selected sites within riffle habitats. We agree that subsurface fines are a critical habitat metric that needs to be evaluated. However, we feel that fine sediment quantities in riffles is not necessarily a good indicator of spawning gravel quality and will be difficult to directly relate to a biological response (i.e., growth or survival), which is a primary goal of the CHaMP protocol. Instead, we suggest that subsurface samples should be collected in areas of potential spawning habitat as determined from an evaluation of suitable depth, substrate size, and velocity criteria (Schuett-Hames et al. 1999). Suitability criteria could be sufficiently general as to include potential spawning habitat used by various salmonid species including Chinook salmon and steelhead. While subsurface fines in riffles may be sensitive to habitat disturbance and changes in sediment transfer, it is within potential spawning areas that subsurface fines are most relevant to egg survival and fish production. In addition, other metrics generated from the CHaMP protocol can be used to evaluate substrate conditions in riffles such as surface sediment pebble counts and visual estimates of fine sediment.

Another reason that we disagree with the subsurface fine sediment methods proposed by CHaMP is that collection of substrate samples within highly variable riffle habitats will likely be very difficult from a physical and practical standpoint. Riffle habitats often contain large cobble- and occasionally boulder-sized substrate that would be very difficult to extract with a shovel. Even if these larger particles are removed from the sample, it is not necessarily the case that the underlying substrate will be composed of finer, more easily managed particle sizes. In addition, it becomes questionable whether the sample is truly representative of the habitat condition if larger particles are subjectively removed to make the extraction of a gravel sample easier.

3. The shovel method for collection of subsurface sediment samples may result in a loss of fine sediment particles as water currents may tend to wash the fine sediment out of the sample as it is retrieved, particularly in swift currents. A McNeil sampler or similar device (e.g., a stilling well) may be advisable to retain fine sediments when collecting the sample. In a comparison of McNeil samples with three different shovel methods, Schuett-Hames et al. (1996) found that only the shovel method with stilling well produced statistically equivalent estimates of percent fines. Also, sieving the samples while wet may result in fine particles sticking to large particles, potentially resulting in a bias towards larger particles in the estimate of percent fines. In addition, weighing the particles while wet may bias the results, as the ratio of water to sediment is likely inversely related to sediment size. We recommend retaining the fine sediment fraction as in Sutherland et al. (2010) and drying and weighing the various fine sediment fractions in the lab. Alternatively, a volumetric approach could be used in the field to estimate fine sediment composition, although this approach would be more time intensive.

4. We recommend dropping embeddedness from the CHaMP protocol in order to save time, reduce redundancy, and eliminate collection of data that are prone to measurement error and subjectivity. The CHaMP authors state on page 39 “Measurement of embeddedness was reviewed extensively by Sylte and Fischenich (2002) and it appears that this attribute has no common definition and is too subjective to be used for monitoring.” On page 107, the CHaMP authors state “Embeddedness – critical flaw in measurement technique (increased fines can = decreased % embeddedness); also no agreed upon definition,” and “Too subjective and not able to assess water flow, DO levels, and other critical elements of interstitial space; poorly defined and typically not measured in all habitat types.” Based on this assessment, embeddedness fails to meet both the first and second criteria for inclusion in the protocol as defined by CHaMP authors on page 8 including: 1) information content, and 2) data form. We would argue that estimation of embeddedness for all

cobble-sized particles encountered during a 200+ particle count would also fail to meet the feasibility criteria defined by CHaMP for inclusion in the protocol.

5. The CHaMP protocol uses a modified version of the EMAP protocol to evaluate fish cover in each channel unit. However, CHaMP has dropped some of the cover elements from the original EMAP protocol including brush and small woody debris, boulders, aquatic macrophytes, and filamentous algae. Given the relatively small time investment required to estimated percent cover for each of these elements, we think it is a mistake to exclude them from the protocol. From the perspective of a fish biologist who has a significant amount of experience conducting snorkel surveys, I contend that all of these cover elements can be heavily used by juvenile salmonids and should not be overlooked. In addition, removal of these categories makes it impossible to cross walk between CHaMP and EMAP datasets, which could be important for utilizing historic data in future analyses of fish habitat.

   Also, the category of artificial structures needs to be clarified. Does this include LWD and boulders that were placed in the stream as part of a restoration project? If so, are they counted twice? If so, does it make sense to include artificially placed LWD and boulders in the same category as tires, old cars, diversions, and other structures? We suggest counting artificially placed LWD in the "woody debris" category, artificial boulders in the "boulder" category, and not including these elements as artificial structures.

6. Seth – You might want to comment on this, but it not likely to be something they can or will change. They have addressed some of your concerns on page 50. We agree the length of reach characterized by habitat assessments is an important sampling consideration. The method for determining site length outlined in CHaMP raises several questions:

   (A) It is proposed that on-site field measurements of bankfull width determine site width category and minimum site length (p. 67-68), which means that location of the top of site is unknown until first visit. This means that if the bottom of the site is located within 50 channel widths of a stream classification boundary (which is likely because sites can be up to 1 km long and Beechie's classification units are relatively short and quite heterogeneous), then the sample site will span classification types. Since classification units are meant to reduce variability in measured habitat characteristics, this could be a problem. How is this issue accounted for?

   (B) The protocol describes how to deal with tributaries when choosing where to measure bankfull width within the sample site (i.e., "skip that measurement," p. 67), which implies that tributaries can intersect but not delineate sample sites. However, several studies demonstrate that tributaries have substantial effects on

riverine processes important for fish such as temperature, stream flow, sediment input, channel gradient, etc. (Rice 2006). Does the CHaMP protocol have a way of accounting for tributaries in delineating sample reaches?

(C) The protocol also advises that bankfull width measurements be skipped where confluences of side channels occur (p. 67) (which we agree with), yet it is not clearly stated that measurements of side channels need to be incorporated into the total reach-scale bankfull width estimate. We recommend adding language such as "ensure that side channels adjacent to the main channel are accounted for when measuring bankfull width."

7. Seth - The benthic macroinvertebrate sampling proposed in CHaMP is scheduled to occur simultaneously along with physical habitat assessments, presenting two potential problems. First, conducting both types of surveys during a single visit may prove inefficient because of time spent waiting for biological sampling to occur—the physical habitat methods outlined in CHaMP are likely to take up to a single day (or more) to complete one site, and the additional invertebrate sampling will considerably slow down the process. Second and most important, the phenology of benthic invertebrates dictates that sampling should occur in a shorter time window (e.g., late summer through early autumn) if one desires less variability in the assemblage, whereas the CHaMP protocol suggests sampling benthic macroinvertebrates mid-June through October (p. 94). To address these concerns, we suggest conducting biological sampling (benthic macroinvertebrates and fish densities, see below) during a separate site visit, concentrated in a shorter time window.

8. The CHaMP benthic macroinvertebrate protocol is compatible with ODEQ/PNAMP's regional water quality monitoring protocols (PNAMP, n.d.) (attached), which incorporates the River Invertebrate Prediction and Classification System (RIVPACS) (Wright 1994). In the interest of coordinating statewide monitoring efforts, we recommend adopting PNAMP's laboratory protocols as well (e.g., invertebrate sub-sampling and minimum taxonomic resolution). Furthermore, PNAMP protocol suggests completing a rapid, one-page land use survey form as additional information that can be related to RIVPACS; we recommend including the land use form in the CHaMP field protocol.

Moderately Important Comments

9. The CHaMP protocol recommends measuring surface sediment particles using a ruler. We suggest using a gravelometer (i.e., template) instead. This approach is commonly used, fast, affordable, and has been shown to reduce measurement error compared with measuring particles by hand (Bunte and Abt. 2001).

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Appendix B

HabitatEntryForms 1.2, User Manual, February 17, 2011

COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION
729 NE Oregon, Suite 200, Portland, Oregon 97232

HabitatEntryForms 1.2
User Manual

CRITFC Manual Updated 02-17-2011

I. About this Manual

i. About this Version 1.2 Manual

The purpose of this manual is to provide instructions on how to install, enter, edit, and report fish habitat data collected during the field season. It is intended that paper datasheets will be used as the primary source of data collection in the field. At the end of the field season, technical staff will use this application to enter data from the original paper datasheets into a database.

The front end forms accessed in this application have been created using Visual Studio 2008, C# programming language, and Telerik G2 2010 application tools. The source code of this application can only be accessed using Visual Studio 2008, which is not provided to the end user. For a copy of the source code please contact the CRITFC GIS and Database Group (GAD). The end user does not have access to the backend database. Still, Client Access Licenses (CALS) are required to run this application. The CALs needed to run this application include Microsoft Server 2008 and SQL Server 2008. For further information on what CALs are necessary to operate this application please contact the CRITFC IT staff.

The database providing the backend support and relational tables is stored on SQL Server 2008 R2/Microsoft 2008 Server. The database has been named GrandeRonde, which is the basin where this field work is being conducted.

ii. Content Overview

This manual has been divided into several sections to including installation wizard, which details how to install the application on a person's machine that is connected to the network where the SQL server resides. The working with the Entry forms sections describes how to enter, edit, and view data from the datasheets. The working with reporting module describes how to view data summed in a final report. Appendix C shows all the columns available within each report. Lastly, the un-installation describes how to install the application in order to install a more recent application or remove the application entirely.

II. Installation Wizard

The HabitatEntryForms Ver 1.2 application has an easy to use installation wizard which helps you install the application to your desktop. A shortcut 

is automatically added to your desktop for the easiest access to the application

1. Obtain a copy of the HabitatEntryForms Ver 1.2 installation zip file from the GAD.
2. Unzip the installation file.
3. In the unzipped installation file, go to the following:

HabitatEntryFormsInstallerVersion1.2.msi

4. Click on the file above and follow instructions shown below by clicking next:

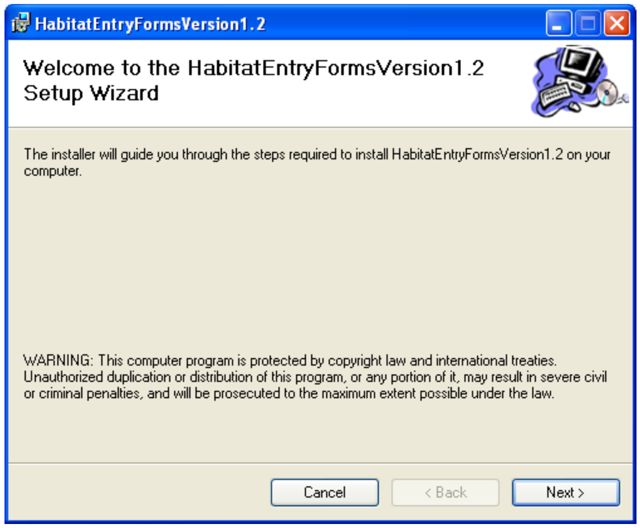

Figure 1. Initial screen for installing the application on the user's desktop.

5. Click next again and continue with the wizard, see below:

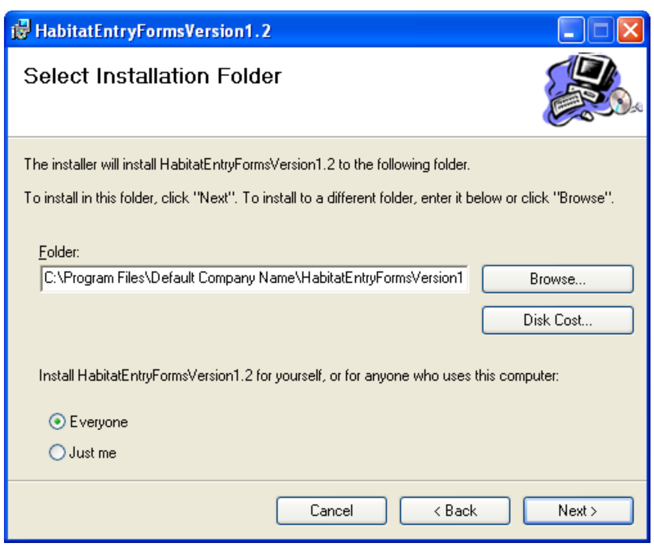

Figure 2. Screen for installing the application to the user's desktop.

6. Lastly the final screen will appear. Click next one last time and wait until you see the following screen.

7.

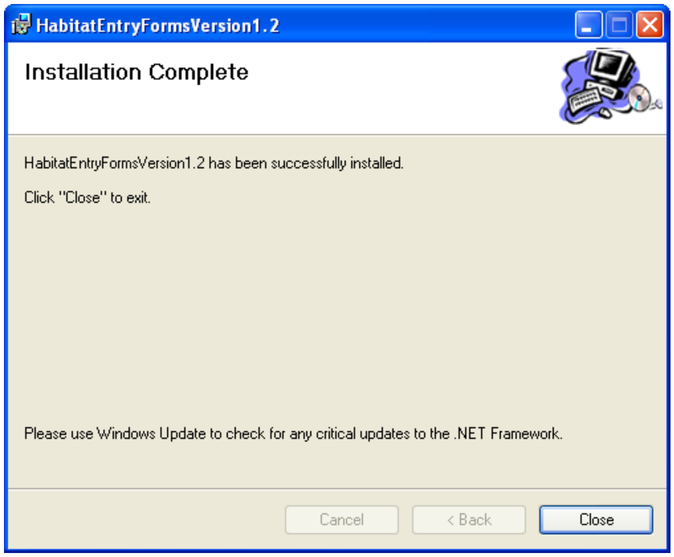

Figure 3. Final screen for installing application.

8. Click "Close" and the icon shown in step 3 will appear on your desktop.

III. Working with Entry Forms

Click on the HabitatEntryFromsver 1.2 icon to start the application. The form that the user first views is the "Home" form. All the rest of the forms allow the end user to enter new data, update existing data, or delete existing data. These forms function as editors and viewers of all data. See below for details on each form available within this application.

iii. Home

This form is the entry and exit point for the application. Using this form allows the user to access all other forms, open, or close the application. This form is the one that allows the end user to access all other forms. You may only close the application using this form.

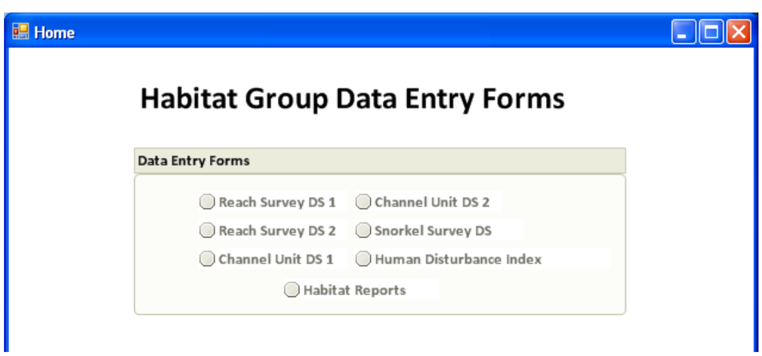

Figure 4. Home form showing the entry and exit point for the application.

1. Click on the circles to get access to any of the forms available. The user can only choose one form at a time for viewing. A check mark will appear in the space provided showing which form is active.
2. After you are finished using the application click the in the right corner of the form to close the application.

Note: When clicking the all other open forms will close.

iv. Field Data edit/entry form

Entering new Field Data

Only one form will allow the user to enter a new Reach. Since all other data forms access the reach data it is essential to ensure that this part of the process is carried out exactly as the directions below describe. The form that allows the user to enter new sets of data for a reach is the Reach Survey Data Sheet(DS) 1 form.

Follow the steps below to enter a new set of datasheets for a reach.

- Select the Reach Survey DS 1 by clicking on the circle to the left of the text.

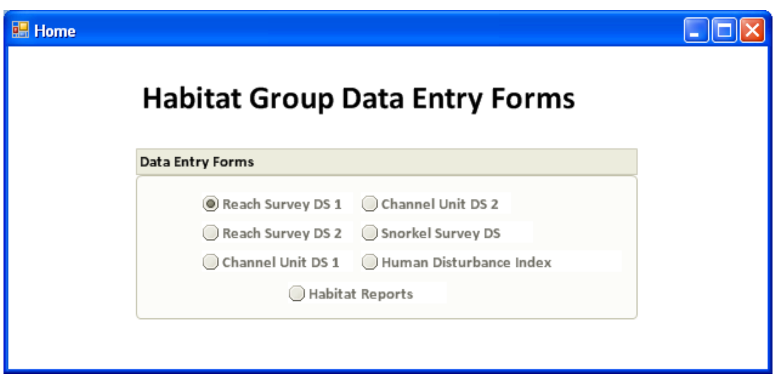

Figure .5 Entry form for the Reach Survey Data Sheet(DS) 1 form selection.

Observe the screen that opens. Do not attempt to overwrite a new reach on top of the data you are observing.

1. Select the from the forms toolbar. This is the only form that contains this icon.

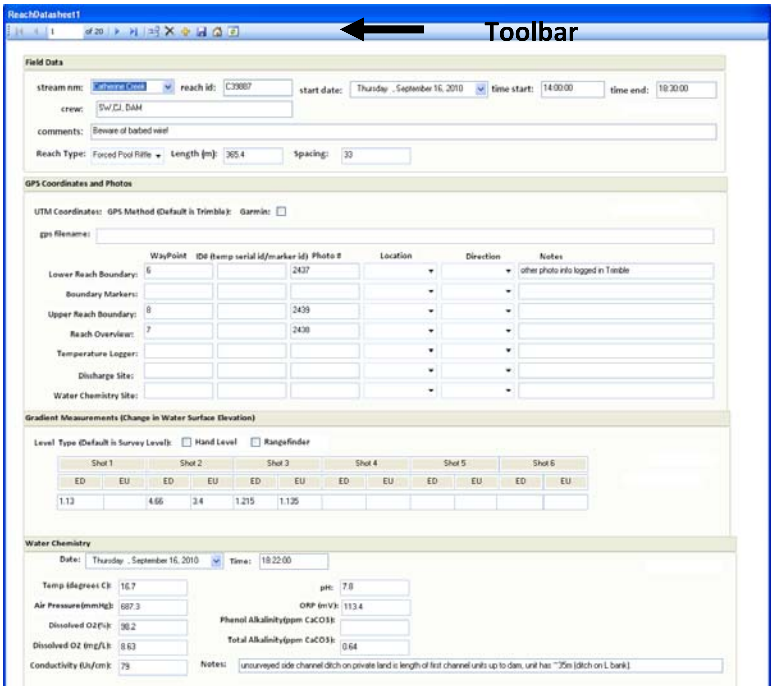

Figure 6. Reach Survey Data Sheet(DS) 1 form and location of the toolbar.

2. Ensure that all the text boxes are blank and one more was added to the scroll icons in the toolbar. If no, then repeat the step above.

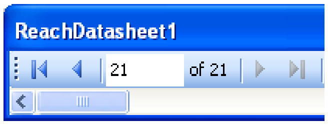

Figure 7. Scroll icons on the toolbar.

3. Enter the stream nm: by selecting a choice from the drop down list. Select tab or enter to move to the next box.

Note: If a stream name is not available. The stream name will need to be added to the Hb_Field_Stream_code table in the GrandeRonde database.

4. Enter the reach id either by pressing enter or using the tab key to scroll through the items. Select tab or enter to move to the next.
5. Enter the start date by selecting the drop down arrow and calendar module. Select tab or enter to move to the next. This is essential since code is included in this text box that will save the

new data in the backend database. Make sure you enter a date and reach id prior to leaving this box or an error will appear.

6. Enter the Time Start and Time End: using the 24 format separated by a colon “00:00”. Select tab or enter to move to the next.
7. Enter the crew’s first and last initials separated by commas. Select tab or enter to move to the next.
8. Continue entering data in the respective textboxes and use the tab key or enter key to scroll through the data.

Updating Field Data

The only form where field data that includes reach or start_date information can be updated is the Reach Survey Data Sheet(DS) 1 form shown in the section above. Please follow the instructions below to update field data. Field data refers to the reach_id and start_date.

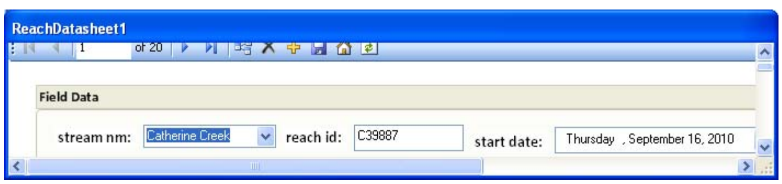

Figure 8. Input boxes where changing of the field_id data (reach id and start date) are to occur.

These data create the field_id (not shown). If the reach_id or start_date are updated in the other forms then the field_id would no longer match up with the reach_id or start_date. To prevent this from happening follow the instructions below. This is not a serious issue, but it is nice for data to be consistent.

1. Enter the updated value into the reach id box or start date box.
2. Select the  icon from the toolbar.
3. Observe the warning box that appears on the desktop.
4. Select the “Yes” to allow the update to occur, select “No” to cancel the procedure.
5. Ensure that the value was changed and that the data reported is similar to what was reported before the change occurred.

Deleting Field Data

If the entire set of reach data was corrupted there is a method to delete the entire set of data. This can be done only using the Reach Survey Data Sheet(DS) 1 form. This procedure will eliminate the data associated with the reach and start_date on all forms. This procedure cannot be undone.

Navigate to the appropriate reach from which you would like to delete all associated data.

1. Select the ✖ from the toolbar
2. Observe the warning box that appears on the desktop.
3. Select the “Yes” to allow the deletion to occur, select “No” to cancel the procedure.
4. Verify that the data was in fact deleted and is not longer available from the scroll bar.

Closing the Form

After you are finished with the field data editing, do the following to close the form.

Select the [Home icon] from the toolbar and the Home screen will appear on the desktop.

v. Data edit/entry forms

The ability of add new field data to the other entry forms is not available. If you need to add a new reach please see the section above. The following sections deal with the rest of the entry forms available from the application. There are a couple types of entry procedures. The forms contains input boxes, input boxes within datagrids, and related datagrids. Regarding the related datagrids see the procedure for editing data within the LWD and spawning patch sections. This data entry procedure requires that the user enter the appropriate channel units prior to entering the spawning patch information. Please see the following sections for details. The grids within the data forms were created to allow the user to enter data one column at a time using the enter key to navigate through the rows.

Entering/Editing/Deleting Data in the Reach Survey DS2 Form

1. Select the Reach Survey DS 2 entry form.

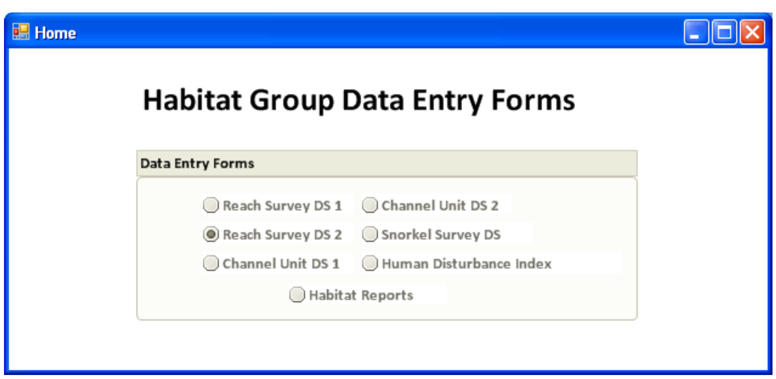

Figure 9. Display of the Reach Survey DS 2 entry form.

2. Observe the screen now displayed on the desktop it should resemble the following.

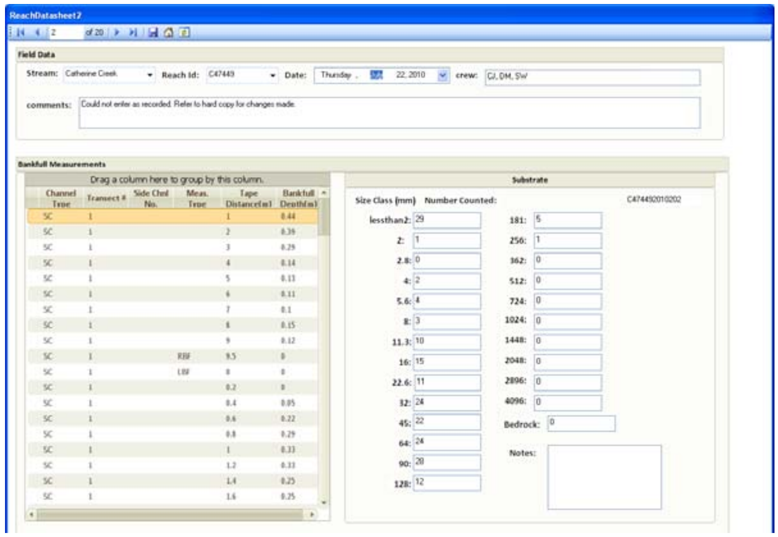

Figure 10. Screen shot of the Reach Survey DS 2 entry form

3. Use the near the scroll icon in the toolbar to navigate to the appropriate reach id.
4. Note the reach_ids are ordered alphabetically.
5. Tab through the input boxes to the “date”.
6. Select the “date” from the drop down arrow.
7. Enter, edit or delete the “comments” input box.
8. Select the “Bankfull Measurements Grid “or “Substrate Section “(if Substrate Section, skip to step# 14).
9. Select a cell and enter or edit data in that cell.

Note: It works well to start entering the tape distance first. Then all other entries can be added based on the location of the tape distance.

10. Use the enter key to navigate down the column and move to the next column using the arrow keys.
11. Check the data entered in the Tape Distance.

Note: Rows cannot be inserted into the gridview although future versions will allow this functionality.

12. If all data looks ok proceed to enter the rest of the columns of data. If you need to delete a row right click on the row and select “Delete Row”.

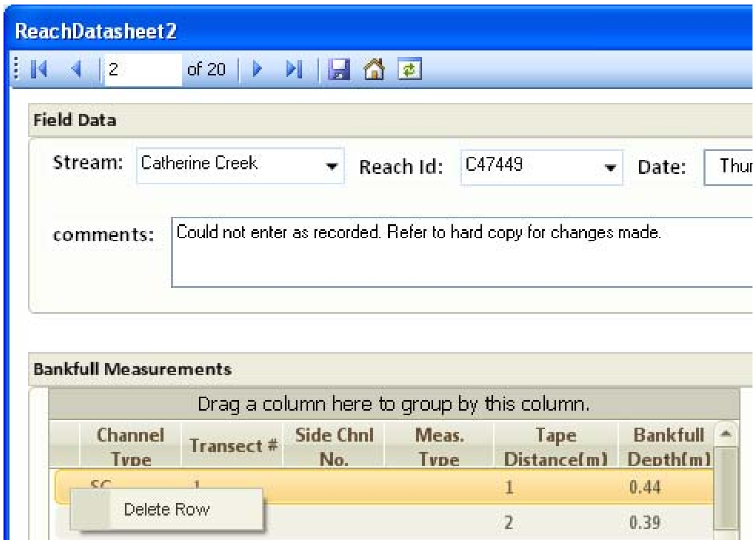

Figure 11. The process of deleting a row from the data grid.

Note: Transect # column accepts only integers. For instance, if a transect cell is report as "1.1" enter a "1" in the transect # column and a "SC" in the channel type column.

13. After all values are entered or edited, check the data.

Note: Channel Type has a default value of MS. Make sure to enter SC for all side channels.

14. Enter the Substrate information.
15. Use the tab or enter key to navigate to the next size class.

Note: Default values are 0, which are added if no other value is entered in a text box. You will not be able to delete the default values and still move to the next substate class.

16. Select the icon to save the data and check the data.
17. Select the from the toolbar and the Home screen will appear on the desktop and close the form.

Entering/Editing/Deleting Data in the Channel unit DS1 Form

1. Select the Channel Unit DS 1 Form on the "Home" form to enter the Channel unit data.

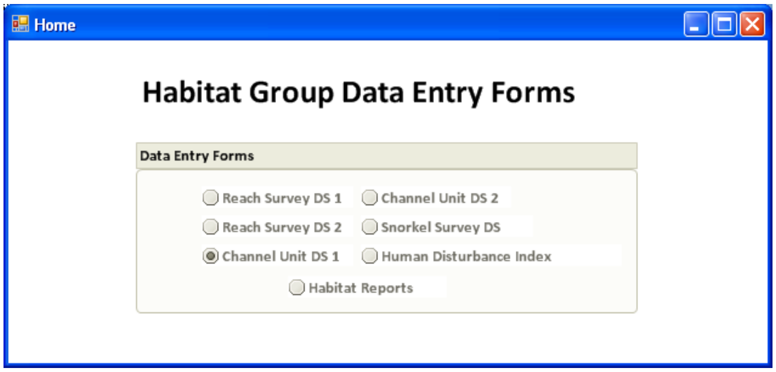

Figure 12. Accessing the Channel Unit DS 1 Form.

2. Observe the Channel Unit DS 1 form on the desktop.

Note: Start with this form and the Channel Unit Description Section for entering Channel Unit data.

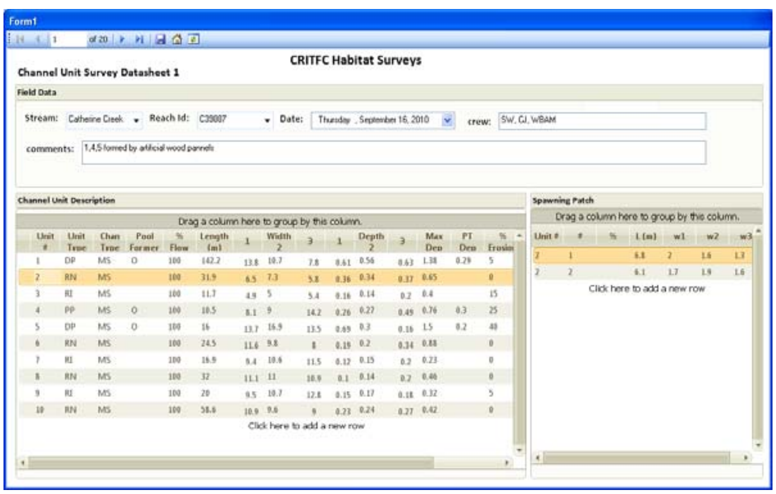

Figure 13. Screen shot of the Channel Unit DS 1 Form showing a selected Channel Unit and associated spawning patches.

3. Use the ▶ near the scroll icon in the toolbar to navigate to the appropriate reach id.
4. Follow steps 1- 7 in the Reach DS 2 Section. Using the Channel Unit DS 1 form.
5. Select the Channel Unit Description grid section.
6. Select a cell and enter or edit data in that cell.
7. Use the enter key to navigate down the column and move to the next column using the arrow keys.
8. Select the icon to save the data and check the data.

9. Follow step 12 in the reach DS 2 section to delete a row and repeat the previous step to save the data.

Entering/Editing/Deleting Data in the Spawning Patch/LWD grid of the Channel unit DS1 and DS2 Forms

1. Select a row in the Channel Unit Description that corresponds to the unit # in which spawning patches are present. Note: the unit# will transfer over from the selected row to the spawning patch grid make sure it is the same #.
2. After you entered data in the row select and check the data.
3. Select the from the toolbar and the Home screen will appear on the desktop and close the form.

Entering/Editing/Deleting Data in the Spawning Patch grid of the Channel unit DS2 Form

1. Select the Channel Unit DS2 form from the “Home” screen.

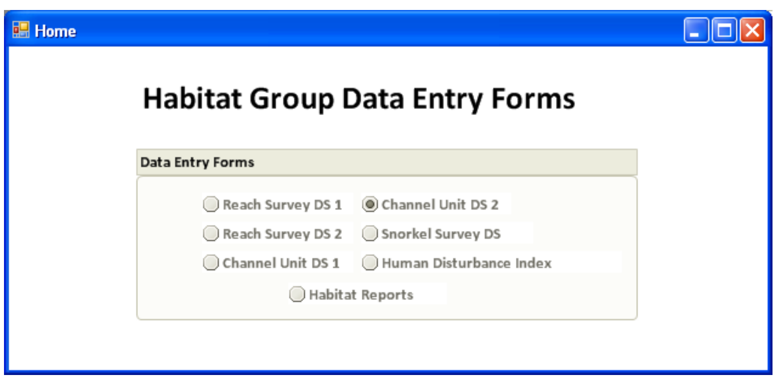

Figure 14. Accessing the Channel Unit DS2

2. Observe the Channel Unit DS2 form and use the near the scroll icon in the toolbar to navigate to the appropriate reach id.
3. Follow steps 3- 7 in the Reach DS 2 Section. Using the Channel Unit DS 2 form.
4. Select the Cover rating grid section.

Note: You must enter data into this section before moving to the LWD section.

5. Select a cell and enter or edit data in that cell.
6. Use the enter key to navigate down the column and move to the next column using the arrow keys.

7. Select the icon to save the data and check the data.
8. Follow step 12 in the reach DS 2 section to delete a row and repeat the previous step to save the data.
9. Select the from the toolbar and the Home screen will appear on the desktop and close the form.
10. See steps 1-3 in the Entering/Editing/Deleting Data in the Spawning Patch/LWD grid of the Channel unit DS1 and DS2 Forms section for entering LWD data into the program.

Entering/Editing/Deleting Data in the Snorkel Survey DS Form

1. Select the Snorkel Survey DS option from the "Home" screen.

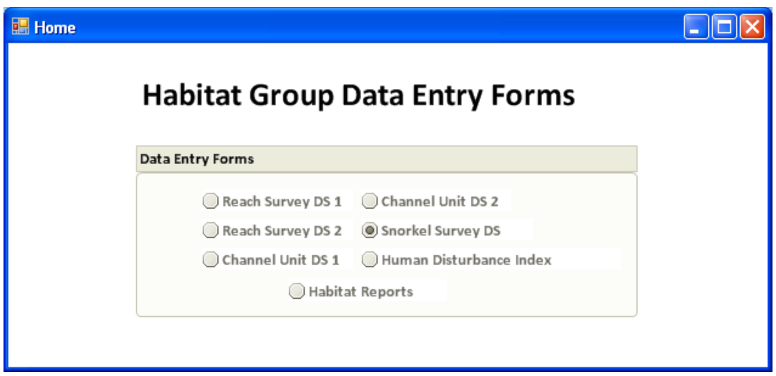

Figure 15. Accessing the Snorkel Survey DS form

2. Observe the Snorkel Survey DS form and use the near the scroll icon in the toolbar to navigate to the appropriate reach id.

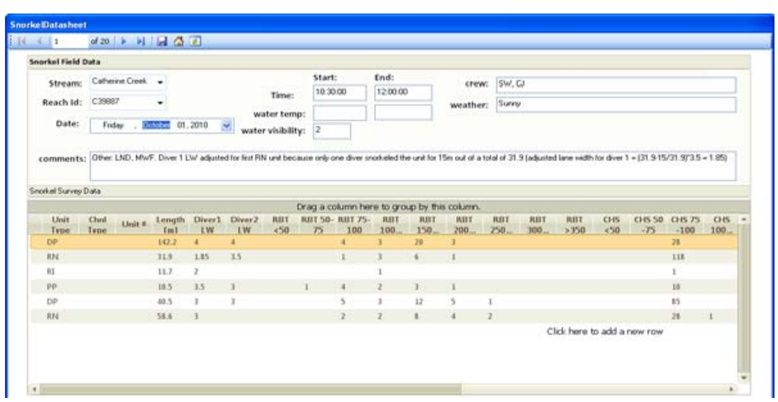

Figure 16. Screen shot of the Snorkel Survey DS Form.

3. Follow steps 3- 7 in the Reach DS 2 Section. Using the Snorkel Survey DS Form.
4. Select the Snorkel Survey Data grid section.

5. Select a cell and enter or edit data in that cell.
6. Use the enter key to navigate down the column and move to the next column using the arrow keys.
7. Select the icon to save the data and check the data.
8. Follow step 12 in the Reach Survey DS 2 section to delete a row and repeat the previous step to save the data.
9. Select the from the toolbar and the Home screen will appear on the desktop and close the form.

Entering/Editing/Deleting Data in the Human Disturbance DS Form

1. Select the Snorkel Survey DS option from the "Home" screen.

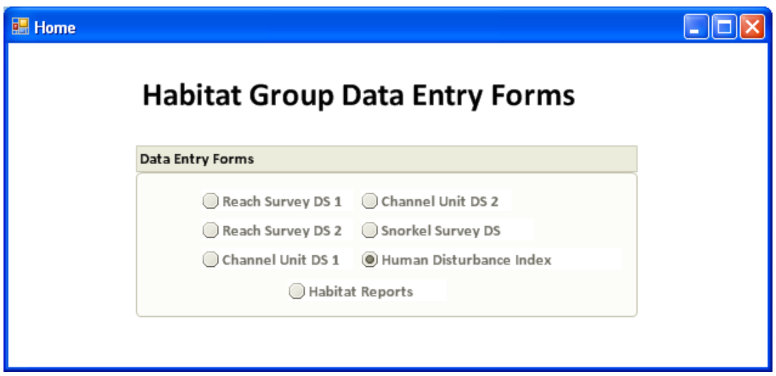

Figure 17. Accessing the Human Disturbance DS form

2. Observe the Snorkel Survey DS form and use the near the scroll icon in the toolbar to navigate to the appropriate reach id.

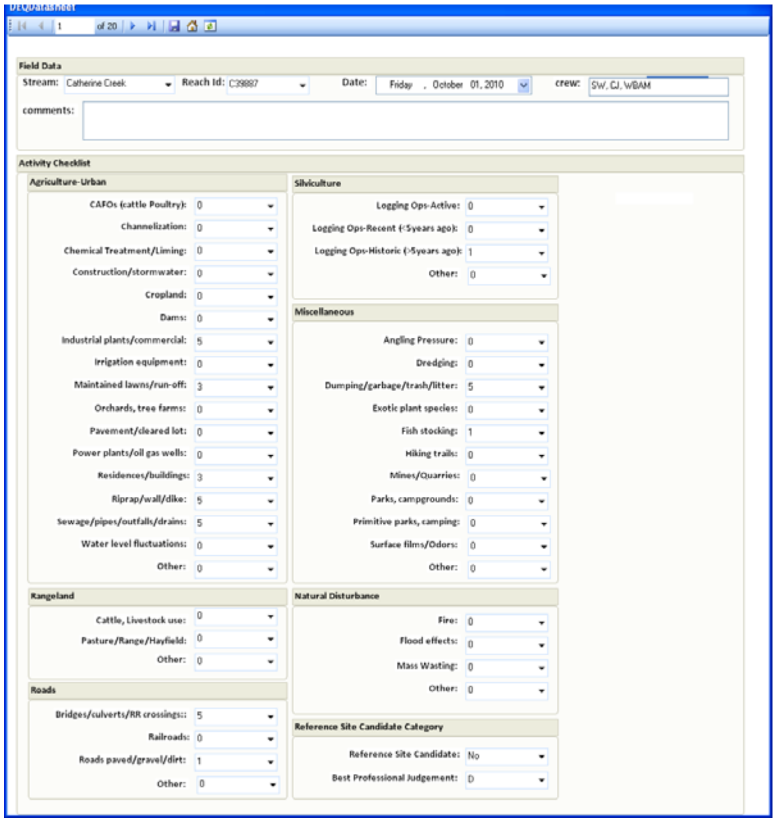

Figure 18. Screen shot of the Human Disturbance DS Form.

3. Follow steps 3- 7 in the Reach DS 2 Section. Using the Human Disturbance DS Form.
4. Select the activity checklist section section.
5. Use the mouse to enter data where necessary.
6. Select the arrow key next to the input box and select a number from the drop down list.
7. Note: If no values are added to an input box then the defaults are “0”. Therefore, only values that are not = “0” are required to enter to this form.
8. Select the  icon to save the data and check the data.
9. Select the  from the toolbar and the Home screen will appear on the desktop and close the form.

IV. Working with the Reporting Module

1. Please create a folder named "export" within your C: drive.
2. Select the Habitat Report option from the “Home” screen.

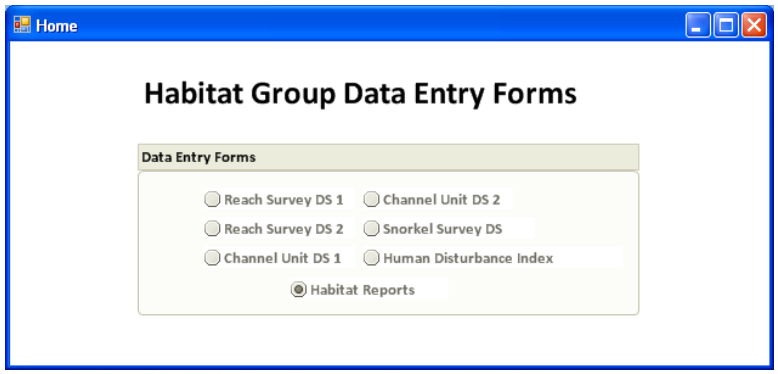

Figure 19. Accessing the Habitat Reports

3. Observe the Habitat Reports choices in the box and use the mouse to click on one.

Figure 20. Screen shot of available Habitat reports.

4. View the data in the grid to make sure you want that report and view the report in the following location: C:/export

Note: You may select as many reports as you would like to create. The reports created in the exports folder (Table 1) are associated with the available columns in each of the reports listed in Appendix A.

Table 1. Available reports and associated names of reports exported to C:/exports.

Available Reports	Reports in C: export Folder	File Type
Reach Scale Metrics	reach_scale_metrics	.txt
Reach-Scale Bankfull	Reach_scale_Bankfull	.csv
Reach-Scale Substrate	Reach_Scale_Substrate	.csv
Snorkel Data	Reach_scale_Snorkel	.txt
Human Disturbance	Reach_scale_Human	.csv
Channel Unit Metrics	Channel_Unit_Metrics	.csv

5. To open the .txt file using excel, right click on the report and select open with excel.
6. Select the first column and scroll to the “Data” tab in excel select “Text to Columns”
7. Observe the wizard screen and follow prompts

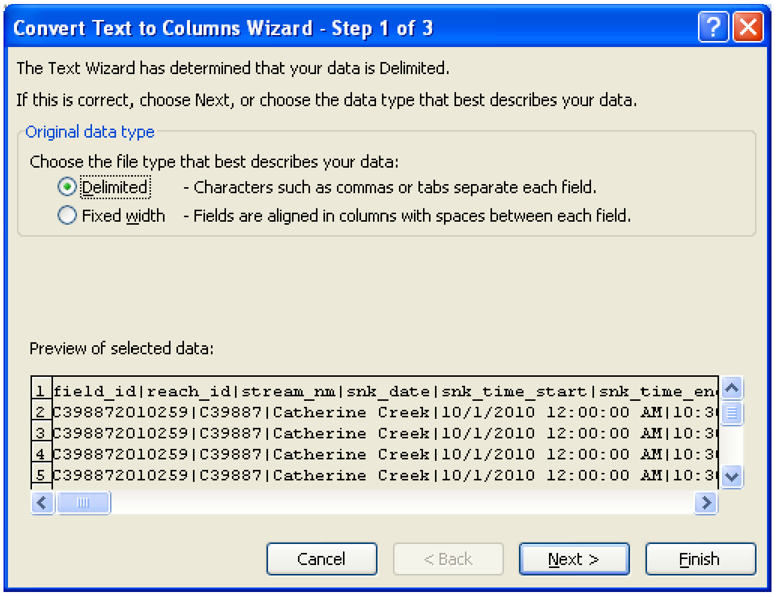

Figure 21. Screen shot of convert Text to columns wizard.

8. Un select the "tab" delimiter and select "Other"
9. Enter a "|" in the input box next to other and select "Finish".

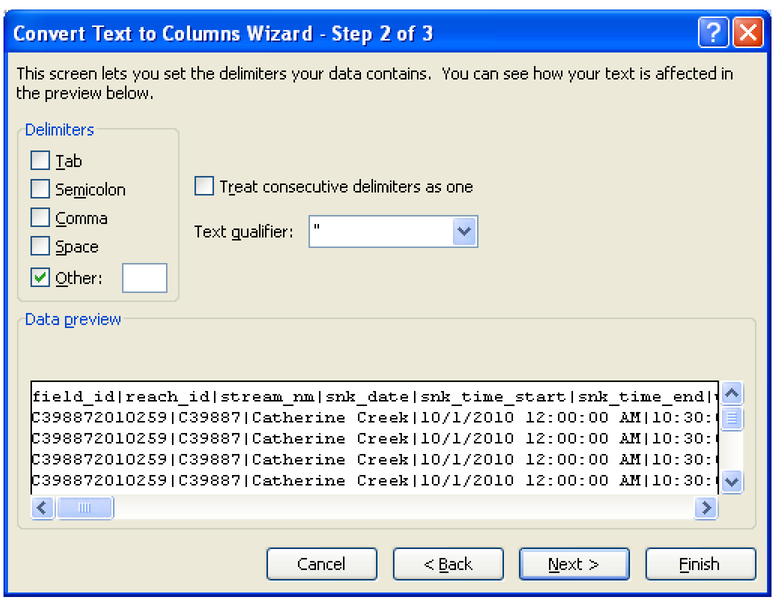

Figure 22. Screen shot of delimiter selected to view the data correctly.

10. Observe the data and save as excel if necessary.

V. Un-installation

To un-install the application please navigate to the control panel and select “Add Remove Program”. Select the ‘HabitatEntryFormsVersion1.2 application and choose remove.

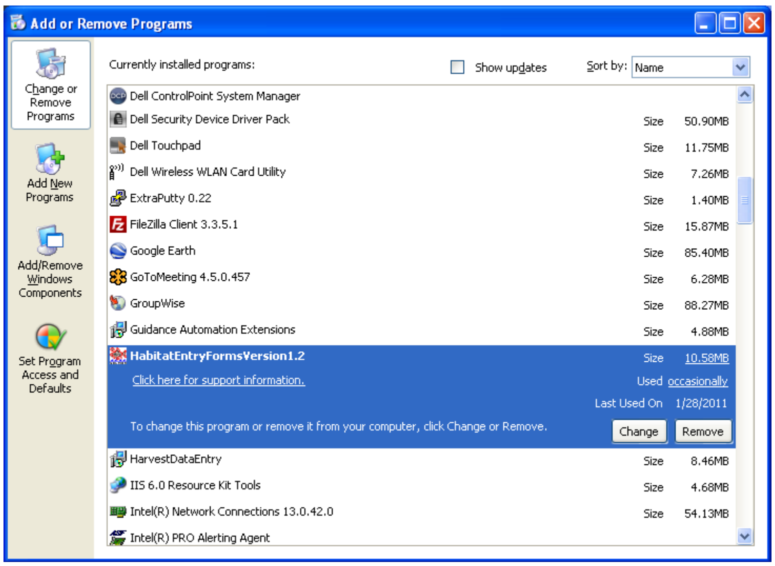

Figure 23. Screen shot of Add or Remove Programs Windows Application.
Click “Yes” to un-install program and wait until finished.

COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION
729 NE Oregon, Suite 200, Portland, Oregon 97232

VI. Appendix A:

(Note: metrics in **bold type** are directly entered from data sheets; metrics in **red bold type** are calculated)

Channel Unit Metrics Report

General (note: these three metrics will be identical with reach-scale data, can be used for cross-referencing)

stream_nm – Name of stream (text)
reach_id – Reach ID number (text, usually a capital letter [U, C, M, or W] followed by a five digit number)
start_date – Date of survey (European date format e.g., 08-Sep-2010)
crew – Initials of crew members

Channel unit characteristics

unit_no – Sequential unit numbering from downstream to upstream (integers 1-100)
chnl_date – Date of survey (European date format e.g., 08-Sep-2010)
unit_typ – Channel unit type (categorical PP, SP, BP, DP, TP, STP, RN, ST, RI, RA, CA, FA, DC, PD, OT)
chan_typ – Channel type designating mainstem or side channel (categorical MS, SC)
pool_frm – Pool former (required only if unit_typ = PP, SP, BP, DP, TP, or STP; categorical W, R, T, B, BR, CB, RB, BD, O)
per_flw – Estimated percent (%) of total flow of mainstem or side channel (continuous 0-100; note: if chan_typ = SC then per_flow must be less than 100)
unit_lng – Longitudial stream length (m) of wetted channel unit (continuous 0-1000)
unit_avwd – Average of three measured wetted widths (m) of channel unit (continuous 0-100)
unit_ar – Surface area (m^2) of wetted channel unit (continuous 0-100)
unit_avdp – Average of three measured wetted depths (m) of channel unit (continuous 0-5)
unit_vol – Volume (m^3) of wetted channel unit (unit_lng * unit_avwd * unit_avdp; continuous 0-100)

unit_mxdp – Maximum wetted depth (m) of channel unit (continuous 0-5)
unit_ptdp – Pool tail depth (m) of channel unit (required only if unit_typ = PP, SP, BP, DP, TP, or STP; continuous 0-1)
unit_resdp – Residual pool depth (unit_mxdp – unit_ptdp; required only if unit_typ = PP, SP, BP, DP, TP, or STP
per_ersn – Percent (%) erosion of channel unit (continuous 0-100)

Spawning patches

no_spwn – Number of spawning patches in channel unit (integer 0-10)

per_spwn – Percent of total channel unit area composed of spawning patches(continuous 0-100)
area_spwn – Total area of spawning patches in channel unit (continuous 0-100). In some cases, length and width of spawning patches were not measured. In these cases, area_spwn is calculated by multiplying per_spwn by unit_ar, divided by 100. If length and width of spawning patches were measured, area_spwn in calculated by multiplying patch length by average patch width.

Large woody debris
lwd_no – Number of pieces of large woody debris in channel unit (integer 0-50)
lwd_nat – Number of NATURAL pieces of large woody debris in channel unit (integer 0-50)
lwd_art – Number of ARTIFICAL pieces of large woody debris in channel unit (integer 0-50)
lwd_vol – Volume (m^3) of large woody debris in channel unit (continuous 0-1000)
lwd_volnat – Volume (m^3) of NATURAL large woody debris in channel unit (continuous 0-1000)
lwd_volart – Volume (m^3) of ARTIFICAL large woody debris in channel unit (continuous 0-1000)
lwd_nokey – Number of KEY pieces of large woody debris in channel (as defined by ODFW > 0.60m width and >12m length) (integer 0-50)

Cover ratings
cov_filalg – Cover rating for filamentous algae (integer 0-6)
cov_macphy – Cover rating for macrophytes (integer 0-6)
cov_lwd – Cover rating for large woody debris (integer 0-6)
cov_brsh – Cover rating for brush (integer 0-6)
cov_oveg – Cover rating for overhanging vegetation (integer 0-6)
cov_ubnk – Cover rating for underhanging bank (integer 0-6)
cov_bld – Cover rating for boulders (integer 0-6)
cov_art – Cover rating for artificial structures (integer 0-6)
cov_tot – Sum total of all cover ratings in each channel unit (continuous 0-48)
cov_qual_tot – Sum total of all cover ratings except filamentous algae in each channel unit (continuous 0-48)

Reach-scale metrics Report

General (note: these three metrics will be identical with habitat unit-scale data, can be used for cross-referencing)
stream_nm – Name of stream (text) Note: We should apply a standard format for stream names to ensure that we don't have multiple different names for the same stream. I would prefer spelling out the entire stream name, using capital letters for each component of the stream name (e.g. Grande Ronde River, Sheep Creek)

reach_id – Reach ID number (text, usually a capitol letter [U, C, M, or W] followed by a five digit number)
surv_date – Date of survey (European date format e.g., 08-Sep-2010)

Overview reach characteristics
crew – Comma-separated list of crew members' initials (text, capital letters separated by comma and space)
rch_start_t – Time survey was started (24-hour format)
rch_end_t – Time survey was ended (24-hour format)
rch_total_t – Total time taken to complete survey (24-hour format)
rch_comments – Comments about the reach (text)
rch_mb_typ – Montgomery & Buffington reach type (categorical text: cascade, step pool, plane bed, pool riffle, dune ripple, colluvial, forced pool-rifle)
rch_lng – Length of reach (m) (continuous 100-800)
trns_spac – Transect spacing (m) (continuous 10-80)
gps_typ – Type of GPS used (Categorical: Trimble or Garmin)
gps_filename – Name of gps file (only applicable if using the Trimble)
lwr_loc_n,lwr_loc_e – UTM of exact downstream boundary (Datum NAD-83, Zone 11)
upr_loc_n,upr_loc_e– UTM of exact upstream boundary (Datum NAD-83, Zone 11)
over_loc_n, over_loc_e - UTM of reach overview photo (Datum NAD-83, Zone 11)
lwr_pic – Reference number of lower reach boundary photo (integer)
upr_pic – Reference number of upper reach boundary photo (integer)
over_pic – Reference number of reach overview photo (integer)
lwr_cam_loc – Location where the photographer is standing (left bank (LB), right bank (RB), mid channel (MC) for the lower boundary photo.
lwr_cam_dir – Direction the camera is facing (upstream (US), downstream (DS), left bank (LB), right bank (RB) for the lower boundary photo.
upr_cam_loc – Location where the photographer is standing (left bank (LB), right bank (RB), mid channel (MC) for the upper boundary photo.
upr_cam_dir – Direction the camera is facing (upstream (US), downstream (DS), left bank (LB), right bank (RB) for the upper boundary photo.
over_cam_loc – Location where the photographer is standing (left bank (LB), right bank (RB), mid channel (MC) for the reach overview photo.
over_cam_dir – Direction the camera is facing (upstream (US), downstream (DS), left bank (LB), right bank (RB) for the reach overview photo.

Gradient

rch_grad – Calculated reach gradient from field measurements (vs. GIS-calculated) (percent (rise/run * 100)). To calculate rise, calculate the elevation difference for each shot, then sum the elevation differences from all shots. Run is given by the reach length. Calculations will vary if using the rangefinder. (See Casey for specifics).
level type – type of level used to measure gradient (surveying level, hand level, or laser rangefinder)

Water chemistry
chem_date – Date that water chemistry metrics were taken, can be different than habitat survey date (European date format)
chem_t – Time of day water chemistry measurements taken (24-hour format)
inst_tmp – Instantaneous water temperature taken in field (^{o}C) (continuous 5-30)
air_prss – Air pressure (mmHg) (continuous)
per_do – Percent dissolved oxygen (%L) (continuous 0-100)
std_do – Standard measure of dissolved oxygen (mg/L) (continuous)
cond – Conductivity (µS/cm)
ph - pH
orp – Oxidative reductive potential (mV) (continuous) (ml)
phn_alk – Phenothalene alkalinity amount (continuous) (ml)
tot_alk – Total alkalinity titration amount (continuous) (ml)

Bankfull channel profile
bkf_wd – Average bankfull width (m) of transects for entire reach (continuous)
bkf_dp – Average bankfull depth (m) of transects for entire reach (continuous)
bkf_rat – Bankfull width to depth ratio of transects for entire reach (continuous)
bkf_side_wd – Average bankfull width (m) of side channel transects for entire reach (continuous)
bkf_side_dp – Average bankfull depth (m) of side channel transects for entire reach (continuous)
bkf_side_rat – Bankfull width to depth ratio of transects for entire reach (continuous)
rch_dp – Average water depth for entire reach (calculate average bankfull depth from all measurements between LEW and REW and subtract the average bankfull depth for LEW and REW; see Casey for details).

Values calculated from Channel Unit Data
no_units – Total number of channel units in reach (integer: 1-100)
side_tot_ln – Length (m) of all side channels in reach
side_wet_ln – Length (m) of wetted side channels in reach
side_wet_ar – Surface area (m^2) of wetted side channels in reach
pool_ar – Total area (m^2) of pools in reach (for unit_typ = PP, SP, BP, DP, TP, or STP) (continuous)
pool_vol – Total volume (m^3) of pools in reach (for unit_typ = PP, SP, BP, DP, TP, or STP) (continuous)

run_ar – Total area (m²) of runs in reach (unit_typ = RN) (continuous).
run_vol – Total volume (m³) of runs in reach (unit_typ =RN) (continuous).
rif_ar – Total area (m²) of riffles in reach (unit_typ = RI) (continuous).
rif_vol – Total volume (m³) of riffles in reach (unit_typ =RI) (continuous).
ra_ar – Total area (m²) of rapids in reach (unit_typ = RA) (continuous).
ra_vol – Total volume (m³) of rapids in reach (unit_typ =RA) (continuous).
ca_ar – Total area (m²) of cascades in reach (unit_typ = CA) (continuous).
ca_vol – Total volume (m³) of cascades in reach (unit_typ =CA) (continuous).
avg_pool_dp –Average depth of pools in reach (unit_typ = PP, SP, BP, DP, TP, or STP)
avg_res_dp – Average residual depth of pools in reach (unit_typ = PP, SP, BP, DP, TP, or STP)
wtavg_ersn – Weighted average percent erosion for all channel units in the reach, where weights are given by the length of each unit.
wtavg_cov – Weighted average of cov_tot for all channel units in the reach, where weights are given by the length of each unit.
wtavg_cov_qual – Weighted average of cov_qual_tot for all channel units in the reach, where weights are given by the length of each unit.
rch_lwd_no – Sum of lwd_no for all channel units in reach (integer 0-100)
rch_lwd_nat – Sum of lwn_nat for all channel units in reach (integer 0-100)
rch_lwd_art – Sum of lwd_art for all channel units in reach (integer 0-100)
rch_lwd_vol – Sum of lwd_vol for all channel units in reach (continuous 0-1000)
rch_lwd_volnat – Sum of lwd_volnat for all channel units in reach (continuous 0-1000)
rch_lwd_volart – Sum of lwd_volart for all channel units in reach (continuous 0-1000)
rch_lwd_nokey – Sum of lwd_nokey for all channel units in reach (integer 0-100)
rch_area_spwn – Sum of area_spwn for all channel units in reach (continuous 0-1000)
pa_rbt – Presence (1) or absence (0) of rainbow trout observed in channel unit
pa_chs_juv – Presence (1) or absence (0) of juvenile Chinook salmon observed in channel unit
pa_chs_adlt – Presence (1) or absence (0) of adult Chinook salmon observed in channel unit
pa_bt – Presence (1) or absence (0) of bull trout observed in channel unit
pa_rss – Presence (1) or absence (0) of Reside shiners observed in channel unit
pa_npm – Presence (1) or absence (0) of Northern pikeminnow observed in channel unit
pa_skd – Presence (1) or absence (0) of speckled dace observed in channel unit
pa_lnd – Presence (1) or absence (0) of longnose dace observed in channel unit
pa_cott – Presence (1) or absence (0) of Cottid *sp.* observed in channel unit
pa_cato – Presence (1) or absence (0) of Catostomid *sp.* observed in channel unit
pa_catf – Presence (1) or absence (0) of catfish observed in channel unit
pa_cent – Presence (1) or absence (0) of Centrarchid *sp.* observed in channel unit
pa_mwf – Presence (1) or absence (0) of mountain whitefish observed in channel unit

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Reach-Scale Substrate Report

Create separate table for entry of surface substrate data. The table should include 2 columns, one for size class (mm) and one for count. Then use methods described in Bunte and Abt (2001) to calculate percentile values (D5, D16, D25, D50, D75, D84, and D95). Size classes include <2, 2, 2.8, 4, 5.6, 8, 11.3, 16, 22.6, 32, 45, 64, 90, 128, 181, 256, 362, 512, 724, 1024, and 1448mm.

Reach-scale snorkel data Report

snrk_date – Date that snorkel survey was conducted (European date format)
snrk_ start_t – Time (24-hour format) of snorkel survey start
snrk_ end_t – Time (24-hour format) of snorkel survey start
snrk_ total_t – Total time snorkeling (24-hour format)
snrk_start_tmp – Temperature at snorkeling start (^{o}C)
snrk_end_temp – Temperature at snorkeling end (^{o}C)
snrk_av_temp – Average temperature of snorkeling period (^{o}C)
snrk_visb – Visibility (ranked integer: 0-3)
snrk_diver – Snorkelers' initials (comma-separated text)
snrk_weath – Short description of weather (text)
snrk_com – Other comments on snorkeling (text)
Habitat unit and reach-scale snorkel data
snrk_unit_typ – [Habitat unit only] Channel unit type during snorkel survey (same categories as unit_typ)
snrk_ar – Area of channel unit (or units in case of reach) (m^2) surveyed by both snorkelers combined [THIS METRIC WILL MOST OFTEN COME FROM SNORKEL DATA SHEET, BUT SOMETIMES COME FROM HABITAT UNIT DATA. In some cases, snorkelers estimated their lane widths, which should be used to calculate snrk_ar.]
no_rbt_und_50 – Number of rainbow trout < 50 mm
no_rbt_50 – Number of rainbow trout 50-75 mm
no_rbt_75 – Number of rainbow trout 75-100 mm
no_rbt_100 – Number of rainbow trout 100-150 mm
no_rbt_150 – Number of rainbow trout 150-200 mm
no_rbt_200 – Number of rainbow trout 200-250 mm
no_rbt_250 – Number of rainbow trout 250-300 mm
no_rbt_300 – Number of rainbow trout 300-350 mm
no_rbt_350 – Number of rainbow trout 350-400 mm
no_rbt_ovr_350 – Number of rainbow trout > 400 mm
no_rbt – Total number of rainbow trout observed in all size classes
dns_rbt_und_50 – Density of rainbow trout (no_rbt_xxx/snrk_ar [m^2]) < 50 mm

dns_rbt_50 – Density of rainbow trout (no_rbt_xxx/snrk_ar [m^2]) 50-75 mm
dns_rbt_75 – Density of rainbow trout (no_rbt_xxx/snrk_ar [m^2]) 75-100 mm
dns_rbt_100 – Density of rainbow trout (no_rbt_xxx/snrk_ar [m^2]) 100-150 mm
dns_rbt_150 – Density of rainbow trout (no_rbt_xxx/snrk_ar [m^2]) 150-200 mm
dns_rbt_200 – Density of rainbow trout (no_rbt_xxx/snrk_ar [m^2]) 200-250 mm
dns_rbt_250 – Density of rainbow trout (no_rbt_xxx/snrk_ar [m^2]) 250-300 mm
dns_rbt_300 – Density of rainbow trout (no_rbt_xxx/snrk_ar [m^2]) 300-350 mm
dns_rbt_350 – Density of rainbow trout (no_rbt_xxx/snrk_ar [m^2]) 350-400 mm
dns_rbt_ovr_350 – Density of rainbow trout (no_rbt_xxx/snrk_ar [m^2]) > 400 mm
dns_rbt – Density of rainbow trout (no_rbt_xxx/snrk_ar [m^2]) in all size classes
no_chs_und_50 – Number of rainbow trout < 50 mm
no_ chs _50 – Number of Chinook salmon 50-75 mm
no_ chs _75 – Number of Chinook salmon 75-100 mm
no_ chs _100 – Number of Chinook salmon 100-150 mm
no_ chs _150 – Number of Chinook salmon 150-200 mm
no_chs_adlt – Number of adult Chinook salmon
no_chs_juv – Total number of juvenile (non-adult) Chinook salmon
dns_chs_und_50 – Density of Chinook salmon (no_chs_xxx/snrk_ar [m^2]) < 50 mm
dns_chs_50 – Density of Chinook salmon (no_chs_xxx/snrk_ar [m^2]) 50-75 mm
dns_chs_75 – Density of Chinook salmon (no_chs_xxx/snrk_ar [m^2]) 75-100 mm
dns_chs_100 – Density of Chinook salmon (no_chs_xxx/snrk_ar [m^2]) 100-150 mm
dns_chs_150 – Density of Chinook salmon (no_chs_xxx/snrk_ar [m^2]) 150-200 mm
dns_chs_adlt – Density of adult Chinook salmon (no_chs_adlt/snrk_ar [m^2])
dns_chs_juv – Density of juvenile Chinook salmon (no_chs_juv/snrk_ar [m^2])
dns_chs_juv_pl – [Reach-scale only] Density of juvenile Chinook salmon (no_chs_juv/snrk_ar [m^2]) in pools only (snrk_unit_typ = PP, SP, BP, DP, TP, or STP)
no_bt – Number of bull trout observed in channel unit
dns_bt – Density of bull trout (no_bt/snrk_ar [m^2] observed in channel unit

Human Disturbance Report

Human disturbance (ranked integer values: 0, 1, 3, or 5 unless noted otherwise)
hdi_ag_cafo – Cattle & poultry
hdi_ ag_chan – Channelization
hdi_ ag_chem – Chemical treatment/liming
hdi_ ag_cnst – Construction/storm water
hdi_ ag_crop – Cropland
hdi_ ag_dam – Dams

hdi_ ag_ind – Industrial plants/commercial
hdi_ ag_irr – Irrigation equipment
hdi_ ag_lwn – Maintained lawns/run-off
hdi_ ag_orch – Orchards, tree farms
hdi_ ag_pav – Pavement/cleared lot
hdi_ ag_pwr – power plants/oil/gas wells
hdi_ ag_rsd – Residences/buildings
hdi_ ag_ripr – Riprap/wall/dike
hdi_ ag_swg – Sewage/pipes/outfalls/drains
hdi_ ag_flct – Water level fluctuations
hdi_ ag_oth – Other disturbances in the agriculture-urban category
hdi_ag_max – Maximum score in the above agriculture-urban category
hdi_rng_catt – Cattle, livestock use
hdi_rng_past – Pasture/range/hayfield
hdi_rng_oth - Other disturbances in the rangeland category
hdi_rng_max – Maximum score in the above rangeland category
hdi_rd_brdg – Bridges/culverts/RR crossings
hdi_rd_rr – Railroads
hdi_rd_rd – Roads paved/gravel/dirt
hdi_rd_oth – Other disturbances in the roads category
hdi_rd_max – Maximum score in the above roads category
hdi_slv_lgact – Logging ops – active
hdi_slv_lgrec – Logging ops – recent (< 5 years ago)
hdi_slv_lghis – Logging ops – history (> 5 years ago)
hdi_slv_oth – Other disturbances in the silviculture category
hdi_slv_max – Maximum score in the above silviculture category
hdi_msc_angl – Angling pressure
hdi_msc_drdg – Dredging
hdi_msc_dmp – Dumping/garbage/trash/litter
hdi_msc_exot – Exotic plant species
hdi_msc_stock – Fish stocking
hdi_msc_hik – Hiking trails
hdi_msc_min – Mines/quarries
hdi_msc_park – Parks, campgrounds
hdi_msc_surf – Surface films/odors
hdi_msc_oth – Other disturbances in the miscellaneous category
hdi_msc_max – Maximum score in the above miscellaneous category
hdi_nat_fire – Fire

hdi_nat_fld – Flood effects
hdi_nat_msw– Mass wasting (landslides)
hdi_rchscore – Sum of maximum scores from each human disturbance category (i.e., sum of hdi_xxx_max scores) NOT INCLUDING natural disturbance (i.e., hdi_nat_xxx) (integer: 0-25)
hdi_refcand – Whether or not (Y or N) the reach is a candidate reference site
best_jdg – Best professional judgment grade (categorical: A-F)

Not Yet Reported

Benthic macroinvertebrates
rivpacs_sc – Calculated RIVPACS score
ephm_dens – Density (no./m2)
plech_dens
trich_dens
ept – Calculated Ephemeroptera, Plechoptera, and Trichoptera index

Not yet reported

Subsurface sediment
Create separate table for entry of subsurface sediment data. The table should include 2 columns, one for size class (mm) and one for weight (g). Then use methods described in Bunte and Abt (2001) to calculate percentile values (D5, D16, D25, D50, D75, D84, and D95). Size classes include 0.125, 0.355, 0.85, 2, 3.35, 4, 6.3, 8, 11.2, 16, 31.5, and 63mm.

Appendix C

Intragravel dissolved oxygen, hydraulic conductivity, and vertical hydraulic gradient (head)

Intragravel dissolved oxygen, hydraulic conductivity, and vertical hydraulic gradient (head)

Hydraulic gradient and hydraulic conductivity work jointly in determining apparent flow velocity through the spawning gravel. Flow velocity determines the ability to remove metabolic wastes from the surface of eggs or alevins incubating in the gravels. Flow velocity and intergravel dissolved oxygen (IGDO) are both vital to the supply of oxygen to developing eggs and alevins. A high IGDO but a low flow velocity result in inadequate transport of DO to the surfaces of eggs or to the gill membranes. These physical and biological linkages are explained in Cuenco and McCullough (1997). Some of the literature illustrating the linkage between flow velocity or IGDO and survival in the incubation life stages was extracted from a comprehensive review of effects of dissolved oxygen by ODEQ (1995).

When water temperatures are high and when embryos are in later stages of development and are larger, metabolic rates tend to increase. Increased metabolic rates result in greater oxygen demand in the intragravel environment, both from living or dead embryos and from other organic matter. At high temperatures the importance of limiting fine sediment in the intergravel environmental is very high. High levels of fine sediment can reduce the permeability (available pore spaces) and with that can reduce hydraulic conductivity.

Measurement of intragravel dissolved oxygen, hydraulic conductivity, and vertical hydraulic gradient (head)

> Excerpt from Cuenco and McCullough (1997) detailing the biological importance of permeability
>
> During incubation, sufficient water must circulate through the egg pocket to supply oxygen and carry away metabolic waste products from embryos. Because the oxygen supply is dependent on the subsurface movement of water in a stream, apparent velocity and permeability of the spawning gravels have been related to spawning success. Apparent velocity is the average rate of seepage expressed as the volume of water flowing per unit time through a unit area of redd (solids plus voids) perpendicular to the direction of flow (Pollard 1955). It is estimated as the product of gravel permeability and hydraulic gradient (Pollard 1955; Vaux 1962). Permeability is the capacity of the gravel to transmit water (Coble 1961). True or pore velocity is the actual velocity of flow through the interstitial spaces and differs from pore to pore (Pollard 1955).
>
> During incubation, sufficient water must circulate through the egg pocket to supply oxygen and carry away metabolic waste products from embryos and alevins. Under natural conditions oxygen lack is a much more likely limiting factor than carbon dioxide excess particularly since it is only under anaerobic conditions that free carbon dioxide can ordinarily reach high levels (Fry 1971). An adequate supply of oxygen depends on the supply of oxygen relative to the oxygen demand of the embryos and alevins. Oxygen supply is a function of interchange between stream and intragravel water or intragravel waterflow (apparent velocity) and stream dissolved oxygen concentration. Stream dissolved oxygen is usually at saturation. Oxygen demand is a function of temperature and stage of development which is critical just before and during hatching (the alevin's respiratory

system is more efficient than the embryo which is limited by the egg capsule, Fry 1971, Donaldson 1955).

Oxygen demand starts out low for newly fertilized embryos and increases to hatching and for alevins (Krogh 1941; Fry 1957; Smith 1957; Davis 1975). Oxygen requirement is basically a function of temperature which sets respiration rate for poikilotherms. In the developing egg, embryo development exerts a high oxygen demand (Smith 1957). To satisfy this demand fully, a high ambient dissolved oxygen concentration is often required. The most critical time for developing eggs as far as oxygen lack is concerned comes just prior to hatching (Lindroth 1942 cited by Fry 1957). Before hatching there is a slight excretion of ammonia only (Smith 1957) while other nitrogenous materials are retained in the egg. The level of protein catabolism is high before, during and after hatching but then settles down to a fairly steady low level which is maintained throughout the yolk-sac stage. Organic matter in the egg pocket can decompose and also consume intragravel oxygen. T

The effect of incubation dissolved oxygen concentration on the survival of eggs and alevins, Sfry has been studied under laboratory conditions (chum, Alderdice et al. 1958; steelhead and chinook, Silver et al. 1963; steelhead and coho, Shumway et al. 1964; sockeye, Brannon 1965; coho, Mason 1969) and under field conditions (chum, Wicket 1954; steelhead, Coble 1961; steelhead and coho newly fertilized egg to 3 weeks post hatch, Phillips and Campbell 1962; pink and chum, McNeil 1969, Wells and McNeil 1970; chum, Koski 1981; rainbow trout, Sowden and Power 1985; chinook, King and Thurow 1991; brown trout, Maret et al. 1993). Although artificial redds may not have the exact morphology of natural redds, IGDO concentrations, temperatures, and fine sediments in artificial redds were not significantly different from those of nearby natural redds (Burton et al. 1990; King and Thurow 1991, Maret et al. 1993)

Excerpts from ODEQ (1995)

Silver et al. (1963) observed that when IGDO in a redd is high, the water velocity necessary for satisfying the requirements on embryos is much less than at moderately reduced oxygen concentrations. Similarly, Shumway et al. (1984) notes that influence of water velocity differences on the size of hatching fry is most pronounced at moderately reduced oxygen concentrations and it decreases at higher concentrations.

It would appear the observations by Coble (1960) may be partially explained by the results and discussion of Silver et al. (1963) and Shumway et al. (1984). Both dissolved oxygen and velocity are important, with the importance of velocity being relatively greater when dissolved oxygen concentrations are moderately reduced (Silver et al. 1963). Most of the dissolved oxygen data presented by Coble, with the exception of one sample near 9 mg/L, appear to be within the "moderately reduced" range.

Procedure

Micro-piezometer insertion into streambed

1. Assemble a steel pointed driver rod and steel slip-fit tube unit.
2. Attach a hammer cap to the top of this unit.
3. Drive the rod and tube into the substrate to the required depth (20 cm)
4. Drive the tube an extra 1 cm into the substrate.
5. Grasp the rod with vice-grip pliers and pull it out of the tube.
6. Insert the micro-piezometer into the tube.
7. Remove the tube by pulling it upward, leaving the micro-piezometer in place at the desired depth.
8. Stomp down the sediment in the vicinity of the micro-piezometer insertion point, allowing fine sediment to infill the crevices around the piezometer tube.

Determining vertical hydraulic gradient

1. Vertical hydraulic gradient (VHG) = $\Delta h/\Delta l$, where Δh is the difference in head between the water level in the piezometer and the level of the stream surface (cm) and Δl is the depth from the streambed surface to the first opening in the piezometer sidewall (normally, the location of the middle of the perforated interval).
2. Measure Δh by inserting an 8-gauge wire with a flat-ground side, scored with large grit sandpaper and chalked down the piezometer tube to a standard depth. Pull out the wire and determine how far below the top of the piezometer tube the water level is. Because the inside diameter of the micro-piezometer is so small, the volume displacement of the wire should be determined to assess the true height of the water within the piezometer.
3. Determine the relative height of the free-flowing water surface by using the same copper rod lowered into a stilling well whose top is at the same elevation with the top of the piezometer and whose bottom is below the water surface level.

4. Calculate the difference in elevations (cm) between the two water surfaces. If the water in the piezometer is higher than inside the stilling well, the VHG is positive. If lower, then the VHG is negative.

Measure IGDO

Intragravel Dissolved Oxygen (IGDO) is measured by drawing a water sample from the depth in the spawning gravel at which salmon eggs are deposited.

1. Attach a short piece of tygon tube to the top of the piezometer. To this is attached an inline shutoff valve. To this is attached another, longer piece of tygon. The other end is attached to a flow cell in which is mounted the YSI dissolved oxygen meter.
2. Allow a volume of water to pass through the flow cell sufficient to fully flush the system with water drawn from the egg pocket depth.
3. Continue using the peristaltic pump to move water through the flow cell past the DO membrane.
4. Read the IGDO levels.
5. Also, use the YSI probe to measure the ambient, surface water DO.
6. Record the water temperature, pH, conductivity, and ORP.

Hydraulic Conductivity

Hydraulic conductivity of streambed sediment is measured using a falling head slug test, which relates the rate of water level change in a narrow well to the horizontal hydraulic conductivity (K_h) of the river substratum.

Equations used for deriving K_h are:

The Hvorslev (1951) equation, or

$$K_h = \frac{(r^2)\log_e\left(L_p / R\right)}{2L_pT_0}$$

where r = micropiezometer radius, L_p L_p = length of the perforations, R = radius of the perforated interval, and T_0 = the basic time lag.

This equation is valid (see Baxter et al. 2003) when L_p / R > 8, the perforated interval is located below the stream bottom, unrestricted flow occurs between the perforated interval and the sediments (i.e., the size and number of perforations do not limit the movement of water between the sediments and piezometer), and the groundwater

movement in the sediment area is not influenced by the presence of an impermeable base or a limited lateral extent of sediments.

The equation used by Baxter and Hauer (2000)

$$K_h = \frac{\pi(d_{piezometer})}{(11)(T_0)}$$

where $(d_{piezometer})$ is the inside diameter of the piezometer.

The Bouwer and Rice (1976) equation

$$K_h = \frac{(r^2)\log_e(R_e / r_w)}{2L_p}(t^{-1} \cdot \log_e \frac{h_0}{h})$$

Baxter et al. (2003) found that if Ls = Lp and $d_{piezometer} = d_{perforated\,interval}$, then this reduces to:

$$K_h = \left[\frac{(0.2501)(d_{piezometer})}{\Delta t}\right]\left[\log_e \frac{h_0}{h}\right]$$

Measure **hydraulic conductivity** by:

1. Attach a long section of tygon tubing to the shutoff valve at the top of the piezometer. This tubing should be totally full of water and held in a U-shape to retain all the water.
2. Position a metric stadia rod next to the piezometer installation.
3. Attach the top end of the tygon tubing to a high point on the stadia rod representing a known and standard elevation above the water surface in the stilling well.
4. As the shutoff valve is opened, start a stopwatch to record the length of time required for the falling water level of reach various points down to the top of the stainless steel piezometer tube.
5. Plot the time against volume of water expelled from the perforated interval. Estimate the time to reach equilibrium.

The K_h values are representative of the horizontal properties of the streambed sediments, the vertical hydraulic conductivity values are estimated from these. Vertical hydraulic conductivity (Kv) is assumed to be 0.10 of horizontal values.

The vertical water flux through the streambed in the vicinity of the piezometer is:

$v = K_v(\Delta h / \Delta l)$, where $(\Delta h / \Delta l)$ is the vertical hydraulic gradient (VHG).

Another Measure of Vertical Hydraulic Gradient

The first measure of vertical hydraulic gradient conducted as described above is measured after the water in the piezometer tube reaches equilibrium by rising in the tube from the depth of the perforated interval. Measurement of the water surface in the piezometer and the stilling well, respectively, are made using a straight wire with chalk.

The second measure can be made by drawing water up the piezometer tube using a vacuum pump connected to a T-connector. The other port on the T-connector leads to a piece of tygon tubing inserted into the water. See Figure from Martinez (2009). The difference in water elevation above the piezometer tube and above the free, river water surface is equal to the VHG (or D_h in the figure from Martinez).

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Appendix D

Evaluation of Surface Sediment Particle Composition

using a GIS-Simulation of a Stream Reach

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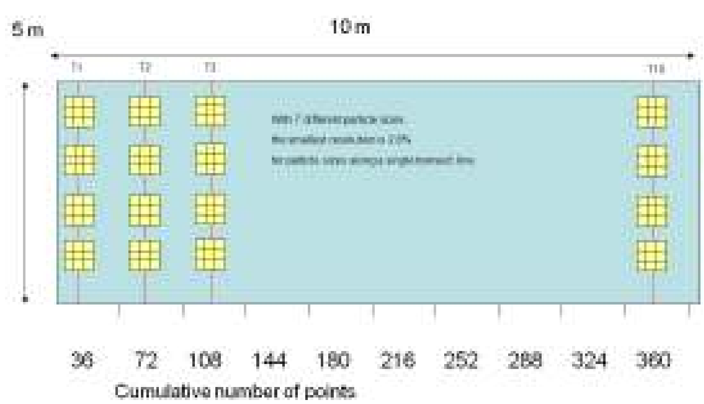
Evaluation of Surface Sediment Particle Composition using a GIS-Simulation of a Stream Reach

A component of

Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators

March 2011

Dale McCullough, David Graves, Saang-Yoon Hyun



Evaluation of Surface Sediment Particle Composition using a GIS-Simulation of a Stream Reach

For estimation of the surface particle size composition of river bed sediment, the Wolman Pebble Count method (Wolman 1954) has been the standard method applied. It has been known for many years that this standard method is biased against both small and large size particles in many field situations where the range of particle sizes runs from silt or fine sand to boulders up to 25 or 50 cm diameter. Bias against fines has been cited due to the frequent inability to grasp fines in crevices located at a location specified on a transect or at a location defined by pacing in the stream. The difficulty is that the fingers reaching toward the crevice encounter larger particles first due to the size of fingers relative to the crevice dimension. Bias against large particles in the particle distribution can occur while pacing in the stream because of the tendency not to walk on large particles. Avoidance of large boulders may interfere with selection of boulders when using the conventional pacing method.

To counteract the bias against the finest size particles in spawning gravels, where the largest size particles is generally less than about 15cm diameter, we developed a 9-cell grid frame constructed from tubular aluminum with legs in the corners so that the frame stands approximately 10 cm off the streambed. An opaque plexiglass tube with a plexiglass collar was mounted in succession on each grid cell. Looking through the "view scope" with cross-hairs on the bottom viewing window, an observed was then able to identify the target particle. This particle was then picked up by hand if its size was large enough, or grasped with long forceps. Particles were then measured with a gravelometer to eliminate bias associated with parallax in measuring particle diameters with a ruler.

Spacing between center points of each grid cell was 20 cm. This spacing was derived from knowledge of the typical largest particle size of spawning gravels and the advice of Bunte and Abt (20xx).

Estimation of the surface particle size distribution involves a number of statistical issues. Among these are:

1) What number of particles needs to be counted to derive an accurate mean percentage surface area covered by each particle class?
2) What effect does grid spacing have on the ability to detect average area covered by each particle size?
3) If interest is limited to only surface fine sediment percentage, does it make any difference whether grid spacing is 2 cm or 20 cm?
4) What precision can be achieved when limiting the particle count to 200 or 400 particles, which is often considered to be the upper practical limit of sampling in a single reach.
5) What is the effect of spatial variation in sediment composition on the ability to detect the mean percent coverage by each particle size class?

In order to address these questions, we created three different simulated stream reaches: (1) Random Reach, (2) Zoned Reach, (3) Simulation 3 or Sim3. The reaches were simulated using ArcGIS (ESRI) by defining a rectangular reach dimension and then randomly placing particles within this area. There were 7 particle size classes use. Each particle size class had a pre-selected percentage cover. Given this percentage cover, the number of particles needed to create this percentage cover was calculated. These are described below.

The three simulated streambeds were as follows:

(1) "Random reach" had a size of 5 m x 10 m. Largest size particles (class 6) were placed randomly first, followed by placement of the next largest particle (class 5), and so on, until class 1 particles were randomly placed. After all class 1 particles were placed, the remaining spaces were assumed to all be the smallest size class. X-Y coordinates were randomly selected for the centroid of each particle class. This point was then buffered to the diameter of the particle that was being located on the simulated streambed. It was then determined whether the particle being placed overlapped any other particle that had been previously placed. If not, the particle's position was fixed and subsequent particles were placed using the same procedure until the desired number of particles were placed to comprise the desired percentage surface coverage by that size class. Particles placed near the boundary of the wetted 5 x 10 m simulated stream reach could overlap the wetted border if the particle radius was greater than the distance from the particle centroid to the wetted edge.

(2) The "Zoned reach" was a 5 m x 20 m simulated reach that had the same overall particle size distribution as the "Random reach" but which had a longitudinal trend of particle sizes from one end to the other. This was intended to represent spatial variation inherent in a natural channel that might be so slight as to not be visually recognized but which could create sampling difficulties in determining the mean of particle size coverage. The effect of this level of spatial variation was examined. The largest particle size classes trended from higher than average from one end to the other while the smallest particle sizes had the reverse trend. The longitudinal particle size trends varied by steps. There were 10 steps of 2 m length. The simulated streambed was constructed in 2-m increments by randomly placing particles in each segment to represent the longitudinal trend.

(3) The "Sim3 reach" had a very different particle size distribution, with much lower levels of coarse particles and higher levels of fines. This simulated reach was 5 m x 10 m. This reach features a random particle placement like was found in the "Random" reach, but having a different particle size distribution.

The particle size classes were:

class 6:	37.5 cm
class 5:	19.25 cm
class 4:	9.625 cm
class 3:	4.875 cm
class 2:	2 cm

class 1: 0.815 cm

class 0: < 0.625 cm (white space = fine grained particles)

The particle size range for class 1 particles was 0.625-1 cm, with a mean of 0.815. All class 1 particles were exactly 0.815 cm diameter. Class 0 particles were all < 0.625 cm. Because all other particle sizes were already placed in the simulated reach, the class 0 particles occupy the remaining space. Consequently, the polygon represented by class 0 particles can have inclusions of other particle size classes and it typically does not represent a single particle of the maximum size class for that particle range.

The particle sizes selected were chosen to represent the mean of a series of particle size bins. Each particle was a perfect circle in plan view. The particle diameter was oriented horizontally and there was no particle overlapping.

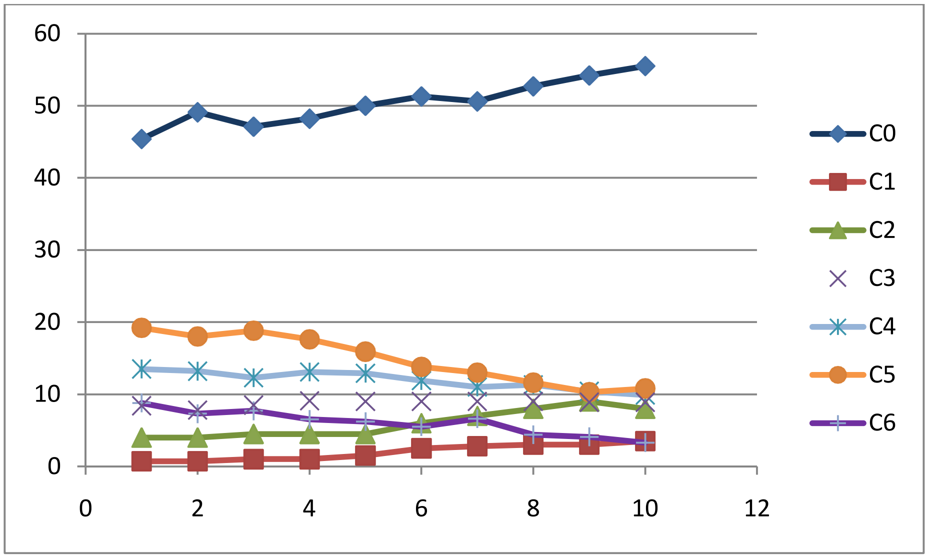
The percentages of surface coverage in the simulated reaches of each particle size were:

	Class0_Pct	Class1_Pct	Class2_Pct	Class3_Pct	Class4_Pct	Class5_Pct	Class6_Pct	
True percentage	50.58	2.00	6.00	11.85	8.82	14.82	5.93	**Random Reach**
True percentage	50.43	1.98	5.93	8.76	11.94	14.91	6.06	**Zoned Reach**
True percentage	18.40	1.94	9.95	18.22	19.68	19.24	12.57	**Sim3**
Size Class	0	1	2	3	4	5	6	
Mean size (cm)	<0.625	0.815	2	4.875	9.625	19.25	37.5	
Size Range (cm)	<0.625	0.625-1	1-3	3-6	6-13	13-25	25-50	

Actual percentages of each particle size by zone

Transect	C0	C1	C2	C3	C4	C5	C6
1	45.4	0.7	4.0	8.4	13.5	19.2	8.8
2	49.1	0.7	4.0	7.8	13.2	18.0	7.3
3	47.1	1.0	4.5	8.5	12.3	18.8	7.7
4	48.2	1.0	4.5	9.1	13.1	17.6	6.5
5	50.0	1.5	4.5	9.0	12.9	15.9	6.2
6	51.3	2.5	6.0	9.0	11.9	13.8	5.5
7	50.6	2.8	7.0	9.0	11.0	13.0	6.6
8	52.7	3.0	8.0	9.0	11.3	11.6	4.4
9	54.2	3.0	9.0	8.9	10.4	10.3	4.1
10	55.5	3.5	8.0	8.9	9.9	10.8	3.3
Mean	50.4	2.0	6.0	8.8	12.0	14.9	6.0

Figure xx. Actual percentages of each particle size class by zone in simulated reach



Sampling procedure. The three different simulated streambeds were sampled by a variety of techniques.

(1) Transect/single points at intervals. The first 1-m length of the 10-m long simulated reach was identified. A random start transect was selected within the first 1-m length. After this selection, either 10 sample transects were spaced at 1-m intervals or 20 transects were spaced at 0.5-m intervals in the longitudinal direction. Given that the reach width was 5 m, sample points were uniformly spaced across each transect in the center of each 5 m/10 pts or 0.5-m interval, producing 10 sample points on each transect. This makes the distance between points laterally equal to 0.5 m. This makes the distance between points laterally equal to 0.5 m.

(2) Grid toss. The grid toss procedure was conducted using a grid frame that was 5 x 5 cells, with each cell having a grid spacing of 2, 5, 10, 20, or 40 cm. When grid spacing was 40 cm, the grid frame measured 2 m x 2 m. The grid frame was placed perpendicular to the longitudinal centerline of the channel at randomly selected points. A random selection of 10 points was made. Each grid frame provided 25 sample points, and a set of 10 points provided 250 sample points total.

(3) Transect/Grid frame. This method selected a random start location for the first transect. After this transect line was selected all other transect lines (10 or 20 for the 10-m long reach, and 20 for the 20-m long reach) were uniformly spaced. On each transect line 4 grid frames were placed in the center of each of 4 equal divisions along the transect. Grids frames used for this analysis had 9 square grid cells that varied from 2, 5, 10, 20, or 40 cm spacing between cell centers. The grid frames were placed in a uniformly spaced pattern across each transect. With 10 transects and 4 grid frame placements per transect, there were 4 x 9 or 36 sample points per transect and 360 points total.

Methods

Sampling schemes used either the Transect method, Grid toss, or Transect/Grid placement method to select sample points.

Random selection of particles from the known population of the simulated streambed is a binomial sampling event. The probability of selecting a particle of any given size class, where the size classes range from C0 to C6, is p and the probability that it is a size other than the given size class is *q* (or 1-*p*). The standard error of the probability of the particle being of the given size class is then, as shown in Zar (p. 526):

$$s_{\hat{p}} = \sqrt{\frac{\hat{p}\hat{q}}{n-1}}$$

We also explored the use of a multinomial calculation procedure for estimating the standard error of the probabilities of percentage cover by each size class. The MLE method was programmed using AD Model Builder, running with R programming language. The output from this program appeared to be identical to that derived using the standard binomial method, so the ease of computing these standard errors using Excel weighed in favor of using the binomial formula.

Results

Application of a grid toss method within the Zoned reach

To test the ability of a random placement of 5 x 5 cell grid frames on the simulated reach, we used the "Zoned" reach, sampled with grid spacings of 2 cm and 20 cm. This sampling method represents a random grid toss approach within the entire 20 x 5 m reach. Standard errors were computed for each addition of 25 points sampled. Relative error was calculated as

$$\frac{\textit{measured value} - \textit{true value}}{\textit{true value}}$$

Absolute error was calculated as

$$\textit{measured value} - \textit{true value}$$

The true value of percentage fines in the Zoned reach was 50.43%. Using the 2-cm grid spacing, it required a particle count of 200 to 1000 to achieve relative errors of about ± 1 to 11.5%, but the error never stabilized. The confidence bounds estimated with 200 particles were ± 14% of the mean. With a sample of 400 particles, the confidence bounds were ± 8.7% of the sample mean. Absolute error was < 6% for total particle counts of 175 to 1000. When using a 20-cm grid spacing, the relative error ranged from 2.8 to 9.9% for total particle counts ranging from 200 to 1000. With total particle counts > 725, relative error appeared to stabilize at < 5%. Absolute error was < 5% for particle counts of 75 to 1000. With particle counts of 200 and 400, the confidence bounds were 14.2 and 10.5%, respectively. Although the relative confidence bounds were similar with grid spacing of 2 cm and 20 cm, the 20 cm spacing provided greater accuracy.

Particle size class 2 had a true value of 5.93% in the Zoned Reach. The ability of the random grid toss method to detect this mean was evaluated. Using a grid frame with 2 cm spacing resulted in detection of the mean with a relative error of 1.1 to 12.3% with a total number of points ranging

from 200 to 525. With between 550 and 1000 points, the relative error was less than 6.5%. Absolute error was < 2% with a total number of points from 25 to 1000. With a grid spacing of 20 cm, relative error was 1 to 18% with a range in total points sampled of 200 to 750. However, absolute error was < 2% for total points ranging from 125 to 1000.

With particle classes 3, 4, 5, and 6 the grid toss method using a 2-cm grid spacing did far worse at estimating the mean percentage cover than did the 20-cm grid spacing. The true percentage cover by these particle size classes was 8.76, 11.94, 14.91, and 6.06%, respectively. The particle diameters were 4.875, 9.625, 19.25, and 37.5 cm, respectively. The problem of capturing a particle of 19.25 cm diameter can be understood by calculating the number of particles expected with a total percentage cover of 14.91%. This total cover would be produced by 128 particles of this diameter. Fitting 128 particles of this size within the simulated reach of 20 x 5 m results in a spacing between particle centers of 88.4 cm or 69.2 cm between closest particle boundaries, assuming a totally uniform particle distribution. The zone reach had a gradient of . A 25-cell grid frame with 2-cm grid cells would have a 10 x 10 cm dimension. The Zoned reach had a gradient of distribution of particle class size 5 going from 10.8% within the first of 10 zones to 19.2% in the last of 10 zones. This pattern of distribution combined with the spacing between particles of class 5 relative to the size of the grid frame (10 x 10 cm) results in few encounters with the large but scattered particles.

As an example of the problem of estimating the percentage cover by larger particle size classes, the Zone reach was sampled using the grid toss (i.e., random placement of 5 x 5 cell grid frames) method. When the grid cell size was 2 cm, and the particle size of interest was class 5 (19.25 cm diameter, with a true percentage cover of 14.91%), the absolute error ranged from 9 to 14.9% with total particle counts up to 400. Absolute error was < 5.3% with particle counts >575. When using a grid spacing of 20 cm, absolute error was < ±1% for all particle counts > 100. Relative error was < ±5% for all particle counts > 100.

Transect sampling with uniformly distributed points on transect lines within the Zoned reach

In order to test the ability to assess the mean surface particle coverage by particle size class, the Zoned Reach was selected to explore the use of the Transect method. The Zoned reach has dimensions of 20 x 5 m. Four different transect sampling routines were applied. The first transect design had 20 transect lines with 5 sample points on each transect line and a total of 100 points. Design two had 20 transect lines, 10 points per transect line, and a total of 200 points. Design three had 20 transect lines, 20 points per transect line, and a total of 400 points. Design four had 40 transect lines, 20 points per line, and a total of 800 points. With design four, the minimum distance between points longitudinally was 0.5 m and 0.25 m laterally. The distance between points, then, exceeds the dimensions of all but the largest particle size diameter.

True percentage of particle sizes for Zoned Reach						
C0	C1	C2	C3	C4	C5	C6
50.43	1.98	5.93	8.76	11.94	14.91	6.06

Transects	Long. Dist. Between transects (m)	Lateral Point spacing (m)	Run	Count	Class0_Pct	Class1_Pct	Class2_Pct	Class3_Pct	Class4_Pct	Class5_Pct	Class6_Pct
20	1	1	1	100	52.0	3.0	6.0	8.0	12.0	13.0	6.0
20	1	0.5	1	200	49.5	3.5	8.0	9.0	9.0	15.5	5.5
20	1	0.25	1	400	52.5	1.8	6.3	8.8	10.3	15.5	5.0
40	0.5	0.25	1	800	49.5	2.0	5.8	8.8	11.6	17.0	5.4

The transect method, used to estimate the percentage fines (class 0 particle), identified the mean surface coverage by fines with only 100 points with an absolute error of 1.6% and a relative error of 3.1%. Adding more points did not appear to improve the ability to detect percentage fine. Class 1 particle size has a very low percentage coverage (1.98%). The mean coverage by this particle size was detected with an absolute error of ± 1.5% with 200 total particles, but < ± 0.23% with 400 and 800 particles. It required 800 total particles, however, to have a low (1%) relative error. With 200 particles, relative error was 77%.

