Assessing the Status and Trends of Spring Chinook Habitat in the Upper Grande Ronde River and Catherine Creek: Annual Report 2015

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Table of Contents

Executive Summary

Background and Objectives

The Columbia River Inter-Tribal Fish Commission (CRITFC) is conducting a fish habitat monitoring program in the Upper Grande Ronde River and Catherine Creek basins designed to evaluate the effectiveness of aggregate restoration actions in improving freshwater habitat conditions and viability of salmonids listed under the Endangered Species Act. Critical uncertainties for fisheries managers in the Columbia Basin are whether habitat restoration actions will yield a net improvement in basin-wide habitat quality, and whether expected improvements in fish production can be brought about by improvements in the quality and quantity of salmon habitat. The primary objectives of this project are to: 1) Assess current status and trends in fish habitat characteristics considered to be key limiting factors (particularly water temperature, pool habitats, streamflow, and fine sediment) to viability of spring Chinook Salmon populations; 2) Evaluate effectiveness of aggregate stream restoration actions aimed at improving key limiting habitat factors; and 3) Develop a life cycle model to link biotic responses of spring Chinook populations to projected changes in stream habitat conditions.

Life Cycle Model as an Organizing Concept

One of the central components of this project is a spring Chinook life cycle model which provides a means to integrate habitat monitoring efforts with recovery planning. The life cycle model is a tool to simulate fish population trends in relation to projected habitat conditions, and to examine the relative benefits of habitat improvements on fish population recovery potential. The fundamental basis of the model is that intrinsic watershed factors (such as geology, climate, or valley morphology) interact with human actions (such as forest harvest, cattle grazing, or stream restoration) to affect processes that drive known limiting factors (e.g., flow, temperature, pool area, etc.), and therefore fish survival via both density-dependent and density-independent processes. This conceptual model represents the general structure of our research program.

The life history model is comprised of several interacting subcomponents that are built independently, each of which provides critical information about the interaction between landscape characteristics, instream habitat conditions, and fish response. Individual subcomponents of the life cycle model, and of our research program, include modeling stream temperature from local riparian and geomorphic conditions, a sediment delivery model, linking fine sediment and water temperature to fish survival, mapping potential natural vegetation, estimating food base and growth potential for salmonids from macroinvertebrate drift data and habitat characteristics, and evaluating the vulnerability of sites to low streamflows. Though these components are described here as providing inputs to the life cycle model, each model is a valid research project in its own right that is likely to yield interesting scientific insights and practical applications for conservation.

Progress and Key Findings from Individual Project Components

Stream Habitat Conditions

- Continued collection and QA/QC of stream habitat condition data using the Columbia Habitat Monitoring Program (CHaMP) methodology. Conducted 26 surveys within spring Chinook salmon extent in 2015, totaling 124 surveys at 63 sites since 2011.
- Funded ODFW to conduct CHaMP surveys in the Minam River—a wilderness reference stream—in 2013-2015. In this 3-year period, ODFW surveyed 15 unique sites and produced data from 20 separate visits.
- Initial summaries of six habitat metrics highlight the diversity of streams present across the Grande Ronde River, Catherine Creek, and Minam River watersheds. The results from the valley setting analysis hold promise for using this stream classification system to extrapolate habitat metrics to un-sampled sections of streams.
- Trend analysis of the six summaries metrics reveals that across spatial extents LWD frequency and temperature metrics have had the most detectible variability over the past five year time period. Percent fines and percent pool volume have remained stable, with no significant trends at nearly every spatial resolution.
- At the ICTRT population scale trends are less detectible, only LWD frequency in two populations have significant trends. At finer resolutions, BSRs and valley classes, trends become more detectible and show negative and positive trends within a single population. This analysis further supports our use of the classification system to more accurately understand the heterogeneity of river form and process within the study area.
- Continued monitoring of stream temperature at 71 sites across three watersheds. Summer temperatures recorded for 37 sites.
- A five-year analysis of temperature data at three representative sites indicated that 2011 was a cooler year than the following four years. In 2015, temperatures at the South Fork Catherine Creek site set records for maximum recorded temperatures. In contrast the two sites within the Grande Ronde Basin had slightly lower temperatures in 2015 compared with 2013 and 2014. Temperatures in the lower mainstem Grande Ronde River continue to be extremely high and prohibitive for juvenile use during the summer months.

Water Temperature Modeling

- We used the Heat Source model to evaluate how habitat restoration actions and climate change could influence water temperatures in the future. A detailed map of current and potential riparian vegetation across the river network was developed to inform the temperature model. Climate change projections were used to estimate climate impacts on water temperature. An historic reconstruction of channel widths using 1880s stream width data was used to estimate how water temperatures would change if channels were restored to historic widths.
- Median water temperatures in the Upper Grande Ronde and Catherine Creek basins could be decreased by about 5.4 and 2.9 °C, respectively, following restoration of riparian vegetation to its historic potential. In addition, a combination of riparian restoration and channel narrowing could reduce median temperatures by 6.5 °C in the Upper Grande Ronde and 3.4 °C in Catherine Creek.

Using a statistical model developed from snorkel survey and habitat data from the Grande Ronde Basin, the projected temperature improvements from riparian and channel restoration translated to increases in Chinook Salmon summer parr abundance of 517% and 74% in the Upper Grande Ronde and Catherine Creek, respectively.

- If riparian conditions and river widths remain largely unchanged, climate change could result in water temperatures that are completely unsuitable for salmonids (i.e., > than 25 °C) across most of the length of the Upper Grande Ronde River. However, basin-wide restoration of both riparian vegetation and channel width could offset these impacts, reducing water temperatures by about 3.6 °C in the Upper Grande Ronde and 2.1 °C in Catherine Creek.
- Conclusions from the temperature modeling analysis include: 1) Maps of priority areas for riparian restoration could provide a valuable tool for restoration planners and practitioners seeking to improve rearing conditions for threatened salmon populations while maximizing the use of limited resources; and 2) Aggressive restoration actions targeting both riparian vegetation and channel width could significantly improve water temperature and fish abundance in the Upper Grande Ronde basin, even in the face of climate change.

Historical Ecology for Setting Restoration Targets

- Stream channel widths from the late 1800s—estimated using Government Land Office surveys— were compared with contemporary values to reveal that although channel widths did not change in a wilderness area (Minam River), channel widths significantly increased in the watersheds impacted by land use (upper Grande Ronde and Catherine Creek). Stream channel widening is likely caused by widespread land use in the impacted watersheds.
- In the impacted watersheds, the average percent channel change was more pronounced in smaller stream types, especially where the river channel was laterally unconfined from hillslopes. These channel types are more susceptible to channel incision and are zones of sediment deposition. Channel widths increased by an average of 54% in large streams, 109% in small/partly confined and confined streams, and 261% in small/laterally unconfined streams.
- Historical channel widths in combination with riparian vegetation scenarios were used to evaluate the potential consequences to water temperature using the Heat Source model and to juvenile Chinook Salmon abundance using regression approaches. Narrowing the channel width to historic values decreased modeled water temperatures (due to decreased solar radiation) and subsequently increased modeled fish abundance.

Restoration Database

- We finalized a master spreadsheet, GIS map, and written report documenting nearly 4500 sites where restoration work was implemented between 1986 and 2014 in the upper Grande Ronde River subbasin.
- After conducted QA/QC measures, we converted data previously stored in MS Excel tables to an ArcGIS Personal Geodatabase, which uses MS Access as the database structure and can therefore be efficiently mapped and queried.

Juvenile Salmonid Abundance

- Completed fifth rotating panel schedule for snorkeling and electrofishing for juvenile fish densities at CHaMP sites in the upper Grande Ronde and Catherine Creek, and third panel of visits in the Minam River, a wilderness system (in collaboration with ODFW La Grande).
- Juvenile Spring Chinook rearing densities decreased after the initial surveys in 2011 in the upper Grande River and Catherine Creek, but have held steady since then, 2012-2015. Populations sampled in 2015 show a possible increase over 2014 estimates. This pattern coincided with increasing water temperatures over the same period but the exact reason for decline is yet to be determined.
- Juvenile Spring Chinook rearing densities in the Minam River increased considerably in 2015 over 2013-2014 densities.

Benthic Macroinvertebrates

- Sampled and processed benthic macroinvertebrates (BMIs) at 60 sites in 2015. For each sample, calculated a suite of metrics including stressor indicator taxa, Grande Ronde IBI, functional feeding composition, PREDATOR model, and density and mass of individuals.
- The distribution of temperature sensitive taxa and fine sediment sensitive taxa was highly correlated with elevation along the Grande Ronde and Catherine Creek mainstems; the proportion of EPT taxa in relation to total taxa was significantly related to elevation on the mainstem Grande Ronde.
- Benthic taxa were spatially distributed throughout the study area in a manner that suggests they were responding to thermal optima. Thermal optimum values computed for both the benthic and drift communities were highly correlated and reflect the local water temperature regime.
- Density of taxa in the benthos is correlated with density in the drift. Low frequency of occurrence of taxa in the benthos (e.g., < 30%) is most commonly associated with low frequency of occurrence in the drift. Taxa that occur at a high frequency in the benthos are typically found at frequencies in the drift that are equal to or less than those in the benthos.

Grazing Potential

- Grazing intensity for a watershed can be used as an index to land disturbance that would contribute to erosion and sediment delivery to stream channels.
- Grazing intensity was calculated in terms of AUMs/ha for the entire area of the Upper Grande Ronde, Catherine Creek, and the Minam River, as well as for individual watersheds contributing to every CHaMP study site.
- Grazing intensity was based on grazing capacity, human land uses, and grazing management decisions.
- Grazing intensity should next be computed for the riparian zone adjoining all CHaMP sites and for the 2 km of riparian zone upstream of each CHaMP site.

Subsurface Fine Sediment

- McNeil core samples for measuring fine sediment concentrations in subsurface substrate materials provide invaluable information for assessing the potential survival of spring chinook eggs to the alevin emergence stage. These core samples assess the composition of gravels at egg-pocket depth (i.e., where the incubating eggs are in the streambed). Voluminous scientific literature attests to the linkage between concentration of fines at depth and survival to emergence of salmon alevins.

- Subsurface fine sediments are relatively stable over time at each CHaMP sampling location, but are expected to change with major peak flow events that could mix surface fines to greater depths in the substrate.
- Surface fine sediments appear to be correlated with subsurface fines.
- Improvements in the sampling of surface fine sediments to make them more quantitative could lead to enhanced correlations with subsurface fines.
- Surface fines are expected to be more variable and responsive to annual fluctuations in sediment delivery and transport which are a function of precipitation and runoff variations, as well as trends in land surface disturbances.

Life Cycle Model

- We continued development of empirical fish-habitat models as the basis for survival and productivity relationships for freshwater stages of a life cycle model. Structural equation models were used to determine the direct and indirect relationships among large woody debris, pool frequencies, and rearing juvenile Chinook Salmon. Linear mixed effects modeling was used to predict juvenile Chinook Salmon rearing capacity based on various water temperature scenarios, in context of distance to spawning areas and various physical watershed attributes.
- The 2015 life cycle modeling analysis is a simulation analysis of the expected benefit to population recovery if habitat is managed in such a way to increase survival, productivity, and capacity. The analysis focuses on spring/summer Chinook Salmon in the Grande Ronde basin, including the Upper Grande Ronde, Catherine Creek, and Minam populations.
- With the same statistical methods used to estimate demographic parameters in previous phases of life cycle model development, a life cycle model was used to project population trends under alternative assumptions about tributary and mainstem environmental conditions. Each alternative assumption represented a specific hypothesis about the population consequences of changes in tributary productivity, tributary capacity, and mainstem survival through the hydrosystem.
- Catherine Creek model fitting results indicate a reasonably high estimated productivity, but a relatively low capacity. The Upper Grande Ronde fitting results show the opposite pattern – lower productivity and higher capacity. Productivity and capacity in the Minam, a wilderness reference area, appear to be fairly high, with capacity at over 20,000 smolts.
- Overall, if the productivity and capacity estimates for the Minam are treated as reference goals for Catherine Creek and the Upper Grande Ronde, we might set a goal that Catherine Creek attain higher capacity levels, and the Upper Grande Ronde attain higher productivities.
- Habitat restoration activities can reduce stream temperatures, increase availability of refuge habitats for predator avoidance, and reduce human and agricultural contact with existing spawning and rearing habitats. The dynamics of how habitat quality affects productivity and capacity are complex, but ultimately translate to increased life-stage survivals via increased productivities and increased availability of spawning and rearing habitats, i.e., capacity.

Coordination and Data Management

- Continued active participation in design and implementation of CHaMP, in survey coordination and data sharing with the Action Effectiveness Monitoring (AEM) program, in data sharing and fish-habitat modeling with the Integrated Status and Effectiveness Monitoring Program (ISEMP).
- Continued contribution to the Grande Ronde-wide fish database with Oregon Department of Fish and Wildlife (ODFW).
- Continued communication with landowners for access to private property; development of methods for summarizing site-specific results for individual landowners.
- Participation in the Grande Ronde Atlas science technical advisory committee and Grande Ronde Expert Panel to continue prioritization and evaluation of restoration activities in the project area.
- Engaged in two American Fisheries Society meeting symposia with collaborators across the region and nationally: (1) presented a paper on fish-habitat modeling using CHaMP data and (2) organized a symposium on integrating food web ecology into evaluation of recovery trends for freshwater fish production.

Conclusions

Significant progress has been made over the last four years in collection of high quality stream habitat and biotic data as well as development of analytical tools needed to quantify status and trends in habitat conditions and fish populations and to evaluate effectiveness of aggregate restoration activities. CHaMP habitat surveys, fish snorkel surveys and benthic macroinvertebrate sampling have been conducted at 120 unique sites throughout the spring Chinook Salmon distribution area in the upper Grande Ronde, Catherine Creek, and Minam River, providing highly precise and spatially referenced data for a large suite of stream habitat and biotic factors. Because fluvial and riparian processes that create fish habitat generally operate over a relatively long time frame (i.e., decades), we don’t feel it would be appropriate or informative at this time to quantify long-term trends in fish habitat conditions. However, the data needed to develop important fish-habitat relationships, habitat-land use relationships, and to parameterize a life cycle model to make projections in fish response to habitat change are now available, and as demonstrated in this report, have been applied successfully to make great strides towards meeting our project objectives.

Introduction

The Columbia River Inter-Tribal Fish Commission is conducting a fish habitat monitoring program in the Upper Grande Ronde River and Catherine Creek basins designed to evaluate the effectiveness of aggregate restoration actions in improving freshwater habitat conditions and viability of ESA-listed spring Chinook Salmon populations. A critical uncertainty for fisheries managers in the Columbia Basin involves determining whether freshwater habitat restoration actions will yield a net improvement in basin-wide habitat quality such that remaining man-caused survival impairments elsewhere during the life cycle can be compensated. Bonneville Power Administration funds our project and has an interest in determining whether expected improvements in salmon habitat and, thereby, fish production can be brought about by improvements in the quality and quantity of salmon habitat.

Habitat restoration in the Upper Grande Ronde River basin and Catherine Creek basin is being conducted by agencies such as the US Forest Service (Upper Grande Ronde mine tailings restoration, where channel damage was done by historic dredge mining of the streambed), the Umatilla Tribe (e.g., McCoy Creek Meadows restoration, where natural river meanders are being restored to a channelized stream), the Oregon Department of Fish and Wildlife, and the Grande Ronde Model Watershed (e.g., riparian fencing, riparian planting, improvement of irrigation diversions). The US Bureau of Reclamation is also conducting studies of water use and availability in Catherine Creek watershed and may implement projects based on their findings.

There have been many studies conducted in recent years examining the current condition of fish habitat in all the subbasins of the Columbia River. Some of the most common impediments to survival of salmon tend to be high water temperatures, increased concentrations of fine sediment in spawning gravel, loss of riparian vegetation, channelization, loss of large woody debris in the channel, loss of large pools for adult fish holding and juvenile rearing, and summertime depletion of streamflows in the channel. Added to these concerns caused by human influence is climate change, which can lead progressively to changes in the timing of runoff from snowmelt, increased summer air temperatures, and change in the seasonal distribution of precipitation.

We are attempting to monitor all habitat factors that have been identified by previous studies as key limiting factors. Our monitoring plan includes measurement of: water temperature, streambed substrate composition and fine sediment concentrations, streamflow, water chemistry, riparian condition, stream channel morphology (including spawning habitat and large pool distribution), large woody debris, benthic macroinvertebrates (diversity and density, which indicate long-term water quality), drifting macroinvertebrates (indicating fish food availability), and fish snorkeling (indicating relative abundance of salmonids and qualitative indices of abundance of non-salmonids). Habitat surveys are conducted in 25 sites per year distributed throughout the currently used spring Chinook spawning and rearing habitat in the Upper Grande Ronde and Catherine Creek basins following methods developed by the Columbia Habitat Monitoring Program (CHaMP; www.champmonitoring.org). In addition, CRITFC has funded ODFW to conduct CHaMP surveys in the Minam River in 2014 and 2015 to provide a set of monitoring sites to act as an unmanaged reference for more heavily disturbed, managed sites in the Upper Grande Ronde and Catherine Creek.

As a means to integrate habitat monitoring efforts with recovery planning, CRITFC is developing a life cycle model. The life cycle model is being designed as a tool to simulate population trends in relation to projected environmental conditions, and to examine the relative benefits of habitat improvements on population

recovery potential. A prototype model was developed which includes all Chinook Salmon populations in the Grande Ronde/Imnaha Major Population Group (MPG) of the Snake River Evolutionarily Significant Unit (ESU), which consists of the Grande Ronde River, Catherine Creek, Lostine/Wallowa, Minam, Wenaha, and Imnaha. Modeling analyses to date have focused on empirical validation of the survival of outmigrating juveniles and returning adults, with particular focus on the environmental and operational variables that influence survival through the hydro system and ocean. This prototype model provides a strong empirical basis for further refinements of the life cycle model to include effects of freshwater habitat conditions on productivity and abundance of rearing juvenile salmonids.

Future refinement of the life cycle model and the research needed to parameterize the model are guided by a basic conceptual model framework. The fundamental basis of the model is that intrinsic watershed factors (such as geology, climate, or valley morphology) interact with human actions (such as forest harvest, cattle grazing, or stream restoration) to affect processes that drive known limiting factors (e.g., flow, temperature, pool area, etc.), and therefore fish survival via both density-dependent and density-independent processes (Figure 1). Current and future habitat conditions can act as predictors of relative change in survival at different life history stages, and therefore affect recovery potential.

The life history model is comprised of several interacting subcomponents that are built independently, each of which provides critical information about the interaction between landscape characteristics, instream habitat conditions, and fish response. Individual subcomponents of the life cycle model, and of our research program, include modeling stream temperature from local riparian and geomorphic conditions; a sediment delivery model describing the influence of soil type, forest harvest, road density, land uses, or bare earth on sediment delivery; a fine sediment model linking survival-to-emergence to fine sediment in spawning gravel; a water temperature model that links summer water temperature metrics to summer juvenile survival; a potential natural vegetation map that will aid in estimating stream shade, LWD input rates, and terrestrial macroinvertebrate inputs that aid in estimating the food base and growth potential for drift-feeding salmonids; and a low flow model that will permit evaluation of site vulnerability to climatic variations in precipitation, snow melt timing, and air temperature variations. Though these components are described here as providing inputs to the life cycle model, each model is a valid research project in its own right that is likely to yield interesting scientific insights and practical applications for conservation.

The primary objectives of this project are to: 1) Assess current status and trends in fish habitat characteristics considered to be key limiting factors (particularly water temperature, pool habitats, streamflow, and fine sediment) to viability of spring Chinook Salmon populations; 2) Evaluate effectiveness of aggregate stream restoration actions aimed at improving key limiting habitat factors; 3) Develop a life cycle model to link biotic responses of spring Chinook populations to projected changes in stream habitat conditions.

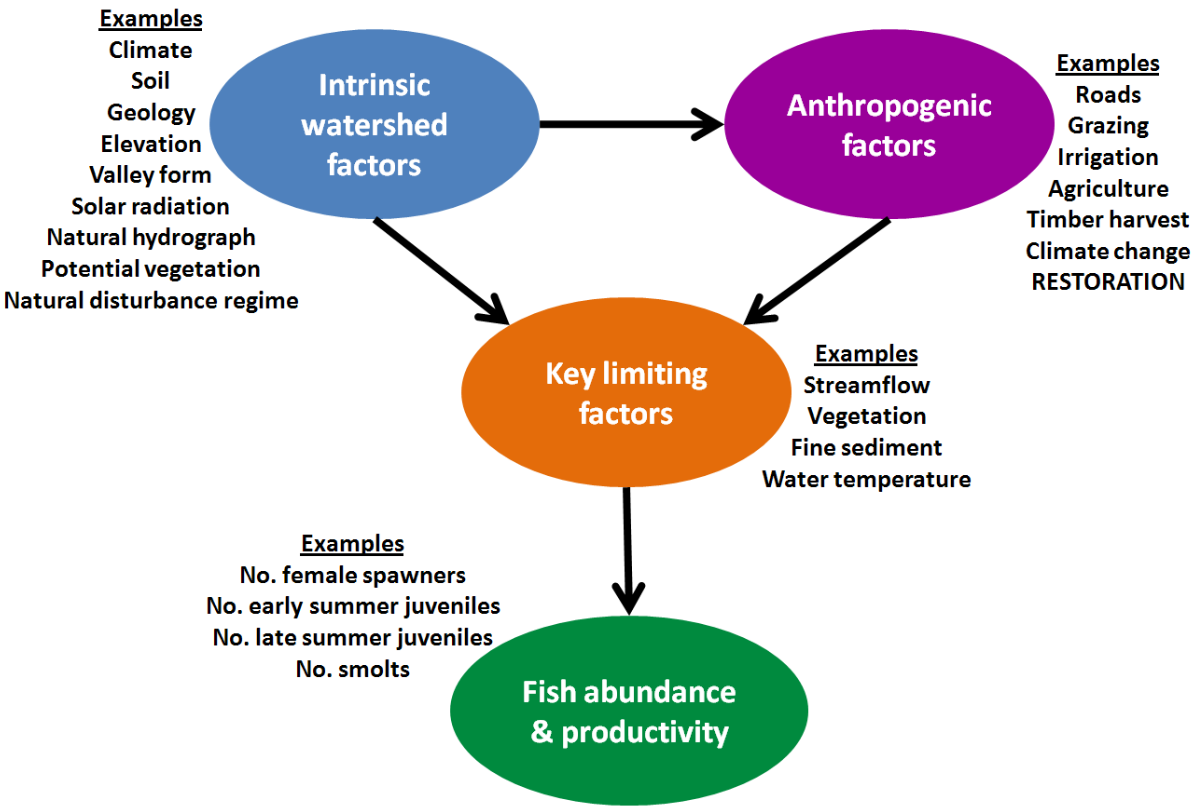


Figure 1. Conceptual framework for relating fish abundance and productivity to watershed characteristics and limiting factors. Direction of arrows indicates direction of influence.

Methods

Study Area

This study is being conducted in the Grande Ronde River and its tributaries, which originates in the Blue Mountains of NE Oregon and flows 334 km to its confluence with Snake River near the town of Rogersburg, Washington (Figure 2). Focal watersheds include the upper Grande Ronde River above the town of La Grande, Catherine Creek, and to a lesser extent, the Minam River, which drain areas of approximately 1,896, 1,051, and 618 km^2 respectively.

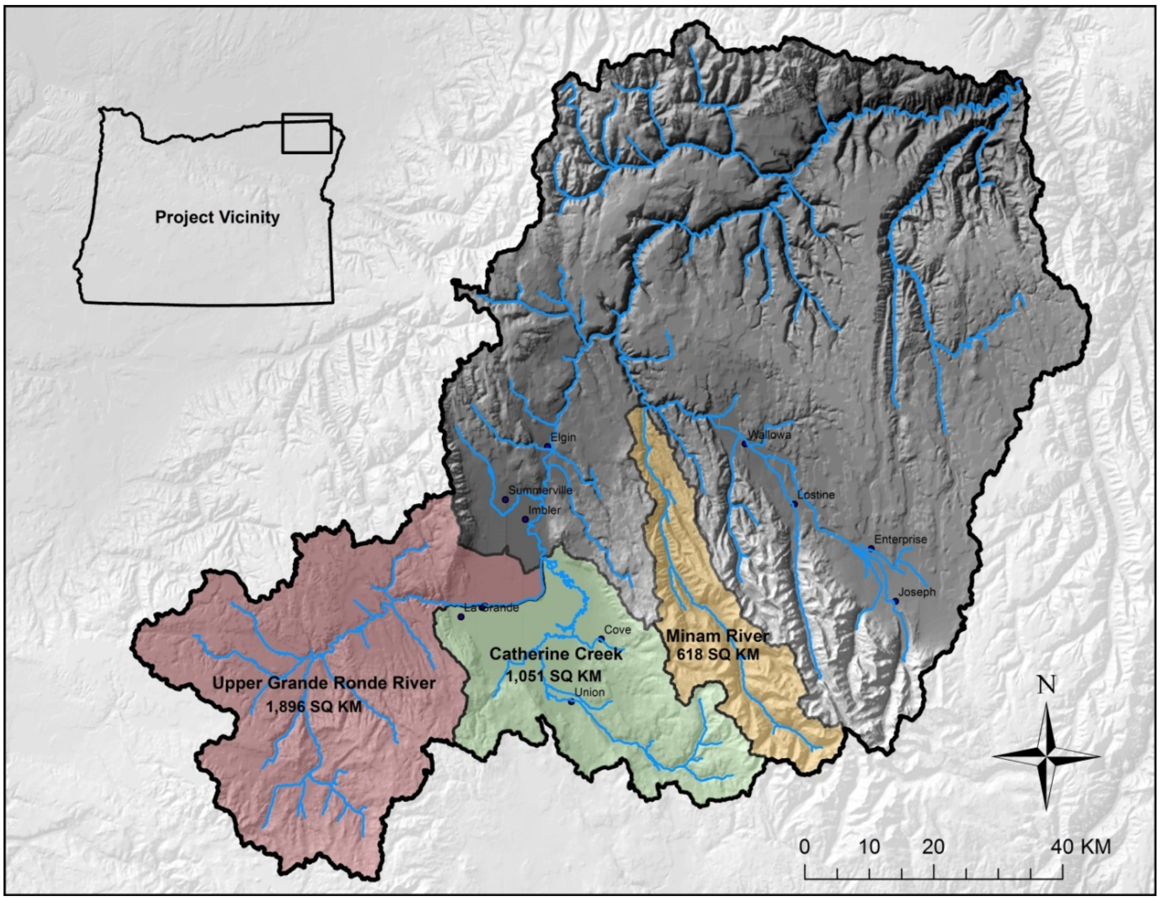


Figure 2. Study area in the Grande Ronde River basin, NE Oregon. Focal watersheds include the Upper Grande Ronde River, Catherine Creek, and Minam River. The Upper Grande Ronde and Catherine Creek are the basins with significantly damaged habitat that is undergoing restoration in various locations. The Minam River basin is the local reference basin that has far less current evidence of human impact.

The topography of the upper portion of the subbasin (i.e., upstream of the Wallowa River confluence) is characterized by rugged mountains in the headwater areas and a broad, low gradient valley between the Blue and Wallowa Mountains. Peaks in the Wallowa Mountains reach a maximum elevation of 2,999 m (9,838 ft), and provide the source of many of the Grande Ronde's tributaries including Catherine Creek and the Wallowa

River. The Blue Mountains reach elevations of 2,347 m (7,700 ft), and are the source of the Grande Ronde River, Wenaha River, and other tributaries. Due to the lower elevation of the Blue Mountains, snow melt generally occurs earlier in these tributaries, often resulting in very low flows during summer.

Surface geology of the Grande Ronde Subbasin is dominated by rocks of the Columbia River Basalt group, with some older granitic intrusives and older volcanics with associated sedimentary deposits present in the headwater areas of the Upper Grande Ronde and Catherine Creek. The climate is characterized by cold, moist winters and warm, dry summers with mean daily air temperatures near La Grande averaging -0.42 °C (31 °F) in January and 21 °C (70 °F) in July. Average annual precipitation ranges from 36 cm (14 in) in the valleys to 152 cm (60 in) in the mountains, with most of the precipitation in the mountains falling as winter snow.

The vegetation community at lower elevations is dominated by grasslands consisting of Idaho fescue/bluebunch wheatgrass (*Festuca idahoensis-Agropyron spicatum*) and bluebunch wheatgrass-Sandberg's bluegrass (*Agropyron spicatum-Poa sandbergii*) (Nowak 2004). As elevation increases, the grasslands transition to shrub/scrub plants, and eventually to coniferous forests in the mountains. Forest species consist of low elevation Ponderosa pine (*Pinus ponderosa*) and lodgepole pine (*Pinus contorta*) associations grading into Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), subalpine fir (*Abies lasiocarpa*), and mountain hemlock (*Tsuga mertensiana*) associations at higher elevations. Riparian vegetation is dominated by black cottonwood (*Populus trichocarpa*) and willow *(Salix* spp.), black hawthorn (*Crataegus douglasii*), mountain alder (*Alnus incana*), and mountain maple (*Acer glabrum*).

Approximately 49% of the land in the Grande Ronde basin is publically owned, of which about 97% is managed by the US Forest Service. The remaining public land is managed by the Bureau of Land Management and the States of Oregon and Washington. With the exception of the Eagle Cap and Wenaha-Tucannon Wilderness Areas, the National Forests are managed for multiple use including timber production, livestock grazing, and recreation. Private property comprises 51% of the land in the basin and is located primarily in lower elevation valleys and along rivers. A large proportion of the private property is used for agriculture including crop production, livestock grazing, and forestry. Only 0.1 % of the land in the Grande Ronde Basin is currently owned by the tribes, although the tribes retain fishing and hunting access rights at all usual and accustomed locations as afforded under the treaties of 1855 and 1863.

Spring Chinook populations in these basins were listed as threatened under the Endangered Species Act in 1992. Population declines over the past century were due in part to severely degraded habitat conditions resulting from intensive anthropogenic disturbances including timber harvest, cattle grazing, levee and road construction, and stream diversions for irrigation. Specifically, stream temperature, streamflow, fine sediment, habitat diversity, and quantity of key habitats such as large pools, have been identified as key limiting factors for recovery of Chinook populations in these basins (Nowak 2004).

Stream Habitat

CHaMP Data Collection

In 2015 we continued to implement the Columbia Habitat Monitoring Program (CHaMP) protocol and sampled 26 sites in the upper Grande Ronde and Catherine Creeks basins. When combined with CHaMP sites surveyed by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and ODFW, including the Minam basin, a total of 154 unique sites (358 site visits) have been surveyed in the Grande Ronde basin. CHaMP is designed as a Columbia River basin-wide habitat status and trends monitoring program built around a single protocol with a programmatic approach to data collection and management. CHaMP will result in the collection and analysis of systematic habitat status and trends information that will be used to assess basin-wide habitat conditions and characterize stream responses to watershed restoration and/or management actions. A detailed description of the CHaMP protocol is provided at http://www.monitoringmethods.org/Protocol/Details/806).

Survey sites were randomly selected using the Generalized Random Tessellation Stratified (GRTS) survey design (Stevens and Olsen 2004), and were distributed with equal probability across all wadable portions of the stream network that were classified as current or historic spawning and rearing areas for spring Chinook Salmon (Figure 3). The spring Chinook distribution area was modified from maps produced by ODFW, StreamNet (StreamNet 2009), the Grande Ronde Subbasin plan (Nowak 2004), and the NOAA’s Interior Columbia Basin Technical Recovery Team (ICTRT), and is described in more detail in McCullough *et al*. (2012).

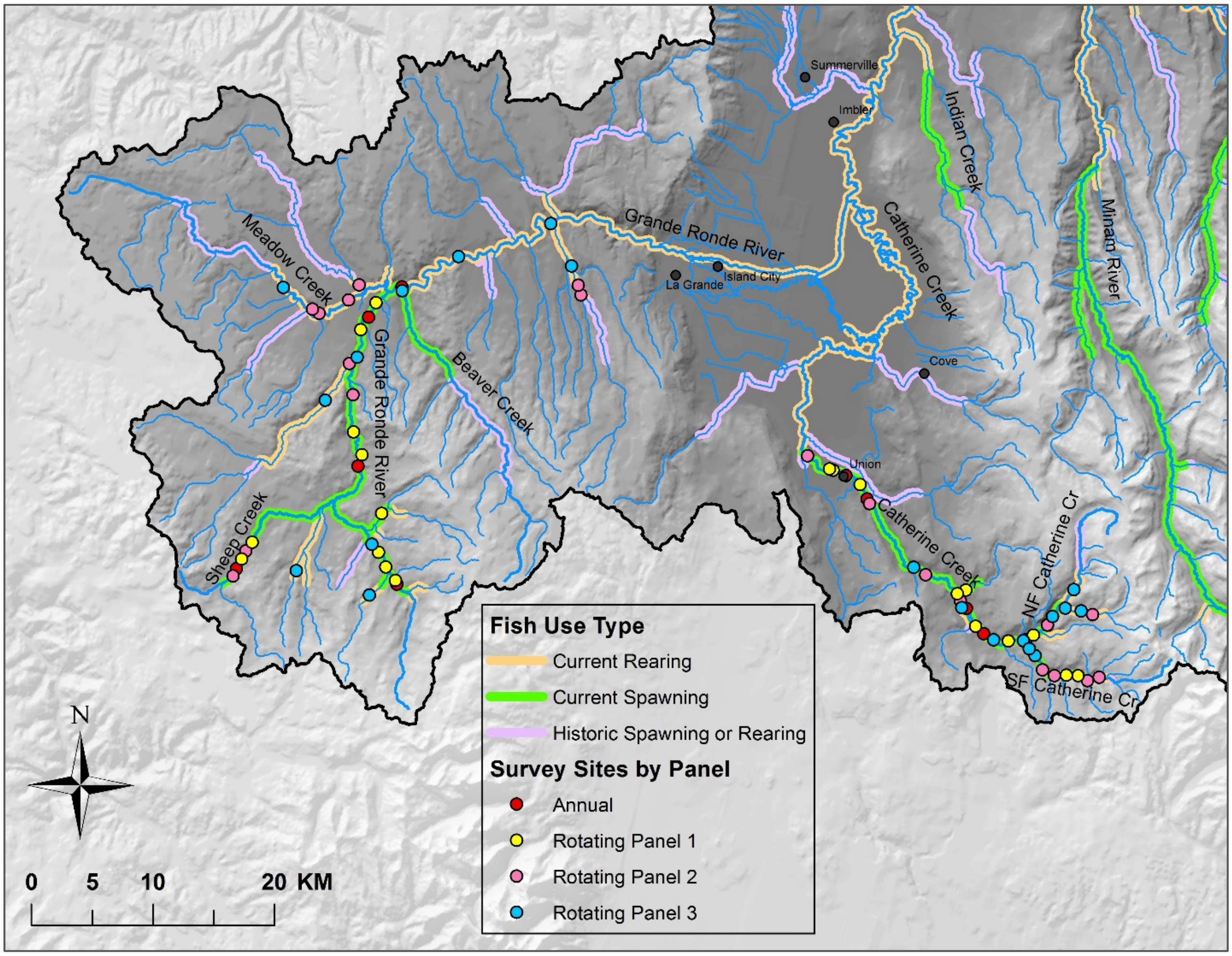


Figure 3. Sample design showing the distribution of CRITFC habitat survey sites in the upper Grande Ronde River and Catherine Creek basins.

We used a 3-year rotating panel design (Table 1) with the intention of achieving a good balance between power to describe current status (i.e., accurate description of spatial variation across the entire sampling extent) and power to detect trends over time. This temporal design includes 5 annual sites and 10 rotating panel sites in the upper Grande Ronde and Catherine Creek basins. Annual sites are surveyed every year and rotating panel sites are surveyed every 3 years. A total of 30 sites are surveyed each year, with a total sample size of 70 unique sites after 3 years. Note that 5 of the 30 sites within CRITFCs target sample frame are surveyed by ODFW each year. The 2015 field season was the fifth year of implementing the protocol in the upper Grande Ronde watershed. This year's surveys were the fifth visit to annual sites and the first revisit to panel 2 sites since the start of the program in 2011. One annual panel site was rejected due to a landowner denying access, dsgn4-000204. This site was replaced by a new, randomly selected site based on the GRTS survey design and was surveyed for the first time this year, CBW05583-491690. In 2015 CRITFC also participated in a CHaMP quality assurance revisit study and resurveyed a ODFWs site (dsgn4-000006) to compare crew variability and site change over the survey season timeframe.

In addition to our CHaMP monitoring in the Upper Grande Ronde and Catherine Creek, CHaMP data were also collected in the Minam River via a subcontract with the Oregon Department of Fish and Wildlife. Minam data

collection using the CHaMP protocol began in 2013, making this year the third year of panel rotations. A total of 10 sites, 5 annuals and 5 rotating panel 3, were surveyed in 2015. Some of this data is still in the QA/QC process and is not included in this report. The Minam River is important to our overall efforts and to those of the ODFW program in providing a reference site that represents minimally disturbed environmental conditions with which to contrast results from the two significantly disturbed watersheds.

Table 1. Rotating panel design for CHaMP sites in the Grande Ronde River and Catherine Creek watersheds. Note that 5 of the 30 sites in our survey design are sampled by ODFW each year.

	Year								
Panel	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Grande Ronde Chinook									
Annual Panel	5	5	5	5	5	5	5	5	5
Rotating Panel 1	10			10			10		
Rotating Panel 2		10			10			10	
Rotating Panel 3			10			10			10
Catherine Creek Chinook									
Annual Panel	5	5	5	5	5	5	5	5	5
Rotating Panel 1	10			10			10		
Rotating Panel 2		10			10			10	
Rotating Panel 3			10			10			10
Total Annual Samples	30	30	30	30	30	30	30	30	30
Total Unique Samples	70								

A large number of stream habitat variables were measured at each site, generating over 100 metrics describing the condition of the stream. Most of the variables measured were chosen because they are directly related to salmonid fish growth and/or survival or because they provide critical information used to describe ecological processes in the stream or broader landscape that may be indirectly related to fish productivity. The measurements were collected using a combination of traditional habitat data collection methods along with use of technical survey equipment (e.g., Total Stations) that allows for the development of detailed topographic maps of the stream channel. A complete list of metrics generated by CHaMP surveys is available at https://www.champmonitoring.org/.

Topographic data are composed of deliberately placed coded points and lines in the stream channel and floodplain that are used to illustrate inflection points in the channel bedform such as pools, the toes and tops of banks, and the thalweg (the location with the highest streamflow) along with important features such as the edge of water, bankfull elevations, and channel unit boundaries (Figure 4, a.). Depending on the channel length and complexity, crews capture between 700 and 1500 points in order to accurately represent a stream reach. The raw data were imported into ArcGIS and processed to create digital elevation models (DEM), channel unit delineations, and water depth maps (Figure 4, b. - d.). These data were evaluated for quality control during the initial processing that occurs directly after the survey. After the field season is completed, the output products from each survey were processed through the River Bathometry Toolkit (RBT) to derive metrics that are potentially important to fish, such as residual pool depth. After the RBT metrics were created,

a second round of quality control analysis is performed to ensure the accuracy of the topographic data. These data were then made available to the public on the program's website (www.champmonitoring.org).

These detailed surveys will become increasingly powerful as the CHaMP program progresses because these surveys can be repeated and overlaid to inform topographic change over time. We have just completed the fifth year of the nine year study design and have started the process of revisiting panel sites. At the end of the nine year period we will have a minimum of three visits at each site and will be able to quantify the degree of channel and habitat change over time at individual sites and start to look at patterns of channel erosion and aggradation across the watershed.

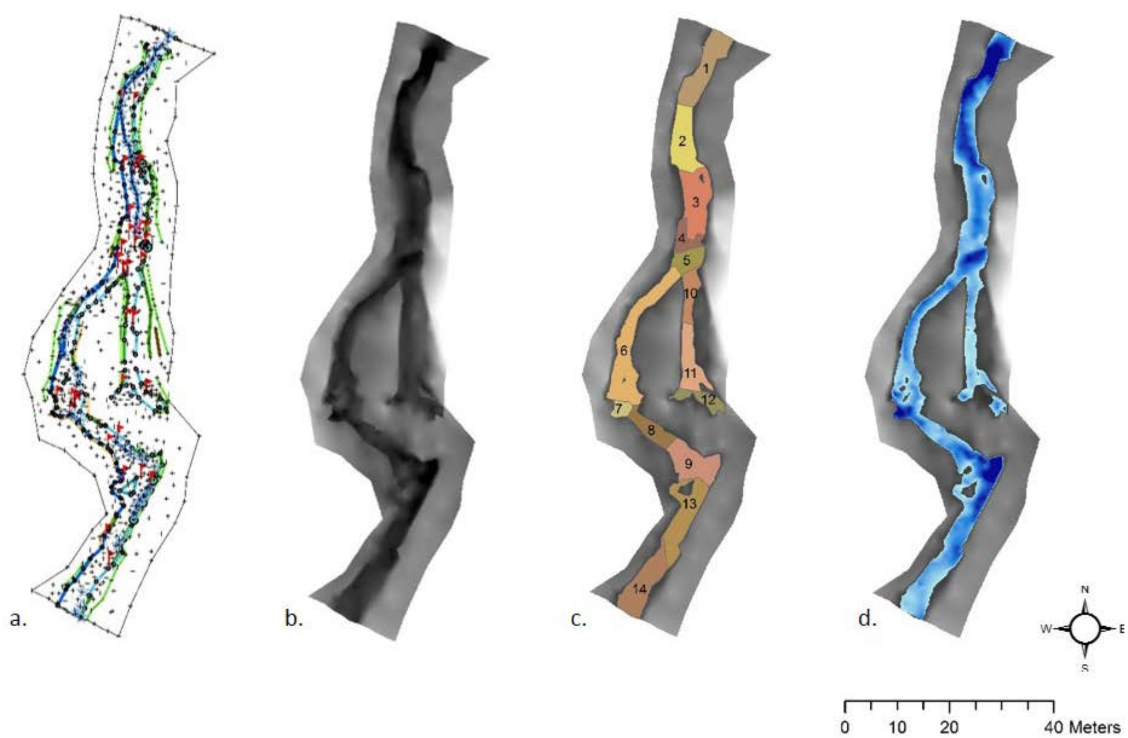


Figure 4. Example of topographic data surveyed conducted on Sheep Creek, site CBW05583-490810 using the CHaMP protocol and a Total Station. The panel depict a) the raw point and line data as surveyed in the field, b) the digital elevation model (DEM), c) channel units overlaid on the DEM, and d) the water depth map produced by analysis at each CHaMP site.

Selected habitat metrics important for Chinook Salmon at various life history stages (percentage area pools, residual pool depth, large woody debris frequency, and percentage fine particles <2 mm) were summarized for all sites across all years by Chinook population group (upper Grande Ronde, Catherine Creek, and Minam), by biologically significant reaches (BSRs), and by valley setting classification (Figure 5). BSR boundaries correspond approximately to the HUC6 watershed boundaries, but were aggregated or modified to better represent significant breaks in physical channel morphology (e.g., tributary junctions or major changes in valley confinement), land ownership, or fish use. BSRs were developed by local experts associated with the Federal Columbia River Power System (FCRPS) Biological Opinion expert panel and restoration implementation group (i.e., Atlas Group) for use in planning and implementing stream restoration actions. Valley setting

classifications are based on the valley confinement and the bankfull width of a stream segment. Valley confinement is defined as the degree to which a stream channel abuts a valley margin and is divided into three categories, confined (against valley margin >90%), partly confined (10 - 90%), and laterally unconfined (against valley margin <10%) (Brierley and Fryirs 2005). The bankfull width categories were separated into two categories, floodplain/constrained (>8 m) and mountain channel (<8 m) (Montgomery and Buffington 1997, Beechie *et al*. 2006). The combination of these characteristics results in six different classification levels: mountain confined (MC), mountain partly confined (MPC), mountain laterally unconfined (MLU), floodplain/constrained confined (FCC), floodplain/constrained partly confined (FCPC), and floodplain/constrained laterally unconfined (FCLU) (Figure 5). This being the fifth year of the study and we additionally investigated the initial trends in the data based on these three spatial extents using the GRTS roll-up weights and the site specific slopes calculated for each metric analyzed.

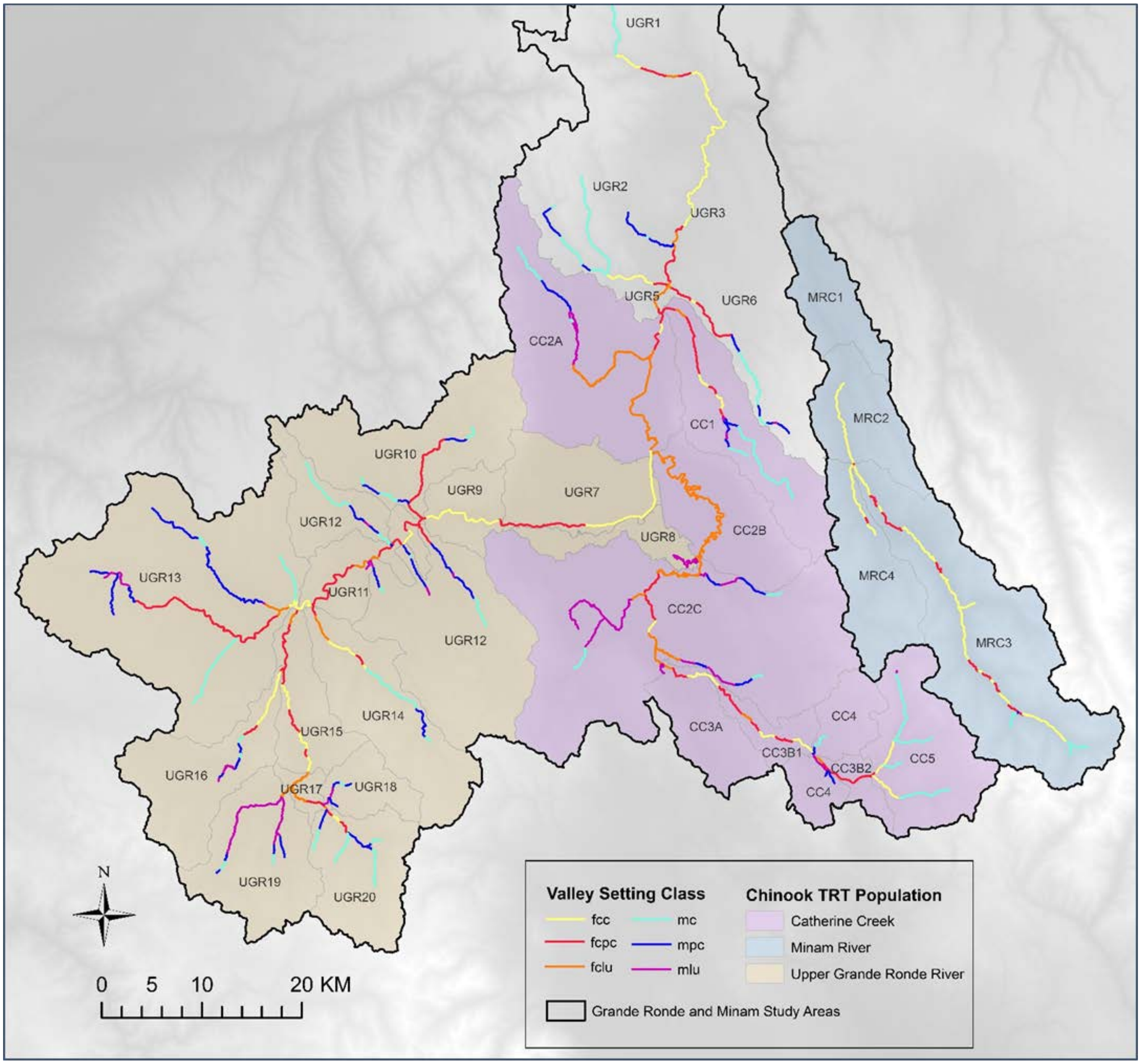


Figure 5: Map showing the three Interior Columbia Basin Technical Recovery Team (TRT) populations within the CRITFC study area and the biologically significant reaches (BSR) within each population. Stream segments display valley setting classifications.

In addition to topographic and habitat characteristics, temperature metrics were calculated. Year round temperature records were collected at all CHaMP sites in the three focal watersheds using Hobo Tidbit and Pro V2 data loggers following the Water Temperature Probe Installation Protocol (https://www.monitoringmethods.org/Method/Details/846). In 2015, temperature data was available for 13 CHaMP sites in the Catherine Creek watershed and 17 CHaMP sites in the Upper Grand Ronde watershed. These sites were visited once in spring and once in fall to download the data and to assess the condition of the temperature loggers. In addition to the sites monitored through the CHaMP protocol, CRITFC has temperature loggers deployed at 12 other locations in the Catherine Creek and upper Grande Ronde watersheds. These loggers filled in areas where temperature data were not sufficiently captured by the CHaMP program and

often are located up- and downstream of significant tributary junctions. The data validation and storage for non-CHaMP sites was conducted by CRITFC staff. The data was validated and summary statistics were calculated to match those metrics derived from the CHaMP data. This database will continue to be updated each year as more temperature data are collected in the field.

Temperature metrics were based off a "summer period" as defined by CHaMP, which is between July 15th and Aug 31st. This timeframe is crucial due to the potentially detrimental influences of high temperatures on salmonids. For every consecutive 7-day period within this 48-day period, rolling averages of maximum temperatures were calculated (7dAM). The number of 7dAM periods where the average maximum temperature exceeds 12˚, 13˚, 16˚, 18˚, 20˚, and 22˚C was evaluated at every site. These water temperature standards were designated based on beneficial uses by various salmonid life history stages as defined by the Oregon Department of Environmental Quality (Sturdevant 2008). Additionally, the average daily temperature, maximum daily temperature, and the maximum 7-day rolling average of maximum temperature (Max7dAM) are reported over the same summer time period. Monthly statistics, average and maximum temperatures, were also calculated. We have reported on the Max7dAM and Average August temperatures as they are used regionally to summarize stream temperatures and would allow for the most direct crosswalk between monitoring programs. Stream data in the Minam was not available at the time of this analysis and therefore were not included in this report.

In future analyses we plan to extrapolate fish density estimates to include un-sampled portions of the watershed by using the combination of the BSR regions and valley setting stream classification. Using GRTS we can compute population estimates based on stream classification type and then calculate BSR-wide estimates based on the proportional stream length of each classification type. We can use the classification to more accurately extrapolate population metrics to BSR reaches where we have few or no CHaMP sites based on stream type.

Subsurface Fine Sediments

We collected sediment core samples using a McNeil core sampler at sites in the Upper Grande Ronde, Catherine Creek, and Minam River basins between 2010 and 2013. There were a total of 12 sites on the Catherine Creek mainstem; 1 in the South Fork Catherine Creek, 1 in the North Fork Catherine Creek, 1 in Fly Creek, 9 in the Grande Ronde mainstem, 1 in Limber Jim, 4 in Meadow Creek, 3 in Sheep Creek, 1 in West Fork Chicken, and 9 Minam sites. These samples were collected in a total of 42 sites distributed in the three major basins. We recently updated the McNeil sediment core database with all remaining sample data.

Core sampling was conducted only at sites with suitable spawning habitat for Chinook Salmon. In addition, some sites were not sampled due to the presence of spawning salmon and/or freshly-built redds. All sediment samples were returned to the lab where they were dried, sieved, and weighed to determine particle size distribution and fine sediment composition. Detailed sampling and processing methods are described in Justice et al. (2012) (https://www.monitoringmethods.org/Protocol/Details/723). For each site, we quantified the proportion of sediment particles in the streambed subsurface that was smaller than 0.83, 2 mm and 6.3 mm in accordance with commonly cited studies examining the effects of fine sediment on egg-to-fry survival of salmonid fishes (Tappel and Bjornn 1983, Chapman and McLeod 1987). Prior to calculating the fraction of fine sediment in each sample, we truncated the data by removing all sediment particles greater than 63mm from

the sample to ensure that estimates of percent fines were not disproportionately affected by the presence of a few anomalously large cobbles as recommended by Church et al. (1987). We compiled all McNeil samples collected between 2010 through 2013 to assess average fine sediment levels for the Upper Grande Ronde and Catherine Creek basins and potential implications for survival of Chinook Salmon eggs.

Watershed Grazing Intensity

Data on livestock grazing on the study basins were obtained from the USFS GIS Department. This information was received as a file geodatabase with three associated Excel spreadsheets that were related to the gdb. Fence data for the Wallowa-Whitman and Umatilla National Forests were linked to the RMU-Arc layer. The AUM data spreadsheet for 2015 was related in a one-to-many relationship because each permit could have grazing use in different seasons and with different AUMs. Permit names also had a one-to-many relationship with allotments because a single allotment can have multiple permits.

Grazing capacity was estimated for the study basins with criteria from Holecheck (1988). This study reported the probability of occurrence of cattle at various distances from water and according to behavioral preference for hillslope gradients.

Table 2. Matrix of distance to water and hillslope gradient classes indicating basic grazing capacity.

			Distance to water				
			1.609	2.4135	3.218	>3.218	km
Slope			1	2	3	4	Class
Class	degrees	Cap (%)	1.00	0.75	0.50	0.00	Cap (%)
1	5.71	1.0	1.00	0.75	0.50	0.00	
2	16.70	0.7	0.70	0.53	0.35	0.00	
3	30.96	0.4	0.40	0.30	0.20	0.00	
4	>30.96	0.0	0.00	0.00	0.00	0.00	

The thresholds for grazing probability created a matrix. For example, slope class 1 and distance class 1 provides a 100% grazing capacity with the combination of effects of slope and distance. With slope >30.96 degrees and distance from water >3.218 km, grazing capacity is reduced to 0%. All classes of grazing capacity were mapped with ArcMap.

A slope map was developed from the 30-m DEM for the study basin. Slope values (degrees) for each pixel in this raster were converted to grazing capacity slope classes (1, 2, 3, and 4) according to slope thresholds (Table 2). A distance from water raster was developed from an overlay of the GR mixed hydro layer (stream network) on the 30-m DEM. Each raster pixel was categorized into distance bins of <1.609, 1.609 to 2.414, 2.414 to 3.218, and > 3.218 km, or distance classes 1, 2, 3, and 4 using Euclidean distance function as described in https://www.youtube.com/watch?v=GNGIzx9STQE. This analysis does not account for the presence of fences that may restrict movement of cattle travelling away from water sources. Also, the presence of natural

barriers, such as steep banks was not included in distance calculations. These barriers could create longer travel paths from water to upslope grazing areas that have suitable conditions.

Additionally, grazing is incompatible with certain land uses, despite the inherent potential there may be for grazing due to slope and distance from water. The 2011 NLCD land cover database (http://www.mrlc.gov/nlcd11_leg.php) was used to delineate zones of 0% grazing capacity due to human land uses or inherent qualities of land units that make grazing impossible. Land types 11 (open water), 12 (perennial ice/snow), 21 (developed, open space, such as housing areas, parks, golf courses), 22 (developed, low intensity, such as housing units), 23 (developed, medium intensity, such as housing), 24 (developed, high intensity, such as apartments, industrial areas), 31 (barren land, rock/sand/clay), and 82 (cultivated crops) were considered to have zero grazing capacity. All other lands were considered to have no reduction in grazing capacity (i.e., grazing capacity = 1.0), other than specified by slope and distance from water. Assignment of values of 0 or 1 to 30-m NLCD pixels for land use classification was made using the Con function in ArcMap.

The three rasters for capacity by slope, distance from water, and land use were multiplied together using raster calculator to produce a new raster (Grz_dx_sl_cov) (Figure 6). This raster has values of 0 to 1, representing 0% capacity and 1 representing 100% capacity. The complete set of grazing capacity values is 0, 0.2, 0.3, 0.35, 0.4, 0.5, 0.525, 0.7, 0.75, and 1.0 (Table 2). This raster represents a realized capacity for grazing, which is a product of inherent features of the land, cattle behavioral preferences, and long-established land uses and land type characteristics. These decimal grazing capacity values were also reclassified to integers (1-10) for the 10 capacity values (Grz_Cap_rec). This raster can be used to calculate potential livestock grazing.

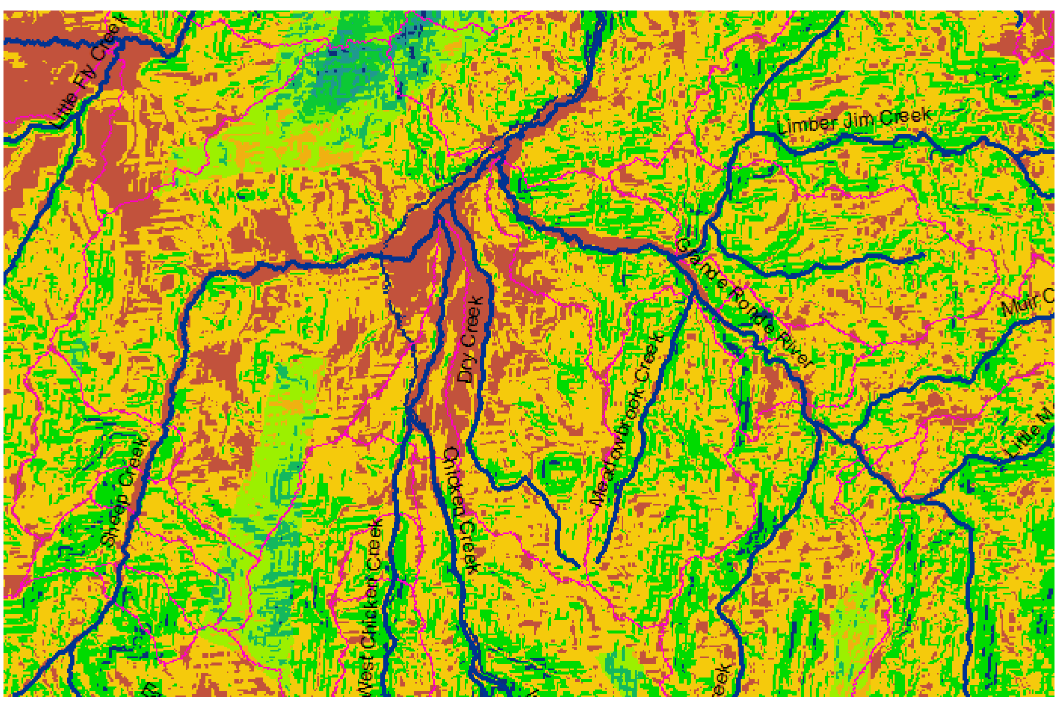


Figure 6. An example of the Grz_dx_sl_cov raster depiction of grazing potential for a portion of the Upper Grande Ronde basin above the confluence of Sheep Creek with the Upper Grande Ronde.

Grazing capacity to this point is a function of slope, distance to water, and land cover. Whether land is grazed also depends, on USFS lands, whether there is a designated allotment, and whether that allotment is currently assigned a level of AUMs. The assigned AUM level does not indicate actual use, but for this analysis we assumed that actual use equals assigned AUM level. If USFS land does not have allotments, we also assumed no cattle grazing, even though broken fences and trespass grazing could invalidate this assumption. We also assumed that on all private land, cattle are grazed at an intensity that would arise from the land's grazing capacity and the AUMs/pixel derived from the AUMs assigned by the USFS to each allotment on federal land. This assumption is based on the idea that USFS range conservation staff study the capacity of allotments to produce forage and sustain grazing. Stocking levels probably are arrived at from years of allotment use, some study of forage consumption rates, and GIS analysis of terrain. Private lands grazing may not be so well attuned to grazing capacity, assuming that grazing intensity on private lands is equal to that on USFS land with respect to grazing capacity of each 30 x 30-m pixel permits estimation of the total grazing intensity within all watersheds contributing to CHaMP study sites.

A Wallow-Whitman GIS website (http://www.fs.usda.gov/main/wallowa-whitman/landmanagement/gis) provided a shapefile of ownership (ProclaimedForest) that was linked by a "union" process in ArcMap with the Forest grazing allotment map (grazing_rmu_unit). Both maps were first clipped to the boundary of the basins (Upper Grande Ronde, Catherine Creek, and Minam River) that encompass all CHaMP study sites used in monitoring by CRITFC, CTUIR, and ODFW (i.e., StreamStatsBasins, dissolved to create the outer boundary of all subbasins). The "union" process retained all of each attribute table associated with each separate shapefile (SurfaceOwnership_U.shp and grazing_rmu_unit_Clip.shp). The new shapefile (SurfaceOwnership_U_Clip_Union.shp) was given a new field (GrazCap) in which all private land was coded as "1," land where ownership = F (either Wallowa-Whitman NF or Umatilla NF) and number of cattle allowed to graze is zero (i.e., AUM =0), land where ownership is not equal to "F" (i.e., any land ownership other than USFS) equals 1, and any land where ownership is F and management allows cattle grazing (i.e., AUM >0) was coded as 1. Filling in the codes into the new field was done by use of "select by attributes" (e.g., to select records where OWN = 'F' AND AUM = 0) and Field Calculator (e.g., to assign a realized capacity of 0 to this condition). The surface ownership classes identified in the OWN column in the union of attribute tables from SurfaceOwnership and the grazing allotment shapefile (grazing_rmu_unit_Clip.shp) include BIA (I), BR (M), Oregon (S), Prineville BLM (B), Private (P), Umatilla NF (F), Vale BLM (B), and Wallowa-Whitman NF (F). This shapefile was converted to a raster with Conversion Tools, polygon to raster, while snapping the raster to Grz_dx_sl_cov (using Environment, Extent, Snap) to line up raster cells. The assignment of 0 or 1 to the land units in the study basin area using the GrzCap field for values, created a new raster Surfaceown_GrzCap2, which codes each 30-m pixel with a 0 or 1, indicating whether the land has permitted grazing or not. A multiplication of two rasters (Surfaceown_GrzCap2 and Grz_dx_sl_cov) produced a new raster grzdxslcovown, which incorporates information about distance to water, slope, land cover (is the land type urban, farmed, barren, water), and ownership (i.e., is the land grazed or not) to estimate actual grazing capacity.

The Grz_dx_sl_cov raster was reclassified to integer values of 1-10, corresponding to grazing capacity of 0, 0.2, 0.3, 0.35, 0.4, 0.5, 0.525, 0.7, 0.75, and 1.0. Zonal Statistics (Tabulate Area) was run on this raster to compute for each allotment the distribution of area (m2) in each of the 10 grazing capacity bins. There were 23 allotments within the study basins that had AUMs assigned to them. For allotments that extended beyond the outer boundary of the study basins (i.e., beyond the outer boundary of StreamStatsBasins), the areas of the

clipped allotments were calculated and the AUMs assigned to the entire original allotment were reduced in proportion to the reduction in allotment area after clipping. Area (m2) of the allotment in each grazing capacity bin within the boundary of the study basin (UG, CC) divided by 900 provided the number of pixels in each grazing capacity bin per allotment (i.e., pixel size was 30 m x 30 m). For each allotment, percentage of each allotment area in each of the 10 grazing capacity bins was computed. These percentages were multiplied by the grazing capacity as a weighting mechanism and totaled by allotment, yielding a total weighted value by allotment. For each of the 10 grazing capacity bins for each allotment, the weight by bin was divided by the total weight of all bins to derive the proportional distribution of AUMs by bin. This proportion value multiplied by the total AUMs assigned to the clipped allotment as a whole computes the AUMs assigned to each grazing capacity bin for each allotment. AUMs per grazing capacity bin divided by the number of pixels per grazing capacity bin determines AUMs/pixel for each grazing capacity. Next, an average AUM/pixel value was computed for each grazing capacity bin for all 23 allotments having grazing. Plotting AUM/pixel averages for the 10 grazing capacity bins derived from the 23 allotments yielded the regression y = 0.0316 x (Figure 7). The regression was made to pass through the origin so that no AUMs would be projected for pixels with grazing capacity of zero.

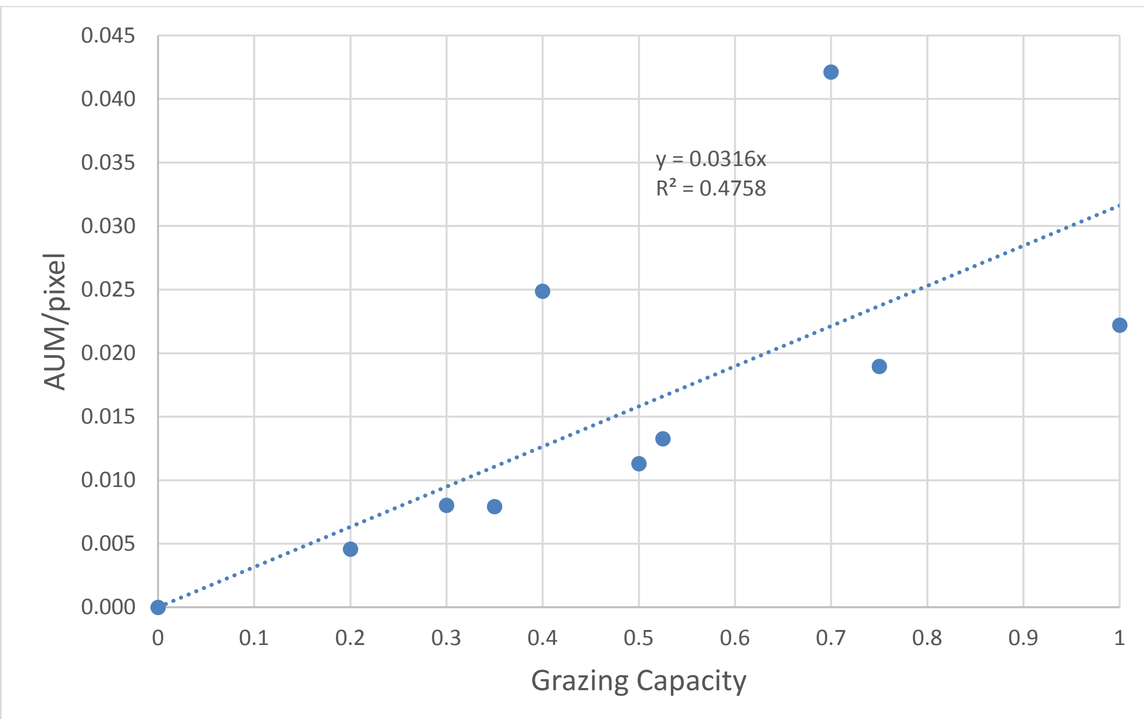


Figure 7. Regression of AUM/pixel vs. grazing capacity. Grazing capacity was mapped in Grz_dx_sl_cov raster based on the influence of distance from water, slope and land cover on potential for cattle to graze on a pixel (30 x 30 m) of land surface.

Actual grazing intensity (AUM/pixel) was derived from USFS allotments that were each analyzed for proportional distribution of grazing capacity. Total permitted AUMs were then distributed into pixels within each allotment in proportion to the grazing capacity distribution. Mean AUM/pixel (describing grazing intensity) by grazing capacity across all allotments was then plotted against the grazing capacity class to

generate a regression formula that could be used to estimate grazing intensity in all areas with study basins in conjunction with ownership (management).

The Grz_dx_sl_cov raster was reclassified to integer values of 1-10, corresponding to grazing capacity of 0, 0.2, 0.3, 0.35, 0.4, 0.5, 0.525, 0.7, 0.75, and 1.0. Zonal Statistics (Tabulate Area) was run on this raster to compute for each allotment the distribution of area (m2) in each of the 10 grazing capacity bins. There were 23 allotments within the study basins that had AUMs assigned to them. For allotments that extended beyond the outer boundary of the study basins (i.e., beyond the outer boundary of StreamStatsBasins), the areas of the clipped allotments were calculated and the AUMs assigned to the entire original allotment were reduced in proportion to the reduction in allotment area after clipping. Area (m2) of the allotment in each grazing capacity bin within the boundary of the study basin (UG, CC) divided by 900 provided the number of pixels in each grazing capacity bin per allotment (i.e., pixel size was 30 m x 30 m). For each allotment, percentage of each allotment area in each of the 10 grazing capacity bins was computed. These percentages were multiplied by the grazing capacity as a weighting mechanism and totaled by allotment, yielding a total weighted value by allotment. For each of the 10 grazing capacity bins for each allotment, the weight by bin was divided by the total weight of all bins to derive the proportional distribution of AUMs by bin. This proportion value multiplied by the total AUMs assigned to the clipped allotment as a whole computes the AUMs assigned to each grazing capacity bin for each allotment. AUMs per grazing capacity bin divided by the number of pixels per grazing capacity bin determines AUMs/pixel for each grazing capacity. Next, an average AUM/pixel value was computed for each grazing capacity bin for all 23 allotments having grazing. Plotting AUM/pixel averages for the 10 grazing capacity bins derived from the 23 allotments yielded the regression $y = 0.0316\ x$ (Figure 7).

The grzdxslcovown raster (Figure 8) was used to create an AUM/pixel raster (i.e., labeled as AUMxPixel3) using Raster Calculator with the regression formula $y = 0.0316\ x$, where x is the grazing capacity value from the grzdxslcovown raster. This raster is based on grazing capacity as a function of distance to water, slope, cover from NLCD, and ownership. The ownership has considerations of whether the owner is "F" or USFS (for example, as discussed above) and has 0 or >0 AUMs assigned.

Zonal Statistics as Table was then run on the AUMxPixel3 raster, where zones (or watershed boundaries upstream of each CHaMP “bottom of site” location) were defined by StreamStatsBasins. This was done using Model Builder in ArcMap (Figure 9).

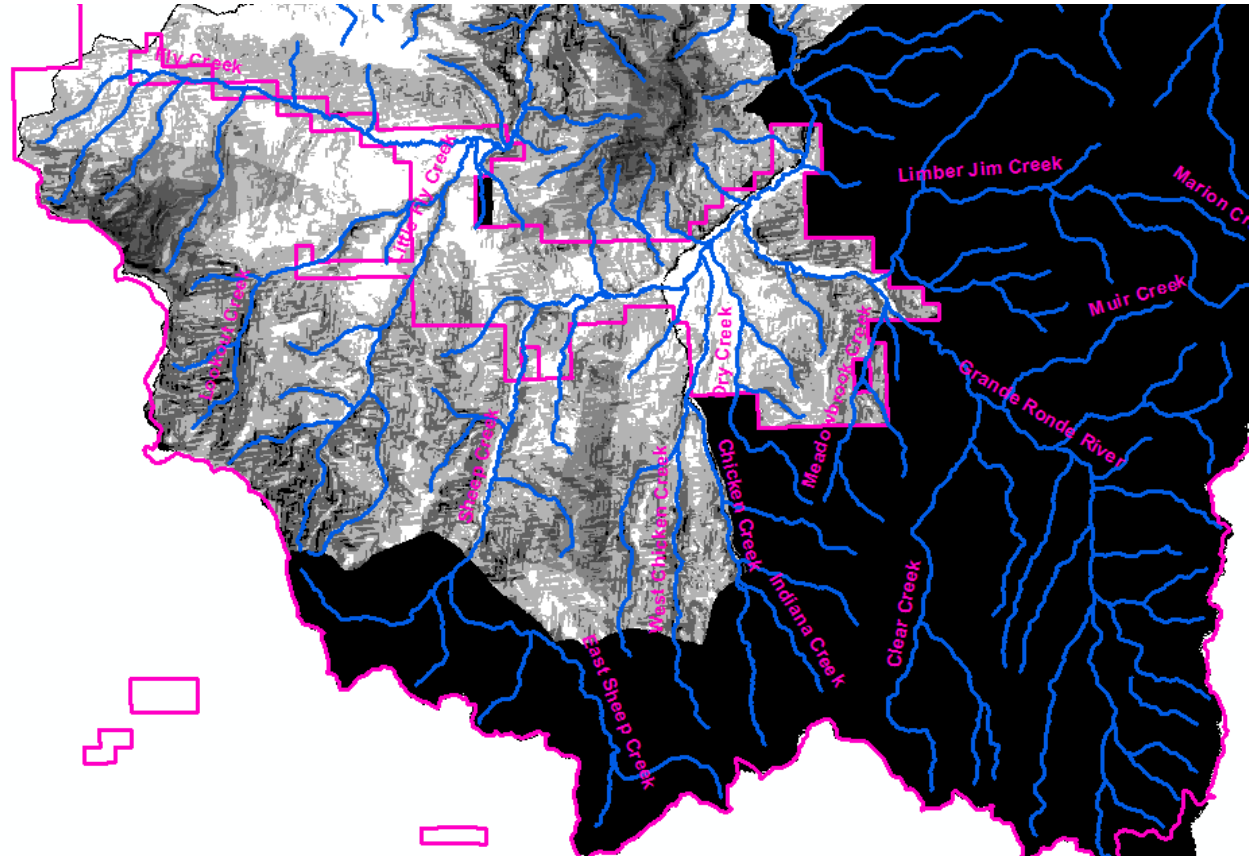


Figure 8. Display of a portion of the grzdxslcovown raster in the upstream end of the Upper Grande Ronde basin, showing ownership boundaries as pink lines. Potential grazing intensity is shown in shades from white to black, where white is highest grazing intensity (i.e., 1.0) and black is zero grazing intensity. Grazing intensity (AUM per pixel) is attributable to the combination of grazing capacity (i.e., based on slope, distance to water, and cover). The addition of grazing management plans (i.e., grazing or no grazing) was able to dictate the expression of the grazing capacity.

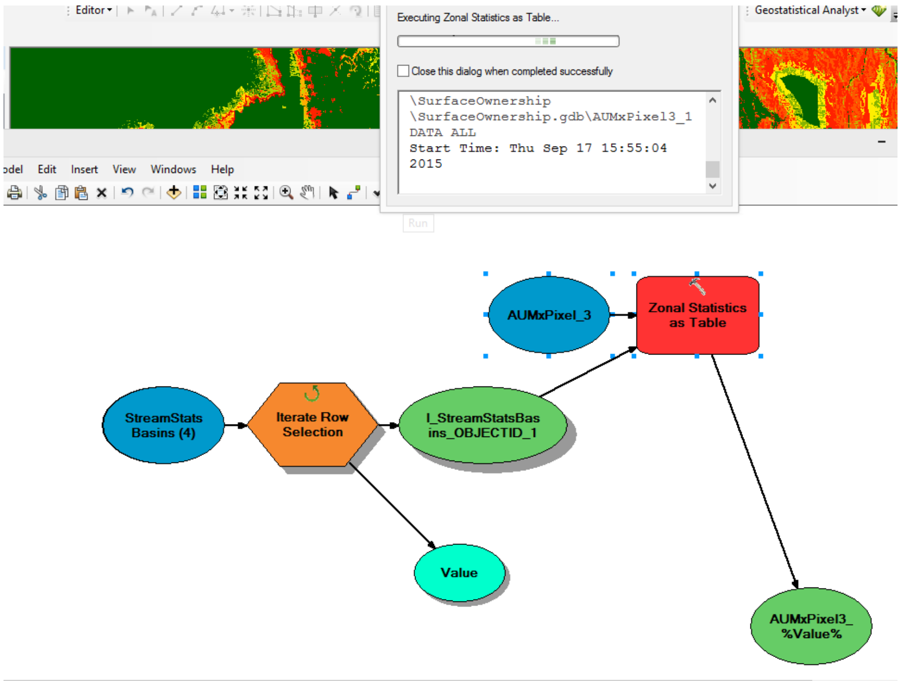


Figure 9. Structure of the Model Builder routine within ArcMap used to conduct Zonal Statistics as Table on AUMxPixel_3 raster data to generate data on the distribution of all grazing intensities by pixel for each of 195 watersheds contained within StreamStatsBasins shapefile. These data were then used to compute total watershed AUM/ha as a measure of grazing intensity.

The individual data created for each of the 195 basins in StreamStatsBasins were combined using Merge into a .dbf file (AUMxPixel3_M). These data were stored in I:Depts\gis\user\Dale\Ownership\SurfaceOwnership.gdb\AUMxPixel3_M. For each of the 195 basins (basins upstream of all CHaMP sites and other basins involved in the USGS low flow study) in our analysis, Zonal Statistics as Table computed the count of pixels, total area, and sum of AUMs. The sum of AUMs per watershed accounts for variation in use of the land surface due to grazing capacity (distance to water, slope, land cover) and management (i.e., assignment of land units to be grazed or not). If grazing capacity is low but greater than 0 in a particular watershed, the estimated total AUMs there would indicate low grazing intensity for the area as a whole. If grazing capacity is high for a particular watershed, a higher average AUM/pixel would occur and a higher AUM/ha for the watershed.

The sum of AUMs for each of the 195 study watersheds was divided by the watershed area and converted to AUM/ha. Because many of the watersheds in the StreamStatsBasins file were analyzed for purposes of developing the low flow model in cooperation with USGS, these were removed from this analysis, leaving only the CHaMP study sites. A total of 128 study sites from 2011-2014 were evaluated for grazing intensity. Grazing intensity was based on the entire watershed area for each of the watersheds contributing to the CHaMP sites. This means that if a portion of a watershed had a management decision for no grazing or had land cover that made grazing impossible (e.g., urban area, open water, ice, rocky slopes, agricultural fields, etc.), the grazing intensity would be based on the entire area and not simply the grazed portion. This estimate then gives an index of average grazing intensity averaged over the entire watershed area. Grazing intensity could be extreme on a portion of the watershed and non-existent on the remainder. In some cases, this situation could

contribute damaging amounts of fine sediment to associated stream channels that would not be compensated for by the ungrazed portion of the watershed.

Water Temperature Modeling

We used the Heat Source water temperature model (Boyd and Kasper 2003) to investigate potential thermal benefits of riparian reforestation and channel narrowing to Chinook Salmon populations in the Upper Grande Ronde River. Legacy land use practices in the basin have significantly reduced streamside vegetation and increased channel width-to-depth ratios across most of the salmon-bearing portion of the watershed, resulting in water temperatures that far exceed the optimal range for growth and survival of salmonid populations (ODEQ 2000). Riparian vegetation restoration has been identified as one of the most important management strategies for improving stream temperatures (Johnson and Jones 2000, Blann *et al.* 2002). As part of a previous contract with The Columbia River Inter-Tribal Fish Commission (CRITFC), Quantum Spatial Inc. (formerly Watershed Sciences) completed stream temperature modeling of 17 streams in the Upper Grande Ronde River basin covering the extent of current and historic Chinook Salmon habitat in the Upper Grande Ronde River and Catherine Creek (Watershed Sciences 2012). We used the model to evaluate a suite of restoration scenarios targeting riparian reforestation and channel narrowing as well as climate change scenarios. By combining restoration scenarios with climate change projections, we were able to evaluate whether future climate impacts could be offset by restoration actions. We translated water temperature simulations into predicted changes in Chinook Salmon summer parr abundance using a statistical model developed from snorkel survey and habitat data collected in the Grande Ronde Basin. Understanding how stream temperature responds to restoration of riparian vegetation, channel morphology and climate change is critical to restoration planners and natural resource managers seeking to prioritize restoration actions and restore imperiled salmonid populations.

A detailed description of the water temperature modeling analysis is provided in Appendix A.

Cold-water Refuge Mapping

Cold-water refuges, defined here as spatially-continuous patches of water with temperatures at least 2 °C less than the ambient water temperature (Kurylyk *et al*. 2014), less than 25 °C, and a surface area at least 1 m^2, can help mediate the effects of warm ambient water temperatures by providing discrete zones of cool water rearing or holding habitat during periods of thermal stress. Preferential fish use of cold-water refuges in warm streams has been well documented (Torgersen *et al*. 1999, Ebersole *et al*. 2003, Sutton *et al*. 2007, Tate *et al*. 2007).

During the summer of 2015, we developed and field-tested a protocol for mapping the spatial distribution and physical characteristics of cold-water refuges in wadable streams with peak ambient water temperatures exceeding 18 °C. These procedures are appropriate for channel unit and microhabitat-scale refuges and do not apply to larger reach or segment-scale refuges (Torgersen 2012). This protocol was intended to be used in combination with pre-existing data on the locations of potential thermal refuges (e.g., thermal infrared (TIR) imagery, previous research, or other anecdotal evidence) to field-verify the locations and physical attributes of existing cold-water refuges. This information may be useful for restoration planning purposes for projects seeking to enhance or protect currently existing cold-water refuges. In addition, this information could be used

in combination with ongoing fish and habitat monitoring and population modeling activities to address how refuge size, connectivity, or frequency influence salmon populations.

The complete protocol is provided in Appendix B.

Riparian Mapping

The Columbia River Inter-Tribal Fish Commission (CRITFC) has sought to develop a spatially based system using CHaMP-derived habitat metrics for modeling abundance, productivity, and growth rate for spring Chinook Salmon in the upper Grande Ronde River and Catherine Creek watersheds in northeastern Oregon. These watersheds have experienced various levels of anthropogenic disturbance, which has compromised the quality of Chinook spawning and rearing habitat. To assess the extent to which current conditions are affecting fish population dynamics, a model of watershed health is being developed based on water temperature, fine sediment (surface and depth), streamflow, and riparian condition.

As a part of the development of a life cycle model to predict the future trends in listed spring chinook populations, the CRITFC Habitat Team identified three key submodels related to spring chinook viability:

(1) A water temperature model (Heat Source) specific to the Grande Ronde basin was developed from LiDAR, FLIR (i.e., TIR), water temperature data logger records, streamflow measurements at key locations in the stream networks in order to predict the ability to restore water temperature to historic levels consistent with pre-development riparian conditions (stand height and cover density).

(2) Linkages between riparian condition (community diversity, height, density) and the freshwater benthic-derived vs. terrestrially-derived macroinvertebrate drift were sought as a means of modeling habitat capability for producing food for spring chinook growth. Riparian canopies that are more diverse by species and structure and denser (canopy cover by layer) are expected to provide substrates for terrestrial invertebrate production. It is expected that greater riparian community diversity and cover by layer would be directly related to diversity and abundance of terrestrial macroinvertebrate inputs to the drift. Also, the diversity and cover of riparian vegetation is known to determine the magnitude and balance of coniferous vs. deciduous litterfall to streams as well as level of aquatic photosynthesis. This allows drawing a linkage between sources of benthic macroinvertebrate food (periphyton vs. detritus) and the benthic macroinvertebrate composition and potential drift magnitude and abundance.

(3) Linkages between riparian cover (community type, cover density) and in-stream measures of surface and subsurface fine sediments were sought as a means of predicting relative levels of fine sediment delivery to CHaMP study sites. Certain types of riparian vegetation have dense and/or deep roots. Measures of riparian cover by layer (ground, shrub, understory, overstory), riparian soil erosivity, and moisture level in riparian environment would be linked to streambank stability and tendency for riparian soils to erode. Erosion in the streamside zone would be expected to contribute to sediment delivery to the stream channel, which would then be linked to observed elevation of surface and subsurface fine sediment in CHaMP study sites.

On April 1, 2013 CRITFC initiated contracts with Alaska Biological Research, Inc. of Anchorage, Alaska (Aaron Wells, Rich Blaha) and Elizabeth Crowe of Fort Collins, Colorado to produce maps of the current and potential natural vegetation communities of the Upper Grande Ronde and Catherine Creeks. These maps were designed to address the three key ecological issues listed above, which are linked to the viability of spring chinook populations in these basins. This project required three years to complete. The final year (2015) included a summer field reconnaissance survey that was used to derive ground-based assessments of plant communities and their environmental context to validate mapping that had been done from existing plant surveys, remote sensing, SCS and USFS soil surveys, and other data. The final report documented the methodology and outputs from this mapping effort.

The study area comprised the historical extent of spring chinook in the Upper Grande Ronde and Catherine Creek basins. The riparian area mapped comprised 7300 hectares (ha) and was defined by a 100-m wide buffer on each side of the center of active river channels for the mainstem and tributaries. Major tributaries mapped as part of this effort include North and South Fork Catherine Creek, Little Creek, Ladd Creek, Five Points Creek, McCoy Creek, Meadow Creek, Fly Creek, Sheep Creek, Clear Creek, Limber Jim Creek, and Beaver Creek. Survey locations were co-located with stream reaches with existing Columbia Habitat Monitoring Program (CHaMP) plots whenever possible.

Data sources evaluated for use in mapping were documented in McCullough et al. (2014). These sources included GIS-based information on vegetation, soils, climate, geomorphology, and other resources plus historical accounts.

Map polygons for plant communities were delineated at a scale of 1:2,000 to 1:3,000 for a final map scale of 1:5,000, which is a scale at which the mapping is valid for landscape analysis. The minimum mapping size for polygons was 0.10 ha for waterbodies, 0.81 ha for complexes, and 0.20 ha for all other classes. Individual ecological components were mapped as compound codes called Integrated Terrain Units (ITUs). Integrated Terrain Units were comprised by data describing physiography, geomorphology, generalized soils, existing vegetation, potential vegetation, and disturbance. Integrated Terrain Unit (ITU) mapping is an integrated approach to mapping landscape elements. It is a multivariate mapping process in which terrain unit map boundaries are visually interpreted and digitized over high resolution imagery so that there is increased coincidence between the boundaries and occurrences of interdependent ITU variables, such as physiography, geomorphology, soils and vegetation units (Jorgenson et al. 2003).

Field crews used several plot types (described below) to ground-truth data, including verification plots, observation plots, photos plot, and LiDAR plots. A total of 82 plots were sampled across the study area, including 57 verification plots, 12 observation plots, 11 LiDAR plots, and 2 photo plots. Observation plots were used to map Level 4 vegetation class and the dominant 6-10 plant species in the plot. Photo plots were used to document vegetation by photos and to collect detailed field notes. LiDAR plots were used to validate canopy height and density data for trees and tall shrubs (> 1.5 m height).

Physiography was coded for all plots as either lowland, riverine, subalpine, or upland. Plots were also classified by geomorphic setting.

Existing vegetation was classified using a four-level hierarchy of existing vegetation classes similar to Viereck et al (1992) that was modified using existing vegetation classification systems from the region (Crowe and

Clausnitzer 1997; Crowe et al 2004; Johnson and Clausnitzer 1992; Johnson and Simon 1987; Wells 2006). Level I comprises major lifeform groups (forest, shrub and herbaceous) as well as vegetation complexes, agricultural land, barren land, developed land and water. Level II divides Level I vegetation classes into broad growth forms (conifer forest, broadleaf/deciduous forest, tall shrub, low shrub, forb and graminoid). Level III depicts canopy closure classes. Level IV identifies the dominant overstory species or species group in a Level III class.

Soil data available from past soil surveys of the area consisted of 123 soil series. Because many of these were capable of producing a variety of plant communities, it was feasible to collapse this soil classification to 14 soil units.

Vegetation classification by Levels I through III are strongly influenced by soil horizon texture, coarse fragment content, profile depth, and chemical composition. Vegetation classification to Level IV involved the use of soil temperature and moisture classes, which influence plant species occurrence, density, and structure.

Potential riparian vegetation was considered to be assemblages of native riparian vegetation occurring in equilibrium with the environment for a given fluvial surface. The fluvial surface specific to each PNV community in a floodplain environment includes the characteristic flood-frequencies and associated deposition and erosion of alluvial particles. Streams were assumed to be connected with the floodplain during seasonal high-water events and the floodplain water table to be accessible to plant roots on abandoned floodplains and lower geomorphic surfaces. This is an important basis for estimating PNV given that many existing stream channels in heavily grazed areas are downcut, which tends to reduce the linkage of the surface stream water with the floodplain and alter near-stream soil moisture regimes. PNV estimated here is based on the assumption of being able to fully restore the geomorphic setting that existed prior to management influence. This might require years of aggradation and enhanced connectivity with the floodplain, development of historic sinuosity, and restoration of hyporheic flows, which could require restoration of PNV riparian communities with their natural LWD delivery rates, restoration of beaver dams, and elimination of confinement by berms from roads.

The potential vegetation types within the study area have been classified and described as plant associations and community types in vegetation classifications (Crowe and Clausnitzer 1997, Crowe et al 2004, Johnson and Clausnitzer 1992, Johnson and Simon 1987, Kauffman et al 1985, and Wells 2006) and climax plant communities in ecological site descriptions (ESDs) (USDA, NRCS, Ecological Sciences Division 2014).

PNV maps were created from 153 plant associations and plant community types and 11 climax plant communities applicable to the mapping area that were organized into plant association groups (PAGs). Development of PAGs followed methodology of Powell et al. (2007) used in the Blue Mountains region of NE Oregon. The PAGs capture the temperature and moisture regimes for the environment associated with the type.

Vegetation polygons were attributed with information on disturbance. For example, forest fire recurrence interval and anthropogenic disturbances, such as agriculture, provide information on natural and human-caused impacts to plant communities. Vegetation polygons were also attributed with erosion sensitivity classes. Erosion sensitivity was evaluated based on soil characteristics, as well as vegetation and geomorphology

Historical Ecology for Setting Restoration Targets

Setting target conditions for restoration of fish habitat typically involves inferring conditions from nearby, undisturbed reference areas or using statistical models to extrapolate the expected, unimpacted conditions from within the existing range of anthropogenic disturbance in a watershed. However when historical information is available, it can provide a more realistic estimate of baseline conditions. To define a historical baselines for fish habitat, we described changes to stream channel widths since the late 1800s, with expectations that magnitude of change would be greater in areas with more intense ranching, logging, agriculture, and other forms of land use. Channel width was used as a proxy of width-to-depth ratios—a more common metric used to describe the effects of land use on channel morphology—because historical estimates of water depths were not available.

Historical estimates of channel width were based on Government Land Office (GLO) surveys (Principle Clerk of Surveys, General Land Office 1855) conducted in the mid to late 1800s. The GLO survey provided information on the quality of conditions for rangeland, agriculture, and forestry for prospective land claims under the Homestead Act of 1862. The survey involved two crew members walking the 1-mile section lines for each of 36 sections in a 640 acre township. In addition to recording the general character of vegetation, soil, and rangeland conditions, surveyors recorded the location and bank-to-bank channel width (active channel width) of any streams or rivers crossed. For each section line that intersected streams within Chinook Salmon spawning and rearing extent, we translated the handwritten surveyor notes into spatial data in a geographic information system (GIS) (ESRI 2011). Estimates of channel width were converted from chains and links (1 chain = 100 links) to meters (1 link = 0.20 m).

Contemporary estimates of channel width were based on Oregon Department of Fish and Wildlife's (ODFW) Aquatic Inventories survey (Moore et al. 2008). The ODFW survey is a rapid assessment of common fish habitat characteristics collected in a spatially continuous fashion across the stream network. Two ODFW surveyors walked smaller streams or canoed larger river sections and recorded the characteristics and location of channel units (i.e., pools, riffles, and glides) with a hand-held global position system (GPS) with accuracy 5-7 m. Data from the 1990s were used as the baseline for present conditions, except where surveys were conducted outside the low flow period (Julian day 200-300). When surveys did not match that criteria we used surveys from years 2000 or 2010 that fell within the low flow period. Whereas surveyors recorded wetted at every channel unit, active channel width was only recorded at every 10th channel unit and at tributary junctions. We therefore developed a linear relationship between wetted and active channel width for extrapolating spatially extensive channel widths comparable to historical GLO surveys:

$$W_A = 5.11 + 1.04 \times W_W,$$

where W_A is the active channel width and W_W is the wetted width in meters measured by ODFW crews (n = 23, R^2 = 0.70, p < 0.001). We then calculated the percent change in channel width from the historical to present periods based on GLO and ODFW estimates of active channel width:

$$\Delta W = \frac{W_P - W_H}{W_H} \times 100,$$

where ΔW is percent change in channel width, W_P is present channel width, and W_H is historic channel width in m. We then evaluated the magnitude of change since the historical period according to watershed identity and

a geomorphic valley setting classification. Watershed identity was defined by the distribution of Chinook populations Catherine Creek (CCC), Upper Grande Ronde (UGC), and Minam River (MRC). The classification system consisted of dividing the stream network into small and large streams using an 8 m bankfull width criteria based on the work of Beechie and Imaki (2014). Next, the stream network was further divided into three different valley types based on valley confinement (laterally unconfined, partly confined, and confined) following the methodology described in the River Styles Framework (Brierley and Fryirs, 2005). We simplified the classification into three classes for this analysis: (1) large streams, (2) small/partly confined and confined streams, and (3) small/laterally unconfined streams. The effect of watershed identity on magnitude of channel change was tested using one-way analysis of variance (ANOVA). One-way ANOVA was also used to test the effect of valley setting on magnitude of channel change, but only for sites in the impacted watersheds (CCC and UGC) because all locations in the Minam River where estimates of channel change existed were in large stream types. Model assumptions were assessed by visually evaluating residuals versus fits, normal Q-Q plots, scale-location plots, residuals versus leverage, and histograms of residuals. Tukey's HSD test was used for post-hoc evaluations of individual group differences.

Estimates of historical stream channel widths were used alongside changes to riparian vegetation as restoration scenarios for water temperature modeling using Heat Source (Boyd and Kasper 2003). Modeled water temperatures based on channel width and riparian scenarios were used along with other factors in a regression model relating juvenile Chinook Salmon rearing densities. Methods for applying the Heat Source model to historical stream width scenarios and the subsequent fish-habitat model are described in Appendix A.

Restoration Database

With the decline of endangered salmon populations in the Columbia basin and uncertainty associated with the extent that tributary restoration actions can significantly help recover populations, it is important to evaluate the influence of habitat restoration on fish habitat at appropriate spatial and temporal scales. Evaluating stream restoration projects at tributary and watershed scales, as opposed to the common practice of evaluating restoration at individual restoration sites, can offer insights into habitat actions required to address limiting factors for freshwater salmon production. A preliminary step in evaluating restoration at tributary and watershed scales is compiling existing information on where, what type, and, to the degree possible, intensity of restoration across the entire project area. We addressed these issues by compiling restoration project information for the Upper Grande Ronde River, with the goal of providing a comprehensive understanding of restoration carried out in the area from the 1986 to 2014 from multiple sources (Table 3). Further details of methods for compiling and mapping restoration information are documented in Appendix D.

Table 3. Data sources for restoration project information in the upper Grande Ronde River Subbasin. Values for total number of unique work sites indicate number of restoration work sites reported by a specific source that were not already reported by another source.

Agency	Source	Data Archive	Year Range	Total Number Of Unique Work Sites
Oregon Watershed Enhancement Board	oregonexplorer.info	Oregon Watershed Restoration Inventory	1992-2013	3837
Grande Ronde Model Watershed	Mason Bailie & grmw.org/projectdb	Grande Ronde Model Watershed Project Database	1987-2013	348
National Oceanic and Atmospheric Administration	Monica Diaz	Pacific Northwest Salmon Habitat Project Database	1986-2012	174
Oregon Department of Fish and Wildlife Grande Ronde Watershed District	Winston Morton	Grande Ronde Fish Habitat Database	1985-2012	32
Bureau of Land Management, Vale District	blm.gov/or/gis/data.php	Interagency Restoration Database	1993-2014	20
The Confederated Tribes of the Umatilla Indian Reservation	Les Naylor	CTUIR Fish Accord Habitat Projects, Limiting Factors and Accomplishments 2008-2014 project information spreadsheets	2008-2014	13
The Freshwater Trust, Flow Restoration for Northeast Oregon	Aaron Maxwell	Freshwater Trust Accomplishments Reports	2013-2014	10
U.S. Forest Service, Wallowa-Whitman National Forest	Kayla Morinaga & Joe Platz	2010-2012 La Grande Ranger District Aquatics Program Accomplishment Reports & Wallowa-Whitman National Forest La Grande Ranger District Restoration Projects within the Grande Ronde River Watersheds (2008-2014) & (1988-2008) project information spreadsheets	1988-2014	8
Bonneville Power Administration	cbfish.org	Taurus Database	1984-2014	6
National Oceanic and Atmospheric Administration	map.critfc.org/flexviewers/pcsrftribal	Pacific Coastal Salmon Recovery Fund	2005-2011	1
		Total Work Sites	1984-2014	4449

The total number of work sites identifies the number of unique work sites incorporated into the data table from each source; duplicate projects were consolidated.

Stream Biota

Juvenile Salmonid Abundance

We conducted snorkel surveys to quantify juvenile Chinook Salmon and steelhead abundance and size in their summer rearing habitats. These data were used to inform fish assemblage structure and to assess potential fish-habitat relationships. CRITFC performed snorkel surveys at all 25 sites where CHaMP habitat data were collected in 2015. In addition to these surveys, the Oregon Department of Fish & Wildlife (ODFW) conducted 73 snorkel surveys in the Upper Grande Ronde (UGR) and Catherine Creek (CC) watersheds, and 10 snorkel surveys in the Minam watershed at all CHaMP sites. The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) also conducted snorkel surveys at 3 sites in the UGR watershed. Snorkel counts were calibrated based on the more actuate mark-recapture electrofishing estimates conducted by ODFW. Methods for calculation of fish abundance from snorkel counts are described in Appendix F.

These three agencies have recognized the need to use a common snorkel survey protocol so that information collected by individual entities can help managers determine whether aggregate habitat restoration actions will yield a net improvement in basin-wide habitat quality and viability of ESA-listed fish species. To this end, we developed a snorkeling protocol, drawing heavily from the protocols of Thurow (1994) and O'Neal (2007) and integrated with the Pacific Northwest Aquatic Monitoring Program (PNAMP) methods, with the intention that this protocol will be implemented by all agencies responsible for data collection in the Upper Grande Ronde, Catherine Creek, Minam River, and potentially other nearby basins. Details about the snorkel survey methodology can be found in White et al. (2012) (https://www.monitoringmethods.org/Protocol/Details/499).

In addition to monitoring generalized trends in fish density over time, we have linked fish densities to local site characteristics and landscape-level variables to help understand patterns driving change. Structural equation modeling (SEM) is a statistical approach to hypothesis testing that accounts for direct and indirect relationships among variables (Grace 2006). SEM evolved from path analysis with several notable improvements including analysis of covariance among variables (versus analysis of correlations), incorporation of hierarchical modeling approaches, and the use of latent variables. SEM is an appropriate tool for fish-habitat modeling when the interrelationships among factors influencing fish abundance or fish performance (growth, survival, etc.) are of interest. In addition to testing hypotheses about interrelationships between fish and their habitat, SEM can also be used to predict fish habitat conditions in unsampled areas. These predictions based on observed relationships can then be incorporated into simulation analyses such as life cycle modeling. Updates to previous years include migrating the analysis from proprietary SPSS-AMOS software to open source R statistical software (Lavaan and semplot packages).

Benthic and Drift Macroinvertebrates

CRITFC has collected benthic macroinvertebrate samples from 2011 through 2015 from all CHaMP sites. Our objective in doing this has been to characterize the capacity of the stream site to generate a food base for the fish communities and to link the macroinvertebrate communities with current conditions and trends in water quality, habitat characteristics, and position in the stream network (e.g., River Continuum). Although benthic macroinvertebrate community composition varies with time (seasonally, annually), it is not likely to vary on a diurnal basis as is the drifting portion of the community. Also, collections of benthic macroinvertebrates were

directed to riffles, whereas drift collections reflect both the riffle that the samples were taken from as well as upstream habitats. Even though drift nets were installed near the downstream end of riffles of average length and at the upstream end of study sites, which were 20 times bankfull width in length, the tendency of drifting organisms to move downstream with the currents and then reattach to the streambed ensures that some specimens collected in nets represent upstream pools, glides, or side channels in addition to riffles.

Benthic samples were collected with either a Hess sampler or a kick net, depending upon the depth, water velocity, or substrate size. Care was taken to sample an area of 1 ft^2 with each sampler. That is, even if a kick net was the sampler of preference given the conditions (e.g., either low or high water depth, high current velocity, large substrate), care was taken to ensure a quantitative sample by gathering all substrate within the 1 ft^2 area upstream of the net mouth so that individual particles could be brushed and all macroinvertebrates directed into the net. Substrate was excavated as deep as feasible, disturbed with a small hand rake, and brushed thoroughly. The mesh size of the collection nets on both sampler types was 500 um, which ensures capture of the majority of small size classes. A total of 8 randomly selected positions in a sequence of riffles within the study site were composited to form a sample, which then represented 8 ft^2 of streambed. Samples were taken from the central area of a series of randomly selected cells in a 3 x 3 matrix of cells overlaid on each riffle. If there were 10 riffles in a study site, samples were collected from randomly selected cells in each of the first 8 riffles. Samples were preserved in 100% ethanol and were sent to Cole Ecological, Inc. for sorting, identification, and analysis of basic community metrics.

Community metrics computed for each sample included:

(1) standard BCI indices
(2) functional feeding group composition
(3) Hilsenhoff metrics
(4) tolerant/intolerant species based on fine sediment and temperature (using, in part, indicator taxa by Huff et al. 2006)
(5) PREDATOR (Western Cordillera and Columbia Plateau model)
(6) total taxa densities
(7) biomass/m^2
(8) Eastern Oregon multimetric index (Hubler 2006), including component metrics of mayfly, stonefly, and caddisfly richness, number of sensitive taxa, number of sediment-sensitive taxa, modified HBI, percentage of tolerant taxa, percentage of sediment tolerant taxa, and community dominance by the single most abundant taxon.
(9) DEQ temperature and fine sediment stressor models.

Drift samples were collected using two custom-made nets, each of 60 cm vertical height by 40 cm width. Nets were placed at the downstream end of a riffle which was located at the upstream end of each CHaMP study site (or immediately above the upstream end so as not to interfere with co-occurring topographic and auxiliary habitat surveys). Net mesh size was 500 *u*m. Nets were typically installed between 9 am to 10:30 am and collected drift for a minimum of 3 hours and up to about 5 hours. Current velocity and water depth was measured at the beginning and end of net deployments to allow calculation of total volume filtered. Nets were not touched during filtration so that it could be inferred that average current velocity in the center of the net mouth would decline linearly throughout the entire deployment period. Attempts were made to retrieve

samples before final current velocities declined significantly (e.g., more than 20%). Efforts were made to set up nets at sites where currents were relatively laminar approaching the net rather than exhibiting strong directional shifts or velocity strength gradients across the face of the net. If velocity variation appeared unavoidable at the net mouth, then three uniformly spaced velocities were averaged to generate initial and final average velocities.

Samples were preserved in 100% ethanol prior to shipping to the laboratory that processed them. Rhithron lab did all drift sample sorting and identification and provided results in tabular form for data analysis. Differences in taxonomic nomenclature between the benthic processing lab (Cole Ecological) and the drift processing lab (Rhithron) were probably minimal given that they each abide by regional standards set up by PNAMP (Pacific Northwest Aquatic Monitoring Partnership). However, these two labs employed different levels of taxonomic resolution depending on specific taxa, which created a significant amount of work to make datasets comparable at the lowest possible resolution. Other differences existed, such as spellings, capitalization, or suffixes added to taxa names that needed to be resolved prior to analysis. Any methodology not fully described here is available either in CHaMP protocol documents (available at www.champmonitoring.org) or at www.monitoringmethods.org (hosted by PNAMP).

Benthic data from Cole Ecological are stored in CRITFC's data storage facility in Portland, Oregon. Drift data from Rhithron is stored by the CHaMP data management team. Habitat data collected in CHaMP is available via champmonitoring.org under the export tab. Analyses conducted here to date have related benthic community indices or benthic taxa distributions to environmental data from CHaMP surveys conducted between 2011 and 2014. CHaMP environmental data used to relate to macroinvertebrate data involved primarily water temperature, elevation, channel gradient, and various substrate size indices. Measures of fine sediment concentrations were of particular interest. CHaMP water temperature data were analyzed to produce the index Max7dAM or the maximum 7-day average of the daily maximum temperatures. This index would find a 7-day average of daily maximum temperatures from hourly temperature data recorded by temperature loggers throughout the summer field season (or from annual records). The highest 7-day average value typically occurs in the July-August period. In addition to this, average August water temperatures were obtained from the NorWeST temperature database (http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temperature.shtml). These data provide estimates for every 1-km interval on the mainstem and major tributaries of our study basins. Values closest to the upstream end of study sites that were not compromised by entry of significant tributaries (e.g, adding greater than 5% of flow or drainage area to the study stream) were taken as the temperatures applying to our CHaMP sites in various analyses. The NorWeST water temperature database was heavily dependent on accumulated water temperature data provided by CRITFC in our study basins from our CHaMP surveys, as well as from other agencies that had worked in these basins in the past, such as ODFW, USFS, or ODEQ.

Various macroinvertebrate datasets were used in the preliminary analyses conducted. Community indices developed from the entire 2011-2014 database of macroinvertebrate samples were used in relating communities to environmental characteristics. Because water temperature values were not available for all years for all sites, regressions on environmental characteristics were based only a site's biotic data only when corresponding water temperatures were available. Several community indices were averaged by site across

the years using pivot tables and these were regressed on water temperature indices averaged for the same years.

Individual taxa abundances were related to water temperature (Max7dAM) for the 2013 macroinvertebrate collections. This was done by plotting abundance against water temperature and placing mean or maximum abundances in temperature bins to evaluate distribution.

Macroinvertebrate data from 2014 was used to compute constancy of taxa among study basins. These data were also used in computing which taxa (family level) were responsible for the greatest differences among study basins.

Benthic taxa were compared to drift taxa in collections from 2013 only. Comparisons were made by plotting regressions and computing regression statistics. Abundances of benthic data were computed as numbers/m^2 and those of drift date were computed as numbers/m^3. Taxonomic identifications were adjusted to lowest operational units that provided exact matches between benthic and drift taxa. Only sites were selected that had both benthic and drift samples in 2013. In 2013 there were 7 of 61 unique CHaMP sites surveyed by the combination of CRITFC and ODFW that had either 3 or 4 samples taken during the field season. These 7 sites with consecutive counts represented a total of 20 samples out of 78 total in 2013. For these sites, average macroinvertebrate data (abundances by taxa and metrics) were calculated using pivot tables. The alternative was to select a single sample to represent the site that was closest to the center of the time period in which other samples were taken. The range of sample dates for all sites sampled a single time during the summer of 2013 was July 9-September 27. Sites that were sampled either 3 or 4 times had sample dates ranging from July 15-October 21. Given the broad range in both sample periods (i.e., for sites sampled either a single time or multiple times), it did not seem inappropriate to average data for the multiply-sampled sites. Future analyses will attempt to assess trends in macroinvertebrates in benthic samples during the summer to early fall season.

Life Cycle Model

This analysis focuses on spring/summer Chinook Salmon in the Grande Ronde basin. The Snake River spring/summer chinook ESU contains several major population aggregates in Idaho, Washington and Oregon. The Grande Ronde/Imnaha Major Population Group (MPG) consists of several populations draining into the Snake River. The Grande Ronde River (GR), Catherine Creek (CC), Lostine/Wallowa (LOS), Minam (MIN), Wenaha (WEN), and Imnaha (IMN) are six populations making up the GRIMPG. This analysis uses data from all six populations as a statistical sample of mainstem survival, and estimates of freshwater productivity and capacity are provided for all six populations, but the analysis is focused on the Upper Grande Ronde, Catherine Creek, and the Minam for long-term population trends. The Northwest Fisheries Science Center of the National Marine Fisheries Service (NMFS) publishes salmon population summaries annually (SPS[1]). We used conversion rates, Zone 6 harvest estimates, and commercial harvest estimates from TAC Biological Assessment Tables to reconstruct the number of adults that would have been present at the mouth of the Columbia, based on the number that were observed on the spawning grounds. Those numbers are used to compare to

[1] https://www.webapps.nwfsc.noaa.gov/apex/f?p=261:home:0

predicted returns to the mouth. Tributary harvest rates and collection for broodstock, which are also used in this back-calculation, were obtained from ODFW population reconstruction tables.

One facet of this analysis is to estimate the effect of environmental conditions in the Columbia River during smolt outmigration on the mainstem outmigration survival. We used a powerhouse contact rate derived from PIT tag data (PITPH) to predict in-river and ocean survival (Tuomikoski et al., 2012). The PITPH index uses the PIT tag detection rate and an estimated fish guidance efficiency to estimate the fraction of fish passing through the powerhouse (bypass and turbine routes combined). This is predicated on the fact that the actual number passing through the powerhouse is the number of bypass detections divided by the guidance efficiency. PITPH implicitly captures traditional spill and surface passage. We also used an index of water travel time (WTT) to predict in-river survival. WTT is obtained by dividing the total volume of reservoirs by the flow rate, with adjustments in McNary pool to account for Columbia River versus Snake River flows (Tuomikoski et al., 2012).

We used SAR and in-river survival rates obtained from PIT tag data for brood years 1992 to 2010. Prior to 1992, SARs were obtained by dividing the returns to the mouth of the Columbia River by number of smolts at the upper dam.

In 2013 and 2014 life cycle analyses, we statistically fit detailed population dynamics models that predicted smolt production, survival through the hydrosystem, and survival in the ocean. We estimated the parameters that minimized a negative log likelihood and provided a best fit to trends in abundance and survival. In this 2015 analysis we used the results of statistical fitting as the basis for predicting abundance trends under alternative potential changes to both tributary and mainstem survival. We develop an Alternative Treatment Evaluation (ATE) method that compares the potential relative benefit of a level of improvement in juvenile mainstem passage survival to a level of improvement in freshwater spawning and rearing productivity. The ATE method factors the uncertainty in parameter estimates into predictions, and therefore predicts the range of possible outcomes from each alternative treatment level.

Markov Chain Monte Carlo (MCMC) simulation was performed during the parameter estimation to obtain estimates of the variability the magnitude of each parameter, which is also known as the posterior density estimate. We used the posterior density estimates as a basis for simulating ranges of possible population trends when alternative treatments were applied to the historical state of each population. The Alternative Treatment Evaluation (ATE) used a different set of parameter values drawn from the saved MCMC posterior values, and each simulation started with empirical spawners from 1964–1968 and parameters from the posterior chain, and used the known conditions in each year (PITPH, WTT, juvenile transportation, commercial and Zone 6 harvest, and upstream migration survival) to predict subsequent spawners of each age in years 1969–2013. Predicted returning spawners in each year after the first complete brood year returns in 1969 were used to predict successive generations, meaning the model spawns itself and does not require empirical spawners past 1968. To examine alternatives, we altered a single variable across a range of values, and simulated repeatedly to see the magnitude of the effect of changing that variable, and also to see what range of outcomes can be expected at each level of the altered variable.

For our ATE analysis, we posed two questions: (1) What is the potential for changes to spawning and rearing productivity to increase long-term adult return abundance, and (2) What is the potential for changes to hydrosystem operations to increase long-term adult return abundance? To address these questions, we simulated a retrospective reconstruction of population trends and looked at the average adult return

abundance $\overline{R}$ in the last ten years of the historical time period (brood years 1999-2008). We simulated a population trend 10,000 times by drawing parameter values randomly from the posterior chain saved in the MCMC simulations. Each of the simulations produced a return abundance trend, the average abundance was recorded, and the result was compiled into a distribution of possible abundances for each level of the control variable (either productivity of hydrosystem operations). We produced a gradient of relative return abundances by iterating through ranges of values of productivity and hydrosystem operation levels.

To examine the potential effect of changes in productivity and capacity, we selected values of each parameter within a specified range, using the range 50–250 smolts per spawner for productivity and 5,000 to 50,000 for capacity. We stepped through these values using the following procedure:

1. Draw a set of parameters Θ_i from the posterior chain.
2. Set a_p = 50 for each of the 6 population productivities and replace the value drawn from the chain with a_p.
3. Simulate $\bar{R}_{p,j,i}$ where *i* is the iteration, and *j* is the level of a_p.
4. Go back to step 2 using a_p+ 10 until all 21 values in the range $a_p \in [50–250]$ have been simulated for productivity and using b_p + 5,000 until all values in the range $b_p \in [5,000-50,000]$ have been simulated for capacity.
5. Go back to step 1 and repeat for 10,000 draws of Θ_i.
6. Use the 6 x 21 x 10,000 $\bar{R}_{p,j,i}$ array to show the range of predicted average abundance for each population p of each level *j*.

To examine the effect of changes to hydro system operations, we use the range 50–100% of historical PITPH values. Simulating using 50–100% of historical PITPH levels gives us a sense of the potential for greater spill levels to bring about increased return abundances, with 50% of historical PITPH representing the best possible treatment level, and 100% being an exact replica of historical values. We used the following logic:

1. Draw a set of parameters Θ_i from the posterior chain.
2. Set the fraction *q* = 0.5.
3. Set $PITPH^*_t$ = *q* x $PITPH_t$ for each year of the index.
4. Simulate $\bar{R}_{p,j,i}$ replace PITPH with PITPH*, where *i* is the iteration, and *j* is the level of *q*.
5. Go back to step 2 using *q* + 0.05 until all 11 values in the range $q \in [0.5,1.0]$ have been simulated.
6. Repeat for 10,000 draws of Θ_i.

Use the 6 x 11 x 10,000 $\bar{R}_{p,j,i}$ array to show the range of predicted average abundance for each population p of each PITPH fraction level *j*.

Coordination and Data Management

Fish Database Development

In order to improve inter-basin communication of fish data, ODFW and CRITFC merged juvenile fish abundance data into one joint database. This decision built from years of partnered data collection efforts, including calibrations of snorkel abundances with mark-recapture data and a shared snorkel survey protocol. The construction of the databases was led by ODFW staff with input from CRITFC scientists. Raw fish counts and site information are inputs to the database and abundance estimates were calculated from previously defined relationships based on Tier 1 unit type (Fast or Slow water units), see Appendix F for calibration equations. Salmonid abundance, linear density, and areal density were reported at the channel unit and site level. Fish community metrics were also reported at a site level. This database will be maintained by ODFW and will continue to be updated on an annual basis.

CHaMP Data Management

Data collected through the Columbia Habitat Monitoring Program (CHaMP) were compiled on the CHaMP programs' website (www.champmonitoring.org). As habitat data are collected in the field, data are uploaded to the CHaMP website on a daily basis where it is stored and maintained by Sitka Technology Group. This website interface allows for quality control analysis post field season of habitat and topographic measurements along with the resulting calculated metrics. After the data are endorsed by watershed analysts and program managers, the data are released to the public and are available for download.

Coordination with regional agencies, tribes, and landowners

We have continued to work closely with staff from the Natural Resources department at the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), which included coordination of field activities and sharing of data and knowledge related to our respective monitoring and restoration programs in the Grande Ronde Basin. CTUIR is now participating in the CHaMP program, which will allow for more direct sharing and compatibility of data collected.

Ongoing participation in the FCPRS BiOp Grande Ronde Atlas Restoration Prioritization ("Grande Ronde Atlas") working group yielded significant progress. Grande Ronde Atlas is a BPA-guided process that incorporates multiple agencies and tribal staff (CTUIR and Nez Perce) to prioritize restoration activities in the sub-basin, based on current and historic life use by salmonids, geomorphic potential for change, proximity to current population core areas, and other factors. CRITFC staff contribute vital information including water temperature data and Heat Source modeling results, spatial distribution of Chinook Salmon redds, summarization of habitat conditions measured in CHaMP and other habitat programs, GIS layers of geomorphic potential for change in river conditions, and fish rearing densities derived from snorkeling and electrofishing in collaboration with ODFW La Grande. The spatial resolution of Grande Ronde Atlas prioritization is the biologically significant reach (BSRs); CRITFC's Accords project uses the same BSRs as one of several hierarchical scales in fish-habitat modeling efforts and in life cycle modeling in order to deliver relevant results to the Atlas group. In 2015, we participated in several Science Technical Advisory Committee meetings in La Grande, as well several small workgroup meetings with BPA staff in Portland to further develop and refine the Atlas process. As an extension

of this work, in 2015 CRITFC staff also participated on the Grande Ronde Expert Panel, tasked with evaluating whether habitat projects funded under the Biological Opinion were helping lead to successful recovery of ESA-listed fish species.

We have continued to maintain a strong collaborative working relationship with staff from Columbia Habitat Monitoring Program (CHaMP). We participated actively in critique and refinement of the CHaMP protocol, shared data, continued co-development of a new rapid habitat assessment protocol, and presented findings from our project at a fish-habitat modeling session of the American Fisheries Society Meeting in Portland. We view the CHaMP program as filling a critical need in the Columbia Basin in that it provides standardized habitat data that can be used to assess status and trends in fish habitat conditions across a wide range of spatial scales, including watersheds that span the ceded lands of all four of our member tribes. We feel that our involvement in the program since its inception has been important in helping to shape and refine the program to make the most of the data collected.

Through the involvement with CHaMP, we have also coordinated with the Action Effectiveness Monitoring (AEM) Program (https://www.aemonitoring.org/), which conducts surveys in many of the same watersheds as CHaMP with a focus on restoration sites. The AEM protocol is being implemented by CTUIR and Tetra Tech in the Grande Ronde basin. We coordinate with survey crews and project managers to assist in data collection and site access. This collaboration fosters relationships in the greater Columbia basin as well as within the Grande Ronde watershed.

CRITFC staff organized and chaired a symposium at the American Fisheries Society, which gathered several nationally recognized food web researchers to discuss how food web ecology can be readily utilized by fisheries managers and practitioners. Under the leadership of CRITFC staff, several symposium participants initiated a review article intended for *Fisheries* highlighting themes of the discussions that ensued at the conference.

Each year CRITFC Habitat staff has contacted private landowners to gain access to their property to conduct habitat surveys. In the process, some landowners express particular interest in the data being collected. Landowner support and involvement in this work is critical to the success of restoration in general and understanding of the results of our efforts. In order to satisfy the requests for information, we have sent individual landowners reports detailing the basic findings arising from studying the stream flowing through their property.

Results

Stream Habitat

CHaMP Data Collection

A summary of six important CHaMP habitat metrics including percentage fines less than 2 mm, large woody debris (LWD) frequency (count/100 m), percentage slow water, residual pool depth (m), average August temperature (˚C), and the maximum 7-day running average maximum temperature (Max7dAM, ˚C) within each Chinook population group, valley setting classification, and Biologically Significant Reaches (BSR) is provided

(Table 4). This data includes sites sampled by both CRITFC and ODFW within the Chinook habitat extent, which encompasses 125 unique sites (n) and 259 visits. Data at each site were averaged across all years, 2011-2015, and then average values and standard deviations were summarized across the various spatial units. At the time of our analysis the some Minam sites were not through the quality control process and the metrics from those sites were not included in the summary statistics. Likewise, temperature data from the Minam sites were unavailable.

The habitat values within the three ICTRT populations show variations across the basins. In the physical habitat metrics, the Grande Ronde and Minam Creeks displayed the greatest differences from one another. The Grande Ronde sites had the highest count of LWD and the highest percent slow water habitat. It also had the shallowest residual pool depth. The Minam was the opposite, sites had the deepest residual pool depth, the least LWD, and the least amount of slow water habitat. The only variable where the Catherine Creek values did not fall in between the Grande Ronde and Minam was the percent fine sediment, which was significantly higher in Catherine Creek than the other two populations. The average August temperature metric showed the Grande Ronde sites had slightly higher values but were overall similar to those observed across the Catherine Creek. However, a greater difference is seen in the maximum 7-day rolling average of the maximum, the Grande Ronde was over 1.5˚C higher the Max7dAM measured in Catherine Creek.

The six valley setting classes showed some metrics where the mean values were separated most notably by the mountain and floodplain/constrained channel characteristic, such as LWD frequency and percent slow water. The three mountain channel types displayed a greater range of metric values, while the three floodplain/constrained channel types metric values were similar, with the exception of except percent fines. The FCLU had very high average percent fines paired with a very large standard deviation and low number of sites for the same metric; this extreme value is likely driven by a few outlier sites with very high fine sediment accumulations. The MC valley setting had the lowest values for both temperature metrics and residual pool depth and the highest LWD frequency by a large margin. These valley types are found most common in the higher elevation headwaters. In contrast, the FCPC and FCLU had the highest temperature values and the lowest LWD frequency. These river types are most common in the mainstem sections of Catherine Creek and the Grande Ronde River. Additionally, within the broad channel classifications of mountain and floodplain/constrained there were trends among the three subcategories. Both temperature metrics trending upwards as the degree of confinement decreased. Alternatively, LWD frequency increased with the degree of confinement.

The summary data presented by BSR demonstrate how variable the number of survey locations can be within different BSRs. There are 21 BSRs that have sites within the three watersheds. The greatest number of survey sites found within a single BSR is 22 in the UGR13 BSR, the Meadow Creek drainage. Conversely, there are three BSRs within the upper Grande Ronde that have only a single survey site, UGR1-Lookingglass Creek, UGR10-Five Points Creek, and UGR18-Limber Jim Creek. Over half of the BSRs have five or fewer sites. This uneven distribution of sites within different BSRs supports the potential use of the valley setting classification in future summarization and extrapolation of metrics. The valley setting classification demonstrates a more evenly spaced sampling effort when compared to the BSRs. The least sampled valley setting classification is the floodplain/constrained laterally unconfined (FCLU, n=9) and the most heavily sampled type was the floodplain/constrained partly confined (FCPC, n=46).

The finer spatial resolution of the BSRs highlight particular sections of the two subbasins where extreme temperatures are detrimental to Chinook Salmon. Five of the 6 Catherine Creek BSRs exceed the ODEQ beneficial use threshold for juvenile salmonid rearing of 18˚C 7dAM for a minimum of one 7-day period, based on the Max7dAM. Additionally, 3 BSRs exceeded the 20˚C threshold set for migration corridors for adult salmon for a minimum of a 7-day period. In the Grande Ronde subbasin 8 of the 11 BSRs exceeded the juvenile rearing threshold and 7 exceeded the adult migration 7dAM temperature. By breaking the subbasins down into smaller spatial extents we can identify areas of particular risk to Chinook Salmon and focus restoration efforts within particular reaches.

Using GRTS weights and site based inter-annual slopes estimates, we conducted a trend analysis for the five year period of study based for each metric at the three different spatial extents. Only sites that had repeat surveys were used in this analysis. These trends likely have a lot of year to year variability but offer an interesting initial look at the past five years of surveying. These trends will become more established as the study design continues and more sites have numerous repeat visits.

Overall, many trends at the different extents were found to be nonsignificant ($\alpha < 0.05$) (Table 5). At almost every spatial extent percent fines and percent slow water had no significant trends. At a population level, significant trends were only observed in LWD frequency within the Minam River and Catherine Creek populations and in residual pool depth in the Minam River. In both populations LWD frequency had negative trends, the trend in the Minam was steeper than that of Catherine Creek. The residual pool depth trend was also negative.

At the BSRs extent, LWD frequency showed change over time, with eight of the thirteen BSRs demonstrating significant trends. Most of trends were negative, with the exception of two BSRs in the upper Grande Ronde, Spring Creek and Sheep Creek drainages (BSR12 and BSR19). There were four BSRs that had negative trends in residual pool depth. Both temperature metrics had eight BSRs, four of which were the same, that demonstrated trends. Most trends were positive, however CC3A (Catherine Creek drainage around the city of Union) and UGR16 (Fly Creek) saw negative trends in one or both temperature metrics.

The two confined valley setting classifications, MC and FCC, along with the MLU had the most change over time with in valley setting classes. Both MC and MLU showed trends in LWD frequency and both temperature metrics, however the direction of change was the opposite; LWD in MC showed a large negative trend and the temperature trend was positive. The trend for LWD in MLU was positive, while both temperature metrics were negative. FCC also saw negative trends in LWD frequency along with a small but negative trend in percent pool fines and a positive trend in percent slow water. FCLU was the most stable valley setting, or at least change was undetected, and had no significant trends in any of the metrics. Both the partly confined valley settings, MPC and FCPC, showed change in residual pool depth but in opposite directions.