With Class 2 particles, the true value was only 5.93%. This value was estimated with an absolute error of no greater than 2.1% with 200 particles. the relative error was 34.9%. It required 400 particles to have a low absolute and relative error. With Class 3 particles, the absolute and relative errors both improved with each increase in particle counts from 100 to 800 total particles. Class 4 particles were present with a true value of 11.94%. The absolute error was 2.9% and relative error was 24.6% with 200 particles. It appears that relative error stabilizes at a low value with as many as 800 particles. With Class 5 particles absolute error was no greater than about 2.1%, but relative error varied from about 4 to 14% and didn't seem to stabilize with increasing points sampled. A similar result occurred with Class 6 particles. These particles had a surface coverage of 6.06%. Transect sampling determined the mean value with absolute error of < 1.1% with all total particle counts. Relative error, however, did not stabilize with increased particle counts, but actually became greater, reaching 17.5% with 400 particles.

Transect sampling with 9-cell grid frames distributed uniformly on transect lines

The Sim3 simulated streambed had a fine sediment surface coverage of 18.40%, which is much lower than both the Random and Zoned reaches. The Sim3 reach was used to test the ability to assess percentage fines where coverage by fines was much lower. A 3 x 3 grid frame with a total of 9 cells spaced at 20 cm apart was used to assess percentage cover by each of the 7 particle size classes. The Sim3 simulated reach was 10 x 5 m and all particles were randomly distributed throughout the entire rectangular reach. Three different sampling designs were employed: (1) 4 grid frames placed on each of 5 equally spaced transect lines, where transect line 1 was randomly located within the first 1 m of reach length and the other 4 transect lines were spaced 2 m apart longitudinally, (2) 4 grid frames placed on each of 5 equally spaced transect lines, where transect line 1 was randomly located within the second m of reach length (i.e., between 1.0 and 2.0 m longitudinally) and the other 4 transect lines were spaced 2 m apart longitudinally, (3) 4 grid frames were placed on each of 10 equally spaced transect lines where transect line 1 was randomly located and the other 9 transect lines were spaced 1 m apart longitudinally, (4) 4 grid frames were placed on each of 20 equally spaced transect lines where transect line 1 was randomly located and

the other 19 transect lines were spaced 0.5 m apart longitudinally. The sampling designs described above had a total of 180, 180, 360, and 720 points, respectively.

The use of a 9-cell grid frame with 20-cm grid spacing was able to identify the mean percentage fines coverage in the Sim3 simulated reach within its 95% confidence limits in both cases (i.e., with the 5 transect lines in odd and even numbered 1-m segments along the 10-m reach length. In these two instances, the confidence limits were ± 5.5 and 6% (absolute percentages), respectively. When evaluating particle Classes 2, 3, 4, 5, and 6 the confidence limits were ± 4.2 to 6.2% (absolute percentages) in all cases. Also, in these size classes, the means with confidence limits bracketed the true values in all cases.

When total sample points were increased from 180 to 360, the confidence limits were reduced substantially. For particle size classes 0, 2, 3, 4, 5, and 6 the confidence limits were ± 3.1 to 4.1% (absolute percentages). For Class 1 particles, the confidence limits were ± 1.5% (absolute value). With all particle sizes the means with confidence limits bracketed the true values for each size class.

When total sample points were increased from 180 to 360, the confidence limits were reduced again. For particle size classes 0, 2, 3, 4, 5, and 6 the confidence limits were ± 2.5 to 2.9% (absolute percentages). With all particle sizes the means with confidence limits bracketed the true values for each size class.

Use of the “Random” reach to explore the grid toss method

Using the Grid toss method, simulated with the GIS analysis of the Random reach, 100 grid frames (5 x 5 grid frame with either a 2-cm or 20-cm grid cell spacing) were tossed at random on the simulated streambed. From this set of 100 tosses, each grid produced 25 sample points each for the 5 x 5 grid. Using this set of 100 grid frame tosses, we randomly selected 10, 16, or 20 of these tosses 1000 times to represent the simulated reach mean and variance by a Monte Carlo technique programmed in Visual Basic with Excel. Sampling was done with replacement. Ten tosses produced a total of 250 sample points; 16 tosses—400 sample points; 20 tosses—500 sample points. Selections of 10, 16, or 20 random tosses were replicated 1000 times to generate a mean and variance. The distribution of the sample means for all 1000 draws of grid frame tosses was also graphed.

The Random reach is 10 x 5 m in dimension and was created using ArcMap (ESRI). The 7 particle sizes were randomly distributed on this 50 m^2 surface with no longitudinal trend in percentage coverage by any particle size. Grid frames with 25 cells (5 x 5 cells) were randomly tossed, as simulated with the GIS until a total of 100 grid frame placements were made. With a total of 100 grid tosses, groups of 10, 16, or 20 of these frames, each with 25 points were randomly selected with replacement until 1000 sets of points were compiled. Statistics on the values derived from sampling were then computed.

True mean	50.58	2.00	6.00	11.85	8.82	14.82	5.93
Size Class	*0*	*1*	*2*	*3*	*4*	*5*	*6*

The fine sediment particle class (C0) had a true coverage of 50.58 in the Random reach determined with the GIS. The grid frame with the 2-cm grid spacing had a mean of 51.39% for 1000 sets of 10 grid tosses, collecting 250 points with each toss. The mean of 100 random tosses from which 1000 sets of 10 were selected had a sample mean of 51.36%. The 1000 Monte Carlo sets of 10 tosses was selected from a sample population of 100 random tosses. Because the 10 x 5 m simulated reach was represented by only 100 random tosses of the grid frame, this element of chance causes the sample to not perfectly reflect the true population mean.

The distribution of the 1000 sample means sampled with a 2-cm grid spacing had a greater range than did the distribution with the 20-cm grid spacing. The mean of 100 random grid tosses with a 20-cm grid frame and a 5 x 5 grid frame (i.e., 25 points per frame) produced 2500 total points to represent the true population mean. This random toss of 100 grid frames had a sample mean of 47.48% for particle size class C0, while the true population mean was 50.58%. When 1000 randomly selected sets of 10 grid tosses were drawn, the mean of all 1000 was 47.54%. The spread of this distribution was much less than for the 2-cm grid spacing data collection. This would indicate that if the mean coverage by fines were to be estimated with only 10 grid tosses and 250 points total in a totally randomly distributed particle condition for a stream reach, there is greater likelihood that an inaccurate mean could be generated with a 2-cm grid spacing than with a 20-cm grid spacing. With the 2-cm grid spacing, 90% of all 1000 sets of 10 grid frames had mean values for the C0 particles ranging from 40.2 to 62.5%; with the 20-cm grid spacing, 90% of all sets of 10 grid frames had means ranging from 41.9 to 53.2%, assuming a normal distribution.

With particle size class C3, the mean of 1000 sets of 10 tosses was 11.48% with a 2-cm grid spacing. When the grid spacing was 20-cm, the mean was 11.95%. The true population mean was 11.85%. The means with the 100 grid frame tosses, representing a total of 2500 points, were 11.44% and 12.00%, respectively. Despite the ability of the 2-cm grid spacing to represent the mean with 2500 total points, the distribution of sample means based on 250 points each or 1000 combinations of sets of 10 grids was much greater with the 2-cm grid spacing. This indicates that there is a greater likelihood of drawing an inaccurate sample mean from a random selection of 10 grid frames with a 2-cm grid spacing than with the 20-cm grid spacing. With the 2-cm grid spacing, 90% of all 1000 sets of 10 grid frames had mean values for the C3 particles ranging from 5.6 to 17.4%; with the 20-cm grid spacing, 90% of all sets of 10 grid frames had means ranging from 8.7 to 15.2%, assuming a normal distribution.

With the larger particle size classes, the 2-cm grid spacing did a poor job relative to the 20-cm spacing of identifying the population mean based on the distribution of sample means for sample sets of 250 points each. For the largest particle size (C6), the mean of the full set of 100 randomly placed grid frames defined a mean of 2.56% and 7.40% coverage, for the 2-cm and 20-cm grid spacings, respectively. Obviously, even 2500 total points from these 100 random grid tosses misrepresented the population. For particle classes 3, 4, and 5, the 100 random grid tosses provided close representation of the population means based on the full 2500 sample points.

However, the distribution of sample means based on random selection of 1000 sets of 10 grids was much greater with the 2-cm spacing than with the 20-cm spacing.

For all particle classes except for C2, the sample (i.e., each set of 10 grid frame tosses, or 250-point sample) standard deviations were lower with the 20-cm grid point spacing than with the 2-cm spacing (Table xx). A plot of the 90% confidence limits shows that 90% of the sample means fall within much narrower bounds when using the 20-cm grid point spacing. The practical implication of this result is that when trends in a particle size class such as fine sediment are tracked, the ability to determine a statistically significant change depends upon collecting data for an appropriate number of sample points and also on the grid point spacing. If there is significant aggregation in particles or non-uniform particle size class distribution within the limits of the sample reach, sampling on transects, either with evenly spaced individual points or uniformly placed grid frames is recommended. If particle sizes are uniformly distributed, a random individual point selection or a random placement of the grid frame is sufficient. However, in the latter case, the spacing of grid points is still important, especially when representing the percentage cover by the larger particle sizes.

References

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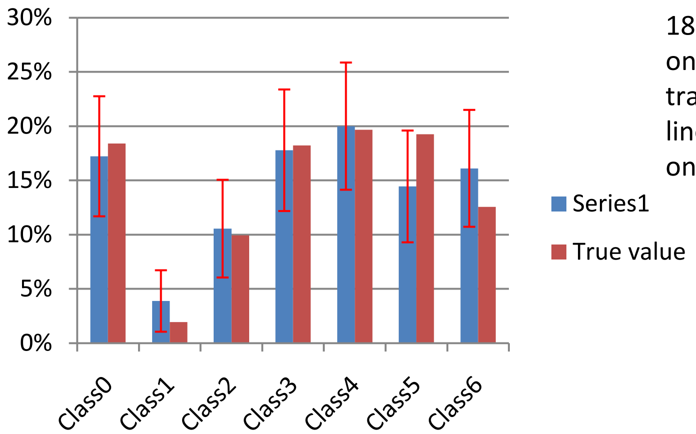
Wolman, M.G. 1954. A method of sampling coarse river-bed material. Transactions of the American Geophysical Union 35(6):951-956.

Application of a grid toss method within the Zoned reach

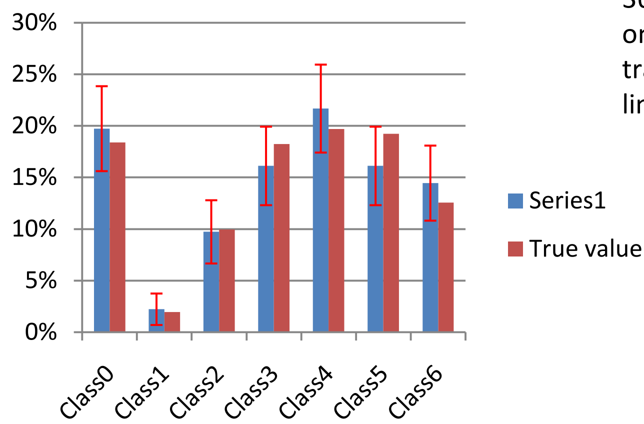
This represents counts of particles from the SIM run 3 data where % of fines is low (18.40%).
This uses a 4 grid placements on 10 transects, where the grid is a 9-cell grid with 20-cm grid spacing.

True values

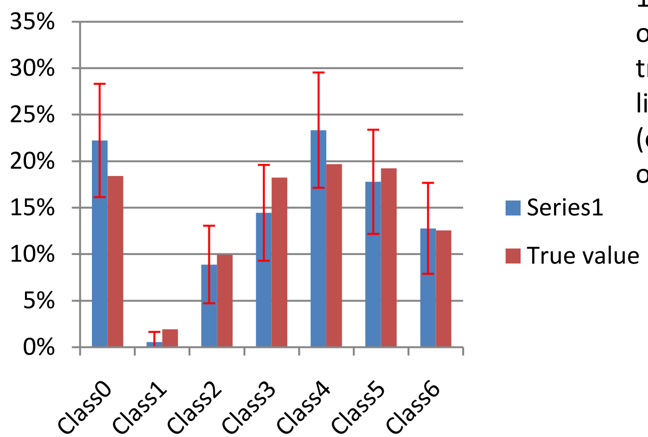
Class0	**Class1**	**Class2**	**Class3**	**Class4**	**Class5**	**Class6**
18.40%	1.94%	9.95%	18.22%	19.68%	19.24%	12.57%



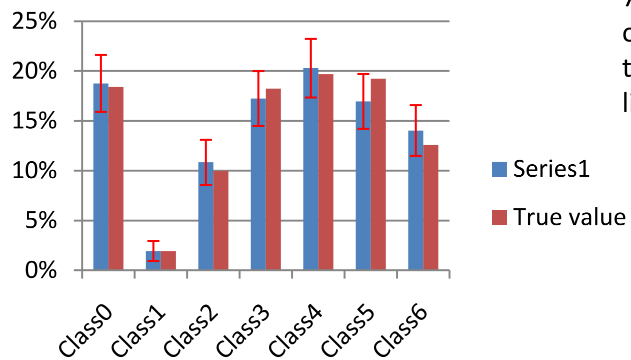
based on 180 pts on 5 transect lines (odd ones)



based on 360 pts on 10 transect lines



based on 180 pts on 5 transect lines (even ones)



based on 720 pts on 20 transect lines

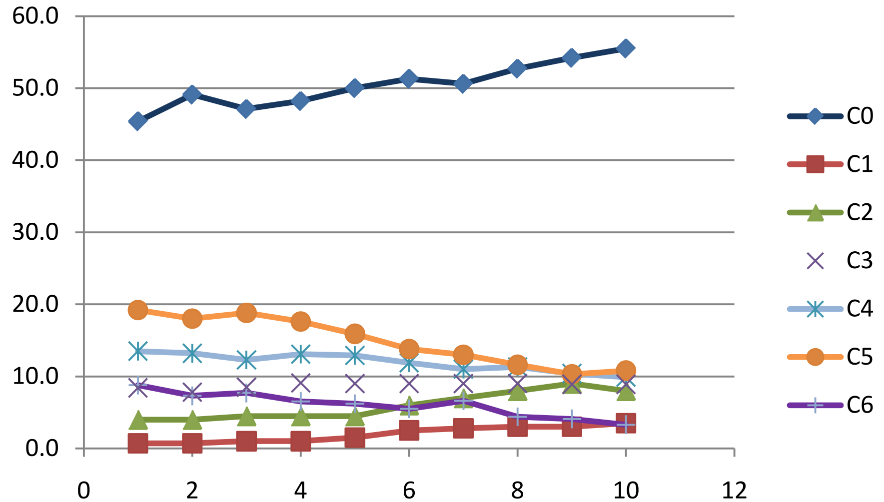
Particle distribution within the Zoned reach

ParticleCoveragebyZone.xls

Actual percentages of each particle size by zone (transect)

Transect	C0	C1	C2	C3	C4	C5	C6
1	45.4	0.7	4.0	8.4	13.5	19.2	8.8
2	49.1	0.7	4.0	7.8	13.2	18.0	7.3
3	47.1	1.0	4.5	8.5	12.3	18.8	7.7
4	48.2	1.0	4.5	9.1	13.1	17.6	6.5
5	50.0	1.5	4.5	9.0	12.9	15.9	6.2
6	51.3	2.5	6.0	9.0	11.9	13.8	5.5
7	50.6	2.8	7.0	9.0	11.0	13.0	6.6
8	52.7	3.0	8.0	9.0	11.3	11.6	4.4
9	54.2	3.0	9.0	8.9	10.4	10.3	4.1
10	55.5	3.5	8.0	8.9	9.9	10.8	3.3
Mean	50.4	2.0	6.0	8.8	12.0	14.9	6.0

Actual percentages of each particle size class by zone in simulated reach



Transect sampling with uniformly distributed points on transect lines within the Zoned reach

SimZone_10x10x2.xls

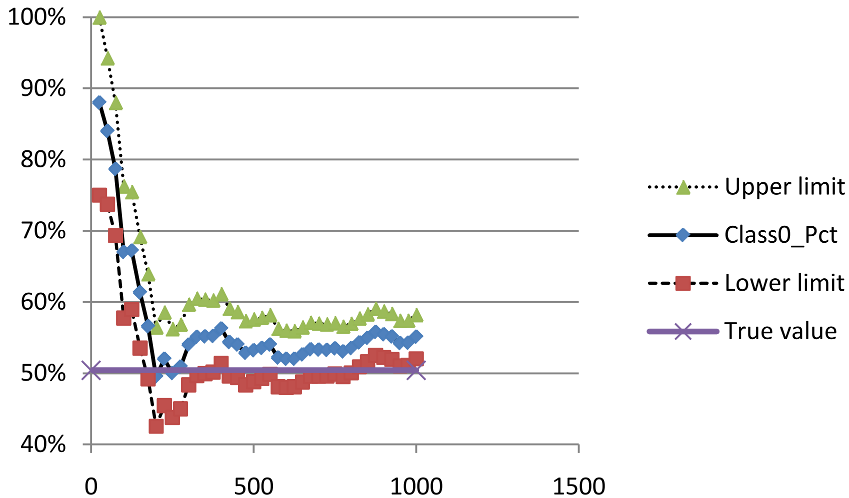
These charts represent the means and 95% confidence limits for random grid tosses in a simulated reach where the grid is a 10 cm x 10 cm grid with grid spacing of 2 cm. There are 25 grid cells in the grid frame. The simulated reach is “zoned” meaning it has 10 segments longitudinally where there are transitions in particle size composition.

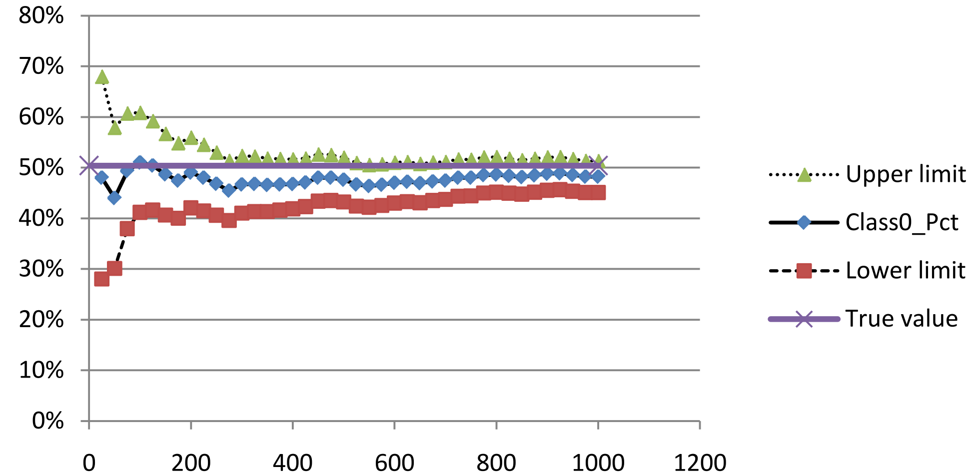
SimZone_100x100x20-results-10draw.xls

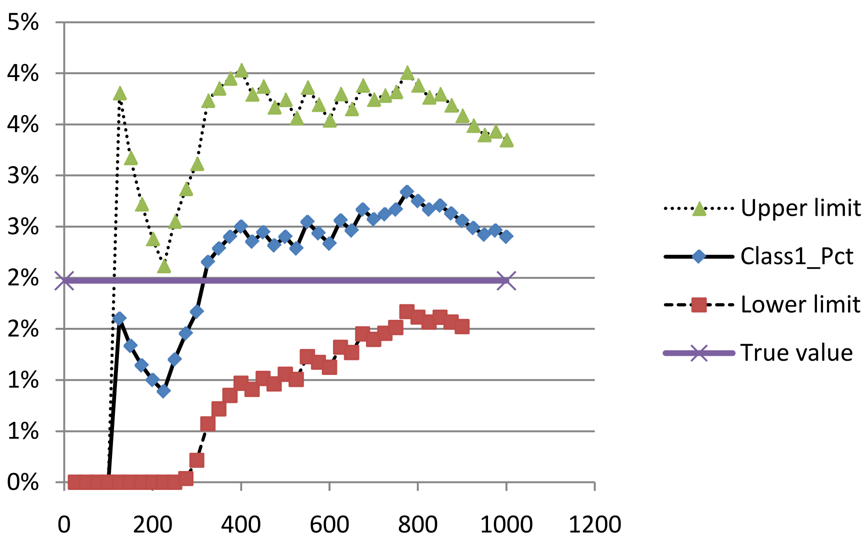
These charts represent the means and 95% confidence limits for random grid tosses in a simulated reach where the grid is a 10 cm x 10 cm grid with grid spacing of 20 cm. There are 25 grid cells in the grid frame. The simulated reach is “zoned” meaning it has 10 segments longitudinally where there are transitions in particle size composition.

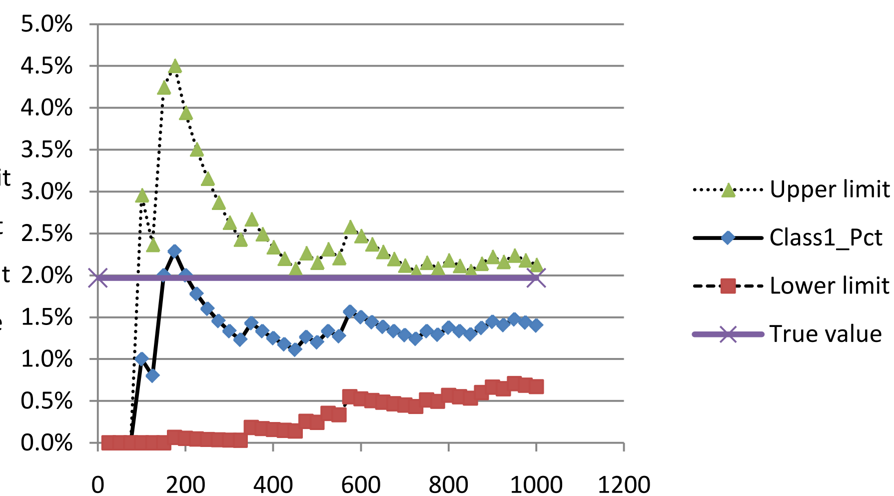
SimZone_10x10x2.xls

SimZone_100x100x20-results-10draw.xls

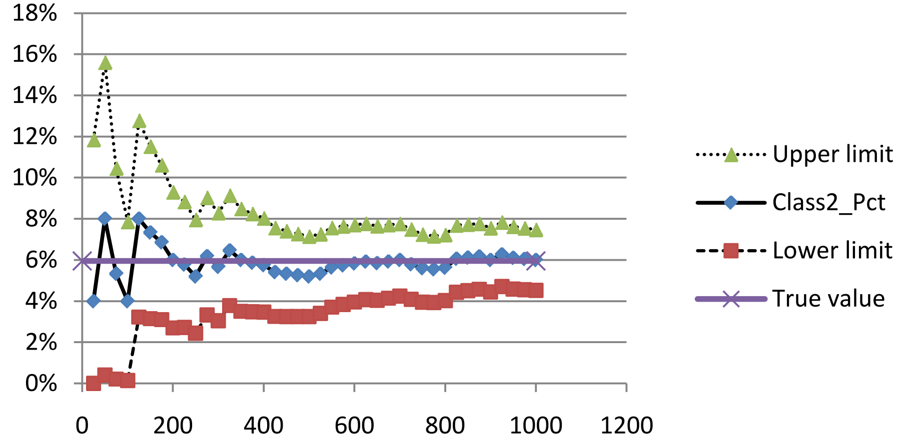




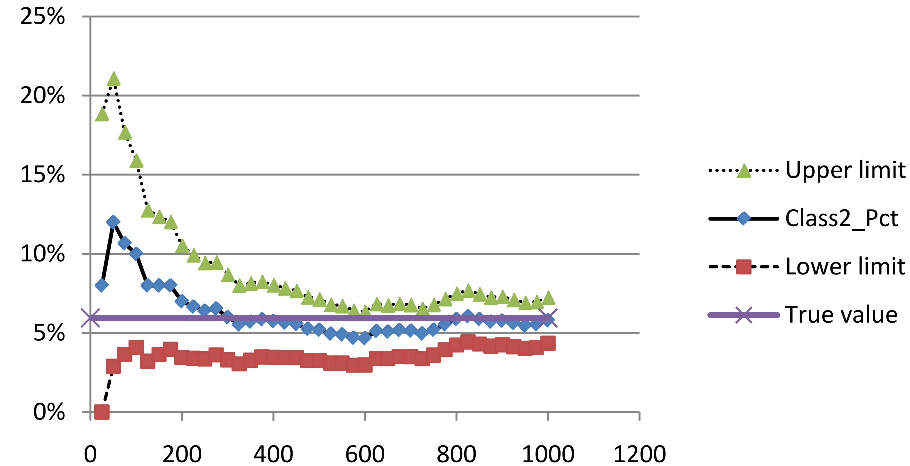


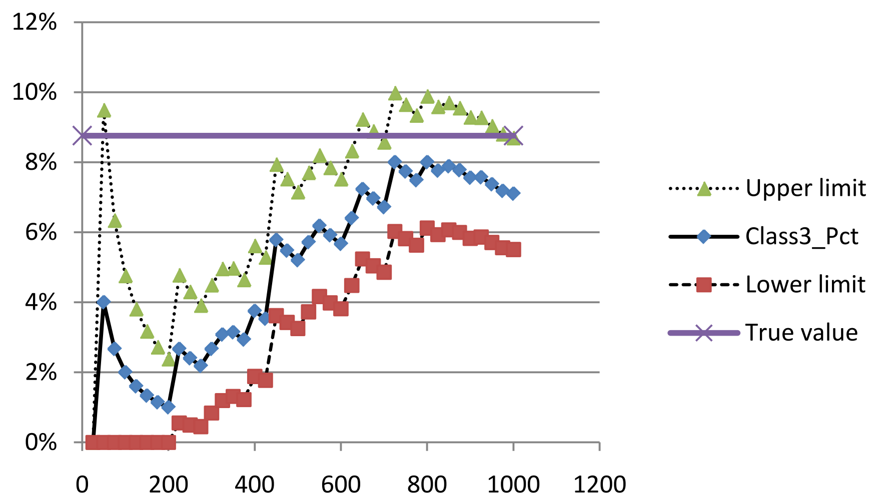


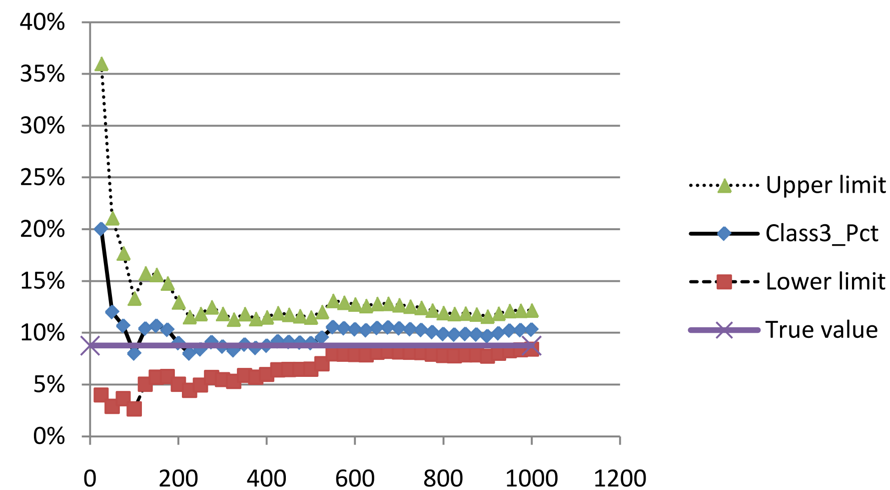
SimZone_10x10x2.xls



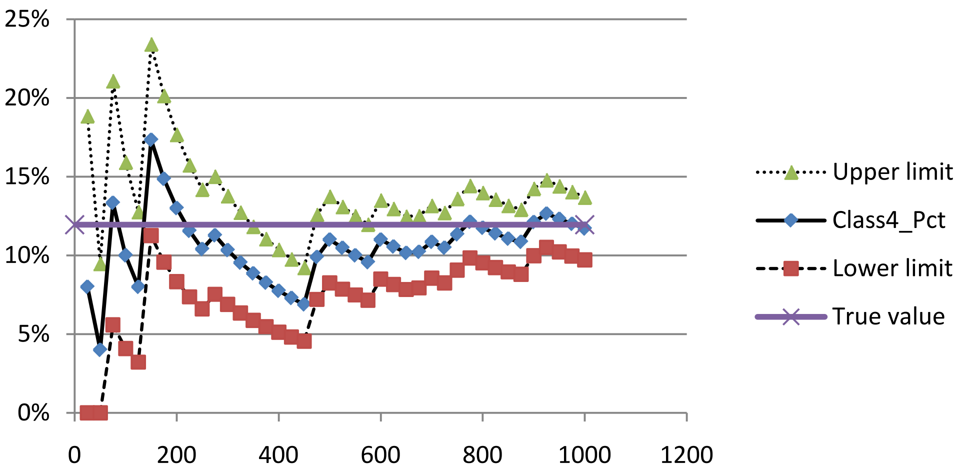
SimZone_100x100x20-results-10draw.xls



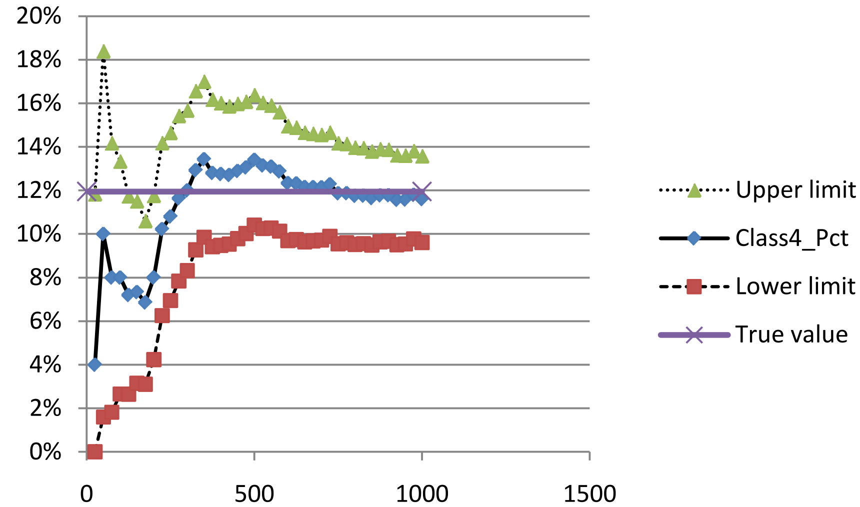


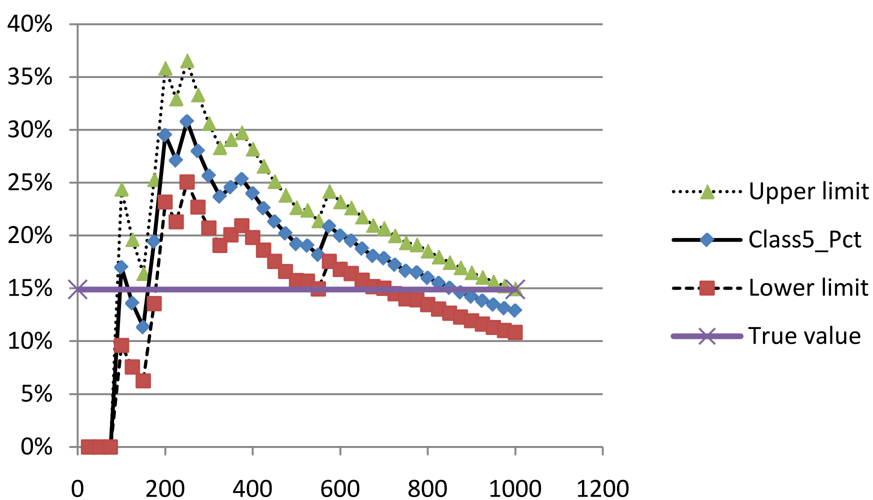


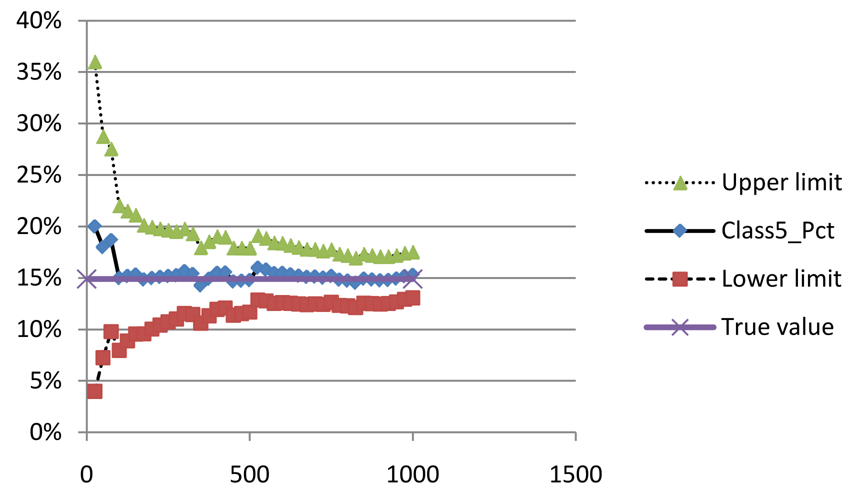
SimZone_10x10x2.xls

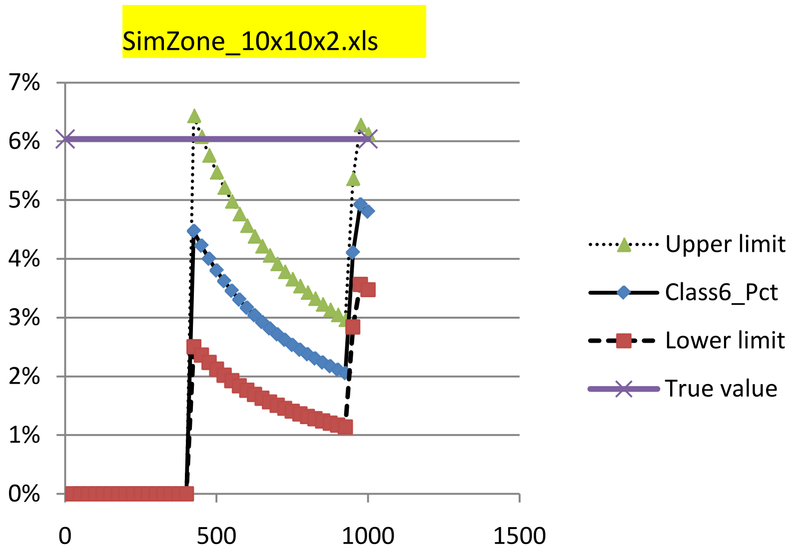


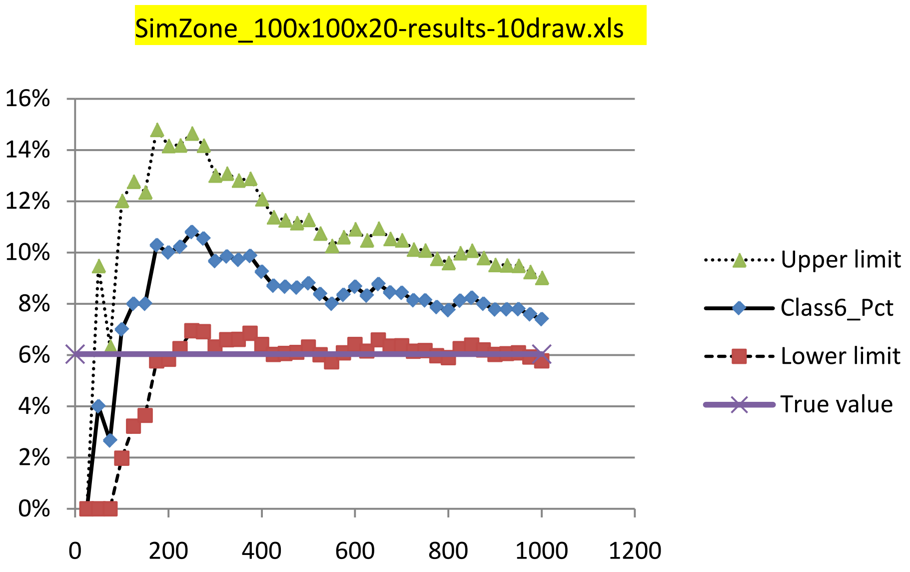
SimZone_100x100x20-results-10draw.xls







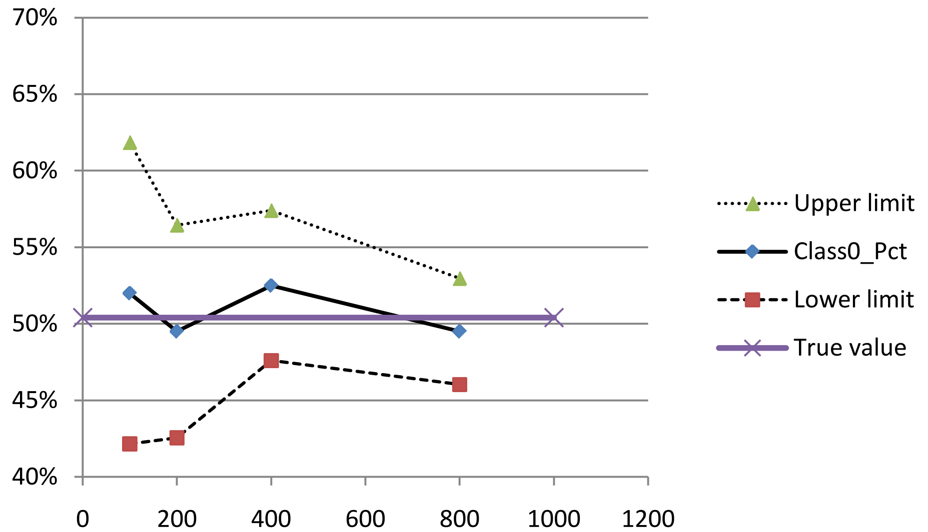

SimZone_10x10x2.xls
7%
6%
5%
4%
3%
2%
1%
0%
0
500
1000
1500
Upper limit
Class6_Pct
Lower limit
True value

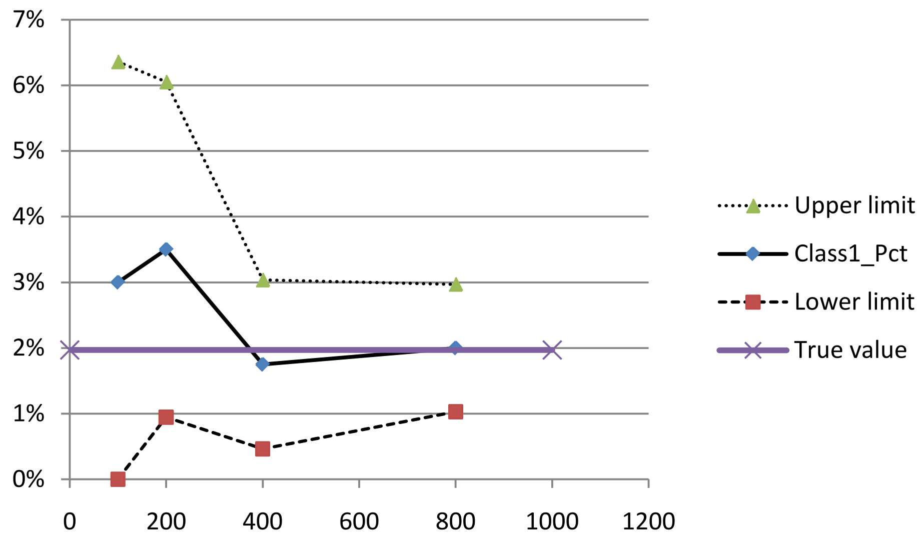

SimZone_100x100x20-results-10draw.xls
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
200
400
600
800
1000
1200
Upper limit
Class6_Pct
Lower limit
True value

Transect sampling with 9-cell grid frames distributed uniformly on transect lines

True percentage of particle sizes for Zoned Reach						
C0	C1	C2	C3	C4	C5	C6
50.43	1.98	5.93	8.76	11.94	14.91	6.06

Transects	Long. Dist. Between transects (m)	Lateral Point spacing (m)	Run	Count	Class0_Pct	Class1_Pct	Class2_Pct	Class3_Pct	Class4_Pct	Class5_Pct	Class6_Pct
20	1	1	1	100	52.0	3.0	6.0	8.0	12.0	13.0	6.0
20	1	0.5	1	200	49.5	3.5	8.0	9.0	9.0	15.5	5.5
20	1	0.25	1	400	52.5	1.8	6.3	8.8	10.3	15.5	5.0
40	0.5	0.25	1	800	49.5	2.0	5.8	8.8	11.6	17.0	5.4




7%
6%
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3%
2%
1%
0%
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200
400
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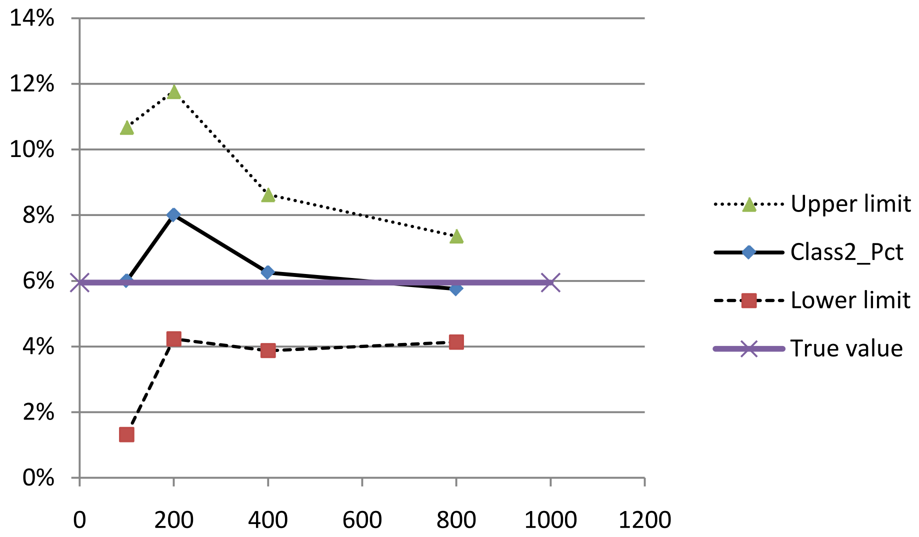
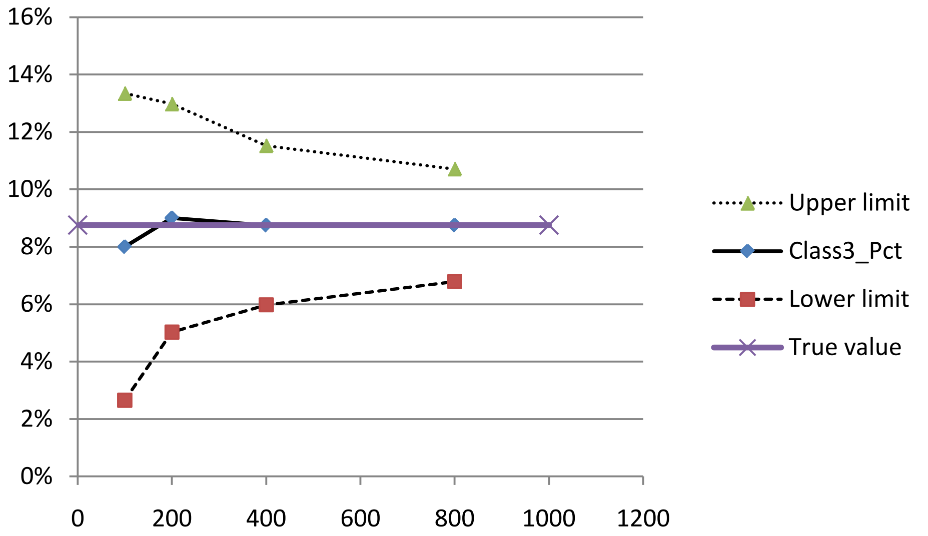
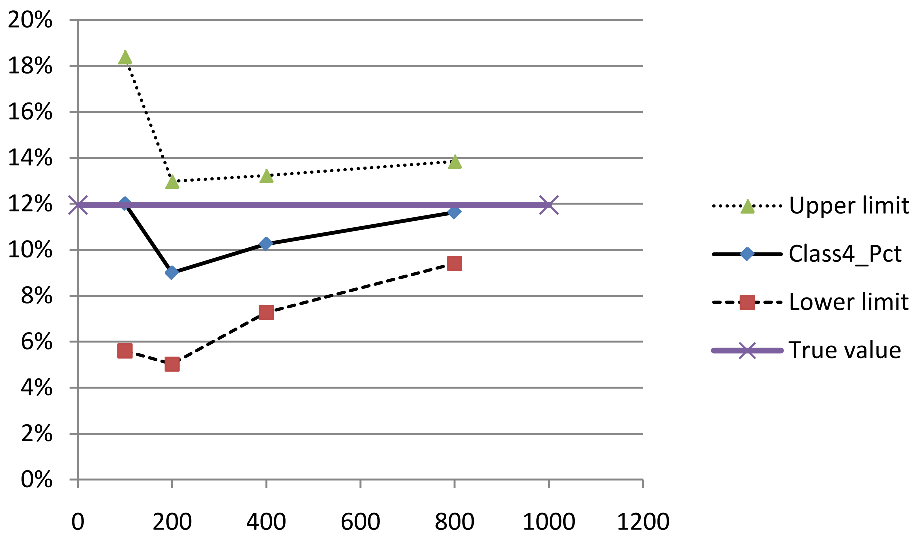
800
1000
1200
Upper limit
Class1_Pct
Lower limit
True value


14%
12%
10%
8%
6%
4%
2%
0%
0
200
400
600
800
1000
1200
Upper limit
Class2_Pct
Lower limit
True value


16%
14%
12%
10%
8%
6%
4%
2%
0%
0
200
400
600
800
1000
1200
Upper limit
Class3_Pct
Lower limit
True value


20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
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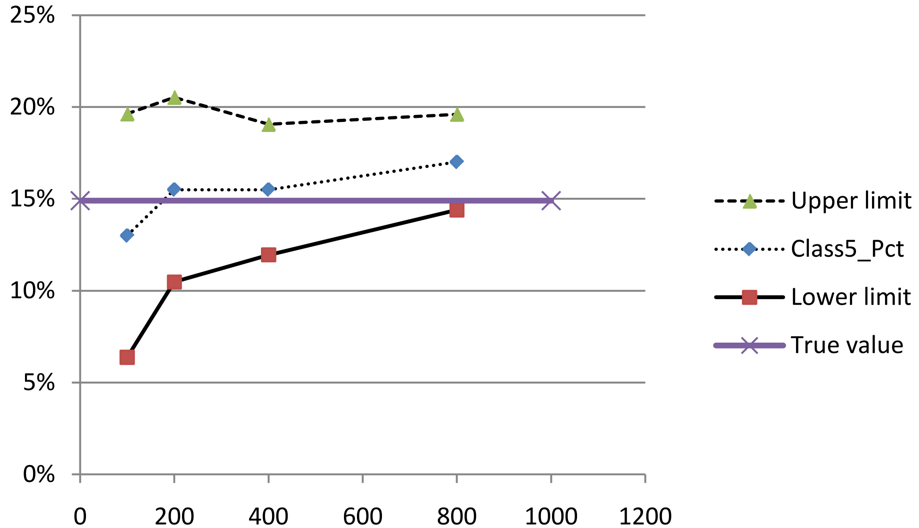
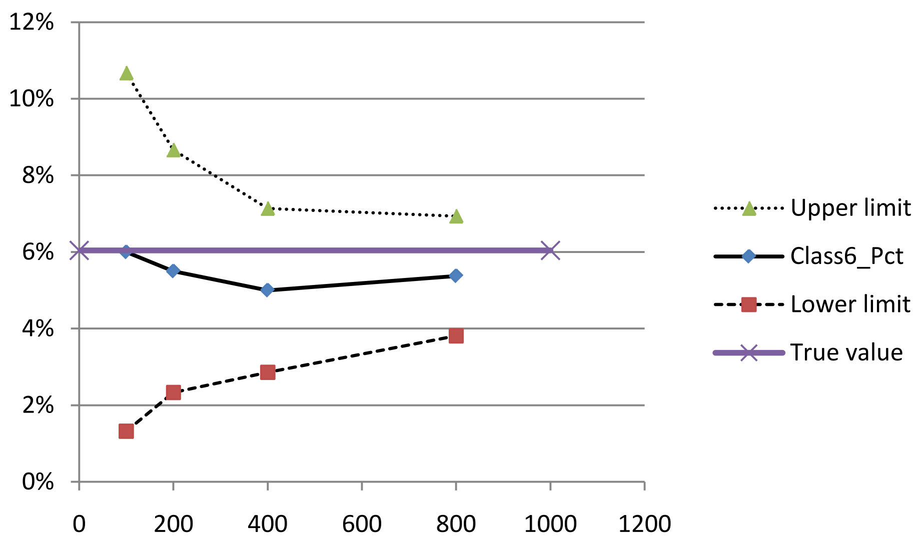
200
400
600
800
1000
1200
Upper limit
Class4_Pct
Lower limit
True value


25%
20%
15%
10%
5%
0%
0
200
400
600
800
1000
1200
Upper limit
Class5_Pct
Lower limit
True value


12%
10%
8%
6%
4%
2%
0%
0
200
400
600
800
1000
1200
Upper limit
Class6_Pct
Lower limit
True value

Use of the "Random" reach to explore the grid toss method

True mean	50.58	2.00	6.00	11.85	8.82	14.82	5.93
Size Class	*0*	*1*	*2*	*3*	*4*	*5*	*6*

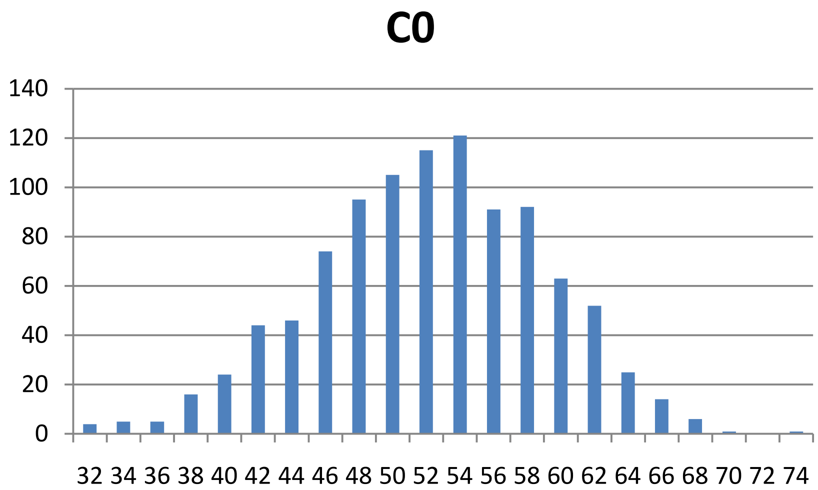
Mean coverage by each particle size class from 100 random tosses in the Random reach with a 5 x 5 grid frame and 2-cm grid spacing

51.36	2.44	5.64	11.44	10.12	16.44	2.56

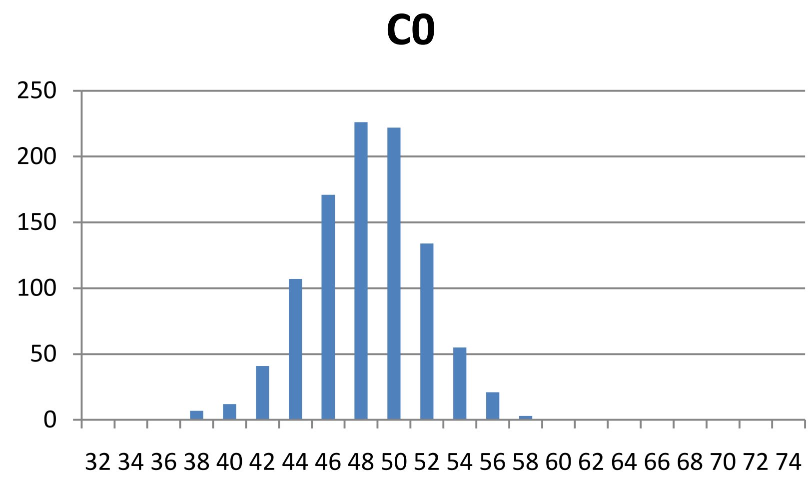
Mean coverage by each particle size class from 100 random tosses in the Random reach with a 5 x 5 grid frame and 20-cm grid spacing

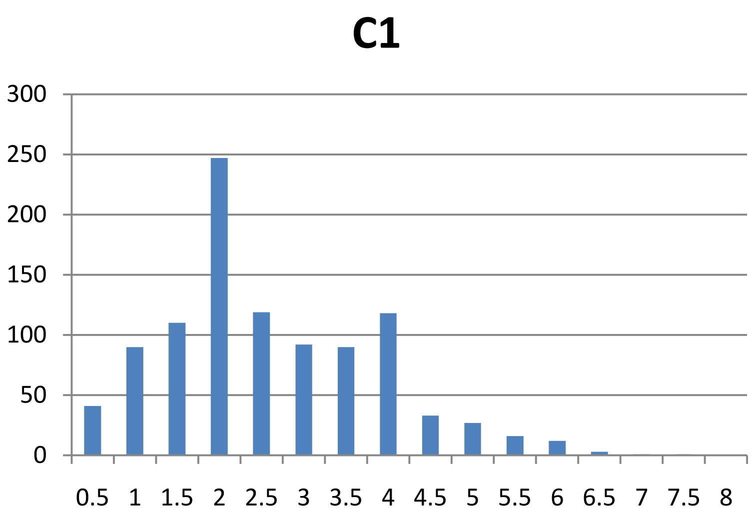
47.48	2.20	6.28	12.00	8.96	15.68	7.40

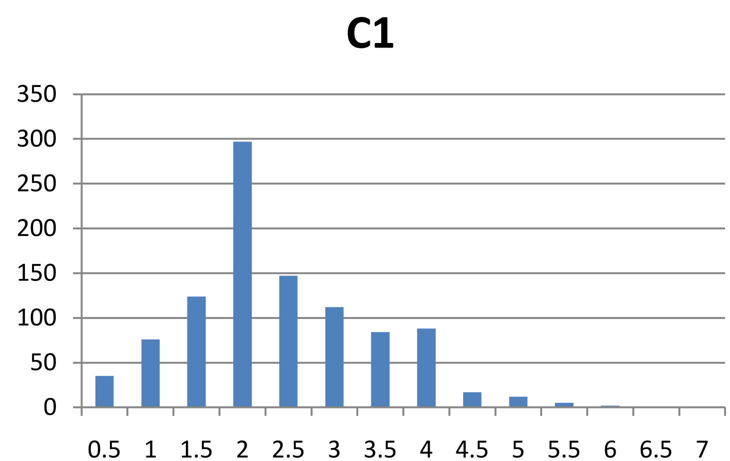
5 x 5 grid frame with 2-cm grid spacing



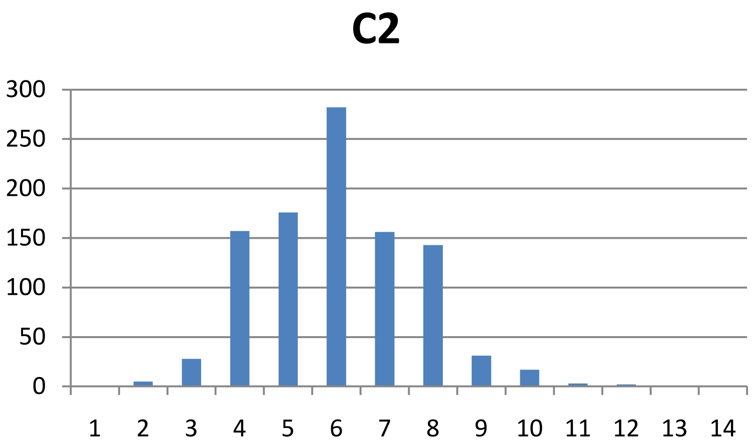
5 x 5 grid frame with 20-cm grid spacing

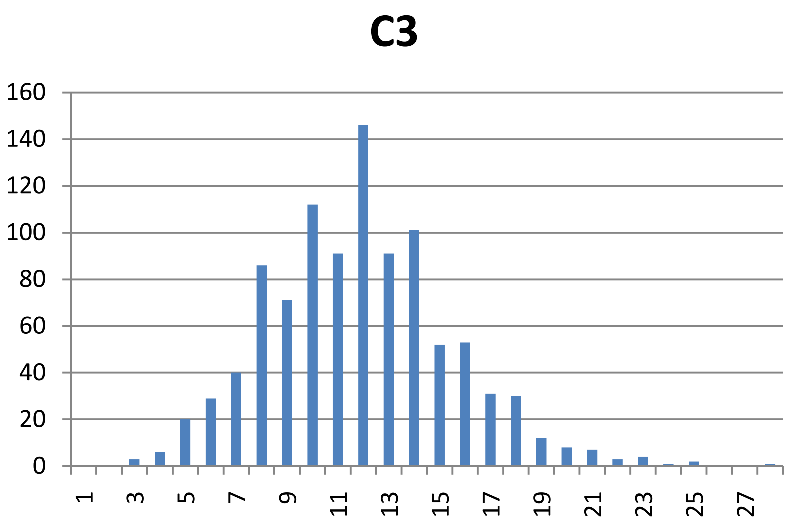




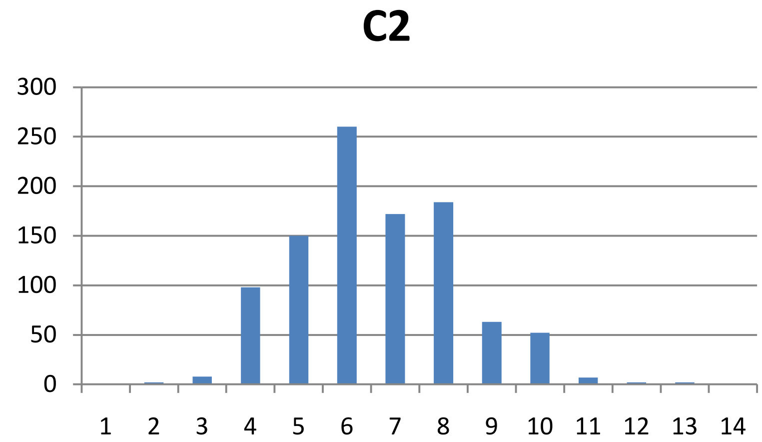


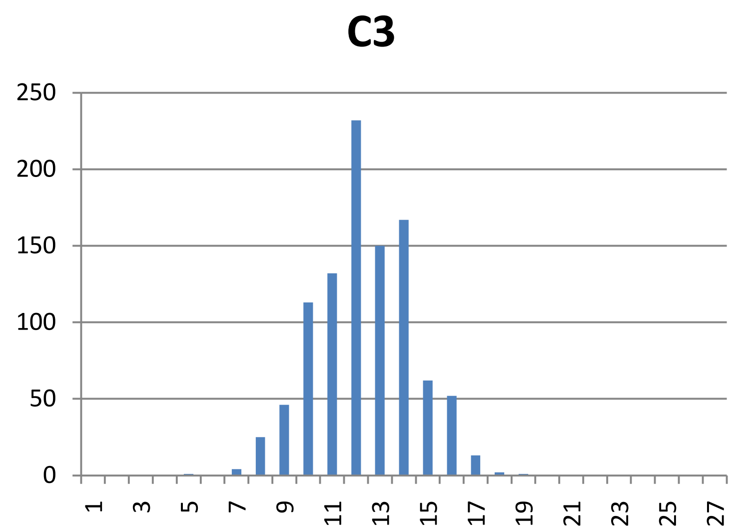
5 x 5 grid frame with 2-cm grid spacing



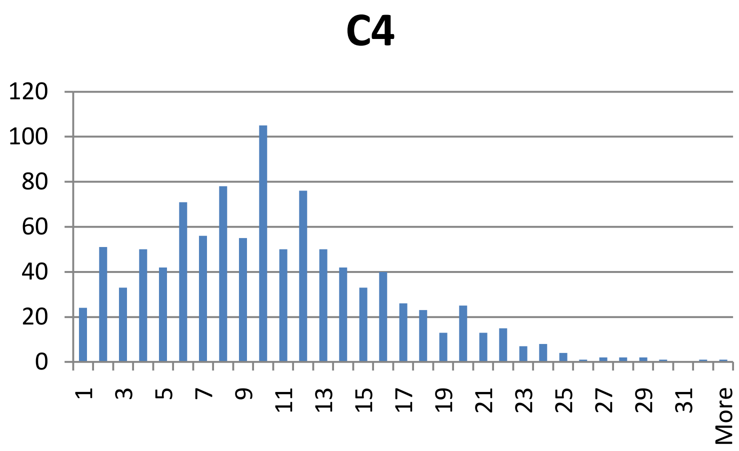


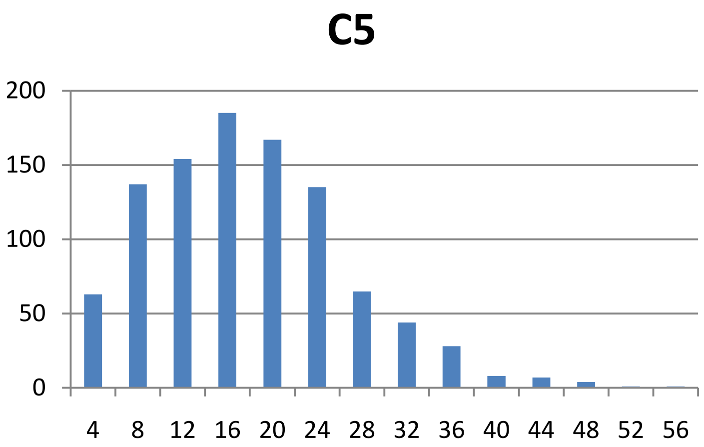
5 x 5 grid frame with 20-cm grid spacing



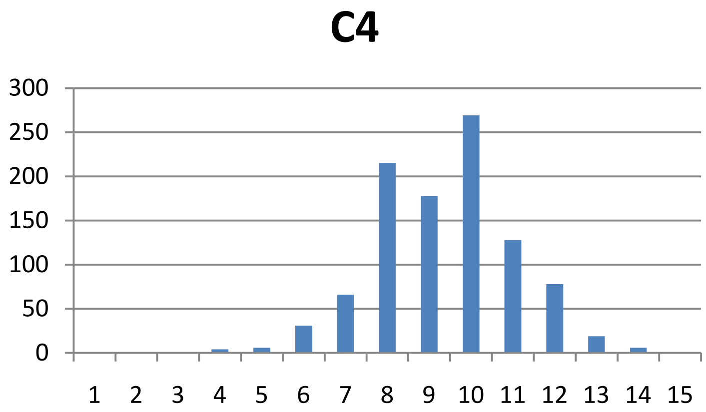


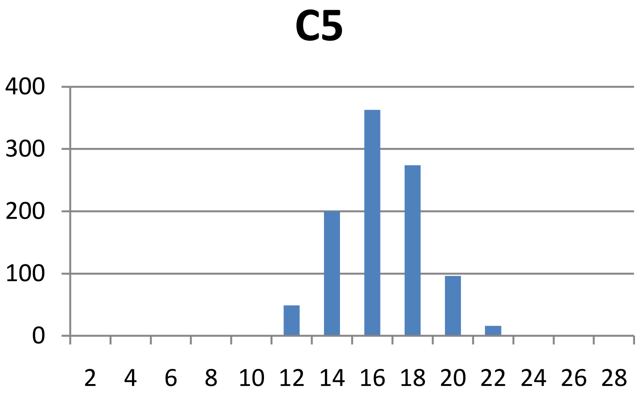
5 x 5 grid frame with 2-cm grid spacing



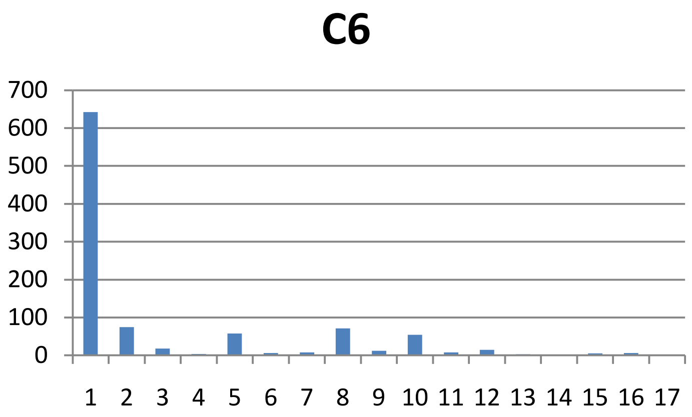


5 x 5 grid frame with 20-cm grid spacing

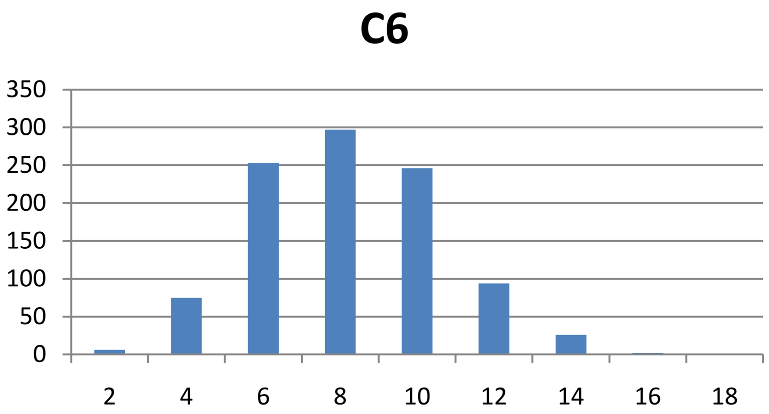




5 x 5 grid frame with 2-cm grid spacing



5 x 5 grid frame with 20-cm grid spacing



5 x 5 grid frame with 2-cm grid spacing, particle size C0

True mean	50.58		2.00		6.00		11.85		8.82		14.82		5.93
Class0_Pct		*Class1_Pct*		*Class2_Pct*		*Class3_Pct*		*Class4_Pct*		*Class5_Pct*		*Class6_Pct*	
Mean	51.388	Mean	2.395	Mean	5.634	Mean	11.476	Mean	10.002	Mean	16.082	Mean	2.571
Standard Error	0.214	Standard Error	0.040	Standard Error	0.050	Standard Error	0.114	Standard Error	0.181	Standard Error	0.275	Standard Error	0.134
Median	51.6	Median	2.4	Median	5.6	Median	11.2	Median	9.6	Median	15.6	Median	0.4
Mode	52	Mode	1.6	Mode	5.2	Mode	10.8	Mode	9.2	Mode	16.4	Mode	0
Standard Devia	6.778	Standard Devia	1.265	Standard Devia	1.572	Standard Devia	3.601	Standard Devia	5.729	Standard Devia	8.703	Standard Devia	4.234
Sample Varian	45.938	Sample Varian	1.601	Sample Varian	2.471	Sample Varian	12.969	Sample Varian	32.816	Sample Varian	75.741	Sample Varian	17.931
Kurtosis	-0.136	Kurtosis	0.061	Kurtosis	-0.007	Kurtosis	0.547	Kurtosis	0.524	Kurtosis	0.635	Kurtosis	5.025
Skewness	-0.176	Skewness	0.607	Skewness	0.335	Skewness	0.446	Skewness	0.670	Skewness	0.661	Skewness	2.051
Range	42	Range	7.2	Range	9.6	Range	24.8	Range	36.8	Range	54.4	Range	30.8
Minimum	30.4	Minimum	0	Minimum	2	Minimum	2.4	Minimum	0	Minimum	0	Minimum	0
Maximum	72.4	Maximum	7.2	Maximum	11.6	Maximum	27.2	Maximum	36.8	Maximum	54.4	Maximum	30.8
Sum	51387.6	Sum	2395.2	Sum	5633.6	Sum	11475.6	Sum	10001.6	Sum	16082.4	Sum	2570.8
Count	1000	Count	1000	Count	1000	Count	1000	Count	1000	Count	1000	Count	1000
CV	13.189%	CV	52.831%	CV	27.905%	CV	31.382%	CV	57.277%	CV	54.115%	CV	164.714%

5 x 5 grid frame with 20-cm grid spacing, particle size C0

True mean	50.58		2.00		6.00		11.85		8.82		14.82		5.93
Class0_Pct		*Class1_Pct*		*Class2_Pct*		*Class3_Pct*		*Class4_Pct*		*Class5_Pct*		*Class6_Pct*	
Mean	47.535	Mean	2.196	Mean	6.215	Mean	11.949	Mean	8.984	Mean	15.640	Mean	7.3968
Standard Error	0.109	Standard Error	0.033	Standard Error	0.053	Standard Error	0.063	Standard Error	0.052	Standard Error	0.067	Standard Error	0.075
Median	47.6	Median	2	Median	6	Median	12	Median	9	Median	15.6	Median	7.2
Mode	47.2	Mode	1.6	Mode	5.2	Mode	12	Mode	9.2	Mode	15.2	Mode	5.6
Standard Deviation	3.433	Standard Deviation	1.034	Standard Deviation	1.685	Standard Deviation	1.999	Standard Deviation	1.654	Standard Deviation	2.133	Standard Deviation	2.370
Sample Variance	11.783	Sample Variance	1.069	Sample Variance	2.840	Sample Variance	3.998	Sample Variance	2.737	Sample Variance	4.551	Sample Variance	5.616
Kurtosis	0.082	Kurtosis	0.227	Kurtosis	-0.058	Kurtosis	-0.022	Kurtosis	0.105	Kurtosis	-0.107	Kurtosis	-0.307
Skewness	-0.144	Skewness	0.539	Skewness	0.360	Skewness	0.014	Skewness	-0.082	Skewness	0.123	Skewness	0.198
Range	21.2	Range	6.8	Range	10.8	Range	14	Range	10.8	Range	12.8	Range	13.2
Minimum	36.4	Minimum	0	Minimum	1.6	Minimum	4.8	Minimum	3.2	Minimum	10	Minimum	1.2
Maximum	57.6	Maximum	6.8	Maximum	12.4	Maximum	18.8	Maximum	14	Maximum	22.8	Maximum	14.4
Sum	47535.2	Sum	2196.4	Sum	6214.8	Sum	11949.2	Sum	8984	Sum	15639.6	Sum	7396.8
Count	1000	Count	1000	Count	1000	Count	1000	Count	1000	Count	1000	Count	1000
CV	7.221%	CV	47.078%	CV	27.118%	CV	16.733%	CV	18.414%	CV	13.641%	CV	32.037%

Figure. Upper and lower confidence limits for sample means (90%) for random toss collection of particle composition with 250 sample points per sample in the “Random” reach, using 2- and 20-cm point spacing

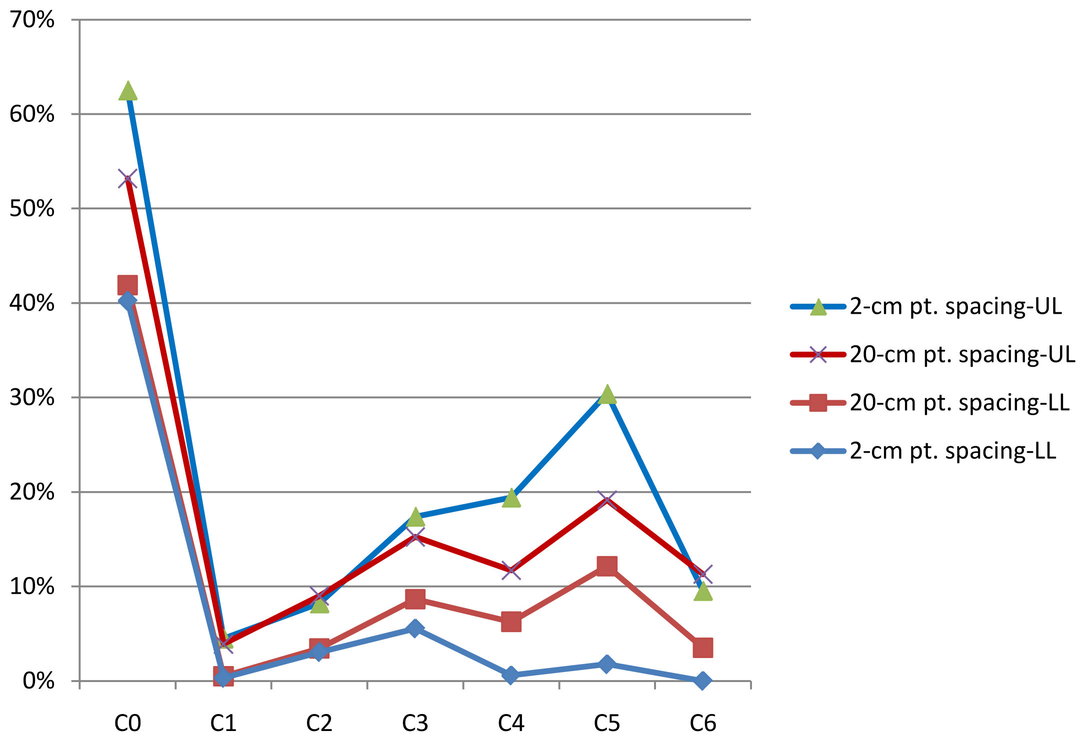


Table . Fractions of a normal distribution falling within or outside confidence limits

zσ	Percentage within CI	Percentage outside CI	Fraction outside CI
0.674σ	50%	50%	1 / 2
1σ	68.268 9492%	31.731 0508%	1 / 3.151 4872
1.645σ	90%	10%	1 / 10
1.960σ	95%	5%	1 / 20
2σ	95.449 9736%	4.550 0264%	1 / 21.977 895
2.576σ	99%	1%	1 / 100
3σ	99.730 0204%	0.269 9796%	1 / 370.398
3.2906σ	99.9%	0.1%	1 / 1000
4σ	99.993 666%	0.006 334%	1 / 15,787
5σ	99.999 942 6697%	0.000 057 3303%	1 / 1,744,278
6σ	99.999 999 8027%	0.000 000 1973%	1 / 506,800,000
7σ	99.999 999 999 7440%	0.000 000 000 2560%	1 / 390,700,000,000

Appendix E

Riparian Metrics for Potential Natural Vegetation

Mapping in the Grande Ronde River

Riparian metrics for potential natural vegetation mapping in the Grande Ronde River

March 30, 2011

Seth White, Dale McCullough, and Casey Justice
Columbia River Inter-Tribal Fish Commission

In 2010-2011, we initiated a contract with plant ecologists to develop a map of potential natural vegetation (PNV) in the project interest areas. The PNV map can provide information about the expected plant and tree community types that are likely to affect riparian shading, food web structure, and possibly stream bank stability. This information can in turn help inform the range of possible historical or future riparian scenarios that will likely impact spring Chinook salmon populations in the upper Grande River, Catherine Creek, and Minam River basins. As part of the planning for this project, we compiled a table of riparian metrics for which the PNV map could potentially account (Table 1). This list was sent to potential contractors for comment, and to date both contractors (Aaron Wells, ABR, Inc. and Elizabeth Crowe, Bozeman, MT) have provided helpful comments.

Our primary purposes for developing a PNV map are listed here, in order of priority:

1) *To provide a map of PNV that can parameterize the Heat Source model.* Heat Source (Boyd & Kasper 2003) relies on information about community types, with each community type having attributes of canopy height, density, and percent overhang. Each categorical community type would be mapped by river reach, and each type would have associated numerical parameters used directly in Heat Source (e.g., Table 2).
2) *To provide a map of PNV that informs about food web structure.* A recent report by the Independent Scientific Advisory Board implicated food webs as a major factor in population declines for Columbia River salmonids (ISAB 2011). A quick review of studies linking riparian metrics with invertebrate community structure, litter fall, and other stream food web inputs indicates great overlap with metrics required for the Heat Source model (Table 1). The most promising framework is the "energy-flow response model" which, for example, models production of autochthonous vs. allochthonous energy sources, terrestrial vs. aquatic macroinvertebrates, and salmonid tissue elaboration based on riparian percent cover and

composition (i.e., deciduous/herbaceous vs. coniferous) (Duncan, M Brusven, and T Bjornn 1989).

3) *To provide information about stream bank stability.* Although we have not conducted literature review on this subject yet, it appears that riparian community types have the potential to be directly linked to measures of stream bank stability via rooting depth and rooting type, for example (Elizabeth Crowe, pers. comm.). This would allow the PNV map to be used to identify potential areas of stream bank instability that would help facilitate planning the locations of important fish habitat restoration projects.

Table 1 lists candidate metrics for PNV mapping and associated response metric and references to the literature. During our literature search, we realized the importance of incorporating disturbance regime in PNV mapping, as events such as flooding and fire will determine the amount of vegetation expected to be present or abundant at a particular site; therefore a few key references for this topic are also provided.

Table 1. Candidate riparian metrics for potential natural vegetation mapping.

Purpose	Riparian metric	Response metric	Reference
Heat Source model	Community types, each with values of riparian canopy height, density, percent overhang, and location	Effective shade and its effect on potential daily solar load	(Boyd and Kasper 2003); Kasper pers. comm.
Food web structure	Riparian canopy types (old growth, clearcut, young-growth alder, young-growth conifer)	Macroinvertebrate counts and biomass density	(Piccolo and Mark S. Wipfli 2002)
	Presence of broadleaf deciduous	Mid-summer to late-autumn production of attached algae and aquatic vascular plants	(Hill, Ryon, and Schilling 1995)
	Continuity of overstory canopy, continuity and structural complexity of understory canopy	Change in primary carbon sources; C:N ratios in food sources	(Deegan and Ganf 2008)
	Density and species composition of understory riparian vegetation	Spider abundance and number of spider families	(Laeser, Baxter, and Fausch 2005)
	Percent canopy cover	Contribution of algal vs. terrestrial food resources	(March and Pringle 2003)
	Riparian percent cover (measured continuously) and composition (i.e., percent deciduous/herbaceous vs. coniferous)	Modeled production of autochthonous vs. allochthonous sources, terrestrial vs. aquatic macroinvertebrates, and salmonid tissue elaboration	(Duncan, M Brusven, and T Bjornn 1989)
	Perimeter/area ratio of riparian habitats (landscape-scale variable)	Organic matter input and productivity	(Polis, WB Anderson, and Holt 1997)

Purpose	Riparian metric	Response metric	Reference
Food web structure (continued)	Three categories of forest canopy structure: none, second-growth deciduous, or old-growth coniferous	Microbial respiration rate and density/biomass of aufwuchs, benthos, drift, salamanders, and trout	(Murphy, Hawkins, and NH Anderson 1981)
	Presence/absence of 2nd growth deciduous riparian vegetation	Changes in solar radiation, water temperature, periphyton accumulation, and allochthonous inputs and storage	(Hetrick et al. 1998)
	Red alder stand density	Invertebrate and detritus transport from fishless headwater streams to downstream, salmonid habitats	(M. S Wipfli and Musslewhite 2004)
	Presence/absence of riparian canopy	Community composition of invertebrates and feeding habits of juvenile salmonids	(Meehan 1996)
	Forested vs. deforested stream reaches	Drift and riparian invertebrate density and diversity	(Vadas 1997)
Indirect influence on food web via disturbance	Natural disturbance regime (e.g., wildfire or floods)	Relative contribution of autochthonous vs. allochthonous production	(ISAB 2011)
	Post-fire vs. reference riparian communities	Shift from detrital to grazing production pathways	(Mihuc and Minshall 2005)
Stream bank stabilization	To be determined		

Table 2. Example of how categories of riparian features are used to provide input (i.e., height and density parameters) to the Heat Source model (from Boyd & Kasper 2003).

Code	Riparian Feature Description	Height (m)	Density (%)
301	Water	0.0	0%
3011	River Bottom - Floodplain	0.0	0%
302	Pastures/Cultivated Field/Lawn	0.0	0%
3025	Young Orchard	3.0	75%
303	Mature Orchard	12.2	75%
304	Barren - Rock	0.0	0%
305	Barren - Embankment	0.0	0%
306	Barren - Campground/Park	0.0	0%
307	Barren - Gravel Pit	0.0	0%
308	Barren - Clearcut	0.0	0%
309	Clearcut, below 50% dense regeneration	4.6	25%
321	Lumber Yard	0.0	0%
400	Barren - Road	0.0	0%
401	Barren - Forest Road	0.0	0%
402	Barren - Railroad	0.0	0%
403	Barren - Ag. Road	0.0	0%
500	Large Mixed Conifer/Hardwood (>75% Canopy)	24.4	75%
501	Small Mixed Conifer/Hardwood (>75% Canopy)	12.2	75%
550	Large Mixed Conifer/Hardwood (>25% Canopy)	24.4	25%
551	Small Mixed Conifer/Hardwood (>25% Canopy)	12.2	25%
600	Large Hardwood	22.9	75%
601	Small Hardwood	12.2	75%
650	Large Hardwood	22.9	25%
651	Small Hardwood	12.2	25%
700	Large Conifer	27.4	75%
701	Small Conifer	12.2	75%
750	Large Conifer	27.4	25%
751	Small Conifer	12.2	25%
800	Shrubs	4.6	75%
850	Shrubs	4.6	25%
900	Grasses	1.0	75%
3248	Developed – Residential buildings	6.1	100%
3249	Developed – Industrial buildings	9.1	100%
3252	Dam	0.0	0%
3253	Pipeline	0.0	0%
3254	WWTP	0.0	0%

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Appendix F

Database Development

Section F-A Milestone Title: Continue Database Development and Implementation

Start-Date: 4/1/2010- End-Date: 3/31/2011

I. Introduction

The continual development of an extensive database to house data collected and gathered by this monitoring project is detailed in this section. The database was established in 2009 using a relational table structure within Microsoft SQL Server 2008 R2 Application. This provides a central location for all data and eliminates the need for database version control. The application is loaded on a virtual server running Microsoft Server 2008 operating system. Client access licenses are required for those viewing and manipulating the data. Data stored in this database at this time includes: temperature, flow, and habitat data see sections below for details. This database is maintained by CRITFC Staff and is routinely backed up to a NAS device as well as an additional virtual server on a daily basis or weekly basis according to the frequency of updates by SQL Maintenance plans. The data is secured within CRITFC and can only be accessed at this time in house. Future plans include the development of websites to access, enter and report this data. Although the access will be secured using Secured socket layering that requires the authentication. Access to this application from the Habitat application will be created in 2011. The habitat application is described in last paragraph of this section.

II. Temperature

This database houses temperature location data for 211 locations in a table (Locations) and a temperature values table (Temperature_Master). Figure 1 provides a map of most of these locations. The Temperature_Master table includes the raw hourly temperature measurements logged at locations managed by several organizations including: CRITFC, US Forest Service (USFS), Confederated Tribes of the Umatilla Indian Reservation (CTUIR), and Oregon Department of Fish and Wildlife (ODFW). Refer to Table 1 for the column headers, data types and data descriptions within these tables. The data typing ensures that certain values are acceptable in the columns. This method also eliminates the potential for one probe referring to numerous locations. To enforce additional referential integrity a field key has been created to ensure duplicates are not uploaded. If available, air temperature and humidity were also uploaded to the database. Table 2 shows the site names and date ranges of data within the database. Additionally, applications were created for automating QA/QC checks and reporting the geographical location, mean, maximum, 7-day maximum, and minimum daily temperatures. The data entered into the Temperature_Master is subjected to a QA/QC process following recommended procedures (Dunham et al. 2005). If data is found to be suspect then the data are flagged in the validation column. CTUIR performed QA/QC of the probe data collected and results are included in Appendix A. After validation, the data is exported to a Summary table. Table 2 also shows the headers for this summary table.

III. Flow

The 15 minute interval logging data is collected by stations that record the height of surface water. This data is then transformed using a stage discharge curve or rating table. This discharge curve or rating table was created by measuring flow at cross sections with known areas (OWRD 2011). This data is maintained and transformed to the mean daily flow in cubic feet per second (MDF) by the Oregon Water Resources Department (OWRD 2011). On an as needed basis the MDF is downloaded to a comma separated file (csv) and uploaded to the database for all site locations within the Grande Ronde Basin. At this time, there are 41 flow site locations in the database. See Figure 2 for a map of these locations. Three other sites have been found in the Grande Ronde; although, the data is not available on the server and thus has not been included in this database. This database houses flow data in a locations table (Locations) and the MDF values in another table (Flow_Master). Refer to Table 1 for the column headers, data types and data descriptions. Similarly to the Temperature data, the data typing ensures that certain values are allowed in the columns and eliminates the potential for site referring to numerous locations. To enforce additional referential integrity a field key has been created to ensure duplicates are not uploaded. Table 2 shows the site names and date ranges of data within the database. An application has been created to automate the process of downloading site data from OWRD station locations, performing QA/QC, and reporting data. CRITFC's process for QA/QC flow data is being constructed. At this time, preliminary data is loaded into the database then updated after it has been qualified as published by OWRD. A field key of Site and date information was created to enforce additional referential integrity a field key has been created to ensure duplicates are not uploaded. Data is exported to a csv file by locations and date. A csv file is used since the rows usually exceed the range allowable for Microsoft Excel 2007. Refer to Table 2 for the details on this exported data.

IV. Habitat

An additional component of the database was developed in 2010 which included the results of habitat surveys conducted during the 2010 field season for 24 locations (Figure 3). An application was created to automate the process of organizing collected data in several tables described in Appendix B. All these tables have typed data and data descriptions which are detailed in Attachment B: This application was developed as a Windows Forms application and therefore will not be made available on a website. This application can run on any PC connected to the internal CRITFC SQL Server. In the future, if needed, this application can be made to be accessible in the field.

Table 1. Descriptions of the tables within the database including: column headers, data types and data descriptions.

Column Headers	Data Type	Description
		Locations Table
fid	int	is a unique number used in the GIS analysis so links to this table are seamless. This data is an auto-generated sequential id.
site_name	Varchar	is a variable character which includes a unique column of data that is Organization.
site	Varchar	is the name of the site given by the contributing organization from which this data originates. Is the unique probe number. Probes were generally used at the same locations each year but some were moved and/or replaced.
start_date	date	is the date the probe was deployed or date data is available (mm/dd/yyyy).
end_date	date	is the date the probe was removed (mm/dd/yyyy).
update_date	date/time	is the date/time the probe was updated (mm/dd/yyyy 24:00:00.00).
easting_utm	Varchar	is the location information for the probe.
northing_utm	Varchar	is the location information for the probe.
utm_zone	integer	is the UTM zone at the location (11).
huc6	Varchar	is the sub-basin id of the probe,which is a 12-digit integer.
season	Varchar	is the monitoring season (summer, winter,or both).
parameter	Varchar	is the type of information that this probe is collecting such as temperature, flow, or sediment
stream	Varchar	is the stream from where this probe is located
project_area	Varchar	is the reference area from which all probes within a certain area are located within such as: Catherine Creek, Grande Ronde, Imnaha, or Minam.
monitoring_statu s	Varchar	is the status of the probe is it decommisioned or on-going.
other	Varchar	is the comment field for additional information.
coordinator	Varchar	is the organization responsible for gathering the probes information.
		Temperature Master Table
site	Varchar	is the name of the site given by the contributing organization from which this data originates. Links to locations table.
modified_date	date/time	is the date/time the data was collected (mm/dd/yyyy 24:00:00.00).
air_temperature_c	float	is the value of the recorded hourly air temperature in degrees celcius.
temperature_c	float	is the value of the recorded hourly stream temperature in degrees celcius.
nist_audit_c	Varchar	is the result of the audit from USFS using criteria from NIST checks on the probes recording the air temperatures.
air_nist_audit_c	Varchar	is the result of the audit from USFS using criteria from NIST checks on the probes recording the stream temperatures.
rhumidity_min	float	is the value of the recorded hourly minimum percent relative humidity.
rhumidity_max	float	is the value of the recorded hourly maximum percent relative humidity.
rhumidity_per	float	is the value of the recorded hourly percent relative humidity.
validation	Varchar	is the result from the qa/qc checks performed by CRITFC using following recommended procedures of USDA Dunham et al. 2005
comments	Varchar	is the comment field for additional information.

Temperature Summary Table

site_name	Varchar	is a variable character which includes a unique column of data that is Organization.
site	Varchar	is the name of the site given by the contributing organization from which this data originates. Is the unique probe number. Probes were generally used at the same locations each year but some were moved and/or replaced.
start_date	date	is the date the probe was deployed or date data is available (mm/dd/yyyy).
end_date	date	is the date the probe was removed (mm/dd/yyyy).
update_date	date/time	is the date/time the probe was updated (mm/dd/yyyy 24:00:00.00).
easting_utm	Varchar	is the location information for the probe.
northing_utm	Varchar	is the location information for the probe.
utm_zone	integer	is the UTM zone at the location (11).
huc6	Varchar	is the sub-basin id of the probe,which is a 12-digit integer.
season	Varchar	is the monitoring season (summer, winter,or both).
coordinator	Varchar	is the organization responsible for gathering the probes information.
avergage	float	is the daily average of temperature recorded on hourly basis in degrees celcius
7day_average	float	is the 7day average of temperature recorded on hourly basis in degrees celcius
max_temp	float	is the daily maximum recorded temperature on hourly basis in degrees celcius
7day_max	float	is the 7 day maximum recorded temperature on hourly basis in degrees celcius
validation	varchar	is the results of the QA/QC on the temperature data. "a" -

Flow Master Table

station_nbr	Varchar	is the name of the site given by the contributing organization from which this data originates. Links to locations table.
record_date	date/time	is the date/time the data was collected (mm/dd/yyyy 24:00:00.00).
mean_daily_flow_cfs	float	is the value of the recorded mean daily flow in cubic feet per second.
published_status	Varchar	is the value of the result based on qa/qc checks. http://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/faq.aspx
estimated	Varchar	is the value of the result based on estimation.
revised	Varchar	is the value of the result that is to replace any other previously reported value.
download_date	date/time	is the date/time the data was uploaded to database(mm/dd/yyyy 24:00:00.00).

Flow Summary Table

site_name	Varchar	is a variable character which includes a unique column of data that is Organization_OrganizationCode.
site	Varchar	is the name of the site given by the contributing organization from which this data originates. Is the unique probe number. Probes were generally used at the same locations each year but some were moved and/or replaced.
start_date	date	is the date the probe was deployed or date data is available (mm/dd/yyyy).
end_date	date	is the date the probe was removed (mm/dd/yyyy).
update_date	date/time	is the date/time the probe was updated (mm/dd/yyyy 24:00:00.00).
easting_utm	Varchar	is the location information for the probe.
northing_utm	Varchar	is the location information for the probe.
utm_zone	integer	is the UTM zone at the location (11).
huc6	Varchar	is the sub-basin id of the probe,which is a 12-digit integer.
season	Varchar	is the monitoring season (summer, winter,or both).
record_date	date/time	is the date/time the data was collected (mm/dd/yyyy 24:00:00.00).
mean_daily_flow_cfs	float	is the value of the recorded mean daily flow in cubic feet per second.

Flow Summary Table cont.		
published_status	Varchar	is the value of the result based on qa/qc checks. http://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/faq.aspx
estimated	Varchar	is the value of the result based on estimation.
revised	Varchar	is the value of the result that is to replace any other previously reported value.
download_date	date/time	is the date/time the data was uploaded to database(mm/dd/yyyy 24:00:00.00).

Table 2. Summary of the temporal data for the temperature and flow Monitoring Locations available in the database.

Site Name	Site ID	Start Date	End Date	Update Date	Missing Years	Northing UTM	Easting UTM	Coord-inator	Stream
Temperature									
01_PelicanCreek	USFS_L1	30-Jul-91	23-Sep-93		1994			USFS	Pelican Creek
02_FivePointsCreek_abv_PelicanCr	USFS_L2	30-Jul-91	10-Jul-92					USFS	Five Points Creek
03_GR_abv_FivePointsCreek	USFS_L3	1-Aug-91	3-Sep-92					USFS	Five Points Creek
04_RockCreek	USFS_L4	1-Aug-91	3-Sep-92					USFS	Rock Creek
05_SpringCreek	USFS_L5	1-Aug-91	1-Oct-02		1996-2001			USFS	Spring Creek
06_JordanCreek	USFS_L6	1-Aug-91	3-Sep-92					USFS	Jordan Creek
07_GR_at_RedBridge	USFS_L7	1-Aug-91	10-Jul-92					USFS	Grande Ronde River
08_BeaverCreek	USFS_L8	1-Aug-91	3-Sep-92					USFS	Beaver Creek
09_GR_blw_MeadowCreek	USFS_L9	2-Aug-91	5-Sep-92					USFS	Grande Ronde River
10_DarkCanyonCreek	USFS_L10	2-Aug-91	14-Sep-96					USFS	Dark Canyon Creek
11_McCoyCreek	USFS_L11	2-Aug-91	29-Jul-92					USFS	McCoy Creek
12_MeadowCreek_near_McIntyreRd	USFS_L12	2-Aug-91	8-Apr-93					USFS	Meadow Creek
13_BurntCorralCreek	USFS_L13	2-Aug-91	10-Sep-07		1993-2001			USFS	Burnt Corral Creek
14_BearCreek	USFS_L14	2-Aug-91	4-Oct-09	4-Oct-09	1992-1995,1997-1999	380343	5011656	USFS	Bear Creek
15_Upper_meadowCreek	USFS_L15	30-Jul-91	7-Sep-08		1993-2001, 2003	380185	5013943	USFS	Meadow Creek
16_MeadowCreek_abv_smolttrap	USFS_L16	30-Jul-91	27-Jul-94		1993			USFS	Meadow Creek
17_BeaverPond_at_Starkeystore	USFS_L17	2-Aug-91	8-Apr-93					USFS	Beaver Pond
18_Fly_Creek	USFS_L18	30-Jul-91	4-Oct-09	4-Oct-09	2006	390232	5007082	USFS	Fly Creek
19_GR_Above_fly_Creek	USFS_L19	29-Jul-91	4-Oct-09	4-Oct-09	2000	390500	5007086	USFS	Grande Ronde River
20_GR_bl_VeyMeadow	USFS_L20	6-Feb-92	20-Nov-02		1999-2000	393193	4997764	USFS	Grande Ronde River
21_LimberJime_abv_SFK	USFS_L21	2-Aug-91	26-Sep-93					USFS	Limber Jim Creek
22_SFK_LimberJim	USFS_L22	31-Jul-91	31-Aug-92					USFS	Limber Jim Creek
23_LimberJim_bl_SFConfluence	USFS_L23	31-Jul-91	4-Oct-09	4-Oct-09	1996,1999, 2003	394966	4994107	USFS	Limber Jim Creek
24_ClearCreek	USFS_L24	31-Jul-91	4-Oct-09	4-Oct-09	1996,1999, 2003	396899	4990799	USFS	Clear Creek
25_GR_above_ClearCreek	USFS_L25	31-Jul-91	4-Oct-09	4-Oct-09	1993,1996, 1997,1999-	397086	4990722	USFS	Grande Ronde River

Site Name	Site ID	Start Date	End Date	Update Date	Missing Years	Northing UTM	Easting UTM	Coord-inator	Stream
26_West_ChickenCreek	USFS_L26	27-Jul-91	4-Oct-09	4-Oct-09	2001 1994,1998	389602	4990037	USFS	Chicken Creek
27_ChickenCreek	USFS_L27	28-Jul-91	4-Oct-09	4-Oct-09	1996, 2000-2001	390475	4988966	USFS	Chicken Creek
28_SheepCreek	USFS_L28	28-Jul-91	30-Sep-91		1992			USFS	Sheep Creek
29_Little_FlyCreek	USFS_L29	28-Jul-91	4-Oct-09	4-Oct-09	1996-1997,2007	381703	4991109	USFS	Little Fly Creek
30_Flyckreek_bl_veyMeeadow	USFS_L30	2-Aug-91	8-Sep-08		1994,1996-2001,2006	385975	4997981	USFS	Fly Creek
31_CatherineCreek_abv_StatePark	USFS_L31	21-Aug-91	15-Sep-96		1992,1995			USFS	Catherine Creek
33a_SFK_CatherineCreek	USFS_L33a	15-Aug-91	22-Oct-00		1992,1995, 1999-2000			USFS	Catherine Creek
33b_NFK_CatherineCreek	USFS_L33b	15-Aug-91	22-Oct-00		1992,1994, 1998			USFS	Catherine Creek
34_BirdTrackSprings	USFS_L34	21-Aug-91	7-Aug-93					USFS	Bird Track Springs
35_CatherineCreek_bl_BottleCreek	USFS_L35	15-Aug-91	19-Aug-94		1992-1993			USFS	Catherine Creek
36_FivePoints_bl_TieCreek	USFS_L36	5-Jun-92	12-Sep-96					USFS	Five Points Creek
37_MFK_CatherineCreek	USFS_L37	15-Aug-91	28-Sep-09	28-Sep-09	1995,1997-2000,2008	451564	5000065	USFS	Middle Fork Catherine Cr.
38_NFK_CatherineCreek	USFS_L38	15-Aug-91	25-Sep-94					USFS	North Fork Catherine Cr.
39_FIvePoints_bl_MTEmilyCreek	USFS_L39	20-Aug-91	4-Jun-92					USFS	Five Points Creek
40a_MTEmilyCreek	USFS_L40a	20-Aug-91	28-Jul-97		1993-1995			USFS	Five Points Creek
40b_NFK_CatherineCreek	USFS_L40b	20-Aug-91	28-Jul-97		1993-1995			USFS	Five Points Creek
41_BigCreek	USFS_L41	15-Aug-91	30-Aug-92		1993-1995			USFS	Big Creek
42_LittleCatherine_Trib1	USFS_L42	26-May-94	4-Oct-94					USFS	Little Catherine Creek
43_LitteCatherineCreek_at_2036	USFS_L43	15-Aug-91	4-Oct-94		1992-1993			USFS	Little Catherine Creek
44_LickCreek	USFS_L44	4-Jun-92	21-Sep-93					USFS	Lick Creek
45_SFK_CatherineCreek_bl_600Bridge	USFS_L45	4-Jun-92	24-Sep-94					USFS	South Fork Catherine Cr.
46_BurntCorralCreek_at_2444040Rd	USFS_L46	9-Jul-92	4-Oct-94					USFS	Burnt Corral Creek
47_LookoutCreek	USFS_L47	9-Jul-92	4-Oct-09	4-Oct-09	1996,1998, 2002	379571	4994279	USFS	Lookout Creek
49_LookoutCreek_Trib1	USFS_L49	9-Jul-92	28-Aug-94					USFS	Lookout Creek
50_EFK_GrandeRonde	USFS_L50	15-Jul-93	13-Nov-00		1998			USFS	Grande Ronde River

Site Name	Site ID	Start Date	End Date	Update Date	Missing Years	Northing UTM	Easting UTM	Coord-inator	Stream
51_WaucupCreek	USFS_L51	14-Jul-93	5-Oct-09	5-Oct-09	1992,1994-2000	373076	5016679	USFS	Waucup Creek
53_GR_above_BlowoutCreek_site53	USFS_L53	9-Jul-92	29-Oct-95		1994			USFS	Grande Ronde River
54_BeaverCreek_ab_Reservoir	USFS_L54	24-Jun-94	28-Sep-09	28-Sep-09	1995,2000, 2005	406640	4998160	USFS	Beaver Creek
55_BeaverCreek_WestFk	USFS_L55	10-Jul-92	28-Sep-09	28-Sep-09	1996,1998, 2000,2005	404328	5000690	USFS	Beaver Creek
56_HoodooCreek	USFS_L56	10-Jul-92	10-Oct-07		1993,1996-1997,1999-2000			USFS	Hoodoo Creek
59_MFK_LimberJim	USFS_L59	12-Jul-92	4-Nov-97		1995			USFS	Limber Jim Creek
60_MeadowCreek_at_WaucupCreek	USFS_L60	14-Jul-93	21-Sep-93					USFS	Meadow Creek
61_SheepCreek	USFS_L61	14-Jul-93	8-Oct-01		1995-1999			USFS	Sheep Creek
62_E_SheepCreek_5182500Rd	USFS_L62	4-May-94	8-Oct-01		1996,1998-1999			USFS	Sheep Creek
63_MillCreek	USFS_L63	10-Jul-93	17-Oct-00		1995-1996,1999			USFS	Mill Creek
64K_Catherine	USFS_L64k	2-Jun-93	19-Jul-93					USFS	Catherine Creek
65a_SFK_CaterhineCreek	USFS_L65a	23-Aug-95	6-Oct-09	6-Oct-09	1998,2007			USFS	Catherine Creek
65b_PoleCreek	USFS_L65b	23-Aug-95	6-Oct-09	6-Oct-09	1998,2000, 2007			USFS	Catherine Creek
66_Beaver_bl_4305RD	USFS_L66	12-Jun-93	9-Aug-98		1996			USFS	Beaver Creek
74_GrandeRonde_at_Bridge5115	USFS_L74	9-Jun-95	4-Oct-09	4-Oct-09	1996,1998	391606	5001530	USFS	Grande Ronde River
75_NRK_CatherineMeadows	USFS_L75	22-Jun-93	23-Sep-07		1994-1999,2001			USFS	Catherine Creek
76_NRK_CatherineMeadows	USFS_L76	4-Aug-93	5-Oct-93					USFS	Catherine Creek
77_JordanCreek	USFS_L77	29-Jul-95	27-Aug-95					USFS	Beaver Creek
78_NFKCatherineCreekblwNFSF	USFS_L78	26-Jul-96	3-Sep-96					USFS	Catherine Creek
79_MilkCreek	USFS_L79	23-Jul-96	12-Sep-96					USFS	Catherine Creek
80_WhiskeyCreek	USFS_L80	23-Jul-96	12-Sep-96					USFS	Beaver Creek
81_McCoyCreek	USFS_L81	24-Jul-96	5-Oct-09	5-Oct-09	1997-2000	379400	5021742	USFS	Meadow Creek
82_RockCreek	USFS_L82	23-Jul-96	12-Sep-96					USFS	Beaver Creek
86_WoodleyCampgound_WooldeyCr	USFS_L86	16-Feb-94	28-Oct-09	28-Oct-09	1995-2000	396424	4991723	USFS	Grande Ronde River
87_NFK_CatherineCreek_G	USFS_L87	27-May-	19-Sep-04		2001-	449757	4997055	USFS	Catherine Creek

Site Name	Site ID	Start Date	End Date	Update Date	Missing Years	Northing UTM	Easting UTM	Coord-inator	Stream
auge		04			2004,2006				
88_FivePointsCreek_Gauge	USFS_L88	24-Apr-94	7-Sep-08		1995-2000	403801	5022726	USFS	Five Points Creek
89_Lower_meadwoCreek_Gauge	USFS_L89	1-Jan-94	28-Oct-09	28-Oct-09	1995-2002,2003, 2005,2008	391717	5013453	USFS	Meadow Creek
90_CatherineCreek_at_Mouth	USFS_L90	9-Jul-02	28-Sep-09	28-Sep-09	2006	449427	4996512	USFS	Catherine Creek
91_BeaverCreekatspillway	USFS_L91	14-Jul-00	29-Sep-03		2001			USFS	Beaver Creek
92_NFK_CatherineCreek_blw_AmeliaCreek	USFS_L92	29-Jul-00	20-Sep-09	20-Sep-09		451672	5006839	USFS	Catherine Creek
93_ChickenCreek_DryCreek	USFS_L93	8-Jun-04	29-Aug-04		2001-2004			USFS	Grande Ronde River
94_NFKCatherineCreekmdwblwproj	USFS_L94	28-Jul-00	11-Oct-00					USFS	Catherine Creek
95_MeadowCreek_abv_21Road	USFS_L95	18-May-01	22-Sep-08			372780	5016795	USFS	Meadow Creek
96_FivePointsCreek_at_Camp1	USFS_L96	30-May-01	5-Oct-09	5-Oct-09	2003	406685	5030102	USFS	Five Points Creek
98_FivePointsCreek_abv_Mt.EmilyCr	USFS_L98	28-Jul-00	19-Sep-07		2001,2004			USFS	Five Points Creek
99_MtEmilyCreek	USFS_L99	28-Jul-00	19-Sep-07		2001,2004			USFS	Five Points Creek
100_FivePointsblwEmilyCreek	USFS_L100	28-Jul-00	18-Oct-00					USFS	Five Points Creek
102_SheepCreeek_at_fsboundary	USFS_L102	30-May-02	4-Oct-09	4-Oct-09		385394	4990563	USFS	Grande Ronde River
105_CollinsCreekatmouth	USFS_L105	19-Jun-08	6-Oct-09	6-Oct-09				USFS	Collins Creek
106_ProngCreekatmouth	USFS_L106	19-Jun-08	6-Oct-09	6-Oct-09				USFS	Prong Creek
107_BigCreekatbridge	USFS_L107	3-Jul-08	4-Oct-09	4-Oct-09				USFS	Big Creek
Umatilla_BEAR1	CTUIR_BEAR1	7-Jun-03	13-Oct-05			399393	5017287	CTUIR	Bear Creek
Umatilla_BEAR2	CTUIR_BEAR2	28-Apr-04	13-Oct-05			399270	5017963	CTUIR	Bear Creek
Umatilla_CLC1	CTUIR_CLC1	22-Jul-09	20-Oct-09	20-Oct-09		396831	4990709	CTUIR	Clear Creek
Umatilla_DC1	CTUIR_DC1	4-Aug-09	29-Nov-09	29-Nov-09		391585	5014172	CTUIR	Dark Canyon
Umatilla_DC2	CTUIR_DC2	4-Aug-09	29-Nov-09	29-Nov-09		391028	5016873	CTUIR	Dark Canyon
Umatilla_END1H	CTUIR_END1H	28-Jun-03	22-Nov-09	22-Nov-09		418707	5035239	CTUIR	End Creek
Umatilla_END2H	CTUIR_END2H	28-Jun-03	5-Nov-08			420142	5035119	CTUIR	End Creek
Umatilla_GR1	CTUIR_GR1	7-Jun-03	10-Oct-07			396714	5017003	CTUIR	Grande Ronde River
Umatilla_GR2	CTUIR_GR2	7-Jun-03	13-Oct-05			399035	5017980	CTUIR	Grande Ronde River
Umatilla_GR3	CTUIR_GR3	7-Jun-03	10-Oct-07			399704	5018253	CTUIR	Grande Ronde River
Umatilla_GR4	CTUIR_GR4	22-Jul-09	20-Oct-09	20-Oct-09		392880	4996948	CTUIR	Grande Ronde River
Umatilla_GR5	CTUIR_GR5	22-Jul-09	21-Oct-09	21-Oct-09		395396	4992447	CTUIR	Grande Ronde River
Umatilla_GR6	CTUIR_GR6	22-Jul-09	19-Oct-09	19-Oct-09		397816	4989952	CTUIR	Grande Ronde River

Site Name	Site ID	Start Date	End Date	Update Date	Missing Years	Northing UTM	Easting UTM	Coord-inator	Stream
Umatilla_GR7	CTUIR_GR7	22-Jul-09	20-Oct-09	20-Oct-09		398779	4989473	CTUIR	Grande Ronde River
Umatilla_GR8	CTUIR_GR8	22-Jul-09	20-Oct-09	20-Oct-09		398767	4989391	CTUIR	Grande Ronde River
Umatilla_JORDAN1	CTUIR_JORDAN1	7-Jun-03	10-Oct-07			399888	5017804	CTUIR	Jordan Creek
Umatilla_JORDAN2	CTUIR_JORDAN2	30-Jul-02	10-Oct-07			399731	5018193	CTUIR	Jordan Creek
Umatilla_MCCOY1H	CTUIR_MCCOY1H	26-Jul-02	23-Nov-09	23-Nov-09		388128	5013925	CTUIR	McCoy Creek
Umatilla_MCCOY2H	CTUIR_MCCOY2H	26-Jul-02	5-Nov-08			388344	5013825	CTUIR	McCoy Creek
Umatilla_MCCOY3H	CTUIR_MCCOY3H	26-Jul-02	14-Oct-06			388602	5013806	CTUIR	McCoy Creek
Umatilla_MCCOY5H	CTUIR_MCCOY5H	26-Jul-02	23-Nov-09	23-Nov-09		389041	5013306	CTUIR	McCoy Creek
Umatilla_MCCOY6H	CTUIR_MCCOY6H	26-Jul-02	21-Jun-08			389037	5013298	CTUIR	McCoy Creek
Umatilla_MCCOY7H	CTUIR_MCCOY7H	7-Jun-03	23-Nov-09	23-Nov-09		390466	5013241	CTUIR	McCoy Creek
Umatilla_MCCOY8H	CTUIR_MCCOY8H	26-Jul-02	5-Nov-08			390480	5013258	CTUIR	McCoy Creek
Umatilla_MEADOW1ST	CTUIR_MEADOW 1	26-Jul-02	18-Nov-06			389614	5012393	CTUIR	Meadow Creek
Umatilla_MEADOW2ST	CTUIR_MEADOW 2	26-Jul-02	10-Oct-07			390427	5013175	CTUIR	Meadow Creek
Umatilla_MEADOW3H	CTUIR_MEADOW 3H	11-May-09	23-Nov-09	23-Nov-09		389876	5012358	CTUIR	Meadow Creek
Umatilla_MEADOW4H	CTUIR_MEADOW 4H	11-May-09	23-Nov-09	23-Nov-09		390742	5013156	CTUIR	Meadow Creek
Umatilla_MEADOW5	CTUIR_MEADOW 5	17-Jul-09	18-Nov-09	18-Nov-09		384373	5011105	CTUIR	Meadow Creek
Umatilla_MEADOW5H	CTUIR_MEADOW 5H	11-May-09	23-Nov-09	23-Nov-09		384373	5011105	CTUIR	Meadow Creek
Umatilla_MEADOW6	CTUIR_MEADOW 6	17-Jul-09	18-Nov-09	18-Nov-09		385359	5010609	CTUIR	Meadow Creek
Umatilla_MEADOW6H	CTUIR_MEADOW 6H	22-May-09	17-Nov-09	17-Nov-09		385359	5010609	CTUIR	Meadow Creek
UtahL_GRRspoolcart	USFS_UtahL	18-Jun-01	5-Oct-01					USFS	Grande Ronde River
UtahM_GRR5125Bridge	USFS_UtahM	18-Jun-01	5-Oct-01					USFS	Grande Ronde River
UtahU_GRRabvWoodleycpgd	USFS_UtahU	17-Jun-01	5-Oct-01					USFS	Grande Ronde River
Bear_Cr_below_Little_Bear_Cr	CRITFC__1	27-Jul-09	7-Oct-09	7-Oct-09		380432	5011812	CRITFC	Bear Creek
Bear_Cr_mouth	CRITFC__2	9-Jul-10				399000	5017922	CRITFC	Bear Creek
Bear_Cr_upper	CRITFC__3	10-Jul-10				400307	5014993	CRITFC	Bear Creek
Beaver_Cr_below_Dry_Beaver_Cr	CRITFC__4	30-Jun-10				398402	5007510	CRITFC	Beaver Creek
Beaver_Cr_below_reservoir	CRITFC__5	30-Jun-10				405224	4999737	CRITFC	Beaver Creek
Beaver_Cr_mouth	CRITFC__6	30-Jun-10				393402	5013482	CRITFC	Beaver Creek
Burnt_Corral_Cr_mouth	CRITFC__7	27-Jul-09	7-Oct-09	7-Oct-09		385480	5010023	CRITFC	Burnt Corral Creek

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CC_above_Ladd_Cr	CRITFC__8	13-Jul-10				426890	5013954	CRITFC	Catherine Creek
CC_above_Little_CC	CRITFC__9	9-Jul-10				443313	4998749	CRITFC	Catherine Creek
CC_above_Little_Cr	CRITFC__10	29-Jun-10				427929	5008245	CRITFC	Catherine Creek
CC_above_Milk_Cr	CRITFC__11	9-Jul-10				443440	4998502	CRITFC	Catherine Creek
CC_above_Mill_Cr	CRITFC__12	29-Jun-10				432041	5016584	CRITFC	Catherine Creek
CC_Booth_Rd_bridge	CRITFC__13	9-Jul-10				434105	5022739	CRITFC	Catherine Creek
CC_E_Union	CRITFC__14	29-Jul-09	7-Oct-09	7-Oct-09		432938	5006556	CRITFC	Catherine Creek
CC_Geckler_Rd_bridge	CRITFC__15	29-Jun-10				431960	5017103	CRITFC	Catherine Creek
CC_Hwy_203	CRITFC__16	29-Jul-09	7-Oct-09	7-Oct-09		438423	5000410	CRITFC	Catherine Creek
CC_Market_Ln_bridge	CRITFC__17	29-Jun-10				430467	5026634	CRITFC	Catherine Creek
CC_mouth	CRITFC__18	29-Jun-10				427232	5028675	CRITFC	Catherine Creek
Chicken_Cr_below_W_Chicken_Cr	CRITFC__19	28-Jun-10				389699	4990991	CRITFC	Chicken Creek
Clear_Cr_mouth	CRITFC__20	26-Jul-09	6-Oct-09	6-Oct-09		396784	4990798	CRITFC	Clear Creek
Clear_Cr_upper	CRITFC__21	26-Jul-09	5-Oct-09	5-Oct-09		395704	4988225	CRITFC	Clear Creek
CC_above_Mill_Cr	CRITFC__12	29-Jun-10				432041	5016584	CRITFC	Catherine Creek
Five_Points_Cr_above_Little_JD_Cr	CRITFC__22	28-Jul-09	6-Oct-09	6-Oct-09		406691	5030106	CRITFC	Five Points Creek
Five_Points_Cr_above_Pelican_Cr	CRITFC__23	25-Jul-09	5-Oct-09	5-Oct-09		402922	5023787	CRITFC	Five Points Creek
Five_Points_Cr_mouth	CRITFC__24	28-Jul-09	5-Oct-09	5-Oct-09		404207	5022231	CRITFC	Five Points Creek
Five_Points_Cr_upper	CRITFC__25	22-Jun-10				409404	5030563	CRITFC	Five Points Creek
Fly_Cr_below_Little_Fly_Cr	CRITFC__26	27-Jul-09	6-Oct-09	6-Oct-09		385647	4997459	CRITFC	Fly Creek
Fly_Cr_below_Squaw_Cr	CRITFC__27	27-Jul-09	6-Oct-09	6-Oct-09		379438	4998954	CRITFC	Fly Creek
Fly_Cr_canyon	CRITFC__28	29-Jun-10				386242	5000369	CRITFC	Fly Creek
Fly_Cr_mouth	CRITFC__29	23-Jun-10				390356	5007242	CRITFC	Fly Creek
GR_above_Bear_Cr	CRITFC__30	9-Jul-10				398984	5017964	CRITFC	Grande Ronde River
GR_above_Beaver_Cr	CRITFC__31	30-Jun-10				393358	5013641	CRITFC	Grande Ronde River
GR_above_CC_mouth	CRITFC__32	29-Jun-10				427121	5028695	CRITFC	Grande Ronde River
GR_above_Clear_Cr	CRITFC__33	26-Jul-09	5-Oct-09	5-Oct-09		396891	4990808	CRITFC	Grande Ronde River
GR_above_Five_Points_Cr	CRITFC__34	28-Jul-09	5-Oct-09	5-Oct-09		404219	5022161	CRITFC	Grande Ronde River
GR_above_Fly_Cr	CRITFC__35	26-Jul-09	5-Oct-09	5-Oct-09		390402	5007051	CRITFC	Grande Ronde River
GR_above_Jordan_Cr	CRITFC__36	7/9/2010				399658	5018280	CRITFC	Grande Ronde River
GR_above_Meadow_Cr	CRITFC__37	26-Jul-09	5-Oct-09	5-Oct-09		391800	5013003	CRITFC	Grande Ronde River
GR_above_Spring_Cr	CRITFC__38	30-Jun-10				401063	5019221	CRITFC	Grande Ronde River
GR_at_2nd_St_Bridge	CRITFC__39	28-Jul-09	6-Oct-09	6-Oct-09		413891	5021553	CRITFC	Grande Ronde River
GR_at_acclimation_site	CRITFC__40	26-Jul-09	25-Aug-09	25-Aug-09		395171	4992610	CRITFC	Grande Ronde River
GR_above_CC_mouth	CRITFC__32	29-Jun-10				427121	5028695	CRITFC	Grande Ronde River
GR_at_Time_and_Half_Brid	CRITFC__41	26-Jul-09	6-Oct-09	6-Oct-09		391497	5001541	CRITFC	Grande Ronde River

Site Name	Site ID	Start Date	End Date	Update Date	Missing Years	Northing UTM	Easting UTM	Coord-inator	Stream
ge									
GR_below_Tanner_Gulch	CRITFC__42	28-Jun-10				399477	4985997	CRITFC	Grande Ronde River
GR_below_Vey	CRITFC__43	27-Jul-09	6-Oct-09	6-Oct-09		393019	4998018	CRITFC	Grande Ronde River
GR_Hilgard_Park	CRITFC__44	30-Jun-10				403115	5021682	CRITFC	Grande Ronde River
GR_mine_tailings	CRITFC__45	#N/A				398740	4989461	CRITFC	Grande Ronde River
GR_Peach_Rd_bridge	CRITFC__46	29-Jun-10				424528	5022243	CRITFC	Grande Ronde River
GR_Reach_U155154	CRITFC__47	10-Jul-10				397788	4989992	CRITFC	Grande Ronde River
Jordan_Cr_mouth	CRITFC__48	9-Jul-10				399725	5018226	CRITFC	Jordan Creek
Ladd_Cr_mouth	CRITFC__49	13-Jul-10				426459	5014624	CRITFC	Ladd Creek
Ladd_Cr_upper	CRITFC__50	30-Jun-10				419609	5007327	CRITFC	Ladd Creek
Limber_Jim_Cr_below_NF	CRITFC__51	26-Jul-09	6-Oct-09	6-Oct-09		395658	4995796	CRITFC	Limber Jim Creek
Limber_Jim_Cr_mouth	CRITFC__52	26-Jul-09	6-Oct-09	6-Oct-09		394822	4993859	CRITFC	Limber Jim Creek
Limber_Jim_Cr_upper	CRITFC__53	26-Jul-09	6-Oct-09	6-Oct-09		397179	4995705	CRITFC	Limber Jim Creek
Little_CC_mouth	CRITFC__56	29-Jul-09	7-Oct-09	7-Oct-09		443477	4998817	CRITFC	Little Catherine Creek
Little_Cr_High_Valley_Rd	CRITFC__57	29-Jul-09	7-Oct-09	7-Oct-09		438641	5006477	CRITFC	Little Creek
Little_Cr_mouth	CRITFC__58	29-Jun-10				427945	5009109	CRITFC	Little Creek
Little_Cr_N_Union	CRITFC__59	29-Jul-09	7-Oct-09	7-Oct-09		432455	5007439	CRITFC	Little Creek
McCoy_Cr_below_Ensign_Cr	CRITFC__60	23-Jun-10				379120	5021821	CRITFC	McCoy Creek
McCoy_Cr_mouth	CRITFC__61	23-Jun-10				390396	5013242	CRITFC	McCoy Creek
Meadow_Cr_above_Bear_Cr	CRITFC__62	27-Jul-09	6-Oct-09	6-Oct-09		380605	5013595	CRITFC	Meadow Creek
Meadow_Cr_above_Dark_Canyon_Cr	CRITFC__63	30-Jun-10				391559	5014075	CRITFC	Meadow Creek
Meadow_Cr_above_McCoy_Cr	CRITFC__64	23-Jun-10				390424	5013171	CRITFC	Meadow Creek
Meadow_Cr_above_Waucup_Cr	CRITFC__65	23-Jun-10				373014	5016747	CRITFC	Meadow Creek
Meadow_Cr_below_FS22_Bridge	CRITFC__66	27-Jul-09	7-Oct-09	7-Oct-09		374169	5016514	CRITFC	Meadow Creek
Meadow_Cr_mouth	CRITFC__67	26-Jul-09	5-Oct-09	5-Oct-09		391914	5013246	CRITFC	Meadow Creek
MF_CC_mouth	CRITFC__68	29-Jul-09	7-Oct-09	7-Oct-09		452560	5003345	CRITFC	Middle Fork Catherine Cr.
Milk_Cr_below_unnamed_trib	CRITFC__69	24-Jun-10				444763	4996989	CRITFC	Milk Creek
Milk_Cr_mouth	CRITFC__70	24-Jun-10				443382	4998470	CRITFC	Milk Creek
Milk_Cr_upper	CRITFC__71	24-Jun-10				444678	4996639	CRITFC	Milk Creek
Mill_Cr_mouth	CRITFC__72	29-Jun-10				432166	5016610	CRITFC	Mill Creek
Mill_Cr_upper	CRITFC__73	29-Jun-10				440465	5014864	CRITFC	Mill Creek
NF_CC_above_Jim_Cr	CRITFC__74	2-Jun-10				452560	5003345	CRITFC	North Fork Catherine Cr.
NF_CC_above_MF_CC	CRITFC__75	29-Jul-09	6-Oct-09	6-Oct-09		451579	5000181	CRITFC	North Fork Catherine Cr.

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NF_CC_mouth	CRITFC__76	29-Jul-09	7-Oct-09	7-Oct-09		449231	4996591	CRITFC	North Fork Catherine Cr.
NF_CC_upper	CRITFC__77	2-Jun-10				451715	5006701	CRITFC	North Fork Catherine Cr.
Pelican_Cr_mouth	CRITFC__78	25-Jul-09	3-Aug-09	3-Aug-09		402828	5023929	CRITFC	Pelican Creek
Rock_Cr_mouth	CRITFC__79	23-Jun-10				403995	5021613	CRITFC	Rock Creek
SF_CC_mouth	CRITFC__80	29-Jul-09	7-Oct-09	7-Oct-09		449253	4996531	CRITFC	North Fork Catherine Cr.
Sheep_Cr_below_5160_Rd	CRITFC__81	28-Jun-10				385376	4990521	CRITFC	Sheep Creek
Sheep_Cr_below_E_Sheep_Cr	CRITFC__82	27-Jul-09	6-Oct-09	6-Oct-09		383815	4986932	CRITFC	Sheep Creek
Spring_Cr_mouth	CRITFC__84	30-Jun-10				401163	5019565	CRITFC	Spring Creek
Spring_Cr_upper	CRITFC__85	10-Jul-10				432455	5007439	CRITFC	Spring Creek
Waucup_Cr_mouth	CRITFC__86	23-Jun-10				373011	5016670	CRITFC	Waucup Creek
Flow									
Bear Cr. at Wallowa	13330700	9-May-95	30-Sep-03			457936	5047574	OWRD	Bear Creek
Bear Cr. nr Wallowa	13330500	1-Apr-15		22-Feb-11		456954	5041638	OWRD	Bear Creek
Flow_Bear_Cr_at_Wallowa	13330700	9-May-95	30-Sep-03			457936	5047574	OWRD	Bear Creek
Flow_Bear-Cr_nr_Wallowa	13330500	1-Apr-15		22-Feb-11		456954	5041638	OWRD	Bear Creek
Flow_CatherineCreek_near Union	13320000	1-Aug-11		22-Feb-11		439170	5000514	OWRD	Catherine Creek
Flow_Five_Points_CR	13318920	1-Oct-92		22-Feb-11		403802	5022671	OWRD	Five Points Creek
Flow_GR_at_Hilgard	13318800	1-Oct-66	30-Nov-81			402526	5021396	OWRD	Grande Ronde
Flow_GR_near_Imbler	13323495	28-Jan-97	18-Sep-03			427854	5038543	OWRD	Grande Ronde
Flow_GR_near_Perry	13318960	1-Oct-96		22-Feb-11		407442	5022746	OWRD	Grande Ronde
Flow_GR_near_Starkey	13317900	15-May-36	31-Oct-37			392630	4996477	OWRD	Grande Ronde
Flow_Imnaha_at_Imnaha	13292000	1-Oct-28		22-Feb-11		5045409	512973	OWRD	Imnaha River
Flow_IndianCr_near_Imbler	13323600	1-Mar-38	30-Sep-50			435929	5031155	OWRD	Indian Creek
Flow_LittleMinamR_near_Cove	13331400	16-Jun-38	30-Sep-43			447920	5012912	OWRD	Minam River
Flow_Lostine_at_Baker_rd_nr_Lostine	13330300	1-Jun-95		22-Feb-11		462633	5042790	OWRD	Lostine River
Flow_Lostine_at_Caudle_Ln_at_Lostine	13330050	1-Aug-95		22-Feb-11		465965	5037441	OWRD	Lostine River
Flow_LostineR_near_Lostine	13330000	1-Sep-12		22-Feb-11		466651	5031849	OWRD	Lostine River
Flow_MeadowCR_above_BearCr	13318060	1-Jul-77		22-Feb-11		380731	5013575	OWRD	Meadow Creek
Flow_MeadowCR_below_DarkCanyon	13318210	1-Oct-92		22-Feb-11		391681	5013502	OWRD	Meadow Creek
Flow_MeadowCR_below_SmithCR	13318050	1-Jul-77	31-Oct-79			374187	5016542	OWRD	Meadow Creek

Site Name	Site ID	Start Date	End Date	Update Date	Missing Years	Northing UTM	Easting UTM	Coord-inator	Stream
Flow_MeadowCR_near_Starkey	13318200	1-Oct-31	30-Sep-35			391391	5013476	OWRD	Meadow Creek
Flow_MinamR_near_Minam	13331500	1-Jun-12		22-Feb-11		443434	5052051	OWRD	Minam River
Flow_NFKCatherineCR_near_MedicalSprings	13319900	1-Oct-92		22-Feb-11		450261	4997463	OWRD	Catherine Creek
Flow_S_Catherine_Ditch	13319700	31-May-66	30-Sep-84			458987	4992247	OWRD	Catherine Creek
Flow_S_Catherine_Medical Springs	13319800	1-May-26	20-Sep-27			453912	4994843	OWRD	Catherine Creek
Flow_WallowaR_below_watercan	13331450	16-Aug-95		22-Feb-11		452042	5050717	OWRD	Wallowa River
Flow_WallowaR_Enterprise	13329765	1-Jun-12		22-Feb-11		469714	5035802	OWRD	Wallowa River
Lostine R. at Baker Rd. nr Lostine	13330300	1-Jun-95		22-Feb-11		462633	5042790	OWRD	Lostine River
Lostine R. at Caudle Ln at Lostine	13330050	1-Aug-95	22-Feb-11	22-Feb-11		465965	5037441	OWRD	Lostine River
Wallowa R. Ab. XC canal nr. Enterprise	13329770	28-Apr-95	24-Jun-09			468526	5037312	OWRD	Wallowa River

Citations

Dunham, J., C. Gwynne, B. Reiman, and D. Martin. 2005. Measuring stream temperature with digital data loggers: A user's guide. USDA Forest Service, Report RMRS-GTR-150WWW, Fort Collins, CO.

OWRD 2011. Oregon Water Resources Department. Accessed site on: March 21, 2011. Using: http://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/ .

Appendix G

Notes on how the CTUIR water temperature data were collected

Appendix A

Notes on how CTUIR temperature data were organized and collated

These data are from the Confederated Tribes of the Umatilla Indian Reservation Grande Ronde Fish Habitat program.

Data covered by this document span the years 2002 to 2009.

1. Data in the raw ASCII files has not been edited or altered. Any edits were carried out and saved in either a Microsoft Excel or Access format.
2. The date for the probes activation and termination were not the same as deployment and/or retrieval, therefore, data outside the deployment/retrieval dates was not used (but is retained in the raw ASCII files).
3. Data for the day of deployment and day of retrieval were removed from the dataset. This was done to provide data where probes at the upstream and downstream sites were recording water temperature at the same time/date.
4. When field notes indicated errors with the probe the data for that time period was removed. These errors could be due to a dead battery or the probes being out of the water.
5. Some probes recorded erratically due to failing batteries and/or being out of the water. These probes/years are detailed as follows:
    a. BEAR1 (2003) weeks 30 through 33 the probe was out of the water so data deleted for that time period.
    b. BEAR1 (2006) probe not working correctly so data deleted.
    c. BEAR2 (2003) no data.
    d. BEAR2 (2006) probe not working correctly.
    e. END1H (2006) no data.
    f. END1H (2008) probe not working correctly weeks 29 through 38 so data deleted for that time period.
    g. END2H (2006) weeks 36 through 39 probe not working.
    h. GR1 (2003) weeks 28 through 30 the probe was out of the water so data for that period was deleted.
    i. GR1 (2006) probe not working correctly so data deleted.
    j. GR2 (2006) probe not working correctly so data deleted.

k. GR3 (2007) for weeks 31 through 40 probe was out of water so data for that period was deleted.
l. JORDAN1 (2002) no data.
m. JORDAN1 (2006) probe not working correctly data deleted.
n. JORDAN1 (2007) probe out of the water weeks 40 through 41 so data deleted.
o. JORDAN2 (2004) no data.
p. JORDAN1 and 2 (2005) probes were out of the water during week 23 so data for that week was deleted.
q. JORDAN2 the channel dries up approximately June through September; however these data are retained so that the timing of this dry period can be plotted each year.
r. LONGLEYAIR (2007) no data.
s. MCCOY1H (2007) data ends week 39.
t. MCCOY2H (2005) record period ends week 41.
u. MCCOY3H (2007) data lost when stream bank collapsed.
v. MCCOY5H (2005) data collection ends week 41.
w. MCCOY5H (2007) week 22 the probe was out of the water so data deleted for that week. Data collection ends week 39.
x. MCCOY6H (2007) probe was in the dry for weeks 22 and 23, then weeks 30 through 33 so these data were deleted.
y. MCCOYAIR (2005) no data.
z. MEADOW1H (2003) no data.
aa. MEADOW1H (2007) probe not working correctly, data deleted.
    i. MEADOW1H and 2H (2008) no data as Starlogger deployed instead of Hobo's.

6. Probe locations were plotted in ARCGIS with the projection being in UTM NAD 83 zone 11N.
7. Problems with the date format in Microsoft Excel made it necessary to import the data table into Microsoft Access with all dates formatted as text, and then export the table back to Excel. The spreadsheet for McCoy Meadows is approximately 154,000 rows and is a compilation of several years of data. This size may contribute to potential problems in Excel, therefore, it may be necessary to split these data into smaller chunks and re-combine them after calculating the 7-day maximum temperatures.
8. Table headers were:
    a. **Date_id and Time_id**. Are the date and hour of recording (split into two columns when imported into Excel).
    b. **Temp_C**. Is the recorded temperature in degrees Celsius.
    c. **Probe_id**. Is the unique probe number. Probes were generally used at the same locations each year but some were moved and/or replaced. A combination of the "Probe_id", "Location" and "Year" will give a unique reference.
    d. **Location**. Is a unique identifier for each monitoring site and is used to link the temperature data table to an X/Y coordinate table in Microsoft Access.

e. **WeekNum**. Is the week of the year (numbered from 1 to 52) and is used when calculating the 7-day maximum temperatures.

f. **Comments**. Is a column for general comments about a probe, particular date or weather conditions etc.

Appendix H

Conceptual Framework, Methods, and Field Test of

a Stream Classification in the Grande Ronde River Basin

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Conceptual Framework, Methods, and Field Test of a Stream Classification in the Grande Ronde River Basin

A component of

Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators

March 2011 DRAFT

Seth White
Dale McCullough
Casey Justice
Denise Kelsey

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INTRODUCTION

A robust stream classification provides a basis for comparing units for analysis, facilitates understanding of ecological processes that vary under different watershed conditions, and creates common ground for administering management activities and communicating findings. Stream classification has a long history of use in aquatic ecology (e.g., Frič 1872; Strahler 1952; Huet 1959; Warren 1979; Vannote *et al.* 1980; Frissell *et al.* 1986; Hawkins *et al.* 1993; Rosgen 1994; Montgomery & Buffington 1997). Classification systems are used, among other reasons, to identify sample units of similar zoogeographic and physio-chemical nature for comparison of site characteristics across broad regions (Stoddard 2004) and for guiding restoration efforts in geomorphically-similar river sections having the capacity to respond to treatments in a similar manner (Ebersole & Liss 1997).

We developed a process-based stream classification *sensu* Montgomery & Buffington (1997) with nested hierarchical spatial scales *sensu* Frissell *et al.* (1986) for the purpose of guiding of site selection and analyses of key limiting factors of Chinook salmon at multiple life history stages (Figure 1). While stratification and site selection for monitoring was based on reach-scale classification only, we envision testing various classification systems at broader spatial scales than our initial, simple classification scheme to examine how model output changes under different classification scenarios (Table 1). Because this project aims to describe the relative influence of anthropogenic factors (e.g., the cumulative effects of land use vs. restoration) on key limiting factors for Chinook salmon using a transparent and reproducible stream classification, findings could later be extrapolated to other basins with similar physio-chemical properties and anthropogenic impacts.

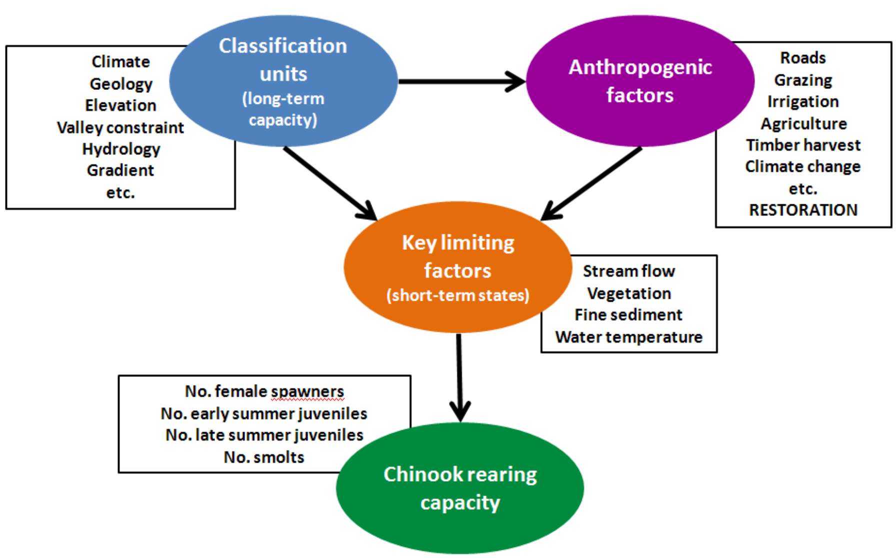


Figure 1. A conceptual framework for modeling spring Chinook rearing capacity. Direction of arrows indicates direction of influence of elements on one another.

Our general approach was to create an *a priori* reach-scale classification composed of a minimal number of classes expected to explain variation in measured habitat metrics. We adopted the perspective introduced by Warren (1979) that the most useful type of classification system describes long-term capacities of watersheds, versus short-term states that either change relatively quickly due to natural processes—as in a classification based solely on channel planform and local morphology (Rosgen 1994)—or can be modified by land use practices. As an example of the latter, Rieman *et al.* (2000) classified Pacific Northwest watersheds based on distribution of forest and fish communities, a perspective that proved useful for describing consistent trends among terrestrial communities. However that classification did not provide consistently comparable units for analysis because sites could conceivably change classes if, for example, a fire burnt through extensive forest or if fish populations declined due to parasites.

The immediate purpose of our classification was to create units for stratification in our sampling strategy. We used generalized random-tessellation stratified design (GRTS) (Stevens 1997) with a panel design in order to sample across the basin in a random yet spatially balanced manner. Classification units were granted probability of sampling according to their relative occurrence, whereas areas where spring Chinook salmon either currently or historically spawned were granted higher probability of sampling.

Steps towards classification include reviewing published literature on classification systems, deciding on a conceptual framework for classification, generating an accurate stream layer at the appropriate level of resolution, modeling and verifying watershed attributes, using those attributes to group stream reaches into classes, and field verification of the classification system. This report documents our methods and decision-making process while developing a conceptual framework for stream classification and a working classification system.

Table 1. Variables for classification of stream reaches at landscape, segment, reach, and channel unit scales.

Phase	Spatial scale	Variables	Explanation	Selected references
Domains	Landscape	Geology	Erodible versus resistant parent material	Walker 1990; Richards *et al.* 1997; Montgomery 1999; DOGAMI 2009
		Ecoregion (Omernik level IV-V)	Expert opinion classification incorporating climate, geology, soils, potential vegetation, and geomorphology relevant to aquatic habitat	Bryce & Clarke 1996; Clarke & Bryce 1997; Stoddard 2004
		Hydrologic landscape region	Incorporating climate, runoff seasonality, aquifer permeability, soil permeability, and topography	Wigington, Leibowitz, Comeleo & Ebersole, unpublished map
		IMW landscape classification	Incorporating climate, land form, geology, and stream form in a classification supporting intensively monitored watersheds (IMWs)	Whittier *et al.* 2010
		Hydrology	Dimensionless ratios describing characteristic low, average, or bankfull flows of watersheds	Orsborn 1990
		Watershed identity	Including upper Grande Ronde, Catherine Creek, and a reference watershed (Minam or Wenaha River)	Omernik & Bailey 1997
		Geographic distance between sites	Used as a null model to compare against all other candidate domains	Pyne *et al.* 2007
	Segment	Reach-scale classifications	Homogenous regions of reach-scale classification units between tributary junctions	Frissell *et al.* 1986
Strata	Reach	Watershed area	Drainage area upstream calculated for the downstream-most cell of each reach	Warren 1979; McCullough 1987
		Stream order	Definition of stream size based on tributary hierarchy	Strahler 1957
		Elevation	Downstream elevation in m of each reach	Huet 1959; Grenouillet *et al.* 2004
		Mean annual precipitation depth	Precipitation depth of upstream watershed area, derived from PRISM climate data	Daly *et al.* 2002; Paulsen & Fisher 2005; Golian *et al.* 2010
		Channel gradient	Mean gradient (% slope) from upstream to downstream stream reach	Frissell *et al.* 1986; Cupp 1989; Rosgen 1994; Lunetta *et al.* 1997; Montgomery & Buffington 1997; Burnett *et al.* 2007

		Channel constraint	Based on ratio of active channel to valley floor width, averaged by reach	Frissell *et al.* 1986; Cupp 1989; Burnett *et al.* 2007
Field testing	Channel unit	Pools, riffles, glides, etc.	Identified in field and used to scale Chinook salmon spawning and rearing estimates	Bisson 1982; Hawkins *et al.* 1993; Bisson *et al.* 2006

GENERATION OF HYDROGRAPHY AND REACH-SCALE ATTRIBUTES

Hydrography layers

A preliminary step in attaining attributes for classifying streams was to generate a new digital steam map (hydrography). Our rationale for creating a new hydrography was that currently available stream layers typically range in scales from 1:24,000 to 1:100,000, even within a given watershed, and therefore do not consistently represent network densities across large spatial extents (Clarke *et al.* 2008). Furthermore, existing stream networks vary in their accurate representation of river channel location (e.g., Figure 2).

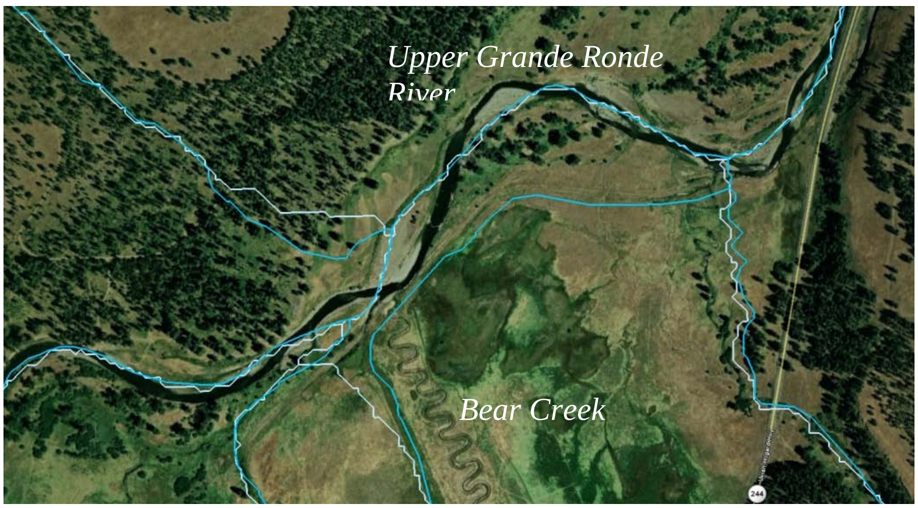


Figure 2. Two hydrographies for the confluence of Bear Creek and upper Grande Ronde River, modeled from the USGS National Hydrography Dataset (NHD) (blue line) and from a 10-m DEM (white line).

We desired an accurate stream layer having consistent network densities across the entire study extent. We used the NetStream software (Miller 2008) to generate a synthetic hydrography from a 10-m digital elevation model (DEM), which was incorporated into a geographic information system (GIS) for visualization and analysis (Figure 3). We generated hydrography layers for the project core watersheds (upper Grande Ronde River and Catherine Creek) beginning at their confluence at the state ditch, and for two candidate reference streams (Wenaha and Minam Rivers). Because the existing USGS National Hydrography Dataset (NHD) stream network was verified using aerial photographs and expert opinion and therefore more-accurately represented areas with extensive irrigation canals, we used the mixed-resolution 1:12,000 - 1:24,000 NHD layer as a mask to guide the newly-modeled Catherine Creek from above the town of Union downstream to its confluence with the Grande Ronde River at the state ditch, and at a stream diversion to a road crossing at the confluence of Catherine and Milk Creeks. In all other cases stream networks were generated from the 10-m DEMs alone. Flow paths of modeled streams over the landscape were verified by visual comparisons with NHD hydrographies and aerial photographs using ArcGIS Explorer (ESRI 2009).

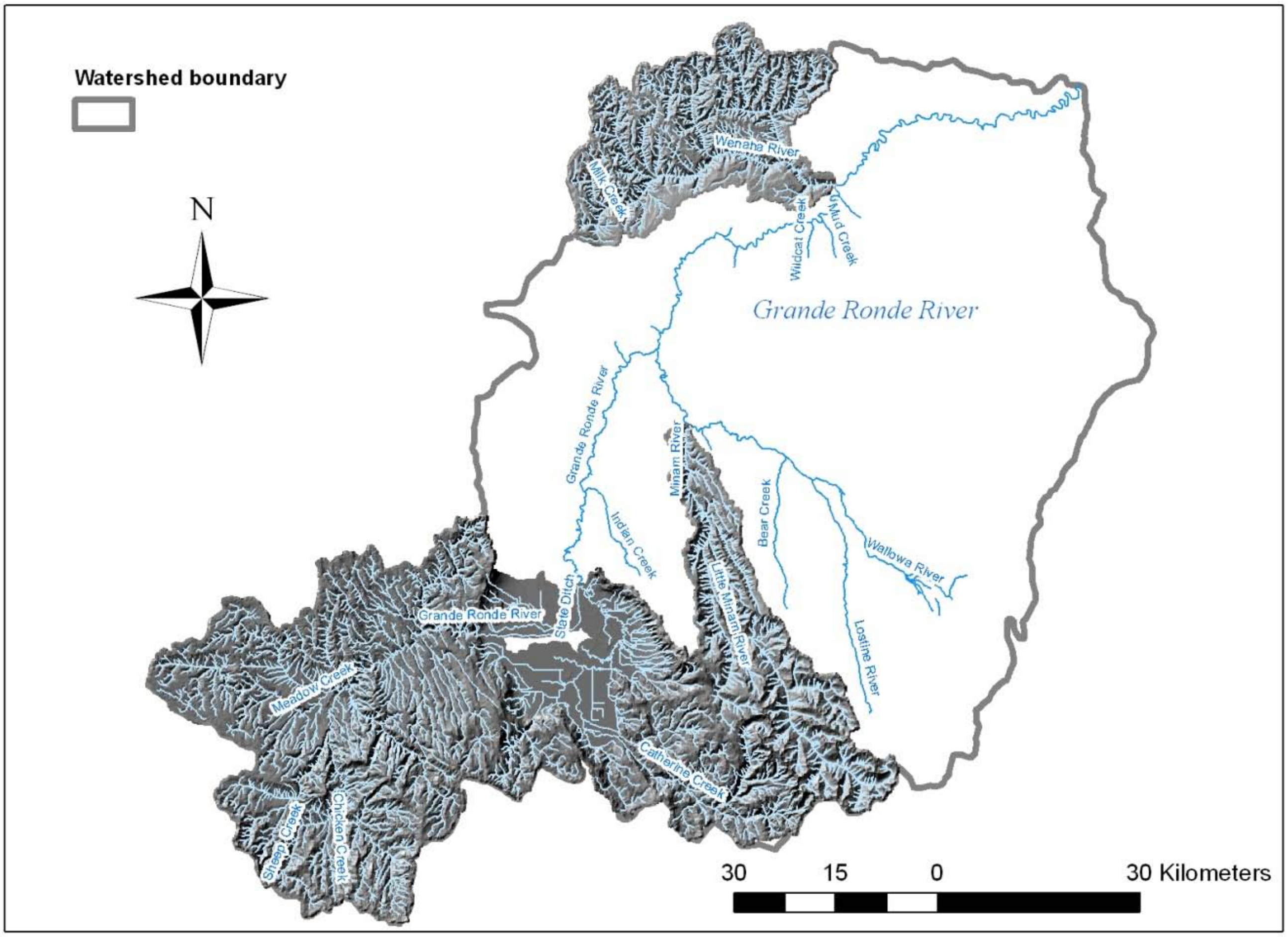


Figure 3. New hydrography layers for the upper Grande Ronde River, Catherine Creek, Minam and Wenaha Rivers derived from 10-m DEMs.

Stream reach attributes

Attributes for classifying streams at the reach scale were derived from the same NetStream software as generating hydrography layers (Miller 2008) and using the methods described by Clarke *et al.* (2008). Parameters for algorithms for generating reach attributes were derived from Oregon Department of Fish and Wildlife (ODFW) Aquatic Habitat Inventory data (*sensu* Moore *et al.* 2008) from the years 1991-1996 in the upper Grande Ronde River and Catherine Creek. The length of reaches was set to 20 times the modeled active-channel width, and reach breaks were additionally enforced at major tributary confluences (those composing the spring Chinook-bearing extent of the watershed), as tributary additions are known to have a major influence on the geomorphic characteristics of mainstems (Rice 1998; Benda *et al.* 2004). Modeled active-channel widths were derived from a power function of watershed area and active-channel width measured in the field in 58 reaches by ODFW crews (Figure 4).

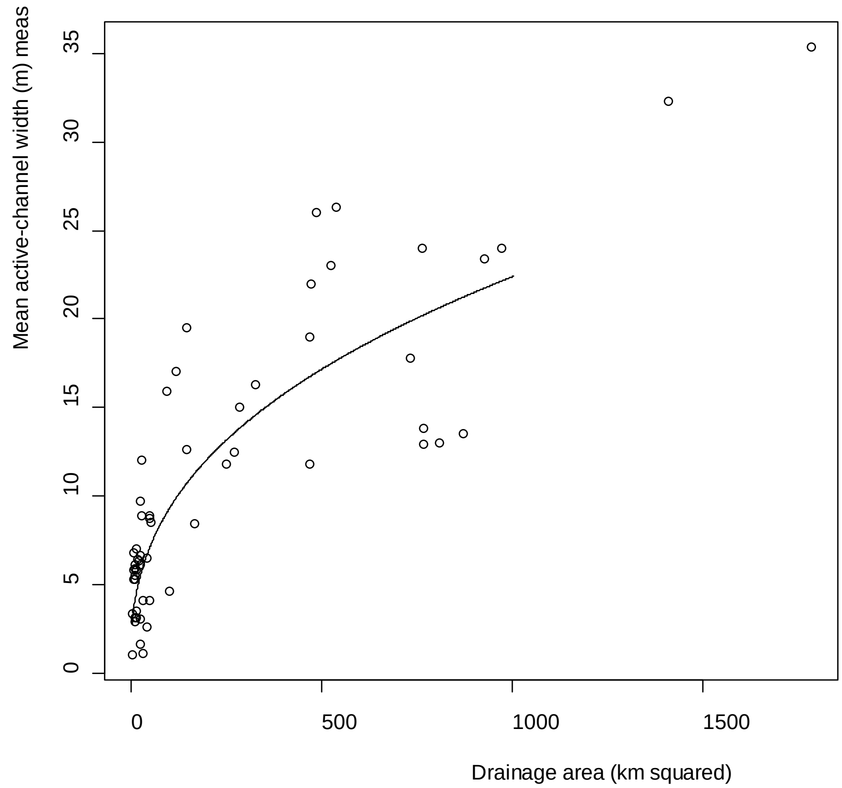


Figure 4. Relationship between field-measured mean active-channel width (W_a) and drainage area (D) ($W_a = 0.449 \times D^{0.385}$) ($R^2 = 0.65$; df = 56; $p < 0.001$).

For each reach, the following attributes for classification were determined:

- Drainage area—For the downstream-most cell of each reach, the contributing watershed area (km^2) was calculated from the 10-m DEM using the D∞ flow accumulation algorithm (Tarboton 1997) for cells upstream of modeled channel initiation points and the D-8 flow algorithm (O'Callaghan & Mark 1984) for cells downstream of those points.
- Stream order—the longitudinal position of each stream reach in the stream network was calculated according to Strahler (1957).
- Elevation—From the 10-m DEM, elevation (m) was determined for the downstream-most cell of each reach.
- Mean annual precipitation—Accumulated mean annual precipitation (mm/year) in the watershed for the downstream-most cell of each reach was derived from the parameter-elevation regressions on independent slopes model (PRISM 2009), calculated along with drainage area so that the resulting value was the accumulated volume divided by drainage area. PRISM data was comprised of a 30-arcsec (800-m) grid of average annual precipitation normals from 1971-2000.
- Mean gradient—Local gradient for each 10-m DEM cell was calculated using a polynomial fit over a centered window, and average values of gradient were assigned to each reach. Length of the centered window varied from a minimum of 30 m and a maximum of 300 m

depending on gradient, with gradients ≥ 0.20 having the minimum and gradients ≤ 0.001 having the maximum window lengths.

- Valley constraint—Designation of valley constraint into two categories (constrained and unconstrained) was achieved through a multistep process which involved first deriving a measure of floodplain width from the 10-m DEM, then calculating valley width index, and finally fitting modeled values of VWI to a logistic regression with ODFW field crew designations of valley form. Floodplain width was calculated using the inundation flow path method (Miller 2008). Cells within 2.5 times the modeled active-channel height were flagged as valley floor and average values of floodplain width were assigned to each reach. Modeled active-channel heights were derived from a power function of watershed area and active-channel heights measured in the field for 58 reaches by ODFW crews (Figure 5).

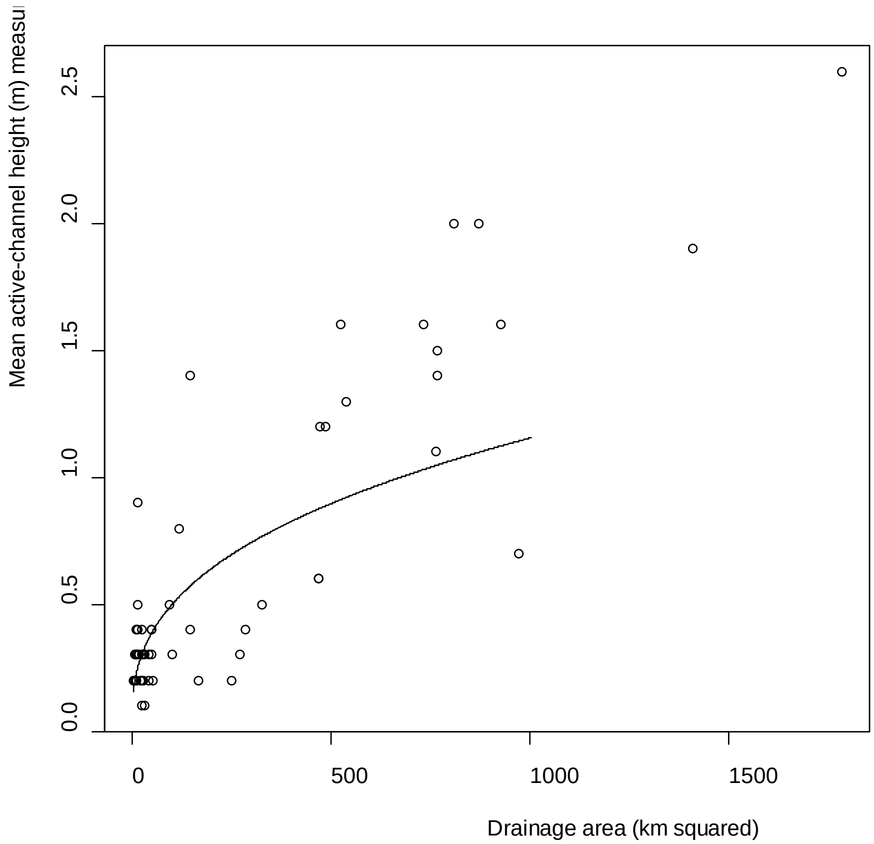


Figure 5. Relationship between field-measured mean active-channel height (H_a) and drainage area (D) ($H_a = -2.389 \times D^{0.367}$) ($R^2 = 0.58$; df = 56; $p < 0.001$).

We then calculated valley width index (*VWI*) as:

where F_a is the modeled reach-average floodplain width and W_a is the modeled reach-average active-channel width (Bain & Stevenson 1999). Our designation of *VWI* was then

compared to field designations of valley constraint in 52 reaches where ODFW crews had determined channel form as “constrained by hillslopes” (n = 17) or one of two unconstrained classes: “anastomosing channel” or “predominantly single channel” (n = 35) (Figure 6).

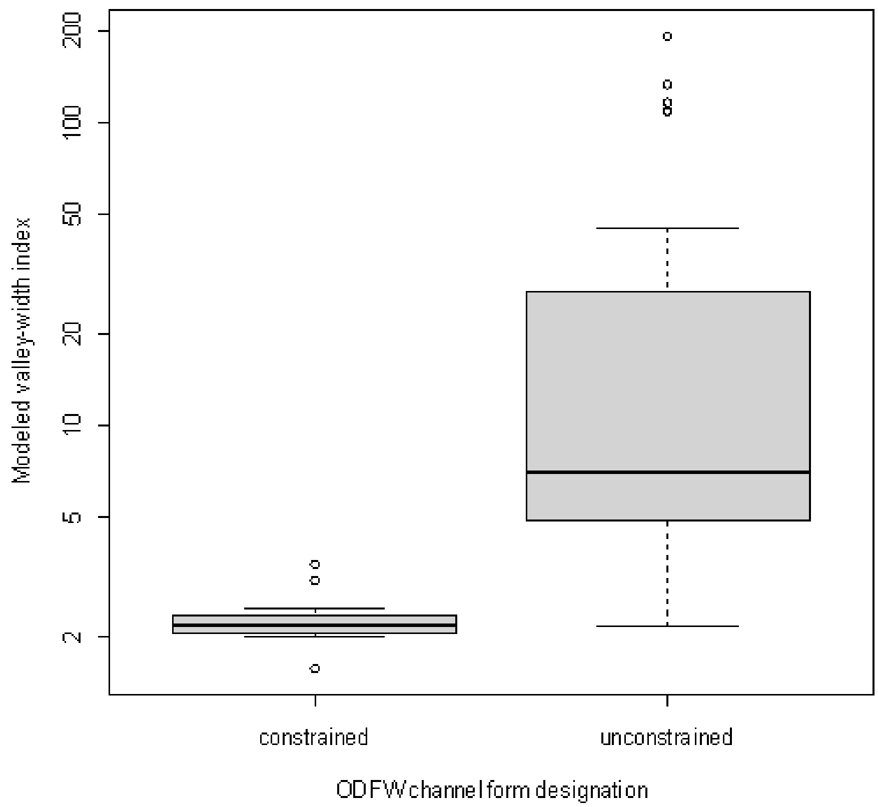


Figure 6. Modeled values of valley-width index for field-determined constrained (n = 17) and unconstrained (n = 35) classes in ODFW reaches. Boxes designate 25th and 75th percentiles, dark solid lines indicates the medians, whiskers indicate the nearest data point within 1.5 times the interquartile range, and outliers are shown as open circles.

Logistic regression indicated that modeled *VWI* was a strong predictor of field-based designation of constrained and unconstrained valley forms (p-value = 0.01). The probability that a given reach was designated unconstrained (P_u) was:

Modeled reaches were then designated as unconstrained if $P_u \geq 0.50$ and constrained if $P_u <$ 0.50. A valley-width index of 2.9 was the approximate cutoff for designations of valley constraint.

CRITERIA FOR REACH-SCALE CLASSIFICATION

Five reach types were delineated using a hierarchical decision tree based on potential for channel-forming processes and character of alluvial deposits along the channel, material transport capacity of reaches, and potential for lateral channel migration (Figure 7).

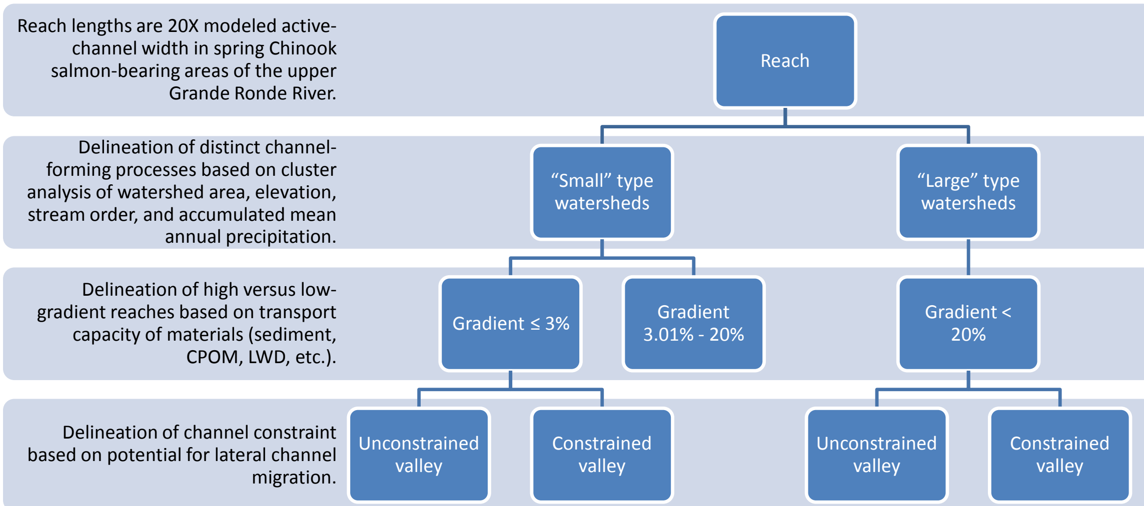


Figure 7. Decision tree for classifying stream reaches into five types.

Watershed size, position, and climate

The first level of reach-scale classification was related to watershed size, position, and climate and was used to delineate reaches having vastly different sediment transport capacity and character of alluvial deposits along the channel. Church (2002) found that the main controlling factors determining thresholds of distinct channel-forming processes were flow regime and regime of sediment supply. We conducted hierarchical clustering analysis using the GIS-derived variables watershed area (catchment area above reach), elevation, stream order, and accumulated mean annual precipitation depth in order to group reaches into two categories, termed "small" and "large" type watersheds. Because of the vastly different magnitudes of variables in cluster analysis, we performed general relativization of column totals in order to give each variable equal weight in determining group memberships. We used Sørensen's (Bray-Curtis) distance measure with flexible beta group linkage method ($\beta = -0.25$); the flexible beta linkage method yields group distances similar to that of Ward's distance at this value of beta (Lance & Williams, 1967), but unlike Ward's linkage method is compatible with Sørensen's distance measure (McCune & Grace, 2002). The resulting dendrogram (having minimal chaining of only 0.10%) was scaled using the objective function, which measures the information lost at each step of clustering (Wishart, 1969), and pruned according to relative trade-offs between information lost and interpretability. We decided that two major groups were sufficient, as additional groups would quickly multiply the final number of classification units and reduce power of analyses. Watershed characteristics varied among the two groups, with small type watersheds having smaller upstream catchment areas, lower order, higher elevation, and more variable precipitation than large type watersheds (Figure 8).

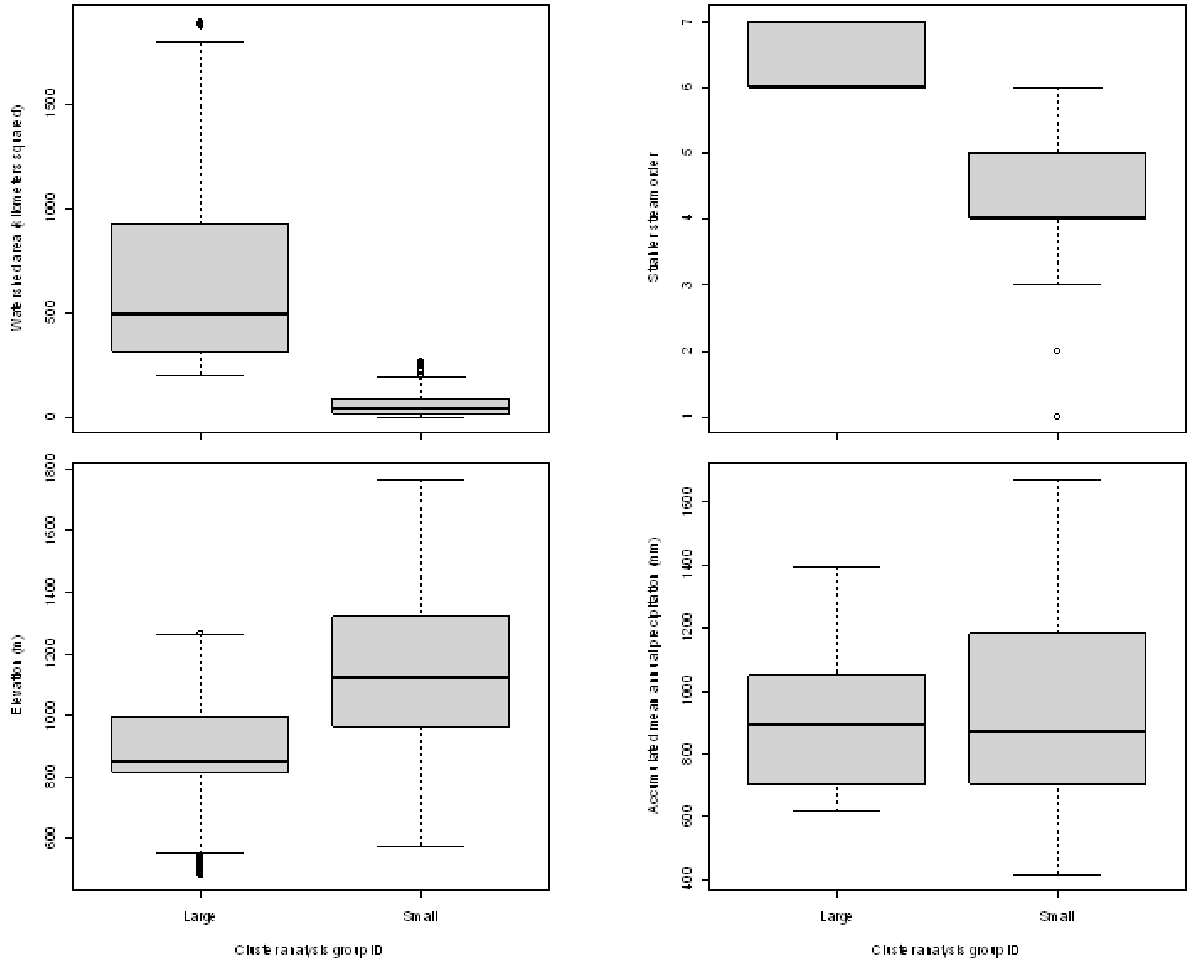


Figure 8. Comparison of watershed characteristics used to group reaches into "large" and "small" types according to upstream drainage area, stream order, elevation, and accumulated mean annual precipitation depth

Material transport capacity

Small type watersheds were further divided according to a 3% gradient threshold (Figure 7), which served as a proxy for transport capacity *sensu* the classification system of Montgomery & Buffington (1997). Montgomery *et al.* (1999) found the 3% gradient threshold delineated steeper step-pool and cascade "transport" reaches from low-gradient pool-riffle and plane-bed "response" and was an important factor determining reproductive strategies (i.e., spawning seasonality and egg burial depths) of salmonids in the Pacific Northwest. Large type watersheds were not delineated according to gradient because all of those reaches had low gradients, far below the 3% threshold, with only one exception: one of the 3,905 modeled reaches within the potential study extent was designated as both large type and transport—this reach was in the lower section of Minam River, with gradient = 3.2%). Because of the extremely rare occurrence of this reach type, large type watersheds were further divided based on valley constraint alone.

Potential for lateral channel migration

Valley constraint is related to the channel's ability to migrate over the floodplain (Hall *et al.* 2007), which in river channels without modifications to flow regime and channel form helps maintain integrity of the riverine ecosystem (Ward & Stanford 1995). In all response reach types (≤ 3% gradient), we delineated constrained versus unconstrained reaches to account for potential channel migration and floodplain connectivity. This final division of reaches equated to five reach types (Figure 7), which were mapped in a GIS (Figure 9).

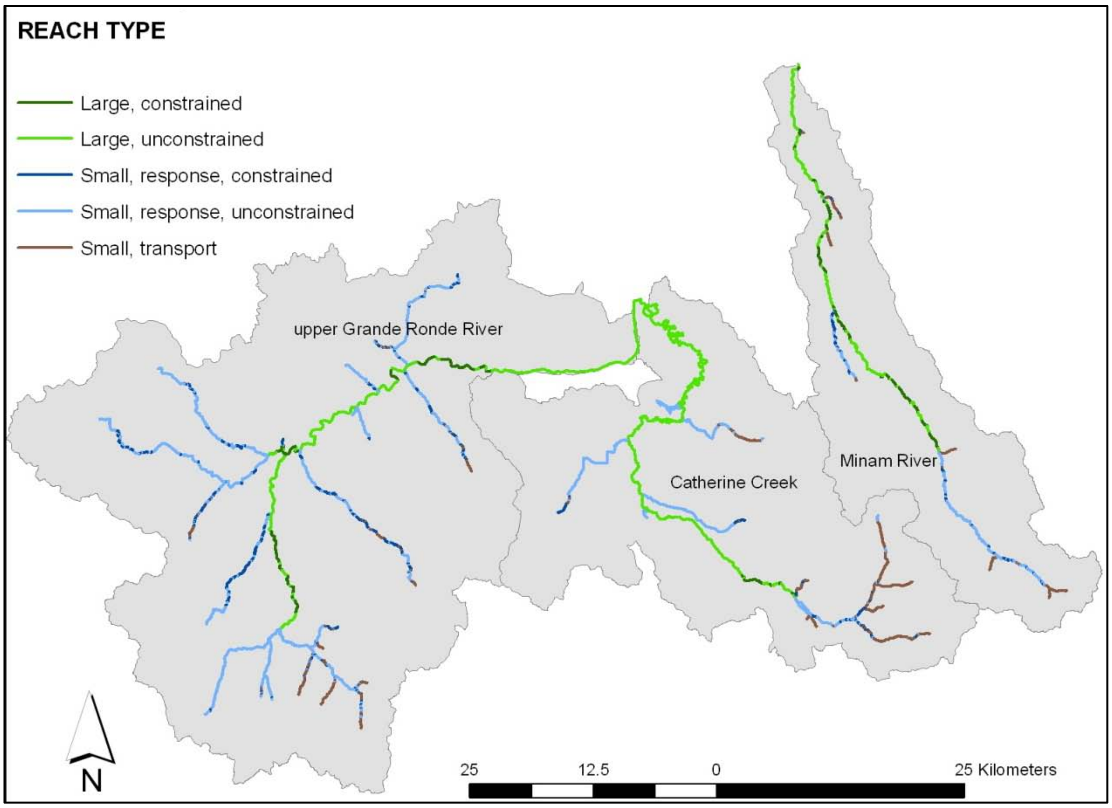


Figure 9. Reach classes in the upper Grande Ronde River, Catherine Creek, and Minam River.

Selection of reference watershed

We selected the Minam River as a reference watershed based on its history of less-intense land use, close genetic relationship between Minam River and Catherine Creek spring Chinook salmon (ICTRT 2003), near proximity to the focal watersheds (Figure 3), and readily available information about spring Chinook salmon from ODFW monitoring (spawning surveys, migration traps, habitat surveys, etc.). The Minam River flows through the Wallowa-Whitman National Forest and Eagle Cap Wilderness Area. The Eagle Cap was established as primitive area in 1930, designated as wilderness in 1940, and registered in the National Wilderness Preservation System in 1964 (www.fs.fed.us). In 1988, the Minam River was registered as a Wild and Scenic River from its headwaters at Minam Lake, 62.8 river km downstream to Cougar Creek (www.rivers.gov). The protected status of the Minam River provides a stark contrast to the

intense current and historical agricultural, grazing, and logging use in the upper Grande Ronde and Catherine Creek basins, and therefore in one sense is an ideal reference condition. However, physical conditions are somewhat different among the basins. While most of the Grande Ronde River and lower sections of Catherine Creek flow out of Miocene and younger volcanic and sedimentary rocks (with some higher elevations in the Grande Ronde River flowing from older, pre-Cenozoic sedimentary and volcanic rock), the Minam River and upper sections of Catherine Creek flow out of Oligocene and lower Miocene volcanic and sedimentary rock (Walker, 1990). Both the Minam River and upper sections of Catherine Creek have notable, U-shaped valleys carved by glaciers, and wetter climate due to the orographic effect. The distribution of reach classes in the Minam River was most similar to that of Catherine Creek, with a smaller proportion of small-type reaches with low gradient and constrained valleys (Figure 10). The upper Grande Ronde River was unique compared to all other watersheds with its high proportion of small-type reaches with low gradient and unconstrained valleys, while the Wenaha River was unique with a high proportion of small, transport reaches. Monitoring of habitat metrics and fish populations in the Minam River will occur in a similar fashion as focal watersheds, but with less intensity.

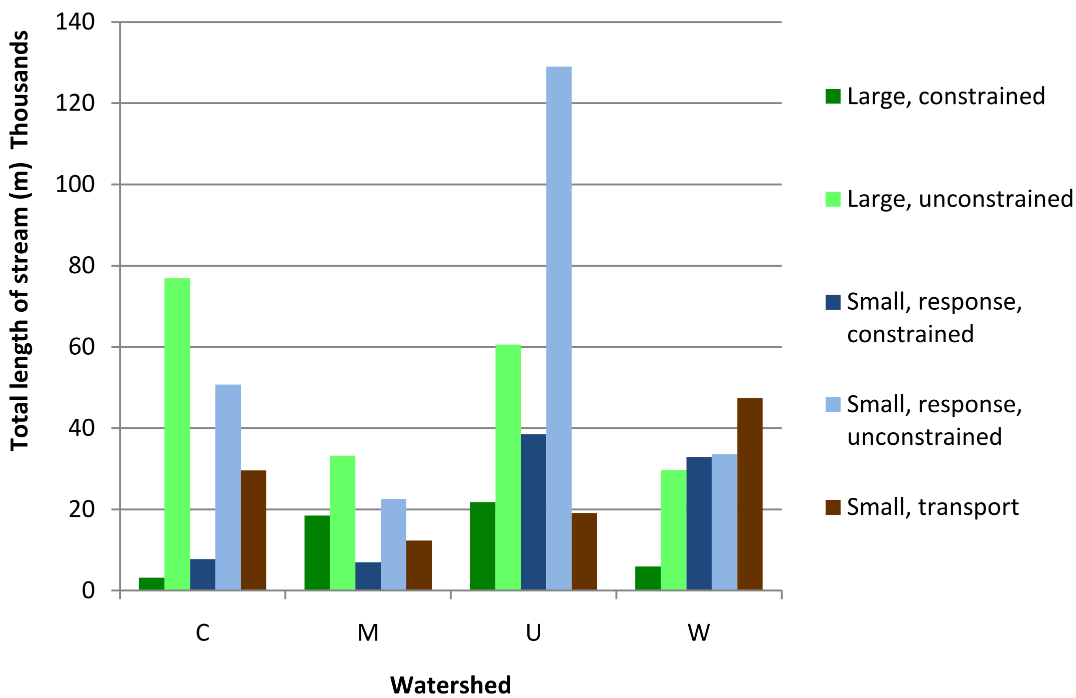


Figure 10. Distribution of geomorphic classes by watersheds (C = Catherine, M = Minam, U = upper Grande Ronde, and W = Wenaha).

DESIGNATION OF SPRING CHINOOK SALMON USE

The spatial extent of the study is the limit of current and historic use by spring Chinook salmon as designated by expert opinion and modeling of intrinsic spawning potential in the upper Grande Ronde River and Catherine Creek watersheds. Current use was designated for the entire Grande Ronde River basin using StreamNet GIS layers (2009), while historic and potential use was designated by Grande Ronde Subbasin Planning (Nowak & Kuchenbecker 2004) and the Interior Columbia River Technical Recovery Team (ICTRT 2007). Using the same sources, we then designated each reach with a predominate spring Chinook salmon life history use. To define river segments used during different life history stages (i.e., spawning, rearing, and migration) we developed a simple rule set to account for discrepancies in designation by the three sources. We assumed that all habitats with any life history designation is also used for migration, that all spawning habitat is potential rearing habitat, and that some rearing habitat is not spawning habitat. Applying this logic resulted in three life history categories: migration only; rearing and migration (henceforth termed “rearing”); and spawning, rearing, and migration (henceforth termed “spawning”). Migration only segments were extremely rare and therefore we excluded them from life history designations, resulting in two final categories: spawning and rearing. Our rule set was as follows:

a) If any source designated a segment as spawning, we also designated the segment as spawning,

b) If any source designated a segment as rearing or migration (and not spawning), we designated as rearing, and

c) All river segments within the boundaries of spring Chinook use but not assigned a designation by any source were designated by us as rearing. For example, if a stream’s headwaters were designated spawning and no designation was previously assigned to its downstream reaches, then we designated that segment as rearing.

For each modeled reach, we assigned the above life history designations by overlaying GIS maps of fish-use—the life history type with the greatest proportion of stream length in the modeled reach designated use type. In most cases, life history designations either covered all or a large majority of the stream length of a modeled reach. The reach classification was used to stratify sampling by reach type, while life history use was employed to designate higher probability of sampling in spawning reaches.

When considering the extent of our study, we did not account for natural or anthropogenic barriers, with the exceptions that ICTRT (2007) considered 200-m reaches having gradient ≥ 20% as impassible by Chinook salmon and that StreamNet (2009) and Subbasin Planning (Nowak & Kuchenbecker 2004) accounted for known natural barriers. Otherwise, accurate and ground-truthed information about barriers was lacking and we did not wish to exclude river segments currently inaccessible to spring Chinook salmon having potential spawning or rearing habitat if barriers were removed. The total number of reaches within the spring Chinook-bearing portion of the four watersheds (upper Grande Ronde, Catherine Creek, Minam and Wenaha Rivers) was 3,905.

VERIFICATION OF CLASSIFICATION

Verification based on field-based measurements of reach characteristics
We hypothesized that our GIS-derived, *a prior* classification system would be related to reach morphology in terms of channel planform and longitudinal profile. In the field, channel-reach morphology sensu Montgomery & Buffington (1997) were visually assessed at 20 sample reaches. Reaches were defined as cascade, step pool, plane bed, pool riffle, dune ripple, or forced pool riffle (no colluvial or bedrock reaches were expected nor encountered within spring Chinook salmon extent). In the field, reaches were identified in the field into categories based on their general appearance, planform morphology, and longitudinal profile (Figure 11), as well as other diagnostic characteristics (Table 2).

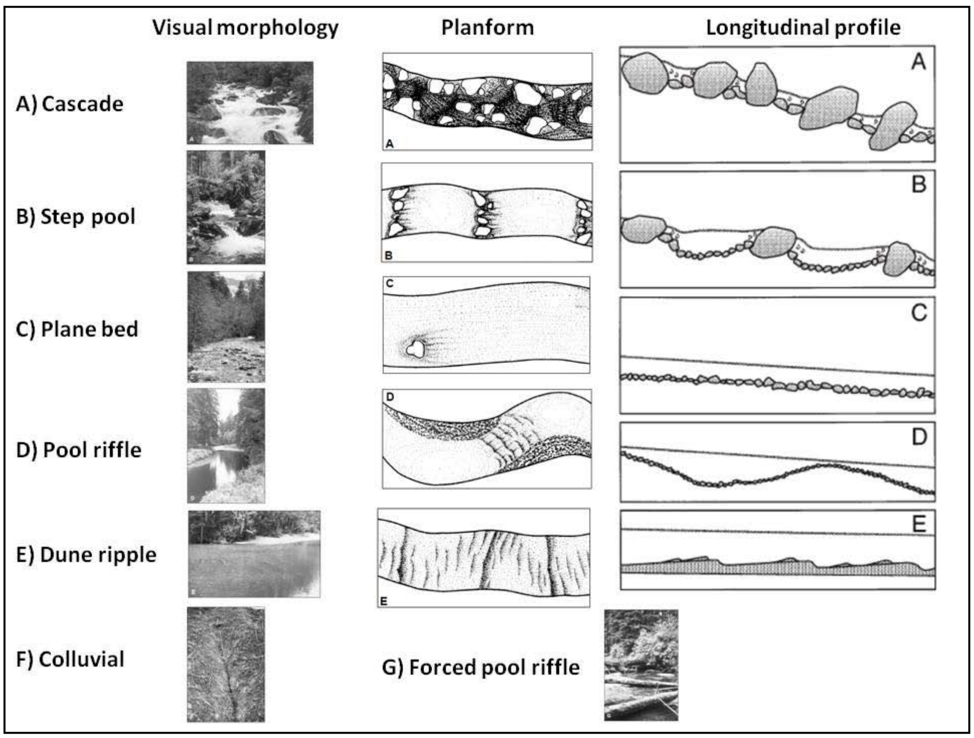


Figure 11. Visual morphology, planform, and longitudinal profiles of Montgomery & Buffington's (1997) channel-reach types.

Table 2. Diagnostic features of channel-reach types, from Montgomery and Buffington (1997).

	Dune ripple	Pool riffle	Plane bed	Step pool	Cascade	Bedrock	Colluvial
Typical bed material	Sand	Gravel	Gravel-cobble	Cobble-boulder	Boulder	Rock	Variable
Bedform pattern	Multilayered	Laterally oscillatory	Featureless	Vertically oscillatory	Random	Irregular	Variable
Dominant roughness elements	Sinuosity, bedforms (dunes, ripples, bars) grains, banks	Bedforms (bars, pools), grains, sinuosity, banks	Grains, banks	Bedforms (steps, pools), grains, banks	Grains, banks	Boundaries (bed and banks)	Grains
Dominant sediment sources	Fluvial, bank failure	Fluvial, bank failure	Fluvial, bank failure, debris flows	Fluvial, hillslope, debris flows	Fluvial, hillslope, debris flows	Fluvial, hillslope, debris flows	Hillslope, debris flows
Sediment storage elements	Overbank, bedforms	Overbank, bedforms	Overbank	Bedforms	Lee and stoss sides of flow obstructions	Pockets	Bed
Typical confinement	Unconfined	Unconfined	Variable	Confined	Confined	Confined	Confined
Typical pool spacing (channel widths)	5 to 7	5 to 7	None	1 to 4	<1	Variable	Unknown

A log likelihood ratio test (G-test) with William's correction (Gotelli & Ellison, 2004) revealed that our *a priori* designation of reaches into constrained, unconstrained, and transport reaches was significantly related to field determination of reach types (G = 10.0, χ^2 *df* = 4, *p-value* = 0.04) (Table 3). Unconstrained valley reaches were typically designated as pool riffle reaches (9 of 12 instances), both transport reaches and no other reach type were designated as step pool reaches, while plane bed reaches occurred in both constrained and unconstrained reach types. The same contingency test revealed that the five *a priori* classes which included small vs. large-type watersheds was not significantly related to field designations of reach types (G = 12.3, χ^2 *df* = 8, *p-value* = 0.14). If GIS-modeled reach types and Montgomery & Buffington reach types are collapsed into response and transport reaches, then no incorrect designations were made between *a priori* vs field-based classification schemes. In other words, all 18 *a priori* response reaches were classified as such in the field, and the two *a priori* transport reaches were also designated as such in the field.

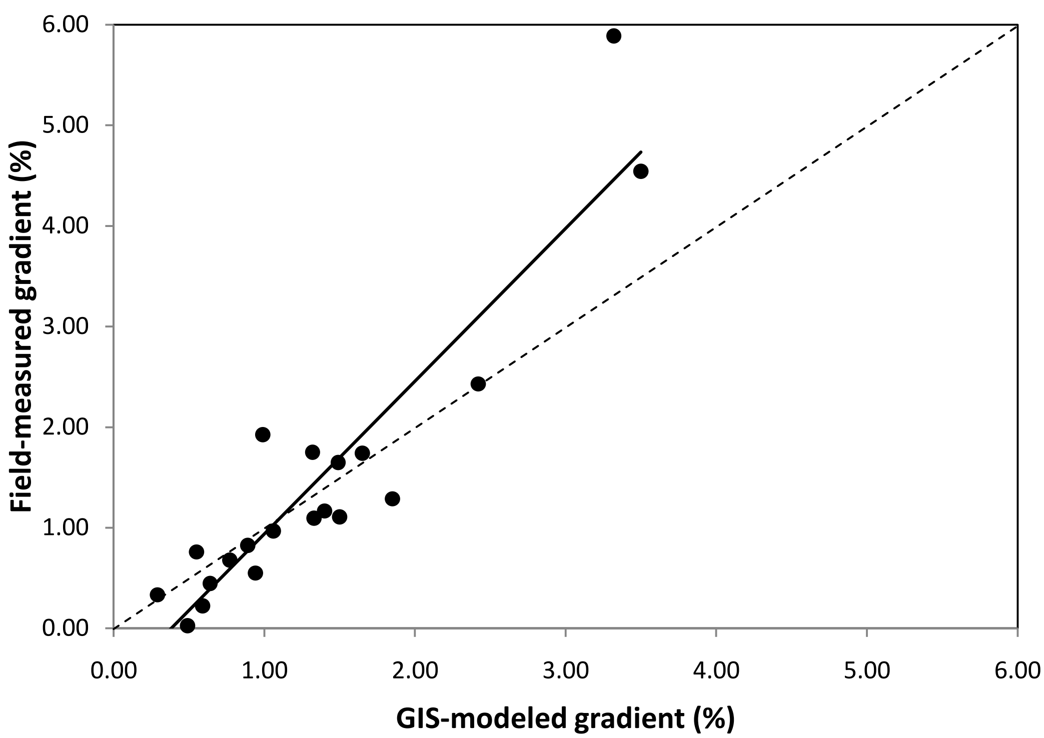
Table 3. Contingency table showing the relationship between field-designated, Montgomery and Buffington reach types and a prior, GIS-modeled reach types (G = 10.0, χ^2 *df* = 4, *p-value* = 0.04).

	A priori reach type			
Montgomery & Buffington reach type	Unconstrained	Constrained	Transport	Row totals
Pool riffle	9	3	0	12
Plane bed	3	3	0	6
Step pool	0	0	2	2
Column totals	12	6	2	20

In the same 20 reaches, we measured reach gradient in the field using a surveying level and compared those measurements to gradients modeled in GIS using a 10-m DEM. For most cases, gradient measured in the field approximated the GIS-modeled value (Figure 12). Because of the high precision of surveying equipment over other methods in measuring gradient (Isaak *et al.*

1999), we considered the error our field measurements as negligible. Rather, we consider the main source of error in gradient measurements to be GIS estimates, which can be especially inaccurate in short, headwater reaches due to the low-resolution of 10-m DEMs. While we noted a good linear fit between field-measured and GIS-modeled gradient (R^2 = 0.85, p < 0.001), examination of 95% confidence intervals of regression coefficients revealed that the model intercept of -0.58, although significant (p = 0.03), was not equal to zero (95% CI = -1.08 to -0.08) and regression slope was significant (p > 0.001) but not equal to one (95% CI = 1.21 to 1.83) as expected. An intercept at or near zero would indicate very low stream gradients measured in the field would also be detectable from the DEM. Instead, we found that GIS-modeling overestimated gradient in nearly flat reaches. A regression slope equal to 1 would indicate that GIS-modeled stream gradients tracked field measurements in a 1:1 manner. On the contrary, we found that GIS modeling tended to underestimate actual gradients, especially in steeper reaches (Figure 12). These results point toward the utility of modeling reach gradient from DEMs derived from high resolution LiDAR, which promises greater accuracy (MacMillan *et al.* 2003).

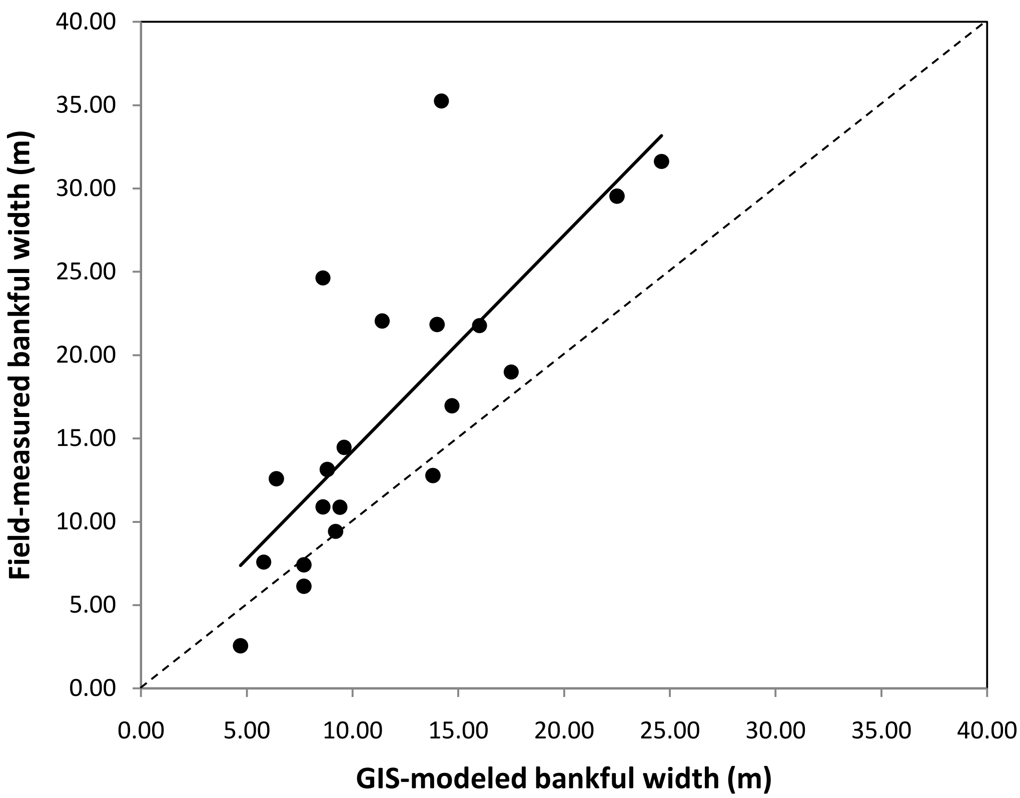
Figure 12. Field-measured (S_{FIELD}) vs. GIS-modeled (S_{GIS}) percent stream slope. Diagonal line is expected 1:1 relationship. Solid diagonal is least-squares regression line (S_{FIELD} = 1.52 x S_{GIS} – 0.58, R^2 = 0.85, p < 0.001).



Field measurements vs. GIS-modeled estimates of bankfull width more closely followed the expected 1:1 relationship as a general trend, but with broadly deviating values (Figure 13).

While we noted a decent linear fit between field-measured and GIS-modeled gradient (R^2 = 0.60, p < 0.001), examination of 95% confidence intervals of regression coefficients revealed that the model intercept of 1.28 was not significant (p = 0.69) and spanned a wide range of values which included zero (95% CI = -5.45 to 8.02). However, the regression slope of 1.52 was significant (p > 0.001) and approximated the expected 1:1 relationship (95% CI = 0.77 to 1.82).

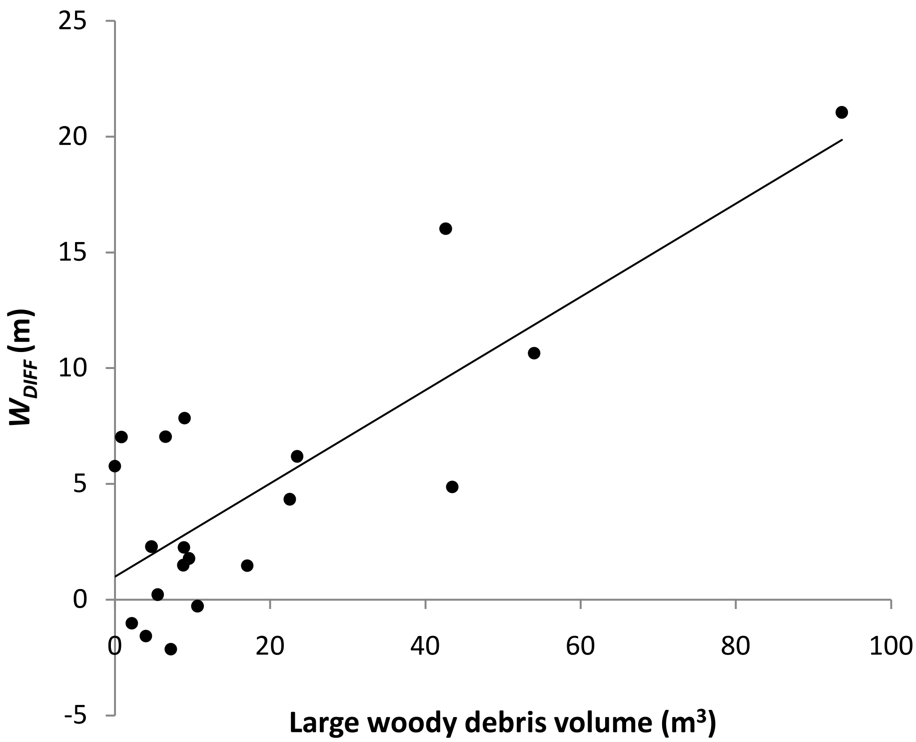
Figure 13. Field-measured (W_{FIELD}) vs. GIS-modeled (W_{GIS}) bankfull width. Diagonal line is expected 1:1 relationship. Solid diagonal is least-squares regression line (W_{FIELD} = 1.30 x W_{GIS} + 1.28, R^2 = 0.60, p < 0.001).