In future modeling efforts we plan to use GRTS to summarize data by valley setting classes and then use distinct river segments in each BSR to roll-up metrics based on the proportion of each class in a BSR. This will allow us to downscale our GRTS estimates from the whole watershed scale to a finer resolution (e.g., BSR) while leveraging knowledge of habitat data in specific river types. The continued exploration of the trends across spatial extents will further our understanding of how habitat metrics are changing within drainages and valley setting. We hope to explore how this method may improve our estimates and extrapolation of habitat variables and fish populations.

Table 4. Summary statistics for six habitat variables measured at all CHaMP sites across the Upper Grande Ronde River, Catherine Creek, and the Minam River. Values for each site were averaged over all survey years, 2011-2015 and then summarized based on three different spatial extents: Interior Columbia Technical Recovery Team (ICTRT) populations, valley confinement classification, and biologically significant reaches (BSR). For each habitat variable, mean, standard deviation (SD), and the number of sites that had data values (n) are recorded. BSR UGR1, UGR2, and UGR6 are outside CRITFCs research area but within the Chinook extent.

Spatial Extent	% Fines <2 mm			LWD Frequency (count/100 m)			% Slow Water			Residual Pool Depth (m)			Average August Temperature (˚C)			Max7dAM (˚C)		
ICTRT Populations	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*
Catherine Creek	21.69	33.50	42	9.57	10.72	41	21.49	14.21	41	0.31	0.18	41	14.14	2.51	29	18.38	3.07	29
Minam River	6.86	5.49	14	6.96	7.61	15	19.88	17.05	15	0.41	0.24	14	NA	NA	0	NA	NA	0
Upper Grande Ronde River	10.52	9.65	60	16.52	18.27	58	27.58	15.68	58	0.29	0.13	58	14.60	1.96	41	19.91	3.48	41
Biologically Significant Reach	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*
CC2A	38.00	47.44	2	1.67	1.38	2	23.32	19.27	2	0.17	0.14	2	18.97	NA	1	22.28	NA	1
CC3A	15.99	9.70	4	8.91	8.26	4	30.76	8.83	4	0.53	0.23	4	17.48	0.52	4	21.90	0.53	4
CC3B1	5.80	4.22	9	10.44	11.15	9	19.56	9.28	9	0.49	0.12	9	17.01	0.62	5	22.15	0.30	5
CC3B2	6.15	4.36	7	12.68	3.66	6	21.79	13.10	6	0.41	0.06	6	14.52	0.71	7	19.19	1.00	7
CC4	40.45	23.70	3	22.26	7.43	3	28.33	6.13	3	0.19	0.08	3	14.60	0.44	2	18.52	0.48	2
CC5	10.71	6.54	17	16.14	12.55	17	16.65	7.39	17	0.33	0.08	17	11.56	0.90	12	15.18	1.19	12
MRC2	1.50	13.86	1	0.78	0	1	NA	NA	0	NA	NA	0	NA	NA	0	NA	NA	0
MRC3	8.54	4.60	7	6.47	7.34	8	21.86	15.86	8	0.39	0.25	8	NA	NA	0	NA	NA	0
MRC4	5.80	7.20	6	13.13	6.94	6	26.27	17.62	6	0.49	0.15	6	NA	NA	0	NA	NA	0
UGR1	4.30	NA	1	6.50	NA	1	10.24	NA	1	0.29	NA	1	NA	NA	0	NA	NA	0
UGR2	1.45	0.22	3	5.73	5.04	3	23.55	0.54	3	0.38	0.10	3	13.54	NA	1	17.85	NA	1
UGR6	4.23	2.50	3	11.69	8.97	3	20.23	11.37	3	0.31	0.02	3	16.54	0.18	2	21.20	0.78	2
UGR10	2.39	NA	1	0.85	NA	1	20.83	NA	1	0.25	NA	1	16.67	NA	1	23.51	NA	1
UGR11	5.40	1.91	5	0.34	0.26	5	15.60	13.92	5	0.40	0.10	5	19.85	0.73	4	27.41	0.56	4
UGR12	6.54	1.87	5	6.73	5.16	5	14.45	4.45	5	0.27	0.09	5	16.40	0.58	2	22.74	0.22	2
UGR13	9.43	7.81	22	19.02	18.06	22	29.19	13.09	22	0.25	0.13	22	14.16	1.56	11	19.08	3.11	11
UGR15	9.91	8.77	9	6.56	3.18	7	20.43	7.69	7	0.44	0.15	7	17.31	0.42	7	24.27	1.3	7
UGR16	7.32	4.72	3	5.08	1.88	3	16.77	1.32	3	0.32	0.03	3	17.08	0.81	2	24.70	1.13	2
UGR18	10.50	NA	1	38.45	NA	1	56.13	NA	1	0.35	NA	1	11.87	NA	1	16.14	NA	1

UGR19	20.94	17.69	8	18.93	9.19	8	45.79	18.86	8	0.25	0.08	8	13.88	1.01	7	20.09	1.93	7
UGR20	17.71	6.71	6	40.90	28.51	6	29.98	15.73	6	0.34	0.13	6	12.84	0.64	6	17.66	1.04	6
Valley Setting Classification	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*
FCC	4.94	4.44	27	7.50	8.18	28	15.19	10.90	28	0.34	0.18	27	15.21	2.45	12	20.49	3.70	12
FCPC	7.41	7.08	46	7.30	15.58	44	21.87	13.54	44	0.37	0.15	44	16.78	1.51	25	23.19	2.49	25
FCLU	52.83	43.08	9	6.15	9.91	8	23.74	24.48	8	0.32	0.29	8	16.79	0.95	7	23.13	1.68	7
MC	9.26	6.22	15	26.90	16.77	15	28.59	8.31	15	0.21	0.08	15	13.45	0.95	12	17.68	1.51	12
MPC	7.76	11.10	12	14.08	9.24	12	22.73	9.64	12	0.32	0.11	12	14.78	1.65	8	19.03	1.64	8
MLU	9.81	12.84	14	9.85	10.84	14	37.65	18.45	14	0.31	0.09	14	15.83	1.57	9	22.89	2.68	9

Table 5: Trend statistics for six habitat variables measured at all CHaMP sites across the Upper Grande Ronde River, Catherine Creek, and the Minam River. Site-based slope estimates were derived from all available visits, 2011-2015 and then summarized based on three different spatial extents: Interior Columbia Technical Recovery Team (ICTRT) populations, valley confinement classification, and biologically significant reaches (BSR). Sites with inadequate numbers of visits were not analyzed. For each habitat variable whether the trend was significant (α < 0.05) was noted and if that was "True" the slope is recorded.

Spatial Extents	% Fines <2 mm		LWD Frequency (count/100 m)		% Slow Water		Residual Pool Depth (m)		Average August Temperature (˚C)		Max7dAM (˚C)	
ICTRT Populations	*Significant*	*Trend*	*Significant*	*Trend*	*Significant*	*Trend*	*Significant*	*Trend*	*Significant*	*Trend*	*Significant*	*Trend*
Catherine Creek	False	NA	**True**	-0.84	False	NA	False	NA	False	NA	False	NA
Minam River	False	NA	**True**	-1.98	False	NA	**True**	-0.021	NA	NA	NA	NA
Upper Grande Ronde River	False	NA	False	NA	False	NA	False	NA	False	NA	False	NA
Biologically Significant Reach	*Significant*	*Trend*	*Significant*	*Trend*	*Significant*	*Trend*	*Significant*	*Trend*	*Significant*	*Trend*	*Significant*	*Trend*
CC3A	False	NA	False	NA	False	NA	**True**	-0.038	**True**	-1.093	**True**	-1.039
CC3B1	False	NA	**True**	-1.649	False	NA	False	NA	False	NA	False	NA
CC3B2	False	NA	False	NA	False	NA	**True**	-0.036	False	NA	**True**	0.546
CC5	False	NA	**True**	-2.692	**True**	1.435	False	NA	**True**	0.117	False	NA
MRC3	False	NA	**True**	-1.203	False	NA	**True**	-0.012	NA	NA	NA	NA
MRC4	False	NA	**True**	-4.299	False	NA	False	NA	NA	NA	NA	NA
UGR11	False	NA	False	NA	False	NA	False	NA	False	NA	**True**	0.689

UGR12	False	NA	**True**	2.554	False	NA	False	NA	NA	NA	NA	NA
UGR13	False	NA	**True**	-5.184	False	NA	False	NA	False	NA	False	NA
UGR15	False	NA	**True**	-1.29	False	NA	False	NA	**True**	0.11	**True**	0.597
UGR16	False	NA	False	NA	False	NA	False	NA	**True**	-0.036	False	NA
UGR19	False	NA	**True**	1.835	False	NA	False	NA	**True**	0.093	**True**	0.336
UGR20	False	NA	False	NA	False	NA	**True**	-0.027	**True**	0.325	**True**	0.574
Valley Setting Classification	*Significant*	*Trend*	*Significant*	*Trend*	*Significant*	*Trend*	*Significant*	*Trend*	*Significant*	*Trend*	*Significant*	*Trend*
FCC	**True**	-1.447	**True**	-3.13	**True**	2.228	False	NA	False	NA	False	NA
FCPC	False	NA	False	NA	False	NA	**True**	-0.018	False	NA	**True**	0.36
FCLU	False	NA	False	NA	False	NA	False	NA	False	NA	False	NA
MC	False	NA	**True**	-7.701	False	NA	False	NA	**True**	0.271	**True**	0.299
MPC	False	NA	False	NA	False	NA	**True**	0.033	False	NA	False	NA
MLU	False	NA	**True**	3.628	False	NA	False	NA	**True**	-1.201	**True**	-1.085

With five years of temperature data we were able to expand our evaluation of trends at unique sites across the watershed. Contrasting temperatures at three sites and August stream discharge measurements on the mainstem Grande Ronde River starts to highlight patterns across the watershed (Table 6). The sites selected for this comparison were South Fork Catherine Creek at the mouth (a CRITFC temperature monitoring site), Sheep Creek (a headwater tributary of the Grande Ronde River), and the Grande Ronde River above Beaver Creek. This year's temperatures were fairly typical at all three sites when compared across years. However, 2015 was a low water year due to the lowest winter snowpack across the state in 35 years (NRCS 2015). This resulted in considerably lower stream flow than have been observed in the previous four year of the study. Discharge was measured by the U.S. Geological Survey (USGS) downstream of our study area on the mainstem Grande Ronde River near Troy, OR (Gage 13333000, U.S. Geological Survey 2016).

In 2015, the South Fork Catherine Creek site had the highest maximum temperature as well as the highest maximum 7-day running average of the maximum temperature observed over the past five years. Even with these slightly higher temperatures this site never exceeded the DEQ temperature threshold described for juvenile salmon and trout rearing streams of the 7-day running average maximum rising above 18˚C during the summer period. Average temperatures at this site were comparable to the past three years. In 2011, temperatures observed at this site, along with the other two site, were significantly lower than all other years; stream discharge recorded at the USGS gage shows that 2011 had much higher discharge than any of the following years.

In 2015, Sheep Creek never exceeded the 7dAM 18˚C threshold and overall had lower temperature than the previous three years. The Grande Ronde River site showed a similar pattern and had slightly lower average and Max7dAM temperatures than over the past three years. Overall however, this Grande Ronde site is representative of the lower section of the watershed where temperatures exceeded the 7dAM 18˚C threshold for the entire summer.

Even within the basin there is a degree of heterogeneity of temperature patterns with the Catherine Creek site responding slightly differently over the years than the two upper Grande Ronde sites. Overall within site variability was low with most metrics varying by less than 2˚C over the five-year period. The overall maximum and the maximum 7-day running average maximum at the Grande Ronde River site varied the greatest amount, approximately 2.5˚C. The combination of CHaMP and CRITFC temperature sites provide a wide distribution of monitoring locations across the basin while targeting dynamic locations such as tributary junctions. These sites will continue to be useful in our attempts to extrapolate temperature predications across the watershed.

Table 6. Annual comparison of temperature metrics (˚C) in three streams across the upper Grande Ronde basin—South Fork Catherine Creek at its mouth, Sheep Creek (a tributary to the Grande Ronde), and the Grande Ronde River. Daily metrics included were average and maximum (Max) stream temperatures. Seven day rolling average maximum weekly temperatures (7dAM) were calculated and the highest 7dAM were reported (Max7dAM) as well as the number of 7dAM periods that exceed specific thresholds (12, 13, 16, 18, 20, 22˚C). There were 42 7-day periods over the reported timeframe. August discharge was recorded from the nearest USGS gage 13333000 Grande Ronde River at Troy, OR.

South Fork Catherine Creek Mouth	Average	Max	Max7dAM	12˚C	13˚C	16˚C	18˚C	20˚C	22˚C	August Discharge (ft^3/sec)
2011	11.75	16.15	15.51	40	34	0	0	0	0	1080
2012	13.38	18.34	17.23	42	40	29	0	0	0	566
2013	13.71	17.89	17.22	42	42	26	0	0	0	594
2014	13.44	18.36	17.22	42	42	21	0	0	0	779
2015	13.39	18.87	17.42	42	42	25	0	0	0	407
Sheep Creek (CBW05583-22866)	Average	Max	Max7dAM	12˚C	13˚C	16˚C	18˚C	20˚C	22˚C	August Discharge (ft^3/sec)
2011	11.93	17.32	16.72	42	42	10	0	0	0	1080
2012	13.11	18.86	17.96	42	42	34	0	0	0	566
2013	13.38	18.98	18.69	42	42	35	9	0	0	594
2014	13.32	19.39	18.39	42	42	27	6	0	0	779
2015	12.67	18.99	17.75	42	42	30	0	0	0	407
Grande Ronde River above Beaver Creek (dsgn4-000245)	Average	Max	Max7dAM	12˚C	13˚C	16˚C	18˚C	20˚C	22˚C	August Discharge (ft^3/sec)
2011	17.98	26.11	25.04	42	42	42	42	41	37	1080
2012	19.17	27.41	26.5	42	42	42	42	42	39	566
2013	19.48	27.97	27.57	42	42	42	42	42	42	594
2014	19.34	28.54	26.85	42	42	42	42	42	38	779
2015	18.66	28.05	26.46	42	42	42	42	42	39	407

Subsurface Fine Sediments

Subsurface fine sediment levels measured at all 42 sites surveyed with McNeil cores from 2010-2013 were generally low to moderate with the Upper Grande Ronde River basin having the highest percentage of fines among the three basins surveyed. The average percentage of fine sediment < 6.3 mm per site in the Grande Ronde River mainstem across years 2010-2013 ranged from 24.43% to 44.38%, whereas sampling in Catherine Creek mainstem revealed an average of 25.20% and a range from 7.36% to 35.58% (Table 7). The sample with the low value of 7.36% fines < 6.3 mm was taken at CHaMP site CBW05583-430250, which was immediately above the outfall of the City of Union sewage outfall. The substrate was well-rounded, natural streambed material, but may have been placed into the stream artificially. The next higher percentage fines < 6.3 mm in Catherine Creek mainstem was 12.55% at CBW05583-340138 (the upstream of two sites on the Ricker property).

If all average annual McNeil core values (each being an average of 9 randomly collected samples from pool tails) collected between 2010 and 2013 are tabulated, the range in values for Catherine Creek mainstem was 7.36 to 35.58% (mean = 25.95%, n=15), Minam River was 22.31 to 41.64% (mean = 28.59%, n = 9), and the mainstem Grande Ronde was 21.48 to 44.38% (mean = 32.50%, n = 15). An ANOVA run on these three groups having an appreciable number of samples revealed a significant (P = 0.034) difference among the three groups. To then investigate where the significant difference in means lay, a Tukey HSD comparison of means was conducted. Among the three groups (CC, MN, and GR), there was a significant q-statistic only for the GR vs. CC contrast (q-stat of 3.83 vs. q-crit of 3.46) on the basis of fines particle percentages less than 6.3 mm.

Percentages of particles less than 6.3 mm and 0.83 mm derived from average values for all stream sites within various major streams are displayed in Figure 10 and Figure 11. Error bars show the 95% confidence limits. Data for the Grande Ronde mainstem is based on 9 sites having 15 samples total (each a composite of results from 9 McNeil cores) taken between 2010 and 2013, while Catherine Creek mainstem was based on 12 sites and a total of 15 samples. The only other streams with sufficient numbers of samples to permit calculation of confidence limits were Meadow Creek (4 sites with 5 samples), Sheep Creek (3 sites), Minam River (3 sites), and Little Minam (3 sites). Because some sites had samples collected in 2, 3, or 4 years (e.g., the Grande Ronde mainstem had a total of 9 sites, and had samples collected in a single year between 2010 and 2013, except for one site with a sample in 4 different years, one with samples in 3 years, and one with samples in 2 years.)

A few CHaMP sites had multiple years in which McNeil samples were taken. In the Upper Grande Ronde, sites dsgn4-000009 had samples for 2010-2013, dsgn4-000202 had samples in 2010-2012, and dsgn4-000205 had samples in 2010-2011. For Catherine Creek, site dsgn4-000010 had samples in 2010-2011, and CBW05583-405674 had samples in 2012-2013. Meadow Creek (site dsgn4-000213) had samples in 2012-2013. These samples provide an ability to plot trends over time in the various fines particle sizes. Trends in fines of diameter less than 0.83 mm (Figure 12), less than 2.0 mm (Figure 13), and less than 6.3 mm (Figure 14) reveal that McNeil fines at any site are relatively stable with time. In addition, if the three sites having three years of McNeil cores each (dsgn4-000009, dsgn4-000010, and dsgn4-000202) are compared, it is clear that, with respect to all three fines particle sizes, the percentages fines from

these sites follow very similar patterns that are distinct. Fines concentrations in the GR site dsgn4-000009 are consistently higher than those in the CC site (dsgn4-000010). The patterns expressed in each particle size are the same. Likewise, the GR site dsgn4-000202 is intermediate between the other two and for the 2012 sample, the values for each fines particle size class match that of the other GR site in 2012. A regression of fines < 0.83 mm for all sites shown in Figure 12 against time reveals no significant trend ($P = 0.079$). A trend expressed across the GR and CC would potentially indicate the influence of widespread storm or snowmelt events that increase the amount of fines incorporated into substrate to a depth of at least 20 cm. On the basis of the limited sampling that has been done, it is difficult to project a significant trend, but McNeil fines appear to be a much more stable, biologically significant index of habitat condition than surface fines measures, which revealed only minimal relationships with benthic macroinvertebrates.

Focusing only on the McNeil fines (< 6.3 mm and < 0.83 mm) from GR site dsgn4-000009 for years 2011-2013 (years that match CHaMP surveys in which surface fines were measured, the trend in McNeil fines (subsurface) can be plotted against surface fines metrics (Figure 15 and Figure 16). McNeil fines less than 6.3 mm and less than 0.83 mm both followed similar trends in decreasing slightly between 2011 and 2012 and then increasing slightly in 2013. Pool tail fines less than 6 mm and less than 0.83 mm followed similar trends of increasing sharply from 2011 to 2012 and then changing only slightly to 2013. The sharp increase in pool tail fines between 2011 and 2012 was the opposite trend experienced in subsurface fines. Wolman pebble counts (d_{16} size) revealed a sharp decrease in size from 2011 to 2012, which indicates a significant decrease in surface particle size. This was followed by only a slight change to 2013, similar to the other measures. While the McNeil trends for both fines fractions mirror the changes in d_{16}, the trends in pool tail fines (< 2 mm and < 6 mm) do not. This may indicate that trends in surface particle fines concentrations do not reflect what is happening at depth.

Relationships between McNeil fines and other surface fines metrics from CHaMP should always be based on multiple sites. All McNeil samples from sites taken over the period from 2010 through 2013, where each sample was a value in a given year and site from averaging data from 9 separate cores, were compared to surface fines measures. McNeil fines (< 0.83 mm) regressed on pool tail fines (< 6 mm) revealed a highly significant trend ($P = 0.00031$), although the R^2 was somewhat low (0.3072) (Figure 17). McNeil fines (% < 0.83 mm) were also significantly related to percentage ocular sand and fines (Figure 18) ($P = 0.0038$), which is substrate material less than 2 mm diameter. McNeil fines (< 6.3 mm) were also regressed on pool tail fines (percentage < 6 mm). This regression was significant ($P = 0.0246$), although the R^2 was low (0.1326).

It is interesting that there is such a significant relationship between McNeil fines (% < 0.83 mm) and pool tail fines (% < 6 mm). Comparing McNeil fines (% < 6.3 mm) with pool tail fines (% < 6 mm) provides a more equal contrast. This regression also is significant ($P = 0.0246$) (Figure 19). Likewise, a regression of McNeil fines (% < 2 mm) was made against pool tail fines (% < 2 mm). This regression was significant ($P = 0.007$) (Figure 20). There was also a significant relationship between McNeil fines (% < 2.0 mm) and pool tail fines (% < 6 mm) ($P = 0.0007$) (Figure 21).

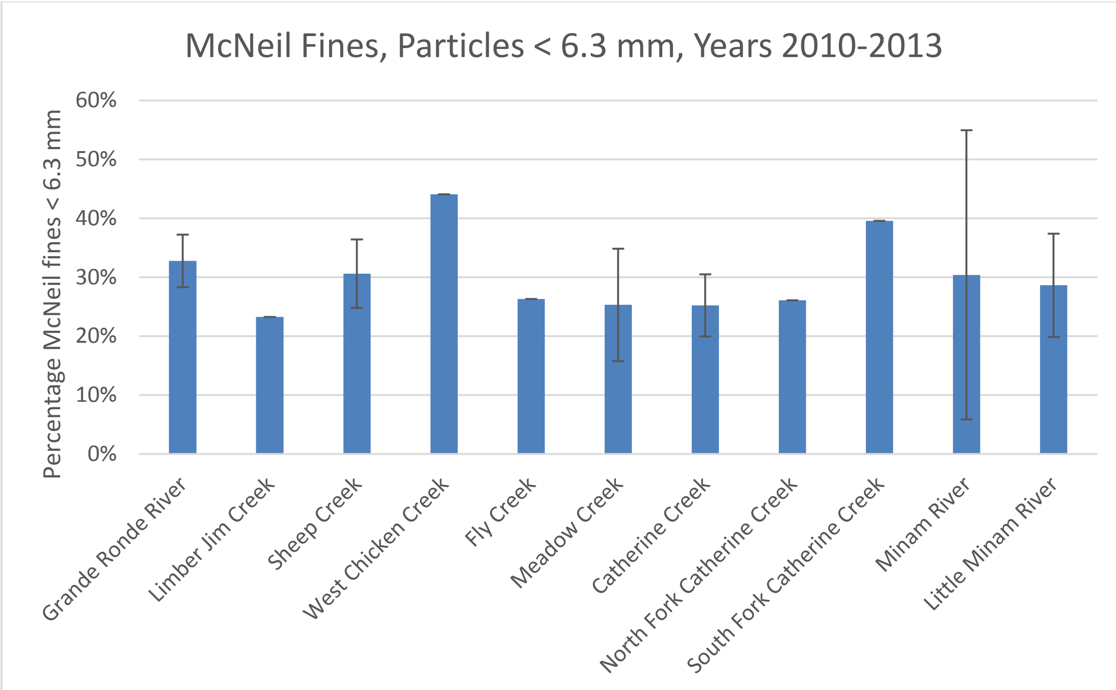


Figure 10. Mean and 95% confidence limits of percentage McNeil fine sediment (< 6.3 mm) found in sample sites from 2010 through 2013 in the mainstem and tributaries of the three major study basins (Upper Grande Ronde, Catherine Creek, and the Minam River).

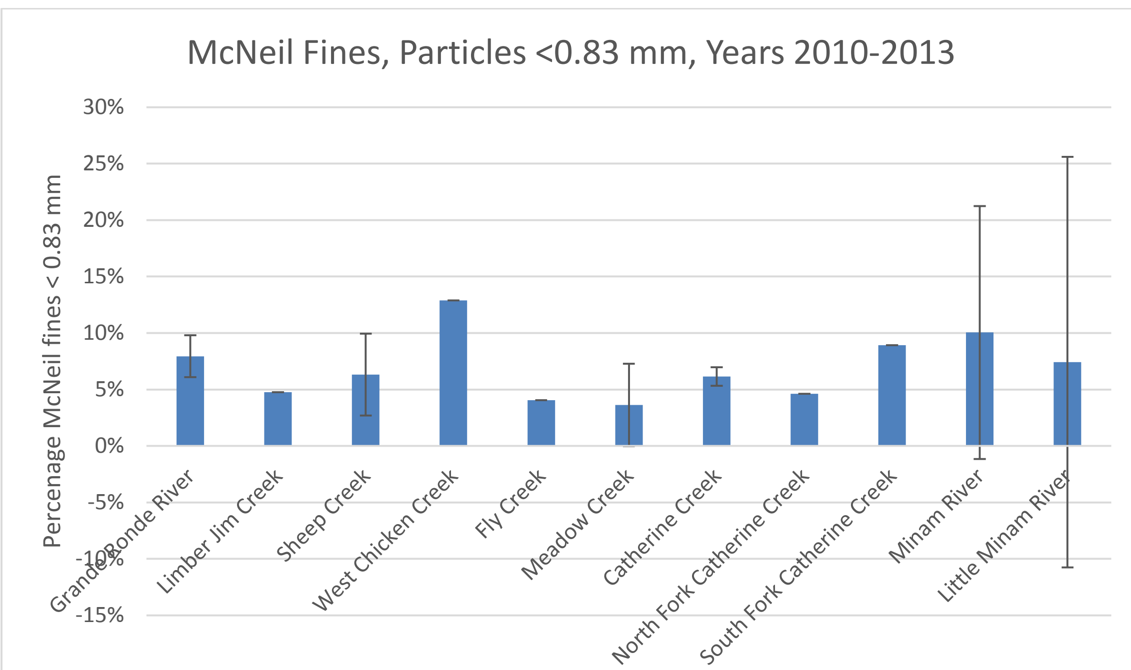
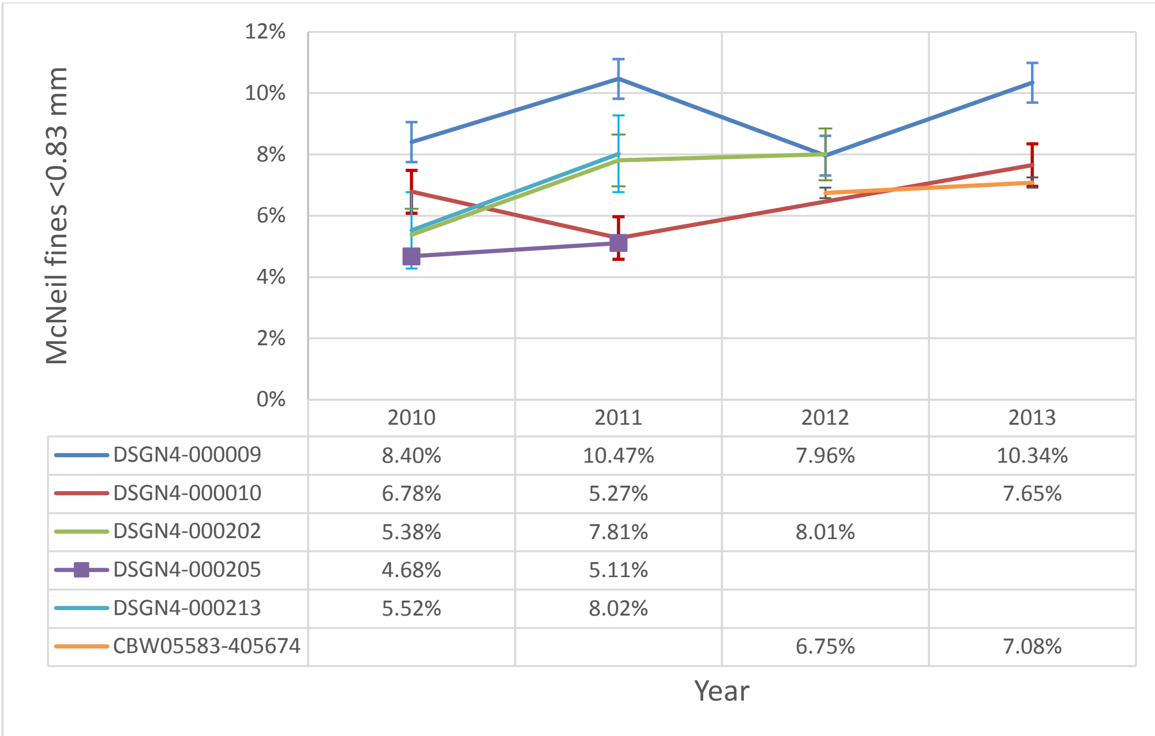
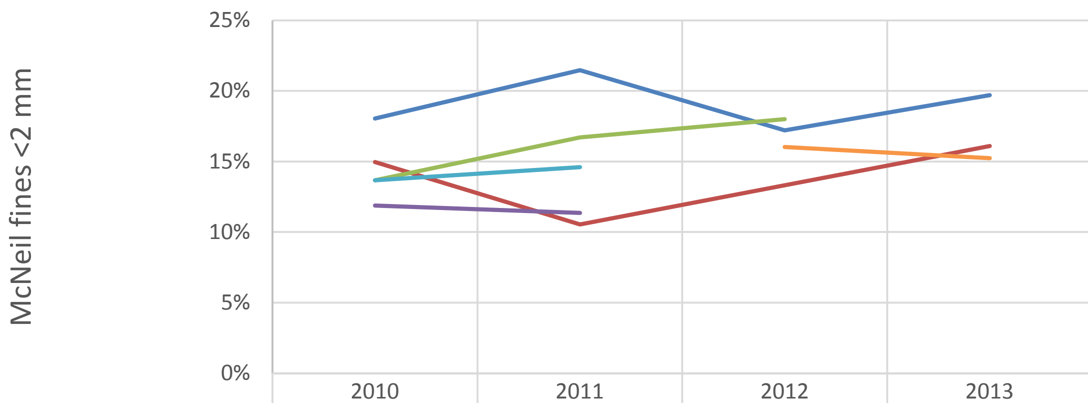


Figure 11. Mean and 95% confidence limits of percentage McNeil fine sediment (< 0.83 mm) found in sample sites from 2010 through 2013 in the mainstem and tributaries of the three major study basins (Upper Grande Ronde, Catherine Creek, and the Minam River).



	2010	2011	2012	2013
DSGN4-000009	8.40%	10.47%	7.96%	10.34%
DSGN4-000010	6.78%	5.27%		7.65%
DSGN4-000202	5.38%	7.81%	8.01%	
DSGN4-000205	4.68%	5.11%		
DSGN4-000213	5.52%	8.02%		
CBW05583-405674			6.75%	7.08%

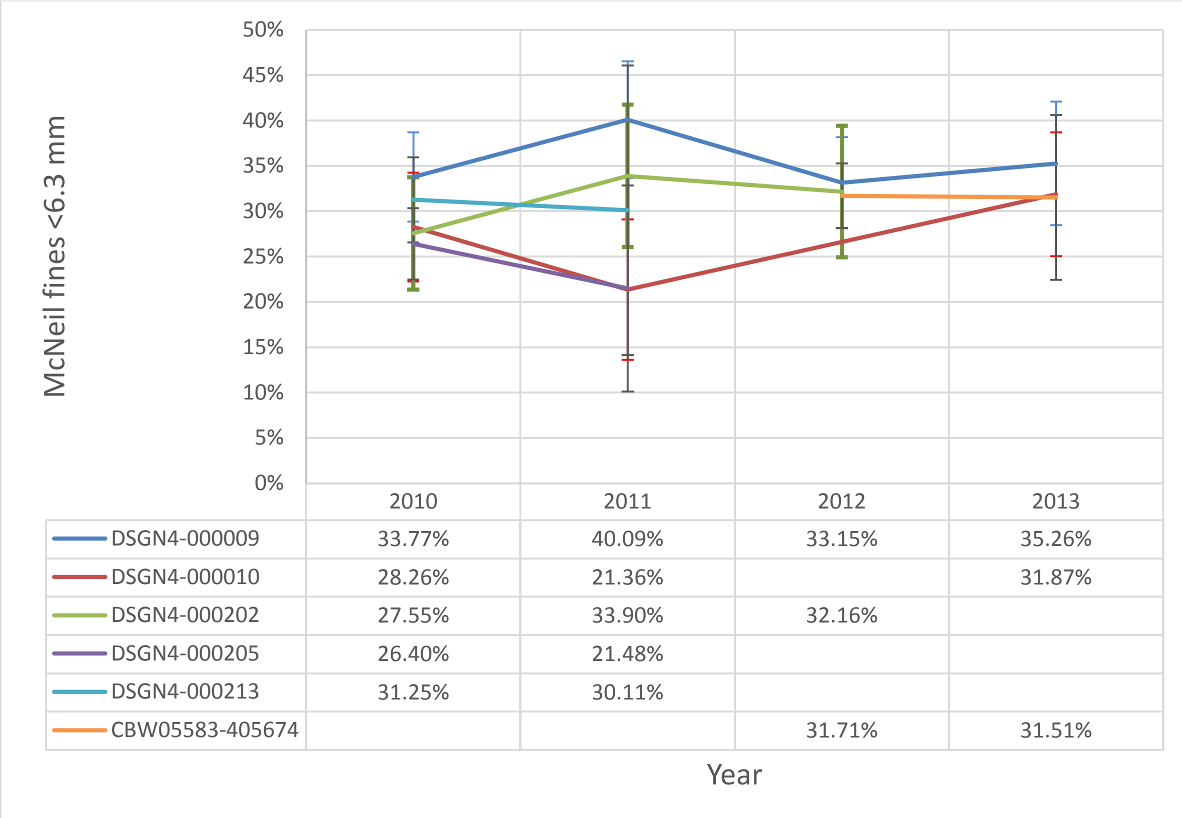
Figure 12. Trends in McNeil core percentage fines (component that is < 0.83 mm diameter) taken in six CHaMP sites from 2010 to 2013. Sites DSGN4- (000009, 000202, and 000205) are in the Grande Ronde River mainstem, DSGN4-000213 is in Meadow Creek, and sites DSGN4-000010 and CBW05583-405674 are in the Catherine Creek mainstem. Values are the annual mean for each site derived from 9 cores processed independently. Error bars represent the 95% confidence limits for the 9 cores taken annually at each site.



	2010	2011	2012	2013
DSGN4-000009	18.04%	21.47%	17.21%	19.70%
DSGN4-000010	14.96%	10.53%		16.08%
DSGN4-000202	13.66%	16.70%	18.00%	
DSGN4-000205	11.89%	11.36%		
DSGN4-000213	13.67%	14.60%		
CBW05583-405674			16.03%	15.23%

Year

Figure 13. Trends in McNeil core percentage fines (component that is < 2 mm diameter) taken in six CHaMP sites from 2010 to 2013. Sites DSGN4- (000009, 000202, and 000205) are in the Grande Ronde River mainstem, DSGN4-000213 is in Meadow Creek, and sites DSGN4-000010 and CBW05583-405674 are in the Catherine Creek mainstem. Values are the annual mean for each site derived from 9 cores processed independently. Error bars represent the 95% confidence limits for the 9 cores taken annually at each site.



	2010	2011	2012	2013
DSGN4-000009	33.77%	40.09%	33.15%	35.26%
DSGN4-000010	28.26%	21.36%		31.87%
DSGN4-000202	27.55%	33.90%	32.16%	
DSGN4-000205	26.40%	21.48%		
DSGN4-000213	31.25%	30.11%		
CBW05583-405674			31.71%	31.51%

Figure 14. Trends in McNeil core percentage fines (component that is < 6.3 mm diameter) taken in six CHaMP sites from 2010 to 2013. Sites DSGN4- (000009, 000202, and 000205) are in the Grande Ronde River mainstem, DSGN4-000213 is in Meadow Creek, and sites DSGN4-000010 and CBW05583-405674 are in the Catherine Creek mainstem. Values are the annual mean for each site derived from 9 cores processed independently. Error bars represent the 95% confidence limits for the 9 cores taken annually at each site.

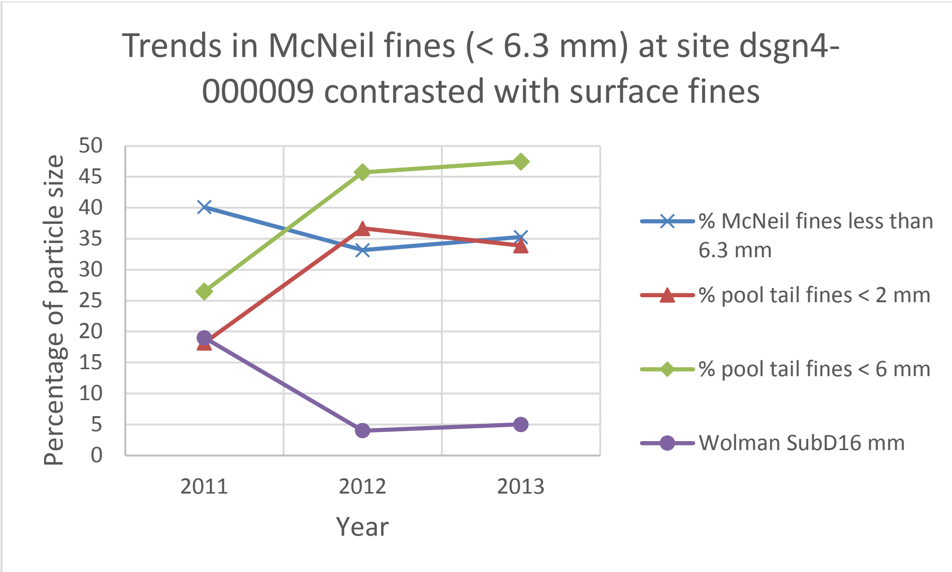


Figure 15. Trends in average annual percentage McNeil fines (< 6.3 mm diameter) at site dsgn4-000009 (Grande Ronde River CHaMP mainstem site) from years 2011-2013 contrasted with selected site-level CHaMP fine sediment metrics for the same site.

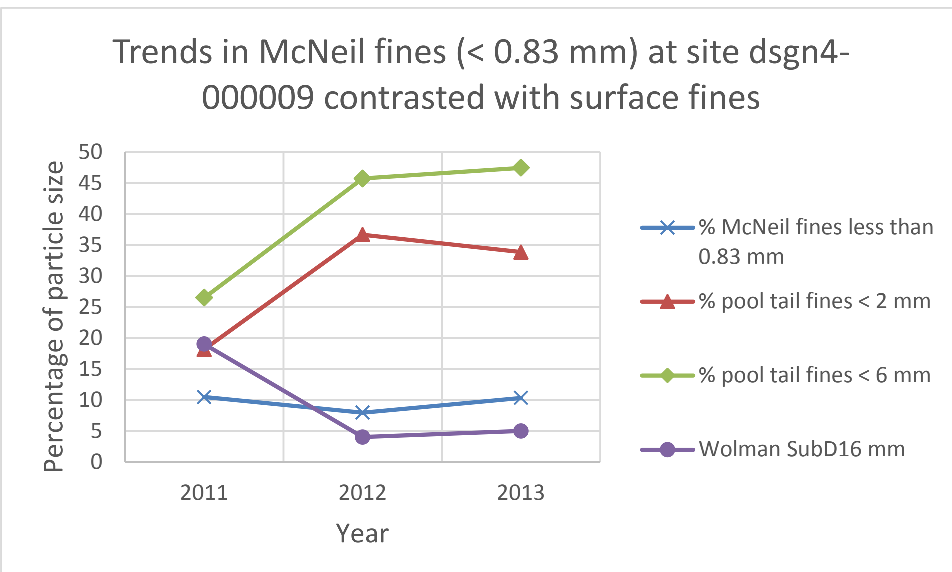


Figure 16. Trends in average annual percentage McNeil fines (< 0.83 mm diameter) at site dsgn4-000009 (Grande Ronde River CHaMP mainstem site) from years 2011-2013 contrasted with selected site-level CHaMP fine sediment metrics for the same site.

Table 7. Statistics on percentage McNeil core samples by stream where each annual value was derived from averaging 9 randomly collected core samples per site. Catherine Creek and Catherine Creek samples represented the mainstem areas. Statistics are based on those samples collected in selected sites per stream between 2010 and 2013 (multi-year averages were calculated for any site with samples in more than one year).

Stream name	Average of percentage fines by particle size class		
	<6.3 mm	<2 mm	<0.85 mm
Grande Ronde River	32.8%	16.7%	7.9%
Limber Jim Creek	23.3%	10.4%	4.8%
Sheep Creek	30.6%	13.5%	6.3%
West Chicken Creek	44.1%	23.4%	12.9%
Fly Creek	26.3%	8.9%	4.0%
Meadow Creek	25.3%	9.0%	3.6%
Catherine Creek	25.2%	13.1%	6.1%
North Fork Catherine Creek	26.1%	10.9%	4.6%
South Fork Catherine Creek	39.6%	19.0%	8.9%
Minam River	30.4%	16.7%	10.0%
Little Minam River	28.6%	12.4%	7.4%
	StdDev (N) by particle size		
Grande Ronde River	5.8% (9)	3.4% (9)	2.4% (9)
Limber Jim Creek	(1)	(1)	(1)
Sheep Creek	2.3% (3)	2.7% (3)	1.5% (3)
West Chicken Creek	(1)	(1)	(1)
Fly Creek	(1)	(1)	(1)
Meadow Creek	6.0% (4)	3.6% (4)	2.3% (4)
Catherine Creek	8.3% (12)	3.7% (12)	1.3% (12)
North Fork Catherine Creek	(1)	(1)	(1)
South Fork Catherine Creek	(1)	(1)	(1)
Minam River	9.9% (3)	6.8% (3)	4.5% (3)
Little Minam River	3.5% (3)	4.9% (3)	7.3% (3)

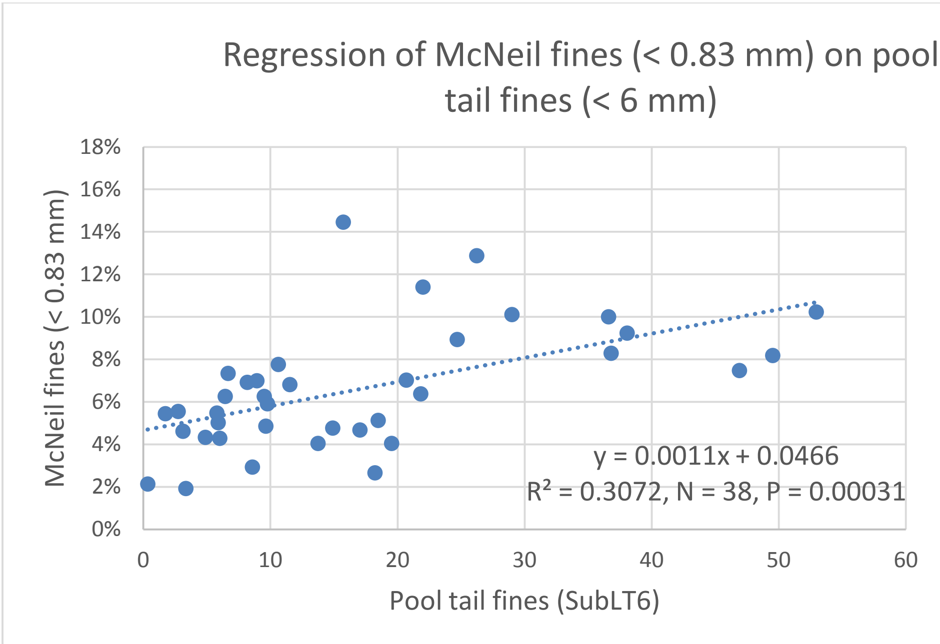


Figure 17. Regression of percentage McNeil core fine sediment concentrations (particles < 0.83 mm diameter) vs. CHaMP-derived pool tail fines data (< 6 mm diameter) taken at the same sites. McNeil fines values per sample site were the average of all annual values available, including samples from 2010-2013; pool tail fines (SubLT6) values were the average values per site for all CHaMP-derived data from 2011-2014, which could represent annual site-level data for annual panel sites, two values per site for rotating panel sites (2011 and 2014, or single annual values for other rotating panel sites (2012, and 2013).

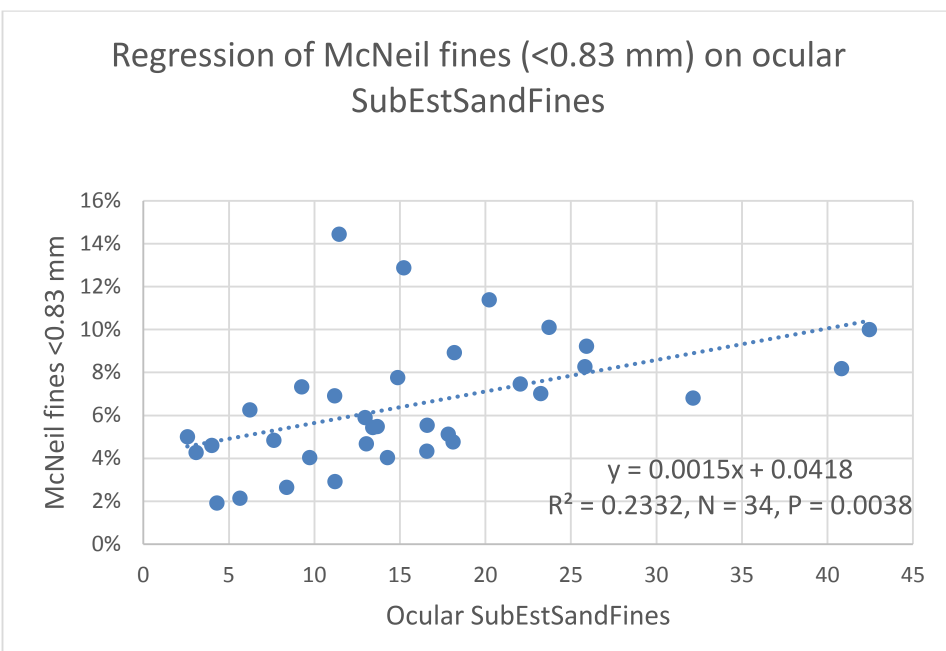


Figure 18. Regression of percentage McNeil core fine sediment concentrations (particles < 0.83 mm diameter) vs. CHaMP-derived ocular SubEstSandFines data taken at the same sites. McNeil fines values per sample site

were the average of all annual values available, including samples from 2010-2013; ocular SubEstSandFines values were the average values per site for all CHaMP-derived data from 2011-2014, which could represent annual site-level data for annual panel sites, two values per site for rotating panel sites (2011 and 2014, or single annual values for other rotating panel sites (2012, and 2013).

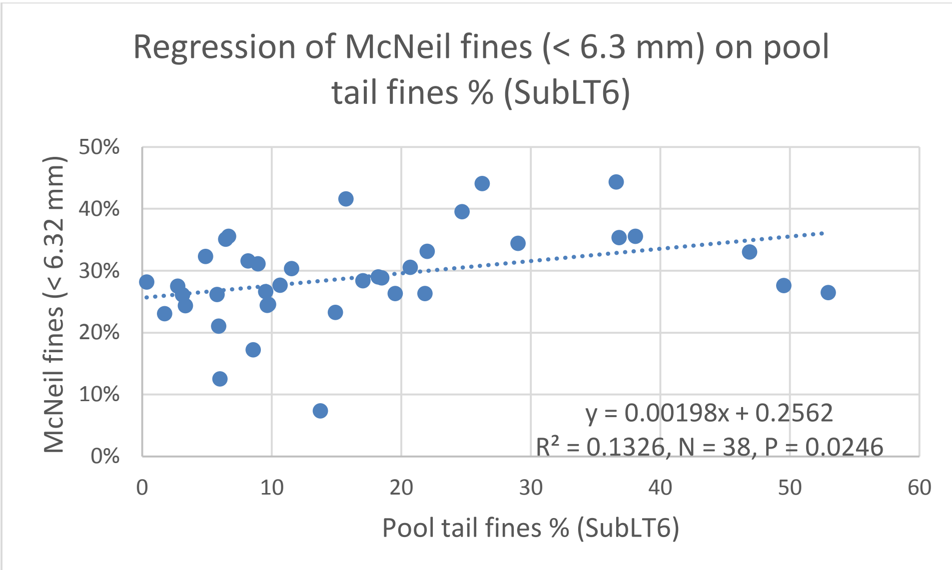


Figure 19. Regression of percentage McNeil core fine sediment concentrations (particles < 6.3 mm diameter) vs. CHaMP-derived pool tail fines data (< 6 mm diameter) taken at the same sites. McNeil fines values per sample site were the average of all annual values available, including samples from 2010-2013; pool tail fines (SubLT6) values were the average values per site for all CHaMP-derived data from 2011-2014, which could represent annual site-level data for annual panel sites, two values per site for rotating panel sites (2011 and 2014, or single annual values for other rotating panel sites (2012, and 2013).

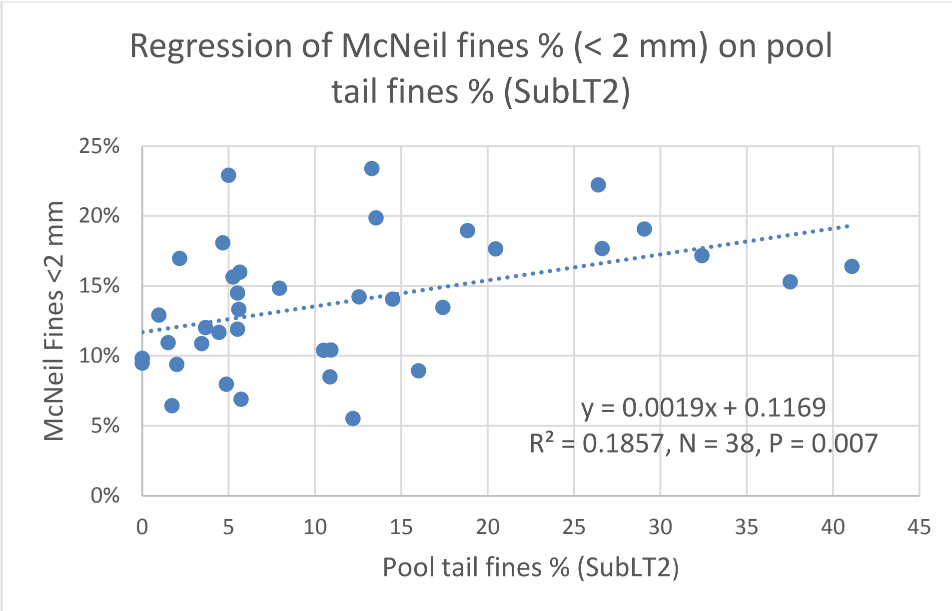


Figure 20. Regression of percentage McNeil core fine sediment concentrations (particles < 2 mm diameter) vs. CHaMP-derived pool tail fines data (< 2 mm diameter) taken at the same sites. McNeil fines values per sample site were the average of all annual values available, including samples from 2010-2013; pool tail fines (SubLT2) values were the average values per site for all CHaMP-derived data from 2011-2014, which could represent annual site-level data for annual panel sites, two values per site for rotating panel sites (2011 and 2014, or single annual values for other rotating panel sites (2012, and 2013).

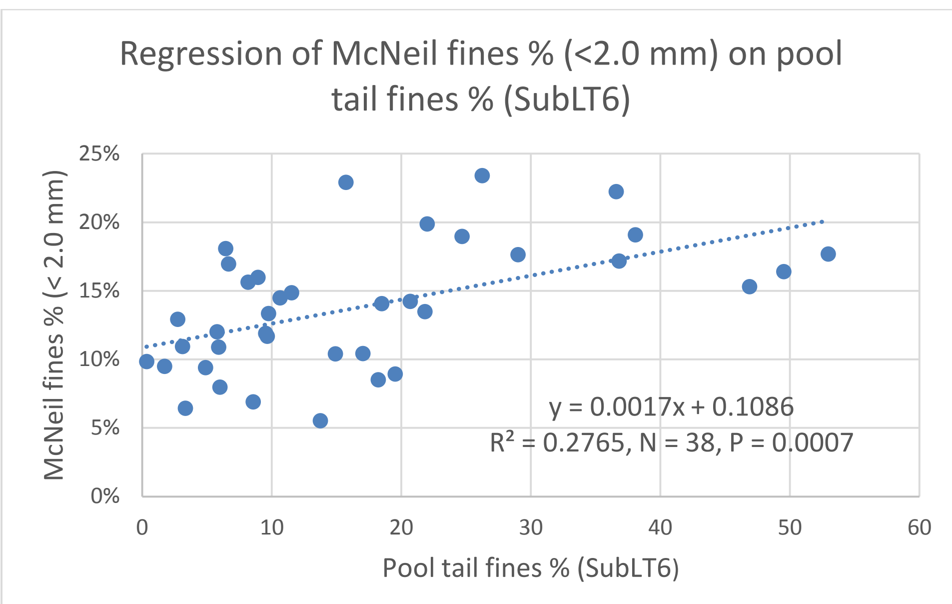


Figure 21. Regression of percentage McNeil core fine sediment concentrations (particles < 2 mm diameter) vs. CHaMP-derived pool tail fines data (< 6 mm diameter) taken at the same sites. McNeil fines values per sample site were the average of all annual values available, including samples from 2010-2013; pool tail fines (SubLT6) values were the average values per site for all CHaMP-derived data from 2011-2014, which could represent

annual site-level data for annual panel sites, two values per site for rotating panel sites (2011 and 2014, or single annual values for other rotating panel sites (2012, and 2013).

Watershed Grazing Intensity

A frequency distribution of AUM/ha shows a significant difference among watersheds in grazing intensity (Figure 21). The maximum AUM/ha was 0.313. Among the 128 CHaMP basins, there are a significant number that have grazing intensities of 0.24-0.28 AUM/ha, but many with grazing intensities lower than 0.08 AUM/ha.

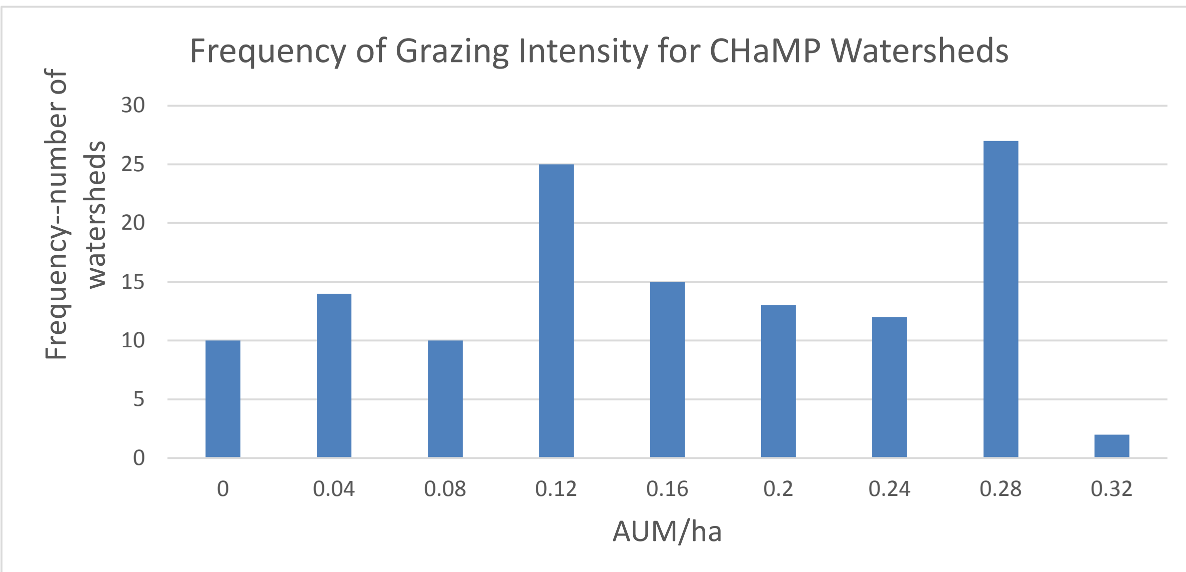


Figure 22. Frequency of grazing intensity for 128 CHaMP watersheds sampled in 2011-2014.

Average grazing intensities (AUM/ha) were calculated for each stream and for mainstem reaches of the Grande Ronde River, Catherine Creek, and the Minam River based on the watersheds contributing to all CHaMP sites within each stream and mainstem reach. The average grazing intensities were sorted by watershed and then by stream (Table 8).

For the Grande Ronde mainstem between elevations of 1422 and 1631, grazing intensities ranged from 0.069 and 0.187 AUM/ha. Above this elevational range, grazing intensities were very low (Figure 23). Catherine Creek had a very stable grazing intensity across all watersheds contributing to CHaMP sites (approx. 151 AUM/ha) between elevations of 1557 and 1632 m. However, at elevations on the mainstem above this range, grazing intensity declined significantly (Figure 24. In the North Fork Catherine Creek grazing intensities ranged from 0.088 to 0.151. On the South Fork, they ranged from 0.058 to 0.111.

On Meadow and McCoy Creeks, grazing intensity ranged from 0.256 to 0.268 AUM/ha. Spring Creek had grazing intensities ranging from 0.233 to 0.247. On Sheep Creek, these values ranged from 0.030 to 0.071. Note that the Sheep Creek intensities upstream of CHaMP sites were all above Vey Ranch, which is heavily grazed in lower Sheep Creek. Grazing intensities summed above CHaMP sites on the mainstem Grande Ronde below Vey Ranch include all private and public-land grazing in the entire watershed above those CHaMP sites.

Table 8. Average grazing intensity (AUM/ha) by stream averaged over all watersheds contributing to all CHaMP sites per stream. Catherine Creek, the Grande Ronde, and the Minam River signify simply the grazing intensities averaged for all watersheds contributing to the mainstem CHaMP sites for each of these streams. CHaMP sites considered were a total of 128 CHaMP watersheds surveyed by CRITFC and ODFW between 2011 and 2014.

Watershed	Stream name	Average of AUM/ha
CC	Catherine Creek	0.135
CC	Little Catherine Creek	0.209
CC	MF Catherine Creek	0.000
CC	Milk Creek	0.239
CC	NF Catherine Creek	0.110
CC	SF Catherine Creek	0.090
CC	WF Ladd	0.155
GR	Burnt Corral Creek	0.273
GR	California Gulch	0.208
GR	Chicken Creek	0.027
GR	Clark Creek	0.257
GR	Dark Canyon Creek	0.245
GR	E Phillips Creek	0.192
GR	Fly Creek	0.227
GR	Gordon Creek	0.220
GR	Grande Ronde River	0.086
GR	Limber Jim Creek	0.000
GR	Little Phillips Creek	0.209
GR	Little Whiskey	0.196
GR	McCoy Creek	0.266
GR	Meadow Creek	0.262
GR	Peet Creek	0.313
GR	Phillips Creek	0.191
GR	Rock Creek	0.197
GR	Sheep Creek	0.049
GR	Spring Creek	0.244
GR	Summer Creek	0.000
GR	W Chicken Creek	0.139
GR	Waucup Creek	0.260
GR	Willow Creek	0.092
IN	Little Indian Creek	0.254

LK	Lookingglass Creek	0.061
MN	Little Minam River	0.018
MN	Minam River	0.000

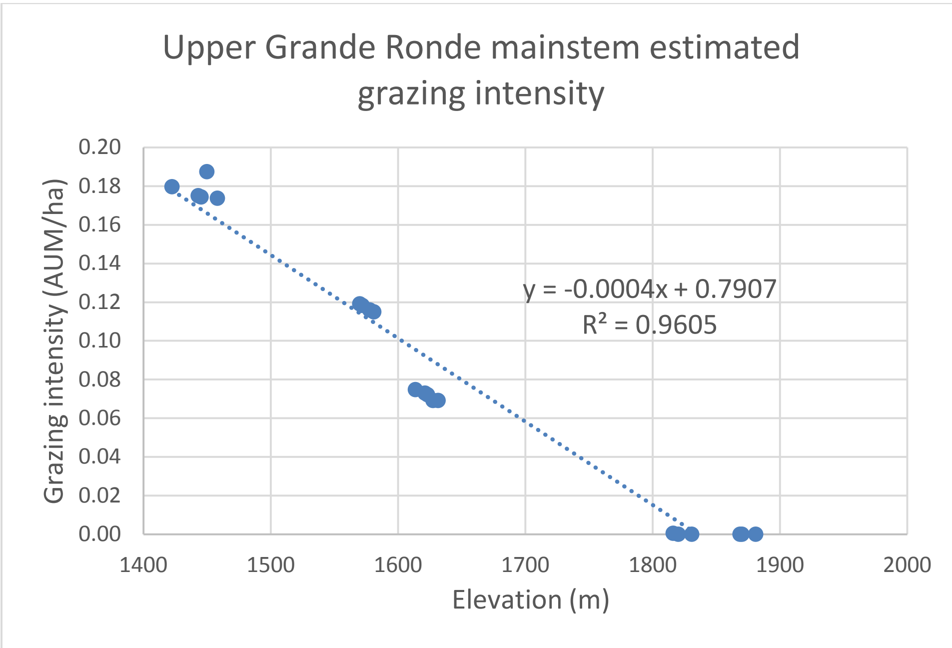


Figure 23. Grazing intensities for each CHaMP site along the mainstem upper Grande Ronde River.

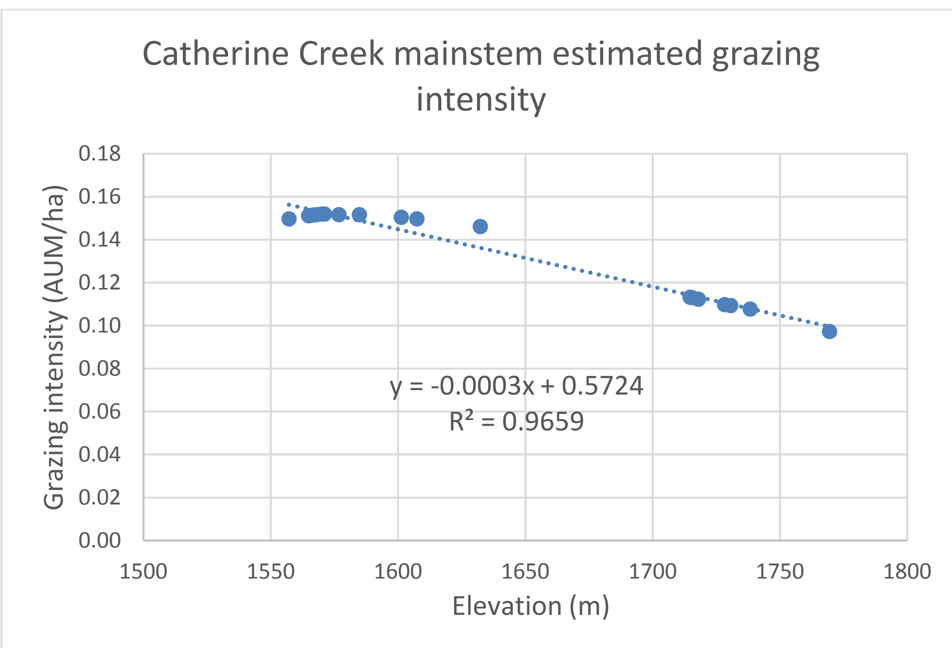


Figure 24. Grazing intensities for each CHaMP site along the mainstem Catherine Creek.

Water Temperature Modeling

Under current climatic, hydrologic and riparian conditions, the vast majority of the Upper Grande Ronde (93 %) and Catherine Creek basins (70 %) had summer temperatures that exceeded the Environmental Protection Agency's (EPA) standard for "core" juvenile salmon rearing of 16 °C (EPA 2003). Stream reaches with temperatures within the optimal range for growth (i.e., 10-16 °C; EPA 2003) were limited to the upper headwaters in both basins. Approximately 80 % of the Upper Grande Ronde Basin and 38 % of the Catherine Creek Basin exceeded a *MWMT* of 20 °C, a general threshold described by the Pacific Northwest Salmon Habitat Indicators Work Group as causing severe impairment to various salmonid life stages including egg development, fry emergence, metabolism, behavior, susceptibility to disease, and mortality (PNWSHIWG 1998). In addition, a large portion of the Upper Grande Ronde Basin (41 %) and some parts of the Catherine Creek Basin (7 %) had maximum summer temperatures that exceeded 25 °C, the upper incipient lethal temperature for Chinook Salmon (Brett 1952, Orsi 1971).

Simulated restoration of riparian vegetation substantially reduced the percentage of the stream network with temperatures above 16 °C from 93 to 73 % in the Upper Grande Ronde, and from 70 to 48 % in Catherine Creek (Figure 4). Similarly, the proportion of habitat with temperatures exceeding 20 °C were reduced from 80 to 42 % in the Upper Grande Ronde and from 38 to 6 % in Catherine Creek. Finally, riparian restoration was predicted to reduce the amount of habitat with temperatures exceeding the incipient lethal limit of 25 °C to 7 % and 0 % in the Upper Grande Ronde and Catherine Creek basins respectively. Despite these substantial potential reductions in water temperature, there are some areas in the lower portions of the Grande Ronde main stem and some tributaries that would continue to have stressful temperature conditions even with restored riparian vegetation.

The model results indicated that median water temperatures in the Upper Grande Ronde and Catherine Creek basins could be decreased by about 5.4 and 2.9 °C respectively following restoration of riparian vegetation to its historic potential (Figure 5). In addition, a combination of riparian restoration and channel narrowing could reduce median temperatures by 6.5 °C in the Upper Grande Ronde and 3.4 °C in Catherine Creek. Using a statistical model developed from snorkel survey and habitat data from the Grande Ronde Basin, the projected temperature improvements from both riparian and channel width restoration translated to increases in Chinook Salmon summer parr abundance of 517% and 74% in the Upper Grande Ronde and Catherine Creek respectively (Figure 9).

If riparian conditions and river widths remain largely unchanged, climate change could result in water temperatures that are completely unsuitable for salmonids (i.e., > than 25 °C) across most of the length of the Upper Grande Ronde River. However, basin-wide restoration of both riparian vegetation and channel width could offset these impacts, reducing water temperatures by about 3.6 °C in the Upper Grande Ronde and 2.1 °C in Catherine Creek.

More detailed results from our temperature modeling analysis are provided in Appendix A.

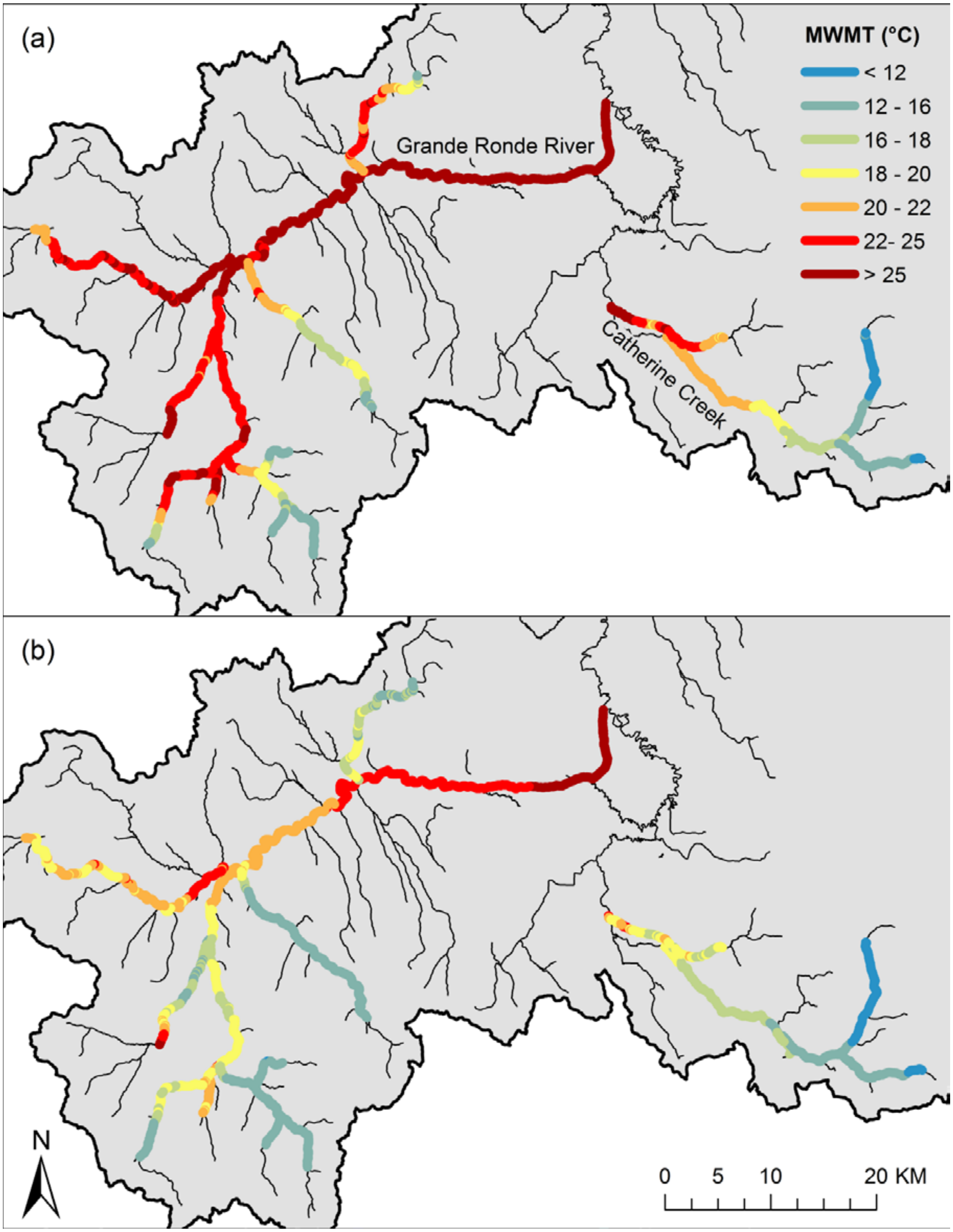


Figure 25. Map of simulated maximum weekly maximum water temperature (*MWMT*; °C) for (a) current conditions and (b) potential natural vegetation (PNV) conditions in the Upper Grande Ronde River and Catherine Creek basins.

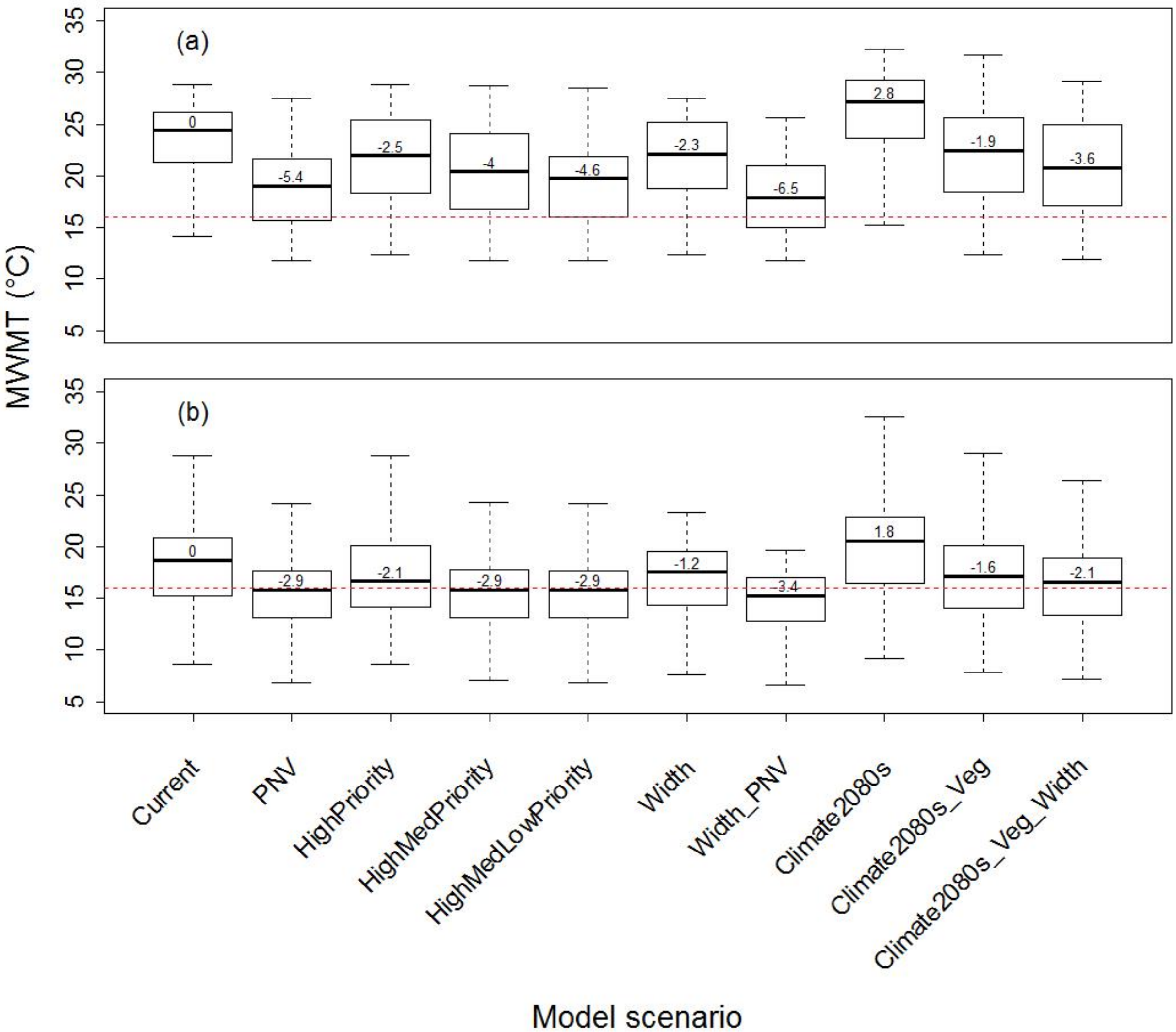


Figure 26. Simulated maximum weekly maximum water temperatures (*MWMT*; °C) for each model scenario in (a) the Upper Grande Ronde River, and (b) Catherine Creek. Each box plot represents the distribution of *MWMT* values across all model nodes within the two focal watersheds including main stem and tributary locations. The numbers within each box represent the change in median temperature from current condition.

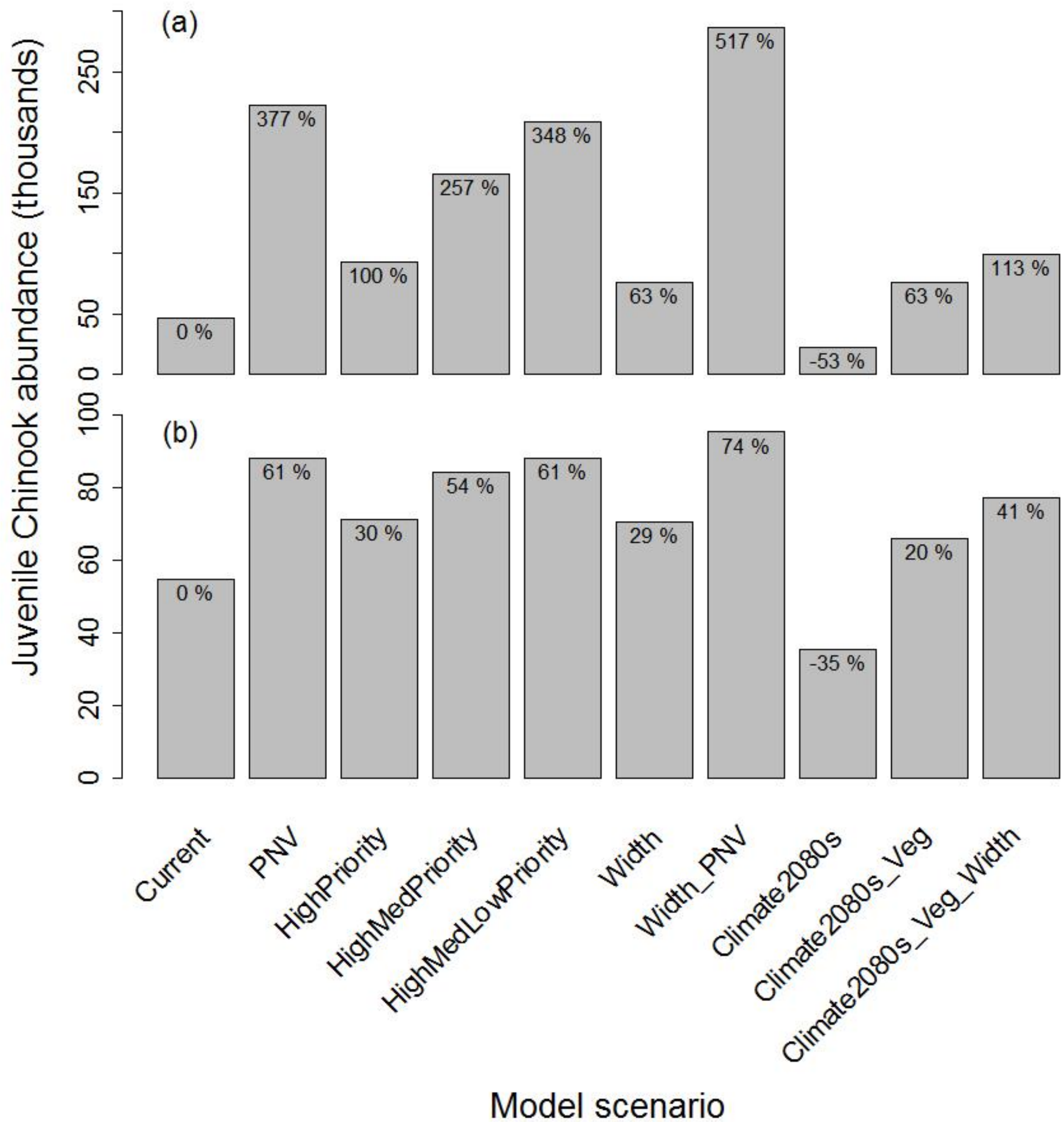


Figure 27. Predicted abundance of juvenile Chinook Salmon for each model scenario in (a) the Upper Grande Ronde River and associated tributaries, and (b) Catherine Creek and associated tributaries. Numbers at the top of each bar indicate the percentage change in abundance from the current condition.

Cold-water Refuge Mapping

The final cold-water refuge map and analysis of associated habitat and biotic data were not completed within the timeframe needed for inclusion in this annual report. These materials will be submitted with the 2016 annual report. The field protocol for mapping of cold-water refuges is provided in Appendix B.

Riparian Mapping

Mapping of riparian vegetation was completed on the historical spring chinook spawning and rearing extent in the Upper Grande Ronde and Catherine Creek watersheds. These watersheds are the geographic extent that defines the populations listed on the Endangered Species Act by NOAA Fisheries. Mapping was completed by a team of riparian vegetation ecologists with extensive experience working in the NE Oregon region and who had written many of the key vegetation survey and classification documents available in the study area. These riparian specialists also drew upon data available from files of USFS vegetation ecologists from the Wallowa-Whitman National Forest.

Mapping was based upon an extensive inventory of vegetation, climate, soils, geomorphology, disturbance, and other resource information available from remote sensing and ground-based surveys in GIS formats. In addition, these riparian specialists conducted a variety of field reconnaissance surveys that validated prior map-based work and allowed extrapolation of ground plot data to similar environmental classes with the aid of visual signatures and textures of vegetation from near infrared imagery and other resource mapping.

The final products from this three-year riparian mapping project are available on the CRITFC data repository. See *Table 9* for a list of all files that constitute the final deliverables from this project. These files include GIS map files (ArcMap) that contain the attribute files describing the environmental characteristics of all vegetation polygons (current and PNV vegetation), the final project report, a list of all plant specimens collected in the 2015 field survey used to confirm plant identifications, tables of PAG canopy cover by species, a complete list of all plant species identified in the two study watersheds, a master list of all environmental resource data and files used or compiled for evaluation, a database of the tabular data incorporated into the final GIS map, and questions for clarification of material included in the final report and responses from the riparian ecologists to these questions.

Table 9. List of files contributing to the final deliverables from the riparian current and PNV vegetation mapping project. Files are available at CRITFC.

CRITFC_Mapping_Final.gdb
Grande_Ronde_Riparian_Mapping_Final_July 2015.pdf
grr_specimen_shipping_list_critfc.xlsx
PAG_Site Index Calculations.xlsx
PAG_Species_Constancy_Canopy Cover_Tables.xlsx
Upper_Grande_Ronde_Catherine_Creek_Plant_Species_List.dbf
Master list of Crowe-data available-resources for mapping.xlsx
RiparianAssessmentSamplingArea-BPA map.pdf
grande_ronde_riparian_2015_tabular_data_deliverable.accdb

Edits and comments-final report-dm-2015.docx
Comments_Riparian_Mapping_March2015_CJ.docx
Response to Edits and comments-final report-ABR and EC.xlsx
Wells_Crowe_attable_2015.xlsx

Historical Ecology for Setting Restoration Targets

There was a significant effect of watershed identity on the percent change in channel width as determined by one-way ANOVA ($F[2, 199] = 9.54$, $p < 0.001$) (Figure 29A). Post-hoc Tukey comparisons revealed that percent change in channel width in Catherine Creek (CCC) was greater than in the Minam River (MRC) by 83.2 (*p-adj* < 0.001, 95% CI = 36.9 – 129.5). Percent change in channel width in the upper Grande Ronde River (UGC) was greater than in the Minam River by 75.7 (*p-adj* < 0.001, 95% CI = 29.5 – 121.9). Percent change in channel width in the upper Grande Ronde River as compared to Catherine Creek was not statistically different, with a change of -7.5 (*p-adj* = 0.85, 95% CI = -40.3 – 25.3). Because the Minam River was more homogenous regarding the presence stream classification types—having a majority of reaches in the large stream category, some reaches in the small/partly confined and confined category, and no reaches in the small/laterally unconfined category—we additionally tested for the effect of watershed identity on percent change in channel width using only sites in the large stream category to ensure the differences were not a function of disparity in stream classification types. Again, we noted a significant effect of watershed identity on the percent change in channel width as determined by one-way ANOVA ($F[2, 167] = 10.85$, $p < 0.001$). Differences in percent change in channel widths among watersheds were confirmed using post-hoc Tukey comparisons (*p-adj*[CCC-MRC] > 0.001, *p-adj*[UGC-MRC] = 0.01, *p-adj*[UGC-CCC] = 0.10). These results provided justification for evaluating percent change in channel width as a function of stream classification for upper Grande Ronde and Catherine Creek watersheds combined, and separately from the Minam River.

For Catherine Creek and upper Grande Ronde River combined, there was a significant effect of stream classification type on the percent change in channel width as determined by one-way ANOVA ($F[2, 170] = 50.14$, $p < 0.001$) (Figure 29B). Post-hoc Tukey comparisons revealed that percent change in channel width in small/partly confined and confined sites (SC) was significantly greater than in large stream sites by 54.6 (p-adj = 0.02, 95% CI = 7.8 – 101.5). Percent change in channel width in small/laterally unconfined sites was significantly greater than in large stream sites by 206.65 (p-adj < 0.001, 95% CI = 157.1 – 256.2). Percent change in channel width in small/laterally unconfined sites was significantly greater than in small/partly confined and confined sites by 152.0 (p-adj < 0.001, 95% CI = 87.4 – 216.7). Table 10 contains a summary of average historic channel width from the 1880s GLO survey, present channel width from 1990s-2000s ODFW survey, and percent change by stream classification type.

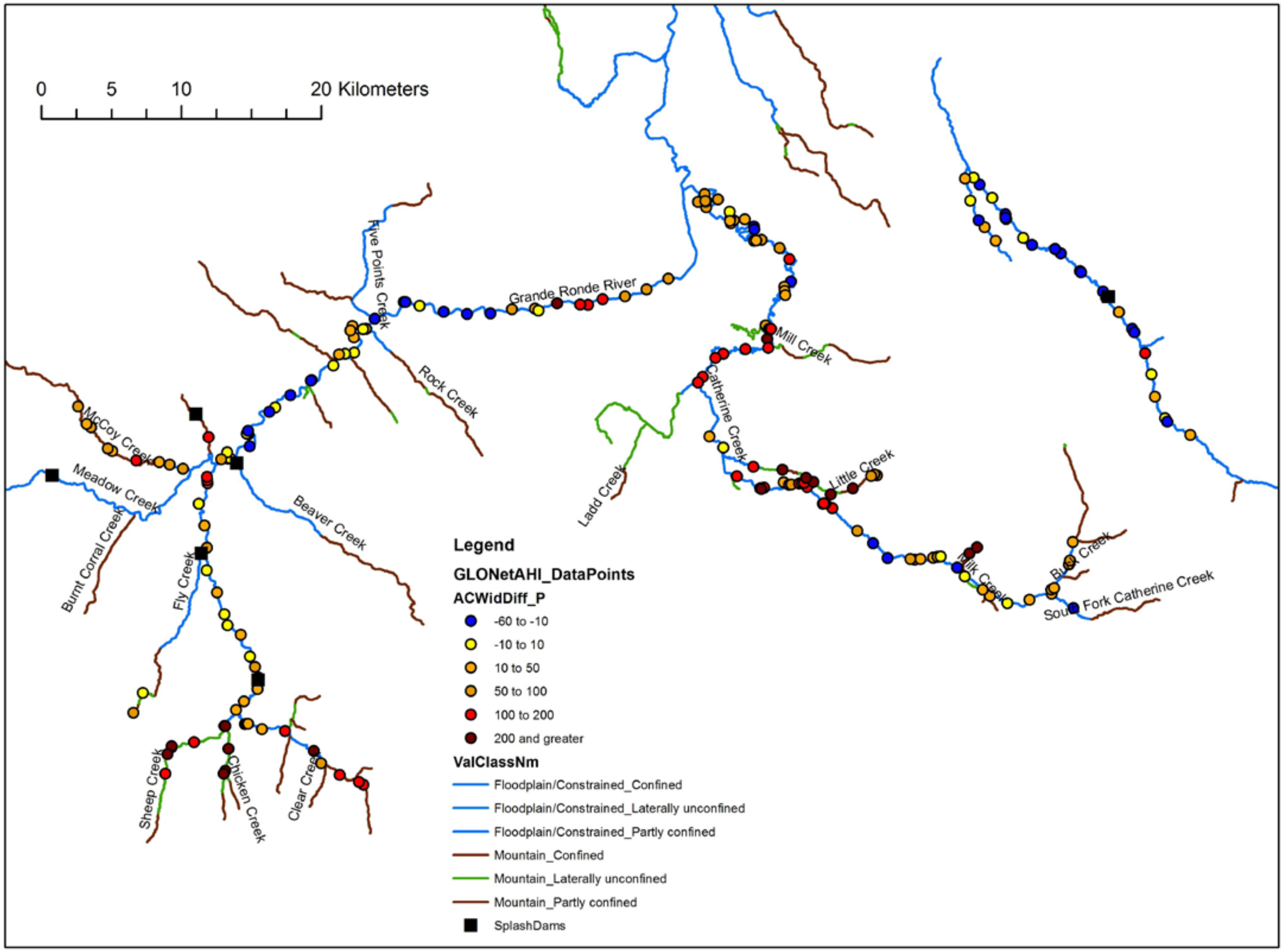


Figure 28. Map of percent change in channel width where GLO survey intersections with ODFW Aquatic Inventory survey. Points represent locations of channel change estimates; colors of points indicate channel narrowing (blue), little or no change (yellow), or channel widening (orange to red).

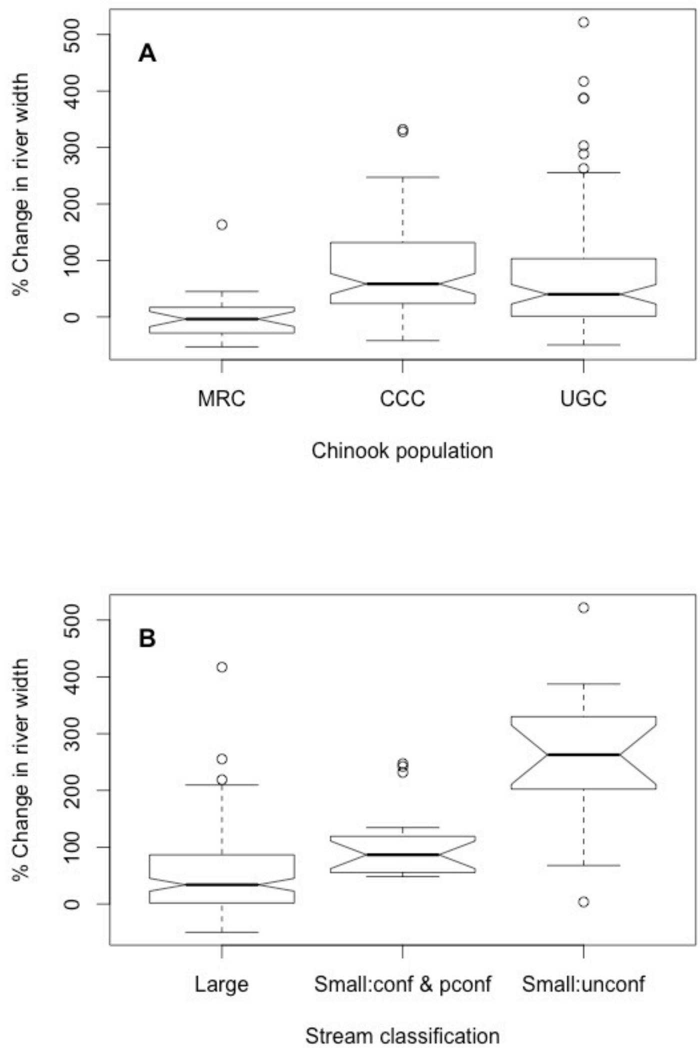


Figure 29. Boxplots of percent change in channel widths from historic (1880s) to present (1990s and later) by A) Chinook population (all locations combined, *n* = 202) and B) Stream type (impacted watersheds only, *n* = 173). Channel width change in Catherine Creek (CCC) and Upper Grande Ronde River (UGC) was significantly different than in the Minam River (MRC), but not from each other. All stream classification groups were significantly different from one another.

Table 10. Average historic channel width from 1880s Government Land Office survey, present channel width from 1990s-2000s ODFW survey, and percent change by stream classification type.

Stream classification type	*Avg historic channel width (m)*	*Avg present channel width (m)*	*Avg increase (m)*	*Avg percent change (%)*
Large streams	16.80	21.12	4.32	53.89
Small/partly confined & confined	4.04	7.88	3.85	108.54
Small/laterally unconfined	2.70	8.31	5.62	260.55

For the purposes of modeling the effect of channel width on water temperature with Heat Source, we divided the stream network into relatively homogeneous stream reaches based on visual inspection of the estimated percentage changes in channel width. The average changes in channel width by reach that were used in the Heat Source model are provided in Table 3. For portions of the study area that were not surveyed either historically or currently, we used average values of percent change from the classification described above in Table 10. Evaluation of the effect of historical stream channel width scenarios on water temperature and rearing juvenile Chinook Salmon abundance is presented in Appendix A.

Table 11. Estimated changes in channel width (m) from historic (1880s) to present in specific stream reaches, used as restoration scenarios in Heat Source modeling.

Population	Stream	River km Min	River km Max	Avg historic width (m)	Avg current width (m)	Avg % change from historic
Catherine Creek	Catherine Cr	0	88.7	10.2	11.8	15.5
	Little Cr	0	14.65	1.1	3.2	187.8
	Milk Cr	0	3.3	0.5	1.5	231.1
	NF Catherine Cr	0	13.4	3.4	5.7	86.8
	SF Catherine Cr	0	10.35	4.4	6.3	64.2
Total				7.8	9.5	51.7
Upper Grande Ronde	Beaver Cr	0	22.9	2.5	4.3	84.6
	Chicken Cr	0	6.45	0.6	2.5	344.1
	Clear Cr	0	3.5	1.1	2.2	108.5
	Five Points Cr	0	16.4	1.8	2.9	68.8
	Fly Cr	0	13.1	1.5	2.6	70.3
	Grande Ronde R	0	97.2	10.1	12.9	56.0
	Limber Jim Cr	0	5.9	1.0	2.8	192.8
	Meadow Cr	0	30.9	1.8	2.9	82.7
	Sheep Cr	0	21.3	0.8	3.0	293.8
Total				5.4	7.5	101.1
Grand total				6.3	8.2	82.6

Restoration Database

In 2015 we finalized work on compiling restoration project data for the upper Grande Ronde River watershed. Nearly 4500 project sites were listed as separate records in a spreadsheet, displaying available project information per site available from data sources. Project activities were categorized into actions and sub-categories (e.g., action: enhancing instream complexity, sub-category: large woody debris addition). A GIS map of restoration projects provides the opportunity for analyzing the distribution of restoration activity throughout the watershed in relation to other landscape features such as ecoregions, topography, and landowner type (Figure 30).

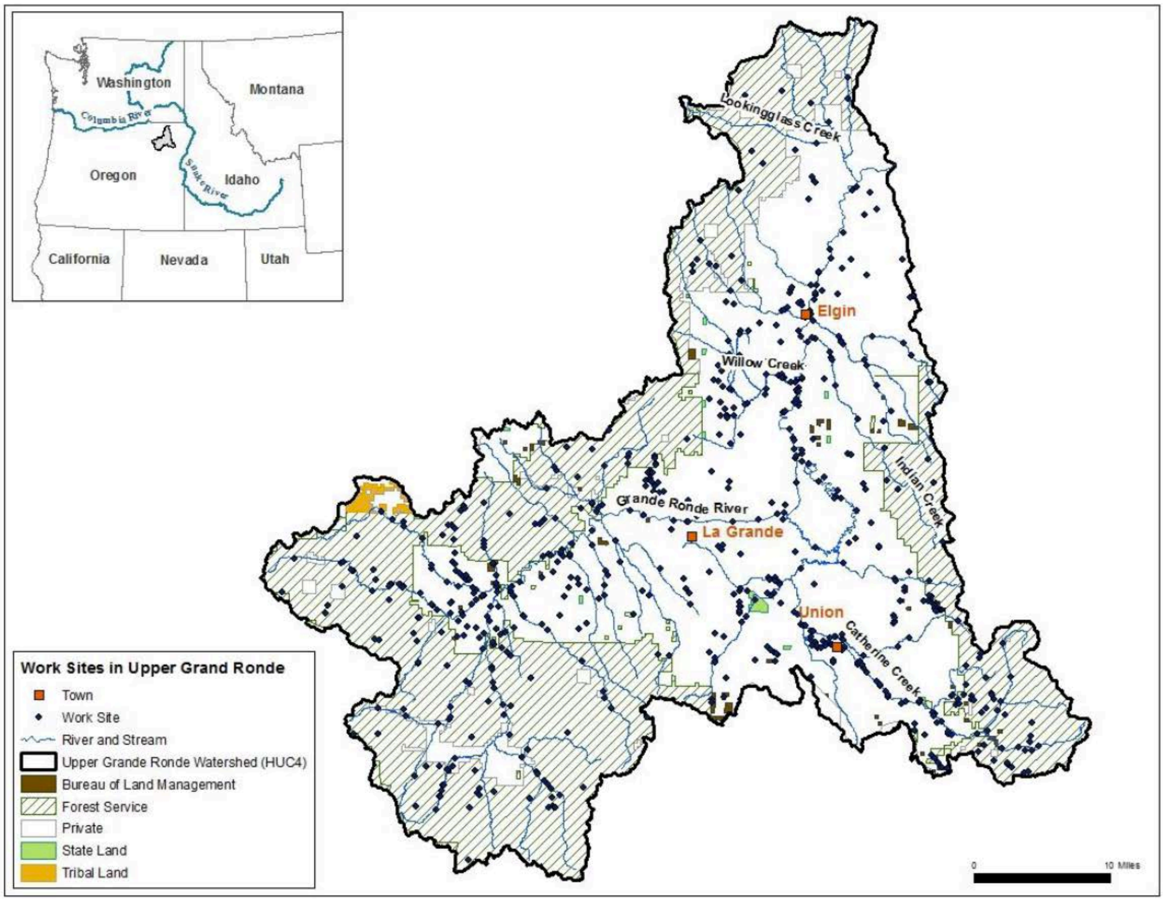


Figure 30. Map of the 705 restoration work sites completed in the upper Grande Ronde River sub-basin between 1986 and 2014. Invasive plant treatments are exlcuded from map.

Data on restoration activities was first stored in an MS Excel spreadsheet, which provided the flexibility to modify data input and create new data when new types of information were encountered in restoration project descriptions. After all known sources of information were collected and the information or created data underwent quality control and quality assurance procedures, a geodatabase was created to convert and store the data for future use. We used an ArcGIS Personal Geodatabase, which uses MS Access as the database structure. This allowed us to create spatial data on site locations and to create stand-alone attribute tables of hierarchical data groupings (e.g., information on restoration projects, which are composed of multiple work sites; or information on individual work sites, which comprise individual projects). The ArcGIS database structure can be joined to the spatial data for mapping or analysis. Because the data are stored in a relational MS Access database, queries and reports can be initiated using the Access features of the database. Detailed metadata tables were also created.

Stream Biota

Juvenile Salmonid Abundance

The 2015 field season marks the completion of five rotating panels and five consecutive visits to annual panels for CHaMP sampling, coupled with associated fish snorkeling and electrofishing to determine late summer rearing capacity. While several analyses of fish distribution and its linkages to local and landscape conditions are underway, a cursory look at juvenile Chinook Salmon rearing densities at site visits in three ICTRT Chinook Salmon populations (Catherine Creek, upper Grande Ronde, and Minam River) and by Tier I channel unit type (slow water/pools, fast water non-turbulent, and fast water turbulent) was instructive. Overall, higher densities were observed in the slow water/pool habitats, followed by the fast water non-turbulent and then fast water turbulent (Table 12). Across habitat types, the Grand Ronde densities have a decreasing trend over the five year sampling time frame. Catherine Creek densities show some decline as well, but over the last two years densities in all three habitat types have increase or stayed stable. Juvenile densities in all three habitats in the Minam River have rising trends and show especially large increases in densities in 2015 over the previous two years of sampling. Slow water/pool habitats showed the most significant gains in density in the Minam River.

At the site-level, both Catherine Creek and the upper Grande Ronde populations broadly show decreasing trends from the initial 2011 surveys. However, Catherine Creek densities do demonstrate an increasing tread over the past two years. These two populations are in areas that have been heavily impacted by land use practiced. The Minam, by comparison, acts as the reference stream, and densities of juvenile Chinook have been increasing over the three year period of data collection (2013-2015) (Figure 31). The surveys in 2015 reveal a large increase in juvenile densities in the Minam over the previous two years.

Table 12. Density (fish/m^2) of juvenile Spring Chinook Salmon by Tier I channel unit type for three ICTRT Chinook populations. Sample size (n) indicates number of sites having a particular channel unit type present, including all within-year repeat visits. No data were available for Minam River 2011-2012.

		Slow/Pool			Fast Non-Turbulent			Fast Turbulent		
Population	Year	Mean	StdDev	n	Mean	StdDev	n	Mean	StdDev	n
Catherine Creek	2011	0.76	0.98	17	0.63	0.63	8	0.2	0.32	17
	2012	0.58	0.61	17	0.33	0.33	9	0.12	0.24	17
	2013	0.24	0.28	20	0.36	0.79	11	0.06	0.11	20
	2014	0.53	0.46	24	0.27	0.36	17	0.08	0.08	24
	2015	0.5	0.5	16	0.4	0.52	18	0.12	0.13	16
Minam	2013	0.25	0.24	9	0.11	0.09	6	0.06	0.07	10
	2014	0.33	0.23	9	0.21	0.28	4	0.07	0.05	9
	2015	1.12	0.44	8	0.33	0.16	6	0.25	0.16	9
Upper Grande Ronde	2011	0.46	0.51	26	0.23	0.31	24	0.11	0.12	20
	2012	0.19	0.41	26	0.08	0.23	24	0.06	0.11	21
	2013	0.2	0.71	71	0.13	0.48	74	0.05	0.16	75
	2014	0.09	0.24	49	0.05	0.19	44	0.03	0.09	49
	2015	0.17	0.47	59	0.07	0.25	44	0.05	0.27	46

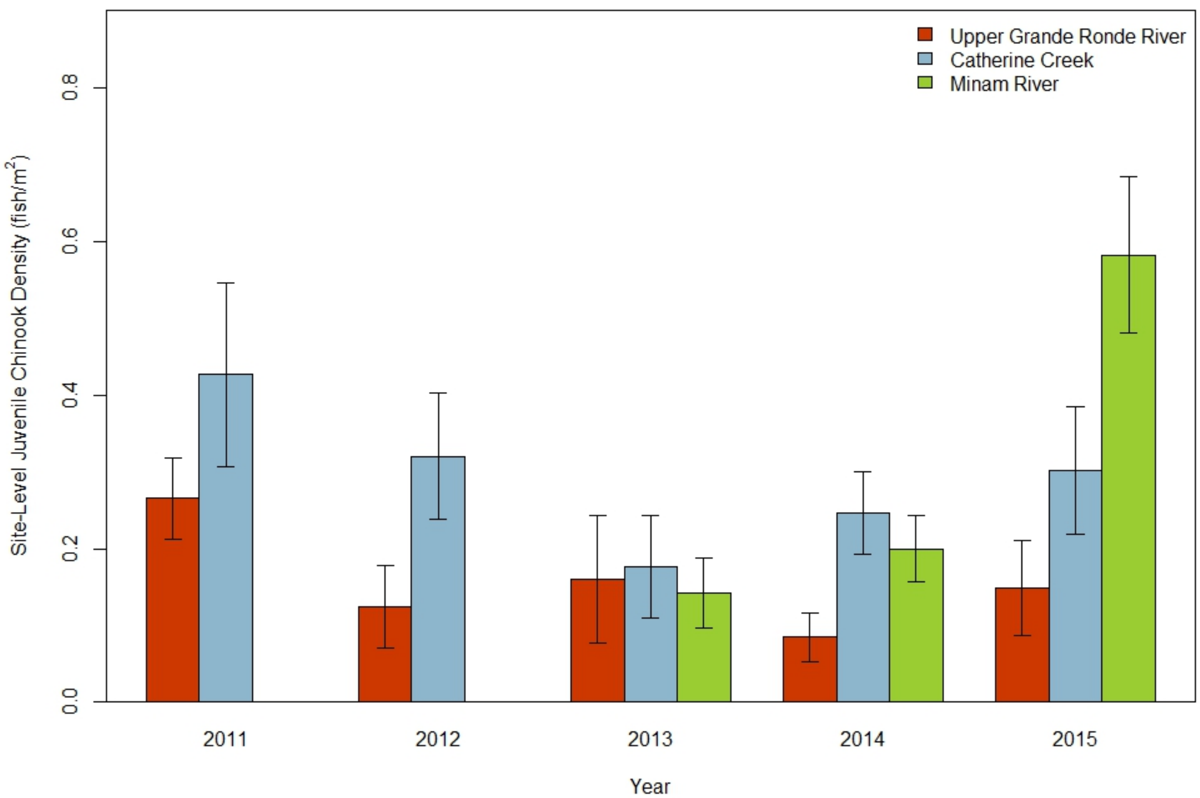


Figure 31. Site-level density (fish/m2) of juvenile Spring Chinook Salmon for three ICTRT Chinook populations, 2011-2015. No data were available for Minam River 2011-2012. Error bars depict +/- one standard error of the mean.

Benthic and Drift Macroinvertebrates

Relationship of community biometrics to environmental conditions

Macroinvertebrate summary biometrics are currently available for sample years 2011-2014. In this 4-year time period, there were 247 samples taken in CHaMP sites. Taxonomic composition of these samples was analyzed with Eastern Oregon (Grande Ronde) IBI, with its numerous metrics, functional feeding group composition, Predator (WCCP Model) analysis in terms of observed/expected ratios, Stressor Indicator Taxa, and Stressor Model results by Michael Cole (Cole Ecological, Inc.), who also provided an updated compilation of metrics for all CHaMP samples each year.

The Eastern Oregon IBI provides a variety of biometrics, including sensitive taxa, sediment sensitive taxa, % tolerant taxa, % sediment tolerant taxa. The Stressor Indicator Taxa also provide data on number of temperature sensitive indicator taxa and % temperature tolerant taxa, as well as the number of fine sediment sensitive and tolerant taxa.

Analyses were performed to examine the relationships between various community biometrics and the two primary habitat limiting factors (water temperature and fine sediment), as well as to elevation, which is typically related to both water temperature and fine sediment. Water temperature and fine sediment generally increase with distance downstream. Water temperature data were generated in CHaMP monitoring from water temperature loggers placed in study sites between 2011 and 2014 and also from August mean NorWeST water temperature data, available for years 2011-2013.

The only drawback in using the Max7dAM temperature data was that temperatures were occasionally missing for CHaMP sites when temperature loggers were missing. Otherwise, these data were the most spatially relevant data available. The NorWeST data for 2011 were based on CRITFC water temperature data and were estimated for nodes distributed throughout the stream networks at 1-km intervals. We matched all CHaMP sites with the nearest NorWeST data estimation site. Unfortunately, years 2012 and 2013 were estimated based on elevation-adjusted air temperature data and 2011 CHaMP data and not from temperature logger data for 2012 and 2013 directly. Data for 2014 were not available for the NorWeST dataset. NorWeST temperature data have the advantage in being available for most sites in the 2011-2013 period.

Benthic samples collected from CHaMP study sites between 2011 and 2014 were evaluated for relationships between known taxa sensitivity to water temperature and measured water temperatures at sites. The highly significant regression of numbers of sensitive taxa and average August water temperatures (Figure 32) provides useful evidence that tabulated values of taxa sensitivity can be used to infer from biotic sampling the water temperature regime of sample sites. Also, the August mean water temperatures (2011-2013) (NorWeST) are a good indicator of thermal sensitivity. Other temperature metrics may be even better at predicting sensitivity. This is to be determined. However, a regression of sensitive taxa from 2011-2014 benthic sampling against Max7dAM temperatures for 2011-2014 provided a comparable R^2.

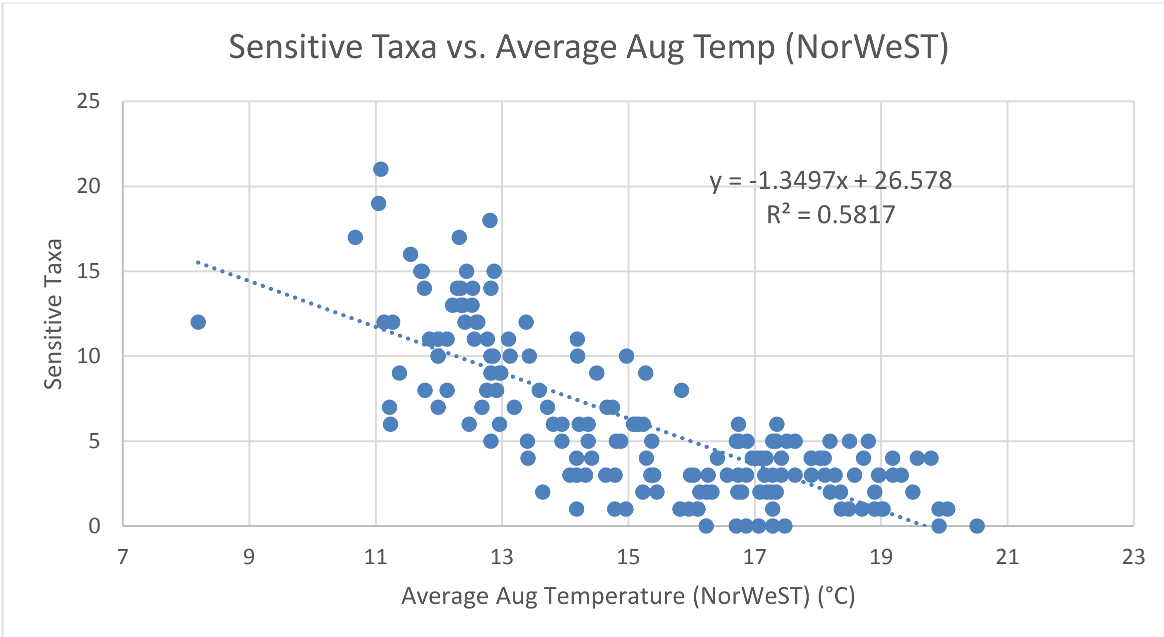


Figure 32. Number of sensitive taxa (Eastern Oregon IBI) regressed against NorWeST average August water temperatures for matching years.

Likewise, taxa that have been classified as tolerant from past regional sampling are significantly related to thermal regime. The higher the Max7dAM temperature (°C) in the Upper Grande Ronde, Catherine Creek, and the Minam River, the greater the number of tolerant taxa (Figure 33).

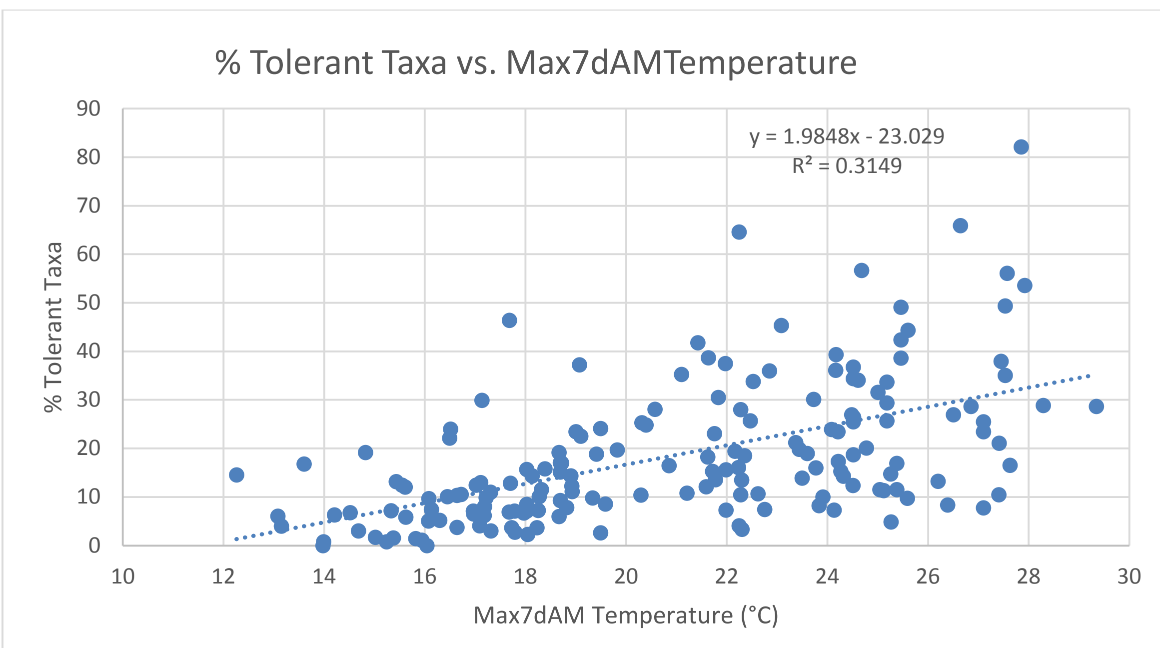


Figure 33. Percentage tolerant taxa (Eastern Oregon IBI) regressed against Max7dAM water temperatures.

Other biometrics that reflect other aspects of the benthic community include the Total Score (IBI). Total Score in the Eastern Oregon (Grande Ronde) IBI is calculated as the sum of scores for (1) taxa richness, (2) mayfly richness, (3) stonefly richness, (4) caddisfly richness, (5) sensitive taxa, (6) sediment sensitive taxa, (7) modified HBI (Hilsenhoff Biotic Index), (8) % tolerant taxa, (9) % sediment tolerant taxa, and (10) % dominant taxa. Scores assigned to each of these 10 metrics were either 1, 3, or 5. The maximum IBI score (sum of all 10 individual metrics) is 50 and the minimum is 10. Ratings were assigned categories of Severe impairment (<27), High impairment (27-34), Moderate impairment (35-41), and No impairment (>41) (Hubler 2006). Total Score (IBI) values for benthic samples collected between 2011 and 2014 regressed on Max7dAM Temperatures for the same time period reveal a highly significant relationship (Figure 34).

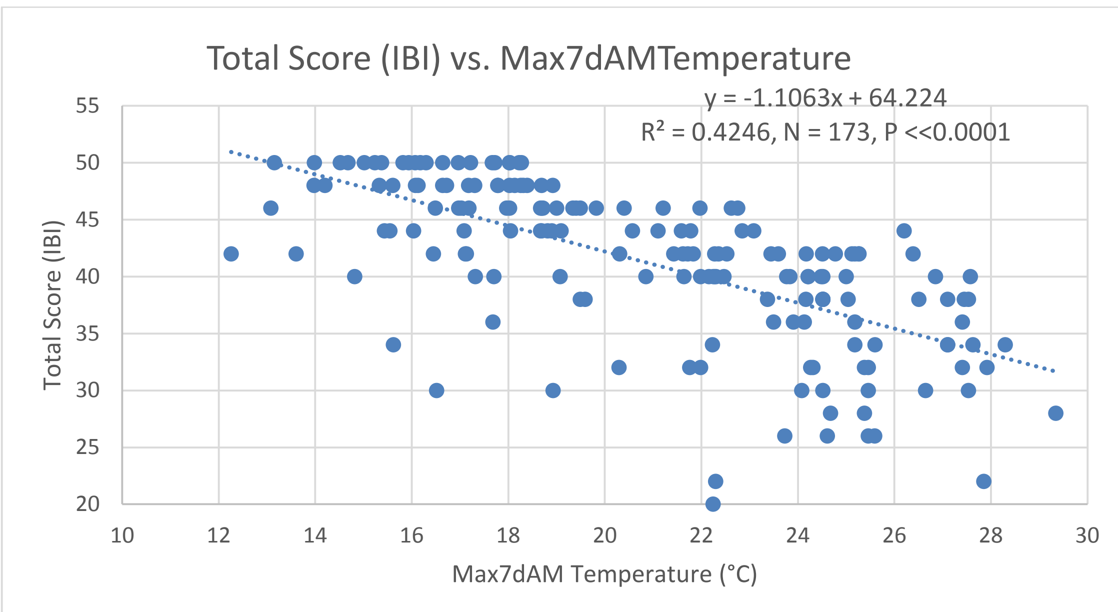


Figure 34. Total score (IBI) vs. Max 7dAM temperatures.

A parallel set of analyses were made to relate fine sediment sensitive taxa (taxa known from regional studies to have distributions and abundances linked to fine sediment) to fine sediment indices derived from CHaMP surveys. There was a highly significant positive relationship between numbers of fine sediment sensitive taxa and riffle substrate composition (Wolman D_{50}) (Figure 35). Despite the strength of this relationship, there was no significant relationship between numbers of sediment sensitive taxa and ocular fines (< 2 mm diameter) or Wolman D_{16} particle size for riffles. The Wolman D_{16} particle size would have been a much more likely linkage to numbers of fine sediment sensitive taxa occurrence. Possibly the bias associated with using Wolman pebble counts to represent fine sediment is a cause of

this result. If so, it would be necessary to assume that $SubD_{50}$ is directly related to fine sediment concentrations, where fines of significance are those less than 2 mm.

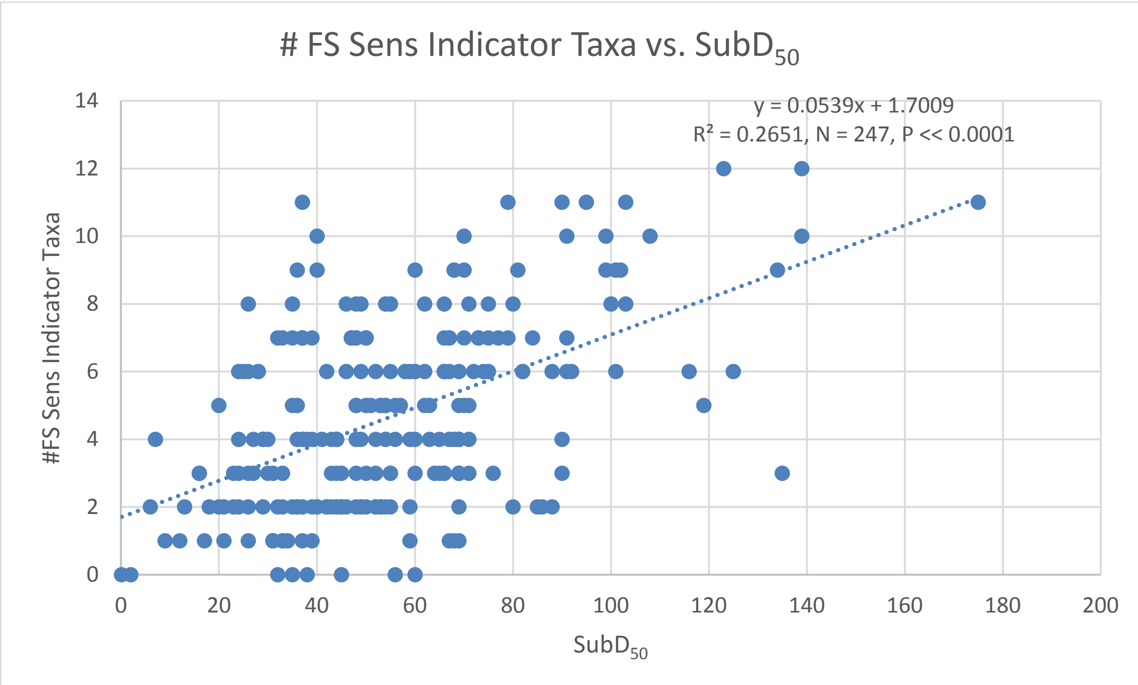


Figure 35. Number of fine sediment sensitive indicator taxa vs. substrate median particle size (D_{50} mm) estimated by Wolman pebble counts for riffle channel units.

Much can be learned from benthic macroinvertebrate community analysis by comparing the taxa frequency, density, or relative abundance in samples taken from different sites or watersheds. A comparison of the three study basins (Upper Grande Ronde or GR, Catherine Creek or CC, and Minam River or MN) reveals some marked differences in taxa frequency based on the sites sampled. This comparison was on the basis of only UG mainstem (13 sites), Catherine Creek mainstem (10 sites) plus the North Fork CC (3 sites) and South Fork CC (3 sites), and Minam mainstem (6 sites) plus Little Minam (3 sites). This provides a basis for calculation of frequencies for the three basins of UG (13 sites), CC (16 sites), and MN (9 sites). By leaving the minor tributaries out of this calculation, it was assumed that biota characteristic of more unique habitats would not be included. In terms only of those taxa that occurred with greater that 50% higher frequency in one basin than other basins, it was found that *Brachycentrus occidentalis, Calineuria californica, Cardiocladius, Microtendipes, Ochrotrichia, Paraleptophlebia,* and *Petrophila* were found at 50% greater frequency among samples in the UGR than either the CC or MN. Taxa found in both CC and MN at 50% higher frequency than the UGR included Capniidae, *Cinygmula*, and *Drunella deceptivus*.

In terms of frequency of occurrence at the family level within all 66 samples taken in 2014 across the Upper Grande Ronde, Catherine Creek, and the Minam River, several taxa were found in a high

percentage of all samples. This frequency of occurrence among sites can be termed constancy. Taxa with a constancy above 75% included Baetidae, Chironomidae, Elmidae, Ephemerellidae, Heptageniidae, Trombidiformes, Chlorperlidae, Perlodidae, Perlidae, Tipulidae, Hydropsychidae, Simuliidae, Branchycentridae, and Nemouridae. Among the Baetidae, it is interesting that *Baetis bicaudatus* was found at a frequency of 50% greater in CC than GR. Also, *Baetis alius/moqui* was found at a frequency 50% greater in MN than GR. Both *Cheumatopsyche* and *Hydropsyche* were found at a frequency that was 25% greater in GR than MN.

The Total Score values computed from the Eastern Oregon IBI provide a relatively holistic community index. There were a total of 20 sites on the mainstem Grande Ronde River that were sampled in annual or rotating panels from 2011-2014. Total Scores averaged for each site were based on either 4, 2, or 1 samples per site in this 4-year time period. The average Total Score values were plotted against elevation, yielding a significant positive relationship. Because other work showed that water temperature increased in a downstream direction (i.e., with declining elevation) on the mainstem GR, it appears logical that Total Score on the mainstem would also be related to elevation (Figure 36).

Temperature sensitive taxa comprised only one of 10 elements of the Total Score (Eastern Oregon IBI). However, when numbers of temperature sensitive taxa were plotted against elevation, there was also a strong regression (Figure 37).

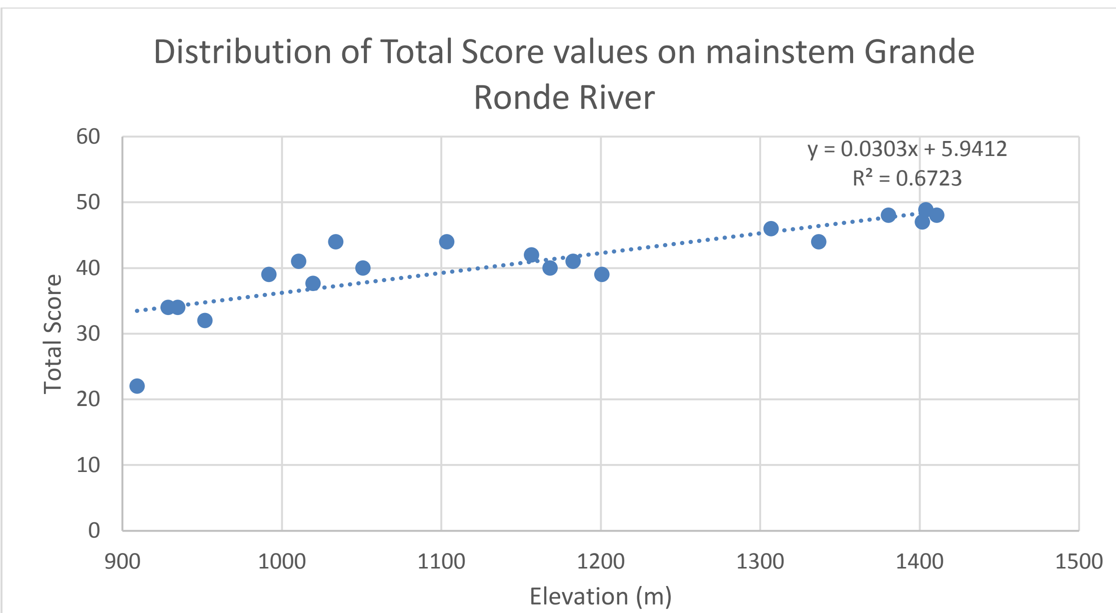


Figure 36. Distribution of Total Score values with elevation (m) on the mainstem Grande Ronde River for benthic macroinvertebrate samples taken during 2011-2014 at a total of 20 sites. Total Scores were averaged by site to account for some sites being annual sites (sampled in all four years) and other sites being rotating panel sites (i.e., sampled in 2011 and 2014, or in 2012, or 2013).