Potential reasons for deviation from expected, GIS-modeled values of bankfull width are numerous and include contribution of basin-scale geomorphic features to stream channel morphology and localized land use. Faustini *et al.* (2003) found that in Western mountainous regions, the expected relationship between drainage area and bankfull width was influenced by the coarseness of bed material, precipitation, elevation, slope, and human disturbance to riparian areas. Paradoxically, Faustini *et al.* (2003) concluded that human disturbance was often *negatively* correlated with bankfull width, contrary to other published literature linking some types of disturbance to channel width. A preliminary examination of our data indicates a the volume of large woody debris positively influences deviation from the expected 1:1 relationship between field-measured and GIS-modeled bankfull width (Figure 14). Large woody debris has previously been implicated in stream channel widening via directing stream flow onto banks

and increasing localized erosion (Montgomery *et al.* 2003). However at time of writing these particular findings are preliminary and warrant further examination.

Figure 14. Relationship between large woody debris (*LWD*) and the difference between field-measured (W_{FIELD}) and GIS-modeled (W_{GIS}) bankful width estimates ($W_{FIELD} - W_{GIS} = W_{DIFF}$). Solid line is least-squares regression (W_{DIFF} = 0.20 x *LWD* + 0.99, R^2 = 0.64).



Verification based on field-based measurements of fish habitat conditions
At all 20 reaches, a set of channel unit and reach-scale characteristics were measured in order to discover relationships between channel morphology, geomorphology, and fish habitat having potential to limit Chinook salmon growth, reproduction and survival (see Justice *et al.* 2010 for a detailed description of habitat measurements). We conducted preliminary analysis of the interrelationships among a set of field-measured and GIS-modeled characteristics appearing to influence multivariate structure in the data (Table 4).

Table 4. Selected field-measured and GIS-modeled variables variables at the reach scale for preliminary multivariate analysis. See Justice *et al.* 2010 for elaboration of field measurements.

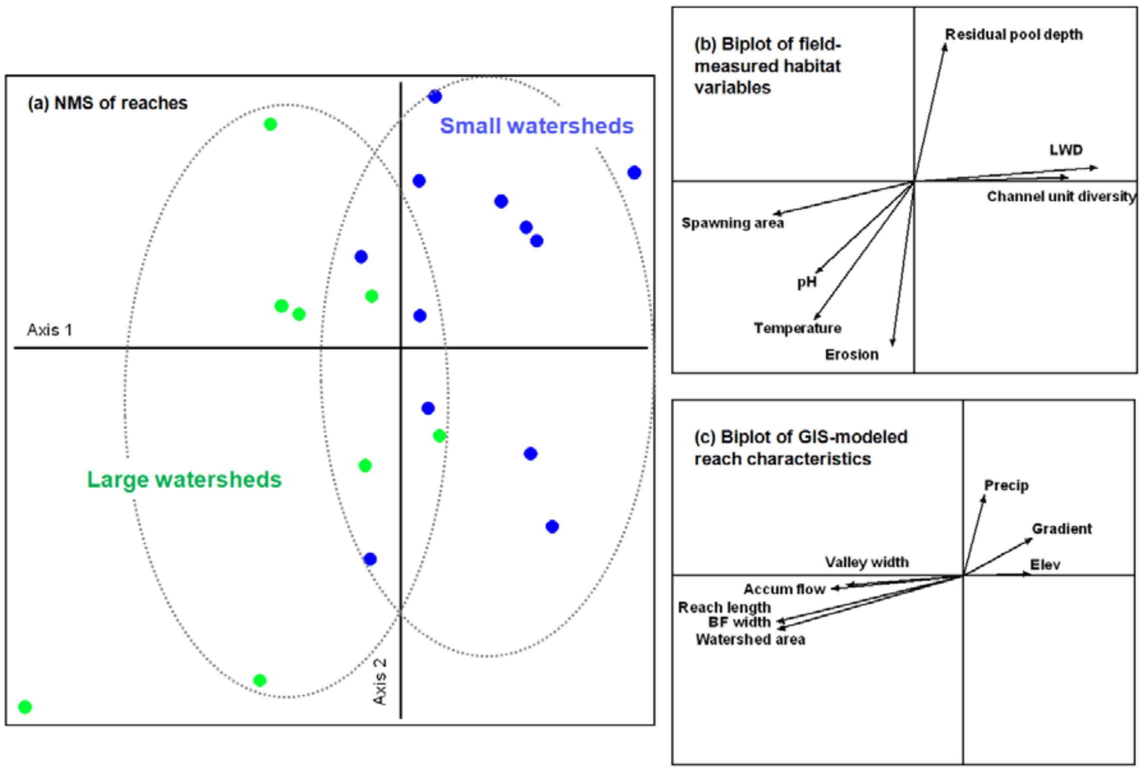
Source of data	Variable name	Description
Field measurements	Residual pool depth	Average depth (m) of maximum pool depth minus pool tail depth
	Spawning area	Wetted area of reach (m^2) meeting criteria for Chinook salmon spawning habitat
	LWD	Volume of large woody debris per area of bankfull stream reach (m^3/m)
	Pool area	Proportion of pool area to wetted area of reach
	D50	Mean surface particle size within reach (D_{50})
	Channel unit diversity	Number of channel units per stream length (channel units/m)
	Erosion	Percent (%) erodible stream bank in reach
	Temperature	Instantaneous water temperature at time of survey (^oC)
	pH	Instantaneous pH of water at time of survey
GIS modeled	Precip	Mean annual precipitation depth (mm), averaged over drainage area to downstream end of reach
	Gradient	Average slope (%) of reach
	Elev	Reach elevation (m)
	Valley width	Modeled width of valley (m)
	Accum flow	Mean annual flow (m^3)
	Reach length	Vector length of stream reach (m)
	BF width	Modeled bankfull width (m)
	Watershed area	Watershed area contributing to reach (m^2)
	Prob valley	Probability (P_u) of designation as a valley reach (See *Stream reach attributes* section of this report)
	VWI	Valley width index, — (See *Stream reach attributes* section)

In order to discover relationships among field-measured and GIS-modeled reach characteristics, we performed nonmetric multidimensional scaling (NMS) on field-measured data. NMS is a multivariate ordination technique that is ideal for ecological datasets because it accommodates non-normal distributions, deals well with data on arbitrary scales, and bypasses assumptions of linearity (McCune & Grace, 2002). We first transformed field data via general relativization by columns in order to express each variable on an equal footing. We used Sorensen's distance measure and a random starting configuration with 250 runs of both real and randomized data. The number of axes in the final solution was chosen based on examining a scree plot of dimensionality vs. stress, with the desire to achieve the smallest number of axes while maintaining low stress. Even with our small sample size of 20, we achieved a 3-axis solution of moderately good fit (stress = 8.38) at 68 iterations of the procedure. This solution was highly significant (p = 0.004) based on Monte Carlo simulations of the probability that randomized data would achieve a similar final stress.

Ecological interpretation of the ordination was facilitated by examination of categorical designations of reaches (i.e., *a priori* classification type vs. Montgomery & Buffington type and land use designations) and on correlations between field-measured variables, GIS-modeled variables, and ordination axes. In addition, we used multiple response permutation procedure (MRRP) to test whether reach classifications explained a significant amount of variance in multivariate structure of fish habitat characteristics. MRPP indicated that our GIS-based, *a priori* classification described a significant amount of variation in the data (*A-statistic* = 0.21, *p-value* = 0.002). Our field-based designations of Montgomery & Buffington reach type also significantly explained fished habitat data structure, but with a much smaller effect size (A = 0.14, p = 0.005). Our field-based judgement of land use intensity via (1) designation of reaches as reference vs. non-reference and (2) assigning a score of 1-5 from excellent to very poor conditions (see Justice *et al.* 2010 for details of procedure) did not explain variance in fish habitat data ($p > 0.05$).

To visualize relationships among field designations of class type, field measurements of fish habitat, and GIS-modeled attributes of reach characteristics with ordination axes; we generated overlays of categorical attributes and biplots of correlations among variables and ordination axes (Figure 15; Figure 16). A display of NMS axis 2 vs. 1, categorized by "small" and "large" reach types (see *Watershed size, position, and climate* section), reveals these two reach types were delineated by the first NMS axis (Figure 15a). Large-type reaches were correlated with a higher proportion of spawning area, and moderately correlated with higher pH and temperature; small-type reaches were correlated with more large woody debirs and greater channel unit diversity (Figure 15b). Relationships between these two reach classes followed expected patterns of correlation among GIS-derived variables used in classification, e.g., large-type reaches had greater flow potential, wider bankfull profiles, and greater contributing watershed area (Figure 15c).

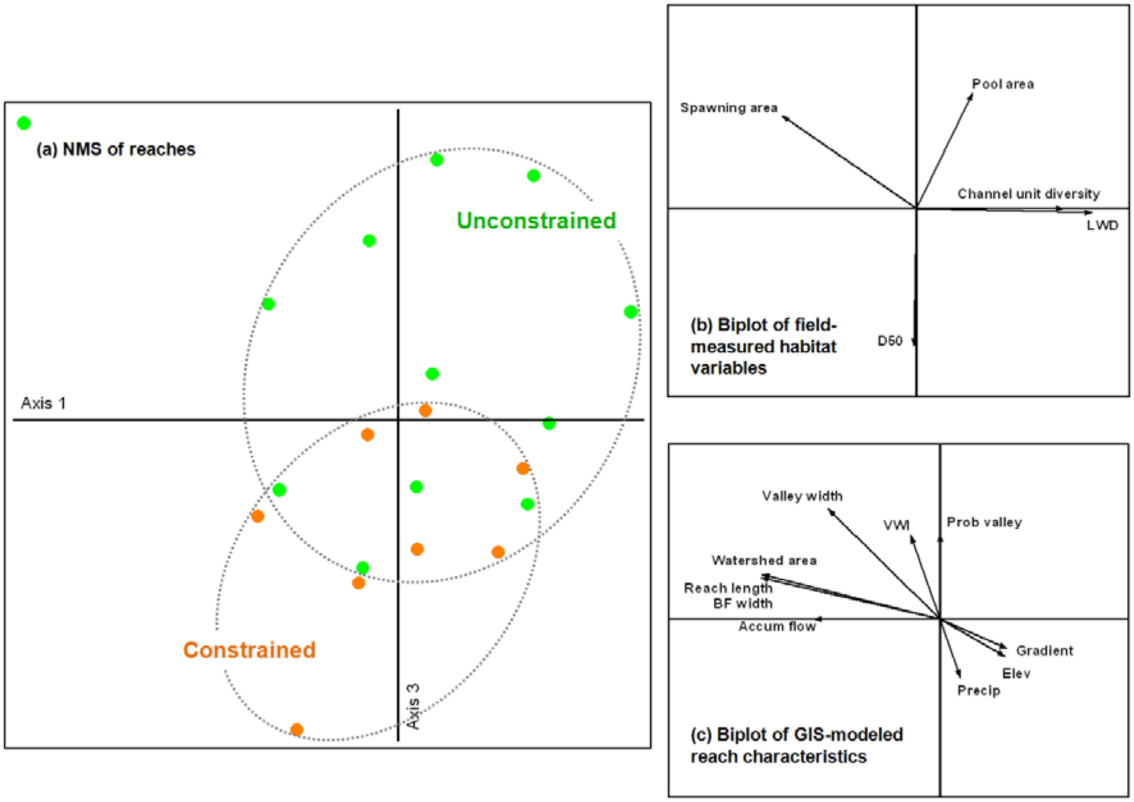
Figure 15. Visualization of NMS axes 2 vs. 1 and (a) overlay of *a priori* classification of watershed size in relation to reaches in fish habitat space, (b) biplot of Pearson correlations among field-measured values and NMS axes, and (c) biplot of Pearson correlations among GIS-modeled values and NMS axes. In biplots, direction and magnitude of arrows represent direction and magnitude (r) of Pearson correlation.



A display of NMS axis 3 vs. 1, categorized by constrained and unconstrained reaches (see *Potential for lateral channel migration* section), reveals these two reach types were delineated by the 3rd NMS axis (Figure 16a). Unconstrained reaches had a higher proportion of spawning area and a greater proportion of pool area than constrained reaches, while constrained watersheds had larger surface particle sizes as measured by increasing D_{50} (Figure 16b). Relationships between these two reach classes followed expected patterns of correlation among GIS-derived variables used in classification, e.g., unconstrained reaches had greater wider valleys while constrained reaches had steeper gradients and higher elevations (Figure 16c).

In summary, variation in the multivariate distribution of fish habitat metrics measured during the 2010 field season was explained by the *a priori* classification of reach type. When examined alongside measured habitat variables, correlations among axes delineating reach designations and measured habitat variables made intuitive sense and lent credibility to the validity of our classification system.

Figure 16. Visualization of NMS axes 3 vs. 1 and (a) overlay of *a priori* classification of constraint type in relation to reaches in fish habitat space, (b) biplot of Pearson correlations among field-measured values and NMS axes, and (c) biplot of Pearson correlations among GIS-modeled values and NMS axes.



Future plans for verification at additional scales

After initial designation of reach-scale classification and when more data become available, several landscape-scale classifications will be tested in a *post hoc* fashion with the goal of further reducing variance in measured habitat metrics (*sensu* Dovciak & Perry 2002; Pyne *et al.* 2007). Candidate attributes for landscape-scale classification come from existing GIS maps of geology, ecoregions, hydrologic landscape regions, and watershed identity (Table 1). Currently unmapped landscape-scale attributes include hydrology and geographic distance between sites. We hypothesize that not any one landscape-scale classification will explain all measured metrics (e.g., distribution of fine sediments, large woody debris, stream temperature, macroinvertebrate index, fish production, and several others) with a high degree of precision, but that some classifications will explain a larger amount of variance in all the metrics on average. Post hoc landscape-scale classifications will be examined in context of the a priori segment and reach classification.

Because of the ephemeral nature of channel units (*sensu* Bisson *et al.* 1982; Hawkins et al. 1993), they will not be used in *a priori* or *post hoc* classifications. Rather, channel units will be measured in the field and their relative distribution within segment/reach-scale classification will be used to scale production estimates of spring Chinook salmon in the life history model.

CONCLUDING REMARKS

Useful classifications encompass broad spatial and temporal scales, integrate structural and functional characteristics under various disturbance regimes, convey information regarding mechanisms controlling instream features, and are created at low cost and high understanding (Naiman 1992). Furthermore, a hierarchical framework provides ecological understanding of watershed-stream relationships that interact at various spatial and temporal scales (Frissell *et al.* 1986). Therefore, our proposed classification system includes spatial scales ranging from landscapes to channel units and encompasses watershed characteristics that can be gathered throughout the entire Grande Ronde basin (and conceivably other basins) using low-cost, publically-available software and data.

A final word on our philosophy of classification systems: as classification systems are often based on poorly-understood notions of how the natural world works (Goodwin 1999), they are best perceived hypotheses rather than representations of an ultimate reality. Therefore, we regard our proposed classification as a question (rather than an answer) that can be tested against empirical data, and modified for future applications. The ultimate goal of our classification system is to help describe the variability in life history parameters for spring Chinook salmon by accounting for intrinsic watershed factors and anthropogenic change (Figure 1). The degree to which our classification meets that goal is the ultimate test of its validity.

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APPENDIX I: INSTRUCTION AND PARAMETER FILES FOR NETSTREAM SOFTWARE

Instruction file for NeTrace

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Instruction file for netrace
==========================================================================================
SHAPEFILE options
------------------------------------------------------------------------------------------
n    Force reach breaks at channel junctions (y/n)
1    1) Fixed-length reaches, or 2) homogenous reaches
2    Gradient calculation method: 1) via contours, 2) poly fit over centered window, 3) none
2    Channel width estimation method: 1 = a + b*(Mean_annual_discharge^c), 2 = a*(Area^b), 3 = none
1    Valley width calculation method: 1 = inundation flow path, 2 = inundation depth, 3 = transect, 4 = none
1    Mean annual discharge (cfs) calculation method 1) = a*(Area^b)*(Prec^c), 2 = a*(Area^b), 3 = none
n    Include lake attribute (even if no lake mask) (y/n)
10   Maximum number of channel networks to trace
```

Parameter file for Bldgrds and NeTrace

```
Input Parameters for Bld_grds and NeTrace
==========================================================================================
=
2         flow direction algorithm (1 for Tarboton, 2 for Tarboton + convergence)
1         sl, number of cells over which slope is calculated (> 1 to address "pocket terracing")
2.0       dig (m); depth of DEM incision for drainage enforcement
2         Channel threshold criteria:(1) Drainage area (2) Specific drainage area.
100.      channel_area_threshold (m2), low gradient
650.      channel_area_threshold (m), high gradient
2.0       c_exp, slope exponent
0.40      S_max, slope above which high-gradient threshold applies
0.25      S_min, slope below which low-gradient threshold applies
1.75      P_min, minimum number of inflowing cells for channel head
28.5      lcheckmax, contiguous length overwhich P_min must be equaled or exceeded for a channel head
30.       Xmin (m), minimum window length for channel gradient estimation
300.      Xmax (m), maximum window length
0.001     Smin, gradient at and below which Xmax applies
0.2       Smax, gradient at and above which Xmin applies
2         Fit Order, integer, polynomial order for fit
50.       junction_length (m) ! channel length used to estimate junction angles
1.5660    cw1_small, channel width function, method 1) CW = cw1 + cw2*(mean_annual_flow^cw3), mean annual
flow m3/sec
0.3850    cw2_small, channel width function, method 2) CW = cw4 + cw1*(Area_km2^cw2)*(Prec_m^cw3)
0.        cw3_small,                with mean annual precip in meters.
0.        cw1_big, or cw4 for method 2        Note that setting cw4 and cw3 to zero gives power function of area
0.           cw2_big
0.        cw3_big
0.091700000 depth_coefficient_1, bank-full depth = depth_coefficient_1*(area_km2**depth_coefficient_2)
0.37      depth_coefficient_2
1         reach method: 1) channel widths, 2) specified length !
20        # of channel widths for a reach, for reach-method 1
50.       minimum reach length in meters, for reach-method 2
500.      maximum reach length in meters, reach-method 2
0.04      area (km2) at and below which minimum reach length is enforced, reach-method 2
100.0     area (km2) at and above which maximum reach length is enforced, reach-method 2
200.      minimum reach length (m) for increasing max_grad_down
200.      maximum reach length (m) for increasing max_grad_down
0.04      Drainage area (sq    km) at and below which minimum reach length applies
50.       Drainage area (sq km) at and above which maximum reach length applies
1.0       Area weight  ing for reach breaks (larger values increase effect of tributary inputs)
2.5       vh, number of bank-full depths above channel to qualify as floodplain
0.03537    Mean annual flow, coefficient 1, AF = c1*(Area^c2)*(Precip^c3)
0.890432941 Mean annual flow, coefficient 2, Area in km2, Mean annual Precip in meters
1.97179604       Mean annual flow, coefficient 3
0.0       gcoef1, field_gradient% = gcoef1 + gcoef2*(DEM_gradient_percent^gcoef3)
1.019785   gcoef2
0.825982   gcoef3
0.20      end of calibrated gradient (tangent)
0.30      start of DEM gradient, linear combination in between
0.010     drainage area threshold (km2) for tracing channels
=====================================================================
```

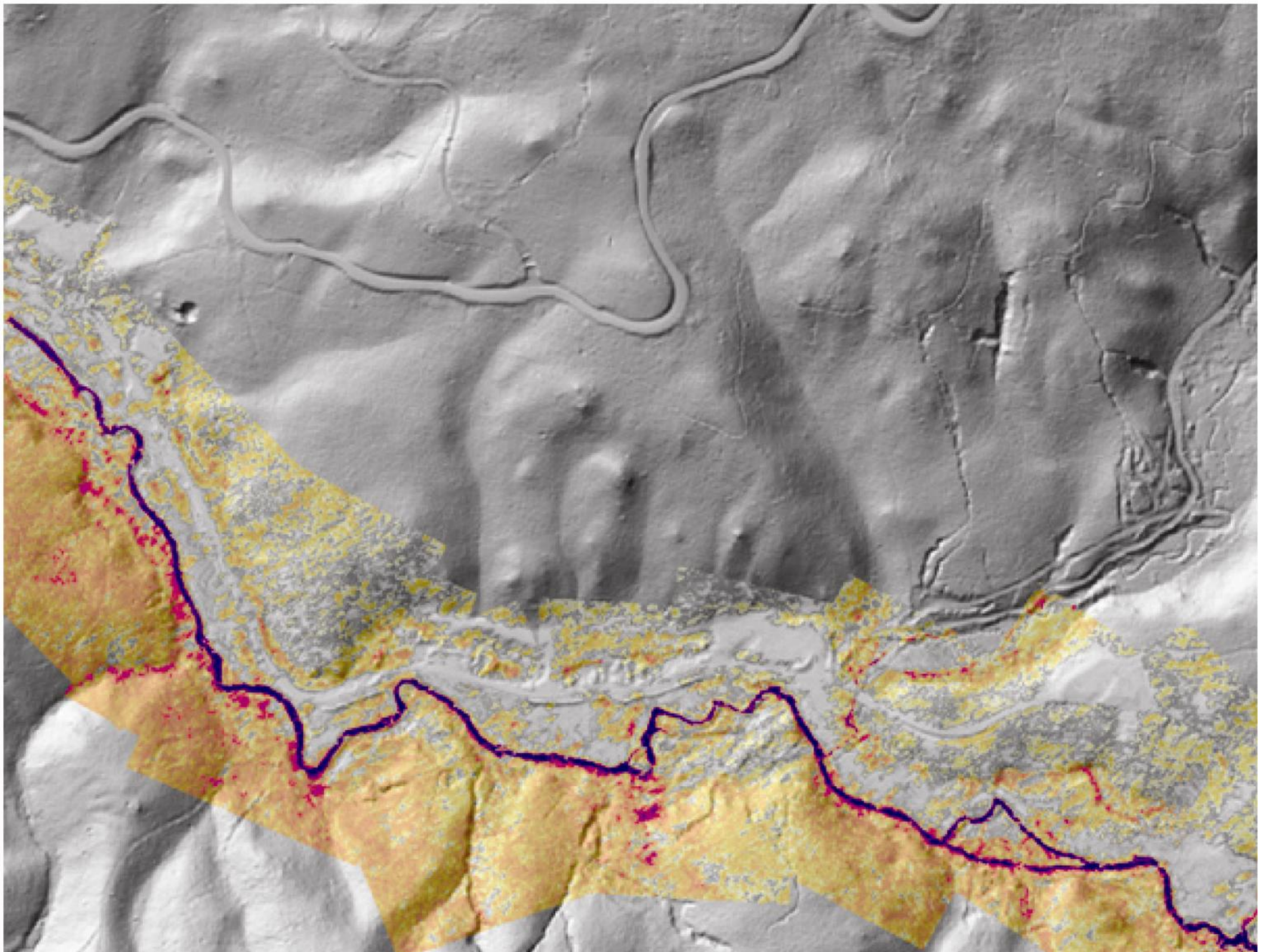
Appendix I

FLIR data collection and analysis

AIRBORNE THERMAL INFRARED REMOTE SENSING

UPPER GRANDE RONDE RIVER BASIN • OREGON

(SURVEY DATE - 8/7-12/2010 • REPORT DATE - 12/13/2010)



COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION

729 NE Oregon Street, Suite 200 - Portland, OR 97232

WATERSHED SCIENCES • 517 SW 2nd Street, Suite 400 - Corvallis, OR 97333

AIRBORNE THERMAL INFRARED REMOTE SENSING
UPPER GRANDE RONDE RIVER BASIN, OREGON

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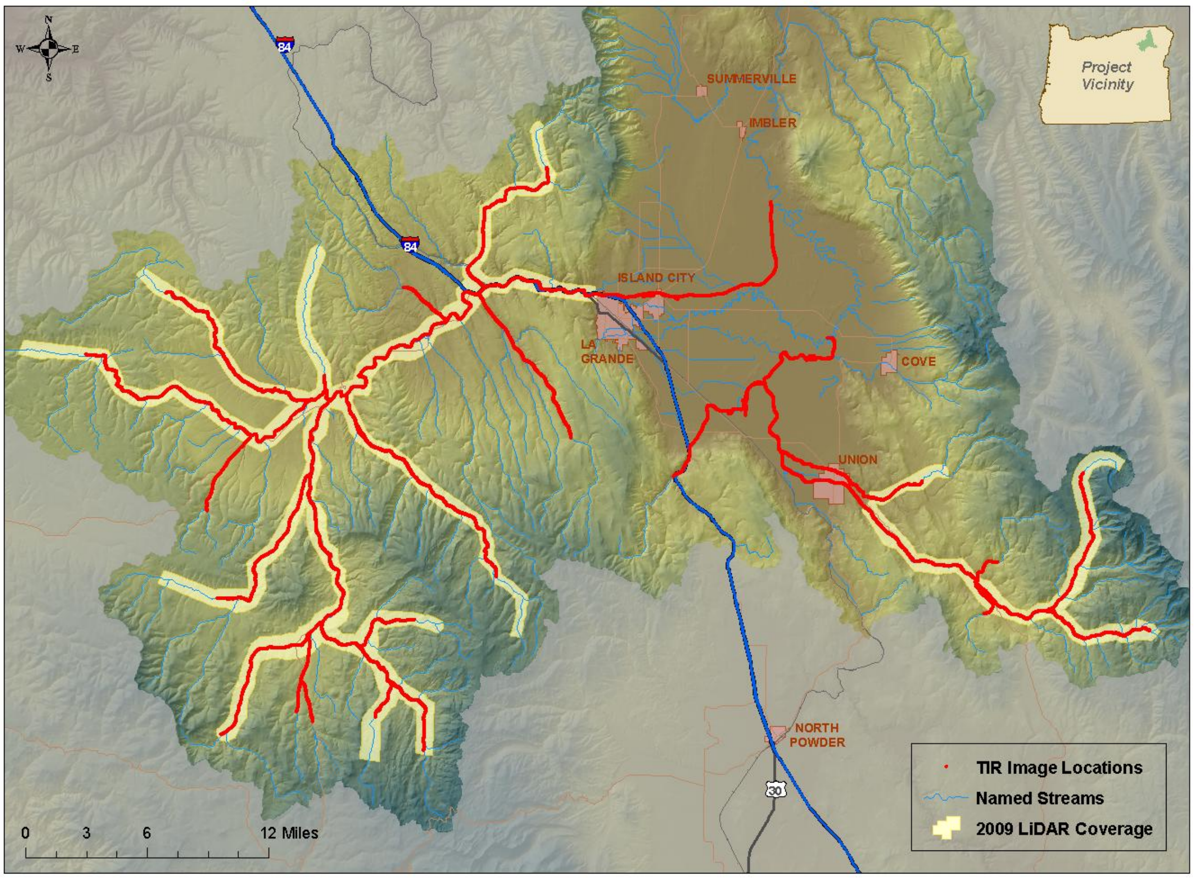
UPPER GRANDE RONDE RIVER AND TRIBUTARIES

CATHERINE CREEK AND TRIBUTARIES

1. Overview

In 2010, the Columbia River Inter-Tribal Fish Commission contracted with Watershed Sciences, Inc. to provide thermal infrared (TIR) imagery for approximately 226 river miles in the Upper Grande Ronde River Basin, Oregon, including 60 miles of the Grande Ronde River and 31 miles of Catherine Creek. The thermal imagery acquisition was an extension of the Upper Grande Ronde LiDAR project flown in September 2009[1] and a pre-cursor to the stream temperature modeling effort which will occur in 2011 (*Figure 1)*. The extents of the 22 stream segments covered in the project area are listed by survey date in Table 1.

Figure 1. A TIR survey in the Upper Grande Ronde River Basin was conducted August 7-12, 2010.



Airborne TIR remote sensing has proven to be an effective method for mapping spatial temperature patterns in rivers and streams. These data are used to establish baseline conditions and direct future ground level monitoring. The TIR imagery illustrates the location and thermal influence of point sources, tributaries, and surface springs. When combined with other spatial data sets, TIR data also illustrates reach-scale thermal responses to changes in morphology, vegetation, and land-use.

[1] Reference Report: "LiDAR Data Collection Phase, Grande Ronde River Basin." December 23, 2009. Prepared by Watershed Sciences, Inc. for the Columbia River Inter-Tribal Fish Commission.

The specific objectives of the TIR image acquisition were:

- Spatially characterize surface temperatures and stream flow conditions for 226 miles of stream in the Upper Grande Ronde River basin (*Figure 1*).
- Develop a longitudinal temperature profile which illustrates basin scale stream temperature patterns.
- Identify and map cool water sources and thermal refugia along current and potential Spring Chinook spawning reaches.
- Create GIS compatible data layers (e.g. thermal image mosaics, spring locations, etc.) that can be used to plan future research, direct ground based monitoring and analysis, and protect and restore critical habitat.

Table 1. Stream segments obtained with TIR in the Upper Grande Ronde River Basin.

Stream Name	Miles Flown	Location
August 7, 2010		
Beaver Creek	13.5	Mouth to La Grande Reservoir
Dark Canyon	0.7	Mouth to Unnamed Tributary
Five Points Creek	9.5	Mouth to Fiddlers Hell Creek
McCoy Creek	11.4	Mouth to the Rock Spring drainage
Spring Creek	2.9	Mouth to South Fork Spring Creek
Rock Creek	9.1	Mouth to unnamed bridge
August 8, 2010		
Burnt Corral Creek	4.5	Mouth to East Burnt Corral Creek
Chicken Creek	4.5	Mouth upstream 4.5 river miles
Clear Creek	2.0	Mouth upstream 2.0 river miles
Fly Creek	9.6	Mouth to Fly Valley
Meadow Creek	18.2	Mouth to Waucup Creek
Sheep Creek	9.1	Mouth to East Fork Sheep Creek
West Chicken Creek	1.6	Mouth to Unnamed Tributary
August 9, 2010		
Grande Ronde River	58.3	State Ditch to Tanner Gulch
Limber Jim Creek	3.9	Mouth to Deadwood Gulch
August 10, 2010		
Ladd Creek	9.2	Mouth to Ladd Canyon Pond Creek
Little Creek	8.7	Mouth to Bates Lane
Little Catherine Creek	1.9	Mouth upstream 1.9 river miles
Milk Creek	2.2	Mouth upstream 2.2 river miles
August 12, 2010		
Catherine Creek	31.3	Mouth the North/South Fork confluence
North Fork Catherine Creek	8.0	Mouth to Catherine Creek Meadow
South Fork Catherine Creek	6.0	Mouth to Collins Creek
TOTAL MILES:	**226.1**	

2. Acquisition

2.1 Airborne Survey - Instrumentation

Images were collected with a FLIR system's SC6000 sensor (8-9.2μm) mounted on the underside of a Bell Jet Ranger Helicopter (*Figure 2*). The SC6000 is a calibrated radiometer with internal non-uniformity correction and drift compensation. General specifications of the thermal infrared sensor are listed in Table 2.

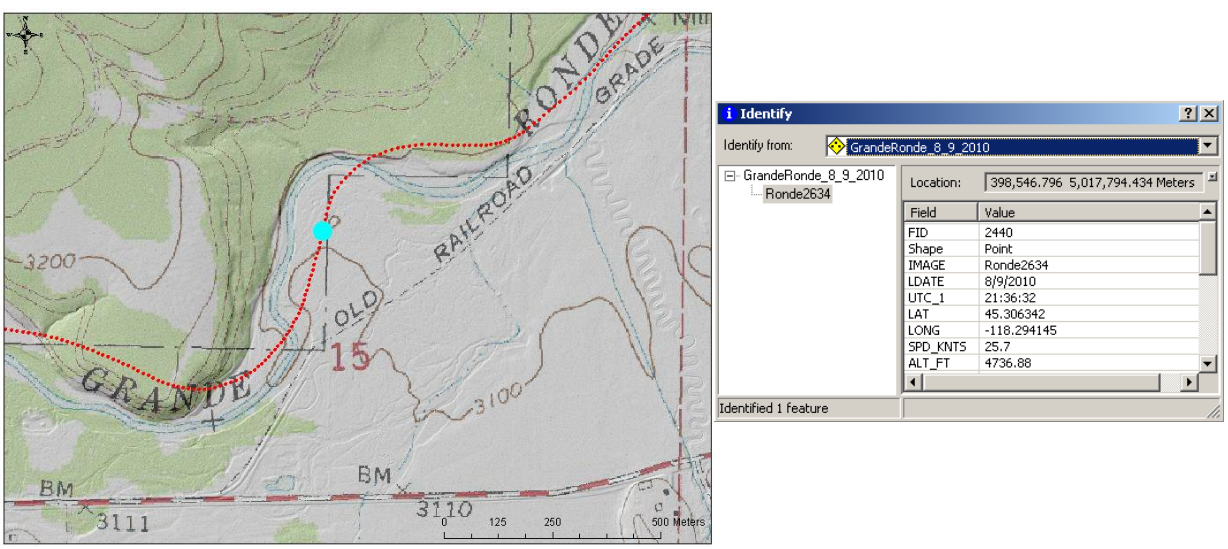
Figure 2. Bell Jet Ranger equipped with a thermal infrared radiometer and high resolution digital camera. The sensors are contained in a composite fiber enclosure attached to the underside of the helicopter which is flown longitudinally along the stream channel.

Table 2. Summary of TIR sensor specifications

Sensor:	FLIR System SC6000 (LWIR)
Wavelength:	8-9.2 μm
Noise Equivalent Temperature Differences (NETD):	0.035°C
Pixel Array:	640 (H) x 512 (V)
Encoding Level:	14 bit
Horizontal Field-of-View:	35.5°

Thermal infrared images were recorded directly from the sensor to an on-board computer as raw counts which were then converted to radiant temperatures. The individual images were referenced with time, position, and heading information provided by a global positioning system (GPS) (*Figure 3*).

Figure 3. Each point on the map represents a thermal image location. The inset box shows the information recorded with each image point during acquisition.



2.2 Image Collection

The aircraft was flown longitudinally along the stream corridor in order to have the stream in the center of the display. The objective was for the stream to occupy 30-60% of the image. The TIR sensor is set to acquire images at a rate of 1 image every second resulting in 40-70% vertical overlap between images.

Flight altitudes were selected in order to optimize resolution while providing an image ground footprint wide enough to capture the active channel. Catherine Creek had a planned flight altitude of 1800 ft (549 m) resulting in a ground sample distance of 0.6 m (1.97.0 ft). A planned flight altitude of 1500 ft (457 m) was selected for the Grande Ronde River and the North and South Forks of Catherine Creek which resulted in a native pixel ground sample distance of 0.5 m (1.64 ft). All other streams had planned flight altitudes of 1300 ft (396 m) which would result in ground sample distances of 0.4 m (1.31 ft). However, due to terrain variations, wind conditions, and stream size, altitudes can vary throughout the flight duration. Little Catherine Creek and Milk Creek were flown lower than planned due to their small size. They were flown at ~1000 ft (305 m) elevation resulting in a ground pixel distance of 0.3 m (0.98 ft). Table 3 summarizes the flight acquisition parameters.

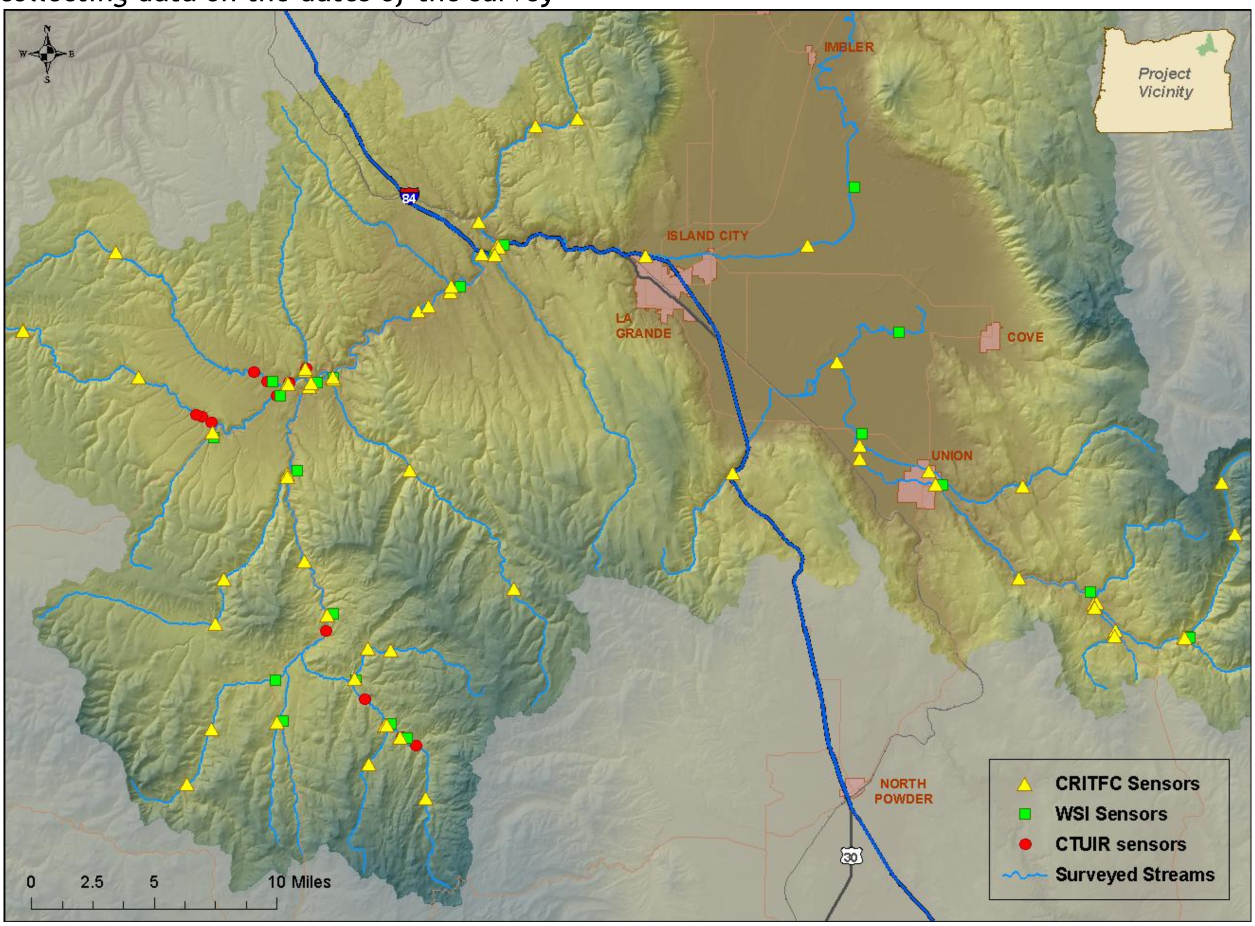
Table 3. Summary of Thermal Image Acquisition Parameters

Catherine Creek	
Flight Above Ground Level (AGL):	1800 ft (549 m)
Image Footprint Width:	1164 ft (355 m)
Pixel Resolution:	1.97 ft (0.60 m)
Grande Ronde River, North and South Fork Catherine Creek	
Flight Above Ground Level (AGL):	1500 ft (457 m)
Image Footprint Width:	969 ft (296 m)
Pixel Resolution:	1.64 ft (0.50 m)
Beaver, Burnt Corral, Chicken, Clear, Dark Canyon, Five Points, Fly, Ladd, Limber Jim, Little, McCoy, Meadow, Rock, Sheep, Spring, West Chicken	
Flight Above Ground Level (AGL):	1300 ft (396 m)
Image Footprint Width:	774 ft (236 m)
Pixel Resolution:	1.31 ft (0.40 m)
Little Catherine Creek and Milk Creek	
Flight Above Ground Level (AGL):	1000 ft (305 m)
Image Footprint Width:	581 ft (177 m)
Pixel Resolution:	0.98 ft (0.30 m)

2.3 Ground Control

Watershed Sciences, Inc. deployed 23 in-stream sensors (Hobo Pros) during the time frame of the flight for calibrating and verifying the thermal accuracy of the TIR imagery. The Hobo Pro data loggers were set to record temperatures at 10-minute intervals and suspended in the water column in areas with good vertical mixing. CRITFC provided data for 64 sensors active during the survey, collecting water temperatures at 30 minute intervals. Confederated Tribes of the Umatilla Indian Reservation (CTUIR) provided data for 14 sensors in the study area. The sensors collected data every hour. All data logger locations are illustrated in Figure 4.

Figure 4. Location of sensors deployed by Watershed Sciences, CRITFC, and CTUIR actively collecting data on the dates of the survey



2.4 Weather and Flow Conditions

Weather conditions on the date of the survey were fair with warm temperatures, low humidity and mostly clear skies. Table 4 summarizes the weather conditions observed at the La Grande Airport (KLGD) on the dates of the survey[2]. No data was collected on August 11, 2010 due to low clouds and cool temperatures. Data from seasonal in-stream thermographs will be needed to assess how water temperatures on the day of the flight compare to average and maximum summer temperatures.

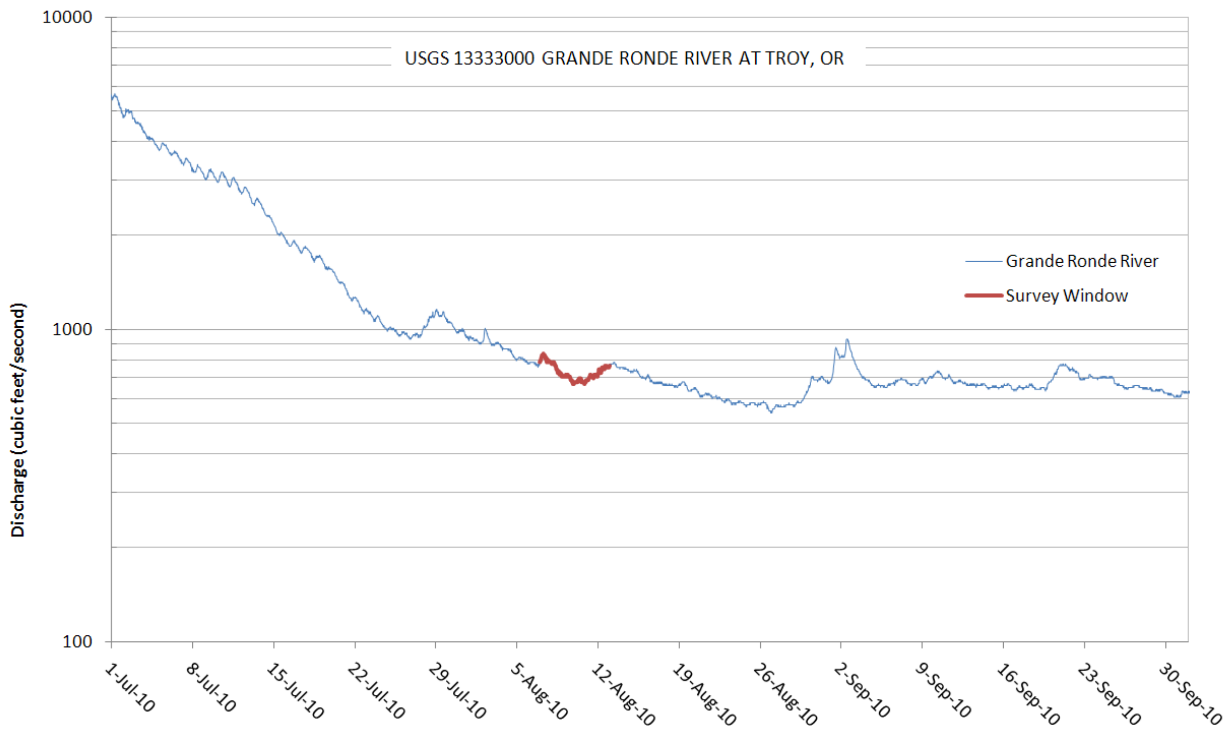
Table 4. Weather conditions measured at the Stanley Airport on August 6, 2010.

Time (PDT)	Temperature (˚F)	% Humidity	Wind Direction	Wind Speed (MPH)	Conditions
August 7, 2010 (Beaver, Five Points, McCoy, Rock, Spring)					
11:55 AM	80.6	28	WSW	8.1	Clear
12:55 PM	84.2	23	NW	15	Clear
1:55 PM	86	22	North	9.2	Clear
2:55 PM	84.2	25	NW	15	Clear
3:55 PM	84.2	25	NNW	17.3	Clear
4:55 PM	84.2	25	NW	11.5	Clear
August 8, 2010 (Burnt Corral, Chicken, Clear, Dark Canyon, Fly, Meadow, Sheep, W. Chicken)					
11:55 AM	75.2	36	NE	3.5	Clear
12:55 PM	78.8	32	Calm	Calm	Clear
1:55 PM	82.4	30	NNW	6.9	Partly Cloudy
2:55 PM	82.4	28	NW	9.2	Scattered Clouds
3:55 PM	82.4	30	NE	8.1	Overcast
4:55 PM	84.2	29	NNE	9.2	Overcast
August 9, 2010 (Upper Grande Ronde, Limber Jim)					
11:55 AM	77	32	Calm	Calm	Clear
12:55 PM	80.6	26	South	6.9	Clear
1:55 PM	82.4	26	Calm	Calm	Scattered Clouds
2:55 PM	84.2	23	NW	18.4	Mostly Cloudy
3:55 PM	84.2	23	NNW	9.2	Partly Cloudy
4:55 PM	82.4	23	North	8.1	Scattered Clouds
August 10, 2010 (Ladd, Little, Little Catherine, Milk)					
11:55 AM	73.4	31	NNW	9.2	Clear
12:55 PM	75.2	27	NE	3.5	Clear
1:55 PM	78.8	26	ENE	8.1	Mostly Cloudy
2:55 PM	78.8	26	North	4.6	Mostly Cloudy
3:55 PM	78.8	26	NW	5.8	Partly Cloudy
4:55 PM	75.2	31	NW	11.5	Clear
August 12, 2010 (Catherine, North and South Forks Catherine)					
11:55 AM	68	60	Calm	Calm	Clear
12:55 PM	75.2	44	NE	3.5	Clear
1:55 PM	78.8	32	East	6.9	Clear
2:55 PM	80.6	26	East	4.6	Clear
3:55 PM	82.4	26	East	6.9	Clear
4:55 PM	80.6	28	Calm	Calm	Partly Cloudy

[2] Source: http://www.wunderground.com

No active USGS flow gages were found for the Upper Grande Ronde River or the tributaries in the survey area; however, one active USGS gage was found 35 miles downstream of the survey on the Lower Grande Ronde River at Troy, OR[3]. The gage shows flows were near the lowest point for the summer; however, it is unclear how the gage at this location translates to the upstream reaches of the river (*Figure 5*). Local flow data from the streams of interest will be needed to further assess the discharge rates.

Figure 5. Discharge measured along the Salmon River at the time of the survey



[3] Source: USGS NWIS Site Information for USA: http://waterdata.usgs.gov/nwis/inventory?

3. Thermal Image Characteristics

3.1 Surface Temperatures

Thermal infrared sensors measure TIR energy emitted at the water's surface. Since water is essentially opaque to TIR wavelengths, the sensor is only measuring water surface temperature. Thermal infrared data accurately represents bulk water temperatures where the water column is thoroughly mixed; however, thermal stratification can form in reaches that have little or no mixing. Thermal stratification in a free flowing river is inherently unstable due to variations in channel shape, bed composition, and in-stream objects (i.e. rocks, trees, debris, etc.) that cause turbulent flow. Stratification can usually be easily detected in the imagery.

3.2 Expected Accuracy

Thermal infrared radiation received at the sensor is a combination of energy emitted from the water's surface, reflected from the water's surface, and absorbed and re-radiated by the intervening atmosphere. Water is a good emitter of TIR radiation and has relatively low reflectivity (~ 4 to 6%). In general, apparent stream temperature changes of < 0.5°C are not considered significant unless associated with a surface inflow (e.g. tributary). However, certain conditions may cause variations in the accuracy of the imagery.

3.2.1 Surface Conditions

Variable water surface conditions (i.e. riffle versus pool), slight changes in viewing aspect, and variable background temperatures (i.e. sky versus trees) can result in differences in the calculated radiant temperatures within the same image or between consecutive images. The apparent temperature variability is generally less than 0.5°C (Torgersen et al. 2001[4]). The occurrence of reflections as an artifact (or noise) in the TIR images is a consideration during image interpretation and analysis.

3.2.2 Differential Heating

In stream segments with flat surface conditions (i.e. pools) and relatively low mixing rates, observed variations in spatial temperature patterns can be the result of differences in the instantaneous heating rate at the water's surface. In the TIR images, indicators of differential surface heating include seemingly cooler radiant temperatures in shaded areas compared to surfaces exposed to direct sunlight.

3.2.3 Feature Size and Resolution

A small stream width logically translates to fewer pure stream pixels and greater integration with non-water features such as rocks and vegetation. Consequently, a narrow channel (relative to the pixel size) can result in higher variability and inaccuracies in the measured radiant temperatures as more 'mixed pixels' are sampled. This is a consideration especially when sampling the radiant temperatures at tributary mouths and surface springs.

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[4] Torgersen, C.E., R. Faux, B.A. McIntosh, N. Poage, and D.J. Norton. 2001. Airborne thermal remote sensing for water temperature assessment in rivers and streams. *Remote Sensing of Environment* 76(3): 386-398.

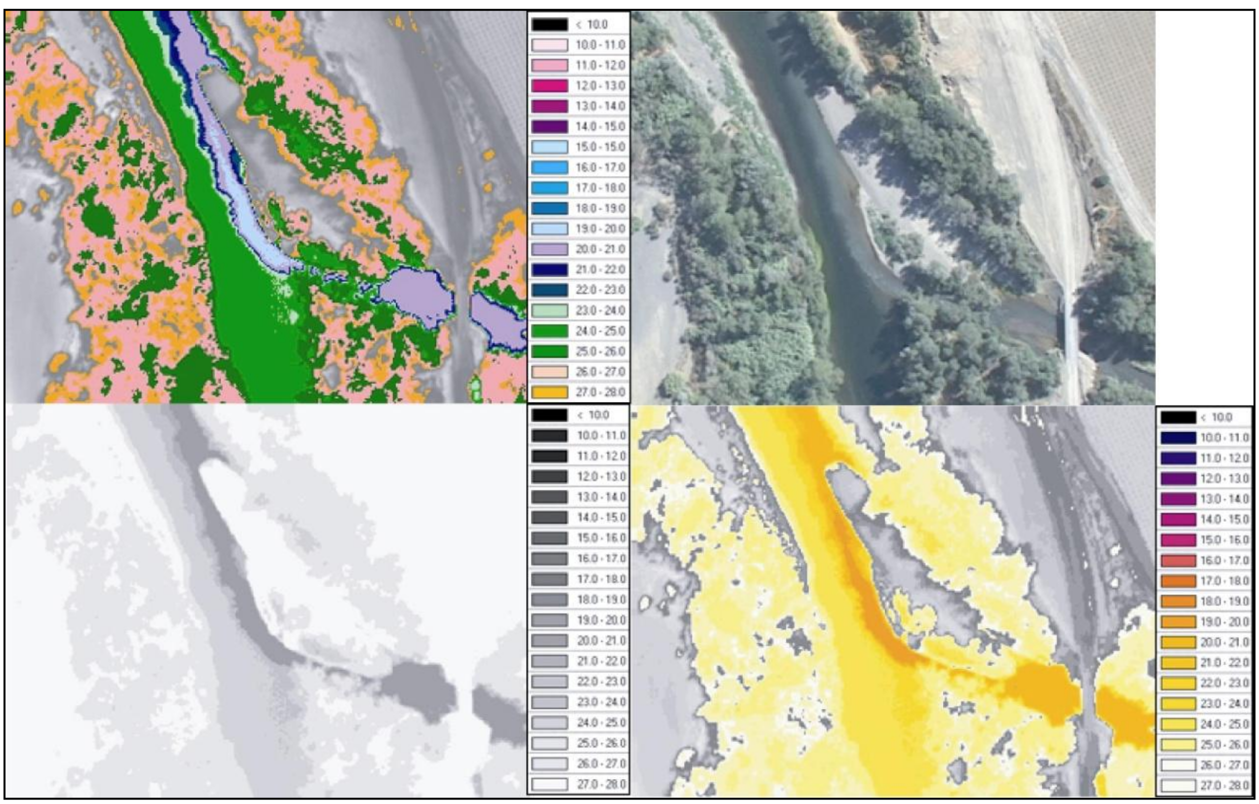
3.3 Image Uniformity

The TIR sensor used for this study uses a focal plane array of detectors to sample incoming radiation. A challenge when using this technology is to achieve uniformity across the detector array. This sensor has a correction scheme which reduces non-uniformity across the image frame. However, differences in temperature (typically <0.5°C) can be observed near the edges of the image frame. During the flight, every effort is made to keep the stream in the center of the image frame. The uniformity differences within frames and slight differences from frame-to-frame are often most apparent in the continuous mosaics.

3.4 Temperatures and Color Maps

The TIR images collected during this survey consist of a single band. As a result, visual representation of the imagery *(in a report or GIS environment*) requires the application of a color map or legend to the pixel values. The selection of a color map should highlight features most relevant to the analysis (i.e. *spatial variability of stream temperatures*). For example, a continuous, gradient style color map that incorporates all temperatures in the image frame will provide a smoother transition in colors throughout the entire image, but will not highlight temperature differences in the stream. Conversely, a color map that focuses too narrowly cannot be applied to the entire river and will washout terrestrial and vegetation features (*Figure 6*).

Figure 6. Example of different color ramps applied to the same TIR image.



4. Data Processing

4.1 Sensor Calibration

Prior to the season, the response characteristics of the TIR sensor are measured in a laboratory environment. The response curves relate the raw digital numbers recorded by the sensor to emitted radiance from a black body. The raw TIR images collected during the survey initially contain digital numbers which are then converted to radiance temperatures based on the pre-season calibration.

The calculated radiant temperatures are adjusted based on the kinetic temperatures recorded at each ground truth location. This adjustment is performed to correct for path length attenuation and the emissivity of natural water. The in-stream data are assessed at the time the image is acquired, with radiant values representing the median of ten points sampled from the image at the data logger location.

4.2 Geo-referencing

During the survey, the images are tagged with a GPS position and heading at the time they are acquired. Since the TIR camera is maintained at vertical down-look angles, the geographic coordinates provide a reasonably accurate index to the location of the image scene. However, due to the relatively small footprint of the imagery and independently stabilized mount, image pixels are not individually registered to real world coordinates. The image index is saved as an ESRI point shapefile containing the image name registered to an X and Y position of the sensor and the time of capture.

4.3 Geo-rectification

Individual TIR frames are manually geo-rectified by finding a minimum of six common ground control points (GCPs) between the image frames and imagery available for the area. The images are then warped using a 1st order polynomial transformation. The 2009 1-meter NAIP imagery was used as a base for the rectification for the Grande Ronde.

4.4 Interpretation and Sampling

Once calibrated, the images are integrated into a GIS in which an analyst interprets and samples stream temperatures. Sampling consists of querying radiant temperatures (pixel values) from the center of the stream channel and saving the median value of a ten-point sample to a GIS database file. The temperatures of detectable surface inflows (e.g. surface springs, tributaries) are also sampled at their mouths. During sampling, the analyst provides interpretations of the spatial variations in surface temperatures observed in the images.

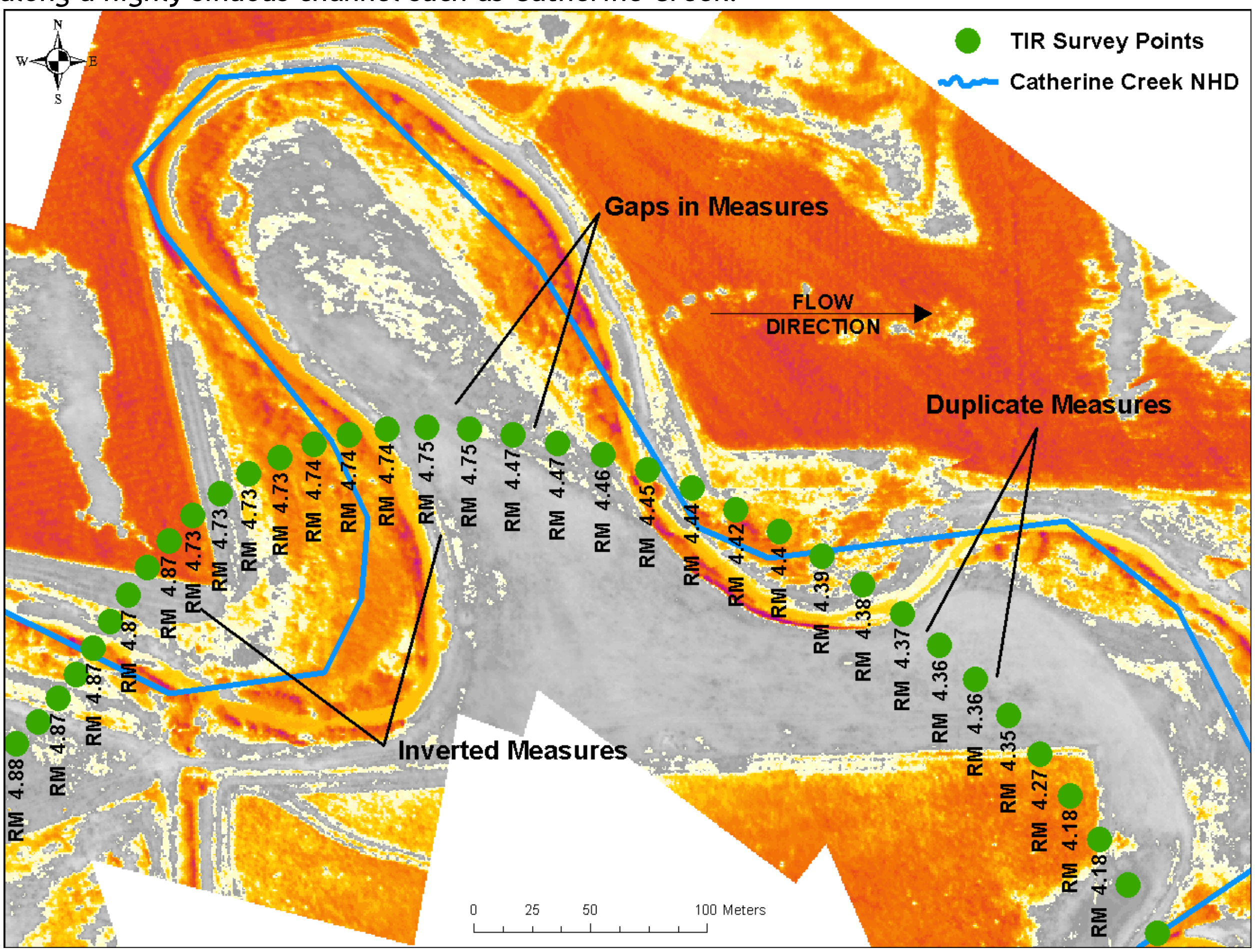
4.5 Temperature Profiles

In order to provide further spatial reference, the image index shapefile is assigned an approximate river mile based on a routed stream layer. The median temperature for each sampled image frame is plotted versus the corresponding river mile to develop a longitudinal temperature profile. The profile illustrates how stream temperatures vary spatially along the stream gradient. The location and median temperature of all sampled surface water inflows (e.g. tributaries, surface springs, etc.) are included on the plot to illustrate how these inflows

influence the main stem temperature patterns. Radiant temperatures are only sampled along what appears to be the main flow channel in the river.

River miles in this report are only approximate and based on the USGS National Hydrography Dataset (NHD) flowlines for the Upper Grande Ronde Basin. Changes in channel morphology over time and the inherent difficulty of measuring a straight flight line against a sinuous river channel add to the difficulty. River measures of tributaries and inflows should be used with discretion outside the scope of this report (*Figure 7)*. A slight modification was made to the Ladd Creek NHD line in order to better measure the natural channel versus the canal.

Figure 7. The image below illustrates discrepancies which occur in measuring river miles along a highly sinuous channel such as Catherine Creek.



5. Thermal Accuracy

Watershed Sciences used data from the CRITFC and Confederated Tribes of the Umatilla Indian Reservation (CTUIR) in-stream data loggers, as well as 23 additional Hobo Pro sensor placements, to calibrate and validate the thermal imagery (*Figure 5*). Table 5 summarizes a comparison between the kinetic temperatures recorded by the in-stream data loggers and the radiant temperatures derived from the TIR images sorted by collection date. The differences between radiant and kinetic temperatures were consistent with other airborne TIR surveys conducted in the Pacific Northwest and within the target accuracy of ±0.5°C with few exceptions. If necessary, data logger temperatures were interpolated based on the 30-minute and 1-hour temperature readings. Results that fell well outside the accuracy limits are highlighted in yellow and discussed in further detail below.

McCoy Creek – The uppermost CRITFC data logger on McCoy Creek recorded temperatures 1.7°C cooler than the radiant temperatures derived from the TIR imagery. The reason for this difference was not immediately apparent from the imagery. However with the confluence of Ensign Creek just above the data logger, the data logger could have been placed in an area of locally cool water that did not mix to the surface and therefore was not detected in the TIR images. Of the three CTUIR data loggers in McCoy Creek, the MCCOY7 sensor showed water temperatures being coldest in the middle of the afternoon raising suspicions of its internal clock settings. The CTUIR sensor at the bridge crossing (RM 0.89) was inconsistent with both the derived radiant temperatures and WSI data logger readings at the same location. It is unclear why the other CTUIR data logger (RM 1.67) did not validate the TIR image calibration.

Grande Ronde River – The 60 mile reach of the Upper Grande Ronde was calibrated with WSI sensors only. The 15 CRITFC sensors and 4 CTUIR sensors were strictly used for validation purposes. Though four sensors along the Grande Ronde showed discrepancies of greater than ±1.0°C, in every case the sensors immediately upstream and downstream calibrated well indicating a possible data logger issue.

Ladd Creek – Of the three data loggers in or near the stream, two gave suspect readings for the time and date of the survey. In-stream temperatures for the 'CC_above_Ladd_Creek' sensor seemed extremely low (17.7°C) given the temperatures and water levels seen in Catherine Creek. The sensor went offline at the end of the day on the 10th and was found dewatered on August 18th making stream temperature readings from this data logger suspect. The sensor at the mouth of Ladd Creek ('Ladd_Cr_mouth') showed a -2.8°C discrepancy between the in-stream sensor and the radiant temperatures. There appears to be a constriction or a culvert at this location in the channel. If the sensor was below the constriction, it is possible that it was measuring cooler water off the bottom of the upstream wetland and did not represent surface water temperatures. A good measurement was obtained at the uppermost sensor so the calibration was based on this location.

Little Creek - The CRITFC data logger reading at the mouth of the Little Creek is suspect given that the imagery shows Little Creek as a warming source to Catherine Creek. The two data loggers upstream and the nearest downstream data logger on Catherine Creek were consistent with the radiant temperatures.

Meadow Creek – Four of the five CTUIR data loggers used for validation purposes in Meadow Creek (MEADOW2, MEADOW5, MEADOW6, and BATTLE1) had temperature readings that appear to be out of sync with the time of day with the coolest temperatures occurring near noon and the warmest temperatures occurring in the middle of the night. Without further information, they cannot be considered accurate.

Table 5. Comparison of radiant temperatures derived from the TIR images and kinetic temperatures from the in-stream monitor. Data shown in blue were not used in the imagery calibrations, but as independent verification of the results.

Stream	Site	Logger_id	Owner	River Mile	TIR_Image	UTC Time	In-Stream Temp	Radiant Temp	Δ°C
8/7/2010									
Beaver Creek									
Grande Ronde R.	GR_above_Beaver_Cr	2395849	WSI	0.00	beaver1881	14:42	24.4	24.3	0.1
Beaver Creek	Beaver_Cr_mouth	2395829	CRITFC	0.11	beaver1907	14:42	21.2	21.3	-0.1
Beaver Creek	Beaver_Cr_above_Dry_Beaver	2395827	CRITFC	5.57	beaver2400	14:52	17.2	16.9	0.3
Beaver Creek	Beaver_Cr_upper	2395858	CRITFC	13.16	beaver2980	15:02	15.1	14.8	0.3
Dark Canyon Creek									
Dark Canyon Creek	Dark_Canyon_Cr_mouth	DC1	CTUIR	0.05	GrandeRonde3167	15:16	21.3	21.0	0.3
Five Points Creek									
Five Points Creek	Five_Points_Cr_mouth	2395854	CRITFC	0.06	fivepts0033	13:46	21.2	21.0	0.2
Five Points Creek	Five_Points_Cr_mouth	1026260	WSI	0.06	fivepts0033	13:46	21.1	21.0	0.1
Five Points Creek	Five_Points_Cr_above_Pelican	2395833	CRITFC	1.42	fivepts0172	13:49	20.0	20.6	-0.6
Five Points Creek	Five_Points_Cr_above_Little_JD	2395799	CRITFC	6.87	fivepts0575	13:55	20.1	19.6	0.4
Five Points Creek	Five_Points_Cr_upper	2395811	CRITFC	8.74	fivepts0714	13:58	16.7	16.5	0.2
McCoy Creek									
Meadow Cr	Mouth	1026261	WSI	d/s	mccoy3020	15:12	24.0	23.8	0.2
Dark Canyon Creek	Dark_Canyon_Cr_mouth	DC1	CTUIR	d/s	mccoy3167	15:16	21.3	21.0	0.3
McCoy Creek	McCoy_Cr_mouth	2395804	CRITFC	0.04	mccoy3246	15:17	24.1	23.9	0.2
McCoy Creek	McCoythermo7	MCCOY7	CTUIR	0.04	mccoy3243	15:18	15.6	23.8	**-8.2**
McCoy Creek	at bridge	1026267	WSI	0.89	mccoy3330	15:18	23.2	22.6	0.6
McCoy Creek	McCoythermo6	MCCOY6	CTUIR	0.89	mccoy3330	15:18	24.7	22.6	**2.1**
McCoy Creek	McCoythermo1	MCCOY1	CTUIR	1.67	mccoy3400	15:19	23.2	21.8	**1.4**
McCoy Creek	McCoy_Cr_below_Ensign_Cr	2395841	CRITFC	11.37	mccoy4338	15:37	14.1	16.1	**-1.7**
Rock Creek									
Grand Ronde R.	U/S Rock Creek	2386980	WSI	u/s	rock0842	14:06	24.1	24.4	-0.3
Rock Creek	Rock_Cr_mouth	2395853	CRITFC	0.19	rock0860	14:08	26.0	25.6	0.4
Spring Creek									
Grande Ronde	GRR at Spring Creek	2386979	WSI	0.00	spring1472	14:28	24.6	25.0	-0.4
Spring Creek	Spring_Cr_mouth	2395846	CRITFC	0.07	spring1480	14:28	21.5	21.1	0.4

Stream	Site	Logger_id	Owner	River Mile	TIR_Image	UTC Time	In-Stream Temp	Radiant Temp	Δ°C
8/8/2010									
Burnt Corral Creek									
Burnt Corral	Burnt_Corral_Cr_mouth	2395869	CRITFC	0.27	burntcorr1498	15:00	21.3	20.6	0.7
Burnt Corral	Burnt_Corral	1026266	WSI	0.61	burntcorr1519	15:01	19.9	20.2	-0.3
Chicken Creek									
Chicken Creek	Chicken_Cr_below_W_Chicken	2395866	CRITFC	2.33	chicken3630	15:49	19.8	20.1	-0.3
Chicken Creek	Chicken_Cr_below_W_Chicken	1026259	WSI	2.33	chicken3630	15:49	20.0	20.1	-0.1
Clear Creek									
Clear Creek	Clear_Cr_mouth	2395843	CRITFC	0.00	clear4003	16:01	15.2	15.3	-0.1
Clear Creek	Clear Creek lower	CLC1	CTUIR	0.05	clear4009	16:01	15.5	14.9	0.6
Clear Creek	Clear_Cr_upper	2395860	CRITFC	1.84	clear4236	16:07	13.2	13.0	0.2
Fly Creek									
Grande Ronde R.	GR d/s Fly Cr.	1026262	WSI	0.00	fly1974	15:12	22.5	22.3	0.2
Fly Creek	Fly_Cr_mouth	2395805	CRITFC	0.08	fly1993	15:12	20.1	20.4	-0.3
Fly Creek	Fly_Cr_Canyon	2395828	CRITFC	5.44	fly2355	15:18	21.5	21.9	-0.4
Fly Creek	Fly_Cr_below_Little_Fly_Cr	2395865	CRITFC	7.56	fly2532	15:21	25.5	25.1	0.4
Meadow Creek									
Grande Ronde R.	Up Stream Meadow	2395845	CRITFC	u/s	meadow0014	14:29	24.6	24.7	-0.1
Meadow Creek	at mouth	1026261	WSI	0.01	meadow0014	14:29	23.9	23.7	0.2
Meadow Creek	Meadow_Cr_mouth	2395826	CRITFC	0.03	meadow0019	14:30	23.2	23.0	0.2
Meadow Creek	Meadow_Cr_above_Dark_Cyn	2395839	CRITFC	0.67	meadow0076	14:30	26.9	26.6	0.3
Meadow Creek	Meadows2 Lower	MEADOW2	CTUIR	1.81	meadow0143	14:32	15.7	24.6	**-8.9**
Meadow Creek	Meadow_Cr_above_McCoy_Cr	2395825	CRITFC	1.82	meadow0144	14:32	24.7	24.4	0.3
Meadow Creek	Meadow1 Upper	MEADOW1	CTUIR	2.61	meadow0199	14:33	27.3	26.6	0.7
Meadow Creek	Meadow Ck Habberstad2 Lower	MEADOW6	CTUIR	6.65	meadow0474	14:37	8.7	25.4	**-16.7**
Meadow Creek	Battle Creek	BATTLE1	CTUIR	7.09	meadow0508	14:38	7.6	22.8	**-15.2**
Meadow Creek	Meadow Ck Habberstad1 Upper	MEADOW5	CTUIR	7.26	meadow0534	14:38	6.9	24.0	**-17.1**
Meadow Creek	Meadow_Cr_above_Bear_Cr	2395800	CRITFC	10.82	meadow0810	14:43	24.0	23.4	0.6
Meadow Creek	Meadow_Cr_above_Waucup_Cr	2395864	CRITFC	17.94	meadow1439	14:53	18.4	18.6	-0.2
Sheep Creek									
Sheep Creek	at Vey Ranch	2386978	WSI	2.04	sheep2857	15:32	24.6	24.6	0.0
Sheep Creek	Sheep_Cr_Rd_junction	2395819	CRITFC	6.10	sheep3177	15:37	22.1	21.9	0.2
Sheep Creek	Sheep_Cr_below_E_Sheep_Cr	2395852	CRITFC	8.71	sheep3368	15:40	15.2	15.2	0.0

Stream	Site	Logger_id	Owner	River Mile	TIR_Image	UTC Time	In-Stream Temp	Radiant Temp	Δ°C
8/9/2010									
Grande Ronde									
Grande Ronde	State Ditch/Market Lane Bridge	1026260	WSI	36.40	GrandeRonde0197	13:50	23.6	24.3	-0.7
Grande Ronde	GR_Peach_Rd_bridge	2395823	CRITFC	40.15	GrandeRonde0490	13:55	24.7	24.9	-0.3
Grande Ronde	GR_at_2nd_St_Bridge	9760482	CRITFC	47.31	GrandeRonde1188	14:10	22.4	23.6	**-1.2**
Grande Ronde	GR_above_Five_Points_Cr	2395842	CRITFC	54.49	GrandeRonde1995	14:25	24.3	23.6	0.7
Grande Ronde	Milgard Jct. State Park	2386980	WSI	55.10	GrandeRonde2064	14:27	23.4	23.1	0.3
Grande Ronde	GR_Hilgard Park	2395862	CRITFC	55.39	GrandeRonde2103	14:27	23.5	23.6	-0.1
Grande Ronde	downstream of Spring Creek	2386979	WSI	58.60	GrandeRonde2397	14:32	24.1	23.0	**1.1**
Grande Ronde	GR_above_Spring_Cr	2395815	CRITFC	58.80	GrandeRonde2420	14:32	23.7	23.0	0.7
Grande Ronde	GR_above_Jordan_Cr	9760475	CRITFC	60.11	GrandeRonde2538	14:34	23.0	23.2	-0.2
Grande Ronde	GR_above_Bear Creek	9760479	CRITFC	60.63	GrandeRonde2595	14:35	23.3	23.2	0.1
Grande Ronde	GR_above_Beaver_Cr	2395849	CRITFC	67.02	GrandeRonde3189	14:47	22.1	22.2	-0.1
Grande Ronde	upstream of Beaver Creek	1026265	WSI	67.21	GrandeRonde3210	14:47	22.2	22.0	0.2
Grande Ronde	GR_above_Meadow_Cr	2395845	CRITFC	68.71	GrandeRonde3354	14:50	22.2	22.3	-0.1
Grande Ronde	downstream of Fly Creek	1026262	WSI	72.87	GrandeRonde3804	14:58	20.9	21.1	-0.2
Grande Ronde	GR_above_Fly_Cr	2395851	CRITFC	73.24	GrandeRonde3834	14:58	20.6	20.4	0.2
Grande Ronde	GR_at_Time_and_Half_Bridge	2395830	CRITFC	77.09	GrandeRonde4121	15:03	18.9	21.4	**-2.5**
Grande Ronde	near GR Guard Station	9783696	WSI	79.99	GrandeRonde4291	15:06	22.8	22.8	0.0
Grande Ronde	GR_below_Vey	2395867	CRITFC	80.05	GrandeRonde4296	15:06	22.0	22.8	-0.8
Grande Ronde	Grande Ronde River lower Vey	GR4	CTUIR	80.74	granderonde4347	15:07	22.4	22.5	-0.1
Grande Ronde	Acclimation Facility	GR5	CTUIR	86.61	granderonde4738	15:14	17.0	17.2	-0.2
Grande Ronde	GR_above_Clear_Cr	2395820	CRITFC	88.38	GrandeRonde4939	15:19	15.8	15.8	0.0
Grande Ronde	Grande Ronde River Mid	GR6	CTUIR	89.16	granderonde4997	15:20	14.7	14.4	0.3
Grande Ronde	GR_Reach_U155154	9760488	CRITFC	89.16	GrandeRonde4997	15:20	14.5	14.4	0.1
Grande Ronde	along Reach U155154	1187769	WSI	89.20	GrandeRonde5000	15:20	14.4	14.8	-0.4
Grande Ronde	Grand Ronde River upper	GR8	CTUIR	89.96	granderonde5059	15:21	13.3	13.2	0.1
Grande Ronde	GR_below_Tanner_Gulch	2395822	CRITFC	92.42	GrandeRonde5240	15:24	11.3	10.9	0.4
Limber Jim Creek									
Limber Jim Creek	first bridge crossing	9793695	WSI	0.11	limberjim5328	15:30	17.4	17.2	0.2
Limber Jim Creek	Limber_Jim_Cr_mouth	2395810	CRITFC	0.38	limberjim5346	15:31	16.5	16.5	0.0
Limber Jim Creek	Limber_Jim_Cr_below_NF	2395836	CRITFC	1.78	limberjim5446	15:32	13.1	12.9	0.2
Limber Jim Creek	Limber_Jim_Cr_upper	2395824	CRITFC	2.82	limberjim5526	15:34	12.4	12.5	-0.1

Stream	Site	Logger_id	Owner	River Mile	TIR_Image	UTC Time	In-Stream Temp	Radiant Temp	Δ°C
8/10/2010									
Ladd Creek									
Catherine Cr.	CC_above_Ladd Cr	9760490	CRITFC	0.00	ladd0492	14:11	17.7	24.2	**-6.5**
Ladd Creek	Ladd_Cr_mouth	9760485	CRITFC	0.03	ladd0492	14:10	20.7	23.5	**-2.8**
Ladd Creek	Ladd_Cr_upper	2395806	CRITFC	8.23	ladd1361	14:28	15.2	15.3	-0.1
Little Catherine Creek									
Catherine Creek	d/s of Little Catherine	1026261	WSI	d/s	Catherine2662	15:03	19.0	18.9	0.1
Little Catherine	Little_CC_mouth	2395812	CRITFC	0.11	Catherine2759	15:06	17.4	17.3	0.1
Little Creek									
Catherine Creek	d/s of Little Creek	9783697	WSI	d/s	little1430	14:34	23.3	22.9	0.4
Little Creek	Little_Cr_mouth	2395848	CRITFC	0.02	little1473	14:34	19.7	23.2	**-3.5**
Little Creek	Little_Cr_N_Union	9760489	CRITFC	3.38	little1721	14:38	20.1	20.1	0.0
Little Creek	Little_Cr_High_Valley_Rd	9760492	CRITFC	8.29	little2154	14:46	18.3	18.5	-0.3
Milk Creek									
Catherine Creek	downstream of mouth	1026261	WSI	d/s	milk2279	14:53	19.1	18.5	0.6
Catherine Creek	CC above Little CC	9760476	CRITFC	0.00	milk2332	14:54	18.1	18.1	0.0
Catherine Creek	CC above Milk Cr	9760474	CRITFC	0.00	milk2349	14:55	17.9	17.7	0.2
Milk Creek	Milk_Cr_mouth	2395838	CRITFC	0.06	milk2353	14:55	16.1	16.5	-0.4
Milk Creek	below_unnamed	2395837	CRITFC	1.41	milk2550	14:59	16.7	16.4	0.3
Milk Creek	Milk_Cr_upper	2395855	CRITFC	1.66	milk2569	15:00	14.7	14.6	0.1

Stream	Site	Logger_id	Owner	River Mile	TIR_Image	UTC Time	In-Stream Temp	Radiant Temp	Δ°C
8/12/2010									
Catherine Creek									
Catherine Creek	CC_above_Little_Cr	2395807	CRITFC	13.40	Catherine2564	16:28	20.7	20.6	0.1
Catherine Creek	CC_E_Union	9760477	CRITFC	17.49	Catherine2297	16:24	20.1	20.3	-0.2
Catherine Creek	CC_Hwy_203	9760478	CRITFC	22.97	Catherine1933	16:18	18.9	18.9	0.0
Catherine Creek	CC_above_Little_CC	9760476	CRITFC	26.73	Catherine1663	16:13	17.9	17.7	0.2
Catherine Creek	CC_above_Milk_Cr	9760474	CRITFC	26.90	Catherine1650	16:13	17.8	17.6	0.2
N.F. Catherine	NF_Mouth	1026266	WSI	31.31	Catherine1332	16:08	15.6	15.5	0.1
S.F. Catherine	SF_Mouth	2386978	WSI	31.37	Catherine1329	16:08	14.3	14.4	-0.1
North Fork Catherine Creek									
N.F. Catherine	Near Mouth	1026266	WSI	0.10	Catherine0083	15:36	15.6	15.6	0.0
N.F. Catherine	NF_CC_mouth	2395796	CRITFC	0.13	Catherine0090	15:36	15.5	15.6	-0.1
N.F. Catherine	NF_CC_upper	2395859	CRITFC	7.45	Catherine0614	15:45	8.7	8.5	0.2
South Fork Catherine Creek									
SF Catherine	mouth	2386978	WSI	0.10	Catherine0693	15:51	14.4	14.4	0.0
SF Catherine	SF_CC_mouth	2395844	CRITFC	0.08	Catherine0693	16:08	14.2	14.4	-0.2

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6. Study Area Results

Median channel temperatures were plotted versus river mile for the streams in the survey area. Tributaries, springs, and seeps sampled during the analysis are included on the longitudinal profiles to provide additional context for interpreting spatial temperature patterns. Significant features such as braids, impoundments, diversions and dam outflows were plotted where relevant.

Due to the nature of the project, the focus of the survey was to capture thermal conditions during peak temperatures. Given the warm temperatures on the days of the survey, features such as hot springs may have been 'washed out' in comparison to the surrounding terrestrial landscape. It is important to reiterate that temperature changes of less than ± 0.5°C in the absence of a point source should be interpreted with caution until verified in the field due to the inherent nature of the thermal imagery.

Springs and seeps are generally differentiated by size and temperature; a feature is considered a spring when it has a defined source and is distinctly cooler than the surrounding waters. Features are called seeps when they are less defined spatially and in temperature; they most commonly occur on the edges of the river banks. If there was any doubt about the source of a feature, they were noted with a '?' in the sampled shapefile. These locations should be verified in the field to confirm the presence of groundwater.

The Upper Grande Ronde River and its tributaries are discussed first, followed by Catherine Creek and its tributaries, with the major focus being on the longer streams in the study area. The sample images contained in this report are not meant to be comprehensive, but to provide examples of river features and interpretations. Color ramps in the sample images are unique for each stream.

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UPPER GRANDE RONDE RIVER AND TRIBUTARIES

8/9/2010

Upper Grande Ronde River
Limber Jim Creek

8/7/2010

Beaver Creek
Dark Canyon Creek
Five Points Creek
McCoy Creek
Rock Creek
Spring Creek

8/8/2010

Burnt Corral Creek
Chicken Creek/West Chicken Creek
Clear Creek
Fly Creek
Meadow Creek
Sheep Creek

6.1 Upper Grande Ronde River

6.1.1 Longitudinal Temperature Profile

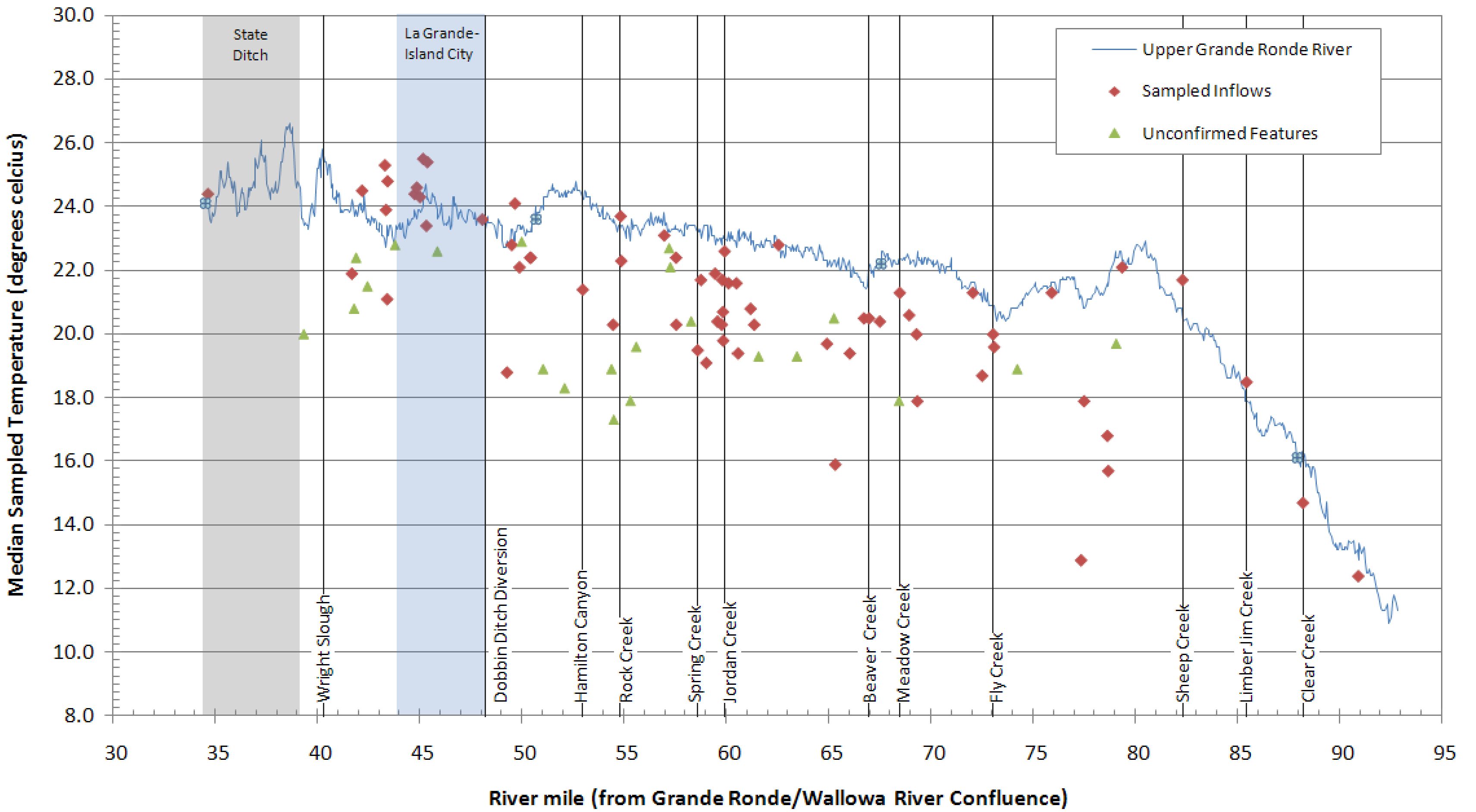


Figure 8. Median sampled temperatures versus river mile for the Upper Grande Ronde River from State Ditch upstream to Tanner Gulch. The locations of detected surface inflows are illustrated on the profile and listed in Table 6. All mileages are referenced from the confluence with the Wallowa River.

Table 6. Tributaries and other surface inflows sampled along the Upper Grande Ronde River with left or right bank designation (looking downstream)

Tributaries	Kilometer	River Mile	Tributary Temp (˚C)	Mainstem Temp (˚C)	Difference
Grande Ronde River (R)	55.70	34.61	24.4	24.3	0.1
seep/shadow (R)	67.04	41.66	21.9	23.9	-2.0
pond (L)	67.85	42.16	24.5	24.1	0.4
gravel pit pond (R)	69.65	43.28	25.3	23.0	2.3
gravel pit pond (R)	69.74	43.33	23.9	22.7	1.2
seep (R)	69.83	43.39	21.1	23.3	-2.2
gravel pit pond (R)	69.86	43.41	24.8	23.4	1.4
gravel pit pond (R)	71.98	44.73	24.4	23.7	0.7
gravel pit pond (R)	72.17	44.84	24.6	23.6	1.0
gravel pit pond (R)	72.42	45.00	24.3	23.9	0.4
gravel pit pond (L)	72.66	45.15	25.5	24.0	1.5
hyporheic flow (R)	72.92	45.31	23.4	24.7	-1.3
gravel pit pond (L)	73.00	45.36	25.4	24.2	1.2
Dobbin Ditch overflow? (L)	77.33	48.05	23.6	23.5	0.1
spring (R)	79.27	49.26	18.8	22.8	-4.0
Unnamed (R)	79.65	49.49	22.8	23.3	-0.5
Unnamed (L)	79.90	49.65	24.1	22.9	1.2
hyporheic flow (R)	80.26	49.87	22.1	23.4	-1.3
Wilson Canyon (R)	81.10	50.39	22.4	23.2	-0.8
Robbs Creek (L)	81.16	50.43	22.4	23.2	-0.8
Hamilton Cyn/Cottonwood Sp (L)	85.24	52.97	21.4	24.3	-2.9
Five Points Creek (L)	87.64	54.46	20.3	23.5	-3.2
Rock Creek (R)	88.25	54.83	23.7	23.3	0.4
hyporheic flow (R)	88.29	54.86	22.3	23.4	-1.1
Unnamed (R)	91.66	56.96	23.1	23.8	-0.7
Whiskey Creek (R)	92.61	57.54	22.4	23.4	-1.0
wet meadow (R)	92.62	57.55	20.3	23.3	-3.0
Spring Creek (L)	94.31	58.60	19.5	23.2	-3.7
Unnamed (R)	94.57	58.76	21.7	23.3	-1.6
hyporheic flow (R)	94.98	59.02	19.1	23.4	-4.3
hyporheic flow (R)	95.68	59.45	21.9	23.1	-1.2
Unnamed (L)	95.87	59.57	20.4	23.0	-2.6
seep (L)	96.20	59.78	20.3	22.8	-2.5
seep (L)	96.25	59.81	21.7	23.0	-1.3
seep (R)	96.30	59.84	20.7	23.0	-2.3
seep (L)	96.32	59.85	19.8	23.1	-3.3
Jordan Creek (R)	96.43	59.92	22.6	23.0	-0.4
seep (R)	96.74	60.11	21.6	23.2	-1.6
side channel (R)	97.34	60.48	21.6	22.7	-1.1
Unnamed (R)	97.45	60.56	19.4	23.2	-3.8
hyporheic flow (L)	98.45	61.17	20.8	23.2	-2.4
spring (R)	98.73	61.35	20.3	22.8	-2.5
side channel (L)	100.64	62.54	22.8	22.8	0.0
side channel (R)	104.46	64.91	19.7	22.3	-2.6
spring (L)	105.13	65.32	15.9	22.3	-6.4
side channel (R)	106.26	66.03	19.4	22.3	-2.9
side channel (R)	107.37	66.72	20.5	21.5	-1.0
Beaver Creek (R)	107.78	66.97	20.5	22.1	-1.6

Tributaries	Kilometer	River Mile	Tributary Temp (°C)	Mainstem Temp (°C)	Difference
hyporheic flow (R)	108.64	67.50	20.4	22.1	-1.7
Meadow Creek (L)	110.21	68.48	21.3	22.4	-1.1
hyporheic flow (R)	110.95	68.94	20.6	22.4	-1.8
Winter Canyon (R)	111.53	69.30	20.0	22.2	-2.2
side channel (R)	111.59	69.34	17.9	22.6	-4.7
hyporheic flow (L)	115.98	72.06	21.3	21.6	-0.3
spring (R)	116.69	72.51	18.7	21.0	-2.3
Fly Creek 1 (L)	117.57	73.05	20.0	20.9	-0.9
seep (L)	117.64	73.10	19.6	20.9	-1.3
Unnamed (L)	122.18	75.92	21.3	21.6	-0.3
spring (L)	124.51	77.36	12.9	21.2	-8.3
seep (L)	124.74	77.51	17.9	20.8	-2.9
Unnamed (R)	126.58	78.65	16.8	21.6	-4.8
seep (L)	126.63	78.69	15.7	21.5	-5.8
Unnamed (L)	127.73	79.37	22.1	22.3	-0.2
Sheep Creek (L)	132.50	82.33	21.7	20.4	1.3
Limber Jim Creek (R)	137.55	85.47	18.5	17.9	0.6
Clear Creek (L)	141.99	88.23	14.7	16.1	-1.4
Unnamed (R)	146.35	90.94	12.4	12.9	-0.5

Unconfirmed Features

Tributaries	Kilometer	River Mile	Tributary Temp (°C)	Mainstem Temp (°C)	Difference
irrigation drain? (R)	63.27	39.31	20.0	23.6	-3.6
seep south of sandbar? (R)	67.23	41.77	20.8	24.0	-3.2
seep? (R)	67.39	41.87	22.4	23.9	-1.5
seep? (R)	68.28	42.43	21.5	23.6	-2.1
spring? (R)	70.46	43.78	22.8	22.8	0.0
hyporheic flow? (R)	73.79	45.85	22.6	23.9	-1.3
seep from Bear Cyn? (L)	80.43	49.98	22.9	23.3	-0.4
wet meadow? (R)	82.13	51.03	18.9	24.0	-5.1
seep/shadow? (R)	83.81	52.08	18.3	24.4	-6.1
seep? (L)	87.52	54.38	18.9	23.6	-4.7
spring? (R)	87.69	54.49	17.3	23.6	-6.3
spring? (R)	89.01	55.31	17.9	22.9	-5.0
seep? (R)	89.47	55.59	19.6	23.4	-3.8
hyporheic/riffle? (R)	92.05	57.20	22.7	23.3	-0.6
seep? (R)	92.15	57.26	22.1	23.2	-1.1
vegetation? (R)	93.79	58.28	20.4	23.4	-3.0
spring? (R)	99.07	61.56	19.3	22.8	-3.5
seep/shadow? (R)	102.10	63.44	19.3	22.7	-3.4
seep? (R)	105.00	65.25	20.5	22.3	-1.8
seep/shadow? (R)	110.15	68.44	17.9	22.3	-4.4
seep/shadow? (L)	119.46	74.23	18.9	20.8	-1.9
seep/shadow? (R)	127.26	79.08	19.7	22.4	-2.7

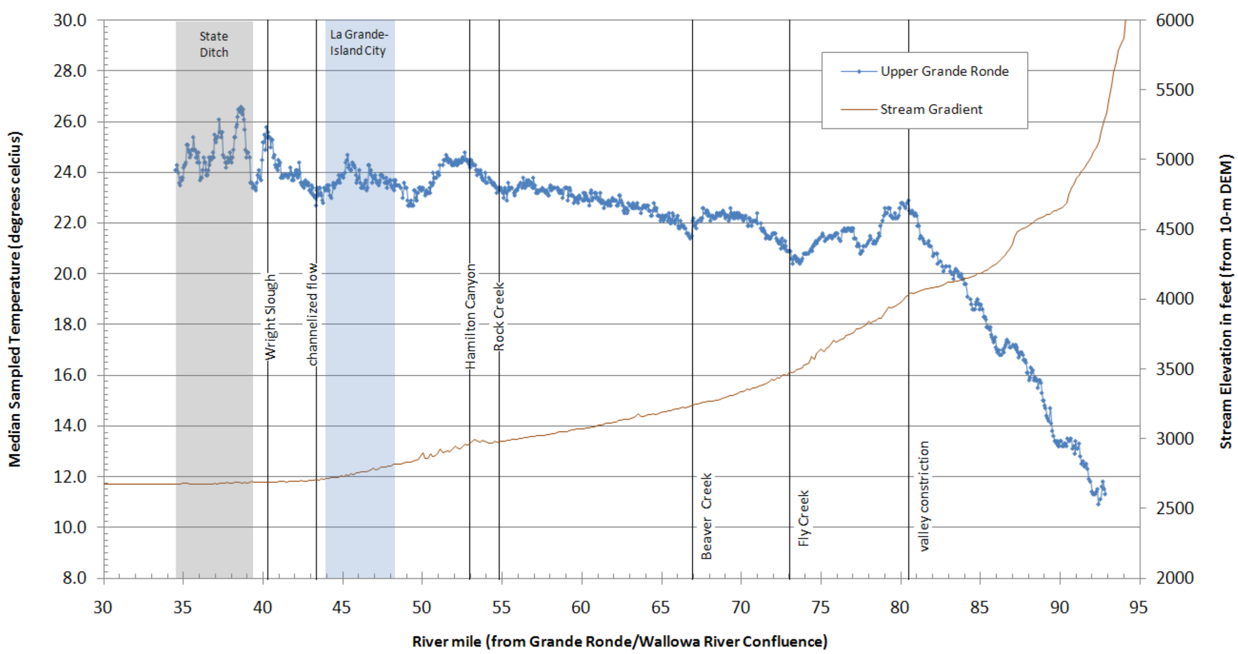
6.1.2 Observations

Approximately 60 miles of the Upper Grande Ronde River were surveyed on August 12, 2010 from the Alicel Lane Bridge (RM 34.52) following State Canal upstream to Tanner Gulch (RM 92.84). Bulk water temperatures ranged from 10.9˚C→26.6˚C, with the coolest temperatures occurring high in the drainage and the warmest temperatures seen along State Canal (*Figure 8*). Twenty-seven tributaries, 24 groundwater features (seeps, springs, and hyporheic flow), 9 ponds, 6 side channels, and 1 wet meadow were sampled in the imagery. Twenty-two other features were sampled but could not be confirmed as true hydrologic features from the available imagery. These locations should be verified in the field.

From Tanner Gulch (RM 92.84) downstream to river mile 80.51, bulk water temperatures showed a steep increase from 10.9→22.9˚C. Neither Sheep Creek (RM 82.33), Limber Jim Creek (RM 85.47), nor Clear Creek (RM 88.23) appeared to have any significant impact on the overall bulk water temperatures along this reach.

Near river mile 80.51, the Upper Grande Ronde enters a narrow canyon with steep intersecting drainages. The river stays confined downstream to river mile 73.69 and bulk water temperatures drop from 22.9→20.4˚C. This section of stream also has a slightly steeper gradient than the reaches upstream and downstream (*Figure 9*). Valley transitions, such as a narrowing of the canyon and changes in gradient typically result in increased subsurface exchange (*Figure 10*). Point source springs and seeps, such as those at river miles 77.36, 77.51, and 78.69, are evidence of groundwater influences. An unnamed tributary (RM 78.65) also contributes significantly colder water to the mainstem along this reach.

Figure 9. A comparison of stream gradient to bulk water temperatures for the Upper Grande Ronde River. Stream elevations were obtained from the 10-m digital elevation model for the area.



From Fly Creek (RM 73.05) downstream to Hamilton Canyon (52.97), bulk water temperatures gradually increase from 20.4→24.8°C. Localized cooling can be seen near the confluence with Beaver Creek and the confluence of Rock Creek.

At Hamilton Canyon, very little surface water inflow can be seen in the imagery, but the appearance of Cottonwood Spring on the Hilgard, OR 7.5-minute quadrangle map indicates that there is groundwater activity in the lower reaches of the canyon. This is likely responsible for the 2°C decrease in bulk water temperatures seen downstream of the Canyon (RM 52.97→RM 49.11)

Below river mile 49.11, the river emerges from the upper canyon, flows through La Grande and Island City and continues into the agricultural land of the Grande Ronde Valley. River temperatures show an expected warming trend through the urban areas until an unexplained 2.0°C decrease from river mile 45.31→43.33. There are several large gravel pit ponds along this reach which may be contributing to subsurface exchange with the mainstem of the river.

At river mile 43.33, the river gradient plateaus and the river becomes channelized as it flows through the State Ditch. Bulk water temperatures would be expected to increase in this type of slow, channelized flow condition, as is seen from river mile 43.33 to Wright Slough (RM 40.28). However, downstream of Wright Slough to the Alicel Lane Bridge, a good deal of variation is seen in the bulk water temperatures. This variation is likely a result of low flows and stratified flow causing differential heating in low mixing zones (*Figure 11*).

Figure 10. The LiDAR image below shows the median sampled temperatures near river mile 80.51. An inflection is seen in the temperature profile at this location indicating probable increased groundwater activity. The valley severely constricts here and the stream gradient steepens likely causing the drop in bulk water temperatures. The three unnamed tributaries shown in the image did not contribute surface water to the mainstem but may be contributing to the increased subsurface exchange.

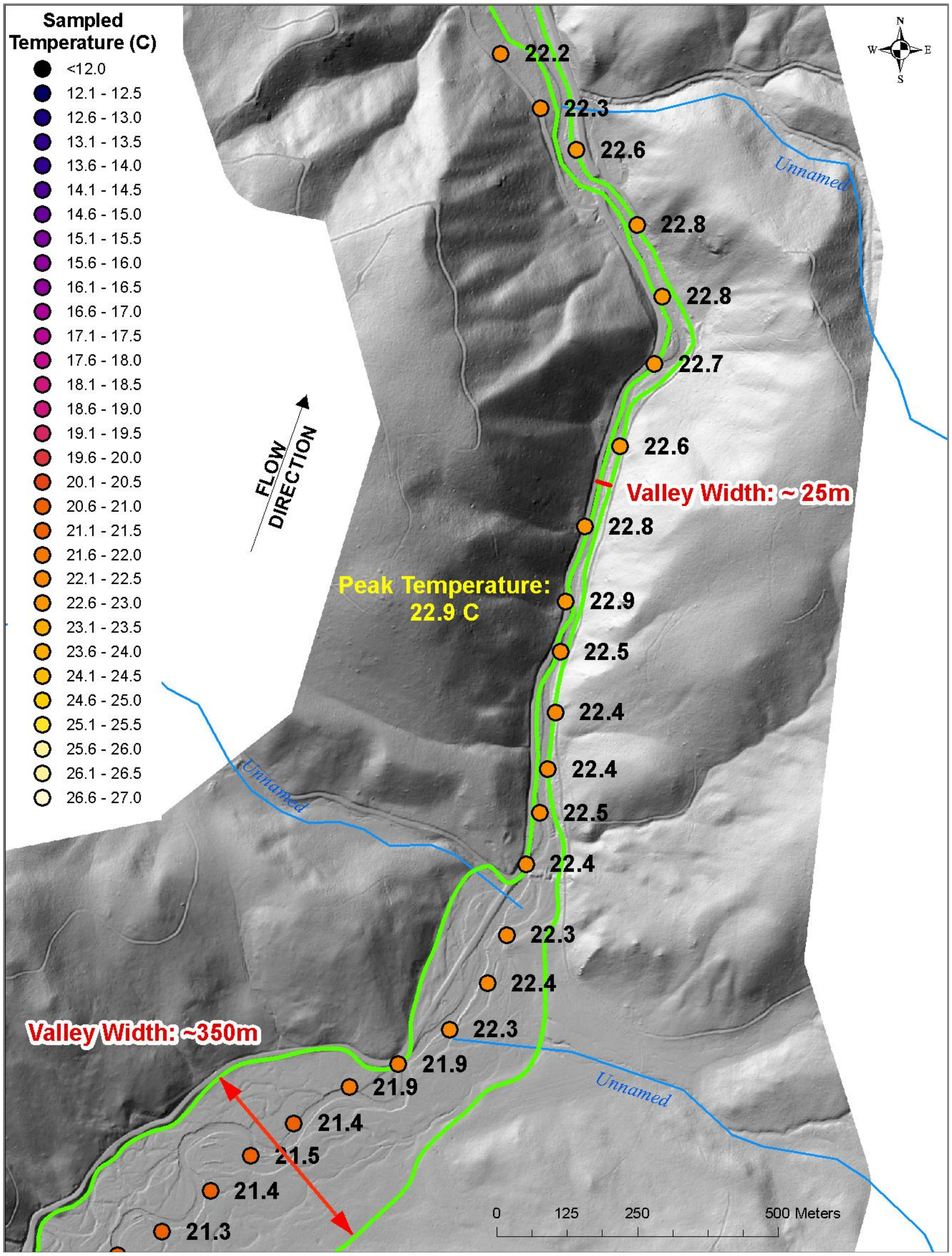
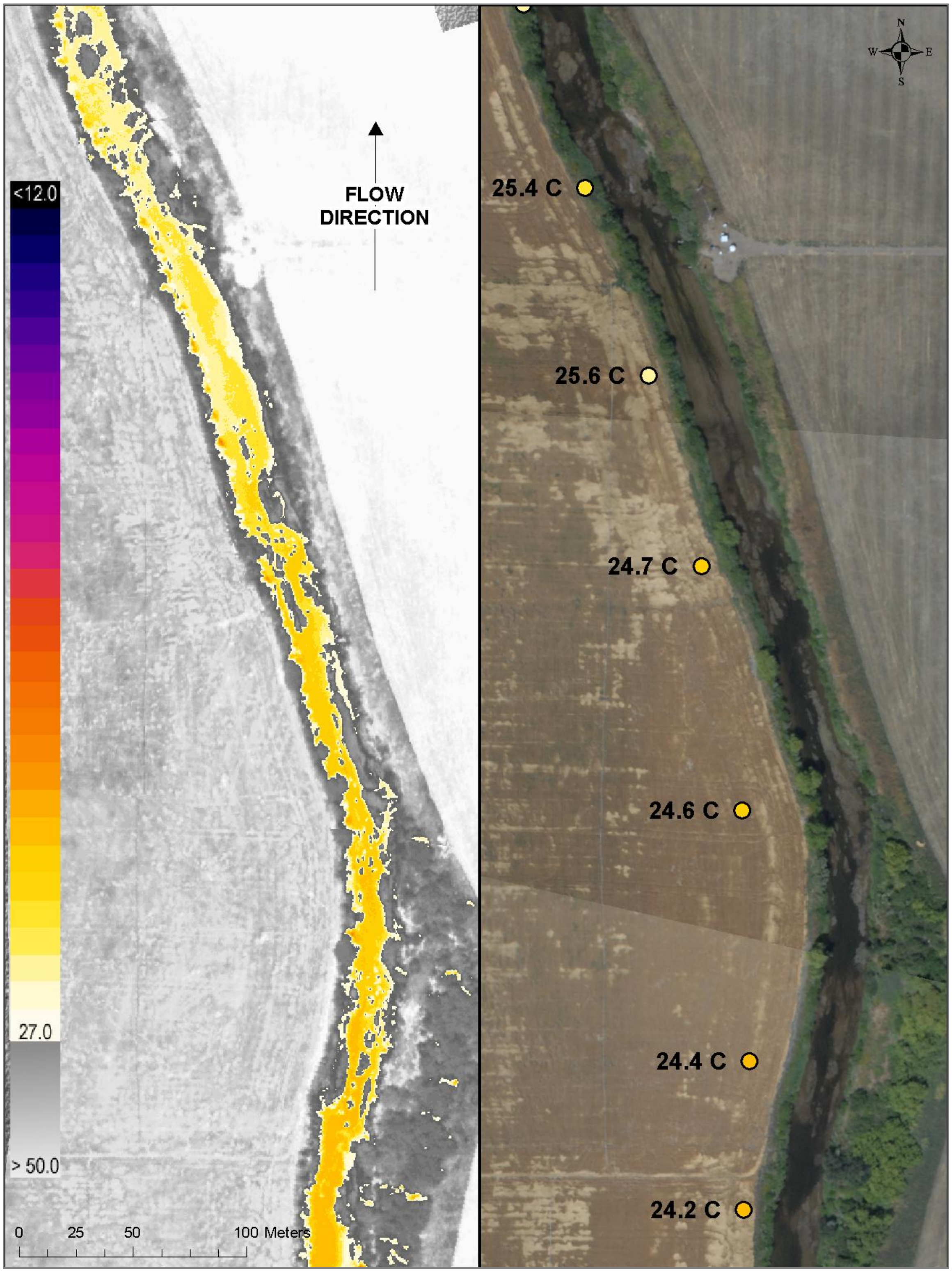
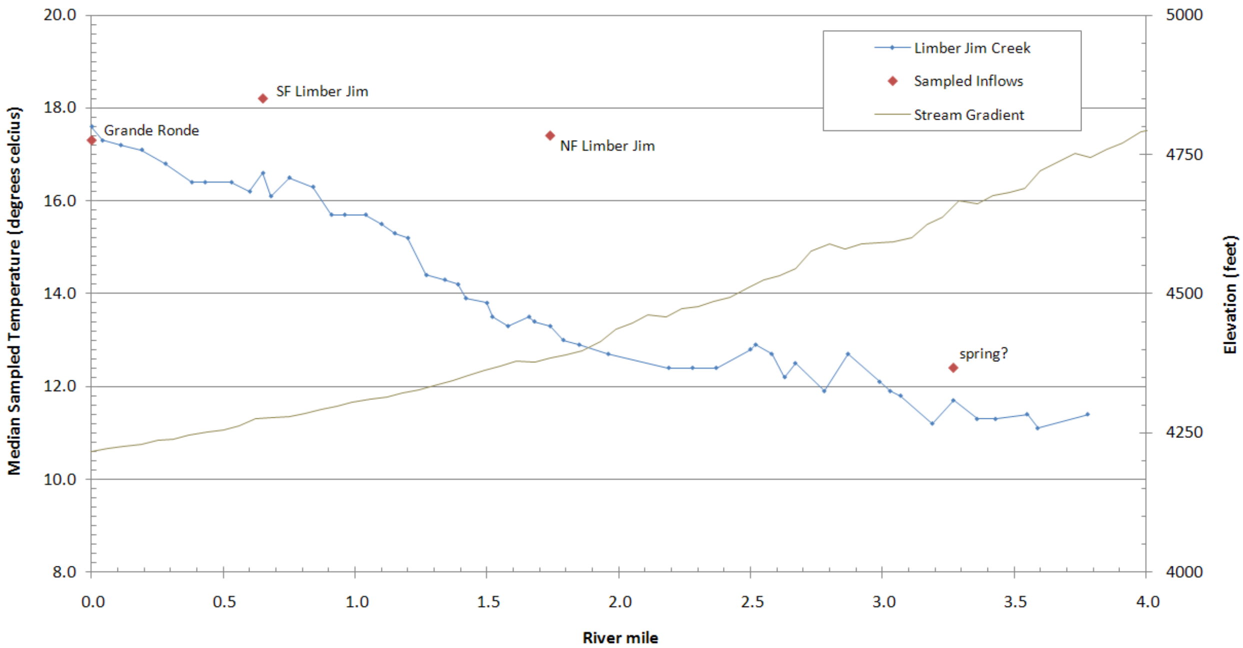


Figure 11. The TIR/natural color image pair below shows the Upper Grande Ronde River along State Ditch (RM 37.50). Along this reach of river, bulk water temperatures vary widely due to the low water conditions and possible stratified flow. The deeper pools are typically 1-2°C cooler than the shallow runs.



6.2 Limber Jim Creek

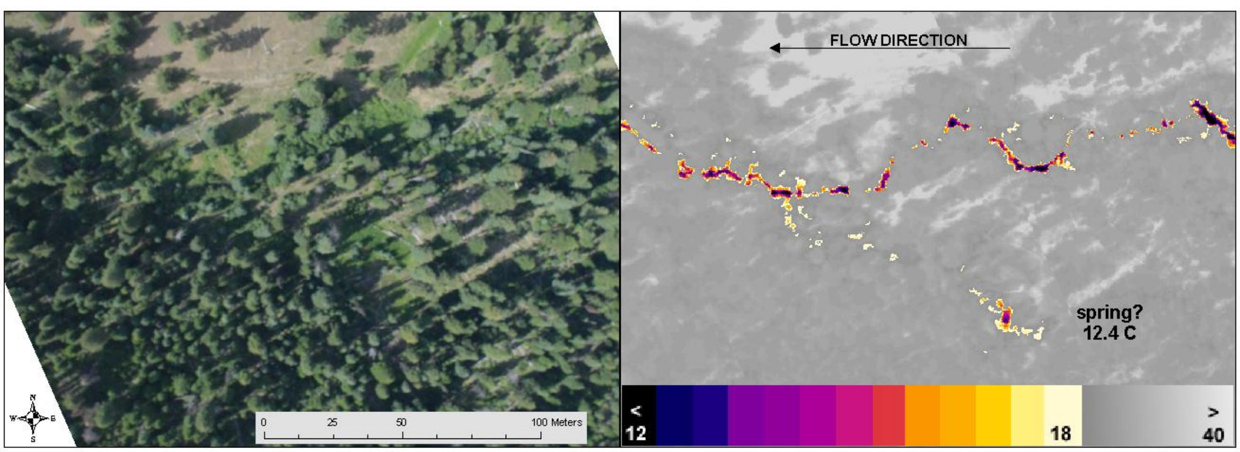
6.2.1 *Longitudinal Temperature Profile*



6.2.2 *Observations*

Just under 4 miles of Limber Jim Creek were surveyed on August 9, 2010 from the mouth upstream to Deadwood Gulch. A typical downstream warming profile was seen from 11.1°C to 17.6°C. Two tributaries, South Fork Limber Jim Creek (18.2°C) and North Fork Limber Jim Creek (17.4°C), and one possible spring at river mile 3.27 (12.4°C) (*Figure 12*) were sampled. All were too small to have a significant impact on bulk water temperatures. No obvious correlation was seen between the thermal profile and the stream gradient.

Figure 12. The natural color/TIR image pair below shows the possible spring at river mile 3.27. All three inflows to Limber Jim Creek were too small to have any impact on the bulk water temperatures.



6.3 Beaver Creek

6.3.1 Longitudinal Temperature Profile

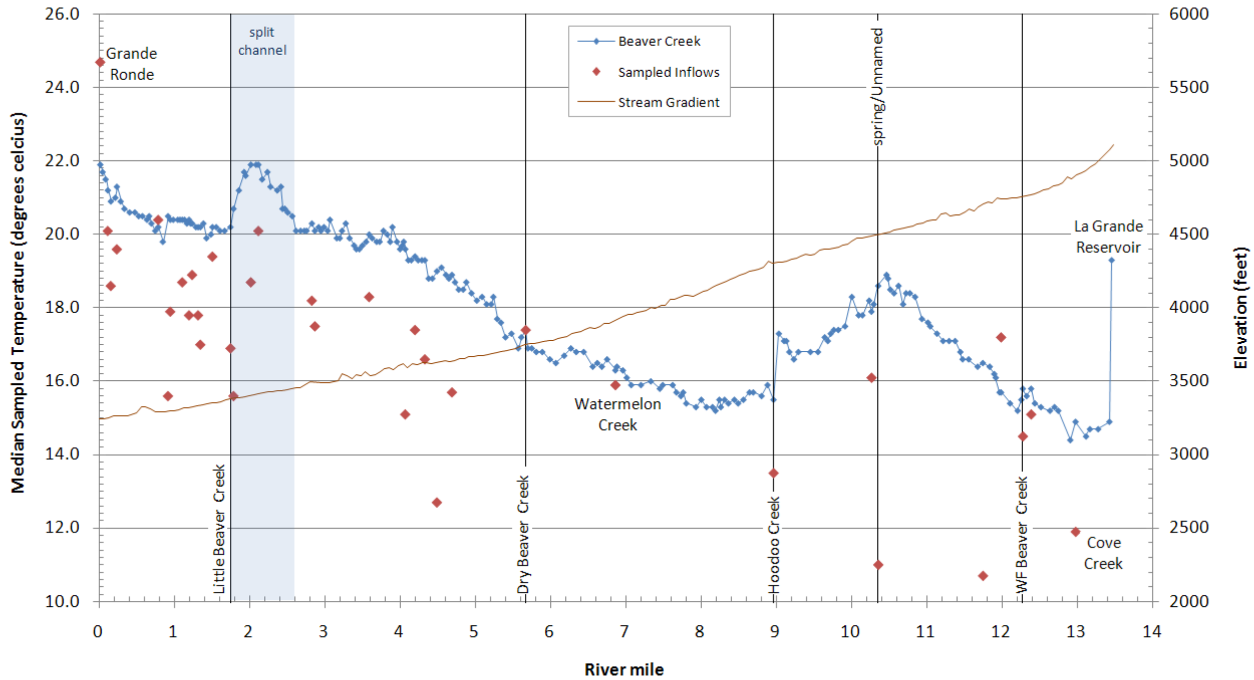


Table 7. Tributaries and other surface inflows sampled along Beaver Creek with left or right bank designation (looking downstream)

Tributaries	Kilometer	River Mile	Tributary Temp (˚C)	Mainstem Temp (˚C)	Difference
Grande Ronde R.	0.03	0.02	24.7	21.9	2.8
side channel (L)	0.19	0.12	20.1	21.2	-1.1
seep (R)	0.26	0.16	18.6	20.9	-2.3
side channel (L)	0.39	0.24	19.6	21.3	-1.7
pond (L)	1.27	0.79	20.4	20.2	0.2
spring (L)	1.48	0.92	15.6	20.5	-4.9
seep (L)	1.53	0.95	17.9	20.4	-2.5
Unnamed (L)	1.79	1.11	18.7	20.4	-1.7
seep/shadow? (L)	1.92	1.20	17.8	20.4	-2.6
hyporheic flow (L)	2.00	1.24	18.9	20.3	-1.4
seep/shadow? (L)	2.13	1.32	17.8	20.2	-2.4
Unnamed (R)	2.18	1.35	17.0	20.2	-3.2
hyporheic seep (R)	2.44	1.51	19.4	20.2	-0.8
Little Beaver (L)	2.82	1.75	16.9	20.2	-3.3
hyporheic flow (L)	2.88	1.79	15.6	20.7	-5.1
seep (R)	3.25	2.02	18.7	21.9	-3.2
seep (R)	3.42	2.12	20.1	21.9	-1.8
hyporheic seep (R)	4.56	2.83	18.2	20.3	-2.1
hyporheic flow (L)	4.62	2.87	17.5	20.1	-2.6
seep? (R)	5.78	3.59	18.3	20.0	-1.7
hyporheic seep (L)	6.55	4.07	15.1	19.6	-4.5
seep (L)	6.75	4.20	17.4	19.4	-2.0

Tributaries	Kilometer	River Mile	Tributary Temp (˚C)	Mainstem Temp (˚C)	Difference
side channel (L)	6.97	4.33	16.6	19.3	-2.7
seep (L)	7.22	4.49	12.7	19.0	-6.3
side channel (L)	7.54	4.69	15.7	18.9	-3.2
Dry Beaver Creek (L)	9.12	5.67	17.4	17.4	0.0
Watermelon Creek (L)	11.04	6.86	15.9	16.3	-0.4
Hoodoo Creek (L)	14.42	8.96	13.5	15.5	-2.0
seep (R)	16.51	10.26	16.1	17.9	-1.8
Unnamed/spring (L)	16.66	10.35	11.0	18.6	-7.6
Unnamed (R)	18.89	11.74	10.7	16.5	-5.8
side channel (R)	19.28	11.98	17.2	15.7	1.5
WF Beaver (L)	19.75	12.27	14.5	15.8	-1.3
side channel (R)	19.93	12.38	15.1	15.8	-0.7
Cove Creek (L)	20.87	12.97	11.9	14.9	-3.0

6.3.2 Observations

Beaver Creek was surveyed on August 7, 2010 from the mouth at the confluence with the Upper Grande Ronde River upstream to the La Grande reservoir. Over the 13.5 miles of the survey, bulk water temperatures ranged from 14.4˚C at the confluence of Cove Creek to 21.9˚C at the mouth. Ten tributaries, 17 seeps and springs, 6 side channels, and 1 pond were sampled in the imagery.

Water exits the La Grande Reservoir at 14.9˚C and immediately begins to warm for the three miles downstream of the dam; however, localized cooling can be seen at the confluences of Cove Creek (11.9˚C) and West Fork Beaver Creek (14.5˚C).

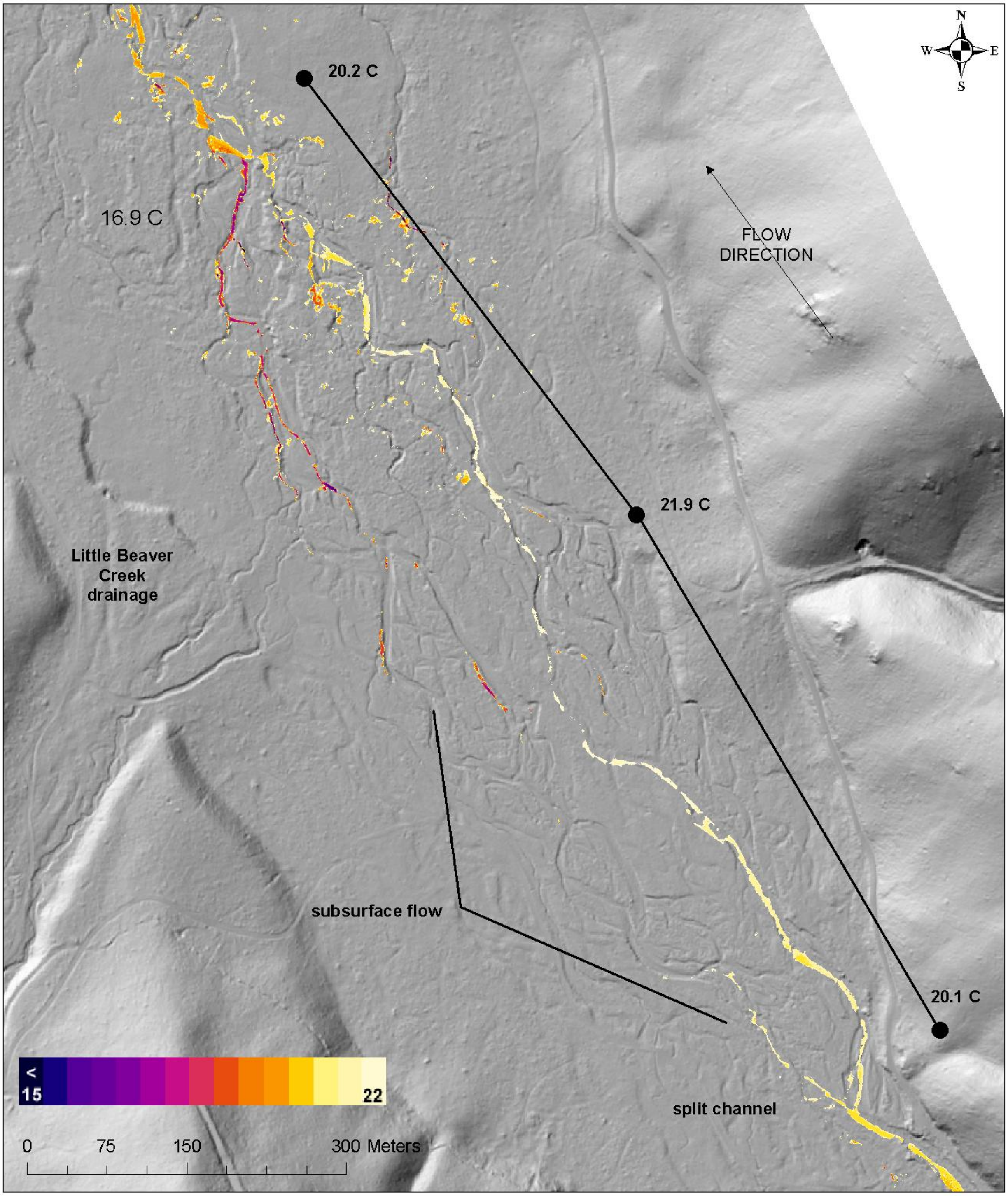
At river mile 10.35, a cold spring (11.0˚C) flowing out of an Unnamed canyon begins a cooling trend that continues downstream to river mile 8.19. Temperatures drop from 18.9˚C to 15.2˚C along this reach. Hoodoo Creek (13.5˚C) also has a further cooling impact along the reach dropping bulk water temperatures from 17.3˚C→15.5˚C.

Diurnal warming again takes control downstream of river mile 8.19 as temperatures rise from 15.2˚C to 20.2˚C over a 4-mile reach (RM 8.19→3.90). Watermelon Creek and Dry Beaver Creek do not appear have an impact on bulk water temperatures along this reach.

Below a constriction in the canyon at river mile 3.90, temperatures plateau near 20.0˚C. This plateau continues for a short distance until the stream splits into two channels at river mile 2.57. The left channel appears to go subsurface for a short distance before reemerging in the Little Beaver Creek channel at 16.9˚C. The right channel warms rapidly with lower flow. The channels rejoin at the Little Beaver Creek confluence (RM 1.75) at 20.2˚C (*Figure 13*).

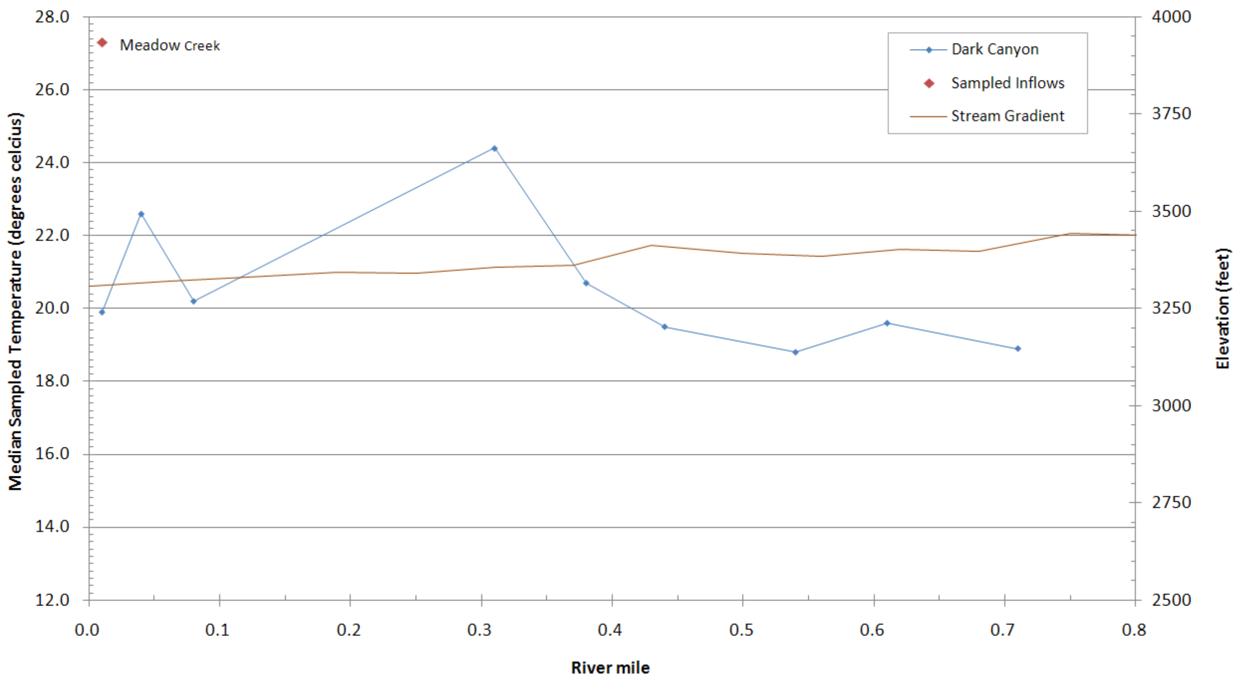
Below Little Beaver Creek, temperatures gradually warm to the profile maximum (21.9˚C) at the confluence with the Upper Grande Ronde River (24.7˚C), where Beaver Creek is a cooling influence.

Figure 13. The TIR/LiDAR image below shows the split channel between river miles 1.75-2.57. The left channel goes subsurface before reappearing at 16.9°C. The right channel warms rapidly with the decreased flows. Only the surface water temperatures are displayed in the thermal mosaic. A slight offset can be seen between the thermal imagery and the LiDAR, as the TIR images were rectified to the NAIP imagery, not the LiDAR.



6.4 Dark Canyon

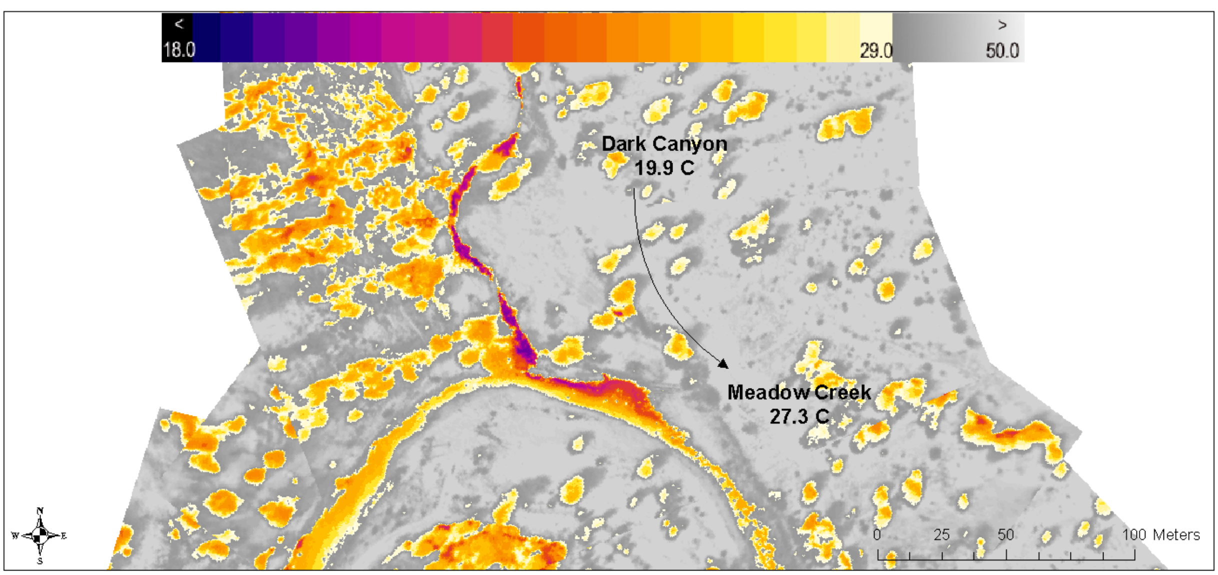
6.4.1 *Longitudinal Temperature Profile*



6.4.2 *Observations*

Less than one mile of Dark Canyon Creek was surveyed on August 7, 2010. There was little visible water for accurate sampling or trend detection. No inflows were seen along the surveyed reach. Dark Canyon acts as a cooling source to Meadow Creek (*Figure 14*).

Figure 14. The TIR image below shows the confluence of Dark Canyon and Meadow Creek. Dark Canyon is a cooling source for Meadow Creek. The TIR image is displayed with the Meadow Creek color ramp.



6.5 Five Points Creek

6.5.1 Longitudinal Temperature Profile

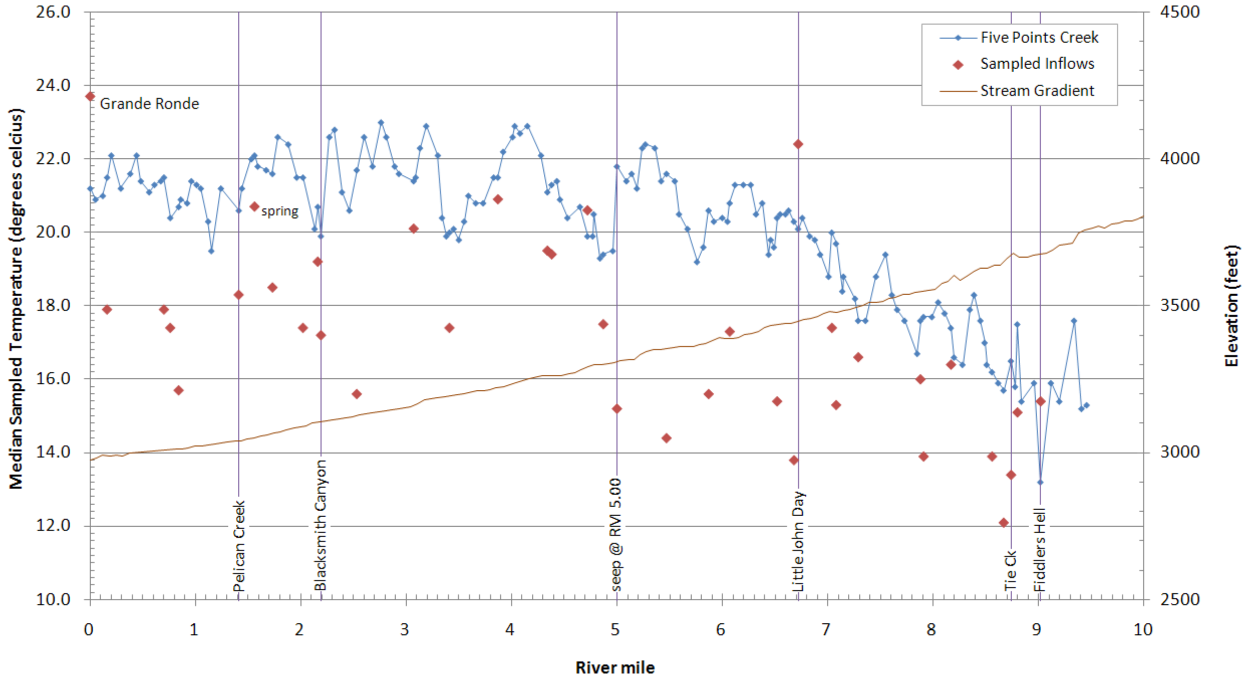


Table 8. Tributaries and other surface inflows sampled along Five Points Creek with left or right bank designation (looking downstream)

Tributaries	Kilometer	River Mile	Tributary Temp (°C)	Mainstem Temp (°C)	Difference
Grande Ronde ( )	0.00	0.00	23.7	21.2	2.5
seep (R)	0.25	0.16	17.9	21.5	-3.6
seep/shadow (R)	1.13	0.70	17.9	21.5	-3.6
seep/shadow (R)	1.22	0.76	17.4	20.4	-3.0
spring in channel (R)	1.36	0.84	15.7	20.7	-5.0
Pelican Creek (R)	2.27	1.41	18.3	20.6	-2.3
Unnamed (L)	2.51	1.56	20.7	22.1	-1.4
seep (L)	2.78	1.73	18.5	21.6	-3.1
seep/shadow (R)	3.26	2.02	17.4	21.5	-4.1
hyporheic seep (R)	3.48	2.16	19.2	20.7	-1.5
Blacksmith Canyon (L)	3.53	2.19	17.2	19.9	-2.7
seep (L)	4.06	2.53	15.6	21.7	-6.1
seep (L)	4.94	3.07	20.1	21.4	-1.3
seep (L)	5.48	3.41	17.4	20.0	-2.6
seep (L)	6.22	3.87	20.9	21.5	-0.6
seep (L)	6.98	4.34	19.5	21.1	-1.6
Unnamed (L)	7.05	4.38	19.4	21.3	-1.9
side channel (L)	7.59	4.72	20.6	19.9	0.7
seep/shadow (L)	7.84	4.87	17.5	19.4	-1.9
seep (L)	8.05	5.00	15.2	21.8	-6.6