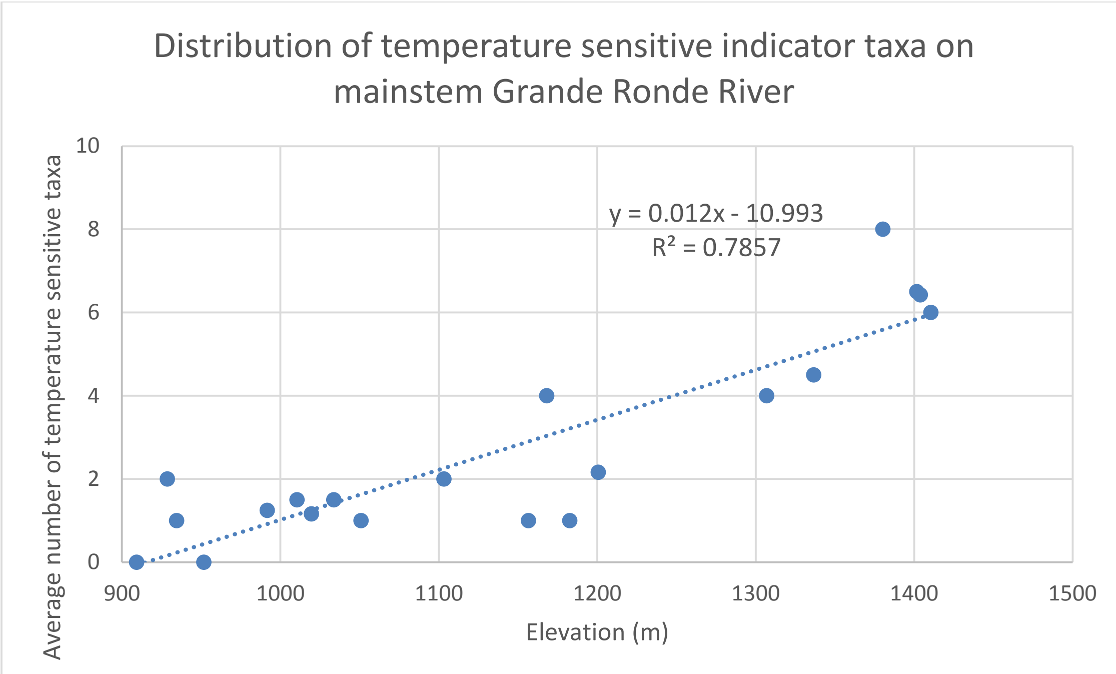


Figure 37. Distribution of average number of temperature sensitive taxa with elevation (m) on the mainstem Grande Ronde River for benthic macroinvertebrate samples taken during 2011-2014.

Temperature sensitive taxa numbers were averaged by site to account for some sites being annual sites (sampled in all four years) and other sites being rotating panel sites (i.e., sampled in 2011 and 2014, or in 2012, or 2013). Fine sediment sensitive taxa numbers (averages by site on the mainstem GR) were also plotted against site elevation (Figure 38). Sediment sensitive taxa declined as elevation declined. It makes physical sense that sediment sensitive taxa would decline as the river becomes larger and gradient lower in a downstream direction. However, it is difficult to explain why fine sediment sensitive or tolerant taxa do not seem as well related to direct CHaMP measures of fine sediment or substrate composition (e.g., D16) in general.

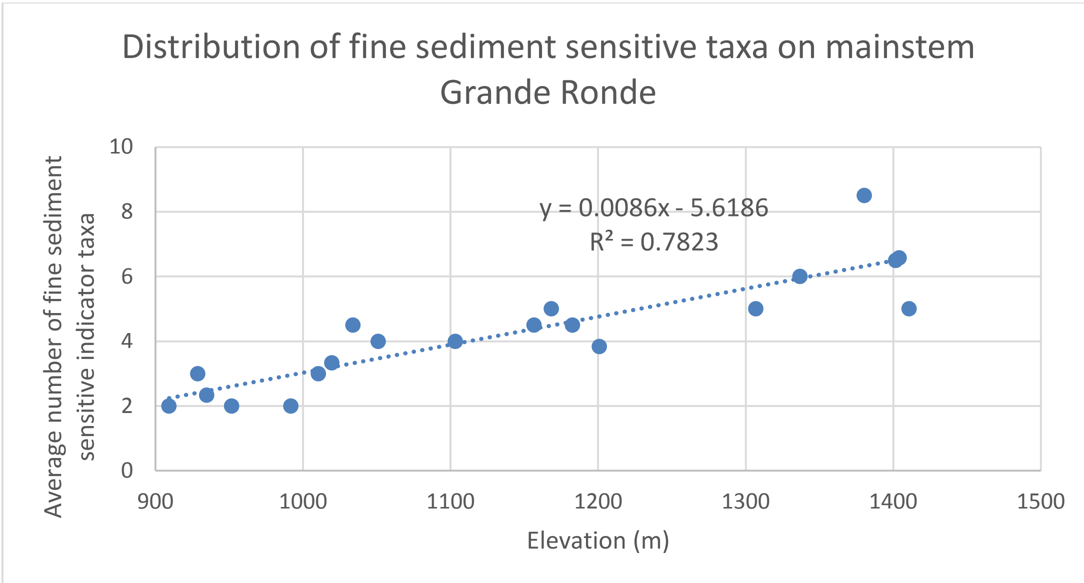


Figure 38. Distribution of fine sediment indicator taxa with elevation (m) on the mainstem Grande Ronde River for benthic macroinvertebrate samples taken during 2011-2014. Fine sediment sensitive taxa numbers were averaged by site to account for some sites being annual sites (sampled in all four years) and other sites being rotating panel sites (i.e., sampled in 2011 and 2014, or in 2012, or 2013).

Total numbers of all Ephemeroptera, Plecoptera, and Trichoptera (i.e., EPT taxa) were summed and divided by the total number of taxa by site on the Grande Ronde River mainstem for 2014. Given the relationship found between numbers of each of these insect orders and water temperatures for samples taken from 2011-2014 (i.e., generally greater number of taxa for each order with colder water), the significant relationship between % EPT taxa/total taxa and elevation is a logical consequence (Figure 39). However, given this result, it was difficult to explain why a regression of % EPT taxa/Total taxa against water temperature (NorWeST, August average for CHaMP sites for 2011-2013) yielded a statistically non-significant negative relationship.

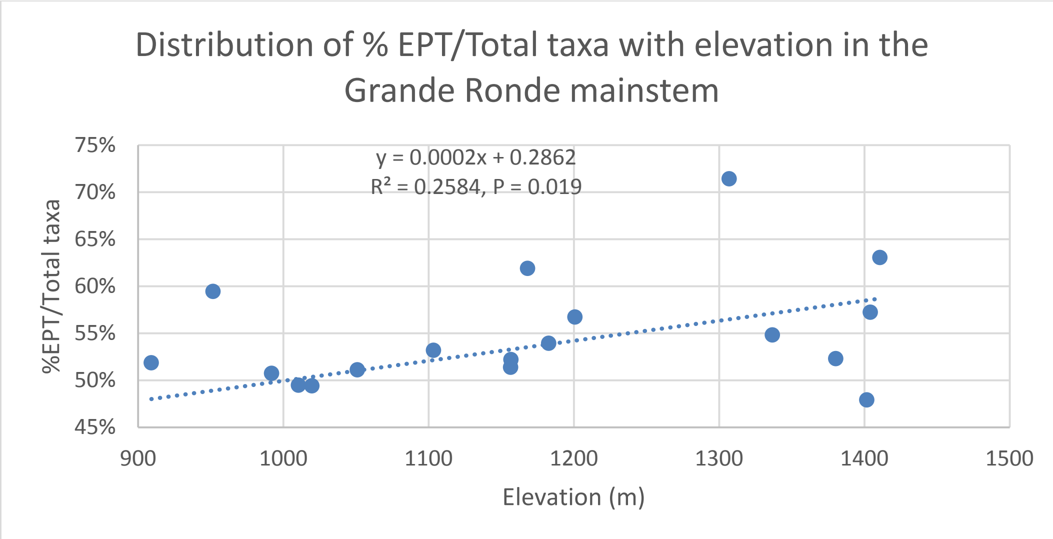


Figure 39. Distribution of % EPT/Total taxa values with elevation (m) on the mainstem Grande Ronde River for benthic macroinvertebrate samples taken during 2011-2014. % EPT taxa/total taxa values were averaged by site to account for some sites being annual sites (sampled in all four years) and other sites being rotating panel sites (i.e., sampled in 2011 and 2014, or in 2012, or 2013).

The taxa for 2013 benthic samples taken at all CHaMP sites (that also had drift samples taken there) had optimum water temperature data tabulated for many of them (Huff et al. 2006, Cole Ecological, Inc. Excel file stressor coding.xlsx). The optimum water temperature values for as many taxa as data were available for from regional macroinvertebrate studies were weighted by $\log_{10}$ abundance in samples to generate a total water temperature index. This value was plotted against NorWeST mean August water temperature data for 2013 (Figure 40). These NorWeST water temperature data were developed by Isaak (http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html) from CRITFC data collected at those sites. The community optimum water temperature index was the sum of all the weighted values for taxa having optimum indices. The benthic community can be used effectively to indicate the actual water temperature regime experienced at each site where the community was sampled. Standard tabled values of weighted average optimum temperatures (method from Huff et al. 2006) developed in the region appear to give a good indicator of the water temperatures recorded at the sites described by these macroinvertebrate communities. Figure 40 also indicates that, even though all macroinvertebrate taxa are distributed along a river continuum and have a fixed value for optimum that might best be reflected in a limited number of CHaMP sites, the shifts in abundances of species having different geographic distribution patterns in relation to water temperature create trends in overall community water temperature optimum indices that are accurately reflected in the water temperature regimes of the sites.

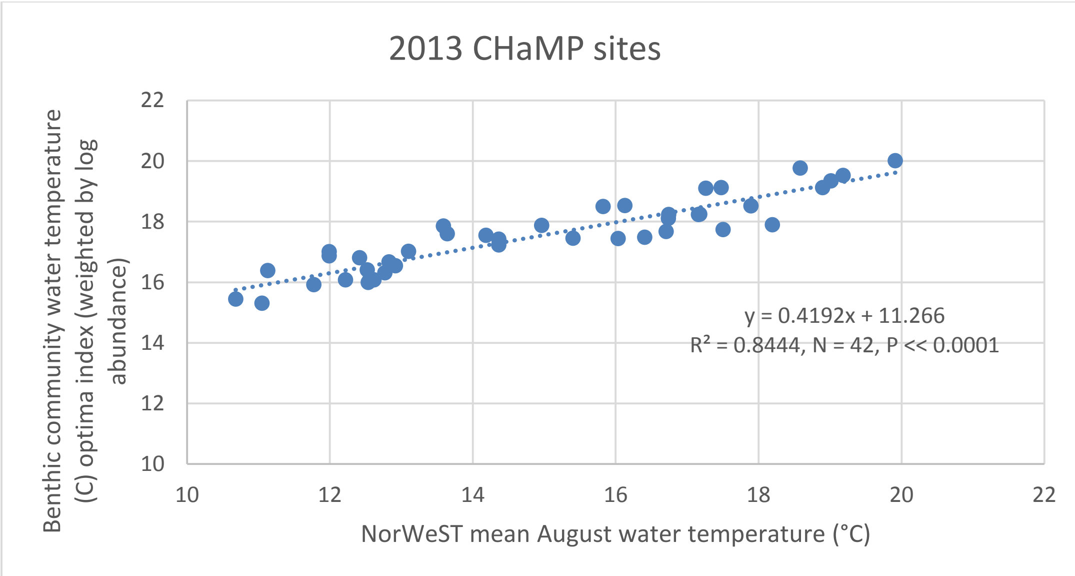


Figure 40. Regression of benthic community water temperature (°C) optimum index for CHaMP sites of 2013 (having matching drift samples) vs. NorWeST mean August water temperature (°C at each site.

The community average upper fine sediment tolerance values were computed for each CHaMP site sampled for benthic macroinvertebrates in 2013 for which matching drift samples were available. Just as for the water temperature optimum calculations, the community average fine sediment upper tolerance values were derived for only those taxa in each sample that had exact taxonomic identification matches to tabulated values for regional taxa. The regression on channel gradient (Figure 41) indicates a logical correspondence. With increasing gradient, the benthic community upper fine sediment tolerance average declined. It is logical to expect that at higher channel gradients, there would be lower levels of tolerance of fine sediment, given that typically fine sediments (percentage surface area covered) are lower at higher gradients. However, since there is also a correspondence between the community composition and water temperature optima on the same longitudinal trajectory, and water temperatures tend to decrease as gradient increases (i.e., upstream), it is likely that gradient is essentially a surrogate for water temperature.

It is strange that benthic community upper tolerance for fine sediment index (weighted by $\log_{10}$ abundance) is not better related to CHaMP multiple measures of fines or substrate composition. However, the benthic macroinvertebrate fine sediment community index was significantly related to ocular sand and fines percentage (Figure 42) based on the tabulated values for fines (< 0.06 mm, Huff et al. 2006), although the R^2 was relatively low. The less than 0.06-mm size fraction is silt/clay in the CHaMP program, while the sand category includes particles less than 2 mm diameter. The moderate relationship between the community sediment tolerance value and ocular sand and fines might be due to fines in the Huff et al. (2006) compilation being based on particles less than 0.06 mm diameter. But general methodological difficulties in measuring fines, using Woman pebble counts (i.e., bias against fine sediment), ocular estimates (i.e., qualitative, visually-based method), and pool-tail fines estimated with

grid devices (i.e., interference with flocculent algal mats during extreme low flow and in late summer) make this a difficult metric to use consistently.

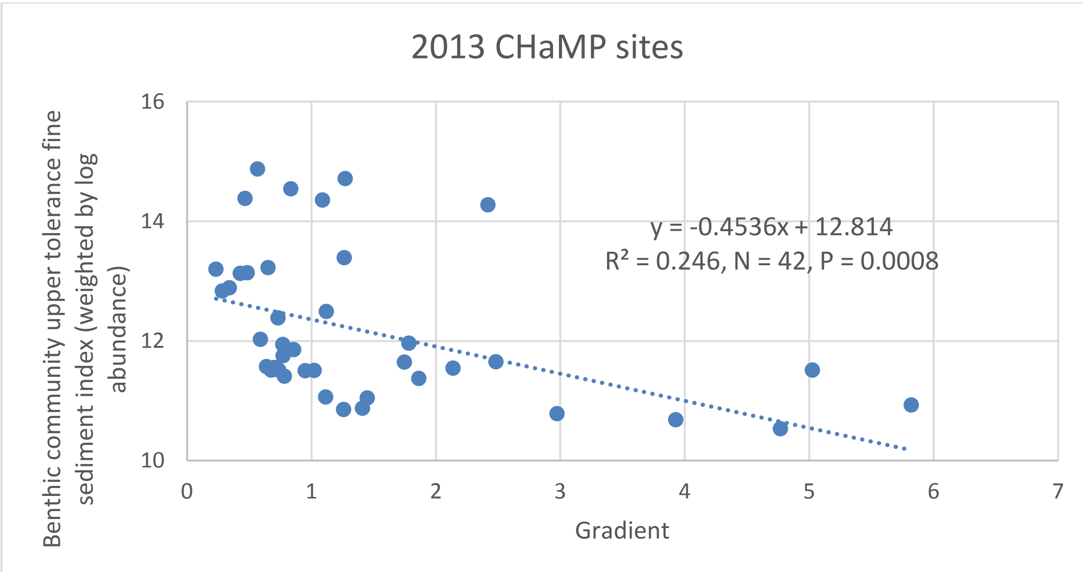


Figure 41. Regression of benthic community upper fine sediment tolerance index (weighted by log_{10} abundance) vs. channel gradient at 2013 CHaMP sites (having matching drift samples).

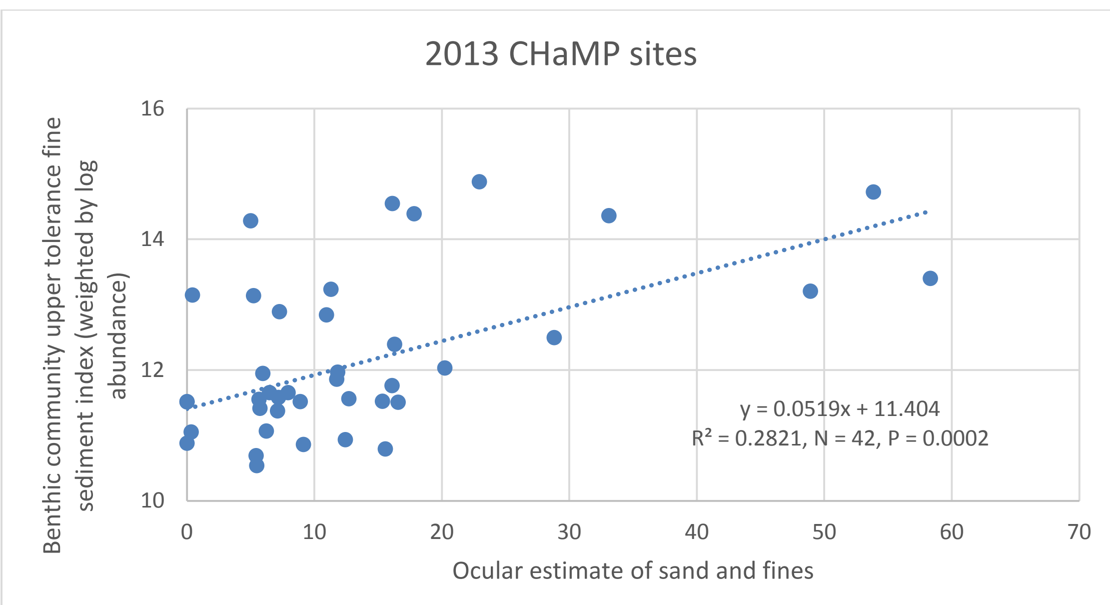


Figure 42. Regression of benthic community upper fine sediment tolerance index (weighted by log_{10} abundance) vs. ocular estimate of sand and fine sediment percentage.

Relationship of individual benthic taxa to environmental conditions

Individual taxa that are found widely throughout either a single basin or across all study basins make good candidates for exploring the relationship between taxon abundance and environmental conditions. Although we have a wide range of environmental conditions available to use in such regressions that were produced from CHaMP auxiliary data collections (e.g., LWD abundance, pool frequency or pool volume, riffle or fast-water percentage of study site area), we have focused our efforts initially on relating macroinvertebrate presence and abundance to water temperature and fine sediment levels.

Hydropsyche is a taxon found throughout the longitudinal trajectory of the study basins. Plotting *Hydropsyche* density (no./m^2) against maximum of the 7-day average of the daily maximum temperature (Max7dAM) reveals a distribution with a maximum density at about 23°C, and a range from about 13 to 29°C (Figure 43). The optimum water temperature listed in Huff et al. (2006) for Hydropsyche was 18.5°C. The tolerance value was listed as 21.7°C, which is 1 SD above the mean for the temperature distribution. This relationship appears to indicate that the Max7dAM temperature found in the summer period is highly reflected in the zone for maximum abundance of this taxon.

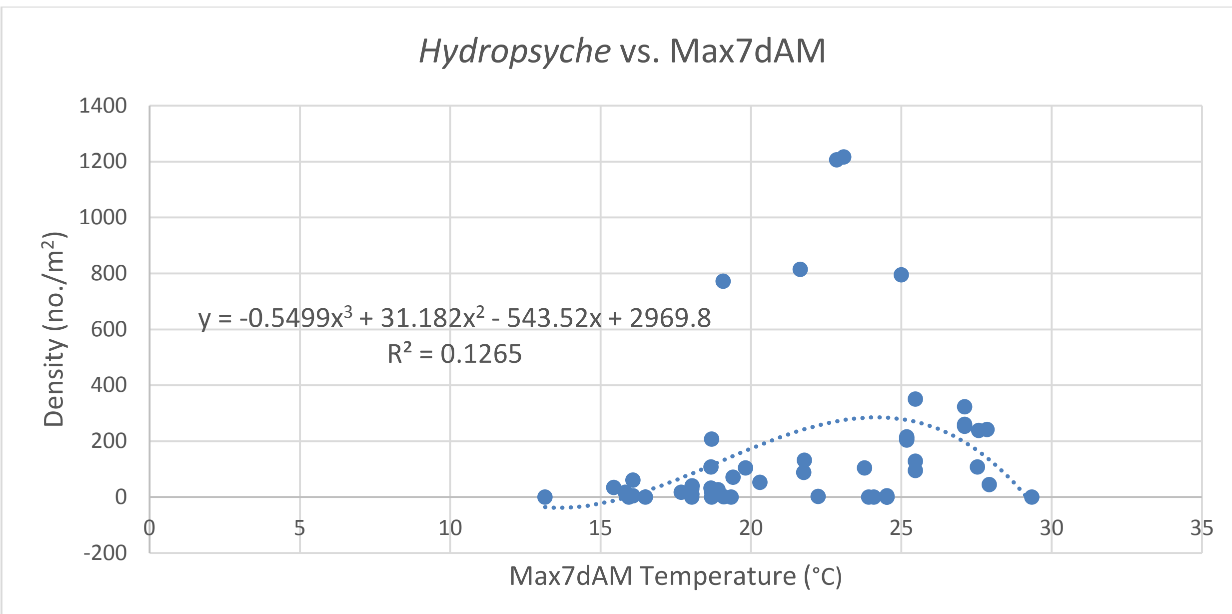


Figure 43. Distribution of *Hydropsyche* against 7-day average of the daily maximum temperature (2013 data).

Analysis of Benthic and Drift Samples

Benthic as well as drift samples were collected in each CHaMP site surveyed each year. Benthic samples per site were a composite of 8-1 ft^2 collections using a Hess sampler (500 *u*m) in low to moderate-sized substrate with low to moderate gradient and depths less than about 40 cm. Under other conditions of substrate size, gradient, and depth a dipnet (500 *u*m) was used. Drift samples were collected with two 40-cm wide and 60-cm tall drift nets (500 *u*m mesh). Comparisons of benthic and drift samples were done to address a variety of questions: (1) Can benthic sampling provide useful data for inferring drift composition and abundance, (2) Do some species found in the benthos drift preferentially, while others

are rarely found in the drift, (3) Are there species found in the drift that are not found in the benthos, implying that they originated from upstream of the study site, or from channel units other than the riffles sampled for benthos?

In order to display the relationship between taxa in the benthos vs. the drift, taxa identified in benthic and drift samples from 2013 were plotted against one another. These points were distributed in zones created to reveal tendencies to drift. Zone 1 has taxa with a benthic frequency of >30%. Zone 2 has taxa with a benthic frequency of <30% (Figure 44). This differentiates magnitude of benthic frequency. Zone 1H and Zone 2H have drift frequency that is higher than the upper limit of deviation from the benthic sample frequency. Zone 1L and Zone 2L have drift frequency that is lower than the lower limit of deviation from the benthic sample frequency. The upper and lower limits of deviation from the 1:1 line representing equal frequency of occurrence of benthic and drift taxa were +35% and -35%, respectively, of the benthic frequency.

All points in Figure 44 represent the average frequency of occurrence of benthos and drift taxa based on 42 sites. There are some sites that have zero frequency of occurrence of a taxon in the benthos, but have positive occurrence of the taxon in the drift. Benthic samples were taken in riffles distributed throughout the study reaches, while the drift samples were taken at the upstream end of the study reach for practical reasons. Drift was collected at the same time that the site was being surveyed for CHaMP. We assumed that the reach entering the study reach had characteristics similar to the study reach and consequently similar benthic community although there are cases where this was probably not accurate. It may also be that a taxon occurred in a clumped distribution and was missed in riffles sampled, or the taxon in the drift originated wholly or largely from channel units other than riffles (e.g., pools) where the benthos was sampled.

Zone 1 benthic taxa have a relatively high frequency of occurrence (i.e., >30% across sites in the Upper Grande Ronde, Catherine Creek, and the Minam River). Among the 42 CHaMP sample sites for 2013, when a taxon occurred in a benthic sample, it was found very seldom at a frequency in drift samples significantly exceeding the benthic frequency (i.e., above the upper limit of deviation in Zone 1). Only *Tanytarsini* and *Narpus concolor* had drift frequencies greatly exceeding the benthic frequencies in Zone 1. Many taxa with benthic frequency >30% had drift in Zone 1L. It is expected that some taxa would drift at a lower rate than they are found in the benthos. However, this would mean that the ability to find certain taxa at a site, even when they generally are found in >30% of all sites can be hard enough that these taxa are not found in the drift at certain sites. Possibly this means that at some sites a given taxon is rare enough by density that the probability of finding it in the drift is low. This argues for assessing the combination of density in sites where the taxon is present as well as frequency of occurrence among sites. A taxon found at most sites in the benthos could always occur at low densities. This could lead to low observation in the drift because drift community composition is based on only 600 individuals (Rhithron) and the occurrence in the drift might be lower than the taxon's relative abundance in the benthos. The frequency of occurrence of macroinvertebrates in the benthos has been based on only 525-550 individuals.

Although we have not computed statistical probabilities of finding taxa that are present in benthic samples when they are collected in benthic samples, this is a task that should be addressed so that we

can estimate confidence in benthic community trends. In the 42 benthic samples from 2013, it was determined that there were from 31 to 92 taxa identified per sample. Individual samples were each 1 ft^2 and eight samples were composited to make the composite sample that was sorted and identified for each site. Average number of individuals per taxon per individual Hess sample ranged from 0.64 to 14.8. The minimum number of individuals per taxon per Hess sample ranged from 0.03 to 1.36. Because 8 Hess samples were taken, there would be 8 times this minimum number of individuals collected per taxon as a minimum.

In these 42 samples there was a range of 231 to 5815 individuals in the composited samples. With samples having less than 550 individuals, the entire composited sample would have been counted. For samples that had somewhat greater numbers of individuals as well as a high number of taxa, the chance of missing taxa that were present could be greater given that there would be a small number of individuals present in the sample for many taxa. In 2013 benthic sampling, based on these 42 samples, there was a minimum number of individuals per taxon ranging from 0.35 to 10.9 for composite samples. The reason for the number less than 1.0 (the logical minimum whole specimen per bottle) was that in 2013 there were a few sites that had 3 to 4 samples taken. For these sites, density by taxon was averaged for samples from June through September, so samples with no individuals for a specific taxon reduced the average below 1. Despite this, there were many taxa that had very low representation in each collection. These samples have a much higher risk of not finding taxa that are present when only 525-550 individuals are counted and identified. Identification of large and rare taxa could account to some extent for taxa that are present in low abundance, but this process tends to mostly emphasize large specimens that are rare. Very small specimens that can be easily overlooked by the insect sorter staff are not likely to be passed on to the taxonomist. Ostermiller and Hawkins (2004) decided not to use rare taxa in their O/E metric analysis. Also, they found that $\geq$ 350 individuals counted per sample was sufficient to derive optimum O/E estimates in a comparison of counts from 50 to 450 per sample.

It is interesting that *Baetis tricaudatus*, a species found in all sites in the benthos, was located in Zone 1L. That is, it was found in the drift at a frequency greater than 35% less than the benthic frequency. *Zaitzevia* was found in >80% of all benthic samples and was located in Zone 1, indicating that the drift frequency did not deviate significantly from the benthic frequency (note: > 35% deviation was taken as the level for significant deviation). Simuliidae had an 81.8% frequency among all sites and *Simulium* appeared in Zone 1. It is, therefore, found in drift at approximately the same rate as the benthos.

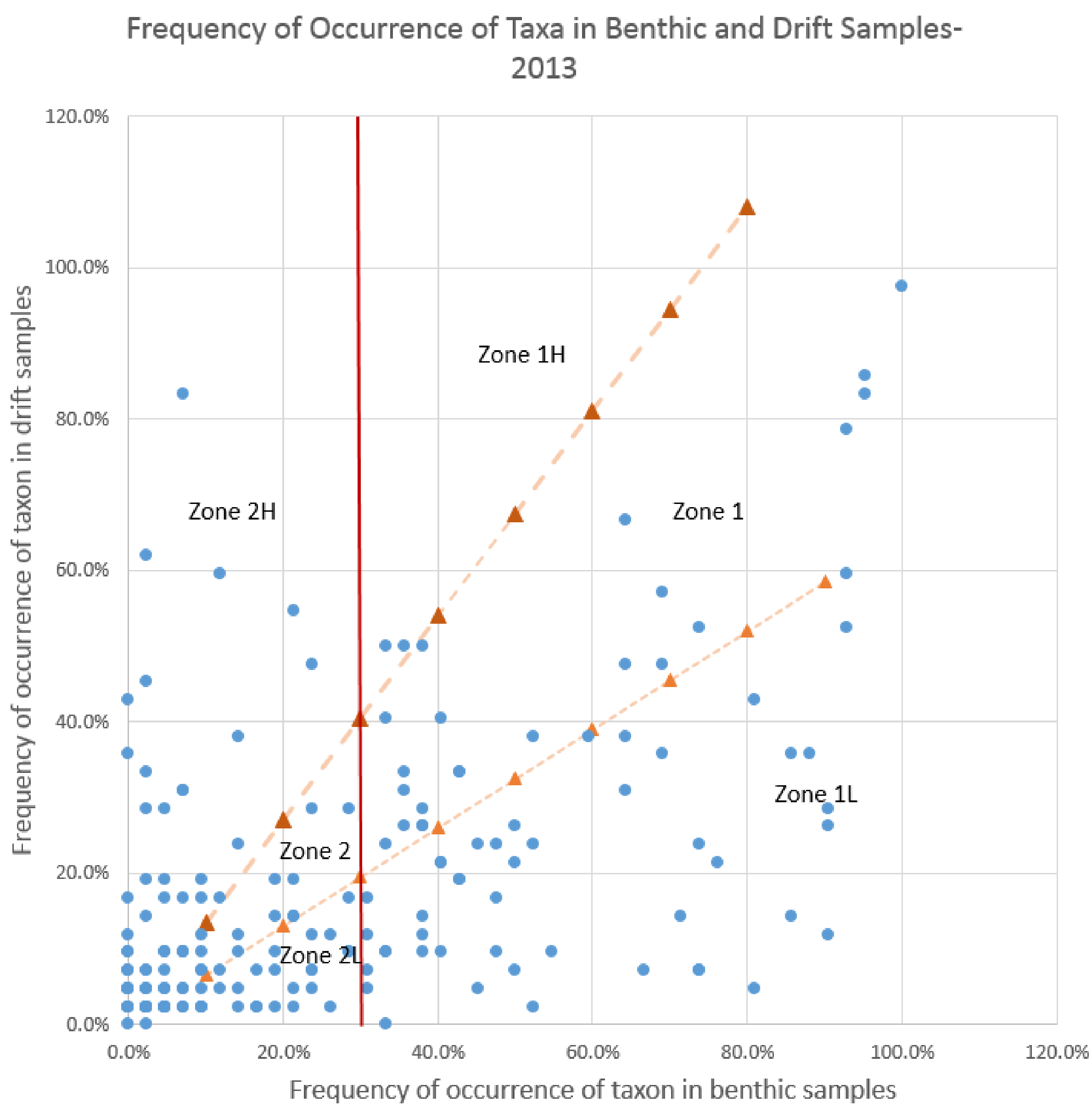


Figure 44. Zonation of frequency of occurrence of taxa in benthic vs. drift samples for all sites surveyed in 2013.

Comparison of relative densities of taxa in the drift vs. benthos

Relative density of various taxa in each of the 42 samples that had matching benthic and drift samples was calculated by dividing the density of that taxon in the benthos or drift by the total density of all taxa in the benthos or drift, respectively, at each site independently.

Hydropsyche drift and benthic relative densities revealed a significant regression exists between drift and the benthic community that supports the drift, but one in which the relative density of this taxon in the drift was about 17% of the relative density in the benthos (Figure 45). As relative density in the

benthos increases, the relative density in the drift increased. Similar highly significant relationships existed for *Eukiefferiella* and *Optioservus*, but poor relationships existed for many other taxa. In regard to *Eukiefferiella* relative densities (as well as all other taxa), the taxon was occasionally found in the drift but not the benthos, but also frequently in the benthos but not the drift.

The exercise of regressing drift relative densities of a taxon against benthic relative densities indicates that it might be more meaningful to contrast absolute density of taxa in the drift vs. benthos rather than relative densities given that if certain other taxa present in the benthos do not appear in the drift or are highly variable entering the drift, the relative densities of that taxon in the drift are affected. Only when the total numbers of all other taxa in drift and benthos maintain a consistent relative abundance ratio would it be possible to use relative abundance of a target taxon to compare drift vs. benthos.

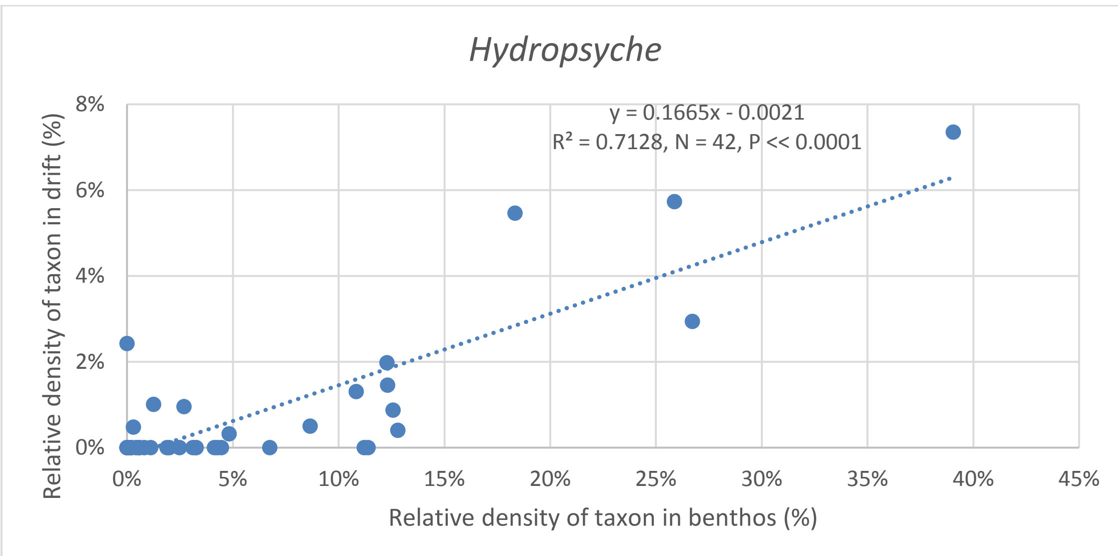


Figure 45. Relative density of *Hydropsyche* in the drift vs. relative density in the benthos for 42 sites in the GR, CC, and MN.

All Hydropsychidae taxa were combined (e.g., *Hydropsyche*, *Cheumatopsyche*) so that density in the drift could be contrasted with that in the benthos for sites having occurrence in both benthos and drift. This regression was not significant (Figure 46). This regression was based on 18 sites out of a total of 42 sites in the GR, CC, and MN that had non-zero values for absolute density for both benthic and drift at each site. It is unclear why *Hydropsyche* had a positive relationship between relative drift and benthic densities, while at the family level, which would include greater presence of the family at all sites, there was no relationship at all in terms of regression of absolute densities. It may be that behavioral drift could be highly variable during the day or with variations in environmental characteristics that may change during the summer season when CHaMP surveys are conducted. Environmental characteristics that could lead to variations in drift rates (drift density) are water temperature and density of particulate matter suspended in the drift that these net-spinners filter from the water.

The beetle larva *Optioservus* showed a positive relationship between absolute density in the drift vs. the benthic density (y = 0.1166X + 45.465, R^2 = 0.1283, n = 32, P=0.04) (Figure 47). There were 32 sites out of 42 that had positive values for absolute density for both drift and benthos at individual sites. In

contrast to the Hydropsychidae, it is possible that *Optioservus* may drift with less temporal variability, creating a greater similarity between drift and benthic density.

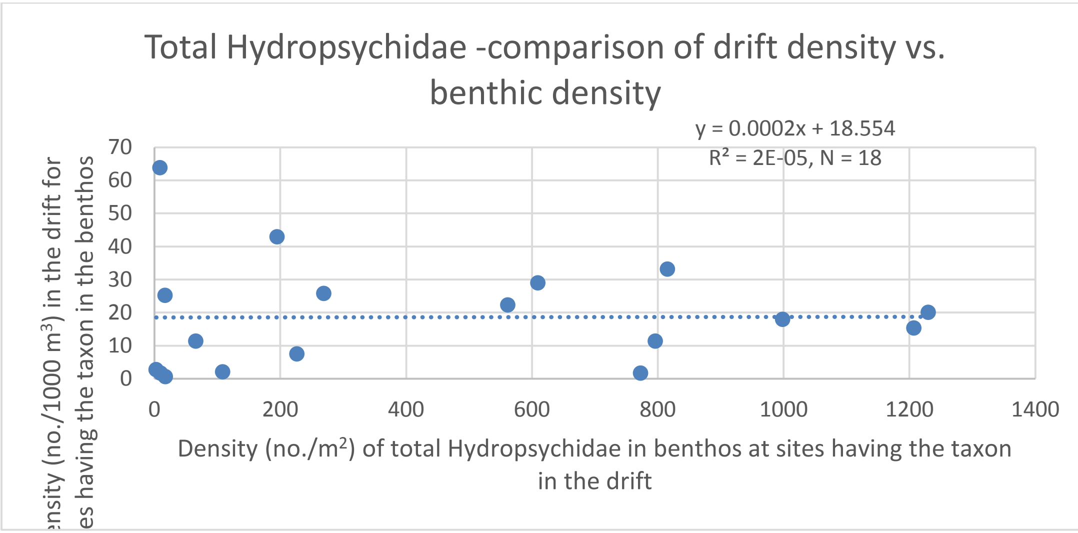


Figure 46. Comparison of density (no./m^3) of Hydropsychidae in the drift vs. density (no./m^2) in the benthos based on sites that had this taxon in both the drift and the benthos.

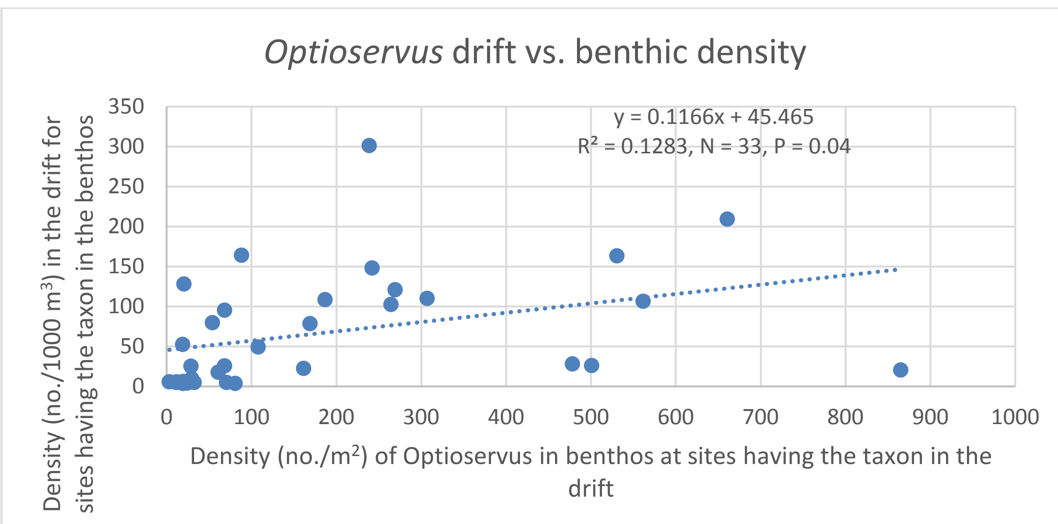


Figure 47. Comparison of density (no./m^3) of *Optioservus* in the drift vs. density (no./m^2) in the benthos based on sites that had this taxon in both the drift and the benthos.

Comparison of drift between watersheds on the basis of frequency of occurrence

There were 19 sites sampled in 2013 for benthos and drift in the upper Grande Ronde and Catherine Creek, respectively. The average frequency of occurrence of taxa in the drift was computed for every taxon found in the benthos for these 38 sites. A plot of drift frequencies for all samples having each

taxon revealed that the two basins are different in their frequencies of occurrence of taxa in the drift when they are present in the benthos (Figure 48). There were several taxa that had zero occurrence in CC when found in GR and vice versa (not depicted in Figure 48; that is, all instances of zeroes for drift or benthic taxa were not included in the average for each taxon from CC and GR that were part of this regression). For the 50 taxa included in the regression, some had significantly higher frequency in the drift in CC than in GR. The converse also occurred. There were 50 taxa in common in the two basins where they had drift occurring in sites where the taxa were found in the benthos for both CC and GR.

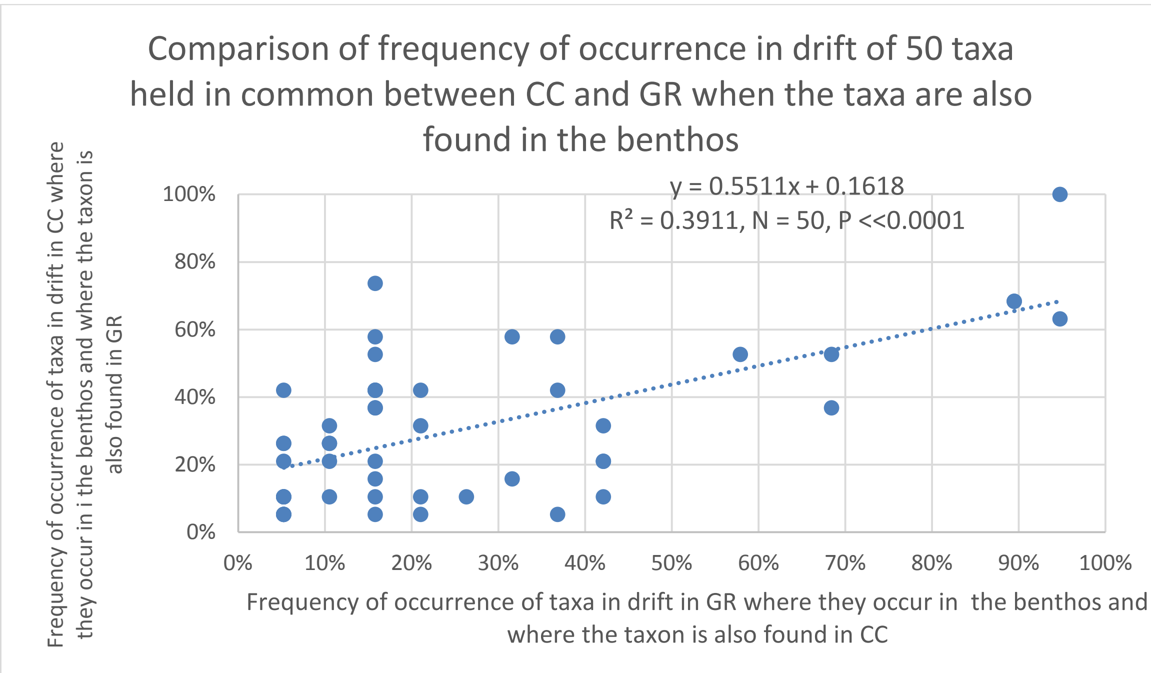


Figure 48. Comparison of frequency of occurrence in the drift of 50 taxa in Catherine Creek and the Upper Grande Ronde River when these taxa are held in common as determined from benthic samples.

Comparison of drift vs. benthos for watersheds on the basis of frequency of occurrence

Taxa that occurred with greater than 30% frequency in the drift in both GR and CC included Trombidiformes, Zaitzevia, Optioservus, Orthocladiinae, Lepidostoma, Polypedilium, Antocha monticola, Hydropsyche, Eukiefferiella, Simulium, and Drunella grandis/spinifera. Sites having greater than 30% frequency in drift in the GR where they occurred in the benthos that had no presence in CC included Hydroptilidae, Tricorythodes, Cardiocladius, and Thienemannimyia Gr.

The GR and CC basins were also evaluated independently for macroinvertebrate occurrence in the drift and the benthos (see Figure 49 for GR). The percentage occurrence in the benthos of each taxon was computed for the 19 GR sites and 19 CC sites. There were 101 taxa in the GR and 80 taxa in CC having occurrence in one or more of the 19 sites each. The percentage occurrence in the drift of each taxon was also computed for each taxon having presence in the benthos at each site. Consequently, some

sites having the taxon present in the benthos had no presence in the drift. When evaluated for all 19 sites, taxa were able to have, for example, greater than 0 up to 100% frequency of occurrence in the benthos, but the corresponding percentage occurrence in the drift was always less than or equal to that for the benthos. It was not possible to have a greater percentage presence in the drift because the frequency of occurrence in the drift was computed only for sites having the taxon in the benthos. The highest frequency possible for the drift in this case would be the same frequency as the benthos. These graphs demonstrate that across the range of percentage occurrence in the benthos of taxa from >0 to 100%, there were some taxa that occurred with nearly the same frequency in the drift, considering only taxa having positive occurrence in both drift and benthos in one or more of the 19 sites. There were also some sites that had much smaller presence in drift than in the benthos. For example, a site that has occurrence in 15 of 19 sites for a given taxon in its basin might have drift of that taxon occurring in only 10 of 19 sites. Most likely, when density is low in the benthos, the ability to detect presence in drift will be reduced.

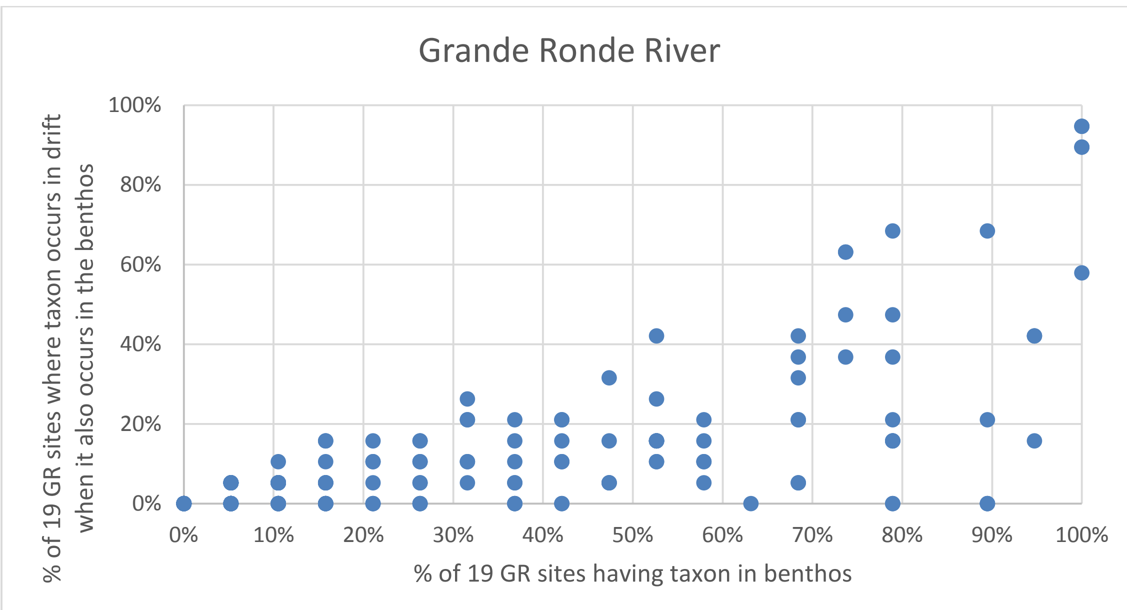


Figure 49. Frequency of occurrence of taxa in the drift in the Upper Grande Ronde River vs. the frequency of occurrence in the benthos based on 19 sites.

Comparison of drift vs. benthic communities in relation to water temperature and fine sediment indices

We used the tabulated values of water temperature optima and fine sediment upper tolerance levels by taxon (Huff et al. 2006) for drift and benthic communities sampled in 2013 to assess the degree of correspondence between these communities. Temperature optima or fine sediment upper tolerance levels by taxon were weighted (log10) by taxon abundance and summed to derive a total community metric for temperature or fine sediment tolerance.

Regressions for the water temperature optima for drift vs. benthic showed a high level correspondence (y = 1.135x - 2.231, R^2 = 0.8705) (Figure 50). This relationship is also very close to 1:1, indicating that the composition of the drift community is a good reflection of the water temperature optima of the benthic community. This relationship also suggests that the organisms collected in the drift originated from the vicinity of the proximal benthic community rather than being an assortment of organisms that had drifted for many kilometers in the stream to reach the study site. This suggests that drift communities are derived from spatially linked benthic communities and that differences in relative abundances are attributable to either diel variations in drift periodicity or different propensities to drift.

Another message from this regression is that the tabulated values for optimal water temperatures for all taxa found in the GR, CC, and MN can be used in conjunction with abundances of taxa from either the benthos or drift to characterize the thermal regime of the study site. It was already pointed out that the benthic community's $\log_{10}$ abundance-weighted average water temperature index is significantly correlated with mean August water temperature (Figure 40). The similarity in community temperature indices between drift and benthic communities was a surprising result, given the variations that occur in community composition between benthos and drift. This may also indicate that temperature tolerant taxa do not preferentially drift at each study site. If this were the case, the thermal regimes described by drift and benthic communities would be different.

A similar result was demonstrated between drift and benthic communities in the 2013 CHaMP samples when the tabulated fine sediment upper tolerance values were applied to the taxa in drift and benthic samples. The tolerance values were weighted by $\log_{10}$ abundance. Again, there was a close relationship (y = 1.0663x + 0.2433, R^2 = 0.5766) between the fine sediment tolerance characteristics of the drift communities and benthic communities.

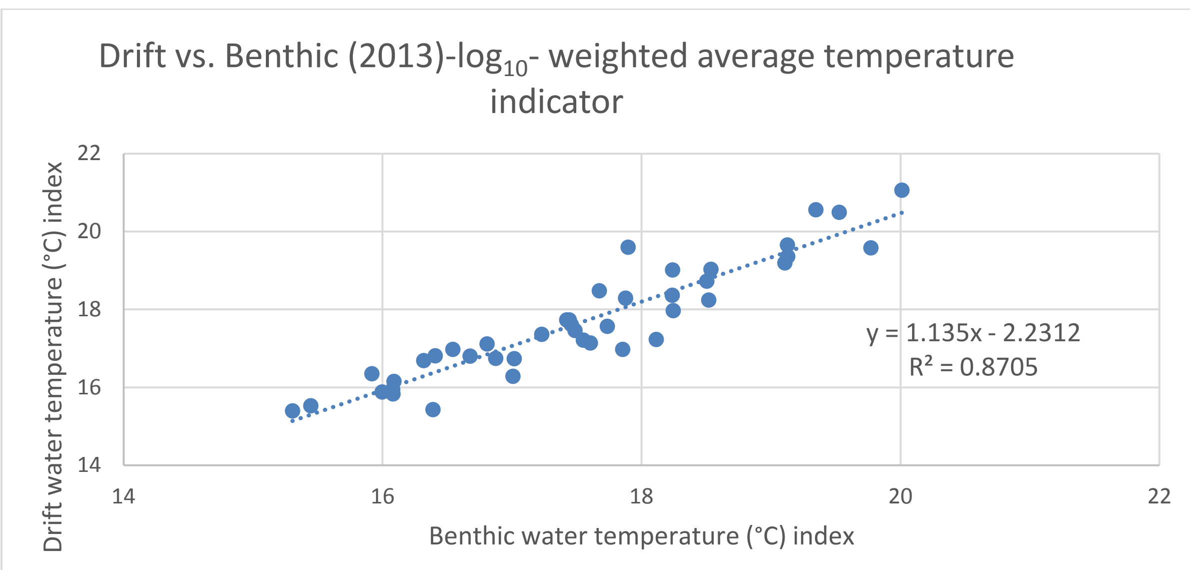


Figure 50. Regression of the drift community water temperature optimum index ($\log_{10}$-weighted by abundance) vs. benthic community water temperature optimum index ($\log_{10}$-weighted by abundance) for 2013 CHaMP sites having both drift and benthic samples.

Life Cycle Model

We fit the model to juvenile and adult abundances and in-river survival and SARs by minimizing a negative log likelihood function. We obtained 1,000 samples of each estimated parameter from the MCMC posterior chains, and used those to simulate the ATE scenarios, which are shown in Figure 51, Figure 52, and Figure 53. We see the predicted increase in long-term average predicted abundance $\bar{R}$ at simulated levels of productivity, capacity, and relative to historical PITPH. Naturally, as productivity increases, predicted abundance increases. Carrying capacities determine the upper bound of the predicted range, so each population has the potential to increase in relation to the magnitude of productivity, but only so much as it is limited by capacity. Because the variability in the posteriors of each parameter carries through to predicted abundance, there is a range of variability around $\bar{R}$. The solid line represents the median predicted value of $\bar{R}$. Boxes represent the range between the 0.25 and 0.75 quantiles, and whiskers represent the outer 0.10 and 0.90 quantile ranges. The shaded regions represent the 95% probability region of the posterior densities of productivity and capacity, i.e., the statistically inferred range of the estimate of the parameter value from the MCMC simulations. The wider the shaded area is, the less certain the statistical estimate of the parameter value, possibly because the value is trending upward or downward, forcing the MCMC algorithm to map out the full range of the trend, or possibly because of random noise. There are noticeable differences among populations in both the magnitudes of predicted $\bar{R}$, and the amount of variability around the prediction.

In all three populations, we can see that there is a predicted increase in $\bar{R}$ if productivity is increased, but in some cases, an increase in productivity would mean increasing smolts per spawner to values where the predicted $\bar{R}$ would be approaching the range where density dependence seems to be affecting potential smolt production. The shaded region of the Minam population falls on the region of predicted $\bar{R}$ where density limitation is fairly pronounced, whereas the Grande Ronde shaded area productivity falls in the region where density dependent limitation is less pronounced (i.e., current abundances are not nearing capacity).

The far right panels of Figure 51-Figure 53 show the predicted increase in $\bar{R}$ at each simulated level of reduced PITPH. Here PITPH=1.0 means simulation at precisely the yearly historical values of PITPH. PITPH=0.5 means simulation at 50% of yearly historical values. Because survival through the mainstem is not modeled as a density dependent process, and because mainstem survival occurs after smolt production, the predicted increases in abundance from reducing the value of PITPH translate to linear increases in abundance. Because the populations all have different estimated productivities and capacities in the tributaries, the predicted increases in $\bar{R}$ are correspondingly different in magnitude. As we would expect, populations with high productivities and capacities would benefit the most from changes to PITPH. For perspective, the net change in $\bar{R}$ for a 50% reduction in annual historical PITPH would translate to around 75%, 150%, and 50% improvements in $\bar{R}$ for Catherine Creek, Grande Ronde, and Minam populations, respectively.

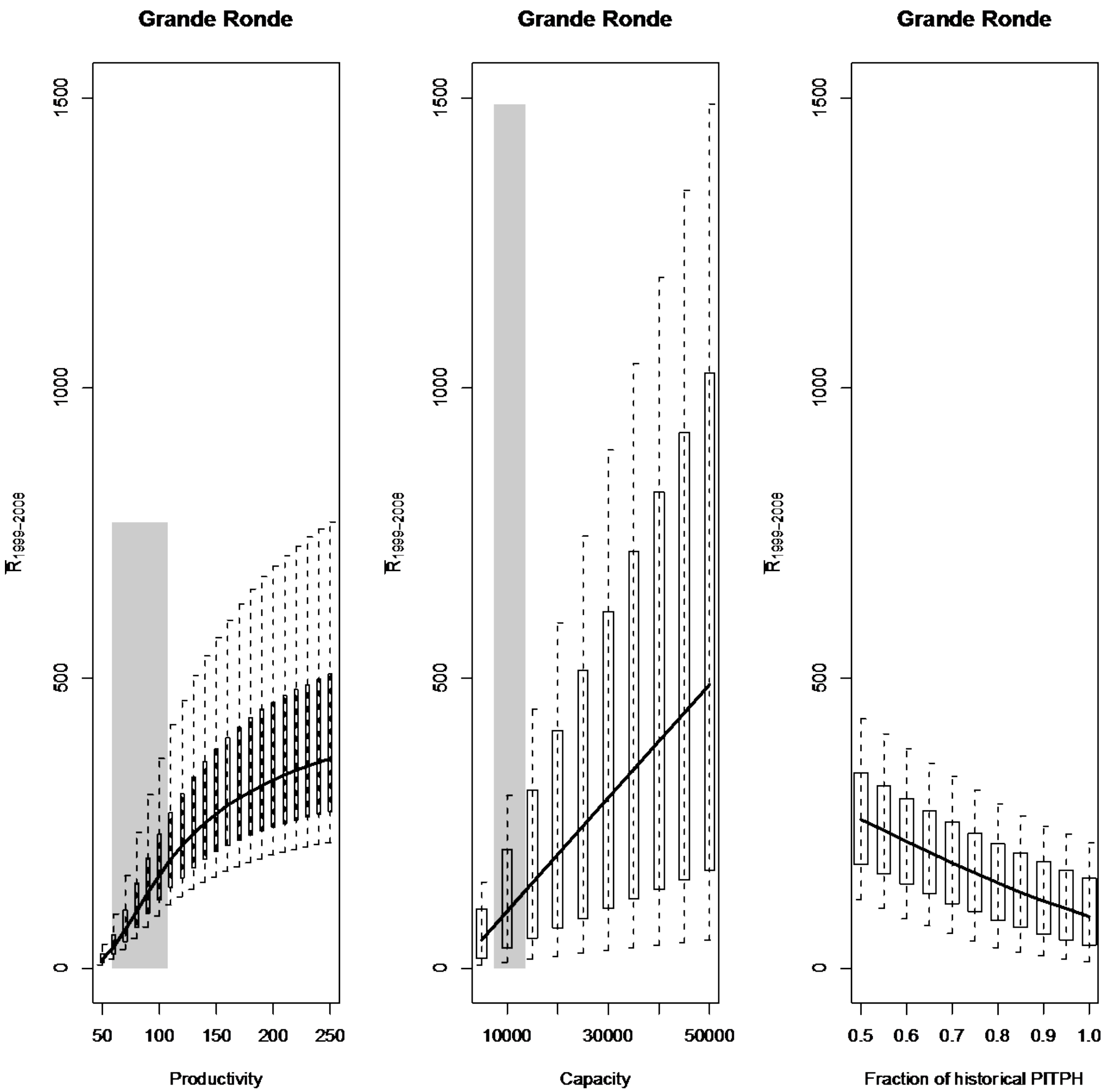


Figure 51. Alternative treatment evaluation of the Upper Grande Ronde. Shaded regions of productivity and capacity represent the 95% probability intervals of the estimated parameters.

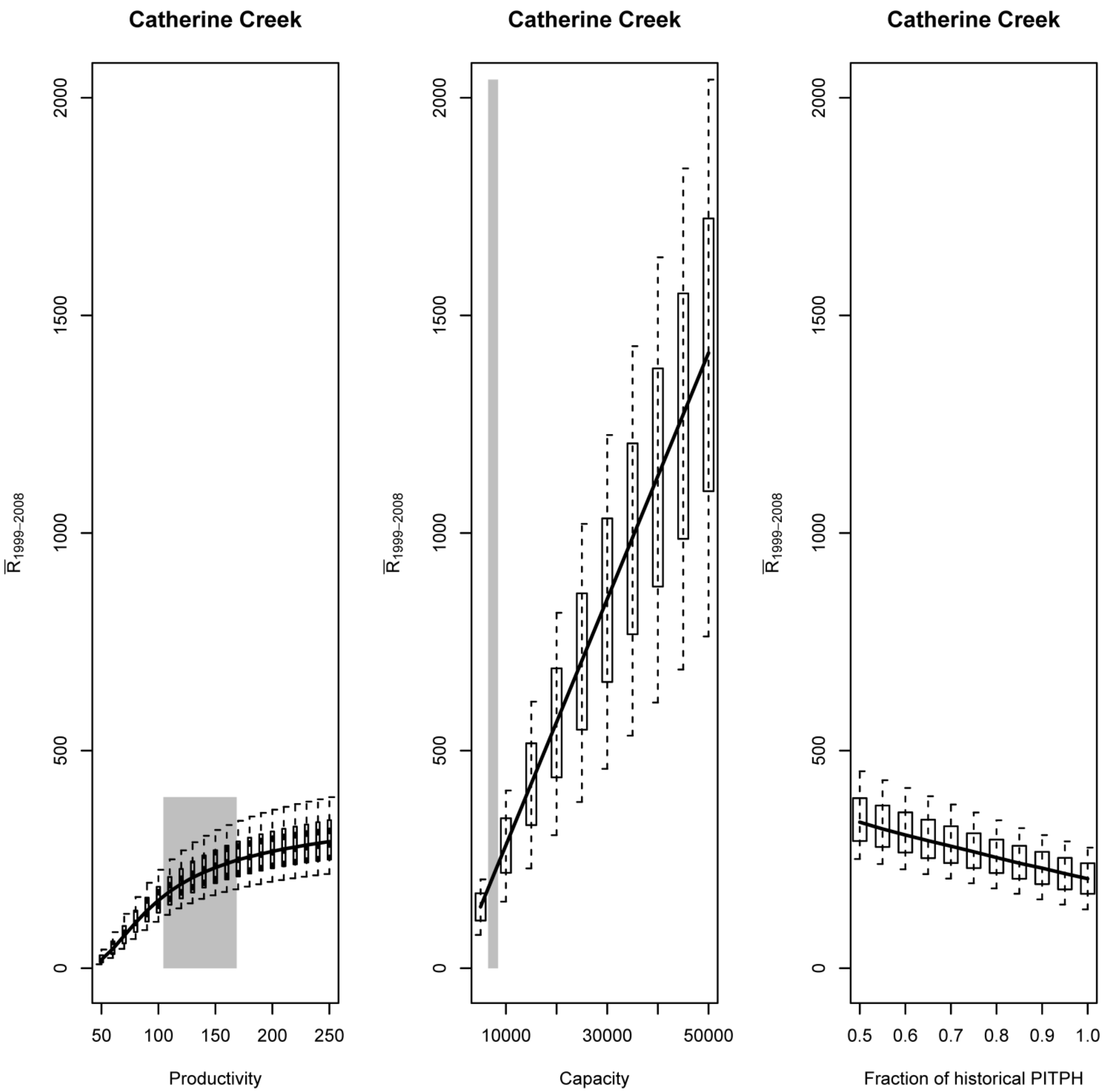


Figure 52. Alternative treatment evaluation of Catherine Creek. Shaded regions of productivity and capacity represent the 95% probability intervals of the estimated parameters.

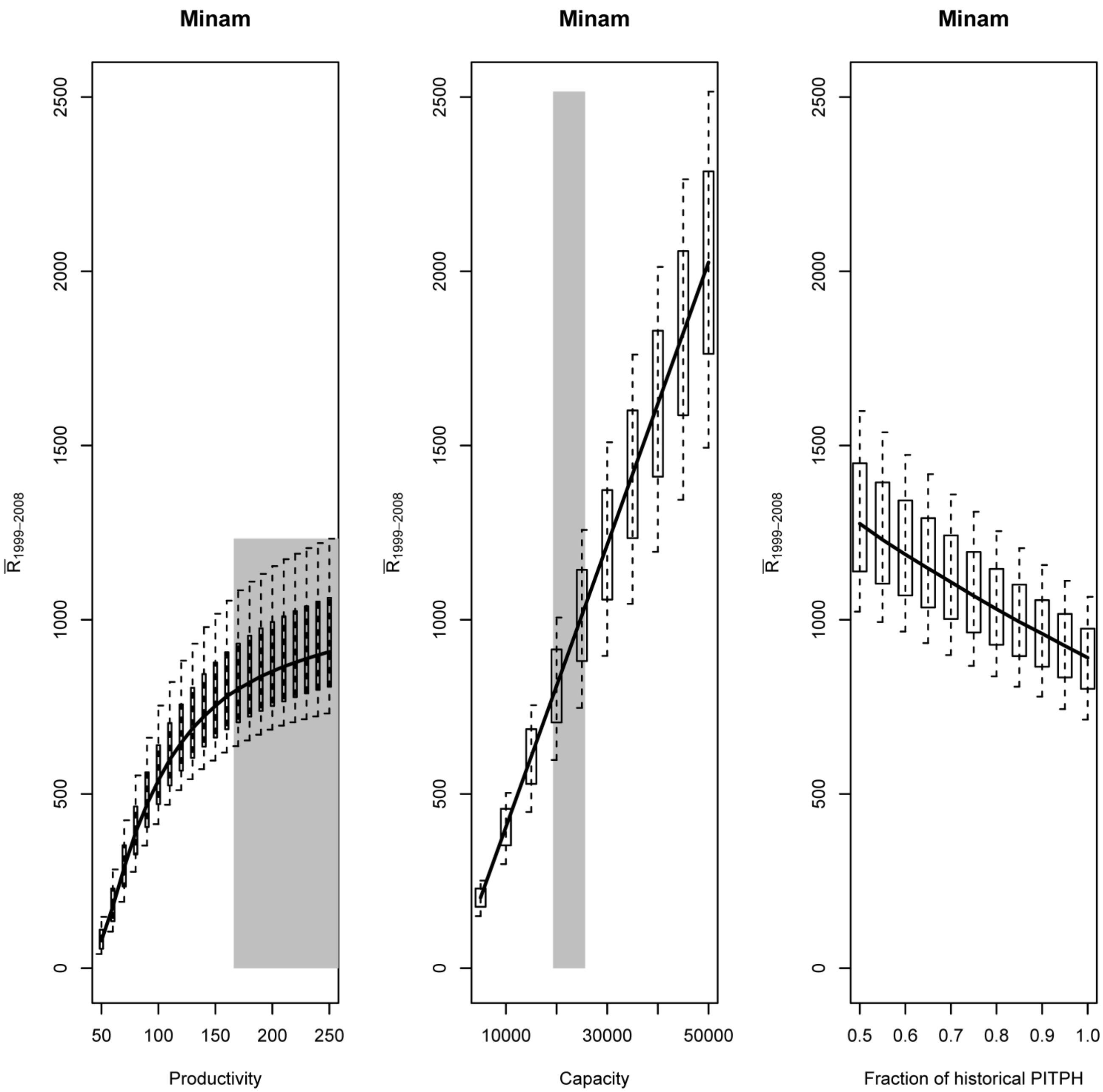


Figure 53. Alternative treatment evaluation of the Minam River. Shaded regions of productivity and capacity represent the 95% probability intervals of the estimated parameters.

Dissemination of Project Findings

Presentations

Co-authorship of student poster on compiling restoration information at River Restoration Northwest annual meeting, Skamania, WA.

Co-authorship of student poster on validating rapid fish assessments at American Indian Science and Engineering Society (AISES) meeting, Pheonix, AZ.

Justice, C., S. White, D. McCullough, M. Blanchard. 2015. Modeling relationships between CHaMP metrics and landscape characteristics in the Upper Grande Ronde River Basin. Oral presentation at the Columbia Habitat Monitoring Program (CHaMP) Advanced Training Workshop, Cove, OR.

Abstract: We analyzed the relationship of three important fish habitat metrics (fine sediment, large woody debris, and pool area) with landscape/land use characteristics in the Grande Ronde River basin with the objective of extrapolating site-level habitat data from CHaMP surveys to a larger spatial scale that would be more useful for life cycle modeling. We used both mixed-effects models and spatial statistical network models to fit relationships between CHaMP habitat metrics and landscape/land use data derived from remote sensing. The best fitting mixed-effects model for large woody debris (LWD) frequency included the explanatory variables elevation (positive effect), bankfull width (negative effect), and tree cover (positive effect), and together explained approximately 90% of the variation in LWD. The top model for percentage pool area included elevation (positive effect), valley width index (positive effect), watershed area (negative effect), slope (negative effect), and large woody debris frequency (positive effect) as explanatory variables, together explaining 88% of the variation in pools. In contrast with LWD frequency and percentage pools, the best fitting model for pool tail fines <2 mm was relatively weak ($r^2 = 0.44$). Despite statistically significant effects of elevation, valley width index, road density, and drainage density, this model was not a reliable predictor of fine sediment in pool tails. Spatial statistical network models showed promise for predicting LWD frequency as a function of landscape/land use characteristics and position in the watershed, but did not compare favorably with mixed-effects models for fine sediment or pool area metrics. These models will be used to predict habitat conditions at unsampled prediction points spaced every 500 m across the stream network. Prediction sites will then be rolled up using block kriging or simple averaging to calculate average habitat conditions at the scale of Biologically Significant Reaches (BSRs), the spatial unit used in our life cycle model.

McHugh, P.A., Blanchard, M., Bouwes, N., Justice, C., White, S., and McCullough D. 2015. Using Spatial Autocorrelation to Improve Network Scale Models of Salmonid Abundance. Oral presentation to the American Fisheries Society Annual Meeting, Portland, OR.

Abstract: Salmonids respond to physical habitat and stream temperatures at multiple spatial scales. At a network scale, these habitat characteristics can vary greatly among tributaries, across property ownership boundaries, and among various landscape settings. Physical properties in conjunction

with biological factors, such as spawning density, dictate spatial structure of a population, the degree to which fish populations are independent from one another. In an effort to model salmonid abundance we employed spatial stream network models (SSNM) to leverage spatial autocorrelation of fish populations across two watersheds, the Middle Fork John Day River and the Grande Ronde River. Both basins originate in the Blue Mountains of eastern Oregon and offer an opportunity to explore fish-habitat relationships and patterns of spatial autocorrelation among neighboring systems. Our models utilized empirical habitat metrics and temperature data in addition to spatial structure to model abundance of juvenile salmonids in these basins. By incorporating spatial autocorrelation into our models of salmonid populations we improved our ability to model fish abundance. We also found that observed physical differences among the tributaries and mainstem rivers along with the wide range of thermal regimes present in the watersheds led to strong spatial patterns that set the framework for population response.

Puls, A., White, S.M., Bellmore, R., Danehy. R. 2015. Introduction to the food web symposium: bringing food web ecology to fish habitat monitoring programs. American Fisheries Society National Meeting, Portland, Oregon.

Abstract: This presentation describes the impetus for the “Moving Beyond Water Quality Indices: How Can Macroinvertebrate Data from Fish Habitat Monitoring Programs Inform Food Web Analyses?” symposium. A Pacific Northwest Aquatic Monitoring Partnership (PNAMP) work group comprised of participants from federal, state, local, and tribal agencies and private consultants has been working on standardization of aquatic macroinvertebrate protocols and data sharing since 2007. At an Oregon Chapter AFS meeting in 2013, we addressed how benthic and drift macroinvertebrate data can be better employed to describe fish habitat quality. Speakers described useful approaches such as indices of biotic integrity (IBIs), observed/expected approaches (e.g., RIVPACS), and composition of ecological guilds (e.g., functional feeding groups). However, a strong recommendation from the symposium was to forge direct linkages between aquatic macroinvertebrates and fish productivity. The current symposium explores this topic by convening experts in food web ecology, especially those employing benthic and/or drift aquatic invertebrate data, to describe the food base for fish. Our goal is to bring relevant concepts from food web ecology to land managers, restoration practitioners, or other non-food web ecologists who desire to integrate food webs into their research or monitoring programs.

White, S.M., Justice, C., McCullough, D., Blanchard, M., Sedell, T., and Benge, G. 2015. Testing hypotheses and predicting fish rearing capacity under restoration and land use scenarios using structural equation modeling. Invited speaker. American Fisheries Society National Meeting, Portland, Oregon.

Abstract: Structural equation modeling (SEM) is a statistical tool based on path analysis that accounts for both direct and indirect effects of interrelated predictor variables. Moreover, SEM is a powerful instrument for developing and testing hypotheses about the causal pathways leading to increased benefit or degradation of conditions for a species of concern. This latter feature of SEM allows the researcher to use knowledge gleaned from discussions with local agency biologists or

direct observations of the system under study. We demonstrate the use of SEM for hypothesis generation and prediction of land use and restoration activities leading to change in juvenile spring Chinook Salmon densities in the upper Grande Ronde River, Catherine Creek, and the Minam River (a reference wilderness stream) in the Blue Mountains of NE Oregon. We build on earlier models linking direct and indirect effects of large wood in the stream channel, pool frequencies, and fish rearing densities to include new data on restoration intensity and land use conditions within various riparian buffer distances laterally and longitudinally along the stream network. Finally, we discuss how SEM can complement data mining or machine learning approaches to exploring relationships in large datasets by providing a priori ecological understanding.

White, S.M. 2015. Unraveling the influence of multiple human pressures on aquatic communities in the Columbia River basin. University of Life Sciences and Natural Resources, Vienna, Austria.

White, S.M. 2015. Led field module at annual CHaMP training, Cove, OR: "Determining the influence of land use on stream habitat: Lessons learned (and not learned) from the Catherine Creek studies, 1995-1998."

White, S.M. 2015. Workshop: Structural equation modeling of fish-habitat relationships. Advanced Trainer Workshop, Columbia River Habitat Monitoring Program, Cove, Oregon.

Publications

Benge, G. 2016. Mapping tributary habitat restoration projects in the upper Grande Ronde River to support landscape analysis. Report for the Environmental Sciences Graduate Program, Oregon State University, Corvallis, Oregon. (Appendix D)

Kelly, V.J. and White, S.M. 2016. A method for characterizing late-season low-flow regime in the Upper Grande Ronde basin. U.S. Geological Survey Waters Science Center Report, Portland, Oregon. (Appendix E)

Wells, A. F., E. Crowe, and R. Blaha. 2015. Riparian vegetation mapping in the Grande Ronde watershed, Oregon: monitoring and validation of spring Chinook habitat recovery and population viability. Page 183. Prepared for Columbia River Inter-Tribal Fish Commission. ABR, Inc.-Environmental Research & Services, Anchorage, AK.

Draft journal articles

Justice, C., S. White, D. McCullough, D. Graves, M. Blanchard. (In preparation). Simulating water temperature and fish response to riparian restoration and climate change in the Upper Grande Ronde River. Intended for *Environmental Management.*

Abstract: We used the Heat Source water temperature model to investigate potential thermal benefits of riparian reforestation and channel narrowing to Chinook Salmon populations in the Upper Grande Ronde River. Legacy land use practices in the basin have significantly reduced streamside vegetation and increased channel width-to-depth ratios across most of the salmon-

bearing portion of the watershed, resulting in water temperatures that far exceed the optimal range for growth and survival of salmonid populations. By combining restoration scenarios with climate change projections, we were able to evaluate whether future climate impacts could be offset by restoration actions. A combination of riparian restoration and channel narrowing was estimated to reduce median water temperatures by 6.5 °C in the Upper Grande Ronde Basin and 3.4 °C in Catherine Creek. Using a statistical model developed from snorkel survey and habitat data from the Grande Ronde basin, these results translated to increases in Chinook summer parr abundance of 517 and 74 % respectively. Although projected climate change impacts on water temperature for the 2080s time period were substantial (i.e., median increase of 2.8 °C in the Upper Grande Ronde, and 1.8 °C in Catherine Creek), we estimated that basin-wide restoration of both riparian vegetation and channel width could offset these impacts, reducing water temperatures by about 3.6 °C in the Upper Grande Ronde and 2.1 °C in Catherine Creek. Understanding how stream temperature responds to restoration of riparian vegetation, channel morphology and climate change is critical to restoration planners and natural resource managers seeking to prioritize restoration actions and restore imperiled salmonid populations.

White, S.M., Justice, C., McCullough, D., Blanchard, M., and Sedell, T. (In preparation). The deep history of deep pool habitats with consequences to rearing juvenile Chinook Salmon. Intended for *Ecological Applications.*

White, S.M., Justice, C., Kelsey, D., and McCullough, D. (In preparation). Every moment a window on all time: using the past as a guide for restoring watersheds. Invited article to special issue of *Elementa: Science of the Anthropocene.*

White, S.M., McHugh, P., Naman, S., Baxter, C., Bellmore, R., Naiman. R., and Danehy, R. (In preparation). Integrating food web perspecties into riverine fish conservation and management: a practical guide. Intended for *Fisheries*.

Discussion/Conclusions

Stream Habitat

CHaMP Data Collection

This year marks the completion of fifth years of habitat data collection using the CHaMP protocol. Use of this protocol has not only provided repeatable and region-wide coordinated methods for habitat surveying, but has also strengthened CRITFC's communication and participation with groups around the Columbia River basin. Summaries of selected CHaMP metrics from 2011-2015 revealed substantial variability in habitat conditions across the three subbasins, Grande Ronde River, Catherine Creek, and Minam River, as well as across Biologically Significant Reach (BSR) boundaries (Table 4). Our data summary also indicated a wide range in the number of sites present within each BSR. This uneven distribution of sites across BSRs has motivated the use of a valley setting classification to extrapolate habitat metrics based on the proportion of valley settings classes in each BSR.

The valley setting classes, based on both stream confinement and bankfull width, demonstrated distinct differences in metrics based on comparing floodplain/constrained classes (bankfull width > 8 m) to mountain classes (bankfull width < 8 m). Large woody debris frequency and percent slow water were two variables that were largely split by the stream size distinctions of floodplain/constrained and mountain. The mountain valley classes had higher percent slow water and higher frequency of large wood. Within the two broad valley classes, mountain and floodplain/constrained, there were observed trends as well. As confinement within the two classes decreased, LWD frequency decreased while temperatures increased. These treads were observed regardless of stream size and indicate the transition from headwater streams to valley streams across the Grande Ronde basin. This transition reflects both topography changes and land used changes. Typically the more confined sites, with higher frequency of LWD and cooler temperatures, were located in the steeper higher elevations parts of the watershed, such as the smaller tributaries in the upper Grande Ronde system, the Catherine Creek forks, and much of the Minam River drainage. Whereas the less confined sites were located in wider valley sections of streams that have more gradual slopes and are often more heavily impacted by current land use practices. These valley class based trends and distinctions support future efforts to use these classifications to extrapolate habitat metrics to un-sampled reaches of rivers.

In utilizing valley setting classifications for extrapolation within BSRs we will be able to leverage higher numbers of sites surveyed within each class. This will overcome the limitations of having very low densities of sites in many of the BSRs. The valley setting classes will allow us to more accurately estimate average habitat conditions within each BSR, which will provide a useful spatial unit to concentrate life cycle modeling and restoration and management planning. As surveying continues over the next four years of the study, we will build on our ability to use CHaMP data in modeling efforts. CRITFC analyses, including landscape/land use metric modeling, structural equation modeling, and life cycle modeling, all depend heavily on CHaMP habitat metrics as important inputs to the assessment of habitat status and trends across the three basins.

The initial trend analysis is preliminary and only based on a five year period for the Grande Ronde and Catherine Creek subbasin and only three years in the Minam. However, it does highlight some important patterns (Table 5). Of the six metrics summaries, LWD frequency had the most variability over the five year period. At the ICTRT population extent both Catherine Creek and the Minam River populations had negatively trending LDW frequencies. At a finer spatial extent, BSRs revealed a patchier pattern. Half the BSRs in Catherine Creek did not have a significant trend, while there were both negative and positive trends in the Grande Ronde subbasin in over half the BSRs. Valley setting classes also displayed trends in both directions supporting the need to look at watershed properties at finer resolutions. Both temperature metrics also displayed significant trends at the BSR and valley setting extents. The majority of temperature trends were positive, but several were negative, highlighting the heterogeneous nature of temperature across a landscape. While, LWD frequencies and temperature displayed change over the five year period, percent fines and percent slow water were very stable and display little to no trends across spatial scales. Residual pool depth displayed significant trends at all three spatial extents but change in this metric was not common. Identifying the metrics that have experienced the most detectible change over the study timeframe is an important initial finding. While only based off of five years at this point, future surveys we will be able to increase our confidence in trend direct and magnitude. This will help us to focus restoration attention to specific reaches and further our understanding of processes at work shaping stream habitat.

The Catherine Creek and Grande Ronde subbasins continue to show some stream temperature heterogeneity in response to summer temperatures and flow conditions (Table 6). This year saw record low snow packs and subsequently low stream flow conditions throughout the state (NRCS 2015). Observed stream temperatures from 2015 monitoring efforts show that the South Fork Catherine Creek site reach its highest temperatures over the past five years, while the two Grande Ronde subbasin sites had slightly more moderate temperatures, below those recorded in 2013 and 2014. Part of the difference in the response between the two subbasins could be related to the relative influence of seasonal snow melt. Even with the 2015 temperatures, the South Fork Catherine Creek, which drains higher elevation mountains, remained below the 7dAM 18˚C threshold for beneficial use for rearing juvenile salmonids (Sturdevant 2008). However, other reaches lower in the Catherine Creek subbasin do exceeded the beneficial use thresholds for both juvenile rearing and migration corridors for adults (7dAM 20˚C). Likewise, many reaches within the Grande Ronde exceeded the both thresholds for the entire summer period. At these levels, temperature restrict access to large segments of the basin and results in high stress conditions affecting both survival and growth. These observations support the need for future restoration and modeling efforts to maximize improvements in temperature regimes across the lower reaches of both subbasins.

Subsurface Fine Sediments

Most survey sites in the Upper Grande Ronde and Catherine Creek had fine sediment concentrations below what might be considered a critical threshold level for survival of incubating eggs. In a laboratory study of Chinook egg survival relative to fine sediment conducted by Tappel and Bjornn (1983), egg survival remained very high (i.e., 96%) until the fraction of fine sediment < 6.35 mm exceeded approximately 30%, after which, survival declined rapidly, approaching 0 at about 60% fines. Median

values for fine sediment < 6.35 mm were 27.7%, 27.1%, and 33.2% in CC, MN, and GR, respectively, based on a total of 15, 9, and 15 samples, respectively, taken across the timespan from 2010 through 2013. Average percentage fines < 6.35 mm were 26.0%, 28.6&, and 32.5%, respectively. Based on either median or average percentage fines (< 6.35 mm), it can be assumed that fine sediment represents an impairment to survival to emergence of spring chinook eggs, although probably small. In addition, if the Minam River is considered to be a reference condition for percentage fines, the absolute difference is very small between that and the mainstem Grande Ronde or Catherine Creek. Based on the low gradient conditions found in Meadow Creek, it appears unusual that the average percentage fines (< 6.35 m) was only 25.3%. This was an average for four sites having a total of 5 samples. West Chicken exhibited a substantially greater concentration of fines (44.1%, < 6.35 mm), but the single year and site sampled makes this a condition that needs greater sampling to determine accurately.

Although it appears that fine sediment concentrations may not be so high as to cause significant impairment in survival to emergence of spring chinook alevins, we recommend various future research actions in response to our current findings:

1) Monitor percentage fines at spawning gravel depth using a McNeil sampler at intervals in the future. This is recommended after significant peak flows that might incorporate surface fines into subsurface materials. It is also recommended to be done every 5 years at a minimum to follow trends in this important physical indicator of survival response.
2) Monitor percentage fines with a McNeil core sampler every 5 years in selected annual sites that are also important spawning sites (e.g., channel gradients are low and substrate materials have d_{50} and d_{90} values conducive to spawning). Repeated measures at the same site are important in assessing trends in fines known to control survival.
3) Improve the assessment of key measures of surface fine sediment to allow generation of values not subject to algal growth.
4) Assess IGDO in relation to both McNeil fines and surface fines. Assess percentage of organic matter incorporated into fine sediment or gravel less than 65 mm diameter.
5) Assess trends in percentage spawning area and percentage pool area or pool volume. It is possible that increases in percentage fines from land surface disturbance (e.g., roads, grazing, forestry) could lead to pool infilling (observed in terms of change in residual pool depth, pool frequency, pool area) and reduction in spawnable area. Measurement of fines within only patches of substrate providing spawning opportunity could bias results of fines assessments toward levels that would support high quality spawning. Spawnable area would be the combination of pool tailout area and area of spawning patches within riffles. Means should be sought to use RBT to evaluate changes in area meeting these characteristics. Usable spawning area is created from stream reaches with suitable substrate size, water velocity, and depth. These factors are also linked to channel gradient. Within a given inherent, water surface gradient expressed over an entire CHaMP site, the distribution of gradients within channel units can be created by distribution of LWD, which creates gradient breaks and zones of sediment substrate sorting.

Measurements of fine sediment (<6 mm and <2 mm) in spawning gravels or changes in substrate composition throughout the reach are linked to subsurface fine sediments. The significant relationships that were found between subsurface fine sediment and surface fines justifies continued measurement of surface fines using CHaMP methodology as a surrogate for the more time consuming McNeil core method. However, taking samples with the McNeil core device is the gold standard for expressing conditions that reflect chinook survival to emergence. When surface fines are high year after year due to the general level of watershed activity and also intrinsic factors, there is a likelihood that fines will infiltrate into streambed substrate or become mixed at depth during infrequent bed-disturbing flows. Surface fines concentrations do exhibit a significant relationship with subsurface fines, but there is a high degree of scatter, indicating a high level of annual variation. In addition, given our experience collecting surface fines data with the various methods available in CHaMP, it appears that much of the annual variation in surface fines measures of a stream site or longitudinal variation within a site could be attributable to methodological difficulties in collecting data in a consistent manner. For example, as water velocities decline and flocculent organic matter collects on pebbles in pool tails, there is increasing difficulty in assessing whether the native streambed has fines or not. Alleviating these problems is likely able to bring about greater recognizable correspondence between surface and subsurface measures of fines.

Watershed Grazing Intensity

Average potential grazing intensity was calculated based on a variety of factors for each of the watersheds contributing to CHaMP study sites from 2011 through 2014. Grazing capacity was taken to be a function of distance to water for a cow and cattle preferences for hillslope gradient and the maximum gradient slope that is grazed. Land cover was evaluated to determine the ability of the land surface to be disturbed by grazing. Land that was designated for uses such as urban development, agricultural use (cultivated fields), open water, rock, ice, or other surfaces not conducive to grazing were attributed with a zero capacity for grazing. In addition, land ownership was a management overlay that also determined whether a plot was allowed to be grazed or not. On a pixel basis (30 x 30-m area in a DEM), land cover with no grazing potential or land ownership that denied grazing was attributed with a zero (0) for grazing. Land cover or ownership that allowed grazing was attributed with a value of one (1). The values for each pixel within the study basins was defined by a raster that represented the product of grazing potentials from distance to water, hillslope gradient, land cover, and land ownership values. AUMs/pixel were calculated for each pixel based on the pixel's potential grazing capacity using the actual AUMs assigned to USFS grazing allotments that had a known distribution of grazing potential.

Grazing intensity (AUMs/ha) calculated for each CHaMP watershed provides a metric that can be used as an index of land disturbance. This index can be used to evaluate the relationship to fine surface sediment in CHaMP study sites or the condition of riparian vegetative cover. It is not feasible to infer that a high grazing intensity as a watershed-wide average would be related to riparian vegetation cover in all cases because the influence of fences was not accounted for in distance from grazing areas to the nearest stream. However, on private land grazing, there is a higher likelihood that no fences exist within the private land separating cattle from the stream and riparian zone.

It was found that the range of mean annual precipitation for the Catherine Creek mainstem was 37.4 to 43.4 inches/year. The upper Grande Ronde mainstem, on the other hand had mean annual precipitation ranging from 26.1 to 34.1 inches/year. It is clear that mean annual precipitation increases with elevation and it would be necessary to calculate values on the basis of a pixel rather than averaged for an entire watershed above each CHaMP site to determine the site specific impact of grazing intensity (AUM/ha or AUM/pixel) on small land surfaces. Basin-wide averages also hide the local high intensity grazing impacts that may contribute to damage in localized stream sites. Because we now have a raster with grazing intensity, we can now assess the potential grazing impacts on riparian corridors or the local side slopes (reach contributing areas). The data on location of fences that is available from the USFS geodatabase may help somewhat in assessing potential cattle damage, but fence maps are not available on private lands.

It is recommended that in the next year we explore the relationship between average watershed grazing intensity or AUM/pixel (finer scale resolution of grazing intensity) and land surface condition. Land surface condition can be evaluated by a number of remote sensing techniques. Among these techniques is the NDVI imagery for land surfaces that are available in a time series from MODIS satellites. Land surfaces that have a high potential for supporting high cattle densities would have a higher probability of becoming depleted in vegetation early in the season. This depends also on other environmental characteristics such as soil water holding potential, aspect, and mean annual precipitation for the pixel. Low elevation, low gradient slopes that are close to water and have lower levels of mean annual precipitation would be more likely to suffer surface damage from grazing than low gradient slopes close to water at high elevation and with higher mean annual precipitation. Modeling sediment delivery potential from grazing will likely require more thought given that steep slopes near water are more likely to deliver fine sediment to streams if they receive the same level of surface impact from grazing.

Efforts made here to identify grazing intensity on a watershed level, or in future work to calculate grazing intensity within riparian areas (adjacent to CHaMP sites or in the riparian zone within 2 km of the top of site) are intended to provide a quantitative measure of watershed disturbance. It is common in published reports on fish-habitat relationships to explain statistically the relationship between various habitat condition metrics and land use or watershed condition. Most often this takes the form of rating watershed disturbance as high, medium, or low. This is a highly subjective attempt to integrate all forms of anthropogenic impact. It may serve to classify in-stream habitat responses but is relatively insensitive to level of impact.

We have previously reported on progress made in developing other measures of watershed disturbance, both anthropogenic and inherent. In addition to measures of grazing intensity, we have reported on or been working on:

1) Calculation of the percentage forest loss and gain from 2000 through 2013. This uses remote sensing data collected annually from LANDSAT satellites and interpreted using methods of Hansen et al. 2013.
2) Estimation of percentage bare earth, using NAIP imagery and GIS techniques to differentiate forest cover, grassland cover, and bare earth.

3) Calculation of road density at watershed, CHaMP site and adjacent riparian zone, and contributing upstream riparian zone scales. The road network was mapped by merging USFS and Tiger road layers, retaining all road metadata where present, and digitizing by hand the roads that were not mapped by either standard source. This demonstrated that there is a high percentage of roads in study watersheds that was not previously mapped that contributes to the high background level of sediment delivery to streams.
4) The road network was subdivided into 100-m segments, each of which was attributed with the adjacent land surface slope and tree cover. Roads cutting across steep hillslopes create cutslopes and fillslopes that generate fine sediment to be carried to streams. At present this analysis exists as an index to the slope erosion potential. However, with the advent of the GRAIP erosion and sediment delivery model, the same information developed in our existing road mapping and association with adjacent forest cover and hillslope gradient can be used with the GRAIP model to actually predict sediment delivery to the nearest streams.
5) We have already used available NLCD land cover maps to calculate a variety of land cover metrics. For example, knowing what percentage of a watershed's area is involved in cultivated agriculture provides a measure of disturbance. Area that is forested vs. rangeland or other measures of cover (e.g., percentage bare earth) provides some measure of erosion potential. NLCD data also can be used to indicate trends in land cover by using cover change metrics. Conversion of forest to farmland would increase the background level of soil erosion. This loss of forest cover would also be reflected in the Hansen global forest change database (which has a higher resolution), but NLCD cover trends extend back to 1992.
6) We have explored the use of MODIS satellite data to examine variations in land surface greenness index to assess vegetation phenology trends. MODIS provides a large number of NDVI indices that have been corrected for variations in atmospheric conditions (e.g., haze, cloudiness). The NDVI (TIN) dataset provides a cumulative NDVI value that represents the entire growing season. It is expected that land uses that alter surface greenness, such as heavy grazing through the summer would alter vegetative phenology, species composition, and plant health in ways that would exacerbate soil erosion. These remote sensing methods provide a multi-year time series that would allow past grazing history to be evaluated or inferred from comparisons of grazed vs. ungrazed plots, accounting for annual variations in mean annual precipitation.
7) LiDAR data produced for CRITFC by Watershed Sciences, Inc. (now Quantum Spatial) were used to compute tree height and cover by watershed. Changes in these values with time will indicate impacts to or restoration of riparian cover.
8) NLCD tree cover data (30-m pixel resolution) was also used to measure tree cover in riparian buffers. These estimates were compared with LiDAR-derived estimates (1-m pixel resolution), which are considered to be the more accurate measures.
9) We have also worked with LandFire data to generate various watershed condition estimates for all 195 watersheds that are part of the StreamStatsBasins file. LandFire remote sensing data of interest include CH (forest canopy height); EVH (existing vegetation height, which provides the average height of dominant vegetation on a 30-m pixel basis); EVC (existing vegetation cover by lifeform); MFRI (mean fire return interval, which has 22 time bins ranging from 0-5 years to greater than 1000 years); and PRS (percentage of replacement severity fires). We used MFRI by

assuming that a useful measure of watershed disturbance would be return interval of fire that was less than 48 years. MFRI may predominantly be an inherent characteristic of a land surface, but there would undoubtedly be a management influence on this. With a 48-year threshold for return interval, it was found that among the 195 watersheds evaluated, there was a range between 16% and 99% of the watershed area that had vegetation with a return interval of less than 48 years. Obviously, a basin that has nearly 100% of its area having a return fire interval less than 48 years is subject to frequent disturbance and more frequent periods where soils are not protected from erosion.

Water Temperature Modeling

Simulated basin-wide restoration of riparian vegetation was predicted to substantially reduce the proportion of stream habitat that exceeded stressful temperature thresholds for Chinook Salmon (e.g., 20 °C). Similar thermal benefits from riparian restoration have been demonstrated using temperature simulation models in the Grande Ronde Basin (ODEQ 2000, Watanabe *et al.* 2005) and elsewhere in the Pacific Northwest (Bond *et al.* 2015, Butcher *et al.* 2010, Theurer *et al.* 1985). The addition of shade to streams has been cited as one of the most significant controls on stream water heating (Beschta *et al.* 1987). Given the magnitude of known levels of water temperature increase that can be caused by relatively short lengths of riparian clearcutting, causing reduction in shading (e.g., as much as 10 °C increases; Beschta *et al.* 1987), it is not valid to discount the importance of restoring riparian shade as a primary means of improving stream thermal conditions. The work reported here illustrates the value of riparian cover restoration on a stream network basis as a key effort in improving habitat conditions for spring Chinook Salmon and steelhead. But we realize that the benefits of riparian vegetation enhancement extend far beyond direct thermal restoration.

Riparian restoration scenarios indicated that the greatest potential reductions in water temperature occurred in the upper to middle portion of the Upper Grande Ronde River (upstream of Five Points Creek; river km 63.4), particularly in areas that were designated as high and medium priority for restoration. Despite substantial potential cooling benefits from riparian restoration demonstrated by our model, we found that large portions of the stream network, particularly in the lower portion of the basin, would continue to exceed the temperature thresholds set by the EPA of 16 °C for “core” juvenile salmon rearing, and 18 °C for salmon migration and “non-core” juvenile rearing even after restoration of riparian vegetation to its natural potential (Figure 5). One reason for this may be the fact that our model did not account for various other ecological factors that can contribute to cooling such as hyporheic exchange (Beechie *et al.* 2013, Poole and Berman 2001) and flow restoration (Seedang *et al.* 2008). However, it is reasonable to assume that some portions of the Upper Grande Ronde Basin, owing to its arid climate, always had water temperatures that were stressful to salmon, particularly in lower parts of the basin where the river is wide and streamside vegetation is dominated by meadow and shrubland habitats with limited potential tree cover. A similar temperature modeling analysis in the John Day River also found that water temperatures, even after restoration of riparian vegetation, channel morphology and streamflow (i.e., natural thermal potential), were still well above biologically based temperature criteria for salmon across a large portion of the stream network (Butcher *et al.* 2010). The potential for riparian vegetation to cool the stream in the lower portions of the basin is diminished due to the large

water volume (inertia) of large rivers and lower ability of riparian vegetation to shade a significant percentage of the stream surface (Poole and Berman 2001).

Simulated reductions in water temperature resulting from channel narrowing (i.e., decreased width-to-depth ratio) are consistent with similar temperature modeling assessments in the Columbia River Basin (ODEQ 2000, Butcher *et al.* 2010), although these reductions were relatively small compared with the temperature changes associated with riparian restoration (Figure 5). Channel narrowing can cause a reduction in water temperature primarily by reducing the surface area of water exposed to solar radiation (LeBlanc *et al.* 1997, Boyd and Kasper 2003). Channel narrowing is also accompanied by an increase in water depth, which can reduce the amount of energy that penetrates through the water to the stream bed, causing a decrease in streambed conduction (Boyd and Sturdevant 1997). Although their methods were different, the ODEQ also found that channel width reductions provided a relatively small cooling benefit compared with vegetation restoration in the Grande Ronde River (ODEQ 2000). In contrast, Butcher *et al.* (2010) found that simulated reductions in channel width of 30 % provided approximately equivalent reductions in water temperature compared with vegetation restoration in the upper 100 kilometers of the John Day River, and substantially greater reductions than vegetation restoration in the lower 325 km of the river (i.e., approximately 2 °C less than the vegetation scenario). Not surprisingly, a combination of channel width reduction and vegetation restoration yielded the greatest reductions in water temperature compared with current conditions (-6.5 °C in the Upper Grande Ronde and -3.4 °C in Catherine Creek).

Estimated percentage changes in Chinook Salmon parr abundance resulting from restoration of riparian vegetation and channel width generally mirrored the patterns observed in water temperature, although in the opposite direction (i.e., lower water temperature equaled higher fish abundance). Most notably, the predicted relative change in fish abundance was considerably higher in the Grande Ronde Basin compared with Catherine Creek (Figure 9). Potential increases in juvenile fish abundance up to 377 % in the Upper Grande Ronde and 61 % in Catherine Creek resulting from restoration of riparian vegetation are encouraging and highlight the tremendous importance of riparian shade for salmon productivity in the basin, particularly in the Upper Grande Ronde.

Results from our water temperature simulation model indicated that aggressive basin-wide restoration actions targeting both riparian vegetation and channel width could significantly improve water temperature and fish abundance in the Upper Grande Ronde Basin, even in the face of climate change. A combination of riparian restoration and channel narrowing was estimated to reduce median water temperatures by 6.5 °C in the Upper Grande Ronde Basin and 3.4 °C in Catherine Creek. Using a statistical model developed from snorkel survey and habitat data from the Grande Ronde basin, these results translated to increases in Chinook summer parr abundance of 517 and 74 % respectively. Although projected climate change impacts on water temperature for the 2080s time period were substantial (i.e., median increase of 2.8 °C in the Upper Grande Ronde, and 1.8 °C in Catherine Creek), we estimate that basin-wide restoration of both riparian vegetation and channel width could offset these impacts, reducing water temperatures by about 3.6 °C in the Upper Grande Ronde and 2.1 °C in Catherine Creek.

The development of priority areas for riparian restoration could provide a valuable tool for restoration planners and practitioners seeking to improve water temperatures for threatened salmon populations in the Grande Ronde Basin while maximizing the use of limited resources. A restoration prioritization framework that utilizes empirical and modeled data to evaluate effective shade (i.e., how shaded is the stream compared with its natural potential?) and accounts for the proximity to currently used spawning areas (i.e., targeting the most productive areas first) provides an advancement over current methods of restoration planning, which are often opportunistic or based on expert judgement. Although riparian vegetation planting should be considered only one important component of a multifaceted approach to watershed restoration which includes a strong emphasis on restoring natural stream processes (i.e., hydrology, channel morphology, floodplain connectivity, channel complexity), the work reported here illustrates the value of riparian cover restoration on a stream network basis as a key effort in improving habitat conditions for spring Chinook Salmon and steelhead.

A more detailed discussion of our water temperature modeling analysis is provided in Appendix A.

Riparian Mapping

The riparian mapping provided by ABR, Inc. (Aaron Wells, Rich Blaha, and others) and Elizabeth Crowe reveals the current and potential natural vegetation (PNV) for the two study watersheds supporting the Upper Grande Ronde and Catherine Creek listed spring chinook populations (Appendix C). This vegetation mapping covers 100 m on each side of the centerline of the stream network for these watersheds that constitute the historic spawning and rearing habitats and associated riparian (or streamside) habitats and is available at a scale for analysis of 1:5000. PNV mapping did not assume that all human disturbances adjoining the river were irreparable changes to the system. For example, downcutting of stream channels was not considered to be a permanent irretrievable change, but was something that could recover with riparian and floodplain restoration actions, thereby leading to restoration of PNV vegetation. In cases where agricultural developments eliminated or constrained riparian vegetation, it was assumed that these areas could be restored.

Mapping of current and PNV riparian vegetation provide the basis by which CRITFC is able to address key objectives that led to initiating this contract. These maps provide the ability to assess the change in vegetation height and cover from current conditions to the stage of 100-year-old plant communities. Follow-up work completed by C. Justice, in cooperation with Elizabeth Crowe, provided the ability to extend estimates of potential tree growth by species to 200 and 300 years, which would in many cases be considered the mature and old growth communities that would provide the most complete shade.

The maps of current and potential natural vegetation make it feasible to characterize CHaMP sites in terms of vegetation and the other environmental characteristics (e.g., soils, erosion susceptibility, disturbance, precipitation, etc.). Vegetation information (height, plant growth forms, cover, species diversity) can be used to characterize the ability of riparian zones to produce terrestrial macroinvertebrates that would seasonally enter the drift. Riparian vegetation characteristics would permit description of the potential contribution of leaf litter and LWD to the stream channels. The leaf litter would vary in composition and quality depending upon the composition by coniferous or deciduous material. The current and PNV states provide the potential to model the potential

contribution of LWD, using a woody debris recruitment model. CRITFC has not yet explored this possibility, but the riparian maps are an essential precursor to this.

The riparian maps also provide a means of characterizing the likely streambank stability of CHaMP sites, the riparian zone within a given distance upstream of and contributory to CHaMP sites, and the entire riparian network. Rooting strength is related to the degree of cover by various plant species. These characteristics were considered in mapping the erosion potential. Erosion of land surfaces and sediment delivery to stream channels depend upon rooting strength, as well as crown cover at multiple layers in the tree and shrub canopy. These factors provide resistance to bank caving and lateral displacement plus resistance to rainsplash-caused surface particle erosion and particle suspension and transport from floodflow or overland flow on saturated upslope areas.

The riparian maps provide watershed restoration specialists guidance for vegetation restoration. The plant communities that comprise restoration endpoints should be referred to in selection of species to be used in planting. Riparian maps of current and PNV were helpful in modeling water temperatures to recognize stream zones where the greatest differential exists in tree cover and tree height. These restoration opportunities were used to create scenarios for efficient staging of restoration effort to accomplish the most rapid improvement in water temperature with riparian recovery.

Attributes embedded in the riparian maps are available for reclassifying the streamside buffer zone according to features of interest. These features include erosion susceptibility, coniferous vs. deciduous composition, soil classes, and disturbance type.

Historical Ecology for Setting Restoration Targets

In combination with other historical data sources, Government Land Office surveys can provide valuable information on watershed conditions prior to major Euro-American settlement and land use impacts (McAllister 2008). These pre-impact descriptions of watershed conditions are not just interesting in an academic sense, but can provide insights into how watershed conditions have changed over time, what are the major drivers, and how fish and other aquatic life may still be responding to land use legacies (Harding et al. 1998). Government Land Office surveys have mainly been used to describe historical vegetation patterns (e.g., Hanberry, Dey, and He 2012), and have less frequently been used to describe changes to channel morphology as in this study.

Using estimates of channel width from 1880s Government Land Office surveys as compared to present day estimates, we noted significant widening of stream channels in the watersheds impacted by anthropogenic land use (upper Grande Ronde River and Catherine Creek) as opposed to a wilderness stream with less human disturbance (Minam River), where channel widening was absent or minimal. Channel widening has been described as one response of unstable, alluvial stream channels to watershed land use via eroding stream banks and channel incision (Thorne 1998; Simon and Rinaldi 2006). The upper Grande Ronde River and Catherine Creek—alongside other watersheds in the American West—have been subjected to intense periods of numerous types to of land use including removal of beaver, logging and associated activities, railroad and road encroachments, diking, ditching, dredging, sheep ranching, and cattle grazing (Robbins and Wolf 1994; Gildemeister 1998; McIntosh et al. 2000). This cocktail of land use has likely contributed to stream channel simplification in numerous

ways, including channel widening as noted in the present study, but also loss of large pools (McIntosh et al. 2000) that are important refugia for spawning and rearing fish (Torgersen et al. 2006). Channel widening in the wilderness stream (Minam River) was absent or minimal, demonstrating both the validity of our method comparing estimates of historic versus present channel widths and the hypothesis that multiple forms of land use are linked to stream channel simplification.

Channel widening as a proportion to original width was more prevalent in smaller channels (bankfull width < 8 m), especially where the channel was laterally unconfined by hillslopes. This was not surprising, given that laterally unconfined stream channels are zones of deposition and net sediment accumulation (Brierley and Fryirs 2005); any anthropomorphic changes in the upstream watershed would register downstream in these unconfined reaches (Allan 2004). The small value of percent channel width for larger streams (bankfull width < 8 m) could merely be a result of the smaller proportion of change from the large historical width (average value = 16.80 m) to present width (21.12 m) as opposed to the average historic and present widths of small, unconfined streams (2.70 and 8.31 m, respectively). However, small channels that were either partly confined or confined by hillslopes exhibited less overall proportional change in channel widths, indicating that width adjustments were indeed more prevalent in laterally unconfined channels. Restoration activities meant to return channels to their historic dimensions may have a greater impact in small, unconfined channels because those channels are most impaired by land use and have a greater capacity for geomorphic change.

Restoration scenarios involving setting channel widths to their historic values yielded positive results in terms of reducing modeled water temperature—through decreased water surface area vulnerable solar radiation—and increasing modeled juvenile Chinook Salmon abundance—through the positive association observed between fish abundance and cool water temperatures (Appendix A). If aggressive restoration actions were successfully implemented in the upper Grande Ronde River (including both riparian vegetation and channel width restoration), temperatures could be reduced by as much as 3.4 °C below the current temperature even in the face of climate change, but these benefits would be limited to the mid to upper portion of the river above Beaver Creek. Fish abundance could be increased by over 100% even in the face of climate change if both riparian vegetation and channel width are restored to their full potential. These findings represent simplistic models of water temperature and fish abundance; further model development is needed to account for connections to subsurface water (hyporheic zones) for water temperature modeling and incorporating a life cycle perspective in fish models.

Stream Biota

Juvenile Salmonid Abundance

We are attempting to link the above information about physical habitat in the study watersheds to biological response—namely juvenile Chinook Salmon rearing densities and various benthic macroinvertebrate indices (BMIs). See Appendix F for detailed descriptions of the methods used in juvenile abundance estimates. Snorkeling and electrofishing (in collaboration with ODFW) revealed that, as expected, juvenile Chinook densities were typically greater in pool habitat than fast non-turbulent (runs) and fast turbulent habitats (riffles) (Table 12). Added perspective from the 2015 data indicate less

of a declining trend in populations (Figure 31). The Minam River in particular demonstrated an increase in juvenile density with 2015 populations estimates much greater than those from 2013 and 2014. The increase in Minam juvenile fish will be interesting to monitor over the coming years to see whether densities in the first two years of the study were depressed or whether 2015 was an unusually high year.

The data from 2015 also lends a slightly more positive impression of the Catherine Creek and Grande Ronde populations. The populations were both strongest in 2011; however, the Catherine Creek populations appear to be increasing over the past two years, and 2015 estimates in the Grande Ronde look to be holding steady rather than continuing to decline. Overall, 2011 continues to be an unusually year with lower temperatures, high summer flows, and higher juvenile fish densities. The declines in juvenile populations since then could be due to the recent variations in temperature and stream flow along with other local environmental factors. Alternatively (or additionally), juvenile densities could be responding to shifts in returning spawner abundances or out-of-basin factors including ocean and mainstem Snake and Columbia River conditions. Our work in assigning likely causal factors for the declines is in the preliminary stages. In the face of lower stream flows and higher water temperatures, the Minam, our reference watershed, will continue to be an essential comparison to the more impacted watersheds of the Grande Ronde and Catherine Creek. Less impacted streams such as wilderness areas or roadless areas have previously been shown to provide a refuge for salmonid populations during droughts even though productivity can be lower overall due to watershed characteristics intrinsic to those areas (higher elevation, simpler riparian communities, colder water temperature, etc.) (White and Rahel 2008).

Benthic and Drift Macroinvertebrates

Conclusions and Recommendations for Further Work on Macroinvertebrates

1. Macroinvertebrate community analysis represents a useful means of revealing trends in habitat quality, such as water temperature and fine sediment.
2. Metrics of community composition that were explored appear to be sensitive to key environmental conditions in the three study basins
3. There are a large number of additional community metrics that are able to be calculated that may prove even more helpful. These will be explored in the coming years of this study.
4. Many of the data explorations reported on here involved a limited number of years of macroinvertebrate sample collection. As of March 2016 CRITFC has macroinvertebrate data for years 2011-2015. This will likely provide a more robust ability to generate community indices and trends. Also, there will be an enhanced ability to estimate the environmental preferences (e.g., optima, tolerance levels) of dominant taxa with a larger data set.
5. Results of analyses done so far seem to indicate a difficulty in explaining macroinvertebrate community distribution in relation to fine sediment or other substrate indices. There are a variety of explanations for why various CHaMP sediment metrics are unable to reveal significant association with community metrics that are inherent with the methods and the time at which the methods are employed (see report). However, it may also be that the influence of water temperature is so overriding that the additional influence of fine sediment is too small.

6. There are a large number of habitat metrics that vary in a downstream direction that could influence the benthic communities beyond water temperature, fine sediment, elevation, or channel gradient. Benthic samples are taken from riffles, so the habitat characteristics that would affect benthic communities would need to create impacts to riffles. Light, litter inputs, turbidity, and nutrients are important habitat components that could alter the benthic communities significantly. Riparian vegetation communities, riparian vegetation cover by trees, shrubs, and vegetative ground cover, light incidence (result of canopy cover, stream orientation and width, topographic shading), and water chemistry (alkalinity, conductivity) all set important conditions that specify potential aquatic productivity and composition. Potential food sources for study sites in relation to water temperature control community composition. This would be reflected in terms of functional feeding group variations. The influence of these and other CHaMP metrics on benthic community composition should be explored next. Multivariate statistics will be employed to reveal the influence of multiple environmental characteristics on community composition (e.g., non-metric multidimensional scaling or NMDS).
7. Results to date have shown that the thermal optimum value integrated for the entire benthic and drift communities are highly correlated. This provides evidence that drift taxa and drift abundances by taxon are tightly linked to the benthic community composition and abundances by taxon. Also, it is probable that average drift distance is short; if the drift community sampled in CHaMP sites actually reflected the communities from kilometers upstream, then the drift integrated thermal optima would differ significantly from that of the benthic community.
8. There appear to be relationships between the density of taxa in the drift and the benthos. This was explored for a single year. It will be important to conduct this analysis on multiple years of drift and benthic data to see whether the patterns remain consistent.
9. Some taxa are very common in the drift at all CHaMP sites, while others are rare. Rarity in the drift can be attributable to rarity in the benthos, origination in upstream habitats, or behavioral or morphological reasons for not drifting. Inclusion of additional years of data will reveal whether taxa that are common in one year during the summer period are also most common in other years.
10. Benthic community composition may vary from year to year. This was not explored yet. We will assess the level of fidelity of common taxa from year to year or try to evaluate whether some taxa are replaced randomly by other taxa or only by those with similar traits.
11. In future data exploration, we will classify taxa by traits. Tables of traits are currently available in sources such as Vieira et al. (2006). Detailed taxonomic classification will hopefully allow taxa to be grouped by common traits that can reveal more clearly a linkage to specific environmental characteristics that change with restoration trends.
12. Certain taxa revealed clear distributional patterns by abundance in relation to water temperature. With more years of data, it will likely be clearer how abundance by taxon varies with water temperature. It may be important to filter abundance data by sample date. That is, we tried to relate abundance of benthic taxa to either the August mean water temperature or the maximum 7-day average of the daily maximum temperature. If the benthic samples were taken in July or in early September, there may be differences in abundances detected assuming that either the maximum summer temperatures had not yet been experienced or that they

already had been experienced and intolerant taxa diminished. The community present in any June period may also be a function of the water temperature maxima at the site the previous year. These complications may need to be explored.

13. The drift community by itself will need to be related to the site environmental characteristics. The benthic community is a function of riffle characteristics, riparian characteristics (producing shade, litter), and upstream inherent characteristics (geologic characteristics responsible for water chemistry; soil and topographic characteristics related to turbidity) or upstream landuse characteristics (road density related to fine sediment delivery and turbidity). But, the drift community is comprised by taxa derived from the benthos and the terrestrial zone. Consequently, its composition is attributable to not just riffles but all other channel units within the site, channel units upstream of the site, and riparian areas adjacent and upstream of the site. Biomass by size class will need to be assessed from instream and terrestrial sources to determine what the food availability is by CHaMP site. Food availability will then be related to fish abundance. Also, benthos-derived (i.e., drift of aquatic origin) biomass by size class will be related to benthic biomass density. Rather than compare the benthic biomass per m^2 against the drift biomass/m3 at a site, it may prove more useful to estimate the amount of suspended biomass per m^2 at an average point in time in the drift to compare with the benthic biomass density. This would involve using the data on water velocity at the drift net mouth as well as water depth to convert the value for biomass per volume filtered to biomass per square meter. This model envisions benthic organisms entering and leaving the drift at the same rate so that an average biomass is suspended above each 1-m^2 area at all times.

    A more complete presentation of benthic and drift macroinvertebrate results and discussion are presented in Appendix G.

Life Cycle Model

A preliminary step in integrating the effects of habitat restoration into life cycle modeling involves developing empirical models of fish-habitat relationships. Empirical models of fish-habitat relationships provide realism in predictions about how fish will likely respond to changes in key limiting habitat factors (Fausch, Hawkes, and Parsons 1988). Since 2011, the Monitoring and Recovery Trends program has continued to collect data on standing crop of summer rearing abundance for juvenile Chinook Salmon, steelhead, and other fish species at CHaMP monitoring sites using snorkel and electrofishing surveys (in collaboration with Oregon Department of Fish & Wildlife). In 2015, we continued development of empirical fish-habitat relationships via structural equation modeling (SEM) (Grace 2006) and linear mixed effects modeling. We used SEM to evaluate relationships among large woody debris, large pool frequencies, and juvenile Chinook Salmon rearing capacity. Tests of mediation in SEM revealed that the primary benefit of large woody debris to fish was an indirect pathway through the association of wood with large pools. We employed linear mixed effects modeling for predicting juvenile Chinook Salmon rearing densities under various water temperature scenarios, while accounting for distance to spawning areas and other physical factors (Appendix A). Empirical models of fish-habitat

relationships can provide a basis for predicting changes to freshwater survival and productivity in life cycle modeling (Bartz et al. 2006).

The habitat monitoring project has been interested in life cycle modeling in order to infer population recovery potential as a result of habitat improvements that affect productivity and capacity. By examining survival through the hydrosystem in greater detail with the models developed here, we provide at the very least a perspective of the potential relative benefit to long-term abundances that might arise from changes to freshwater spawning and rearing survival and hydro system operations.

We present the relative benefits of changes to tributary productivity and changes to hydrosystem operations. Results show that anywhere from 50% to 150% change in $\bar{R}$ could be expected if PITPH were reduced to 50% of its historical value, whereas the benefits of increasing productivity were limited by capacity in some cases. This is because PITPH only affects smolt survival in a density independent way, whereas there is density dependence in smolt production. We therefore examined the sensitivity to changes in capacity as well, and found that increases in capacity translate to linear responses in $\bar{R}$, but with variability around the prediction determined by the variation in the posterior estimates in productivity. The question then becomes: "Are there reasons to believe that improvements to habitat conditions aimed at improving productivity can affect both productivity and capacity?" It would seem to be the case, but most likely because if the quality of the habitat improves, habitat can sustain more fish per unit area. Habitat restoration activities can reduce stream temperatures, increase availability of refuge habitats for predator avoidance, and reduce human and agricultural contact with existing spawning and rearing habitats. The dynamics of how habitat quality affects productivity and capacity are complex, but ultimately translate to increased life-stage survivals via increased productivities and increased availability of spawning and rearing habitats, i.e., capacity. In fact, if spawning and rearing temperatures are reduced from critically high temperatures at a large enough spatial scales to affect productivity, the likely outcome would be that new areas would become habitable that would otherwise not have been occupied, which would result in a simultaneous increase in capacity.

Catherine Creek model fitting results indicate a reasonably high estimated productivity, but a relatively low capacity. As a result, any potential increase to long-term simulated $\bar{R}$ by increasing productivity meets density dependent limitation because of the low capacity (in the 7,000–9,000 smolts range). When we examine the relative benefit that might be effected via changes to capacity directly, the increase is dramatic, but it begs the question: "Is it possible to increase capacity from 8,000 to 12,000, a 50% increase in capacity?" The Upper Grande Ronde fitting results show the opposite pattern – lower productivity and higher capacity. Productivity and capacity in the Minam appear to be fairly high, with capacity at over 20,000 smolts. This is not surprising, since the Minam is a wilderness area. It appears that it would take an increase in both productivity and capacity to equal the benefit that can be realized from lowering PITPH to 50% of historical. It should be noted that the predicted increases in $\bar{R}$ in the right panels are being simulated using the estimated historical productivity and capacity levels. If treatment levels of both are higher, so is the predicted increase from a 50% PITPH treatment, i.e., a triple-action benefit.

Figure 51, Figure 52, and Figure 53 provide visual guidance for the evaluation of potential production from historical and alternative treatment levels. We have shown that abundance can increase as a result

of alternative treatments. A target $\bar{R}$ can be achieved by means of selecting a target productivity, capacity, or PITPH treatment level. In either of the three cases, there may be implementation issues. There may be a time lag between an action and realized treatment level, delaying the population abundance increase. There may also be a physical limitation on the attainability of a treatment level. The required capacity may exceed historically attainable levels, or flow levels may not permit spills necessary to attain target PITPH levels, or productivity levels are already relatively high, and further improvements are not practical. Despite any caveats to the limitations in attaining productivity or capacity improvements, however, it must be noted that action on both fronts is likely to be most effective. Ultimately, where habitat improvements are needed, they provide the highest long-term abundance gains, particularly where capacity is increased. Overall, if the productivity and capacity estimates for the Minam are treated as reference goals for Catherine Creek and the Upper Grande Ronde, we might set a goal that Catherine Creek attain higher capacity levels, and the Upper Grande Ronde attain higher productivities. In any case, habitat improvements that increase capacity would have the additional benefit of opening up new areas to spawning and rearing, which would increase spatial diversity.

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Appendix A – Water Temperature Modeling

Simulating Water Temperature and Fish Response to Riparian Restoration and Climate Change in the Upper Grande Ronde River

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Introduction

We used the Heat Source water temperature model (Boyd and Kasper 2003) to investigate potential thermal benefits of riparian reforestation and channel narrowing to Chinook Salmon populations in the Upper Grande Ronde River. Legacy land use practices in the basin have significantly reduced streamside vegetation and increased channel width-to-depth ratios across most of the salmon-bearing portion of the watershed, resulting in water temperatures that far exceed the optimal range for growth and survival of salmonid populations (ODEQ 2000). Riparian vegetation restoration has been identified as one of the most important management strategies for improving stream temperatures (Johnson and Jones 2000, Blann *et al.* 2002). As part of a previous contract with The Columbia River Inter-Tribal Fish Commission (CRITFC), Quantum Spatial Inc. (formerly Watershed Sciences) completed stream temperature modeling of 17 streams in the Upper Grande Ronde River basin covering the extent of current and historic Chinook Salmon habitat in the Upper Grande Ronde River and Catherine Creek (Watershed Sciences 2012). We used the model to evaluate a suite of restoration scenarios targeting riparian reforestation and channel narrowing as well as climate change scenarios. By combining restoration scenarios with climate change projections, we were able to evaluate whether future climate impacts could be offset by restoration actions. We translated water temperature simulations into predicted changes in Chinook Salmon summer parr abundance using a statistical model developed from snorkel survey and habitat data collected in the Grande Ronde Basin. Understanding how stream temperature responds to restoration of riparian vegetation, channel morphology and climate change is critical to restoration planners and natural resource managers seeking to prioritize restoration actions and restore imperiled salmonid populations.

Methods

Study Area

The Grande Ronde River originates in the Blue Mountains of northeast Oregon and flows roughly 334 km north/northeast to its confluence with the Snake River near the town of Rogersburg, Washington (Figure 1). Catherine Creek, one of the major tributaries to the Grande Ronde River, originates in the Wallowa Mountains and flows approximately 105 km west/northwest to its confluence with the Grande Ronde River near the town of La Grande, Oregon. The Upper Grande Ronde River (upstream of the Catherine Creek confluence) and Catherine Creek drain areas of approximately 1,896 and 1,051 km², respectively.

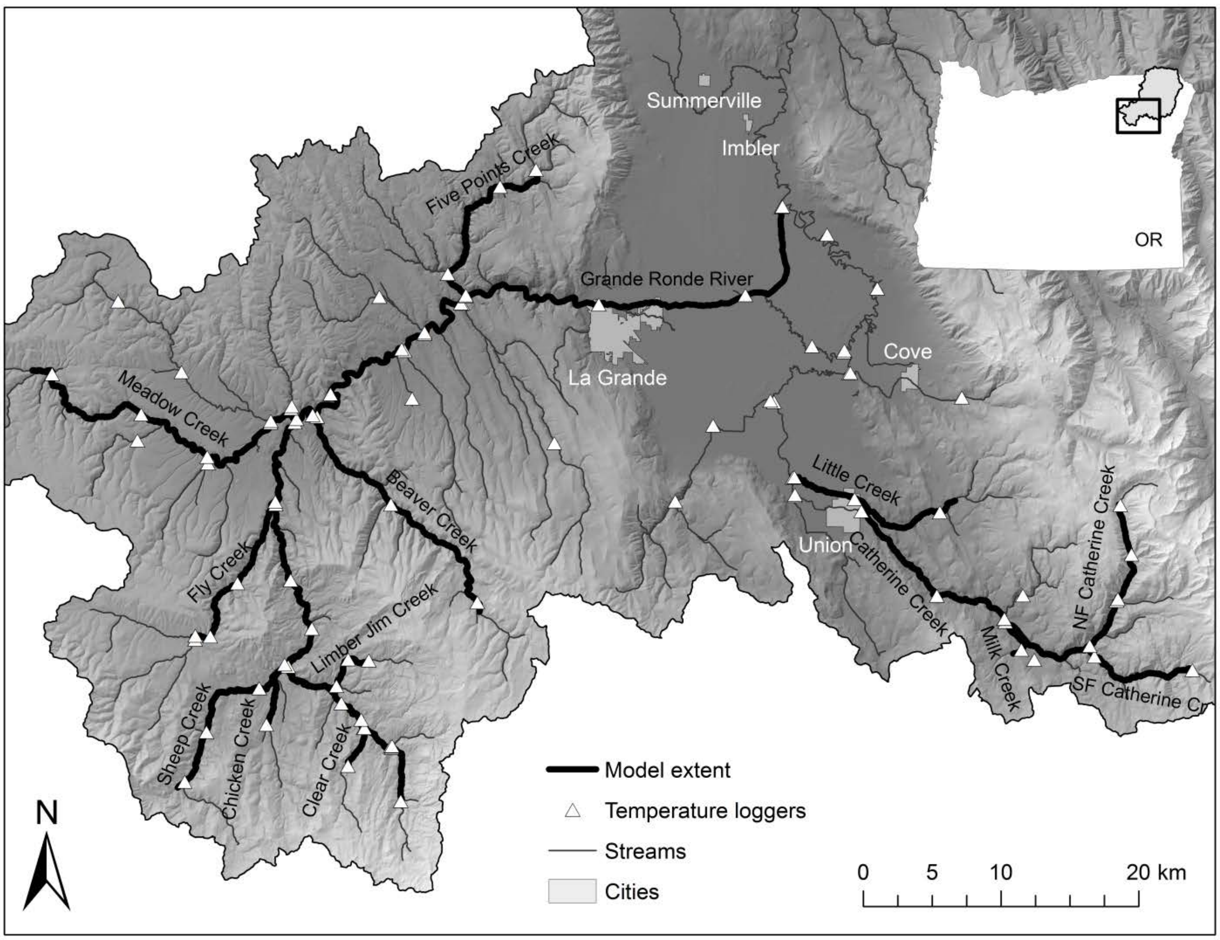

Figure 1. Map of the study area in the Upper Grande Ronde River and Catherine Creek basins in NE Oregon showing the stream segments that were modeled using Heat Source.