Unnamed (L)	8.81	5.47	14.4	21.6	-7.2
side channel (L)	9.44	5.87	15.6	20.6	-5.0
seep (L)	9.77	6.07	17.3	20.8	-3.5

Tributaries	Kilometer	River Mile	Tributary Temp (˚C)	Mainstem Temp (˚C)	Difference
seeps (L)	10.50	6.52	15.4	20.4	-5.0
side channel (L)	10.75	6.68	13.8	20.3	-6.5
side channel (R)	10.82	6.72	22.4	20.1	2.3
side channel (R)	11.33	7.04	17.4	20.0	-2.6
side channel (L)	11.39	7.08	15.3	19.7	-4.4
hyporheic seep (L)	11.73	7.29	16.6	17.6	-1.0
side channel (L)	12.68	7.88	16.0	17.6	-1.6
side channel (L)	12.73	7.91	13.9	17.7	-3.8
hyporheic seep (L)	13.14	8.17	16.4	17.4	-1.0
seep (L)	13.77	8.56	13.9	16.2	-2.3
spring (L)	13.95	8.67	12.1	15.7	-3.6
Tie Creek (L)	14.07	8.74	13.4	16.5	-3.1
spring/side channel (R)	14.17	8.80	15.1	17.5	-2.4
Fiddlers Hell (L)	14.51	9.02	15.4	13.2	2.2

6.5.2 Observations

Five Points Creek was surveyed on August 7, 2010 from the mouth at Hilgard Junction for 9.5 miles upstream to just beyond Fiddlers Hell Creek. Bulk water temperatures ranged from 13.2˚C at Fiddlers Hell to 23.0˚C at river mile 2.76. Seven tributaries, 8 side channels, and 21 seeps and springs were sampled in the imagery.

The longitudinal profile was highly variable due to numerous groundwater contributions seen throughout the survey which result in strong localized cooling troughs. However, the overall shape indicates a typical pattern of warming in the upper 5.5 miles followed by a plateau between 20.0˚C and 22.0˚C. The stream is shallow and rocky throughout its length and the strong groundwater returns indicate a gaining/losing stream system with a shallow water table.

Notable cooling sources include Fiddlers Hell (15.4˚C), the seep at river mile 5.00 (15.2˚C), Blacksmith Canyon (17.2˚C) and the spring at river mile 0.84 (15.7˚C). Five Points Creek (21.2˚C) was a cooling source to the Upper Grande Ronde River (23.7˚C).

6.6 McCoy Creek

6.6.1 Longitudinal Temperature Profile

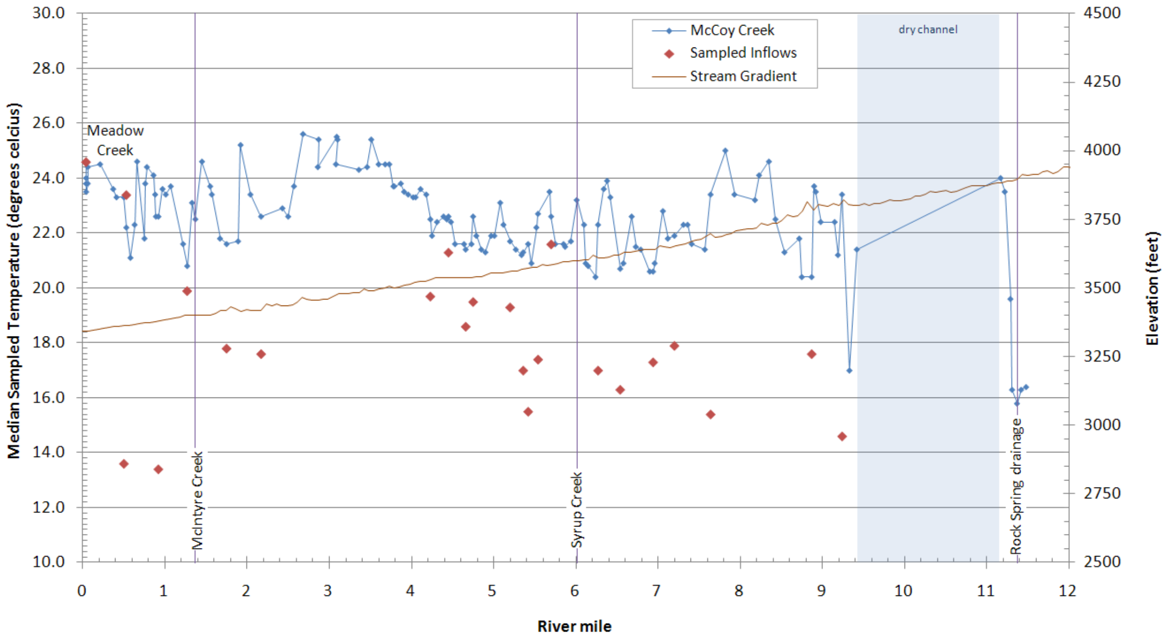


Table 9. Tributaries and other surface inflows sampled along McCoy Creek with left or right bank designation (looking downstream)

Tributaries	Kilometer	River Mile	Tributary Temp (˚C)	Mainstem Temp (˚C)	Difference
Meadow Creek ( )	0.07	0.04	24.6	24.6	0.0
spring in pond (L)	0.81	0.50	13.6	23.3	-9.7
old channel (L)	0.85	0.53	23.4	22.2	1.2
spring off channel (L)	1.48	0.92	13.4	22.6	-9.2
pond (R)	2.04	1.27	19.9	20.8	-0.9
seep/shadow? (R)	2.82	1.75	17.8	21.6	-3.8
spring? (R)	3.49	2.17	17.6	22.6	-5.0
seep? (R)	6.80	4.23	19.7	22.5	-2.8
Unnamed (R)	7.17	4.45	21.3	22.6	-1.3
seep (R)	7.50	4.66	18.6	21.4	-2.8
seep? (R)	7.64	4.75	19.5	22.6	-3.1
seep/side channel (R)	8.36	5.20	19.3	21.7	-2.4
spring (L)	8.63	5.36	17.0	21.3	-4.3
spring (L)	8.72	5.42	15.5	21.6	-6.1
hyporheic flow (L)	8.91	5.54	17.4	22.7	-5.3
seep/shadow (R)	9.18	5.70	21.6	22.6	-1.0
spring? (R)	10.09	6.27	17.0	22.3	-5.3
spring? (R)	10.53	6.54	16.3	20.7	-4.4
seep/shadow (L)	11.16	6.94	17.3	20.6	-3.3
seep/shadow (R)	11.59	7.20	17.9	21.9	-4.0
Unnamed (L)	12.29	7.64	15.4	23.4	-8.0
spring? (R)	14.27	8.87	17.6	20.4	-2.8
spring/shadow (R)	14.87	9.24	14.6	23.4	-8.8

6.6.2 Observations

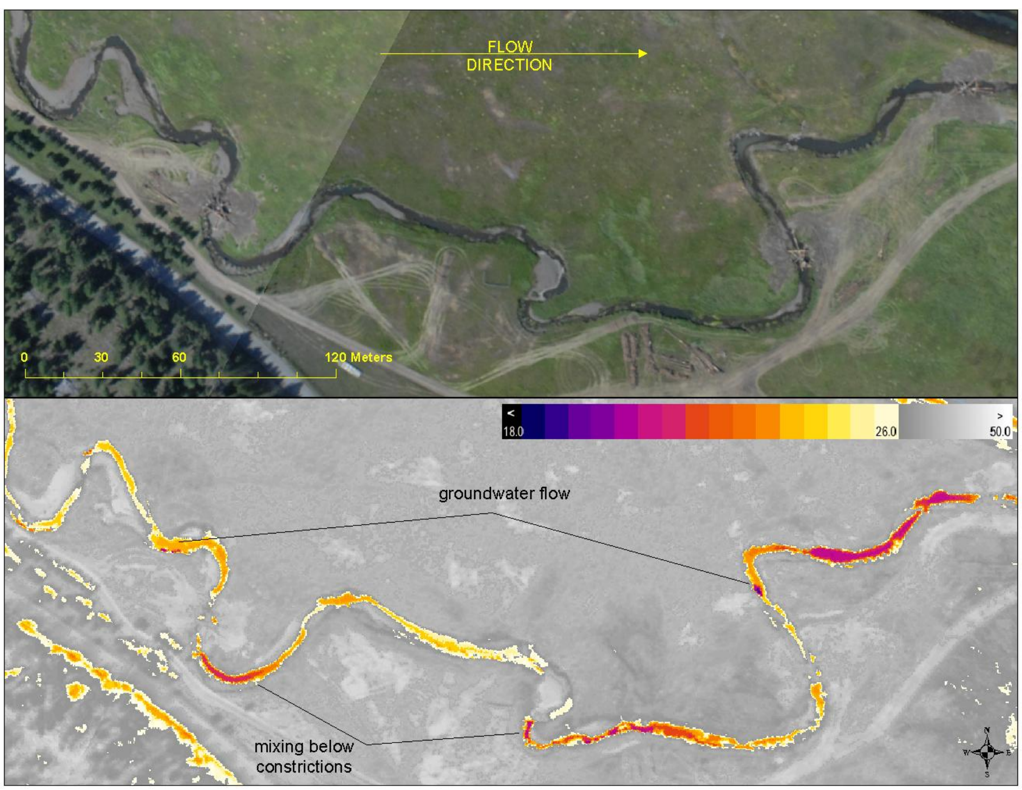
McCoy Creek was surveyed on August 7, 2010 from Meadow Creek upstream to the Rock Spring drainage (RM 11.37). Two unnamed tributaries, 18 seeps and springs, and two pond features were sampled in the imagery.

The minimum survey temperature occurred at the confluence with the Rock Spring drainage (15.8°C). Immediately following, the stream channel went dry between river miles 9.42-11.16. The stream re-emerges at river mile 9.42 at 21.4°C. Temperatures are highly variable until river mile 4.66, but center around 22.0°C. There were many cold features sampled along the reach, but due to heavy shadows, many could not be confirmed as certain groundwater inflows.

Downstream of river mile 4.66, a warming trend is seen for almost two miles with temperatures rising from 21.4°C→25.6°C. Temperatures peaked at river mile 2.68 in a very narrow section of canyon.

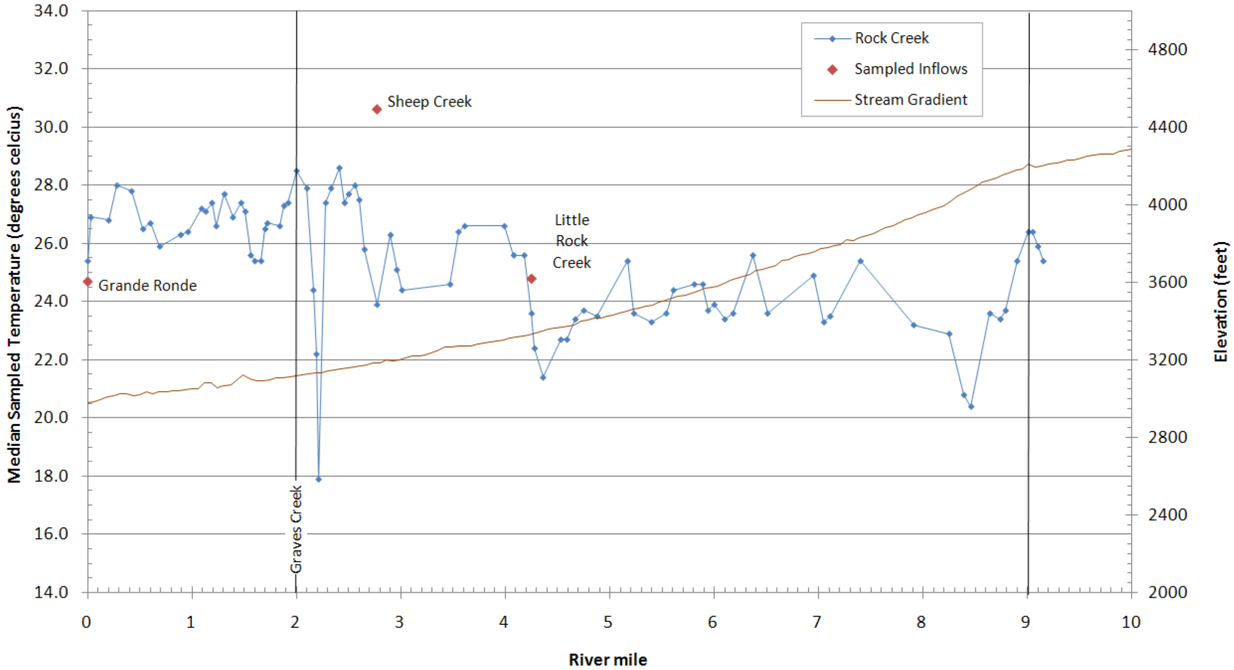
Below river mile 2.68, the canyon opens into a wide valley where a major channel restoration effort is underway. Along this reach, the TIR imagery shows a high degree of localized spatial variability in stream surface temperatures. The imagery suggests that there areas of shallow sub-surface upwelling particularly around woody debris check dams and below channel constrictions. The imagery also suggests that there might be some degree of surface stratification between these mixing zones (*Figure 15*).

Figure 15. The TIR/natural color image pair below shows the spatial variability in surface temperatures through the restoration area of the lower meadow of McCoy Creek.



6.7 Rock Creek

6.7.1 Longitudinal Temperature Profile



6.7.2 Observations

Rock Creek was surveyed on August 7, 2010 from the Upper Grande Ronde River 9 miles upstream to an unnamed bridge. Two tributaries were sampled: Sheep Creek at river mile 2.77 (30.6˚C) and Little Rock Creek (RM 4.25, 24.8˚C). The stream was very shallow and rocky throughout the surveyed area, which leads to increased variability due to mixed pixel sampling. Heavy shadows also obscured the stream in areas, making sampling and interpretation of the imagery less certain.

At the upstream end of the survey, temperatures immediately begin to cool as the stream exits an open meadow area and flows into a narrow forested canyon. Temperatures drop from 26.4˚C→20.4˚C over a 1/2 -mile reach (RM 8.95→8.46). Downstream of this point, the canyon widens slightly and temperatures rebound and plateau (with a good deal of variability) to near 24.0˚C.

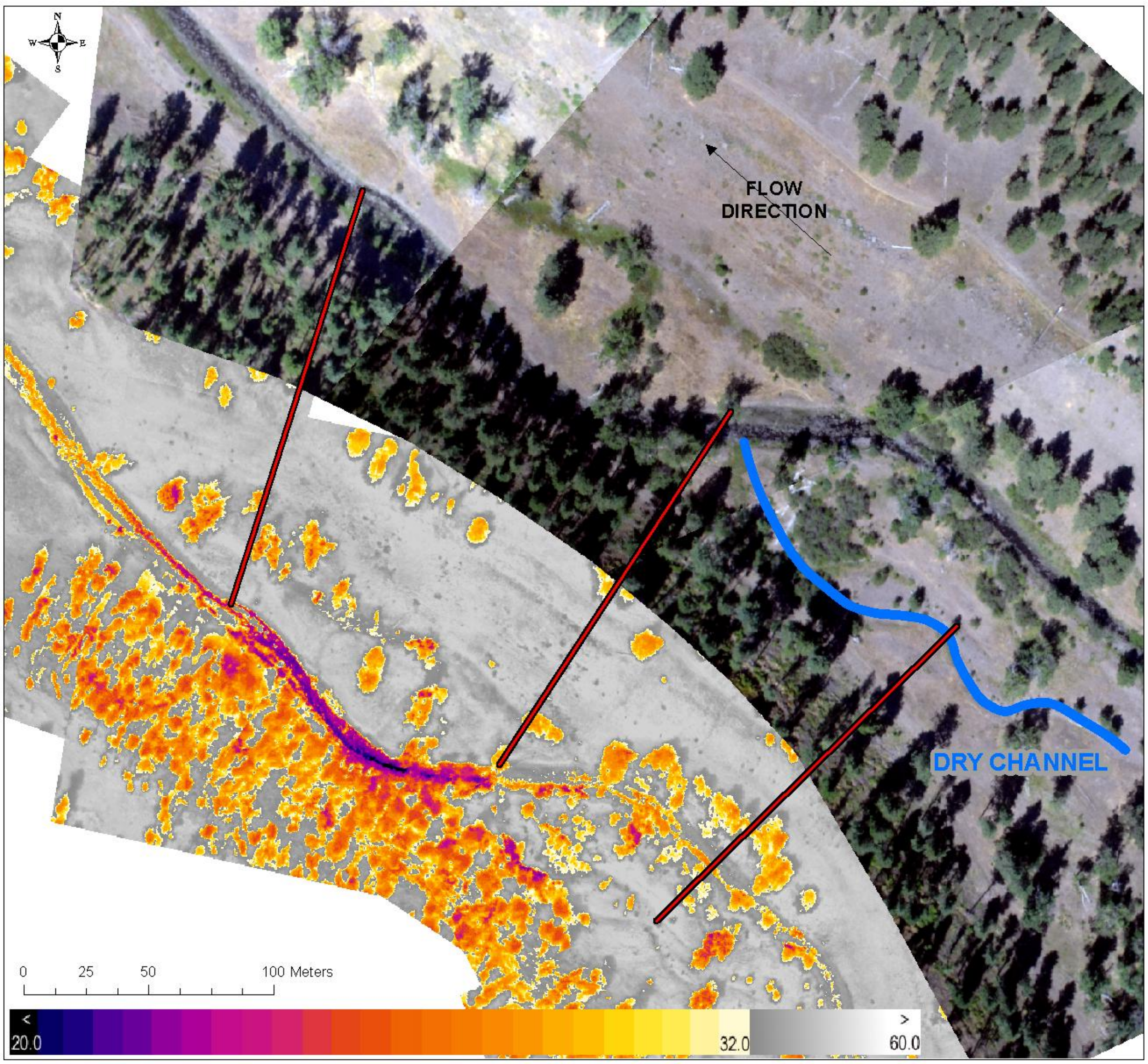
Just upstream of Little Rock Creek, temperatures again drop sharply from 25.4˚C→21.4˚C in less than one mile (RM 5.17→4.36). There is no apparent change in the canyon characteristics or vegetation regime along this reach, but the temperature decrease suggests increased groundwater interaction.

Temperatures warm rapidly from river mile 4.36→3.99 as Rock Creek merges with Little Rock Creek, though Little Rock Creek contains no water upstream of the immediate confluence. Sheep Creek (30.6˚C) is a warming influence raising bulk water temperatures by over 4.0˚C (23.9˚C→28.0˚C).

A third cooling spike occurs downstream of river mile 2.41 with sudden appearance of cooler water in the channel (28.6°C→17.9°C). A similar thermal signature is seen when streams go subsurface for a distance and re-emerge after mixing with a shallow groundwater table, as seen at the Beaver Creek/Little Beaver Creek confluence. In this case, the main channel does not dewater; however there is a dry side channel immediately upstream which is possibly providing a subsurface flow route allowing for hyporheic interaction (*Figure 16*).

Though not contributing surface water to the system, the Graves Creek drainage (RM 2.00) is likely a contributing factor to the cooling seen below river mile 2.00 (28.5°C→25.4°C). The lower 1 mile of stream shows temperatures fluctuating near 27.0°C, with Rock Creek acting as a warming source to the Upper Grande Ronde (24.7°C) at the confluence.

Figure 16. The TIR/natural color image pair below shows the groundwater feature at river mile 2.41. The natural color image is unscaled.



6.8 Spring Creek

6.8.1 Longitudinal Temperature Profile

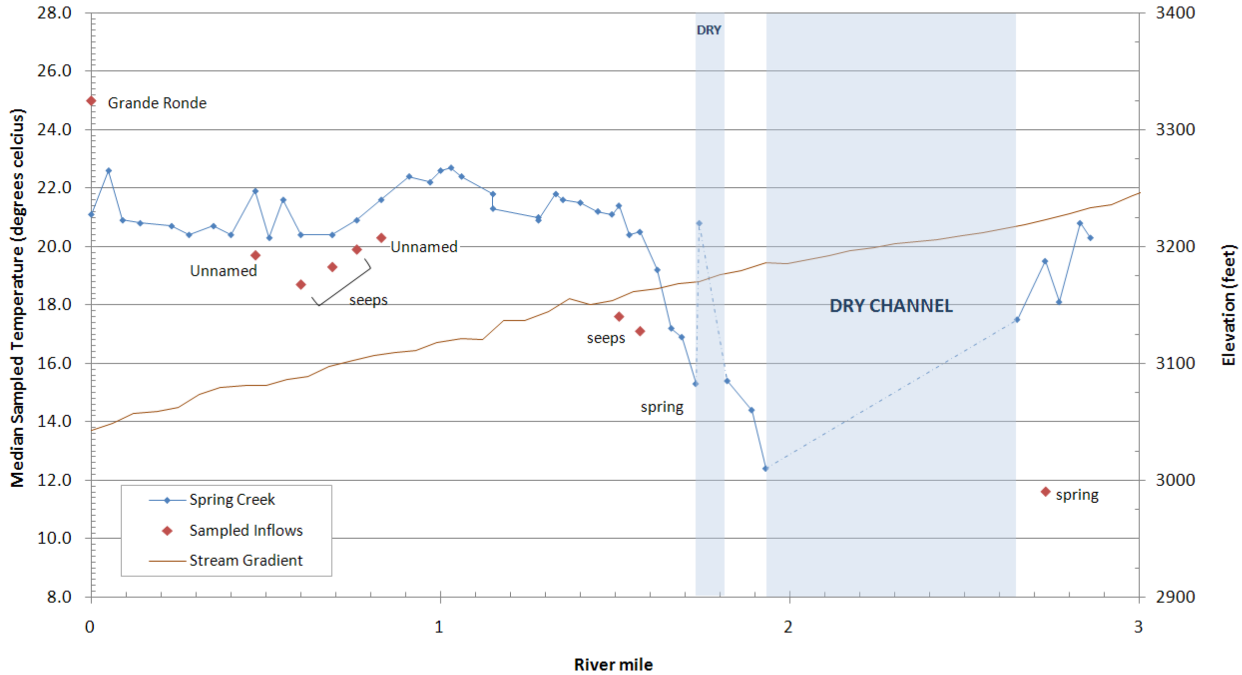


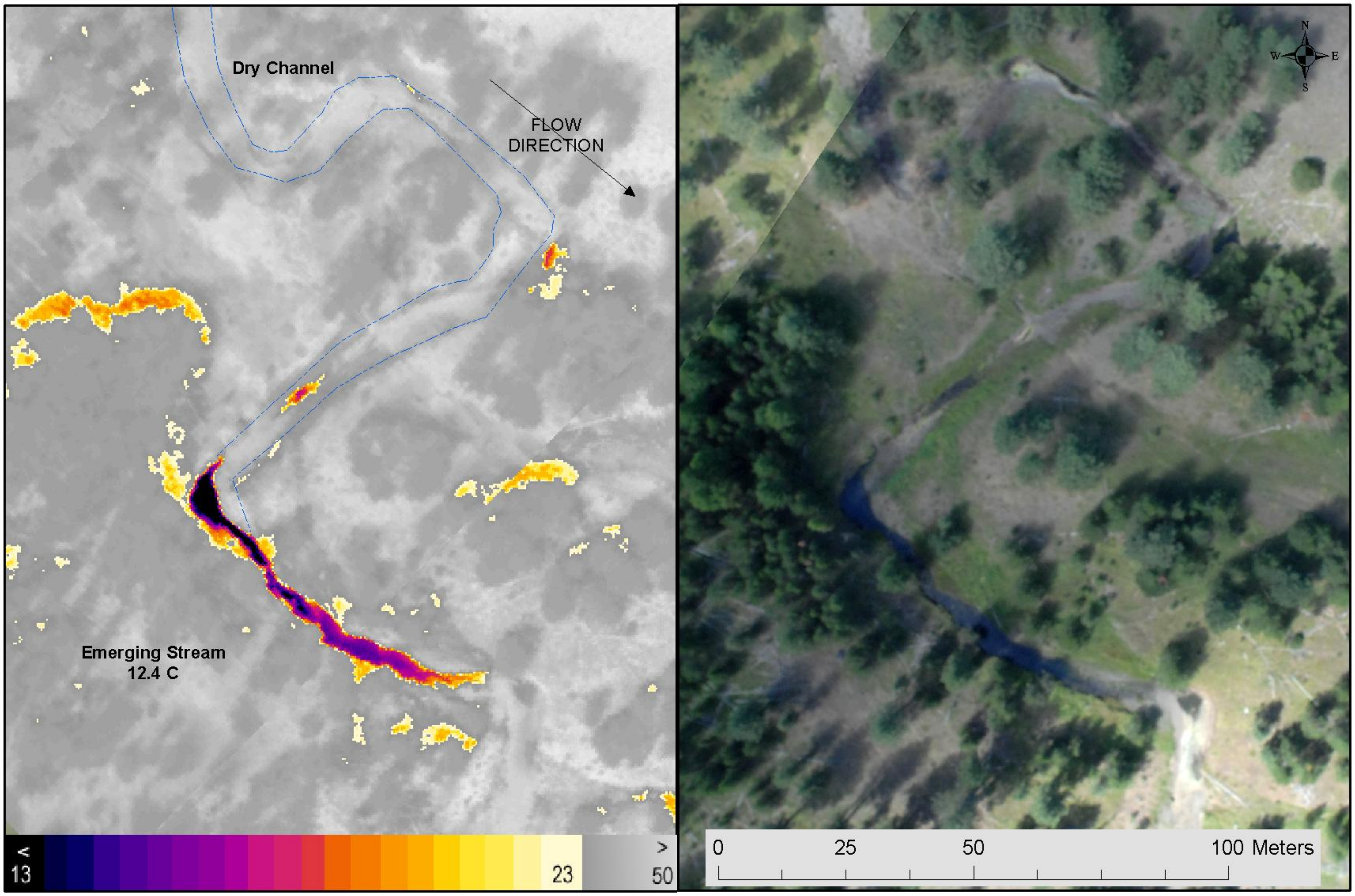
Table 10. Tributaries and other surface inflows sampled along Spring Creek with left or right bank designation (looking downstream)

Tributaries	Kilometer	River Mile	Tributary Temp (°C)	Mainstem Temp (°C)	Difference
Grande Ronde R. ( )	0.00	0.00	25.0	21.1	3.9
Unnamed? (R)	0.75	0.47	19.7	21.9	-2.2
seep/side channel (R)	0.97	0.60	18.7	20.4	-1.7
seep (R)	1.10	0.69	19.3	20.4	-1.1
seep/shadow? (R)	1.22	0.76	19.9	20.9	-1.0
Unnamed/shadow? (R)	1.34	0.83	20.3	21.6	-1.3
seep (R)	2.43	1.51	17.6	21.4	-3.8
seeps (R)	2.53	1.57	17.1	20.5	-3.4
spring (R)	4.39	2.73	11.6	19.5	-7.9

6.8.2 Observations

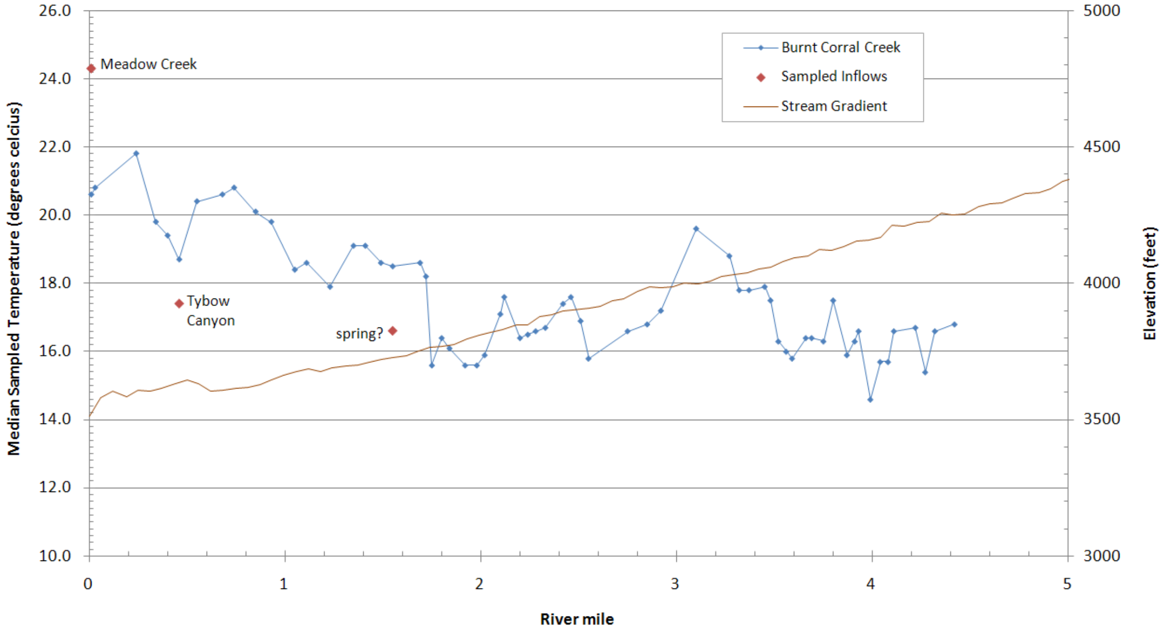
Three miles of Spring Creek were surveyed on August 7, 2010. The upper reach of the survey shows temperatures between 17.5°C and 20.8°C before the stream goes subsurface at river mile 2.65. At river mile 1.93, the stream emerges with the signature of a spring at 12.1°C (*Figure 17*). This gaining/losing stream pattern continues downstream to river mile 1.73. Below river mile 1.73, flows stabilize and warm until river mile 1.51. Downstream of river mile 1.51, the stream enters a narrower section of canyon and temperatures begin to plateau near 22.0°C with further cooling seen below river mile 0.91.

Figure 17. The TIR/Natural Color image pair below shows the emerging stream at river mile 1.93. When stream flows go subsurface, mix with the hyporheic or shallow groundwater zone and re-emerge, the resulting thermal return is similar to a spring.



6.9 Burnt Corral Creek

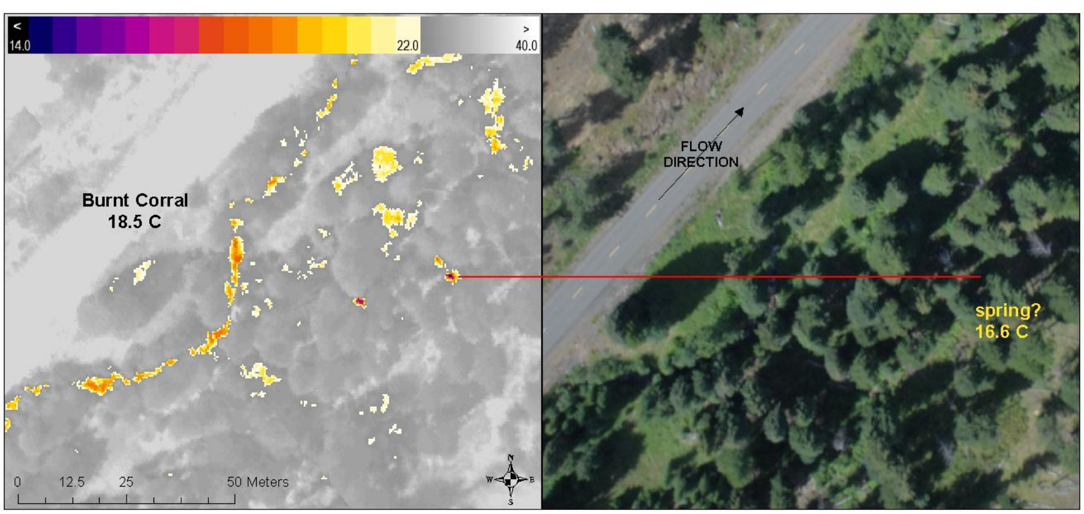
6.9.1 Longitudinal Temperature Profile



6.9.2 Observations

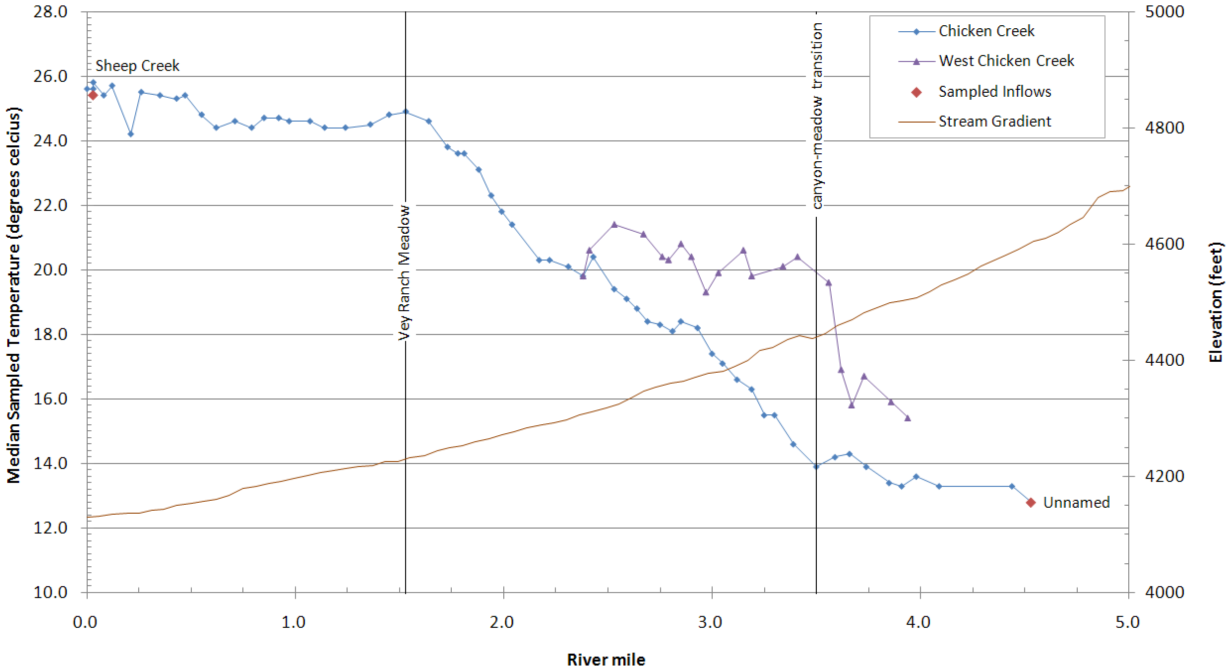
Approximately 4.5 miles of Burnt Corral Creek were surveyed on August 8, 2010 from the mouth upstream to East Burnt Corral Creek. The creek was very narrow with heavy streamside vegetation making sampling difficult. The visible pools that could be sampled resulted in a highly variable longitudinal profile. Only two inflows were sampled: Tybow Canyon (17.4°C) and a possible spring at river mile 1.55 (16.6°C) (*Figure 18*). It is difficult to interpret any thermal trends due to the variability seen in the profile.

Figure 18. The TIR/natural color image pair below shows the potential small spring at river mile 1.55. Even with high resolution color imagery, it was difficult to discern features in such a narrow, heavily vegetated stream.



6.10 Chicken Creek/West Chicken Creek

6.10.1 Longitudinal Temperature Profile



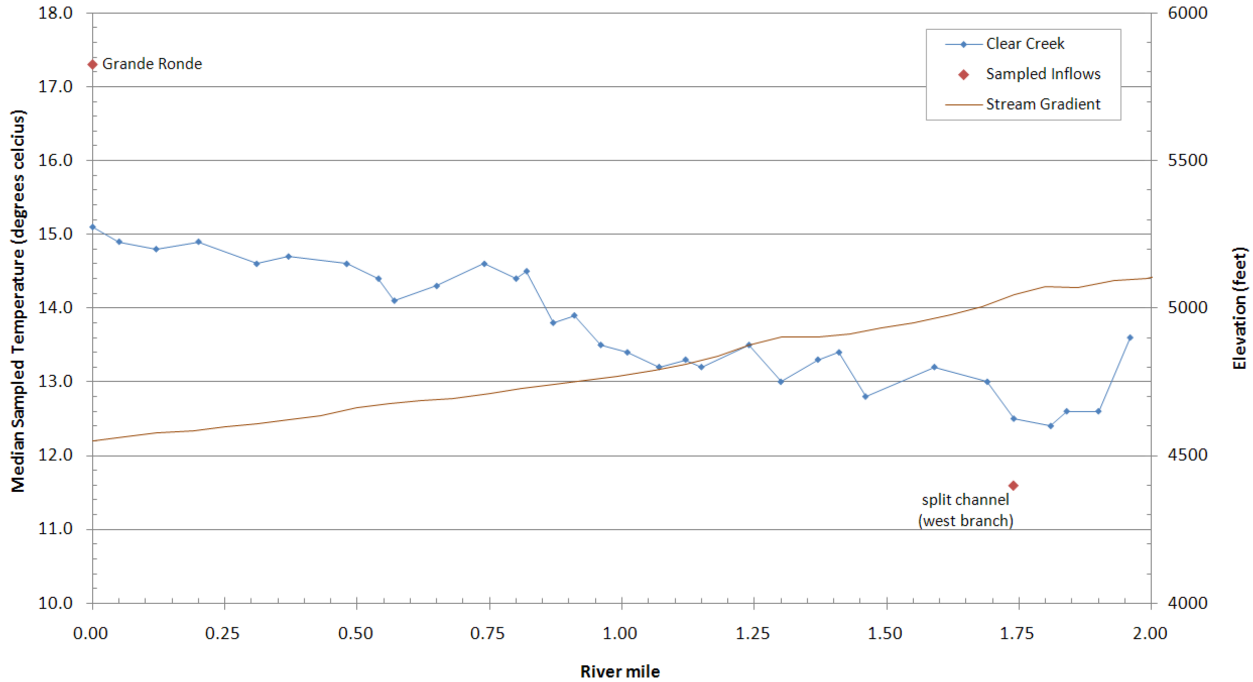
6.10.2 Observations

Just under five miles of Chicken Creek and 1.5 miles of West Chicken Creek were surveyed on August 8, 2010. One unnamed inflow (12.8˚C) was sampled to Chicken Creek at the head of the survey. Chicken Creek shows subsurface influences above river mile 3.50 with temperatures staying depressed between 12.8˚C and 14.3˚C. Downstream of river mile 3.50, the canyon widens slightly and the creek enters a more open meadow regime. Temperatures warm rapidly for 2 miles to river mile 1.53 (14.0˚C→24.9˚C). As Chicken Creek enters the broad Vey Ranch meadow, temperatures again stabilize near 25.0˚C as there is likely groundwater interaction between Sheep Creek, Dry Creek, and Chicken Creek.

West Chicken Creek sampled warmer than Chicken Creek, though the narrowness of the creek and the short distance of the survey preclude drawing any significant conclusions from the longitudinal profile.

6.11 Clear Creek

6.11.1 Longitudinal Temperature Profile



6.11.2 Observations

Two miles of Clear Creek were sampled on August 8, 2010. Temperatures ranged from 12.4˚C→15.1˚C. The divided channel seen at the upper end of the survey was the only sampled feature (11.6˚C). The meadow at that location was likely created by water pooling upstream of the landslide seen in the LiDAR imagery (*Figure 19*). Further investigation of aerial photos would be needed to determine the age of the landslide.

Figure 19. The bare-earth LiDAR/NAIP/TIR image below shows the landslide and meadow complex at river mile 1.74.

6.12 Fly Creek

6.12.1 Longitudinal Temperature Profile

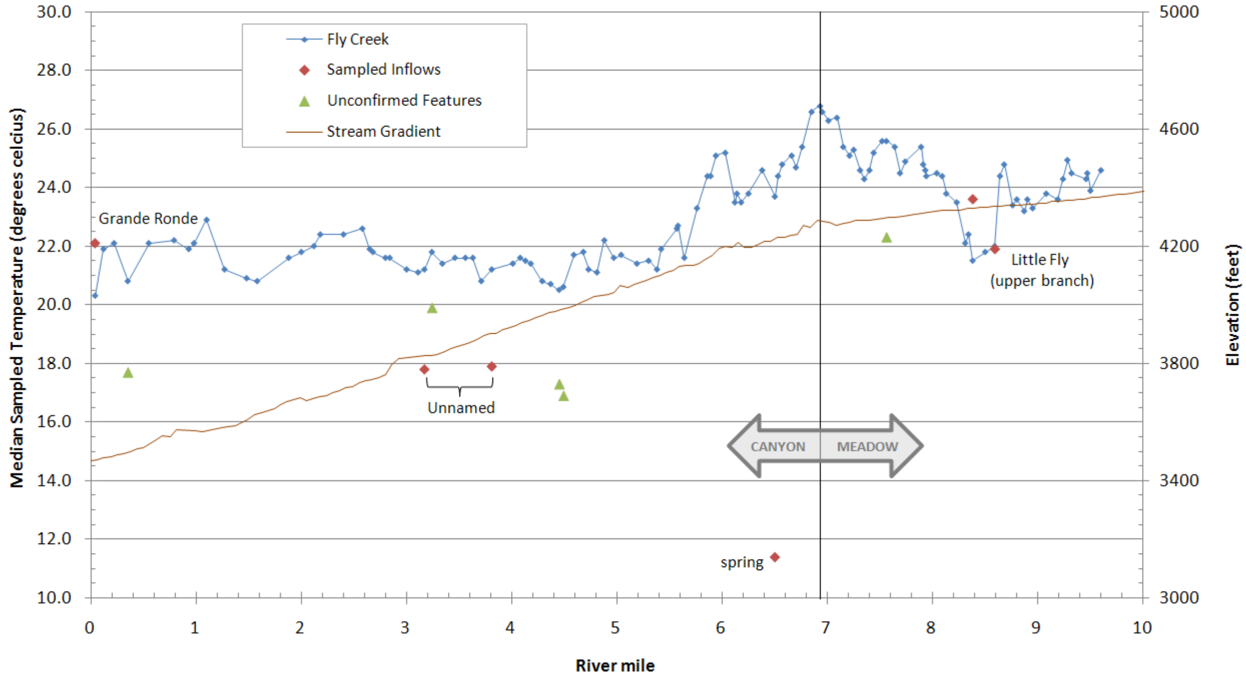


Table 11. Tributaries and other surface inflows sampled along Fly Creek with left or right bank designation (looking downstream)

Tributaries	Kilometer	River Mile	Tributary Temp (˚C)	Mainstem Temp (˚C)	Difference
Grande Ronde ( )	0.06	0.04	22.1	20.3	1.8
Unnamed (R)	5.10	3.17	17.8	21.2	-3.4
Unnamed (L)	6.13	3.81	17.9	21.2	-3.3
spring (L)	10.45	6.50	11.4	23.7	-12.3
Little Fly Ck-lower (R)	13.48	8.38	23.6	21.5	2.1
Little Fly Ck-upper (R)	13.83	8.59	21.9	22.0	-0.1
Unconfirmed Features					
Tributaries	**Kilometer**	**River Mile**	**Tributary Temp (˚C)**	**Mainstem Temp (˚C)**	**Difference**
seep? (R)	0.56	0.35	17.7	20.8	-3.1
seep? (L)	5.22	3.24	19.9	21.8	-1.9
seep? (R)	7.16	4.45	17.3	20.5	-3.2
spring? (R)	7.22	4.49	16.9	20.6	-3.7
seep? (L)	12.17	7.56	22.3	25.6	-3.3

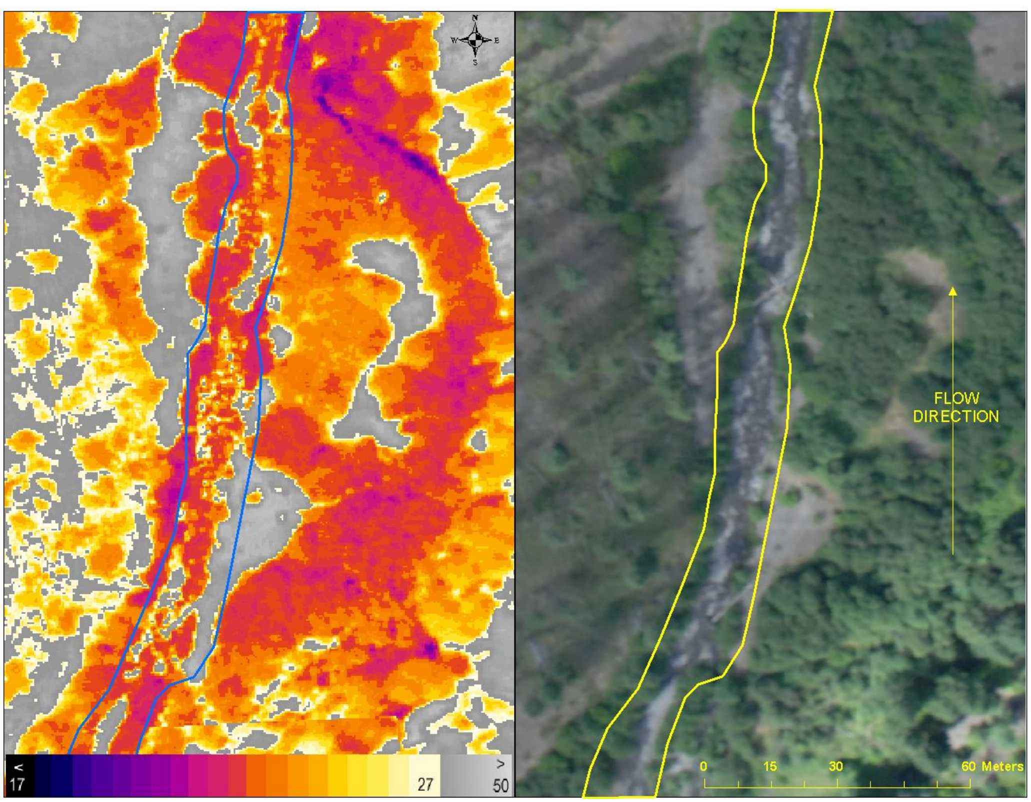
6.12.2 Observations

Approximately ten miles of Fly Creek were surveyed on August 8, 2010 from the mouth at the Grande Ronde River upstream to Fly Valley. The thermal imagery was difficult to sample given that the stream was very shallow in the lower reaches with many visible rocks which leads to mixed pixel sampling and increased variability. In addition, the vegetation had radiant temperatures which were colder than the stream temperature making it difficult to distinguish springs and seeps (*Figure 20*). The cooler temperatures from the vegetation were characteristic of rapid terrestrial cooling due to cloud cover. Five definite inflows were sampled as well as 5 features that could not be confirmed with the available imagery.

The longitudinal profile was interesting in that the stream cools as it flows downstream. From river mile 9.60 downstream to 6.93, the stream flows through Fly Valley, a heavily grazed open meadow with no streamside vegetation. Temperatures sampled near 24.0°C until the confluence with Little Fly Creek, which was a cooling source that lowered temperatures from 24.4°C→21.6°C. Downstream of Little Fly Creek, bulk water temperatures warmed to the survey maximum of 26.8°C at river mile 6.93.

At river mile 6.93, the canyon constricts severely, steepens, and becomes more forested. This increased vegetative cover as well as subsurface influence due to the change in valley width and stream gradient likely contributes to the cooling seem downstream until river mile 4.45 (26.8°C→20.5°C). Below this point, temperatures plateau near 21.5°C in the final reach to the mouth.

Figure 20. The TIR/natural color image pair below shows the difficulty in locating the stream when terrestrial vegetation displays cooler radiant temperatures than the stream.



6.13 Meadow Creek

6.13.1 Longitudinal Temperature Profile

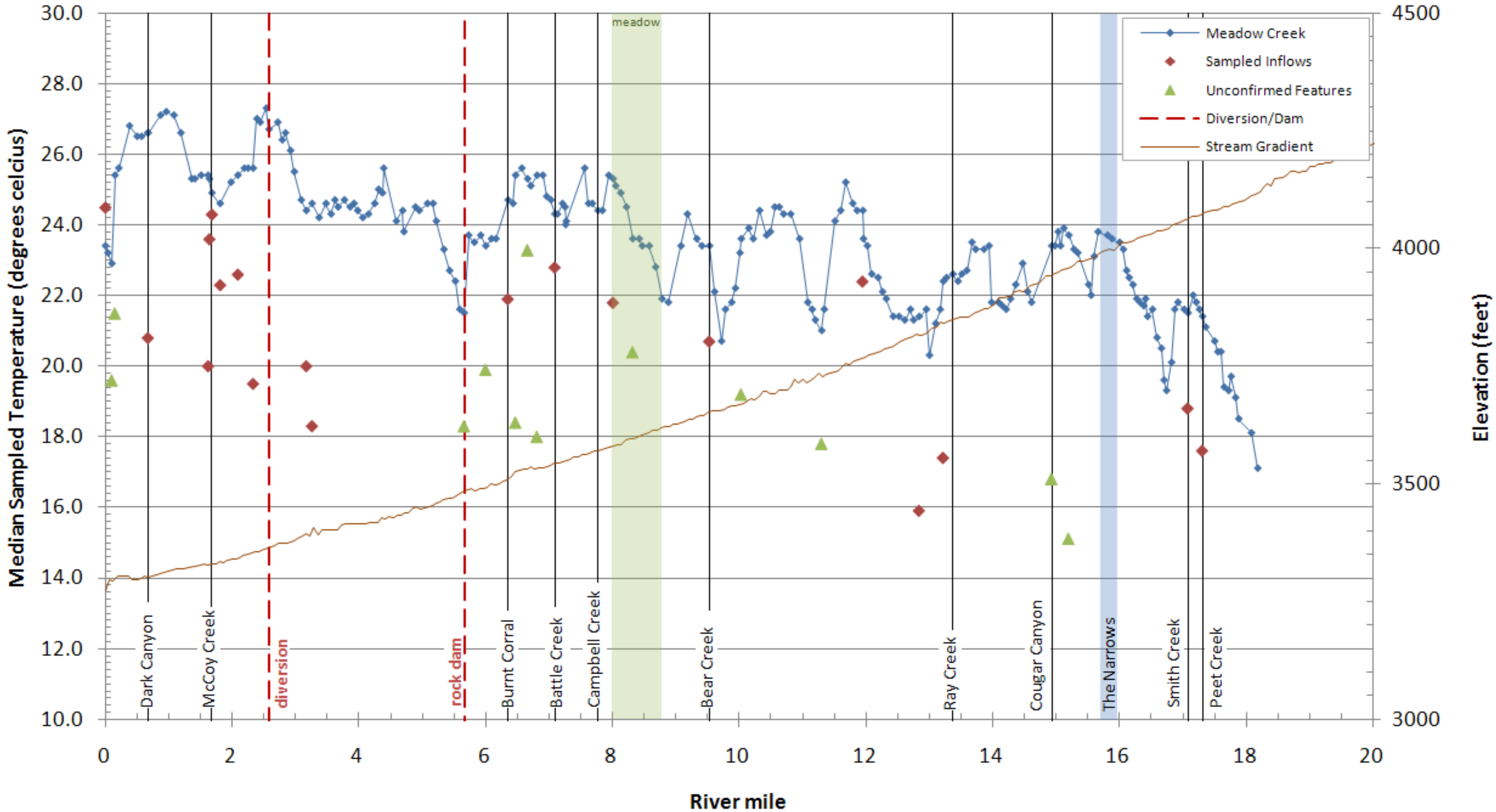


Figure 21. Median sampled temperatures versus river mile for Meadow Creek. The locations of detected surface inflows are illustrated on the profile and listed in Table 12.

Table 12. Tributaries and other surface inflows sampled along Meadow Creek with left or right bank designation (looking downstream)

Tributaries	Kilometer	River Mile	Tributary Temp (°C)	Mainstem Temp (°C)	Difference
Grande Ronde ( )	0.00	0.00	24.5	23.4	1.1
Dark Canyon (L)	1.07	0.67	20.8	26.6	-5.8
Starkey Creek (R)	2.61	1.62	20.0	25.4	-5.4
hyporheic seep (R)	2.64	1.64	23.6	25.3	-1.7
McCoy Creek (L)	2.71	1.68	24.3	24.9	-0.6
drain (R)	2.91	1.81	22.3	24.6	-2.3
Old McCoy (L)	3.36	2.09	22.6	25.4	-2.8
Starkey Creek seep (R)	3.74	2.33	19.5	25.6	-6.1
seeps in pool (R)	5.11	3.17	20.0	24.4	-4.4
seep (L)	5.24	3.26	18.3	24.6	-6.3
Burnt Corral (R)	10.21	6.35	21.9	24.7	-2.8
Battle Creek (R)	11.41	7.09	22.8	24.3	-1.5
side channel (L)	12.89	8.01	21.8	25.3	-3.5
Bear Creek (R)	15.33	9.53	20.7	23.4	-2.7
seep (L)	19.23	11.95	22.4	24.4	-2.0
side channel (R)	20.67	12.84	15.9	21.4	-5.5
seep/side channel (R)	21.27	13.22	17.4	22.4	-5.0
Smith Creek (L)	27.48	17.08	18.8	21.5	-2.7
Peet Creek (R)	27.86	17.31	17.6	21.4	-3.8
Unconfirmed Features					
Tributaries	**Kilometer**	**River Mile**	**Tributary Temp (°C)**	**Mainstem Temp (°C)**	**Difference**
seep/shadow? (R)	0.16	0.10	19.6	22.9	-3.3
seep/shadow? (R)	0.24	0.15	21.5	25.4	-3.9
seep/shadow? (R)	9.10	5.66	18.3	21.5	-3.2
seep? (L)	9.66	6.00	19.9	23.4	-3.5
side channel/seep? (R)	10.41	6.47	18.4	25.4	-7.0
seep/veg? (R)	10.73	6.66	23.3	25.3	-2.0
veg/shadow? (R)	10.95	6.81	18.0	25.4	-7.4
seep/veg? (R)	13.39	8.32	20.4	23.6	-3.2
seep/rock outcrop? (R)	16.14	10.03	19.2	23.6	-4.4
seep/shadow? (R)	18.18	11.30	17.8	21.0	-3.2
Cougar Cyn/shadow? (R)	24.02	14.93	16.8	23.4	-6.6
seep/shadow? (R)	24.46	15.20	15.1	23.7	-8.6

6.13.2 Observations

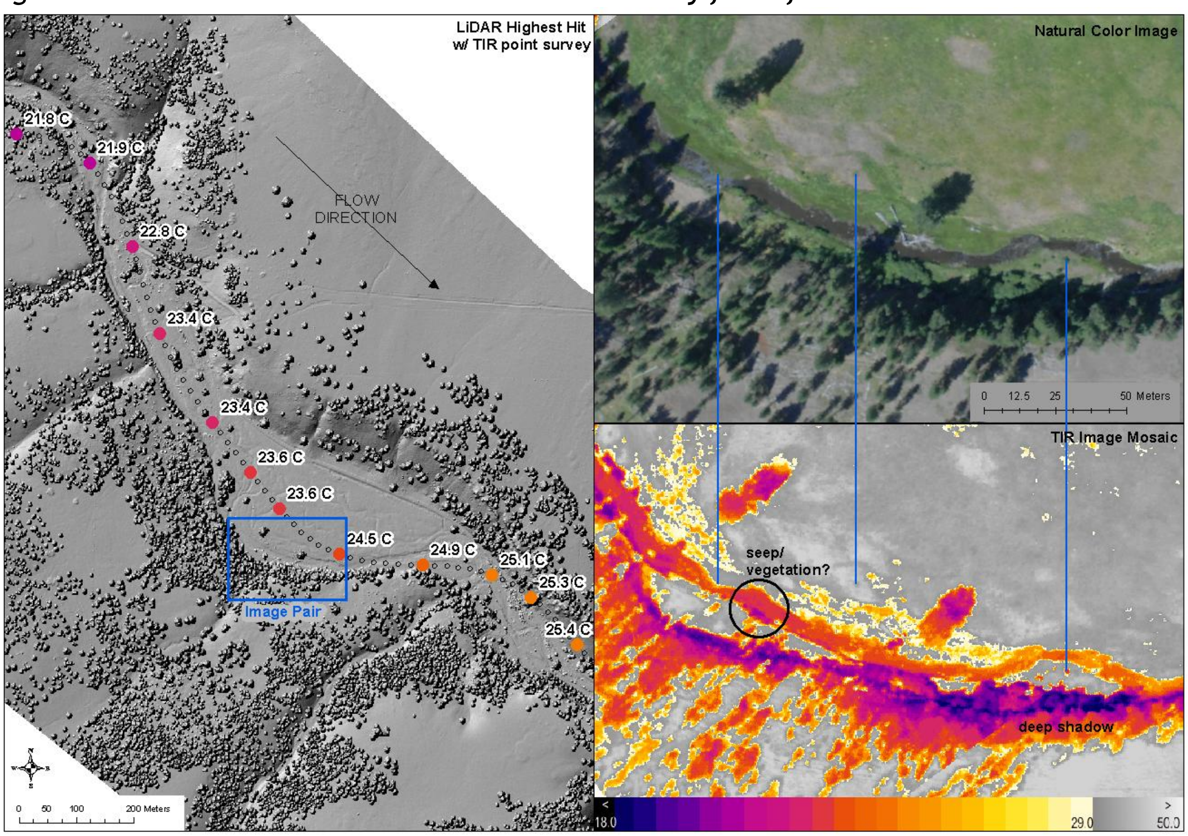
Eighteen miles of Meadow Creek were surveyed on August 8, 2010 from the mouth at the Grande Ronde River upstream to Waucup Creek. Bulk water temperatures were highly variable but ranged from 17.1°C at the upper end of the survey to 27.3°C at the diversion at river mile 2.58 (*Figure 21*). Nine tributaries, 6 seeps, 2 side channel/drains and 1 diversion were seen in the imagery. Twelve additional locations appeared as cold features in the thermal imagery, but could not be validated with the natural color photos due to deep shadows. These features should be confirmed in the field before further analyses are conducted.

A rapid warming (17.1°C→23.8°C) was seen from the head of the survey downstream through The Narrows with the exception of one cold pool at river mile 16.74. Downstream of the Narrows (RM15.66) to river mile 2.98, the creek stays confined to the canyon, flowing through alternating forest and meadow conditions. Temperatures fluctuate between 20.3°C→25.6°C with large variations over short distances.

It is difficult to determine any extended trends along this reach with so much local variability; however, general conclusions can be drawn to explain the localized variations. Bulk water temperatures tend to warm in open meadow conditions (e.g. RM 7.94→RM 8.78) (*Figure 22*). Temperatures tend to show a decrease downstream of narrow spots in the canyon (e.g. RM 11.69→RM 11.27). Manifestations of groundwater influence can commonly be seen in these reaches as evidenced by seeps and springs. The sharp temperature drop at river mile 5.66 is likely due to cold water seeping under the rock dam at Camp Elkanah.

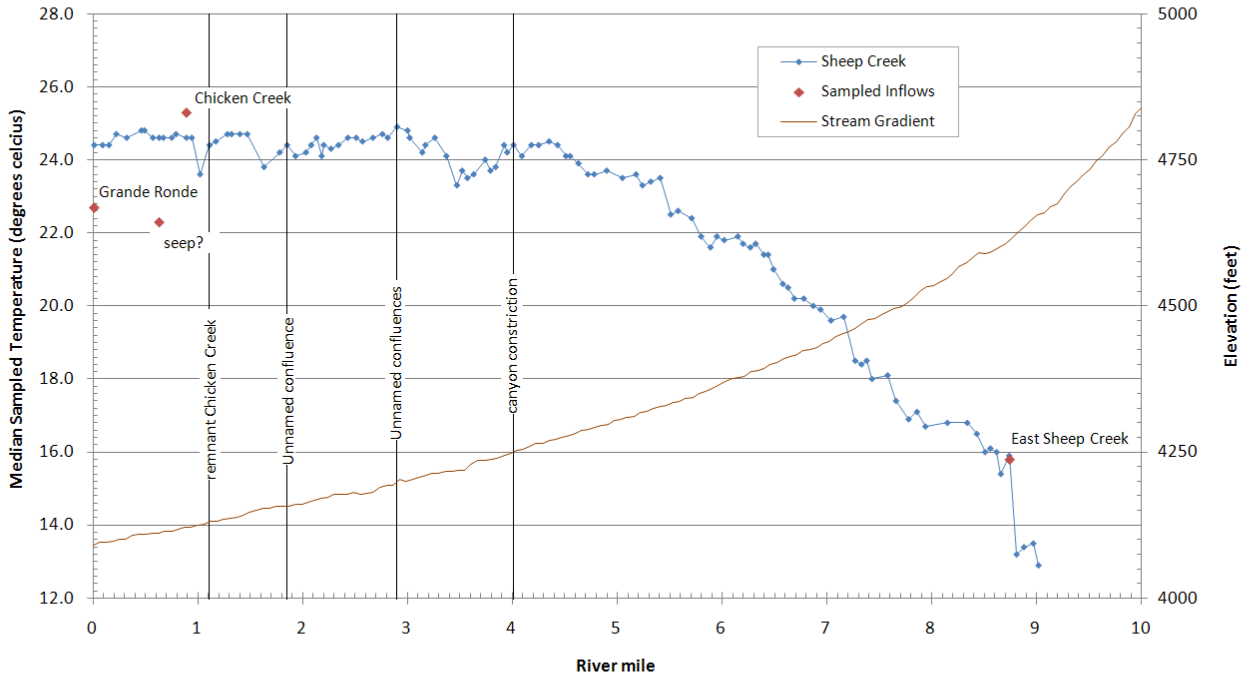
Below river mile 2.98, the canyon opens into a wide valley and temperatures warm for a short distance until the Starkey/McCoy Creek drainages create a cooling environment. Below the McCoy Creek confluence, temperatures again warm until the confluence of Dark Canyon which keeps temperatures depressed for the final reach to the Upper Grande Ronde.

Figure 22. The highest hit LiDAR image below illustrates the warming trend seen along the open reach below Meadow Cow Camp (RM 7.94→RM 8.78). The natural color/TIR mosaic inset on the right shows one example of heavy shadows showing cold thermal returns which should not be confused with cold inflows. If there was any uncertainty about the existence of a seep or spring, it was sampled in the imagery and designated with a '?' as with the signature in the circle. The blue tie lines are strictly for reference.



6.14 Sheep Creek

6.14.1 Longitudinal Temperature Profile



6.14.2 Observations

Nine miles of Sheep Creek were surveyed on August 8, 2010 from the mouth upstream to East Sheep Creek (RM 8.74). East Sheep Creek (15.8°C), Chicken Creek (25.3°C), and a potential seep at river mile 0.63 (22.3°C) were the only sampled inflows. Nine other drainages, Dry Creek, Warm Mineral Spring, and 7 unnamed streams, were shown in the NHD layer, but none had visible surface water that allowed for adequate sampling.

East Sheep Creek had a warming effect on Sheep Creek raising the bulk water temperatures from 13.2°C→15.9°C. Temperatures steadily increased downstream of East Sheep Creek to river mile 4.35 in a typical diurnal warming pattern where the rate of warming slows as the stream gradient becomes less steep. Temperatures plateau near 24.5°C for the lower 4 miles of river.

Localized cooling is seen immediately below river mile 4.01, likely due to a slight constriction in the canyon at this location (24.4°C→23.3°C). A gradual decrease in bulk water temperatures can be seen downstream of the Unnamed confluences near river mile 2.90 (24.9°C→24.1°C) and further cooling below the Unnamed confluence at river mile 1.85 (24.4°C→23.6°C). The cooling spike seen just above the Chicken Creek confluence at river mile 1.11 is likely due to remaining subsurface influences where the former Chicken Creek confluence was located (24.4°→23.6°C).

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CATHERINE CREEK AND TRIBUTARIES

8/12/2010

Catherine Creek
North Fork Catherine Creek
South Fork Catherine Creek

8/10/2010

Ladd Creek
Little Creek
Little Catherine Creek
Milk Creek

6.15 Catherine Creek

6.15.1 Longitudinal Temperature Profile

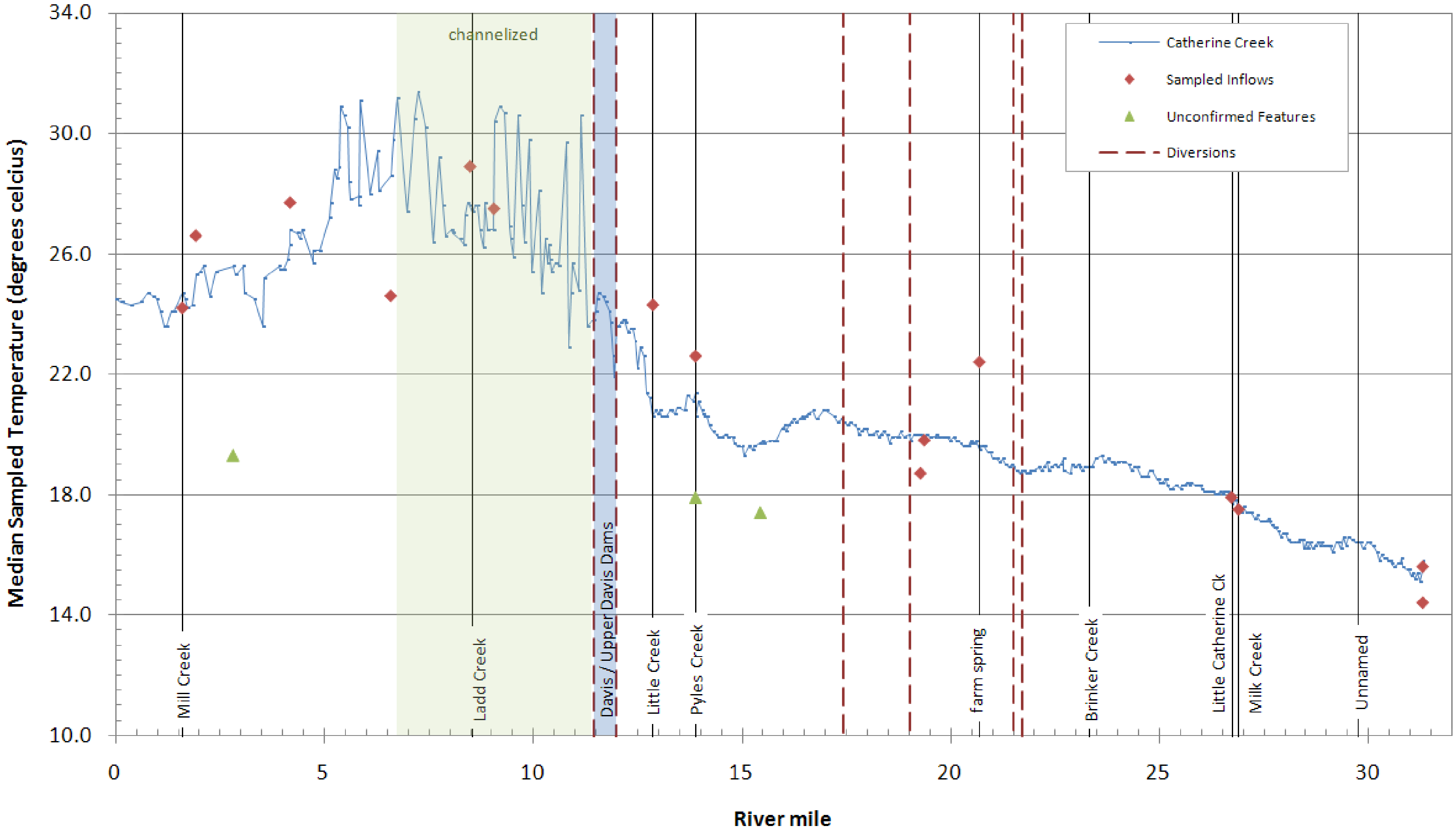


Figure 23. Median channel temperatures plotted versus river mile for Catherine Creek. The locations of detected surface inflows are illustrated on the profile and listed in Table 13.

Table 13. Tributaries and other surface inflows sampled along Catherine Creek with left or right bank designation (looking downstream)

Tributaries	Kilometer	River Mile	Tributary Temp (°C)	Mainstem Temp (°C)	Difference
Mill Creek (R)	2.57	1.60	24.2	24.7	-0.5
slough (L)	3.09	1.92	26.6	25.3	1.3
slough (L)	6.73	4.18	27.7	26.8	0.9
McAlister Slough (L)	10.60	6.59	24.6	28.6	-4.0
canal (R)	13.67	8.49	28.9	27.6	1.3
flooded canal (R)	14.58	9.06	27.5	26.8	0.7
Little Creek (R)	20.71	12.87	24.3	20.6	3.7
Pyles Creek (L)	22.35	13.89	22.6	20.6	2.0
pond 1 (R)	31.02	19.28	18.7	20.0	-1.3
pond 2 (R)	31.17	19.37	19.8	19.9	-0.1
Seep to pond on farm (R)	33.30	20.69	22.4	19.5	2.9
Little Catherine Creek (R)	43.01	26.73	17.9	17.7	0.2
Milk Creek (L)	43.30	26.90	17.5	17.6	-0.1
South Fork Catherine (L)	50.40	31.31	14.4	15.8	-1.4
North Fork Catherine (R)	50.40	31.31	15.6	15.8	-0.2
Unconfirmed Features					
Tributaries	**Kilometer**	**River Mile**	**Tributary Temp (°C)**	**Mainstem Temp (°C)**	**Difference**
steep bank/seep? (R)	4.53	2.82	19.3	25.6	-6.3
steep bank/seep? (L)	22.33	13.88	17.9	21.4	-3.5
seep/shadows? (R)	24.83	15.43	17.4	19.7	-2.3

Dams/Diversion	Kilometer	River Mile
Davis Dam/Diversion	18.41	11.44
Upper Davis Dam	19.24	11.95
diversion	19.30	11.99
diversion	28.04	17.43
diversion	30.63	19.03
diversion-small	34.60	21.50
diversion-small	34.93	21.70

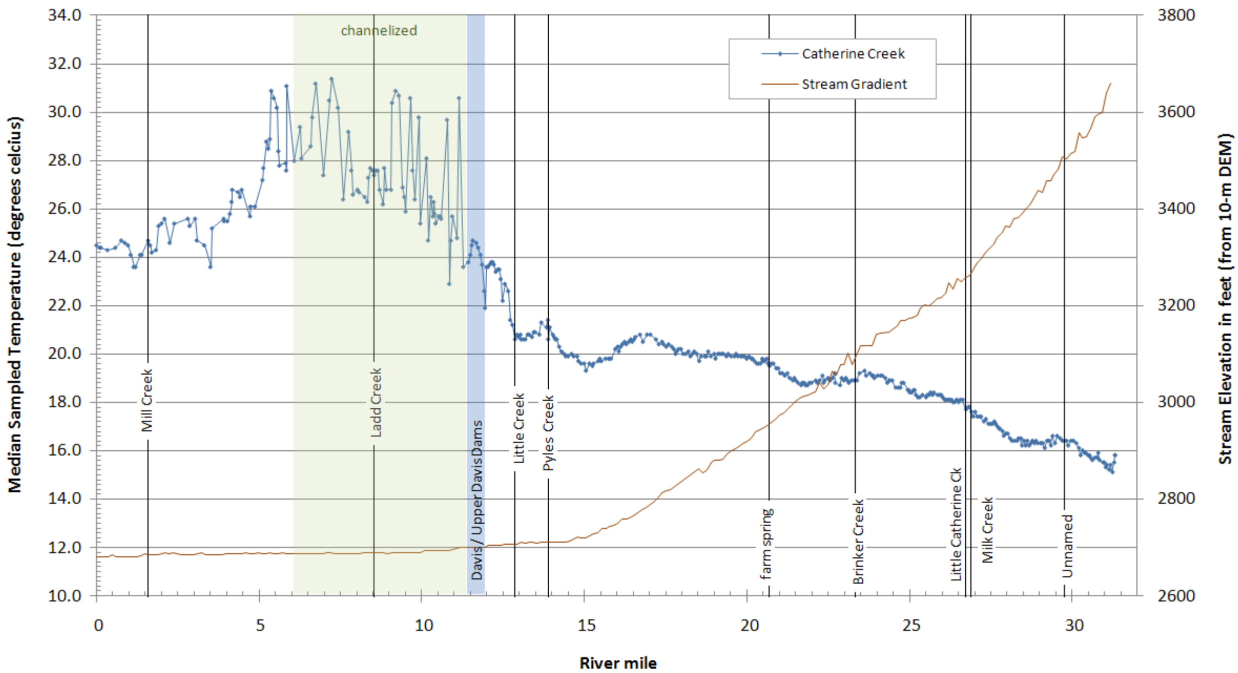
6.15.2 Observations

Approximately 31 miles of Catherine Creek were surveyed on August 12, 2010 from the mouth at the Old Grande Ronde River upstream to the confluence of North and South Fork Catherine Creek. Seven tributaries, 1 seep, 5 ponds/sloughs, and 2 canals were sampled in the imagery (*Figure 23*). Six active diversions and 2 dams were seen in the imagery. Bulk water temperatures ranged from 15.2°C near the North and South Fork confluence (RM 31.31) to 31.4°C at river mile 7.23 along the low water reach below Ladd Creek.

Temperatures show a gradual increase from the Forks (RM 31.31) downstream to river mile 16.93 (15.2°C→20.8°C). Localized cooling can be seen at 3 different locations: downstream of the unnamed stream at river mile 29.75, Brinker Creek (RM 23.32), and the farm spring (RM 20.69). None of these features have a visible surface water contribution to Catherine Creek, but subsurface interaction is suggested by the plateaus seen in the longitudinal profile. The slight inflection seen at the confluences of Little Catherine Creek and Milk Creek indicates a decrease in the rate of warming which also suggests groundwater interaction.

At river mile 16.93, bulk water temperatures decrease 1.5˚C (20.8→19.3˚C) over 1.88 miles. It is unclear what is causing this decrease in temperatures as the stream flows through Union, Oregon. There appear to be no significant inflows or outflows, no changes in stream gradient, morphology or vegetation type along this reach (*Figure 24*).

Figure 24. A comparison of stream gradient to bulk water temperatures for Catherine Creek. Stream elevations were obtained from the 10-m digital elevation model for the area.



As the stream gradient flattens, temperatures begin to increase downstream of river mile 15.05. A short cooling reach is seen downstream of Pyles Creek (RM 13.89) though it appears to be contributing warmer surface water (22.6˚C). A significant point source warming (24.3˚C) is seen at the confluence with Little Creek at river mile 12.87.

When Catherine Creek reaches Upper Davis Dam (RM 11.95) and Davis Dam (RM 11.44), a significant amount of flow is diverted out of the main channel. The low flows seen below the dams result in highly variable temperatures and potentially stratified water conditions. The river is also highly channelized for 4.80 miles below the dam. The Ladd Creek confluence appears to have a significant impact on bulk water temperatures, though it was not contributing enough surface water for accurate sampling (*Figure 25*).

Near river mile 6.64, the river resumes a more natural meandering flow, and water levels begin to rebound below river mile 5.38. In this more natural flow regime, a 6.4˚C temperature decrease is seen in the lower 5 miles of the river (*Figure 26*).

Of the six diversions seen along Catherine Creek, the increase in the warming rate downstream of the diversions at river mile 21.50 and 21.70 and the Davis Dams indicates that these diversions do have an impact on the temperature profile of the stream. The diversions at river miles 19.03 and 17.43 have a less quantifiable effect.

Figure 25. The TIR/natural color image pair below shows the confluence of Ladd Creek and Catherine Creek (RM 8.54). Despite the low flow of Ladd Creek and the highly variable temperatures along the reach due to low water, Ladd Creek does appear to have a cooling effect on the temperatures of Catherine Creek. The black and red graphic lines are strictly for reference.

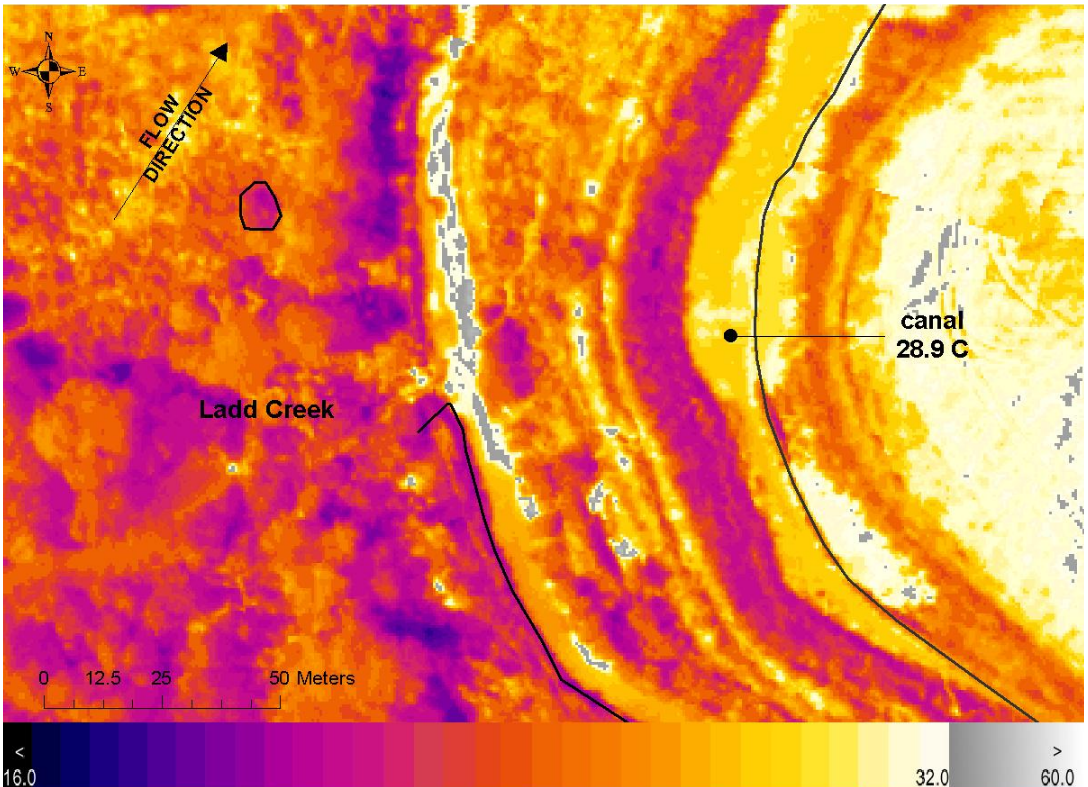
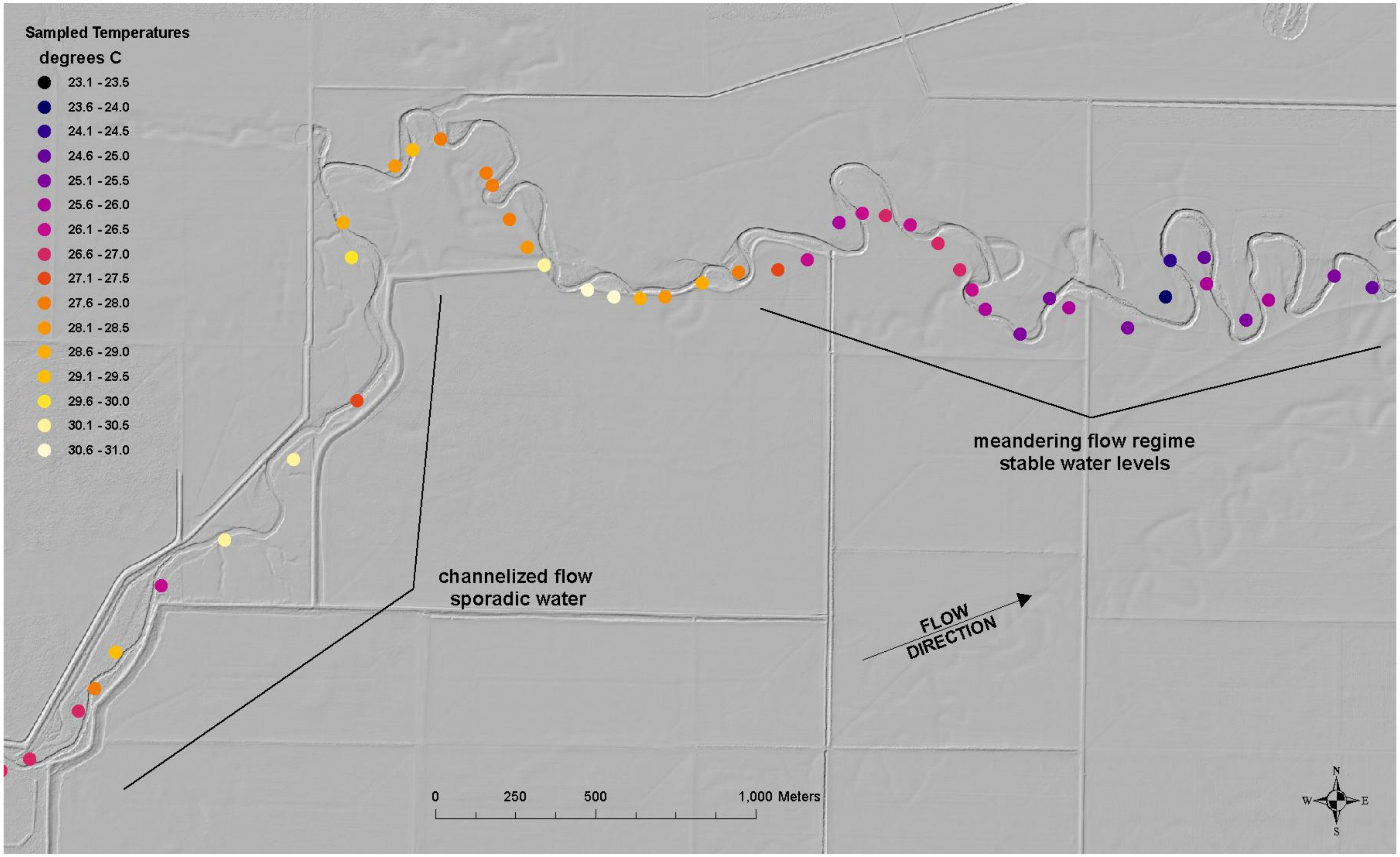


Figure 26. The LiDAR bare earth hillshade below shows the transition between the confined, channelized river and the sinuous meandering channel near river mile 6.64. Along this reach, water levels begin to rebound and a 6.4°C temperature decrease is seen in the lower 5 miles of the river as the river returns to a more natural flow regime. The point color ramp is exaggerated for this image.



6.16 North Fork Catherine Creek

6.16.1 Longitudinal Temperature Profile

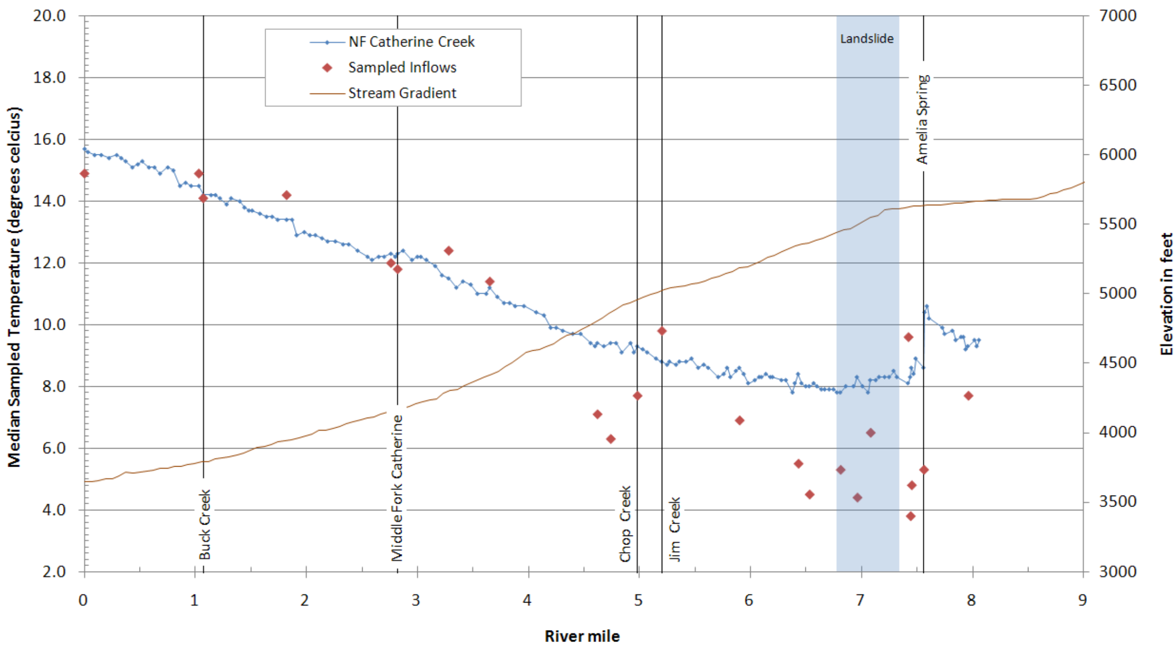


Table 14. Tributaries and other surface inflows sampled along North Fork Catherine Creek with left or right bank designation (looking downstream)

Tributaries	Kilometer	River Mile	Tributary Temp (˚C)	Mainstem Temp (˚C)	Difference
Catherine Creek	0.00	0.00	14.9	15.7	-0.8
Lick Ck (R)	1.66	1.03	14.9	14.5	0.4
Buck Creek (L)	1.72	1.07	14.1	14.2	-0.1
side channel (L)	2.93	1.82	14.2	13.4	0.8
hyporheic flow? (L)	4.43	2.76	12.0	12.3	-0.3
Middle Fork (L)	4.55	2.82	11.8	12.3	-0.5
Unnamed (R)	5.28	3.28	12.4	11.5	0.9
Unnamed (R)	5.87	3.65	11.4	11.2	0.2
spring (L)	7.44	4.62	7.1	9.4	-2.3
spring (L)	7.63	4.74	6.3	9.4	-3.1
Chop Creek (L)	8.01	4.98	7.7	9.3	-1.6
Jim Creek (L)	8.37	5.20	9.8	8.8	1.0
seep (R)	9.49	5.90	6.9	8.6	-1.7
seep (L)	10.35	6.43	5.5	8.4	-2.9
spring (L)	10.50	6.53	4.5	8.0	-3.5
side channel (R)	10.96	6.81	5.3	7.8	-2.5
spring (L)	11.19	6.96	4.4	8.3	-3.9
spring (L)	11.40	7.08	6.5	8.2	-1.7
Unnamed (R)	11.93	7.42	9.6	8.1	1.5
spring (L)	11.97	7.44	3.8	8.3	-4.5
seep (R)	11.99	7.45	4.8	8.6	-3.8
Amelia Spring (L)	12.16	7.56	5.3	8.6	-3.3
Unnamed (R)	12.82	7.96	7.7	9.3	-1.6

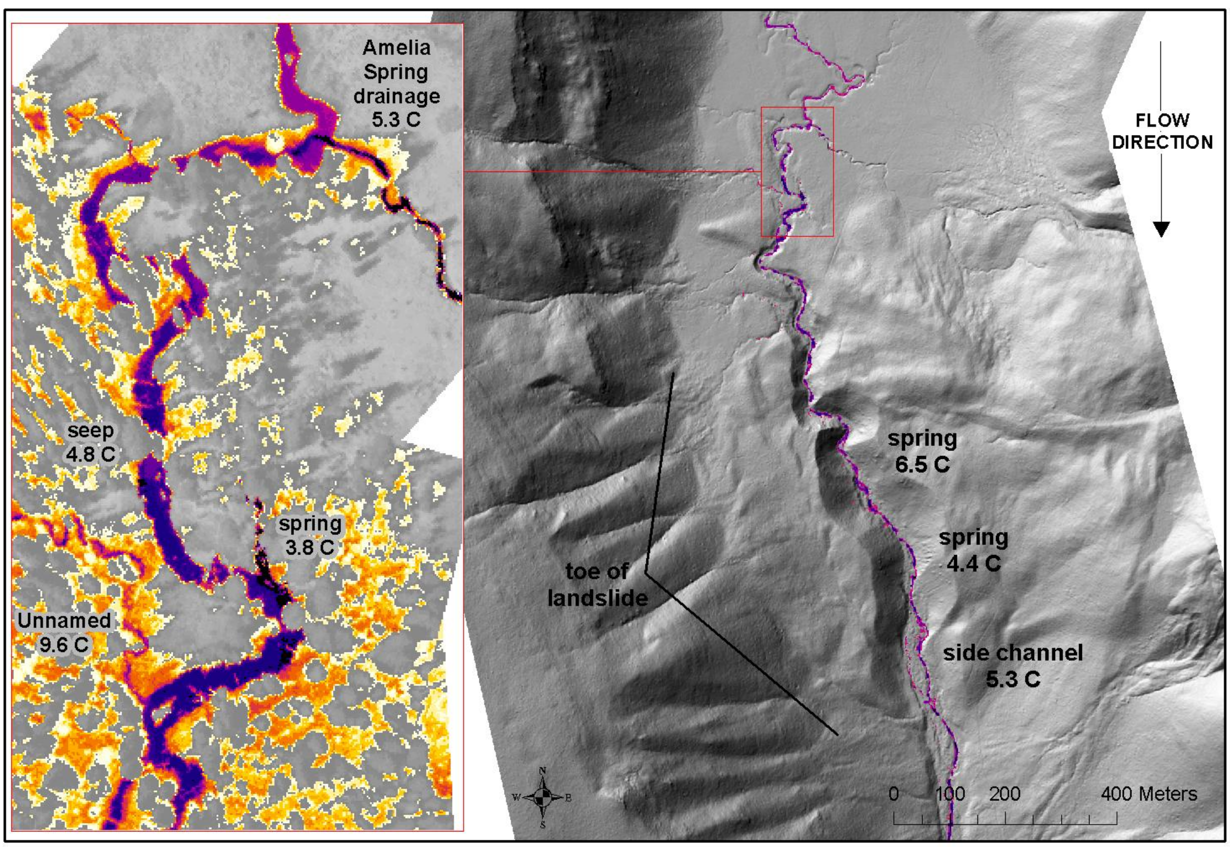
6.16.2 Observations

Approximately eight miles of North Fork Catherine Creek were surveyed on August 12, 2010 from the mouth at Catherine Creek upstream to Catherine Creek meadow. Temperatures ranged from 7.8°C upstream to 15.7°C at the mouth. Ten tributaries, 10 springs/seeps, and 2 side channels were sampled in the imagery.

In the upper mile of the survey, the Amelia Spring drainage (RM 7.56) lowers bulk water temperatures 2.0°C from 10.6°C→8.6°C. Temperatures stay depressed for approximately one mile as the stream flows out of the meadow and cuts through the toe of an inactive mature landslide between river miles 6.79-7.34. Several springs are seen along this reach which indicates increased groundwater activity (*Figure 27*).

In the lower 6.5 miles of the survey, the bulk water temperatures show a steady warming trend from the meadow downstream to the mouth. Most of the inflows are small and have minimal downstream influence on the stream temperatures. There are no obvious correlations between the stream gradient and temperature profile.

Figure 27. The TIR/bare earth LiDAR image shows the landslide at river mile 5.0.



6.17 South Fork Catherine Creek

6.17.1 Longitudinal Temperature Profile

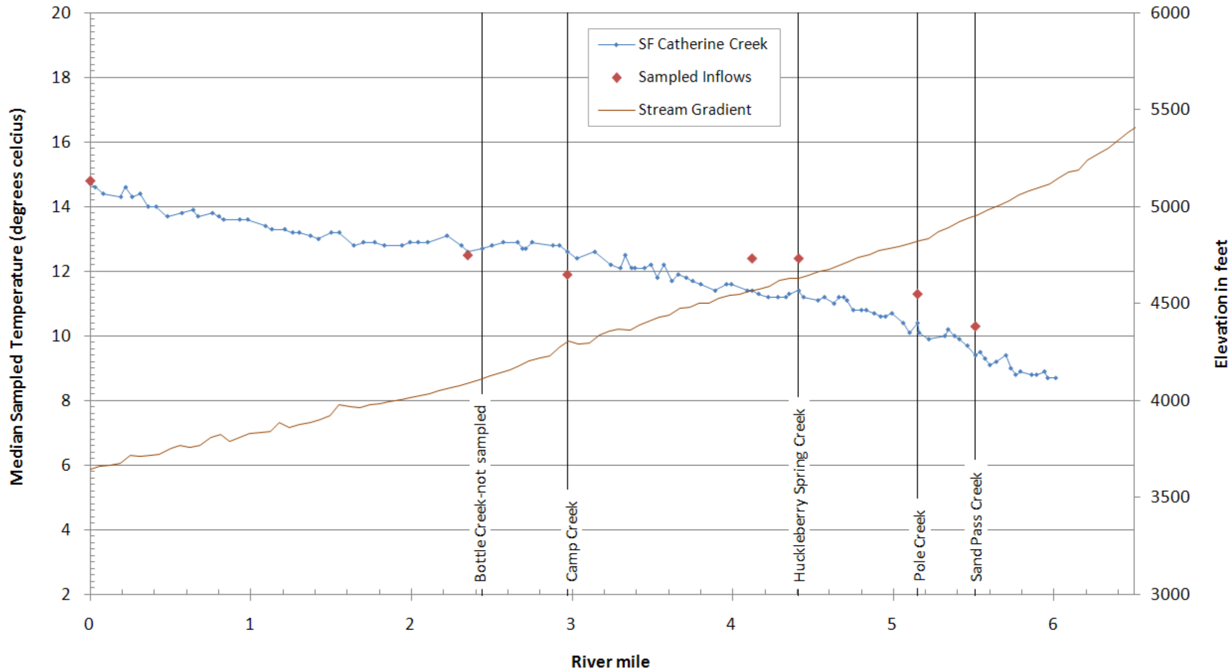


Table 15. Tributaries and other surface inflows sampled along South Fork Catherine Creek with left or right bank designation (looking downstream)

Tributaries	Kilometer	River Mile	Tributary Temp (°C)	Mainstem Temp (°C)	Difference
Catherine Creek	0.00	0.00	14.8	14.7	0.1
side channel (R) ( )	3.77	2.35	12.5	12.6	-0.1
Camp Creek (L)	4.78	2.97	11.9	12.6	-0.7
side channel (R) ( )	6.63	4.12	12.4	11.4	1.0
Huckleberry Spring Creek (L)	7.09	4.41	12.4	11.4	1.0
Pole Creek (R)	8.29	5.15	11.3	10.4	0.9
Sand Pass Creek (R)	8.87	5.51	10.3	9.4	0.9

6.17.2 Observations

Six miles of South Fork Catherine Creek were surveyed on August 12, 2010. Four named streams and two side channels were sampled as inflows in the imagery. Temperatures ranged from 8.7°C upstream to 14.7°C at the mouth at Catherine Creek. Temperatures showed a gradual increase downstream as expected on a warm summer day. A plateau near 12.9°C was seen in the bulk water temperatures below Camp Creek (RM 1.64-2.97) indicating subsurface interactions. No definitive correlations were seen between water temperatures and stream gradient.

6.18 Ladd Creek

6.18.1 Longitudinal Temperature Profile

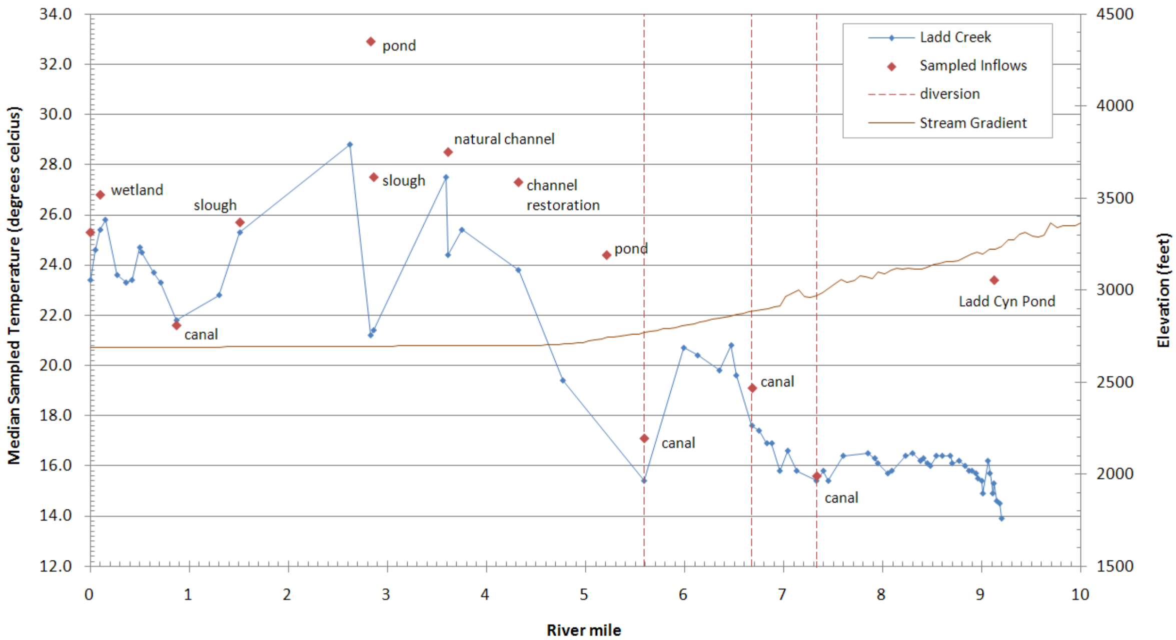


Table 16. Tributaries and other surface inflows sampled along Ladd Creek with left or right bank designation (looking downstream)

Tributaries	Kilometer	River Mile	Tributary Temp (°C)	Mainstem Temp (°C)	Difference
Catherine Creek	0.00	0.00	25.3	23.4	1.9
adjacent wetland (R)	0.15	0.10	26.8	25.4	1.4
canal (R)	1.40	0.87	21.6	21.8	-0.2
slough (R)	2.43	1.51	25.7	25.3	0.4
pond (R)	4.55	2.83	32.9	21.2	11.7
slough (L)	4.60	2.86	27.5	21.4	6.1
natural channel (R)	5.81	3.61	28.5	24.4	4.1
channel restoration (R)	6.94	4.32	27.3	23.8	3.5
pond (L)	8.38	5.21	24.4	no water	--
Canal/diversion (R)	8.99	5.59	17.1	15.4	1.7
Canal/diversion (R)	10.74	6.68	19.1	17.6	1.5
Canal/diversion (L)	11.79	7.33	15.6	15.4	0.2
Ladd Canyon Pond (R)	14.68	9.12	23.4	15.3	8.1

6.18.2 Observations

Nine miles of Ladd Creek were surveyed on August 10, 2010 from the mouth at Catherine Creek upstream to Ladd Canyon Pond Creek. Twelve features including 3 diversions were sampled in the imagery. Temperatures ranged from 13.9°C upstream to 28.8°C at river mile 2.62. Below the diversion at river mile 5.59, there are few areas of visible surface water. Water levels are low and in the lower reaches, the channel is heavily laden with aquatic vegetation. These conditions result in highly variable and mixed pixel sampling.

6.19 Little Creek

6.19.1 Longitudinal Temperature Profile

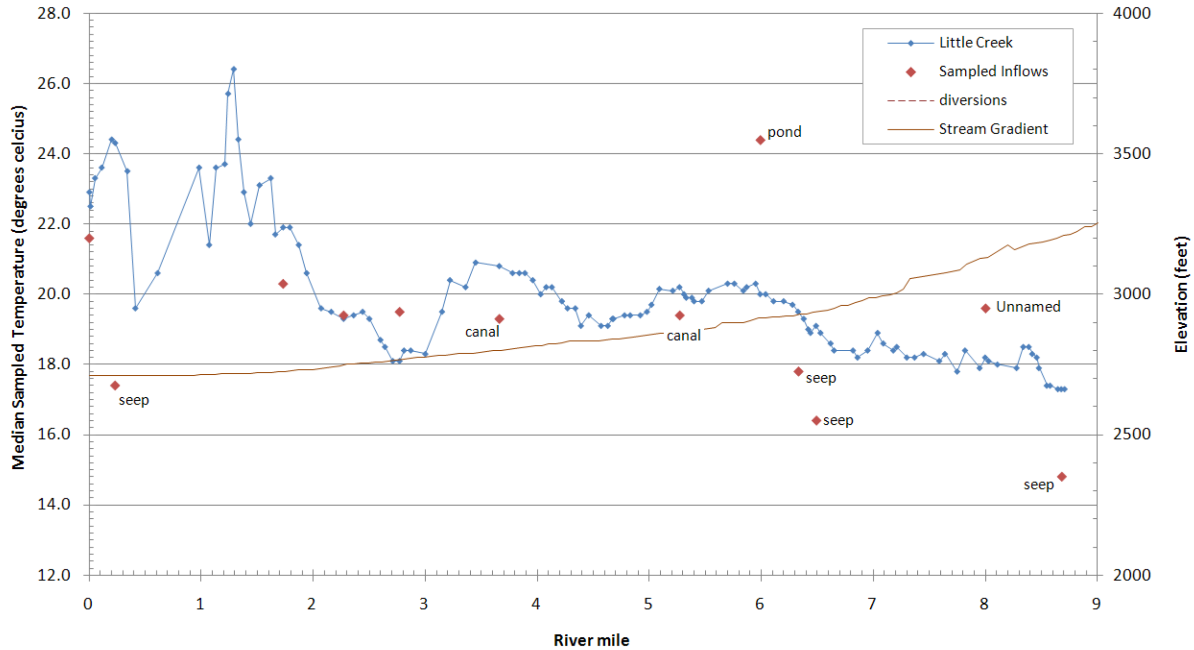


Table 17. Tributaries and other surface inflows sampled along Little Creek with left or right bank designation (looking downstream)

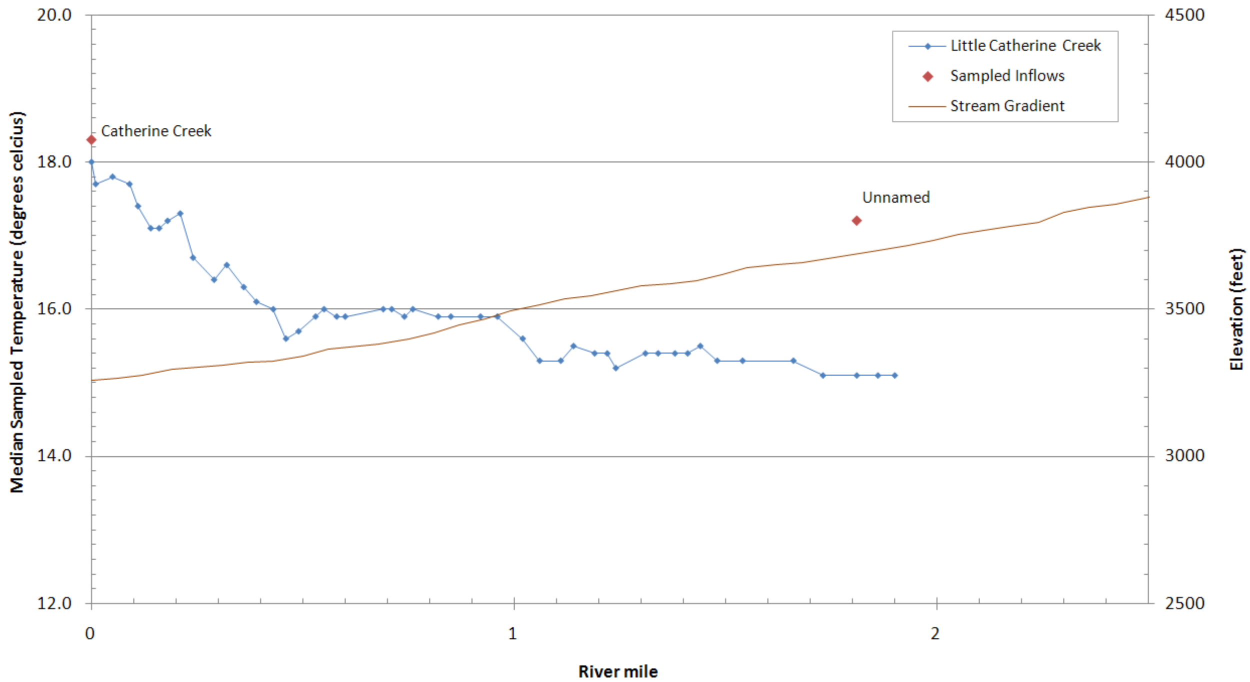
Tributaries	Kilometer	River Mile	Tributary Temp (°C)	Mainstem Temp (°C)	Difference
Catherine Creek	0.00	0.00	21.6	22.9	-1.3
irrigation seep? (R)	0.37	0.23	17.4	24.3	-6.9
canal (L)	2.78	1.73	20.3	21.9	-1.6
canal (L)	3.65	2.27	19.4	19.3	0.1
canal (R)	4.45	2.77	19.5	18.1	1.4
canal (L)	5.88	3.66	19.3	20.8	-1.5
canal (L)	8.48	5.27	19.4	20.2	-0.8
pond (L)	9.64	5.99	24.4	20.0	4.4
seep (L)	10.19	6.33	17.8	19.5	-1.7
seep (L)	10.45	6.49	16.4	19.1	-2.7
Unnamed (L)	12.87	8.00	19.6	18.2	1.4
seep (L)	13.97	8.68	14.8	17.3	-2.5

6.19.2 Observations

Nine miles of Little Creek were surveyed on August 10, 2010. Eleven features including 5 diversions were sampled in the imagery. Temperatures ranged from 17.3°C upstream to 26.4°C at river mile 1.29. The thermal plateau from river mile 6.65→8.28 and the cooling reaches at river miles 2.77→3.45 and 4.39→5.70 indicate subsurface influences are keeping temperatures depressed. As expected, temperatures rise downstream of each diversion as the volume of water in the main channel decreases.

6.20 Little Catherine Creek

6.20.1 Longitudinal Temperature Profile

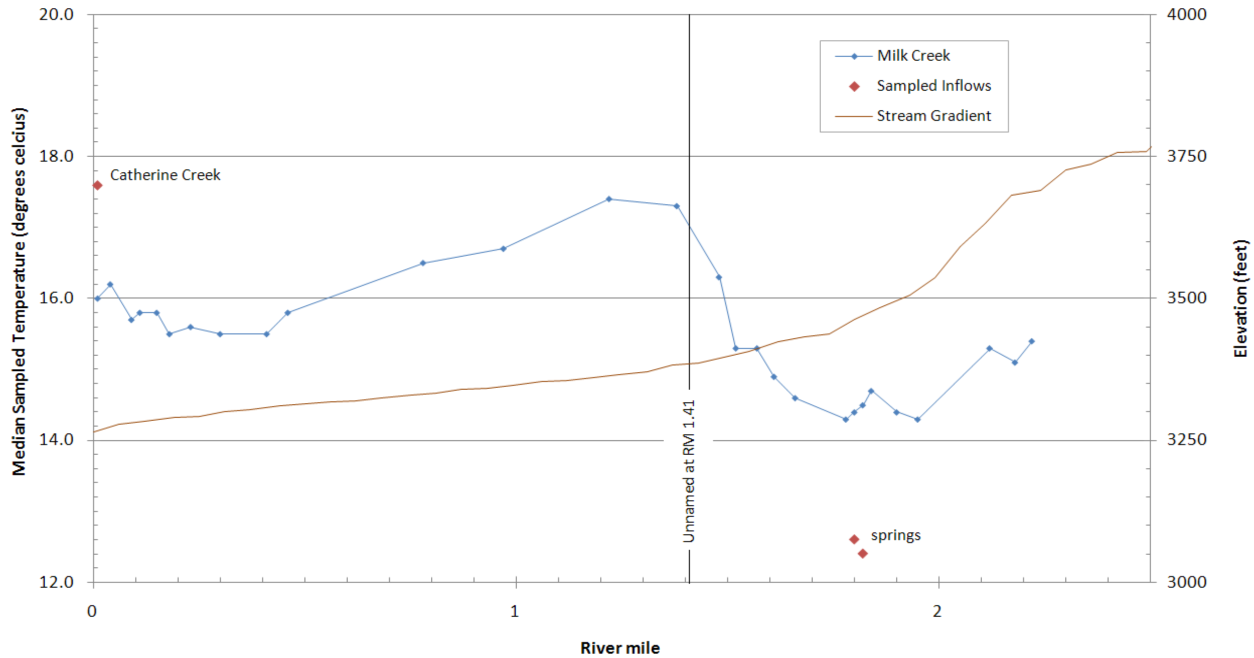


6.20.2 Observations

Just under two miles of Little Catherine Creek were surveyed on August 10, 2010. Temperatures ranged from 15.1°C upstream to 18.0°C at the confluence with Catherine Creek. Temperatures stay stable above river mile 0.46, between 15.1°C and 16.0°C. Below river mile 0.46, a warming is seen as the stream exits the canyon in the final run to Catherine Creek. One unnamed inflow was sampled at river mile 1.81 (17.2°C). No significant correlations were seen between bulk water temperatures and stream gradient.

6.21 Milk Creek

6.21.1 *Longitudinal Temperature Profile*



6.21.2 Observations

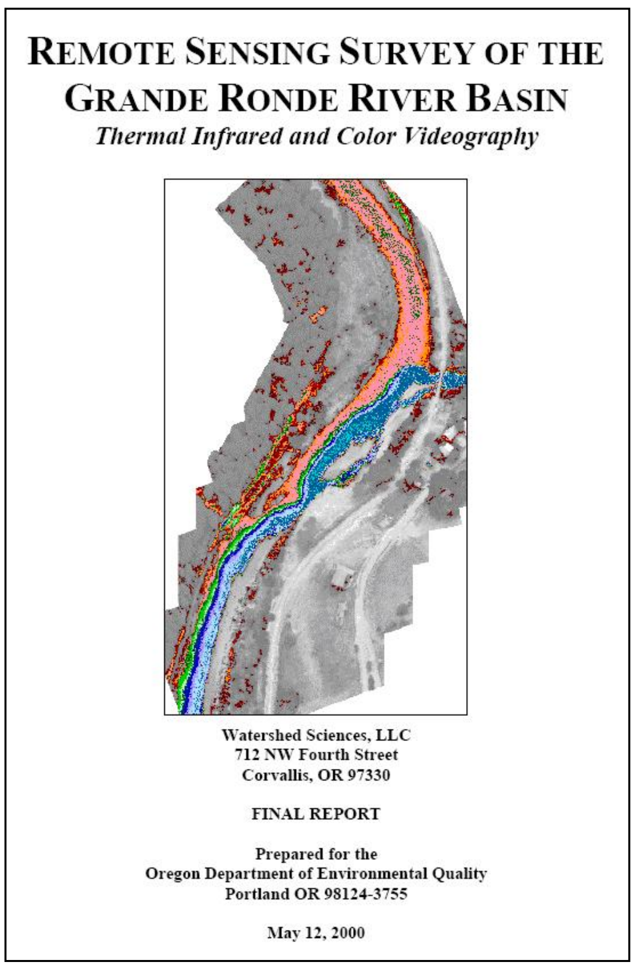
Two miles of Milk Creek were surveyed on August 10, 2010. Temperatures ranged from 14.3°C at the spring complex (RM 1.80) to 17.4°C at river mile 1.22. The two springs, sampled at 12.4°C and 12.6°C, occur as the stream exits the canyon and the stream gradient begins to flatten. With such a small stream, it is difficult to infer trends over such a short distance; however, there appears to be subsurface influences lowering the bulk water temperatures below the Unnamed tributary at river mile 1.41.

7. 1999/2010 Thermal Comparison

Watershed Sciences performed a similar thermal analysis in the Upper Grande Ronde Basin in August 1999[5] for the Oregon Department of Environmental Quality. Ten of the streams in the 2010 study area were surveyed including the Upper Grande Ronde River, Beaver Creek, Fly Creek, Limber Jim Creek, McCoy Creek, Meadow Creek, Sheep Creek, Catherine Creek, North Fork and South Fork Catherine Creek.

Air temperatures were 3-5°F warmer during the time frame of the 1999 flights (Appendix 1). No discharge data was found in the vicinity of the survey for the 1999 flight; however, the downstream flow gage at Troy, Oregon showed higher flow rates in 1999 (Appendix 2). As mentioned, it is unclear how well the gage, located 35 miles downstream, reflects the Upper Grande Ronde flow rates. Local discharge data would be needed to do a thorough data comparison.

Slight shifts may be visible in the profiles due to the difference in methodologies in calculating the river mile measures. Profiles were matched to the extent possible in the case of a distinct inflow or river marker such as a bridge.


REMOTE SENSING SURVEY OF THE GRANDE RONDE RIVER BASIN

Thermal Infrared and Color Videography

Watershed Sciences, LLC
712 NW Fourth Street
Corvallis, OR 97330

FINAL REPORT

Prepared for the
Oregon Department of Environmental Quality
Portland OR 98124-3755

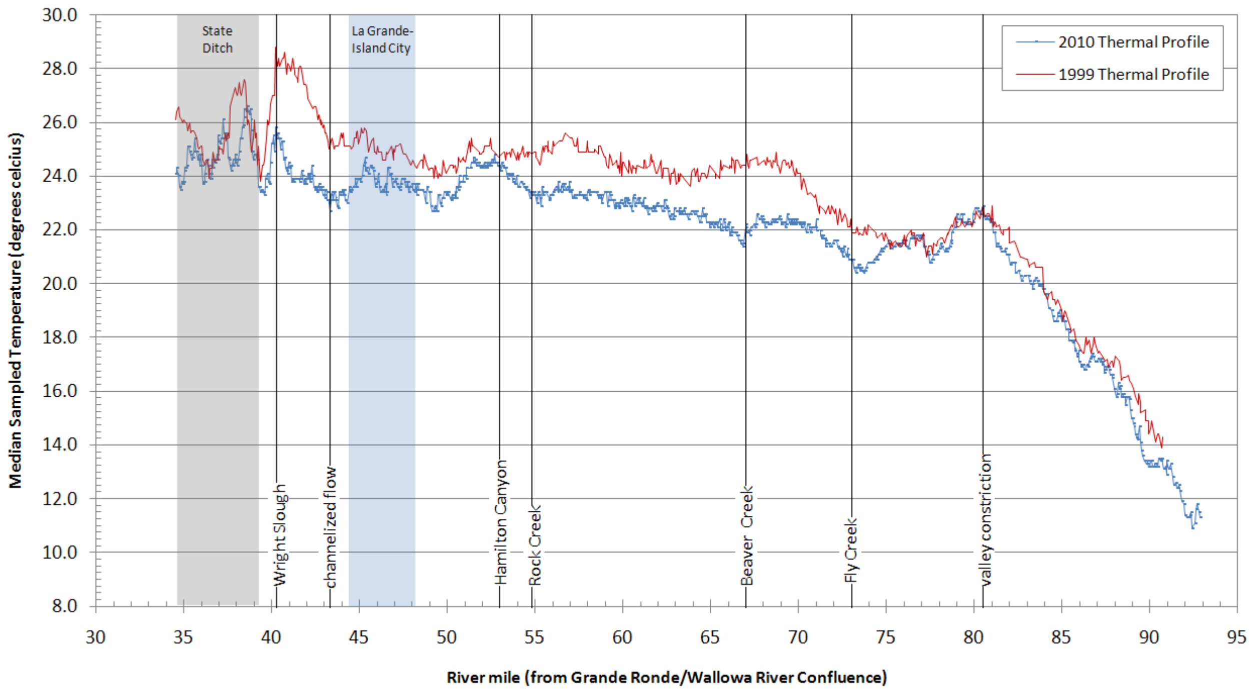
May 12, 2000

[5] Reference Report: "Remote Sensing Survey of the Grande Ronde River Basin: Thermal Infrared and Color Videography." Prepared by Watershed Sciences, LLC for the Oregon Department of Environmental Quality. May 12, 2000.

7.1 Upper Grande Ronde River

A comparison of the 1999/2010 longitudinal profiles for the Upper Grande Ronde River is shown in Figure 28. The overall shape of the profiles is very similar with temperature increases and decreases seen in the same locations. In the upper canyon upstream of river mile 75.0, temperatures are nearly identical; however, below river mile 75.0, the profiles diverge with 1999 sampled water temperatures being on average 2.0°C warmer. Air temperatures in 1999 averaged near 90°F, 5-10°F warmer than the 2010 survey, which likely accounts for the warmer temperatures.

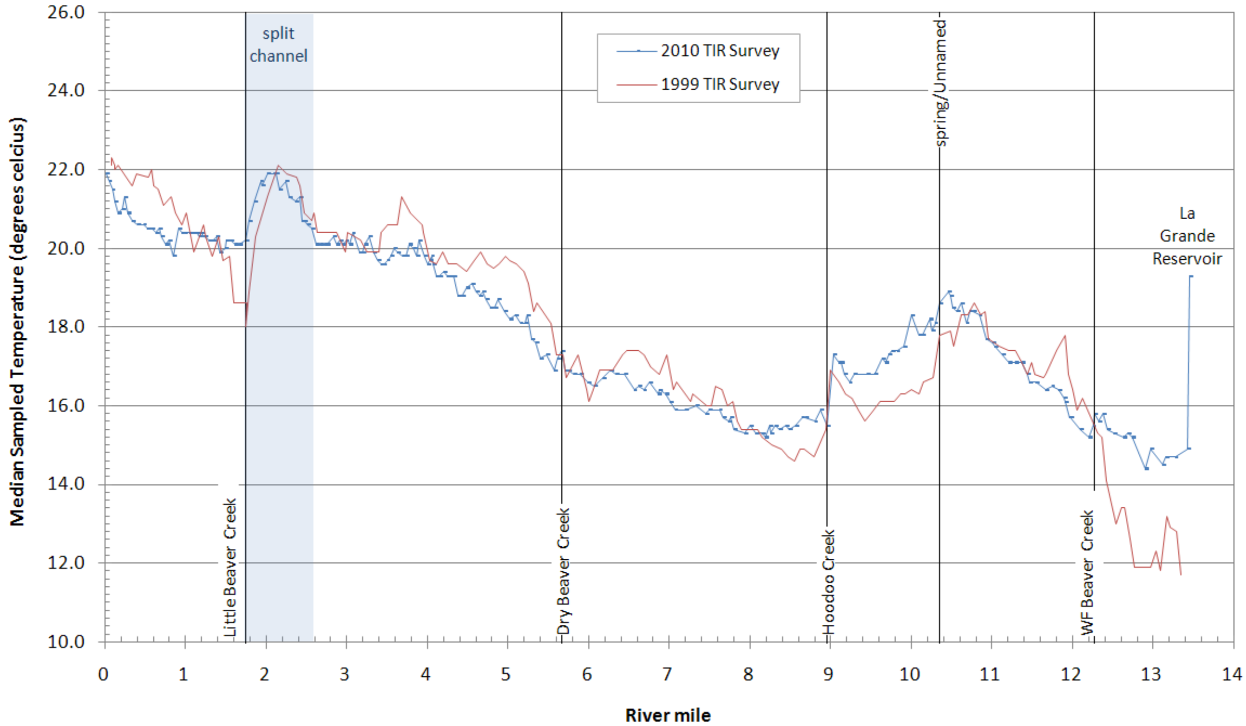
Figure 28. Comparison of the 1999 and 2010 thermal longitudinal profiles for the Upper Grande Ronde River



7.2 Beaver Creek

The 1999/2010 comparison shows similar profiles with a strong cooling trend below the spring at river mile 10.35, cooling at Hoodoo Creek, and the split channel response seen upstream of Little Beaver Creek. There was more variability in the 1999 survey and stronger cooling responses possibly indicating lower water levels (*Figure 29*). Further investigation of historic dam releases from the reservoir would confirm any difference in flow levels.

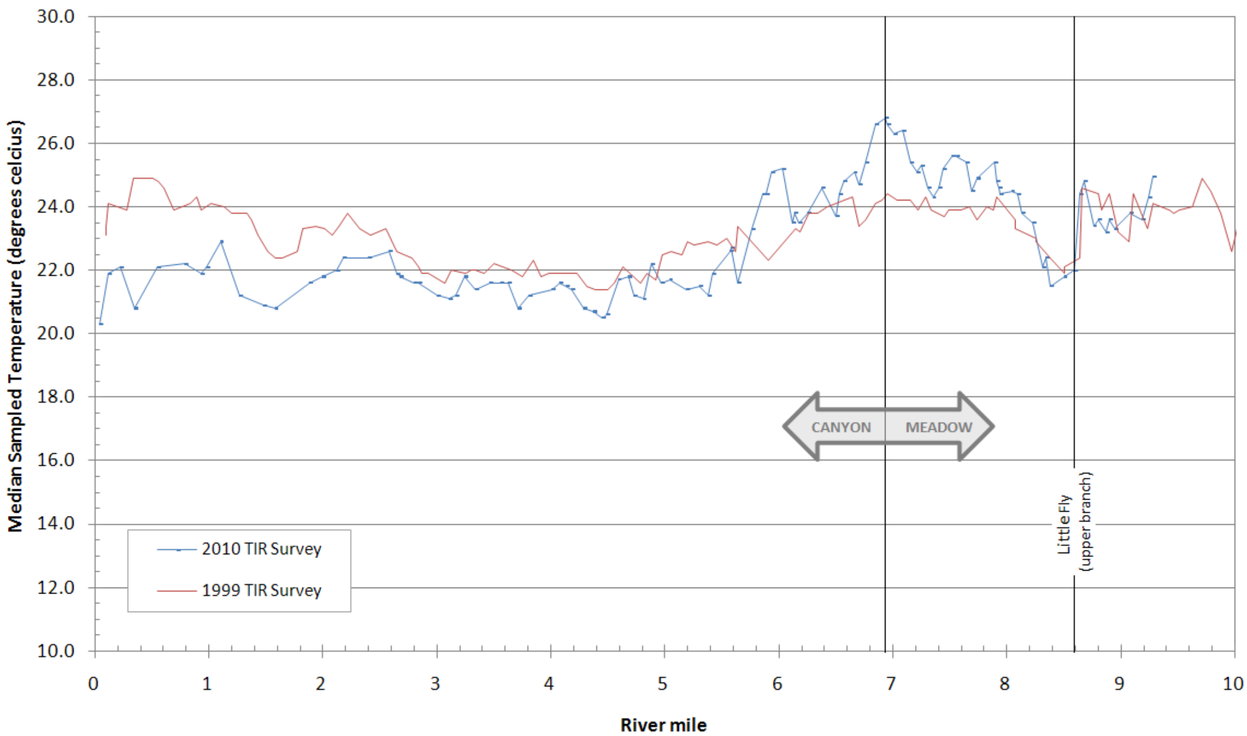
Figure 29. A comparison of the 1999 and 2010 thermal longitudinal profiles for Beaver Creek



7.3 Fly Creek

The 1999/2010 longitudinal profiles for Fly Creek are similar in shape; however, the 2010 profile had slightly lower temperatures downstream and higher temperatures near the meadow/canyon transition. The lower temperatures in the canyon would be expected given the slightly cooler air temperatures in 2010. It is unclear why the 2010 water temperatures are higher near the valley constriction (*Figure 30*). Further investigations of flow rates and grazing activity would be needed to fully analyze the profile differences.

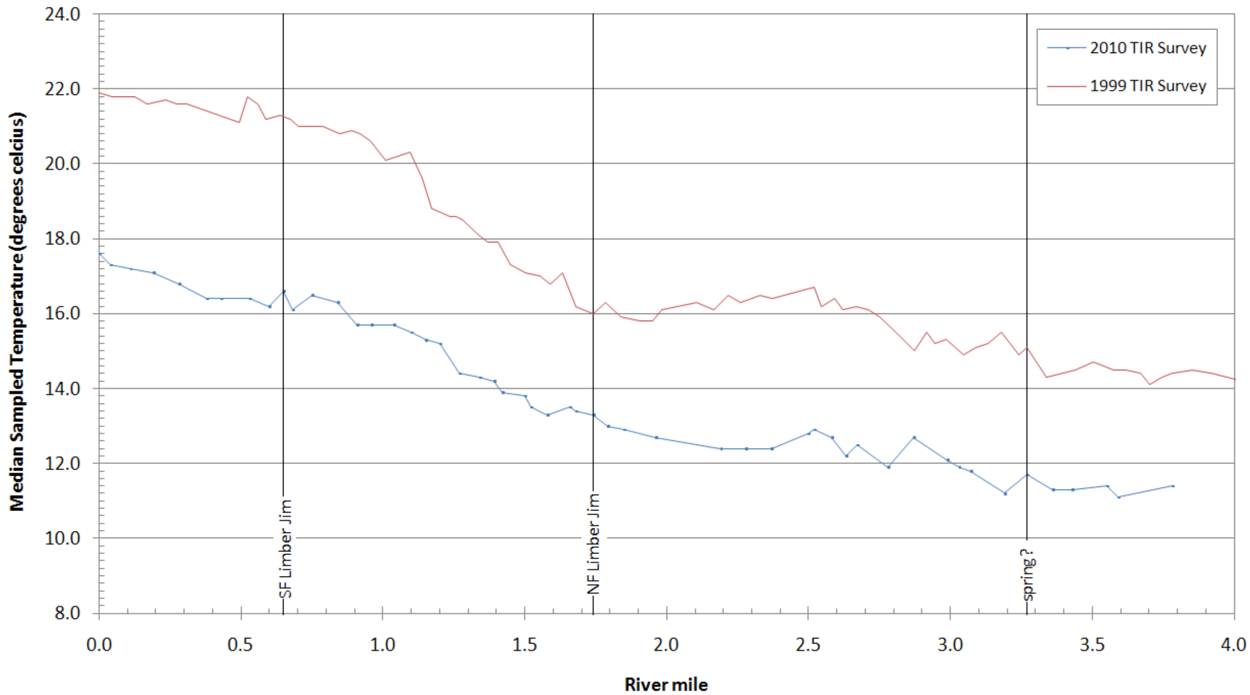
Figure 30. A comparison of the 1999 and 2010 thermal longitudinal profiles for Fly Creek



7.4 Limber Jim Creek

While the thermal profiles for Limber Jim Creek have similar shapes in 1999 and 2010, the thermal profile in 1999 was almost 4°C warmer than the 2010 profile (*Figure 31*). Air temperatures were slightly warmer in 1999, but not by enough to warrant such a large temperature difference. Further analysis would be needed to determine the cause of such a large temperature shift.

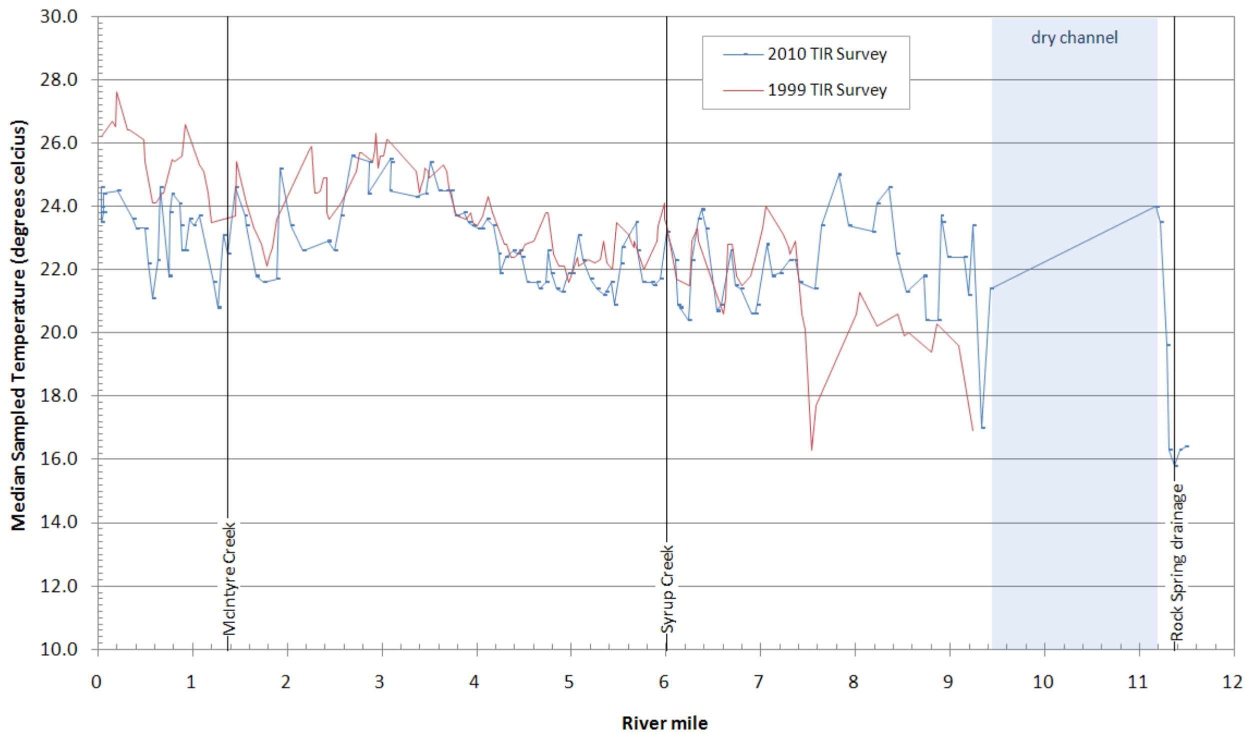
Figure 31. A comparison of the 1999 and 2010 thermal longitudinal profiles for Limber Jim Creek



7.5 McCoy Creek

While the longitudinal profiles for Meadow Creek are similar from 1999 to 2010, the extreme variability in temperatures makes it difficult to draw any conclusive results in the upper reaches (Figure 32). It does appear that temperatures have decreased (-2.0°C) in the reach below McIntyre Creek where the channel has been restored to its natural flow regime. Further analysis would be needed to confirm the significance of the temperature decrease, correcting for differences in daily air temperatures and flow rates.

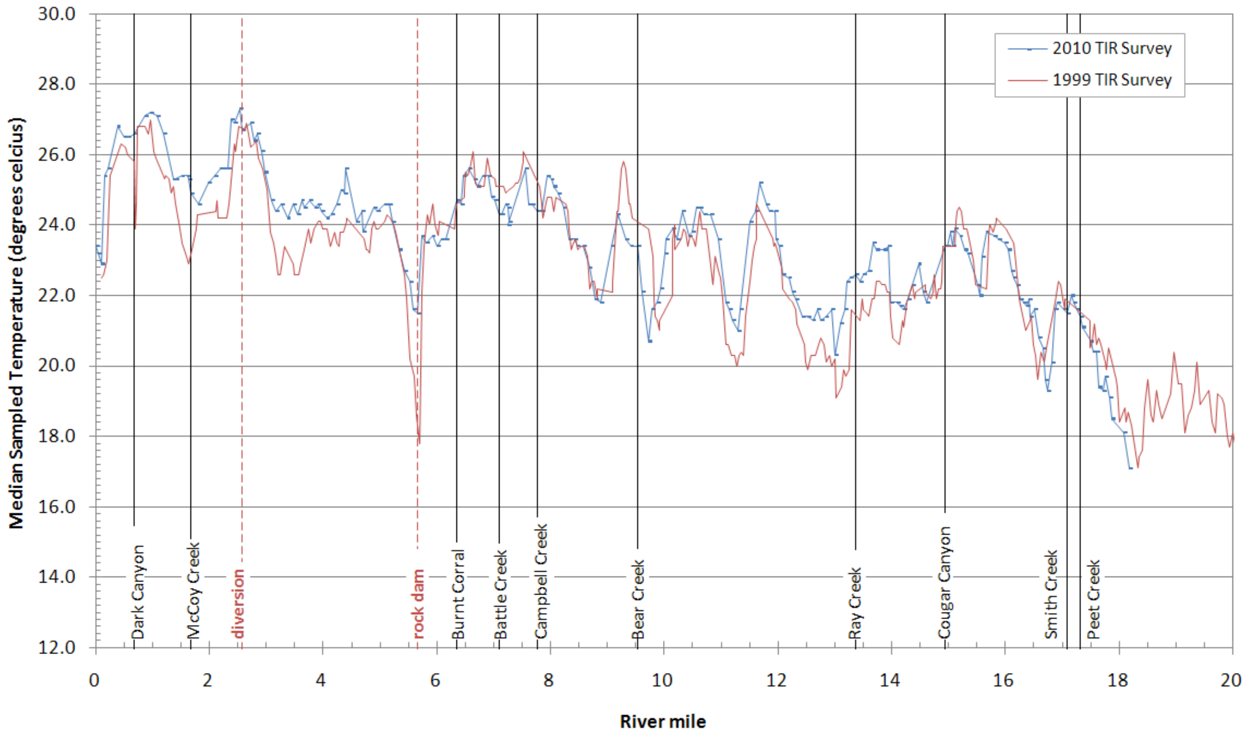
Figure 32. A comparison of the 1999 and 2010 thermal longitudinal profiles for McCoy Creek



7.6 Meadow Creek

The thermal longitudinal profile for the 1999 and 2010 Meadow Creek surveys are nearly identical (*Figure 33*). The cooling and warming responses are slightly greater in the 1999 survey indicating lower water levels.

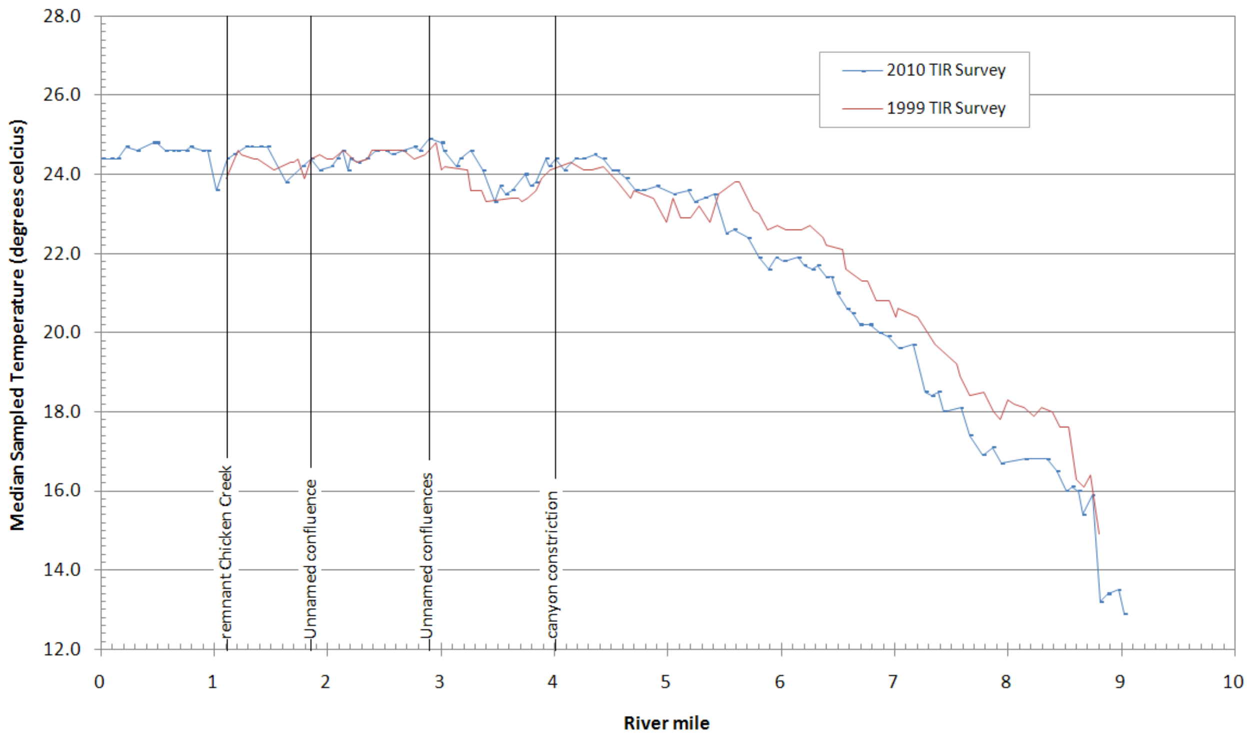
Figure 33. A comparison of the 1999 and 2010 thermal longitudinal profiles for Meadow Creek



7.7 Sheep Creek

The longitudinal temperature profiles for Sheep Creek for 1999/2010 were almost identical though the 1999 survey began at Chicken Creek (*Figure 34*). The bulk water temperatures in the upper 5 miles of stream were approximately 1˚C warmer in 1999, likely due to air temperatures being approximately 5˚F warmer than in 2010 (Appendix A).

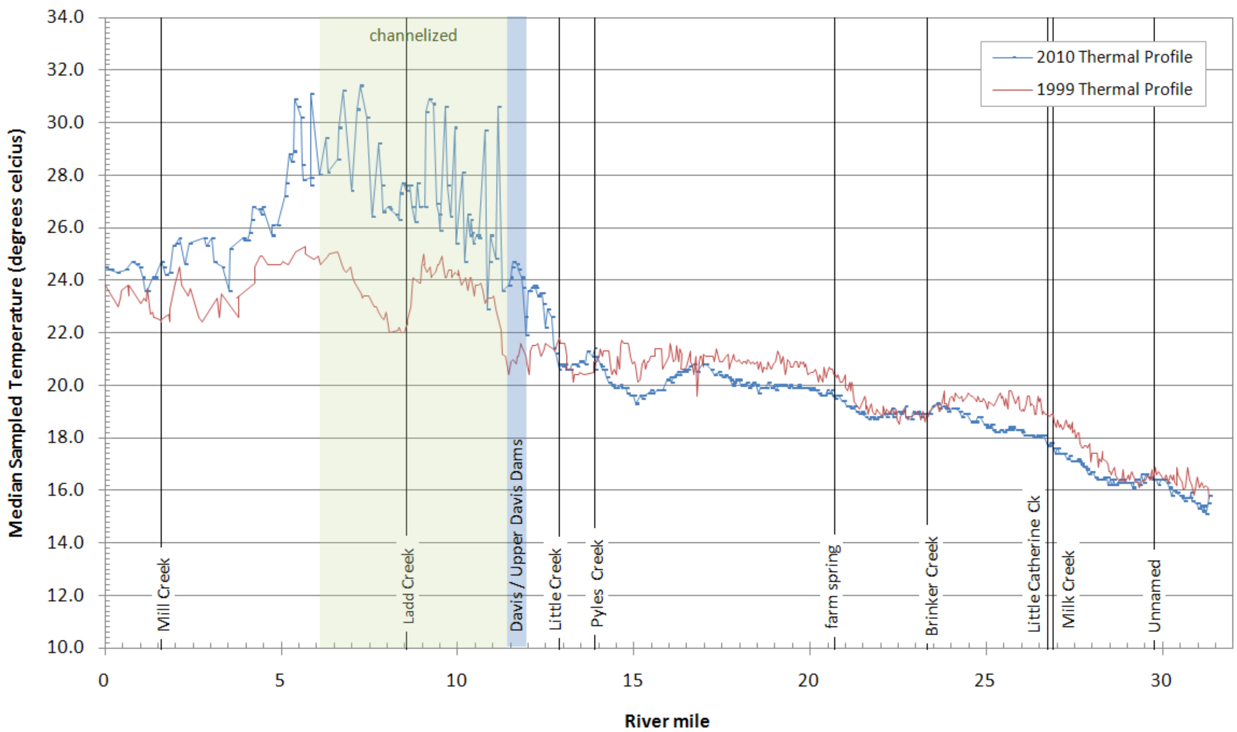
Figure 34. A comparison of the 1999 and 2010 thermal longitudinal profiles for Sheep Creek



7.8 Catherine Creek

The thermal profile comparison for Catherine Creek (*Figure 35*) shows slightly higher water temperatures in 1999 upstream of the dams and significantly lower, more stable temperatures downstream of the dams. This suggests that flows were higher downstream of the dam in 1999. With the more stable temperatures in 1999, the impact of Ladd Creek as a cooling point source is more obvious.

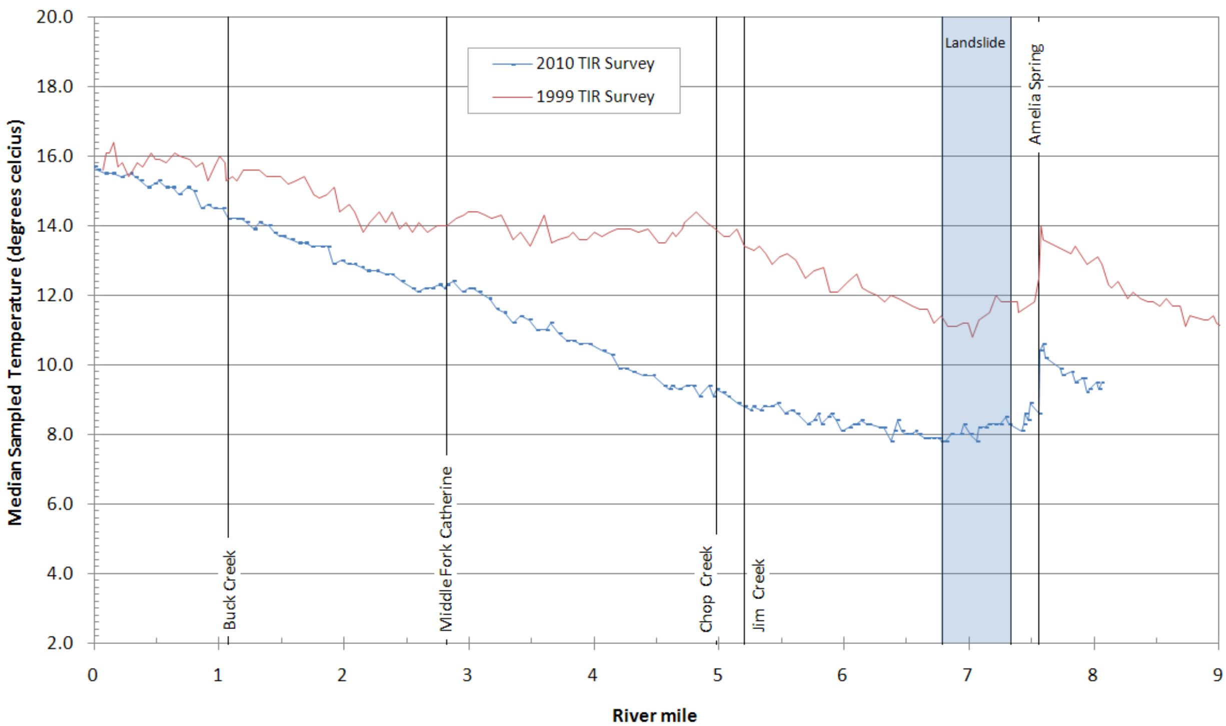
Figure 35. A comparison of the 1999 and 2010 thermal longitudinal profiles for Catherine Creek



7.9 North Fork Catherine Creek

The 1999/2010 profile comparison (*Figure 36*) shows higher water temperatures in 1999 (+0-4°C), but a slower rate of warming. Air temperatures were similar on the dates of the survey for the North Fork so it is unclear what is causing the difference in the profiles. Lower flow rates would likely result in warmer temperatures; however a steeper rate of warming would then be expected, which is not what is reflected in the profile.

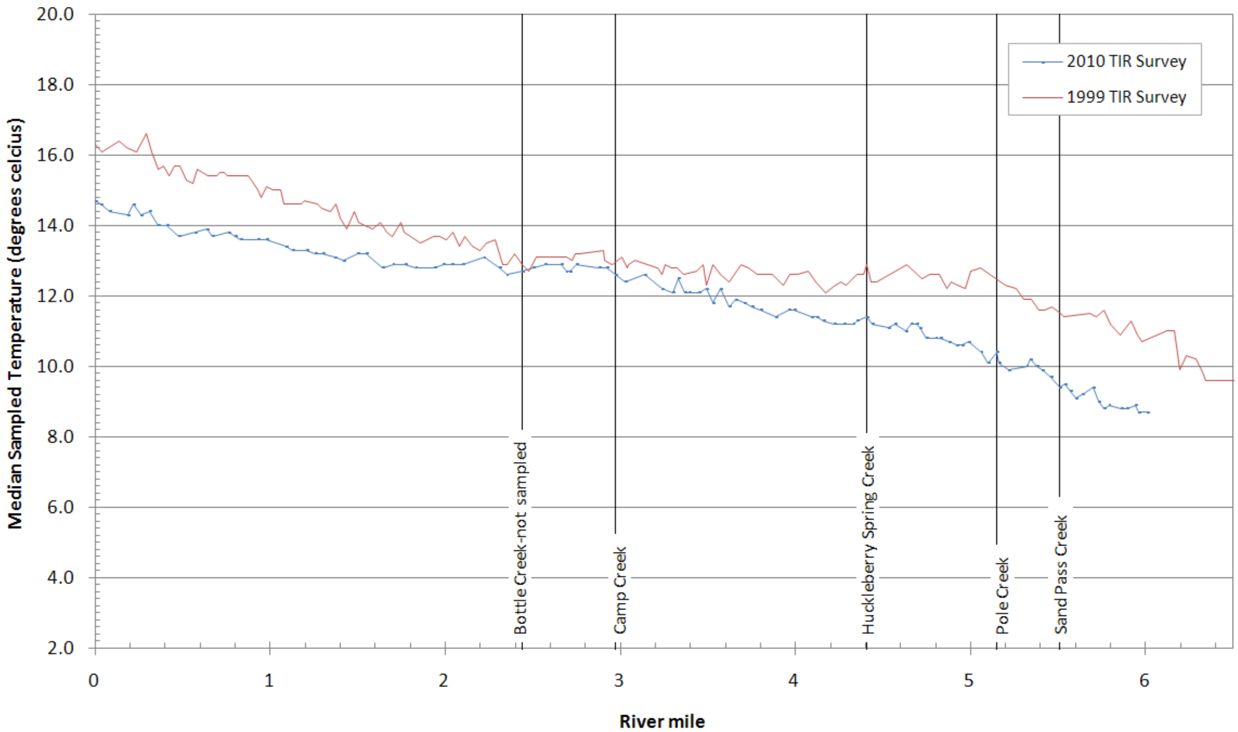
Figure 36. A comparison of the 1999 and 2010 thermal longitudinal profiles for North Fork Catherine Creek



7.10 South Fork Catherine Creek

Water temperatures in 1999 in South Fork Catherine Creek sampled approximately 2°C warmer than in 2010 (*Figure 37*). The temperature plateau seen below Camp Creek is present in the 1999 profile which reaffirms a constant source of groundwater influence along that reach.

Figure 37. A comparison of the 1999 and 2010 thermal longitudinal profiles for South Fork Catherine Creek



8. Projection, Datum and Units

Geo-corrected mosaics, surveys, and shapefiles are delivered in the following projection:

Projection:	UTM Zone 11
Horizontal Datum:	NAD83
Units:	meters

9. Deliverables

The TIR imagery is provided in two forms: individual un-rectified frames and continuous geo-rectified mosaics at varying resolutions: 0.3, 0.4, 0.5, and 0.6 meters (*See Table 3*).

The mosaics allow for easy viewing of the continuum of temperatures along the stream gradient, but also show edge match differences and geometric transformation effects. The un-rectified frames are useful for viewing images at their native resolutions and are often better for detecting smaller thermal features. Radiant temperatures are calibrated for the emissive characteristics of water and may not be accurate for terrestrial features.

Vector Data:	• *Thermal Surveys*. Sampled TIR point shapefiles by stream, showing image locations, sampled temperatures, and image interpretations. • *Natural Color Photo Indices*. Point shapefiles for photo points. • *Hydrography*. NHD Flowline shapefiles.
Raster Data:	• *Thermal Mosaics*. Continuous mosaics of the geo-rectified TIR image frames at varying resolutions in ERDAS Imagine (*.img) format. (Cell value = radiant temperature * 10) • *Thermal Singles Unrectified*. Calibrated TIR images in Erdas Imagine (*.img) format. (Cell value = radiant temperature * 10) • *Natural Color Unrectified*. Unrectified Natural color images in JPEG format
Spreadsheets:	*Long Profiles*. Excel spreadsheets by survey date containing the longitudinal temperature profiles for each stream
Data Project:	*ArcMap project* (*.mxd) containing the thermal surveys and thermal mosaics displayed with the corresponding colorramps.
Data Report:	Full report containing introduction, methodology, accuracy, and analysis

Appendix 1 – Daily air temperatures in La Grande, Oregon

2010			1999		
Date	Time (PDT)	Temperature (˚F)	Date	Time (PDT)	Temperature (˚F)
McCoy, Beaver					
8/7/2010	11:55 AM	80.6	8/26/1999	11:55 AM	77.0
	12:55 PM	84.2		12:55 PM	82.4
	1:55 PM	86.0		1:55 PM	86.0
	2:55 PM	84.2		2:55 PM	87.8
	3:55 PM	84.2		3:55 PM	87.8
	4:55 PM	84.2		4:55 PM	89.6
Meadow, Fly, Sheep					
8/8/2010	11:55 AM	75.2	8/26/1999	11:55 AM	77.0
	12:55 PM	78.8		12:55 PM	82.4
	1:55 PM	82.4		1:55 PM	86.0
	2:55 PM	82.4		2:55 PM	87.8
	3:55 PM	82.4		3:55 PM	87.8
	4:55 PM	84.2		4:55 PM	89.6
Upper Grande Ronde					
8/9/2010	11:55 AM	77.0	8/20/1999	11:55 AM	78.8
	12:55 PM	80.6		12:55 PM	84.2
	1:55 PM	82.4		1:55 PM	87.8
	2:55 PM	84.2		2:55 PM	89.6
	3:55 PM	84.2		3:55 PM	91.4
	4:55 PM	82.4		4:55 PM	91.4
Limber Jim					
8/9/2010	11:55 AM	77.0	8/26/1999	11:55 AM	77.0
	12:55 PM	80.6		12:55 PM	82.4
	1:55 PM	82.4		1:55 PM	86.0
	2:55 PM	84.2		2:55 PM	87.8
	3:55 PM	84.2		3:55 PM	87.8
	4:55 PM	82.4		4:55 PM	89.6
Catherine, North and South Forks Catherine					
8/12/2010	11:55 AM	68.0	8/21/1999	11:55 AM	78.8
	12:55 PM	75.2		12:55 PM	80.6
	1:55 PM	78.8		1:55 PM	80.6
	2:55 PM	80.6		2:55 PM	82.4
	3:55 PM	82.4		3:55 PM	80.6
	4:55 PM	80.6		4:55 PM	82.4
Not Flown in 1999: Rock, Five Points, Spring, Burnt Corral, Dark Canyon, Chicken, West Chicken, Clear, Ladd, Little, Milk, Little Catherine					

Source: Weather Underground http://www.wunderground.com

Appendix 2 – Mean discharge rates for the Grande Ronde River at Troy, Oregon (USGS 13333000)

Surveyed Stream	2010		1999	
	Date	Mean Discharge (ft3/s)	Date	Mean Discharge (ft3/s)
McCoy, Beaver	8/7/2010	804	8/26/1999	833
Meadow, Fly, Sheep	8/8/2010	745	8/26/1999	833
Upper Grande Ronde	8/9/2010	699	8/20/1999	948
Limber Jim	8/9/2010	699	8/26/1999	833
Catherine, North and South Forks Catherine	8/12/2010	751	8/21/1999	927
Not Flown in 1999: Rock, Five Points, Spring, Burnt Corral, Dark Canyon, Chicken, West Chicken, Clear, Ladd, Little, Milk, Little Catherine				

Source: USGS National Water Information System http://waterdata.usgs.gov/nwis

Appendix J

Analysis of Sediment Size in Catherine Creek, Minam River, and Upper Grande Ronde River

COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION
729 NE Oregon, Suite 200, Portland, Oregon 97232
Telephone 503 238 0667
Fax 503 235 4228

Analysis of Sediment Size in Catherine Creek, Minam River, and Upper Grande Ronde River

A component of

Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators

March 2011

Casey Justice

Dale McCullough

Seth White

Summary

We evaluated substrate size composition at 20 different sites in the Catherine Creek, Minam River, and Upper Grande Ronde River basins during the summer of 2009 (10 Jul – 17 Sep) as part of a broad-scale habitat monitoring project designed to evaluate status and trends in habitat conditions for spring Chinook salmon. The percentage of surface particles less than 6.3 mm ranged from 0.9 to 34.1% across sites with Catherine Creek sites having the highest percent surface fines of the sites measured (mean = 17.4%) and Minam River sites having the lowest (mean = 8.8 %). Percent fines < 6.3 mm in subsurface samples was generally higher and more consistent across sites compared with surface samples, with values ranging from 22.3% in the Little Minam River to 33.8% in the mainstem Grande Ronde River upstream of Clear Creek. Using predictive formulas that describe the relationship between fine sediment and Chinook egg-to-fry survival (Tappel and Bjornn 1983), estimated survival across all sites ranged from 64.4 to 89.6% (mean = 79.7%), with the lowest predicted survival occurring in Catherine Creek near the town of Union. Overall, these data are helpful in describing sediment conditions at a select number of sites in the Grande Ronde basin, but more extensive sampling will be required to evaluate status and trends in fine sediment levels.

Methods

Surface sediment sampling

We measured streambed particle size in 20 randomly distributed sites in Grande Ronde basin including 5 sites in the Catherine Creek basin, 4 sites in the Minam River basin, and 11 sites in the Upper Grande Ronde River basin during summer (10 Jul – 17 Sep), 2010 (Table 1; Figure 1). Sample sites were randomly selected using the Generalized Random Tessellation Stratified (GRTS) survey design. Details of the survey design and monitoring methods are described in Justice et al. (2010) and will not be discussed at length here. At each site, we conducted a standard Wolman pebble count at systematically spaced transects within each reach using a target sample size of 100 particles (Wolman 1954). Streambed particles were removed by hand and measured along their median axis using a standard US SAH-97 gravelometer.

The proportion of particles retained in each size class p_r was estimated as:

$$p_r = \frac{X}{n},$$

where X is the number of particles retained in each size class, and n is the total number of particles in the sample. The standard error for p_r in each size class was calculated using a standard formula for a binomial distribution (Zar 1999):

$$s_{p_r} = \sqrt{\frac{p_{r(1-p_r)}}{n-1}}.$$

The 95% confidence limits for the p_r were computed using a relationship between the F distribution and the binomial distribution as described in Zar (1999). The lower confidence limit for p_r is:

$$L_1 = \frac{X}{X + (n - X + 1)F_{a(2),v_1,v_2}},$$

where $v_1 = 2(n - X + 1)$, and $v_2 = 2X$.

The upper confidence limit for p_r is:

$$L_2 = \frac{(X+1)F_{a(2),v_1',v_2'}}{n-X+(X+1)F_{a(2),v_1',v_2'}},$$

where $v_1' = 2(X+1)$, and $v_2' = 2(n-X)$.

This method for estimating standard error and confidence intervals relies on the assumption that the frequencies within individual size classes are binomially distributed, and that frequencies among size classes are completely independent. These assumptions are not technically accurate because the frequency data collected for multiple size classes are actually multinomially distributed and some degree of covariance between size classes is expected. To account for this, we also computed proportions for each size class and associated standard errors assuming multinomially distributed frequency data using a maximum likelihood approach. We compared the difference between these two approaches using the data from the Grande Ronde above Five Points Creek and found that the standard error for p_r differed by less than $2X10^{-5}$ on average across all size classes. Because the difference was essentially negligible, we proceeded with calculations based on a binomial distribution for ease of calculation.

Cumulative size frequency distributions were calculated for each site by summing the p_r and confidence limits from all smaller size classes. The proportion of particles finer than a given size class p_f was then calculated by simply lagging the size class by one. For example, p_r for size class 2mm becomes p_f for size class 3.35mm.

The percentage of fine sediment particles less than 2 and 6.3mm were estimated for each site because these metrics are commonly used to evaluate effects of fine sediment on egg-to-fry survival of salmonid fishes (Chapman and McLeod 1987). Additionally, we estimated percentile values D5, D16, D50, D84, and D95 for each site, which are often used as descriptive statistics to compare two or more particle size distributions. Percentile values were estimated using logarithmic interpolation, which means that the mm size classes were log transformed prior to

linear interpolation (Bunte and Abt 2001). For example, the particle size of a desired percentile *x* was computed from:

$$D_x = e^{\left((\ln(x_2) - \ln(x_1)) * \left(\frac{y_x - y_1}{y_2 - y_1}\right) + \ln(x_1)\right)},$$

where y_1 and y_2 are the cumulative percent frequencies just below and above the desired cumulative frequency y_x, and x_1 and x_2 are the particle sizes in mm corresponding with the cumulative frequencies y_1 and y_2.

Table 1. Description of sediment sampling sites in the upper Grande Ronde River, Catherine Creek, and Minam River basins during summer, 2010.

Basin	Stream	Reach ID	Sample Date	Sample Type	UTM Easting	UTM Northing
Catherine	Catherine Creek	C39887	9/16/2010	Surface, Subsurface	431808.657756	5006732.257640
Catherine	Catherine Creek	C47449	7/21/2010	Surface, Subsurface	443968.588279	4998224.509580
Catherine	North Fork Catherine Creek	C53882	7/29/2010	Surface	449305.146630	4996659.801310
Catherine	North Fork Catherine Creek	C57610	9/16/2010	Surface	451456.670398	5000044.795180
Catherine	South Fork Catherine Creek	C51288	9/14/2010	Surface	455504.151142	4994701.822820
Grande Ronde	Beaver Creek	U99999	8/24/2010	Surface, Subsurface	398001.544463	5008309.620010
Grande Ronde	Fly Creek	U115205	8/11/2010	Surface	385854.596383	4997916.968420
Grande Ronde	Grande Ronde River	U111108	7/27/2010	Surface, Subsurface	390902.441283	5010925.685610
Grande Ronde	Grande Ronde River	U127576	7/12/2010	Surface	392549.937637	4998780.140260
Grande Ronde	Grande Ronde River	U155154	7/10/2010	Surface, Subsurface	397786.846071	4989994.805490
Grande Ronde	Grande Ronde River	U45702	7/20/2010	Surface, Subsurface	400054.778558	5018994.445300
Grande Ronde	Grande Ronde River	U69053	8/13/2010	Surface	392829.883605	5013594.026260
Grande Ronde	Meadow Creek	U100985	9/17/2010	Surface	374824.397848	5015534.562290
Grande Ronde	Meadow Creek	U74443	8/12/2010	Surface, Subsurface	390763.300100	5013250.771600
Grande Ronde	Spring Creek	U37635	7/30/2010	Surface	400358.806811	5020199.692060
Grande Ronde	West Chicken Creek	U131944	7/28/2010	Surface	389648.687112	4990487.106730
Minam	Little Minam River	M53072	8/5/2010	Surface	448801.664532	5021776.558770
Minam	Little Minam River	M9999	8/5/2010	Surface, Subsurface	448720.692731	5021989.373970
Minam	Minam River	M53240	8/2/2010	Surface, Subsurface	451241.375876	5021502.295210
Minam	Minam River	M53247	8/3/2010	Surface	452630.707863	5021195.426320

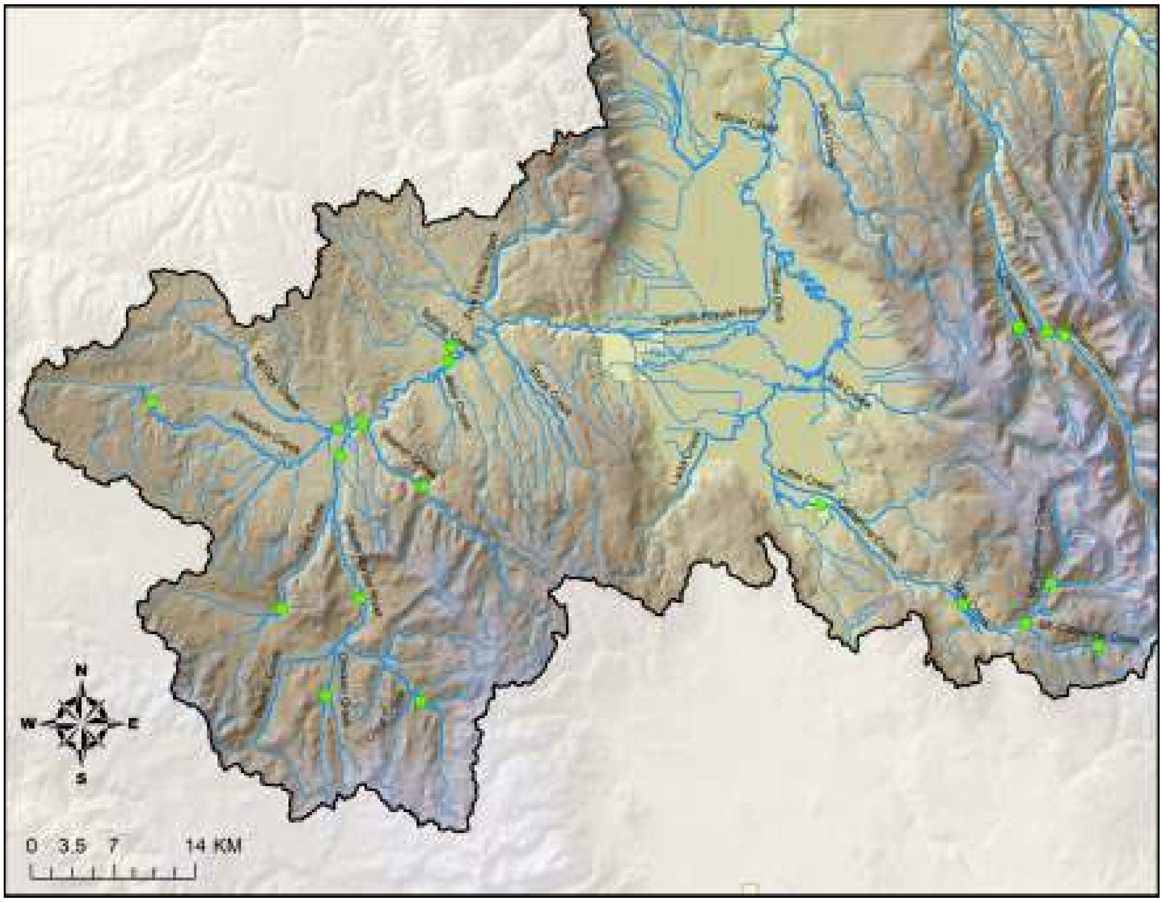


Figure 1. Sediment sampling sites in the Upper Grande Ronde River, Catherine Creek, and Minam River basins during summer, 2010.

Subsurface sediment sampling

We measured subsurface sediment size composition in potential spawning areas in 9 out of the 20 reaches sampled in the Catherine Creek, Minam River, and Upper Grande Ronde River basins (Table 1; Figure 1). Subsurface samples were not collected in all 20 reaches because many of these reaches did not contain suitable spawning gravels. Prior to collecting samples, we delineated “patches” of potential spawning habitat within each reach based on literature-derived criteria for depth, velocity, area, and dominant substrate size (Justice et al. 2010). Nine potential spawning patches were randomly selected within each reach, and a random location within each patch was identified for collection of a core sample. We used a modified McNeil sampler to extract core samples from each location. Core dimensions on the sampler were 20 cm diameter

by 20 cm height, producing bulk samples ranging in mass from 7 to 15 kg (mean = 11 kg) (Figure 2).

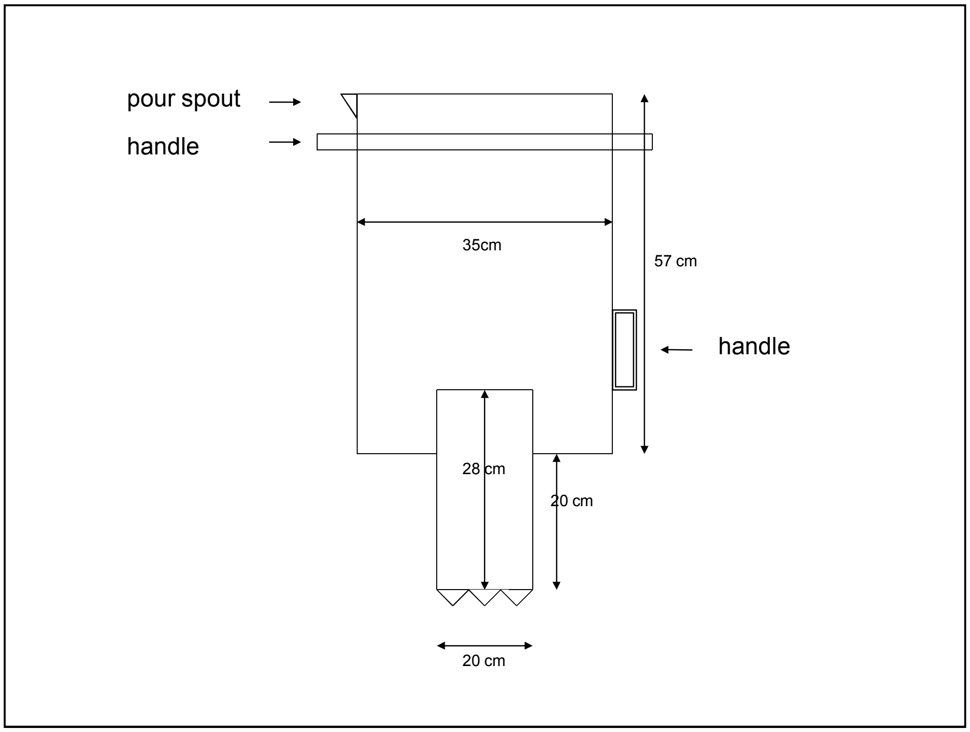


Figure 2. Diagram of modified stainless steel McNeil sediment sampler.

Bulk samples were transported to the lab where they were dried in a drying oven at approximately 110°C. After returning samples to room temperature, they were sorted using an automatic sieve shaker for a period of 10 minutes. Sieve sizes included 0.125, 0.355, 0.85, 2, 3.35, 4, 6.3, 8, 11.2, 16, 31.5, and 63 mm. The mass of particles in each size class was weighed to the nearest 0.1 grams, and the sorted sediment was saved for use in fine sediment infiltration studies

Using methods similar to those previously described for surface sediment sampling, we calculated cumulative sediment size distribution curves for each bulk sample and computed an average cumulative distribution curve for each site. The percentage of sediment particles finer than 0.85, 3.35, 6.3, and 9.5 mm was estimated for each site. Prior to calculating the fraction of fine sediment in each sample, we truncated the data by removing all sediment particles > 63mm from the sample to correspond as closely as possible with a study of sediment effects on

salmonid embryo survival by Tappel and Bjornn (1983). Figures of cumulative size distributions for each site were generated from the non-truncated dataset. Similarly, we estimated percentile values D5, D16, D50, D84, and D95 for each site using the non-truncated data using logarithmic interpolation as described previously.

Confidence intervals for the proportion of sediment particles finer than a given size criteria p_f and percentile values (e.g., D5) were calculated using the standard formula for the confidence interval of a mean (Zar 1999):

$$\bar{X} \pm t_{\alpha(2),v} s_{\bar{X}},$$

where

$$s_{\bar{x}} = \sqrt{\frac{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}{n(n-1)}}.$$

In this case, values of p_f or percentile were substituted for X_i in the above formula. We selected an α value of 0.05 for computation of 95% confidence intervals.

We examined the potential implications of observed levels of subsurface fine sediment on Chinook egg-to-fry survival using predictive formulas developed from laboratory studies. Perhaps the most thorough evaluation of the effects of fine sediment on salmonid survival to emergence was done by Tappel and Bjornn (1983), who evaluated the survival impacts of different combinations of fine sediment including particles less than 0.85 and 9.5 mm. The proportion of fine sediment in the spawning gravels explained approximately 93% of the variability in Chinook survival to emergence. The relationship relating fine sediment to percent survival to emergence s_e was given by:

$$s_e = 93.4 - 0.171 p_{9.5} \cdot p_{0.85} + 3.87 p_{0.85},$$

where $p_{9.5}$ and $p_{0.85}$ denote the percentage of sediment particles in the spawning gravel that is less than 9.5 and 0.85 mm respectively. Note that the spawning gravels used in the study by Tappel and Bjornn (1983) were limited to particles less than 25.4 mm, so it was necessary to

truncate our sediment data to exclude particles exceeding this size criteria to ensure comparability with their study results.

We also used an alternative relationship developed by Irving and Bjornn (1984) based on the same data as Tappel and Bjornn (1983) to compare survival estimates based on different size criteria. In this study, the authors developed a relationship between survival to emergence and the percentage of sediment particles smaller than 6.35 mm $p_{6.35}$:

$$s_e = \frac{96.0}{1+e^{-8.1+0.2p_{6.35}}}.$$

Confidence intervals for survival estimates were computed by inputting the 95% confidence intervals for $p_{9.5}$, $p_{0.85}$, and $p_{6.35}$ estimated from the sediment data into the survival formulas above. The resulting 95% confidence intervals for the survival estimates do not incorporate variability in the predictive relationships from Tappel and Bjornn (1983) and Irving and Bjornn (1984), and as a result, they likely underestimate the amount of variation in predicted survival rates.

Results

Surface Sediment

The percentage of surface fine sediment < 6.3 mm across all sites ranged from 0.9 to 34.1% (mean = 14.3%), with the Grande Ronde River upstream of Clear Creek (Reach U155154) having the highest fine sediment loading of the sites evaluated (Table 2; Figure 3). On average, Minam River sites had the lowest amount of fine sediment < 6.3 mm (mean = 8.8%), while Catherine Creek sites had the highest (mean = 17.4%). Similar patterns were observed for fine sediment < 2mm (Figure 4). The size frequency distribution of streambed particles appeared to be bimodal, with a relatively small peak in particle frequencies occurring at 2mm, and a second larger peak occurring between 45 and 90 mm (Figures 3-5). The particle size distribution varied widely across sites (Figures 6-8), consistent with the large range in channel size, location, and geomorphic reach type observed across sites.

The fifth percentile, or D5 of the cumulative sediment size distribution ranged from 0.1 to 28.8 mm across all sites (mean = 4.8 mm), with the Minam River (Reach M53247) having largest D5 value and Meadow Creek (Reach U100985) having the smallest (Table 3). Consistent with patterns in percent fines, D5 was generally highest in Minam River sites (mean = 11.3 mm) and lowest in Catherine Creek sites (mean = 0.9 mm). Median particle size, or D50 ranged from 26.5 to 272.1 mm across all sites (mean = 75.7), with the Minam River (Reach M53247) having the largest dominant particle size.

Table 2. Percentage of surface sediment particles finer than 2 mm and 6 mm measured at 20 sites in the Catherine Creek, Minam River, and Upper Grande Ronde River basins during summer 2010.

		Percent Fines < 2 mm			Percent Fines < 6.35 mm		
Stream	Reach ID	Estimate	LCI	UCI	Estimate	LCI	UCI
Catherine Creek Basin							
Catherine Creek	C39887	9.4	5.0	15.9	13.2	7.9	20.3
Catherine Creek	C47449	15.0	10.3	20.9	17.8	12.7	24.0
South Fork Catherine Creek	C51288	3.6	1.0	9.0	8.6	4.1	15.4
North Fork Catherine Creek	C53882	22.9	16.5	30.4	28.6	21.6	36.4
North Fork Catherine Creek	C57610	13.7	8.4	20.8	19.1	12.7	26.9
Average		12.9	8.2	19.4	17.4	11.8	24.6
Min		3.6	1.0	9.0	8.6	4.1	15.4
Max		22.9	16.5	30.4	28.6	21.6	36.4
Minam River Basin							
Little Minam River	M53072	2.0	0.2	6.9	4.9	1.6	11.1
Minam River	M53240	11.8	6.1	20.2	21.5	13.7	31.2
Minam River	M53247	1.9	0.2	6.5	2.8	0.6	7.9
Little Minam River	M9999	3.3	0.9	8.3	6.1	2.6	12.0
Average		4.7	1.9	10.5	8.8	4.6	15.6
Min		1.9	0.2	6.5	2.8	0.6	7.9
Max		11.8	6.1	20.2	21.5	13.7	31.2
Upper Grande Ronde River Basin							
Meadow Creek	U100985	27.8	19.6	37.2	28.1	19.9	37.6
Grande Ronde River	U111108	4.3	1.4	9.9	7.3	3.3	13.6
Fly Creek	U115205	12.6	6.9	20.6	23.1	15.4	32.4
Grande Ronde River	U127576	4.9	1.4	12.2	15.7	8.6	25.5
West Chicken Creek	U131944	4.5	1.5	10.1	13.5	7.8	21.2
Grande Ronde River	U155154	15.1	8.5	24.0	34.1	24.6	44.6
Spring Creek	U37635	4.7	1.5	10.6	10.0	5.1	17.3
Grande Ronde River	U45702	7.6	3.3	14.5	12.1	6.6	19.9
Grande Ronde River	U69053	2.8	0.6	8.0	4.7	1.5	10.7
Meadow Creek	U74443	7.0	3.3	12.9	14.1	8.6	21.4
Beaver Creek	U99999	0.0	0.0	3.3	0.9	0.0	4.9
Average		8.3	4.4	14.8	14.9	9.2	22.6
Min		0.0	0.0	3.3	0.9	0.0	4.9
Max		27.8	19.6	37.2	34.1	24.6	44.6

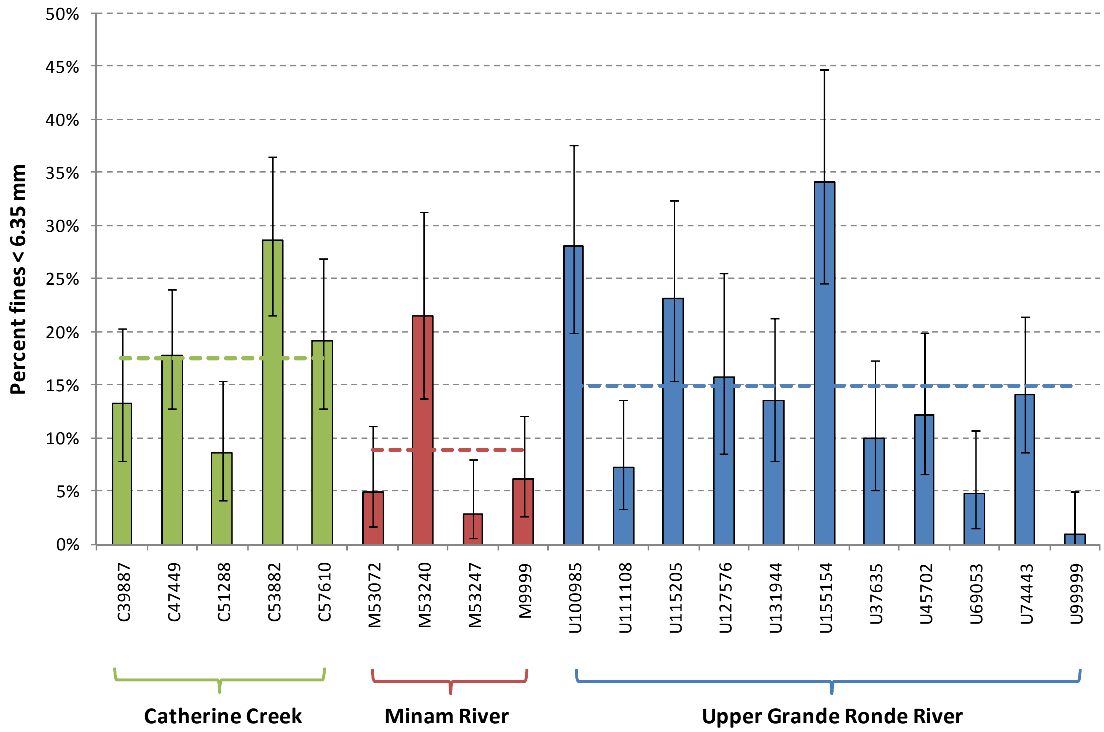


Figure 3. Percent fines < 6.35 mm from surface pebble counts at 20 sites in the Catherine Creek, Minam River, and Upper Grande Ronde River basins during summer 2010.

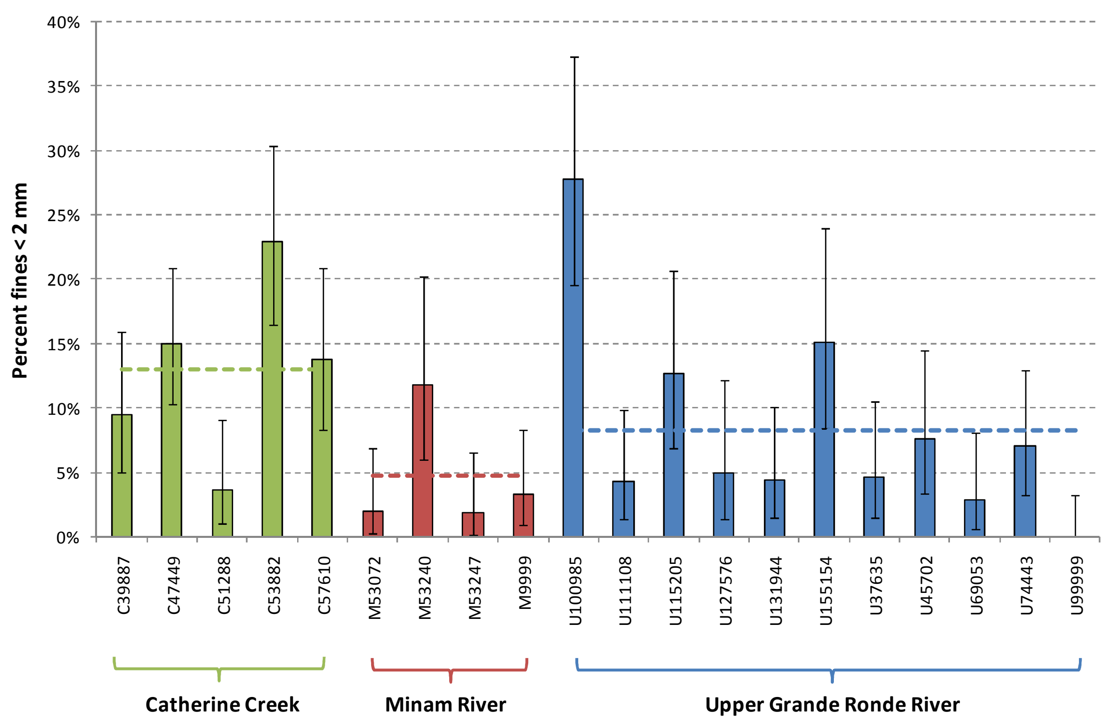


Figure 4. Percent fines < 2 mm from surface pebble counts at 20 sites in the Catherine Creek, Minam River, and Upper Grande Ronde River basins during summer 2010.

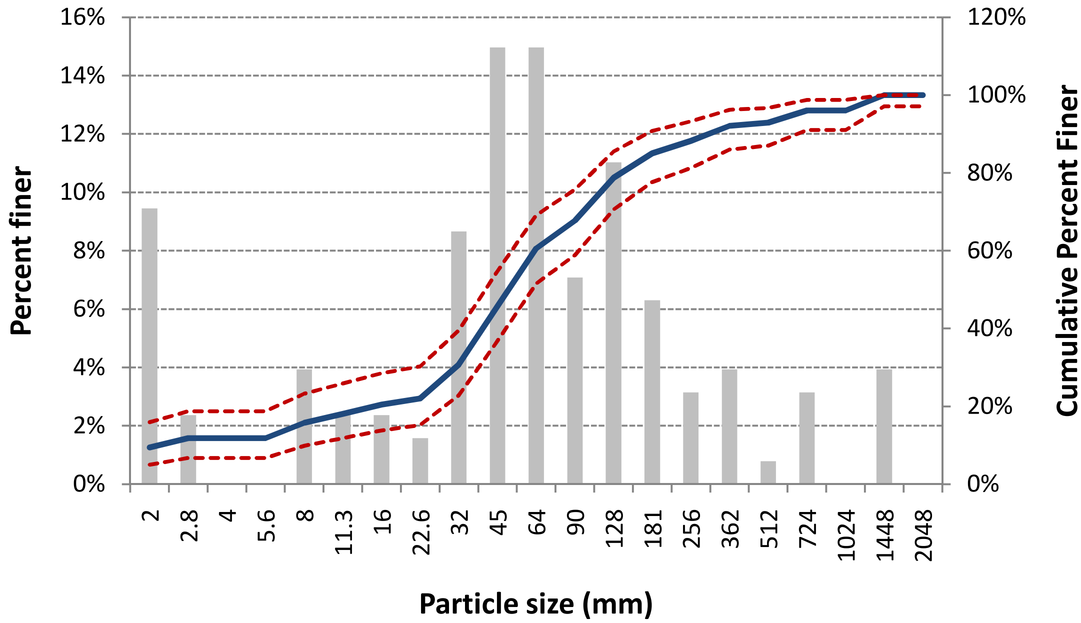


Figure 5. . Surface sediment size distribution for Catherine Creek near Union (Reach C39887) during summer 2010. Dashed lines denote the 95% confidence interval for the cumulative distribution.

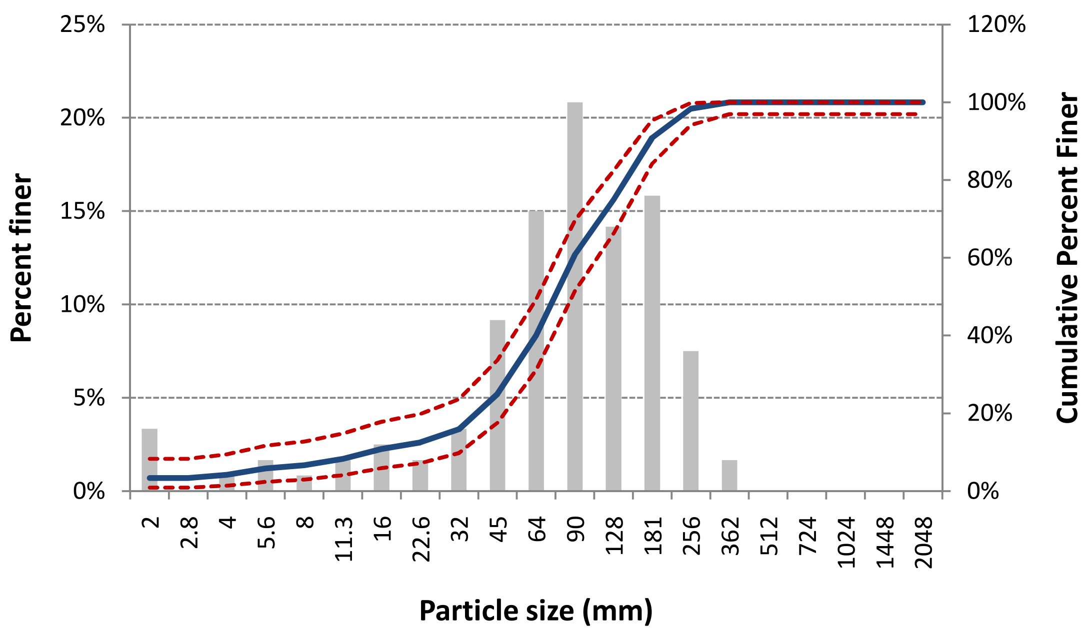


Figure 6. Surface sediment size distribution for the Little Minam River (Reach M9999) during summer 2010. Dashed lines denote the 95% confidence interval for the cumulative distribution.

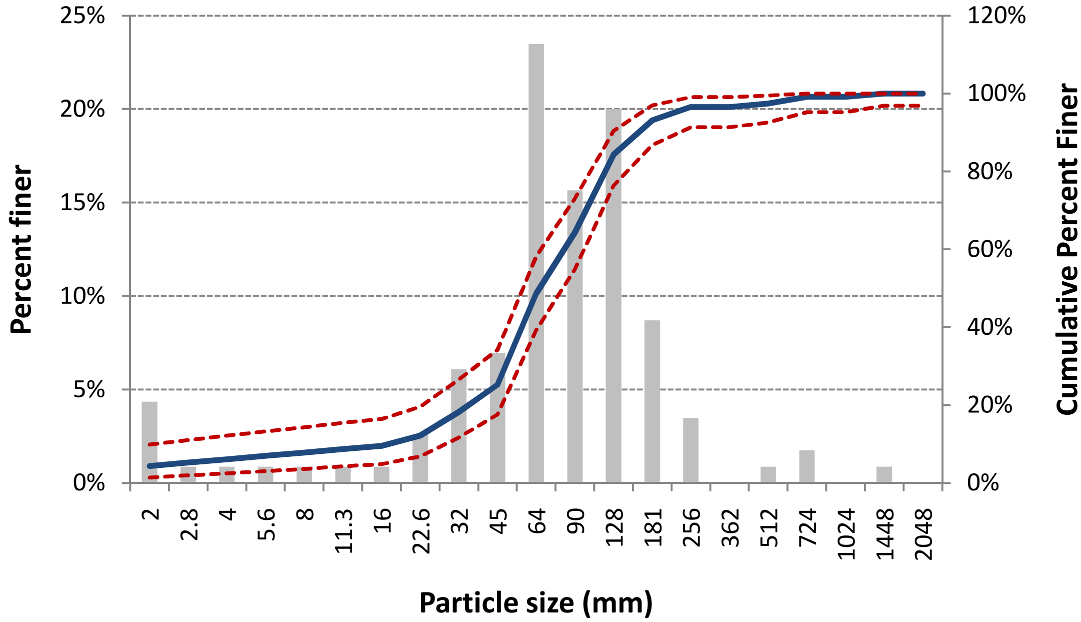


Figure 7. Surface sediment size distribution for the Grande Ronde River near Starkey store (Reach U111108) during summer 2010. Dashed lines denote the 95% confidence interval for the cumulative distribution.

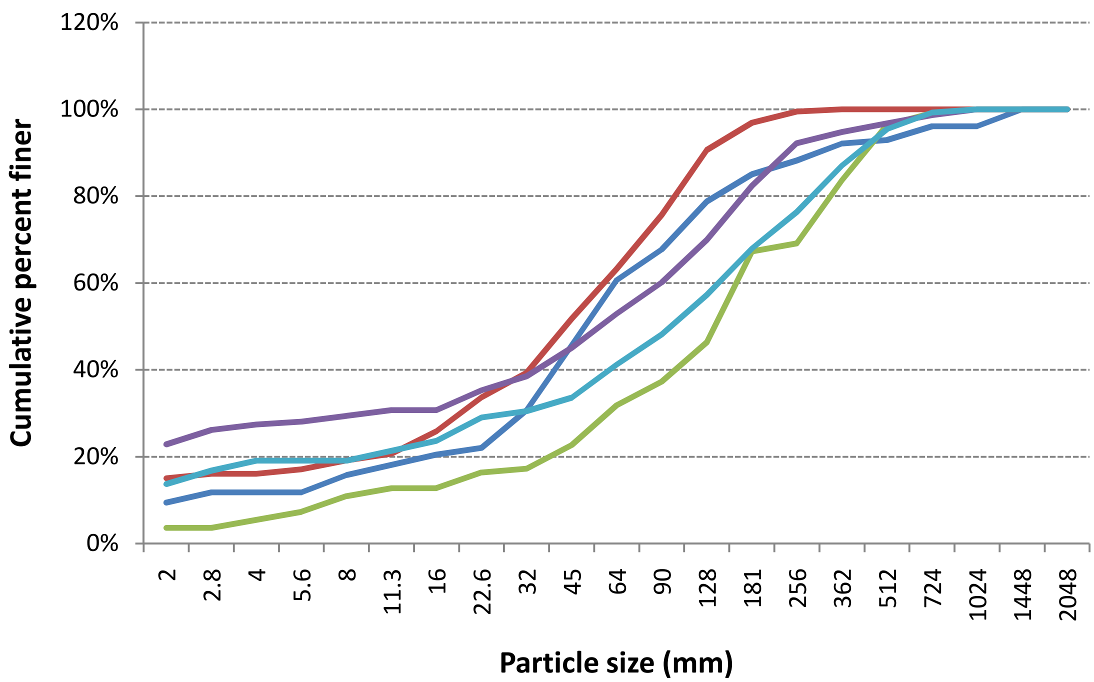


Figure 8. Cumulative particle size distribution curves from surface pebble counts at 5 sites in the Catherine Creek basin during summer 2010.

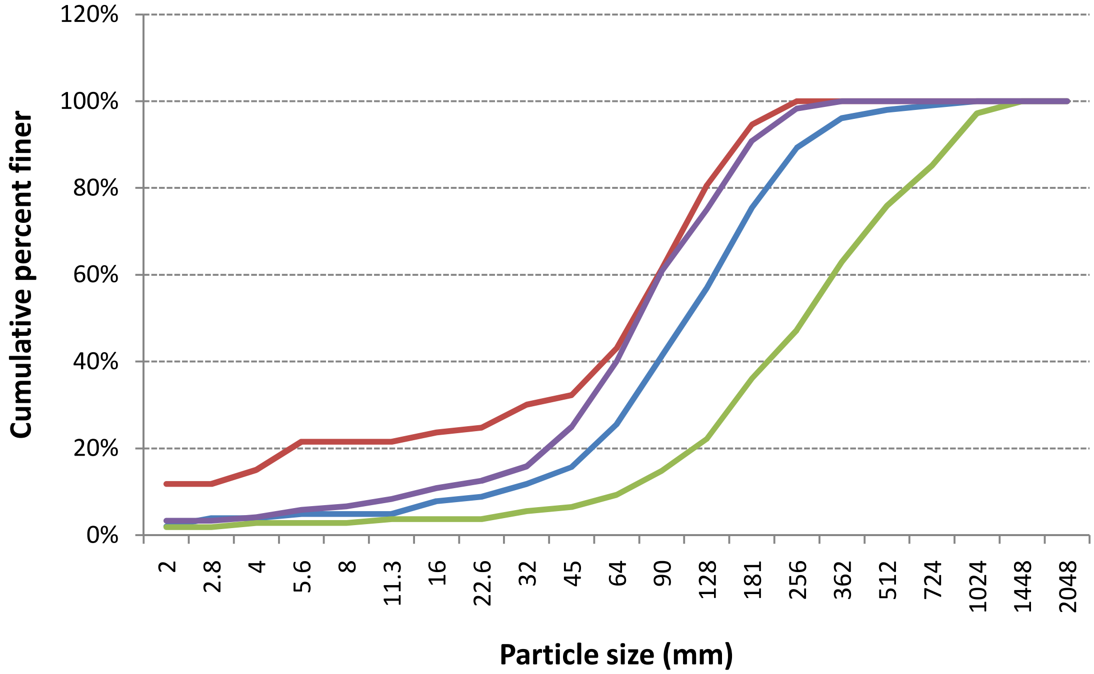


Figure 9. Cumulative particle size distribution curves from surface pebble counts at 4 sites in the Minam River basin during summer 2010.

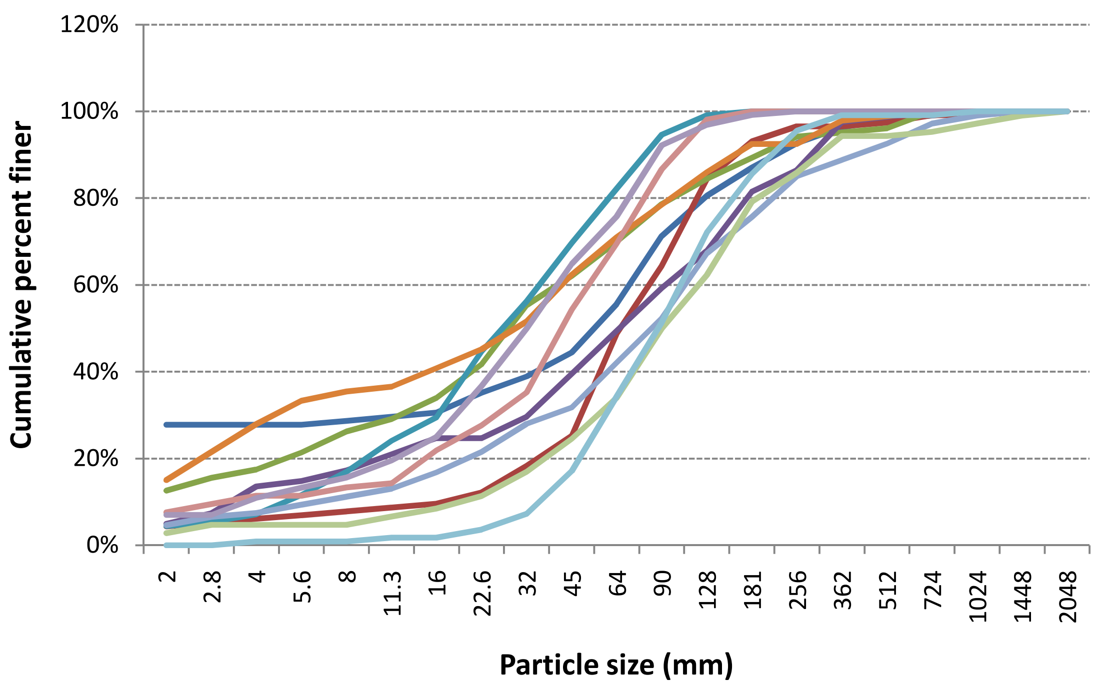


Figure 10. Cumulative particle size distribution curves from surface pebble counts at 11 sites in the upper Grande Ronde River basin during summer 2010.

Table 3. Percentile values for surface fine sediment particle size (mm) measured at three sites in the Grande Ronde River basin in summer, 2009. Summary statistics across sites include the mean, standard deviation (SD) and coefficient of variation (CV= 100* S.D./mean).

		Percentile Particle Size (mm)						
Stream	Reach ID	D5	D16	D25	D50	D75	D84	D95
Catherine Creek Basin								
Catherine Creek	C39887	0.4	8.3	25.4	49.8	113.6	170.9	644.1
Catherine Creek	C47449	0.2	2.7	15.1	42.8	88.4	109.5	162.9
North Fork Catherine Creek	C53882	0.1	0.7	2.5	56.1	147.4	191.9	376.9
North Fork Catherine Creek	C57610	0.2	2.6	17.4	96.9	242.3	328.2	503.2
South Fork Catherine Creek	C51288	3.7	21.8	49.1	135.9	294.7	365.6	493.3
Average		0.9	7.2	21.9	76.3	177.3	233.2	436.1
Min		0.1	0.7	2.5	42.8	88.4	109.5	162.9
Max		3.7	21.8	49.1	135.9	294.7	365.6	644.1
Minam River Basin								
Little Minam River	M53072	11.4	45.5	62.9	109.7	179.4	224.4	342.8
Little Minam River	M9999	4.7	32.2	45.0	75.4	128.0	155.9	219.4
Minam River	M53240	0.3	4.2	23.0	72.9	115.5	139.1	185.4
Minam River	M53247	28.8	95.2	137.2	272.1	499.5	692.6	960.5
Average		11.3	44.3	67.0	132.5	230.6	303.0	427.1
Min		0.3	4.2	23.0	72.9	115.5	139.1	185.4
Max		28.8	95.2	137.2	272.1	499.5	692.6	960.5
Upper Grande Ronde River Basin								
Beaver Creek	U99999	25.9	43.3	52.9	87.6	138.0	173.8	251.6
Fly Creek	U115205	0.2	3.1	7.3	27.9	78.1	124.4	343.7
Grande Ronde River	U111108	2.6	28.1	44.5	65.8	108.6	127.2	220.0
Grande Ronde River	U127576	2.0	6.6	23.1	65.4	153.4	216.0	334.5
Grande Ronde River	U155154	0.2	2.1	3.4	29.3	76.8	116.4	301.3
Grande Ronde River	U45702	0.6	12.2	19.3	41.7	71.4	85.4	116.4
Grande Ronde River	U69053	8.4	30.1	45.8	90.0	166.0	232.3	652.5
Meadow Creek	U100985	0.1	0.5	1.4	53.7	103.6	153.9	320.7
Meadow Creek	U74443	0.7	8.3	16.0	32.0	62.4	75.9	111.2
Spring Creek	U37635	2.1	14.8	27.2	83.3	175.8	246.3	615.2
West Chicken Creek	U131944	2.4	7.5	12.0	26.5	52.3	67.3	92.6
Average		4.1	14.2	23.0	54.8	107.9	147.2	305.4
Min		0.1	0.5	1.4	26.5	52.3	67.3	92.6
Max		25.9	43.3	52.9	90.0	175.8	246.3	652.5

Subsurface sediment

The percentage of fine sediment (i.e., < 6.3 mm) in subsurface samples was generally higher and more consistent across sites than in surface samples with values ranging from 22.3% in the Little Minam River to 33.8% in the Grande Ronde River above Clear Creek (mean across sites = 28.2%) (Table 4). The average D5 in the subsurface ranged from 0.7 mm in the Grande Ronde River above Clear Creek (Reach U155154) to 1.6 mm in the Little Minam River (Reach M9999) (mean across sites = 1.1 mm) (Table 5). Similarly, median particle size (D50) ranged from 24.5 mm in Meadow Creek to 39.7 mm in the Little Minam River (mean across sites = 31.9 mm).

Consistent with the surface sediment distributions, the frequency distributions of subsurface particles appeared to have a bimodal distribution with a smaller peak occurring around 2 mm, and a second larger peak occurring around 63 to 90 mm (Figure 11). In contrast with the surface sediment data, the subsurface sediment size composition was generally very consistent across sites as evidenced by the tight clustering of cumulative distribution curves (Figure 12). This is to be expected to some degree because the subsurface samples were all taken in locations that were previously selected based on depth, velocity, and substrate size criteria.

Predicted egg-to-fry survival rates based on sediment size criteria of 0.85 and 9.5 mm (Tappel and Bjornn 1983) ranged from 64.4% to 89.6% (mean across sites = 79.7%), with Catherine Creek near Union (Reach C39886) having the lowest estimated survival rate (Table 6). Predicted survival rates based on a size criteria of 6.3 mm (Irving and Bjornn 1983) were slightly higher, ranging from 76.2 to 93.5% (mean across sites = 86.7%). Overall, fine sediment levels in the spawning gravels were generally low and very similar across the 9 sites evaluated suggesting that survival to emergence at these sites would be expected to be fairly high. However, a sample size of 9 is insufficient to make conclusive generalizations about fine sediment conditions in Chinook spawning areas, and additional years of data will be necessary to adequately characterize the spawning gravel quality in these basins.

Table 4. Percentage of fine sediment in subsurface bulk samples (truncated data[a]) measured at 9 sites in the Catherine Creek, Minam River, and Upper Grande Ronde River basins during summer 2010. Calculations of percent finer are provided for four commonly used particle size criteria including 0.85, 3.35, 6.3, and 9.5 mm.

								95 % Confidence Interval	
Basin	Stream	Reach ID	Avg. % Finer	Stdev	n	SE	CV	Lower	Upper
			Percent Fines < 0.85 mm						
Catherine	Catherine Creek	C39887	8.4	2.6	7	1.0	30.9	6.0	10.8
Catherine	Catherine Creek	C47449	6.8	2.5	9	0.8	37.2	4.8	8.7
Grande Ronde	Beaver Creek	U99999	2.9	0.6	2	0.4	19.7	0.0	8.0
Grande Ronde	Grande Ronde River	U111108	5.4	5.5	9	1.8	101.6	1.2	9.6
Grande Ronde	Grande Ronde River	U155154	8.4	2.6	9	0.9	31.2	6.4	10.4
Grande Ronde	Grande Ronde River	U45702	4.7	1.2	9	0.4	25.4	3.8	5.6
Grande Ronde	Meadow Creek	U74443	5.5	1.3	6	0.5	22.8	4.2	6.8
Minam	Little Minam River	M9999	4.8	1.9	5	0.9	40.0	2.4	7.1
Minam	Minam River	M53240	6.4	1.4	5	0.6	22.4	4.7	8.2
			Percent Fines < 3.35 mm						
Catherine	Catherine Creek	C39887	23.4	4.8	7	1.8	20.7	18.9	27.9
Catherine	Catherine Creek	C47449	20.6	6.1	9	2.0	29.4	15.9	25.3
Grande Ronde	Beaver Creek	U99999	15.9	0.4	2	0.3	2.3	12.7	19.2
Grande Ronde	Grande Ronde River	U111108	19.9	7.4	9	2.5	37.0	14.3	25.6
Grande Ronde	Grande Ronde River	U155154	25.1	6.4	9	2.1	25.5	20.2	30.0
Grande Ronde	Grande Ronde River	U45702	18.0	3.6	9	1.2	20.1	15.2	20.8
Grande Ronde	Meadow Creek	U74443	21.4	3.4	6	1.4	16.1	17.7	25.0
Minam	Little Minam River	M9999	14.9	4.4	5	2.0	29.3	9.5	20.4
Minam	Minam River	M53240	18.1	4.6	5	2.0	25.2	12.5	23.8
			Percent Fines < 6.3 mm						
Catherine	Catherine Creek	C39887	33.7	6.3	7	2.4	18.8	27.8	39.6

Basin	Stream	Reach ID	Avg. % Finer	Stdev	n	SE	CV	95 % Confidence Interval Lower	Upper
Catherine	Catherine Creek	C47449	28.3	7.8	9	2.6	27.6	22.3	34.3
Grande Ronde	Beaver Creek	U99999	23.8	1.5	2	1.1	6.4	10.2	37.4
Grande Ronde	Grande Ronde River	U111108	27.5	8.1	9	2.7	29.3	21.3	33.8
Grande Ronde	Grande Ronde River	U155154	33.8	6.4	9	2.1	18.9	28.9	38.7
Grande Ronde	Grande Ronde River	U45702	26.4	5.1	9	1.7	19.5	22.5	30.4
Grande Ronde	Meadow Creek	U74443	31.3	4.5	6	1.8	14.3	26.6	35.9
Minam	Little Minam River	M9999	22.3	5.2	5	2.3	23.1	15.9	28.7
Minam	Minam River	M53240	27.1	6.8	5	3.0	25.1	18.7	35.6
			Percent Fines < 9.5 mm						
Catherine	Catherine Creek	C39887	42.8	7.7	7	2.9	17.9	35.7	49.9
Catherine	Catherine Creek	C47449	34.9	9.8	9	3.3	28.1	27.4	42.5
Grande Ronde	Beaver Creek	U99999	30.5	3.1	2	2.2	10.3	2.3	58.6
Grande Ronde	Grande Ronde River	U111108	33.9	8.4	9	2.8	24.9	27.4	40.3
Grande Ronde	Grande Ronde River	U155154	39.3	5.7	9	1.9	14.4	34.9	43.6
Grande Ronde	Grande Ronde River	U45702	33.7	6.2	9	2.1	18.5	28.9	38.4
Grande Ronde	Meadow Creek	U74443	39.2	5.0	6	2.0	12.8	33.9	44.4
Minam	Little Minam River	M9999	28.7	5.9	5	2.6	20.4	21.4	36.0
Minam	Minam River	M53240	34.2	8.5	5	3.8	24.8	23.6	44.7

[a]Data were truncated at 64 mm (i.e., all particles > 63 mm were excluded from the sample) to correspond as closely as possible with a study by Tappel and Bjornn (1983).

Table 5. Percentile values for sediment particle size distributions from subsurface bulk samples (non-truncated data) measured at five sites in the Catherine Creek, Minam River, and Upper Grande Ronde River basins during summer, 2010.

									95 % Confidence Interval	
Basin	Stream	Reach	Percentile	Avg Particle Size (mm)	Stdev	n	SE	CV	Lower	Upper
Catherine	Catherine Creek	C39887	D5	0.8	0.2	7	0.1	0.2	0.6	1.0
Catherine	Catherine Creek	C47449	D5	1.1	0.6	9	0.2	0.6	0.6	1.5
Grande Ronde	Beaver Creek	U99999	D5	1.3	0.1	2	0.0	0.1	0.7	1.9
Grande Ronde	Grande Ronde River	U111108	D5	1.2	0.5	9	0.2	0.4	0.8	1.6
Grande Ronde	Grande Ronde River	U155154	D5	0.7	0.3	9	0.1	0.4	0.5	1.0
Grande Ronde	Grande Ronde River	U45702	D5	1.1	0.4	9	0.1	0.3	0.9	1.4
Grande Ronde	Meadow Creek	U74443	D5	1.0	0.2	6	0.1	0.2	0.7	1.2
Minam	Little Minam River	M9999	D5	1.6	1.3	5	0.6	0.8	0.0	3.2
Minam	Minam River	M53240	D5	0.9	0.1	5	0.1	0.1	0.8	1.0
Catherine	Catherine Creek	C39887	D16	3.7	1.3	7	0.5	0.4	2.4	4.9
Catherine	Catherine Creek	C47449	D16	6.3	6.6	9	2.2	1.1	1.2	11.4
Grande Ronde	Beaver Creek	U99999	D16	4.9	0.8	2	0.5	0.2	0.0	11.8
Grande Ronde	Grande Ronde River	U111108	D16	4.7	1.8	9	0.6	0.4	3.3	6.1
Grande Ronde	Grande Ronde River	U155154	D16	3.0	1.7	9	0.6	0.6	1.7	4.2
Grande Ronde	Grande Ronde River	U45702	D16	4.6	2.3	9	0.8	0.5	2.8	6.4
Grande Ronde	Meadow Creek	U74443	D16	3.4	1.0	6	0.4	0.3	2.3	4.4
Minam	Little Minam River	M9999	D16	7.6	5.8	5	2.6	0.8	0.4	14.8
Minam	Minam River	M53240	D16	4.5	1.0	5	0.4	0.2	3.3	5.7
Catherine	Catherine Creek	C39887	D50	28.9	12.8	7	4.9	0.4	17.0	40.8
Catherine	Catherine Creek	C47449	D50	35.4	13.3	9	4.4	0.4	25.2	45.6
Grande Ronde	Beaver Creek	U99999	D50	30.1	7.4	2	5.2	0.2	0.0	96.7

									95 % Confidence Interval	
Basin	Stream	Reach	Percentile	Avg Particle Size (mm)	Stdev	n	SE	CV	Lower	Upper
Grande Ronde	Grande Ronde River	U111108	D50	35.5	7.1	9	2.4	0.2	30.0	41.0
Grande Ronde	Grande Ronde River	U155154	D50	31.8	14.3	9	4.8	0.4	20.8	42.7
Grande Ronde	Grande Ronde River	U45702	D50	28.1	10.4	9	3.5	0.4	20.1	36.1
Grande Ronde	Meadow Creek	U74443	D50	24.5	7.4	6	3.0	0.3	16.8	32.3
Minam	Little Minam River	M9999	D50	39.7	17.3	5	7.8	0.4	18.2	61.2
Minam	Minam River	M53240	D50	33.1	5.0	5	2.2	0.2	26.9	39.3
Catherine	Catherine Creek	C39887	D84	69.1	15.3	7	5.8	0.2	55.0	83.3
Catherine	Catherine Creek	C47449	D84	71.6	8.5	9	2.8	0.1	65.1	78.2
Grande Ronde	Beaver Creek	U99999	D84	68.3	4.2	2	3.0	0.1	30.5	106.1
Grande Ronde	Grande Ronde River	U111108	D84	70.7	7.8	9	2.6	0.1	64.7	76.7
Grande Ronde	Grande Ronde River	U155154	D84	66.0	10.6	9	3.5	0.2	57.9	74.2
Grande Ronde	Grande Ronde River	U45702	D84	63.5	12.9	9	4.3	0.2	53.6	73.4
Grande Ronde	Meadow Creek	U74443	D84	67.1	7.4	6	3.0	0.1	59.4	74.9
Minam	Little Minam River	M9999	D84	65.7	15.2	5	6.8	0.2	46.8	84.6
Minam	Minam River	M53240	D84	69.3	7.7	5	3.4	0.1	59.8	78.9
Catherine	Catherine Creek	C39887	D95	82.6	6.2	7	2.4	0.1	76.8	88.3
Catherine	Catherine Creek	C47449	D95	83.1	4.7	9	1.6	0.1	79.5	86.7
Grande Ronde	Beaver Creek	U99999	D95	82.6	1.6	2	1.1	0.0	68.3	96.8
Grande Ronde	Grande Ronde River	U111108	D95	83.2	3.3	9	1.1	0.0	80.6	85.7
Grande Ronde	Grande Ronde River	U155154	D95	80.6	6.1	9	2.0	0.1	75.9	85.3
Grande Ronde	Grande Ronde River	U45702	D95	77.5	10.2	9	3.4	0.1	69.7	85.4
Grande Ronde	Meadow Creek	U74443	D95	82.1	2.7	6	1.1	0.0	79.3	85.0
Minam	Little Minam River	M9999	D95	74.7	14.9	5	6.6	0.2	56.2	93.1
Minam	Minam River	M53240	D95	82.6	3.4	5	1.5	0.0	78.5	86.8

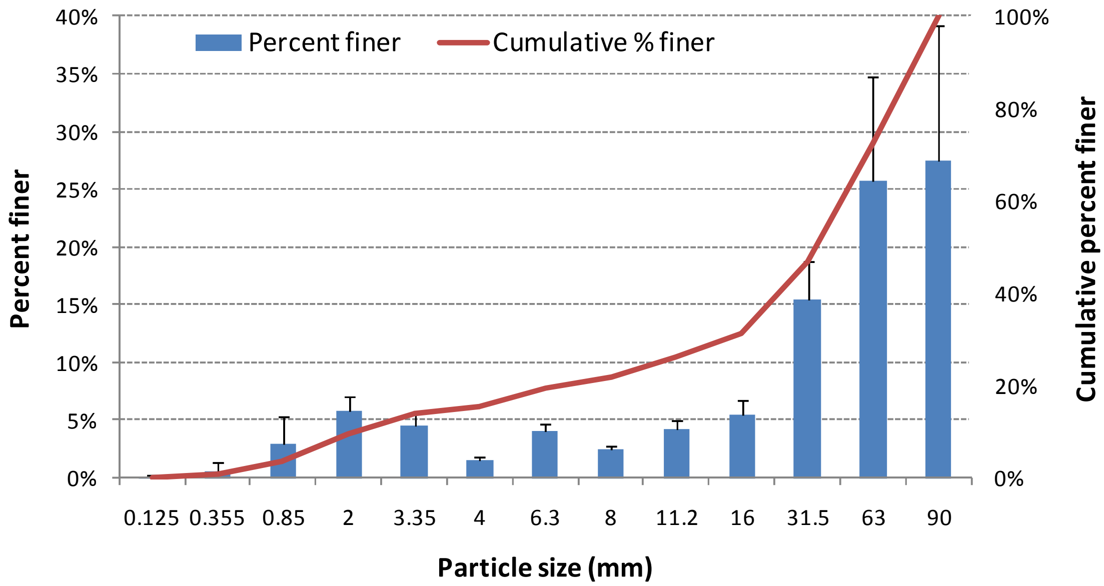


Figure 11. Average sediment size distribution from subsurface bulk samples collected in the Upper Grande Ronde River near Starkey (Reach U111108) during summer 2010. Error bars denote the standard deviation of the percent finer for each size class.

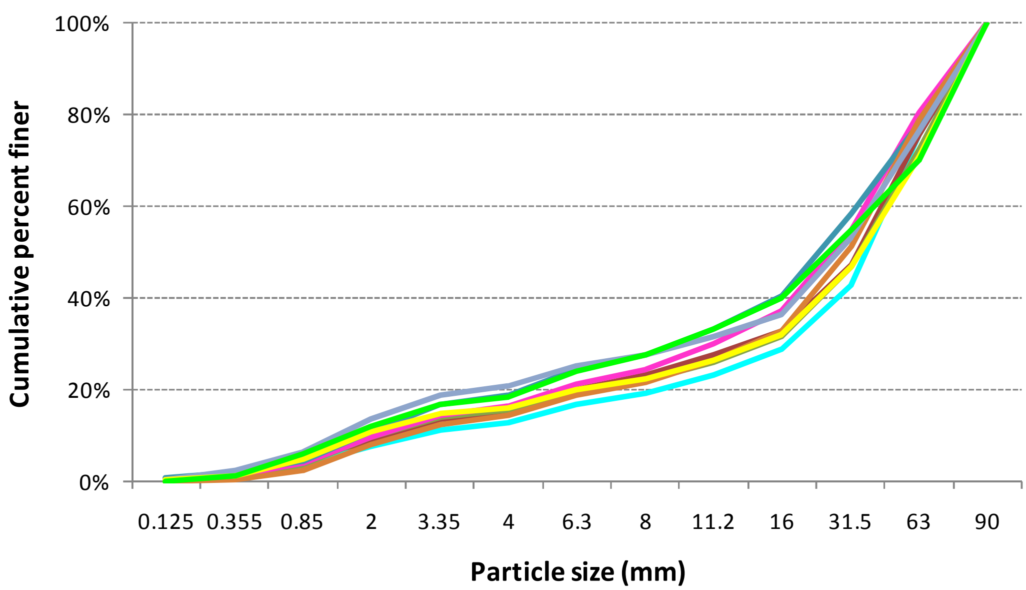


Figure 12. Average cumulative sediment size distribution curves from 9 sites in the Catherine Creek, Minam River, and Upper Grande Ronde River basins during summer 2010.

Table 6. Predicted egg-to-fry survival and associated 95% confidence intervals for 9 sites in the Catherine Creek, Minam River, and Upper Grande Ronde River basins during summer 2010.

				95 % Confidence Interval	
Basin	Stream	Reach ID	Survival Est.	Lower	Upper
Percent fines < 0.85 and 9.5 mm (Tappel and Bjornn 1983)					
Catherine	Catherine Creek	C39887	64.4	42.9	80.0
Catherine	Catherine Creek	C47449	79.1	63.8	89.4
Grande Ronde	Beaver Creek	U99999	89.6	44.4	93.4
Grande Ronde	Grande Ronde River	U111108	83.1	64.4	92.4
Grande Ronde	Grande Ronde River	U155154	69.5	56.0	80.0
Grande Ronde	Grande Ronde River	U45702	84.6	78.3	89.4
Grande Ronde	Meadow Creek	U74443	77.8	67.9	85.3
Minam	Little Minam River	M9999	88.5	77.2	93.9
Minam	Minam River	M53240	80.7	62.3	92.6
Percent fines < 6.3 mm (Irving and Bjornn 1984)					
Catherine	Catherine Creek	C39887	76.4	52.5	89.0
Catherine	Catherine Creek	C47449	88.4	74.6	93.6
Grande Ronde	Beaver Creek	U99999	92.7	62.3	95.8
Grande Ronde	Grande Ronde River	U111108	89.3	76.2	94.0
Grande Ronde	Grande Ronde River	U155154	76.2	56.6	87.5
Grande Ronde	Grande Ronde River	U45702	90.6	84.9	93.5
Grande Ronde	Meadow Creek	U74443	82.9	68.5	90.4
Minam	Little Minam River	M9999	93.5	87.7	95.3
Minam	Minam River	M53240	89.8	69.9	94.8

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Appendix K

Summary of Stream Temperature in the Upper Grande Ronde River and Catherine Creek during Summer 2010

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Summary of Stream Temperature in the Upper Grande Ronde River and Catherine Creek During Summer 2010

A component of

Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators

March 2011

Casey Justice

Dale McCullough

Seth White

Methods

We summarized stream temperature data collected from 77 sites throughout the Upper Grande Ronde River and Catherine Creek basins during the summer of 2010 (22 Jun – 29 Sep) (Table 1; Figure 1). Stream temperature measurements were mostly limited to areas within the range of historical spawning or rearing habitat for spring Chinook salmon as defined by the NOAA Technical Recovery Team (TRT) (Pers. Comm. Damon Holzer, NOAA). Exact logger locations within the drainage network were based on data requirements for calibration of a basin-wide heat source temperature model similar to that described in Boyd and Kasper (2003). Continuous stream temperature data will provide a ground truth for temperature measurements made with forward looking infrared (FLIR) technology (Watershed Sciences 2010), as well as information about temporal patterns in stream temperature that cannot be adequately assessed using FLIR.

Loggers were placed near the mouth of all tributary streams contributing at least 5% of the total mainstem discharge and in the mainstem just upstream of tributary confluences. Additional loggers were deployed at mainstem sites to capture longitudinal variation in mainstem temperatures. We did not deploy loggers at some sites because access was denied by private landowners, or because those sites were already being monitored by other agencies.

Temperature data was recorded at half-hour intervals using Onset Hobo U22 Pro v2 temperature loggers (accuracy = 0.2 °C). Prior to deployment, we checked the accuracy each logger using methods described in Ice et al. (1999). We compared the temperature measurements from each logger with measurements made with a National Institute of Standards and Technology (NIST) certified thermometer to ensure an accuracy of at least 0.3 °C. Temperature loggers were secured to the streambed using ¼ inch rebar stakes and stainless steel cable, or were cabled to tree roots along the channel margin. Most loggers were placed in steel housings to protect against physical damage and direct solar radiation. Accuracy checks were repeated after field deployment to determine if logger accuracy was maintained throughout the entire sampling period. A subset of the loggers was redeployed to collect winter and spring temperatures.

After downloading data from all of the temperature loggers, we checked the data for quality assurance using methods described in Dunham et al. (2005). Specifically, we flagged all observations that fell below -1 °C or above 30 °C, or if the rate of change was greater than 3°C between successive hourly or daily measurements. All flagged observations were then verified with personnel involved in data logger programming and field sampling, and obvious erroneous observations were removed from the database. Additionally, we examined plots of daily temperature observations to check for evidence of dewatering during the sampling period.

We calculated various temperature metrics to characterize thermal conditions at each sampling location during summer. Prior to calculating temperature metrics, we limited the data to include the summer period only (15 Jul – 15 Sep) to ensure that temperature conditions were comparable across sites. Thirteen logger sites were dropped from the analysis because they were dewatered during a portion of the summer. Most of these sites were located in lower Catherine Creek, where a significant portion of the streamflow was diverted for irrigation. This resulted in a total of 64 sites with continuous temperature data through the summer period including 18 sites in the Catherine Creek basin and 46 sites in the Upper Grande Ronde basin.

Temperature metrics included average daily temperature for the summer period (Avg), the highest instantaneous temperature recorded (Max), the lowest instantaneous temperature recorded (Min), the maximum weekly average temperature (MWAT), the maximum weekly maximum temperature (MWMT), and the greatest consecutive number of days that the daily maximum temperature exceeded the thresholds 16, 18, 20 and 24°C. MWAT was calculated as the maximum 7-day moving average of the daily average temperatures, while MWMT was defined as the maximum 7-day moving average of the daily maximum temperatures. MWMT was adopted as the statistical measure of the stream temperature standard used by Oregon Department of Environmental Quality (ODEQ) in their total maximum daily load (TMDL) evaluations (ODEQ 2000). We examined the correlation between these different temperature metrics using simple linear correlation. Correlations between different metrics should highlight potential statistical redundancies among the various metrics, and likewise, identify those metrics that provide unique information about thermal conditions in the Grande Ronde Basin.

Results

Average summer stream temperatures (mean from 15 Jul – 15 Sep) in the Catherine Creek basin ranged from 7.4 to 21.2 °C (mean = 14 °C), with the warmest temperatures observed in Lower Catherine Creek at the Booth Road bridge (Table 2; Figure 2). In the upper Grande Ronde basin, average summer temperatures ranged from 9 to 20.9 °C (mean = 14.7 °C) with the lower mainstem at Peach Road bridge having the highest average water temperature (Figure 3). Similarly, maximum weekly maximum temperatures (MWMT) ranged from 11.4 °C in upper North Fork Catherine Creek to 26.7 °C in lower Catherine Creek at the Booth Road bridge (mean = 19.5 °C) (Figure 4). MWMT in the Grande Ronde basin ranged from 12.5 to 29.1 (mean = 21.8), with the warmest MWMT recorded at the mouth of Rock Creek (Figure 5).

The consecutive number of days that maximum temperatures exceeded temperature thresholds (16, 18, 20, and 24°C) was more variable than the other temperature metrics evaluated, but the general patterns across sites were similar. For example, the number of days that maximum temperatures exceeded 24 °C in the Catherine Creek basin ranged from 0 to 29 (mean = 2), with the highest cumulative days exceeding 24 °C occurring in lower Catherine Creek at Booth Road bridge. In the upper Grande Ronde basin, consecutive days exceeding 24 °C ranged from 0 to 38 (mean = 6), with the longest period of high temperatures occurring in the mainstem Grande Ronde River at Peach Road bridge.

Stream temperatures peaked between the last week of July and first week of August at most sites (Figures 6-9). In the Catherine Creek basin, only headwater tributaries including Middle Fork Catherine Creek, North Fork Catherine Creek, South Fork Catherine Creek, and upper Milk Creek met the water temperature standard of 17.8 °C MWMT as defined by the Oregon Department of Environmental Quality (ODEQ 2000) (Table 2). This temperature standard represents the level above which significant impacts to salmonid spawning, egg incubation, and fry emergence are expected to occur. Similarly, sites in the upper Grande Ronde basin with temperatures below the ODEQ standard were limited to a hand full of tributaries such as Clear Creek and upper Limber Jim Creek, and the upper most reaches of the mainstem Grande Ronde River.

We found strong correlations between most of the temperature metrics we evaluated with the exception of the cumulative days exceeding 16 and 24 °C, which were only moderately correlated ($r = 0.577$; Table 3). The weaker correlation between these two metrics was likely due to the large number of zero values for days > 24 °C. The strong correlation among temperature metrics suggests that the all of the metrics provide relatively consistent information with respect to quantifying thermal patterns in stream temperature. The correlations among different temperature metrics may be useful for comparing the equivalence of information from other agencies or sites where temperature data may be limited to a single temperature metric such as MWAT.

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Table 1. Temperature logger sites in Catherine Creek and the Grande Ronde River deployed during the summer of 2010.

Number	Stream	Site	UTM_Easting	UTM_Northing	Start Date	Stop Date	Days
		Catherine Creek Basin					
1	Catherine Creek	CC_above_Ladd_Cr	426890.235001	5013953.698190	7/14/2010	9/20/2010	61
2	Catherine Creek	CC_above_Little_CC	443312.522430	4998749.379550	7/10/2010	9/20/2010	73
3	Catherine Creek	CC_above_Little_Cr	427928.720000	5008245.310000	6/30/2010	8/17/2010	49
4	Catherine Creek	CC_above_Milk_Cr	443439.700451	4998502.423770	7/10/2010	9/20/2010	73
5	Catherine Creek	CC_above_Mill_Cr	432041.150000	5016584.090000	6/30/2010	9/20/2010	40
6	Catherine Creek	CC_Booth_Rd_bridge	434105.404070	5022739.401780	7/10/2010	9/20/2010	73
7	Catherine Creek	CC_E_Union	432938.349721	5006556.417080	7/10/2010	9/20/2010	73
8	Catherine Creek	CC_Geckler_Rd_bridge	431959.860000	5017102.830000	6/30/2010	9/20/2010	38
9	Catherine Creek	CC_Hwy_203	438423.021628	5000409.656610	7/10/2010	9/20/2010	73
10	Catherine Creek	CC_Market_Ln_bridge	430466.670000	5026634.440000	6/30/2010	7/7/2010	8
11	Catherine Creek	CC_mouth	427231.770000	5028674.620000	6/30/2010	7/11/2010	12
12	Ladd Creek	Ladd_Cr_mouth	426459.034942	5014624.418830	7/14/2010	9/20/2010	69
13	Ladd Creek	Ladd_Cr_upper	419609.320000	5007326.650000	7/1/2010	9/28/2010	90
14	Little Catherine Creek	Little_CC_mouth	443476.943129	4998817.484080	6/25/2010	9/20/2010	88
15	Little Creek	Little_Cr_High_Valley_Rd	438641.428019	5006476.962780	7/10/2010	9/22/2010	75
16	Little Creek	Little_Cr_mouth	427945.140000	5009108.530000	6/30/2010	9/20/2010	83
17	Little Creek	Little_Cr_N_Union	432454.677224	5007439.367420	7/10/2010	9/20/2010	73
18	Middle Fork Catherine Creek	MF_CC_mouth	452560.100000	5003344.700000	7/1/2010	9/22/2010	84
19	Milk Creek	Milk_Cr_below_unnamed_trib	444762.936587	4996989.034350	6/25/2010	9/20/2010	88
20	Milk Creek	Milk_Cr_mouth	443381.867543	4998469.613570	6/25/2010	9/20/2010	88
21	Milk Creek	Milk_Cr_upper	444678.328389	4996638.621110	6/25/2010	9/20/2010	88
22	Mill Creek	Mill_Cr_mouth	432166.410000	5016609.630000	6/30/2010	9/20/2010	36
23	Mill Creek	Mill_Cr_upper	440465.350000	5014863.680000	6/30/2010	9/20/2010	73
24	North Fork Catherine Creek	NF_CC_above_Jim_Cr	452560.100000	5003344.700000	6/25/2010	9/28/2010	55
25	North Fork Catherine Creek	NF_CC_mouth	449231.210444	4996591.305780	6/25/2010	9/20/2010	88
26	North Fork Catherine Creek	NF_CC_upper	451714.790000	5006701.230000	6/25/2010	9/28/2010	96
27	South Fork Catherine Creek	SF_CC_mouth	449252.613094	4996530.912450	6/25/2010	9/20/2010	88
		Grande Ronde Basin					
28	Bear Creek	Bear_Cr_below_Little_Bear_Cr	380431.524643	5011812.008070	6/24/2010	9/21/2010	90

Number	Stream	Site	UTM_Easting	UTM_Northing	Start Date	Stop Date	Days
29	Bear Creek	Bear_Cr_mouth	399000.455499	5017922.086670	7/10/2010	9/20/2010	73
30	Bear Creek	Bear_Cr_upper	400307.231665	5014993.354040	7/11/2010	9/29/2010	81
31	Beaver Creek	Beaver_Cr_below_Dry_Beaver_Cr	398402.070000	5007509.670000	7/1/2010	9/26/2010	88
32	Beaver Creek	Beaver_Cr_below_reservoir	405223.540000	4999736.580000	7/1/2010	9/28/2010	90
33	Beaver Creek	Beaver_Cr_mouth	393402.070000	5013482.330000	7/1/2010	9/29/2010	91
34	Burnt Corral Creek	Burnt_Corral_Cr_mouth	385479.930675	5010023.237920	6/24/2010	9/21/2010	90
35	Chicken Creek	Chicken_Cr_below_W_Chicken_Cr	389699.092793	4990990.634270	6/29/2010	9/23/2010	87
36	Clear Creek	Clear_Cr_mouth	396784.276032	4990798.436150	6/30/2010	9/20/2010	83
37	Clear Creek	Clear_Cr_upper	395704.274600	4988224.580000	6/30/2010	9/29/2010	92
38	Five Points Creek	Five_Points_Cr_above_Little_JD_Cr	406690.703761	5030105.607490	6/23/2010	9/21/2010	91
39	Five Points Creek	Five_Points_Cr_above_Pelican_Cr	402922.246062	5023786.519890	6/22/2010	9/20/2010	91
40	Five Points Creek	Five_Points_Cr_mouth	404206.805610	5022230.760380	6/23/2010	9/20/2010	90
41	Five Points Creek	Five_Points_Cr_upper	409403.783434	5030563.238600	6/23/2010	9/21/2010	91
42	Fly Creek	Fly_Cr_below_Little_Fly_Cr	385646.985172	4997459.221300	6/29/2010	9/23/2010	87
43	Fly Creek	Fly_Cr_canyon	386241.508462	5000369.208950	6/30/2010	9/23/2010	86
44	Fly Creek	Fly_Cr_mouth	390356.323213	5007241.759020	6/24/2010	9/29/2010	98
45	Grande Ronde River	GR_2nd_St_Bridge	413890.630307	5021553.271600	7/10/2010	9/21/2010	74
46	Grande Ronde River	GR_above_Bear_Cr	398984.281530	5017964.048400	7/10/2010	9/20/2010	73
47	Grande Ronde River	GR_above_Beaver_Cr	393357.970000	5013640.650000	7/1/2010	9/21/2010	83
48	Grande Ronde River	GR_above_CC_mouth	427121.340000	5028694.560000	6/30/2010	7/4/2010	5
49	Grande Ronde River	GR_above_Clear_Cr	396890.901500	4990808.481570	7/1/2010	9/20/2010	82
50	Grande Ronde River	GR_above_Five_Points_Cr	404219.486990	5022160.804910	6/23/2010	9/20/2010	90
51	Grande Ronde River	GR_above_Fly_Cr	390401.743489	5007051.137430	7/1/2010	9/20/2010	82
52	Grande Ronde River	GR_above_Jordan_Cr	399658.493914	5018279.741070	7/10/2010	9/20/2010	73
53	Grande Ronde River	GR_above_Meadow_CR	391800.056823	5013002.501560	6/30/2010	9/20/2010	83
54	Grande Ronde River	GR_above_Spring_Cr	401063.246574	5019220.702550	7/1/2010	9/20/2010	82
55	Grande Ronde River	GR_below_Tanner_Gulch	399477.120000	4985997.000000	6/29/2010	9/27/2010	91
56	Grande Ronde River	GR_below_Vey	393018.774509	4998017.825500	6/29/2010	9/20/2010	84
57	Grande Ronde River	GR_Hilgard_Park	403114.780000	5021681.510000	7/1/2010	9/20/2010	82
58	Grande Ronde River	GR_Peach_Rd_bridge	424528.000000	5022243.000000	6/30/2010	9/20/2010	83
59	Grande Ronde River	GR_Reach_U155154	397787.858586	4989992.133320	7/11/2010	9/27/2010	79
60	Grande Ronde River	GR_Time_and_Half_Bridge	391496.746717	5001540.840600	6/26/2010	9/20/2010	87

Number	Stream	Site	UTM_Easting	UTM_Northing	Start Date	Stop Date	Days
61	Jordan Creek	Jordan_Cr_mouth	399725.446315	5018225.691550	7/10/2010	8/19/2010	41
62	Limber Jim Creek	Limber_Jim_Cr_below_NF	395657.685403	4995795.802990	6/26/2010	9/27/2010	94
63	Limber Jim Creek	Limber_Jim_mouth	394821.559521	4993859.119760	6/26/2010	9/27/2010	94
64	Limber Jim Creek	Limber_Jim_upper	397178.570862	4995704.675090	7/1/2010	9/27/2010	89
65	McCoy Creek	McCoy_Cr_below_Ensign_Cr	379119.710596	5021820.931170	6/24/2010	9/21/2010	90
66	McCoy Creek	McCoy_Cr_mouth	390396.174636	5013241.676590	6/24/2010	9/21/2010	90
67	Meadow Creek	Meadow_Cr_above_Bear_Cr	380605.176455	5013595.346750	6/24/2010	9/21/2010	90
68	Meadow Creek	Meadow_Cr_above_Dark_Canyon_Cr	391558.889767	5014074.616870	7/1/2010	9/20/2010	82
69	Meadow Creek	Meadow_Cr_above_McCoy_Cr	390423.877377	5013170.822970	6/24/2010	9/21/2010	90
70	Meadow Creek	Meadow_Cr_above_Waucup_Cr	373013.956468	5016747.215960	6/24/2010	9/21/2010	90
71	Meadow Creek	Meadow_Cr_mouth	391913.702850	5013246.367380	6/24/2010	9/20/2010	89
72	Rock Creek	Rock_Cr_mouth	403994.532809	5021612.752740	6/24/2010	9/20/2010	89
73	Sheep Creek	Sheep_Cr_below_5160_Rd	385376.343348	4990520.827080	6/29/2010	9/23/2010	87
74	Sheep Creek	Sheep_Cr_below_E_Sheep_Cr	383815.294478	4986932.326780	6/29/2010	9/23/2010	87
75	Spring Creek	Spring_Cr_mouth	401162.860765	5019564.631390	7/1/2010	8/26/2010	57
76	Spring Creek	Spring_Cr_upper	432454.677224	5007439.367420	7/11/2010	7/25/2010	15
77	Waucup Creek	Waucup_Cr_mouth	373011.176037	5016670.423690	6/24/2010	9/21/2010	90

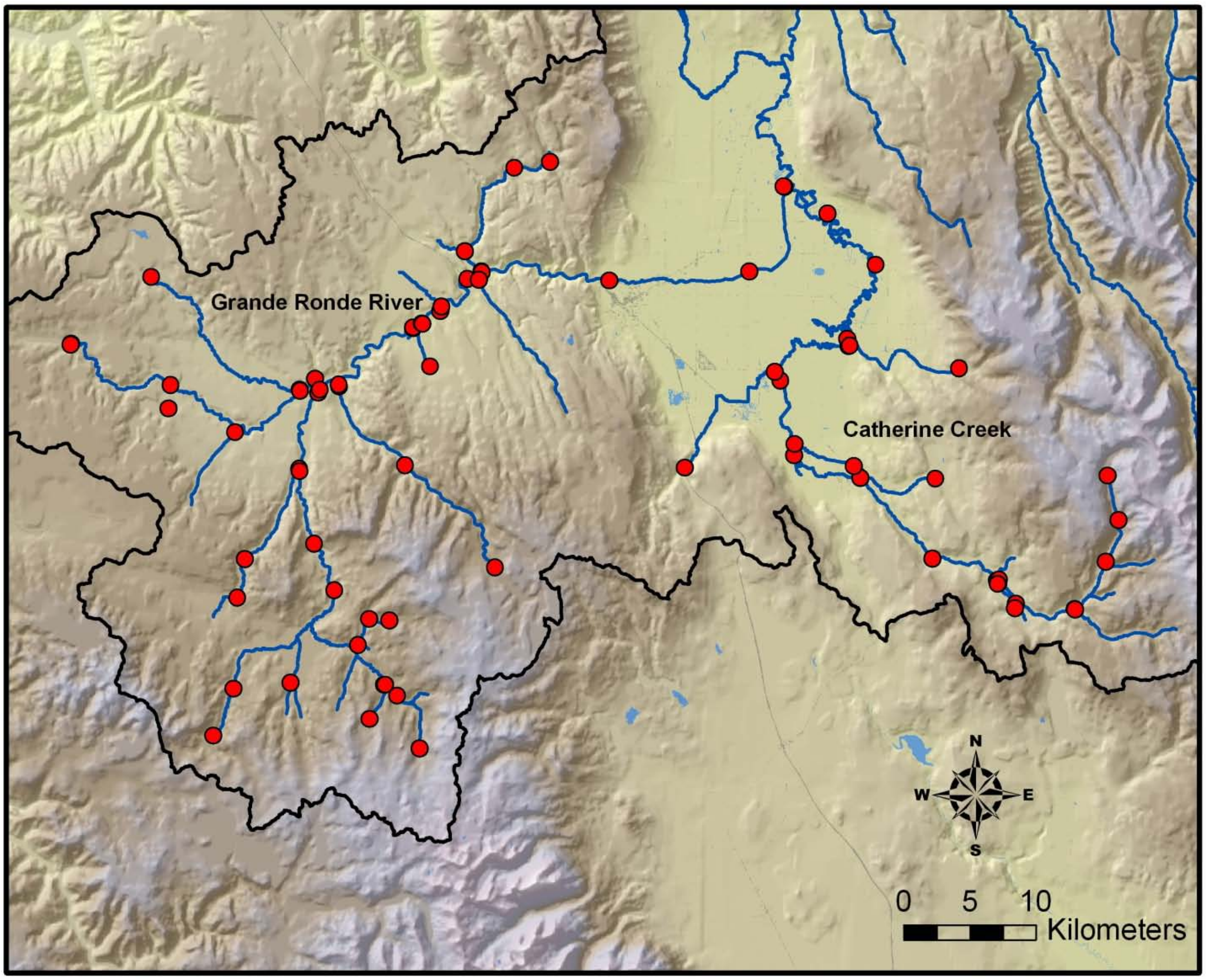

Figure 1. Temperature monitoring sites in the Upper Grande Ronde River and Catherine Creek basins, 2010.

Table 2. Summary of stream temperatures (°C) at 64 sites in Catherine Creek and the Grande Ronde River during the summer of 2010 (15 Jul – 15 Sep). Temperature metrics include average daily temperature for the summer period (Avg), the highest instantaneous temperature recorded during summer (Max), the lowest instantaneous temperature recorded during summer (Min), the maximum weekly average temperature (MWAT), the maximum weekly maximum temperature (MWMT), and the greatest consecutive number of days that the daily maximum temperature exceeded thresholds of 16, 18, 20 and 24°C. Values of MWMT exceeding the ODEQ temperature standard of 17.8 °C are highlighted in red.

							Consecutive Days Daily Max Exceeded			
Stream	Site	Avg	Max	Min	MWAT	MWMT	16 °C	18 °C	20 °C	24 °C
Catherine Creek Basin										
Catherine Creek	CC_above_Little_CC	13.4	20.3	6.1	15.8	19.5	43	13	2	0
Catherine Creek	CC_above_Milk_Cr	13.3	20.2	6.2	15.8	19.4	43	13	2	0
Catherine Creek	CC_Booth_Rd_bridge	21.2	27.3	15.2	24.4	26.7	67	59	48	29
Catherine Creek	CC_E_Union	15.8	22.6	8.5	18.5	21.8	48	43	12	0
Catherine Creek	CC_Hwy_203	14.3	21.6	6.7	16.9	20.9	44	27	11	0
Ladd Creek	Ladd_Cr_mouth	18.7	27.4	8.2	23.7	25.4	45	40	36	13
Ladd Creek	Ladd_Cr_upper	13.5	19.3	7.8	15.8	18.6	27	7	0	0
Little Catherine Creek	Little_CC_mouth	13.4	20.0	6.3	15.8	19.3	43	12	1	0
Little Creek	Little_Cr_High_Valley_Rd	14.1	21.1	7.2	16.5	20.3	44	20	5	0
Little Creek	Little_Cr_mouth	17.5	25.5	12.5	20.9	21.5	57	38	12	1
Little Creek	Little_Cr_N_Union	16.7	24.8	9.0	19.6	23.6	48	48	38	1
Middle Fork Catherine Creek	MF_CC_mouth	9.8	13.6	5.2	11.6	13.0	0	0	0	0
Milk Creek	Milk_Cr_below_unnamed_trib	13.1	19.9	6.5	15.4	19.2	38	11	0	0
Milk Creek	Milk_Cr_mouth	13.5	19.8	5.3	16.2	19.0	38	11	0	0
Milk Creek	Milk_Cr_upper	12.7	17.6	7.5	14.8	17.0	16	0	0	0
North Fork Catherine Creek	NF_CC_mouth	11.4	17.8	5.5	13.6	17.1	12	0	0	0
North Fork Catherine Creek	NF_CC_upper	7.4	11.9	3.4	8.8	11.4	0	0	0	0
South Fork Catherine Creek	SF_CC_mouth	11.5	17.1	4.9	13.9	16.3	4	0	0	0
Average		14.0	20.4	7.3	16.5	19.5	34	19	9	2
Min		7.4	11.9	3.4	8.8	11.4	0	0	0	0
Max		21.2	27.4	15.2	24.4	26.7	67	59	48	29
Grande Ronde River Basin										
Bear Creek	Bear_Cr_below_Little_Bear_Cr	13.9	23.4	5.5	17.0	22.1	50	37	14	0

Stream	Site	Avg	Max	Min	MWAT	MWMT	Consecutive Days Daily Max Exceeded			
							16 °C	18 °C	20 °C	24 °C
Bear Creek	Bear_Cr_mouth	13.8	21.3	8.2	14.8	20.6	30	17	9	0
Bear Creek	Bear_Cr_upper	14.3	22.7	6.1	17.4	21.2	41	29	13	0
Beaver Creek	Beaver_Cr_below_Dry_Beaver_Cr	13.1	19.1	6.3	15.6	18.0	13	3	0	0
Beaver Creek	Beaver_Cr_below_reservoir	11.9	16.6	8.0	14.2	16.2	3	0	0	0
Beaver Creek	Beaver_Cr_mouth	14.9	23.2	6.9	17.0	22.1	56	30	13	0
Burnt Corral Creek	Burnt_Corral_Cr_mouth	13.6	22.5	5.4	16.4	21.8	48	13	11	0
Chicken Creek	Chicken_Cr_below_W_Chicken_Cr	12.3	21.0	3.9	15.0	20.2	35	13	5	0
Clear Creek	Clear_Cr_mouth	10.7	16.5	4.6	13.1	15.7	2	0	0	0
Clear Creek	Clear_Cr_upper	9.8	14.1	5.5	11.8	13.6	0	0	0	0
Five Points Creek	Five_Points_Cr_above_Little_JD_Cr	14.5	21.2	8.4	16.7	20.8	53	24	11	0
Five Points Creek	Five_Points_Cr_above_Pelican_Cr	15.9	25.2	8.1	18.2	24.6	56	53	29	10
Five Points Creek	Five_Points_Cr_mouth	15.6	23.3	9.3	17.9	22.5	56	52	13	0
Five Points Creek	Five_Points_Cr_upper	11.9	17.0	7.6	13.4	16.7	13	0	0	0
Fly Creek	Fly_Cr_below_Little_Fly_Cr	16.7	26.7	6.6	20.0	25.6	56	55	36	11
Fly Creek	Fly_Cr_canyon	14.4	25.0	5.1	18.1	23.3	54	38	35	1
Fly Creek	Fly_Cr_mouth	15.2	23.3	8.3	17.9	22.1	58	36	14	0
Grande Ronde River	GR_2nd_St_Bridge	18.8	27.2	9.6	22.3	25.8	48	48	47	11
Grande Ronde River	GR_above_Bear_Cr	18.4	27.4	8.1	21.6	26.4	48	48	48	13
Grande Ronde River	GR_above_Beaver_Cr	17.3	27.5	7.1	20.7	26.4	56	55	47	13
Grande Ronde River	GR_above_Clear_Cr	11.4	18.2	4.8	13.6	17.4	11	2	0	0
Grande Ronde River	GR_above_Five_Points_Cr	19.2	28.5	8.9	22.5	27.2	65	56	55	13
Grande Ronde River	GR_above_Fly_Cr	15.8	24.4	6.2	19.2	23.2	55	46	13	1
Grande Ronde River	GR_above_Jordan_Cr	18.1	27.1	8.0	21.2	26.1	48	48	48	12
Grande Ronde River	GR_above_Meadow_CR	17.0	26.9	7.0	20.2	25.8	55	54	46	11
Grande Ronde River	GR_above_Spring_Cr	18.4	27.6	8.1	21.5	26.6	57	55	54	13
Grande Ronde River	GR_below_Tanner_Gulch	9.0	13.0	4.1	11.2	12.5	0	0	0	0
Grande Ronde River	GR_below_Vey	15.7	24.8	5.8	18.6	23.7	55	53	28	1
Grande Ronde River	GR_Hilgard_Park	18.6	28.1	2.8	22.2	26.7	59	56	55	13
Grande Ronde River	GR_Peach_Rd_bridge	20.9	29.6	11.7	24.3	28.5	77	60	53	38
Grande Ronde River	GR_Reach_U155154	10.8	16.8	4.6	12.9	16.2	5	0	0	0

Stream	Site	Avg	Max	Min	MWAT	MWMT	Consecutive Days Daily Max Exceeded			
							16 °C	18 °C	20 °C	24 °C
Grande Ronde River	GR_Time_and_Half_Bridge	15.6	21.5	7.6	18.6	20.9	46	37	16	0
Limber Jim Creek	Limber_Jim_Cr_below_NF	9.9	14.9	3.8	12.1	14.0	0	0	0	0
Limber Jim Creek	Limber_Jim_mouth	11.7	19.3	4.4	14.1	18.3	13	4	0	0
Limber Jim Creek	Limber_Jim_upper	9.5	13.7	4.0	11.5	13.0	0	0	0	0
McCoy Creek	McCoy_Cr_below_Ensign_Cr	12.2	19.6	6.4	14.2	18.6	24	6	0	0
McCoy Creek	McCoy_Cr_mouth	17.8	26.8	7.9	20.9	25.4	64	56	50	11
Meadow Creek	Meadow_Cr_above_Bear_Cr	16.2	25.7	7.4	19.6	24.7	64	55	36	9
Meadow Creek	Meadow_Cr_above_Dark_Canyon_Cr	18.2	29.8	7.3	21.6	28.3	57	56	56	22
Meadow Creek	Meadow_Cr_above_McCoy_Cr	17.8	27.1	8.7	20.8	25.7	64	56	50	11
Meadow Creek	Meadow_Cr_above_Waucup_Cr	13.6	21.6	5.5	17.1	20.3	48	22	4	0
Meadow Creek	Meadow_Cr_mouth	17.6	27.8	7.6	21.0	26.2	64	56	50	22
Rock Creek	Rock_Cr_mouth	17.3	30.4	6.6	21.0	29.1	64	56	56	24
Sheep Creek	Sheep_Cr_below_5160_Rd	13.4	22.7	4.5	16.1	22.2	36	28	12	0
Sheep Creek	Sheep_Cr_below_E_Sheep_Cr	10.2	16.4	4.6	12.4	15.7	1	0	0	0
Waucup Creek	Waucup_Cr_mouth	13.9	23.3	5.2	17.6	21.7	49	35	13	0
Average		14.7	22.8	6.6	17.5	21.8	40	31	23	6
Min		9.0	13.0	2.8	11.2	12.5	0	0	0	0
Max		20.9	30.4	11.7	24.3	29.1	77	60	56	38

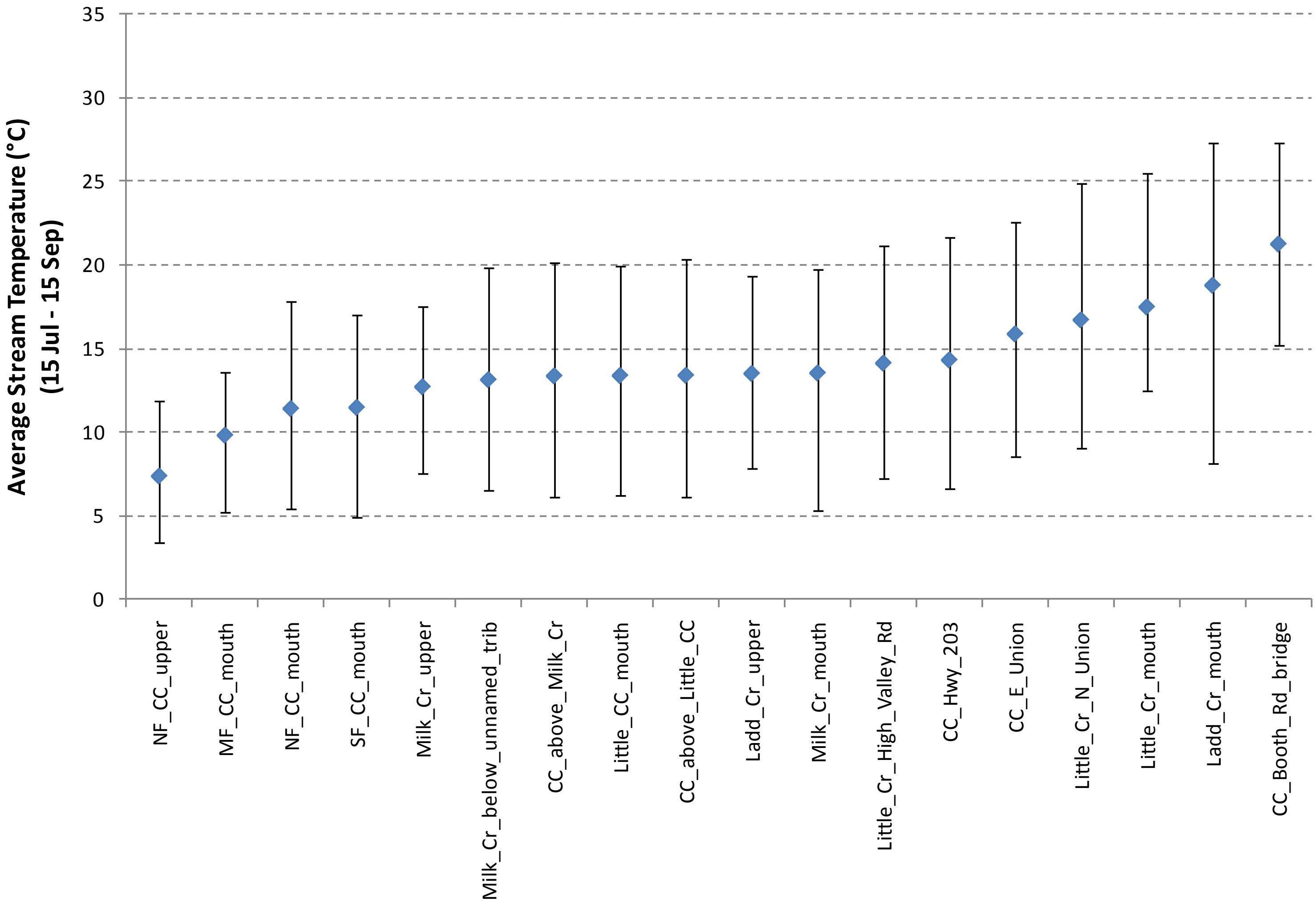

Figure 2. Average daily stream temperature (°C) at 18 sites in the Catherine Creek basin during summer (15 Jul – 15 Sep) 2010. Error bars represent the highest (Max) and lowest (Min) instantaneous temperatures recorded during summer.

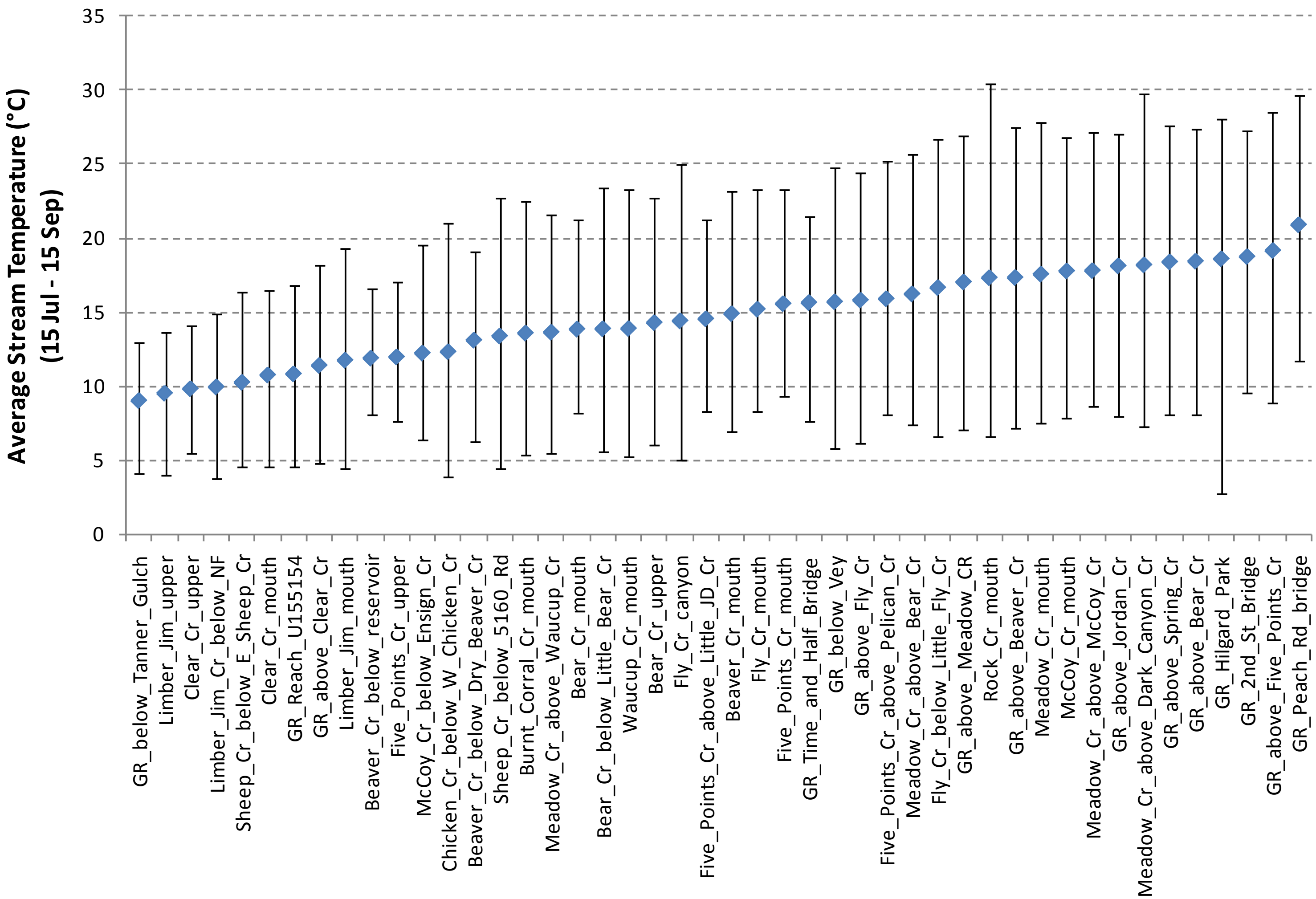

Figure 3. Average daily stream temperature (°C) at 46 sites in the Grande Ronde River basin during summer (15 Jul – 15 Sep) 2010. Error bars represent the highest (Max) and lowest (Min) instantaneous temperatures recorded during summer.

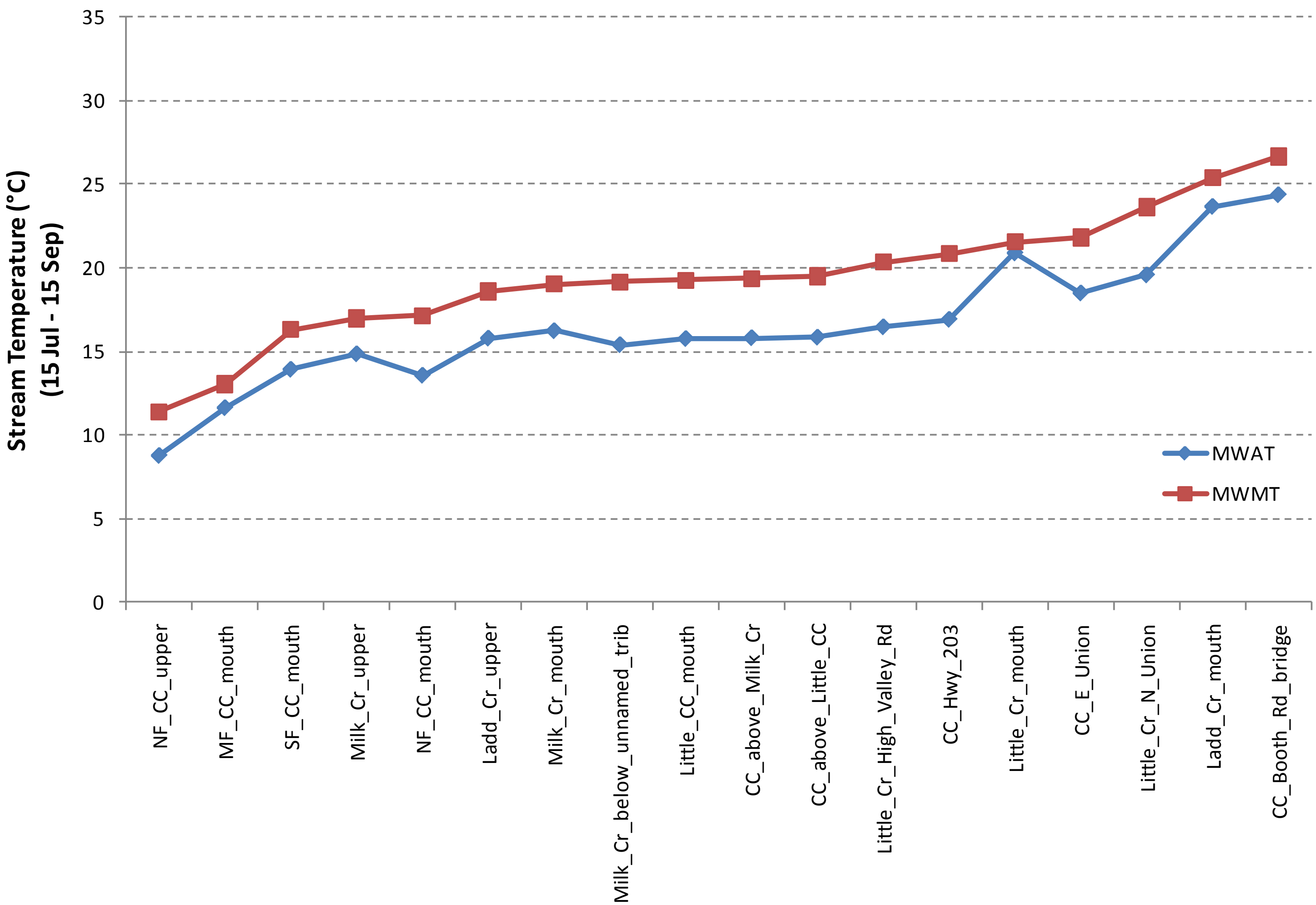

Figure 4. Maximum weekly average temperature (MWAT; °C) and maximum weekly maximum temperature (MWMT) at 18 sites in the Catherine Creek basin during summer (15 Jul – 15 Sep) 2010. Data were sorted by MWMT in ascending order.

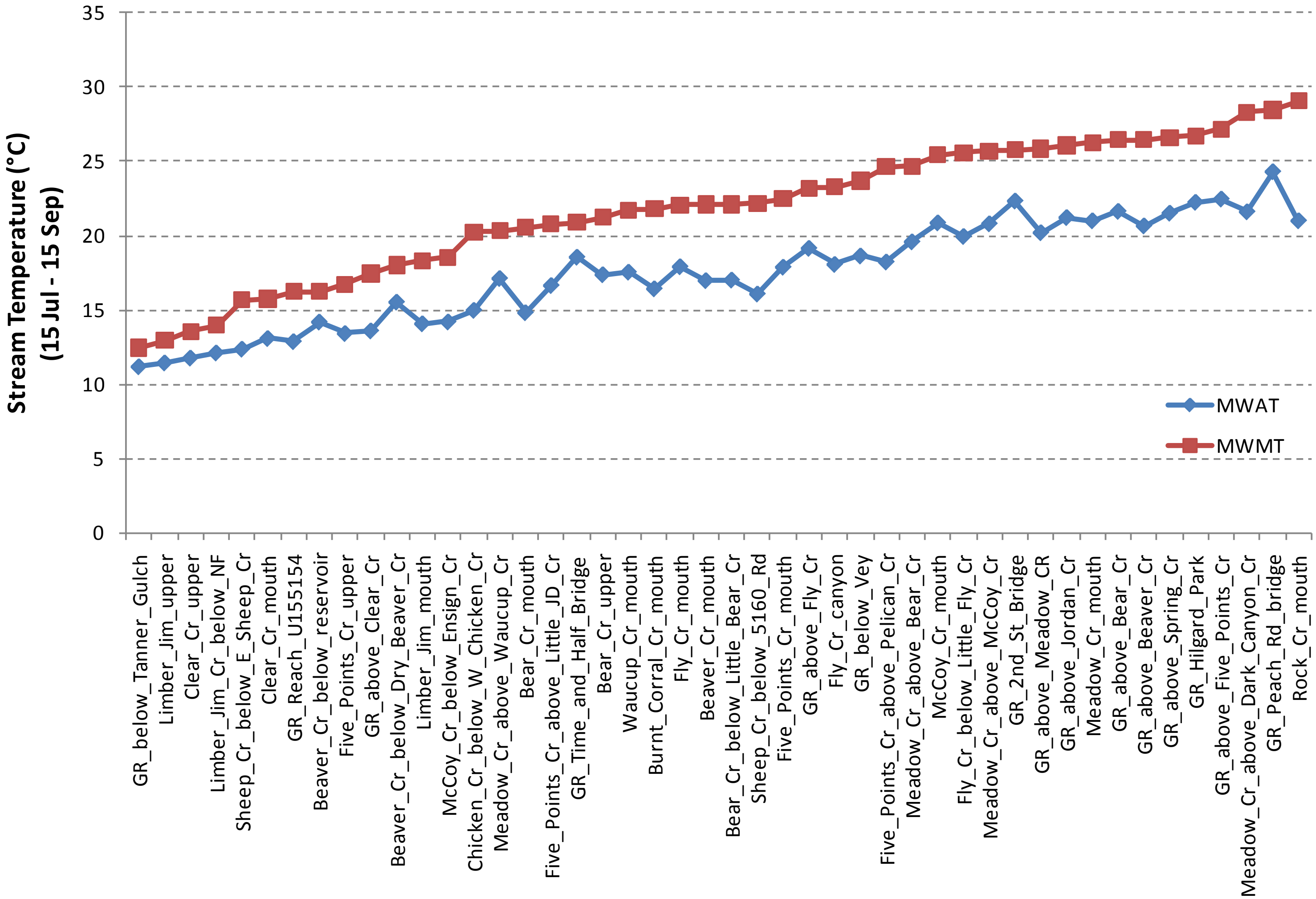

Figure 5. Maximum weekly average temperature (MWAT; °C) and maximum weekly maximum temperature (MWMT) at 46 sites in the Grande Ronde River basin during summer (15 Jul – 15 Sep) 2010. Data were sorted by MWMT in ascending order.

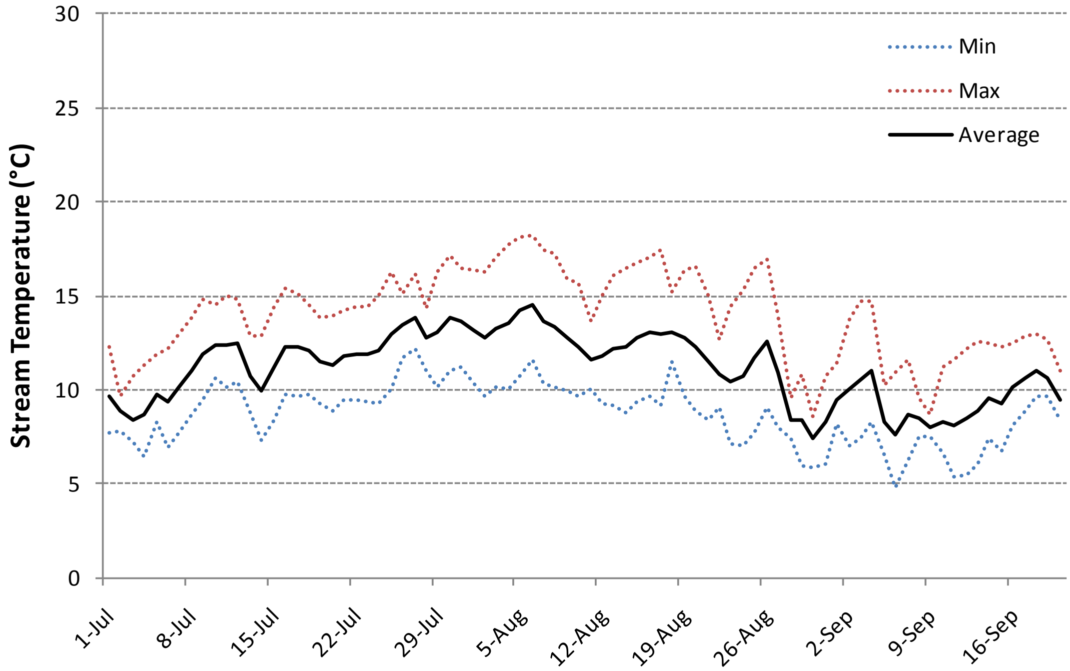

Figure 6. Daily average, minimum, and maximum stream temperatures (°C) in the Grande Ronde River upstream of Clear Creek from 1 Jul – 20 Sep, 2010.

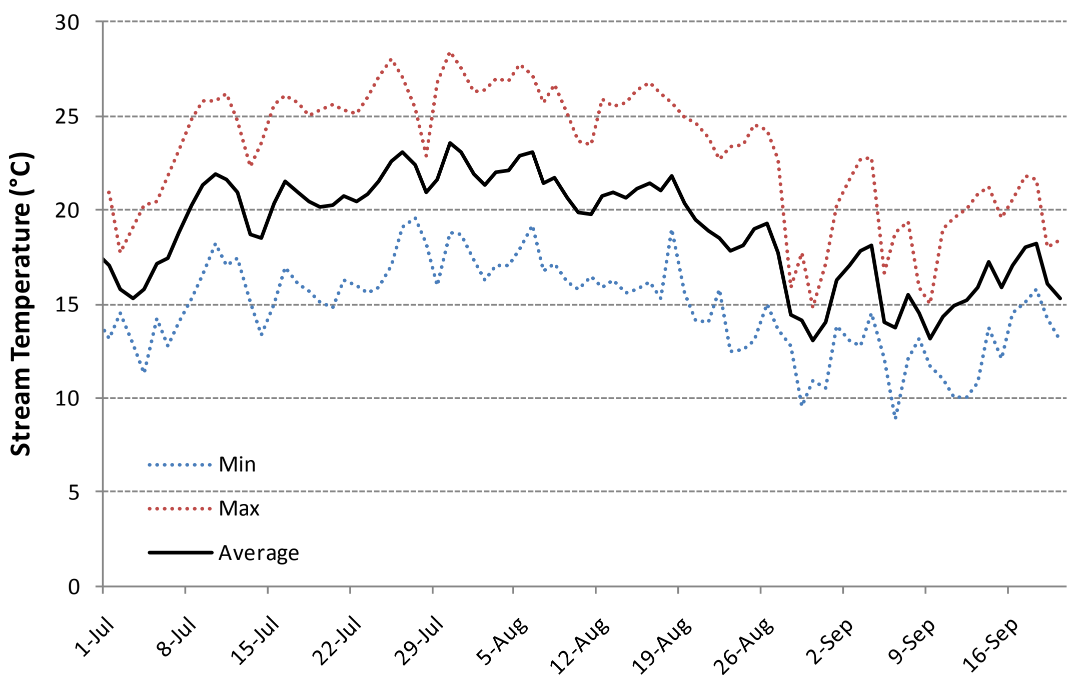

Figure 7. Daily average, minimum, and maximum stream temperatures (°C) in the Grande Ronde River upstream of Five Points Creek from 1 Jul – 20 Sep, 2010.

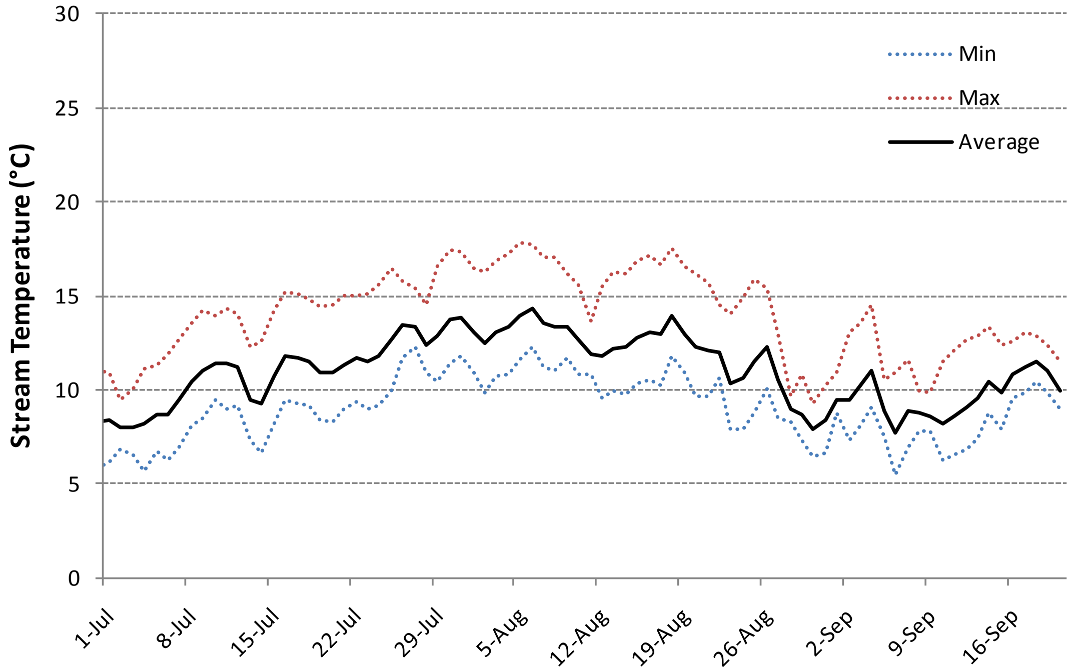

Figure 8. Daily average, minimum, and maximum stream temperatures (°C) in North Fork Catherine Creek at the mouth from 1 Jul – 20 Sep, 2010.

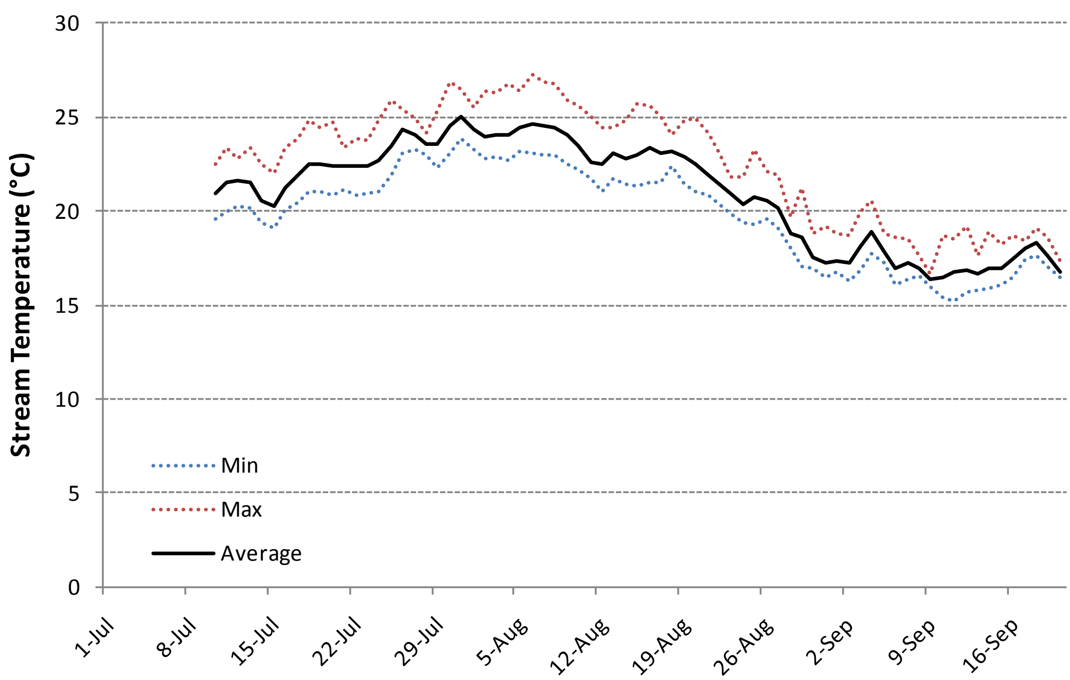

Figure 9. Daily average, minimum, and maximum stream temperatures (°C) in Catherine Creek at the east end of Union from 10 Jul – 20 Sep, 2010.

Table 3. Correlation matrix for each of eight temperature metrics used to evaluate stream temperature in Catherine Creek and the Grande Ronde River.

	Avg	Max	MWAT	MWMT	Days>16°C	Days>18°C	Days>20°C	Days>24°C
Avg	1.000							
Max	0.954	1.000						
MWAT	0.992	0.962	1.000					
MWMT	0.952	0.995	0.954	1.000				
Days>16°C	0.886	0.916	0.884	0.915	1.000			
Days>18°C	0.913	0.935	0.915	0.935	0.902	1.000		
Days>20°C	0.874	0.890	0.878	0.895	0.746	0.901	1.000	
Days>24°C	0.754	0.719	0.749	0.732	0.577	0.695	0.836	1.000

Appendix L

Summary of 2010 Stream Flow and Hydrologic Data

Resources in the Grande Ronde River basin

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Summary of 2010 Stream Flow and Hydrologic Data Resources in the Grande Ronde River basin

A component of

Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators

March 2011

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Introduction

We summarize stream flow records from 2010 and document hydrologic data sources and data capture techniques in the Grande Ronde River basin, with special focus on the upper Grande Ronde, Catherine Creek, and Minam River. This report does not intend to provide detailed hydrological analysis nor do we draw final conclusions relevant to policy and management. In some cases we do provide our initial impressions of how factors related to stream flow may limit salmonid or other fish populations, but those conclusions are preliminary and warrant further investigation.

The main objectives of this report were to:

1. Document available stream flow data in the Grande Ronde River basin,
2. Describe the development of a stream flow database to be housed at CRITFC,
3. Update progress on installation of new flow gauges and (very) preliminary flow rating curves,
4. Document sources and describe data used for a Heat Source model, and
5. Provide brief summaries of three important hydrographs in the basins for water year 2010.

1. Available stream flow data in the Grande Ronde River basin

All known flow gauge sites within the Grande Ronde were mapped in GIS, using information from the Oregon Water Resources Division website (OWRD 2011), which has detailed and updated spatial data on the location of the sites. This entailed adding additional gauges that were previously unknown to us during our search for gauges in 2009. There are 32 sites in the Grande Ronde, 15 are decommissioned and 17 are still active. The spatial data for the sites created by CRITFC also have a variety of attribute data to help link the locations to raw data collected for the sites and stored at CRITFC (in a SQL database) and to other data in the basin. For this purpose the attributes for each site will contain HUC6 number, LLID number, Site Number (USGS number) and CRITFC Study area (text). The HUC6 and LLID fields will be used to link to fish and habitat data housed by StreamNet that uses the two data fields to

organize records. The SiteNumber and Study Area, will be used within the CRITFC database to query for data on flow and then join results to spatial data for mapping. The database stores all flow data from the Grande Ronde sites and is designed to download future data sets generated by the active gauges. The spatial layer on Grande Ronde flow gauges created for CRITFC's use will be stored in a file geodatabase with metadata.

A recent use of the flow gauge sites spatial layer was to analyze the watershed area above each gauge using GIS tools and models. The OWRD website lists the drainage area above the gauge and our analysis, after mapping the sites and extracting watershed area using an independent model, confirmed that the information from OWRD was correct.

An updated map of flow gauges in the project interest area (Figure 1) reveals that flow data are distributed haphazardly both across the landscape and through time. For example, in Catherine Creek the only long-term flow data (1912 – present) exists at a single location halfway between Little Creek and the North and South Fork confluence, excluding the influence of several important tributaries downstream. In the upper Grande Ronde above La Grande, long-term flow records are inconsistent and will have to be pieced together from several different gauges for the lower mainstem portions of the river (downstream of Spring Creek confluence). The Minam River, on the other hand, has a long-term flow gauge (1912 – present) conveniently located just above its confluence with the Wallowa River. In other parts of the Grande Ronde basin, flow records are disproportionately concentrated in Wallowa and Lostine River mainstems, excluding large portions of the basin (Figure 1).

2. Development of stream flow database

Oregon Water Resources Department maintains databases of stream gauge data in the basin (OWRD 2011). At CRITFC, we are developing a data capture program to access stream flow records, perform quality control measures, and compute standard stream flow statistics in a user-friendly format. At this time, there are 41 flow site locations in the database. For more details on stream flow data capture

program and associate stream temperature and fish habitat monitoring database, see the *Continue Database Development and Implementation* section of the Monitoring Recovery Trends 2010 annual report.

3. Newly-installed flow gauges

In 2010, we installed two new flow gauges in areas that were under-represented in terms of flow records: Sheep Creek (upper Grande Ronde basin) and South Fork Catherine Creek (Catherine Creek basin) (Figure 1). Due to high water in late Spring, we could not access streams for installation of flow gauges until July. Installation involved choosing an appropriate location with relatively uniform cross-section at each stream, measuring cross-sectional bankfull morphology, anchoring a protective stilling well to house the pressure transducer, and securing an additional pressure transducer to a nearby tree branch to account for changes in barometric pressure when developing flow rating curves. Cross-sectional measurements will be used in estimating peak flows during the high flow period, via the indirect slope-area method (Benson & Dalrymple 1967).

Throughout the 2010 field season, we measured stream flow on several occasions at the two gauges, commencing in late September. Although the frequency of visitation to the new gauged sites was not nearly enough to develop a flow-rating curve confidence, preliminary examination of barometric pressure-corrected water depth level vs. discharge indicates that stage-discharge relationships can be developed from gauges at these sites if more data are collected in the future (Figure 2, Figure 3).

4. Hydrographic data for Heat Source model

To provide point-in-time stream flow data for a Heat Source model (Boyd & Kasper 2003), we dedicated a portion of mid-summer 2010 to measuring discharge at important tributaries in the study basins (Table 1). Except for one reading as early as July 23, this brief time window began August 11 and commenced

August 26. Discharge levels ranged from nearly 33 cubic feet per second (cfs) in the upper Catherine Creek mainstem to zero flow in upper sections of several small tributaries and in the extensively irrigated Grande Ronde valley (Figure 4). During the time of our field work, we intended to measure stream flow in lower mainstem Catherine Creek because we had deployed several thermal data loggers there. However, we found that while at Prescott ditch stream flow was as high as 24 cfs, just a few river kilometers downstream, below the confluence of Pyles Creek, stream discharge had dropped to 5 cfs. Further downstream above the confluence of Ladd Creek and further points downstream, the stream was either totally dry or puddled with no apparent flow (Figure 5).

In addition to point-time data, we accessed summer (June 1 – October 1) stream flow data from the eight active OWRD gauging stations in upper Grande Ronde and Catherine Creek (Table 2), for input into the Heat Source model.

5. Brief summary of selected hydrographs

While this report does not document stream flow patterns in detail, we did visually examine hydrographic records at the downstream-most gauging stations for the three streams of interest: upper Grande Ronde River near Perry (Figure 6), Catherine Creek at Union (Figure 7), and Minam River at Minam (Figure 8) for water year 2010 (1 October 2009 – 30 September 2010). In all three rivers, stream flows peaked in early June followed by a gradual decline in the hydrograph through late July. At that point in time, the Catherine Creek hydrograph took an extreme departure from the others due to water extractions above Union (Figure 7). Stream flow in Catherine Creek at Union dropped below 1 cfs in mid-August and dropped to nearly zero flow in mid-September before rising towards winter flows of approximately 8 cfs. Clearly, any fish using portions of Catherine Creek from Union downstream to the confluence of the Grande Ronde River have the potential to be impacted by unnaturally low flows. Stream levels in the Minam River (which flows through a wilderness area and is therefore not impacted by water withdrawals) also tapered off after Spring floods in early June, reaching base flows in late August (Figure 8). Stream flows in the Minam River remained relatively constant through winter excepting a large flood in early-late January.

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Dalrymple, T., M. A Benson, and Geological Survey (US). 1967. *Measurement of peak discharge by the slope-area method*. USGPO.

Boyd, M., and B. Kasper. 2003. Analytical methods for dynamic open channel heat and mass transfer: Methodology for the Heat Source Model Version 7.0.

OWRD 2011. Oregon Water Resources Department. Accessed site on: March 21, 2011. Using: http://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/ .

Tables

Table 1. Point-in-time stream flow measurements (cubic feet per second, CFS) in the upper Grande Ronde River and Catherine Creek basins, 2010, for input into Heat Source model.

Stream name	Site name	Date	CFS
Beaver Creek	Beaver_Cr_below_Dry_Beaver	8/24/2010	4.21
	Beaver_Cr_below_reservoir	8/19/2010	0.96
	Beaver_Cr_mouth	8/24/2010	3.90
Burnt Corral Creek	N/A	8/20/2010	0.24
Catherine Creek	above little Catherine creek	8/18/2010	32.86
	above Milk Creek	8/18/2010	30.28
	CC_above_Little_Cr	8/18/2010	5.08
	east end of union	8/18/2010	24.04
Chicken Creek	below forks	8/19/2010	1.78
Clear Creek	mouth	8/19/2010	1.78
	upper	8/19/2010	1.67
Five Points Creek	above little john day creek	8/25/2010	0.68
	above pelican	8/17/2010	0.57
	Five_Points_Cr_mouth	8/17/2010	1.44
	Upper End	8/25/2010	0.42
Fly Creek	above mouth	8/18/2010	1.01
	below little fly	8/19/2010	0.72
	middle section	8/26/2010	0.33
Jordan Creek	mouth	8/18/2010	0.00
Ladd Creek	Ladd_Cr_below_I84_overpass	8/19/2010	1.02
Limber Jim	Limber_Jim_below_NF	8/14/2010	2.35
	Limber_Jim_mouth	8/14/2010	2.34
	Limber_Jim_upper	8/14/2010	2.53
Little Catherine Creek	mouth	8/18/2010	1.97
Little Creek	north end of Union	8/18/2010	1.24
	upper High Valley Rd	8/19/2010	2.65
McCoy Creek	McCoy_Cr_below_Ensign_Cr	8/26/2010	0.06
	McCoy_Cr_mouth	8/23/2010	0.14
Meadow Creek	above bear creek	8/20/2010	1.58
	above dark canyon	8/19/2010	3.58
	above McCoy Creek	8/23/2010	2.01