The Upper Grande Ronde River and Catherine Creek spring Chinook Salmon populations are part of the Snake River Spring/Summer Chinook evolutionary significant unit (ESU), which was listed as threatened

under the Endangered Species Act in 1992. The Interior Columbia Technical Recovery Team (ICTRT) set minimum abundance threshold criteria for recovery of these populations at 1,000 naturally produced spawners in the Upper Grande Ronde and 750 in Catherine Creek. Natural-origin spawner abundance estimates in the Upper Grande Ronde River between 1955 and 2011 have ranged from 0 in 1989 to 1,029 in 1969 with a recent 10-year geometric mean of 43 (National Oceanic and Atmospheric Administration Salmon Population Summary database; https://www.webapps.nwfsc.noaa.gov/apex/f?p=261:1:; downloaded on 15 March 2016). Catherine Creek natural-origin spawner abundance has ranged from 0 in 1990 to 3,161 in 1960 (recent 10-year geometric mean = 120).

The topography of the Upper Grande Ronde basin is characterized by rugged mountains in the headwater areas and a broad, low gradient valley between the Blue and Wallowa Mountains. Peaks in the Wallowa Mountains reach a maximum elevation of 2,999 m, and provide the source of many of the Grande Ronde’s tributaries including Catherine Creek and the Wallowa River. The Blue Mountains are the source of the Upper Grande Ronde River and tributaries draining the western portion of the basin and reach elevations of 2,347 m. Due to the lower elevation of the Blue Mountains, snowmelt generally occurs earlier in these tributaries than in the Wallowa Mountain tributaries, often resulting in very low base flows during summer.

Surface geology of the Upper Grande Ronde basin is dominated by volcanic rocks of the Grande Ronde Basalt group with lesser portions of the basin consisting of surficial sediments and some plutonic intrusives in the headwater areas. Geology within the Catherine Creek basin is composed of approximately 57 % volcanic rocks, 41 % surficial sediments, and minimal amounts of plutonic rocks. The climate is characterized by cold, moist winters and warm, dry summers with mean daily air temperatures near La Grande averaging -0.42 °C (31 °F) in January and 21 °C (70 °F) in July (Nowak *et al.* 2004). Average annual precipitation ranges from 36 cm (14 in) in the valleys to 152 cm (60 in) in the mountains, with most of the precipitation in the mountains falling as winter snow.

Approximately 42 % of the land in the Upper Grande Ronde River and Catherine Creek basins is publically owned, most of which is managed by the US Forest Service. With the exception of the Eagle Cap Wilderness Area, the National Forests in these drainages are managed for multiple use including timber production, livestock grazing, and recreation. Private property comprises about 58 % of the land in the basins and is located primarily in lower elevation valleys and along rivers. A large proportion of the private property is used for agriculture, including crop production, livestock grazing, and forestry. Only 0.2 % of the land in the Upper Grande Ronde River and Catherine Creek basins is currently owned by Indian tribes, although the tribes retain fishing and hunting access rights at all usual and accustomed locations as afforded under the treaties of 1855 and 1863.

Temperature Model

We used a deterministic water temperature model, Heat Source (Boyd and Kasper 2003), to simulate water temperature and flow dynamics in major salmon-bearing streams of the Upper Grande Ronde River Basin (Figure 1). The model was originally developed and calibrated by Quantum Spatial (formerly Watershed Sciences Inc.) using ground-level hourly stream temperature, discharge, and channel geometry measurements collected at discrete locations throughout the basin by CRITFC, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), and the US Forest Service (Watershed Sciences 2012). Remotely sensed, continuous data collected by Quantum Spatial were also incorporated into the model, including LiDAR data to measure stream channel elevation and riparian canopy height, and thermal infrared (TIR) data to capture a snapshot of peak daily water temperatures throughout the stream network. The model was calibrated for a 10-week period between July 10, 2010 and September 20, 2010. This period was chosen to best represent summer base-flow conditions when water temperatures are typically highest and salmonids are consequently at risk.

The model integrates stream channel geometry, hydrology, climatic conditions, and riparian vegetation cover and height to simulate stream temperature and effective shade at 100 meter intervals (termed model nodes) throughout the stream network. Vegetation shade was evaluated using a radial sampling method in which a series of transects were extended in each of 7 directions (S, SW, W, etc.) from each model node and vegetation height was measured from the LiDAR data at 4 different points spaced 10-15 m along each transect. Using information about the angle of the sun at different times of day, the model calculates the amount of solar radiation that penetrates through the riparian vegetation and reaches the stream. Climate data, including air temperature, cloud cover, relative humidity, and wind speed were recorded by the National Weather Service at the La Grande airport and by the US Forest Service at the J Ridge weather station in the Upper Grande Ronde basin (Data downloaded from the National Oceanic and Atmospheric Administration’s National Centers for Environmental Information website http://www.ncdc.noaa.gov/cdo-web/ on 19 April 2011).These climate data were incorporated into the model using lapse rates to correct for elevation differences between the location of the meteorological instruments and the stream sites. Streamflow data were downloaded from the Oregon Department of Water Resources web site (http://apps.wrd.state.or.us/apps/sw/hydro_report/) on approximately January 2011.

Model parameters from the calibrated 2010 model (hereby referred to as current conditions) were used as a baseline for evaluating a suite of model scenarios representing different assumptions about potential riparian restoration, channel morphology restoration, and climate change. We evaluated a total of 10 model scenarios as described in Table 1. We summarized the water temperature predictions for each model scenario by calculating the maximum 7-day running average of the daily maximum temperature in degrees Celsius, hereby referred to as maximum weekly maximum temperature (*MWMT*) for each model output node. This temperature metric is consistent with the water quality standards that have been recommended by the United States Environmental Protection Agency (EPA 2003) to ensure protection of different salmon life stages in Pacific Northwest streams.

Water temperature predictions were summarized by major population area (i.e., Upper Grande Ronde River and Catherine Creek) to simplify model outputs and aid in interpretation of the results. Specifically,

model results for the Upper Grande Ronde River Basin included a combination of all Heat Source model nodes for the mainstem Grande Ronde River and all modeled tributaries upstream of the Catherine Creek confluence including Five Points Creek, Beaver Creek, Meadow Creek, Fly Creek, Sheep Creek, Limber Jim Creek and Clear Creek. Similarly, results for the Catherine Creek Basin included a combination of all model nodes for mainstem Catherine Creek and all modeled tributaries including Little Creek, Milk Creek, North Fork Catherine Creek, and South Fork Catherine Creek.

Table 1. Description of 10 model scenarios used to evaluate the influence of riparian restoration and climate change on water temperature.

Model number	Model name	Model description
1	Current	Baseline model calibrated using 2010 temperature, climate, vegetation, and hydrologic conditions
2	PNV	Maximum potential vegetation canopy cover and height.
3	HighPriority	Vegetation in high priority sites set to maximum potential cover and height. All other areas were set to current conditions.
4	HighMedPriority	Vegetation in high and medium priority sites set to maximum potential cover and height. All other areas were set to current conditions.
5	HighMedLowPriority	Vegetation in high, medium, and low priority sites set to maximum potential cover and height. Very low priority areas were set to current conditions.
6	Width	Wetted stream width was reduced in accordance with observed changes in river width from 1880's to present.
7	Width_PNV	Wetted stream width was reduced in accordance with observed changes in river width from 1880's to present plus vegetation set to maximum potential.
8	Climate2080s	Air temperature and streamflow were adjusted in accordance with climate model projections for the 2080s (2060-2099)
9	Climate2080s_Veg	2080's climate projections plus vegetation height at 75 years
10	Climate2080s_Veg_Width	2080's climate projections plus vegetation height at 75 years plus restored channel width

Potential Vegetation

To simulate restoration of riparian vegetation, it was first necessary to estimate the potential height and density (i.e., canopy cover) of trees and shrubs in the riparian zone under natural historic conditions (i.e., prior to intensive anthropogenic disturbance). To do this, we contracted with a team of riparian ecologists with extensive experience in the Blue Mountains region to develop a detailed map of current

vegetation and potential natural vegetation (PNV) along the entire extent of the Chinook-bearing portion of the Upper Grande Ronde watershed (Wells *et al.* 2015).

The riparian zone within a 100m buffer on either side of the active river channel was classified into polygons called integrated terrain units (ITUs), which represent relatively homogenous areas with similar ecological components including physiography, geomorphology, soils, vegetation, and disturbance. Remotely sensed data such as LiDAR, digital elevation models (DEM), aerial imagery, and soil maps were used as the primary means of delineating the ITU boundaries. The ITUs provided a standardized physical template by which all ecological components of the riparian zone were organized.

Potential vegetation composition within each ITU was determined using the methodology employed for the Blue Mountains National Forest lands as described in Powell *et al.* (2007). This approach involved combining plant associations and/or plant community types that had been previously described and classified within the study area (Crowe and Clausnitzer 1997, Crowe *et al.* 2004, Johnson and Clausnitzer 1992, Johnson and Simon 1987, Kauffman *et al.* 1985, and Wells 2006) into plant association groups (PAGs) “representing similar ecological environments as characterized by temperature and moisture regimes” (Powell *et al.* 2007). Field plot data including photographs, vegetation composition and soils were used to inform and verify the mapping of the plant association groups. Detailed methods on the riparian mapping can be found in Wells *et al.* (2015).

Potential tree and shrub cover (i.e., canopy density) was estimated from extensive field measurements of canopy cover collected within each PAG as documented in local vegetation classifications (Crowe and Clausnitzer 1997, Crowe *et al.* 2004, Johnson and Clausnitzer 1992, Johnson and Simon 1987, and Wells 2006). Field measurements of constancy (proportion of total vegetation plots in which a species occurred) and average cover (percent canopy cover for a species averaged over all vegetation plots where the species was present) were compiled and averaged by PAG. We used this data to estimate total potential tree cover by summing the product of constancy and average cover across all tree species and tree types (i.e., dominant overstory, subdominant overstory, and understory trees) within each PAG. Similarly, total potential shrub cover was calculated by summing the product of constancy and cover for all tall shrub species within each PAG. This method may tend to overestimate tree cover by summing across multiple tree types and species without accounting for potential overlap in the foliage of different tree types and/or species. However, in the absence of quantitative information about the degree of overlap by PAG, we assumed a straight summation represented the best available information.

These tree and shrub cover data were used as inputs in the Heat Source model by randomly assigning a subset of the Heat Source sample nodes within each PAG to trees or shrubs such that the final proportion of sample nodes assigned to each plant type was equal to the potential canopy cover values estimated from the plant association data. Any sample nodes with a current vegetation height of 3m or greater were automatically assigned to trees prior to the random selection process. After assigning the correct proportion of sample nodes to trees, the remaining sample nodes were subject to a similar process to determine which sample nodes would be assigned to shrubs. Sample nodes with a current vegetation height of 1.5-3 m were assigned to shrubs, and the remaining nodes were then randomly

assigned to shrubs such that the final proportion of sample nodes assigned to shrubs equaled the potential shrub cover value.

Potential tree height was estimated from species-specific dominant tree height growth curves from the regional forestry literature (Barrett 1978, Clendenen 1977, Cochran 1979, Cochran 1985, Dahms 1975, Herman *et al.* 1978, Monserud 1985, Nussbaum 1996). Within each PAG, we calculated a weighted-average growth curve by averaging all species-specific growth curves weighted by the average canopy cover value for each species. We used these growth curves to estimate the average tree height under fully restored PNV conditions. Height at 300 years was assumed to represent the maximum potential tree height due to limitations with extrapolating the growth curves too far beyond the range of the data. We also estimated tree height at 75 years from current to correspond approximately with the time frame for which climate projections were available.

Potential shrub height was obtained from Steele and Geier-Hayes (1987, 1989, 1992, 1993, 1994) and from species descriptions in the Fire Effects Information System (2015). Shrub heights were weighted by average cover of each species within shrub PAGs to produce an average maximum shrub canopy height.

We developed four riparian restoration scenarios (model scenarios 2-5) by dividing stream network into priority areas (high, medium, low, and very low priority). We started by weighting each model node by its distance from current spawning areas. Sites within the current spawning area were given a weight of 1, and the weight declined to 0 as the distance from spawning increased. This weighting scheme was based on a “restore from the core” perspective in which the most productive areas were restored first, then additional areas were subsequently restored moving in a downstream (i.e. less productive) direction. For each model node *i,* the distance weight (DW_i) was given by the formula:

Equation 1: $$DW_i = e^{-0.075 \times d_i},$$

where d_i is the distance in kilometers from the model node to the nearest spawning area.

Next we assigned each model node a weight based on the difference in current effective shade versus potential effective shade. Effective shade is a simulated output from the Heat Source model and is defined as the fraction of the potential solar radiation that is blocked by streamside vegetation. Sites with the greatest difference between current and potential shade received a weight of 1, and the weight declined to zero as the difference in shade decreased. This approach essentially assigns the greatest weight to areas that have the largest shade deficit, and thus the greatest potential to benefit from riparian restoration. The shade weight (SW_i) at each model node *i* was given by the formula:

Equation 2: $$SW_i = (SP_i - SC_i)/SDMax,$$

where SP_i is the effective shade under fully restored PNV conditions, SC_i is the effective shade under current conditions, and *SDMax* is the maximum difference in effective shade between PNV and current

conditions across all model nodes. Shade differences were divided by SDMax to ensure that the shade weights ranged from 0 to 1, consistent with the distance weights.

A final weight for each model node was then calculated as the product of the distance and shade weights. Final weights were then averaged over 1km stream segments and simplified into categories of high, med, low, and very low priority (Figure 2). Model nodes with final weights that were at or above the 75th percentile of all final weight values were assigned to the high priority category. Model nodes between the 50th and 75th percentile were assigned to the medium category. Model nodes with weights between the 25th and 50th percentile were assigned as low priority, and nodes with weights below the 25th percentile were assigned as very low priority. The resulting four riparian restoration scenarios (model scenarios 2-5) were implemented in Heat Source by setting the tree and shrub cover and height values to their maximum potential within selected priority areas including: 1) high priority (scenario , 2) high and medium priority, 3) high, medium and low priority, and 4) high, medium, low, and very low priority (i.e., PNV scenario 2).

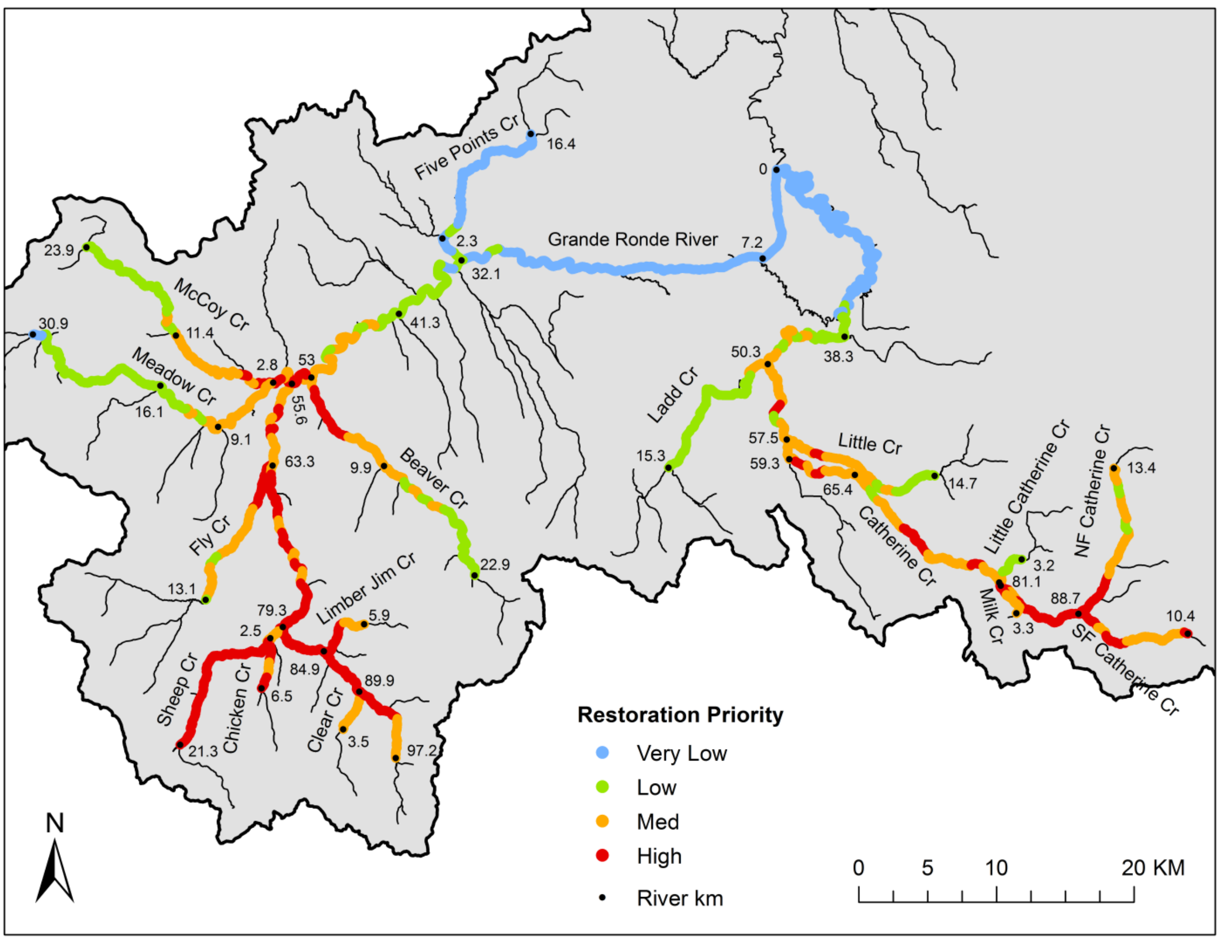

Figure 2. Map of restoration priority areas in the Upper Grande Ronde and Catherine Creek basins.

Climate Change

Projected changes in monthly air temperature and stream discharge for future climate change scenarios were obtained from the University of Washington Climate Impacts Group (UWCIG) (Littell *et al.* 2011, UWCIG 2011). For this assessment, we used a composite climate model derived from the A1B scenario family, which included an average of the ten global climate models with the best performance at predicting historical summer temperature and precipitation trends. The A1B scenario family lies near the high end of the spectrum of projected changes to emissions, and assumes "very high economic growth, global population peaking mid-century and then declining, and energy needs being met by a balance of fossil fuels and alternative technologies" (UWCIG 2010). The UWCIG downscaled the outputs of these models to generate relative changes to monthly climate variables (including air temperature, precipitation, and discharge) by fourth-field hydrologic units (HUC4) for a future time period, 2070-2099 (2080s).

In order to use these data in our assessment, we first needed to adjust for the differences between the baseline period in our study (2010) and the baseline period use by the UWCIG (1916-2006). To do this, we used the Pacific Northwest Index , a climate index developed by Ebbesmeyer and Strickland (1995) and summarized online by the UWCIG (2012) to study climate effects on salmon productivity. The index includes measurements of air temperature, precipitation, and snowpack at three stations in the Pacific Northwest for the year between 1891 and 2011. Although the sites are not in the Grande Ronde Basin, and the data is on an annual basis, they provide a good indication of the climate trends in different historical periods in the Northwest, which are not otherwise easily available for this region during these time periods. Using this index, we calculated the difference between the 2010 period and the 1916-2006 period to be as follows: air temperature + 0.8 °C; precipitation +1.6 %. These differences were then used to modify the future climate changes scenario adjustments so that they appropriately pertained to the 2010 baseline period (i.e., for each scenario, subtracting 0.8 °C from the adjustment to air temperature and dividing the adjustment to streamflow by 101.6 %). The final set of monthly projected changes in air temperature and streamflow used in the Heat Source model are provided in Table 2.

Table 2. Projected changes in monthly air temperature and streamflow resulting from climate change for the 2080s time period.

	Month			
Climate projections	July	August	September	Average
Air temperature increase from 2010 (°C)	4.7	5.0	4.3	4.7
Change in streamflow from 2010 (%)	-21.2	-20.7	-18.3	-20.1

Channel Width

Setting target conditions for restoration of fish habitat typically involves inferring conditions from nearby, undisturbed reference areas or using statistical models to extrapolate the expected, unimpacted conditions from within the existing range of anthropogenic disturbance in a watershed. However when

historical information is available, it can provide a more realistic estimate of baseline conditions. To define a historical baseline for channel width, we described changes to river channel widths since the late 1800s, with expectations that magnitude of change would be greater in areas with more intense ranching, logging, agriculture, and other forms of land use. River width was used as a proxy of width-to-depth ratios—a more common metric used to describe the effects of land use on channel morphology—because historical estimates of water depths were not available.

Historical estimates of river width were based on Government Land Office (GLO) surveys (Principle Clerk of Surveys, General Land Office 1855) conducted in the mid to late 1800s. The GLO survey provided information on the quality of conditions for rangeland, agriculture, and forestry for prospective land claims under the Homestead Act of 1862. The survey involved two crew members walking the 1-mile section lines for each of 36 sections in a 640 acre township. In addition to recording the general character of vegetation, soil, and rangeland conditions, surveyors recorded the location and bank-to-bank river width (active channel width) of any streams or rivers crossed. For each section line that intersected streams within Chinook Salmon spawning and rearing extent, we translated the handwritten surveyor notes into spatial data in a geographic information system (GIS). Estimates of river width were converted from chains and links (1 chain = 100 links) to meters (1 link = 0.20 m).

Contemporary estimates of river width were based on Oregon Department of Fish and Wildlife's (ODFW) Aquatic Inventories survey (Moore *et al.* 2008). The ODFW survey is a rapid assessment of common fish habitat characteristics collected in a spatially continuous fashion across the river network. Two ODFW surveyors walked or canoed river sections and recorded the characteristics and location of channel units (i.e., pools, riffles, and glides) with a hand-held global position system (GPS) with accuracy 5-7 m. Data from the 1990s were used as the baseline for "present" conditions, except where surveys were conducted outside the low flow period (Julian day 200-300). When surveys did not match that criteria we used surveys from years 2000 or 2010 that fell within the low flow period. Whereas surveyors recorded wetted width at every channel unit, active channel width was only recorded at every 10^{th} channel unit and at tributary junctions. We therefore developed a linear relationship between wetted and active channel width for extrapolating spatially extensive river widths comparable to historical GLO surveys:

Equation 3: $$W_A = 5.11 + 1.04 \times W_W,$$

where W_A is the active channel width and W_W is the wetted width in meters measured by ODFW crews (n = 23, R^2 = 0.70, p < 0.001). We then calculated the percent change in river with from the historical to present periods based on GLO and ODFW estimates of active channel width:

Equation 4: $$\Delta W = \frac{W_P - W_H}{W_H} \times 100,$$

where ΔW is percent change in river width, W_P is present river width, and W_H is historic river width in m. We then evaluated the magnitude of change since the historical period according to watershed identity and a geomorphic valley setting classification. Watershed identity was defined by the distribution of Chinook populations Catherine Creek (CCC), Upper Grande Ronde (UGC), and Minam River (MRC). The classification system consisted of dividing the stream network into small and large streams using an 8 m bankfull width criteria based on the work of Beechie and Imaki (2014). Next, the stream network was further divided into three different valley types based on valley confinement (laterally unconfined, partly confined, and confined) following the methodology described in the River Styles Framework (Brierley and Fryirs, 2005). We simplified the classification into three classes for this analysis: (1) large streams, (2) small/partly confined and confined streams, and (3) small/laterally unconfined streams. For Catherine Creek and upper Grande Ronde River combined, there was a significant effect of stream classification type on the percent change in river width as determined by one-way ANOVA ($p < 0.001$).

For the purposes of modeling the effect of channel width on water temperature with Heat Source, we divided the river network into relatively homogeneous river reaches based on visual inspection of the estimated percentage changes in river width. For portions of the study area that were not surveyed either historically or currently, we used average values of percent change from the classification described above. The average changes in channel width by reach that were used in the Heat Source model are provided in Table 3.

Table 3. Estimated changes in channel bottom width (m) from historic (1880s) to current (2010).

Population	Stream	River km Min	River km Max	Avg historic width (m)	Avg current width (m)	Avg % change from historic
Catherine Creek	Catherine Cr	0	88.7	10.2	11.8	15.5
	Little Cr	0	14.65	1.1	3.2	187.8
	Milk Cr	0	3.3	0.5	1.5	231.1
	NF Catherine Cr	0	13.4	3.4	5.7	86.8
	SF Catherine Cr	0	10.35	4.4	6.3	64.2
Total				7.8	9.5	51.7
Upper Grande Ronde	Beaver Cr	0	22.9	2.5	4.3	84.6
	Chicken Cr	0	6.45	0.6	2.5	344.1
	Clear Cr	0	3.5	1.1	2.2	108.5
	Five Points Cr	0	16.4	1.8	2.9	68.8
	Fly Cr	0	13.1	1.5	2.6	70.3
	Grande Ronde R	0	97.2	10.1	12.9	56.0
	Limber Jim Cr	0	5.9	1.0	2.8	192.8
	Meadow Cr	0	30.9	1.8	2.9	82.7
	Sheep Cr	0	21.3	0.8	3.0	293.8
Total				5.4	7.5	101.1
Grand total				6.3	8.2	82.6

Fish Abundance

To evaluate how simulated water temperature scenarios would influence abundance of Chinook Salmon summer parr, we developed a statistical model of parr density using snorkel survey data collected by CRITFC and ODFW in the Grande Ronde basin between 2011 and 2014. Specifically, we used a linear mixed-effects model with Chinook parr density (fish/m) as the dependent variable, and watershed area (km^2), gradient, *MWMT* (°C), and average redd density 2 km upstream of each site (redds/100 m) as fixed-effect explanatory variables. This set of explanatory variables was selected based on both the availability of spatially continuous data within our study area, and on our understanding of some the key habitat and biological factors driving the distribution of juvenile salmonids in the Grande Ronde basin (Nowak 2004, Cooney *et al.* 2007).

The snorkel survey dataset consisted of 77 randomly selected sites, some of which were surveyed every year and some of which were surveyed every 3 years. This sampling design resulted in a total sample size of 129. As a result of this repeated measures survey design, not all data points were independent. Thus, we used a mixed-effects model with "site" as a random grouping factor to utilize all of the data without violating the assumption of independence (Pinheiro and Bates 2000). Snorkel counts at each site were expanded using a correction factor developed from paired mark-recapture and snorkel survey data to account for fish that were not observed by snorkelers (Jonasson *et al.* 2015).

Watershed area and gradient estimates were obtained from NetMap (http://www.terrainworks.com; downloaded on 31 October 2014). This landscape analysis software calculates as suite of stream and watershed parameters using remotely sensed data such as digital elevation models, PRISM climate data (Daly *et al.* 1994; http://www.prism.oregonstate.edu/) and NHD hydrography data (http://nhd.usgs.gov/data.html). Water temperature data was measured at each site using HOBO water temperature loggers as part of the Columbia Habitat Monitoring Program (CHaMP; https://www.champmonitoring.org/).

Redd densities were calculated from Global Positioning System (GPS) coordinates of all Chinook Salmon redds surveyed by ODFW (La Grande Fish Research Office) between 2010 and 2013. Redd locations were joined to the NetMap stream layer using ArcGIS and redd densities were calculated for each 100m stream reach. Redd densities were extrapolated into areas that were not surveyed by ODFW using a stream classification system described above (see channel width). Unsurveyed areas consisted of two types of stream reaches including: 1) reaches that were within the current spawning extent but were not surveyed because of landowner permission issues, and 2) reaches that were outside of the current spawning extent but within the historic spawning extent and were not surveyed because high water temperatures or other impaired habitat conditions precluded spawning.

The average redd density by river class was calculated for all years combined (2010-2013) and was subsequently used to estimate the density of redds in unsurveyed areas within the model extent. Finally, we applied a temperature screen of 22 °C *MWMT* (i.e., redd densities in unsurveyed reaches with *MWMT* > 22 °C were set to 0) to ensure that redds were not extrapolated into areas with temperatures exceeding the upper tolerance limits for Chinook spawning. This temperature screen was previously

applied in the Grande Ronde basin to estimate historical capacity of Chinook Salmon (Cooney *et al.* 2007).

Fish density, watershed area, and redd density were log transformed (natural logarithm) prior to analysis to ensure normality and homogeneity of variance. We added a small constant to parr density and redd density values prior to log transforming to avoid problems with log transformation of zero values. Specifically, we added 0.005 to the parr density values and 0.02 to the redd density values. The relationship between temperature and fish density was assumed to follow a piecewise functional relationship with a threshold temperature of 18 °C (i.e., no effect of temperature on fish density below 18 °C, and a negative effect of temperature above 18 °C). This threshold was based on visual inspection of the raw data and documentation in the literature of 18 °C as a common upper threshold for rearing preference of juvenile salmonids (EPA 2003, Welsh *et al.* 2001).

We used the linear-mixed effects model to estimate Chinook Salmon parr density (fish/m) within each NetMap reach for each of the 10 model scenarios. We then converted these density estimates into abundance for each NetMap reach by multiplying the estimated fish density by the length of each NetMap reach. Reach-scale abundance estimates were then summed for each population area (Upper Grande Ronde and Catherine Creek) to calculate total population abundance.

Results

Water Temperature

Simulated water temperatures from the calibrated 2010 model tracked very closely with measured FLIR data (Figure 3). Root mean square error (RMSE) for all main stem and tributary models ranged from 0.26 to 1.16 °C (mean = 0.62 °C), indicating good model accuracy across the model extent. Detailed model calibration results and longitudinal temperature profiles for each modeled stream within the study area are provided in Watershed Sciences (2012).

Predicted maximum weekly maximum water temperatures (*MWMT*) varied considerably across the study extent, with cooler temperatures in the headwaters (near 12 °C) and progressively warmer temperatures in lower elevation portions of the watershed (Figure 4). Under current conditions, the vast majority of the Upper Grande Ronde (93 %) and Catherine Creek basins (70 %) had summer temperatures that exceeded the Environmental Protection Agency's (EPA) standard for "core" juvenile salmon rearing of 16 °C (EPA 2003). Stream reaches with temperatures within the optimal range for growth (i.e., 10-16 °C; EPA 2003) were limited to the upper headwaters in both basins. Approximately 80 % of the Upper Grande Ronde Basin and 38 % of the Catherine Creek Basin exceeded a *MWMT* of 20 °C, a general threshold described by the Pacific Northwest Salmon Habitat Indicators Work Group as causing severe impairment to various salmonid life stages including egg development, fry emergence, metabolism, behavior, susceptibility to disease, and mortality (PNWSHIWG 1998). In addition, a large portion of the Upper Grande Ronde Basin (41 %) and some parts of the Catherine Creek Basin (7 %) had maximum summer temperatures that exceeded 25 °C, the upper incipient lethal temperature for Chinook Salmon (Brett 1952, Orsi 1971).

Simulated restoration of riparian vegetation substantially reduced the amount of habitat with temperatures above 16 °C from 93 to 73 % in the Upper Grande Ronde, and from 70 to 48 % in Catherine Creek (Figure 4). Similarly, the proportion of the watersheds with temperatures exceeding 20 °C were reduced from 80 to 42 % in the Upper Grande Ronde and from 38 to 6 % in Catherine Creek. Finally, riparian restoration was predicted to reduce the amount of habitat with temperatures exceeding the incipient lethal limit of 25 °C to 7 % and 0 % in the Upper Grande Ronde and Catherine Creek basins respectively. Despite these substantial potential reductions in water temperature, there are some areas in the lower portions of the Grande Ronde main stem and some tributaries that would continue to have stressful temperature conditions even with restored riparian vegetation.

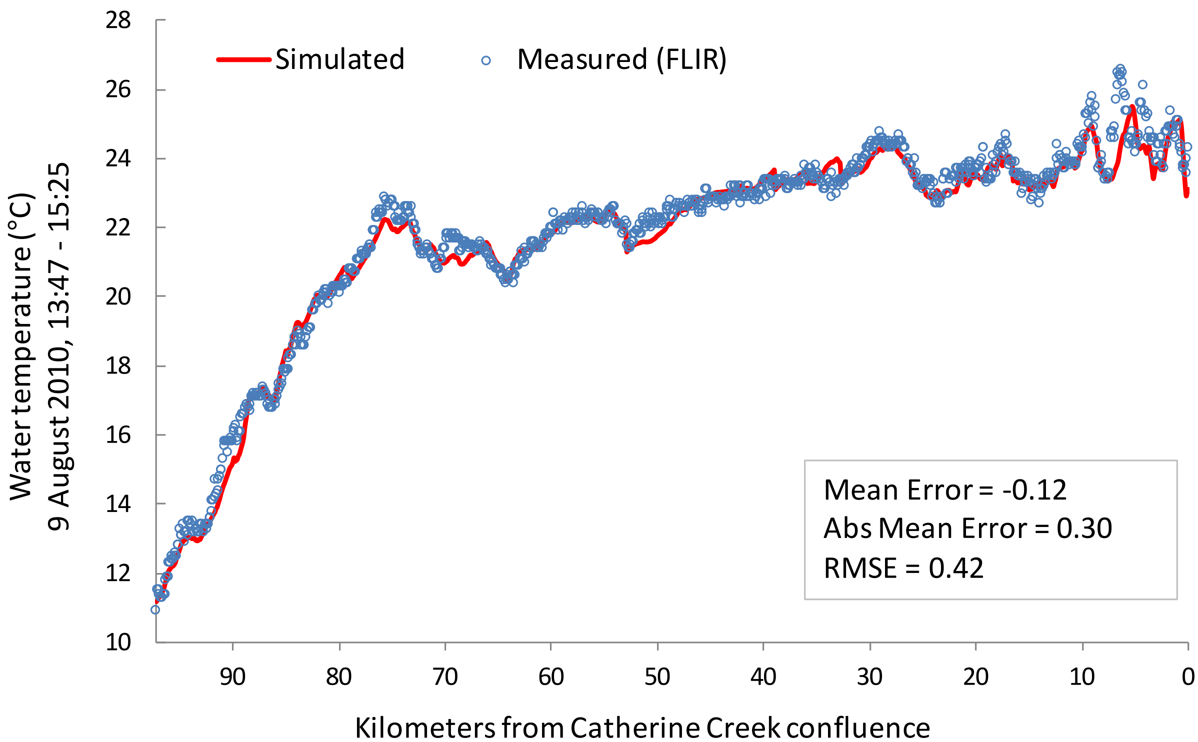

Figure 3. Model calibration results for the Grande Ronde River main stem showing the measured water temperature from the forward looking infrared imagery (FLIR) (blue circles) and the simulated temperature (red line) for 9 August 2010, 13:47-15:25.

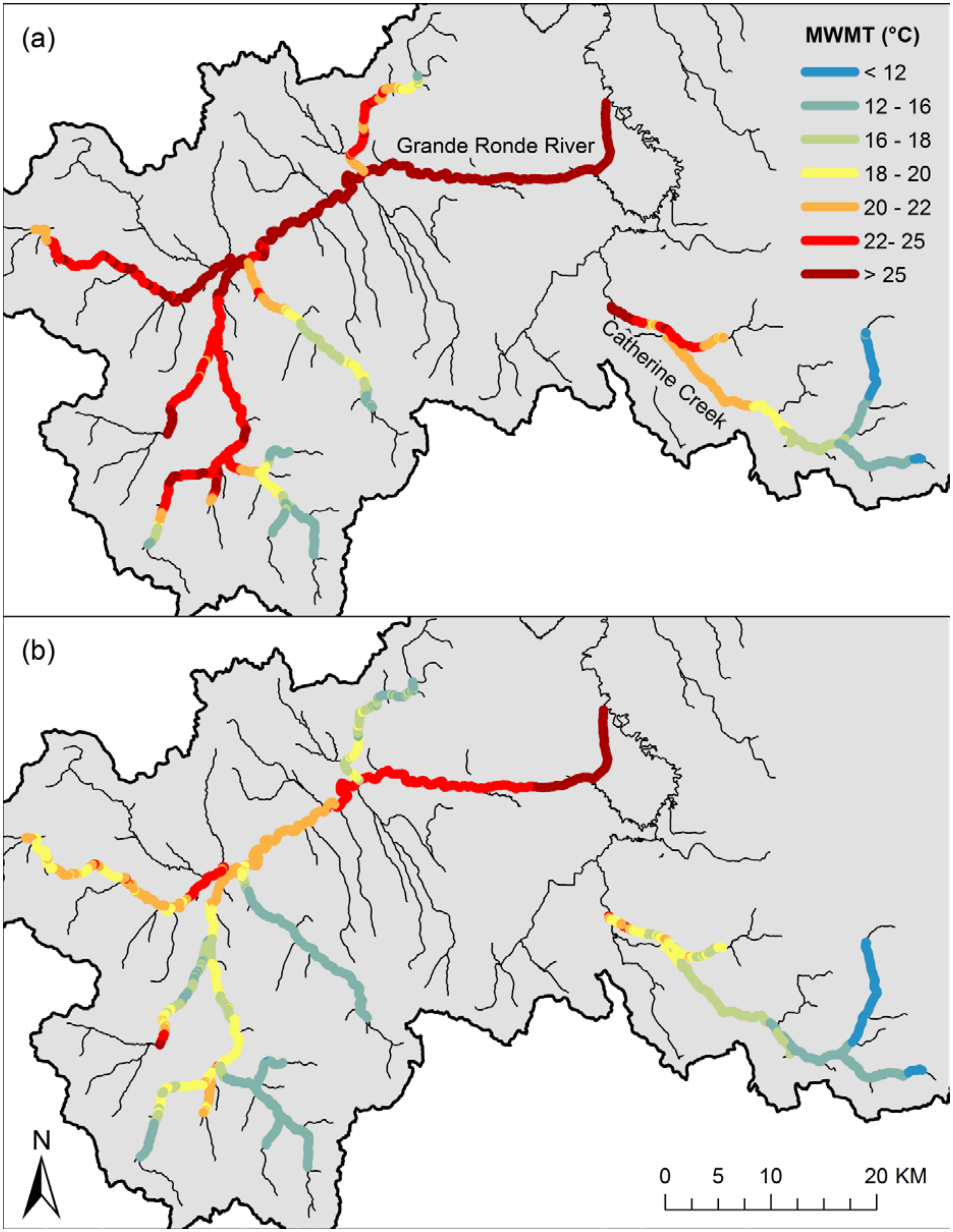

Figure 4. Map of simulated maximum weekly maximum water temperature (*MWMT*; °C) for (a) current conditions and (b) potential natural vegetation (PNV) conditions in the Upper Grande Ronde River and Catherine Creek basins.

Water temperatures under current conditions were substantially higher in the Upper Grande Ronde River Basin (median = 24.4 °C) compared with the Catherine Creek Basin (median = 18.7 °C; Figure 5). In addition, the predicted relative temperature change resulting from both restoration actions and climate change was substantially higher in the Grande Ronde compared with Catherine Creek (Figure 5). For example, the predicted change in median water temperature relative to the current condition for the fully restored PNV scenario was -5.4 °C in the Grande Ronde, compared with -2.9 °C for Catherine Creek. The combined restoration of both riparian vegetation and channel width (model scenario 7) was estimated to reduce median water temperatures by 6.5 °C in the Grande Ronde compared with 3.4 °C in Catherine Creek. On the other hand, climate change was projected to increase median water temperature in the Grande Ronde by 2.8 °C, compared with an increase of 1.8 °C in Catherine Creek. Finally, a combination of climate change, vegetation restoration, and channel narrowing resulted in a predicted net decrease in median water temperature of 3.6 °C in the Grande Ronde compared with a decrease of 2.1 °C in Catherine Creek.

The current (i.e., 2010) longitudinal profile of water temperatures in the mainstem Grande Ronde River showed rapidly increasing water temperatures from about 12.5 °C near its headwaters (river kilometer 97) to about 25.5 °C just downstream of Vey Meadows (river km 75.5; Figure 6). At that point, the river enters a canyon with considerable topographic shade and higher tree cover, and consequently, river temperatures declined moderately to about 22.5 °C near the mouth of Fly Creek (river km 63.4). From that point down to its confluence with Catherine Creek, the river temperature increased gradually with some relatively minor cooling effects at tributary junctions to a maximum of about 29 °C.

Comparison of the mainstem Grande Ronde River temperature profile under current conditions with the four riparian restoration scenarios indicated that the expected cooling benefits from riparian reforestation would be greatest in the upper to middle portion of the river (i.e., from about Vey Meadows down to Five Points Creek), but the potential for cooling diminished rapidly as the river entered the lower Grande Ronde Valley near river km 22 (Figure 6). Simulated riparian restoration in high priority sites alone demonstrated that substantial reductions in maximum weekly maximum water temperature up to 6.9 °C (mean = 2.2 °C) below current conditions could be achieved by focusing restoration efforts only on high priority areas, but these benefits would diminish rapidly downstream of Beaver Creek (river km 53). Similarly, simulated restoration of high and medium priority areas resulted in water temperature reductions of up to 7.2 °C (mean = 3.2 °C) below current. Cooling benefits from this scenario extended further downstream to about river km 40, after which the stream was predicted to warm rapidly to a level similar to current conditions. Additional restoration of riparian areas classified as low priority could extend the cooling benefits further downstream, resulting in a mean decrease in water temperature of 3.7 °C. Finally, riparian restoration to PNV conditions throughout the watershed could reduce maximum weekly maximum temperatures in the main stem by approximately 4.2 °C on average. However, post-restoration water temperatures in the lower portion of the river (i.e., below river km 32) were predicted to be quite high (> 22 °C), suggesting that restoration of these low and very low priority areas would likely provide limited additional thermal benefit for salmonids in the mainstem Grande Ronde River.

Climate change projections for the 2080s (2070-2099) resulted in water temperature increases in the mainstem Grande Ronde River as high as 3.9 °C *MWMT* (mean = 3.3 °C) above the current condition, with maximum summer water temperatures exceeding the lethal limit for Chinook Salmon (i.e., 25 °C) across most of the river length (Figure 7). However, extensive riparian restoration could offset these impacts and even reduce water temperature by as much as 3.4 °C (mean = 0.2 °) below the current condition (scenario 9), particularly in the middle and upper portions of the river above Beaver Creek. Between Beaver Creek and Five Points Creek, the water temperature profile under the combined riparian restoration and climate change scenario was very similar to the current condition. Downstream of Five Points Creek, water temperatures were predicted to rise gradually, approaching a maximum of about 30 °C near the State Ditch (river km 7).

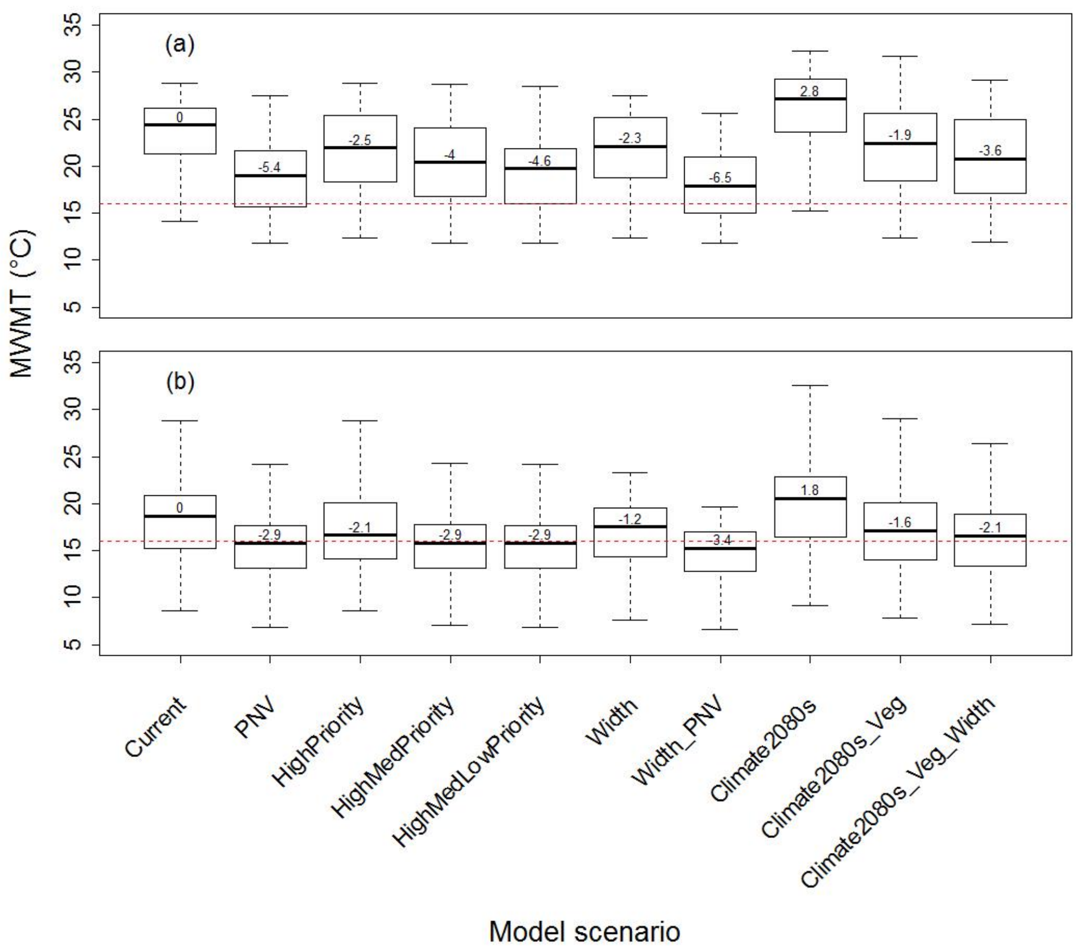

Figure 5. Simulated maximum weekly maximum water temperatures (*MWMT*; °C) for each model scenario in (a) the Upper Grande Ronde River, and (b) Catherine Creek. Each box plot represents the distribution of *MWMT* values across all model nodes within the two focal watersheds including main stem and tributary locations. The numbers within each box represent the change in median temperature from current condition.

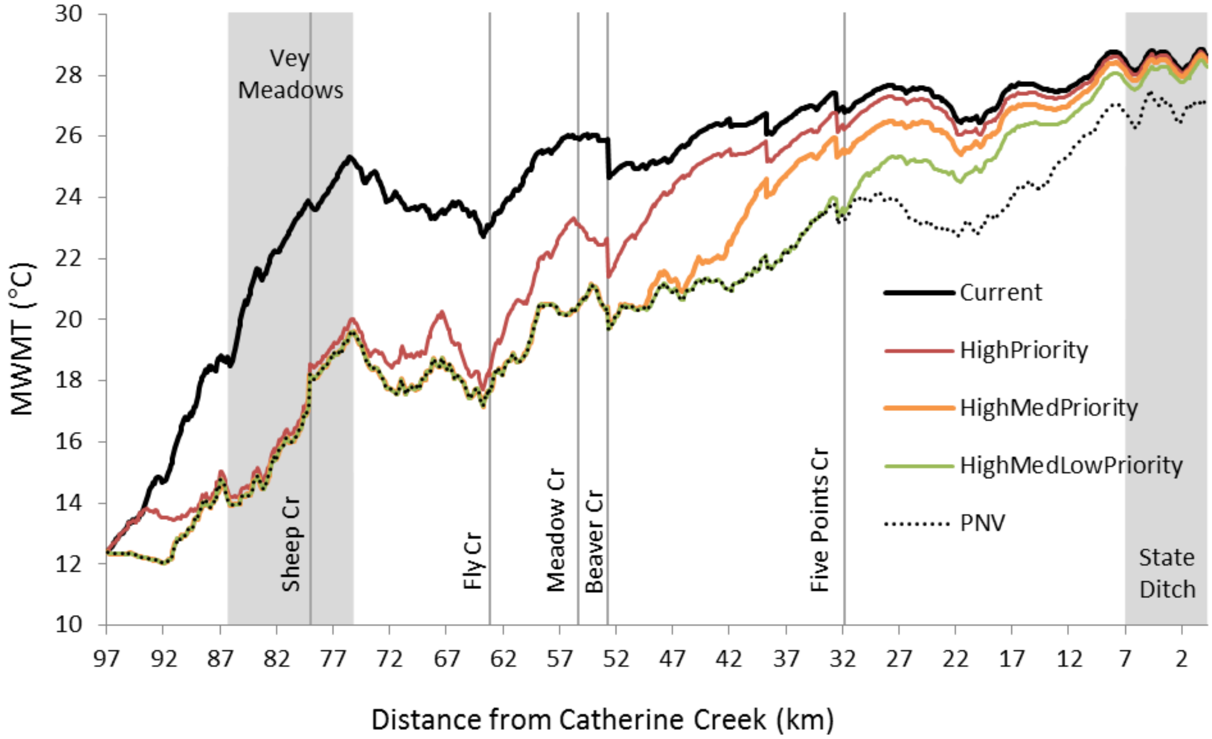

Figure 6. Simulated maximum weekly maximum water temperature (*MWMT*; °C) in the mainstem Grande Ronde River from the headwaters to the Catherine Creek confluence under current conditions and four riparian restoration scenarios.

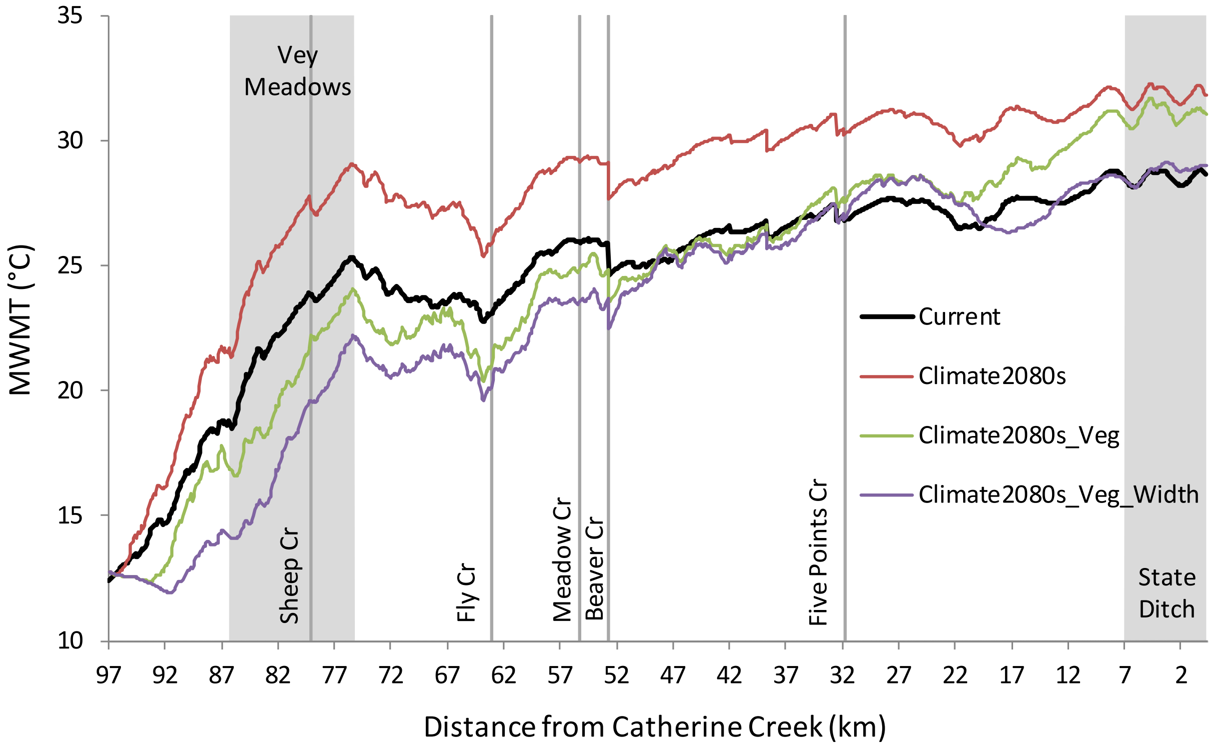

Figure 7. Simulated maximum weekly maximum water temperature (*MWMT*; °C) in the mainstem Grande Ronde River from the headwaters to the Catherine Creek confluence for four model scenarios including current conditions, 2080s climate conditions, 2080's climate conditions plus riparian vegetation restoration, and 2080's climate conditions plus riparian and channel width restoration.

Combining channel width restoration with riparian reforestation could provide even more substantial reductions in water temperature in the mainstem Grande Ronde River despite the warming effects of climate change (Figure 7). The combined climate, vegetation, and channel width scenario (scenario 10) produced a mean temperature reduction of 1.5 °C below the current condition, with reductions as high as 6.2 °C. Like model scenario 9, these temperature reductions were limited primarily to the area upstream of Beaver Creek. Downstream of Beaver Creek, the predicted temperature profile for scenario 10 tracked closely with current conditions.

Fish Abundance

A linear mixed effects model that included watershed area, gradient, water temperature, and redd density as fixed effects and site as a random effect explained approximately 51 % of the variation in Chinook Salmon parr density. Temperature explained the greatest proportion of the model variation (31.5 %), followed by redd density (14.7 %), gradient (2.8 %) and drainage area (1.8 %). The temperature-density relationship was a piecewise function that was flat up to 18 °C, and then declined to near 0 at 28 °C (Figure 8). All fixed-effect model terms were statistically significant at the $\alpha = 0.05$

level ($p < 0.01$). The random grouping factor (site) explained a negligible amount of the total variation in the data (site standard deviation < 0.001, residual standard deviation = 1.761), but was included in the model nevertheless to ensure that the model assumption of independence was satisfied. Diagnostic plots as well as formal tests of normality indicated that model assumptions were satisfied (Shapiro-Wilks Test, $p < 0.05$). The final model used to predict fish abundance was given by the following formula:

Equation 5:

$$\log(Density + 0.005) = \beta_0 + \beta_1 * \log(Area) + \beta_2 * Gradient + \beta_3 * (MWMT - 18) + \beta_4 * \log(Redds + 0.02),$$

Where, *Density* is the estimated density of Chinook Salmon summer parr (fish/m) at each site, *Area* is the watershed area upstream of the site (km²), *Gradient* is the stream gradient, *MWMT* is the maximum weekly maximum water temperature (°C), and *Redds* is the average density of Chinook Salmon redds 2 km upstream from the site (redds/100 m). Model coefficients are given by the following:

$$\beta_0 = -2.0194 \text{ (SE } = 1.1259),$$

$$\beta_1 = 0.7222 \text{ (SE } = 0.2084),$$

$$\beta_2 = -51.8642 \text{ (SE } = 17.8852),$$

$$\beta_3 = \begin{cases} 0, if\ MWMT \leq 18 \\ -0.2859 \text{ (SE} = 0.0714), if\ MWMT > 18 \end{cases},$$

$$\beta_4 = 0.7127 \text{ (SE } = 0.1147).$$

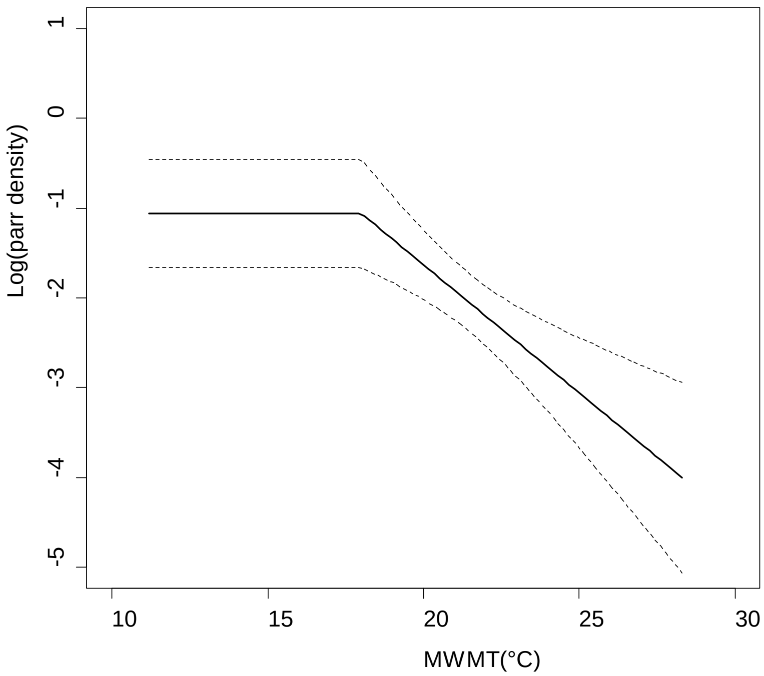

Figure 8. Relationship between log(fish density (fish/m)) and maximum weekly maximum water temperature (*MWMT*; °C) estimated using a linear mixed-effects model.

Predicted abundance of Chinook Salmon summer parr under current (i.e., 2010) conditions in the Upper Grande Ronde and Catherine Creek basins was approximately 46,000 and 55,000 respectively (Figure 9). Riparian reforestation to full PNV conditions could potentially increase abundance to 222,000 in the Upper Grande Ronde (377 % increase) and 88,000 in Catherine Creek (61 % increase). Restoration of vegetation in high priority areas only was estimated to increase abundance to about 93,000 in the Upper Grande Ronde (100 % increase), and 71,000 in Catherine Creek (30 % increase). Expanding vegetation restoration into include both high and medium priority areas (model scenario 4) could increase abundance to 166,000 (257 % increase) and 84,000 (54 % increase) in the Upper Grande Ronde and Catherine Creek respectively. Finally, restoration of high, medium, and low priority areas was estimated to increase abundance to 208,000 (348 % increase) in the Upper Grande Ronde and 88,000 (61 % increase) in Catherine Creek. Interestingly, restoration of medium priority sites provided the greatest incremental increase in abundance in the Upper Grande Ronde, whereas restoration of high priority sites provided the greatest relative increase in abundance in Catherine Creek. Riparian restoration in low priority areas provided little additional benefit in terms of total fish abundance in Catherine Creek (7 % increase over HighMed scenario). In contrast, restoration of low priority sites in the Upper Grande Ronde produced a substantial additional increase in fish abundance (91 % increase over the HighMed scenario).

Simulated narrowing of the river channel produced a substantial increase in predicted fish abundance, although the effect was relatively low compared with the expected benefits from riparian restoration.

For example, fish abundance in the Upper Grande Ronde was predicted to increase by 63 % following restoration of channel morphology, compared with 377 % following riparian reforestation (Figure 9). Similarly, channel narrowing was estimated to increase fish abundance by 29 % in Catherine Creek compared with a predicted increase of 61 % resulting from riparian restoration. Combining channel width reductions with riparian reforestation produced the greatest predicted increases in fish abundance, with a potential increase of 517 % in the Upper Grande Ronde and 74 % in Catherine Creek.

Projected water temperature increases resulting from climate change for the 2080s time period were predicted to reduce fish abundance by approximately 53 % in the Upper Grande Ronde and 35 % in Catherine Creek, assuming riparian vegetation cover and height remain similar to current conditions. However, if riparian vegetation was restored concurrently with these climate changes, we estimate that fish abundance could increase by 63 % in the Upper Grande Ronde and 20 % in Catherine Creek. Additionally, if channel width reductions were combined with riparian restoration, we estimate that fish abundance could increase by as much as 113 % in the Upper Grande Ronde and 41 % in Catherine Creek, despite the warming effects of climate change.

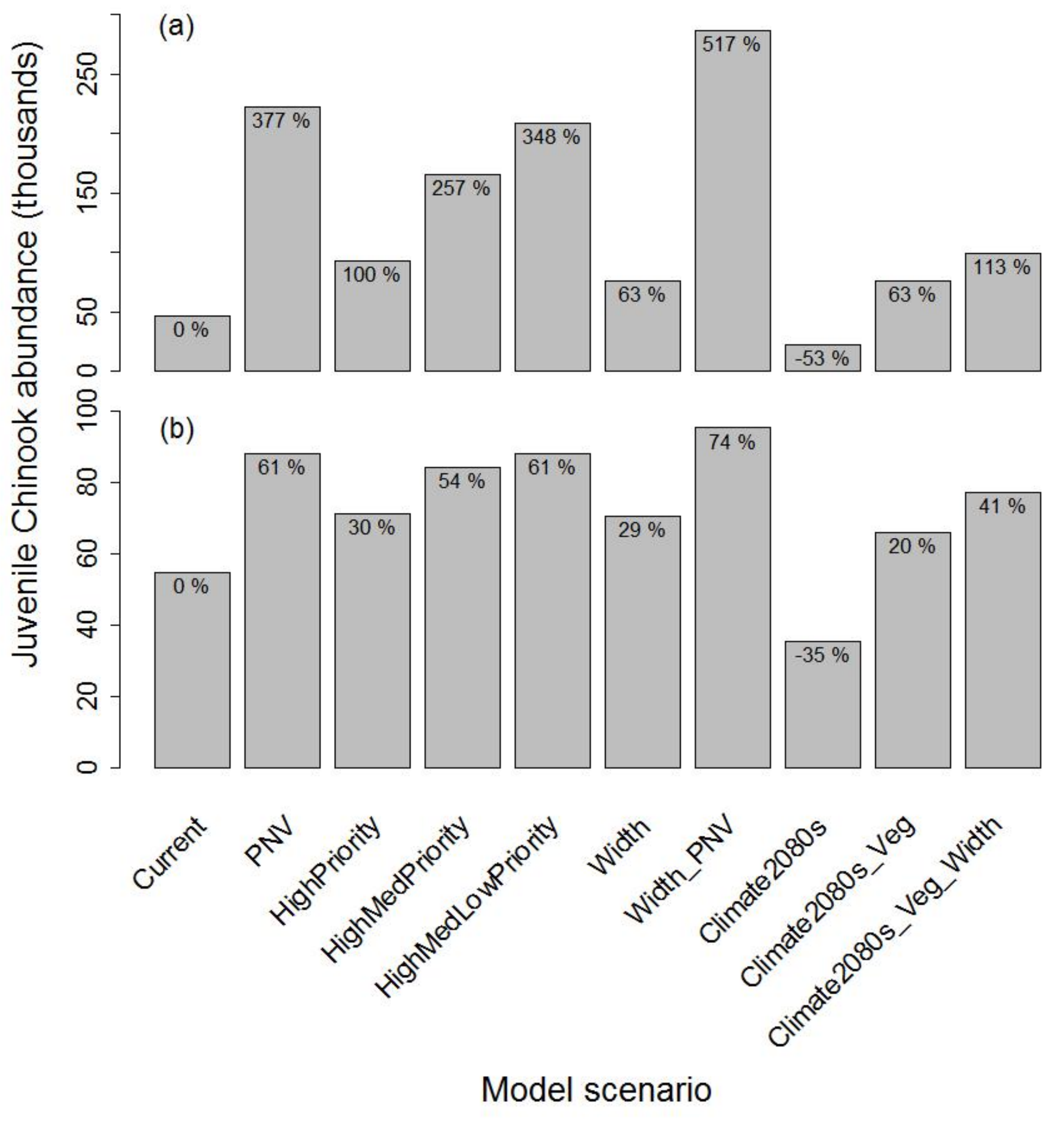

Figure 9. Predicted abundance of juvenile Chinook Salmon for each model scenario in (a) the Upper Grande Ronde River and associated tributaries, and (b) Catherine Creek and associated tributaries. Numbers at the top of each bar indicate the percentage change in abundance from the current condition.

Discussion

Water Temperature

Model simulations for current conditions indicated high water temperatures in excess of the upper limit for optimal Chinook Salmon growth (16 °C; EPA 2003) and survival (25 °C; Brett 1952, Orsi 1971) across large portions of the Upper Grande Ronde Basin. These results are consistent with previous water temperature assessments in the Grande Ronde Basin (ODEQ 2000), and highlight the need for continued focus on water temperature as a key limiting habitat factor for viability of threatened Chinook Salmon in the basin. Although the baseline model on which these results were based was calibrated using climate and hydrologic conditions from a single year (i.e., 2010), examination of historical air temperature and streamflow data indicated that 2010 was a fairly average year. For example, average summer air temperature (July – September) measured in the city of La Grande (station 354622) between 1965 and 2010 ranged from 13.9 to 21.4 °C (mean = 18.2 °C), compared with an average summer temperature of 17.4 °C in 2010 (2010 percentile = 27 %). Similarly, average summer streamflow (cfs; July - September) in the Grande Ronde River near Perry (station 13318960) between 1993 and 2014 ranged from 20 to 241 cfs (mean = 66 cfs), while summer streamflow in 2010 averaged 55 cfs (2010 percentile = 57 %).

Simulated basin-wide restoration of riparian vegetation was predicted to substantially reduce the proportion of stream habitat that exceeded stressful temperature thresholds for Chinook Salmon (e.g., 20 °C). Similar thermal benefits from riparian restoration have been demonstrated using temperature simulation models in the Grande Ronde Basin (ODEQ 2000, Watanabe *et al.* 2005) and elsewhere in the Pacific Northwest (Bond *et al.* 2015, Butcher *et al.* 2010, Theurer *et al.* 1985). The addition of shade to streams has been cited as one of the most significant controls on stream water heating (Beschta *et al.* 1987). Given the magnitude of known levels of water temperature increase that can be caused by relatively short lengths of riparian clearcutting, causing reduction in shading (e.g., as much as 10 °C increases; Beschta *et al.* 1987), it is not valid to discount the importance of restoring riparian shade as a primary means of improving stream thermal conditions. The work reported here illustrates the value of riparian cover restoration on a stream network basis as a key effort in improving habitat conditions for spring Chinook Salmon and steelhead. But we realize that the benefits of riparian vegetation enhancement extend far beyond direct thermal restoration.

Restoration of riparian vegetation has significant ecological and physical benefits beyond creation of shade (Seedang *et al.* 2008). Rooting of willows, cottonwood, birch, and alders near and slightly above the high water line on bars contributes to channel narrowing via sediment deposition and capture of soils from suspension (Boon and Raven 2012). Over time this leads to channel bed aggradation and reduction in steep banks and downcutting (Beechie *et al.* 2013), which in turn, improves the bi-directional flow of surface water into floodplain alluvium (Arrigoni *et al.* 2008). Development of mature and old-growth riparian stands restores processes of large wood recruitment to stream channels which can enhance in-channel and lateral storage of sediments, improve sorting of gravels, increase complexity in hyporheic flow paths and exchange between surface and subsurface flow (i.e. hyporheic exchange), create scour leading to pool formation, and provide cover for rearing fish from predators and high flows. Because these important ecological benefits of riparian restoration were not accounted for

in the model, we feel our estimates of thermal restoration represent a minimum level achievable from riparian restoration in general.

Other restoration actions such as channel reconstruction and levee removal that are designed to increase channel complexity (i.e., sinuosity, side channel frequency, instream structure) and floodplain connectivity have the potential to cool water temperatures by increasing hyporheic exchange (Beechie *et al.* 2013, Poole and Berman 2001), although the specific influence of hyporheic flow on ambient channel water temperature is complex and can exhibit a range of effects including cooling, buffering, lagging, or a combination of the three (Arrigoni *et al.* 2008). Although we assume that increasing hyporheic exchange would provide some direct thermal benefits to fish populations in the Grande Ronde Basin, modeling its effects on temperature on a basin-wide scale would require development of predictive tools to estimate where and how much hyporheic exchange could be improved within the stream network, as well as development of mechanistic or correlative relationships between hyporheic exchange and water temperature. It is likely that a more flexible statistical modeling framework other than Heat Source would be needed for this task. Although development of such tools is beyond the scope of this project, it would be a valuable area of study for future research.

Summer base flow is another factor that can strongly influence water temperature but was not explored thoroughly with our model outside the context of climate change. Historical accounts indicate that forests in the Grande Ronde Basin prior to intense timber harvest activities were more extensive and were composed of much larger trees, with considerably higher water storage capacity (Gildemeister 1998). Such forests could sustain a higher base flow for a longer period of time than forests that have been heavily harvested, and thereby contribute to cooler water temperatures during the warmest time of year. However, without a credible way to quantify the potential increase in summer base flow that could result from increases in upland forest cover and tree size, we did not attempt to explore this factor in our model. In addition, flow restoration, where water has been diverted for irrigation or other consumptive uses, is an important tool for cooling stream water temperatures (Seedang *et al.* 2008). Given the small number of water diversions occurring within our model extent, and to provide simplicity and clarity to the analysis, we decided not to explore model runs that included flow restoration.

Riparian restoration scenarios indicated that the greatest potential reductions in water temperature occurred in the upper to middle portion of the Upper Grande Ronde River (upstream of Five Points Creek; river km 63.4), particularly in areas that were designated as high and medium priority for restoration. Despite substantial potential cooling benefits from riparian restoration demonstrated by our model, we found that large portions of the stream network, particularly in the lower portion of the basin, would continue to exceed the temperature thresholds set by the EPA of 16 °C for “core” juvenile salmon rearing, and 18 °C for salmon migration and “non-core” juvenile rearing even after restoration of riparian vegetation to its natural potential (Figure 5). One reason for this may be the fact that our model did not account for various other ecological factors that can contribute to cooling as noted above (i.e., hyporheic exchange, flow restoration). However, it is reasonable to assume that some portions of the Upper Grande Ronde Basin, owing to its arid climate, always had water temperatures that were stressful to salmon, particularly in lower parts of the basin where the river is wide and streamside vegetation is dominated by meadow and shrubland habitats with limited potential tree cover. A similar temperature

modeling analysis in the John Day River also found that water temperatures, even after restoration of riparian vegetation, channel morphology and streamflow (i.e., natural thermal potential), were still well above biologically based temperature criteria for salmon across a large portion of the stream network (Butcher *et al.* 2010). The potential for riparian vegetation to cool the stream in the lower portions of the basin is diminished due to the large water volume (inertia) of large rivers and lower ability of riparian vegetation to shade a significant percentage of the stream surface (Poole and Berman 2001).

Although our model results indicated substantial potential reductions in water temperature in response to riparian reforestation (i.e., -5.4 °C median temperature in the Upper Grande Ronde Basin and – 2.9 °C in the Catherine Creek Basin), these estimates are conservative compared with previous predictions from the Upper Grande Ronde Total Maximum Daily Load (TMDL) analysis by the Oregon Department of Environmental Quality (ODEQ 2000). Because the ODEQ model was based on a different spatial extent and different climate and hydrologic conditions (i.e., 1999 instead of 2010), a direct comparison of model outputs could be misleading. To account for this, we parameterized our model using the potential riparian vegetation assumptions used in the ODEQ analysis. The resulting model produced maximum weekly maximum water temperature estimates in the mainstem Grande Ronde River that were 10.4 °C below the current condition on average, compared with 4.2 °C below current for our PNV scenario. This large difference is due to the simplified vegetation classification and relatively liberal assumptions regarding potential tree canopy density that were used in the ODEQ analysis. Specifically, ODEQ used a classification system from Clausnitzer and Crowe (1997) to divide the basin into four different physiographic units and two different elevation zones (> 4800 ft, and < 4800 ft), resulting in five unique classes. Tree density within each class was simply assumed to be 80 % across the board with no justification as to the source of this value. This assumption seams unrealistically high for many parts of the watershed that are characterized by meadows, various shrublands, and dry forests. In contrast, our riparian classification consisted of 63 unique plant association groups that were mapped using a rigorous methodology that accounted for differences in physiography, geomorphology, soils, moisture, and temperature regimes (Wells *et al.* 2015). Potential tree canopy density values for our riparian classification ranged from 0 to 80 % (mean = 35 %). Although both approaches are uncertain and represent only hypotheses about potential tree cover under natural historic conditions, we feel that our model represents the best available science regarding riparian vegetation potential and therefore provides more realistic predictions of water temperature.

Water temperatures in the Grande Ronde Basin were substantially more sensitive to changes in riparian restoration, channel width, and climate change compared with Catherine Creek. Catherine Creek has its headwaters in the Wallowa Mountains, which are higher in elevation than the Blue Mountains which drain into the Upper Grande Ronde. As a result, snowmelt occurs later in the Catherine Creek system, resulting in higher sustained base flows during summer and cooler water temperatures. These higher summer base flows in Catherine Creek provide a buffering capacity against warming (i.e., it takes more energy to warm a higher volume of water). In addition, effective shade under current conditions was higher in Catherine Creek (mean = 43 %) than in the Upper Grande Ronde (mean = 22 %), indicating that there was less potential for improvement in riparian shade in Catherine Creek.

Simulated reductions in water temperature resulting from channel narrowing (i.e., decreased width-to-depth ratio) are consistent with similar temperature modeling assessments in the Columbia River Basin (ODEQ 2000, Butcher *et al.* 2010), although these reductions were relatively small compared with the temperature changes associated with riparian restoration (Figure 5). Channel narrowing can cause a reduction in water temperature primarily by reducing the surface area of water exposed to solar radiation (LeBlanc *et al.* 1997, Boyd and Kasper 2003). Channel narrowing is also accompanied by an increase in water depth, which can reduce the amount of energy that penetrates through the water to the stream bed, causing a decrease in streambed conduction (Boyd and Sturdevant 1997). Although their methods were different, the ODEQ also found that channel width reductions provided a relatively small cooling benefit compared with vegetation restoration in the Grande Ronde River (ODEQ 2000). In contrast, Butcher *et al.* (2010) found that simulated reductions in channel width of 30 % provided approximately equivalent reductions in water temperature compared with vegetation restoration in the upper 100 kilometers of the John Day River, and substantially greater reductions than vegetation restoration in the lower 325 km of the river (i.e., approximately 2 °C less than the vegetation scenario). Not surprisingly, a combination of channel width reduction and vegetation restoration yielded the greatest reductions in water temperature compared with current conditions (-6.5 °C in the Upper Grande Ronde and -3.4 °C in Catherine Creek).

Fish Abundance

The negative relationship we observed between juvenile Chinook Salmon density and water temperature is largely consistent with findings from similar field studies of salmonid populations throughout the Pacific Northwest (Li *et al.* 1994, Thompson *et al.* 2012, Madriñán 2008, Ebersole *et al.* 2001, Frissell 1992, Welsh *et al.* 2001). Although the temperature threshold of 18 °C was selected subjectively rather than being fit by the data, the threshold corresponded to the observed peak in abundance in the raw data and was consistent with other studies that have identified 18 °C as an upper limit for rearing preference temperatures for juvenile salmonids (Welsh *et al.* 2001, EPA 2003).

Abundance estimates for current conditions were based on water temperature conditions from 2010 and average redd density estimates from 2010 to 2013. These estimates were intended to represent an approximate basin-wide average summer parr abundance under current climatic and hydrologic conditions, and provide a baseline by which to compare relative expected benefits or impacts from the various restoration and climate scenarios we examined. These abundance estimates appear to be reasonable compared with summer parr abundance estimates derived from the ODFW smolt trapping and PIT-tag data. For example, ODFW's summer parr abundance estimates in the Upper Grande Ronde River between 2009 and 2013 ranged from 36,297 to 227,463 (geometric mean = 77,885) compared with our estimate of 46,489 (Brian Jonasson, ODFW, personal communication). Similarly, ODFW's abundance estimates in Catherine Creek for the same time period ranged from 24,732 to 116,382 (geometric mean = 70,422), compared with our estimate of 54,791.

We acknowledge that these abundance estimates are very rough, and that the model is lacking some explanatory variables that could have a substantial impact on juvenile abundance such as pool frequency and large woody debris. In addition, density-dependence factors were not considered explicitly in the form of a standard stock-recruitment function (i.e., Beverton-Holt or Ricker). That said,

the model was based on empirical data collected within our study area and provides reasonable relationships between a known limiting habitat factor (i.e., water temperature) and juvenile Chinook Salmon abundance. While the actual estimates of abundance may be uncertain, we assume that the relative changes in abundance as a function of water temperature are reasonable. Utilizing the temperature results from this analysis within the context of a life-cycle model that properly accounts for density-dependent factors, temperature impacts on multiple life stages, and gradual recolonization of currently unused habitats via straying is an objective of ongoing research by both CRITFC and ODFW in the basin and promises to shed more light on the potential for stream restoration actions to improve salmon population viability.

Estimated percentage changes in Chinook Salmon parr abundance resulting from restoration of riparian vegetation and channel width generally mirrored the patterns observed in water temperature, although in the opposite direction (i.e., lower water temperature equaled higher fish abundance). Most notably, the predicted relative change in fish abundance was considerably higher in the Grande Ronde Basin compared with Catherine Creek (Figure 9). Potential increases in juvenile fish abundance up to 377 % in the Upper Grande Ronde and 61 % in Catherine Creek resulting from restoration of riparian vegetation are encouraging and highlight the tremendous importance of riparian shade for salmon productivity in the basin, particularly in the Upper Grande Ronde.

Conclusions

Results from our water temperature simulation model indicated that aggressive basin-wide restoration actions targeting both riparian vegetation and channel width could significantly improve water temperature and fish abundance in the Upper Grande Ronde Basin, even in the face of climate change. A combination of riparian restoration and channel narrowing was estimated to reduce median water temperatures by 6.5 °C in the Upper Grande Ronde Basin and 3.4 °C in Catherine Creek. Using a statistical model developed from snorkel survey and habitat data from the Grande Ronde basin, these results translated to increases in Chinook summer parr abundance of 517 and 74 % respectively. Although projected climate change impacts on water temperature for the 2080s time period were substantial (i.e., median increase of 2.8 °C in the Upper Grande Ronde, and 1.8 °C in Catherine Creek), we estimate that basin-wide restoration of both riparian vegetation and channel width could offset these impacts, reducing water temperatures by about 3.6 °C in the Upper Grande Ronde and 2.1 °C in Catherine Creek.

The development of priority areas for riparian restoration could provide a valuable tool for restoration planners and practitioners seeking to improve water temperatures for threatened salmon populations in the Grande Ronde Basin while maximizing the use of limited resources. A restoration prioritization framework that utilizes empirical and modeled data to evaluate effective shade (i.e., how shaded is the stream compared with its natural potential?) and accounts for the proximity to currently used spawning areas (i.e., targeting the most productive areas first) provides an advancement over current methods of restoration planning, which are often opportunistic or based on expert judgement. Although riparian vegetation planting should be considered only one important component of a multifaceted approach to watershed restoration which includes a strong emphasis on restoring natural stream processes (i.e., hydrology, channel morphology, floodplain connectivity, channel complexity), the work reported here illustrates the value of riparian cover restoration on a stream network basis as a key effort in improving habitat conditions for spring Chinook Salmon and steelhead.

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Appendix B – Cold-water Refuge Mapping

Protocol for Field Measurements of Cold-water Refuges

Columbia River Inter-Tribal Fish Commission

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Introduction

High water temperature is an important habitat factor limiting abundance, productivity and spatial distribution of cold-water fish species in many streams across the Pacific Northwest. Cold-water refuges, defined here as spatially-continuous patches of water with temperatures at least 2 °C less than the ambient water temperature (Kurylyk *et al*. 2014), less than 25 °C, and a surface area at least 1 m², can help mediate the effects of warm ambient water temperatures by providing discrete zones of cool water rearing or holding habitat during periods of thermal stress. Preferential fish use of cold-water refuges in warm streams has been well documented (Torgersen *et al*. 1999, Ebersole *et al*. 2003, Sutton *et al*. 2007, Tate *et al*. 2007).

This protocol provides a set of field-based procedures for evaluating the spatial distribution and physical characteristics of cold-water refuges in wadable streams with peak ambient water temperatures exceeding 18 °C. These procedures are appropriate for channel unit and microhabitat-scale refuges and do not apply to larger reach or segment-scale refuges (Torgersen 2012). This protocol is intended to be used in combination with pre-existing data on the locations of potential thermal refuges (e.g., thermal infrared (TIR) imagery, previous research, or other anecdotal evidence) to field-verify the locations and physical attributes of existing cold-water refuges. This information may be useful for restoration planning purposes for projects seeking to enhance or protect currently existing cold-water refuges. In addition, this information could be used in combination with ongoing fish and habitat monitoring and population modeling activities to address how refuge size, connectivity, or frequency influence salmon populations.

Methods

The locations and descriptive information of previously-identified cold-water refuges within the area of interest should be assembled and organized prior to collection of field data. A shapefile containing

refuge boundaries and/or midpoint coordinates as well as associated aerial imagery should be loaded to a GPS-enabled electronic data logger or other GPS unit to aid in navigation to refuge sites. Any descriptive information such as refuge identification number, location description, refuge type, size, and temperature should be available during field surveys to further aid in refuge identification and documentation. In addition, landowner permission should be secured prior to conducting field surveys of cold-water refuges.

Thermal refuge surveys should be conducted during the period of summer base flow and maximum annual stream temperature (July 1 - September 1), when cold-water refuges are most important to fish and when contrast between refuge and ambient temperatures are maximized. In addition, surveys should be conducted during the warmest time of day (1200 – 1800) to maximize the probability of detecting thermal refuges and to minimize the effect of temporal variation on refuge measurements.

After navigating to a potential refuge, cautiously approach the refuge site and visually scan the water using polarized glasses for fish prior to conducting any habitat measurements. Make note of whether the refuge is occupied by salmonids (see fish use below). Use an underwater view scope if necessary to distinguish salmonids from other fish species.

Next, use a digital temperature probe with a recommended accuracy of at least 0.2 °C (e.g., Atkins 35200-K, accuracy 0.1 °C) mounted to a telescoping pole to determine if the water temperature in the refuge meets the criteria of being at least 2 °C lower than the ambient temperature and ≤ 25 °C. Sweep the probe from side to side within 5 cm from the stream bottom. Ambient water temperature is measured in the mainstem channel just upstream of the refuge mixing zone. Next, visually estimate the surface area of the refuge to determine if it meets the minimum size criteria of ≥ 1 m^2.

If time permits, it is recommended to briefly investigate areas in the near vicinity of previously-identified refuges that have geomorphic characteristics often associated with cold-water refuges (e.g., alcoves, small side channels, downstream edges of large gravel bars, and deep pools), but that were not detected in the TIR data.

Refuge Characteristics

Record the following information at all potential refuge locations:

Refuge ID: Unique refuge identification number. If the refuge was previously identified from TIR imagery or other sources, the refuge will have a refuge ID number. Use the refuge boundary shapefile, aerial imagery and any descriptive information to determine the correct refuge ID number. If previously-unidentified refuges are discovered during the course of the field survey, they should be assigned a new ID number starting with a number that will not overlap with the original set of ID numbers (e.g., 1001).

Stream Name: Name of the stream that the refuge is in or is directly connected to.

Survey Date: Date that the refuge was surveyed (MM/DD/YYYY).

Organization and Surveyor Name: Name of organization or agency that you work for and full name of the surveyor(s).

Refuge Status: Status of the refuge or potential refuge (i.e., Qualifying-previously identified, Qualifying-new, Non-qualifying, Not accessible).

> Qualifying-previously identified – Cold-water refuges that were previously identified from the TIR data or other sources *and* that meet the temperature and size criteria specified above.
>
> Qualifying-new – Cold-water refuges that were newly identified in the field (i.e., were not present in TIR data or identified from previous research) *and* meet the temperature and size criteria.
>
> Non-qualifying – The potential refuge location that was previously identified from TIR data or other sources does not meet the temperature and size criteria specified above. Some features may have been falsely delineated as cold-water refuges based on thermal anomalies in the TIR data resulting from shadows or moist vegetation, but these thermal anomalies are not detectable in the field. In other instances, changes in channel geomorphology, discharge, or groundwater inputs may have changed flow and temperature dynamics within the previously-identified refuges, rendering them non-qualifying.
>
> Not accessible – Potential cold-water refuges that could not be surveyed in the field because access was denied by landowners or conditions were unsafe or infeasible for surveying.

Record the following information at all <u>qualifying</u> refuges:

Midpoint Coordinates: GPS coordinates (latitude and longitude in decimal degrees using datum WGS84) taken at the midpoint of the refuge, GPS accuracy (in meters), and time that location was recorded (hh:mm; 24 hour format). If an external GPS device is used to collect a waypoint at the refuge, record the waypoint number.

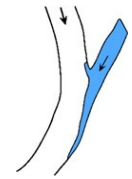
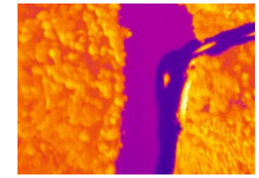
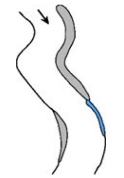
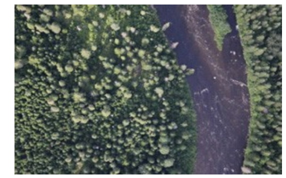
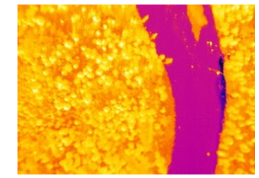
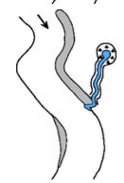
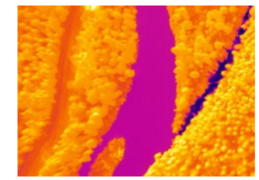
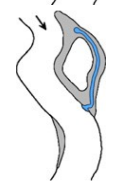
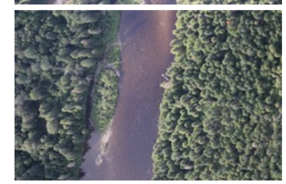
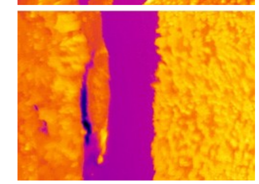
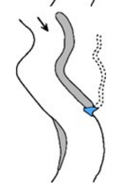
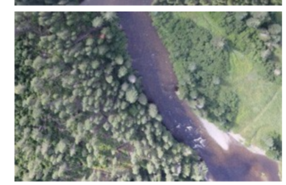
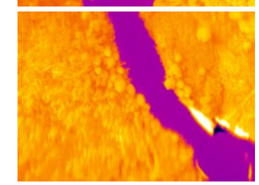
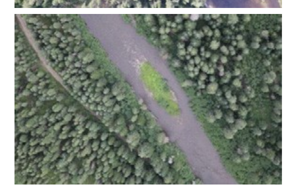
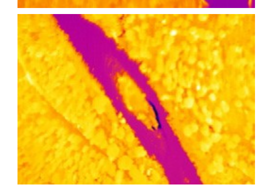
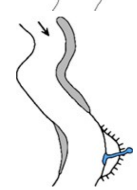
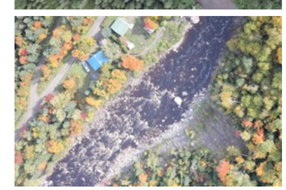
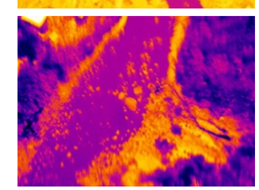
Channel Location: The location of the refuge relative to the centerline of the main channel (looking downstream): Left, Right, Middle.

Refuge Type: Classification of refuge type from Dugdale *et al*. (2013) and references cited therein based on refuge geomorphology, refuge forming processes, and source of cold water (Table 1). Refuge types include: tributary confluence plume, lateral seep, springbrook, cold side channel, cold alcove, hyporheic upwelling, and wall-base channel. For previously identified refuges, the refuge type will be provided in advance of the field survey, but the final refuge type will need to be modified in some cases based on conditions observed in the field.

Refuge Photos: Take at least one photo of the refuge that captures the dominant geomorphic characteristics of the refuge, and ideally, shows the refuge connection to the main channel. It is recommended to include a depth rod in the photo for scale.

Notes: Record any notes that may aid in future identification of the refuge location, comments about processes that likely formed the refuge, or other important descriptive information about the refuge that is not captured by other components of the survey.

Table 1. Descriptions and examples of cold-water refuge types (Dugdale *et al*. (2013).

Thermal refuge	Description	Schematic	Optical image example	TIR image example
Tributary confluence plume	Thermal plumes created prior to mixing where a cold tributary discharges into the main (warmer) river channel.			
Lateral seep	Elongated bank side filaments of cold water inflow observed when the active river channel intersects zones of groundwater flow (often in steep terraces or valleys).			
Springbrook	Cold-water channels flowing from springs, marshland or depressions adjacent to the channel; often associated with abandoned channels. Also includes springs within the main channel.			
Cold side channel	Cold secondary channels flowing in ephemeral flood pathways and normally completely wetted only during periods of high flow.			
Cold alcove	Zones of cold water found at the downstream edge of a bar and often associated with emergence of an abandoned channel or formed when groundwater pathways converge and accumulate in a backwater.			
Hyporheic upwelling	Resurgence of hyporheic flow from the streambed found at the downstream ends of gravel bars, mid-channel islands or in sequence with pool-riffle bedforms.			
Wall-base channel	Runoff-fed channels emerging from terraces or steep valley walls and then flowing over the immediate floodplain into the river channel.			

Surface Area: Average length and width (meters) measured with a measuring tape, stadia rod, or laser rangefinder at three equally-spaced transects for each dimension (Figure 1). For example, refuge width is measured at 25, 50, and 75% along the length of the refuge. Refuge boundaries may be delineated with flagging attached to rocks to aid in surface area measurements. If it's difficult or redundant to measure three length transects because the refuge is very long (approximately > 30 m), sinuous, or heavily vegetated, then simply measure the maximum length of the refuge. For refuges with very irregular shapes, it may be helpful to sketch the refuge on a field notebook and document where widths, lengths, depths and temperatures were measured. Be sure to record the refuge ID on the sketch.

Depth: Maximum and average depth (meters). To calculate average depth, a single depth measurement is made using a depth rod along each width transect at a location visually-estimated as the average (Figure 1).

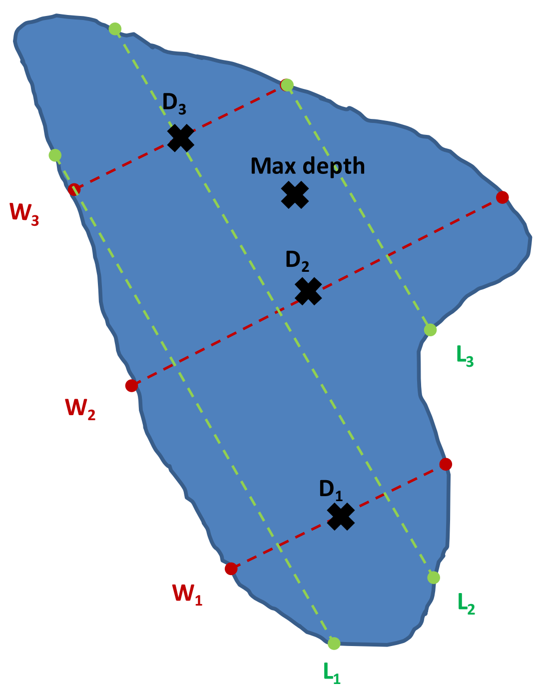


Figure 1. Depiction of a hypothetical cold-water refuge indicating locations of length, width, and depth measurements.

Instantaneous Water Temperature: Water temperature (°C) within each refuge is measured with a digital temperature probe (Atkins 35200-K, accuracy 0.1 °C) at both the water surface and the stream bottom at the midpoint of each of the three width transects. In addition, the minimum water temperature within the refuge is also recorded. For ambient water temperature, a single temperature measurement is made in the mainstem channel upstream of the refuge mixing zone in a well-mixed location with flowing water at approximately mid-depth.

Refuge Crest Depth: The refuge crest, similar to a pool crest, is the shallowest lateral cross section of the streambed within the wetted flow path connecting the refuge to the main channel. The refuge crest depth is measured at the deepest point along the refuge crest cross section. If the flow path is not continuously wetted, the depth is recorded as zero.

Distance to Main Channel: Distance (meters) from the nearest edge of the refuge to the main channel. Where cold-water refuges are immediately adjacent, within, or extend to the main channel, the distance is recorded as zero.

Refuge Water Velocity: Visually estimate whether the water within the refuge is (on average), Not Moving, Slow (> 0 – 0.1 m/s), Moderate to Fast (> 0.1 – 1.1 m/s), or Very Fast (> 1.1 m/s). Use a velocity meter to periodically calibrate your eye to true water velocity.

Substrate Composition: Extracted from the Columbia Habitat Monitoring Program (CHaMP) protocol (CHaMP 2014).

i. Visually survey the substrate composition of each refuge and record the percentage of each substrate size class (Table 2) within the wetted surface area.
ii. Round estimates to the nearest 5%.
iii. You may not be able to see the entire wetted surface area of a refuge due to visual obstructions (aquatic vegetation, wood, other debris, or surface turbulence). When this occurs, estimate the area you can see.
iv. The total of all classes should equal 100%.
v. If a thin, continuous layer of fine sediment is covering a larger particle, then measure the fine sediment, not the larger underlying particle. Conversely, individual fine sediment particles resting on top of larger rocks are not counted.

Table 2. Ocular substrate size classes. Estimate b-axis diameter of particles.

Substrate Type	Size class (mm)	Description
Bedrock	N/A	Exposed bedrock surface
Boulders	> 256	Basketball size and greater
Cobbles	64 to 256	Tennis ball to basketball size
Coarse gravel	16 to 64	Marble to tennis ball size
Fine gravel	2 to 16	Small pebble to marble size
Sand	0.06 to 2	Smaller than ladybug size, but visible as particles and gritty between fingers
Fines	< 0.06	Silt and clay that is not gritty between fingers

Fish Cover: Extracted from the Columbia Habitat Monitoring Program (CHaMP) protocol (CHaMP 2014).

i. Visually estimate the proportion of the wetted surface area within each refuge that is covered by each of the fish cover elements listed in Table 3. Fish cover provided by

boulders and undercut banks is measured separately (see “Substrate Composition” and “Undercut Banks” sections).

ii. All fish cover elements must be within the wetted channel or ≤ 1 m above the water’s surface.

iii. Round measurements to the nearest 5%.

Table 3. Definitions of fish cover elements (not including undercuts or boulders) evaluated at each refuge.

Cover Element	Cover Element Definition
Woody debris	Wetted area of the refuge covered by dead woody debris. There is no size requirement for woody debris to be considered fish cover. Include boards, railroad ties, wood placed for restoration purposes, etc.
Overhanging vegetation and live tree roots	Wetted area of the refuge covered by live, terrestrial vegetation. Live tree roots suspended over the water and/or submerged. Non-qualifying undercuts are included, qualifying undercuts are not (Section 8.5).
Aquatic vegetation	Wetted area of the refuge covered by aquatic macrophytes and filamentous algae.
Artificial structures	Wetted area of the refuge covered by artificial structures including materials discarded in the stream (tires, old cars, concrete, etc.). Rip-rap and logs placed for restoration purposes are not included in this category.

Undercut Banks: Quantify the surface area of undercut banks in cold-water refuges.

Step 1. Identify qualifying undercut banks.

i. Undercut banks are continuous cave-like features in the stream bank formed by overhanging bank material and/or tree roots.

ii. Qualifying undercut banks:

   a. Provide fish cover at the time of sampling.
   b. Have a width ≥ 0.2 m.
   c. Have a length ≥ 1 m long, measured along the edge of water.
   d. Include undercuts with ceilings ≤ 1 m above the water surface (Figure 2).

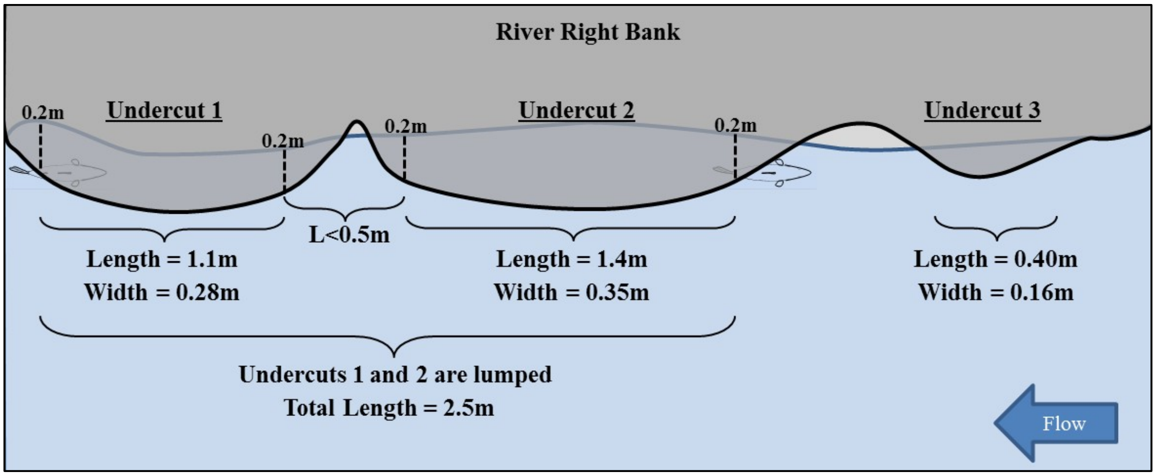


Figure 2. Top down view depicting three undercuts. Undercut 1 and 2 both meet minimum length and width requirements and are considered one undercut because the width separating them is < 0.50 m. Undercut 3 does not meet the minimum length or width requirements and is not recorded.

Step 2. Estimate the length of the undercut.

i. Determine the upstream and downstream boundaries of the undercut and measure the length along the edge of water.
ii. Measure only the portion of the undercut that meets the minimum width requirement (Figure 2).
iii. When there are two or more qualifying undercuts separated by a distance of less than 0.5 m, consider them one undercut but do not account for the distance between them in the length estimate.

Step 3. Measure and record the width of qualifying undercuts.

i. Measure the <u>wetted</u> widths of the undercut parallel to the water's surface and perpendicular to the direction of flow.
ii. Undercut width is measured as the <u>wetted</u> horizontal distance from the outermost edge of the overhanging bank to the back "wall" of the undercut at its widest point (Figure 3).
iii. Measure undercut widths at three points located at 25, 50 and 75% of the qualifying undercut length. The average width of the three points must be ≥ 0.2 m to qualify.

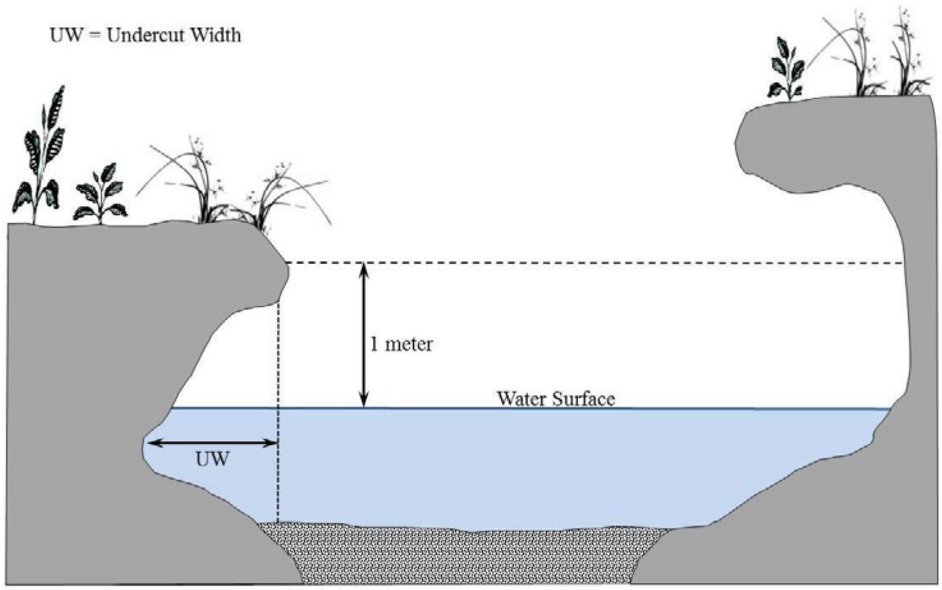


Figure 3. Where to measure the wetted width of an undercut bank (left). The bank on the right has a cave-like feature, but its ceiling is > 1 m above the water's surface; therefore, it does not qualify as an undercut bank.

Continuous Water Temperature: Hourly water temperature (°C) from July 15 to August 31 in the refuge and ambient mainstem channel measured with Onset Hobo Tidbit loggers at 20 randomly selected refuges. The sample is stratified by refuge type in proportion to their occurrence within the study area. Loggers within each refuge are placed at the stream bottom in a location representing the approximate mean temperature. Loggers in the main channel are placed upstream of the refuge mixing zone in a well-mixed location. Be cognizant of declining water levels through the season when placing the loggers and select deeper locations that are likely to remain wetted throughout the summer period.

Record Logger ID, installation date and time, installation method (e.g., cabled to stake, cabled to tree, epoxied to boulder), GPS coordinates and accuracy where the loggers are installed, and descriptive notes about the logger location as necessary.

Solar Access: Measure solar access (percent of solar radiation reaching the water surface) using a Solmetric SunEye device and record the skyline number(s) in the data logger. If the refuge length is ≤ 30 m, collect a single SunEye image at the midpoint of the refuge. If the refuge length is > 30 m, collect 2 SunEye images spaced evenly along the length of the refuge. On the SunEye, record the refuge ID number. See the SunEye instruction manual for further details.

Fish Use: Record presence or absence of salmonids and non-salmonids in the refuge. Record salmonid species observed if they are identifiable. If possible, record the dominant species present in the refuge (i.e., most common salmonid or non-salmonid species). Species codes include the following: *O. mykiss* (steelhead/Rainbow Trout) (OM), Chinook Salmon (CH), Coho Salmon (CO), Bull Trout (BT), Brook Trout (BK), Cutthroat Trout (CT), Redside Shiner (RS), Northern Pikeminnow (NP), Mountain Whitefish (MW), sucker (suck), dace (dace), cyprinids (CY), lamprey (LY), sculpins (scul), catfishes (catf), and sunfishes (sunf).

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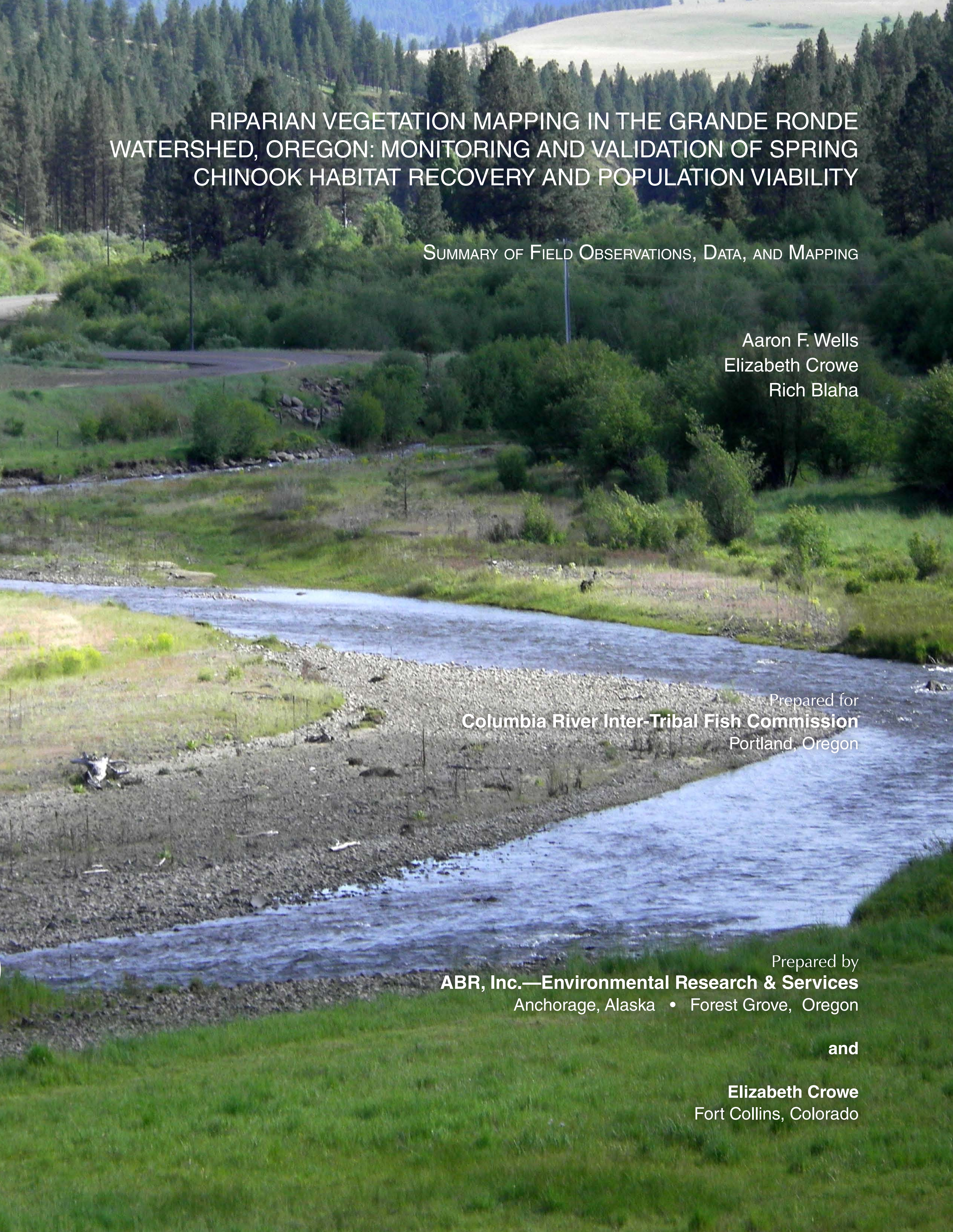
Appendix C – Riparian Mapping



RIPARIAN VEGETATION MAPPING IN THE GRANDE RONDE WATERSHED, OREGON: MONITORING AND VALIDATION OF SPRING CHINOOK HABITAT RECOVERY AND POPULATION VIABILITY

Summary of Field Observations, Data, and Mapping

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Portland, Oregon

Prepared by
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Anchorage, Alaska • Forest Grove, Oregon

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Elizabeth Crowe
Fort Collins, Colorado

RIPARIAN VEGETATION MAPPING IN THE GRANDE RONDE WATERSHED, OREGON: MONITORING AND VALIDATION OF SPRING CHINOOK HABITAT RECOVERY AND POPULATION VIABILITY

Phase 3: Summary of Field Observations, Data, and Mapping

Prepared for

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACKNOWLEDGMENTS

We thank Dale McCullough, Seth White and Casey Justice of the Columbia River Inter-Tribal Fish Commission for their assistance with field work, field accommodations and field vehicles in the summer of 2014. We appreciate their great advice on the direction of this project and production of the ensuing report, as well as their patience with our delays in our production schedule.

INTRODUCTION

The Columbia River Inter-Tribal Fish Commission (CRITFC) seeks to develop a spatially-based system for modeling abundance, productivity, and growth rate for spring Chinook salmon in the upper Grande Ronde watershed in northeastern Oregon (Figure 1). This watershed has experienced various levels of anthropogenic disturbance, which has compromised the quality of Chinook spawning and rearing habitat. To assess the extent to which current conditions are affecting fish population dynamics, a model of watershed health will be developed based on water temperature, fine sediment (surface and depth), stream flow, and riparian condition. CRITFC is particularly interested in determining the potential to restore the water temperature regime in the watershed, which will require developing a water temperature model. Maps of the current vegetation and potential natural vegetation (PNV) communities are critical to supporting this model.

ABR, Inc.—Environmental Research & Services (ABR) and Elizabeth Crowe worked collaboratively to create a map of existing and potential natural vegetation throughout the extent of the spring Chinook spawning and rearing zone in the upper Grande Ronde watershed. The study was conducted in phases, with phases 1 and 2 focused on development of mapping concepts and draft mapping, respectively.

OBJECTIVES

Phase 3 objectives included:

1. Complete field surveys designed to collect data on vegetation and soil characteristics in the study area
2. Finalize the Integrated Terrain Unit (ITU) mapping initiated in Phase 2, including physiography, geomorphology, soils, existing and potential vegetation, and disturbance.
3. Summarize canopy height and density of existing vegetation by ITU map polygon using existing LiDAR data
4. Assign height classes to potential vegetation classes using data obtained from pre-existing vegetation classifications
5. Prepare a report summarizing the mapping and field observations and data

STUDY AREA

The study area encompasses approximate 7,300 hectares (ha) of the Grande Ronde River watershed in northeast Oregon (Figure 1). The study area is defined by a 100 m buffer along each side of the center of active river channels, including the mainstem of the Grande Ronde River and Catherine Creek and major tributaries from the convergence of Catherine Creek with the Grande Ronde upstream to the headwaters. Major tributaries mapped as part of this effort include North and South Fork Catherine Creek, Little Creek, Ladd Creek, Five Points Creek, McCoy Creek, Meadow Creek, Fly Creek, Sheep Creek, Clear Creek, Limber Jim Creek, and Beaver Creek.

METHODS

FIELD

Field surveys were conducted 3–11 June 2015 by two field crews. Each field crew consisted of two individuals, including a field observer, skilled in field botany, vegetation ecology, and soil science; and a field assistant, who assisted with soil pit excavation, recording data, and conducting canopy height and cover measurements. Field crews were based in La Grande, Oregon and traveled to the field each day via pickup truck. The Phase 2 draft mapping was used to stratify the field survey locations across the study area. Field survey locations were limited to public lands or private lands where prior access had been arranged. Survey locations were co-located with stream reaches with existing Columbia Habitat Monitoring Program (CHaMP) plots whenever possible. Field crews used several plot types (described below) to ground-truth data, including verification plots, observation plots, photos plot, and LiDAR plots. A total of 82 plots were sampled across the study area, including 57 verification plots, 12 observation plots, 11 LiDAR plots, and 2 photo plots (Figure 2).

Field data (with the exception of LiDAR plot data, see below) was recorded on rugged, GPS-enabled tablet computers using proprietary digital data forms with built-in data dictionaries

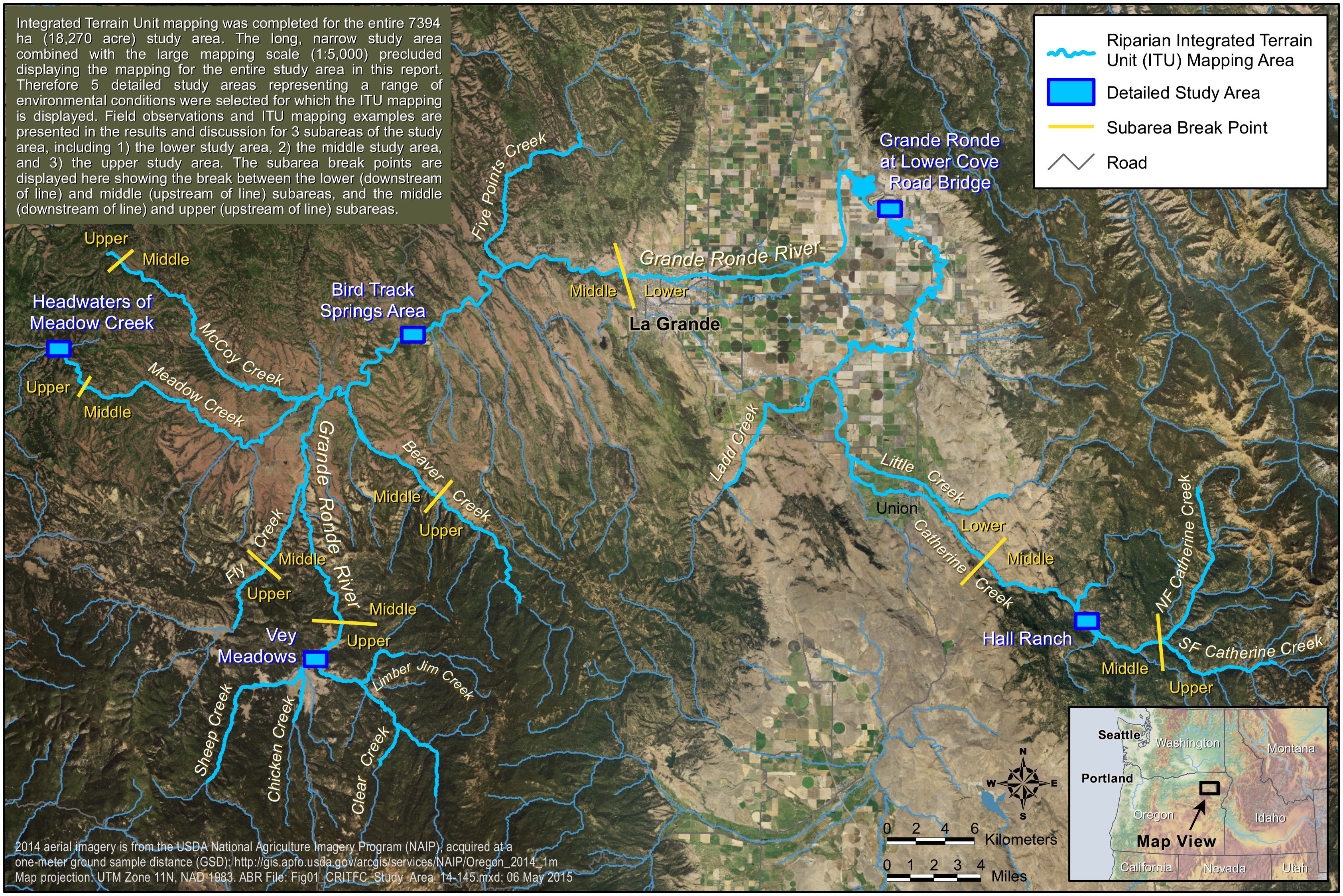


Figure 1. Overview of riparian vegetation mapping study area, including the extent of Integrated Terrain Unit (ITU) mapping, subarea break points, and the detailed study areas at the headwaters of Meadow Creek, Vey Meadows, Bird Track Springs, Hall Ranch, and lower Grande Ronde at Lower Cove Road bridge depicted in subsequent figures. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

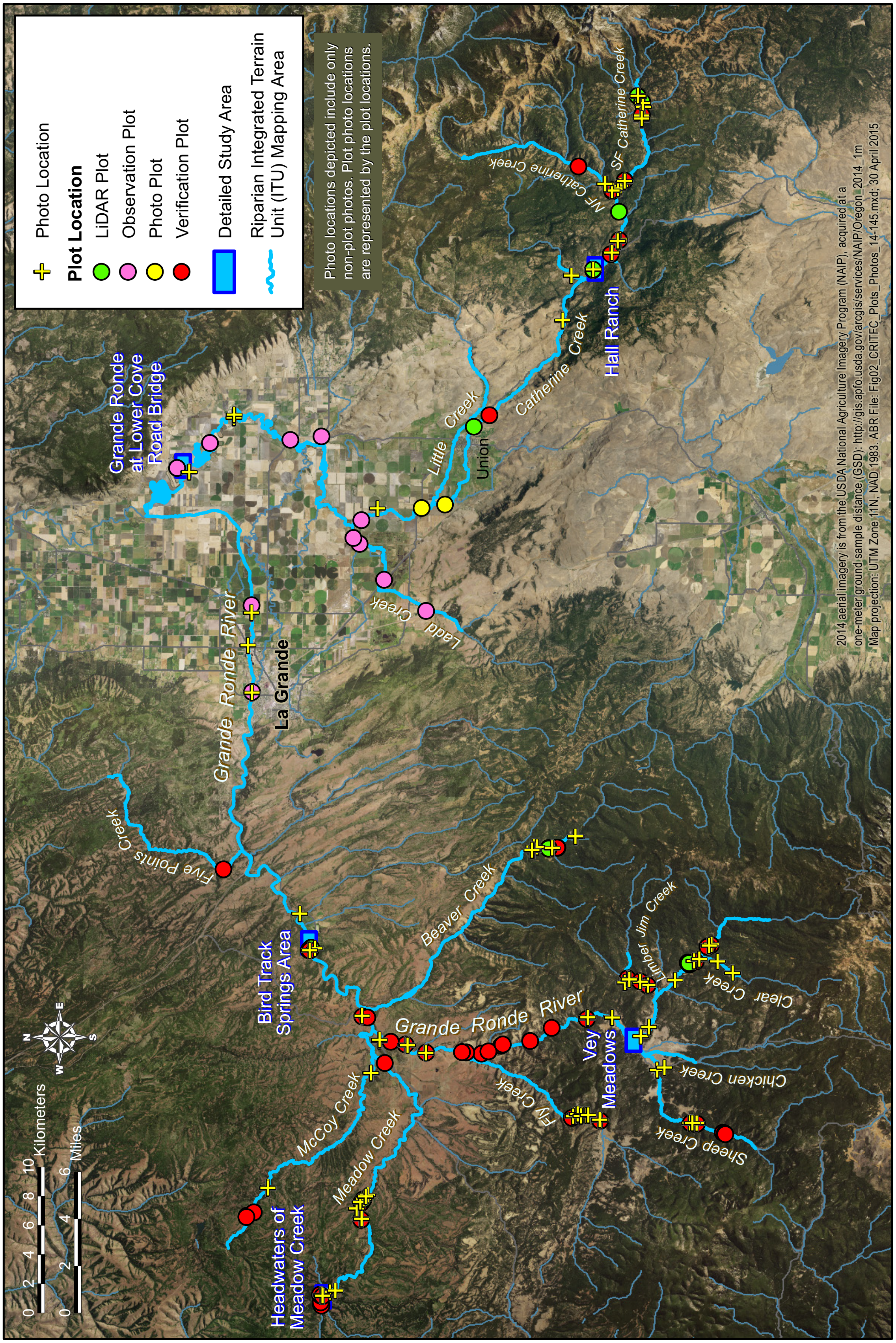


Figure 2. Field plot and photo locations sampled as part of the riparian vegetation mapping study in the Grande Ronde River watershed, northeastern Oregon, 2014.

(Figure 3). The digital data forms integrate directly with the tablet GPS for recording the geographic coordinates (latitude, longitude, elevation) of each plot. Geographic coordinates were also recorded at the center of each plot using a hand-held recreation grade DeLorme Earthmate PN60 GPS unit.

Photos were taken at all plots, and included representative landscape and ground cover views, and photos of the soil pit face. In addition to the plot photos, we captured several types of non-plot photos opportunistically as we traveled to field survey locations, including rapid ground truth photos, methods photos, photos of people, and panoramic photos. Photos were taken using a GPS-enabled Ricoh G700 SE camera with integrated compass. Plot photos were renamed each day in the field to include the plot identifier code followed by a unique number enclosed in parentheses (e.g., grr_v01-01_2014 (1).JPG). Other types of photos were not renamed, but were instead organized into separate photos by photo type.

VERIFICATION PLOTS

Verification plots included the most comprehensive suite of variables and were designed to capture data on vegetation and environment, including soils. Variables measured or estimated at verification plots are described in Appendix 1, and include all variables with data type "Plot," "General Environment," "Soils," and "Vegetation." Plot variables describe the plot itself, including a unique plot identification code (plot_id), plot dimensions (plot_radius_code), observer initials (env_observer_code), and the date and time at which data collection was initiated (env_field_start_timestamp).

a b

Figure 3. Data was recorded in the field on rugged, GPS-enabled tablet computers (a) using proprietary digital data forms. The right panel (b) of the figure above shows the first page of the data form used to record general environment data. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

General Environment

General environment variables include physiography; slope gradient and aspect—two basic descriptors of topography that affect microclimate and soil drainage; and descriptors of geomorphology and surface form at several spatial scales, including surface terrain, microtopography, and macrotopography. Observations of recent disturbance were also recorded (disturbance_class_code).

Soils

Soils were sampled using a small (30×30×40 cm) soil pit or plug (Figure 4). To prepare the soil pit or plug, soil materials were excavated carefully, keeping the organic surface layer intact and placing all soil materials on a tarp to protect the soil surface. Upon completing the soils description, soil materials were placed back in the pit and the organic surface layer replaced. Soils variables collected describe the dominant soil texture in the

Figure 4. A series of 4 images depicting soil pit excavation and rehab of pit after completion of soil description, including (from upper left), (a) excavation using tile spade, (b) completed soil pit with intact organic surface plug and excavated soil on tarp, (c) close up of completed soil pit, and (d) soil pit filled in with surface plug in place and rehabilitation complete. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

upper 40 cm of the soil profile, including the dominant mineral soil texture (soil_dominant_mineral_code_40cm); the dominant texture, which could include organic soil material (soil_dominant_texture_code_40cm); and the upper depth of a soil layer with 15% or more rock fragments (soil_rock_depth_probe_cm). The methods focus on the upper 40 cm because this section of the soil profile is easily accessed by hand excavating, is minimally invasive to the landscape, is representative of the present geomorphic environment, and is the most pertinent when considering erosion resistance. We also measured and recorded thickness of the surface organic layer (soil_surface_organic_thick_cm), which provides indirect information on frequency of flooding and sedimentation. Lastly, we recorded the soil moisture status (soil_moisture_code) and water table depth (water_depth_cm).

Vegetation

Vegetation cover data were recorded semi-quantitatively by ocularly estimating percent foliar cover for each of the most common 10–15 species within the plot area. Foliar cover was estimated in increments of 1% for cover values between 1 and 10%, and in 5% increments for cover greater than 10%. Isolated individuals or species with very low cover were assigned a "trace" cover value of 0.1%. Percent cover of abiotic ground cover classes (e.g., bare soil) was recorded using the same methods described above. We collected vegetation structure data by life form groups (e.g., tall shrubs) independent of the individual species cover estimates as an internal check for errors in overall cover estimates and `as an aid to vegetation classification. Crown (e.g., dominant) and size class (e.g., timber) of the dominant needleleaf and broadleaf trees were recorded for forested plots. The existing vegetation class was also recorded at each plot as Level 4 vegetation classes, a four-level hierarchy of existing vegetation classes similar to Viereck et al (1992) which was developed using vegetation classifications that encompass the study area. Plant taxonomy follows Hitchcock and Cronquist (1973) with species codes based on the USDA Plants Database (USDA and NRCS 2015). Voucher specimens were collected for species that were difficult to identify in the field; the specimens were then examined by crew members in the evening with a dissecting scope and identified to species when possible. Specimens that were difficult to identify with certainty were pressed and later sent to a specialist for verification (see Office Methods, below). A listing of all plant species encountered in the field is provided in Appendix 2.

OBSERVATION PLOTS

A reduced set of variables were measured at observation plots; these plots were designed to rapidly capture observations in the field for use in ground-truthing. At observations plots we classified and recorded the level 4 vegetation class; recorded the dominant 6–10 plant species within the plot area (percent foliar cover was not estimated), and recorded detailed field notes. Vegetation structure data were not recorded and we did not excavate a soil pit. General environment data were recorded opportunistically as time allowed.

PHOTO PLOTS

Photos plots comprised the most reduced set of variables recorded and were the most rapid to sample. Detailed field notes were recorded and photos were taken to represent the plot area. Vegetation and general environment data were recorded opportunistically as time allowed. No soils data were recorded, as a soil pit was not excavated.

LIDAR PLOTS

LiDAR plots focused on verifying the LiDAR canopy height and density data. A Geographic Resource Solutions (GRS) densitometer was used to estimate canopy cover of trees and tall shrubs (>1.5 m in height). Densitometer sampling occurred along two 20 meter long transects placed perpendicular to one another. The transects were centered at the middle of the plot and oriented along the cardinal directions (Figure 5). Starting at the plot center, the field observer traversed each transect stopping at sampling points spaced 2 m apart to sight through the densitometer upwards towards the canopy for a total of 20 sampling points (Figure 6. In long, narrow vegetation stands or patches of vegetation smaller than 20 m in diameter, transect length and orientation were modified to fit within the stand. Sample point spacing was also modified so that a total of 20

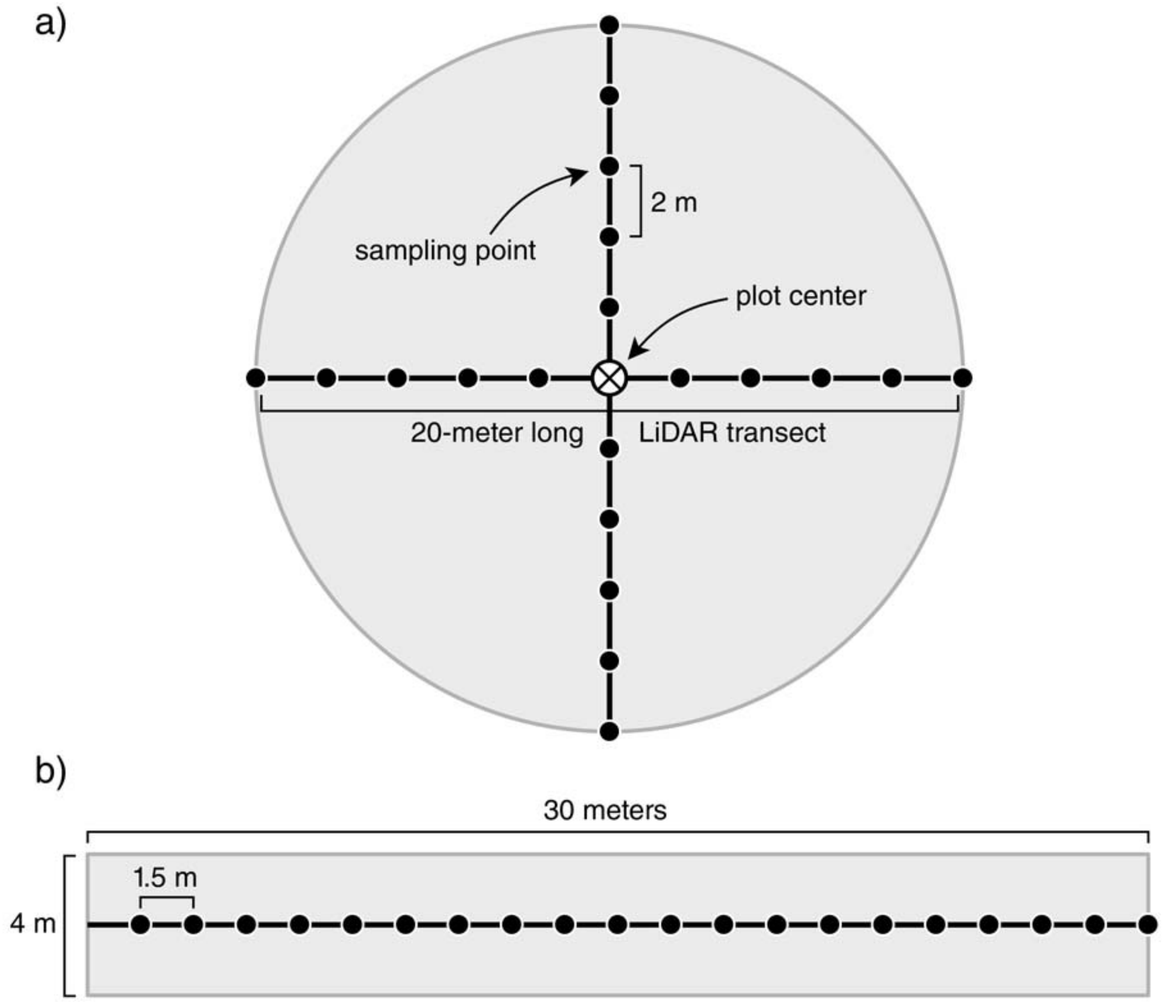


Figure 5. Schematic diagram of densitometer transects and sample points at LiDAR plots showing the standard layout (a), and an example of the layout in a non-standard plot typical of narrow, linear stands of vegetation (b). Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

equally spaced sampling points would fit along the transect. At each sampling point, if any part of a tall shrub or tree intersected the densitometer crosshairs, a "hit" was counted and the species hit recorded on a paper datasheet. If a tall shrub or tree did not intersect the densitometer crosshairs, then "no hit" was recorded. Tree and tall shrub heights were estimated using a laser rangefinder featuring automatically calculating heights. The field observer selected 1–3 individuals of the dominant tree or tall shrub species in a plot that were characteristic of the predominant size class. The field observer positioned themselves at least 10 m away from the target tree with a clear view and sighted the base and top of the tree with the laser rangefinder (Figures 6 and 7). The laser rangefinder then calculated the heights based on the two distance measurements and the angle between the base and top of the tree. The heights were recorded on a paper datasheet along with the tree or tall shrub species code. In extremely thick vegetation, typically tall shrub stands, use of the laser range finder was impossible; instead, tall shrub heights were estimated ocularly into the following categories: 1.5–3 m, 3–5 m, and >5 m.

Figure 6. Photographs illustrating data collection at LiDAR plots, including use of a densitometer to estimate canopy density (a), and use of a laser rangefinder to estimate tree and tall shrub heights (b). Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

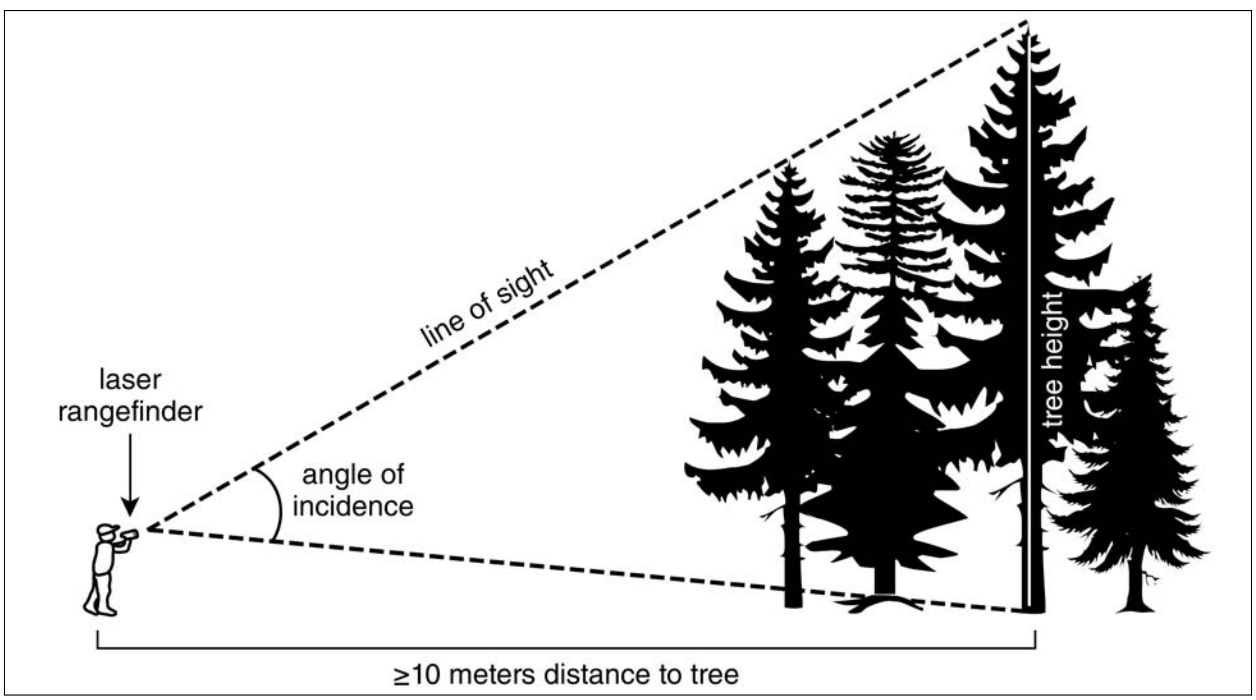


Figure 7. Schematic diagram of field observer using a laser range finder to estimate tree and tall shrub heights at LiDAR plots. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

OFFICE

DATA INTEGRATION

Tabular Data

In the office, the data collected on the handheld tablet computers was uploaded to the project PostgreSQL (PostgresSQL Global Development Group 2014) database. During the upload process a series of Quality Assurance and Quality Control (QAQC) routines were performed to ensure that all data were accounted for. LiDAR plot data from paper datasheets were entered into digital format and subsequently uploaded to the project database. These data also were proofed to ensure all data were entered into the database.

Plot Location Data

Plot location data collected on the handheld tablet computers was uploaded to the project database as described above. The plot locations collected on the handheld DeLorme GPS units were processed as described below. In the office, the raw GPS Exchange Format (gpx) files were backed up on the ABR server. The GPX to Features tool in the Conversion tools in ArcToolBox was used to convert the gpx files to an ArcGIS compatible feature class. The accuracy of the plot locations feature class was verified by comparing it against the plot locations collected on the tablet computers. The handheld GPS locations were considered the definitive plot locations. An exception to this was when plot locations were missing from the handheld GPS; in these instances the plot location recorded on the tablet was used instead. Upon completing the plot location review, a final plot location feature class was created and the final plot locations were uploaded to the project database.

Field Photos

Field photos also were backed up on the ABR server in preparation for further processing. The location and heading information assigned to each photo by the GPS-enabled cameras in the field was extracted from the Exchangeable image file format (Exif) data associated with each photo using Python and the Pexif library. The extracted Exif information was then inserted into the project database and used to create a view that references the photo files and constructs a relative path to each photo. We then used the photo locations and the PostGIS extension to PostgreSQL to create an ESRI ArcGIS file geodatabase that contained the photo locations and headings. The photos were then copied to the network folder specified in the relative path field in the database, thus making them available as a relative hyperlink within ArcMap when used in conjunction with the photo location geodatabase. A QAQC review of the photo locations was then conducted by comparing the photo locations against the plot locations. Plot photos that were located outside of the plot area were reviewed and adjusted as needed to place them within the plot. Non-plot photos were reviewed for accuracy based on field notes and the locations were adjusted as needed.

Plant specimens

Voucher specimens collected and pressed in the field were cataloged in the office and entered into the project database. Specimens requiring verification were sent to Carex Consultants, Inc. in Moscow, ID and were verified and annotated by Joy Mastrogiuseppe. The verifications were then entered into the project database. The specimens will be delivered to CRITFC along with the other data deliverables upon completion of the project.

CLASSIFICATION OF ECOLOGICAL COMPONENTS

We classified and mapped several ecosystem components in the study area using standardized classification and coding systems developed for northeastern Oregon. The classification systems are described in detail below.

Physiography and Geomorphology

Physiography characterizes the dominant tectonic and geomorphic processes controlling the landscape and was classified following Jorgenson et al. (2008) with modifications for northeastern Oregon when appropriate (Tables 1 and 2). The geomorphology classification incorporates landforms and landscape processes into an integrated process-geomorphic classification (Tables 1 and 3). For example, Meander Active Overbank Deposit (Fmoa) incorporates the concepts of floodplain (landform) with flood recurrence interval (process); for Fmoa, the flood recurrence interval is estimated at 2–25 years.

Table 1. Standard classification system developed for classifying and mapping physiography and geomorphology in the Grande Ronde River watershed, northeastern Oregon, 2014.

Code	Title
PHYSIOGRAPHY CODING	
L	Lowland
R	Riverine
S	Subalpine
U	Upland
GEOMORPHOLOGY CODING	
Bx	Bedrock - undifferentiated
ch	Hillside Colluvium
ff	Alluvial Fan
fmoa	Meander Active Overbank Deposit
fmob	Meander Abandoned Overbank Deposit
fmoi	Meander Inactive Overbank Deposit
Fmolp	Levee-protected Floodplain
fmrac	Meander Coarse Active Channel Deposit
fmri	Meander Inactive Channel Deposit
Fmrox	Old Oxbow
fto	Old Alluvial Terrace
ftr	Recent Alluvial Terrace
H	Human Modified
Of	Organic Fen
Wh	Human Modified Waterbody
Wr	Rivers and Streams

Soils

The base map for delineating ITUs is a merger of soil mapping layers produced by the Union County Soil Survey (Dyksterhuis and High 1985) and the Wallowa-Whitman National Forest Soils Database (USDA, NRCS, Soil Survey Division_a 2013). This layer contains 111 soil series. As an additional mapping reference, data from unpublished riparian soil mapping on the Wallowa-Whitman National Forest (Ottersberg 2012) were used where available. These riparian soil map units contain an additional 12 soil series. Many of the soil series were similar enough to support nearly identical existing vegetation types and/or potential plant association groups (PAGs). Consequently, the soil series were aggregated into generalized soil units to simplify ITU mapping (Appendix 3). The soil series were aggregated by reviewing profile descriptions and typical pedons for each series from the three data sources discussed above and from official soils series descriptions (USDA, NRCS, Soil Survey Division_b 2013). Soil cross sectional diagrams (Appendix 4) were created for all series and compared to determine which could be combined. The criteria used as the basis for combining series included horizon textural classes; horizon coarse fragment content (gravels, cobbles, stones); depth to root restricting layers (e.g. bedrock, duripans, clay) and/or perched water tables; strong chemical characteristics; and soil temperature and soil moisture classes. Horizon texture, coarse fragment content, profile depth, and chemical composition strongly influence Levels I through III of the vegetation classification. Soil temperature and moisture classes are also very important influences on plant species occurrence, density, and structure and will be considered when polygons are attributed with Level IV classes. Ultimately, 14 generalized soil units were developed from the original 123 soil series (Tables 4 and 5). Four additional non-soil classes were added to the soil classification for mapping purposes, including Roads, Rock Outcrop, Urban Complex, and Water.

Existing Vegetation

A four-level hierarchy of existing vegetation classes (Appendix 5; Table 6) similar to Viereck et al (1992) was developed using vegetation classifications that encompass the study area (Crowe and Clausnitzer 1997; Crowe et al 2004; Johnson and Clausnitzer 1992; Johnson and Simon 1987; Wells 2006). Level I comprises major lifeform groups (forest, shrub and herbaceous) as well as vegetation complexes, agricultural land, barren land, developed land and water. Level II divides Level I vegetation classes into broad growth forms (conifer forest, broadleaf/deciduous forest, tall shrub, low shrub, forb and graminoid). Level III depicts canopy closure classes. Level IV identifies the dominant overstory species or species group in a Level III class. The mapping codes and descriptions for Level IV existing vegetation are found in Table 7.

Table 2. Physiography class descriptions. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Physiography Class	Description
L : Lowland	Flat to gently sloping and concave areas of the landscape at elevations lower than adjacent uplands. Typically zones of water accumulation.
R : Riverine	Areas of the landscape subject to regular (<5–25 yrs) to irregular (25–100 yrs) channel and overbank flooding by rivers or streams
S : Subalpine	Moderate to steeply sloping and convex areas of the landscape in the upper elevation range of forested vegetation. In the study area subalpine physiography is limited to elevations greater than approximately 1,450–1,500 m.
U : Upland	Moderate to steeply sloping and convex areas of the landscape at elevations below subalpine physiography. Typically water shedding.

Potential Vegetation

Potential upland vegetation (also refered to as the climax community) is defined for this mapping project as the "...stable condition that would result if the present climatic and biotic conditions continues, and there were no further disturbances by fire, grazing, logging, blow downs, large-scale insect-caused mortality, etc." (Daubenmire 1968). Potential riparian vegetation is defined for this mapping project as assemblages of native riparian vegetation occurring together in equilibrium with the environment for a given fluvial surface. This fluvial surface environment includes characteristic flooding frequencies and the associated deposition and erosion of long-term average quantities and sizes of particles. Streams are assumed to be connected with the floodplain during seasonal high-water events and the floodplain water table to be accessible to plant roots on abandoned floodplains and lower geomorphic surfaces. The potential vegetation types within the study area have been classified and described as plant associations and community types in vegetation classifications (Crowe and Clausnitzer 1997, Crowe et al 2004, Johnson and Clausnitzer 1992, Johnson and Simon 1987, Kauffman et al 1985, and Wells 2006) and climax plant communities in ecological site descriptions (ESDs) (USDA, NRCS, Ecological Sciences Division 2014).To simplify mapping of potential vegetation, the 153 plant associations and plant community types and 11 climax plant communities applicable to the mapping area were organized into plant association groups (PAGs). Three additional plant community types were added based on field plot sampling in 2014. The PAG development process followed the methodology employed for the Blue Mountains National Forest lands by Powell et al. (2007). The first step is to divide the vegetation into physiognomic groups. We used the groupings created for existing vegetation, coniferous forests, deciduous forests, shrubland and herblands. The next step is to group plant associations, community types, and climax plant communities into groups "representing similar ecological environments as characterized by temperature and moisture regimes" (Powell et al 2007). Relative scales of temperature and moisture were developed that are only applicable to the group of plant associations and plant community types located in the mapping area. These scales do not represent absolute biophysical environments with quantifiable atmospheric or soil temperature and moisture ranges. Rather, they are based on best professional judgement of the relative differences in environment in which the PAGs occur. For example, the Cool-moist Grand Fir Forest PAG occupies sites with cooler daily temperatures (especially below the overstory tree canopy) and higher average annual soil moisture than the Warm Dry Grand Fir Forest PAG. 56 PAGs were created and eight miscellaneous categories were used in mapping non-vegetated areas. The canopy closure classes to which forest and shrub PAGs were assigned correspond to the average canopy closure of the plant associations in the published

Table 3. Geomorphic class descriptions. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Code and Title	Description
Bx : Bedrock - undifferentiated	Areas unlain by bedrock within the upper 50 cm of the soil surface. This class may include metamorphic, igneous, or sedimentary rock types.
ch : Hillside Colluvium	Unconsolidated, unsorted earth material being transported or deposited on side slopes and/or at the base of slopes by mass movement (e.g., direct gravitational action) and by local, unconcentrated runoff (USDA, NRCS 2015a).
ff : Alluvial Fan	A low, outspread mass of loose materials and/or rock material, commonly with gentle slopes, shaped like an open fan or a segment of a cone, deposited by a stream (best expressed in semiarid regions) at the place where it issues from a narrow mountain or upland valley; or where a tributary stream is near or at its junction with the main stream (USDA, NRCS 2015a).
fmoa : Meander Active Overbank Deposit	Vertical accretion deposits on low portions of the floodplain environment in close proximity to the meandering river channels. Flood return intervals are approximately 2 to 25 years on these surfaces. The deposits are comprised of silts and fine sands that have a laminar, interbedded structure formed by changes in velocity and deposition during waxing and waning floods. Frequent flooding and sedimentation results in surface organics rarely accumulating more than 5cm between flood events (i.e., buried organic horizons are ≤ 5cm thick).
fmob : Meander Abandoned Overbank Deposit	Vertical accretion deposits of meandering floodplains that no longer are associated with the present fluvial regime or where flooding is sufficiently infrequent that recent fluvial sediments form a negligible component of surface material. Flood return intervals are approximately 100 to 250 years. Surface materials often include a mixture of fluvial, eolian, and organic materials.
fmoi : Meander Inactive Overbank Deposit	Vertical accretion deposits formed on higher portions of the overbank environment in close proximity to meandering river channels in areas subject to infrequent flooding. Flood return intervals are approximately 25 to 100 years. Soils are typically comprised of interbedded organics, silts and fine sands.
Fmolp : Levee-protected Floodplain	A floodplain cut off from annual overbank flooding by a levee.
fmrac : Meander Coarse Active Channel Deposit	Lateral accretion deposits formed in meandering channels that wind freely in regular to irregular, well-developed, S-shaped curves. Channels range from highly sinuous to only slightly meandering. Riverbed material can range from from gravels and cobbles to gravelly-cobbly sand, and lateral accretion deposits along point bars typically are sandier. Surface organic materials are absent, or if present are not imbedded into the mineral soil surface, and are therefore often washed away by flood waters. These deposits occur primarily on mid-channel and lateral bars.
fmri : Meander Inactive Channel Deposit	Mixed lateral and vertical accretion deposits in inactive (“high water” or “cut-off”) channels of meander rivers that are flooded only during high-water events. Riverbed material often has a thin layer of fine-grained material over the coarse channel deposits and surface is usually vegetated.

Table 3. Continued.

Code and Title	Description
Fmrox : Old Oxbow	The crescent-shaped, often ephemeral body of standing water situated by the side of a stream in the abandoned channel (oxbow) of a meander after the stream formed a neck cutoff and the ends of the original bend were silted up.
fto : Old Alluvial Terrace	Relatively flat surfaces resulting from the dissection of former floodplain areas. Old terraces are typically higher in elevation than Recent Alluvial Terraces (relative to the present day river channel), are never subject to flooding under the current regime (above the 100yr flood stage), and were formed previous to the end of the Little Ice Age (> 150 years).
ftr : Recent Alluvial Terrace	Relatively flat surfaces resulting from the dissection of former floodplain areas. Recent terraces are typically lower in elevation than Old Alluvial Terraces (relative to the present day river channel), are never subject to flooding under the current regime (above the 100yr flood stage), and were formed since the end of the Little Ice Age (< 150 years).
H : Human Modified	A terrestrial geomorphic unit that has been modified by humans, typically by use of heavy machinery.
Of : Organic Fen	Minerotrophic wetlands with thick (>40 cm) organic matter accumulations developed in basins fed by mineral-rich surface water or groundwater.
Wh : Human Modified Waterbody	A natural waterbody modified byhumans or a waterbody created by humans.
Wr : Rivers and Streams	A natural, freshwater surface stream of considerable volume and generally with a permanent base flow, moving in a defined channel toward a larger river, lake, or sea (USDA, NRCS 2015a)

Table 4. Standard classification system developed for classifying and mapping generalized soils in the Grande Ronde River watershed, northeastern Oregon, 2014.

Code	Title
AsilovCF	Ashy silt loam over coarse frags
AsilovL	Ashy silt loam over loam
AsilovSk	Ashy silt loam over skeletal
DpCF	Deep w/coarse fragments
DpSiCL	Deep - silt to clay loam
LGr	Loamy-gravelly
LiShC	Lithic/Shallow to Clay
LovSk	Loam over skeletal
LSil	Loam/Silt Loam
LSilbr	Loam/Silt Loam - brackish
LSilor	Loam/Silt Loam - organic-rich
MDpCF	Mod. deep w/coarse frags
Roads	Roads
Rock	Rock Outcrop
SSkEnt	Sandy-skeletal Entisols
StmBkHG	Streambanks - high gradient
Water	Water

Table 5. Generalized soil class descriptions. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Code and Title	Description
AsilovCF : Ashy silt loam over coarse frags	Soils with ashy silt loam textures within 50 cm below soil surface and horizons with sandy loam to gravelly loam textures between 50 cm and 100 cm below soil surface
AsilovL : Ashy silt loam over loam	Soils with ashy silt loam textures within 50 cm below soil surface and horizons with ashy silt loam or silt loam textures between 50 cm and 100 cm below soil surface
AsilovSk : Ashy silt loam over skeletal	Soils with ashy silt loam textures within 50 cm below soil surface and horizons with at least 35% gravels, cobbles and/or stones between 50 cm and 100cm below soil surface
DpCF : Deep w/coarse fragments	Soils without bedrock or clay horizon within 100 cm below soil surface; at least one horizon within 50 cm below soils surface contain at least 15% gravels, cobbles or stones
DpSiCL : Deep - silt to clay loam	Soils without bedrock or clay horizon within 100 cm below soil surface; horizon textures within 50 cm below soil surface are silt loam to clay loam
LGr : Loamy-gravelly	Soils occurring on alluvial fans with silt loam, loam, sandy loam or gravelly silt loam textures within 50 cm below soil surface
LiShC : Lithic/Shallow to Clay	Soils with bedrock or clay horizon within upper 50 cm below soil surface
LovSk : Loam over skeletal	Soils with at least one horizon with loam or sandy loam texture above a horizon with at least 35% gravels, cobbles or stones all within 50 cm below soil surface
LSil : Loam/Silt Loam	Mollisols and soils in which all horizons within 50 cm below soil surface have textures of silt loam or loam and less than 15% gravels, cobbles or stones
LSilbr : Loam/Silt Loam - brackish	Soils occurring in contemporary or prehistoric lake basins with at least one horizon with silt loam texture within 50 cm below soil surface
LSilor : Loam/Silt Loam - organic-rich	Mollisols and Histosols (organic soils) occurring in valley bottom meadows
MDpCF : Mod. deep w/coarse frags	Soils with bedrock or clay horizon within 100 cm below soil surface; at least one horizon within 50 cm below soils surface contain at least 15% gravels, cobbles or stones
Roads : Roads	Soil, gravel or paved road surface
Rock : Rock Outcrop	Rock outcrop
SSkEnt : Sandy-skeletal Entisols	Entisols (poorly developed soils) with sandy textures and at least 35% by volume gravels, cobbles and/or stones within 50cm below soil surface
StmBkHG : Streambanks - high gradient	Soils with high ash content and high water tables occurring along streambanks of narrow, high elevation streams
Water : Water	River, stream, lake or pond
Urban : Urban Complex	Developed areas in cities and townships encompassing a complex of homes, yards, roads, sidewalks, and stores.

Table 6. Standard classification system developed for classifying and mapping existing vegetation (level IV classes) in the Grande Ronde River watershed, northeastern Oregon, 2014.

Code	Title
bbg	Barren
bpa	barren agricultural
bpvh	Barren partially vegetated herbaceous
fbcc	Closed Black Cottonwood Forest
fbcs	Open Willow Forest (lower valley)
fboc	Open Black Cottonwood Forest
fbos	Closed Willow Forest (lower valley)
fbwc	Black Cottonwood Woodland
fmbcdfc	Closed Black Cottonwood-Douglas-fir Forest
fmbcdfo	Open Black Cottonwood-Douglas-fir Forest
fmbceso	Open Black Cottonwood-Engelmann Spruce Forest
fmbcgfo	Open Black Cottonwood-Grand Fir Forest
fmbcppo	Open Black Cottonwood-Ponderosa Pine Forest
fncdf	Closed Douglas-fir Forest
fnces	Closed Engelmann Spruce Forest
fncg	Closed Grand Fir Forest
fncl	Closed Lodgepole Pine Forest
fncpp	Closed Ponderosa Pine Forest
fndfw	Douglas-fir Woodland
fngfw	Grand Fir Woodland
fnodf	Open Douglas-fir Forest
fnoes	Open Englemann Spruce Forest
fnog	Open Grand Fir Forest
fnol	Open Lodgepole Pine Forest
fnopp	Open Ponderosa Pine Forest
fnscf	Closed Subalpine Fir Forest
fnsfo	Open Subalpine Fir Forest
fnsfw	Subalpine Fir Woodland
fnwl	Lodgepole Pine Woodland
fnwpp	Ponderosa Pine Woodland
hca	agricultural croplands
hfm	Forb Meadow
hgd	Dry Graminoid Meadow
hgm	Moist Graminoid Meadow
hgw	Wet Graminoid Meadow
hgwmcc	Wet-Moist Graminoid Meadow Complex
hpa	agricultural pasture
hus	Upland Steppe
rd	Roads
smxlc	Closed Low Elevation Mixed Shrubland
smxlo	Open Low Elevation Mixed Shrubland
ssa	Sitka Alder
stcat	Closed Thinleaf Alder
stcbh	Closed Black Hawthorn
stcw	Closed Tall Willow
stoat	Open Thinleaf Alder
stobh	Open Black Hawthorn
stow	Open Tall Willow
suc	Closed Upland Shrubland
suo	Open Upland Shrubland
ub	Buildings and Other Structures
wf	Fresh Water
xa	agricultural complex
xd	Urban Complex
xr	Riverine Complex

classifications. The PAG canopy closure classes do not correspond to the canopy closure classes in Level III of the existing vegetation classification. For example, a polygon in which the existing vegetation was mapped as Closed Douglas-fir may be potential vegetation mapped as Open Moist Douglas-fir Forest. A forest stand may have a greater number of trees in a denser pattern with a greater canopy closure in a mid-seral (or mid-development) stage than it does in a later (climax) stage.

Three riverine complexes of PAGS were classified to describe areas along narrow streams where individual fluvial surfaces and their associated PAGs were too small to be mapped as separate polygons. Four low elevation complexes were created to depict mosaics of PAGs that could occur on the fluvial surfaces of restored riverine systems in the lower elevations of the mapping area.

Appendix 6 provides a crosswalk between the PAGs and the plant associations, community types and climax plant communities from the literature, while Table 8 lists the potential vegetation mapping codes and titles. Appendix 7 provides descriptions of the complex potential vegetation classes. Figure 8 is an example of how a forest stand develops from an early seral stage to its potential plant association. The diagram illustrates the complexity of the pathways that stand

Table 7. Existing vegetation class descriptions. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Code and Title	Description
bbg : Barren	Barren areas of the landscape with less than 5% cover of vascular species.
bpa : barren agricultural	Agricultural lands with less than 5% cover of vascular species.
bpvh : Barren partially vegetated herbaceous	Partially vegetated areas of the landscape with 5 to 25% cover of vascular species.
fbcc : Closed Black Cottonwood Forest	Forested areas with ≥60% cover of *Populus trichocarpa*.
fbcs : Open Willow Forest (lower valley)	Forested areas with 25–60% cover of *Salix alba* var. *vitellina*.
fboc : Open Black Cottonwood Forest	Forested areas with 25–60% cover of *Populus trichocarpa*.
fbos : Closed Willow Forest (lower valley)	Forested areas with ≥60% cover of *Salix alba* var. *vitellina*.
fbwc : Black Cottonwood Woodland	Forested areas with 10–25% cover of *Populus trichocarpa*.
fmbcdfc : Closed Black Cottonwood-Douglas-fir Forest	Forested area with ≥60% cover of tree species. *Populus trichocarpa* and *Pseudotsuga menziesii* both contributing 25–75% of the tree cover.
fmbcdfo : Open Black Cottonwood-Douglas-fir Forest	Forested area with 25–60% cover of tree species. *Populus trichocarpa* and *Pseudotsuga menziesii* both contributing 25–75% of the tree cover.
fmbceso : Open Black Cottonwood-Engelmann Spruce Forest	Forested area with 25–60% cover of tree species. *Populus trichocarpa* and *Picea engelmannii* both contributing 25–75% of the tree cover.
fmbcgfo : Open Black Cottonwood-Grand Fir Forest	Forested area with 25–60% cover of tree species. *Populus trichocarpa* and *Abies grandis* both contributing 25–75% of the tree cover.
fmbcppo : Open Black Cottonwood-Ponderosa Pine Forest	Forested area with 25–60% cover of tree species. *Populus trichocarpa* and *Pinus ponderosa* both contributing 25–75% of the tree cover.
fncdf : Closed Douglas-fir Forest	Forested areas with ≥60% cover of *Pseudotsuga menziesii*.
fnces : Closed Engelmann Spruce Forest	Forested areas with ≥60% cover of *Picea engelmannii*.
fncg : Closed Grand Fir Forest	Forested areas with ≥60% cover of *Abies grandis*.
fncl : Closed Lodgepole Pine Forest	Forested areas with ≥60% cover of *Pinus contorta*.
fncpp : Closed Ponderosa Pine Forest	Forested areas with ≥60% cover of *Pinus ponderosa*.
fndfw : Douglas-fir Woodland	Forested areas with 10–25% cover of *Pseudotsuga menziesii*.
fngfw : Grand Fir Woodland	Forested areas with 10–25% cover of *Abies grandis*.
fnodf : Open Douglas-fir Forest	Forested areas with 25–60% cover of *Pseudotsuga menziesii*.
fnoes : Open Englemann Spruce Forest	Forested areas with 25–60% cover of *Picea engelmannii*.
fnog : Open Grand Fir Forest	Forested areas with 25–60% cover of *Abies grandis*.
fnol : Open Lodgepole Pine Forest	Forested areas with 25–60% cover of *Pinus contorta*.
fnopp : Open Ponderosa Pine Forest	Forested areas with 25–60% cover of *Pinus ponderosa*.
fnscf : Closed Subalpine Fir Forest	Forested areas with ≥ 60% cover of *Abies lasiocarpa*.
fnsfo : Open Subalpine Fir Forest	Forested areas with 25–60% cover of *Abies lasiocarpa*.
fnsfw : Subalpine Fir Woodland	Forested areas with 10–25% cover of *Abies lasiocarpa*.
fnwl : Lodgepole Pine Woodland	Forested areas with 10–25% cover of *Pinus contorta*.
fnwpp : Ponderosa Pine Woodland	Forested areas with 10–25% cover of *Pinus ponderosa*.
hca : agricultural croplands	Agricultural lands planted with crops.

Table 7. Continued.

Code and Title	Description
hfm : Forb Meadow	Non-forested areas with <25% shrubs and ≥25% forbs.
hgd : Dry Graminoid Meadow	Non-forested areas with <25% shrubs and ≥25% grasses, sedges, or rushes. Soils dry for most of the growing season.
hgm : Moist Graminoid Meadow	Non-forested areas with <25% shrubs and ≥25% grasses, sedges, or rushes. Soils moist for most of the growing season.
hgw : Wet Graminoid Meadow	Non-forested areas with <25% shrubs and ≥25% grasses, sedges, or rushes. Soils wet for most of the growing season.
hgwmcc : Wet-Moist Graminoid Meadow Complex	Non-forested areas with <25% shrubs and ≥25% grasses, sedges, or rushes . Soils moisture status through the growing season a complex of wet and moist.
hpa : agricultural pasture	Agricultural lands used for pasturing livestock.
hus : Upland Steppe	Non-forested areas with <25% shrubs and ≥25% grasses that occur in upland physiographic areas.
rd : Roads	Soil, gravel or paved road surface
smxlc : Closed Low Elevation Mixed Shrubland	Tall shrublands with ≥75% cover of a mix of Mackenzie's (Rigid) Willow, Coyote Willow, Black Hawthorn, Red-osier Dogwood and Woods Rose.
smxlo : Open Low Elevation Mixed Shrubland	Tall shrublands with 25–74%% cover of a mix of Mackenzie's (Rigid) Willow, Coyote Willow, Black Hawthorn, Red-osier Dogwood and Woods Rose.
ssa : Sitka Alder	Tall shrublands with ≥25% cover of *Alnus sinuata*.
stcat : Closed Thinleaf Alder	Tall shrublands with ≥75% cover of *Alnus incana*.
stcbh : Closed Black Hawthorn	Tall shrublands with ≥75% cover of *Crataegus douglasii*.
stcw : Closed Tall Willow	Tall shrublands with ≥75% cover of willows (*Salix* sp.).
stoat : Open Thinleaf Alder	Tall shrublands with 25–74% cover of *Alnus incana*.
stobh : Open Black Hawthorn	Tall shrublands with 25–74% cover of *Crataegus douglasii*.
stow : Open Tall Willow	Tall shrublands with 25–74% cover of willows (*Salix* sp.)
suc : Closed Upland Shrubland	Upland physiographic areas with ≥75% cover of shrubs.
suo : Open Upland Shrubland	Upland physiographic areas with 25–74% cover of shrubs.
ub : Buildings and Other Structures	Buildings and other man-made structures, including but not limited to homes, barns, garages, and warehouses.
wf : Fresh Water	Freshwater waterbodies, including rivers, streams, ponds, and lakes.
xa : agricultural complex	Agricultural areas encompassing a complex of farm homes, barns, pastures, yards, driveways, and croplands.
xd : Urban Complex	Developed areas in cities and townships encompassing a complex of homes, yards, roads, sidewalks, and stores.
xr : Riverine Complex	Riverine areas with 3 or more types of vegetation with no one type encompassing more than 2/3 of the area.

Table 8. Standard classification system developed for classifying and mapping potential vegetation in the Grande Ronde River watershed, northeastern Oregon, 2014.

Code	Title
a	Agricultural Fields
bbg	Barren
fbbcwf	Black Cottonwood/Willows Floodplain Forest
fbcf	Black Cottonwood Floodplain Forest
fbclf	Low Elevation Black Cottonwood Floodplain Forest
fbcmmlfc	Low Elevation Black Cottonwood/Moist Meadow Floodplain Complex
fbct	Black Cottonwood Terrace Forest
fbww	White Willow Forest
fdfd	Dry Douglas-fir Forest
fdflm	Low Elevation Moist Douglas-fir Forest
fdfm	Moist Douglas-fir Forest
fdfmo	Open Moist Douglas-fir Forest
fdfwm	Warm-moist Douglas-fir Forest
fes	Engelmann Spruce Forest
fgfc	Cold Grand Fir Forest
fgfcm	Cool-moist Grand Fir Forest
fgfcmo	Open Cool-moist Grand Fir Forest
fgfes	Grand fir-Engelmann Spruce Forest
fgfeso	Open Grand fir-Engelmann Spruce Forest
fgfwd	Warm-dry Grand Fir Forest
fgfwdo	Open Warm-dry Grand Fir Forest
flpd	Dry Lodgepole Pine Forest
flpmm	Lodgepole Pine Moist Meadow
flpwm	Lodgepole Pine Wet Meadow
fppd	Dry Ponderosa Pine Forest
fppm	Moist Ponderosa Pine Forest
fppmo	Open Moist Ponderosa Pine Forest
fsfd	Dry Subalpine Fir Forest
fsfes	Subalpine Fir-Engelmann Spruce Forest
fsfeso	Open Subalpine Fir-Engelmann Spruce Forest
hbwif	Bluebunch Wheatgrass-Idaho Fescue Herbland
hfmm	Moist Forb Meadow Herbland
hgfgb	Graminoid-Forb Gravel Bar Herbland
hgmccwmc	Cold Wet-Moist Meadow Complex Herbland
hgmcwmc	Wet-Moist Meadow Complex Herbland
hmcm	Cold-moist Meadow Herbland

Table 8. Continued.

Code	Title
hmd	Dry Meadow Herbland
hmm	Moist Meadow Herbland
hss	Subalpine Steppe Herbland
husd	Dry Upland Steppe Herbland
husgbwc	Dry Upland Steppe-Moist Great Basin Wildrye Complex
hwm	Wet Meadow Herbland
hwmc	Cold Wet Meadow Herbland
rd	Roads
ro	Rock
sbh	Black Hawthorn Shrubland
scs	Red-osier Dogwood Shrubland
smaf	Mountain Alder Floodplain Shrubland
smalf	Low Elevation Mountain Alder Floodplain Shrubland
smawm	Mountain Alder Wet Meadow Shrubland
smm	Moist Meadow Shrubland
smmgrlfc	Low Elevation Moist Shrub/Graminoid Floodplain Complex
smxl	Low Elevation Mixed Shrubland
ssa	Sitka Alder Shrubland
sud	Upland Dry Shrubland
sum	Upland Moist Shrubland
swgb	Willows Gravel Bar Shrubland
swmm	Tall Willows Moist Meadow Shrubland
swmmgrblfc	Low Elevation Brackish Wet-Moist Shrub/Graminoid Floodplain Complex
swmmgrlfc	Low Elevation Wet-Moist Shrub/Graminoid Floodplain Complex
swwm	Tall Willows Wet Meadow Shrubland
ub	Buildings and Other Structures
wf	Fresh Water
wpps	Ponderosa Pine Steppe Woodland
xd	Developed Sites
xrl	Low-elevation Riverine Complex
xrm	Mid-elevation Riverine Complex
xru	Upper-elevation Riverine Complex
xu	Urban Complex

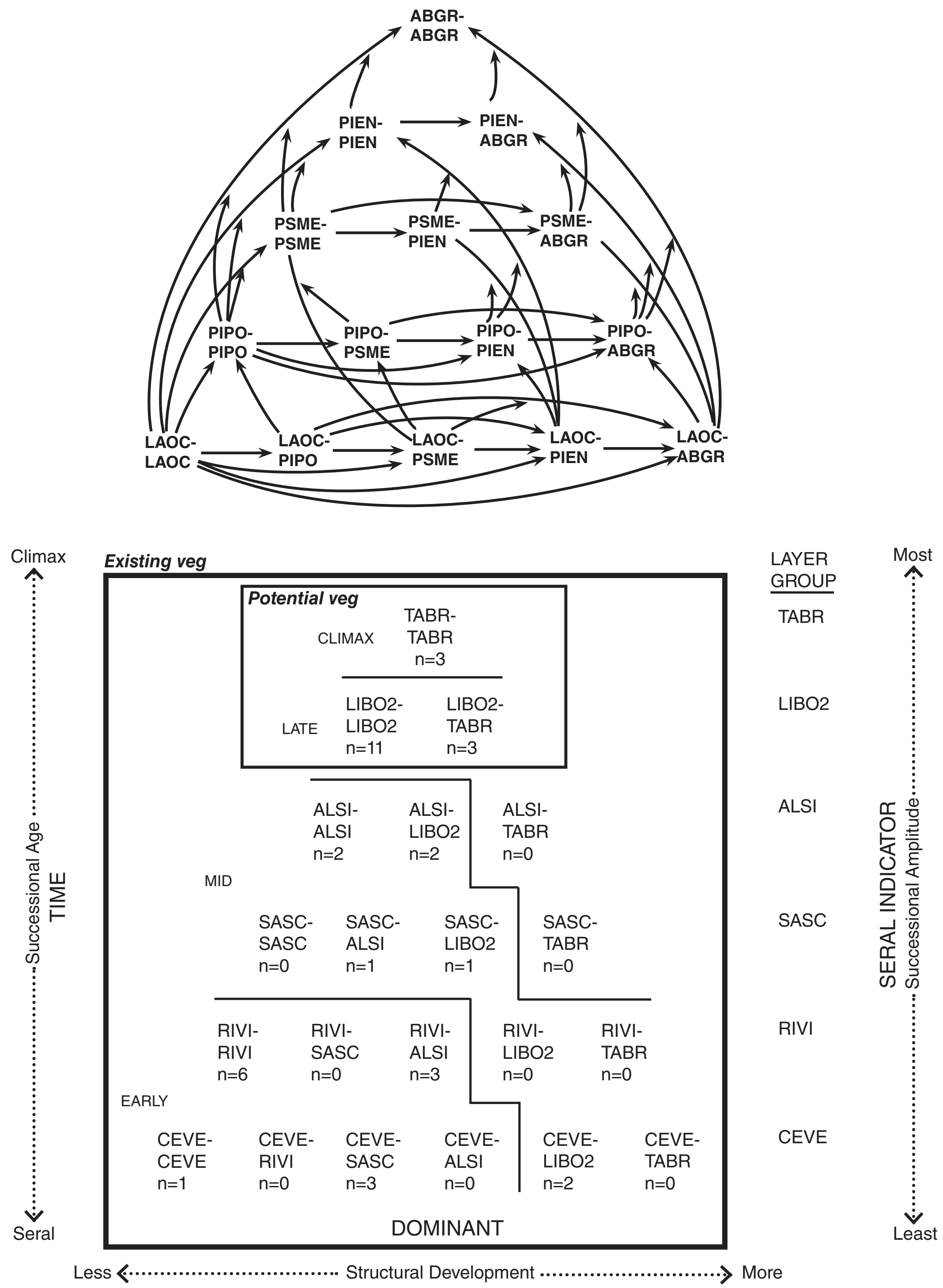


Figure 8. Succession classification diagrams of the Grand fir/Pacific yew/queen's cup beadlily plant association showing the successional pathways for the tree layer (above) and the successional dynamics of the shrub layer (below). The diagrams illustrate the conceptual relationship between the existing and potential vegetation classification. The existing vegetation classification may include any seral stage from early through climax, while the potential vegetation includes only late and climax seral stages. Figure modified from Figure 2 and 3 of Clausnitzer (1993), respectively.

development can take and why it is not possible for every existing Level IV vegetation type to be directly correlated to only one potential vegetation type (PAG).

Disturbance

Disturbance characterizes recent (<10–20 years) or ongoing landscape disturbance, and includes both natural (e.g., forest fire) and anthropogenic (e.g., agricultural field) classes (Tables 9 and 10).

Table 9. Standard classification system developed for classifying and mapping disturbance in the Grande Ronde River watershed, northeastern Oregon, 2014.

Code	Title
A	ABSENT, NONE (mature vegetation)
DC	Disturbance complex
Ha	Agricultural Field
Hac	Crops
Haf	Feedlot/livestock holding pen
Hag	Livestock Grazing
Hah	Hayfield
Hc	Clearings (Non-agricultural or undifferentiated)
Hcl	Logged
Hd	Human Developed Sites (urban complex)
Hdr	Residential Development
He	Excavation/Pits (undifferentiated)
Hf	Fill
Hfgrp	Paved Road
Hfgru	Unpaved road
Hft	Mine Tailings
Hp	Pasture
Hrr	Railroad
Hsb	Building
Hsisd	Abandoned/historic splash dam
Hwc	Canal
Hwd	Ditch
Hwe	Water-filled excavation
Hwi	Drainage Impoundment
Hwl	Levee
Nf	Fire
Ngfd	Fluvial Deposition
Ngfe	Fluvial Erosion/channel migration

MAPPING OF ECOLOGICAL COMPONENTS

AERIAL IMAGERY

Polygon delineation was completed on-screen in a Geographic Information System (GIS) by photo-interpretation of aerial imagery. Field plot data were used to inform the mapping of vegetation types based on ocular interpretation of the aerial imagery color and texture signatures. Mapping was typically initiated in areas with field plot data to build a relationship between the photo signatures and the ground data (Figure 9). The mapping was then carried outward into sections of the study area without plot data; the interpretation of photo signatures in these areas extrapolated from areas with plot data. The primary aerial imagery used for mapping included the 2014, 2012 and 2011 NAIP natural color imagery (streamed from NAIP,1.0-m pixel resolution) and the 2012 4-band (including near-infrared [NIR]) 1.0-m resolution NAIP imagery acquired July-August 2012 (Figure 10). The imagery was obtained from the National Aerial Imagery Program (NAIP). The NIR band provided additional information that assisted in differentiating between vegetation classes (e.g., needleleaf vs. broadleaf). Secondarily, mapping was conducted on a CRITFC-supplied NAIP natural color orthophotography mosaic acquired in 2009 with 1.0-m pixel resolution. Google Earth was used to supplement the NAIP imagery and provided a higher-resolution imagery to aid in the interpretation of aerial imagery signatures.

LIDAR

A LiDAR dataset (1.0-m resolution), provided by CRITFC and generated by Watershed Sciences, Inc. (2009), and LiDAR data of the lower watershed, flown by the U.S. Bureau of Reclamation in 2007 and 2009, were also used to assist the mapping effort. The BareEarth raster datasets were further processed by ABR into an elevation-independent hillshade, using the ESRI Spatial Analyst toolset in ArcMap 10.2.1 (Figure 11 upper panel). This was used to delineate valley bottom and channel location, physiography, geomorphic surfaces, and disturbances, particularly under forest canopy. The Canopy mosaic datasets from WSI and the generated data from BOR were used to assess tree and shrub

Table 10. Disturbance class descriptions. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Code and Title	Description
A : ABSENT, NONE (mature vegetation)	No recent disturbance. Recent disturbance includes any disturbance occurring within the last 5 to 10 years.
DC : Disturbance complex	Areas on the landscape with 3 or more disturbance types that co–occur spatially and cannot be split into individual disturbance types given the minimum map unit size, and no single disturbance type is dominant (>2/3 of the area)
Ha : Agricultural Field	Active or abandoned agricultural fields.
Hac : Crops	Agricultural lands cultivated with crops.
Haf : Feedlot/livestock holding pen	Areas of landscape utilized as livestock feedlots or holding pens.
Hag : Livestock Grazing	Areas of the landscape affected by regular (annual or bi-annual) livestock grazing.
Hah : Hayfield	Agricultural lands cultivated as hayfields
Hc : Clearings (Non-agricultural or undifferentiated)	Areas cleared of vegetation unrelated to agriculture.
Hcl : Logged	Areas of the landscape that have experienced recent logging.
Hd : Human Developed Sites (urban complex)	Developed areas in cities and townships encompassing homes, yards, roads, sidewalks, and stores, or a combination of these mapped as a complex
Hdr : Residential Development	Areas of residential development, including ranches and homesteads.
He : Excavation/Pits (undifferentiated)	Recently excavated areas of the landscape.
Hf : Fill	Areas of the landscape characterized by gravel or other fill material.
Hfgrp : Paved Road	Paved roads
Hfgru : Unpaved road	Unpaved roads, including gravel and dirt roads.
Hft : Mine Tailings	Areas of the landscape characterized by mine tailings
Hp : Pasture	Agricultural lands utilized as pasture for livestock.
Hrr : Railroad	Tracks and other railroad related infrastructure.
Hsb : Building	Areas of the landscape affected by buildings and other structures. Typically mapped with the vegetation class "Buildings and Other Structures"
Hsisd : Abandoned/historic splash dam	Remnants of a splash dam historically used for logging and since abandoned.
Hwc : Canal	Canals and areas of the landscape otherwise affected by canals.
Hwd : Ditch	Ditches and areas of the landscape otherwise affected by ditches.

Table 10. Continued.

Code and Title	Description
Hwe : Water-filled excavation	Small waterbodies created by soil excavation and subsequent infilling by water
Hwi : Drainage Impoundment	Reservoirs or other waterbodies created by the impoundment of water
Hwl : Levee	An artificial embankment constructed along the bank of a watercourse to protect land from inundation and/or to confine streamflow to its channel (USDA, NRCS 2015a).
Nf : Fire	Areas of the landscape affected by recent wildfire.
Ngfd : Fluvial Deposition	Riverine areas affected by recent fluvial sediment deposition.
Ngfe : Fluvial Erosion/channel migration	Riverine areas affected by recent fluvial erosion or channel migration.

height and density (e.g., Open vs. Closed Needleleaf Forest) (Figure 11 lower panel).

ANCILLARY GIS DATASETS

In addition to the aerial imagery and LiDAR, several ancillary datasets were used to assist the mapping process (Table 11). The Forest Cover Loss 2000–2013 layer from Hansen et al. (2013) in conjunction with the Oregon Department of Forestry Fire Occurrence layer (ODF 2015) was used as a check on the mapping of the disturbance classes, "Logging" and "Fire". Polygons occurring in areas with forest cover loss between the years 2000–2013 were compared to locations of fire occurrences between 1993–2013. Map polygons that occurred in areas where forest loss and fires occurred during the above period were confirmed as forest fire disturbance, while polygons in areas where forest loss occurred and fires were absent were confirmed as logging disturbance. The Forest Cover Loss data was mapped at a relatively coarse resolution (30-m pixels) compared to the ITU mapping. Consequently, in some cases, the Forest Cover Loss data did not capture changes in forest cover in the study area. For these cases we relied on the Fire Occurrence Layer to assign forest fire disturbance to map polygons, and on the time series of NAIP Imagery (2009–2014) to confirm recent forest cover loss due to logging.

The 2013 TIGER/Line Shapefile of primary and secondary roads in Oregon (U.S. Census Bureau 2013) was compared to the mapping of roads. The roads that were mapped matched well with the TIGER layer. The TIGER roads layer shows many additional roads than were mapped, but these roads were not visible in either the LiDAR, the NAIP, or other imagery used in mapping.

The Wallowa-Whitman National Forest existing vegetation polygon shapefile (USDA Forest Service, Wallowa-Whitman National Forest, 2004), the Wallowa-Whitman National Forest Soils Database (USDA, NRCS, Soil Survey Division_a) and Union County Soil Survey Survey (Dyksterhuis and High 1985) were used to verify existing vegetation and determine potential vegetation. Vegetation information found in both the soil series descriptions in the Survey document and in the official soil series descriptions (USDA, NRCS, Soil Survey Division_b) was compiled and joined to the attribute table for the Union County Soil Survey polygon shapefile. In addition, unpublished riparian ecological unit inventory line mapping (Ottersberg 2012) provided verification of vegetation mapping along narrow streams on National Forest lands.

The U.S. Forest Service ecology program plot shapefile (USDA, Forest Service, Wallowa-Whitman National Forest, 2015a) was used to verify potential vegetation mapping. All plot points are attributed with the classified potential plant association or plant community type. The Blue Mountains range pasture boundary shapefile (USDA, Forest Service, Wallowa-Whitman National Forest, 2015b) and the Blue Mountains Surface ownership shapefile (USDA, Forest Service, Wallowa-Whitman National Forest, 2015c) were used to determine current land uses as they pertained to mapping disturbance attributes.

MAPPING STANDARDS

Map polygons were delineated at a mapping scale of 1:2,000 to 1:3,000 for a final map scale (the scale at which the mapping is valid for landscape analysis) of 1:5,000. The minimum mapping size for polygons (a ‘polygon’ is defined here as an area delineated on the map as a single unit) was 0.10 ha for waterbodies, 0.81 ha for complexes, and 0.20 ha for all other classes. Exceptions to the minimum map unit size included polygons that occurred on the edge of the mapping and would continue outside the mapping boundary if the study area boundary were to be extended. Minimum width for mapping the active (i.e., permanently flooded) riverbed was set at 5 m, below which the stream bed was not mapped but was instead aggregated with the surrounding floodplain. Several complex vegetation classes were used to map highly heterogeneous areas associated with dynamic geomorphic processes and anthropogenic disturbance. Complexes were used for polygons where at least 3 vegetation classes were present, the dominant cover type occupied <65% of the polygon, and inclusions were below the minimum size for mapping.

INTEGRATED TERRAIN UNITS

Individual ecological components were mapped simultaneously as compound codes called Integrated Terrain Units (ITUs). Integrated Terrain Units comprise five parameters assigned to each map polygon describing physiography, geomorphology, generalized soils, existing vegetation, potential vegetation, and disturbance (e.g., Lowland/Meander Abandoned Overbank Deposit/ Ashy silt loam over loam/Lodgepole Pine Woodland/Lodgepole Pine Moist Meadow/ Absent). The mapping parameters were attributed using a standardized coding scheme (Tables W–Z); following from the above example, e.g., L/fmob/AsilovL/fnwl/flpmm/A (Figure 10).

AGGREGATION OF ECOLOGICAL COMPONENTS

ECOTYPES

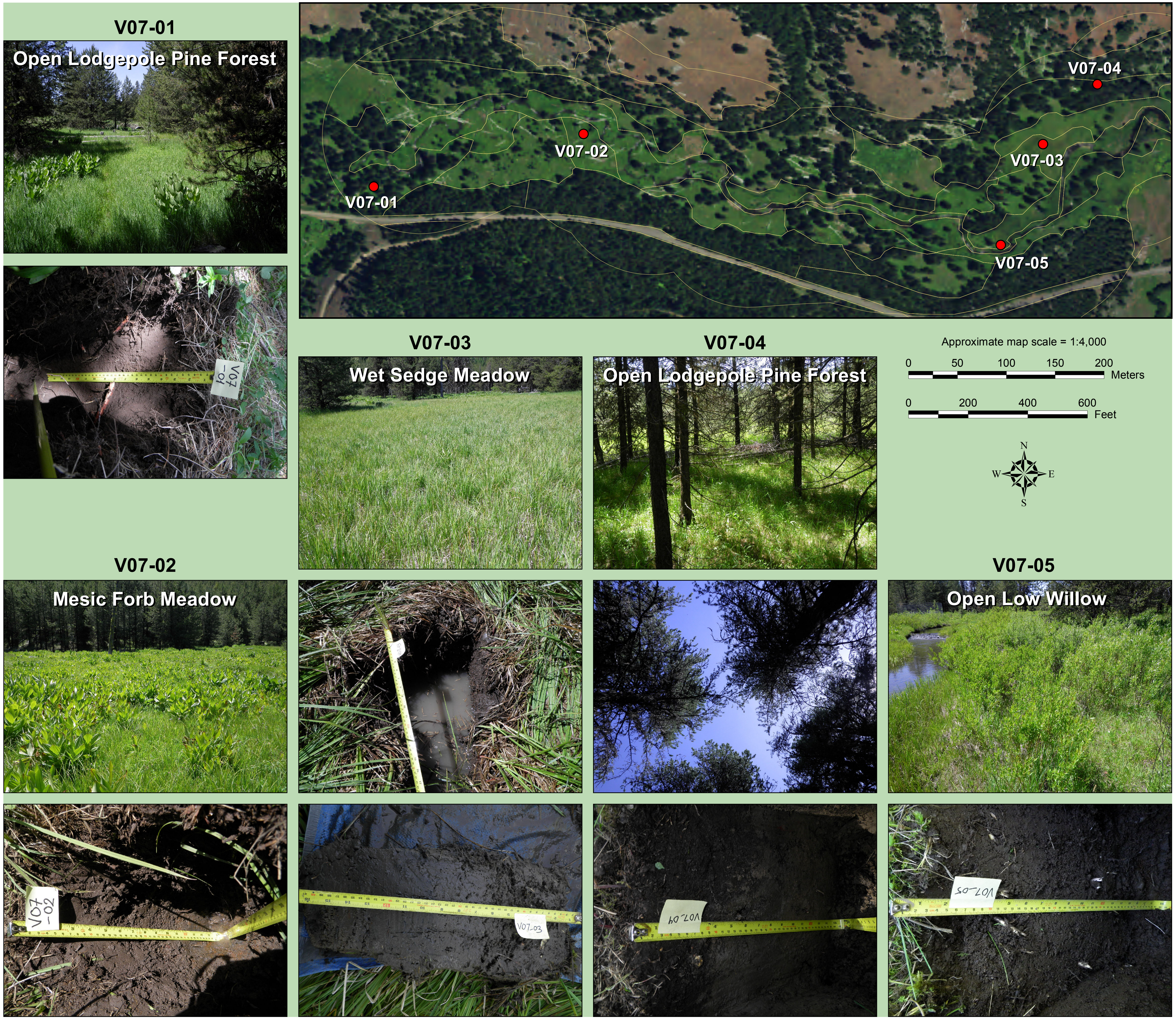
Individual ecological components for each polygon in the ITU mapping were concatenated to create ITU code combinations (e.g., L/fmob/AsilovL/fnwl/flpmm/A). The ITU code combinations were aggregated based on physiography, and similarities in soils and existing vegetation into ecological types (ecotypes). Ecotypes are local-scale ecosystems that represent a hierarchical organization of physical and biological variables. The advantage of this hierarchical methodology is that the combination of physiography (strongly associated with geomorphic units), soils, and vegetation composition and structure yields classes that effectively differentiate both soil characteristics and vegetation composition.

Ecotype classes were assigned to each unique ITU code combination to create a crosswalk (Appendix 8). The ITU/ecotype crosswalk was then joined to the ITU mapping layer in ArcGIS based on the ITU field and each polygon assigned an ecotype. The ITU mapping layer could then be symbolized on ecotype to create the ecotype map.

EROSION SENSITIVITY CLASSES

Erosion sensitivity classes were generated by aggregating ITU code combinations based on existing vegetation, geomorphology, and soils (Table 12). The erosion sensitivity classification incorporates characteristics of soils that make them more or less prone to erosion. For instance, sandy soils are more prone to erosion than loamy soils, and soils with higher coarse fragment content are less prone to erosion than soils with fewer coarse fragments. Integrated with soil characteristics in the erosion sensitivity classification are vegetation characteristics that either increase or decrease a soil’s susceptibility to erosion. For instance, dense, multi-layer forested vegetation protects the soil surface and reduces erosion, while vegetation dominated by annual grasses increases the susceptibility of erosion (Figure 12). Lastly, soil moisture is incorporated into the erosion classification for herbaceous types. The drier the soils, the more prone to erosion because the rooting layer is typically shallower and the roots less dense. In contrast, wetter soils typically have a thicker rooting zone and denser roots, resulting in a reduced sensitivity to erosion. Similar to ecotypes, erosion sensitivity classes were assigned to each unique ITU code combination to create a crosswalk (Appendix 8). The ITU/erosion sensitivity crosswalk was then joined to the ITU mapping layer in ArcGIS based on the ITU field and each

Figure 9.
Map of integrated terrain units and field plot locations with field verification photographs, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

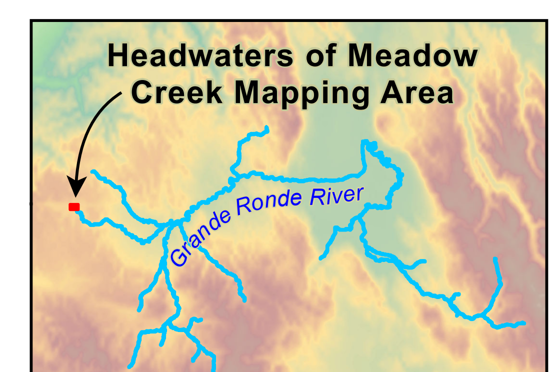


● Verification Plot

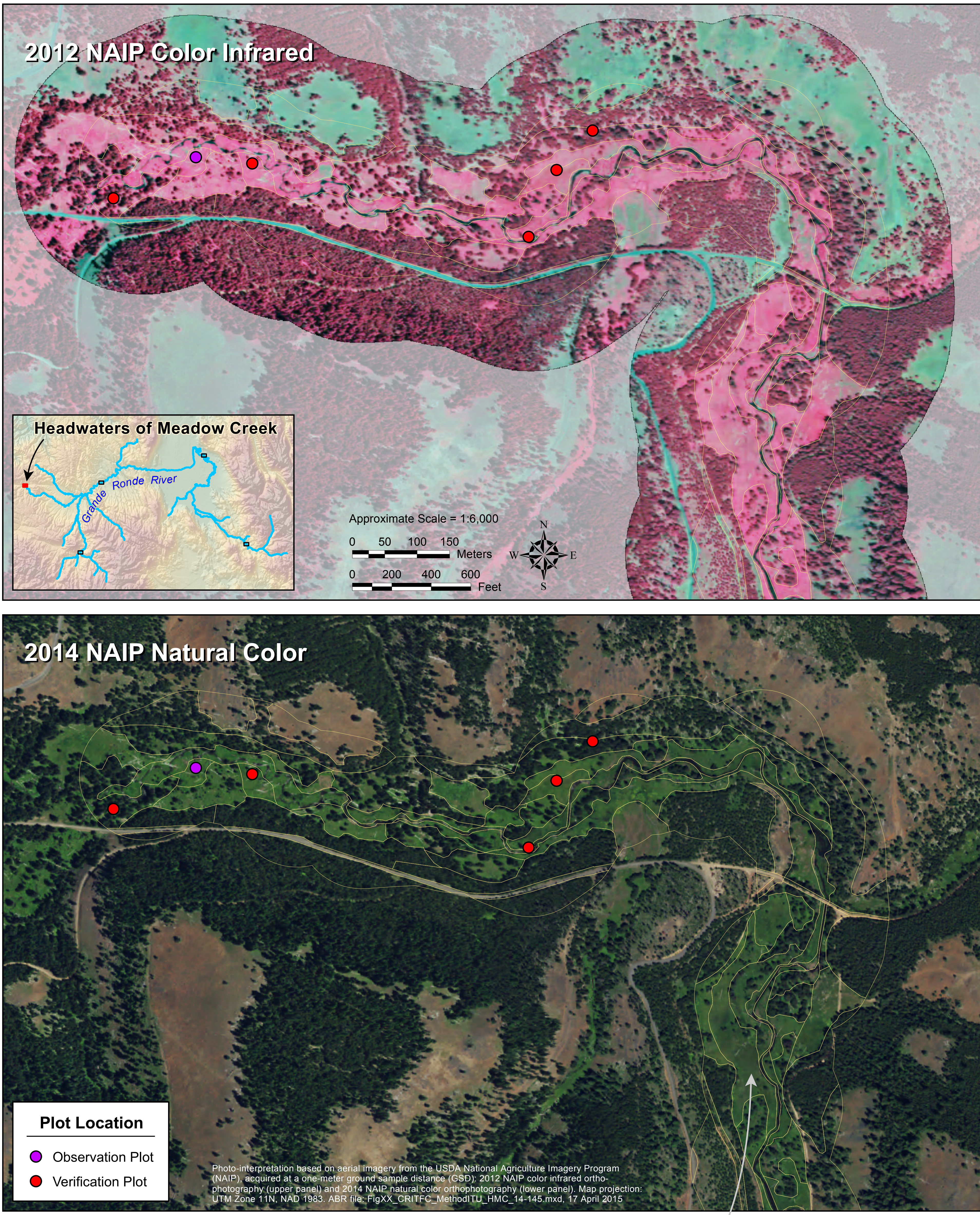
Integrated Terrain Unit (ITU) Mapping

Field plot data, including photographs (shown here for transect v07) and tabular data on vegetation composition and soils (not shown), were used to inform the mapping of vegetation types based on ocular interpretation of the aerial imagery color and texture signatures. Mapping was typically initiated in areas with field plot data to build a relationship between the photo signatures and the ground data. The mapping was then carried outward into sections of the study area without plot data; the interpretation of photo signatures in these areas extrapolated from areas with plot data.

2014 aerial imagery is from the USDA National Agriculture Imagery Program (NAIP), acquired at a one-meter ground sample distance (GSD).



Map projection: UTM Zone 11N, NAD 83. ABR file: Fig09_CRITFC_PlotsFieldPhotos_HMC_14-1451.mxd, 08 Jun 2015



Integrated Terrain Unit (ITU) mapping is an integrated approach to mapping landscape elements. It is a multivariate mapping process in which terrain unit map boundaries are visually interpreted and digitized over high-resolution imagery so that there is increased coincidence between the boundaries and occurrences of interdependent ITU variables, such as physiography, geomorphology, soils and vegetation units (Jorgenson et al. 2003). The method of combining various ITUs allows for the preparation of thematic maps that can be customized for specific study needs, including the base maps physiography, geomorphology, soils, existing and potential vegetation, and disturbance, as well as derived maps, including ecotype and erosion sensitivity maps.

Integrated Terrain Unit (ITU) Mapping

ITU Polygon

ITU Code example:

fmob	L	LSilor	hgm	hmm	Hag
Geomorphology	Physiography	Generalized Soils	Existing Veg Level 4	Potential Vegetation	Disturbance

fmob : Meander Abandoned Overbank Deposit /
L : Lowland /
LSilor : Loam/Silt Loam - organic-rich /
hgm : Moist Graminoid Meadow /
hmm : Moist Meadow Herbland /
Hag : Livestock Grazing

Figure 10. Map of integrated terrain units and field plot locations overlaid on the NAIP aerial imagery, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

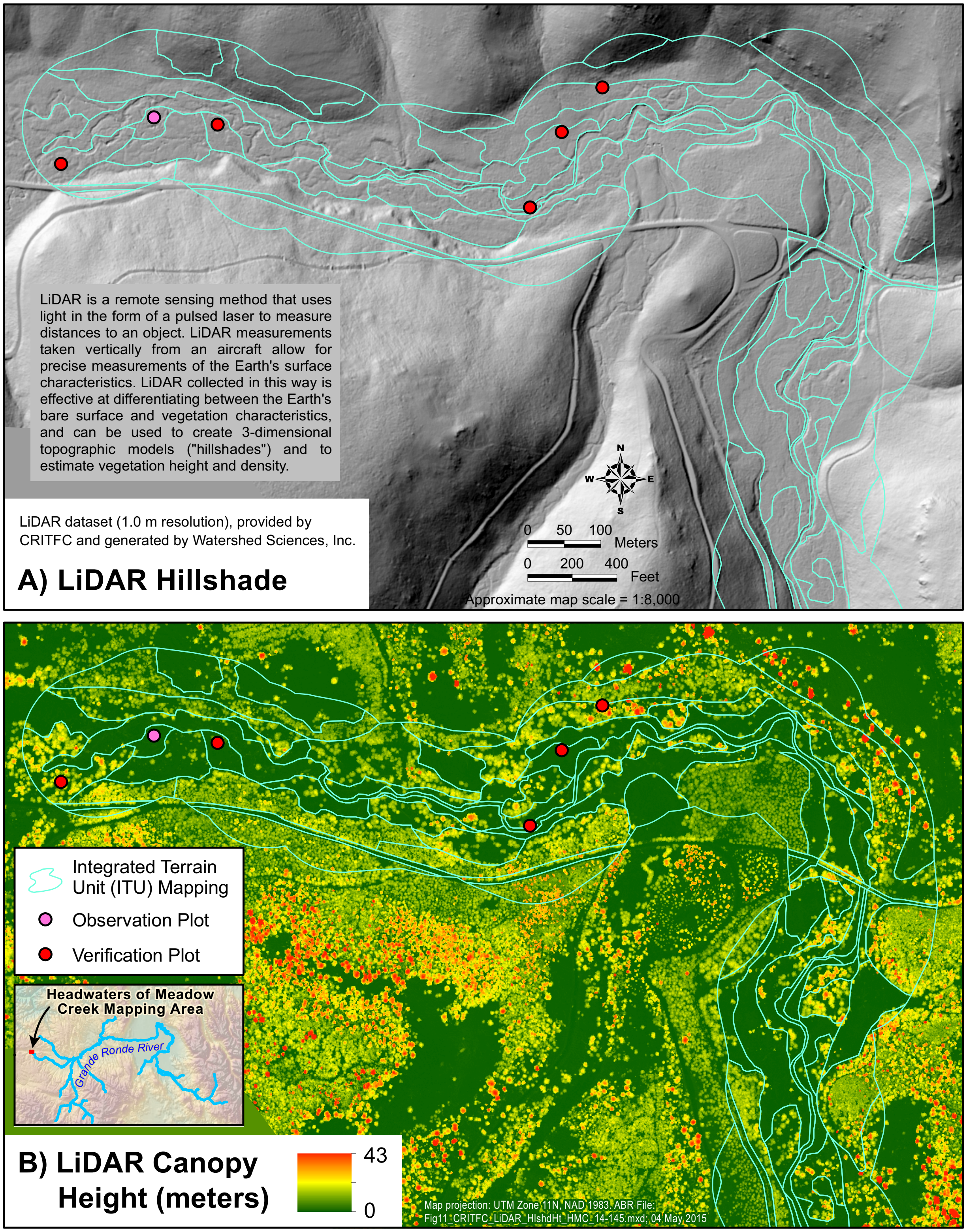


Figure 11. Integrated Terrain Unit (ITU) mapping and field plot location depicting A) the LiDAR hillshade used for delineating topographic features, and B) the LiDAR canopy height data used for determining vegetation height and structure classes (e.g., closed tall vs. open low shrub), headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Table 11. List of GIS data sources used.

Category of Data	Type of Data	Spatial Data File Name	Source of Spatial Data	Link to Spatial Data
Base Layers	NAIP Photography 2012	N.A.	ArcGIS Server	Stream from: http://gis.apfo.usda.gov/ArcGIS/Services/NAIP/Oregon_2012_1m_NC/ImageServer
	NAIP Photography 2011	N.A.	ArcGIS Server	Stream from: http://gis.apfo.usda.gov/ArcGIS/Services/NAIP/Oregon_2012_1m_NC/ImageServer
	NAIP Photography 2014	N.A.	ArcGIS Server	Stream from: http://gis.apfo.usda.gov/ArcGIS/Services/NAIP/Oregon_2012_1m_NC/ImageServer
	NAIP Photography 2012	naip4b_sa	USGS National Map	http://viewer.nationalmap.gov/viewer/
	Natural Color Aerial Photography	These are .jpg images, not spatial data.	CRITFC	NA - not available online
	Natural Color Aerial Photography Indices	Indices are organized into spatial files by stream, e.g. Beaver_Creek.shp.	CRITFC	NA - not available online
	LiDAR	LiDAR.gdb	CRITFC	NA - not available online
	LiDAR	cc2007_be_dem	BOR	NA - not available online
	LiDAR	cc2007_hh_dem	BOR	NA - not available online
	LiDAR	wc2007_be_dem	BOR	NA - not available online
	LiDAR	wc2007_hh_dem	BOR	NA - not available online

Table 11. Continued.

Category of Data	Type of Data	Spatial Data File Name	Source of Spatial Data	Link to Spatial Data
Soils	W-W and Umatilla NF - Riparian EUI Line Segment Mapping Units	WW_lineseg_fluv.shp	Craig Busskohl, Soil Quality and Ecosystems, NRCS National Soil Survey Center; phone: (402) 437-5316	NA - not available online
	Blue Mtns Landtype Associations	LTA_02_05_2013.shp	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml
Upland Vegetation	W-W Existing Vegetation	Vegetation_Stand.shp	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml
	Union County Historical Vegetation -1958	veghist_union_1958.shp	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml
Geology	Oregon Geologic Data Compilation	G_MAP_UNIT.SHP	OR geospatial library / DOGAMI	http://spatialdata.oregonexplorer.info/geoportal/catalog/search/resource/details.page?uuid={D9B42C23-07E9-496F-8188-7C06A6D0E891}

Table 11. Continued.

Category of Data	Type of Data	Spatial Data File Name	Source of Spatial Data	Link to Spatial Data
Water/Valleys	Valley/Stream Segment Classification	originally part of gronde_gis_data0.gdb\Hydrography in \PNVData_08-Feb-2013\v10\; NetStream_reaches_cu	CRITFC	NA - not available online
Data Points and Associated Data for Existing Riparian Work	USFS Ecology Plot Points and Data	EcologyPlot.shp	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml
Fire and Harvest Occurrence History	Blue Mountains NFs Fire History Points	FireHistoryPoints.shp	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml
	Blue Mountains NFs Fire History Polygons	FireHistoryPl.shp	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml
	Fire Occurrence	ODF Fires	Oregon Department of Forestry	http://www.oregon.gov/odf/Pages/gis/GISDataExport.aspx

Table 11. Continued.

Category of Data	Type of Data	Spatial Data File Name	Source of Spatial Data	Link to Spatial Data
	Forest Cover Loss	Forest Cover Loss 2000-2013	Earth Engineer Partners	http://earthenginepartners.appspot.com/science-2013-global-forest
Infrastructure	2013 TIGER/Line Shapefile	Roads_FS_Tiger_CRITFC_100m_terrainslope.shp	CRITFC	NA - not available online
Management Designations	Blue Mountains NF Range Pastures	rum_subunit.shp	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml
	Blue Mountains Surface Ownership	SurfaceOwnership.shp	Malheur, Umatilla, Wallowa-Whitman National Forests GIS Data Library	http://www.fs.fed.us/r6/data-library/gis/umatilla/index.shtml

Table 12. Erosion sensitivity class descriptions. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Title	Description
High	The erosion sensitivity class with the greatest susceptibility to erosion. This class includes barren and partially vegetated area and vegetated areas with relatively simple canopy structure and shallow root systems. Soils are typically dry to moist, and sandy and/or unconsolidated.
Low	The erosion sensitivity class with the lowest susceptibility to erosion. This class includes vegetated areas with robust, complex canopy structure and deep root systems. Soils are typically well consolidated, moist to wet, loamy or organic, and/or high in coarse fragments.
Moderate	The erosion sensitivity class with a medium susceptibility to erosion. This class includes grasslands and forblands with soils that are typically well consolidated, dry to moist, and high in coarse fragments. This class also includes riverine complexes that are characterized by a mosaic of vegetation and soil types that include both high (barrens and partially vegetated sand and cobble bars) and low (forests on floodplains and terraces) erosion sensitivity classes.
Negligible	This erosion sensitivity class includes areas on the landscape where erosion is not typically an issue, including human developments, roads, and waterbodies.

polygon assigned an erosion sensitivity class. The ITU mapping layer could then be symbolized on erosion sensitivity to create the erosion sensitivity map.

EXISTING VEGETATION CANOPY HEIGHT, DENSITY, AND COMPLEXITY

LiDAR data, provided by CRITFC (Watershed Sciences, 2009) and the U.S. Bureau of Reclamation (2007, 2009) was compiled for the study area, and processed using ArcGIS 10.2.1 with the Spatial Analyst extension. Three procedures were performed on the data.

First, the canopy rasters were summarized across all height strata by Mean Canopy Height, Maximum Canopy Height, and Standard Deviation (SD) of Mean Canopy Height by ITU polygon, using the Extract to Table tool. Second, the mean and SD of canopy heights were calculated for 3 height strata of interest (0–1.5 m, >1.5 m–3 m, and >3 m) using the Con (Conditional) tool. The generated rasters were run through the Extract to Table tool for joining to the ITU geodatabase. Finally, the rasters were reclassified into “Canopy Hit” or “No hit” along the height strata, and the resulting raster was extracted in a similar fashion to the Mean/SD data. The number of hits were then summed and divided by the area of the individual polygons to get a canopy coverage value. Depending on what information is needed, the ITU mapping layer can be symbolized on any of the relevant metrics to summarize canopy information.

For the purposes of this study, SD was used as the metric of canopy complexity. A high SD is indicative of many different canopy heights within the polygon and suggests a complex height character of the vegetation in that polygon. A small SD indicates a more uniform stand, with less complexity.

Some notes regarding the LiDAR data. The LiDAR data summaries by map polygon matched well with the vegetation on the ground, based on visual review of field photos. There are some variations, however, depending on canopy/LiDAR hits present, size of polygons, and data processing glitches.

Values coded as <null> occur when there is no LiDAR for an area, no occurrences of a hit within a height strata (e.g., no high hits in an exclusively low grassland polygon), or the aforementioned glitches.

There are some rare exceptionally high hits (e.g., 706 m) that are likely the result of a bird,

Figure 12. Field photos showing examples of streambank erosion along middle Meadow Creek (a) and upper Sheep Creek (b). In the upper photo large blocks of soil have been eroded from the adjacent terrace which is dominated by meadow foxtail *(Alopecurus pratensis)* an introduced perennial grass with a weak, shallow root system. In the lower photo a portion of fence is suspended following erosion of soil around it. For scale, shovel in upper photo is approximately 1.1 meters tall. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

balloon, or tower in the mapping area at the time the LiDAR data was collected. Those outliers were retained. Lastly, it is important to note that the LiDAR data summaries are supplementary to the field observations, and are not replacements for field data.

POTENTIAL VEGETATION HEIGHTS

Potential vegetation density was estimated using canopy cover averages for trees and shrubs in each PAG. Data for canopy cover were taken from datasets used in developing local vegetation classifications (Crowe and Clausnitzer 1997, Crowe et al 2004, Johnson and Clausnitzer 1992, Johnson and Simon 1987, and Wells 2006). Canopy cover data for each potential vegetation class are provided in an Excel spreadsheet that accompanies this report (PAG_Species_ Constancy_Canopy_Cover_Tables.xlsx).

Using site index information in the upland vegetation classifications for the Blue Mountains (Johnson and Simon 1987, Johnson and Clausnitzer 1992), the average height of trees in most of the forested PAGs was calculated. The site indices in these classifications were for the estimated height of individual species in 100-year old stands in plant associations. The species site indices were weighted by average cover of each species within the plant association to produce an average 100-year stand height for each plant associations. These average 100-year stand heights were then averaged for the PAGs to which the plant association had been assigned (see Appendix 6). Where data were lacking for coniferous PAGs (except for Lodgepole Pine), the average stand height of a similar PAG was assigned. For example, Open Subalpine Fir-Engelmann Spruce Forest was assigned the same 100-year stand height as Subalpine Fir-Engelmann Spruce Forest. Dry Lodgepole Pine Forest was assigned a 100-year stand height based on site index values for Lodgepole Pine found in the dry Subalpine Fir plant associations (Johnson and Simon 1987, Johnson and Clausnitzer 1992). Lodgepole Pine/Wet Meadow and Lodgepole Pine/Moist Meadow were assigned a 100-year stand height based on some height and age data collected for these plant associations that were never published. The Black Cottonwood PAGS were assigned a 100-year stand height of 31 m (DeBell 1990). White Willow was assigned a 100-year stand height of 22 m based on the LiDAR height data for polygons mapped as White Willow because the trees we observed in the field appeared to have reached their full height potential.

Potential shrub heights were obtained from Steele and Geier-Hayes (1987, 1989, 1992, 1993, 1994) and from species descriptions in the Fire Effects Information System (2015). Shrub heights were weighted by average cover of each species within shrub PAGs to produce an average maximum shrub canopy height. Potential vegetation canopy height data for each potential vegetation class were compiled into a crosswalk table. The crosswalk table was then imported into ArcGIS and a tabular join between the ITU mapping and the crosswalk was used to assign potential height classes to each polygon based on the potential vegetation class.

LIDAR FIELD VERIFICATION

LiDAR field plot data were summarized and compared to the estimates of existing vegetation canopy height and density data by map polygon. First, a spatial join was conducted between the LiDAR plot locations and the ITU mapping to extract the height and density data for each map polygon associated with each plot. Second, the LiDAR plot densitometer data was aggregated to percent cover for each species by dividing the number of hits of each lifeform, including trees and tall shrubs, by the total number of densitometer measurements within a plot (i.e., 20). Third, the mean and SD of LiDAR plot height data was calculated across all tree species within a plot. We the plotted paired bar charts for each plot that compare the LiDAR plot data against the density and mean height for each ITU map polygon estimated from the LiDAR data. For density we compared the combined cover of tall shrubs and trees from the plot data against the combined density of the 1.5–3.0 m and >3.0 m strata layers (i.e., cano_1pt5to3_density + cano_gt3_density). For height we compared the mean and standard deviation of trees measured in the LiDAR plots against the mean and SD of the mean >3.0 m strata layer (e.g., cano_gt3_mean and cano_gt3_SD) from the ITU mapping.

RESULTS AND DISCUSSION

INTEGRATED TERRAIN UNIT MAPPING

Integrated Terrain Unit mapping was completed for the entire 7,394 ha (18,270 acre) study area (Figure 1). The long, narrow study area, combined with the large mapping scale (1:5,000) precluded displaying the mapping for the entire study area in this report. Instead, 5 detailed study areas representing a range of representative environmental conditions were selected for which the ITU mapping is displayed (Figure 1). Figures 13–21 display the full suite of individual ITU mapping components for the headwaters of Meadow Creek detailed study area. These figures *do not* represent the full range of ITU mapping classes encompassing the entire study area, rather, the headwaters of Meadow Creek detailed study area maps are presented as an example of the final products of the ITU mapping. Tables 13–19 display the total area of all individual ITU components summarized *across the entire study area*.

MAPPING OF AGGREGATED ECOLOGICAL COMPONENTS

ECOTYPES AND EROSION SENSITIVITY CLASSES

A total of 2,078 unique ITU code combinations from across the entire study area were aggregated into 66 ecotype classes and 4 erosion sensitivity classes. Figures 22 and 23 display the ecotype and erosion sensitivity mapping for the headwaters of Meadow Creek detailed study area. Tables 20 and 21 display the total area of all ecotype and erosion sensitivity classes summarized *across the entire study area*.

EXISTING VEGETATION CANOPY HEIGHT, DENSITY, AND COMPLEXITY

Canopy height and density were estimated from LiDAR data and mapped across the study area in 4 canopy height categories as described in Methods above. Canopy complexity was mapped as an expression of the standard deviation of mean canopy height across all canopy layers. Figures 24–27 present examples of the canopy height and density mapping, and Figure 28 displays the canopy complexity mapping in the headwaters of Meadow Creek detailed study area.

POTENTIAL VEGETATION CANOPY HEIGHT

A potential vegetation canopy height corresponding to each PAG was assigned to individual polygons following the methods outlined above. A map of potential vegetation canopy heights is not provided in this report. However, the potential vegetation canopy heights can be symbolized in ArcGIS using the field “PNV_Height_m_100y” in the ITU mapping layer.

FIELD OBSERVATIONS AND MAPPING

Field observations and ITU mapping examples are presented in the following sections for 3 subareas of the study area, including 1) the lower study area, 2) the middle study area, and 3) the upper study area (Figure 1). The subareas were partitioned based on the approximate elevation breaks lower (<900 m), middle (900–1,200 m), and upper (>1,200 m). Figure 29 shows the locations of field photos displayed in figures in the following sections.

LOWER STUDY AREA

Agriculture has been an important land use in the Grande Ronde Valley since post-European settlement, and as such, agricultural development covers much of the present-day valley (Figure 30). Figures 31 and 32 display the existing and potential vegetation, and geomorphology and disturbance mapping for the Lower Cove Road bridge detailed study area on Catherine Creek. The mapping shows that agricultural development occupies most of the floodplain, leaving a narrow corridor of existing native riparian vegetation, including Closed and Open Black Hawthorn (*Crataegus douglasii*) and Closed and Open Low Elevation Mixed Shrubland characterized by *Salix exigua, S. rigida, Cornus stolonifera, and Rosa gymnocarpa*. The corridor is surrounded by agricultural fields (Figure 33). The Catherine Creek channel in much of the the Grande Ronde Valley (Reaches 1–7 in Catherine Creek Tributary Assessment [U.S. Bureau of Reclamation 2012a]) is deeply incised with a narrow floodplain. Many portions of floodplains and former oxbows in the lower study area are cut-off from annual flooding by levees, i.e., Levee-protected Floodplain (Figure 32). In other sections of the lower study area, floodplain agricultural lands abut the river channel (Figure 34).

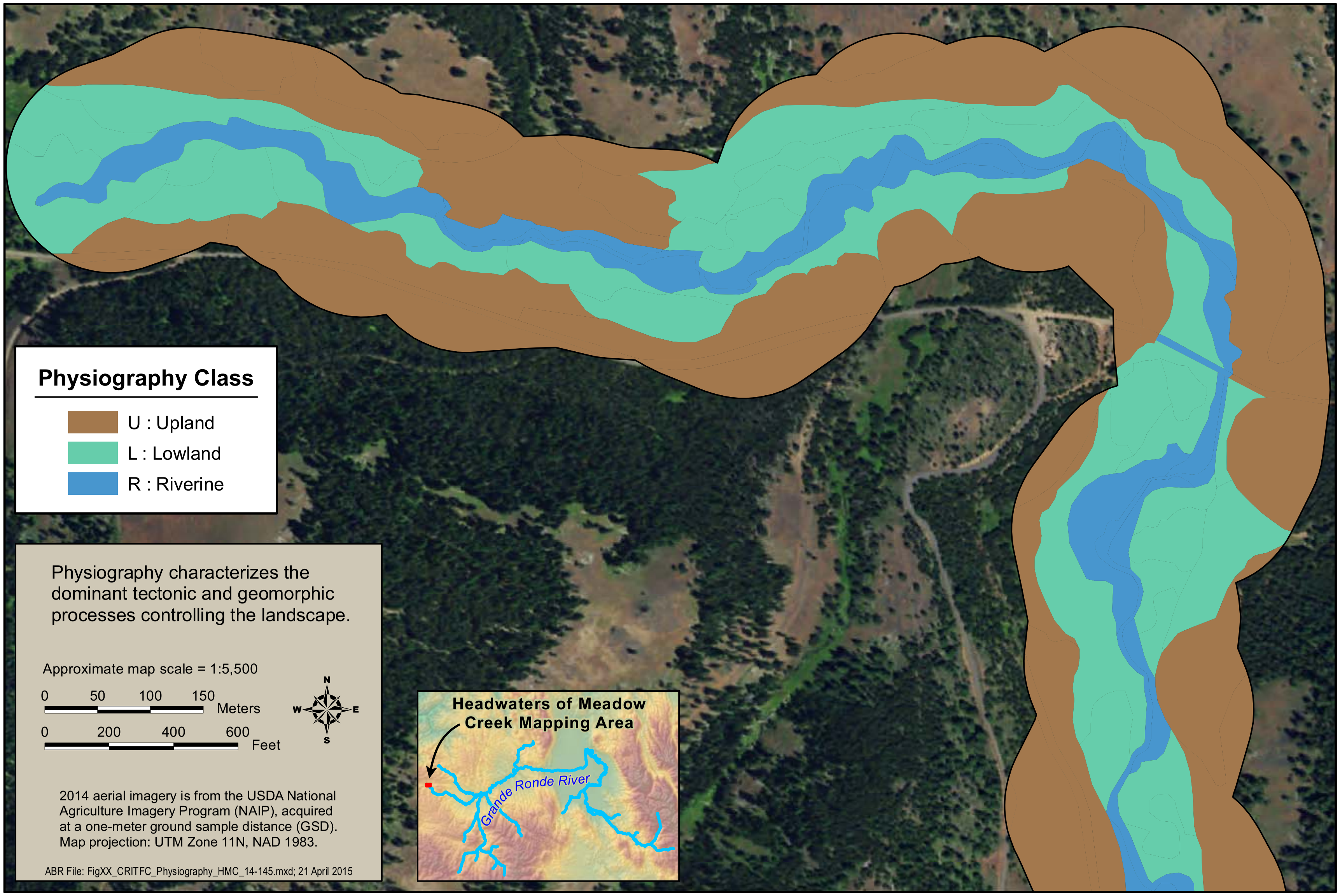


Figure 13. Integrated terrain unit mapping depicting physiography, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

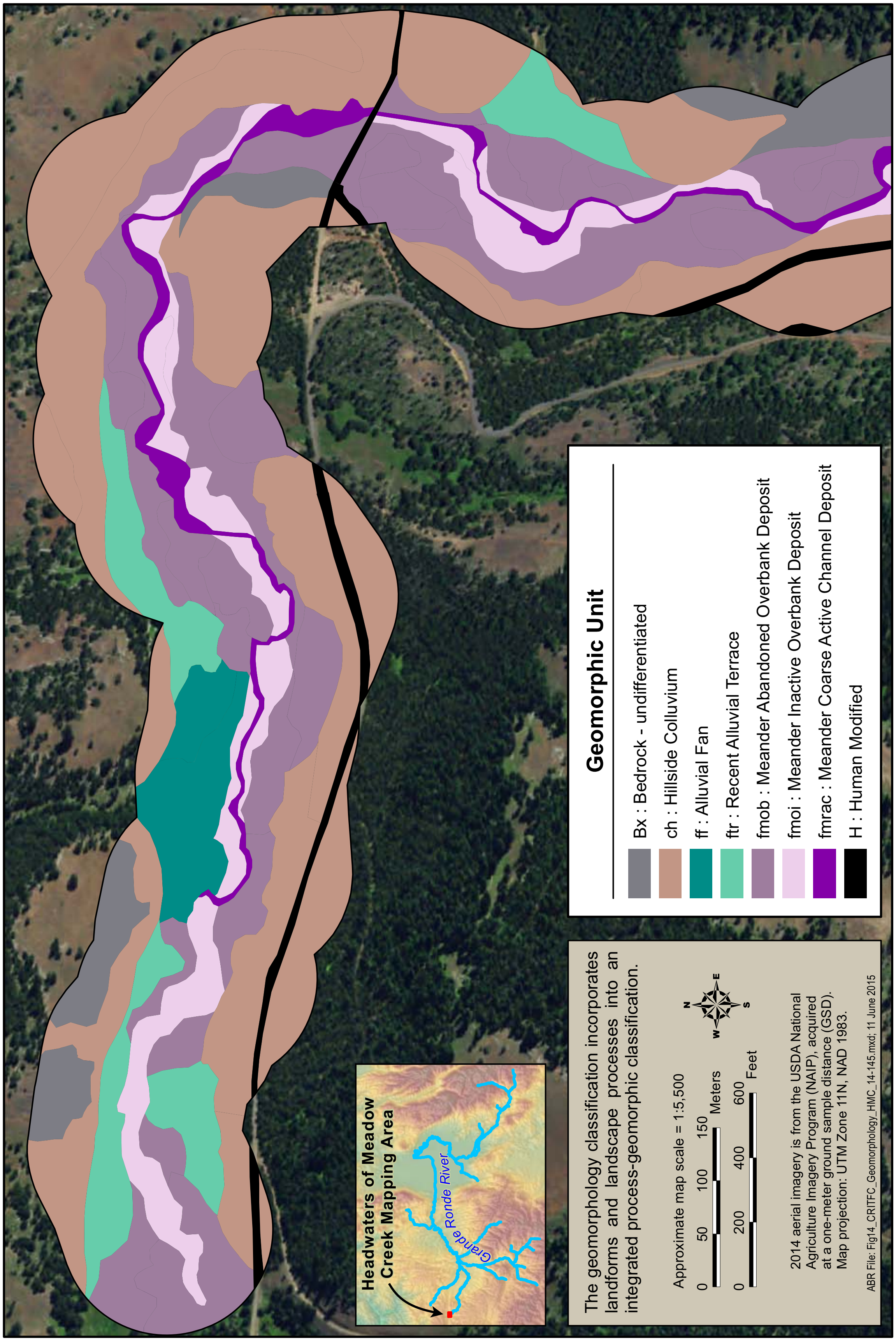


Figure 14. Integrated terrain unit mapping depicting geomorphology, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

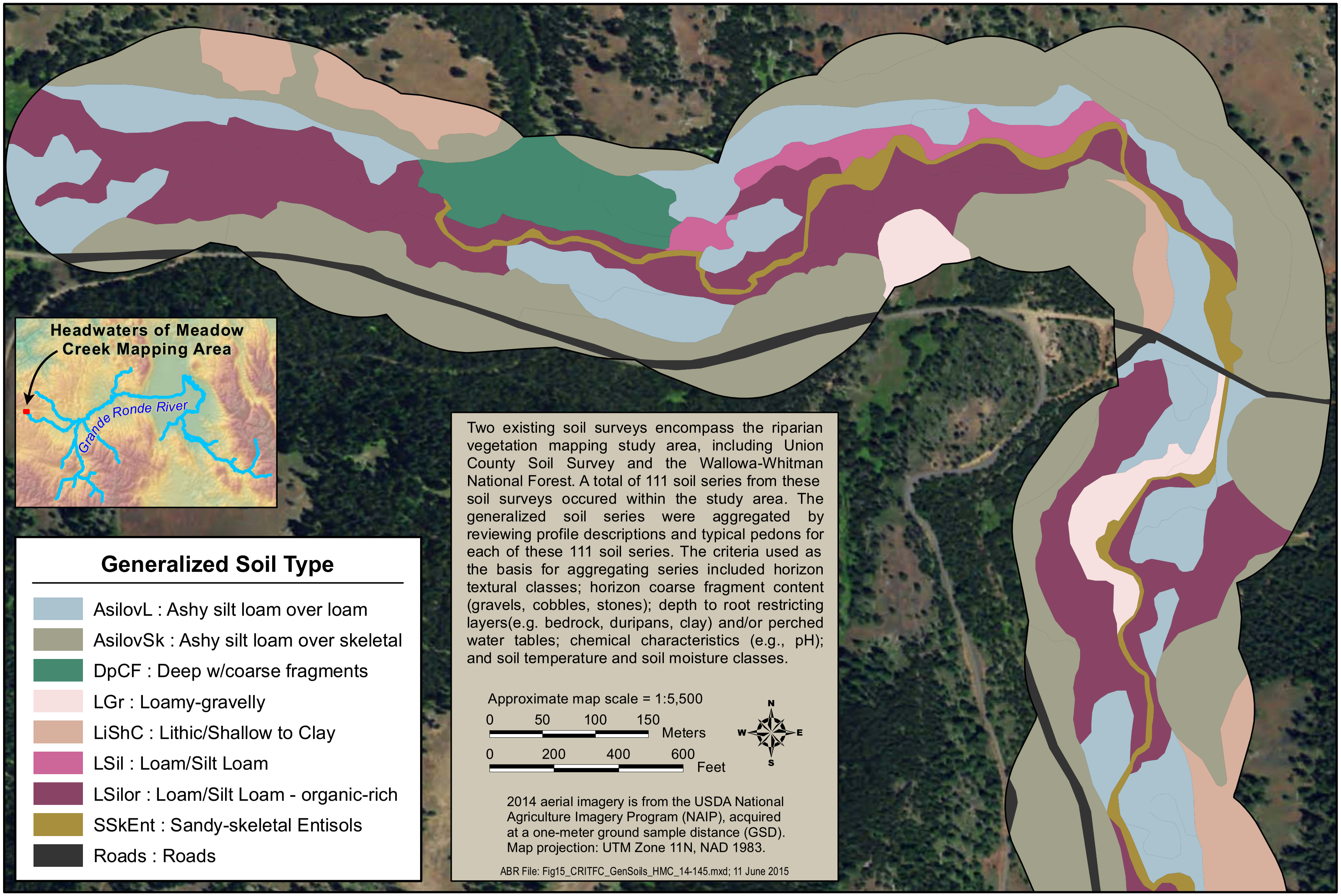


Figure 15. Integrated terrain unit mapping depicting generalized soils, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

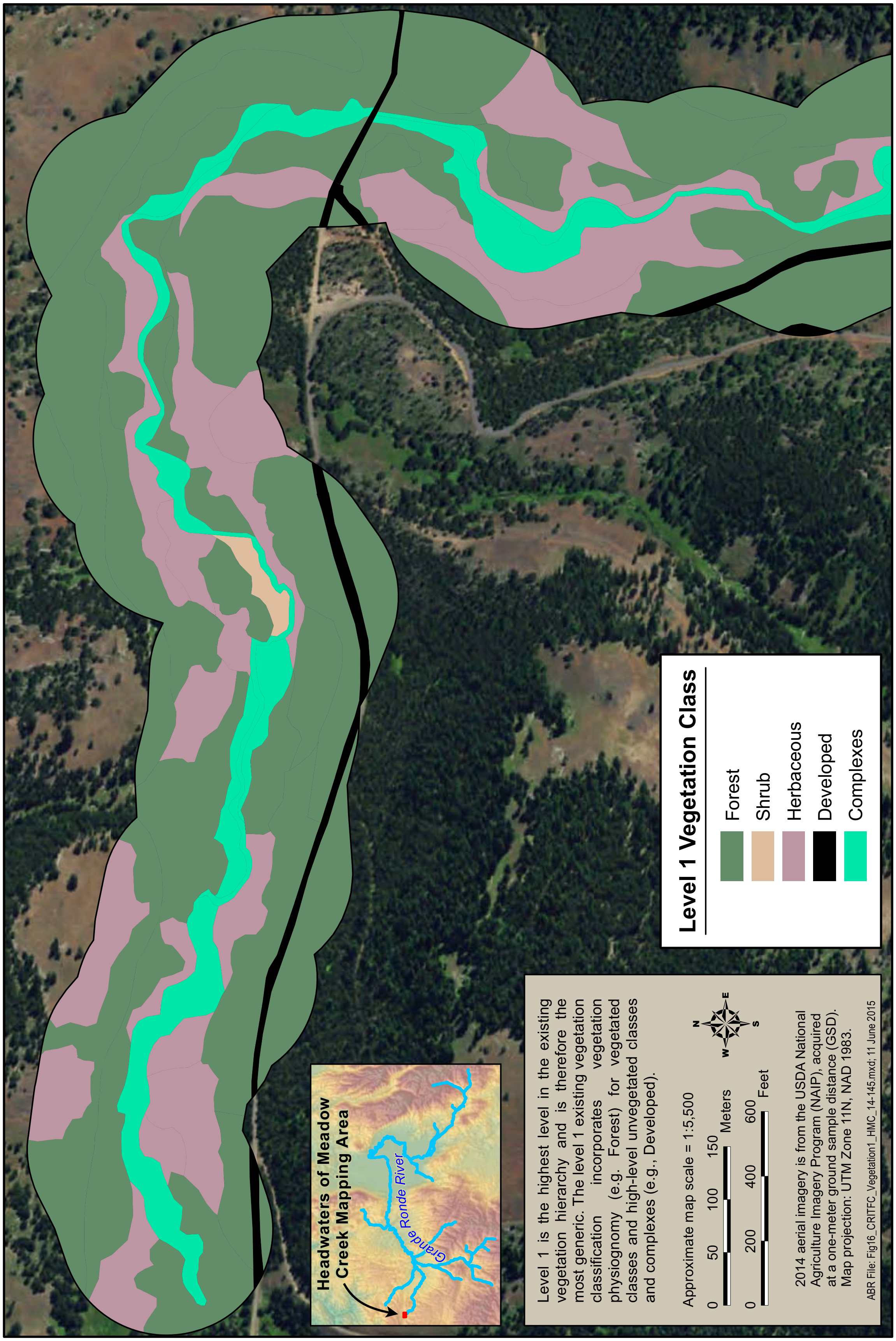


Figure 16. Integrated terrain unit mapping depicting the level 1 existing vegetation classes, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

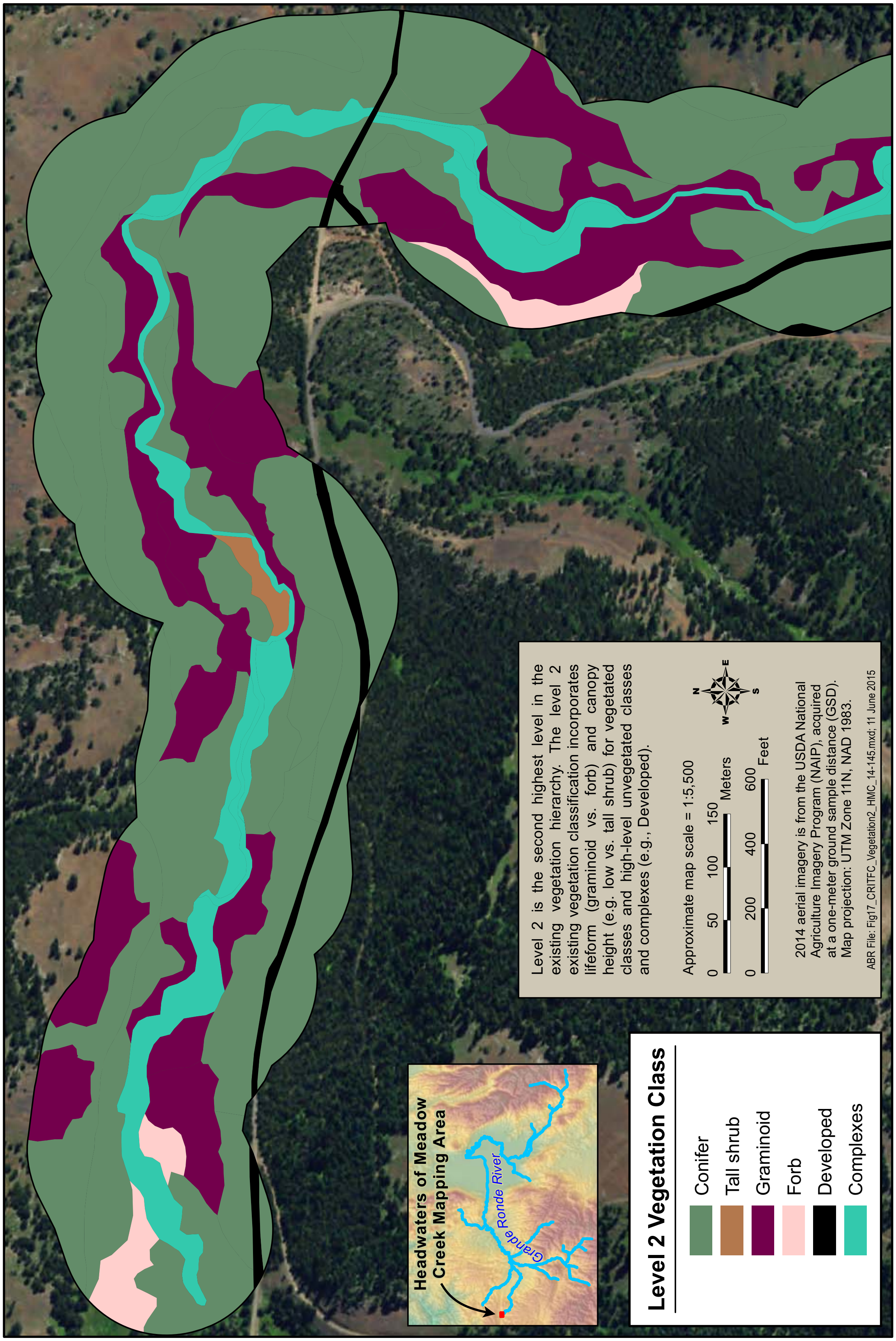


Figure 17. Integrated terrain unit mapping depicting the level 2 existing vegetation classes, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

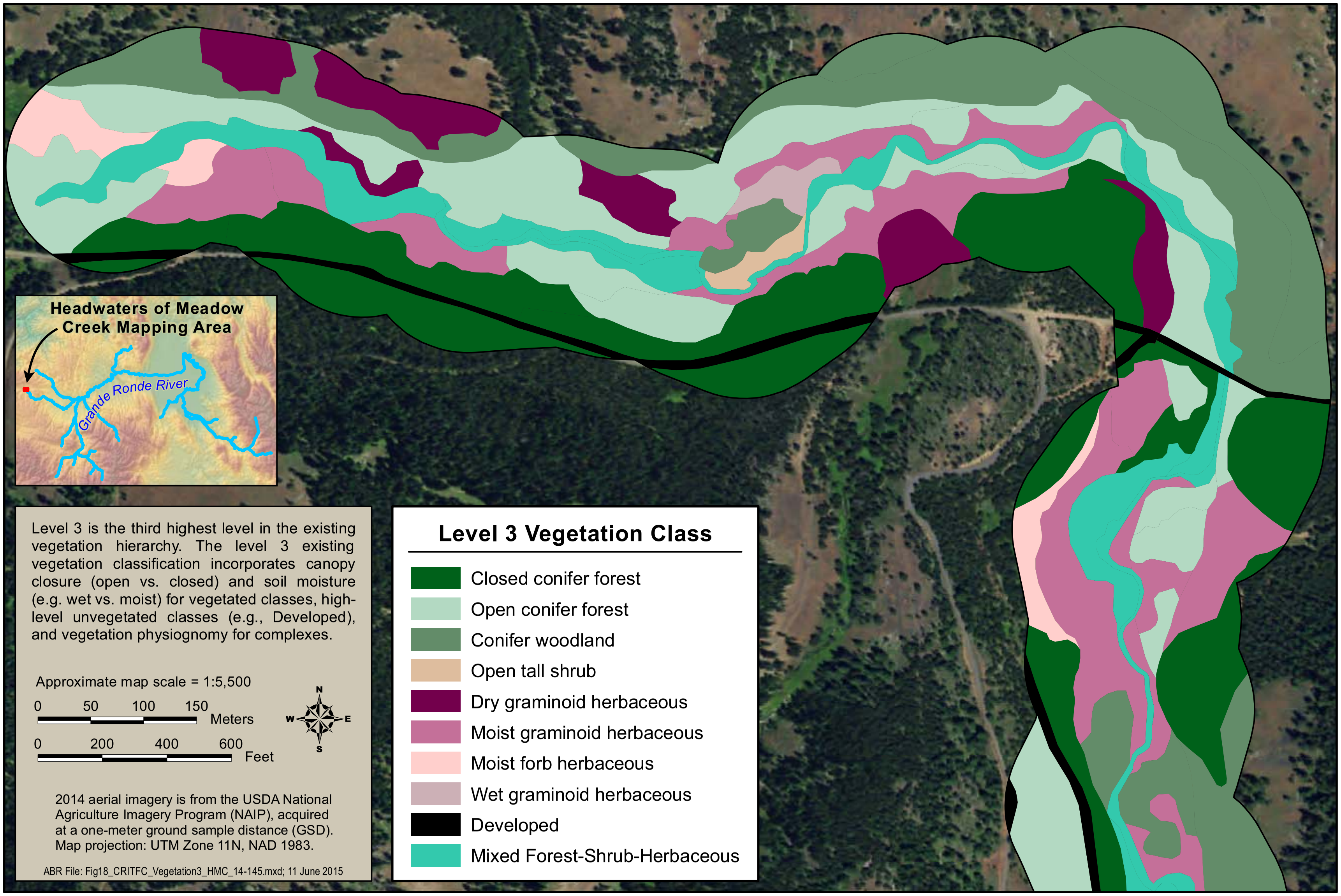


Figure 18. Integrated terrain unit mapping depicting the level 3 existing vegetation classes, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

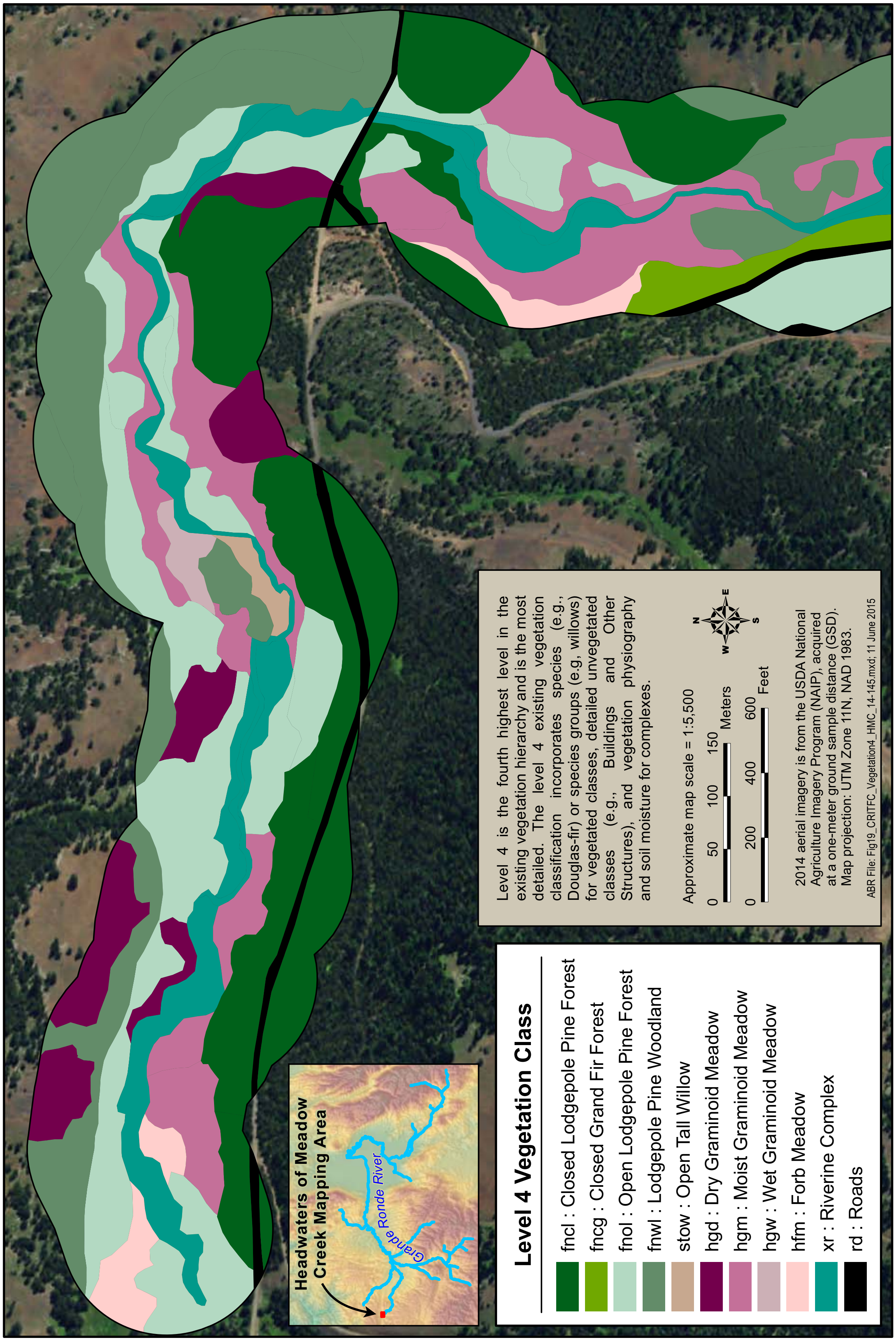


Figure 19. Integrated terrain unit mapping depicting the level 4 existing vegetation classes, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

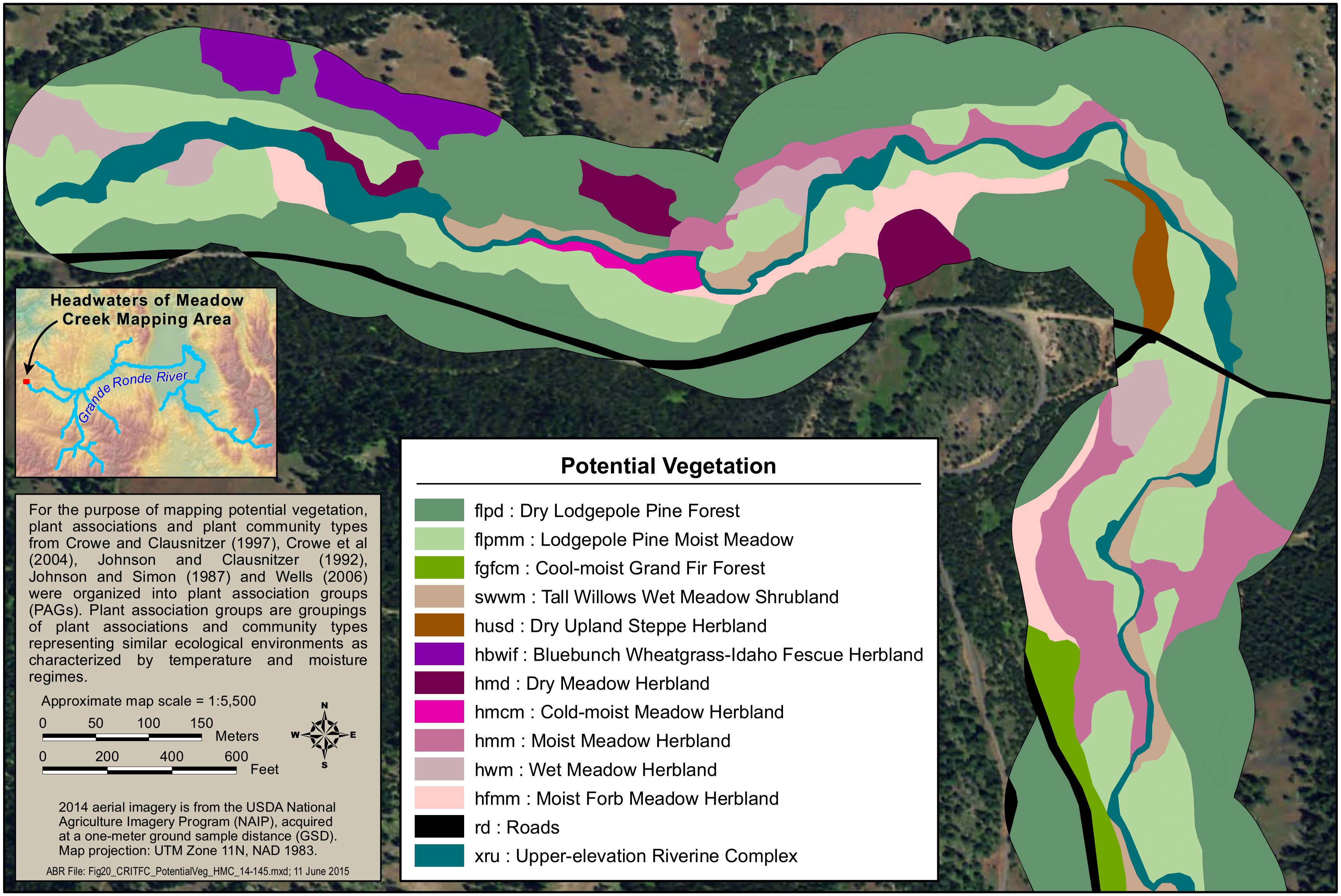


Figure 20. Integrated terrain unit mapping depicting potential vegetation, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

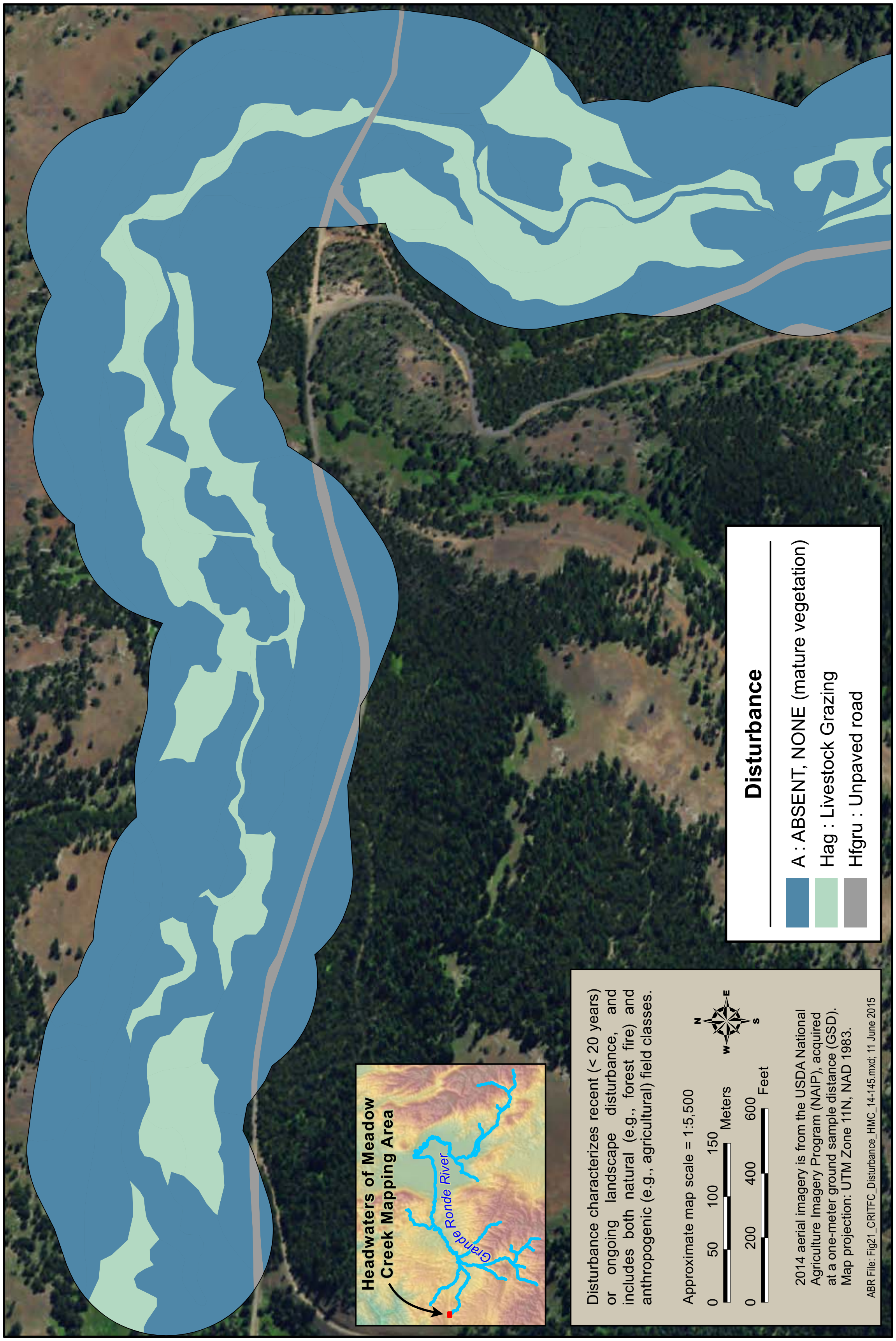


Figure 21. Integrated terrain unit mapping depicting disturbance, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Table 13. Areal extent of physiography and geomorphology classes mapped in the riparian mapping study area. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Code and Title	Hectares	Acres	Percent
PHYSIOGRAPHY			
L : Lowland	2871.6	7095.9	38.8%
R : Riverine	1476.0	3647.2	20.0%
S : Subalpine	153.4	379.1	2.1%
U : Upland	2892.6	7147.9	39.1%
Grand Total	7393.6	18270.1	
GEOMORPHOLOGY			
	Hectares	Area	Percent
Bx : Bedrock - undifferentiated	256.0	632.5	3.5%
ch : Hillside Colluvium	2439.4	6028.0	33.0%
ff : Alluvial Fan	98.0	242.1	1.3%
fmoa : Meander Active Overbank Deposit	441.8	1091.6	6.0%
fmob : Meander Abandoned Overbank Deposit	1749.2	4322.5	23.7%
fmoi : Meander Inactive Overbank Deposit	488.1	1206.1	6.6%
Fmolp : Levee-protected Floodplain	368.9	911.6	5.0%
fmrac : Meander Coarse Active Channel Deposit	391.3	967.0	5.3%
fmri : Meander Inactive Channel Deposit	28.0	69.1	0.4%
Fmrox : Old Oxbow	8.6	21.2	0.1%
fto : Old Alluvial Terrace	136.5	337.3	1.8%
ftr : Recent Alluvial Terrace	332.7	822.1	4.5%
H : Human Modified	454.9	1124.2	6.2%
Of : Organic Fen	8.1	20.0	0.1%
Wh : Human Modified Waterbody	23.5	58.2	0.3%
Wr : Rivers and Streams	168.5	416.4	2.3%
Grand Total	7393.6	18270.1	

Table 14. Areal extent of generalized soil classes mapped in the riparian mapping study area. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

	Hectares	Acres	Percent
AsilovCF : Ashy silt loam over coarse frags	12.0	29.7	0.2%
AsilovL : Ashy silt loam over loam	201.7	498.5	2.7%
AsilovSk : Ashy silt loam over skeletal	412.7	1019.7	5.6%
DpCF : Deep w/coarse fragments	223.6	552.5	3.0%
DpSiCL : Deep - silt to clay loam	11.2	27.7	0.2%
LGr : Loamy-gravelly	225.5	557.1	3.0%
LiShC : Lithic/Shallow to Clay	999.0	2468.5	13.5%
LovSk : Loam over skeletal	829.8	2050.5	11.2%
LSil : Loam/Silt Loam	1581.7	3908.5	21.4%
LSilbr : Loam/Silt Loam - brackish	783.5	1936.1	10.6%
LSilor : Loam/Silt Loam - organic-rich	72.6	179.5	1.0%
MDpCF : Mod. deep w/coarse frags	1034.6	2556.5	14.0%
Roads : Roads	312.5	772.3	4.2%
Rock : Rock Outcrop	22.1	54.5	0.3%
SSkEnt : Sandy-skeletal Entisols	470.9	1163.7	6.4%
StmBkHG : Streambanks - high gradient	5.0	12.3	0.1%
Water : Water	195.2	482.4	2.6%
Grand Total	7393.6	18270.1	

Table 15. Areal extent of level 1 and 2 existing vegetation classes mapped in the riparian mapping study area. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

	Hectares	Acres	Percent
LEVEL 1			
Agricultural	780.1	1927.7	10.6%
Barren	58.6	144.7	0.8%
Complexes	555.0	1371.4	7.5%
Developed	422.6	1044.3	5.7%
Forest	3063.1	7569.0	41.4%
Herbaceous	1823.9	4506.9	24.7%
Shrub	499.1	1233.2	6.7%
Water	191.3	472.8	2.6%
Grand Total	7393.6	18270.1	
LEVEL 2			
Agricultural	780.1	1927.7	10.6%
Barren	58.6	144.7	0.8%
Complexes	555.0	1371.4	7.5%
Conifer	2784.7	6881.1	37.7%
Deciduous/Broadleaf	278.4	688.0	3.8%
Developed	422.6	1044.3	5.7%
Forb	7.1	17.4	0.1%
Graminoid	1816.8	4489.4	24.6%
Tall shrub	499.1	1233.2	6.7%
Water	191.3	472.8	2.6%
Grand Total	7393.6	18270.1	

Table 16. Areal extent of level 3 existing vegetation classes mapped in the riparian mapping study area. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

	Hectares	Acres	Percent
Agricultural	780.1	1927.7	10.6%
Barren	58.6	144.7	0.8%
Closed conifer forest	794.6	1963.6	10.7%
Closed deciduous forest	47.9	118.5	0.6%
Closed tall shrub	240.2	593.6	3.2%
Conifer woodland	632.6	1563.1	8.6%
Deciduous woodland	12.3	30.3	0.2%
Developed	422.6	1044.3	5.7%
Dry graminoid herbaceous	676.4	1671.5	9.1%
Herbaceous	111.9	276.4	1.5%
Mixed Forest-Shrub-Herbaceous	443.1	1095.0	6.0%
Moist forb herbaceous	7.1	17.4	0.1%
Moist graminoid herbaceous	1036.5	2561.4	14.0%
Open conifer forest	1357.5	3354.4	18.4%
Open deciduous forest	218.2	539.2	3.0%
Open tall shrub	258.9	639.6	3.5%
Water	191.3	472.8	2.6%
Wet graminoid herbaceous	103.8	256.6	1.4%
Grand Total	7393.6	18270.1	

Table 17. Areal extent of level 4 existing vegetation classes mapped in the riparian mapping study area. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

	Hectares	Acres	Percent
bbg : Barren	31.4	77.6	0.4%
bpa : barren agricultural	620.2	1532.6	8.4%
bpvh : Barren partially vegetated herbaceous	27.2	67.1	0.4%
fbcc : Closed Black Cottonwood Forest	15.8	39.1	0.2%
fbcs : Open Willow Forest (lower valley)	34.5	85.4	0.5%
fboc : Open Black Cottonwood Forest	138.2	341.4	1.9%
fbos : Closed Willow Forest (lower valley)	27.2	67.2	0.4%
fbwc : Black Cottonwood Woodland	12.3	30.3	0.2%
fmbcdfc : Closed Black Cottonwood-Douglas-fir Forest	4.9	12.2	0.1%
fmbcdfo : Open Black Cottonwood-Douglas-fir Forest	11.2	27.7	0.2%
fmbceso : Open Black Cottonwood-Engelmann Spruce Forest	5.9	14.6	0.1%
fmbcgfo : Open Black Cottonwood-Grand Fir Forest	6.3	15.5	0.1%
fmbcppo : Open Black Cottonwood-Ponderosa Pine Forest	22.1	54.6	0.3%
fncdf : Closed Douglas-fir Forest	199.8	493.8	2.7%
fnces : Closed Engelmann Spruce Forest	5.3	13.1	0.1%
fncg : Closed Grand Fir Forest	336.0	830.3	4.5%
fncl : Closed Lodgepole Pine Forest	145.6	359.8	2.0%
fncpp : Closed Ponderosa Pine Forest	26.7	65.9	0.4%
fndfw : Douglas-fir Woodland	217.8	538.2	2.9%
fngfw : Grand Fir Woodland	99.0	244.7	1.3%
fnodf : Open Douglas-fir Forest	518.5	1281.2	7.0%
fnoes : Open Englemann Spruce Forest	35.4	87.5	0.5%
fnog : Open Grand Fir Forest	478.9	1183.5	6.5%
fnol : Open Lodgepole Pine Forest	200.6	495.8	2.7%
fnopp : Open Ponderosa Pine Forest	108.6	268.3	1.5%
fnscf : Closed Subalpine Fir Forest	81.2	200.7	1.1%
fnsfo : Open Subalpine Fir Forest	15.4	38.1	0.2%
fnsfw : Subalpine Fir Woodland	2.8	6.8	0.0%
fnwl : Lodgepole Pine Woodland	97.9	242.0	1.3%
fnwpp : Ponderosa Pine Woodland	215.0	531.4	2.9%
hca : agricultural croplands	150.7	372.4	2.0%
hfm : Forb Meadow	7.1	17.4	0.1%
hgd : Dry Graminoid Meadow	388.0	958.9	5.2%
hgm : Moist Graminoid Meadow	1036.5	2561.4	14.0%
hgw : Wet Graminoid Meadow	103.8	256.6	1.4%
hgwmcc : Wet-Moist Graminoid Meadow Complex	111.9	276.4	1.5%
hpa : agricultural pasture	1.5	3.8	0.0%

Table 17. Continued.