	mouth	8/18/2010	3.64
	above Waucup creek	8/26/2010	0.22
Middle Fork Catherine Creek	MF_Cath_Cr_mouth	8/19/2010	6.60
Milk Creek	mouth	8/18/2010	0.86
	Upper End	8/19/2010	0.96
North Fork Catherine Creek	NF_Cath_Cr_above_Jim_Cr_mouth	8/25/2010	6.87
	NF_Cath_Cr_above_MF	8/19/2010	10.25
	NF_Cath_Cr_upper	8/25/2010	3.59
Rock Creek	mouth	8/18/2010	0.20
Sheep Creek	Sheep_Cr_below_E_Sheep	8/19/2010	2.34
South Fork Catherine Creek	Below Prong Creek	8/19/2010	9.63
	mouth	8/19/2010	12.04

Spring Creek	mouth	8/18/2010	0.16
Waucup Creek	mouth	8/26/2010	0.37
Grande Ronde River	above bear creek	8/18/2010	30.09
	above clear creek	8/19/2010	10.86
	above five points	8/17/2010	26.87
	above fly creek	8/18/2010	19.68
	above Jordan Creek	8/18/2010	29.68
	above spring creek	8/18/2010	29.80
	at second street	8/17/2010	13.46
	below vey	8/18/2010	21.43
	GR_above_Beaver_Cr	8/18/2010	26.22
	GR_above_Meadow_CR	8/11/2010	27.37
	GR_at_Hillgard_Park	8/17/2010	29.35
	GR_at_Peach_Rd_bridge	8/17/2010	2.56
	GR_at_Time_Half_Bridge	8/11/2010	23.00
	GR_below_Tanner_Gulch	8/20/2010	5.65
	Reach U155154	8/19/2010	10.86
Bear Creek (trib to GR)	mouth next to huge ponderosa p	8/18/2010	0.68
	upper	8/23/2010	0.00
Bear Creek (trib to Meadow)	below Little Bear Creek	8/20/2010	0.02
Sheep Creek	Sheep gauge	8/19/2010	2.37
South Fork Catherine Creek	SFCC gauge	7/23/2010	19.98

Table 2. OWRD gauging stations used for summer stream flow input (June 1 – October 1, 2010) to Heat Source model.

Site code	Site name	Start year	UTM Easting	UTM Northing
13320300	Catherine Cr. at Union, Or.	1996	431726	5006846
13320000	Catherine Cr. nr Union, Or.	1911	439170	5000514
13318920	Five Points Cr. at Hilgard, Or.	1992	403802	5022671
13317850	Grande Ronde R. bl Clear Cr, nr Starkey, Or.	1992	396462	4991647
13318960	Grande Ronde R. nr Perry, Or.	1996	407442	5022746
13318060	Meadow Cr. ab Bear Cr. nr Starkey, Or.	1977	380731	5013575
13318210	Meadow Cr. bl Dark Can, nr Starkey, Or.	1992	391681	5013502
13319900	N fk Catherine cr. nr Medical Springs, Or.	1992	450261	4997463

Figures

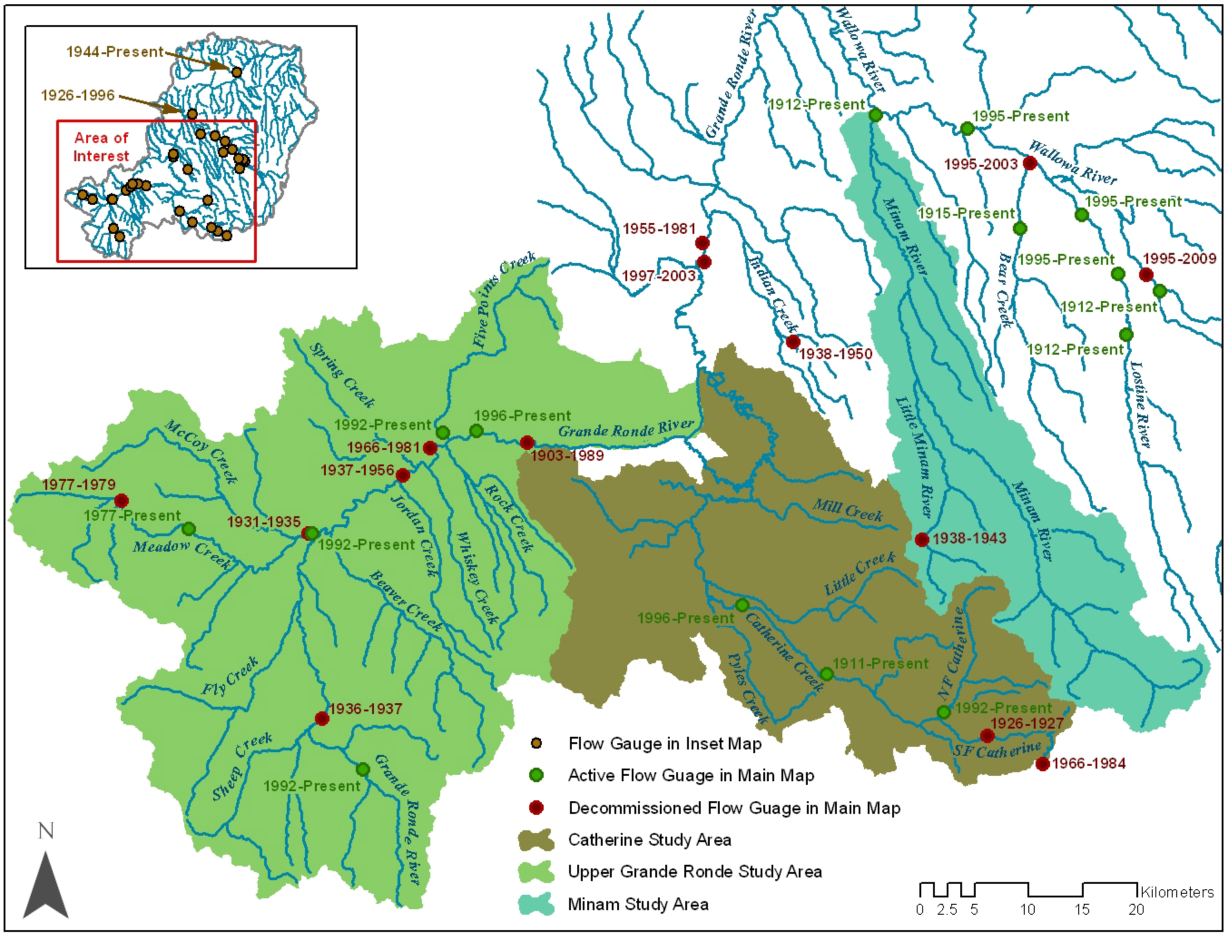

Figure 1. Map of active and decommissioned flow gauges in the Grande Ronde River basin.

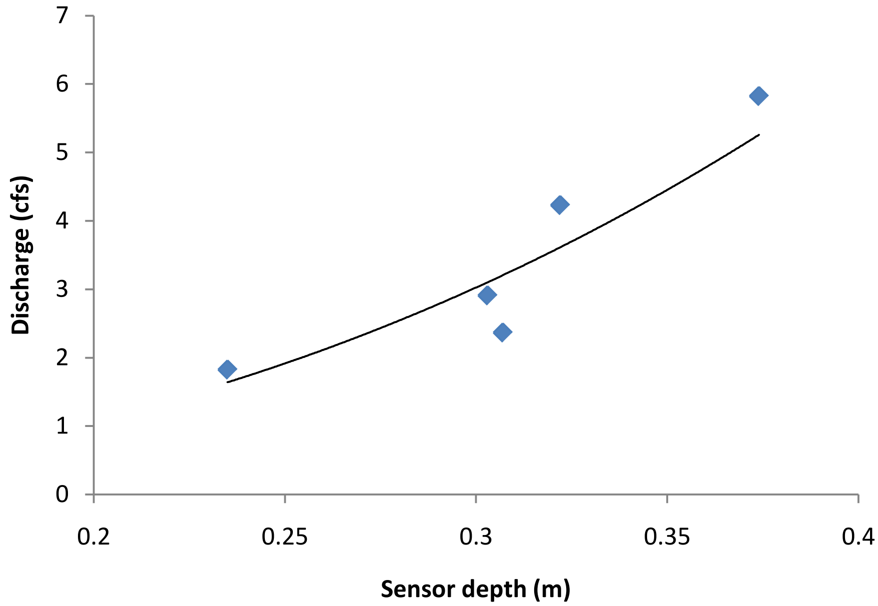

Figure 2. Stage-discharge relationship for Sheep Creek, 2010 (Q = 61.88 x $D^{2.51}$, R^2 = 0.83). Sensor depths are corrected for barometric pressure.

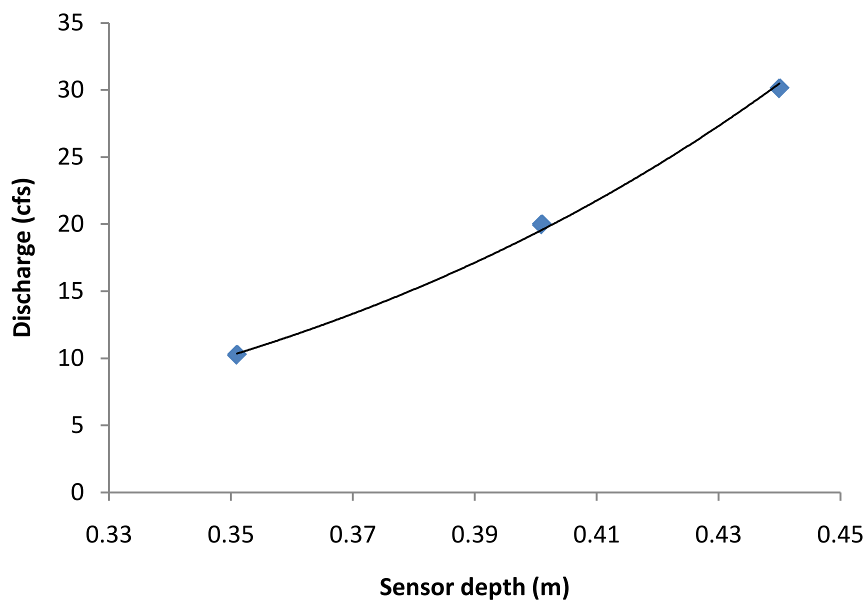

Figure 3. Stage-discharge relationship for South Fork Catherine Creek, 2010 (Q = 1541.3 x $D^{4.79}$, R^2 = 0.99). Sensor depths are corrected for barometric pressure.

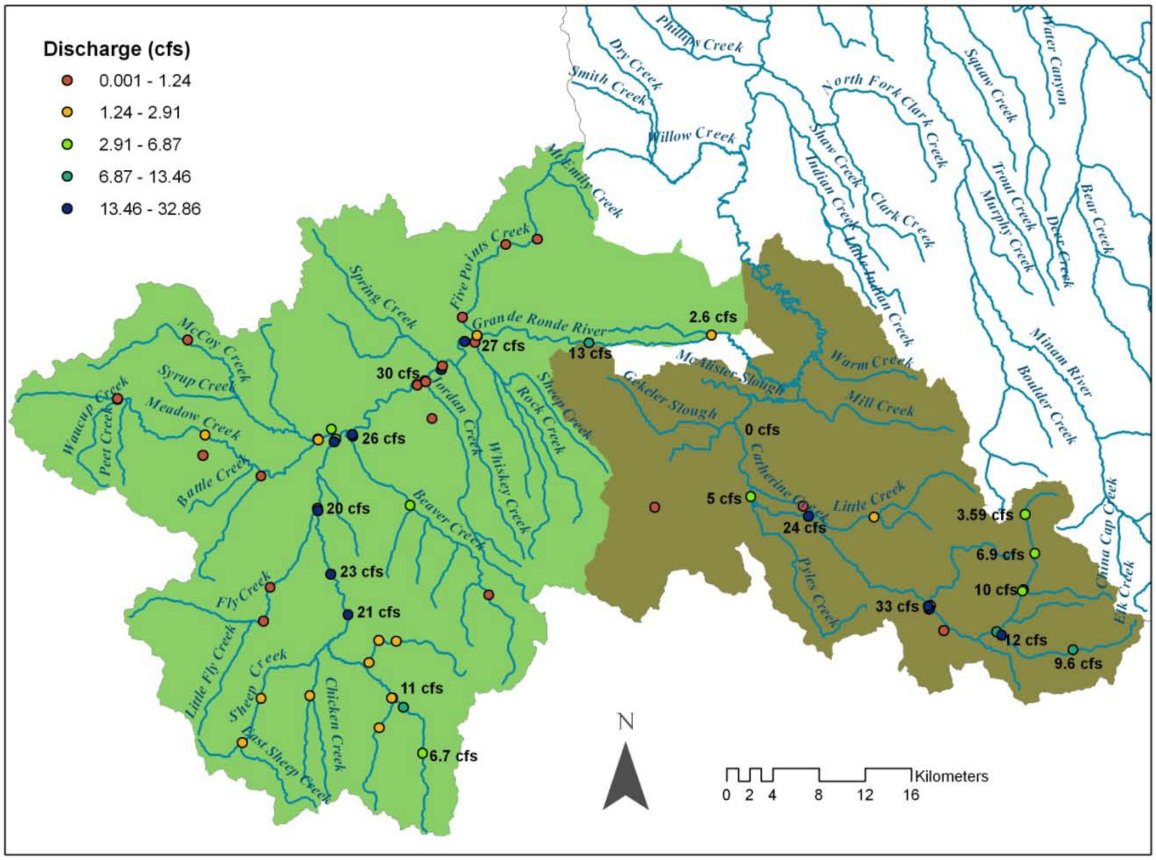

Figure 4. Map of mid-summer 2010 stream flow measurements. Bold type represents stream flow of selected points along mainstem upper Grande Ronde River and Catherine Creek and its North and South Forks.

Figure 5. Dry streambed in mainstem Catherine Creek just upstream of Ladd Creek, mid-July 2010.

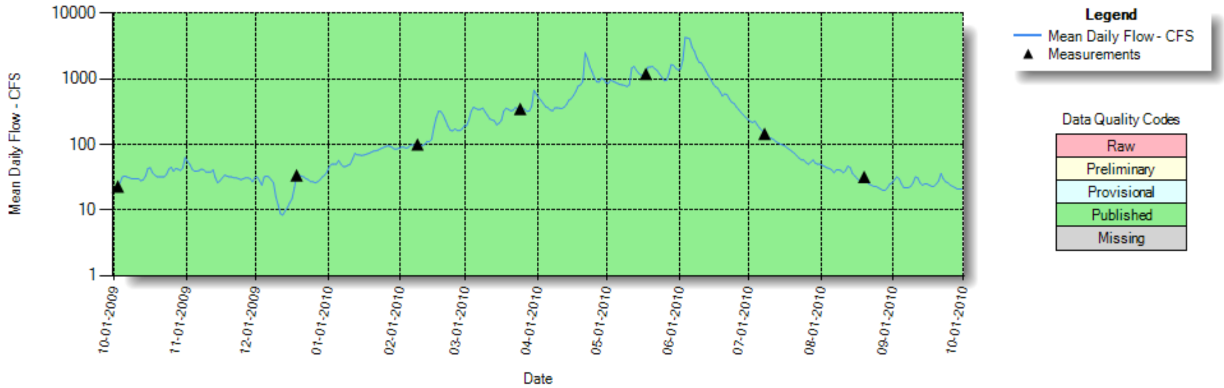

Figure 6. Hydrograph for water year 2010 in the Grande Ronde River near Perry, OR (Station ID 13318960). Source: http://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/

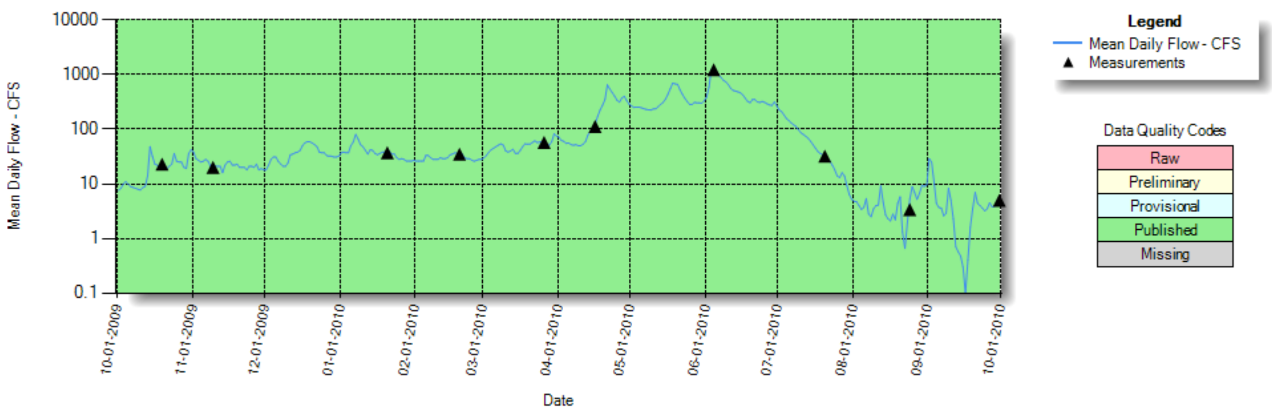

Figure 7. Hydrograph for water year 2010 in Catherine Creek at Union, OR (Station ID 13320300). Source: http://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/

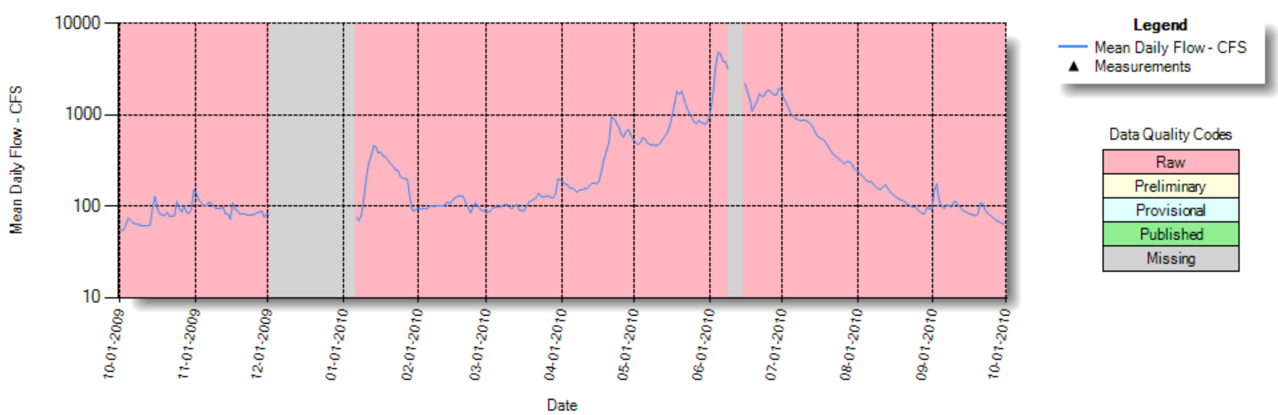

Figure 8. Hydrograph for water year 2010 in the Minam River at Minam, OR (Station ID 13320300). Source: http://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/

Appendix M

List of files in the Grande Ronde Geodatabase

List of files in the Grande Ronde Geodatabase

1. Bio_Fish
    a. Brkt_v09
        i. ODFW distribution layer for brook trout.
    b. Bull_v12
        i. ODFW distribution layer for bull trout.
    c. Coho_v12
        i. ODFW distribution layer for coho salmon.
    d. Dist_anadromous_GrandeR
        i. This dataset is a record of fish distribution and life history stage of anadromous fishes, based upon the best professional judgement of local fish biologists, as of year 2003 in the Pacific Northwest (Oregon, Washington, and Idaho). These data were collected by biologists at the state fish & wildlife agencies of Washington (Washington Department of Fish and Wildlife), Oregon (Oregon Department of Fish and Wildlife) and Idaho (Idaho Department of Fish and Game). Data were then compiled by StreamNet staff into paper maps or event tables at the state level. These event tables were submitted to the StreamNet regional staff at Pacific States Marine Fisheries Commission (PSMFC) where this regional distribution coverage was created from these event tables. All data are referenced to the PNW 1:100,000 River Reach Hydrography (http://www.streamnet.org/pnwr/pnwrhome) on the LLID-based stream routing system.
    e. Dist_Fall_Chinook_GrandeR
        i. This dataset is a record of fish distribution and life history stage of chinook salmon, based upon the best professional judgement of local fish biologists, as of year 2003 in the Pacific Northwest (Oregon, Washington, and Idaho). These data were collected by biologists at the state fish & wildlife agencies of Washington (Washington Department of Fish and Wildlife), Oregon (Oregon Department of Fish and Wildlife) and Idaho (Idaho Department of Fish and Game). Data were then compiled by StreamNet staff into paper maps or event tables at the state level. These event tables were submitted to the StreamNet regional staff at Pacific States Marine Fisheries Commission (PSMFC) where this regional distribution coverage was created from these event tables.
    f. Dist_ Spring_Chinook_GrandeR

    i. This dataset is a record of fish distribution and life history stage of spring chinook salmon, based upon the best professional judgment of local fish biologists, as of year 2003 in the Pacific Northwest (Oregon, Washington, and Idaho). These data were collected by biologists at the state fish & wildlife agencies of Washington (Washington Department of Fish and Wildlife), Oregon (Oregon Department of Fish and Wildlife) and Idaho (Idaho Department of Fish and Game). Data were then compiled by StreamNet staff into paper maps or event tables at the state level. These event tables were submitted to the StreamNet regional staff at Pacific States Marine Fisheries Commission (PSMFC) where this regional distribution coverage was created from these event tables.

g. Dist_Summer_Steelhead_GrandeR
    i. This dataset is a record of fish distribution and life history stage of summer steelhead salmon, based upon the best professional judgement of local fish biologists, as of year 2003 in the Pacific Northwest (Oregon, Washington, and Idaho). These data were collected by biologists at the state fish & wildlife agencies of Washington (Washington Department of Fish and Wildlife), Oregon (Oregon Department of Fish and Wildlife) and Idaho (Idaho Department of Fish and Game). Data were then compiled by StreamNet staff into paper maps or event tables at the state level. These event tables were submitted to the StreamNet regional staff at Pacific States Marine Fisheries Commission (PSMFC) where this regional distribution coverage was created from these event tables.

h. Fish_barriers
    i. Regional data from ODFW representing known barriers to fish passage. Clipped to the Grande Ronde. For metadata see http://rainbow.dfw.state.or.us/nrimp/information/fishbarrierdata.htm

i. Juv_release
    i. This point shapefile depicts locations where juvenile spring chinook salmon and steelhead were released into the mainstem and tributaries of the Grande Ronde River. The points located at anadromous fish hatcheries are the exact latitude and longitude release points while the other points were placed according to the data available. If the location was near a bridge or a bend in the stream then the locations' latitude and longitude were recorded. The shapefile was created by adding xy data and then exporting that event into a shapefile. Fields in the attribute tables were added to describe and to quantify the the points. The attributes associated with these points include hatchery source of the fish released, what stock they originated from, age at release (in terms of life stage), total number

released, marked and no-marked fish numbers, purpose of releasing fish and funding source.

j. ODFW_spawnindex
    i. Basic data created from the Report "Grande_Ronde_ODFW_spawning_report2004.pdf" located at I:\Depts\gis\project\MOA_Habitat_Monitoring\Grande Ronde\GIS working files\Spawning. Denise turned it into a shapefile and created some attribute fields. After comparing the locations, it became obvious that the report had incorrect information. This version has not been changed to correct locations. Each reach has a begin and end point. The beginning point of one reach may be in the same location as the end point of another index reach.
k. ofpbds_barriers
l. Rain_v09
    i. ODFW distribution layer for rainbow trout. Metadata can be found at http://rainbow.dfw.state.or.us/nrimp/information/fishdistdata.htm
m. Redds_2009
    i. Contains the GPS points identified by Casey Justice, Dale McCullough, and the CTUIR staff in GPS surveys after the ODFW/CTUIR/CRITFC redd counting crews flagged redds for the 2009 spawning season.
n. Redds_odfw_2004_2008
    i.
o. TRT_grandronde200ms
    i. This metadata imported from David Grave's previous REMAND version: "This data set was obtained from Damon Holzer (NOAA Upper Columbia TRT) in June of 2006. It shows distribution and habitat characteristics of Spring Chinoook in the Upper Grande Ronde Basin. Attribute definitions are not available but Dale McCullough may be familiar with many of the attributes. The WC_Factor is a derived value from the habitat characteristics and known distribution of Spring Chinook, which defines the Spring Chinook spawning quality of each stream segment as High (1), Medium (0.5), or Poor (0)." Any applications where spring chinook spawning habitat are important. A clipped version of this data set with only the upper watershed was used to define the path of the Upper Grande Ronde FLIR flight (to be conducted in 2010).

2. Bio_Invert
3. Bio_Other
4. Climate
5. DEM
6. Habitat_Flow

a. CRITFC_Flow_Gauges
b. critfc_flow_sites
c. external_agency_flowgauge_sites
d. Flow_station
    i. This DRAFT spatial dataset includes point flow stations and descriptions based primarily on data from the US Geological Survey (USGS) and US Forest Service (USFS) for Oregon daily flow. Each point represents a location where data for daily flow were gathered, analyzed, and associated with a stream reach for purposes of modeling fish habitat. The flow stations represented here are locations where flow data were gathered, analyzed and presented to each Oregon subbasin team for their work with Mobrand Biometric's Ecosystem Diagnostic and Treatment (EDT; http://www.mobrand.com/MBI/edt.html) model during the 2002-2004 Oregon Subbasin Planning effort.
e. Gauges_gr_v2a
    i. USGS stream gauge locations--developed by the Grande Ronde subbasin planning team (Austin Streetman, Spatial Dynamics?). This folder contains another shapefile called flow_stations.shp that should be compared to gauges_gr_v2a.shp since it contains corrected gauge locations obtained by TOAST from USGS.

7. Habitat_Other
    a. external_agency_water_quality_sites
    b. ODFW_ahi_hs
    c. ODFW_ahi_rs
    d. Str_303d02
        i. 303d listed waterchourses of Oregon in 2002, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets I:\Depts\gis\data\hydro\or\303d. Metadate can be found at http://www.sscgis.state.or.us/data/metadata/k100/streams303d_02.html
    e. Str_303d98
        i. 303d listed waterchourses of Oregon in 1998, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets I:\Depts\gis\data\hydro\or\303d. Metadata can be found at http://www.sscgis.state.or.us/data/metadata/k100/98303.pdf
8. Habitat_Sed
    a. critfc_sediment_sites
9. Habitat_Temp
    a. critfc_temp_sites

b. critfc_temp_sites_2010
c. external_agency_temp_sites
d. Wq_station
    i. This DRAFT spatial dataset includes point (continuous temperature and water quality grab sample) stations and descriptions based on data from the Oregon Department of Enviromental Quality (ODEQ) laser database or sent directly to us by ODEQ staff. Each point represents a location where data were gathered, analyzed, and associated with a stream reach for purposes of modeling fish habitat.

10. HabitatProjects
    a. Bpa_projects_GrandeR
        i. BPA habitat projects completed or ongoing at the time of Subbasin Planning 2002-2004. Metadata can be found at I:\Depts\gis\project\subbasin_planning\new_work\Grande Ronde\gis_data\metadata and file is called meta_bpa_projects.doc.
    b. GRMW_project_pts
        i. Assuming that Casey received this data from Grande Ronde Model Watershed from their sponsored projects.
11. HLR
    a. Aquifer_Permeability_Class
    b. Climate_Aquifer_Permeability_Class
    c. Climate_Class
    d. DEM_Stream_Network
    e. HLR_Class
    f. Hydrologic_Assessment_Units
    g. Oregon_Aquifer_Groups
    h. Seasonality_Subclass
    i. Soil_Permeability_Class
    j. Terrain_Class
12. Hydro_paek
    a. Beaver_natpaek_pts
        i. The Arc Hydro model was used to build a stream network. Several cell thresholds values were used for Stream Definition in an attempt to build a network that resemble a 24k scale stream layer in number of streams. For the 10 m DEM used a default of 13,000 produced a large number of streams. The value of 7000 produced a 24k scale number of streams most of which matched the locations of known streams. Known streams reference is the StreamNet mixed hydro layer. However to get a realistic stream length the high resolution NHD layer was used. So from the NHD layer streams were selected that matched the StreamNet layer. This new

layer of known streams was used to compare and selected the modeled streams from ArcHydro. Parts of the NHD layer were sometimes used to substitute parts of the modeled layer in valleys were streams are channelized or forced into canals. Once the streams were selected from the modeled layer the feature was smoothed using the PAEK algorithm with a 30 m smoothing tolerance. A 30 m smoothing tolerance produced a stream with a similar length to the NHD length for the same stream. Using this smoothed modeled stream this point layer was created starting at the mouth and placing a point every 10 m. Built to estimate slope along the stream. Starting at the mouth of the stream a point was place every 10 m and then the elevation value from a USGS 10m DEM was extracted from the DEM and associated with each pt. Result is that the elevation of the stream is known every 10 meters.

b. Catherineatpaek_pts
c. Clear_natpaek_pts
d. fivepoint_natpaek_pts
e. Flynatpaek_pts
f. Ladd_nhd_natpaek_pts
g. limberjim_natpaek_pts
h. Littlecathnatpaek_pts
i. Littlenatpaek_pts
j. Mccoy_natpaek_pts
k. meadow_natpaek_pts
l. milknhd_spchonly_pts
m. mill_nhd_natpaek_pts
n. nfcathnatpaek_pts
o. oldgr_natpaek_pts
p. pelican_natpaek_pts
q. pyles_natpaek_pts
r. rock_natpaek_pts
s. sfcathnatpaek_pts
t. sheep_natpaek_pts
u. spring_natpaek_pts
v. ugr_natpaek_pts
w. whiskey_natpaek_pts

13. Hydrography
    a. Cath_boundary
        i. This is the Catherine Cr boundary as it is currently. Which means it includes the old Grande Ronde River channels that are no longer carry the Grande Ronde River since the State Ditch went in. The HUC 6

boundaries were selected from the wdb_huc6 layer CRITFC has in GIS data sets. It is the latest HUC 6 boundaries for the region and matches 10 m DEM data ridge tops. This data has been reprojected into the project's UTM projection.

b. Cath_boundary_Buf
    i. This is the Catherine Cr boundary buffered out 300m to capture 10m DEM cells on the other side of ridges. This was done to work with watershed models (TauDEM and Arc Hydro). The boundary is as it is currently. Which means it includes the old Grande Ronde River channels that are no longer carry the Grande Ronde River since the State Ditch went in. The HUC 6 boundaries were selected from the wdb_huc6 layer CRITFC has in GIS data sets. It is the latest HUC 6 boundaries for the region and matches 10 m DEM data ridge tops. This data has been reprojected into the project's UTM projection.
c. cath_cut_layer
d. Cath_HUC6
    i. These are the HUC 6 boundaries for Catherine Cr as it is currently. Which means it includes the old Grande Ronde River channels that are no longer carry the Grande Ronde River since the State Ditch went in. The boundaries were selected from the wdb_huc6 layer CRITFC has in GIS data sets. It is the latest HUC 6 boundaries for the region and matches 10 m DEM data ridge tops. This data has been reprojected into the project's UTM projection.
e. cu_modeled_reaches
f. GR_boundary
    i. This is the Grande Ronde boundary created from HUC 6 boundaries that were selected from the wdb_huc6 layer CRITFC has in GIS data sets. It is the latest HUC 6 boundaries for the region and matches 10 m DEM data ridge tops. This data has been reprojected into the project's UTM projection.
g. GR_HUC6
    i. These are the HUC 6 boundaries for Grande Ronde. The boundaries were selected from the wdb_huc6 layer CRITFC has in GIS data sets. It is the latest HUC 6 boundaries for the region and matches 10 m DEM data ridge tops. This data has been reprojected into the project's UTM projection.
h. GR_mixed_hydro
    i. CLIPPED for the GRANDE RONDE BASIN. This whole-stream routed hydrography layer serves as the base hydrography for the StreamNet project's Linear Referencing System (LRS). To distinguish this hydrography layer from the previous system(s), StreamNet refers to it as

"MSHv1" (Mixed-scale hydrography, version 1). At version1: this dataset includes all routed streams present in the PNW River Reach Files (PNWRF3), StreamNet's previous base hydrography. In addition, those features within the state of Washington are now depicted at a higher resolution (1:24k scale) and densified to include all named streams present in Washington Department of Fish and Wildlife's 1:24k hydrography layer, and additional unnamed streams from that source where fish data exists and is compiled across the region. Future versions of this dataset will include similar improvements for StreamNet's other partner states (Oregon, Idaho, and Montana). In addition, the extent of StreamNet's regional hydrography has expanded to include integration with the 1:100k scale routed hydrography for California (CalHydro). While the StreamNet project does not manage fish data for California, the integration of California hydrography facilitates collaboration with StreamNet's partner project, "CalFISH". For more information about the CalFISH project, visit http://www.CalFISH.org. For more information about the source data contributing to this dataset, see the lineage section of this metadata record. The primary purpose of this dataset is to provide a route system ideal for storing, organizing, and displaying stream related fisheries and habitat data across the Pacific Northwest and California at the best practically available source scale. An on-going effort involves improving the resolution of the source datasets that makeup this regional layer. In addition to providing a regionally standard LRS, the MSHv1 can support many different types of GIS analysis including: buffering around reaches, stream network routing, and basin characteristics analysis.

i. Hydro100K
    i. 100k resolution streams and rivers clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets. Metadata can be found at http://www.sscgis.state.or.us/data/metadata/k100/rivers.pdf
j. Minam_boundary
k. minam_cut_layer
l. minam_huc6
m. NHD_named
    i. The National Hydrography Dataset (NHD) is a feature-based database that interconnects and uniquely identifies the stream segments or reaches that make up the nation's surface water drainage system. NHD data was originally developed at 1:100,000-scale and exists at that scale for the whole country. This high-resolution NHD, generally developed at 1:24,000/1:12,000 scale, adds detail to the original 1:100,000-scale NHD.

(Data for Alaska, Puerto Rico and the Virgin Islands was developed at high-resolution, not 1:100,000 scale.) Local resolution NHD is being developed where partners and data exist. The NHD contains reach codes for networked features, flow direction, names, and centerline representations for areal water bodies. Reaches are also defined on waterbodies and the approximate shorelines of the Great Lakes, the Atlantic and Pacific Oceans and the Gulf of Mexico. The NHD also incorporates the National Spatial Data Infrastructure framework criteria established by the Federal Geographic Data Committee. The NHD is a national framework for assigning reach addresses to water-related entities, such as industrial discharges, drinking water supplies, fish habitat areas, wild and scenic rivers. Reach addresses establish the locations of these entities relative to one another within the NHD surface water drainage network, much like addresses on streets. Once linked to the NHD by their reach addresses, the upstream/downstream relationships of these water-related entities--and any associated information about them--can be analyzed using software tools ranging from spreadsheets to geographic information systems (GIS). GIS can also be used to combine NHD-based network analysis with other data layers, such as soils, land use and population, to help understand and display their respective effects upon one another. Furthermore, because the NHD provides a nationally consistent framework for addressing and analysis, water-related information linked to reach addresses by one organization (national, state, local) can be shared with other organizations and easily integrated into many different types of applications to the benefit of all.

n. NHD_unnamed
o. ugr_cut_layer
p. UpGR_boundary
q. UpGR_HUC6
r. Wallowa_boundary
s. Wallowa_HUC6
t. wen_cut_layer
u. Wenaha_boundary
v. Wenaha_HUC6
w. WildScenicRiv_GrandeR
    i. Wild and Scenic rivers of PNW, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets I:\Depts\gis\data\hydro\region.

14. Landscape
    a. Contour200ft

        i. Created from a cont200_ne coverage at I:\Depts\gis\data\contour\or\, clipped to the Grande Ronde Basin. Does not include WA portion of the Grande Ronde Basin. Reprojected to the project's UTM projection. See the or_cont100_metadata.htm for info on the data.

    b. WhittierLandscapeClassifications

15. LandUse
    a. Allstatehwy_GR
        i. State highways from the Western US, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets.
    b. Allushwy_GR
        i. US highways in the Western US, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets.
    c. BLM_Vale_GR
        i. This is a BLM roads layer from the Vale District. It has been clipped to the Grande Ronde watershed and reprojected to the project's UTM projection. Original data stored in CRITFC's GIS data sets. This roads layer seems to be the most complete set of data. A Transportation geodatabase was downloaded from USFS site of the Wallowa/Whitman NF, but the data was not as detailed as the BLM layer and only covers the NF. The one layer saved from this Transportation geodatabase was the Trails (NF Trails) which the BLM layer does not have.
    d. Dams
        i. Dam layer, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets. Metadata can be found at http://rainbow.dfw.state.or.us/nrimp/information/damdata.htm
    e. Dynaroads_GR
        i. This data set displays road names and was clipped to the Grande Ronde and reprojected to the project's UTM projection. Original data stored in CRITFC's GIS data sets.
    f. GR_Hwys_all
        i. This is a combination of several layers of roads and Hwys to show all Hwys (US and State) within the Grande Ronde Basin. This was created mostly for mapping. The data was reprojected in to the project's UTM projection.
    g. LandOwners

            i. Landowners of PNW, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data setsI:\Depts\gis\data\boundary

h. NF_Trail
    i. Trail Routes of the Wallowa Whitman National Forest and surronding areas
i. Quad24K_GrandeR
    i. USGS 24k Quad map boundaries, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets. Metadata can be found at http://www.sscgis.state.or.us/data/metadata/k24/quadindex7_5.html
j. Towns_GrandeR
    i. Towns of PNW, clipped to the Grande Ronde Subbasin and reprojected into the project's UTM projection. Original data stored in CRITFC's GIS data sets I:\Depts\gis\data\base\region.
k. Union_County_tax_lots_2008

16. NetMap
    a. basin_ugr1
    b. lake_ugr1
    c. reach_ugr1
    d. roaddrain_ugr1
    e. roads_ugr1
    f. roadseg_ugr1
    g. roadX_ugr1
    h. tribs_ugr1
17. ODFVeg
18. Monitoring Sites
    a. Coopmon
        i. Sent to us on July 22, 2009 from Coby Menton coby@grmw.org. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This whole set of sites is outside of the CRITFC study area and therefore remains unaltered.
    b. CTUIR_ODFW_Temp_logger
        i. Sent to CRITFC on August 26, 2009 from Leslie Naylor, Assistant Fish Habitat Biologist, CTUIR Grande Ronde Fish Habitat Project, 1-541-215-2245, LesNaylor@ctuir.com. Original name of shapefile was CTUIR_ODFW_Temperature_Loggers2009.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was outside of the CRITFC study area.

c. DEQambsites
    i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original name of shapefile was DEQambsites.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was outside of the CRITFC study area.
d. GRBstreamgage
    i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original name of shapefile was GRBstreamgage.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was outside of the CRITFC study area.
e. SA_CTUIR_ODFW_Temp_logger
    i. Sent to CRITFC on August 26, 2009 from Leslie Naylor, Assistant Fish Habitat Biologist, CTUIR Grande Ronde Fish Habitat Project, 1-541-215-2245, LesNaylor@ctuir.com. Original CTUIR_ODFW_Temperature_Loggers2009.shp has points located outside the study area (SA). CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was inside of the CRITFC study area. The data was already in the correct projection.
f. SA_DEQambsites_pro
    i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original shapefile is DEQambsites.shp and has points outside the study area (SA). CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was inside of the CRITFC study area. The data needed to be reprojected to the Watershed Sciences projection.
g. SA_GRBstreamgage_pro
    i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original shapefile is GRBstreamgage.shp and contains points outside the study area (SA). CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was inside of the CRITFC study area. The data needed to be reprojected to the Watershed Sciences projection.
h. SA_UnionSWCDmon_pro

i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original shapefile is UnionSWCDmon.shp and contains points outside the study area (SA). CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was inside of the CRITFC study area. The data needed to be reprojected to the Watershed Sciences projection.

i. SA_WQ_LaGrandeRD_pro
    i. Past and Present Water Quality Monitoring Stations of the Blue Mountains of North East Oregon and South East Washington. Shows spatial location of Monitoring stations. CRITFC received this dataset from Kayla Moringa on July 30, 2009. Fisheries Technician, La Grande Ranger District, Wallowa-Whitman National Forest, 541-962-8536, kmorinaga@fs.fed.us. Original shapefile was wqms_check_shapefile_07302009.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites is within the CRITFC study area and has been reprojected to match Watershed Sciences projection.

j. SA_wwwatermonpoints_pro
    i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original shapefile is wwwatermonpointclp.shp and contains points outside the study area (SA). CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was inside of the CRITFC study area. The data needed to be reprojected to the Watershed Sciences projection.

k. Streamflowgage
    i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original name of shapefile was streamflowgage.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This whole set of sites is outside of the CRITFC study area and therefore remains unaltered.

l. Temperaturegage
    i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original name of shapefile was temperaturegage.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This whole set of sites is outside of the CRITFC study area and therefore remains unaltered.

m. UnionSWCDmon
    i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original name of shapefile was UnionSWCDmon.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was outside of the CRITFC study area.
n. WQ_sites_LaGrandeRD
    i. Past and Present Water Quality Monitoring Stations of the Blue Mountains of North East Oregon and South East Washington. Shows spatial location of Monitoring stations. CRITFC received this dataset from Kayla Moringa on July 30, 2009. Fisheries Technician, La Grande Ranger District, Wallowa-Whitman National Forest, 541-962-8536, kmorinaga@fs.fed.us. Original name of shapefile was wqms_check_shapefile_07302009.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites is outside of the CRITFC study area.
o. Wwwatermonpoints
    i. Sent to CRITFC on July 22, 2009 from Coby Menton, Grande Ronde Model Watershed, 541-426-0389 (office) 541-398-0151 (cell), coby@grmw.org. Original name of shapefile was wwwatermonpointclp.shp. CRITFC is looking for other monitoring sites in the Grande Ronde so that we do not duplicate other efforts. This portion of the sites was outside of the CRITFC study area.

19. Photos
20. RestProjects
    a. bpa_projects_GrandeR_1
    b. GRMW_project_pts_1
21. SubPlan_Data
    a. Obstructions_edt
        i. This data set includes a spatial representation of obstructions to fish passage and descriptions that were modeled for Ecosystem Diagnosis and Treatment (EDT) for the 2002-2004 Subbasin Planning effort. The obstructions include both natural and manmade barriers, and may be either partial or full obstructions depending on life stage, time of year, and species. The GIS representation of these obstructions were developed by the local Subbasin Planning team along with the EDT Habitat reaches. In Oregon teams coordinated with the Technical Outreach and Assistance Team (CRITFC; sponsored by the Columbia River Inter-Tribal Fish Commission). The reaches were created to spatially define habitat units to

be processed by Mobrand Biometrics' Ecosystem Diagnosis and Treatment (EDT; http://www.mobrand.com/MBI/edt.html) model as part of the Subbasin Planning effort mandated by the Northwest Power and Conservation Council (NPCC) in 2003. (http://www.nwcouncil.org/fw/subbasinplanning/Default.htm). Supplementary Information. This dataset is intended to be used by local Subbasin Planning team members as spatial reference for rated reaches and identified obstructions as has been required by the EDT model. Reaches that do not correspond with the available hydrography have been digitized according to stream locations depicted on the 1:24,000 (24K) USGS DRG quadrangles.

b. Reach_edt
    i. This spatial dataset includes linear aquatic habitat reaches ("reaches") and descriptions primarily based on the available Oregon 1:100,000 scale routed hydrography for the specified subbasin (or partial subbasin). Each reach was defined as such because it has unique aquatic habitat characteristics which separate it from surrounding aquatic habitat, such as temperature, gradient, water quality, etc. The dataset also includes obstruction reaches, which may partially or fully impede focal species passage. The reaches were originally developed during the 2002-2004 Subbasin Planning effort to define habitat units to be attributed, rated, and processed by the Ecosystem Diagnosis and Treatment (EDT) model (see details below). Many of the EDT ratings and results attributes are available in a separate table (edt_reach_attributes.dbf) that can be appended to the reaches via the unique item, REACHNAME. It is strongly recommended that data users consult the Mobrand Biometric, Inc. EDT website (http://www.mobrand.com/MBI/edt.html) and the related Guidelines for Rating Selected Level 2 Environmental Attributes (http://www.mobrand.com/MBI/pdfs/AttributeRatings-June2004.pdf) to fully understand the EDT process and attribute definitions presented in this shapefile.

22. USFSVeg
    a. existingvegetation
    b. historicvegetation_1900
    c. potentialvegetation
    d. RHCA
    e. USFS_RiparianPlots

23. WatershedSciences
    a. FLIR_flight_modified
    b. LIDAR_FlightCoverage

c. MonSites
    i. Data from Watershed Sciences. Indicates where they believe Temperature monitoring should occur for temperature modeling with the FLIR flight data.
d. TIR_Recommended
    i. Data from Watershed Sciences indicating where they recommend that FLIR flights should occur to cover Spring Chinook Spawning areas.

Appendix N

ABR proposal for macroinvertebrate sample processing and analysis

BENTHIC MACROINVERTEBRATE SAMPLE PROCESSING, TAXONOMY, AND ANALYSIS SERVICES

A PROPOSAL

Prepared for

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CONTENTS

INTRODUCTION

The Columbia River Inter-Tribal Fish Commission (CRITFC) has initiated biological monitoring in selected streams in northeast Oregon to determine habitat quality, as indicated by responses of macroinvertebrate communities to restoration efforts. CRITFC is seeking a qualified contractor to perform macroinvertebrate sample processing and identification services, and to perform analyses of these data in order to determine habitat quality and effects on biota in relation to restoration activities. ABR, Inc.—Environmental Research & Services proposes to perform these services for CRITFC. In this proposal, ABR recommends methods that are most appropriate for addressing project goals, which we understand to be as follows:

- Determine long-term trends in habitat quality in the study streams (to be assessed with benthic samples)
- Determine fish food abundance and provide information to relate to future fish growth rate studies (to be assessed with drift samples)

In the following section, we present detailed methods, and in some cases, options and attendant costs, for processing and identification of both benthic (Hess) and drift samples. We recommend an approach for determining benthic and drift sample biomass, as well as attendant costs for deriving these estimates. We also offer recommended approaches (predictive models, individual metrics, and multimetric approaches) for analyzing the data. Following the Technical Approach section, we provide company and staff experience and qualifications, followed by a list of references for benthic sample processing and taxonomy services. On the final page of this response, we provide price quotes for each of the services offered in our proposal.

TECHNICAL APPROACH

RECOMMENDED LABORATORY PROCEDURES

METHOD FOR SUBSAMPLING

ABR will follow standard operating procedures and adhere to a rigorous quality assurance plan (see following sub-section) in the execution of these services for CRITFC. ABR proposes to process both Hess and drift samples using standard subsampling methods employed by both the Oregon Department of Environmental Quality (DEQ) and Washington Department of Ecology (DOE) and as described in detail in ABR's Macroinvertebrate Sample Processing Standard Operating Procedures and Quality Assurance Plan. Each sample will be subsampled using a 30-square Caton gridded tray to remove 525-550 organisms, unless the 525-550 target is not met, in which case the entire sample will be sorted.

LEVEL OF IDENTIFICATION FOR MAJOR TAXA (BENTHIC SAMPLES)

ABR recommends using the standard levels of resolution for northwest benthic macroinvertebrate samples, as established by the Northwest Biological Assessment Workgroup (please see Table 1 for a complete listing of suggested levels of resolution). These standards generally include identification of all major taxonomic groups to genus/species. Because ecological attributes (tolerance values, in particular) can vary among species within a genus, this additional information may allow for changes in community conditions to be detected at a finer scale than would genus-level information, alone.

We propose only one noteworthy exception to these standards: retain Chironomidae at the subfamily level, rather than identify to genus-species. We make this recommendation based on our experience that Chironomidae data at the genus/species level provide little, if any, additional insight into macroinvertebrate community conditions under most circumstances, yet add to sample identification costs. Because we understand that these data may be desired, we have included cost quotes for benthic sample taxonomy both with and without Chironomidae identified to genus/species.

All taxonomic work will be performed by NABS-certified taxonomists, Dr. Michael Cole and Ms. Ann Gregoire.

LEVEL OF IDENTIFICATION FOR MAJOR TAXA (DRIFT SAMPLES)

ABR will identify all aquatic stages of macroinvertebrates found in drift samples to the lowest practical levels of resolution (same as those for benthic samples). Aerial adult stages of aquatic insects will be identified to the family level. We recommend that terrestrial macroinvertebrates be left at the order level because family-level resolution will not likely provide additional insight into riparian condition beyond that which can be immediately observed from direct field surveys of riparian conditions. However, ABR can provide family-level identification services for the terrestrial component according to the pricing stated in the price quote.

METHODS FOR ESTIMATING DENSITY & BIOMASS BY TAXON & SIZE CLASS

Densities of each taxon in each benthic sample will be determined simply by multiplying the number of organisms counted in the subsample by the inverse of the fraction of sample sorted, and then dividing by a correction factor of 0.743 to express the result as number of organisms per m^2. Densities in drift samples can be calculated with knowledge of the riffle depth (height of water column in drift net) and mean water velocity during the 12-hour drift collection period. ABR can make these calculations if these data are provided, or CRITFC can make the calculations from the raw count data provided.

Several methods are available for estimating biomass for each taxon in each sample. These include 1) weighing each size class of each taxon from every sample or 2) measuring organism lengths and then using length-weight relationships to estimate weights. The latter

approach can be further divided into either deriving length-weight relationships from a subset of organisms of each taxon in the sample set or using existing length-weight relationships. A number of factors must be considered in the choice of approach taken. First, macroinvertebrates preserved in ethanol are known to lose a substantial portion of their dry mass through leaching of organic compounds into the ethanol (e.g., Howmiller 1972, Dermott and Paterson 1974, Leuven et al. 1985). Because the samples in this study have been preserved in ethanol, they are not suitable for deriving accurate biomass estimates via weighting of sample material. Furthermore, CRITFC wishes to archive all samples for further identification in the future, if necessary. Directly obtaining dry mass from samples will require sacrificing the samples, rendering them no longer available for such future work. As such, we recommend measuring the lengths of subsampled macroinvertebrates and using previously determined length-weight formulas for estimating ash-free dry weights as measures of biomass. Length-weight formulas could be empirically derived from the project data, but this approach is time consuming, requires specialized equipment (dessicator and muffle furnace), and would significantly increase contractor costs. Furthermore, this approach also requires sacrificing samples, rendering them no longer available for future work.

Several regional studies have used previously established length-weight formulas for estimating macroinvertebrate biomass from length measurements (S. Estrella, WA DOE, personal communication; Wipfli and Gregovich 2002; Musslewhite and Wipfli 2004). More recently, the WA DOE has established using these existing length-weight relationships as Standard Operating Procedure for estimating biomass in DOE drift samples (Estrella 2008). Researchers at the WA DOE and the United States Forest Service (USFS), PNW Research Station maintain a library of up-to-date publications containing length-weight regression equations for terrestrial and aquatic insects. Accordingly, if CRITFC deems these data as necessary to assist with determining fish food abundance, we recommend the use of this approach that utilizes existing length-weight formulas.

Using this approach, each organism would be measured to the nearest millimeter using micrometers on high-power stereo-microscopes. The most appropriate length-weight formula would be selected for each taxon and then biomass calculated for each organism. The costs associated with this process, including data entry and analysis, are included in the Cost Quote section of this proposal.

RECOMMENDED DATA ANALYSES

Because many macroinvertebrate community attributes are responsive to changes in habitat conditions, and some are more responsive than others depending on the size and nature of the change, we recommend analysis with a variety of tools. This allows for a robust assessment of the community using a number of measures of community structure, condition and taxonomic composition. We recommend the full suite of measures listed in the RFP for this work, including:

- Standard BCI indices
- Functional feeding group composition
- Hilsenhoff metrics

- Tolerant/intolerant species based on fine sediment and temperature conditions (using, in part, indicator taxa identified by Huff et al. 2006)
- PREDATOR (Western Cordillera and Columbia Plateau model)
- Total taxa densities
- Biomass per m^2 (if desired by the client, see additional costs in the Cost Quote section)

Furthermore, we recommend using these additional tools:

- Eastern Oregon multimetric index (Hubler 2006) and its component metrics
- DEQ temperature and fine sediment stressor models

The multimetric index referenced above was developed for use with eastern Oregon macroinvertebrate samples and has been used in recent years by the DEQ (e.g., Hubler 2006) as well as others to assess community structure and condition (e.g., Lemke and Cole 2006). Component metrics include mayfly richness, stonefly richness, caddisfly richness, the number of sensitive taxa, the number of sediment-sensitive taxa, a modified HBI, percentage of tolerant taxa, percentage of sediment tolerant taxa, and community dominance by the single most abundant taxon.

More recently, the DEQ has developed weighted-average inference models (stressor models) that allow further characterization of benthic communities in relation to temperature and fine-sediment stressors (Huff et al. 2006). These models are run on C2 software and the results can be used to identify potential sources of impairment, namely elevated fine sediment inputs and water temperature. ABR is capable of running these models and providing the results to CRITFC.

All raw taxonomic and count data would be entered into an Access database. ABR would provide both raw and summarized data to CRITFC exported from Access into Excel format (Raw data can also be provided in Access at no additional cost, if desired). Raw data would be provided in both matrix (sample x taxon) and column format (each taxon from each sample in a unique row). Computed densities, metrics, PREDATOR scores, and other summarized data would be provided in Excel, either as a separate worksheet, or at the bottom of the raw data matrix (as in the examples provided). Please see the accompanying Excel file with examples that illustrate how raw data could be provided. ABR packages and presents raw data to each client in a manner that best suites their individual needs. ABR will work with CRITFC to determine the best format.

Table 1. Recommended levels of taxonomic resolution for CRITFC benthic (Hess) samples, derived from taxonomic standards established by the Northwest Biological Assessment Workgroup.

1 **Ephemeroptera** – Genus level except as noted below:
- Baetidae – species as allowed by specimen conditions and maturity
- Ephemerellidae – species in almost all cases
- Heptageniidae – genus only except for *Epeorus* (*albertae, longimanous, grandis*, etc.)
- Leptophlebiidae – genus except for *Paraleptophlebia* to species

2 **Plecoptera** - genus level except as noted below and for monotypic genera:
- Capniidae – genus where possible
- Chloroperlidae – genus in late instars
- Leuctridae – genus, species for monotypics
- Nemouridae – genus, species for *Zapada* (*cinctipes, frigida* etc.) and where keys permit.
- Peltoperlidae – genus, species for monotypics
- Perlidae – species
- Perlodidae – genus, except *Isoperla* to species
- Pteronarcidae – species
- Taeniopterygidae- genus

3 **Trichoptera** - genus level except as noted below (and species where keys permit):
- Hydropsychidae – *Parapsyche* to species, other to genus
- Lepidostoma- denote case type (panel, turret, sand)
- Limnephilidae- genus, except to species where keys permit and for monotypics
- *Rhyacophila*- to species group except to species where keys permit and as noted below:
  - Betteni gr. - *R. malkini*
  - Lieftinchi gr. - *R. arnaudi*
  - Sibirica gr. - *R. blarina* and *R. narvae*

4 **Coleoptera** - Family level except for the following:
- Psephenidae- genus
- Hydrophilidae- genus
- Haliplidae- genus
- Dytiscidae. – genus
- Elmidae- species where keys permit.

5 **Diptera** - genus level for all families except for:
- Chironomidae – subfamily/tribe (can go to genus, species if preferred)
- Ceratopogonidae - sub family, except genus where possible
- Tabanidae, Dolichopodidae, Ephydridae, Sciomyzidae, Syrphidae – genus where keys permit

6 **Hemiptera** - genus level.
7 **Odonata** - genus level, except to species where keys permit.
8 **Lepidoptera** - genus level
9 **Megaloptera –** genus level
10 **Gastropoda –** genus level where possible
11 **Bivalva –** family level (except to genus or species where possible).
12 **Amphipoda –** genus level.
13 **OSTRACODA** – Order
14 **OLIGOCHAETA** – Class (i.e., leave at Oligochaeta)
15 **HIRUDINEA –** genus level as keys allow
16 **TURBELLARIA** – Phylum (i.e., leave at Turbellaria)
17 **NEMATA and NEMATOMORPHA** - Phylum
18 **NEMERTEA –** genus (Prostoma)
19 **TROMBIDIFORMES –** Order

QUALITY ASSURANCE AND QUALITY CONTROL

ABR maintains a rigorous quality assurance program for our macroinvertebrate assessment projects. ABR's procedures and standards for our laboratory sample processing and taxonomy work are well documented and are described in detail in our *Standard Operating Procedures* and *Quality Assurance Plan* developed and maintained by Dr. Cole. Our aim is to provide the highest quality of macroinvertebrate data by including the following elements into our QA/QC program:

1) Development of internal standard operating and quality assurance procedures.
2) Internal training of all ABR staff performing sample processing (includes a written test).
3) Development of project specifications sheets and project-specific protocols, as necessitated.
4) Adherence to written protocols in each step of sample processing.
5) Proper labeling and logging-in of samples received, and tracking of samples as they move through the processing, identification, and analysis phases of the project.
6) Standardized record keeping of each sample processed.
7) Sorting efficacy QC inspections of a specified portion (or the entire lot) of each sample lot received (normally 10% unless otherwise specified by the client) and documentation of such inspection.
8) Internal taxonomic QC inspections of a subset of samples of each sample lot received, as requested by the client. Normally, this would include re-identification of 10% of the samples by a second ABR taxonomist.
9) Documentation of results of quality-control activities and corrective actions taken.
10) Regular attendance of taxonomic and taxonomy quality assurance workshops.
11) NABS certification of ABR taxonomists.
12) Use of extensive and up-to-date taxonomic literature.
13) Assembly of a synoptic voucher collection for each new ABR project. Voucher specimens with be retained by ABR for a minimum of 5 years.
14) Independent validation of specimens using research taxonomists and other outside experts on an as-needed basis.
15) Thorough documentation of uncertain identifications through illustrating and photographing characters used to make the determination.

ABR employs two highly trained and NABS-certified taxonomists, Dr. Michael Cole and Ms. Ann Gregoire (Please refer to Key Personnel Section for more information), who will perform all taxonomic work. ABR maintains a running tally of taxonomic agreement between project and quality control (QC) taxonomists. Correspondence between project and QC taxonomists are calculated with the Bray-Curtis similarity index. ABR maintains a high level of accuracy that consistently meets or exceeds our 95% data quality objective. Our current running average (calculated for the most recent 50 samples QC checked for taxonomic accuracy) is 98.0%.

TECHNICAL LITERATURE CITED

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QUALIFICATIONS

EXPERIENCE WITH SIMILAR PROJECTS

ABR has provided macroinvertebrate sample processing, taxonomy, analysis and reporting services for more than ten years. In 2009, ABR processed and identified benthic macroinvertebrates from nearly 900 samples collected throughout the Pacific Northwest (Washington and Oregon) and the state of Alaska. The taxonomic needs of a diverse group of 17 clients were met last year. Clients included local municipalities; county, state, and federal agencies; special purpose districts; soil and water conservation districts (SWCDs), non-profit organizations; watershed councils; and Native American tribes:

Local Municipalities: City of Portland, City of Gresham, and City of Lake Oswego (OR)

Counties: King County (WA), Clackamas County, Water Environment Services (OR), Multnomah County (OR)

State Agencies: Oregon Department of Fish and Wildlife (OR)

Federal Agencies: National Park Service (AK)

Special Purpose District: Clean Water Services (OR)

Soil and Water Conservation Districts: Clackamas County Soil and Water Conservation District (OR), West Multnomah Soil and Water Conservation District (OR)

Non-profit Organizations: The Nature Conservancy (WA), The Xerces Society (OR)

Watershed Councils: Middle Fork Willamette Watershed Council (OR), South Coast Watershed Council (OR)

Native American Tribes: Colville Confederated Tribes (WA), Confederated Tribes and Bands of the Yakama Nation (WA)

KEY PERSONNEL

Project Manager and Project Taxonomist:

Dr. Michael B. Cole, Senior Aquatic Scientist
Ph.D. Fisheries Biology, The Pennsylvania State University, 1998; M.S. Zoology, University of Maine, 1994; B.S. Environmental Science, Rollins College, 1992

Certifications:

- North American Benthological Society, Group 1e – General Arthropods (**Crustacea, Coleoptera, Diptera, Hemiptera, Odonata, Trombidiformes**), Level 2 taxonomist
- North American Benthological Society Group 2e/w – EPT (**Ephemeroptera, Plecoptera, Trichoptera**), Level 2 taxonomist
- North American Benthological Society Group 3e/w – **Chironomidae**, Level 2 taxonomist

Dr. Michael Cole has more than 18 years of experience identifying macroinvertebrates from across North America with an emphasis on taxa of the Pacific Northwest. For the past 11 years, Dr. Cole has performed contract taxonomic work for clients in the government, non-profit, academic, and industry sectors. He routinely performs taxonomic identification work of macroinvertebrates for biological assessment, biomonitoring, and applied research studies. Dr. Cole's taxonomic experience and training includes identifying Chironomidae to genus/species (he has identified specimens to genus/species from many hundreds of benthic samples) and Oligochaeta to genus and species. Dr. Cole has amassed a master voucher collection numbering more than 5,000 aquatic invertebrate specimens in his years of taxonomic work and regularly attends professional taxonomic workshops and trainings. Recent workshops include an advanced Chironomidae workshop (taught by Bob Bode and Rhonda Mendel), a mayfly workshop (taught by Dr. Pat Randolph and Luke Jacobus of the Purdue mayfly lab), a stonefly workshop (taught by Dr. Ken Stewart), and two Oligochaeta workshops (one taught by Steve Fend, the other taught by Mark Wetzel) and two Molluska workshops (one taught by Dr. Terrance Frest, the other taught by Dr. Rob Dillon).

Project Taxonomist:

Ann Gregoire, M.S., Research Biologist III
M.S. Stream Ecology, Arizona State University, 1996; B.A. Biology, Dartmouth College, 1992

Certifications:

- North American Benthological Society Group 2w (Ephemeroptera, Plecoptera, Trichoptera), Level 2 taxonomist.

Ms. Gregoire is an ABR taxonomist with more than 11 years of experience identifying freshwater macroinvertebrates in the Pacific Northwest. In her 5 years as an ABR taxonomist, Ms. Gregoire has identified many hundreds of samples from throughout the Pacific Northwest.

Ms. Gregoire regularly attends the Northwest Taxonomic Workgroup meetings and has recently attended workshops covering Odonata, Diptera, mayflies, stoneflies, and mollusks. Ms. Gregoire is familiar with and has considerable experience identifying taxa that occur in rivers, streams, and wetlands of the Pacific Northwest, including western Washington State.

Macroinvertebrate Laboratory Supervisor:

Nicholas Haxton, M.S., Research Biologist I
M.S. Environmental Science, Indiana University, 2002; B.A. Environmental Science and Biology, The Colorado College, 1998

As ABR's Macroinvertebrate Laboratory Supervisor, Mr. Haxton would oversee the sub-sampling and sample sorting of the benthic macroinvertebrate samples, and would coordinate sample pick up/delivery from CRTIFC. Owing to CRITFC's close proximity to our Forest Grove lab, Mr. Haxton would pick up the samples at CRITFC's offices in Portland. Mr. Haxton would also sort samples for this project.

REFERENCES

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