	Hectares	Acres	Percent
hus : Upland Steppe	288.4	712.6	3.9%
rd : Roads	312.5	772.3	4.2%
smxlc : Closed Low Elevation Mixed Shrubland	105.7	261.2	1.4%
smxlo : Open Low Elevation Mixed Shrubland	100.3	247.9	1.4%
ssa : Sitka Alder	0.9	2.3	0.0%
stcat : Closed Thinleaf Alder	45.5	112.3	0.6%
stcbh : Closed Black Hawthorn	33.2	82.1	0.4%
stcw : Closed Tall Willow	35.8	88.6	0.5%
stoat : Open Thinleaf Alder	56.9	140.7	0.8%
stobh : Open Black Hawthorn	31.7	78.4	0.4%
stow : Open Tall Willow	33.1	81.8	0.4%
suc : Closed Upland Shrubland	19.0	47.0	0.3%
suo : Open Upland Shrubland	36.8	90.9	0.5%
ub : Buildings and Other Structures	41.1	101.7	0.6%
wf : Fresh Water	191.3	472.8	2.6%
xa : agricultural complex	7.6	18.8	0.1%
xd : Urban Complex	68.9	170.3	0.9%
xr : Riverine Complex	443.1	1095.0	6.0%
Grand Total	7393.6	18270.1	

Table 18. Areal extent of potential vegetation classes mapped in the riparian mapping study area. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

	Hectares	Acres	Percent
a : Agricultural Fields	8.5	21.0	0.1%
bbg : Barren	13.1	32.5	0.2%
fbbcwf : Black Cottonwood/Willows Floodplain Forest	150.6	372.2	2.0%
fbcf : Black Cottonwood Floodplain Forest	48.2	119.2	0.7%
fbclf : Low Elevation Black Cottonwood Floodplain Forest	104.2	257.5	1.4%
fbcmmlfc : Low Elevation Black Cottonwood/Moist Meadow Floodplain Complex	213.2	526.8	2.9%
fbct : Black Cottonwood Terrace Forest	78.4	193.8	1.1%
fbww : White Willow Forest	1.1	2.7	0.0%
fdfd : Dry Douglas-fir Forest	142.8	352.8	1.9%
fdflm : Low Elevation Moist Douglas-fir Forest	15.4	38.0	0.2%
fdfm : Moist Douglas-fir Forest	144.2	356.4	2.0%
fdfmo : Open Moist Douglas-fir Forest	47.2	116.5	0.6%
fdfwm : Warm-moist Douglas-fir Forest	793.0	1959.4	10.7%
fes : Engelmann Spruce Forest	14.5	35.9	0.2%
fgfc : Cold Grand Fir Forest	175.9	434.6	2.4%
fgfcm : Cool-moist Grand Fir Forest	255.3	630.9	3.5%
fgfcmo : Open Cool-moist Grand Fir Forest	207.6	512.9	2.8%
fgfes : Grand fir-Engelmann Spruce Forest	21.6	53.4	0.3%
fgfeso : Open Grand fir-Engelmann Spruce Forest	16.0	39.6	0.2%
fgfwd: Warm-dry Grand Fir Forest	239.4	591.5	3.2%
fgfwdo : Open Warm-dry Grand Fir Forest	75.4	186.3	1.0%
flpd : Dry Lodgepole Pine Forest	203.7	503.3	2.8%
flpmm : Lodgepole Pine Moist Meadow	193.0	476.8	2.6%
flpwm : Lodgepole Pine Wet Meadow	13.9	34.4	0.2%
fppd : Dry Ponderosa Pine Forest	169.1	417.9	2.3%
fppm : Moist Ponderosa Pine Forest	120.6	298.1	1.6%
fppmo : Open Moist Ponderosa Pine Forest	41.2	101.8	0.6%
fsfd : Dry Subalpine Fir Forest	50.3	124.4	0.7%
fsfes : Subalpine Fir-Engelmann Spruce Forest	63.2	156.2	0.9%
fsfeso : Open Subalpine Fir-Engelmann Spruce Forest	6.6	16.3	0.1%
hbwif : Bluebunch Wheatgrass-Idaho Fescue Herbland	337.8	834.6	4.6%
hfmm : Moist Forb Meadow Herbland	3.3	8.1	0.0%
hgfgb : Graminoid-Forb Gravel Bar Herbland	6.4	15.8	0.1%
hgmccwmc:Cold Wet-Moist Meadow Complex Herbland	7.0	17.4	0.1%
hgmcwmc:Wet-Moist Meadow Complex Herbland	111.5	275.6	1.5%
hmcm : Cold-moist Meadow Herbland	3.9	9.8	0.1%

Table 18. Continued.

	Hectares	Acres	Percent
hmd : Dry Meadow Herbland	33.2	82.1	0.4%
hmm : Moist Meadow Herbland	93.4	230.8	1.3%
hss : Subalpine Steppe Herbland	10.3	25.4	0.1%
husd : Dry Upland Steppe Herbland	49.5	122.3	0.7%
husgbwc : Dry Upland Steppe-Moist Great Basin Wildrye Complex	41.4	102.2	0.6%
hwm : Wet Meadow Herbland	47.7	118.0	0.6%
hwmc : Cold Wet Meadow Herbland	0.9	2.3	0.0%
rd : Roads	312.5	772.3	4.2%
ro : Rock	14.6	36.2	0.2%
sbh : Black Hawthorn Shrubland	52.8	130.4	0.7%
scs : Red-osier Dogwood Shrubland	2.2	5.5	0.0%
smaf : Mountain Alder Floodplain Shrubland	68.9	170.4	0.9%
smalf : Low Elevation Mountain Alder Floodplain Shrubland	22.2	54.9	0.3%
smawm : Mountain Alder Wet Meadow Shrubland	43.6	107.8	0.6%
smm : Moist Meadow Shrubland	2.5	6.3	0.0%
smmgrlfc : Low Elevation Moist Shrub/Graminoid Floodplain Complex	44.1	109.0	0.6%
smxl : Low Elevation Mixed Shrubland	199.1	492.1	2.7%
ssa : Sitka Alder Shrubland	0.9	2.3	0.0%
sud : Upland Dry Shrubland	4.2	10.4	0.1%
sum : Upland Moist Shrubland	52.1	128.6	0.7%
swgb : Willows Gravel Bar Shrubland	31.2	77.0	0.4%
swmm : Tall Willows Moist Meadow Shrubland	44.1	109.0	0.6%
swmmgrblfc : Low Elevation Brackish Wet-Moist Shrub/Graminoid Floodplain Complex	61.9	153.0	0.8%
swmmgrlfc : Low Elevation Wet-Moist Shrub/Graminoid Floodplain Complex	1227.7	3033.8	16.6%
swwm : Tall Willows Wet Meadow Shrubland	28.8	71.2	0.4%
ub: Buildings and Other Structures	36.2	89.4	0.5%
wf : Fresh Water	190.0	469.4	2.6%
wpps : Ponderosa Pine Steppe Woodland	96.1	237.4	1.3%
xd : Developed Sites	11.0	27.2	0.1%
xrl : Low-elevation Riverine Complex	34.9	86.1	0.5%
xrm : Mid-elevation Riverine Complex	237.0	585.7	3.2%
xru : Upper-elevation Riverine Complex	142.7	352.7	1.9%
xu : Urban Complex	58.6	144.8	0.8%
Grand Total	7393.6	18270.1	

Table 19. Areal extent of disturbance classes mapped in the riparian mapping study area. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

	Hectares	Acres	Percent
A : ABSENT, NONE (mature vegetation)	3108.3	7680.8	42.0%
DC : Disturbance complex	288.2	712.2	3.9%
Ha : Agricultural Field	608.7	1504.2	8.2%
Hac : Crops	150.8	372.5	2.0%
Haf : Feedlot/livestock holding pen	2.6	6.3	0.0%
Hag : Livestock Grazing	1643.8	4062.0	22.2%
Hah : Hayfield	477.8	1180.6	6.5%
Hc : Clearings (Non-agricultural or undifferentiated)	24.7	61.1	0.3%
Hcl : Logged	55.1	136.2	0.7%
Hd : Human Developed Sites (urban complex)	78.1	193.0	1.1%
Hdr : Residential Development	52.4	129.4	0.7%
He : Excavation/Pits (undifferentiated)	4.2	10.4	0.1%
Hf : Fill	32.0	79.0	0.4%
Hfgrp : Paved Road	130.3	321.9	1.8%
Hfgru : Unpaved road	153.4	379.0	2.1%
Hft : Mine Tailings	10.4	25.8	0.1%
Hp : Pasture	8.5	20.9	0.1%
Hrr : Railroad	17.8	44.1	0.2%
Hsb : Building	6.4	15.8	0.1%
Hsisd : Abandoned/historic splash dam	0.5	1.2	0.0%
Hwc : Canal	64.9	160.5	0.9%
Hwd : Ditch	6.6	16.3	0.1%
Hwe : Water-filled excavation	10.5	25.8	0.1%
Hwi : Drainage Impoundment	2.1	5.2	0.0%
Hwl : Levee	48.4	119.7	0.7%
Nf : Fire	156.3	386.1	2.1%
Ngfd : Fluvial Deposition	27.3	67.4	0.4%
Ngfe : Fluvial Erosion/channel migration	223.7	552.7	3.0%
Grand Total	7393.6	18270.1	

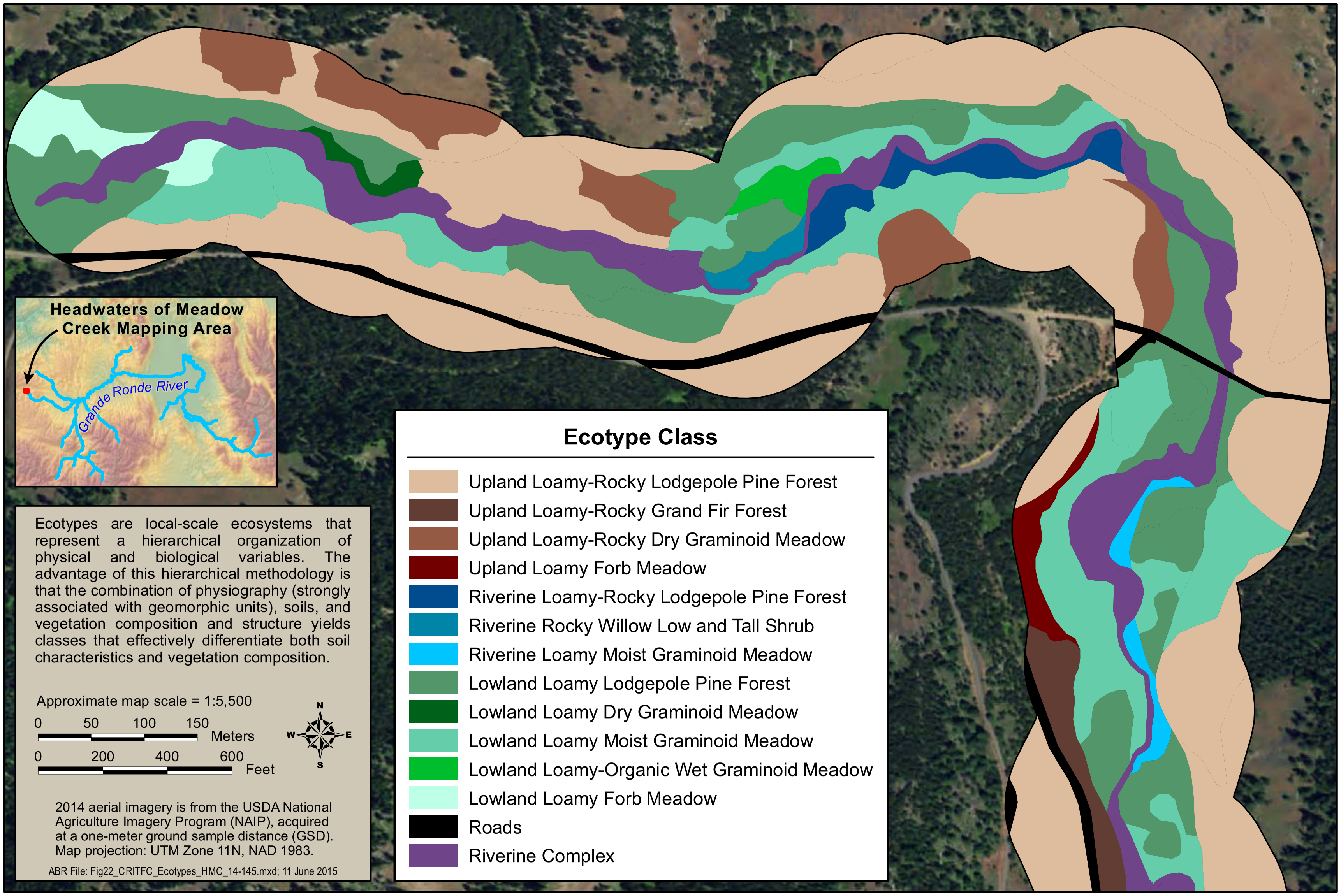


Figure 22. Integrated terrain unit mapping depicting ecotypes, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

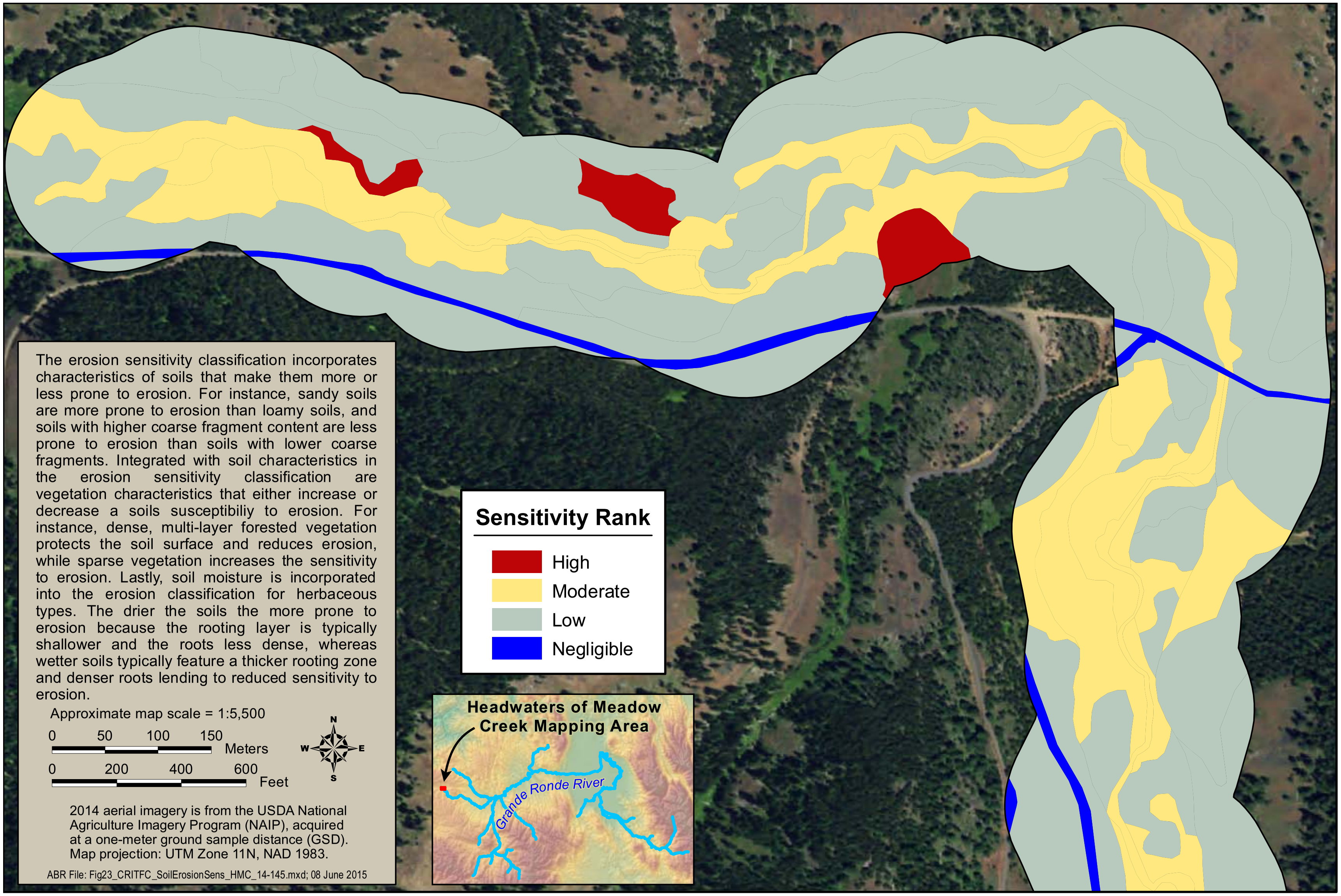


Figure 23. Integrated terrain unit mapping depicting soil erosion sensitivity classes, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Table 20. Areal extent of ecotype classes mapped in the riparian mapping study area. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

	Hectares	Acres	Percent
Freshwater	191.3	472.8	2.6%
Human Developments	110.1	272.0	1.5%
Loamy Human-modified Barrens and Partially Vegetated	632.5	1563.0	8.6%
Lowland Loamy Agricultural Lands	573.0	1415.9	7.7%
Lowland Loamy Black Cottonwood Forest	67.3	166.4	0.9%
Lowland Loamy Black Hawthorn Tall Shrub	33.9	83.7	0.5%
Lowland Loamy Douglas-fir Forest	83.8	207.2	1.1%
Lowland Loamy Dry Graminoid Meadow	204.1	504.4	2.8%
Lowland Loamy Forb Meadow	6.5	16.0	0.1%
Lowland Loamy Grand-fir Forest	81.9	202.3	1.1%
Lowland Loamy Lodgepole Pine Forest	85.9	212.3	1.2%
Lowland Loamy Low Elevation Mixed Shrubland	11.7	28.8	0.2%
Lowland Loamy Moist Graminoid Meadow	499.8	1235.1	6.8%
Lowland Loamy Ponderosa Pine Forest	66.5	164.4	0.9%
Lowland Loamy Spruce Forest	30.4	75.1	0.4%
Lowland Loamy Subalpine Fir Forest	6.4	15.8	0.1%
Lowland Loamy Thinleaf Alder Tall Shrub	16.5	40.8	0.2%
Lowland Loamy Willow Forest	14.8	36.5	0.2%
Lowland Loamy Willow Low and Tall Shrub	26.6	65.6	0.4%
Lowland Loamy-Organic Wet Graminoid Meadow	176.1	435.2	2.4%
Lowland Rocky Dry Graminoid Meadow	33.6	83.0	0.5%
Lowland Rocky Moist Graminoid Meadow	12.4	30.7	0.2%
Riverine Complex	441.1	1090.1	6.0%
Riverine Loamy Black Cottonwood Forest	101.2	250.0	1.4%
Riverine Loamy Douglas-fir Forest	48.8	120.5	0.7%
Riverine Loamy Forb Meadow	0.2	0.5	0.0%
Riverine Loamy Low Elevation Mixed Shrubland	193.7	478.5	2.6%
Riverine Loamy Moist Graminoid Meadow	66.0	163.2	0.9%
Riverine Loamy Ponderosa Pine Forest	15.8	39.1	0.2%
Riverine Loamy Spruce Forest	10.3	25.5	0.1%
Riverine Loamy Subalpine Fir Forest	3.9	9.7	0.1%
Riverine Loamy Willow Forest	47.0	116.1	0.6%
Riverine Loamy-Organic Wet Graminoid Meadow	9.1	22.6	0.1%
Riverine Loamy-Rocky Dry Graminoid Meadow	7.7	19.0	0.1%
Riverine Loamy-Rocky Grand Fir Forest	45.0	111.2	0.6%
Riverine Loamy-Rocky Hawthorn Tall Shrub	29.3	72.4	0.4%
Riverine Loamy-Rocky Lodgepole Pine Forest	20.5	50.6	0.3%
Riverine Loamy-Rocky Wet Graminoid Meadow	11.9	29.5	0.2%

Table 20. Continued.

	Hectares	Acres	Percent
Riverine Rocky Barrens and Partially Vegetated	23.1	57.1	0.3%
Riverine Rocky Black Cottonwood Forest	45.2	111.8	0.6%
Riverine Rocky Moist Graminoid Meadow	47.3	116.9	0.6%
Riverine Rocky Thinleaf Alder Tall Shrub	83.9	207.3	1.1%
Riverine Rocky Willow Low and Tall Shrub	42.0	103.8	0.6%
Roads	312.5	772.3	4.2%
Rocky Sitka Alder Tall Shrub	0.9	2.3	0.0%
Subalpine Loamy-Rocky Grand Fir Forest	50.3	124.4	0.7%
Subalpine Loamy-Rocky Lodgepole Pine Forest	28.3	70.0	0.4%
Subalpine Loamy-Rocky Subalpine Fir Forest	67.0	165.5	0.9%
Subalpine Organic-rich Wet Graminoid Meadow	0.2	0.6	0.0%
Subalpine Rocky Dry Graminoid Meadow	2.8	7.0	0.0%
Upland Loamy Forb Meadow	0.4	0.9	0.0%
Upland Loamy-Rocky Douglas-fir Forest	807.5	1995.3	10.9%
Upland Loamy-Rocky Dry Graminoid Meadow	428.2	1058.2	5.8%
Upland Loamy-Rocky Grand Fir Forest	736.7	1820.5	10.0%
Upland Loamy-Rocky Lodgepole Pine Forest	309.5	764.7	4.2%
Upland Loamy-Rocky Low Elevation Mixed Shrubland	0.7	1.8	0.0%
Upland Loamy-Rocky Moist Graminoid Meadow	16.2	40.0	0.2%
Upland Loamy-Rocky Ponderosa Pine Forest	268.0	662.1	3.6%
Upland Loamy-Rocky Subalpine Fir Forest	22.1	54.7	0.3%
Upland Loamy-Rocky Thinleaf Alder Tall Shrub	2.0	5.0	0.0%
Upland Rocky Barrens and Partially Vegetated	18.8	46.4	0.3%
Upland Rocky Black Cottonwood Forest	0.9	2.3	0.0%
Upland Rocky Black Hawthorn Tall Shrub	1.8	4.4	0.0%
Upland Rocky Human-modified Barrens and Partially Vegetated	4.3	10.7	0.1%
Upland Rocky Willow Tall Shrub	0.4	0.9	0.0%
Upland Rocky-Loamy Undiffentiated Shrubland	55.8	137.9	0.8%
Grand Total	7393.6	18270.1	

Table 21. Areal extent of erosion sensitivity classes mapped in the riparian mapping study area. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

	Hectares	Area	Percent
High	1534.0	3790.6	20.7%
Low	3848.6	9510.1	52.1%
Moderate	1397.0	3452.2	18.9%
Negligible	614.0	1517.2	8.3%
Grand Total	7393.6	18270.1	

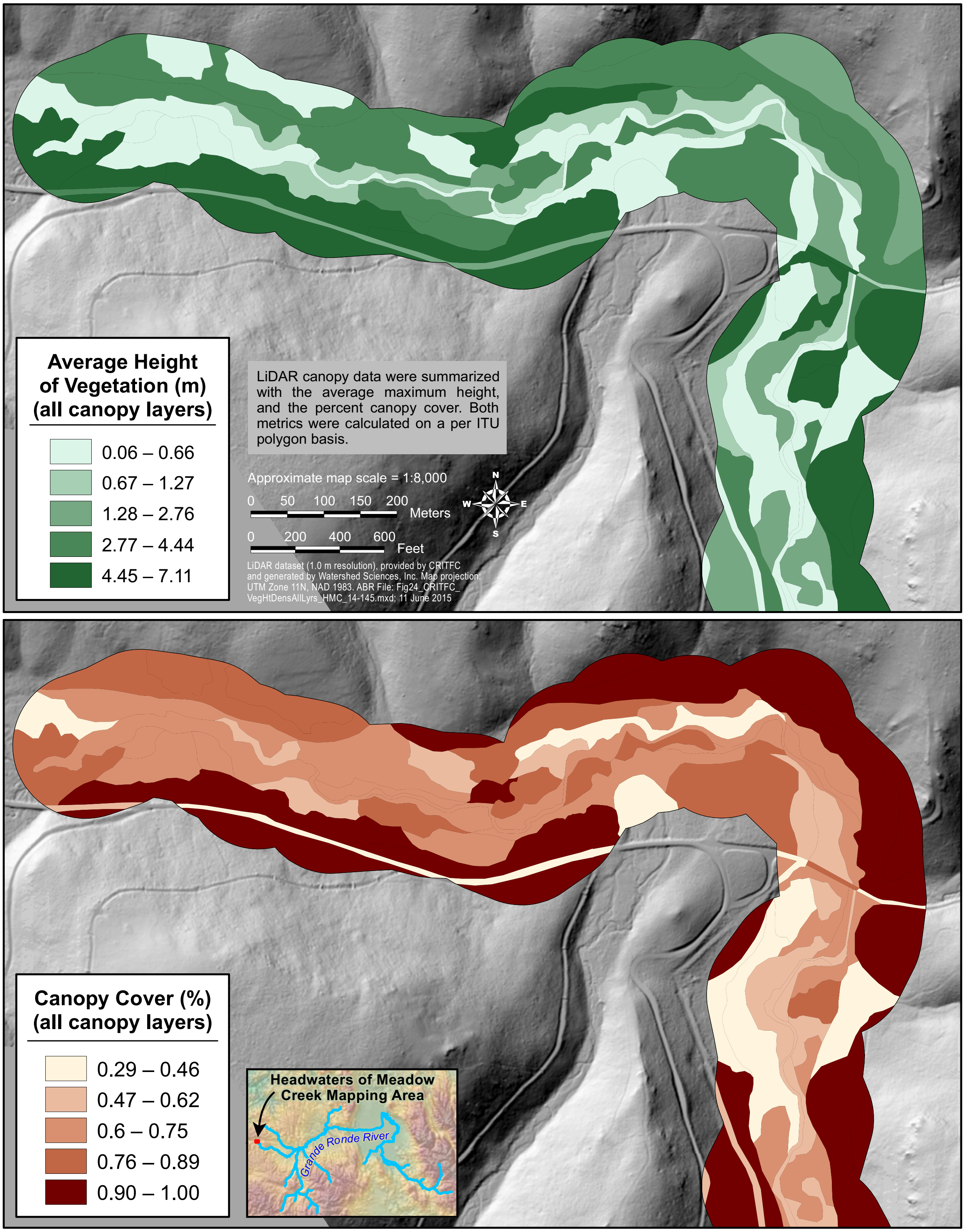


Figure 24. Maps of average height (upper) and density (lower) of existing vegetation across all canopy layers by map polygon as summarized from LiDAR data, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

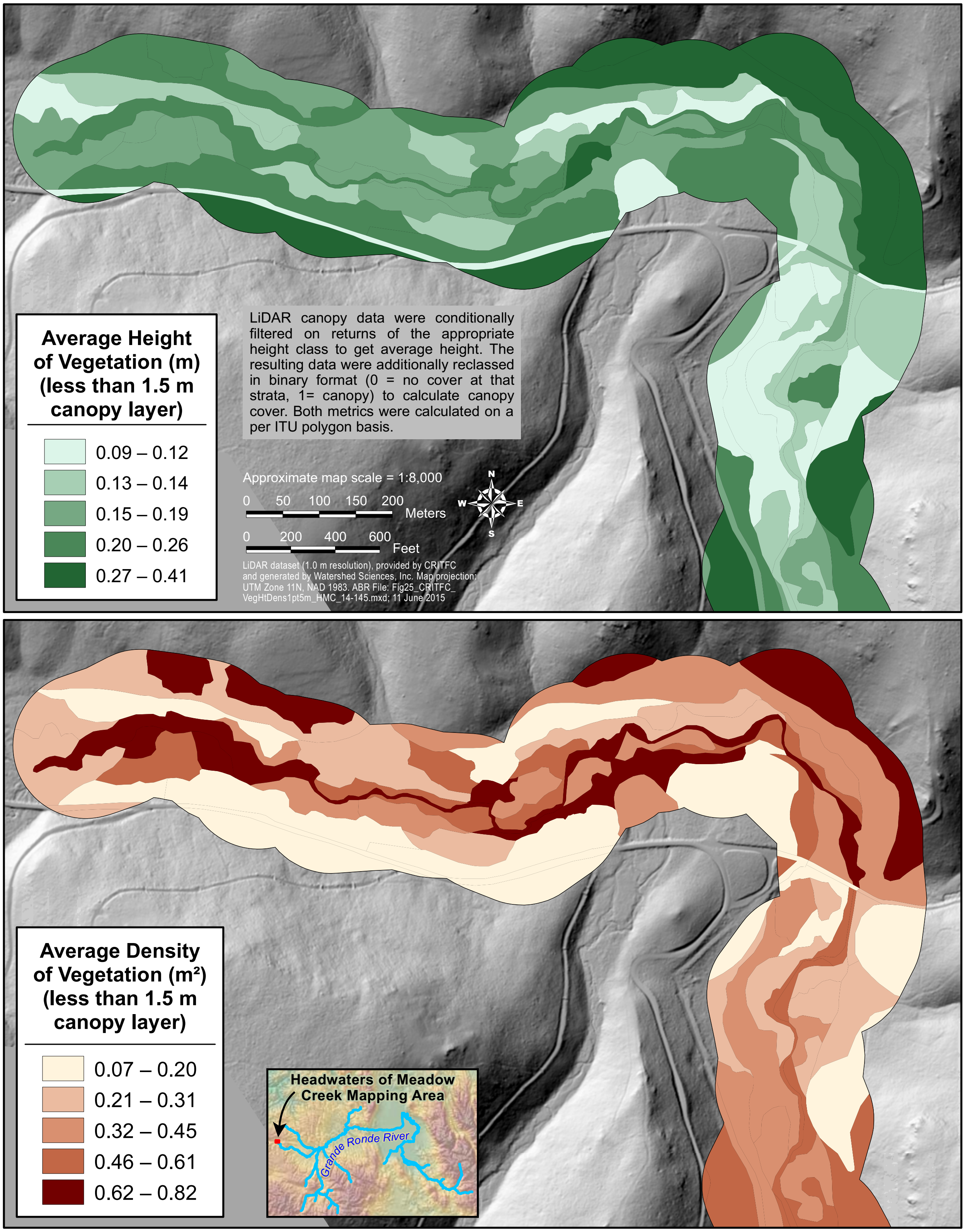


Figure 25. Maps of average height (upper) and density (lower) of existing vegetation for the less than 1.5 meter canopy layer by map polygon as summarized from LiDAR data, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

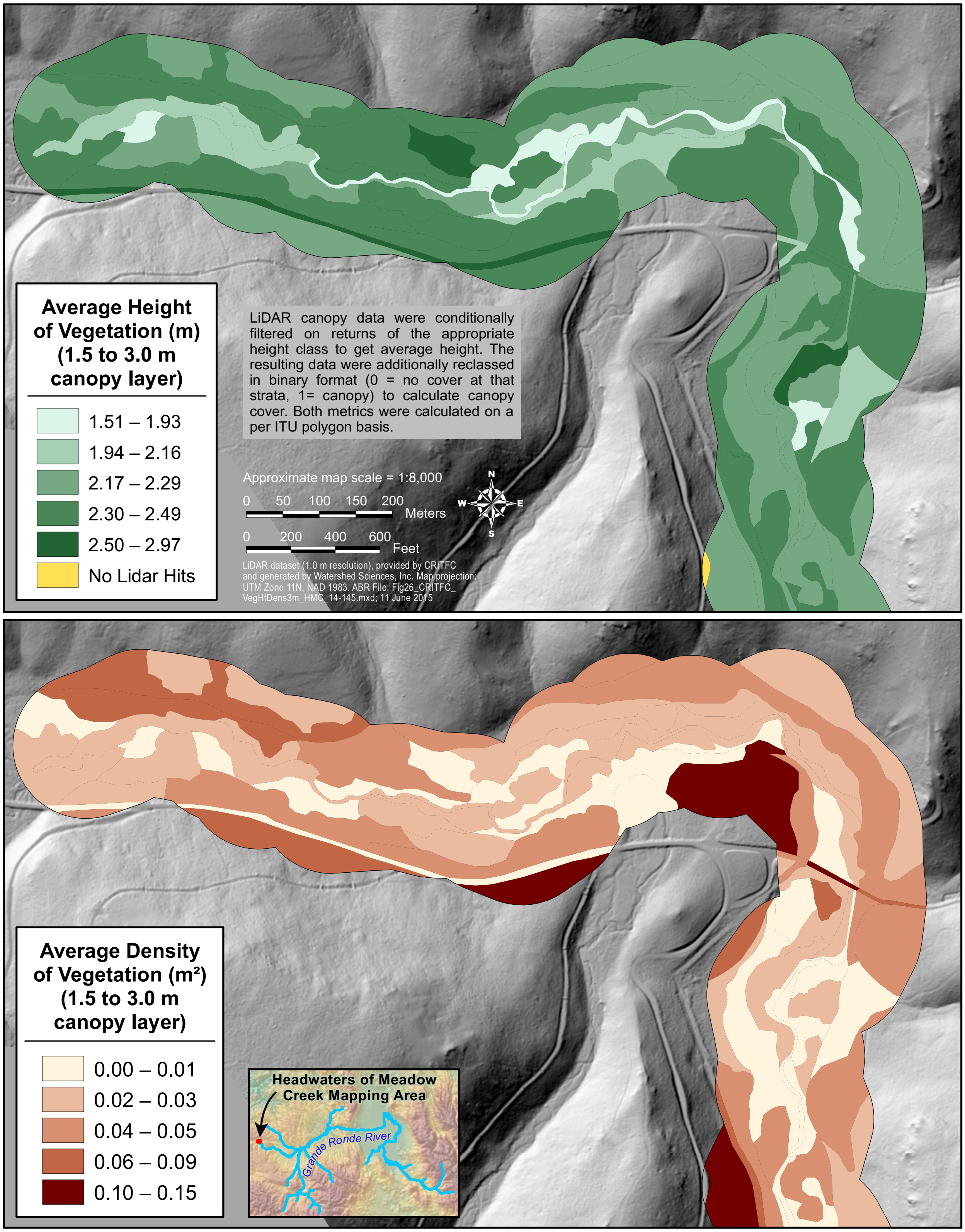


Figure 26. Maps of average height (upper) and density (lower) of existing vegetation for the 1.5 to 3.0 meter canopy layer by map polygon as summarized from LiDAR data, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

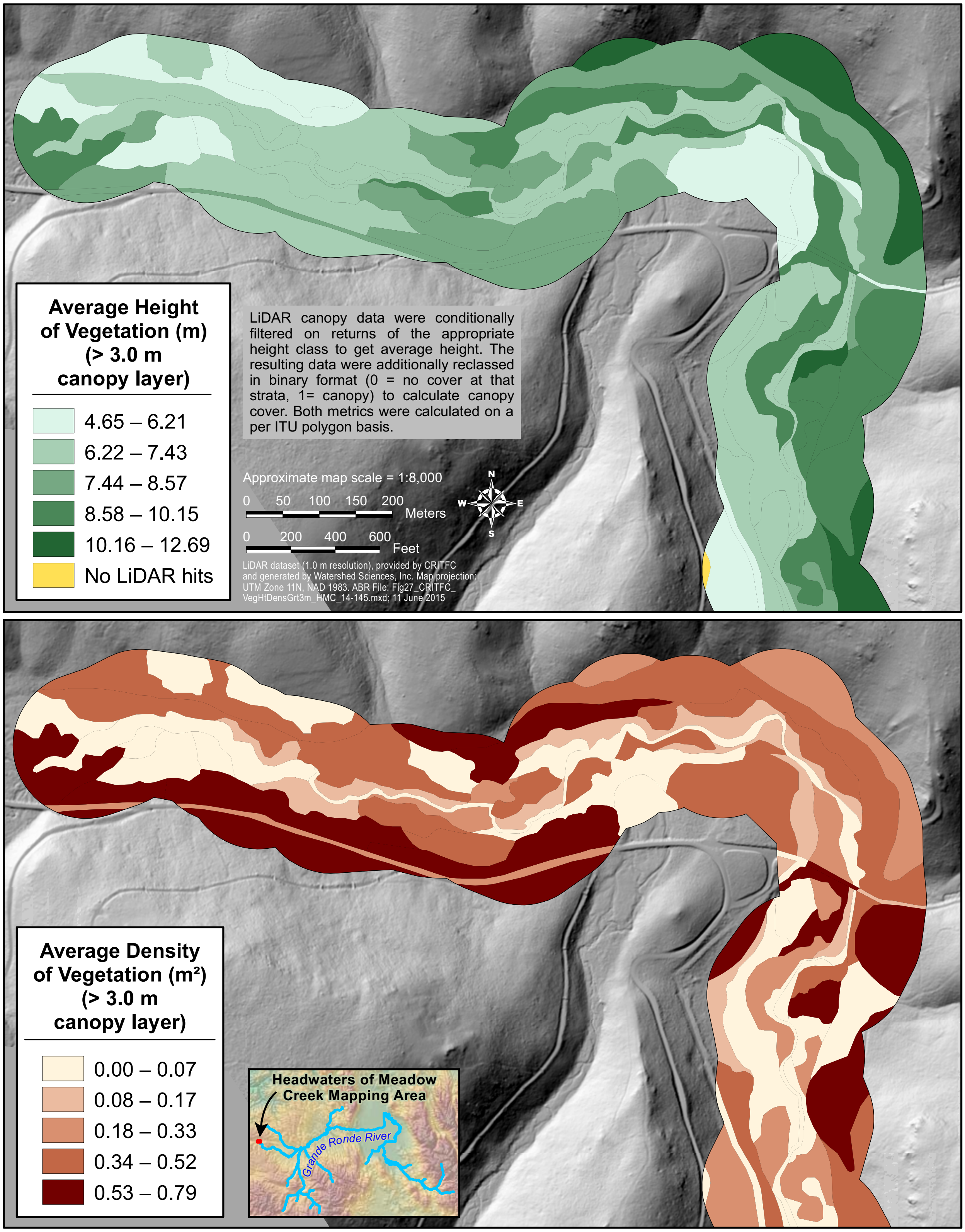


Figure 27. Maps of average height (upper) and density (lower) of existing vegetation for the >3.0 meter canopy layer by map polygon as summarized from LiDAR data, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

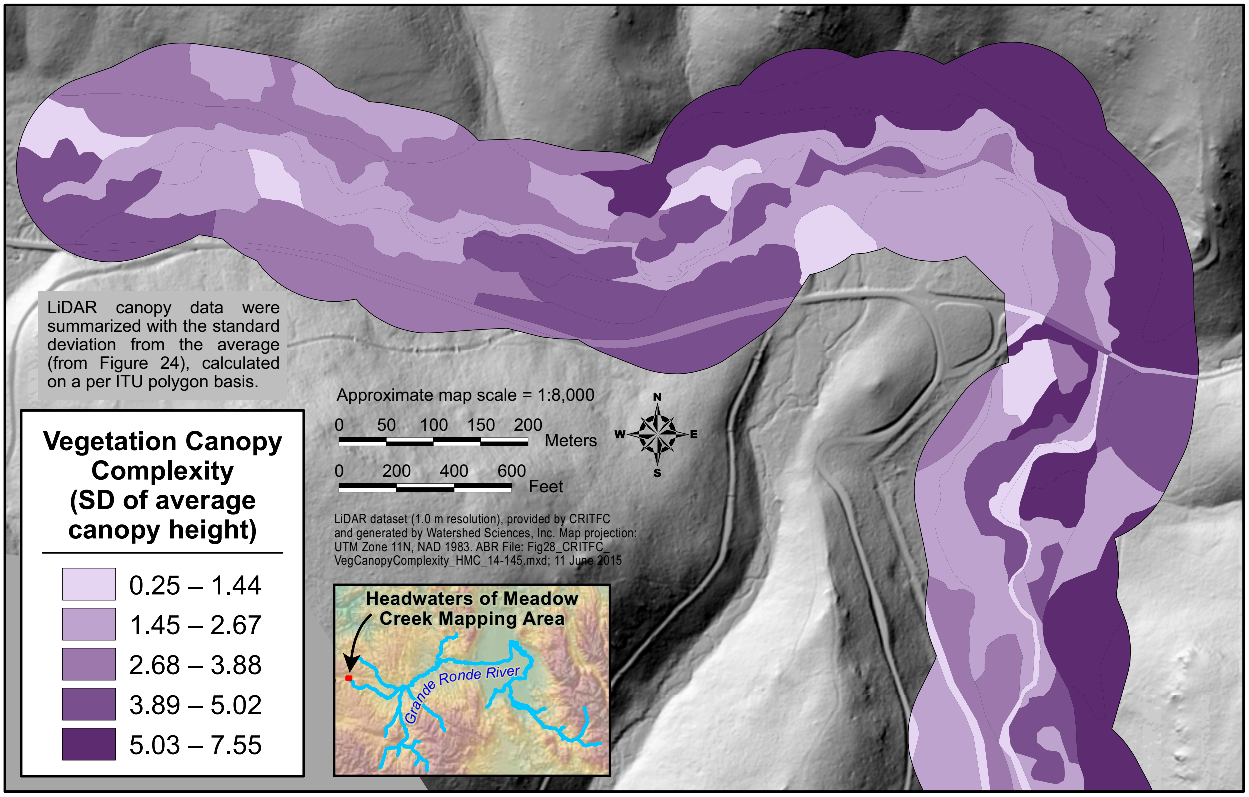


Figure 28. Vegetation canopy complexity as expressed by the standard deviation of average canopy height across all canopy layers as summarized from LiDAR data, headwaters of Meadow Creek. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

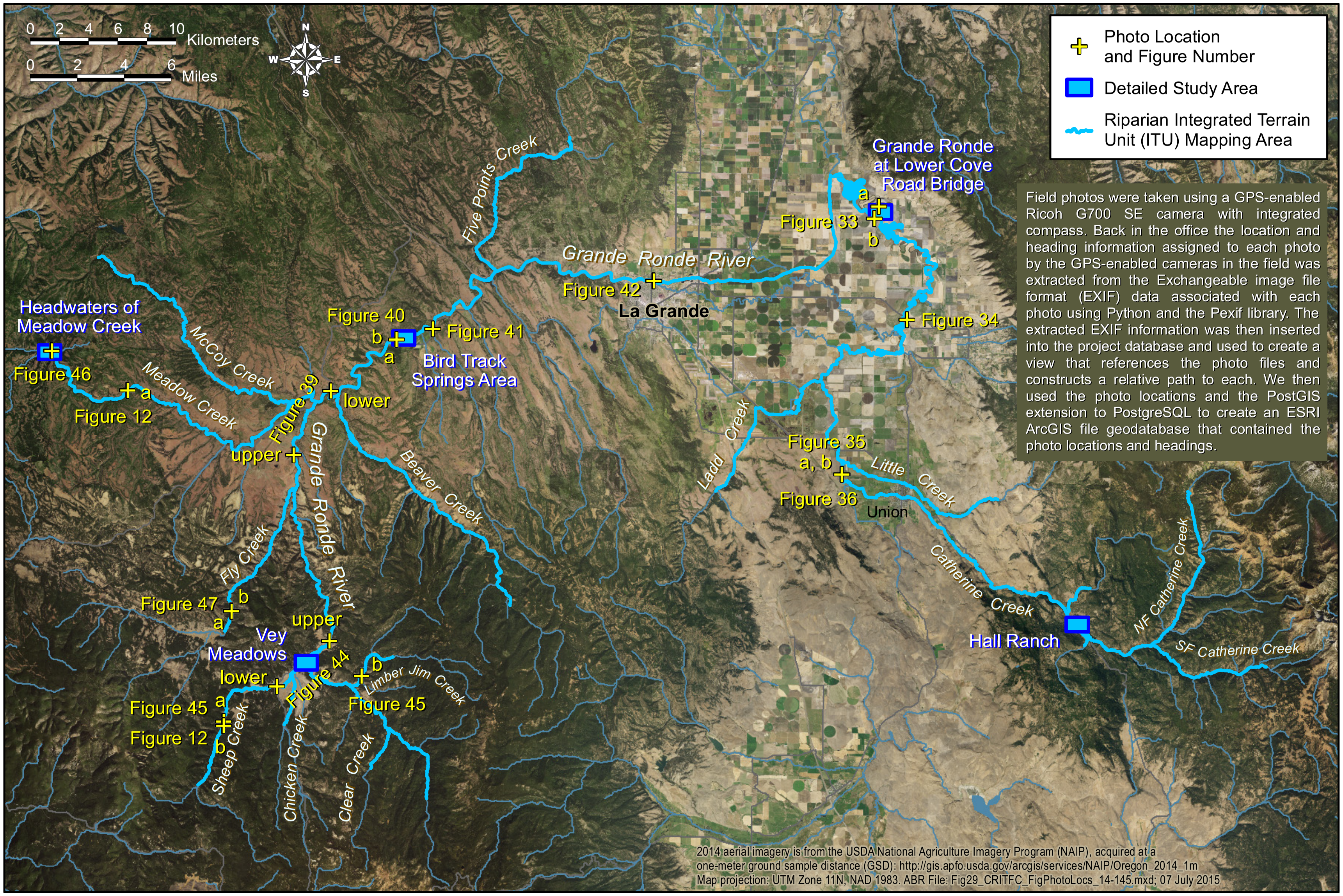


Figure 29. Map of study area showing location of photos presented in subsequent figures. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

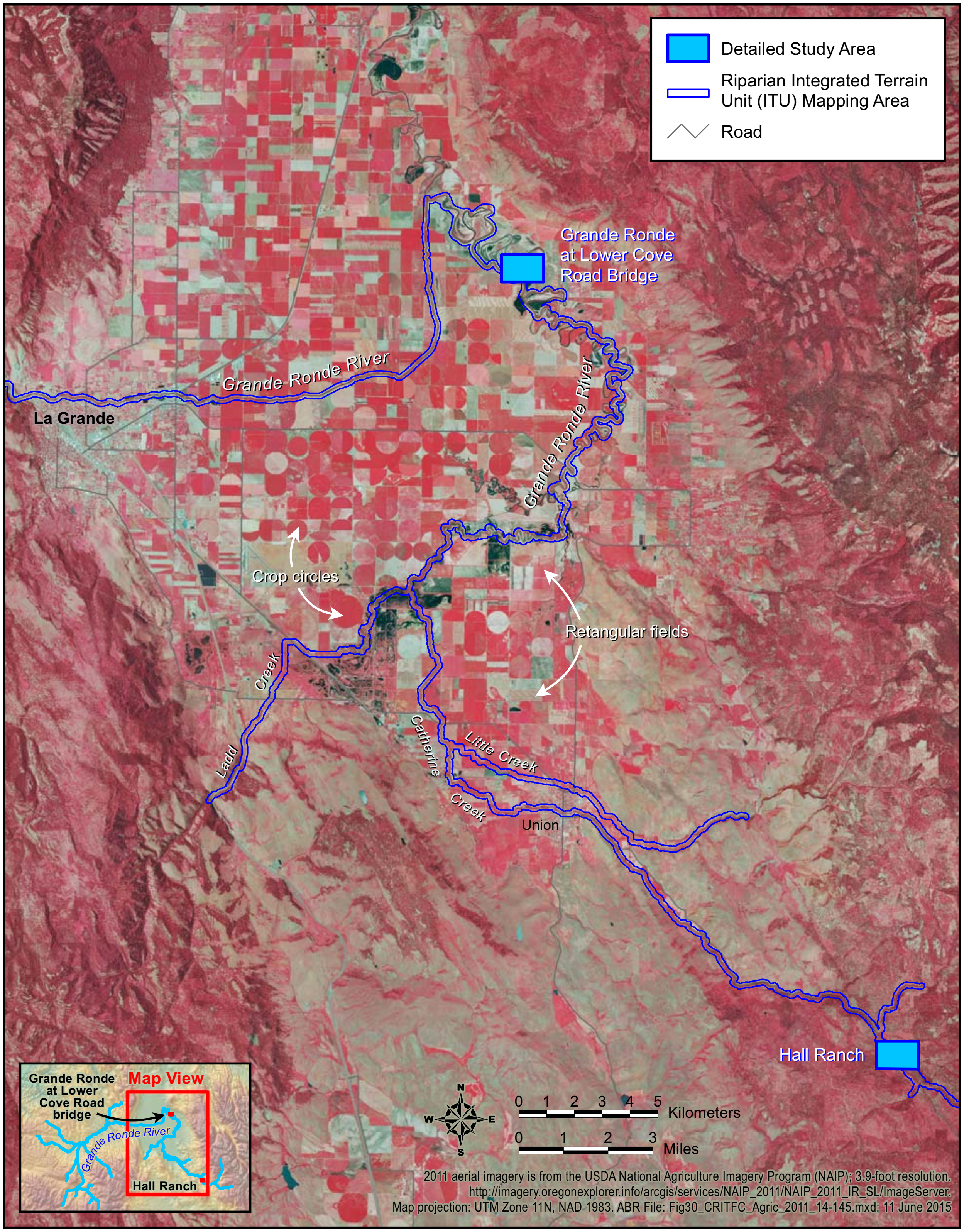


Figure 30. Aerial image of the Grande Ronde Valley from the 2011 NAIP IR imagery showing the extent of agricultural lands (crop circles and rectangular fields) in the valley as of 2011. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

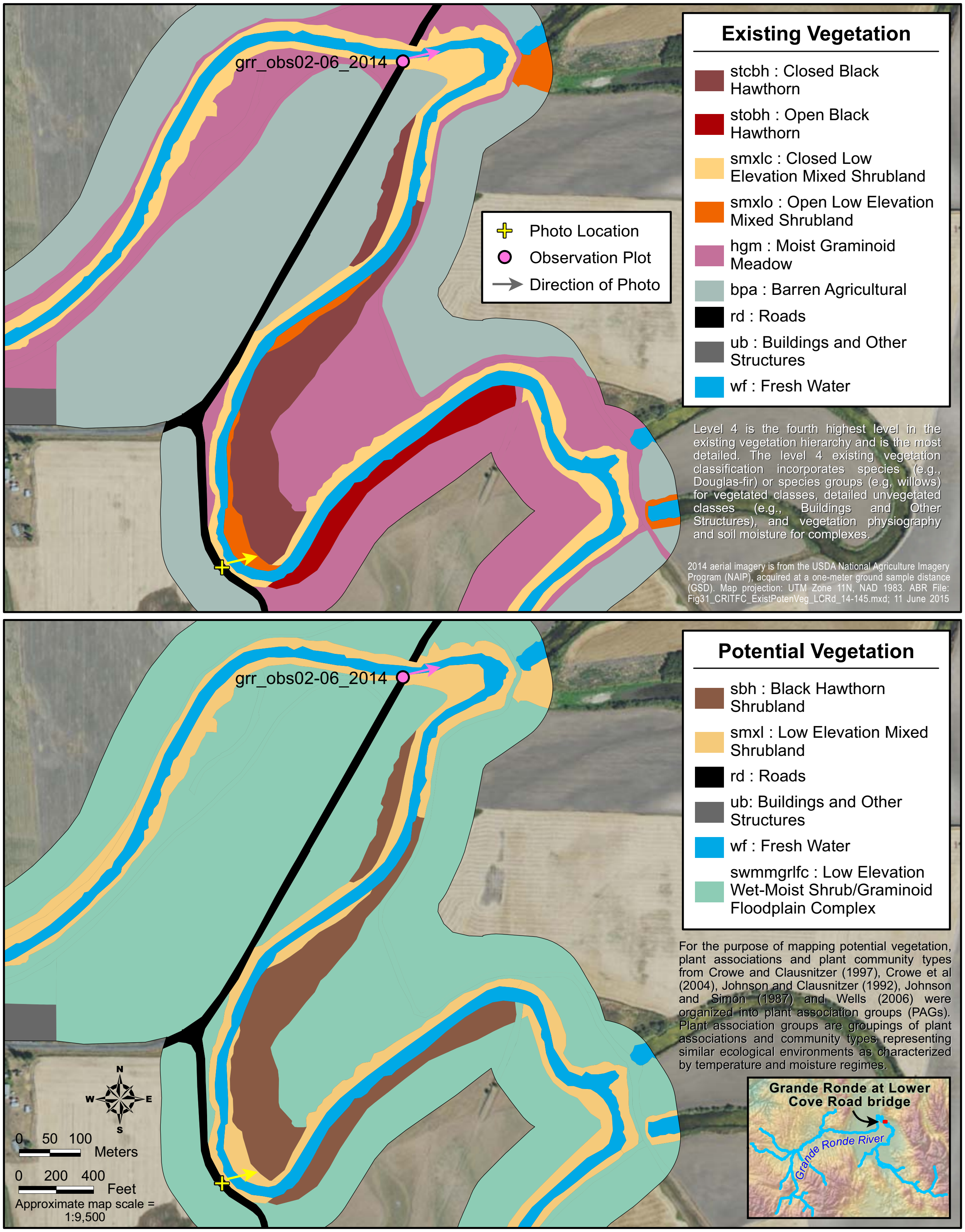


Figure 31. Grande Ronde at Lower Cove Road bridge detailed study area showing maps of existing (upper) and potential (lower) vegetation, and field plot and photo locations. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

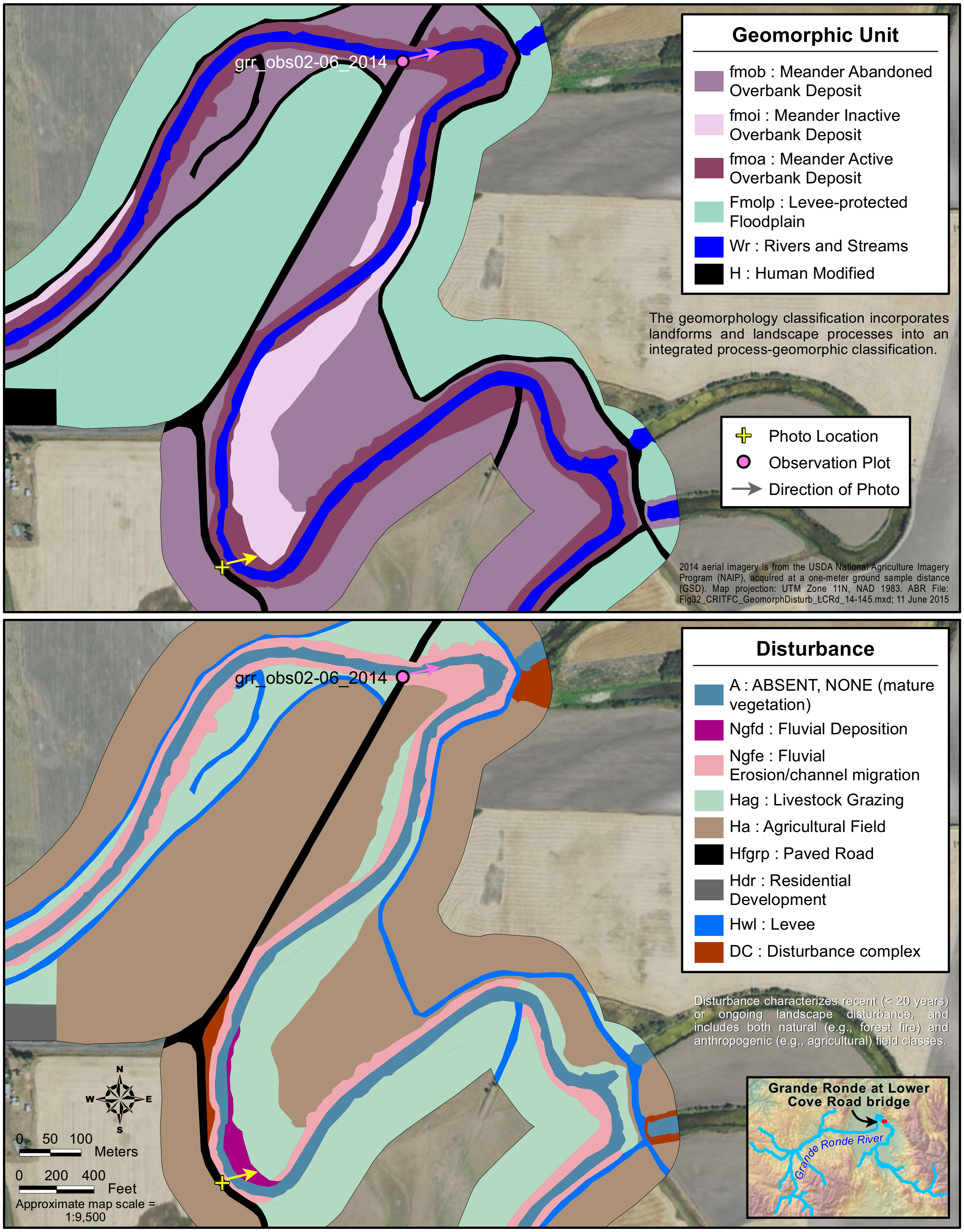


Figure 32. Grande Ronde at Lower Cove Road bridge detailed study area showing maps of geomorphology (upper) and disturbance (lower), and field plot and photo locations. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Figure 33. Field photos from the Lower Cove Road bridge detailed study area showing existing vegetation including a photo from plot grr_obs02-06_2014 (a) and a nearby unnamed photo point (b). Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Figure 34. Field photo from plot grr_obs02-05_2014 at Highway 82 bridge between Cove and Island City, Oregon, showing agricultural lands extending directly to the river channel. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Field observations in the Grande Ronde Valley revealed a low cover of shrub and forested vegetation on active floodplains. Historical records from pre-European settlement indicate that the floodplains (active, inactive and abandoned) of the Grande Ronde River and Catherine Creek in the Valley were extensive, and much of the valley was wet and “swampy” and covered by graminoid-dominated vegetation (Gildemeister 1998). The historical accounts also suggest that black cottonwood (*Populus trichocarpa* ssp. *balsamerifera*), willows (*Salix* spp.) and other hardwood shrubs were generally restricted to streambanks and active floodplains immediately adjacent to stream channels in the Grande Ronde Valley (U.S. Bureau of Reclamation 2012b). In 2014, small, relic stands of large cottonwood forest were observed in several locations through-out the Grande Ronde Valley, and in some cases catkins were observed (Figure 35). These stands could serve as a seed source for cottonwood establishment in the lower study area. However, younger cottonwood stands (sapling and pole-sized) were not observed in the lower study area, reflecting a noteworthy gap in cottonwood age structure. Along with a seed source, natural recruitment of cottonwood is dependent on moist, sandy bedding surfaces without competition from dense herbaceous vegetation, and an appropriate flow regime (Scott et al. 1997). A lack of appropriate bedding surfaces and flow regime are likely a contributing factor to the lack cottonwood regeneration in the lower study area. Another obstacle along many kilometers of lower Catherine Creek and the Grande Ronde River in the valley is ubiquitous cover of streambanks and floodplains

Figure 35. Field photo showing a relic poplar stand (a), including close up showing catkins in seed (b), in lower Grande Ronde Valley. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

by reed canarygrass (*Phalaris arundinacea*), which grows in a dense, nearly monocultural, rhizomatous stand 0.6–2 m tall (Waggy 2010). This “carpet” of reed canary grass can compete aggressively with cottonwood and other hardwood seedlings depriving them of light, moisture and nutrients (Tu 2004, Wisconsin Reed Canary Grass Working Group 2009).

In the Lower Cove Road bridge detailed study area, much of the potential vegetation is mapped as Low Elevation Wet-Moist Shrub/Graminoid Floodplain Complex. Restoration of the floodplain vegetation in the lower study area to potential vegetation, such as that mapped in the Lower Cove Road bridge detailed study area would require restoring the natural flow regime to the floodplain and oxbows. This might be accomplished by raising the water table and removing levees, but widespread irrigation (which lowers the water table) and channelization along the main stem of the Grande Ronde in the lower study area make these approaches to floodplain restoration challenging. An alternative approach to restoring native vegetation to the floodplain is described in Hall et al. (2011). They planted dormant pole cuttings of black cottonwood and willows along incised channels of Bridge Creek within John Day Fossil Beds National Monument in eastern Oregon. The cuttings were established successfully by planting them upwards of 2 meters in depth, such that they were in contact with the water table, and were covered with vented plastic tree covers.

Stands of white willow (*Salix alba* var. *vitellina*), an introduced, tree-sized willow, were observed more commonly than cottonwood stands in the lower study area (Figure 36). These forest stands are mapped as Closed and Open Willow Forest in the level 4 existing vegetation mapping. White willow may be a suitable surrogate for cottonwood on floodplains in the lower study area, contributing shade and large woody debris to the river channel. We mapped potential vegetation for polygons on active floodplains with existing white willow (and sometimes scattered black cottonwood

Figure 36. Field photo of a white willow (*Salix alba var. vitellina*) stand in lower river Grande Ronde Valley. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

trees) as Black Cottonwood/Willows Floodplain Forest. These sites may be Low Elevation Black Cottonwood Floodplain Forest or Low Elevation Tall Willows Floodplain Shrubland.

Four potential vegetation complexes were mapped along the Grande Ronde River from La Grande to its present-day confluence with Catherine Creek confluence; along Catherine Creek throughout the Catherine Creek Tributary Assessment's Reaches 1 and 2 and through portions of Reaches 3–7 (U.S. Bureau of Reclamation 2012a); along most of Little Creek; and along Ladd Creek from the former extent of Tule Lake and its associated wetlands downstream to its confluence with Catherine Creek. Complexes were assigned to polygons according to the generalized soil mapping unit attributed to each polygon. The morphology of the floodplain soil series within each generalized soil mapping unit reflects long-term depositional system dynamics, such as flooding frequency, sediment load, sediment size, and rate of lateral stream channel migration (Leopold et al 1964); these characteristics help predict the types of vegetation communities most likely to have developed on these soils. In addition, vegetation reported to occur on the soil series was described in the Union County Soil Survey (Dyksterhuis and High 1985); the Official Soil Series Descriptions (USDA, NRCS, Soil Survey Division_b 2013); and the Ecological Site Descriptions (USDA, NRCS, Ecological Sciences Division 2014), corresponding to the soil map units. Using soil morphology, vegetation descriptions, general historical accounts of vegetation in the Grande Ronde Valley, and the hydraulics that were de- scribed for the lower reaches of Catherine Creek (U.S. Bureau of Reclamation 2012b), potential vegetation complexes were mapped using best professional judgement.

The Low Elevation Wet-Moist Shrub/Graminoid Floodplain Complex was mapped on the lower section of the Grande Ronde River near the confluence with Wright Slough down to the confluence with Catherine Creek and on Catherine Creek in Reach 1 and in portions of Reach 2 (U.S. Bureau of Reclamation 2012a). This complex of potential vegetation would be characterized by shrubby vegetation types, and possibly some white willow stands, along active stream channel banks and the banks of younger oxbows. Inactive channels, oxbow channels and lower floodplain surfaces (i.e. areas of long-term soil saturation throughout the growing season) would be occupied by wet meadows and some remnant stands of low elevation mixed shrubland or low elevation tall willow communities, which would no longer be expanding in size or self-perpetuating. Slightly elevated inactive and abandoned floodplains would be occupied by moist meadows with possibly some scattered white willows and small remnant patches of shrubs. Black hawthorn (*Crataegus douglasii*) stands may also occur on drier surfaces. This potential vegetation was mapped predominantly on the Loam/Silt Loam generalized soil mapping unit. The fine textures of these soils indicate that flooding episodes are gentle and the sediment load is fine-textured. The hydraulics of Reaches 1 and 2 are "indicative of an ephemeral lake or estuary" (U.S. Bureau of Reclamation 2012b). In Reach 1 the valley gradient averages 0.03% and the stream gradient 0.01%, and in Reach 2 the valley gradient averages 0.04% and the stream gradient averages 0.03% (U.S. Bureau of Reclamation 2012b). Sinuosity in Reach 1 is 2.4 and is described as meandering to tortuous. Shear stresses in Reach 1 are so low that only fine-grained sediments are transported and there is little bank erosion potential (U.S. Bureau of Reclamation 2012b). In addition, channel bed materials are loose fine sands, silts and clayey silts (U.S. Bureau of Reclamation 2012b). The vegetation reported to occur on the soil series where this complex was mapped is sedges (*Carex* spp.) and rushes (*Juncus* spp.) on the wet meadows; tufted hairgrass (*Deschampsia cespitosa*) with some sedges and rushes on the moist meadows; and Great Basin wildrye (*Elymus cinereus*), threadleaf sedge (*Carex filifolia*) and bluebunch wheatgrass (*Agropyron spicatum*) on the driest of the moist meadow sites. Streambank vegetation, i.e., shrub stands, were probably not included because of the mapping scale of the Union County Soil Survey (Dyksterhuis and High 1985).

The Low Elevation Moist Shrub/Graminoid Floodplain Complex was mapped on a section of the lower reach of the Grande Ronde River and in a few locations on the lower section of Reach 1 of Catherine Creek. The generalized soil mapping

unit is Loam/Silt Loam. The soil series in these sections were drier soils supporting primarily Great Basin wildrye (*Elymus cinereus*), threadleaf sedge (*Carex filifolia*), and bluebunch wheatgrass (*Agropyron spicatum*). Shrub communities would occur along active stream channel banks and oxbow banks. Black hawthorn stands may also occur on inactive and abandoned floodplains.

The Low Elevation Brackish Wet-Moist Shrub/Graminoid Complex was mapped on sections of lower Ladd Creek in the historic location of Tule Lake and its associated wetlands and along a few sections of Catherine Creek in Reach 2. This complex was mapped on the Loam/Silt Loam–brackish generalized soil mapping unit. These soils are similar to those in the Loam/Silt Loam generalized soil mapping unit but have high concentrations of sodium, to which particular grasses and shrub dominant species are tolerant. Low elevation mixed shrubland and low elevation tall willows floodplain shrublands would occur on streambanks and active floodplains. In addition, greasewood (*Sarcobatus vermiculatus*)/Great Basin wildrye communities would occur on active and inactive floodplains. Basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*)/Great Basin wildrye communities would occur on abandoned floodplains and recent terraces. These three complexes are unlikely to support abundant (if any) cottonwood stands because of the high water tables in the fine-textured floodplain soils and slower flows and more stable discharge in the channels. This situation would be exacerbated by the introduction of natural or artificial beaver dams. Cottonwoods are much less tolerant of long-term inundation and saturated soils than willow species (Amlin and Rood 2001). Cottonwood seedlings (and even saplings) that may be established during one spring runoff can be completely killed in one season of inundation of as little as 5 cm (Amlin and Rood 2001, Noble 1979).

The Low Elevation Black Cottonwood/Moist Meadow Floodplain Complex was mapped along reaches of the Grande Ronde River from La Grande downstream to the confluence with Wright Slough, along lower Little Creek, and along Catherine Creek in small sections of Reaches 2 and 5 and in larger sections of Reaches 4 and 6 (Hall Ranch) (U.S. Bureau of Reclamation 2012a). This complex was mapped where riparian vegetation has been removed or highly altered and it was not possible to map the potential vegetation as Low Elevation Black Cottonwood Forest or Moist Meadow in individual polygons. The complex occurs primarily on the Loam over Skeletal generalized soil mapping unit with some units on the Loam/Silt Loam mapping unit. The Loam over Skeletal soils are associated with channel deposits and active and recently inactive floodplains and would support the mountain alder (*Alnus incana*) and black cottonwood plant association groups. Moist meadows and moist ponderosa pine (*Pinus ponderosa*) forest would occur on the Loam/Silt loam soils on recent alluvial terraces.

MIDDLE STUDY AREA

The Grande Ronde River and Catherine Creek in the middle study area are montane rivers characterized by sections of broader, unconstrained reaches with gentle to moderate gradients, and narrower, moderately constrained reaches with moderately high gradients. The middle study area is a patchwork of private lands and National Forest lands managed by the Wallowa-Whitman National Forest. Cattle grazing and logging, including splash dam logging in the early 19th century, are important land uses that have affected riparian areas in the Grande Ronde watershed, including the middle study area, beginning in the early- to mid-nineteenth century, and in the case of cattle grazing, continuing today (Wissmar et al. 1994). Field studies using grazing exclosures have demonstrated that cattle grazing in riparian areas in the Grande Ronde and Catherine Creek riparian areas affected the height and density of woody vegetation, including willows and cottonwoods (Green and Kauffman 1995, Case and Kauffman 1997).

Splash dam logging is a type of logging that uses instream structures to temporarily impound water that is later used to float harvested logs down river in "log drives". While the technique was an efficient means of moving a large quantity of harvested timber downstream, it resulted in alterations to the geomorphology of stream and river channels (Phelps 2011). Geomorphic alterations (increased bed scour and bank erosion) were related to the physical impacts of the flooding and tons of large wood coursing through aquatic

ecosystems resulting in massive bed scour and erosion. Prior to blowing the splash dams in-channel large woody debris was removed and large boulders and beaver dams were dynamited. The net result of these impacts were changes to the natural flow regime, stream channel entrenchment, and reductions in fine sediment resulting from increased flows and removal of large wood.

Figures 37 and 38 display selected attributes of the ITU mapping for representative areas of middle Catherine Creek and the Grande Ronde River, respectively. Figure 37 displays the existing and potential vegetation near Hall Ranch along Catherine Creek. The existing vegetation in this area is characterized by scattered Closed and Open Mountain Alder stands directly adjacent to the active river channel. The total cover of Mountain Alder is much lower than the potential along this reach of Catherine Creek and some stands have been replaced by Black Hawthorn, likely as a result of historic livestock over-grazing. Closed and Open Ponderosa Pine Forest and Ponderosa Pine Woodland occur on the lower floodplain. Moist and wet graminoid meadow characterize much of the upper floodplain and terraces. Black cottonwood existing vegetation types occur in relatively small, isolated stands in the Hall Ranch detailed study area. However, a large proportion of the potential vegetation in this area is mapped as various types of black cottonwood forest, including Black Cottonwood Floodplain Forest, Low Elevation Black Cottonwood Floodplain Forest, and Low Elevation Black Cottonwood/Moist Meadow Floodplain Complex. This complex comprises Low Elevation Mountain Alder Floodplain along streambanks and active overbank deposit surfaces; Low Elevation Black Cottonwood Floodplain Forest along streambanks and on active and inactive overbank deposit surfaces; Moist Ponderosa Pine on inactive to abandoned floodplains; Moist Meadows on slightly drier sections of backwater areas; and Wet Meadows on backwater areas where water ponds following flooding. The Hall Ranch area likely had a high beaver population historically, which would have resulted in a very complex system of vegetation types across the valley. The riverine complex along Catherine Creek from just above the North Fork-South Fork confluence to approximately 130 meters below the confluence with Little Catherine Creek is a Low-elevation Riverine Complex.

Hall Ranch corresponds to Reach 6 in the Catherine Creek Tributary Assessment (U.S. Bureau of Reclamation 2012b). Reach 4 in this assessment is a similarly unconfined reach and the historical assemblage of vegetation communities was probably similar to Reach 6. Restoration of both of these reaches would likely result in similar riparian systems.

Black cottonwood stands in the lower study area were observed infrequently during field surveys, particularly the younger, smaller size classes, including seedling, sapling, and pole-sized stands. Cobble bars throughout the middle river were commonly observed to have little to no regeneration of woody species, including willows and black cottonwood, and also lacked fine sediments to serve as seed beds (Figure 39). Sapling- and pole-sized poplar stands were observed at Bird Track Springs Interpretive Site on the Wallowa-Whitman National Forest (Figures 38 and 40). However, these instances of younger aged poplar were rare, and we more commonly observed older, larger aged poplar stands (Figure 41) or a complete lack of cottonwood forests altogether. An age-structure more typical of successful naturally regenerating populations of poplar is a combination of these size/age classes along a given river reach as was observed on the alluvial bars and banks in the Grande Ronde River near Riverside Park in La Grande (Figure 42). The limited extent of younger aged poplar in the middle study area is likely related to a combination of changes in channel morphology due to splash dam logging and physical removal of seedlings and saplings due to browsing by cattle and wild ungulates. Restoration of black cottonwood in the middle study area would require a combination of the following: cottonwood live stakes and live pole plantings installed into the floodplain surfaces down to within proximity of the the low summer flow groundwater capillary fringe, building grazing exclosures around the plantings, and installing engineered log jams (Abbe et al. 2003) to create mid-channel islands and lateral floodplains that will trap bedload and fine sediments. The fine sediment will serve as future seed beds and seedling safe sites (Polzin and Rood 2006) to enhance natural regeneration.

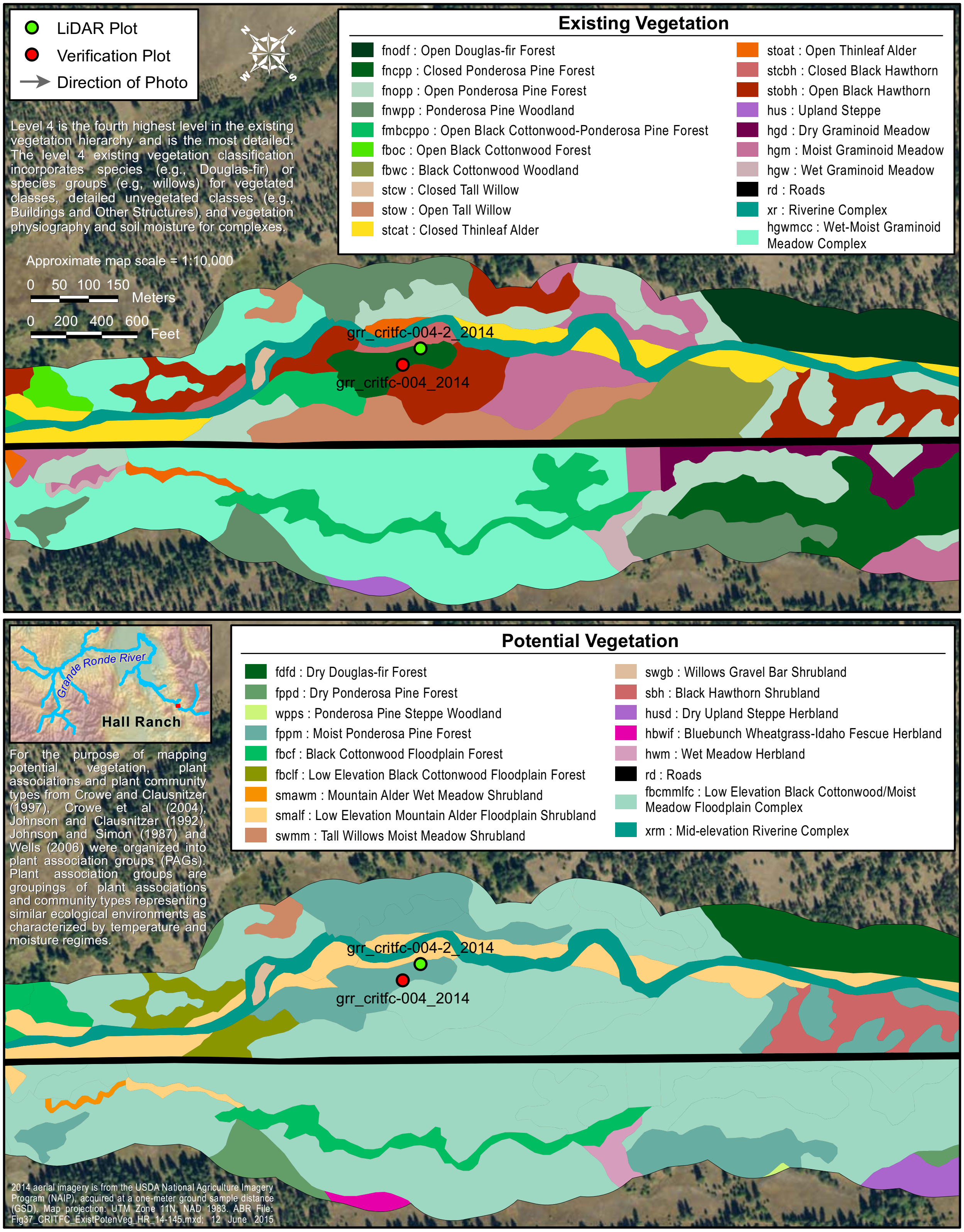


Figure 37. Hall Ranch detailed study area showing maps of existing (upper) and potential (lower) vegetation, and field plot and photo locations. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

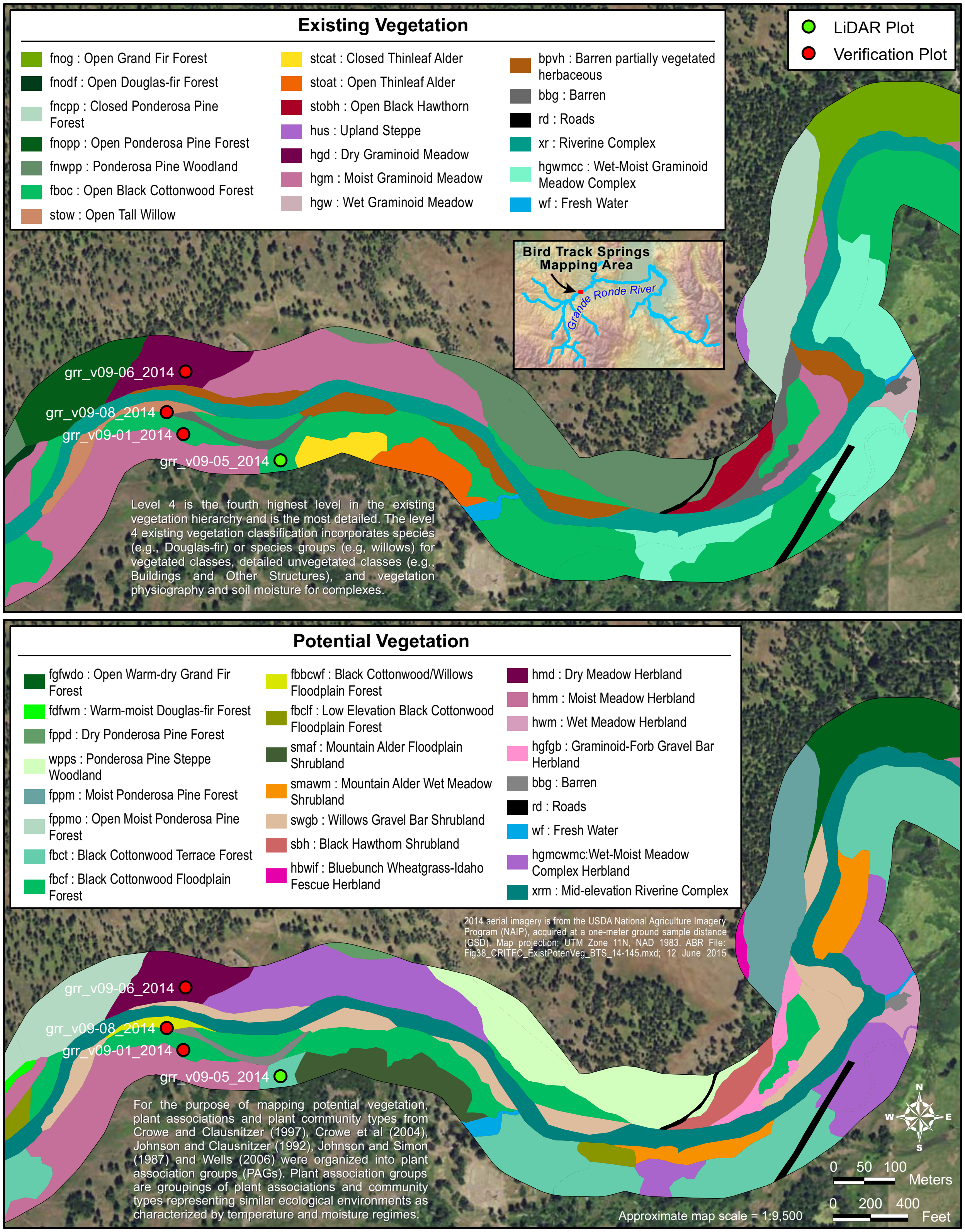


Figure 38. Bird track springs detailed study area showing maps of existing (upper) and potential (lower) vegetation, including plot locations. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Figure 39. Photos showing examples of barren cobble bars with little to no woody vegetation regeneration on main stem of Grande Ronde River. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Figure 40. Field photos of pole-sized cottonwood at plot grr_09-01_2014 (a) and sapling-sized poplar and willow at plot grr_09-08_2014 (b), Bird Track Springs Interpretive Site, Wallowa-Whitman National Forest. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Figure 41. Photo of large, mature cottonwood stand (highlighted in red) on the main stem of the Grande Ronde River. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Figure 42. Panoramic field photo of mature black cottonwood *(Populus trichocarpa)* along the river banks (dashed yellow outline) and black cottonwood saplings and willows on a cobble bar (solid red outline) at Riverside Park in La Grande. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Low elevation shrub communities along Little Catherine Creek starting at approximately one km upstream from the confluence with Catherine Creek were observed to be in excellent ecological condition. The shrub layer was diverse and the shrubs had grown to their full height potential. The herbaceous understory was composed almost entirely of native plant species, an extremely rare occurrence in low elevation shrub communities in the Blue Mountains.

The section of Five Points Creek within the mapping buffer has a narrow to moderately-wide valley bottom. Within the upper 1500 m of the mapping buffer the potential vegetation is a High-elevation Riverine complex surrounded by Grand Fir Forest. This section in currently not within a livestock grazing allotment. Below this section downstream to approximately 500 m above the confluence with Pelican Creek the valley bottom is dominated throughout most of its length by Warm-moist Douglas-fir Forests and Mountain Alder Floodplain Shrublands with scattered Black Hawthorn and Black Cottonwood stands. There may have been more Black Cottonwood in this drainage historically. Remnants of a historic unpaved road that ran from side to side up the Five Points Creek valley bottom were mapped. Over time the road has been obliterated in a piecemeal fashion by erosion as the stream has changed course. There are many remnant channels and abundant down wood evident in the LiDAR imagery indicating that the stream channels moves laterally within the valley bottom on a relatively frequent basis. From 500 m above the Pelican Creek confluence down to the Grande Ronde River to the city of La Grande is a Low-elevation Riverine Complex characterized by abundant Black Cottonwood.

UPPER STUDY AREA

Vey Meadows

The upper study area includes the headwaters of the numerous 3rd and 4th order streams and rivers that form the Grande Ronde River and Catherine Creek (Figure 1). The upper study area is characterized by broad, low-gradient meadows and steep, constrained forested reaches. Vey Meadows, a private inholding located at the confluence of the mainstem of the Grande Ronde River with Sheep Creek, is one of the more prominent meadows in the upper study area. Figure 43 displays the existing and potential vegetation map for a portion of Vey Meadows. The existing vegetation for large areas of Vey Meadows is Moist Graminoid Meadow. Active channel deposits and areas of the floodplain directly adjacent to the active river channel are mapped as Riverine Complex, which includes barren river bars, small patches of moist and wet meadow, and small stands of lodgepole pine. Field observations made from the road in 2014 revealed a general lack of woody vegetation throughout Vey Meadows, namely willows on active channel deposits and lower floodplain surfaces and lodgepole pine on upper floodplain surfaces and terraces (Figure 44). The potential vegetation in Vey Meadows as presented in the ITU mapping is somewhat more complex, and prominently features woody vegetation (Figure 43). In addition to woody vegetation, the potential vegetation features a mosaic of moist and wet meadows. The potential vegetation in Vey Meadows in large part reflects field observations and mapping of existing vegetation in similar meadows in the study area, namely the upper portions of Meadow Creek (Figure 19) that are part of the Starkey Experimental Forest. The Starkey Experimental Forest is enclosed by a game-proof fence (installed in 1987) for much of its 28,000 acres and was established to study population dynamics of native ungulates and responses of vegetation to varying levels of grazing and browsing. The existing vegetation at the headwaters of Meadow Creek features a mosaic of woody vegetation, including stands of lodgepole pine and willows, and herbaceous vegetation, including wet and moist graminoid meadows and moist forb meadows. The key difference affecting existing vegetation between Vey Meadows and the section of Meadow Creek displayed in Figure 19 is the reduction in grazing intensity along Meadow Creek for the last 18 years. Field studies from the Starkey Experimental Forest have demonstrated that cattle grazing in riparian areas in the Grande Ronde and Catherine Creek riparian areas affected the height and density of woody vegetation, including willows (Case and Kauffman 1997). Figure 45 illustrates this, showing field observations from 2014 of browsed willows in an unenclosed area along upper Sheep Creek and

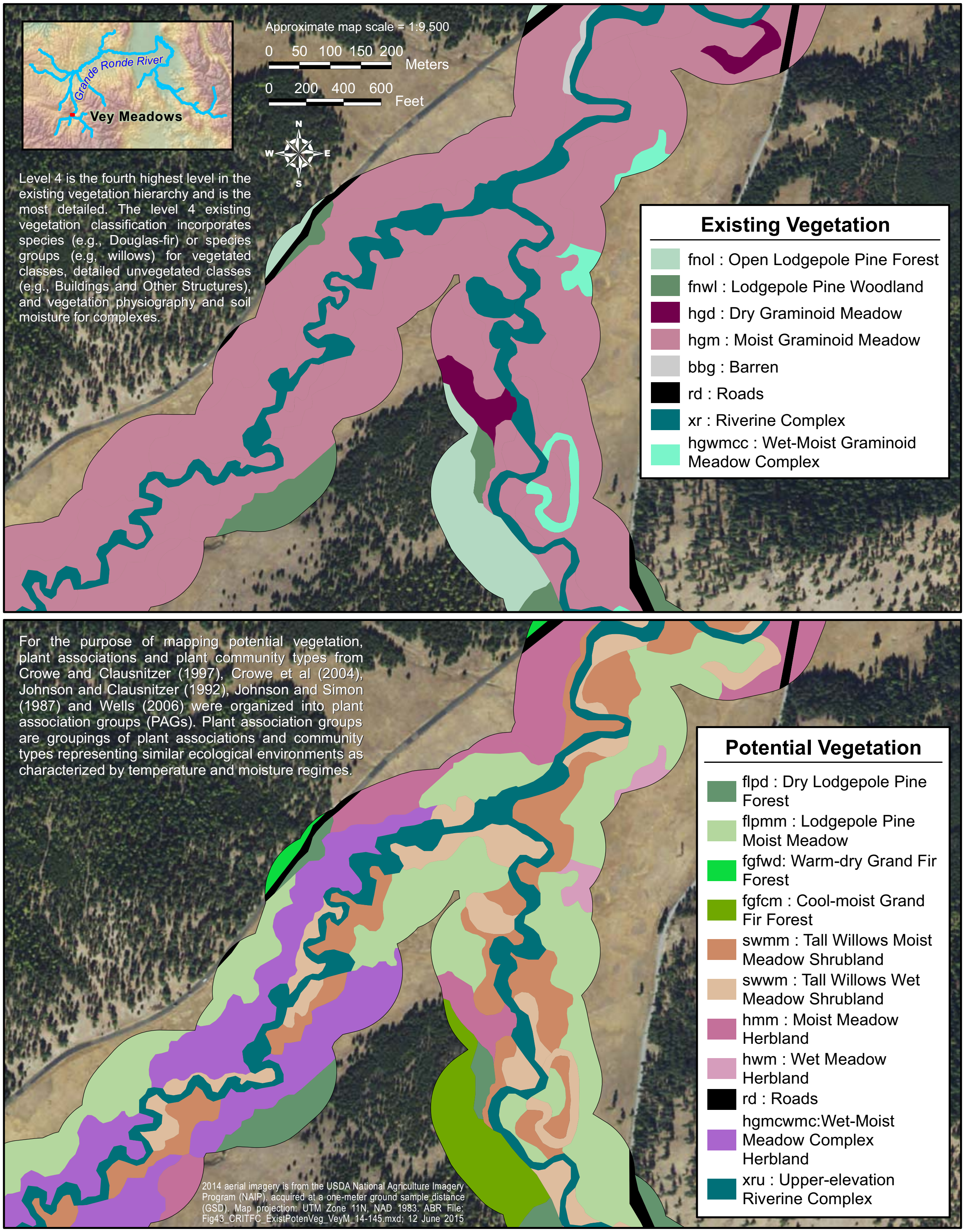


Figure 43. Vey Meadows detailed study area showing maps of existing (upper) and potential (lower) vegetation. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Figure 44. Photos of Vey Meadows taken from Forest Road 5160 showing the lack of woody vegetation on the floodplain. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

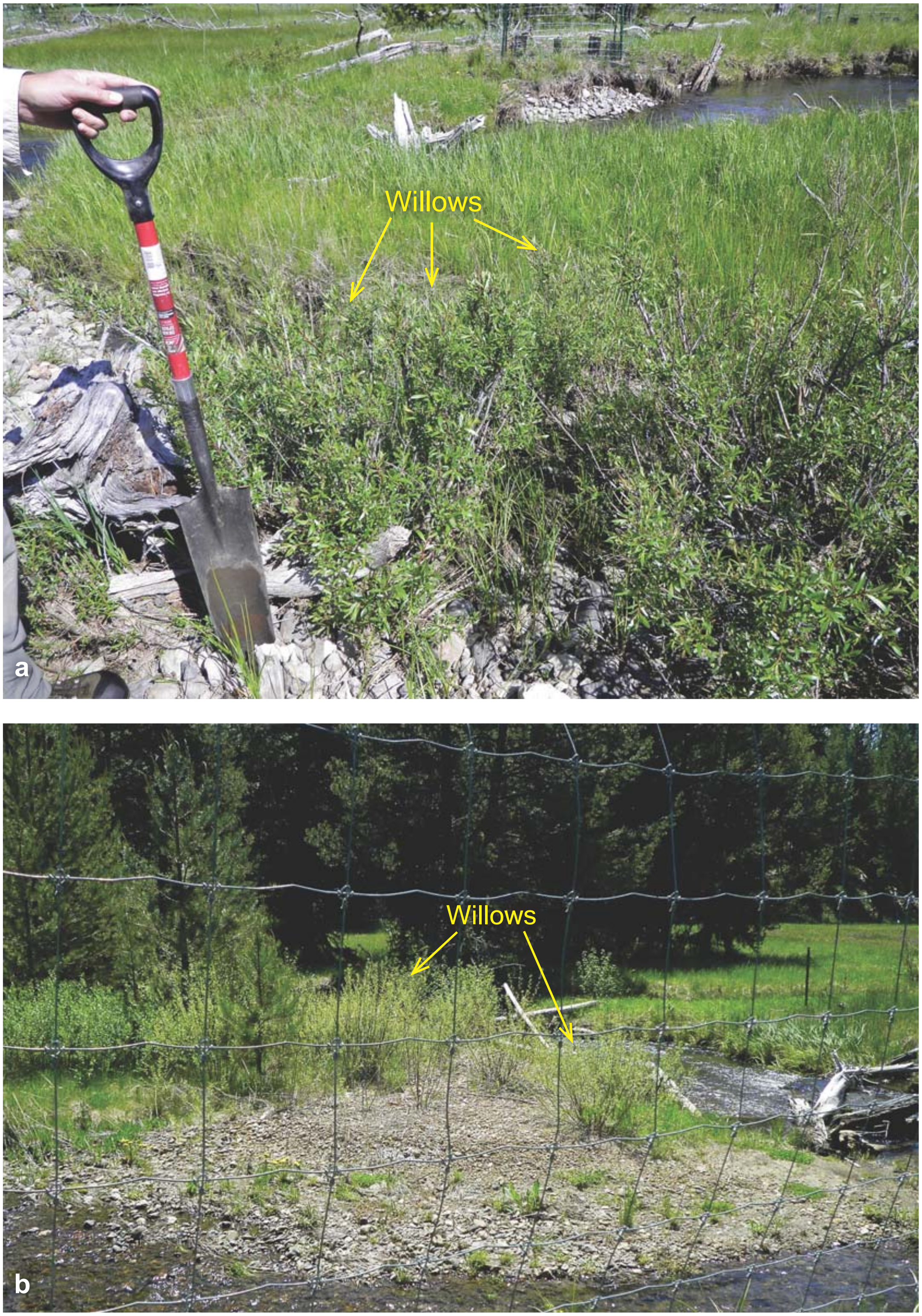


Figure 45. Field photos showing examples of browsed willows in an unfenced area in upper Sheep Creek (a) and unbrowsed willows in a fenced area along Limber Jim Creek (b). For scale, shovel in upper photo is approximately 1.1 meters tall, and willows in lower photos are 1.0–1.5 meters tall. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

unbrowsed willows in a small enclosure along Limber Jim Creek.

Beaver Creek

Through most of the Beaver Creek drainage, the valley bottom is narrow. The potential vegetation (and most existing vegetation) in the upper part of the drainage is cool, moist habitat with Grand Fir-Engelmann Spruce Forest and Mountain Alder Floodplain Shrublands intermixed with open wet meadows and Lodgepole Pine transitioning to Cool-moist Grand Fir Forest and pockets of Cold Grand Fir Forest. Within the National Forest boundary there is no livestock grazing, so the riparian vegetation is in relatively good condition with potential or nearly potential canopy cover. The riverine complex that occurs from about 2 km downstream of confluence with Dry Beaver Creek to the upper end of the mapping buffer is a High Elevation Riparian Complex. Below the confluence with Dry Beaver Creek, the valley bottom transitions to the Low Elevation Riverine Complex and is dominated by scattered stands of Warm-moist Douglas Fir Forest, Black Cottonwood stands, Low Elevation Mountain Alder Floodplain Shrublands (with higher occurrence and canopy cover of tall willows) and Moist Meadows, probably comprising primarily introduced grass species. Below the National Forest Boundary is private land grazed by livestock and canopy cover of shrubs and herbaceous plants is significantly lower than potential. The riverine complex that occurs from the confluence with Grande Ronde River to about 2 km downstream of confluence with Dry Beaver Creek is a Mid Elevation Riparian Complex.

Catherine Creek

The North Fork of Catherine Creek is a narrow drainage that has cut through old terraces formed by Pleistocene glacial deposits from the upper end of the mapping buffer to approximately 500 m downstream from the confluence with Boot Hill Creek (USDA, Forest Service, Wallowa-Whitman National Forest 2002). The valley bottom vegetation comprises primarily Dry Subalpine Fir Forest on the old terraces and wet meadows in the upstream end of the mapping buffer and Subalpine Fir-Englemann Spruce Forest on moister sideslopes downstream. From the Jim Creek confluence downstream to the Middle Fork Catherine Creek confluence, more Open Cool-moist Grand Fir Forest, Engelmann Spruce Forest, and Mountain Alder Floodplain Shrublands on actively flooded fluvial surfaces occurs. Between the Middle Fork Catherine Creek confluence and the South Fork Catherine Creek confluence, Mountain Alder Floodplain Shrublands occurs on streambanks, alluvial bars, active floodplains, and in side channels. There are occasional Black Cottonwood Floodplain Forest stands on active floodplains. Engelmann Spruce Forest occurs on inactive floodplains and Cool-moist Grand Fir Forests occur on Inactive and abandoned floodplains on the east side of the creek. Open Warm-dry Grand Fir Forest and perhaps scattered Warm-moist Douglas Fir Forest occur on some inactive floodplains on the west side of the creek. The riverine complex from the upper end of the mapping boundary to approximately one km upstream from confluence with South Fork Catherine Creek is an Upper-elevation Riverine Complex.

The South Fork of Catherine Creek flows generally from east to west and accordingly, the south-facing sideslopes comprise warmer and drier vegetation types. These include a mix of Dry Douglas-fir Forest and Bluebunch Wheatgrass-Idaho Fescue grasslands with scattered Ponderosa Pine Steppe Woodlands and Warm-moist Douglas-fir Forest. The north-facing side-slopes and valley bottom are dominated by Cool-moist Grand Fir Forest and Open Cool-moist Grand Fir Forests. Mountain Alder Floodplain Shrubland occurs on banks and small active overbank deposits. From 1220 m elevation (approximate 4.3 km upstream of the confluence with North Fork Catherine Creek), the valley bottom is wider and more Engelmann Spruce occurs in the Cool-moist Grand Fir Forests.

Riparian restoration in the upper study area

In meadows in the upper study area, woody vegetation is unlikely to establish naturally without the aid of grazing exclosures in riparian (i.e., riverine) areas. Optimally, the exclosures would use controlled access points (USDA NRCS 2007), whereby long sections of the riparian area are enclosed using game proof fencing with short period breaks in the fencing, or access points. The

breaks allow cattle and native ungulates access to the stream for drinking water. Ideally, streambanks and the streambed would be armored with gravel at access points to reduce erosion.

Using grazing exclosures in meadows throughout the study area, particularly in Vey Meadows, would greatly improve the likelihood of woody vegetation regeneration in riverine areas and promote the vegetative potential in these meadows. However, another challenge to promoting the development of potential vegetation in meadows in the study area is the decoupling of the floodplain and river discharge, including ground water and high water flood events. Down-cutting of streams and the resulting channel incisement is an important factor limiting floodplain-ground water-high water interactions. Channel incisement has also been identified as a primary factor of habitat degradation limiting Chinook and steelhead in the Grande Ronde Subbasin (NPCC 2004, Pollock et al. 2014).

The North America beaver (*Castor canadensis*) has been considered a keystone species by some (Naiman et al. 1986) and an "ecosystem engineer" by others, due to the variety of ways that beavers alter and enhance stream and riparian ecosystems, including geomorphology (Pollock et al. 2007), plant species richness (Wright et al. 2002), and water chemistry (Smith et al. 1989). Historically, beavers have undoubtedly played an important role in shaping the geomorphology and potential vegetation in meadows throughout the study area. Trapping records from the Hudson Bay Company report large yields of beaver pelts from the Grande Ronde and Wallowa Basins in the early 1800's (Grant 2010), suggesting a large population of beavers at that time. However by the late 1830's, yields were down and presently, the beaver population in the Grande Ronde basin is considered to be extremely low; availability of suitable habitat being one of the more important factors limiting the possibility of a population resurgence. The decimation of the beaver populations in Grande Ronde basin have contributed in part to the degradation of stream and riparian habitats since European settlement. This is because beaver dams act as obstructions in stream channels, thereby reducing the stream power and velocity, which in turn reduces the erosive potential of floodwaters and allows sediment to accumulate. Beaver dams or beaver dam analogues can be used to restore incised stream channels (Pollock et al. 2014). This is illustrated in Figure 46, which shows a beaver dam along upper Meadow Creek and the aggraded channel, a small pool, and willow stand upstream of the dam. The beaver dam is contributing to a higher soil water table upstream on the floodplain, encouraging willows along this section of the stream. Beaver dam analogues, also termed artificial beaver dams, are ideal for situations where beaver populations are low and the success of reintroducing beavers uncertain due to existing habitat limitations, as is the case in the Grande Ronde Basin. One approach to implementing stream and riparian restoration to enhance potential vegetation in meadows in the study area would be to use flow-choke structures, a type of artificial beaver dam, similar to DeVries et al. (2012) study on Benewah Creek in north-western Idaho. This study showed positive results one to two years after installing flow-choke structures, including more persistent natural beaver dams being built close to the artificial structures and increased flooding upstream of flow-choke structures as designed (K.L. Fetherston, personal communications).

In steeper, confined stream reaches natural or artificial beaver dams may be less effective due to the increased stream power that would readily destroy beaver dams. Instead, large woody debris plays a more important role here. For instance, in upper Fly Creek, the channel steepens and narrows downstream from Fly Creek Meadows. In 2014, a log jam was observed along upper Fly Creek (Figure 47) that was composed largely of logs with clean cut ends suggesting that the logs had been added to the stream in an attempt to restore large woody debris to the channel. However, the log jam itself appeared to have developed naturally, likely during a flood event that forced the logs downstream, where they eventually lodged into place forming the jam. Upstream of the jam, the river bed was aggraded approximately 0.5 m above the river bed on the downstream side of the dam. Additionally, a side channel has formed upstream of the jam. During high water events, floodwaters are forced down the side channel (as evidenced by flotsam observed on the floodplain and along the side channel) and onto the floodplain; thus, enhancing riparian habitat and stimulating

Figure 46. Beaver dam along upper Meadow Creek showing the aggraded channel and small pool upstream of the dam, with a willow stand (dashed red outline) in the background. For scale, shovel in upper photo is approximately 1.1 meters tall. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Figure 47. Field photos of a log jam on upper Fly Creek, including a photo from downstream of the log jam looking upstream (a), and a panoramic photo from upstream of the jam looking downstream (b). Note in the upper photo that many of the logs were likely placed in the stream as large woody as evidenced by the clean cut ends. These logs were then pushed downstream during large spring flood events forming the jam. For scale, the biologist in the photo is approximate 1.7 meters tall. The lower photo shows the aggraded river bed on the upstream side of the jam. Field observations indicate that the jam is redirecting flood waters into a lateral channel during high flow events thus reconnecting the river with the floodplain. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

increased floodplain-floodwater interactions. Along steeper stream reaches in the upper study area, natural or engineered log jams may be a useful restoration tool for entrenched channels along steep, constrained stream reaches.

LIDAR FIELD VERIFICATION

Figure 48 displays the paired bar charts comparing mean and SD of tree heights measured in the field (Mean Tree Height) at LiDAR plots against the mean and SD of canopy hit heights in the >3 m strata layer (Mean LiDAR Tree Canopy Height). The chart indicates that in most cases, the mean tree heights measured in the field for the map polygon were greater than the mean canopy hit heights estimated from LiDAR data for that polygon.This is related to methods used for measuring tree heights in the field as opposed to how the LiDAR canopy height data were summarized. In the field, tree height was measured from the ground level to the very top of the tree, thereby accounting for the total height of the tree. The LiDAR data summarizes the mean height of canopy hits greater than 3 m in height. Hence, the mean height of canopy hits in the LiDAR data includes hits of canopy below the top of tree, resulting in an overall lower mean height. However, in many of these cases the SD of mean heights overlaps, indicating that the mean canopy hit height as estimated from the LiDAR data falls within the variability of the tree heights measured in the field. Other sources of error include differences between the tree heights in the plot as compared to tree heights in the map polygon, which represents a larger spatial area than the plot. Errors and glitches in the LiDAR data, as described in the Methods section, also are factors.

Figure 49 displays the paired bar charts comparing the hit density (%) of trees (>3 m) and tall shrubs (1.5–3.0 m) as estimated in the field (Canopy Density) against the hit density for the map polygon associated with each plotas summarized in the LiDAR data (Canopy Hit Density). Compared to the height data summaries, which showed a clear trend of higher heights based on the field measurements, the density data is somewhat less clear. In some cases, the plot data matches reasonably well with the LiDAR canopy hit density data (e.g., grr_critfc-013_2014), but in others the canopy density estimates are off substantially in one, or the other, direction (e.g., grr_critfc-001_2014, grr_v40-01_2014). In the case of field plot data having reasonable alignment with the LiDAR canopy hit density data, the canopy density in the field plot, which in most cases is circular with a 10 m radius, is representative of the canopy density in the map polygon. In contrast, plots that are misaligned with the LiDAR canopy hit data for the polygon have the opposite situation; the canopy density in the plot is not representative of the broader map polygon in which it is located. For instance, the canopy density as estimated in the field at plot grr_critfc-001_2014 is lower than the canopy hit density in the map polygon. The vegetation at the plot is Ponderosa Pine Woodland, and features few, large, widely spaced ponderosa pine. The plot dimensions were not large enough to capture the wide spacing of the trees in this polygon. The opposite was true for plot grr_v40-01_2014, which was located in a small Closed Tall Thin Alder stand. In this instance, the canopy density estimated in the field was higher than the canopy hit density in the map polygon, which includes a broader area and is mapped as Douglas-fir Woodland. The closed alder stand where the plot is located is an inclusion within the map unit and has a higher canopy density than the broader polygon. Based on these results, we recommend that the protocols for the LiDAR field plots be modified to encompass a larger area within each polygon. Perhaps several transects that extend across the entire polygon could be included and spaced to ensure that height and density measurements more fully capture the polygon.

SUMMARY

The Columbia River Inter-Tribal Fish Commission (CRITFC) seeks to develop a spatially-based system for modeling abundance, productivity, and growth rate for spring Chinook salmon in the upper Grande Ronde watershed in northeastern Oregon. ABR, Inc.—Environmental Research & Services (ABR) and Elizabeth Crowe worked collaboratively to create a map of existing and potential natural vegetation throughout the extent of the spring Chinook spawning and rearing zone in the upper Grande Ronde watershed. The

study area encompasses approximate 7,300 hectares (ha) of the Grande Ronde River watershed in northeast Oregon. The study area is defined by a 100 m buffer along each side of the center of active river channels, including the mainstem of the Grande Ronde River and Catherine Creek and major tributaries. Field surveys were conducted 3–11 June 2015 by two field crews to collect data on vegetation and soils for map verification. Field crews were based in La Grande, Oregon and traveled to the field each day via pickup truck. A total of 82 plots were sampled across the study area, including 57 verification plots, 12 observation plots, 11 LiDAR plots, and 2 photo plots.

We classified and mapped several ecosystem components in the study area using standardized classification and coding systems developed for northeastern Oregon. Map polygon delineation was completed on-screen in a Geographic Information System (GIS) by photo-interpretation of aerial imagery. A LiDAR dataset was also used to assist the mapping effort and to estimate height and density of existing vegetation within map polygons. Individual ecological components were mapped simultaneously as compound codes called Integrated Terrain Units (ITUs). Integrated Terrain Units comprise five parameters assigned to each map polygon describing physiography, geomorphology, generalized soils, existing vegetation, potential vegetation, and disturbance. Individual ecological components for each polygon in the ITU mapping were concatenated to create ITU code combinations. The ITU code combinations were aggregated based on physiography, and similarities in soils and existing vegetation into ecological types and erosion sensitivity classes. Potential vegetation height and density were estimated using canopy cover averages for trees and shrubs in each Plant Association Group (PAG), the data for which were taken from datasets used in developing local vegetation classifications. The potential vegetation heights were then assigned to each map polygon based on the PAG.

The long, narrow study area, combined with the large mapping scale (1:5,000) precluded displaying the mapping for the entire study area in this report. Instead, 5 detailed study areas representing a range of representative environmental conditions were selected for which the ITU mapping is displayed. Field observations and ITU mapping examples are presented for discussion purposes for 3 subareas of the study area, including 1) the lower study area, 2) the middle study area, and 3) the upper study area.

In the lower study area, agriculture has been an important land use in the Grande Ronde Valley since post-European settlement, and as such, agricultural development covers much of the present-day valley. The Catherine Creek channel in much of the the Grande Ronde Valley is deeply incised with a narrow floodplain. Many portions of floodplains and former oxbows in the lower study area are cut-off from annual flooding by levees. In other sections of the lower study area, floodplain agricultural lands abut the river channel.

The Grande Ronde River and Catherine Creek in the middle study area are montane rivers characterized by sections of broader, unconstrained reaches with gentle to moderate gradients, and narrower, moderately constrained reaches with moderately high gradients. Cattle grazing and logging, including splash dam logging in the early 19th century, are important land uses that have affected riparian areas in the Grande Ronde watershed, including the middle study area, beginning in the early- to mid-nineteenth century, and in the case of cattle grazing, continuing today. Field studies using grazing exclosures have demonstrated that cattle grazing in riparian areas in the Grande Ronde and Catherine Creek riparian areas affected the height and density of woody vegetation, including willows and cottonwoods. Black cottonwood stands in the lower study area were observed infrequently during field surveys, particularly the younger, smaller size classes, including seedling, sapling, and pole-sized stands. Cobble bars throughout the middle river were commonly observed to have little to no regeneration of woody species, including willows and black cottonwood, and also lacked fine sediments to serve as seed beds. Restoration of black cottonwood in the middle study area would require a combination of planting cuttings on floodplain surfaces down to the water table; building grazing exclosures around the plantings; and installing engineered log jams. The log jams would create mid-channel and lateral bars with fine

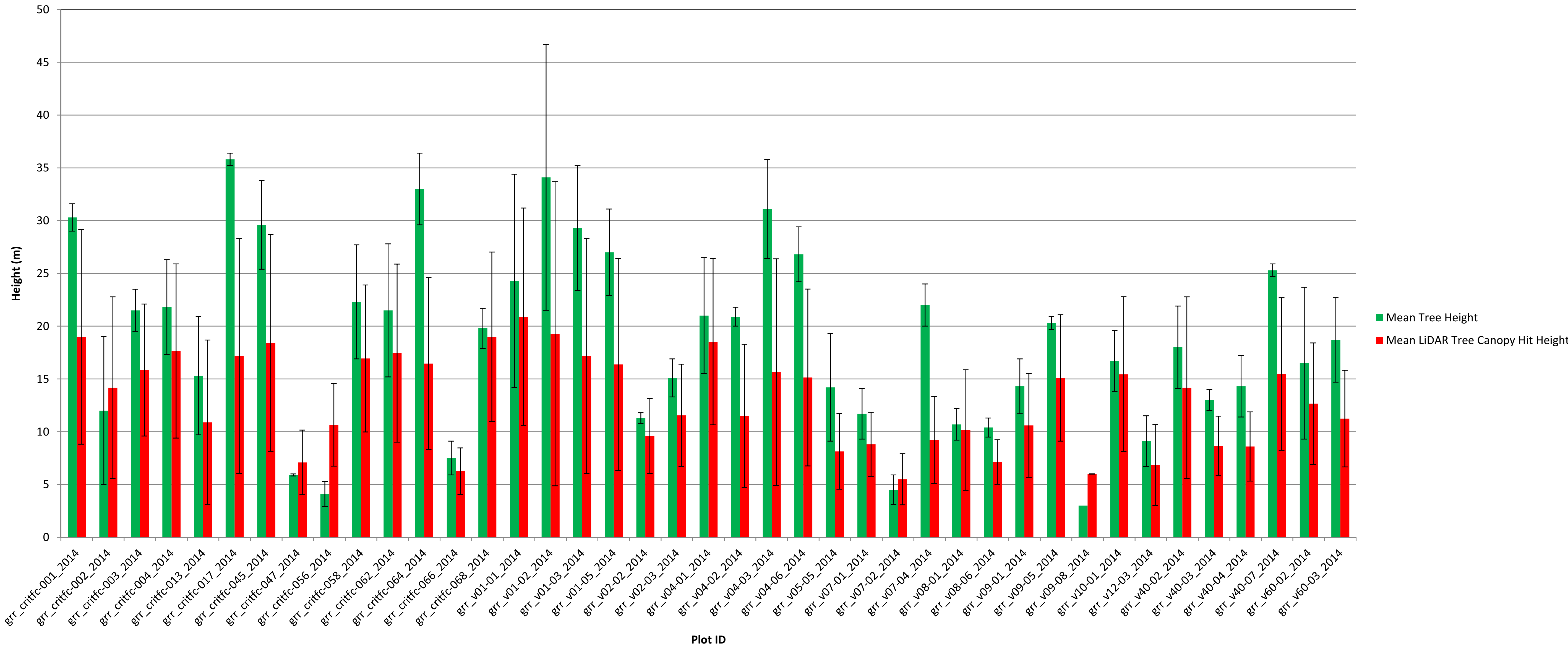


Figure 48. Paired bar chart showing the average tree height and standard deviation as measured at LiDAR plots in the field versus the average height and standard deviation of LiDAR canopy hits in the >3 m strata in the ITU map polygon within which each plot is located.

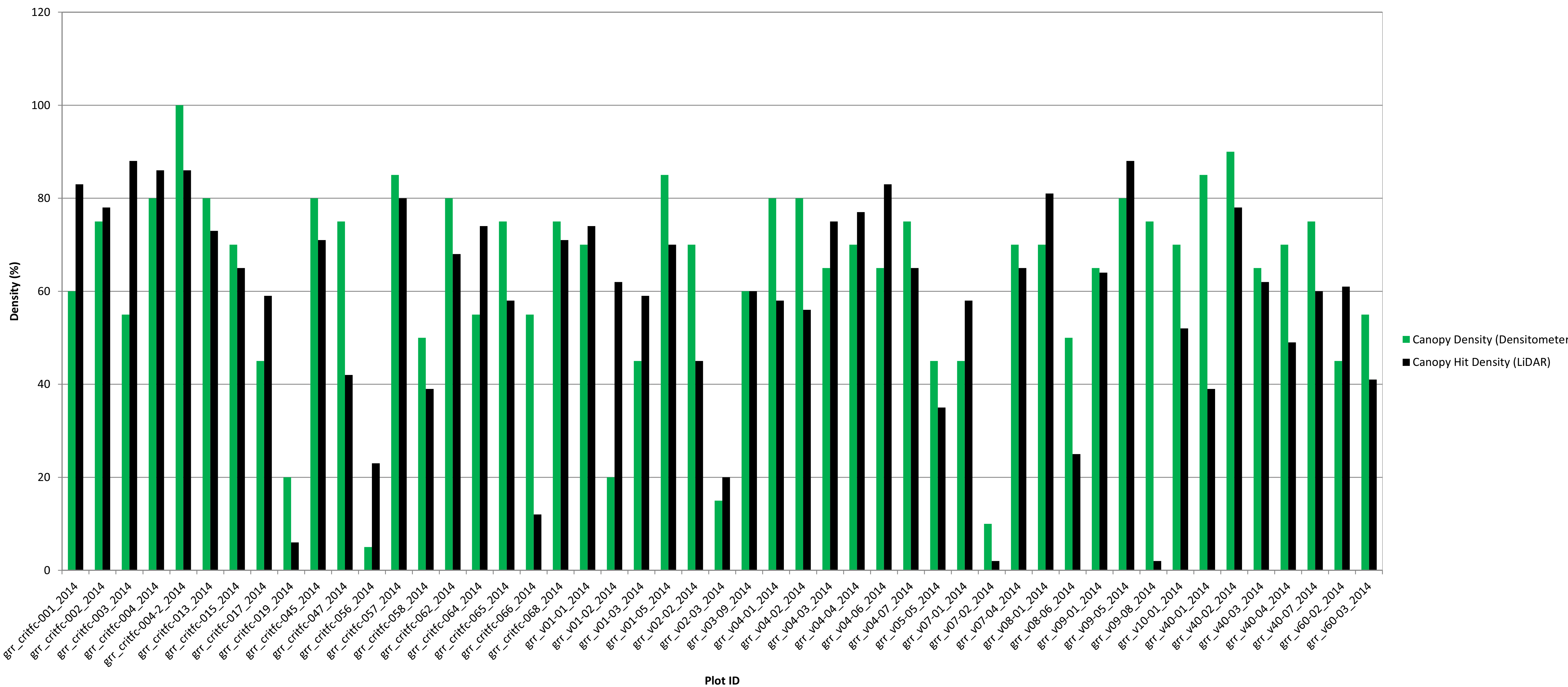


Figure 49. Paired bar chart showing the average canopy density as estimated in the field at LiDAR plots versus the percent density of LiDAR canopy hits in the >1.5 m strata in the ITU map polygon within which each plot is located.

sediments to serve as seed beds and seedling safe sites to enhance natural regeneration.

The upper study area includes the headwaters of the numerous 3rd and 4th order streams and rivers that form the Grande Ronde River and Catherine Creek. The upper study area is characterized by broad, low-gradient meadows and steep, constrained forested reaches. Vey Meadows, a private inholding located at the confluence of the mainstem of the Grande Ronde River with Sheep Creek, is one of the more prominent meadows in the upper study area. The existing vegetation for large areas of Vey Meadows is Moist Graminoid Meadow. Active channel deposits and areas of the floodplain directly adjacent to the active river channel are mapped as Riverine Complex, which includes barren river bars, small patches of moist and wet meadow, and small stands of lodgepole pine. Field observations made from the road in 2014 revealed a general lack of woody vegetation throughout Vey Meadows. In meadows in the upper study area, woody vegetation is unlikely to establish naturally without the aid of grazing exclosures in riparian (i.e., riverine) areas. Additionally, artificial beaver dams can be used to restore incised stream channels and raise the water table in the floodplain to encourage establishment of woody species. In steeper, confined stream reaches natural or artificial beaver dams may be less effective due to the increased power of floodwater that would readily destroy beaver dams. Instead natural or engineered log jams may be a useful restoration tool for entrenched channels along steep, constrained stream reaches.

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Appendix 1. Data attributes measured or estimated and recorded in the field, including the data type, the name of the database table within with the data attribute is stored, and the name and a brief description of the data attribute. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Data Type	Table Name	Data Attribute Name	Data Attribute Description
General Environment	els	aspect_declin_degrees	Declination setting of the compass used to record aspect in degrees. East is negative, west is positive, zero is magnetic north.
General Environment	els	aspect_degrees	Slope aspect at the plot, recorded in degrees.
General Environment	els	disturbance_class_code	Disturbance class, either natural or human induced.
General Environment	els	macrotopography_code	Mesoscale descriptor of surface form, evaluated over a broad area (tens of meters to hundreds of meters).
General Environment	els	microtopography_code	Microscale descriptor of surface form, evaluated in immediate vicinity of plot (meters to tens of meters).
General Environment	els	physiography_code	General description of landscape unit and depositional process.
General Environment	els	slope_degrees	Slope gradient at the plot, recorded in degrees.
General Environment	els	surface_terrain_code	Terrain unit code describing the present geomorphic deposition and form.
LiDAR	vpi_hit	hit_id	Identifier for a hit at a vegetation point-intercept point. Generally sequential and corresponding to hit order from highest to lowest, starting with the highest hit as hit_id=1.
LiDAR	vpi_hit	line_id	Identifier for a sampling line at a vegetation point-intercept plot.
LiDAR	vpi_hit	point_id	Identifier for a sampling point on a vegetation point-intercept line. Generally sequential from the start of the line to the end, with the first point on the line as point_id=1.
LiDAR	vpi_hit	veg_field_taxonomy_code	The species code recorded in the field.
LiDAR	woody_height	veg_field_taxonomy_code	The species code recorded in the field.
LiDAR	woody_height	woody_height_meters	The height in meters of a tree or shrubs species as measured in the field using a laser range finder.
Plot	els	els_plot_type_code	Single letter code to identify the type of plot.

Appendix 1. Continued.

Data Type	Table Name	Data Attribute Name	Data Attribute Description
Plot	els	env_field_start_timestamp	Timestamp recorded when the environmental data collection form is initialized at the plot.
Plot	els	env_observer_code	Initials of the field environmental observer.
Plot	all tables	plot_id	Unique code identifying the field plot.
Plot	els	plot_radius_code	The area evaluated for an individual plot.
Soil	els	soil_dominant_mineral_code_40cm	Most abundant mineral soil type in the upper 40 cm of the profile.
Soil	els	soil_dominant_texture_code_40cm	Most abundant soil material, mineral or organic, in the upper 40 cm of the profile.
Soil	els	soil_moisture_code	A measure of the representative soil moisture within the upper 40 cm of the soil profile.
Soil	els	soil_rock_depth_probe_cm	Depth in centimeters from soil surface to the upper depth of a horizon with >15% rock fragments.
Soil	els	soil_surface_organic_thick_cm	The total thickness in centimeters of uninterrupted surface organic material from the soil surface
Soil	els	water_depth_cm	The depth from the soil surface to the water table. Recorded as a negative value if water table is below the soil surface, and positive if above the soil surface.
Vegetation	els	veg_structure_ecotype_code	Simplified vegetation structure code, which is a component of the field ecotype calculated field.
Vegetation	veg	bare_soil_cover	Total % cover of all bare mineral soil (< 2 mm). This does not include rock fragments, moss/lichens, or litter.
Vegetation	veg	bedrock_cover	Total % cover of all exposed bedrock.
Vegetation	veg	broadleaf_tree_cover	Total % cover of all broadleaf tree species, including seedlings, but excluding dwarfed trees, see below.
Vegetation	veg	broadleaf_tree_crown_code	Typical position of broadleaf trees in the canopy.
Vegetation	veg	broadleaf_tree_size_code	Typical size class of broadleaf trees.
Vegetation	veg	cladonia_cladina_cover	Total % cover of all species of cladonia and cladina.

Appendix 1. Continued.

Data Type	Table Name	Data Attribute Name	Data Attribute Description
Vegetation	veg	dwarf_broadleaf_tree_cover	Total % cover of broadleaf trees growing in a dwarfed condition (~3-4m max ht) due to environmental constraints, typically high wind or persistent drought.
Vegetation	veg	dwarf_needleleaf_tree_cover	Total % cover of needleleaf trees growing in a dwarfed condition (~3-4m max ht) due to environmental constraints, e.g. high elevation, shallow active layer.
Vegetation	veg	dwarf_shrub_cover	Total % cover of all species of dwarf (<0.2 m) shrubs.
Vegetation	veg	feathermoss_cover	Total % cover of all feather mosses (e.g. hylspl, tomnit, pticri, plesch). Leave blank if unsure.
Vegetation	veg	forbs_cover	Total % cover of all forb species (includes club mosses, equisetum).
Vegetation	veg	graminoids_cover	Total % cover of all live gramminoids (exclude standing litter unless current year growth).
Vegetation	veg	litter_alone_cover	Total % cover of litter with no canopy above, litter exposed directly to the sky (i.e., no overtopping vegetation). This is typically a small number.
Vegetation	veg	litter_cover	Total % cover of all litter on plot. Typically this is a large number.
Vegetation	veg	low_shrub_cover	Total % cover of all species of low (0.2--1.5 m) shrubs.
Vegetation	veg	needleleaf_tree_cover	Total % cover of all needleleaf tree species, including seedlings, but excluding dwarfed trees, see below.
Vegetation	veg	needleleaf_tree_crown_code	Typical position of needleleaf trees in the canopy.
Vegetation	veg	needleleaf_tree_size_code	Typical size class of needleleaf trees.
Vegetation	veg	other_cover	Total % cover of abiotic ground cover types not already described.
Vegetation	veg	sphagnum_cover	Total % cover of all sphagnum moss species.
Vegetation	veg	standing_dead_cover	Total % cover of all standing dead trees.
Vegetation	veg	surface_fragment_cover	Total percent cover of all exposed coarse fragments (> 2 mm), e.g., gravels, cobbles, stones, boulders.
Vegetation	veg	tall_shrub_cover	Total % cover of all species of tall (>1.5 m) shrubs.
Vegetation	veg	total_lichens_cover	Total % cover of all lichens, including crustose lichens.
Vegetation	veg	total_mosses_cover	Total % cover of all mosses.

Appendix 1. Continued.

Data Type	Table Name	Data Attribute Name	Data Attribute Description
Vegetation	veg	veg_completeness_code	Degree of intensity in vegetation sampling. Typically T plots are complete (c), V plots are partial (p) or dominants are (d).
Vegetation	veg	veg_cutpoint_viereck_4_code	If vegetation is on the cusp between two veg_class4 classes, an alternative vegetation class is selected. If vegetation is not on the cusp then the cutpoint will be the same as veg_viereck_4_code.
Vegetation	veg	veg_observer_code	Initials of the field botanist.
Vegetation	veg	veg_viereck_4_code	The vegetation class from the Level IV of the Alaska Vegetation Classifcation (Viereck) after changes made during during data quality control/quality assurance review.
Vegetation	veg	water_cover	Total % cover of standing water above the soil surface.
Vegetation	veg	whole_tussocks_cover	Total % cover of whole tussocks mounds.
Vegetation	veg_cover	cover_percent	Percent cover of the species within the plot area, based on ocular estimation.
Vegetation	veg_cover	veg_field_taxonomy_code	The species code recorded in the field.

Appendix 2. Listing of all species encountered during field surveys, including the structure class and USDA Plants code. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Structure Class	Scientific Name	USDA Plants Species Code
Deciduous Tree	*Acer negundo*	acne2
Deciduous Tree	*Larix occidentalis*	laoc
Deciduous Tree	*Populus trichocarpa*	potr15
Deciduous Tree	*Salix alba var. vitellina*	saalv
Dwarf Shrub	*Arctostaphylos uva-ursi*	aruv
Dwarf Shrub	*Berberis repens*	bere
Dwarf Shrub	*Pachistima myrsinites*	pamy
Dwarf Shrub	*Vaccinium scoparium*	vasc
Evergreen Tree	*Abies grandis*	abgr
Evergreen Tree	*Abies lasiocarpa*	abla
Evergreen Tree	*Picea engelmannii*	pien
Evergreen Tree	*Pinus contorta*	pico
Evergreen Tree	*Pinus ponderosa*	pipo
Evergreen Tree	*Pseudotsuga menziesii*	psme
Forbs	*Achillea millefolium*	acmi2
Forbs	*Aconitum columbianum*	acco4
Forbs	*Agoseris glauca*	aggl
Forbs	*Allium validum*	alva
Forbs	*Anemone piperi*	anpi
Forbs	*Angelica arguta*	anar3
Forbs	*Arctium minus*	armi2
Forbs	*Arnica chamissonis*	arch3
Forbs	*Arnica cordifolia*	arco9
Forbs	*Artemisia ludoviciana*	arlu
Forbs	*Aster occidentalis*	asoc
Forbs	*Athyrium filix-femina*	atfi
Forbs	*Besseya rubra*	beru
Forbs	*Camassia cusickii*	cacu2
Forbs	*Camassia quamash*	caqu2
Forbs	*Chimaphila umbellata*	chum
Forbs	*Chrysanthemum leucanthemum*	chle80
Forbs	*Circaea alpina*	cial
Forbs	*Clintonia uniflora*	clun2
Forbs	*Corallorhiza trifida*	cotr3
Forbs	*Cynoglossum officinale*	cyof
Forbs	*Delphinium occidentale*	deoc

Appendix 2. Continued.

Structure Class	Scientific Name	USDA Plants Species Code
Forbs	*Epilobium angustifolium*	epan2
Forbs	*Equisetum arvense*	eqar
Forbs	*Equisetum hyemale*	eqhy
Forbs	*Eriogonum heracleoides*	erhe2
Forbs	*Euphorbia esula*	eues
Forbs	*Fragaria vesca*	frve
Forbs	*Fragaria virginiana*	frvi
Forbs	*Frasera speciosa*	frsp
Forbs	*Galium aparine*	gaap2
Forbs	*Galium boreale*	gabo2
Forbs	*Galium triflorum*	gatr3
Forbs	*Geum macrophyllum*	gema4
Forbs	*Geum triflorum*	getr
Forbs	*Gymnocarpium dryopteris*	gydr
Forbs	*Habenaria dilatata*	hadi7
Forbs	*Heracleum lanatum*	hela4
Forbs	*Hypericum perforatum*	hype
Forbs	*Iris missouriensis*	irmi
Forbs	*Ligusticum canbyi*	lica2
Forbs	*Linnaea borealis*	libo3
Forbs	*Lithospermum ruderale*	liru4
Forbs	*Lupinus polyphyllus*	lupo2
Forbs	*Menyanthes trifoliata*	metr3
Forbs	*Mertensia ciliata*	meci3
Forbs	*Montia perfoliata*	mope3
Forbs	*Pedicularis groenlandica*	pegr2
Forbs	*Penstemon procerus*	pepr2
Forbs	*Penstemon rydbergii*	pery
Forbs	*Polemonium occidentale*	pooc2
Forbs	*Polemonium viscosum*	povi
Forbs	*Potentilla gracilis*	pogr9
Forbs	*Pterospora andromedea*	ptan2
Forbs	*Pyrola asarifolia*	pyas
Forbs	*Ranunculus acris*	raac3
Forbs	*Ranunculus occidentalis*	raoc
Forbs	*Ranunculus repens*	rare3
Forbs	*Ranunculus uncinatus*	raun
Forbs	*Rudbeckia occidentalis*	ruoc2
Forbs	*Rumex occidentalis*	ruoc3
Forbs	*Sanguisorba occidentalis*	saoc2

Appendix 2. Continued.

Structure Class	Scientific Name	USDA Plants Species Code
Forbs	*Sanguisorba sitchensis*	sasi10
Forbs	*Sedum lanceolatum*	sela
Forbs	*Senecio foetidus*	sefo
Forbs	*Senecio integerrimus*	sein
Forbs	*Senecio pseudaureus*	seps2
Forbs	*Senecio serra*	sese2
Forbs	*Senecio triangularis*	setr
Forbs	*Sidalcea oregana*	sior
Forbs	*Smilacina racemosa*	smra
Forbs	*Smilacina stellata*	smst
Forbs	*Taraxacum officinale*	taof
Forbs	*Thalictrum fendleri*	thfe
Forbs	*Thalictrum occidentale*	thoc
Forbs	*Thalictrum venulosum*	thve
Forbs	*Thermopsis montana*	thmo6
Forbs	*Trautvetteria caroliniensis*	trca
Forbs	*Trifolium longipes*	trlo
Forbs	*Trifolium pratense*	trpr2
Forbs	*Trifolium repens*	trre3
Forbs	*Trillium petiolatum*	trpe3
Forbs	*Urtica dioica*	urdi
Forbs	*Valeriana sitchensis*	vasi
Forbs	*Veratrum californicum*	veca2
Forbs	*Veratrum viride*	vevi
Forbs	*Viola adunca*	viad
Forbs	*Viola glabella*	vigl
Grasses	*Alopecurus pratensis*	alpr3
Grasses	*Arrhenatherum elatius*	arel3
Grasses	*Bromus carinatus*	brca5
Grasses	*Bromus inermis*	brin2
Grasses	*Bromus pumpellianus*	brpu3
Grasses	*Bromus tectorum*	brte
Grasses	*Bromus vulgaris*	brvu
Grasses	*Calamagrostis canadensis*	caca4
Grasses	*Calamagrostis rubescens*	caru
Grasses	*Catabrosa aquatica*	caaq3
Grasses	*Cinna latifolia*	cila2
Grasses	*Dactylis glomerata*	dagl
Grasses	*Deschampsia atropurpurea*	deat2
Grasses	*Deschampsia cespitosa*	dece

Appendix 2. Continued.

Structure Class	Scientific Name	USDA Plants Species Code
Grasses	*Elymus cinereus*	elci2
Grasses	*Elymus glaucus*	elgl
Grasses	*Festuca arundinacea*	fear3
Grasses	*Festuca idahoensis*	feid
Grasses	*Festuca rubra*	feru2
Grasses	*Festuca subulata*	fesu
Grasses	*Glyceria striata*	glst
Grasses	*Koeleria cristata*	kocr
Grasses	*Melica subulata*	mesu
Grasses	*Phalaris arundinacea*	phar3
Grasses	*Phleum pratense*	phpr3
Grasses	*Poa bulbosa*	pobu
Grasses	*Poa nemoralis L.*	pone
Grasses	*Poa nervosa*	pone2
Grasses	*Poa nevadensis*	pone3
Grasses	*Poa pratensis*	popr
Grasses	*Poa sandbergii*	posa12
Grasses	*Poa trivialis*	potr2
Grasses	*Stipa lettermanii*	stle4
Grasses	*Ventenata dubia*	vedu
Low Shrub	*Clematis ligusticifolia*	clli2
Low Shrub	*Lonicera involucrata*	loin5
Low Shrub	*Lonicera utahensis*	lout2
Low Shrub	*Ribes aureum*	riau
Low Shrub	*Ribes cereum*	rice
Low Shrub	*Ribes hudsonianum*	rihu
Low Shrub	*Ribes lacustre*	rila
Low Shrub	*Rosa gymnocarpa*	rogy
Low Shrub	*Rosa woodsii*	rowo
Low Shrub	*Rubus idaeus*	ruid
Low Shrub	*Rubus parviflorus*	rupa
Low Shrub	*Salix boothii*	sabo2
Low Shrub	*Salix commutata*	saco2
Low Shrub	*Salix wolfii*	sawo
Low Shrub	*Sambucus cerulea*	sace3
Low Shrub	*Shepherdia canadensis*	shca
Low Shrub	*Spiraea betulifolia*	spbe2
Low Shrub	*Symphoricarpos albus*	syal
Low Shrub	*Vaccinium membranaceum*	vame

Appendix 2. Continued.

Structure Class	Scientific Name	USDA Plants Species Code
Sedges and Rushes	*Carex aquatilis*	caaq
Sedges and Rushes	*Carex brunnescens*	cabr15
Sedges and Rushes	*Carex deweyana*	cade9
Sedges and Rushes	*Carex filifolia*	cafi
Sedges and Rushes	*Carex geyeri*	cage2
Sedges and Rushes	*Carex hoodii*	caho5
Sedges and Rushes	*Carex laeviculmis*	cala13
Sedges and Rushes	*Carex lanuginosa*	cala30
Sedges and Rushes	*Carex microptera*	cami7
Sedges and Rushes	*Carex praegracilis*	capr5
Sedges and Rushes	*Carex praticola*	capr7
Sedges and Rushes	*Carex rossii*	caro5
Sedges and Rushes	*Carex rostrata*	caro6
Sedges and Rushes	*Carex sheldonii*	cash
Sedges and Rushes	*Juncus balticus*	juba
Sedges and Rushes	*Scirpus microcarpus*	scmi2
Tall Shrub	*Acer glabrum*	acgl
Tall Shrub	*Alnus incana*	alin2
Tall Shrub	*Alnus sinuata*	alsi3
Tall Shrub	*Amelanchier alnifolia*	amal2
Tall Shrub	*Betula occidentalis*	beoc2
Tall Shrub	*Cornus stolonifera*	cost4
Tall Shrub	*Crataegus douglasii*	crdo2
Tall Shrub	*Holodiscus discolor*	hodi
Tall Shrub	*Physocarpus malvaceus*	phma5
Tall Shrub	*Prunus virginiana*	prvi
Tall Shrub	*Salix amygdaloides*	saam2
Tall Shrub	*Salix bebbiana*	sabe2
Tall Shrub	*Salix exigua*	saex
Tall Shrub	*Salix geyeriana*	sage2
Tall Shrub	*Salix lasiandra*	sala5
Tall Shrub	*Salix lemmonii*	sale
Tall Shrub	*Salix rigida*	sari2
Tall Shrub	*Salix scouleriana*	sasc
Tall Shrub	*Salix sitchensis*	sasi2

Appendix 3. Cross-reference table showing relationship between generalized soil classes, soil series, physiography, landforms, and soil taxonomic classes. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Generalized Soil Series Title (Code)	Physiography	Characteristic Landforms	Soil Series	Soil Taxonomic Class
Ashy silt loam over coarse frags (AsilovCF)	U/L	Terraces	Bigwall ashy silt loam	Ashy Typic Vitrixerands
			Collegecreek ashy loam	Ashy over loamy Typic Vitrixerands
			Digit ashy silt loam	Ashy over loamy Typic Vitricryands
			Tamara ashy silt loam	Ashy over loamy Alfic Udivitrands
Ashy silt loam over loam (AsilovL)	U/L	Terraces	Bigbouldercreek ashy silt loam	Ashy Typic Udivitrands
			Tolo ashy silt loam	Ashy over loamy Alfic Vitrixerands
			Wolot silt loam	Ashy over loamy Alfic Vitrixerands
		Toeslopes/Footslopes	Collegecreek ashy loam	Ashy over loamy Typic Vitrixerands
			Peaviner gravelly ashy sandy clay loam	Fine, smectitic Vertic Palexerolls
Ashy silt loam over skeletal (AsilovSk)	U/L	Ridgetops and sideslopes	Syrupcreek ashy silt loam	Ashy over loamy-skeletal Alfic Udivitrands
		Sideslopes/Terraces	Limberjim ashy silt loam	Ashy over loamy-skeletal Alfic Udivitrands
		Terraces	Bucketlake stony ashy silt loam	Ashy over loamy-skeletal Typic Vitricryands
			Bullroar ashy silt loam	Ashy over loamy-skeletal Alfic Udivitrands
			Icedee ashy silt loam	Ashy over loamy Alfic Vitricryands
			Rebarrow ashy silt loam	Ashy over loamy Alfic Udivitrands
			Tertoo cobbly, ashy silt loam	Ashy over loamy-skeletal Typic Vitrixerands

Appendix 3. Continued.

Generalized Soil Series Title (Code)	Physiography	Characteristic Landforms	Soil Series	Soil Taxonomic Class
Deep w/coarse fragments (DpCF)	U	back slopes; toeslopes; footslopes	Emily ashy silt loam	Loamy-skeletal Vitrandic Haploxerolls
		mountain slopes	Bulgar cobbly ashy silt loam	Ashy over loamy-skeletal Typic Udivitrands
			Dunstan ashy silt loam	Clayey-skeletal, smectitic Vitrandic Haploxeralfs
			Fourthcreek ashy silt loam	Ashy over loamy Typic Vitrixerands
			Gutridge gravelly ashy silt loam	Ashy over loamy-skeletal Typic Udivitrands
			Lakefork gravelly ashy silt loam	Ashy-skeletal Typic Udivitrands
			Marblepoint stony ashy silt loam	Loamy-skeletal Andic Haplocryepts
			Pasturecreek gravelly ashy silt loam	Loamy-skeletal Andic Eutrudepts
			Warfield gravelly ashy sandy loam	Loamy-skeletal Vitrandic Haploxerepts
		mountain slopes; plateaus	Bigcow gravelly ashy silt loam	Loamy-skeletal Andic Haploxerepts
			Getaway stony ashy silt loam	Loamy-skeletal Vitrandic Argixerolls
			Harl very gravelly ashy silt loam	Ashy-skeletal Typic Udivitrands
			Klickson ashy silt loam	Loamy-skeletal Vitrandic Argixerolls
			MountEmily ashy silt loam	Ashy over loamy-skeletal Typic Vitricryands
			Pinuscreek ashy silt loam	Loamy-skeletal Andic Haploxeralfs
Deep - silt to clay loam (DpSiCL)	U	hillslopes	McMurdie silt loam, bedrock substratum	fine, smectitic Calcic Pachic Argixerolls
			Palouse silt loam	fine-silty Pachic Ultic Haploxerolls
		mountain slopes	Geisercreek ashy silt loam	Ashy over clayey Alfic Udivitrands
			Gorhamgulch ashy silt loam	Ashy over loamy Typic Udivitrands
		mountain slopes; plateaus	Nibolob ashy silt loam	Fine-loamy Vitrandic Argixerolls

Appendix 3. Continued.

Generalized Soil Series Title (Code)	Physiography	Characteristic Landforms	Soil Series	Soil Taxonomic Class
Lithic/Shallow to Clay (LiShC)	U	hillslopes	Gwinly very cobbly silt loam	Clayey-skeletal, smectitic Lithic Argixerolls
			Ramo silty clay loam	Fine, smectitic Typic Argixerolls
			Rockly very gravelly loam	Loamy-skeletal Lithic Haploxerolls
			Starkey very stony silt loam	Clayey-skeletal, smectitic Typic Argixerolls
			Ukiah silty clay loam	Fine, smectitic Vertic Argixerolls
		mountain slopes	Btree ashy slit loam	Ashy over clayey-skeletal Alfic Udivitrands
			Cowsley very stony silt loam	fine, smectitic Xeric Argialbolls
			Flyvalley ashy silt loam	Ashy Lithic Udivitrands
			Powderriver gravelly ashy sandy loam	Loamy-skeletal Lithic Haploxerepts
			Unitylake ashy silt	Fine, smectitic Vertic Palexeralfs
		mountain slopes; plateaus	Anatone very cobbly silt loam	Loamy-skeletal Lithic Haploxerolls
			Bocker very cobbly silt loam	Loamy-skeletal Lithic Haploxerolls
			Burgerbutte extremely cobbly ashy sandy loam	Loamy-skeletal Lithic Humicryepts
			Fivebeaver gravelly ashy silt loam	Loamy-skeletal Lithic Ultic Haploxerolls
			Fivebit extremely stony loam	Loamy-skeletal Lithic Ultic Haploxerolls
			Harlow very stony clay loam	Clayey-skeletal Lithic Argixerolls
			Lowerbluff ashy silt loam	Ashy Lithic Vitrixerands
			Roostercomb extremely gravelly clay loam	Clayey-skeletal Typic Argixerolls
Loam over skeletal (LovSk)	R	Low Floodplains	Dardry loam	Loamy-skeletal Cumulic Ultic Haploxerolls
			Melloe loam	Loamy-skeletal Typic Endoaquolls
			Mugwump sandy loam	Loamy-skeletal Cumulic Hapludolls
			Terlough gravelly silt loam	Loamy-skeletal Aquic Hapludolls
			Voats fine sandy loam	Sandy-skeletal Fluventic Haploxerolls

Appendix 3. Continued.

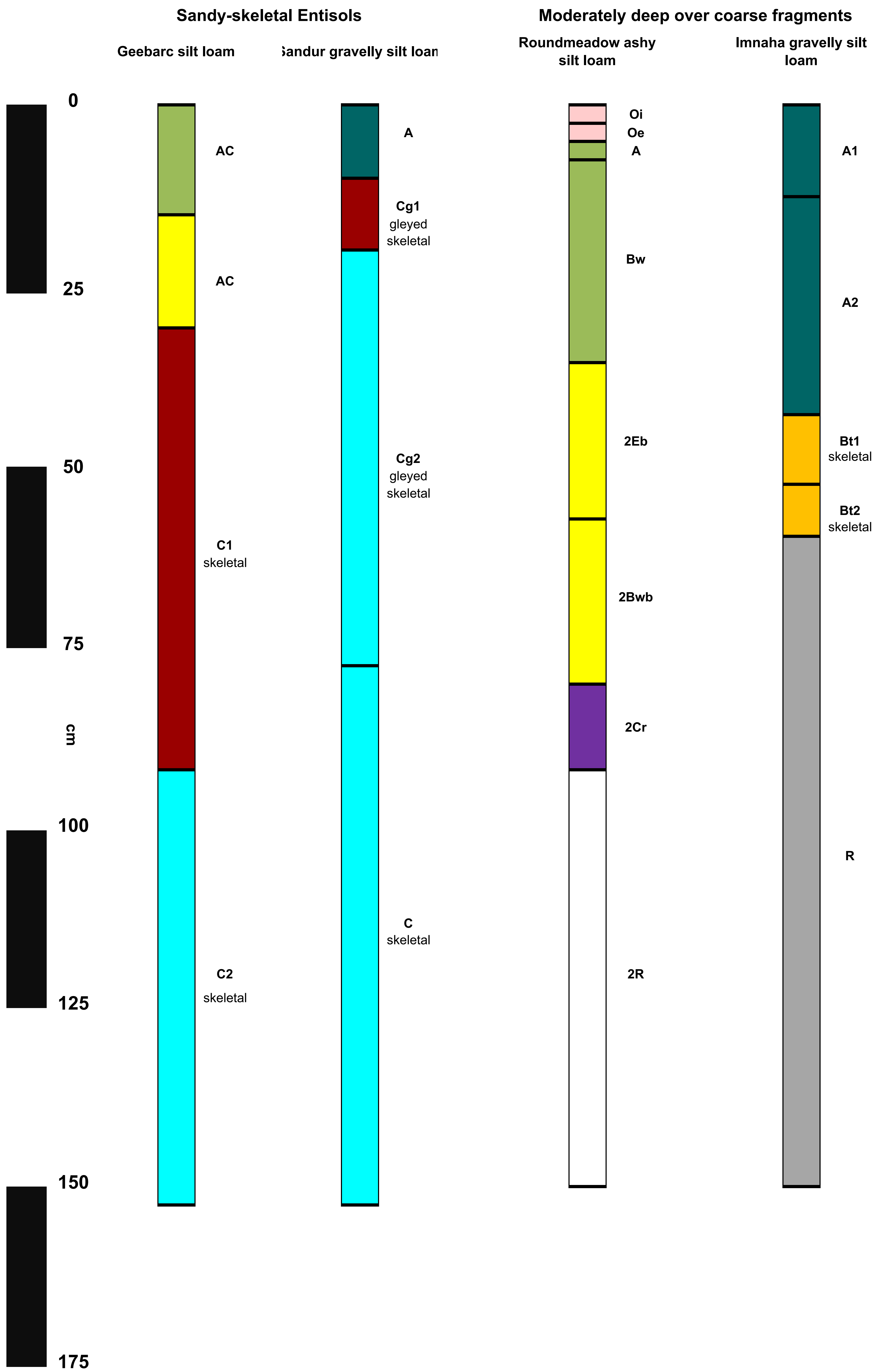
Generalized Soil Series Title (Code)	Physiography	Characteristic Landforms	Soil Series	Soil Taxonomic Class
Loam/Silt Loam - brackish (LSilbr)	R/L	Higher Floodplains	Bandarrow silt loam	Coarse-loamy Typic Cryaquolls
			Broady	Loamy Aquic Haplocryolls
			Catherine silt	Fine-silty Cumulic Endoaquolls
			Catherine silty clay loam	Fine-silty Cumulic Endoaquolls
			Terrodd silt loam	Fine-loamy Aquic Cumulic Hapludolls
			Typic Cryaquolls	Typic Cryaquolls
			Veazie loam	Coarse-loamy over sandy or sandy-skeletal Cumulic Haploxerolls
	U/L	Terraces	Alicel fine sandy loam/loam/silt loam	fine-loamy Pachic Haploxerolls
			Bodale loam	Coarse-loamy Cumulic Haplocryolls
			Hutchinson variant silt loam	fine, smectitic Argic Durixerolls
			Imbler fine sandy loam	coarse-loamy Pachic Haploxerolls
			Jett silt loam	fine-silty Cumulic Haploxerolls
			La Grande silt/silty clay loam	fine-silty Pachic Haploxerolls
			Tovame silt loam	Coarse-loamy Cumulic Hapludolls
			Ultic Haploxerolls	Sandy-skeletal Ultic Haploxerolls
			Verdeplane	Fine-loamy Pachic Hapludolls
			Witknee very fine sandy loam	Coarse-loamy Aquic Hapludolls
Loam/Silt Loam - organic-rich (LSilor)	L	Lake Basins/Salty Soils	Hooly ash silt loam	medial over loamy Typic Endoaquands
			Hoopal fine sandy loam	coarse-loamy Typic Duraquolls
			Hot Lake ashy silt loam	medial over loamy Aquic Haploxerands
			Umapine silt loam	coarse-silty Typic Halaquepts
Loam/Silt Loam (LSil)	R/L	Meadows	Bandarrow silt loam	Coarse-loamy Typic Cryaquolls
			Melloe loam	Loamy-skeletal Typic Cryaquolls
			Tovame silt loam	Coarse-loamy Pachic Hapludolls
			Typic Cryaquolls	Typic Cryaquolls
			Typic Haplosaprists	Coarse-loamy Typic Haplosaprists

Appendix 3. Continued.

Generalized Soil Series Title (Code)	Physiography	Characteristic Landforms	Soil Series	Soil Taxonomic Class
Loamy-gravelly (LGr)			Peaviner gravelly ashy sandy clay loam	Fine, smectitic Vertic Palexerolls
	U	Alluvial Fans	Collegecreek ashy loam	Ashy over loamy Typic Vitrixerands
			La Grande silt/silty clay loam	fine-silty Pachic Haploxerolls
			Phys (gravelly) silt loam	loamy-skeletal Typic Argixerolls
			Riceton	Coarse-loamy Ultic Haploxerolls
Mod. deep w/coarse frags (MDpCF)	U	glacial valley floors; cirque basins	Mudlakebasin ashy silt loam	Ashy over loamy-skeletal Typic Vitricryands
		hillslopes	Klicker stony silt loam (40-65% slopes)-north/south slopes	Loamy-skeletal Vitrandic Argixerolls
			Lookingglass silt loam/very stony silt loam	fine, smectitic Xeric Argialbolls
			Royst very stony silt loam	Clayey-skeletal, smectitic Pachic Argixerolls
			Watama silt loam	fine-loamy Pachic Haploxerolls
		mountain slopes	Angelbasin ashy silt loam	Loamy-skeletal Andic Dystrocryepts
			Bler ashy silt loam	Clayey-skeletal, smectitic Vitrandic Palexerolls
			Endcreek ashy silt loam	Ashy over loamy-skeletal Typic Vitrixerands
			Flycreek ashy silt loam	Ashy over clayey Alfic Udivitrands
			Hall Ranch stony loam	Fine-loamy Ultic Haploxerolls
			Olot silt loam	Ashy over loamy-skeletal Typic Vitrixerands
			Peaviner gravelly ashy sandy clay loam	Loamy-skeletal Vitrandic Argixerolls
			Roundmeadow ashy silt loam	Coarse-loamy Andic Haploxerepts
			Threecent ashy silt loam	Ashy over clayey Alfic Udivitrands
		mountain slopes; plateaus	Bennettcreek ashy silt loam	Loamy-skeletal Vitrandic Haploxeralfs
			Bolony ashy silt loam	Fine-loamy Vitrandic Argixerolls
			Bunchpoint ashy silt loam	Coarse-loamy Vitrandic Haploxerolls
			Deardorf stony ashy loam	Ashy over loamy-skeletal Typic Udivitrands
			Downeygulch gravelly ashy silt loam	Coarse-loamy Vitrandic Haploxerepts

Appendix 3. Continued.

Generalized Soil Series Title (Code)	Physiography	Characteristic Landforms	Soil Series	Soil Taxonomic Class
			Kamela stony ashy silt loam	Loamy-skeletal Vitrandic Haploxerepts
			Klicker stony (ashy) silt loam	Loamy-skeletal Vitrandic Argixerolls
			Larabee ashy loam	Loamy-skeletal Vitrandic Argixerolls
			McCartycreek cobbly ashy silt loam	Loamy-skeletal Vitrandic Haploxerolls
			Snell very stony loam	Clayey-skeletal Pachic Argixerolls
			Troutmeadows ashy silt loam	Ashy over loamy-skeletal Typic Vitricryands
			Webbgulch very gravelly ashy loam	Loamy-skeletal Vitrandic Haploxerepts
			Wonder stony ashy silt loam	Loamy-skeletal Andic Haploxerepts
Sandy-skeletal Entisols (SSkEnt)	R	Gravel bars/Incipient floodplains	Caulditch	Sandy-skeletal Typic Cryaquents
			Geebarc silt loam	Sandy-skeletal Oxyaquic Cryorthents
			Gulliford very gravelly loamy sand	Sandy-skeletal Oxyaquic Udorthents
			Sandur gravelly silt loam	Sandy-skeletal Aeric Endoaquents
Streambanks - high gradient (StmBkHG)	R	Streambanks	Aquic Vitricryands	Ashy over loamy Aquic Vitricryands
Roads (Roads)	various	Human modified	not applicable	not applicable
Rock Outcrop (Rock)	U	cliffs and rock outcrops	not applicable	not applicable
Urban Complex (Urban)	various	Human modified	not applicable	not applicable
Water (Water)	R	River, stream, lake or pond	not applicable	not applicable



Appendix 4. Block diagrams depicting typical soil texture, rock fragments, and soil horizons for soil series within generalized soil classes. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Appendix 5. Cross-reference table showing the relationship between level 1, 2, 3, and 4 existing vegetation classes. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Level I	Level II	Level III	Level IV Existing Vegetation Domain Code
Forest	Conifer	Closed conifer forest	fnscf : Closed Subalpine Fir Forest
(trees >3m tall and canopy cover 10%+)	(75%+ cover by conifers)	(60–100% tree canopy cover)	fncl : Closed Lodgepole Pine Forest
			fncg : Closed Grand Fir Forest
			fnces : Closed Engelmann Spruce Forest
			fncdf : Closed Douglas-fir Forest
			fncpp : Closed Ponderosa Pine Forest
		Open conifer forest	fnsfo : Open Subalpine Fir Forest
		(11–59% tree canopy cover)	fnog : Open Grand Fir Forest
			fnodf : Open Douglas-fir Forest
			fnopp : Open Ponderosa Pine Forest
			fnoes : Open Englemann Spruce Forest
			fnol : Open Lodgepole Pine Forest
		Conifer woodland	fnsfw : Subalpine Fir Woodland
		(10–24% tree canopy cover)	fngfw : Grand Fir Woodland
			fndfw : Douglas-fir Woodland
			fnwpp : Ponderosa Pine Woodland
			fnwes : Engelmann Spruce Woodland
			fnwl : Lodgepole Pine Woodland
	Deciduous/Broadleaf	Closed deciduous forest	fbcc : Closed Black Cottonwood Forest
	(<75% cover by conifers;	(60–100% tree canopy cover)	fbos : Closed Willow Forest (lower valley)
	75%+ cover by deciduous trees)		fbqac : Closed Quaking Aspen Forest
			fmbcdfc : Closed Black Cottonwood-Douglas-fir Forest
			fmbcesc : Closed Black Cottonwood-Engelmann Spruce Forest
			fmbcgfc : Closed Black Cottonwood-Grand Fir Forest

Appendix 5. Continued.

Level I	Level II	Level III	Level IV Existing Vegetation Domain Code
			fmbcppc : Closed Black Cottonwood-Ponderosa Pine Forest
		Open deciduous forest	fboc : Open Black Cottonwood Forest
		(25–59% tree canopy cover)	fbcs : Open Willow Forest (lower valley)
			fbqao : Open Quaking Aspen Forest
			fmbcdfo : Open Black Cottonwood-Douglas-fir Forest
			fmbceso : Open Black Cottonwood-Engelmann Spruce Forest
			fmbcgfo : Open Black Cottonwood-Grand Fir Forest
			fmbcppo : Open Black Cottonwood-Ponderosa Pine Forest
		Conifer woodland	fbwc : Black Cottonwood Woodland
		(10–24% tree canopy cover)	fbqaw : Quaking Aspen Woodland
			fmbcdfw : Black Cottonwood-Douglas-fir Woodland
			fmbcesw : Black Cottonwood-Engelmann Spruce Woodland
			fmbcgfw : Black Cottonwood-Grand Fir Woodland
			fmbcppw : Black Cottonwood-Ponderosa Pine Woodland
Shrub	Tall shrub	Closed tall shrub	ssa : Sitka Alder
(25%+ cover of shrubs or 10%+ cover of dwarf trees)	(Shrubs more than 1.5 m tall)	(75%+ canopy cover)	stcat : Closed Thinleaf Alder
			stcw : Closed Tall Willow
			stcbh : Closed Black Hawthorn
			suc : Closed Upland Shrubland
			smxlc : Closed Low Elevation Mixed Shrubland
		Open tall shrub	stoat : Open Thinleaf Alder
		(25–74% canopy cover)	stow : Open Tall Willow
			stobh : Open Black Hawthorn
			suo : Open Upland Shrubland
			smxlo : Open Low Elevation Mixed Shrubland
	Low shrub (Shrubs less than 1.5m tall)	Closed low shrub (75%+ canopy cover)	slwc : Closed Low Willow
		Open low shrub (25–74% canopy cover)	slow : Open Low Willow

Appendix 5. Continued.

Level I	Level II	Level III	Level IV Existing Vegetation Domain Code
Herbaceous	Graminoid	Dry graminoid herbaceous	hgd : Dry Graminoid Meadow
(Less than 10% tree cover and less than 25% shrub cover)	(graminoid plants dominant)	(well-drained, dry sites)	hus : Upland Steppe
		Moist graminoid herbaceous (moist sites, without standing water)	hgm : Moist Graminoid Meadow
		Wet graminoid herbaceous (wet sites; standing water present part of year; includes bogs, marshes and fens)	hgw : Wet Graminoid Meadow
	Forb (forb plants dominant)	Forb herbaceous	hfm : Forb Meadow
Complexes		Herbaceous Complex	hgwmcc : Wet-Moist Graminoid Meadow Complex
		Shrub-Herbaceous Complex	swmmgrlfc : Low Elevation Wet-Moist Shrub/Graminoid Floodplain Complex
		Mixed Forest-Shrub-Herbaceous Complex	xr : Riverine Complex
			xu : Upland Complex
Agricultural	Agricultural	Agricultural	hpa : agricultural pasture
			hca : agricultural croplands
			bpa : barren agricultural
			xa : agricultural complex
Barren	Barren	Barren	bbg : Barren
			bpvh : Barren partially vegetated herbaceous
Developed	Developed	Developed	rd : Roads
			ub : Buildings and Other Structures
			xd : Urban Complex
Water	Water	Water	wf : Fresh Water

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Appendix 6. Cross-reference table between potential vegetation classes (PAGs) and plant associations or plant community types. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

Plant Association Group (PAG)	Range of Average Canopy Cover	Domain Code: Description	Plant Association/Plant Community Type–Common Name	Plant Association/Plant Community Type–Scientific Name	Source
Dry Subalpine Fir Forest	25–100%	fsfd : Dry Subalpine Fir Forest	Subalpine Fir/Grouse Huckleberry	*Abies lasiocarpa/Vaccinium scoparium*	4
			Subalpine Fir/Grouse Huckleberry/Skunk-leaved Polemonium	*Abies lasiocarpa/Vaccinium scoparium/Polemonium pulcherrimum*	3, 4
			Subalpine Fir/Skunk-leaved Polemonium	*Abies lasiocarpa/Polemonium pulcherrimum*	3
			Lodgepole Pine(Subalpine Fir)/Grouse Huckleberry	*Pinus contorta(Abies lasiocarpa)/Vaccinium scoparium*	3, 4
Subalpine Fir-Engelmann Spruce Forest	25–100%	fsfes : Subalpine Fir-Engelmann Spruce Forest	Subalpine Fir/Twinflower	*Abies lasiocarpa/Linnaea borealis*	3, 4
			Subalpine Fir/Queen's Cup Beadlily	*Abies lasiocarpa/Clintonia uniflora*	3, 4
			Subalpine Fir/Arrowleaf Groundsel	*Abies lasiocarpa/Senecio triangularis*	1
			Subalpine Fir/Big Huckleberry	*Abies lasiocarpa/Vaccinium membranaceum*	3, 4
Open Subalpine Fir-Engelmann Spruce Forest	25–59%	fsfeso : Open Subalpine Fir-Engelmann Spruce Forest	Subalpine Fir/Ladyfern	*Abies lasiocarpa/Athyrium filix-femina*	1
			Subalpine Fir/Soft-leaved Sedge	*Abies lasiocarpa/Carex disperma*	1
Dry Lodgepole Pine Forest	25–59%	flpd : Dry Lodgepole Pine Forest	Lodgepole Pine(Grand Fir)/Pinegrass	*Pinus contorta(Abies grandis)/Calamagrostis rubescens*	4
			Lodgepole Pine(Grand Fir)/Grouse Huckleberry	*Pinus contorta(Abies grandis)/Vaccinium scoparium/Calamagrostis rubescens*	4
Lodgepole Pine Moist Meadow	25–59%	flpmm : Lodgepole Pine Moist Meadow	Lodgepole Pine/Bluejoint Reedgrass	*Pinus contorta/Calamagrostis canadensis*	1
			Lodgepole Pine/Woolly Sedge	*Pinus contorta/Carex lanuginosa*	1
			Lodgepole Pine/Tufted Hairgrass	*Pinus contorta/Deschampsia cespitosa*	1
			Lodgepole Pine/Kentucky Bluegrass	*Pinus contorta/Poa pratensis*	1
Lodgepole Pine Wet Meadow	25–59%	flpwm : Lodgepole Pine Wet Meadow	Lodgepole Pine/Aquatic Sedge	*Pinus contorta/Carex aquatilis*	1
			Lodgepole Pine/Holm's Rocky Mountain Sedge	*Pinus contorta/Carex scopulorum*	7
Cold Grand Fir Forest	25–59%	fgfc : Cold Grand Fir Forest	Grand Fir/Grouse Huckleberry	*Abies grandis/Vaccinium scoparium*	4
			Grand Fir/Grouse Huckleberry-Twinflower	*Abies grandis/Vaccinium scoparium-Linnaea borealis*	4
Grand Fir-Engelmann Spruce Forest	25–100%	fgfes : Grand fir-Engelmann Spruce Forest	Grand Fir/Rocky Mountain Maple	*Abies grandis/Acer glabrum*	3, 4
Open Grand Fir-Engelmann Spruce Forest	25–59%	fgfeso : Open Grand fir-Engelmann Spruce Forest	Grand Fir/Rocky Mountain Maple-Floodplain	*Abies grandis/Acer glabrum-Floodplain*	1
			Grand Fir/Rocky Mountain Maple-Mallow Ninebark	*Abies grandis/Acer glabrum-Physocarpus malvaceus*	3
			Grand Fir/Ladyfern	*Abies grandis/Athyrium filix-femina*	1
			Grand Fir/Common Snowberry-Floodplain	*Abies grandis/Symphoricarpos albus-Floodplain*	1
Engelmann Spruce Forest	25–59%	fes : Engelmann Spruce Forest	Engelmann Spruce/Ladyfern	*Picea engelmannii/Athyrium filix-femina*	1
			Engelmann Spruce/Columbia Brome	*Picea engelmannii/Bromus vulgaris*	1
			Engelmann Spruce/Soft-leaved Sedge	*Picea engelmannii/Carex disperma*	1
			Engelmann Spruce/Drooping Woodreed	*Picea engelmannii/Cinna latifolia*	1

Plant Association Group (PAG)	Range of Average Canopy Cover	Domain Code: Description	Plant Association/Plant Community Type–Common Name	Plant Association/Plant Community Type–Scientific Name	Source
Engelmann Spruce Forest (continued)			Engelmann Spruce/Red-osier Dogwood	*Picea engelmannii/Cornus stolonifera*	1
			Engelmann Spruce/Common Horsetail	*Picea engelmannii/Equisetum arvense*	1
			Engelmann Spruce/Arrowleaf Groundsel	*Picea engelmannii/Senecio triangularis*	1
Cool-moist Grand Fir Forest	25–100%	fgfcm : Cool-moist Grand Fir Forest	Grand Fir/Queen's Cup Bead-lily	*Abies grandis/Clintonia uniflora*	3, 4
			Grand Fir/Twinflower	*Abies grandis/Linnaea borealis*	3, 4
			Grand Fir/Pacific Yew/Queen's Cup Beadlily	*Abies grandis/Taxus brevifolia/Clintonia uniflora*	3, 4
			Grand Fir/Pacific Yew-Twinflower	*Abies grandis/Taxus brevifolia-Linnaea borealis*	4
Open Cool-moist Grand Fir Forest	25–59%	fgfcmo : Open Cool-moist Grand Fir Forest	Grand Fir/Big Huckleberry	*Abies grandis/Vaccineum membranaceum*	3, 4
Warm-dry Grand Fir Forest	25–100%	fgfwd: Warm-dry Grand Fir Forest	Grand Fir/Elk Sedge	*Abies grandis/Carex geyeri*	4
Open Warm-dry Grand Fir Forest	25–59%	fgfwdo : Open Warm-dry Grand Fir Forest	Grand Fir/Pinegrass	*Abies grandis/Calamagrostis rubescens*	3, 4
			Grand Fir/Birchleaf Spiraea (Blue Mountains)	*Abies grandis/Spiraea betulifolia*	3, 4
Warm-moist Douglas-Fir Forest	25–59%	fdfwm : Warm-moist Douglas-fir Forest	Douglas-fir/Rocky Mountain Maple-Mallow Ninebark	*Pseudotsuga menziesii/Acer glabrum-Physocarpus malvaceus*	3
			Douglas-fir/Rocky Mountain Maple-Mallow Ninebark-Floodplain	*Pseudotsuga menziesii/Acer glabrum-Physocarpus malvaceus-Floodplain*	1
			Douglas-Fir/Oceanspray	*Pseudotsuga menziesii/Holodiscus discolor*	4
			Douglas-Fir/Mallow Ninebark	*Pseudotsuga menziesii/Physocarpus malvaceus*	3, 4
Moist Douglas-fir Forest	60–100%	fdfm : Moist Douglas-fir Forest	Douglas-fir/Common Snowberry	*Pseudotsuga menziesii/Symphoricarpos albus*	3, 4
			Douglas-fir/Common Snowberry-Floodplain	*Pseudotsuga menziesii/Symphoricarpos albus-Floodplain*	1
Low Elevation Moist Douglas-fir Forest	10–59%	fdflm : Low Elevation Moist Douglas-fir Forest	Douglas-fir/Western Birch	*Pseudotsuga menziesii/Betula occidentalis*	2
			Douglas-fir/Black Hawthorn-Common Snowberry	*Pseudotsuga menziesii/Crataegus douglasii-Symphoricarpos albus*	2
Open Moist Douglas-Fir Forest	10–59%	fdfmo : Open Moist Douglas-fir Forest	Douglas-Fir/Birchleaf Spiraea	*Pseudotsuga menziesii/Spiraea betulifolia*	3
			Douglas-fir/Mountain Snowberry (Wallowa Mountains)	*Pseudotsuga menziesii/Symphoricarpos oreophilis*	3, 4
Dry Douglas-fir Forest	25–100%	fdfd : Dry Douglas-fir Forest	Douglas-fir/Pinegrass	*Pseudotsuga menziesii/Calamagrostis rubescens*	3, 4
			Douglas-fir/Elk Sedge	*Pseudotsuga menziesii/Carex geyeri*	4
Moist Ponderosa Pine Forest	25–100%	fppm : Moist Ponderosa Pine Forest	Ponderosa Pine/Kentucky Bluegrass	*Pinus ponderosa/Poa pratensis*	1
			Ponderosa Pine/Black Hawthorn/Kentucky Bluegrass	*Pinus ponderosa/Crataegus douglasii/Poa pratensis*	8

Plant Association Group (PAG)	Range of Average Canopy Cover	Domain Code: Description	Plant Association/Plant Community Type–Common Name	Plant Association/Plant Community Type–Scientific Name	Source
Open Moist Ponderosa Pine Forest	25–59%	fppmo : Open Moist Ponderosa Pine Forest	Ponderosa Pine/Common Snowberry	*Pinus ponderosa/Symphoricarpos albus*	3, 4
			Ponderosa Pine/Common Snowberry-Floodplain	*Pinus ponderosa/Symphoricarpos albus-Floodplain*	1
			Ponderosa Pine Community Type	*Pinus ponderosa Community Type*	5
Dry Ponderosa Pine Forest	25–59%	fppd : Dry Ponderosa Pine Forest	Ponderosa Pine/Pinegrass	*Pinus ponderosa/Calamagrostis rubescens*	4
			Ponderosa Pine/Elk Sedge	*Pinus ponderosa/Carex geyeri*	4
Ponderosa Pine Steppe Woodland	10–24%	wpps : Ponderosa Pine Steppe Woodland	Ponderosa Pine/Bluebunch Wheatgrass	*Pinus ponderosa/Agropyron spicatum*	3, 4
			Ponderosa Pine/Idaho Fescue	*Pinus ponderosa/Festuca idahoensis*	3, 4
White Willow Forest	60–100%	fbww : White Willow Forest	White Willow	*Salix alba*	8
Black Cottonwood/Willows Floodplain Forest	25–59%	fbbcwf : Black Cottonwood/Willows Floodplain Forest	Black Cottonwood/Shining Willow	*Populus balsamerifera* ssp. *trichocarpa/Salix lucida*	2
			Black Cottonwood/Arroyo Willow	*Populus balsamerifera* ssp. *trichocarpa/Salix lasiolepis*	2
Low Elevation Black Cottonwood Floodplain Forest	25–59%	fbclf : Low Elevation Black Cottonwood Floodplain Forest	Black Cottonwood/Lewis' Mockorange	*Populus balsamerifera* ssp. *trichocarpa/Philadelphus lewisii*	2
			Black Cottonwood/Western Birch	*Populus balsamerifera* ssp. *trichocarpa/Betula occidentalis*	2
			Black Cottonwood/Black Hawthorn	*Populus balsamerifera* ssp. *trichocarpa/Crataegus douglasii*	2
Black Cottonwood Floodplain Forest	25–59%	fbcf : Black Cottonwood Floodplain Forest	Quaking Aspen/Rocky Mountain Maple	*Populus balsamerifera* ssp. *trichocarpa/Acer glabrum*	1
			Black Cottonwood/Mountain Alder-Red-osier Dogwood	*Populus balsamerifera* ssp. *trichocarpa/Alnus incana-Cornus stolonifera*	1
Black Cottonwood Terrace Forest	25–100%	fbct : Black Cottonwood Terrace Forest	Black Cottonwood/Common Snowberry	*Populus balsamerifera* ssp. *trichocarpa/Symphoricarpos albus*	1
Sitka Alder Shrubland	60–100%	ssa : Sitka Alder Shrubland	Sitka Alder	*Alnus sinuata*	4
Mountain Alder Floodplain Shrubland	60–100%	smaf : Mountain Alder Floodplain Shrubland	Mountain Alder-Red-osier Dogwood/Mesic Forb	*Alnus incana-Cornus stolonifera/Mesic Forb*	1
			Mountain Alder-Currants/Mesic Forb	*Alnus incana-Ribes* spp.*/Mesic Forb*	1
			Mountain Alder-Common Snowberry	*Alnus incana-Symphoricarpos albus*	1
			Mountain Alder/Ladyfern	*Alnus incana/Athyrium filix-femina*	1
			Mountain Alder/Bluejoint Reedgrass	*Alnus incana/Calamagrostis canadensis*	1
			Mountain Alder/Dewey's Sedge	*Alnus incana/Carex deweyana*	1
			Mountain Alder/Densely-tufted Sedge	*Alnus incana/Carex lenticularis var. lenticularis*	1
			Mountain Alder/Tall Mannagrass	*Alnus incana/Glyceria elata*	1
			Mountain Alder/Common Cowparsnip	*Alnus incana/Heracleum lanatum*	1
			Mountain Alder/Kentucky Bluegrass	*Alnus incana/Poa pratensis*	1
			Mountain Alder/Common Horsetail	*Alnus incana/Equisetum arvense*	1

Appendix 6. Continued.

Plant Association Group (PAG)	Range of Average Canopy Cover	Domain Code: Description	Plant Association/Plant Community Type–Common Name	Plant Association/Plant Community Type–Scientific Name	Source
Low Elevation Mountain Alder Floodplain Shrubland	60–100%	smalf : Low Elevation Mountain Alder Floodplain Shrubland	Mountain Alder-Water Birch	*Alnus incana-Betula occidentalis*	2
			Mountain Alder-Red-osier Dogwood-Lewis' Mockorange	*Alnus incana-Cornus sericea-Philadelphus lewisii*	2
			Western Birch-Lewis' Mockorange	*Betula occidentalis-Philadelphus lewisii*	2
			Western Birch-Lewis' Mockorange-Western Serviceberry-Common Snowberry	*Betula occidentalis-Philadelphus lewisii-Amelanchior alnifolia-Symphoricarpos albus*	2
Mountain Alder/Wet Meadow Shrubland	25–100%	smawm : Mountain Alder Wet Meadow Shrubland	Mountain Alder/Woolly Sedge	*Alnus incana/Carex lanuginosa*	1
			Mountain Alder/Smallfruit Bulrush	*Alnus incana/Scirpus microcarpus*	1
			Mountain Alder/Wideleaf Sedge	*Alnus incana/Carex amplifolia*	1
			Mountain Alder/Aquatic Sedge	*Alnus incana/Carex aquatilis*	1
			Mountain Alder/Bladder Sedge	*Alnus incana/Carex utriculata*	1
Red-osier Dogwood Shrubland	60–100%	scs : Red-osier Dogwood Shrubland	Red-osier Dogwood	*Cornus stolonifera*	1
Low Elevation Tall Willows Wet Meadow Shrubland	25–59%	swlwm : Low Elevation Tall Willows/Wet Meadow Shrubland	Shining Willow/Wet Graminoid	*Salix lucida* ssp. *lasiandra/Wet Graminod*	2
			Coyote Willow/Creeping Spikerush-Three Square Bulrush	*Salix exigua/Eleocharis pauciflora-Schoenoplectus americanus*	2
Low Elevation Tall Willows Floodplain Shrubland	25–100%	swlf : Low Elevation Tall Willows Floodplain Shrubland	Tall Willows/Reed Canarygrass	*Salix* spp.*/Phalaris arundinacea*	8
			Shining Willow	*Salix lucida sps. lasiandra*	2
			Coyote Willow-Shining Willow-Red-osier Dogwood	*Salix exigua-Salix lucida ssp. lasiandra-Cornus sericia*	2
			Arroyo Willow-Woods Rose-Red-osier Dogwood	*Salix lasiolepis-Rosa woodsii-Cornus sericea ssp. Sericea*	2
Tall Willows Moist Meadow Shrubland	25–100%	swmm : Tall Willows Moist Meadow Shrubland	Tall Willows/Mesic Forb	*Salix* spp.*/Mesic Forb*	1
			Tall Willows/Woolly Sedge	*Salix* spp.*/Carex lanuginosa*	1
			Tall Willows/Kentucky Bluegrass	*Salix* spp.*/Poa pratensis*	1
Tall Willows Wet Meadow Shrubland	25–59%	swwm : Tall Willows Wet Meadow Shrubland	Tall Willows/Aquatic Sedge	*Salix* spp.*/Carex aquatilis*	1
			Tall Willows/Bladder Sedge	*Salix* spp.*/Carex utriculata*	1
Tall Willlows Gravel Bar Shrubland	60–100%	swgb : Willows Gravel Bar Shrubland	Coyote Willow	*Salix exigua*	1
			Rigid Willow	*Salix rigida*	1
			Gravel Bar/Willow spp./Mixed Forb	*Gravel bar/Salix* spp.*/Mixed Forb*	5
Black Hawthorn Shrubland	60–100%	sbh : Black Hawthorn Shrubland	Black Hawthorn	*Crataegus douglasii*	5
			Black Hawthorn	*Crataegus douglasii*	1
			Black Hawthorn-Common Snowberry	*Crataegus douglasii-Symphoricarpos albus*	2

Appendix 6. Continued.

Plant Association Group (PAG)	Range of Average Canopy Cover	Domain Code: Description	Plant Association/Plant Community Type–Common Name	Plant Association/Plant Community Type–Scientific Name	Source
Low Elevation Mixed Shrub	25–100%	smxl : Low Elevation Mixed Shrubland	Mackenzie's (Rigid) Willow-Coyote Willow-Black Hawthorn-Red-osier Dogwood-Woods Rose/Reed Canarygrass	*S. rigida ssp. Mackenziana, S. exigua, C. stolonifera, R. woodsii, C. douglasii/Phalaris arunidinacea*	8
			Mackenzie's (Rigid) Willow-Woods Rose	*Salix prolixa (S. rigida* ssp. *Mackenziana)-Rosa woodsii*	2
Dry Upland Shrubland	25–59%	sud : Upland Dry Shrubland	Curlleaf Mountain Mahogany	*Cercocarpus ledifolius*	3, 4
			NRCS Ecol. Site R009XY014OR - Deep Loam (Black Hawthorn/Bluebunch Wheatgrass-Idaho Fescue	*NRCS Ecol. Site R009YT014OR - Deep Loam (Crataegus douglasii/Agropyron spicatum-Festuca idahoensis*	6
Moist Meadow Shrubland	25–59%	smm : Moist Meadow Shrubland	Shrubby Cinquefoil/Tufted Hairgrass	*Potentilla fruticosa/Deschampsia cespitosa*	1
			Shrubby Cinquefoil/Kentucky Bluegrass	*Potentilla fruticosa/Poa pratensis*	1
			NRCS Ecol. Site R010XY007OR - Sodic Bottom (Greasewood/Elymus cinereus-Distichlis spicata)	*NRCS Ecol. Site R010XY007OR - Sodic Bottom (Sarcobatus vermiculatus/Elymus cinereus-Distichlis spicata)*	6
Moist Upland Shrubland	25–100%	sum : Upland Moist Shrubland	Mallow Ninebark-Common Snowberry	*Physocarpus malvaceus-Symphoricarpos albus*	3, 4
			Common Snowberry-Rose	*Symphoricarpos albus-Rosa* spp.	3
Subalpine Steppe Herbland	---	hss : Subalpine Steppe Herbland	Green Fescue	*Festuca viridula*	4
			Green Fescue-Hood's Sedge	*Festuca viridula-Carex hoodii*	3
			Green Fescue-/Spurred Lupine	*Festuca viridula-Lupinus laxiflorus*	3
Dry Upland Steppe-Moist Great Basin Wildrye Complex		husgbwc : Dry Upland Steppe-Moist Great Basin Wildrye Complex	NRCS Ecol. Site R009XY005OR - Mountain Swale (Great Basin Wildrye-Bluebunch Wheatgrass-Idaho Fescue	*NRCS Ecol. Site R009XY005OR - Mountain Swale (Elymus cinereus-Agropyron spicatum-Festuca idahoensis)*	6
			NRCS Ecol. Site R009XY004OR - [Alluvial] Fan (Great Basin Wildrye-Bluebunch Wheatgrass)	*NRCS Ecol. Site R009XY004OR - [Alluvial] Fan (Elymus cinereus-Agropyron spicatum)*	6
Bluebunch Wheatgrass-Idaho Fescue Herbland	---	hbwif : Bluebunch Wheatgrass-Idaho Fescue Herbland	Idaho Fescue-Bluebunch Wheatgrass/Silky Lupine	*Festuca idahoensis-Agropyron spicatum/Lupinus sericeus*	3
			Idaho Fescue-Bluebunch Wheatgrass-Arrowleaf Balsamroot	*Festuca idahoensis-Agropyron spicatum-Balsamorhiza sagittata*	3
			Idaho Fescue-Hood's Sedge	*Festuca idahoensis-Carex hoodii*	3
			Idaho Fescue-Prairie Junegrass (Ridgetops)	*Festuca idahoensis-Koeleria cristata (Ridgetops)*	3
			Idaho Fescue-Prairie Junegrass (High Elevation)	*Festuca idahoensis-Koeleria cristata (High Elevation)*	3
			NRCS Ecol. Site R009XY013OR - Loamy (Idaho Fescue-Bluebunch Wheatgrass)	*NRCS Ecol. Site R009XY013OR - Loamy (Festuca idahoensis-Agropyron spicatum)*	6

Plant Association Group (PAG)	Range of Average Canopy Cover	Domain Code: Description	Plant Association/Plant Community Type–Common Name	Plant Association/Plant Community Type–Scientific Name	Source
Bluebunch Wheatgrass-Idaho Fescue Herbland (continued)			NRCS Ecol. Site R009XY021OR - Shallow Clayey; NRCS Ecol. Site R009XY016OR - Clayey (Idaho Fescue-Bluebunch Wheatgrass-Sandberg's Bluegrass)	*NRCS Ecol. Site R009XY021OR - Shallow Clayey; NRCS Ecol. Site R009XY016OR - Clayey (Festuca idahoensis-Agropyron spicatum-Poa sandbergii)*	6
			NRCS Ecol. Site R009XY036OR - Mountain Shallow South (Idaho Fescue-Bluebunch Wheatgrass-Arrowleaf Balsamroot)	*NRCS Ecol. Site R009XY036OR - Mountain Shallow South (Festuca idahoensis-Agropyron spicatum-Balsamorhiza sagittata)*	6
Dry Upland Steppe Herbland	---	husd : Dry Upland Steppe Herbland	Sandberg's Bluegrass-Onespike Oatgrass	*Poa sandbergii-Danthonia unispicata*	3, 4
			Bluebunch Wheatgrass-Sandberg's Bluegrass-Onespike Oatgrass	*Agropyron spicatum-Poa sandbergii-Danthonia unispicata*	4
			Bluebunch Wheatgrass-Sandberg's Bluegrass	*Agropyron spicatum-Poa sandbergii*	3, 4
			Bluebunch Wheatgrass-Sandberg's Bluegrass-Onespike Oatgrass	*NRCS Ecol. Site R009XY027OR - Mountain Very Shallow (Agropyron spicatum-Poa sandbergii-Danthonia unispicata)*	6
			Bluebunch Wheatgrass-Sandberg's Bluegrass-Narrowleaf Skullcap	*Agropyron spicatum-Poa sandbergii-Scutellaria angustifolia*	3
			Bluebunch Wheatgrass-Creamy Eriogonum	*Agropyron spicatum-Eriogonum heracleoides*	3
Dry Meadow Herbland		hmd : Dry Meadow Herbland	Common Timothy	*Phleum pratense*	1
			Kentucky Bluegrass	*Poa pratensis*	1
			Idaho Fescue-Bluebunch Wheatgrass/Silky Lupine	*Festuca idahoensis-Agropyron spicatum/Lupinus sericeus*	3
			Sandberg's Bluegrass-Onespike Oatgrass	*Poa sandbergii-Danthonia unispicata*	3, 4
Graminoid-Forb Gravel Bar Herbland	---	hgfgb : Graminoid-Forb Gravel Bar Herbland	Densely-tufted Sedge	*Carex lenticularis var. lenticularis*	1
			Drooping Woodreed	*Cinna latifolia*	1
			Tall Mannagrass	*Glyceria elata*	1
			Smallfruit Bulrush	*Scirpus microcarpus*	1
			Common Horsetail	*Equisetum arvense*	1
			Arrowleaf Groundsel	*Senecio triangularis*	1
Cold-wet Meadow Herbland	---	hwmc : Cold Wet Meadow Herbland	Holm's Rocky Mountain Sedge	*Carex scopulorum*	1, 7
			Few-flowered Spikerush	*Eleocharis pauciflora*	1, 7
			Silvery Sedge	*Carex canescens*	1, 7
Cold-moist Meadow Herbland	---	hmcm : Cold-moist Meadow Herbland	Jones' Sedge	*Carex jonesii*	7
			Black Alpine Sedge	*Carex nigricans*	7
			Mid-Montane (Blue Mtns NFs) Wetland Classification	*Deschampsia cespitosa*	1

Appendix 6. Continued.

Plant Association Group (PAG)	Range of Average Canopy Cover	Domain Code: Description	Plant Association/Plant Community Type–Common Name	Plant Association/Plant Community Type–Scientific Name	Source
Cold Wet-Moist Meadow Complex Herbland	---	hgmccwmc:Cold Wet-Moist Meadow Complex Herbland	Holm's Rocky Mountain Sedge	*Carex scopulorum*	1, 7
			Few-flowered Spikerush	*Eleocharis pauciflora*	1, 7
			Silvery Sedge	*Carex canescens*	1, 7
			Jones' Sedge	*Carex jonesii*	7
			Black Alpine Sedge	*Carex nigricans*	7
			Tufted Hairgrass	*Deschampsia cespitosa*	1
Wet Meadow Herbland	---	hwm : Wet Meadow Herbland	Aquatic Sedge	*Carex aquatilis*	1
			Big-leaved Sedge	*Carex amplifolia*	1
			Cusick's Sedge	*Carex cusickii*	1
			Sawbeak Sedge	*Carex stipata*	1
			Bladder Sedge	*Carex utriculata*	1
			Inflated Sedge	*Carex vesicaria var. vesicaria*	1
			Creeping Spikerush	*Eleocharis palustris*	1
Moist Meadow Herbland	---	hmm : Moist Meadow Herbland	Tufted Hairgrass	*Deschampsia cespitosa*	1
			NRCS Ecol. Site R010XY004OR - Meadow (Tufted Hairgrass)	*NRCS Ecol. Site R010XY004OR - Meadow (Deschampsia cespitosa)*	6
			NRCS Ecol. Site R010XY005OR - Loamy Bottom (Great Basin wildrye)	*NRCS Ecol. Site R010XY005OR - Loamy Bottom (Elymus cinereus)*	6
			Woolly Sedge	*Carex lanuginosa*	1
			Bluejoint Reedgrass	*Calamagrostis canadensis*	1
			Nebraska Sedge	*Carex nebrascensis*	1
			Baltic Rush	*Juncus balticus*	1
			Meadow Foxtail	*Alopecurus pratensis*	1
			Small-winged Sedge	*Carex microptera*	1
			Kentucky Bluegrass	*Poa pratensis*	1
Wet-Moist Meadow Complex Herbland	---	hgmcwmc:Wet-Moist Meadow Complex Herbland	Aquatic Sedge	*Carex aquatilis*	1
			Big-leaved Sedge	*Carex amplifolia*	1
			Cusick's Sedge	*Carex cusickii*	1
			Sawbeak Sedge	*Carex stipata*	1
			Bladder Sedge	*Carex utriculata*	1
			Inflated Sedge	*Carex vesicaria var. vesicaria*	1
			Creeping Spikerush	*Eleocharis palustris*	1
			Tufted Hairgrass	*Deschampsia cespitosa*	1

Appendix 6. Continued.

Plant Association Group (PAG)	Range of Average Canopy Cover	Domain Code: Description	Plant Association/Plant Community Type–Common Name	Plant Association/Plant Community Type–Scientific Name	Source
Wet-Moist Meadow Complex Herbland (continued)			NRCS Ecol. Site R010XY004OR - Meadow (Tufted Hairgrass)	*NRCS Ecol. Site R010XY004OR - Meadow (Deschampsia cespitosa)*	6
			NRCS Ecol. Site R010XY005OR - Loamy Bottom (Great Basin wildrye)	*NRCS Ecol. Site R010XY005OR - Loamy Bottom (Elymus cinereus)*	6
			Woolly Sedge	*Carex lanuginosa*	1
			Bluejoint Reedgrass	*Calamagrostis canadensis*	1
			Nebraska Sedge	*Carex nebrascensis*	1
			Baltic Rush	*Juncus balticus*	1
			Meadow Foxtail	*Alopecurus pratensis*	1
			Small-winged Sedge	*Carex microptera*	1
			Kentucky Bluegrass	*Poa pratensis*	1
Moist Forb Meadow Herbland	---	hfmm : Moist Forb Meadow Herbland	False Hellebore	*Veratrum* spp.	1
Miscellaneous Mapping Units		a : Agricultural Fields bbg : Barren rd : Roads ro : Rock ub: Buildings and Other Structures wf : Fresh Water xd : Developed Sites xu : Urban Complex			

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8 Classified from field plots sampled in 2014.

Appendix 7. Cross-reference table between potential vegetation complexes and plant association groups (PAGs) or ecological site descriptions (ESDs) and geomorphic units. Riparian vegetation mapping study in the Grande Ronde River watershed, Oregon, 2014.

			Geomorphic Surface(s) on Which Component Could Occur						
PAG Complex	Domain Code: Description	Complex Components: Plant Association Group (PAG); Ecological Site Description (ESD)	Meander Coarse Active Channel Deposit	Meander Inactive Channel Deposit	Meander Active Overbank Deposit	Meander Inactive Overbank Deposit	Meander Abandoned Overbank Deposit	Recent Alluvial Terrace	Old Oxbow
Low Elevation Black Cottonwood-Moist Meadow Floodplain Complex	fbcmmlfc : Low Elevation Black Cottonwood/Moist Meadow Floodplain Complex	Low Elevation Mountain Alder Floodplain Shrubland	X	X					
		Black Cottonwood/Willows Floodplain Forest	X	X	X				
		Low Elevation Black Cottonwood Floodplain Forest	X	X	X	X			
		White Willow Forest		X					
		Black Cottonwood Terrace Forest					X	X	
		Moist Ponderosa Pine Forest						X	
		Moist Meadow Herbland					X	X	
Low Elevation Moist Shrub/Graminoid Floodplain Complex	smmgrlfc : Low Elevation Moist Shrub/Graminoid Floodplain Complex	Low Elevation Mixed Shrubland	X	X	X				X
		White Willow Forest		X	X				
		Low Elevation Tall	X	X	X				

Appendix 7. Continued.

PAG Complex	Domain Code: Description	Complex Components: Plant Association Group (PAG); Ecological Site Description (ESD)	Geomorphic Surface(s) on Which Component Could Occur: Meander Coarse Active Channel Deposit	Meander Inactive Channel Deposit	Meander Active Overbank Deposit	Meander Inactive Overbank Deposit	Meander Abandoned Overbank Deposit	Recent Alluvial Terrace	Old Oxbow
		Willows Floodplain Shrubland							
		Black Hawthorn Shrubland				X	X	X	
		NRCS Ecol. Site R010XY003OR - Wet Meadow: Sedges-Tufted Hairgrass							X
		Moist Meadow Herbland				X	X	X	
Low Elevation Wet-Moist Shrub/Graminoid Floodplain Complex	swmmgrlfc : Low Elevation Wet-Moist Shrub/Graminoid Floodplain Complex	Low Elevation Mixed Shrubland		X	X	X			X
		White Willow Forest		X	X				
		Low Elevation Tall Willows Floodplain Shrubland	X	X	X				
		Low Elevation Tall Willows Wet Meadow Shrubland		X	X				
		Black Hawthorn Shrubland				X	X	X	
		NRCS Ecol. Site R010XY003OR - Wet	X	X					X

Appendix 7. Continued.

PAG Complex	Domain Code: Description	Complex Components: Plant Association Group (PAG); Ecological Site Description (ESD)	Meander Coarse Active Channel Deposit	Meander Inactive Channel Deposit	Meander Active Overbank Deposit	Meander Inactive Overbank Deposit	Meander Abandoned Overbank Deposit	Recent Alluvial Terrace	Old Oxbow
		Meadow: Sedges-Tufted Hairgrass							
		Moist Meadow Herbland					X	X	
Low Elevation Brackish Wet-Moist Shrub/Graminoid Meadow Floodplain Complex	swmmgrblfc : Low Elevation Brackish Wet-Moist Shrub/Graminoid Floodplain Complex	Low Elevation Mixed Shrubland		X	X	X			X
		White Willow Forest		X	X				
		Low Elevation Tall Willows Floodplain Shrubland	X	X	X				
		Low Elevation Tall Willows Wet Meadow Shrubland		X	X				
		NRCS Ecol. Site R010XY003OR - Wet Meadow: Sedges-Tufted Hairgrass		X	X				X
		NRCS Ecol. Site R010XY007OR - Sodic Bottom: Greasewood/Great Basin Wildrye-			X	X			

Appendix 7. Continued.

PAG Complex	Domain Code: Description	Complex Components: Plant Association Group (PAG); Ecological Site Description (ESD)	Geomorphic Surface(s) on Which Component Could Occur: Meander Coarse Active Channel Deposit	Meander Inactive Channel Deposit	Meander Active Overbank Deposit	Meander Inactive Overbank Deposit	Meander Abandoned Overbank Deposit	Recent Alluvial Terrace	Old Oxbow
		Saltgrass							
		NRCS Ecol. Site R010XY005OR - Loamy Bottom: Basin Big Sagebrush/Great Basin Wildrye					X	X	
		Moist Meadow Herbland						X	
Low Elevation Riverine Complex	xrl : Low-elevation Riverine Complex	Barrens (sand, gravel, cobble bars)	X						
		Graminoid-Forb Gravel Bar Herbland	X	X					
		Tall Willlows Gravel Bar Shrubland	X	X					
		Low Elevation Tall Willows Floodplain Shrubland			X				
		White Willow Forest		X					
		Low Elevation Black Cottonwood Floodplain Shrubland			X				
		Warm-moist Douglas-fir Forest			X	X			

Appendix 7. Continued.

PAG Complex	Domain Code: Description	Complex Components: Plant Association Group (PAG); Ecological Site Description (ESD)	Geomorphic Surface(s) on Which Component Could Occur: Meander Coarse Active Channel Deposit	Meander Inactive Channel Deposit	Meander Active Overbank Deposit	Meander Inactive Overbank Deposit	Meander Abandoned Overbank Deposit	Recent Alluvial Terrace	Old Oxbow
Mid Elevation Riverine Complex	xrm : Mid-elevation Riverine Complex	***Gentler Reaches***							
		Barrens (sand, gravel, cobble bars)	X						
		Graminoid-Forb Gravel Bar Herbland	X	X					
		Tall Willlows Gravel Bar Shrubland	X						
		Black Cottonwood Floodplain Forest			X				
		Steeper Reaches							
		Mountain Alder Floodplain Shrubland	X		X				
Upper Elevation Riverine Complex	xru : Upper-elevation Riverine Complex	***Gentler Reaches***							
		Barrens (sand, gravel, cobble bars)	X						
		Graminoid-Forb Gravel Bar Herbland	X	X					
		Aquatic Sedge Meadows		X					
		Tall Willows Moist Meadow Shrubland			X	X			

Appendix 7. Continued.

PAG Complex	Domain Code: Description	Complex Components: Plant Association Group (PAG); Ecological Site Description (ESD)	Geomorphic Surface(s) on Which Component Could Occur: Meander Coarse Active Channel Deposit	Meander Inactive Channel Deposit	Meander Active Overbank Deposit	Meander Inactive Overbank Deposit	Meander Abandoned Overbank Deposit	Recent Alluvial Terrace	Old Oxbow
		Tall Willows Wet Meadow Shrubland			X				
		Lodgepole Pine Moist Meadow				X			
		Dry Lodgepole Pine Forest				X			
		Steeper Reaches							
		Mountain Alder Floodplain Shrublands	X		X				
		Engelmann Spruce Forest			X				
		Cool-moist Grand Fir Forest			X	X			
		Subalpine Fir-Engelmann Spruce Forest			X	X			

Appendix 8. ITU code combination × ecotype × erosion sensitivity crosswalk.

Ecotype	Erosion Sensitivity	ITU
Freshwater	Negligible	L/Fmrox/Water/wf/wf/A
		L/Fmrox/Water/wf/wf/Ha
		L/Fmrox/Water/wf/wf/Hag
		L/Of/Water/wf/wf/Hp
		L/Wh/Water/wf/swmmgrblfc/Hwe
		L/Wh/Water/wf/swmmgrlfc/Hwc
		L/Wh/Water/wf/swwm/Hwe
		L/Wh/Water/wf/wf/Hag
		L/Wh/Water/wf/wf/Hwc
		L/Wh/Water/wf/wf/Hwd
		L/Wh/Water/wf/wf/Hwe
		L/Wh/Water/wf/wf/Hwi
		L/Wh/Water/wf/wf/Ngfe
		R/Fmrox/Water/wf/wf/A
		R/Fmrox/Water/wf/wf/Hag
		R/Fmrox/Water/wf/wf/Hwi
		R/H/Water/wf/wf/Hwi
		R/Wh/Water/wf/swmmgrlfc/Hwc
		R/Wh/Water/wf/wf/Hag
		R/Wh/Water/wf/wf/Hwc
		R/Wh/Water/wf/wf/Hwd
		R/Wr/Water/wf/wf/A
		R/Wr/Water/wf/wf/Hag
		R/Wr/Water/wf/wf/Hwc
		R/Wr/Water/wf/wf/Ngfe
Human Developments	Negligible	L/ff/LGr/ub/husgbwc/Hdr
		L/fmob/LovSk/ub/ub/Hdr
		L/fmob/LovSk/ub/xd/Hdr
		L/fmob/LovSk/xd/xu/DC
		L/fmob/LovSk/xd/xu/Hd
		L/fmob/LSil/ub/ub/Hd
		L/fmob/LSil/ub/ub/Hdr
		L/fmob/LSil/ub/ub/Hsb
		L/fmob/LSil/xd/xu/Hd
		L/fmob/LSilbr/ub/ub/Hd
		L/fmob/MDpCF/ub/ub/Hdr
		L/Fmolp/LSil/ub/ub/Hdr
		L/fto/LovSk/ub/ub/Hdr
		L/fto/LovSk/xd/xu/Hd
		L/fto/LSil/xd/xu/Hd

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Human Developments (continued)		L/ftr/AsilovSk/ub/ub/Haf
		L/ftr/LovSk/ub/fbcmmlfc/Hsb
		L/ftr/LovSk/ub/xd/Hdr
		L/ftr/LSil/ub/ub/Hdr
		L/ftr/LSil/ub/xd/Hdr
		L/H/LovSk/ub/ub/Hag
		L/H/LovSk/ub/ub/Hdr
		L/H/LovSk/xd/fbcmmlfc/Hd
		L/H/LovSk/xd/hmm/Hd
		L/H/LSil/ub/ub/Hdr
		L/H/LSil/xd/xd/Hd
		L/H/LSil/xd/xu/Hd
		L/H/LSil/xd/xu/Hdr
		L/H/LSilbr/ub/ub/Hsb
		R/fmoa/LSil/ub/ub/Hsb
		R/fmoi/LovSk/ub/swgb/Hdr
		R/fmoi/LovSk/ub/xd/Hdr
		R/fmoi/LSil/ub/ub/Hd
		R/H/LSil/ub/ub/Hsb
		U/ch/LGr/ub/ub/Hdr
		U/ch/LiShC/ub/ub/Hdr
		U/ch/LSil/ub/fdfm/Hdr
		U/ch/MDpCF/ub/ub/Hdr
		U/ch/StmBkHG/xd/fppm/DC
		U/ff/MDpCF/ub/ub/Hdr
		U/fto/LSil/ub/ub/Hdr
		U/H/LiShC/ub/ub/Hdr
Loamy Human-modified Barrens and Partially Vegetated	High	L/ff/LGr/bpa/husgbwc/Ha
		L/ff/LGr/bpvh/hmd/Hag
		L/fmob/DpSiCL/bpa/swmmgrlfc/Ha
		L/fmob/LovSk/bbg/fbcmmlfc/DC
		L/fmob/LovSk/bbg/fbcmmlfc/Haf
		L/fmob/LovSk/bpa/fbcmmlfc/Ha
		L/fmob/LovSk/bpa/fbcmmlfc/Hah
		L/fmob/LovSk/bpvh/fdfd/Hc
		L/fmob/LovSk/bpvh/fppm/Hag
		L/fmob/LovSk/bpvh/hmm/DC
		L/fmob/LovSk/bpvh/ub/Hd
		L/fmob/LSil/bpa/fbcmmlfc/Ha
		L/fmob/LSil/bpa/smmgrlfc/Ha

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Loamy Human-modified Barrens and Partially Vegetated (continued)		L/fmob/LSil/bpa/smmgrlfc/Hah
		L/fmob/LSil/bpa/smxl/Ha
		L/fmob/LSil/bpa/swmmgrlfc/Ha
		L/fmob/LSil/bpa/swmmgrlfc/Hah
		L/fmob/LSil/bpa/swmmgrlfc/Hwd
		L/fmob/LSilbr/bbg/bbg/Hf
		L/fmob/LSilbr/bpa/swmmgrblfc/Ha
		L/fmob/LSilbr/bpa/swmmgrlfc/DC
		L/fmob/LSilbr/bpa/swmmgrlfc/Ha
		L/fmob/LSilbr/bpa/swmmgrlfc/Hah
		L/fmob/LSilbr/bpa/swmmgrlfc/Hwl
		L/fmoi/LSilbr/bbg/swmmgrblfc/Hag
		L/Fmolp/LSil/bbg/swmmgrlfc/Ha
		L/Fmolp/LSil/bpa/smmgrlfc/Ha
		L/Fmolp/LSil/bpa/swmmgrlfc/Ha
		L/Fmolp/LSilbr/bbg/swmmgrblfc/Ha
		L/Fmolp/LSilbr/bpa/swmmgrblfc/Ha
		L/Fmolp/LSilbr/bpa/swmmgrlfc/Ha
		L/Fmolp/LSilbr/bpa/swmmgrlfc/Hah
		L/Fmrox/LSilbr/bbg/swmmgrlfc/Hag
		L/ftr/LovSk/bpa/fbcmmlfc/Ha
		L/ftr/LSil/bpvh/flpmm/Hag
		L/H/LovSk/bbg/bbg/Hag
		L/H/LSil/bbg/bbg/Hsisd
		L/H/LSil/bbg/bbg/Hwi
		L/H/LSil/bbg/bbg/Hwl
		L/H/LSil/bbg/fbcmmlfc/Hwl
		R/fmob/LSil/bpa/swmmgrlfc/Ha
		R/fmoi/LGr/bpvh/fbcf/Hc
		R/fmoi/LSil/bbg/bbg/Haf
		R/fmoi/LSil/bpa/swmmgrlfc/Ha
		R/fmoi/LSil/bpa/swmmgrlfc/Hag
Lowland Loamy Agricultural Lands	High	L/fmob/AsilovSk/hgm/hmm/Hah
		L/fmob/DpSiCL/hgm/swmmgrlfc/Hah
		L/fmob/LiShC/hgm/fbclf/Hp
		L/fmob/LovSk/hgm/fbbcwf/Hah
		L/fmob/LovSk/hgm/fbclf/Ha
		L/fmob/LovSk/hgm/fbclf/Hah
		L/fmob/LovSk/hgm/fbcmmlfc/Haf
		L/fmob/LovSk/hgm/fbcmmlfc/Hah

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Agricultural Lands (continued)		L/fmob/LovSk/hgm/hmm/Ha
		L/fmob/LovSk/hgm/hmm/Hah
		L/fmob/LovSk/hgm/swmmgrlfc/Hah
		L/fmob/LovSk/hgwmcc/hgmcwmc/Hp
		L/fmob/LovSk/hpa/a/Ha
		L/fmob/LovSk/xa/a/Ha
		L/fmob/LSil/hca/swmmgrblfc/Hac
		L/fmob/LSil/hca/swmmgrlfc/Hac
		L/fmob/LSil/hgm/fbcmmlfc/Ha
		L/fmob/LSil/hgm/fbcmmlfc/Hah
		L/fmob/LSil/hgm/fppm/Haf
		L/fmob/LSil/hgm/hmm/Ha
		L/fmob/LSil/hgm/hmm/Hah
		L/fmob/LSil/hgm/hmm/Hp
		L/fmob/LSil/hgm/smxl/Ha
		L/fmob/LSil/hgm/swmmgrlfc/Ha
		L/fmob/LSil/hgm/swmmgrlfc/Hah
		L/fmob/LSil/hgm/swmmgrlfc/Hp
		L/fmob/LSil/hgw/fbcmmlfc/Hah
		L/fmob/LSil/hgw/hwm/Hp
		L/fmob/LSil/hgwmcc/swmmgrlfc/Hah
		L/fmob/LSil/hpa/hmm/Hp
		L/fmob/LSil/xa/ub/DC
		L/fmob/LSilbr/hca/swmmgrblfc/Hac
		L/fmob/LSilbr/hca/swmmgrlfc/Hac
		L/fmob/LSilbr/hgm/smxl/Ha
		L/fmob/LSilbr/hgm/swmmgrlfc/Hah
		L/fmob/LSilbr/hgwmcc/fbcmmlfc/Hah
		L/fmob/LSilor/hgw/hwm/Ha
		L/fmoi/LSilbr/hgw/swmmgrlfc/Ha
		L/Fmolp/LSil/hca/swmmgrlfc/Hac
		L/Fmolp/LSil/hgm/fbbcwf/Hah
		L/Fmolp/LSil/hgm/swmmgrlfc/Ha
		L/Fmolp/LSil/hgm/swmmgrlfc/Hah
		L/Fmolp/LSil/hpa/swmmgrlfc/Hp
		L/Fmolp/LSilbr/hca/swmmgrlfc/Hac
		L/Fmolp/LSilbr/hgm/swmmgrlfc/Ha
		L/Fmolp/LSilbr/hgm/swmmgrlfc/Hah
		L/fmri/LSil/hgw/swmmgrlfc/Hah
		L/Fmrox/LSil/hgw/swmmgrlfc/Ha
		L/Fmrox/LSilbr/hgm/swmmgrlfc/Ha

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Agricultural Lands (continued)		L/Fmrox/LSilbr/hgm/swmmgrlfc/Hah
		L/Fmrox/LSilbr/hgw/hwm/Ha
		L/fto/LSil/hgm/hmm/Ha
		L/ftr/LiShC/hgw/hwm/Hp
		L/ftr/LSil/hgm/a/Ha
		L/ftr/LSil/hgm/hmm/Hah
		L/ftr/LSil/xa/a/Ha
		L/ftr/LSilor/hgw/hwm/Ha
		L/ftr/LSilor/hgwmcc/hwm/Ha
		L/H/LSil/hgm/swmmgrlfc/Hah
Lowland Loamy Black Cottonwood Forest	Low	L/fmob/AsilovSk/fboc/fbclf/DC
		L/fmob/AsilovSk/fmbcgfo/fgfcmo/A
		L/fmob/LGr/fboc/fbct/DC
		L/fmob/LGr/fmbcdfo/fdfm/A
		L/fmob/LovSk/fbcc/fbclf/DC
		L/fmob/LovSk/fbcc/fbct/DC
		L/fmob/LovSk/fboc/fbcf/A
		L/fmob/LovSk/fboc/fbclf/A
		L/fmob/LovSk/fboc/fbclf/DC
		L/fmob/LovSk/fboc/fbcmmlfc/Hwc
		L/fmob/LovSk/fboc/fbct/A
		L/fmob/LovSk/fboc/fbct/DC
		L/fmob/LovSk/fbwc/fbcmmlfc/A
		L/fmob/LovSk/fbwc/fbct/A
		L/fmob/LovSk/fbwc/fbct/DC
		L/fmob/LovSk/fbwc/fbct/Hd
		L/fmob/LovSk/fmbcdfo/fbclf/A
		L/fmob/LovSk/fmbcdfo/fdfmo/A
		L/fmob/LovSk/fmbceso/fes/A
		L/fmob/LovSk/fmbceso/fgfcm/A
		L/fmob/LovSk/fmbcgfo/fgfcmo/A
		L/fmob/LovSk/fmbcppo/fbclf/A
		L/fmob/LovSk/fmbcppo/fbcmmlfc/A
		L/fmob/LovSk/fmbcppo/fbct/DC
		L/fmob/LovSk/fmbcppo/fppm/A
		L/fmob/LSil/fbcc/fbclf/A
		L/fmob/LSil/fbcc/fbclf/DC
		L/fmob/LSil/fbcc/swmmgrlfc/A
		L/fmob/LSil/fboc/fbcf/Hag
		L/fmob/LSil/fboc/fbclf/DC

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Black Cottonwood Forest		L/fmob/LSil/fboc/fbclf/Hd
		L/fmob/LSil/fboc/fbclf/Hdr
		L/fmob/LSil/fboc/fbct/A
		L/fmob/LSil/fboc/fbct/DC
		L/fmob/LSil/fboc/fbct/Hd
		L/fmob/SSkEnt/fboc/fbct/A
		L/fmri/LovSk/fboc/fbclf/Ha
		L/fmri/LovSk/fmbcppo/fbcf/A
		L/fmri/LSil/fboc/fbclf/Hwc
		L/Fmrox/LovSk/fboc/fbct/DC
		L/H/LovSk/fboc/fbct/DC
		L/H/LSil/fboc/fbclf/Hdr
		L/H/LSil/fboc/fbct/Hc
Lowland Loamy Black Hawthorn Tall Shrub	Low	L/fmob/AsilovSk/stcbh/sbh/Hag
		L/fmob/LGr/stcbh/sbh/A
		L/fmob/LGr/stobh/sbh/Hag
		L/fmob/LGr/stobh/smaf/Hag
		L/fmob/LovSk/stcbh/fbct/Hag
		L/fmob/LovSk/stcbh/fppm/Hag
		L/fmob/LovSk/stcbh/sbh/A
		L/fmob/LovSk/stcbh/sbh/Hag
		L/fmob/LovSk/stobh/fbcf/Hag
		L/fmob/LovSk/stobh/fbclf/Hag
		L/fmob/LovSk/stobh/fbcmmlfc/Hag
		L/fmob/LovSk/stobh/fdfwm/Hag
		L/fmob/LovSk/stobh/fppm/Hag
		L/fmob/LovSk/stobh/sbh/A
		L/fmob/LovSk/stobh/sbh/DC
		L/fmob/LovSk/stobh/sbh/Hag
		L/fmob/LovSk/stobh/smalf/Hag
		L/fmob/LSil/stcbh/fbbcwf/Hag
		L/fmob/LSil/stcbh/fppm/Hag
		L/fmob/LSil/stcbh/sbh/A
		L/fmob/LSil/stcbh/sbh/DC
		L/fmob/LSil/stcbh/sbh/Hag
		L/fmob/LSil/stcbh/sbh/Hdr
		L/fmob/LSil/stobh/fbcmmlfc/Hag
		L/fmob/LSil/stobh/fdfm/Hag
		L/fmob/LSil/stobh/sbh/A
		L/fmob/LSil/stobh/sbh/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Black Hawthorn Tall Shrub (continued)		L/fmob/LSil/stobh/swmmgrlfc/Hag
		L/ftr/LovSk/stcbh/sbh/Hag
		L/ftr/LovSk/stobh/sbh/Hag
		L/ftr/LSil/stcbh/sbh/Hag
Lowland Loamy Douglas-fir Forest	Low	L/ff/DpCF/fncdf/fdfm/A
		L/fmob/AsilovL/fnodf/fdfwm/A
		L/fmob/AsilovSk/fncdf/fdflm/Hc
		L/fmob/AsilovSk/fncdf/fdfwm/A
		L/fmob/AsilovSk/fndfw/fdfm/A
		L/fmob/AsilovSk/fndfw/fdfwm/A
		L/fmob/AsilovSk/fnodf/fdfd/A
		L/fmob/AsilovSk/fnodf/fdfwm/A
		L/fmob/LGr/fndfw/fdfmo/A
		L/fmob/LGr/fndfw/fdfwm/A
		L/fmob/LGr/fnodf/fdfm/A
		L/fmob/LGr/fnodf/fdfwm/A
		L/fmob/LiShC/fnodf/fdfwm/A
		L/fmob/LovSk/fncdf/fdfd/Hc
		L/fmob/LovSk/fncdf/fdfm/A
		L/fmob/LovSk/fncdf/fdfwm/A
		L/fmob/LovSk/fndfw/fdfm/A
		L/fmob/LovSk/fndfw/fdfwm/A
		L/fmob/LovSk/fnodf/fdfm/A
		L/fmob/LovSk/fnodf/fdfmo/A
		L/fmob/LovSk/fnodf/fdfmo/DC
		L/fmob/LovSk/fnodf/fdfwm/A
		L/fmob/LovSk/fnodf/fdfwm/Hcl
		L/fmob/LovSk/fnodf/fdfwm/Hsb
		L/fmob/LSil/fncdf/fdfm/Nf
		L/fmob/LSil/fncdf/fdfwm/A
		L/fmob/LSil/fndfw/fdfm/A
		L/fmob/LSil/fndfw/fdfm/Ngfe
		L/fmob/LSil/fndfw/fdfwm/A
		L/fmob/LSil/fndfw/fdfwm/DC
		L/fmob/LSil/fnodf/fdfm/A
		L/fmob/LSil/fnodf/fdfm/DC
		L/fmob/LSil/fnodf/fdfmo/A
		L/fmob/LSil/fnodf/fdfwm/A
		L/fmob/LSil/fnodf/fdfwm/DC
		L/fmob/LSil/fnodf/fdfwm/Hc

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Douglas-fir Forest (continued)		L/fmob/LSil/fnodf/fdfwm/Nf
		L/fmob/MDpCF/fncdf/fdfwm/A
		L/fmob/MDpCF/fndfw/fdfm/A
		L/fmob/MDpCF/fndfw/fdfwm/A
		L/fmob/MDpCF/fnodf/fdfwm/Haf
		L/fmob/SSkEnt/fndfw/fdfmo/DC
		L/fmob/StmBkHG/fndfw/fdfwm/A
		L/fto/AsilovSk/fnodf/fdfd/A
		L/fto/LGr/fncdf/fdfwm/A
		L/fto/LiShC/fncdf/fdfwm/A
		L/fto/LSil/fncdf/fdfd/DC
		L/fto/LSil/fncdf/fdfm/DC
		L/fto/LSil/fncdf/fdfmo/A
		L/fto/LSil/fnodf/fdfd/DC
		L/fto/LSil/fnodf/fdfmo/DC
		L/fto/MDpCF/fnodf/fdfd/A
		L/fto/MDpCF/fnodf/fdfm/A
		L/ftr/AsilovL/fncdf/fdfd/Hc
		L/ftr/AsilovL/fnodf/fdfwm/A
		L/ftr/AsilovSk/fnodf/fdfm/A
		L/ftr/AsilovSk/fnodf/fdfmo/He
		L/ftr/AsilovSk/fnodf/fdfwm/A
		L/ftr/LovSk/fndfw/fdfm/A
		L/ftr/LovSk/fndfw/fdfwm/A
		L/ftr/LovSk/fnodf/fdfm/A
		L/ftr/LSil/fncdf/fdfd/Hag
		L/ftr/LSil/fnodf/fdfd/A
		L/ftr/LSil/fnodf/fdfm/A
		L/ftr/LSil/fnodf/fdfm/Nf
		L/ftr/LSil/fnodf/fdfwm/A
Lowland Loamy Dry Graminoid Meadow	High	L/ff/LSil/hus/hbwif/DC
		L/fmob/AsilovSk/hgd/fdfm/Hag
		L/fmob/AsilovSk/hus/husd/Hf
		L/fmob/DpCF/hgd/smaf/Hsisd
		L/fmob/LovSk/hgd/fbcmmlfc/DC
		L/fmob/LovSk/hgd/fbcmmlfc/Ha
		L/fmob/LovSk/hgd/fbcmmlfc/Hag
		L/fmob/LovSk/hgd/fbct/DC
		L/fmob/LovSk/hgd/fbct/Hag
		L/fmob/LovSk/hgd/fdfm/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Dry Graminoid Meadow (continued)		L/fmob/LovSk/hgd/fdfm/Hc
		L/fmob/LovSk/hgd/fdfm/Nf
		L/fmob/LovSk/hgd/fdfwm/Hag
		L/fmob/LovSk/hgd/fdfwm/Hc
		L/fmob/LovSk/hgd/flpd/Hag
		L/fmob/LovSk/hgd/flpmm/Hag
		L/fmob/LovSk/hgd/fppd/Hag
		L/fmob/LovSk/hgd/fppm/Hag
		L/fmob/LovSk/hgd/fppm/Hc
		L/fmob/LovSk/hgd/fppmo/Hag
		L/fmob/LovSk/hgd/hmd/Hag
		L/fmob/LovSk/hgd/scs/Hag
		L/fmob/LovSk/hgd/smaf/Hag
		L/fmob/LovSk/hgd/smaf/Hc
		L/fmob/LovSk/hgd/smawm/Hag
		L/fmob/LovSk/hgd/smm/DC
		L/fmob/LovSk/hgd/swmm/Hag
		L/fmob/LSil/hgd/a/Ha
		L/fmob/LSil/hgd/fbcmmlfc/DC
		L/fmob/LSil/hgd/fbcmmlfc/Hd
		L/fmob/LSil/hgd/fdfm/A
		L/fmob/LSil/hgd/fdfm/Hag
		L/fmob/LSil/hgd/fgfwd/Hag
		L/fmob/LSil/hgd/flpmm/Hag
		L/fmob/LSil/hgd/fppm/Hag
		L/fmob/LSil/hgd/hmd/A
		L/fmob/LSil/hgd/hmd/Ha
		L/fmob/LSil/hgd/hmd/Hag
		L/fmob/LSil/hgd/hmd/Hdr
		L/fmob/LSil/hgd/hmm/Hag
		L/fmob/LSil/hgd/hwm/Hag
		L/fmob/LSil/hgd/smaf/Hag
		L/fmob/LSil/hgd/swmmgrlfc/Hwc
		L/fmob/LSil/hus/hbwif/Hag
		L/fmob/LSilor/hgd/hmd/Hag
		L/fmob/LSilor/hgd/hmm/Hag
		L/fmob/LSilor/hgd/swwm/Hag
		L/fto/LiShC/hus/hbwif/Hag
		L/fto/LovSk/hgd/fppd/Hag
		L/fto/LovSk/hgd/fppm/Hag
		L/fto/LovSk/hgd/fppm/Hdr

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Dry Graminoid Meadow (continued)		L/fto/LSil/hgd/flpd/Hag
		L/fto/LSil/hgd/hbwif/Hc
		L/fto/LSil/hgd/hgmcwmc/Hag
		L/fto/LSil/hgd/hmd/A
		L/fto/LSil/hgd/hmd/DC
		L/fto/LSil/hgd/hmd/Hag
		L/fto/LSil/hgd/hmm/A
		L/fto/LSil/hgd/hmm/Hag
		L/fto/LSil/hus/hbwif/Hc
		L/ftr/AsilovL/hgd/fdfwm/Hag
		L/ftr/AsilovL/hgd/fppm/Hc
		L/ftr/AsilovL/hus/husd/DC
		L/ftr/AsilovSk/hgd/flpd/Hag
		L/ftr/AsilovSk/hgd/hmm/Hag
		L/ftr/LiShC/hus/hbwif/Hag
		L/ftr/LovSk/hgd/fdfm/Hag
		L/ftr/LovSk/hgd/fppm/Hag
		L/ftr/LovSk/hgd/hmd/Hag
		L/ftr/LSil/hgd/a/Ha
		L/ftr/LSil/hgd/fdfd/Hag
		L/ftr/LSil/hgd/fdfm/Hag
		L/ftr/LSil/hgd/fdfm/Nf
		L/ftr/LSil/hgd/fdfwm/Hag
		L/ftr/LSil/hgd/fgfwd/Hag
		L/ftr/LSil/hgd/flpd/Hag
		L/ftr/LSil/hgd/flpmm/Hag
		L/ftr/LSil/hgd/fppd/Ha
		L/ftr/LSil/hgd/fppm/Hag
		L/ftr/LSil/hgd/hgmcwmc/Hag
		L/ftr/LSil/hgd/hmd/A
		L/ftr/LSil/hgd/hmd/Hag
		L/ftr/LSil/hgd/hmd/Hc
		L/ftr/LSil/hgd/hmd/Hdr
		L/ftr/LSil/hgd/hmm/Hag
		L/ftr/LSil/hgd/hwm/Hag
		L/ftr/LSilor/hgd/hwm/Hag
		L/H/DpCF/hgd/fppd/Hf
		L/H/DpCF/hgd/sbh/Hf
		L/H/LiShC/hus/hbwif/Hf
		L/H/LovSk/hgd/fbcmmlfc/Hag
		L/H/LovSk/hgd/fbcmmlfc/Hf

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Dry Graminoid Meadow (continued)		L/H/LovSk/hgd/hmd/Hf
		L/H/LovSk/hus/husd/Hf
		L/H/LSil/hus/hbwif/A
		L/H/LSil/hus/hbwif/He
		L/H/LSil/hus/husd/Hf
Lowland Loamy Forb Meadow	Moderate	L/fmob/LovSk/hfm/fdfwm/Hag
		L/fmob/LSil/hfm/fdfwm/Hag
		L/fmob/LSilor/hfm/hwm/Hag
		L/ftr/LSil/hfm/hmcm/A
Lowland Loamy Grand-fir Forest	Low	L/ff/LovSk/fnog/fgfwdo/A
		L/fmob/AsilovL/fncg/fgfcm/A
		L/fmob/AsilovSk/fncg/fgfcm/A
		L/fmob/AsilovSk/fncg/fgfcmo/A
		L/fmob/AsilovSk/fncg/fgfwd/A
		L/fmob/AsilovSk/fncg/fgfwdo/A
		L/fmob/AsilovSk/fngfw/fgfcmo/A
		L/fmob/AsilovSk/fnog/fdfwm/A
		L/fmob/AsilovSk/fnog/fgfc/A
		L/fmob/AsilovSk/fnog/fgfcm/A
		L/fmob/AsilovSk/fnog/fgfcmo/A
		L/fmob/AsilovSk/fnog/fgfcmo/Hcl
		L/fmob/AsilovSk/fnog/fgfeso/A
		L/fmob/AsilovSk/fnog/fgfwdo/A
		L/fmob/DpCF/fngfw/fgfes/A
		L/fmob/LovSk/fncg/fgfcm/A
		L/fmob/LovSk/fngfw/fgfcm/A
		L/fmob/LovSk/fngfw/fgfcmo/A
		L/fmob/LovSk/fnog/fdfwm/A
		L/fmob/LovSk/fnog/fgfcm/A
		L/fmob/LovSk/fnog/fgfcmo/A
		L/fmob/LovSk/fnog/fgfwd/A
		L/fmob/LSil/fncg/fgfcmo/A
		L/fmob/LSil/fngfw/fgfwd/A
		L/fmob/LSil/fnog/fgfcm/A
		L/fmob/LSil/fnog/fgfcmo/A
		L/fmob/LSil/fnog/fgfwd/A
		L/fmob/MDpCF/fnog/fgfcmo/A
		L/fmob/MDpCF/fnog/fgfes/Hft
		L/fto/AsilovL/fncg/fgfcm/A
		L/fto/AsilovSk/fnog/fgfcm/A
		L/fto/AsilovSk/fnog/fgfcmo/A

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Grand-fir Forest (continued)		L/fto/AsilovSk/fnog/fgfwdo/DC
		L/ftr/AsilovL/fncg/fgfcm/A
		L/ftr/AsilovL/fnog/fgfcm/A
		L/ftr/AsilovSk/fngfw/fgfcm/DC
		L/ftr/AsilovSk/fnog/fgfcm/A
		L/ftr/AsilovSk/fnog/fgfeso/A
		L/ftr/AsilovSk/fnog/fgfwd/A
		L/ftr/LiShC/fngfw/fgfcm/A
		L/ftr/LovSk/fncg/fgfcm/A
		L/ftr/LovSk/fnog/fgfcm/A
		L/ftr/LSil/fnog/fgfcm/A
		L/ftr/LSil/fnog/fgfcmo/A
		L/ftr/LSil/fnog/fgfwd/A
		L/ftr/MDpCF/fnog/fgfc/A
		L/H/DpCF/fnog/fgfc/Hft
Lowland Loamy Lodgepole Pine Forest	Low	L/fmob/AsilovL/fncl/flpmm/A
		L/fmob/AsilovL/fnol/flpmm/A
		L/fmob/AsilovL/fnwl/flpmm/A
		L/fmob/AsilovSk/fncl/flpd/A
		L/fmob/AsilovSk/fnol/flpd/A
		L/fmob/AsilovSk/fnol/fsfeso/Nf
		L/fmob/AsilovSk/fnwl/flpmm/A
		L/fmob/AsilovSk/fnwl/flpwm/A
		L/fmob/LGr/fnwl/flpmm/A
		L/fmob/LGr/fnwl/flpwm/Hcl
		L/fmob/LovSk/fncl/flpmm/A
		L/fmob/LovSk/fncl/flpmm/Hft
		L/fmob/LovSk/fncl/flpwm/A
		L/fmob/LovSk/fnol/flpmm/A
		L/fmob/LovSk/fnol/flpwm/A
		L/fmob/LovSk/fnol/fppm/A
		L/fmob/LovSk/fnwl/flpmm/A
		L/fmob/LovSk/fnwl/flpmm/Hag
		L/fmob/LovSk/fnwl/flpmm/Hcl
		L/fmob/LovSk/fnwl/flpwm/A
		L/fmob/LovSk/fnwl/fppm/Hag
		L/fmob/LSil/fncl/flpmm/A
		L/fmob/LSil/fnol/flpmm/A
		L/fmob/LSil/fnwl/flpmm/A
		L/fmob/LSil/fnwl/flpmm/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Lodgepole Pine Forest (continued)		L/fmob/LSil/fnwl/flpmm/Hcl
		L/fmob/LSil/fnwl/flpwm/Hag
		L/fmob/LSilor/fncl/flpmm/A
		L/fmob/LSilor/fnol/flpmm/A
		L/fmob/SSkEnt/fncl/flpmm/Hft
		L/fmob/SSkEnt/fnol/flpmm/Hft
		L/fmob/SSkEnt/fnwl/flpmm/Hft
		L/fto/LiShC/fncl/fgfcmo/Nf
		L/fto/LiShC/fncl/flpd/A
		L/fto/LSil/fncl/flpd/A
		L/fto/LSil/fncl/flpmm/A
		L/fto/LSil/fnol/flpd/A
		L/fto/LSil/fnol/flpd/DC
		L/fto/LSil/fnol/flpmm/A
		L/fto/LSil/fnwl/flpd/Hag
		L/fto/LSil/fnwl/flpmm/Hag
		L/ftr/AsilovL/fncl/flpmm/A
		L/ftr/AsilovL/fnol/fgfcm/A
		L/ftr/AsilovL/fnol/flpd/A
		L/ftr/AsilovL/fnol/flpmm/A
		L/ftr/AsilovL/fnwl/flpmm/Hag
		L/ftr/AsilovSk/fnol/fgfwd/Nf
		L/ftr/LiShC/fncl/flpmm/A
		L/ftr/LiShC/fnol/flpmm/A
		L/ftr/LiShC/fnwl/flpmm/Hag
		L/ftr/LovSk/fncl/flpmm/A
		L/ftr/LovSk/fnol/flpmm/A
		L/ftr/LovSk/fnwl/flpmm/A
		L/ftr/LSil/fncl/flpd/A
		L/ftr/LSil/fncl/flpmm/A
		L/ftr/LSil/fnol/flpd/A
		L/ftr/LSil/fnol/flpmm/A
		L/ftr/LSil/fnwl/fgfcmo/Nf
		L/ftr/LSil/fnwl/flpd/A
		L/ftr/LSil/fnwl/flpd/Hag
		L/ftr/LSil/fnwl/flpmm/A
		L/ftr/LSil/fnwl/flpmm/Hag
		L/ftr/LSil/fnwl/flpmm/Hft

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Low Elevation Mixed Shrubland	Low	L/fmob/DpSiCL/smxlc/smxl/Hag
		L/fmob/LovSk/smxlc/fbcmmlfc/Ha
		L/fmob/LovSk/smxlc/smxl/DC
		L/fmob/LSil/smxlc/smmgrlfc/Ha
		L/fmob/LSil/smxlc/smxl/Hag
		L/fmob/LSil/smxlc/smxl/Hwc
		L/fmob/LSil/smxlc/swmmgrlfc/Hwd
		L/fmob/LSil/smxlo/smxl/DC
		L/fmob/LSil/smxlo/smxl/Ha
		L/fmob/LSil/smxlo/smxl/Hf
		L/fmob/LSil/smxlo/smxl/Hwc
		L/fmob/LSilbr/smxlc/swmmgrlfc/Ha
		L/fmob/LSilbr/smxlc/swmmgrlfc/Hag
		L/fmob/LSilbr/smxlo/smxl/Ha
		L/fmob/LSilbr/smxlo/swmmgrlfc/Hag
		L/fmob/Water/smxlo/smxl/DC
		L/Fmolp/LSil/smxlc/swmmgrlfc/Hag
		L/Fmolp/LSil/smxlo/smxl/DC
		L/Fmrox/LSil/smxlc/smxl/DC
		L/Fmrox/LSil/smxlc/smxl/Ha
		L/Fmrox/LSilbr/smxlc/smxl/DC
		L/fto/LiShC/smxlc/smxl/Hag
		L/H/LSilbr/smxlc/swmmgrlfc/Hwd
		L/Wh/LGr/smxlc/smxl/Hwc
		L/Wh/LGr/smxlo/smxl/Hwc
		L/Wh/LGr/smxlo/smxl/Hwd
Lowland Loamy Moist Graminoid Meadow	Moderate	L/ff/DpCF/hgm/fppm/Hag
		L/ff/LSil/hgm/hmm/Hag
		L/fmob/AsilovL/hgm/flpmm/Hag
		L/fmob/AsilovSk/hgm/hmcm/DC
		L/fmob/AsilovSk/hgm/hmm/A
		L/fmob/AsilovSk/hgm/hmm/Hcl
		L/fmob/LovSk/hgm/fbcmmlfc/DC
		L/fmob/LovSk/hgm/fbcmmlfc/Hag
		L/fmob/LovSk/hgm/fbcmmlfc/Hd
		L/fmob/LovSk/hgm/fbct/Hag
		L/fmob/LovSk/hgm/fdfm/Hag
		L/fmob/LovSk/hgm/fdfm/Hc
		L/fmob/LovSk/hgm/fdfwm/DC

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Moist Graminoid Meadow (continued)		L/fmob/LovSk/hgm/fdfwm/Hag
		L/fmob/LovSk/hgm/fdfwm/Hc
		L/fmob/LovSk/hgm/fdfwm/Hcl
		L/fmob/LovSk/hgm/flpmm/Hag
		L/fmob/LovSk/hgm/flpmm/Hcl
		L/fmob/LovSk/hgm/fppm/Hag
		L/fmob/LovSk/hgm/hgmcwmc/Hag
		L/fmob/LovSk/hgm/hmm/A
		L/fmob/LovSk/hgm/hmm/DC
		L/fmob/LovSk/hgm/hmm/Hag
		L/fmob/LovSk/hgm/hwm/Hag
		L/fmob/LovSk/hgm/sbh/Hag
		L/fmob/LovSk/hgm/smaf/Hag
		L/fmob/LovSk/hgm/smawm/Hc
		L/fmob/LovSk/hgm/swmm/Hag
		L/fmob/LovSk/hgm/swmmgrlfc/DC
		L/fmob/LovSk/hgm/swwm/Hag
		L/fmob/LovSk/hgm/xd/Hdr
		L/fmob/LSil/hgm/fbbcwf/Hag
		L/fmob/LSil/hgm/fbclf/Hag
		L/fmob/LSil/hgm/fbcmmlfc/Hag
		L/fmob/LSil/hgm/fbcmmlfc/Hwl
		L/fmob/LSil/hgm/fbct/Hag
		L/fmob/LSil/hgm/fbct/Hf
		L/fmob/LSil/hgm/fdfm/Hag
		L/fmob/LSil/hgm/flpmm/Hag
		L/fmob/LSil/hgm/flpmm/Hcl
		L/fmob/LSil/hgm/fppm/Hag
		L/fmob/LSil/hgm/hfmm/Hag
		L/fmob/LSil/hgm/hgmcwmc/Hag
		L/fmob/LSil/hgm/hmcm/Hag
		L/fmob/LSil/hgm/hmm/DC
		L/fmob/LSil/hgm/hmm/Hag
		L/fmob/LSil/hgm/hwm/Hag
		L/fmob/LSil/hgm/sbh/Hag
		L/fmob/LSil/hgm/swmm/Hag
		L/fmob/LSil/hgm/swmmgrlfc/DC
		L/fmob/LSil/hgm/swmmgrlfc/Hag
		L/fmob/LSil/hgm/swmmgrlfc/Hdr
		L/fmob/LSil/hgm/swmmgrlfc/Hwc
		L/fmob/LSil/hgm/swmmgrlfc/Hwl

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Moist Graminoid Meadow (continued)		L/fmob/LSil/hgm/swwm/Hag
		L/fmob/LSilbr/hgm/fbcmmlfc/Hag
		L/fmob/LSilbr/hgm/swmmgrblfc/DC
		L/fmob/LSilbr/hgm/swmmgrblfc/Hag
		L/fmob/LSilbr/hgm/swmmgrlfc/Hag
		L/fmob/LSilbr/hgm/swmmgrlfc/Hwl
		L/fmob/LSilor/hgm/flpmm/A
		L/fmob/LSilor/hgm/flpmm/Hag
		L/fmob/LSilor/hgm/hfmm/Hag
		L/fmob/LSilor/hgm/hgmcwmc/Hag
		L/fmob/LSilor/hgm/hmm/Hag
		L/fmob/LSilor/hgm/hwm/Hag
		L/fmoi/LSil/hgm/swmmgrlfc/Hag
		L/fmoi/LSilbr/hgm/swmmgrblfc/Hag
		L/fmoi/LSilbr/hgm/swmmgrlfc/Hag
		L/Fmolp/LSil/hgm/fbbcwf/DC
		L/Fmolp/LSil/hgm/smxl/Ngfe
		L/Fmolp/LSil/hgm/swmmgrlfc/DC
		L/Fmolp/LSil/hgm/swmmgrlfc/Hag
		L/Fmolp/LSil/hgm/swmmgrlfc/Hwc
		L/Fmolp/LSilbr/hgm/fbbcwf/DC
		L/Fmolp/LSilbr/hgm/fbbcwf/Hag
		L/Fmolp/LSilbr/hgm/hmm/Hag
		L/Fmolp/LSilbr/hgm/swmmgrlfc/DC
		L/Fmolp/LSilbr/hgm/swmmgrlfc/Hag
		L/Fmolp/LSilbr/hgm/swmmgrlfc/Hwc
		L/fmri/LovSk/hgm/fbcmmlfc/Hag
		L/fmri/LovSk/hgm/hmm/Ngfe
		L/fmri/LSil/hgm/swmmgrlfc/Hag
		L/fmri/LSilbr/hgm/swmmgrlfc/Hag
		L/fto/AsilovCF/hgm/hmm/Hag
		L/fto/LiShC/hgm/hmm/Hag
		L/fto/LiShC/hgm/swmm/DC
		L/fto/LSil/hgm/flpd/Hag
		L/fto/LSil/hgm/flpmm/Hag
		L/fto/LSil/hgm/hmm/DC
		L/fto/LSil/hgm/hmm/Hag
		L/fto/LSil/hgm/swmm/Hag
		L/fto/LSilor/hgm/fgfcmo/Hag
		L/fto/LSilor/hgm/hgmcwmc/Hag
		L/ftr/AsilovCF/hgm/hmm/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Moist Graminoid Meadow (continued)		L/ftr/AsilovL/hgm/fdfwm/Hc
		L/ftr/AsilovL/hgm/flpmm/Hcl
		L/ftr/AsilovSk/hgm/hmm/DC
		L/ftr/DpCF/hgm/hmm/DC
		L/ftr/LiShC/hgm/hmm/Hag
		L/ftr/LovSk/hgm/fbcmmlfc/Hag
		L/ftr/LSil/hgm/fbclf/Hag
		L/ftr/LSil/hgm/fbcmmlfc/Hag
		L/ftr/LSil/hgm/fdfd/Hag
		L/ftr/LSil/hgm/fdfm/Hag
		L/ftr/LSil/hgm/fdfm/Hdr
		L/ftr/LSil/hgm/flpmm/Hag
		L/ftr/LSil/hgm/flpmm/Hcl
		L/ftr/LSil/hgm/fppd/Hag
		L/ftr/LSil/hgm/fppm/Hag
		L/ftr/LSil/hgm/hgmcwmc/DC
		L/ftr/LSil/hgm/hgmcwmc/Hag
		L/ftr/LSil/hgm/hmcm/Hag
		L/ftr/LSil/hgm/hmm/A
		L/ftr/LSil/hgm/hmm/DC
		L/ftr/LSil/hgm/hmm/Hag
		L/ftr/LSil/hgm/hwm/Hag
		L/ftr/LSil/hgm/swmm/Hag
		L/ftr/LSil/hgm/swwm/Hag
		L/ftr/LSilor/hgm/flpmm/Hag
		L/ftr/LSilor/hgm/hgmcwmc/Hag
		L/ftr/LSilor/hgm/hmm/Hag
		L/ftr/LSilor/hgm/hwm/Hag
		L/ftr/LSilor/hgm/swmm/Hag
		L/H/LiShC/hgm/hmm/Nf
		L/H/LovSk/hgm/hmm/DC
		L/H/LSil/hgm/fbbcwf/Hwl
		L/H/LSil/hgm/hmm/Hwl
		L/H/LSil/hgm/smxl/Hag
		L/H/LSil/hgm/smxl/Hwl
		L/H/LSil/hgm/swmmgrlfc/Hwd
		L/H/LSil/hgm/swmmgrlfc/Hwl
		L/H/LSilbr/hgm/fbbcwf/Hwl
		L/H/LSilbr/hgm/swmmgrblfc/Hag
		L/H/LSilbr/hgm/swmmgrblfc/Hf
		L/H/LSilbr/hgm/swmmgrlfc/Hwl

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Moist Graminoid Meadow (continued)		L/Wh/LovSk/hgm/fbcmmlfc/Hwc
		L/Wh/LSil/hgm/fbbcwf/Hwc
		L/Wh/LSil/hgm/swmmgrlfc/Hwc
		L/Wh/LSilbr/hgm/fbbcwf/Hwc
		L/Wh/LSilbr/hgm/swmmgrlfc/Hwe
Lowland Loamy Ponderosa Pine Forest	Low	L/ff/AsilovCF/fncpp/fppm/A
		L/ff/LGr/fnwpp/fppm/A
		L/ff/LovSk/fnopp/fppmo/A
		L/fmob/LGr/fnwpp/fppmo/DC
		L/fmob/LovSk/fncpp/fbcmmlfc/A
		L/fmob/LovSk/fncpp/fppm/A
		L/fmob/LovSk/fncpp/fppm/Ngfd
		L/fmob/LovSk/fnopp/fbclf/A
		L/fmob/LovSk/fnopp/fbcmmlfc/A
		L/fmob/LovSk/fnopp/fbcmmlfc/Ha
		L/fmob/LovSk/fnopp/fppm/A
		L/fmob/LovSk/fnopp/fppm/DC
		L/fmob/LovSk/fnopp/fppm/Hag
		L/fmob/LovSk/fnopp/fppm/Hdr
		L/fmob/LovSk/fnopp/fppmo/A
		L/fmob/LovSk/fnwpp/fbcmmlfc/A
		L/fmob/LovSk/fnwpp/fdfd/A
		L/fmob/LovSk/fnwpp/fppd/A
		L/fmob/LovSk/fnwpp/fppm/A
		L/fmob/LovSk/fnwpp/fppmo/A
		L/fmob/LSil/fncpp/fppm/A
		L/fmob/LSil/fnopp/fppd/A
		L/fmob/LSil/fnopp/fppm/A
		L/fmob/LSil/fnopp/fppmo/A
		L/fmob/LSil/fnopp/swmmgrlfc/Ha
		L/fmob/LSil/fnwpp/fppm/A
		L/fmob/LSil/fnwpp/fppmo/A
		L/fmoi/LovSk/fnwpp/fppm/Hag
		L/fto/LovSk/fnwpp/fppd/A
		L/fto/LovSk/fnwpp/swgb/A
		L/fto/LSil/fnwpp/fppd/DC
		L/fto/MDpCF/fnwpp/wpps/A
		L/ftr/AsilovSk/fnopp/fppd/A
		L/ftr/LovSk/fnopp/fbcmmlfc/A
		L/ftr/LovSk/fnopp/fdfd/A

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Ponderosa Pine Forest (continued)		L/ftr/LovSk/fnwpp/fppd/A
		L/ftr/LovSk/fnwpp/fppm/A
		L/ftr/LSil/fncpp/fppd/A
		L/ftr/LSil/fnwpp/fppm/A
		L/ftr/LSil/fnwpp/wpps/A
		L/ftr/MDpCF/fnopp/fdfd/A
Lowland Loamy Spruce Forest	Low	L/fmob/LovSk/fnces/fes/A
		L/fmob/LovSk/fnces/fgfcm/A
		L/fmob/LovSk/fnoes/fes/A
		L/fmob/LovSk/fnoes/fgfcm/A
		L/fmob/LovSk/fnoes/fgfcmo/A
		L/fmob/LovSk/fnoes/fgfeso/A
		L/fmob/LSil/fnces/fgfeso/A
		L/fmob/LSil/fnoes/fgfeso/A
		L/ftr/AsilovL/fnoes/fes/A
		L/ftr/AsilovL/fnoes/fsfes/A
		L/ftr/LSil/fnces/fgfeso/A
Lowland Loamy Subalpine Fir Forest	Low	L/fmob/AsilovSk/fnscf/fsfes/A
		L/fmob/DpCF/fnscf/fsfes/A
		L/fmob/DpCF/fnsfo/fsfd/A
		L/fmob/DpCF/fnsfw/fsfes/A
		L/fmob/LSilor/fnscf/fsfes/A
		L/fmob/LSilor/fnsfo/fsfes/A
		L/ftr/AsilovSk/fnscf/fsfd/A
		L/ftr/AsilovSk/fnscf/fsfes/A
Lowland Loamy Thinleaf Alder Tall Shrub	Low	L/ff/DpCF/stcat/fdfm/Hdr
		L/fmob/AsilovSk/stoat/smaf/A
		L/fmob/LGr/stcat/fdfwm/A
		L/fmob/LGr/stcat/smaf/A
		L/fmob/LGr/stcat/smaf/Hag
		L/fmob/LGr/stoat/smaf/Hag
		L/fmob/LiShC/stcat/smalf/Hag
		L/fmob/LovSk/stcat/smaf/A
		L/fmob/LovSk/stcat/smaf/DC
		L/fmob/LovSk/stcat/smaf/Hag
		L/fmob/LovSk/stcat/smaf/Hc
		L/fmob/LovSk/stcat/smalf/DC
		L/fmob/LovSk/stcat/smalf/Hag
		L/fmob/LovSk/stoat/fbclf/DC

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Thinleaf Alder Tall Shrub (continued)		L/fmob/LovSk/stoat/fdfwm/A
		L/fmob/LovSk/stoat/smaf/A
		L/fmob/LovSk/stoat/smaf/DC
		L/fmob/LovSk/stoat/smaf/Hag
		L/fmob/LovSk/stoat/smalf/Hag
		L/fmob/LSil/stcat/smaf/Hag
		L/fmob/LSil/stoat/smaf/Hag
		L/fmob/LSil/stoat/smalf/Hag
		L/fmob/MDpCF/stcat/fbclf/Hag
		L/fmob/MDpCF/stcat/smalf/Hag
		L/fmob/MDpCF/stoat/fbcmmlfc/Hag
		L/fmob/SSkEnt/stcat/fdfwm/Hag
		L/fmob/SSkEnt/stcat/smaf/Hft
		L/fmri/LovSk/stoat/smalf/Hag
		L/H/LovSk/stoat/smawm/DC
Lowland Loamy Willow Forest	Low	L/fmob/LovSk/fbos/fbww/A
		L/fmob/LSil/fbcs/fbbcwf/DC
		L/fmob/LSil/fbos/fbww/Hag
		L/fmob/LSilbr/fbos/swmmgrlfc/Hag
		L/fmob/LSilbr/fbos/swmmgrlfc/Hwd
		L/fmoi/LSilbr/fbos/fbbcwf/Hag
		L/Fmolp/LSil/fbos/fbww/Hag
		L/Fmolp/LSilbr/fbcs/fbbcwf/A
		L/Fmrox/LSil/fbos/swmmgrlfc/Hag
		L/H/LSil/fbos/swmmgrlfc/Hwd
		L/H/LSilbr/fbcs/swmmgrlfc/Hwl
		L/Wh/LSil/fbos/swmmgrlfc/Hwc
Lowland Loamy Willow Low and Tall Shrub	Low	L/fmob/LGr/stow/swwm/A
		L/fmob/LovSk/stcw/fbcmmlfc/DC
		L/fmob/LovSk/stcw/fbcmmlfc/He
		L/fmob/LovSk/stcw/sbh/Hag
		L/fmob/LovSk/stcw/swmm/Hag
		L/fmob/LovSk/stow/fbbcwf/A
		L/fmob/LovSk/stow/swmm/Hag
		L/fmob/LSil/stcw/fbbcwf/DC
		L/fmob/LSil/stcw/swmmgrlfc/Hag
		L/fmob/LSil/stow/fbcmmlfc/DC
		L/fmob/LSil/stow/swmm/Hag
		L/fmob/LSil/stow/swmmgrlfc/Hag
		L/fmob/LSil/stow/swmmgrlfc/Hah

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy Willow Low and Tall Shrub (continued)		L/fmob/LSil/stow/swwm/A
		L/fmob/MDpCF/stcw/fdfm/DC
		L/fmoi/LSil/stcw/fbbcwf/Hag
		L/fmoi/LSil/stcw/swmmgrlfc/Hag
		L/fmoi/LSilbr/stcw/fbbcwf/Hag
		L/fmoi/LSilbr/stcw/swmmgrlfc/Hag
		L/Fmolp/LSilbr/stcw/swmmgrlfc/Hac
		L/fmri/LovSk/stow/fbcmmlfc/Hag
		L/Fmrox/LSil/stow/swwm/DC
		L/fto/MDpCF/stcw/swmm/DC
		L/ftr/LSil/stcw/swmm/DC
		L/Wh/LovSk/stow/swwm/Hwe
		L/Wh/LSilbr/stow/swmmgrlfc/Hwc
		L/Wh/Water/stow/swmmgrlfc/Hwe
Lowland Loamy-Organic Wet Graminoid Meadow	Low	L/fmob/LovSk/hgw/fbclf/Hag
		L/fmob/LovSk/hgw/hgmcwmc/Hag
		L/fmob/LovSk/hgw/hwm/Hag
		L/fmob/LovSk/hgwmcc/fbcmmlfc/Hag
		L/fmob/LovSk/hgwmcc/hgmcwmc/DC
		L/fmob/LovSk/hgwmcc/hgmcwmc/Hag
		L/fmob/LovSk/hgwmcc/swmm/Hag
		L/fmob/LSil/hgw/hwm/DC
		L/fmob/LSil/hgw/hwm/Hag
		L/fmob/LSil/hgw/swmmgrlfc/Hag
		L/fmob/LSil/hgwmcc/hgmcwmc/A
		L/fmob/LSil/hgwmcc/hgmcwmc/DC
		L/fmob/LSil/hgwmcc/hgmcwmc/Hag
		L/fmob/LSil/hgwmcc/hwm/Hag
		L/fmob/LSil/hgwmcc/swmmgrlfc/Hag
		L/fmob/LSil/hgwmcc/swwm/Hag
		L/fmob/LSilbr/hgw/swmmgrblfc/Hag
		L/fmob/LSilbr/hgw/swmmgrlfc/Hag
		L/fmob/LSilbr/hgwmcc/fbbcwf/Ngfe
		L/fmob/LSilbr/hgwmcc/hgmcwmc/Hag
		L/fmob/LSilbr/hgwmcc/swmmgrlfc/Hag
		L/fmob/LSilor/hgw/hwm/A
		L/fmob/LSilor/hgw/hwm/Hag
		L/fmob/LSilor/hgw/swwm/Hag
		L/fmob/LSilor/hgwmcc/hwm/Hag
		L/fmoi/LSil/hgw/swmmgrlfc/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Loamy-Organic Wet Graminoid Meadow (continued)		L/fmoi/LSilbr/hgw/swmmgrblfc/Hag
		L/fmoi/LSilbr/hgw/swmmgrlfc/Hag
		L/fmoi/LSilbr/hgwmcc/swmmgrlfc/Hag
		L/Fmolp/LSilbr/hgw/swmmgrblfc/Hag
		L/fmri/AsilovSk/hgw/hwm/A
		L/fmri/LovSk/hgw/smawm/Hag
		L/Fmrox/LSilbr/hgw/swmmgrlfc/Hag
		L/fto/LSil/hgw/hwm/Hag
		L/fto/LSil/hgwmcc/hgmcwmc/Hag
		L/fto/LSilor/hgw/hwm/A
		L/fto/LSilor/hgw/hwm/Hag
		L/fto/LSilor/hgwmcc/hwm/Hag
		L/ftr/AsilovSk/hgw/hwm/Hag
		L/ftr/LSil/hgw/hmcm/Hag
		L/ftr/LSil/hgw/hwm/DC
		L/ftr/LSil/hgwmcc/hwm/Hag
		L/ftr/LSilor/hgw/hwm/Hag
		L/ftr/LSilor/hgw/hwmc/A
		L/ftr/LSilor/hgw/swwm/Hag
		L/ftr/LSilor/hgwmcc/hwm/Hag
		L/H/LovSk/hgw/hwm/Hwd
		L/H/LSil/hgw/hwm/Hwd
		L/H/LSilor/hgw/hwm/Hrr
		L/Of/LSilor/hgw/hwm/A
		L/Of/LSilor/hgw/hwmc/Hag
		L/Of/LSilor/hgwmcc/hgmccwmc/Hag
		L/Of/LSilor/hgwmcc/hgmcwmc/A
		L/Wh/LovSk/hgw/fbcmmlfc/Hwc
		L/Wh/LSil/hgw/fbcmmlfc/Hwc
		L/Wh/LSil/hgw/hwm/Hwc
		L/Wh/LSil/hgw/swmmgrlfc/Hwc
		L/Wh/LSilbr/hgw/swmmgrlfc/Hwc
		L/Wh/LSilor/hgwmcc/swmmgrlfc/Hwe
		L/Wh/Water/hgw/swmmgrlfc/Hwc
		L/Wh/Water/hgw/swmmgrlfc/Hwd
Lowland Rocky Dry Graminoid Meadow	High	L/ff/LGr/hgd/fppm/Hag
		L/ff/LGr/hgd/hmd/Hah
		L/ff/LGr/hgd/husgbwc/Ha
		L/ff/LGr/hgd/husgbwc/Hag
		L/ff/LGr/hgd/husgbwc/Hah

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Lowland Rocky Dry Graminoid Meadow (continued)		L/ff/LGr/hus/husgbwc/Hag
		L/ff/LGr/hus/husgbwc/Hp
		L/fmob/LGr/hgd/fbct/Hag
		L/fmob/LGr/hgd/fdfwm/DC
		L/fmob/LGr/hgd/fppm/Hag
		L/fmob/LGr/hgd/smaf/Hag
		L/fmob/LGr/hgd/smawm/Hag
		L/fmob/MDpCF/hgd/hmd/Hag
		L/fmob/SSkEnt/hgd/hmd/DC
		L/fmob/SSkEnt/hgd/smaf/Hc
		L/ftr/LGr/hgd/fdfm/Hag
		L/H/LGr/hus/husd/Hf
		L/H/LGr/hus/husgbwc/Hf
Lowland Rocky Moist Graminoid Meadow	Moderate	L/fmob/LGr/hgm/fbct/Hag
		L/fmob/LGr/hgm/fppmo/DC
		L/fmob/LGr/hgm/hgmcwmc/Hag
		L/fmob/LGr/hgm/hmm/DC
		L/fmob/LGr/hgm/hmm/Hag
		L/fmob/LGr/hgm/swmm/A
		L/fmob/LGr/hgm/swmm/Hag
		L/fmob/LGr/hgm/swwm/Hag
		L/fmob/SSkEnt/hgm/hmm/Hag
Riverine Complex	Moderate	L/fmob/LGr/xr/smawm/Hag
		L/fmob/SSkEnt/xr/smawm/Hag
		L/Wh/LSilbr/xr/swmmgrlfc/Hwc
		R/fmoa/LGr/xr/fbbcwf/Hag
		R/fmoa/LGr/xr/swwm/Hag
		R/fmoa/LovSk/xr/fes/A
		R/fmoa/LovSk/xr/xru/A
		R/fmoa/LovSk/xr/xru/Hag
		R/fmoa/SSkEnt/xr/fbbcwf/Hag
		R/fmoa/SSkEnt/xr/fbcf/Ngfd
		R/fmoa/SSkEnt/xr/hgfgb/Ngfe
		R/fmoa/SSkEnt/xr/sbh/Ngfe
		R/fmoa/SSkEnt/xr/swgb/Ngfe
		R/fmoi/LGr/fboc/fbct/DC
		R/fmoi/LGr/xr/fbbcwf/Hag
		R/fmoi/LGr/xr/fbcf/Hag
		R/fmoi/LGr/xr/fbct/Hc
		R/fmoi/LGr/xr/fdfm/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Complex (continued)		R/fmoi/LGr/xr/flpmm/Hag
		R/fmoi/LGr/xr/hmcm/Hag
		R/fmoi/LGr/xr/smaf/A
		R/fmoi/LGr/xr/smaf/Hag
		R/fmoi/LGr/xr/smawm/Hag
		R/fmoi/LGr/xr/swmm/Hag
		R/fmoi/LGr/xr/swwm/A
		R/fmoi/LGr/xr/swwm/Hag
		R/fmoi/LovSk/xr/fbcmmlfc/Hah
		R/fmoi/LovSk/xr/fbct/Hag
		R/fmoi/LovSk/xr/flpmm/A
		R/fmoi/LovSk/xr/flpmm/Hag
		R/fmoi/LovSk/xr/smaf/A
		R/fmoi/LovSk/xr/xru/Hag
		R/fmoi/LSilor/xr/hmcm/A
		R/fmoi/LSilor/xr/swwm/A
		R/fmoi/LSilor/xr/swwm/Hag
		R/fmoi/LSilor/xr/xru/A
		R/fmoi/SSkEnt/xr/smaf/A
		R/fmrac/LovSk/xr/hgfgb/Hag
		R/fmrac/SSkEnt/xr/fdfwm/Ngfe
		R/fmrac/SSkEnt/xr/hgfgb/Ngfe
		R/fmrac/SSkEnt/xr/swgb/Hag
		R/fmrac/SSkEnt/xr/swgb/Ngfe
		R/fmrac/SSkEnt/xr/xrl/Ngfe
		R/fmrac/SSkEnt/xr/xrm/A
		R/fmrac/SSkEnt/xr/xrm/DC
		R/fmrac/SSkEnt/xr/xrm/Hag
		R/fmrac/SSkEnt/xr/xrm/Ngfe
		R/fmrac/SSkEnt/xr/xru/A
		R/fmrac/SSkEnt/xr/xru/Hag
		R/fmri/LGr/xr/fdfwm/Hag
		R/fmri/LGr/xr/swgb/Ngfd
		R/fmri/SSkEnt/xr/fbcf/Hag
Riverine Loamy Black Cottonwood Forest	Low	R/fmoa/LiShC/fboc/fbclf/A
		R/fmoa/LovSk/fboc/fbbcwf/Ngfe
		R/fmoa/LovSk/fboc/fbcf/A
		R/fmoa/LovSk/fboc/fbcf/Hd
		R/fmoa/LovSk/fboc/fbclf/A
		R/fmoa/LovSk/fboc/fbclf/DC

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Loamy Black Cottonwood Forest (continued)		R/fmoa/LovSk/fboc/fbclf/Hwc
		R/fmoa/LovSk/fboc/fbclf/Ngfd
		R/fmoa/LovSk/fboc/fbclf/Ngfe
		R/fmoa/LovSk/fmbcdfc/fdflm/A
		R/fmoa/LovSk/fmbcdfo/fbclf/A
		R/fmoa/LovSk/fmbceso/fbcf/A
		R/fmoa/LovSk/fmbcppo/fbcf/A
		R/fmoa/LovSk/fmbcppo/fbclf/A
		R/fmoa/LovSk/fmbcppo/fbclf/Hag
		R/fmoa/LovSk/fmbcppo/fppmo/A
		R/fmoa/LSil/fboc/fbclf/A
		R/fmoa/LSil/fboc/fbclf/Hwc
		R/fmob/LovSk/fboc/fbclf/A
		R/fmoi/LovSk/fbcc/fbcf/A
		R/fmoi/LovSk/fbcc/fbclf/A
		R/fmoi/LovSk/fbcc/fbclf/DC
		R/fmoi/LovSk/fbcc/fbclf/Ngfd
		R/fmoi/LovSk/fbcc/fbct/A
		R/fmoi/LovSk/fboc/fbcf/A
		R/fmoi/LovSk/fboc/fbcf/DC
		R/fmoi/LovSk/fboc/fbcf/Hag
		R/fmoi/LovSk/fboc/fbcf/Ngfd
		R/fmoi/LovSk/fboc/fbclf/A
		R/fmoi/LovSk/fboc/fbclf/DC
		R/fmoi/LovSk/fboc/fbclf/Ngfe
		R/fmoi/LovSk/fboc/fbct/A
		R/fmoi/LovSk/fboc/fbct/DC
		R/fmoi/LovSk/fbwc/fbcf/A
		R/fmoi/LovSk/fbwc/fbct/A
		R/fmoi/LovSk/fbwc/fbct/DC
		R/fmoi/LovSk/fmbcdfo/fbclf/A
		R/fmoi/LovSk/fmbcdfo/fdfwm/A
		R/fmoi/LovSk/fmbcdfo/fdfwm/DC
		R/fmoi/LovSk/fmbceso/fes/A
		R/fmoi/LovSk/fmbceso/fgfcm/A
		R/fmoi/LovSk/fmbcgfo/fgfcmo/A
		R/fmoi/LovSk/fmbcppo/fbcf/A
		R/fmoi/LovSk/fmbcppo/fbclf/A
		R/fmoi/LovSk/fmbcppo/fppmo/A
		R/fmoi/LSil/fbcc/fbcf/Hd
		R/fmoi/LSil/fbcc/fbclf/Hdr

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Loamy Black Cottonwood Forest (continued)		R/fmoi/LSil/fboc/fbcf/A
		R/fmoi/LSil/fboc/fbcf/DC
		R/fmoi/LSil/fboc/fbclf/A
		R/fmoi/LSil/fboc/fbclf/Hd
		R/fmoi/LSil/fmbcppo/fppmo/A
		R/fmrac/LovSk/fboc/fbcf/DC
Riverine Loamy Douglas-fir Forest	Low	R/fmoa/LGr/fndfw/fdfwm/A
		R/fmoa/LiShC/fnodf/fdfmo/A
		R/fmoa/LovSk/fnodf/fdfwm/A
		R/fmoa/SSkEnt/fndfw/fdfwm/A
		R/fmoi/LGr/fncdf/fdfwm/A
		R/fmoi/LGr/fndfw/fdfwm/A
		R/fmoi/LGr/fnodf/fdfm/A
		R/fmoi/LGr/fnodf/fdfwm/A
		R/fmoi/LiShC/fndfw/fdfwm/A
		R/fmoi/LovSk/fncdf/fdfm/A
		R/fmoi/LovSk/fncdf/fdfwm/A
		R/fmoi/LovSk/fndfw/fdfm/A
		R/fmoi/LovSk/fndfw/fdfmo/A
		R/fmoi/LovSk/fndfw/fdfmo/Ngfe
		R/fmoi/LovSk/fndfw/fdfwm/A
		R/fmoi/LovSk/fndfw/fdfwm/DC
		R/fmoi/LovSk/fndfw/fdfwm/Nf
		R/fmoi/LovSk/fnodf/fdfd/A
		R/fmoi/LovSk/fnodf/fdfm/A
		R/fmoi/LovSk/fnodf/fdfwm/A
		R/fmoi/LovSk/fnodf/fdfwm/DC
		R/fmoi/LSil/fnodf/fdfm/A
		R/fmoi/LSil/fnodf/fdfmo/A
		R/fmoi/LSil/fnodf/fdfwm/A
		R/fmoi/MDpCF/fncdf/fdfwm/A
		R/fmoi/MDpCF/fndfw/fdfwm/A
		R/fmoi/MDpCF/fnodf/fdfm/DC
		R/fmoi/MDpCF/fnodf/fdfwm/A
		R/fmoi/SSkEnt/fndfw/fdfwm/A
		R/fmoi/SSkEnt/fnodf/fdfd/Ngfe
		R/fmoi/SSkEnt/fnodf/fdfwm/A
Riverine Loamy Forb Meadow	Moderate	R/fmoi/LGr/hfm/swmm/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Loamy Low Elevation Mixed Shrubland	Low	R/fmoa/LovSk/smxlc/fbclf/Hag
		R/fmoa/LovSk/smxlc/smxl/Hwc
		R/fmoa/LovSk/smxlo/smxl/Hwc
		R/fmoa/LSil/smxlc/smxl/Hag
		R/fmoa/LSil/smxlc/smxl/Hah
		R/fmoa/LSil/smxlc/smxl/Hwc
		R/fmoa/LSil/smxlc/smxl/Ngfd
		R/fmoa/LSil/smxlc/smxl/Ngfe
		R/fmoa/LSil/smxlo/fbbcwf/Ngfe
		R/fmoa/LSil/smxlo/smxl/Hag
		R/fmoa/LSil/smxlo/smxl/Hwc
		R/fmoa/LSil/smxlo/smxl/Ngfd
		R/fmoa/LSil/smxlo/smxl/Ngfe
		R/fmoa/LSilbr/smxlc/smxl/Hag
		R/fmoa/LSilbr/smxlc/smxl/Hwc
		R/fmoa/LSilbr/smxlc/smxl/Ngfe
		R/fmoa/LSilbr/smxlo/fbbcwf/Ngfe
		R/fmoa/LSilbr/smxlo/smxl/Hag
		R/fmoa/LSilbr/smxlo/smxl/Hwc
		R/fmoa/LSilbr/smxlo/smxl/Ngfd
		R/fmoa/LSilbr/smxlo/smxl/Ngfe
		R/fmoa/LSilbr/smxlo/swmmgrlfc/Hag
		R/fmoa/LSilbr/smxlo/swmmgrlfc/Ngfe
		R/fmoa/SSkEnt/smxlc/smxl/Hwc
		R/fmoa/SSkEnt/smxlc/smxl/Ngfd
		R/fmoi/LovSk/smxlo/smxl/DC
		R/fmoi/LSil/smxlc/smxl/Hag
		R/fmoi/LSil/smxlc/smxl/Hwc
		R/fmoi/LSil/smxlc/swmmgrlfc/Hag
		R/fmoi/LSil/smxlo/smmgrlfc/Hag
		R/fmoi/LSil/smxlo/smxl/Ha
		R/fmoi/LSil/smxlo/smxl/Hag
		R/fmoi/LSil/smxlo/smxl/Hwc
		R/fmoi/LSil/smxlo/smxl/Ngfe
		R/fmoi/LSil/smxlo/swmmgrlfc/Hag
		R/fmoi/LSilbr/smxlc/smxl/Hag
		R/fmoi/LSilbr/smxlc/smxl/Ngfe
		R/fmoi/LSilbr/smxlc/swmmgrlfc/Hag
		R/fmoi/LSilbr/smxlc/swmmgrlfc/Ngfe
		R/fmoi/LSilbr/smxlo/smxl/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Loamy Low Elevation Mixed Shrubland (continued)		R/fmoi/LSilbr/smxlo/smxl/Ngfe
		R/fmoi/LSilbr/smxlo/swmmgrlfc/Hag
		R/fmoi/LSilbr/smxlo/swmmgrlfc/Ngfe
		R/fmoi/Water/smxlc/swmmgrlfc/Ha
		R/fmrac/SSkEnt/smxlo/smxl/A
		R/Fmrox/LSil/smxlc/smxl/Ha
		R/H/LSil/smxlo/smxl/Hwc
		R/H/LSilbr/smxlc/smxl/Hwc
Riverine Loamy Moist Graminoid Meadow	Moderate	R/fmoa/LovSk/hgm/fbcf/DC
		R/fmoa/LovSk/hgm/fbclf/DC
		R/fmoa/LovSk/hgm/hmm/DC
		R/fmoa/LovSk/hgm/hmm/Ha
		R/fmoa/LSil/hgm/fbbcwf/DC
		R/fmoa/LSil/hgm/fbbcwf/Hag
		R/fmoa/LSil/hgm/fbbcwf/Ngfe
		R/fmoa/LSil/hgm/smxl/Hag
		R/fmoa/LSil/hgm/smxl/Hwc
		R/fmoa/LSil/hgm/smxl/Ngfe
		R/fmoa/LSilbr/hgm/fbbcwf/Ngfe
		R/fmoa/LSilbr/hgm/smxl/Hag
		R/fmoa/LSilbr/hgm/smxl/Hwc
		R/fmoa/LSilbr/hgm/smxl/Ngfe
		R/fmoa/LSilbr/hgm/swmmgrblfc/Hag
		R/fmoa/Water/hgm/smxl/Hag
		R/fmoi/LovSk/hgm/fbclf/Hag
		R/fmoi/LovSk/hgm/fbcmmlfc/Hag
		R/fmoi/LovSk/hgm/fbct/Hag
		R/fmoi/LovSk/hgm/fbct/Hc
		R/fmoi/LovSk/hgm/fbct/Nf
		R/fmoi/LovSk/hgm/fdfwm/DC
		R/fmoi/LovSk/hgm/hmm/A
		R/fmoi/LovSk/hgm/hmm/Ha
		R/fmoi/LovSk/hgm/hmm/Ngfd
		R/fmoi/LovSk/hgm/sbh/Hag
		R/fmoi/LovSk/hgm/smaf/Hag
		R/fmoi/LovSk/hgm/smawm/Hag
		R/fmoi/LovSk/hgm/swmm/Hag
		R/fmoi/LovSk/hgm/swwm/Hag
		R/fmoi/LSil/hgm/fbbcwf/Hag
		R/fmoi/LSil/hgm/fbclf/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Loamy Moist Graminoid Meadow (continued)		R/fmoi/LSil/hgm/fbcmmlfc/Hag
		R/fmoi/LSil/hgm/fdfm/Hag
		R/fmoi/LSil/hgm/flpmm/Hcl
		R/fmoi/LSil/hgm/hfmm/Hag
		R/fmoi/LSil/hgm/hmm/Ha
		R/fmoi/LSil/hgm/hmm/Hag
		R/fmoi/LSil/hgm/hwm/Hag
		R/fmoi/LSil/hgm/smawm/Hag
		R/fmoi/LSil/hgm/smmgrlfc/Hag
		R/fmoi/LSil/hgm/smxl/Ha
		R/fmoi/LSil/hgm/smxl/Hag
		R/fmoi/LSil/hgm/swmmgrlfc/DC
		R/fmoi/LSil/hgm/swmmgrlfc/Hag
		R/fmoi/LSil/hgm/swmmgrlfc/Hah
		R/fmoi/LSil/hgm/swwm/Hag
		R/fmoi/LSilbr/hgm/smxl/Ha
		R/fmoi/LSilbr/hgm/smxl/Hag
		R/fmoi/LSilbr/hgm/swmmgrlfc/DC
		R/fmoi/LSilbr/hgm/swmmgrlfc/Ha
		R/fmoi/LSilbr/hgm/swmmgrlfc/Hag
		R/fmoi/LSilor/hgm/swwm/Hag
		R/fmoi/Water/hgm/smxl/Hag
		R/fmrac/LSil/hgm/hgfgb/Ngfe
		R/fmrac/LSilbr/hgm/hgfgb/Ngfe
		R/fmri/LSil/hgm/hwm/Ha
		R/fmri/LSil/hgm/swmmgrblfc/Hag
Riverine Loamy Ponderosa Pine Forest	Low	R/fmoa/LGr/fnwpp/fppm/A
		R/fmoa/LovSk/fnopp/fppm/Hag
		R/fmoi/LGr/fnwpp/fppmo/A
		R/fmoi/LovSk/fncpp/fppm/A
		R/fmoi/LovSk/fnopp/fbcmmlfc/A
		R/fmoi/LovSk/fnopp/fdfwm/A
		R/fmoi/LovSk/fnopp/fppm/A
		R/fmoi/LovSk/fnopp/fppm/DC
		R/fmoi/LovSk/fnopp/fppmo/A
Riverine Loamy Spruce Forest	Low	R/fmoa/LGr/fnoes/fgfcm/A
		R/fmoa/LovSk/fnces/fgfcm/A
		R/fmoi/LGr/fnoes/fes/A
		R/fmoi/LGr/fnoes/fgfeso/A
		R/fmoi/LovSk/fnces/fgfeso/A

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Loamy Spruce Forest (continued)		R/fmoi/LovSk/fnoes/fes/A
		R/fmoi/LovSk/fnoes/fgfeso/A
Riverine Loamy Subalpine Fir Forest	Low	R/fmoi/LovSk/fnsfo/fsfd/A
		R/fmoi/LovSk/fnsfo/fsfes/A
		R/fmoi/LovSk/fnsfo/fsfeso/A
		R/fmoi/LSil/fnscf/fsfes/A
Riverine Loamy Willow Forest	Low	R/fmoa/LSil/fbcs/fbbcwf/A
		R/fmoa/LSil/fbcs/fbbcwf/Hah
		R/fmoa/LSil/fbcs/fbbcwf/Ngfe
		R/fmoa/LSil/fbos/fbbcwf/DC
		R/fmoa/LSil/fbos/fbbcwf/Hd
		R/fmoa/LSil/fbos/fbbcwf/Ngfd
		R/fmoa/LSil/fbos/fbclf/Hah
		R/fmoa/LSilbr/fbcs/fbbcwf/A
		R/fmoa/LSilbr/fbcs/fbbcwf/Ngfe
		R/fmoa/LSilbr/fbos/fbbcwf/Hag
		R/fmoa/LSilbr/fbos/fbbcwf/Ngfe
		R/fmrac/SSkEnt/fbos/fbbcwf/Ngfe
		R/H/LSil/fbcs/swmmgrlfc/Hwc
Riverine Loamy-Organic Wet Graminoid Meadow	Low	R/fmoa/LSil/hgwmcc/hgmcwmc/DC
		R/fmoa/LSil/hgwmcc/hgmcwmc/Hag
		R/fmoa/LSilor/hgw/swwm/Hag
		R/fmoa/LSilor/hgwmcc/swwm/Hag
		R/fmoi/LSil/hgwmcc/hgmcwmc/DC
		R/fmoi/LSilor/hgw/hwm/Hag
		R/fmoi/LSilor/hgw/swwm/Hag
		R/fmri/LSilbr/hgw/hwm/Hag
		R/Fmrox/LSilbr/hgw/hwm/Hag
		R/Wh/LSilbr/hgw/swmmgrblfc/Hwd
Riverine Loamy-Rocky Dry Graminoid Meadow	High	R/fmoa/LGr/hgd/fbbcwf/Hag
		R/fmoa/LGr/hgd/swgb/Hag
		R/fmoa/LovSk/hgd/hmd/DC
		R/fmoi/LGr/hgd/fbbcwf/Hag
		R/fmoi/LGr/hgd/fbcf/Hag
		R/fmoi/LGr/hgd/fdfm/Hag
		R/fmoi/LGr/hgd/smaf/Hag
		R/fmoi/LGr/hgd/smawm/Hag
		R/fmoi/LovSk/hgd/fdfm/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Loamy-Rocky Dry Graminoid Meadow (continued)		R/fmoi/LovSk/hgd/hmm/Hag
		R/fmoi/MDpCF/hgd/smaf/Hag
		R/fmri/LGr/hgd/fbbcwf/Hag
		R/fmri/LGr/hgd/smaf/Hag
Riverine Loamy-Rocky Grand Fir Forest	Low	R/fmoa/LGr/fnog/fgfc/A
		R/fmoa/LovSk/fncg/fgfcm/A
		R/fmoa/SSkEnt/fncg/fgfwdo/A
		R/fmoi/LGr/fngfw/fgfcm/A
		R/fmoi/LGr/fnog/fgfcm/A
		R/fmoi/LiShC/fncg/fgfc/A
		R/fmoi/LovSk/fncg/fdfwm/A
		R/fmoi/LovSk/fncg/fgfcm/A
		R/fmoi/LovSk/fncg/fgfcmo/A
		R/fmoi/LovSk/fncg/fgfwd/A
		R/fmoi/LovSk/fngfw/fgfcmo/A
		R/fmoi/LovSk/fnog/fdfwm/A
		R/fmoi/LovSk/fnog/fgfcm/A
		R/fmoi/LovSk/fnog/fgfcmo/A
		R/fmoi/LovSk/fnog/fgfcmo/Hag
		R/fmoi/LovSk/fnog/fgfes/A
		R/fmoi/LovSk/fnog/fgfeso/A
		R/fmoi/LovSk/fnog/fgfwdo/A
		R/fmoi/LSil/fncg/fgfcm/A
		R/fmoi/LSil/fnog/fgfcmo/A
		R/fmoi/SSkEnt/fncg/fgfwdo/A
		R/fmoi/SSkEnt/fnog/fdfwm/A
		R/fmoi/SSkEnt/fnog/fgfcmo/A
		R/fmoi/SSkEnt/fnog/fgfwdo/A
Riverine Loamy-Rocky Hawthorn Tall Shrub	Low	R/fmoa/LGr/stobh/fbbcwf/Hag
		R/fmoa/LGr/stobh/sbh/A
		R/fmoa/LGr/stobh/sbh/Hag
		R/fmoa/LovSk/stcbh/smalf/Hag
		R/fmoa/LovSk/stobh/smalf/Hag
		R/fmoa/LSil/stcbh/sbh/Hag
		R/fmoa/LSil/stobh/sbh/Hag
		R/fmoi/LGr/stcbh/fbct/Hag
		R/fmoi/LGr/stcbh/sbh/A
		R/fmoi/LGr/stcbh/sbh/Hag
		R/fmoi/LGr/stobh/sbh/A

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Loamy-Rocky Hawthorn Tall Shrub (continued)		R/fmoi/LGr/stobh/sbh/Hag
		R/fmoi/LovSk/stcbh/sbh/A
		R/fmoi/LovSk/stcbh/sbh/Hag
		R/fmoi/LovSk/stobh/fbcmmlfc/Hag
		R/fmoi/LovSk/stobh/sbh/A
		R/fmoi/LovSk/stobh/sbh/DC
		R/fmoi/LovSk/stobh/sbh/Hag
		R/fmoi/LSil/stcbh/sbh/Hag
		R/fmoi/LSil/stcbh/smxl/DC
		R/fmoi/LSil/stobh/swmmgrlfc/Hag
		R/fmoi/LSilbr/stobh/sbh/Hag
		R/fmoi/SSkEnt/stobh/sbh/Ngfd
Riverine Loamy-Rocky Lodgepole Pine Forest	Low	R/fmoa/LGr/fnol/flpmm/A
		R/fmoa/LGr/fnwl/flpwm/Hag
		R/fmoa/LGr/fnwl/flpwm/Hcl
		R/fmoi/LGr/fncl/flpmm/A
		R/fmoi/LGr/fncl/flpwm/A
		R/fmoi/LGr/fnol/flpmm/A
		R/fmoi/LGr/fnol/flpwm/A
		R/fmoi/LGr/fnol/flpwm/Hcl
		R/fmoi/LGr/fnwl/flpmm/A
		R/fmoi/LGr/fnwl/flpmm/Hag
		R/fmoi/LGr/fnwl/flpwm/Hag
		R/fmoi/LGr/fnwl/flpwm/Hcl
		R/fmoi/LovSk/fncl/flpd/A
		R/fmoi/LovSk/fncl/flpwm/A
		R/fmoi/LovSk/fnol/flpmm/A
		R/fmoi/LovSk/fnol/flpwm/A
		R/fmoi/LovSk/fnwl/flpmm/A
		R/fmoi/LovSk/fnwl/flpwm/Hag
		R/fmoi/LovSk/fnwl/smawm/Hag
		R/fmoi/LSil/fnol/flpmm/A
		R/fmoi/LSil/fnol/flpwm/A
		R/fmoi/LSilor/fnol/flpmm/A
		R/fmoi/LSilor/fnol/flpwm/A
		R/fmoi/LSilor/fnwl/flpmm/Hag
		R/fmoi/SSkEnt/fncl/flpmm/Hft
		R/fmoi/SSkEnt/fnwl/flpmm/Hft
		R/fmri/LGr/fnwl/flpwm/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Loamy-Rocky Wet Graminoid Meadow	Low	R/fmoa/LGr/hgwmcc/swwm/Hag
		R/fmoa/LovSk/hgwmcc/hgmcwmc/Hag
		R/fmoa/LovSk/hgwmcc/swwm/Hag
		R/fmoa/LSil/hgw/hwmc/Hag
		R/fmoi/LGr/hgw/hwm/DC
		R/fmoi/LGr/hgwmcc/fbct/Hc
		R/fmoi/LGr/hgwmcc/smawm/DC
		R/fmoi/LovSk/hgw/fbclf/Hah
		R/fmoi/LovSk/hgwmcc/fbclf/Hah
		R/fmoi/LovSk/hgwmcc/fbcmmlfc/Hag
		R/fmoi/LovSk/hgwmcc/swwm/Hag
		R/fmoi/LSil/hgw/fbclf/Hag
		R/fmoi/LSil/hgw/hwm/DC
		R/fmoi/LSil/hgw/hwm/Hag
		R/fmoi/LSil/hgw/smawm/Hag
		R/fmoi/LSil/hgw/smawm/He
		R/fmoi/SSkEnt/hgwmcc/hgmcwmc/DC
		R/fmri/LGr/hgw/hwm/Hag
		R/fmri/LGr/hgw/smawm/Hag
		R/fmri/LGr/hgw/swwm/Hag
		R/fmri/LGr/hgwmcc/swwm/Hag
		R/fmri/LSil/hgw/swmmgrlfc/Hag
		R/fmri/SSkEnt/hgw/hwm/DC
Riverine Rocky Barrens and Partially Vegetated	High	R/fmoa/LGr/bpvh/fbclf/Hag
		R/fmoa/LGr/bpvh/swgb/A
		R/fmoa/LovSk/bpvh/hgfgb/Hag
		R/fmoa/MDpCF/bbg/bbg/Ngfd
		R/fmoa/SSkEnt/bbg/bbg/Hwc
		R/fmoa/SSkEnt/bbg/bbg/Ngfd
		R/fmoa/SSkEnt/bbg/swgb/A
		R/fmoa/SSkEnt/bpvh/smaf/Hag
		R/fmoa/SSkEnt/bpvh/swgb/A
		R/fmoa/SSkEnt/bpvh/swgb/Hag
		R/fmoi/LGr/bpvh/smaf/Hag
		R/fmoi/LGr/bpvh/smawm/Hag
		R/fmoi/SSkEnt/bbg/fbct/A
		R/fmoi/SSkEnt/bbg/hmm/A
		R/fmrac/LovSk/bpvh/hgfgb/Ngfe
		R/fmrac/SSkEnt/bbg/bbg/Ngfd

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Rocky Barrens and Partially Vegetated (continued)		R/fmrac/SSkEnt/bbg/bbg/Ngfe
		R/fmrac/SSkEnt/bbg/hgfgb/Hag
		R/fmrac/SSkEnt/bbg/hgfgb/Ngfd
		R/fmrac/SSkEnt/bbg/swgb/A
		R/fmrac/SSkEnt/bbg/swgb/Hag
		R/fmrac/SSkEnt/bbg/swgb/Ngfd
		R/fmrac/SSkEnt/bpvh/fbbcwf/Ngfd
		R/fmrac/SSkEnt/bpvh/hgfgb/A
		R/fmrac/SSkEnt/bpvh/hgfgb/DC
		R/fmrac/SSkEnt/bpvh/hgfgb/Ngfe
		R/fmrac/SSkEnt/bpvh/swgb/Hag
		R/fmrac/SSkEnt/bpvh/swgb/Ngfd
		R/fmrac/SSkEnt/bpvh/swgb/Ngfe
		R/fmri/SSkEnt/bbg/bbg/Ngfe
		R/fmri/SSkEnt/bbg/swgb/A
		R/fmri/SSkEnt/bbg/swgb/Hag
		R/fmri/SSkEnt/bpvh/fbbcwf/Hag
		R/fmri/SSkEnt/bpvh/hgfgb/DC
		R/fmri/SSkEnt/bpvh/swgb/A
		R/fmri/SSkEnt/bpvh/swgb/Hag
Riverine Rocky Black Cottonwood Forest	Low	R/fmoa/LGr/fboc/fbcf/DC
		R/fmoa/LGr/fboc/fbcf/Ngfd
		R/fmoa/LGr/fboc/fbclf/A
		R/fmoa/LGr/fboc/fbclf/Hag
		R/fmoa/SSkEnt/fbcc/fbclf/Hag
		R/fmoa/SSkEnt/fboc/fbcf/Ngfe
		R/fmoa/SSkEnt/fboc/fbclf/A
		R/fmoa/SSkEnt/fboc/fbclf/DC
		R/fmoa/SSkEnt/fboc/fbclf/Hag
		R/fmoa/SSkEnt/fbwc/fbbcwf/DC
		R/fmoa/SSkEnt/fmbcppo/fbclf/DC
		R/fmoi/LGr/fboc/fbcf/A
		R/fmoi/LGr/fboc/fbcf/DC
		R/fmoi/LGr/fboc/fbclf/Hdr
		R/fmoi/LGr/fbwc/fbbcwf/A
		R/fmoi/LGr/fmbcppo/fppmo/A
		R/fmoi/MDpCF/fboc/fbclf/A
		R/fmoi/SSkEnt/fbcc/fbclf/Ngfd
		R/fmoi/SSkEnt/fboc/fbcf/A
		R/fmoi/SSkEnt/fmbcdfo/fbclf/DC

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Rocky Black Cottonwood Forest (continued)		R/fmrac/SSkEnt/fboc/fbbcwf/DC
		R/fmrac/SSkEnt/fboc/fbclf/Ngfd
		R/fmrac/SSkEnt/fbwc/fbclf/Ngfe
		R/fmri/LGr/fboc/fbcf/DC
		R/fmri/SSkEnt/fboc/fbcf/A
		R/fmri/SSkEnt/fboc/fbcf/Ngfd
		R/fmri/SSkEnt/fboc/fbclf/Ngfe
Riverine Rocky Moist Graminoid Meadow	Moderate	R/fmoa/LGr/hgm/fbbcwf/A
		R/fmoa/LGr/hgm/fbbcwf/Hag
		R/fmoa/LGr/hgm/fbcf/Hag
		R/fmoa/LGr/hgm/flpmm/Hag
		R/fmoa/LGr/hgm/smaf/Hag
		R/fmoa/LGr/hgm/smawm/Hag
		R/fmoa/LGr/hgm/swgb/Hag
		R/fmoa/LGr/hgm/swmm/Hag
		R/fmoa/LGr/hgm/swwm/Hag
		R/fmoa/SSkEnt/hgm/fbclf/Hag
		R/fmoa/SSkEnt/hgm/hgfgb/DC
		R/fmoa/SSkEnt/hgm/hmm/Hag
		R/fmoa/SSkEnt/hgm/smaf/Hag
		R/fmoa/SSkEnt/hgm/smawm/Hcl
		R/fmoa/SSkEnt/hgm/smawm/Hft
		R/fmoa/SSkEnt/hgm/swwm/Hag
		R/fmoi/LGr/hgm/fbbcwf/Hag
		R/fmoi/LGr/hgm/fbcf/Hc
		R/fmoi/LGr/hgm/fbclf/Hag
		R/fmoi/LGr/hgm/fbclf/Ngfd
		R/fmoi/LGr/hgm/fbct/A
		R/fmoi/LGr/hgm/fbct/Hag
		R/fmoi/LGr/hgm/fdfm/Hag
		R/fmoi/LGr/hgm/smaf/A
		R/fmoi/LGr/hgm/smaf/Hag
		R/fmoi/LGr/hgm/smawm/Hag
		R/fmoi/LGr/hgm/smawm/Hc
		R/fmoi/LGr/hgm/swmm/Hag
		R/fmoi/LGr/hgm/swwm/Hag
		R/fmoi/SSkEnt/hgm/hmm/DC
		R/fmoi/SSkEnt/hgm/hmm/Hag
		R/fmoi/SSkEnt/hgm/smawm/Hft
		R/fmrac/SSkEnt/hgm/fbclf/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Rocky Moist Graminoid Meadow (continued)		R/fmrac/SSkEnt/hgm/hgfgb/Ngfd
		R/fmrac/SSkEnt/hgm/hgfgb/Ngfe
		R/fmrac/SSkEnt/hgm/swgb/A
		R/fmri/LGr/hgm/hwm/Hag
		R/fmri/LGr/hgm/smawm/Hag
		R/fmri/LGr/hgm/swwm/Hag
		R/fmri/SSkEnt/hgm/swgb/A
		R/fmri/SSkEnt/hgm/swgb/Hag
		R/fmri/SSkEnt/hgm/swgb/Ngfd
		R/Wr/SSkEnt/hgm/smxl/Ngfe
Riverine Rocky Thinleaf Alder Tall Shrub	Low	R/fmoa/DpSiCL/stoat/smalf/Hag
		R/fmoa/LGr/stcat/smaf/A
		R/fmoa/LGr/stcat/smalf/Hag
		R/fmoa/LGr/stoat/smaf/A
		R/fmoa/LGr/stoat/smaf/Ngfd
		R/fmoa/LGr/stoat/smalf/Hag
		R/fmoa/LGr/stoat/smawm/A
		R/fmoa/LGr/stoat/smawm/Hag
		R/fmoa/LiShC/stcat/fbclf/DC
		R/fmoa/LiShC/stcat/smalf/Hag
		R/fmoa/LovSk/stcat/fbcmmlfc/Hag
		R/fmoa/LovSk/stcat/smaf/Hag
		R/fmoa/LovSk/stcat/smalf/Hag
		R/fmoa/LovSk/stcat/smalf/Ngfd
		R/fmoa/LovSk/stoat/smaf/DC
		R/fmoa/LovSk/stoat/smaf/Hag
		R/fmoa/LovSk/stoat/smaf/Hc
		R/fmoa/LovSk/stoat/smaf/Ngfe
		R/fmoa/LovSk/stoat/smalf/DC
		R/fmoa/LovSk/stoat/smalf/Hag
		R/fmoa/LovSk/stoat/smawm/Hag
		R/fmoa/LSil/stcat/smaf/Hag
		R/fmoa/LSil/stoat/smaf/DC
		R/fmoa/SSkEnt/stcat/fdfwm/Hag
		R/fmoa/SSkEnt/stcat/fdfwm/Ngfd
		R/fmoa/SSkEnt/stcat/smaf/Hag
		R/fmoa/SSkEnt/stcat/smalf/Hag
		R/fmoa/SSkEnt/stcat/smawm/A
		R/fmoa/SSkEnt/stoat/smaf/DC
		R/fmoa/SSkEnt/stoat/smaf/Ngfd

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Rocky Thinleaf Alder Tall Shrub (continued)		R/fmoa/SSkEnt/stoat/smawm/Hag
		R/fmoi/LGr/stcat/smaf/A
		R/fmoi/LGr/stcat/smaf/Ha
		R/fmoi/LGr/stcat/smaf/Hag
		R/fmoi/LGr/stcat/smalf/Hag
		R/fmoi/LGr/stcat/smawm/A
		R/fmoi/LGr/stcat/swwm/A
		R/fmoi/LGr/stoat/smaf/A
		R/fmoi/LGr/stoat/smaf/Hag
		R/fmoi/LGr/stoat/smawm/A
		R/fmoi/LGr/stoat/smawm/Hag
		R/fmoi/LovSk/stcat/fbcf/Hag
		R/fmoi/LovSk/stcat/smaf/A
		R/fmoi/LovSk/stcat/smaf/Hag
		R/fmoi/LovSk/stcat/smalf/Hag
		R/fmoi/LovSk/stoat/fbcf/Hag
		R/fmoi/LovSk/stoat/fdfwm/Hag
		R/fmoi/LovSk/stoat/smaf/A
		R/fmoi/LovSk/stoat/smaf/DC
		R/fmoi/LovSk/stoat/smaf/Hag
		R/fmoi/LovSk/stoat/smawm/A
		R/fmoi/LovSk/stoat/smawm/Hag
		R/fmoi/LSil/stoat/smaf/DC
		R/fmoi/MDpCF/stoat/smaf/DC
		R/fmoi/SSkEnt/stcat/fdfwm/Hag
		R/fmoi/SSkEnt/stcat/smaf/Ngfd
		R/fmoi/SSkEnt/stoat/smaf/Ngfd
		R/fmrac/LovSk/stcat/smaf/Ngfd
		R/fmrac/LovSk/stcat/smalf/Ngfe
		R/fmri/LGr/stoat/smawm/Hag
		R/fmri/LovSk/stoat/smawm/Hag
Riverine Rocky Willow Low and Tall Shrub	Low	R/fmoa/LGr/stow/fbbcwf/A
		R/fmoa/LGr/stow/fbbcwf/Hag
		R/fmoa/LGr/stow/fbcf/Hag
		R/fmoa/LovSk/stcw/swgb/Ngfe
		R/fmoa/LovSk/stcw/swwm/Hag
		R/fmoa/LovSk/stow/swgb/Ngfe
		R/fmoa/LSil/stcw/fbbcwf/Hag
		R/fmoa/LSil/stow/fbbcwf/DC
		R/fmoa/LSilbr/stcw/swgb/Ngfe

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Riverine Rocky Willow Low and Tall Shrub (continued)		R/fmoa/SSkEnt/stcw/swgb/DC
		R/fmoa/SSkEnt/stcw/swgb/Ngfd
		R/fmoa/SSkEnt/stcw/swgb/Ngfe
		R/fmoa/SSkEnt/stcw/swmm/Hag
		R/fmoa/SSkEnt/stow/fbbcwf/A
		R/fmoa/SSkEnt/stow/swgb/Ngfd
		R/fmoa/SSkEnt/stow/swgb/Ngfe
		R/fmoa/SSkEnt/stow/swmm/Ngfe
		R/fmoi/LGr/stow/fbbcwf/Hag
		R/fmoi/LGr/stow/fdfwm/Hag
		R/fmoi/LGr/stow/swmm/Hag
		R/fmoi/LovSk/stcw/swmm/Hag
		R/fmoi/LovSk/stow/fbbcwf/A
		R/fmoi/LovSk/stow/fppmo/Hag
		R/fmoi/LovSk/stow/swgb/DC
		R/fmoi/LovSk/stow/swgb/Hag
		R/fmoi/LovSk/stow/swgb/Ngfd
		R/fmoi/LovSk/stow/swmm/A
		R/fmoi/LSilor/stow/swwm/A
		R/fmoi/MDpCF/stcw/swmm/DC
		R/fmrac/LovSk/stcw/swgb/A
		R/fmrac/LovSk/stcw/swgb/Ngfd
		R/fmrac/LSilbr/stcw/swgb/Ngfe
		R/fmrac/LSilbr/stow/swgb/Ngfe
		R/fmrac/SSkEnt/stcw/swgb/Ngfe
		R/fmrac/SSkEnt/stow/fbbcwf/Ngfd
		R/fmrac/SSkEnt/stow/fbbcwf/Ngfe
		R/fmrac/SSkEnt/stow/fbcf/Hag
		R/fmrac/Water/stcw/swgb/Hag
		R/fmri/LovSk/stcw/swgb/Ngfd
		R/fmri/LovSk/stow/fbbcwf/Hag
		R/H/LSil/stow/swmmgrlfc/Hwc
Roads	Negligible	L/H/Roads/rd/rd/Hf
		L/H/Roads/rd/rd/Hfgrp
		L/H/Roads/rd/rd/Hfgru
		L/H/Roads/rd/rd/Hrr
		L/H/Roads/rd/rd/Hwl
		R/H/Roads/rd/rd/Hfgrp
		R/H/Roads/rd/rd/Hfgru
		S/H/Roads/rd/rd/Hfgru
		U/H/Roads/rd/rd/Hf

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Roads (continued)		U/H/Roads/rd/rd/Hfgrp
		U/H/Roads/rd/rd/Hfgru
		U/H/Roads/rd/rd/Hrr
Rocky Sitka Alder Tall Shrub	Low	S/ch/DpCF/ssa/ssa/Hag
		U/ch/LiShC/ssa/ssa/A
Subalpine Loamy-Rocky Grand Fir Forest	Low	S/ch/AsilovSk/fncg/fsfd/A
		S/ch/AsilovSk/fnog/fgfwd/A
		S/ch/AsilovSk/fnog/fgfwdo/A
		S/ch/DpCF/fnog/fgfc/A
		S/ch/LiShC/fnog/fgfc/A
		S/ch/LiShC/fnog/fgfwdo/A
		S/ch/MDpCF/fnog/fgfc/A
		S/ch/MDpCF/fnog/fgfcmo/A
		S/ch/MDpCF/fnog/fgfwd/A
		S/ch/MDpCF/fnog/fgfwdo/A
		S/ff/LGr/fnog/fgfcmo/A
		S/H/LiShC/fnog/fsfd/A
Subalpine Loamy-Rocky Lodgepole Pine Forest	Low	S/ch/AsilovSk/fnol/flpd/A
		S/ch/DpCF/fnol/fgfc/Nf
		S/ch/DpCF/fnol/flpd/A
		S/ch/MDpCF/fnol/fgfc/A
		S/ch/MDpCF/fnol/fgfc/Nf
		S/H/LiShC/fnol/fgfc/A
Subalpine Loamy-Rocky Subalpine Fir Forest	Low	S/ch/AsilovSk/fnscf/fsfd/A
		S/ch/AsilovSk/fnscf/fsfes/A
		S/ch/DpCF/fnscf/fsfd/A
		S/ch/DpCF/fnscf/fsfes/A
		S/ch/DpCF/fnsfo/fsfd/A
		S/ch/DpCF/fnsfw/hss/A
		S/ch/MDpCF/fnscf/fgfc/A
		S/ch/MDpCF/fnsfo/fsfd/A
		S/ff/DpCF/fnscf/fsfes/A
		S/ff/LGr/fnscf/fsfes/A
		S/fto/AsilovSk/fnscf/fsfd/A
		S/fto/DpCF/fnscf/fsfd/A
		S/fto/DpCF/fnscf/fsfes/A
		S/fto/DpCF/fnsfo/fsfd/A

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Subalpine Organic-rich Wet Graminoid Meadow	Low	S/Of/LSilor/hgw/hwmc/Hag
Subalpine Rocky Dry Graminoid Meadow	High	S/ch/DpCF/hus/hbwif/Hag
		S/ch/DpCF/hus/hss/Hag
		S/fto/DpCF/hus/hss/Hag
Upland Loamy Forb Meadow	Moderate	U/ch/AsilovSk/hfm/hfmm/A
Upland Loamy-Rocky Douglas-fir Forest	Low	U/Bx/LiShC/fncdf/fdfd/A
		U/Bx/LiShC/fncdf/fdfwm/A
		U/Bx/LiShC/fndfw/fdfwm/A
		U/Bx/LiShC/fndfw/fdfwm/Nf
		U/Bx/LiShC/fnodf/fdfd/A
		U/Bx/LiShC/fnodf/fdfwm/A
		U/Bx/LiShC/fnodf/fdfwm/Nf
		U/Bx/MDpCF/fnodf/fdfd/A
		U/ch/AsilovCF/fncdf/fdfwm/A
		U/ch/AsilovL/fncdf/fdflm/A
		U/ch/AsilovL/fncdf/fdfm/A
		U/ch/AsilovL/fncdf/fdfwm/A
		U/ch/AsilovL/fndfw/fdfm/Hcl
		U/ch/AsilovL/fndfw/fdfwm/A
		U/ch/AsilovL/fndfw/fdfwm/Hcl
		U/ch/AsilovL/fndfw/fdfwm/Nf
		U/ch/AsilovL/fnodf/fdfm/A
		U/ch/AsilovL/fnodf/fdfmo/A
		U/ch/AsilovL/fnodf/fdfmo/DC
		U/ch/AsilovL/fnodf/fdfwm/A
		U/ch/AsilovL/fnodf/fdfwm/Nf
		U/ch/AsilovSk/fncdf/fdfd/A
		U/ch/AsilovSk/fncdf/fdfwm/A
		U/ch/AsilovSk/fncdf/fdfwm/DC
		U/ch/AsilovSk/fndfw/fdfwm/A
		U/ch/AsilovSk/fnodf/fdfd/A
		U/ch/AsilovSk/fnodf/fdfm/A
		U/ch/AsilovSk/fnodf/fdfmo/A
		U/ch/AsilovSk/fnodf/fdfwm/A
		U/ch/DpCF/fncdf/fdfd/A
		U/ch/DpCF/fncdf/fdfm/A
		U/ch/DpCF/fncdf/fdfwm/A
		U/ch/DpCF/fncdf/fdfwm/Hd

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Upland Loamy-Rocky Douglas-fir Forest (continued)		U/ch/DpCF/fndfw/fdfd/A
		U/ch/DpCF/fndfw/fdfm/A
		U/ch/DpCF/fndfw/fdfwm/A
		U/ch/DpCF/fnodf/fdfmo/A
		U/ch/DpCF/fnodf/fdfwm/A
		U/ch/LGr/fnodf/fdfwm/A
		U/ch/LiShC/fmbcdfo/fdfwm/Hd
		U/ch/LiShC/fncdf/fdflm/DC
		U/ch/LiShC/fncdf/fdfmo/A
		U/ch/LiShC/fncdf/fdfwm/A
		U/ch/LiShC/fndfw/fdfd/A
		U/ch/LiShC/fndfw/fdfm/A
		U/ch/LiShC/fndfw/fdfmo/A
		U/ch/LiShC/fndfw/fdfwm/A
		U/ch/LiShC/fndfw/fdfwm/DC
		U/ch/LiShC/fndfw/fgfwdo/A
		U/ch/LiShC/fndfw/hbwif/A
		U/ch/LiShC/fnodf/fdfd/A
		U/ch/LiShC/fnodf/fdfm/A
		U/ch/LiShC/fnodf/fdfmo/A
		U/ch/LiShC/fnodf/fdfwm/A
		U/ch/LovSk/fncdf/fdfwm/A
		U/ch/MDpCF/fncdf/fdfd/A
		U/ch/MDpCF/fncdf/fdflm/A
		U/ch/MDpCF/fncdf/fdflm/Hc
		U/ch/MDpCF/fncdf/fdfm/A
		U/ch/MDpCF/fncdf/fdfm/Nf
		U/ch/MDpCF/fncdf/fdfmo/A
		U/ch/MDpCF/fncdf/fdfwm/A
		U/ch/MDpCF/fncdf/fdfwm/DC
		U/ch/MDpCF/fncdf/fdfwm/Nf
		U/ch/MDpCF/fndfw/fdfd/A
		U/ch/MDpCF/fndfw/fdfd/DC
		U/ch/MDpCF/fndfw/fdfd/Hag
		U/ch/MDpCF/fndfw/fdfd/Nf
		U/ch/MDpCF/fndfw/fdfmo/A
		U/ch/MDpCF/fndfw/fdfwm/A
		U/ch/MDpCF/fndfw/fdfwm/Hcl
		U/ch/MDpCF/fndfw/fdfwm/Nf
		U/ch/MDpCF/fndfw/wpps/A
		U/ch/MDpCF/fnodf/fdfd/A

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Upland Loamy-Rocky Douglas-fir Forest (continued)		U/ch/MDpCF/fnodf/fdfd/Hag
		U/ch/MDpCF/fnodf/fdfd/Hdr
		U/ch/MDpCF/fnodf/fdfd/Nf
		U/ch/MDpCF/fnodf/fdfm/A
		U/ch/MDpCF/fnodf/fdfm/Nf
		U/ch/MDpCF/fnodf/fdfmo/A
		U/ch/MDpCF/fnodf/fdfmo/DC
		U/ch/MDpCF/fnodf/fdfwm/A
		U/ch/MDpCF/fnodf/fdfwm/DC
		U/ch/MDpCF/fnodf/fdfwm/Hcl
		U/ch/MDpCF/fnodf/fdfwm/Nf
		U/ch/StmBkHG/fnodf/fdfd/A
		U/ch/StmBkHG/fnodf/fdfwm/A
		U/ff/AsilovSk/fnodf/fdfm/A
		U/ff/AsilovSk/fnodf/fdfwm/A
		U/ff/DpCF/fnodf/fdfd/A
		U/ff/DpCF/fnodf/fdfwm/A
		U/ff/LiShC/fnodf/fdfwm/A
		U/ff/MDpCF/fndfw/fdfwm/A
		U/ff/MDpCF/fnodf/fdfd/A
		U/ff/MDpCF/fnodf/fdfwm/A
		U/fto/LSil/fmbcdfc/fdflm/DC
		U/fto/LSil/fndfw/fdflm/Hdr
		U/fto/LSil/fnodf/fdflm/DC
		U/fto/LSil/fnodf/fdfwm/DC
		U/fto/MDpCF/fncdf/fdfwm/DC
		U/fto/MDpCF/fndfw/fdfwm/DC
		U/ftr/AsilovL/fnodf/fdfwm/A
		U/H/LiShC/fndfw/fdfd/Hf
		U/H/Rock/fndfw/fdfd/He
Upland Loamy-Rocky Dry Graminoid Meadow	High	U/ff/AsilovSk/hus/hbwif/Hag
		U/ff/DpCF/hgd/fppd/Hag
		U/ff/DpCF/hgd/hmd/Hag
		U/ff/LGr/hus/hbwif/Hag
		U/ff/LGr/hus/husgbwc/Hag
		U/ff/LGr/hus/husgbwc/Hah
		U/ff/LSil/hgd/hmd/A
		U/ff/LSilor/hgd/hmd/A
		U/ff/MDpCF/hus/hbwif/Hag
		U/fmob/DpCF/hgd/fdfm/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Upland Loamy-Rocky Dry Graminoid Meadow (continued)		U/fmob/LGr/hgd/hmd/A
		U/fto/LSil/hgd/hmd/DC
		U/fto/MDpCF/hus/fdfmo/Hcl
		U/fto/MDpCF/hus/hbwif/Hag
		U/fto/SSkEnt/hgd/hmd/Hag
		U/ftr/AsilovL/hgd/hmd/A
		U/H/DpCF/hus/fgfcmo/Hag
		U/H/DpSiCL/hgd/fppm/Hag
		U/H/LGr/hus/husd/Hf
		U/H/LovSk/hus/husd/Hf
		U/H/MDpCF/hus/husd/DC
		U/H/MDpCF/hus/husd/Hf
	Low	U/Bx/LiShC/hgd/a/Ha
		U/Bx/LiShC/hgd/fgfc/A
		U/Bx/LiShC/hgd/flpd/A
		U/Bx/LiShC/hgd/hbwif/A
		U/Bx/LiShC/hgd/hbwif/Nf
		U/Bx/LiShC/hgd/husd/A
		U/Bx/MDpCF/hgd/husd/A
		U/Bx/Rock/hus/hbwif/Hag
	Moderate	U/ch/AsilovL/hgd/hbwif/A
		U/ch/AsilovL/hgd/hmd/Hag
		U/ch/AsilovL/hgd/wpps/Hag
		U/ch/AsilovL/hus/hbwif/Hag
		U/ch/AsilovL/hus/hss/Hag
		U/ch/AsilovSk/hgd/fgfc/Hcl
		U/ch/AsilovSk/hgd/hbwif/A
		U/ch/AsilovSk/hgd/husd/A
		U/ch/AsilovSk/hgd/husd/Hag
		U/ch/AsilovSk/hus/hbwif/A
		U/ch/AsilovSk/hus/hbwif/Hag
		U/ch/AsilovSk/hus/hss/Hag
		U/ch/AsilovSk/hus/husd/A
		U/ch/DpCF/hgd/fgfc/A
		U/ch/DpCF/hgd/fppd/Hag
		U/ch/DpCF/hgd/hbwif/A
		U/ch/DpCF/hgd/husd/A
		U/ch/DpCF/hgd/sum/Hag
		U/ch/DpCF/hus/hbwif/A
		U/ch/DpCF/hus/hbwif/Hag
		U/ch/DpSiCL/hus/hbwif/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Upland Loamy-Rocky Dry Graminoid Meadow (continued)		U/ch/LGr/hus/hbwif/Hag
		U/ch/LGr/hus/husd/Hf
		U/ch/LiShC/hgd/fppm/DC
		U/ch/LiShC/hgd/hbwif/Hag
		U/ch/LiShC/hgd/hmd/Hag
		U/ch/LiShC/hgd/hmd/Hc
		U/ch/LiShC/hgd/husd/A
		U/ch/LiShC/hus/fgfcmo/Hag
		U/ch/LiShC/hus/hbwif/A
		U/ch/LiShC/hus/hbwif/DC
		U/ch/LiShC/hus/hbwif/Ha
		U/ch/LiShC/hus/hbwif/Haf
		U/ch/LiShC/hus/hbwif/Hag
		U/ch/LiShC/hus/hbwif/Nf
		U/ch/LiShC/hus/hss/A
		U/ch/LiShC/hus/hss/Hag
		U/ch/LiShC/hus/husd/Hag
		U/ch/LiShC/hus/husd/Nf
		U/ch/LovSk/hus/husd/Hag
		U/ch/LSil/hus/hbwif/Hag
		U/ch/LSil/hus/hss/Hag
		U/ch/LSilor/hgd/husd/A
		U/ch/LSilor/hus/fgfcmo/Hag
		U/ch/LSilor/hus/hss/Hag
		U/ch/MDpCF/hgd/fdfd/DC
		U/ch/MDpCF/hgd/fdfd/Hc
		U/ch/MDpCF/hgd/fdfwm/Hcl
		U/ch/MDpCF/hgd/hbwif/A
		U/ch/MDpCF/hgd/hbwif/Hag
		U/ch/MDpCF/hgd/hbwif/Nf
		U/ch/MDpCF/hus/fdfwm/Hcl
		U/ch/MDpCF/hus/fgfwdo/Hcl
		U/ch/MDpCF/hus/hbwif/A
		U/ch/MDpCF/hus/hbwif/DC
		U/ch/MDpCF/hus/hbwif/Hag
		U/ch/MDpCF/hus/hbwif/Hcl
		U/ch/MDpCF/hus/hbwif/Hdr
		U/ch/MDpCF/hus/hbwif/He
		U/ch/MDpCF/hus/husd/A
		U/ch/MDpCF/hus/sum/Hag
		U/ch/Rock/hus/hbwif/A

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Upland Loamy-Rocky Dry Graminoid Meadow (continued)		U/ch/Rock/hus/hbwif/Hag
		U/ch/StmBkHG/hgd/fdfd/Hc
		U/ch/StmBkHG/hgd/hmd/A
Upland Loamy-Rocky Grand Fir Forest	Low	U/Bx/LiShC/fngfw/fgfwd/A
		U/Bx/LiShC/fnog/fdfwm/A
		U/Bx/LiShC/fnog/fgfcm/A
		U/Bx/LiShC/fnog/fgfwd/A
		U/ch/AsilovCF/fncg/fgfcm/A
		U/ch/AsilovCF/fncg/fgfes/A
		U/ch/AsilovL/fncg/fdfwm/A
		U/ch/AsilovL/fncg/fgfc/A
		U/ch/AsilovL/fncg/fgfwd/A
		U/ch/AsilovL/fnog/fgfwdo/A
		U/ch/AsilovSk/fncg/fdfwm/A
		U/ch/AsilovSk/fncg/fgfc/A
		U/ch/AsilovSk/fncg/fgfcm/A
		U/ch/AsilovSk/fncg/fgfcmo/A
		U/ch/AsilovSk/fncg/fgfwd/A
		U/ch/AsilovSk/fngfw/fgfc/Hcl
		U/ch/AsilovSk/fngfw/fgfcm/Hcl
		U/ch/AsilovSk/fngfw/fgfcmo/A
		U/ch/AsilovSk/fngfw/fgfwd/A
		U/ch/AsilovSk/fngfw/fgfwdo/A
		U/ch/AsilovSk/fnog/fdfwm/A
		U/ch/AsilovSk/fnog/fgfc/A
		U/ch/AsilovSk/fnog/fgfcm/A
		U/ch/AsilovSk/fnog/fgfcmo/A
		U/ch/AsilovSk/fnog/fgfcmo/Hcl
		U/ch/AsilovSk/fnog/fgfwd/A
		U/ch/AsilovSk/fnog/fgfwdo/A
		U/ch/DpCF/fncg/fdfwm/A
		U/ch/DpCF/fncg/fgfc/A
		U/ch/DpCF/fncg/fgfcm/A
		U/ch/DpCF/fncg/fgfcmo/A
		U/ch/DpCF/fncg/fgfes/A
		U/ch/DpCF/fncg/fgfwd/A
		U/ch/DpCF/fncg/fgfwdo/A
		U/ch/DpCF/fngfw/fgfwdo/A
		U/ch/DpCF/fnog/fgfc/A
		U/ch/DpCF/fnog/fgfcmo/A

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Upland Loamy-Rocky Grand Fir Forest (continued)		U/ch/DpCF/fnog/fgfwd/A
		U/ch/DpCF/fnog/fgfwdo/A
		U/ch/DpSiCL/fncg/fgfcm/A
		U/ch/LiShC/fncg/fdfwm/A
		U/ch/LiShC/fncg/fgfc/A
		U/ch/LiShC/fncg/fgfcm/A
		U/ch/LiShC/fncg/fgfcmo/A
		U/ch/LiShC/fncg/fgfwd/A
		U/ch/LiShC/fncg/fgfwdo/A
		U/ch/LiShC/fngfw/fgfc/A
		U/ch/LiShC/fngfw/fgfcm/A
		U/ch/LiShC/fngfw/fgfcm/Hcl
		U/ch/LiShC/fngfw/fgfcmo/A
		U/ch/LiShC/fngfw/fgfwd/A
		U/ch/LiShC/fngfw/fgfwdo/A
		U/ch/LiShC/fnog/fgfc/A
		U/ch/LiShC/fnog/fgfcm/A
		U/ch/LiShC/fnog/fgfcmo/A
		U/ch/LiShC/fnog/fgfwd/A
		U/ch/LiShC/fnog/fgfwdo/A
		U/ch/LovSk/fncg/fgfcm/A
		U/ch/LSil/fnog/fgfcm/Hf
		U/ch/LSilor/fngfw/fgfwdo/A
		U/ch/LSilor/fnog/fgfcm/A
		U/ch/MDpCF/fncg/fdfwm/A
		U/ch/MDpCF/fncg/fgfc/A
		U/ch/MDpCF/fncg/fgfcm/A
		U/ch/MDpCF/fncg/fgfcmo/A
		U/ch/MDpCF/fncg/fgfes/A
		U/ch/MDpCF/fncg/fgfwd/A
		U/ch/MDpCF/fngfw/fdfwm/A
		U/ch/MDpCF/fngfw/fgfcm/A
		U/ch/MDpCF/fngfw/fgfcmo/A
		U/ch/MDpCF/fngfw/fgfcmo/Hcl
		U/ch/MDpCF/fngfw/fgfwd/A
		U/ch/MDpCF/fngfw/fgfwdo/A
		U/ch/MDpCF/fnog/fdfwm/A
		U/ch/MDpCF/fnog/fgfc/A
		U/ch/MDpCF/fnog/fgfcm/A
		U/ch/MDpCF/fnog/fgfcmo/A
		U/ch/MDpCF/fnog/fgfcmo/Hcl

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Upland Loamy-Rocky Grand Fir Forest (continued)		U/ch/MDpCF/fnog/fgfes/A
		U/ch/MDpCF/fnog/fgfwd/A
		U/ch/MDpCF/fnog/fgfwdo/A
		U/ch/Rock/fngfw/fgfwdo/A
		U/ch/Rock/fnog/fgfc/A
		U/ch/Water/fncg/fgfwd/A
		U/ff/AsilovSk/fncg/fgfcm/A
		U/ff/AsilovSk/fncg/fgfcmo/A
		U/ff/AsilovSk/fnog/fgfcmo/A
		U/ff/DpCF/fnog/fdfwm/A
		U/ff/DpCF/fnog/fgfcmo/A
		U/ff/LGr/fnog/fgfcmo/A
		U/ff/MDpCF/fncg/fgfcm/A
		U/ff/MDpCF/fnog/fgfcmo/A
		U/fto/AsilovSk/fncg/fgfcm/A
		U/fto/LiShC/fnog/fgfcmo/A
		U/fto/MDpCF/fnog/fgfcmo/A
		U/ftr/AsilovSk/fnog/fgfcm/A
Upland Loamy-Rocky Lodgepole Pine Forest	Low	U/Bx/LiShC/fncl/flpd/A
		U/Bx/LiShC/fnol/flpd/A
		U/Bx/LiShC/fnwl/flpd/A
		U/ch/AsilovCF/fnol/fgfwd/Nf
		U/ch/AsilovCF/fnol/flpd/A
		U/ch/AsilovL/fncl/fgfwd/A
		U/ch/AsilovL/fncl/flpd/A
		U/ch/AsilovL/fnol/fgfc/A
		U/ch/AsilovL/fnol/fgfwd/Nf
		U/ch/AsilovL/fnol/flpd/A
		U/ch/AsilovL/fnwl/fgfc/A
		U/ch/AsilovL/fnwl/flpd/A
		U/ch/AsilovL/fnwl/flpmm/A
		U/ch/AsilovSk/fncl/fgfcm/A
		U/ch/AsilovSk/fncl/flpd/A
		U/ch/AsilovSk/fnol/fgfcmo/A
		U/ch/AsilovSk/fnol/flpd/A
		U/ch/AsilovSk/fnwl/fgfwd/Nf
		U/ch/AsilovSk/fnwl/flpd/A
		U/ch/DpCF/fncl/flpd/A
		U/ch/DpCF/fnol/fgfcm/Nf
		U/ch/DpCF/fnol/fgfwd/Nf

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Upland Loamy-Rocky Lodgepole Pine Forest (continued)		U/ch/DpCF/fnol/flpd/A
		U/ch/LiShC/fncl/fgfc/A
		U/ch/LiShC/fncl/fgfcm/A
		U/ch/LiShC/fncl/fgfcmo/Nf
		U/ch/LiShC/fncl/fgfwd/Nf
		U/ch/LiShC/fncl/flpd/A
		U/ch/LiShC/fncl/fsfd/A
		U/ch/LiShC/fnol/fgfc/A
		U/ch/LiShC/fnol/fgfcm/A
		U/ch/LiShC/fnol/fgfcm/Nf
		U/ch/LiShC/fnol/fgfcmo/Nf
		U/ch/LiShC/fnol/fgfwd/A
		U/ch/LiShC/fnol/fgfwd/Nf
		U/ch/LiShC/fnol/flpd/A
		U/ch/LiShC/fnwl/fgfcm/A
		U/ch/LiShC/fnwl/fgfcm/Nf
		U/ch/LiShC/fnwl/fgfcmo/Nf
		U/ch/LiShC/fnwl/fgfwd/A
		U/ch/LiShC/fnwl/fgfwd/Nf
		U/ch/LiShC/fnwl/flpd/A
		U/ch/LiShC/fnwl/flpd/Hag
		U/ch/LiShC/fnwl/flpmm/A
		U/ch/LiShC/fnwl/flpmm/DC
		U/ch/LiShC/fnwl/wpps/Nf
		U/ch/LSilor/fnol/fgfcmo/Nf
		U/ch/LSilor/fnol/flpd/A
		U/ch/LSilor/fnwl/fgfwd/Nf
		U/ch/MDpCF/fncl/fgfcm/Nf
		U/ch/MDpCF/fncl/fgfwd/Nf
		U/ch/MDpCF/fncl/flpd/A
		U/ch/MDpCF/fnol/fgfcm/Nf
		U/ch/MDpCF/fnol/fgfwd/A
		U/ch/MDpCF/fnol/fgfwd/Nf
		U/ch/MDpCF/fnol/flpd/A
		U/ch/MDpCF/fnwl/fgfwd/Nf
		U/ch/SSkEnt/fnol/flpd/A
		U/ff/DpCF/fnol/flpd/A
		U/ff/MDpCF/fnol/flpd/A
		U/fmob/AsilovSk/fncl/flpd/A
		U/fmob/MDpCF/fnol/flpmm/A
		U/fto/LSilor/fnol/flpd/A

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Upland Loamy-Rocky Lodgepole Pine Forest (continued)		U/H/AsilovSk/fncl/fgfcm/Hf
		U/H/AsilovSk/fnwl/flpd/A
		U/H/LiShC/fnwl/fgfcmo/Nf
		U/H/LiShC/fnwl/fsfd/He
		U/H/SSkEnt/fnol/flpd/Hft
Upland Loamy-Rocky Low Elevation Mixed Shrubland	Low	U/ch/LGr/smxlc/smxl/Hag
		U/ch/LiShC/smxlo/smxl/Hag
Upland Loamy-Rocky Moist Graminoid Meadow	Moderate	U/ch/AsilovL/hgm/hmm/A
		U/ch/AsilovL/hgm/hmm/DC
		U/ch/AsilovSk/hgm/hmcm/A
		U/ch/AsilovSk/hgm/hmm/Hag
		U/ch/AsilovSk/hgm/husd/Hag
		U/ch/DpCF/hgm/husd/Hag
		U/ch/DpCF/hgwmcc/hgmcwmc/Hag
		U/ch/DpSiCL/hgm/fdfwm/Hsb
		U/ch/DpSiCL/hgm/fppm/Hag
		U/ch/LiShC/hgm/fgfcmo/Hcl
		U/ch/LiShC/hgm/hmm/DC
		U/ch/LiShC/hgm/hmm/Hag
		U/ch/LiShC/hgw/hwm/Hag
		U/ch/MDpCF/hgm/fsfd/A
		U/ch/MDpCF/hgm/hmm/Hag
		U/ch/MDpCF/hgm/sum/Hag
		U/ff/DpCF/hgm/fdfwm/Hag
		U/ff/DpCF/hgm/fppm/Hag
		U/ff/DpCF/hgm/hmm/A
		U/fto/AsilovL/hgm/hmm/Hag
		U/H/LiShC/hgm/sum/Hah
		U/H/LovSk/hgm/fbclf/Hsb
Upland Loamy-Rocky Ponderosa Pine Forest	Low	U/Bx/LiShC/fnopp/fppd/A
		U/Bx/LiShC/fnwpp/fppd/A
		U/Bx/LiShC/fnwpp/fppd/Nf
		U/ch/AsilovL/fncpp/fdfd/Nf
		U/ch/AsilovL/fnopp/wpps/A
		U/ch/AsilovL/fnwpp/fdfd/Nf
		U/ch/AsilovL/fnwpp/fppd/A
		U/ch/AsilovL/fnwpp/fppd/Nf
		U/ch/AsilovL/fnwpp/fppmo/A

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Upland Loamy-Rocky Ponderosa Pine Forest (continued)		U/ch/AsilovL/fnwpp/wpps/A
		U/ch/AsilovSk/fncpp/fppm/A
		U/ch/DpCF/fnopp/fppd/A
		U/ch/DpCF/fnopp/fppm/A
		U/ch/DpSiCL/fnopp/fppm/A
		U/ch/LiShC/fncpp/fppd/A
		U/ch/LiShC/fncpp/fppm/A
		U/ch/LiShC/fnopp/fdfd/Nf
		U/ch/LiShC/fnopp/fdfwm/Nf
		U/ch/LiShC/fnopp/fppd/A
		U/ch/LiShC/fnopp/fppm/A
		U/ch/LiShC/fnopp/fppmo/A
		U/ch/LiShC/fnopp/wpps/A
		U/ch/LiShC/fnopp/wpps/DC
		U/ch/LiShC/fnwpp/fdfwm/Nf
		U/ch/LiShC/fnwpp/fppd/A
		U/ch/LiShC/fnwpp/fppm/A
		U/ch/LiShC/fnwpp/fppmo/A
		U/ch/LiShC/fnwpp/wpps/A
		U/ch/LovSk/fnopp/fppmo/DC
		U/ch/LovSk/fnwpp/fppd/A
		U/ch/LovSk/fnwpp/wpps/A
		U/ch/LSil/fnwpp/fppd/A
		U/ch/LSil/fnwpp/fppm/A
		U/ch/MDpCF/fncpp/fdfwm/Nf
		U/ch/MDpCF/fncpp/fppd/A
		U/ch/MDpCF/fnopp/fppd/A
		U/ch/MDpCF/fnopp/fppd/DC
		U/ch/MDpCF/fnopp/fppd/Nf
		U/ch/MDpCF/fnopp/fppm/A
		U/ch/MDpCF/fnopp/fppmo/A
		U/ch/MDpCF/fnopp/wpps/A
		U/ch/MDpCF/fnwpp/fppd/A
		U/ch/MDpCF/fnwpp/fppd/Hcl
		U/ch/MDpCF/fnwpp/fppd/Nf
		U/ch/MDpCF/fnwpp/fppmo/A
		U/ch/MDpCF/fnwpp/wpps/A
		U/ch/MDpCF/fnwpp/wpps/DC
		U/ch/MDpCF/fnwpp/wpps/Hcl
		U/ff/DpCF/fnwpp/fppd/A
		U/ff/LiShC/fnwpp/wpps/A

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Upland Loamy-Rocky Ponderosa Pine Forest (continued)		U/ff/MDpCF/fnwpp/wpps/A
		U/fto/AsilovSk/fnopp/fppd/A
		U/H/LiShC/fnwpp/fppm/A
		U/H/MDpCF/fnopp/fppm/Hf
Upland Loamy-Rocky Subalpine Fir Forest	Low	U/ch/AsilovSk/fnscf/fgfes/A
		U/ch/AsilovSk/fnscf/fsfes/A
		U/ch/AsilovSk/fnsfo/fsfes/A
		U/ch/AsilovSk/fnsfo/fsfeso/A
		U/ch/LiShC/fnscf/fsfd/A
		U/ch/LiShC/fnsfo/fsfd/A
		U/ch/MDpCF/fnscf/fsfd/A
		U/ch/MDpCF/fnsfo/fsfd/A
Upland Loamy-Rocky Thinleaf Alder Tall Shrub	Low	U/ch/MDpCF/stcat/smaf/DC
		U/ch/MDpCF/stcat/smaf/Hag
		U/fto/LovSk/stcat/smaf/DC
Upland Rocky Barrens and Partially Vegetated	High	U/Bx/LiShC/bpvh/ro/A
		U/Bx/Rock/bbg/ro/A
		U/Bx/Rock/bbg/ro/Hag
		U/Bx/Rock/bpvh/ro/A
		U/Bx/Rock/bpvh/ro/Hag
		U/ch/LiShC/bbg/bbg/A
		U/ch/LiShC/bbg/ro/A
		U/ch/LiShC/bbg/ro/Hag
		U/ch/LiShC/bpvh/bbg/A
		U/ch/LiShC/bpvh/bbg/Hag
		U/ch/MDpCF/bbg/ro/Nf
		U/ch/Rock/bbg/ro/Hag
		U/fto/StmBkHG/bbg/swmm/Ngfe
Upland Rocky Black Cottonwood Forest	Low	U/ff/DpCF/fbwc/fbct/A
		U/H/MDpCF/fboc/fbct/DC
Upland Rocky Black Hawthorn Tall Shrub	Low	U/ch/LiShC/stcbh/fppm/Hag
		U/ch/LiShC/stobh/sbh/Hag
		U/ch/MDpCF/stobh/fdfm/Hag
		U/ch/MDpCF/stobh/sbh/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Upland Rocky Human-modified Barrens and Partially Vegetated	High	U/ch/DpSiCL/bpvh/ub/Hdr
		U/ch/LiShC/bpvh/bbg/He
		U/ch/LiShC/bpvh/ub/Hdr
		U/ch/MDpCF/bpvh/hmd/Hc
		U/H/DpCF/bbg/bbg/He
		U/H/DpCF/bbg/bbg/Hft
		U/H/LGr/bbg/husgbwc/Hp
		U/H/LiShC/bpvh/bbg/He
		U/H/SSkEnt/bbg/bbg/Hc
		U/H/SSkEnt/bpvh/bbg/Hft
		U/Wh/LGr/bbg/bbg/Hf
Upland Rocky Willow Tall Shrub	Low	U/H/MDpCF/stcw/swmm/Hf
Upland Rocky-Loamy Undiffentiated Shrubland	Low	L/fmob/LSil/suo/sum/Hag
		L/fmob/MDpCF/suo/sum/Hf
		L/fto/LSil/suo/sum/Hd
		L/H/LSil/suc/sum/Hf
		R/fmoa/DpSiCL/suc/sum/Hag
		R/fmoa/LiShC/suc/sum/Hag
		U/Bx/LiShC/suo/sud/A
		U/Bx/LiShC/suo/sum/A
		U/ch/AsilovL/suc/sum/Hag
		U/ch/AsilovL/suc/sum/Hcl
		U/ch/AsilovL/suo/sum/DC
		U/ch/AsilovL/suo/sum/Hag
		U/ch/AsilovSk/suo/scs/A
		U/ch/AsilovSk/suo/sum/A
		U/ch/DpCF/suc/sum/A
		U/ch/DpCF/suc/sum/Hag
		U/ch/DpCF/suo/fppm/Hsisd
		U/ch/DpSiCL/suc/sum/Hag
		U/ch/LGr/suc/sum/Hag
		U/ch/LiShC/suc/sum/Hag
		U/ch/LiShC/suo/smxl/Hag
		U/ch/LiShC/suo/sud/A
		U/ch/LiShC/suo/sum/A
		U/ch/LiShC/suo/sum/Hag
		U/ch/MDpCF/suc/sud/Hag
		U/ch/MDpCF/suc/sum/DC
		U/ch/MDpCF/suc/sum/Hag

Appendix 8. Continued.

Ecotype	Erosion Sensitivity	ITU
Upland Rocky-Loamy Undiffentiated Shrubland (continued)		U/ch/MDpCF/suc/sum/Hcl
		U/ch/MDpCF/suo/smxl/Hag
		U/ch/MDpCF/suo/sum/A
		U/ch/MDpCF/suo/sum/Hag
		U/ch/Rock/suo/sud/Hag
		U/ch/StmBkHG/suo/scs/A
		U/H/LiShC/suo/sum/Hf
		U/H/MDpCF/suc/sum/Hf

Appendix D – Restoration Database

Mapping Tributary Habitat Restoration Projects in the Upper Grande Ronde River to Support Landscape Analysis

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January 19, 2016

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Contents

List of Tables

List of Figures

Abstract

Stream restoration is increasingly being administered in the Pacific Northwest to improve salmon habitat function and fish abundance, among other goals. Although numerous restoration projects have been completed, many consisting of multiple sites and activity types, few projects have been consistently monitored for effectiveness. Furthermore, monitoring is often conducted at the spatial scale of individual sites, which fails to account for larger scale watershed functions. To support the evaluation of potentially far reaching effects of restoration, restoration project information was compiled and mapped and a method for assessing restoration intensity across work sites was developed. This project is the first step in evaluating the cumulative effect of decades of restoration efforts on habitat condition across a large project area. Restoration project information, including restoration type and associated metrics, was collected for the Upper Grande Ronde River watershed. A total of 4,449 work sites were compiled for the study area, coming from 10 different data archives, with a total of 71 unique metrics relevant to stream habitat function. The predominant time period of projects was from 1994-2014, although some projects were completed in 2015. Metrics include measurements and descriptions of restoration work completed. A data table was created to organize separate work sites, with metrics organized by the type of restoration, referred to as the sub-category. Information about spatial location was available for most work sites and was uploaded into a geographic information system (GIS) to generate a shapefile of work site mid-points. The mid-points were subsequently used to analyze the correspondence between mapped restoration efforts and restoration detected during field visits. Habitat monitoring reaches from the Columbia Habitat Monitoring Program (CHaMP) were visually surveyed for the presence of restoration activities expected based on the GIS map. Of projects that were mapped in GIS, there was a wide range of correspondence in detecting those activities in the field, from 100 percent for floodplain reconnection projects, to 33 percent for planting projects. Stream length treated per work site sub-category is proposed as one means of describing restoration intensity across all work sites, based on that being the most commonly reported and therefore consistently available metric. Further investigation into the statistical significance of using the stream length treated per work site sub-category, and the development of ratings or rankings as a means of assessing restoration, is needed to determine the usefulness in predicting habitat improvements achieved through different restoration techniques.

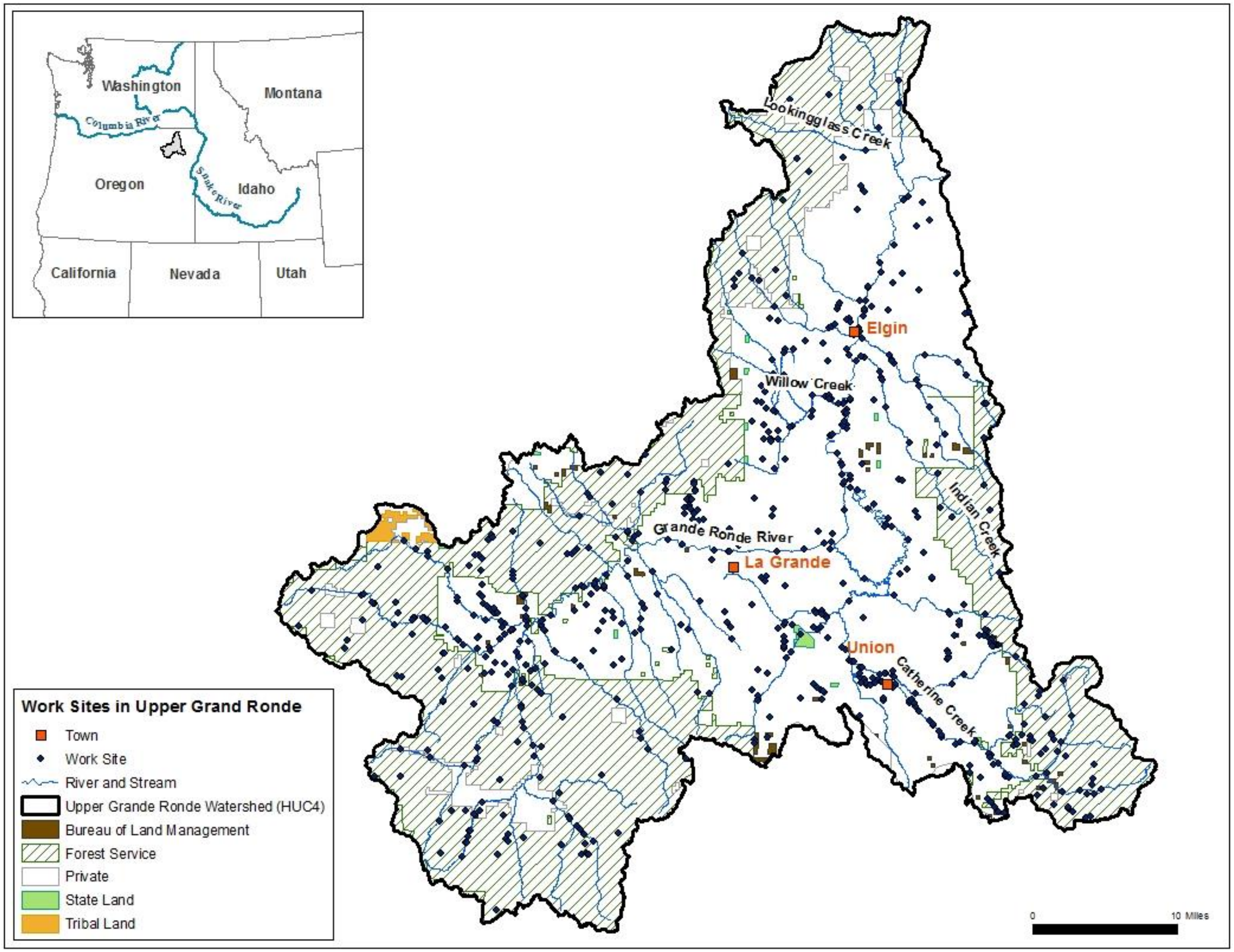
I. Introduction

The decline of endangered salmon populations in the Columbia River basin has led to extensive efforts to restore these populations through habitat restoration. Stream restoration projects have been used as a way of recovering salmon habitat to improve fish productivity and meet requirements of the endangered species act (ESA) (Roni, Pess, Beechie, & Hanson, 2014). Although this method of salmon recovery has been widely accepted, few quantitative studies have been completed to confirm the intended results (Whiteway, Biron, Zimmermann, Venter, & Grant, 2010). Furthermore the monitoring that is conducted typically focuses on site-specific responses of habitat conditions, not including biological responses or an evaluation of change across a watershed (Roni, Pess, Beechie, & Hanson, 2014). Evaluating stream restoration projects from a landscape perspective—as opposed to individual sites—can offer insights into habitat actions required to address factors affecting freshwater salmon production (Fausch, Torgersen, Baxter, & Li, 2002).

A landscape refers to an area of land (at any scale) containing a pattern that affects and is affected by an ecological process of interest (McGarigal, 2001). A landscape perspective, then, involves the study of these landscape patterns, the interactions among the elements of this pattern, and how these patterns and interactions change over time. A preliminary step in evaluating restoration from a landscape perspective is compiling existing information on where restoration actions occurred, what type of restoration was completed, and the intensity of restoration actions across the study area. This can be challenging, as many stream restoration projects are implemented independently, with little coordination between agencies on the types of data collected (Palmer & Allen, 2006). While some project-level effectiveness monitoring data are available for a few restoration projects, most projects have implementation information that can be compiled in assessing the extent and intensity of past restoration over a larger area. These data can be used to develop restoration intensity metrics, which may be linked to biological responses. Such efforts will likely provide key information for understanding fish-habitat relationships and eventually assist in the development of a salmon life cycle model.

This work is part of the Columbia River Inter-Tribal Fish Commission's (CRITFC) Monitoring Recovery Trends project (McCullough D. , 2009), which is funded by the 2008 Columbia Basin Fish Accords Memorandum of Agreement between the Three Treaty Tribes and the Federal Columbia River Power System (FCRPS) Action Agencies. The Monitoring Recovery Trends project evaluates the status and trends of spring Chinook Salmon habitat in the Upper Grande Ronde River (including Catherine Creek and Minam River) of NE Oregon (Figure 1). Instream and riparian monitoring is conducted using the Columbia Habitat Monitoring Program (CHaMP) by CRITFC, in collaboration with Oregon Department of Fish and Wildlife's (ODFW) La Grande field office. The CHaMP program includes the collection of topographic information and habitat metrics critical to salmon health. The CHaMP data is separate from the stream restoration information compiled for this project. However, having both data for the same area will ultimately allow for an analysis of the relationships between stream restoration and habitat metrics. The spatial scope of both of these data also supports the overall goal of evaluating stream restoration from a landscape perspective.

Figure 1. Map of the Upper Grande Ronde River watershed showing 705 restoration work sites implemented between the years 1986 and 2014. This map does not show work sites that only implemented invasive plant removal due to that information being incomplete.



The objectives of this project were to:

1) Compile restoration project information from all known data sources for the Upper Grand Ronde River basin, including metrics by restoration type.
2) Create a spatial data layer directly corresponding to the compiled restoration information.
3) Assess the correspondence between restoration locations reported by agencies and restoration projects visually identified while in the field.
4) Propose alternative methods of assessing restoration intensity across a study area when metrics reported by agencies are inconsistent.

II. Methods

a. Compilation of projects

Study Area

The study area for this project is the Upper Grande Ronde River watershed (Figure 1), part of the Grande Ronde River Subbasin located in northeastern Oregon. The area encompasses both the Upper Grande Ronde River and Catherine Creek spring Chinook Salmon populations, which are the main focus of this project and listed under the Endangered Species Act (ESA). The study area also serves as important habitat for Lookingglass spring Chinook Salmon, and the watershed boundary replicates the extent of the Upper Grande Ronde steelhead population (McCullough D. A., et al., 2015). Restoration work sites extend throughout the Upper Grande Ronde River watershed, distributed within local fish populations. The watershed lies mostly within Union County, with La Grande being the largest city in the catchment. Property ownership in the watershed is mostly split between private landowners and the Forest Service, with small parcels held by the state, the Bureau of Land Management (BLM), and the tribes. The Grande Ronde River Subbasin is part of the larger Snake River Basin, a tributary of the Columbia River. Intensive land use in this area, including timber harvest, livestock grazing, and agricultural production, has led to declines in Chinook populations (McIntosh, et al., 1994). These land use changes have generated a need for stream restoration and effectiveness monitoring (McCullough D. A., et al., 2015).

Data Sources

Sources of restoration project information were identified and recorded in a data table. Data sources were found through online research; contacting federal, state, and tribal land management agencies; meetings with CRITFC staff; personal contacts made at the 2015 River Restoration Northwest symposium, and correspondence with members of the Grande Ronde Atlas Science Technical Advisory Committee meeting on July 31st, 2014. See Table 1 for a list of restoration project sources, range of dates captured, and number of work sites per source. The Department of State Lands removal-fill/general authorizations permits for Union County were also reviewed for potentially unaccounted for restoration projects, but no permits were filed for the study area.

Table 1. Source information for the restoration work site data table within the Upper Grande Ronde River watershed.

Agency	Source	Data Archive	Year Range	Total Number Of Unique Work Sites
Oregon Watershed Enhancement Board	oregonexplorer.info	Oregon Watershed Restoration Inventory	1992-2013	3837
Grande Ronde Model Watershed	Mason Bailie & grmw.org/projectdb	Grande Ronde Model Watershed Project Database	1987-2013	348
National Oceanic and Atmospheric Administration	Monica Diaz	Pacific Northwest Salmon Habitat Project Database	1986-2012	174
Oregon Department of Fish and Wildlife Grande Ronde Watershed District	Winston Morton	Grande Ronde Fish Habitat Database	1985-2012	32
Bureau of Land Management, Vale District	blm.gov/or/gis/data.php	Interagency Restoration Database	1993-2014	20
The Confederated Tribes of the Umatilla Indian Reservation	Les Naylor	CTUIR Fish Accord Habitat Projects, Limiting Factors and Accomplishments 2008-2014 project information spreadsheets	2008-2014	13
The Freshwater Trust, Flow Restoration for Northeast Oregon	Aaron Maxwell	Freshwater Trust Accomplishments Reports	2013-2014	10
U.S. Forest Service, Wallowa-Whitman National Forest	Kayla Morinaga & Joe Platz	2010-2012 La Grande Ranger District Aquatics Program Accomplishment Reports & Wallowa-Whitman National Forest La Grande Ranger District Restoration Projects within the Grande Ronde River Watersheds (2008-2014) & (1988-2008) project information spreadsheets	1988-2014	8
Bonneville Power Administration	cbfish.org	Taurus Database	1984-2014	6
National Oceanic and Atmospheric Administration	map.critfc.org/flexviewers/pcsrftribal	Pacific Coastal Salmon Recovery Fund	2005-2011	1
		Total Work Sites	1984-2014	4449

The total number of work sites identifies the number of unique work sites incorporated into the data table from each source; duplicate projects were consolidated.

Data Table Development and Mapping

Restoration project information was compiled into a comprehensive data table for the study area. The predominant time period of projects is from 1994-2014, although some projects from 2015 are also included in the final data table. Restoration data from 2015 was incomplete due to the timing of this project, therefore it was not the focus and is not included in the analysis or work site counts. Work sites were listed as separate records (i.e., rows in the spreadsheet), displaying project information per site (i.e., columns). Restoration action types and sub-categories for all projects in the database were identified based on project titles, project descriptions, project notes, and the type of metrics reported. Restoration actions are defined as broad restoration categories (e.g., fish passage or instream structures), while sub-categories are more specific ways of carrying out each action (e.g., large woody debris addition as a sub-category of instream structures). Actions and sub-categories were modified from the Bonneville Power Administration's (BPA) Action Effectiveness Monitoring (AEM) program, which accounts for most types of restoration in the study area (Roni, Scranton, & O'Neal, 2013). Each project was categorized into these actions and sub-categories, signifying each type of restoration for each work site (see Appendix 1 for metadata on the restoration project data table). Further modifications to BPA's AEM actions and sub-categories list have been detailed in the project work flow, attached as Appendix 2. The metrics 'site length' and 'site area' are based on the largest reported treatment length or area metric per work site. Information about the intensities of individual sub-categories is still within the data table, but is not comparable across numerous work sites due to inconsistent reporting. If only one value of site length or area treated was reported for projects with multiple sites, that measurement was evenly split between each work site.

Spatial location was collected for each work site, corresponding to the midpoints of restoration projects. The inconsistent reporting of treatment boundaries (upstream and downstream edges) limited what could be used to represent site locations. Once added into a GIS, the data table was converted into a shapefile (a spatial data layer used in the creation of GIS maps).

Duplicate information about individual projects was identified through mapped locations, project descriptions, and project names. When duplicate information was found, only data from the primary source was reported in the table. The primary source is the land management agency that conducted the restoration work, therefore the originator of the data. In cases where multiple agencies reported different values for a metric, it was assumed the primary source reported the most accurate information. Data from secondary sources was incorporated into the table when it provided additional detail. A combination of data from multiple sources was recorded when different metrics were reported by different agencies (e.g., if the primary source reported 3 km of large woody debris installation and a secondary source reports 2 km of tree planting for same work site).

b. Comparison of mapped versus observed restoration

In the summer of 2014, CRITFC and ODFW habitat crews conducted visual assessments for the presence of restoration activities. These field assessments occurred during regularly-scheduled visits to 54 CHaMP reaches for surveys of fish abundance and benthic macroinvertebrates. The locations were annual and rotating panel 1 CHaMP sites (visited annually or once every three years for habitat monitoring, respectively). CHaMP reaches range from 120 meters to 600 meters in length, depending on bankfull channel width. A restoration field checklist (Appendix 3) was developed based on the format of the Oregon Department of Environmental Quality's (ODEQ) Human Disturbance Index Reach Checklist. Restoration activities were rated on a Likert scale (0, 1, 3, or 5) to document the effect of restoration on stream function for each restoration sub-category. The restoration assessment field checklist contained instructions on use, how to assess restoration function, a notes section, and a separate column of sub-categories requiring prior site knowledge for identification. One constraint in developing the field checklist was that filling out the sheet should take no longer than 5-10 minutes per site, considering the existing time constraints of field crews. To alert field crews to potential restoration work that may be encountered during their visits to stream reaches, restoration work sites were identified in a GIS within a 500 meter buffer of each CHaMP site extent polygon. The 500 meter buffers extend above and below the stream reach, as well as into the adjacent riparian area. A list of these restoration work sites was provided to crews prior to their field visits.

For selected restoration sub-categories, percent match was calculated as the proportion of mapped projects that were also detected in the field. Sub-categories were chosen based on prevalence and interest from restoration implementers and researchers. Results of this comparison have implications for the accuracy of restoration work site reporting, including the type of work completed and the location of the work site; whether or not mapped restoration is actually present, and if it is not, making sure it is reflected in the data table when conducting future analysis; and the longevity of restoration types, checking the true timeframe of projects in the field.

c. Restoration intensity

Inconsistent reporting within and between agencies constrained what could be used to develop a uniform measure of restoration intensity. Because site length and/or area treated was most commonly reported across agencies, those metrics were most likely to serve as consistent measure of restoration intensity across the project area.

Each restoration action sub-category was assigned a corresponding response time and longevity in the data table to express when a work site is expected to affect stream and streamside habitat. Response time refers to how quickly restoration provides beneficial effects to habitat function, while longevity indicates how long restoration lasts before becoming ineffectual. For example, an engineered pool may have an immediate effect on fish cover (quick response time), but may deteriorate and lose function rapidly (short longevity). Alternatively, a planting project may take 10-20 years before effectively shading a waterway (lengthy response time), but potentially last for decades to centuries (prolonged longevity). To account for this in the restoration assessment method, a table of response time and

longevity information was developed based on the work of Beechie, et al. (2013). Response time and longevity descriptions not derived from Beechie, et al. (2013) were extrapolated from related sub-categories and expert opinion. Table 2 shows the time frames for each sub-category. For further details see the work flow document (Appendix 2).

Table 2.Table of response time, longevity, probability of success, processes, and habitat restored per sub-category, modified from Beechie, et al., (2013).

Sub-Categories	Response Time in Years	Longevity in Years	Probability of Success	Success Notes	Processes Restored Connectivity	Processes Restored Sediment	Processes Restored Hydrology	Processes Restored Riparian	Habitat Restored Floodplain	Habitat Restored Riffle	Habitat Restored Pool	Habitat Restored Spawning	Habitat Restored Cover	Habitat Restored Area
Fish Passage - Diversion Screening	1-5	<10	moderate*	based on other fish passage ratings	x									
Fish Passage - Removal of Barriers	1-5	>50	high		x									x
Instream Structures - Large Woody Debris Additions	1-5	10-50	moderate to high	originally rated low to high		x	x			x	x	x	x	
Instream Structure - Bank Stabilization	1-5	10-50	moderate to high	originally rated low to high		x		x					x	
Instream Structures - Boulder Addition	1-5	10-50	moderate to high	originally rated low to high						x	x		x	
Instream Structure - Beaver Activity	1-5	10-50	moderate to high*	based on instream structures ratings, originally rated low to high	x	x	x	x	x		x			
Instream Structures - Engineered Pools	1-5	<10	moderate to high*	based on instream structures ratings, originally rated low to high			x				x			
Instream Structures - Modification/Remova l of Bank Armoring	5-20	>50	moderate to high*	based on instream structures ratings, originally rated low to high	x	x	x		x					
Instream Structure - Nutrient Addition	1-5	<10	moderate to high											
Off-Channel/Floodplain - Levee Set-Back or Removal	5-20	>50	high*	based on other fish passage ratings	x	x	x	x	x					
Off-Channel/Floodplain - Floodplain Reconnection or Creation	1-5	>50	moderate		x	x	x	x	x					
Off-Channel/Floodplain - Remeandering	1-5	>50	moderate*	based on other off-channel ratings	x		x	x	x	x	x	x		

Sub-Categories	Response Time in Years	Longevity in Years	Probability of Success	Success Notes	Processes Restored Connectivity	Processes Restored Sediment	Processes Restored Hydrology	Processes Restored Riparian	Habitat Restored Floodplain	Habitat Restored Riffle	Habitat Restored Pool	Habitat Restored Spawning	Habitat Restored Cover	Habitat Restored Area
Off-Channel/Floodplain - Side-Channel/Alcove Construction	1-5	>50	moderate		x	x	x	x	x	x	x	x	x	x
Off-Channel/Floodplain - Thermal Refugia	5-20	>50	moderate*	based on other off-channel ratings			x		x				x	
Off-Channel/Floodplain - Wetland Restoration	5-20	>50	moderate*	based on other off-channel ratings				x	x					
Riparian Improvement - Installed Fencing	>50	>50	moderate to high			x		x	x					
Riparian Improvement - Planting	>50	>50	moderate to high			x		x	x					
Riparian Improvement - Invasive Plant Removal	1-5	<10	moderate*	based on personal observation				x	x					
Sediment Reduction/Addition - Road Decommissioning	5-20	>50	high		x	x			x					
Sediment Reduction/Addition - Improving Agricultural/Forestry Practices	5-20	10-50	moderate			x		x				x	x	
Sediment Reduction/Addition - Spawning Gravel Addition	1-5	10-50	moderate to high*	based on personal observation					x	x	x	x	x	
Acquisition & Protection - Land Acquisition, Lease, or Easement	>50	>50	moderate*			x		x	x				x	
Flow Augmentation - Water Lease or Purchase	1-5	>50	high		x		x							x
Flow Augmentation - Irrigation Improvement	1-5	10-50	moderate*			x	x					x		
Flow Augmentation - Mitigate Point Source Impacts	1-5	10-50	high*				x							x

*** indicates an estimated value or a deviation from reference materials, based on expert opinion**

III. Results and Discussion

a. Compilation of projects

Overall, 4,449 work sites were identified reporting 71 different restoration metrics. Several of the ten data archives reported multi-agency collaboration on individual projects, with a total of 36 individual grantees taking part in the restoration on the Upper Grande Ronde River watershed. Table 3 summarizes the restoration sub-categories and reported metrics incorporated in the data table. A programmatic approach to reporting restoration activities between all land management agencies could reduce the numerous different ways that work sites are currently documented, allowing agencies to compare data for similar types of projects.

In December of 2015, the final map and table of restoration from this project was used to supplement information on restoration efforts for the Upper Grande Ronde River Expert Panel process. The Expert Panel process is a multi-agency work group that assesses the benefit of restoration to fish habitat as directed by the Federal Columbia River Power System (FCRPS) Biological Opinion. The restoration map provided invaluable information on the location and intensity of restoration that otherwise would have been missing from the Expert Panel meeting (Seth White, pers. comm.).

Table 3. Number of restoration projects and work sites by action and sub-category, and the number of times each project has an associated metric measurement reported (labeled No. Instances Metric Reported). The total number of work sites and projects are less than the sums of No. of Work Sites and No. Projects columns because multiple restoration activities were conducted at several projects.

Action	Sub-Category	No. Projects	No. of Work Sites	Metric	No. Instances Metric Reported by Project
Fish Passage	Diversion Screening	17	17	Cubic Feet per Second Diverted	15
				Number of Passage Improvements	3
	Removal of Barriers	67	84	Miles Unblocked Stream	34
				Number of Passage Improvements	59
Instream Structures	Large Woody Debris Additions	127	160	Miles Large Woody Debris	96
				Log Weirs (# Installed)	9
				Acres Large Woody Debris	8
				Number Logs Pieces	31
				Number Logjam Structures	25
	Bank Stabilization	78	97	Miles Streambank Stabilization	68
				Acres Streambank Stabilization	8
				Jetties, Barbs (Number of)	15
				Rock Weirs, Cross Veins (Number of)	15
	Boulder Addition	36	46	Miles Boulders	25
				Acres Boulders	2
				Number Boulder Structures	5
				Boulders (Number of)	11
	Beaver Activity Observed	1	1		0
	Engineered Pools	8	9	Number Pools Created	4
	Modification/Removal of Bank Armoring	0	0		0
	Nutrient Addition	0	0		0
Off-Channel / Floodplain	Levee Set-Back or Removal	13	13	Acres Riparian Habitat Created	1
				Miles of Dike Removal or Modification Riparian	2
	Floodplain Reconnection or Creation	36	36	Miles Floodplain Restored	16
				Acres Floodplain Restored	15
	Remeandering	28	39	Acres Channel Reconfiguration	2
				Miles Channel Reconfiguration	16
				Miles Main Channel Created	9
	Side-Channel/Alcove Construction	15	22	Acres Side Channel Created	1
				Miles Side Channel Created	8
				Backwater Alcoves in Feet	4
				New Spring/Tributary Channels in Feet	2
	Thermal Refugia	1	1		0
	Wetland Restoration	19	25	Acres Wetland Habitat Restored	11
Riparian Improvement	Installed Fencing	189	227	Stream Miles Fenced	151
				Planting Miles Fenced	6
				Upland Miles Fenced	4

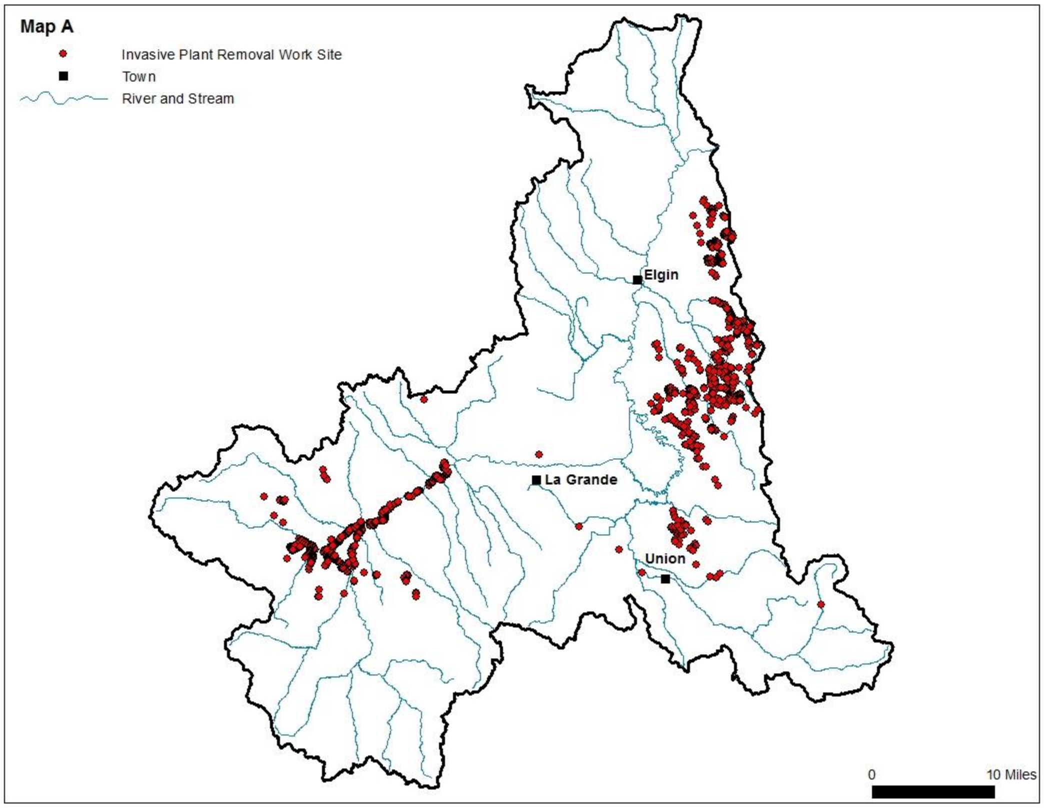
Action	Sub-Category	No. Projects	No. of Work Sites	Metric	No. Instances Metric Reported by Project
				Average Buffer Width Fencing	4
				Riparian Acres Protected by Fencing	144
				Upland Acres Protected by Fencing	16
				Acres Wetland Habitat Protected by Fencing	2
				X-Fencing (Number of)	19
	Planting	180	215	Number Plants Planted	25
				Riparian Miles Planted and/or Seeded	123
				Acres Riparian Planted and/or Seeded	99
				Upland Miles Planted and/or Seeded	5
				Acres Upland Planted and/or Seeded	17
				Wetland Acres Planted and Seeded	4
				Seeding in Pounds	18
				Sedge/Rush Mats in Feet	5
	Invasive Plant Removal	17	3762	Miles Upland Invasive Control	0
				Miles Riparian Invasive Control	12
				Acres Riparian Invasive Control	11
				Acres Upland Invasive Control	8
Sediment Reduction / Addition	Road Decommissioning	54	73	Feet Average Buffer Width Road Obliteration	3
				Miles of Trail/Road Recontoured/Removed	45
				Miles Trail/Road Recontoured/Removed Upland	3
				Acres Road Obliterated	8
	Improving Agricultural/Forestry Practices	77	109	Acres Improved Agriculture	57
	Spawning Gravel Addition	5	5	Miles Treated Spawning Gravel	2
Acquisition & Protection	Land Acquisition, Lease, or Easement	54	56	Acres of Acquisition, Lease, or Easement	31
				Stream Miles of Acquisition, Lease, or Easement	32
				Years out Acquisition, Lease, or Easement	2
Flow Augmentation	Water Lease or Purchase	27	28	CFS Purchased or Leased	10
				Acres of Acquisition, Lease, or Easement Pertaining to Water Lease or Purchase	8
				Instream Dates	8
	Irrigation Improvements	12	15	Acres Improved Irrigation	1
	Mitigate Point Source Impacts	4	4	Miles Toxic Cleanup	1
				Acres Toxic Cleanup	1
		546	4449	Site Length	380
		546	4449	Site Acres	316

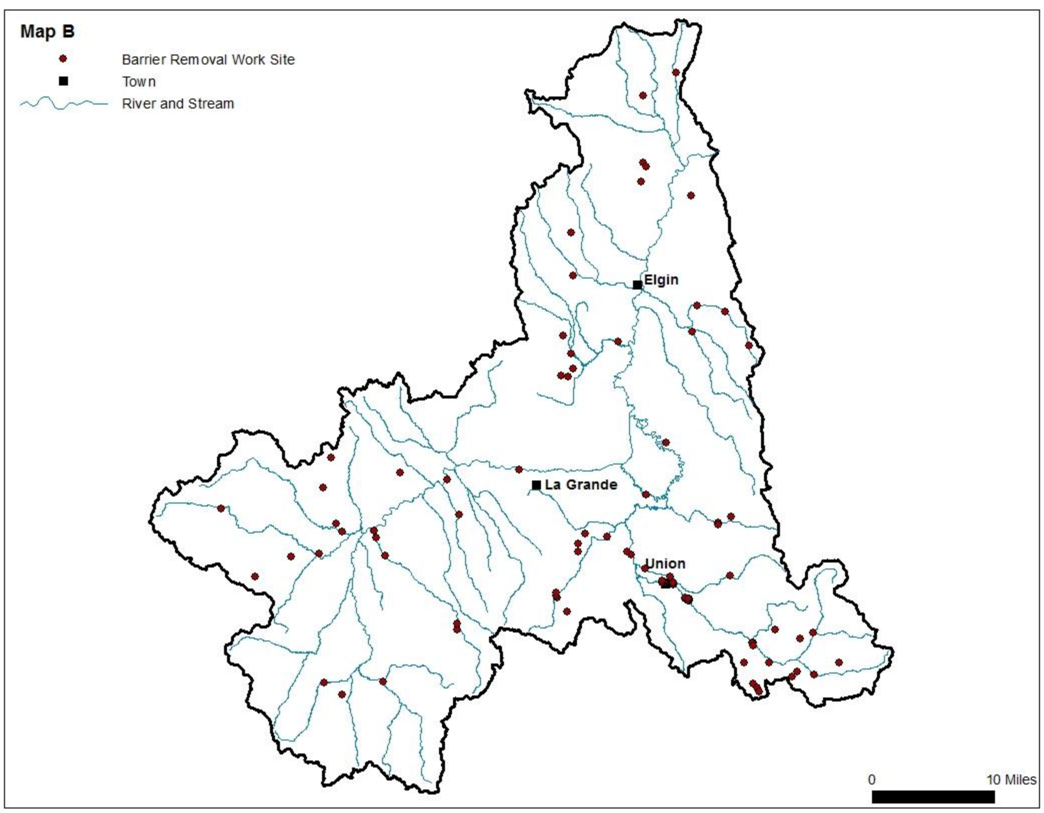
Sub-categories with 0s in the Projects and Work Sites columns indicate that none of those types of projects occurred in the study area.

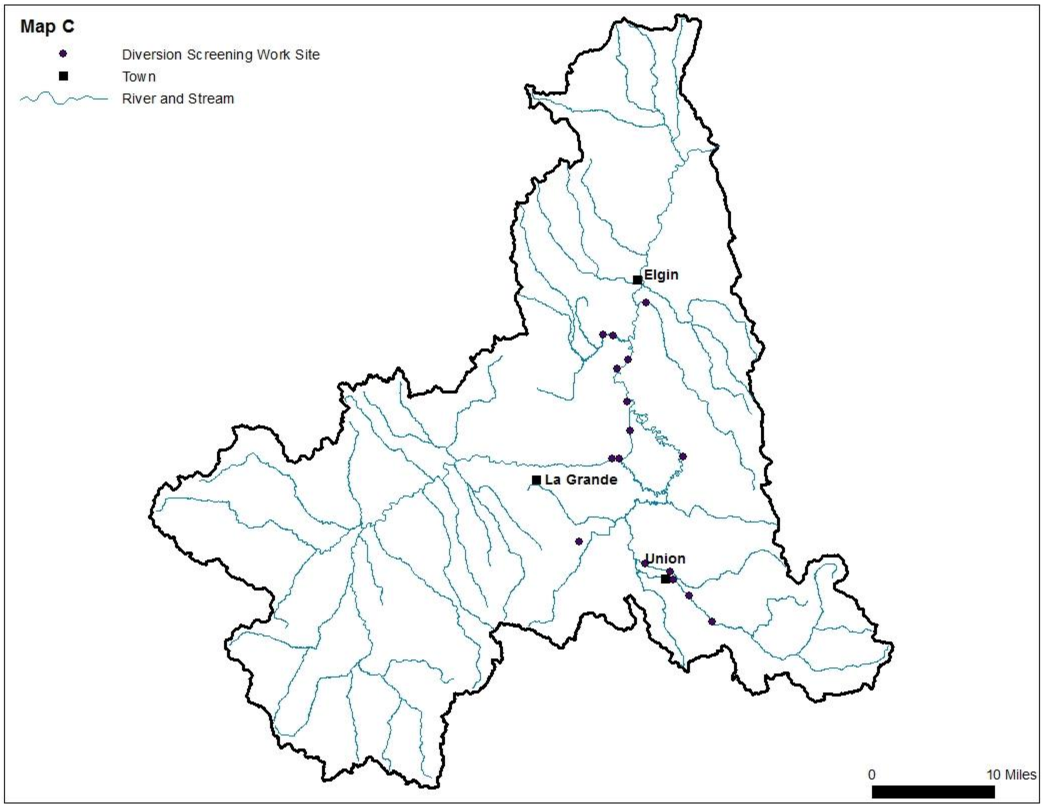
The map of work sites (Figure 1) shows the extensive, uniformly distributed restoration work sites completed in the Upper Grande Ronde watershed. This map does not include exclusive invasive plant removal projects because of incomplete data for that restoration activity. Because invasive plant removals have only an indirect effect on instream habitat for salmonids, there was no concerted effort to fill in this missing information. A large portion of these projects were mapped along the northeastern border of the Upper Grande Ronde basin, as well as along the mainstem Grande Ronde River upstream of La Grande, and just northeast of Union along Catherine Creek (Figure 2A).

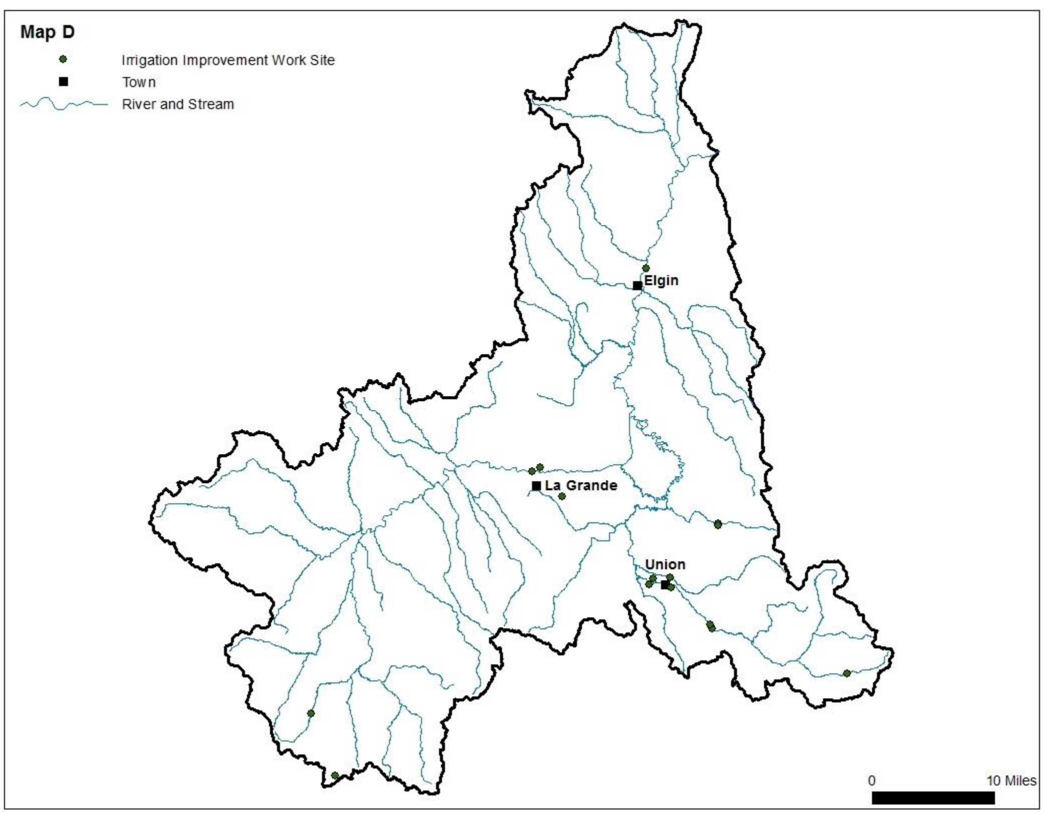
A large cluster of barrier removal projects were mapped in the lower reaches of mainstem Catherine Creek, but were overall spread throughout the watershed (Figure 2B). Diversion screening projects were mapped exclusively in the upper portions of Catherine Creek and middle sections of the Upper Grande Ronde River (Figure 2C). Irrigation improvements were clustered around Union and near the confluence of Catherine and Little Catherine Creeks, with a few notable exceptions in the headwaters of both the Grande Ronde River and Catherine Creek (Figure 2D). Most road decommissioning projects were mapped in the Upper Grande Ronde and within headwater streams of the study area (Figure 2E). Levee setback or removal projects were focused along the lower reaches of Catherine Creek, near its confluence with the Grande Ronde River (Figure 2F). A cluster of side channel/alcove projects were mapped along the lower portions of McIntyre Creek, but overall appear evenly dispersed throughout the watershed (Figure 2G). When comparing project types a considerable amount of overlap exists between large woody debris and planting projects (Figure 2H & 3I respectively).

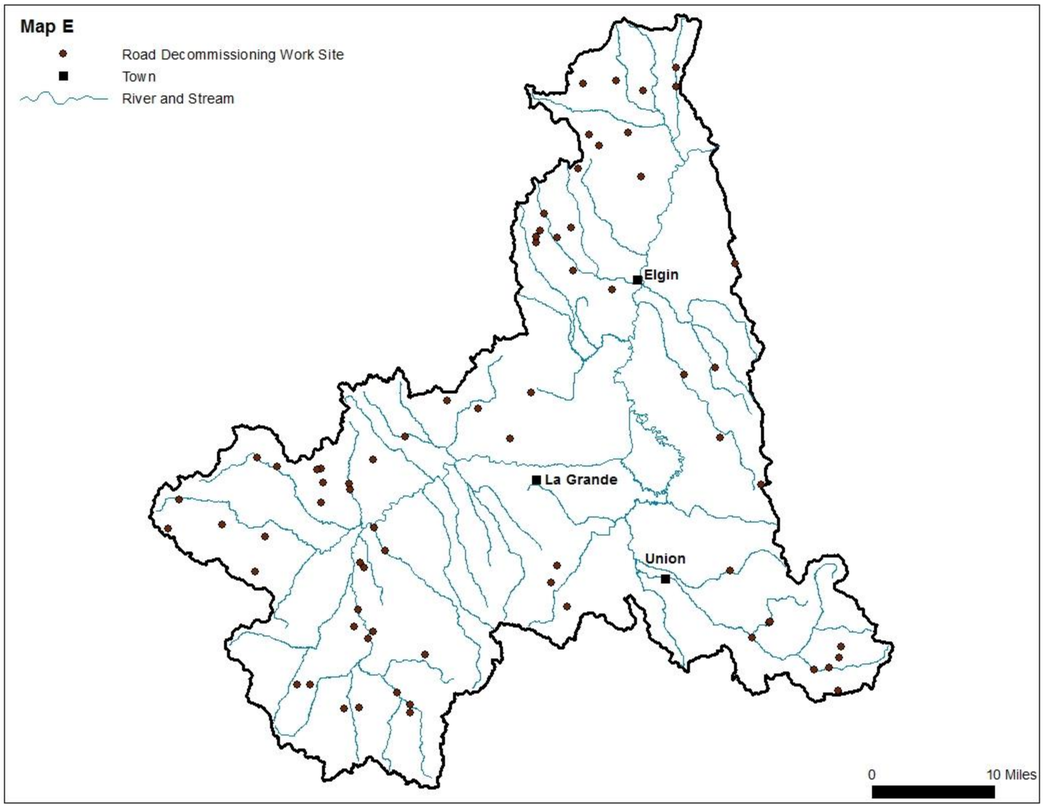
Figure 2. Maps A-I showing the location of restoration work sites by sub-category in the Upper Grande Ronde.



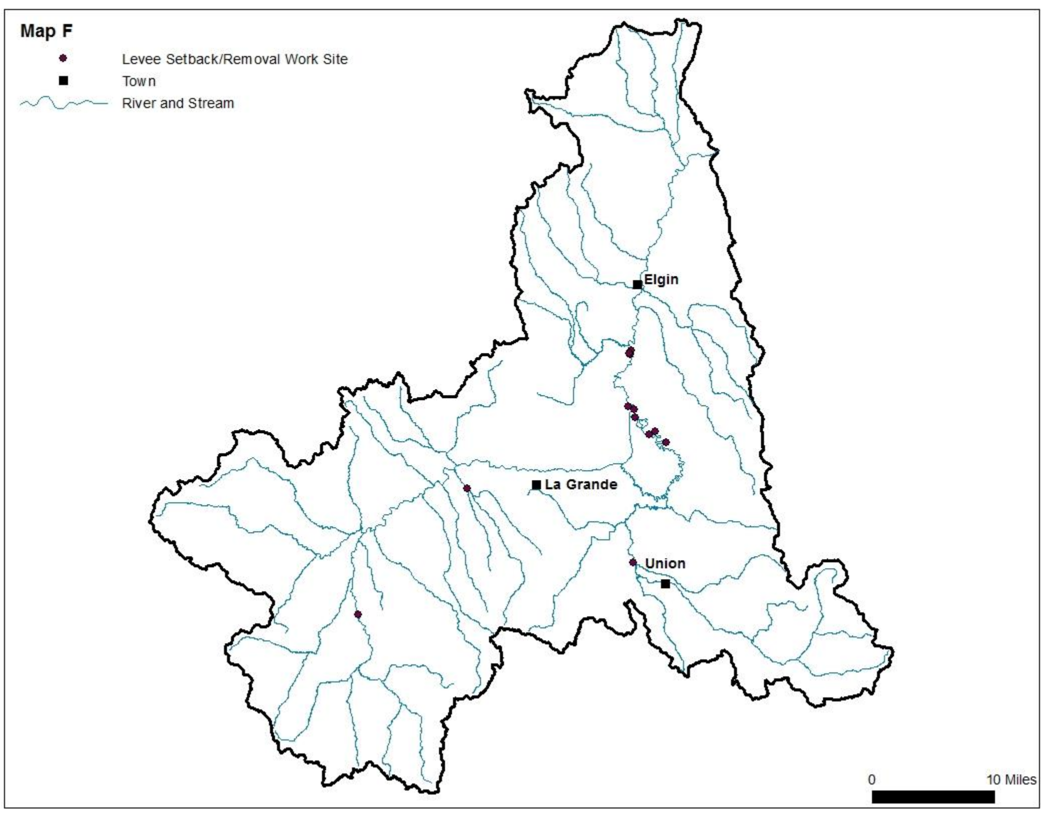



Map C
Diversion Screening Work Site
Town
River and Stream
Elgin
La Grande
Union
0
10 Miles

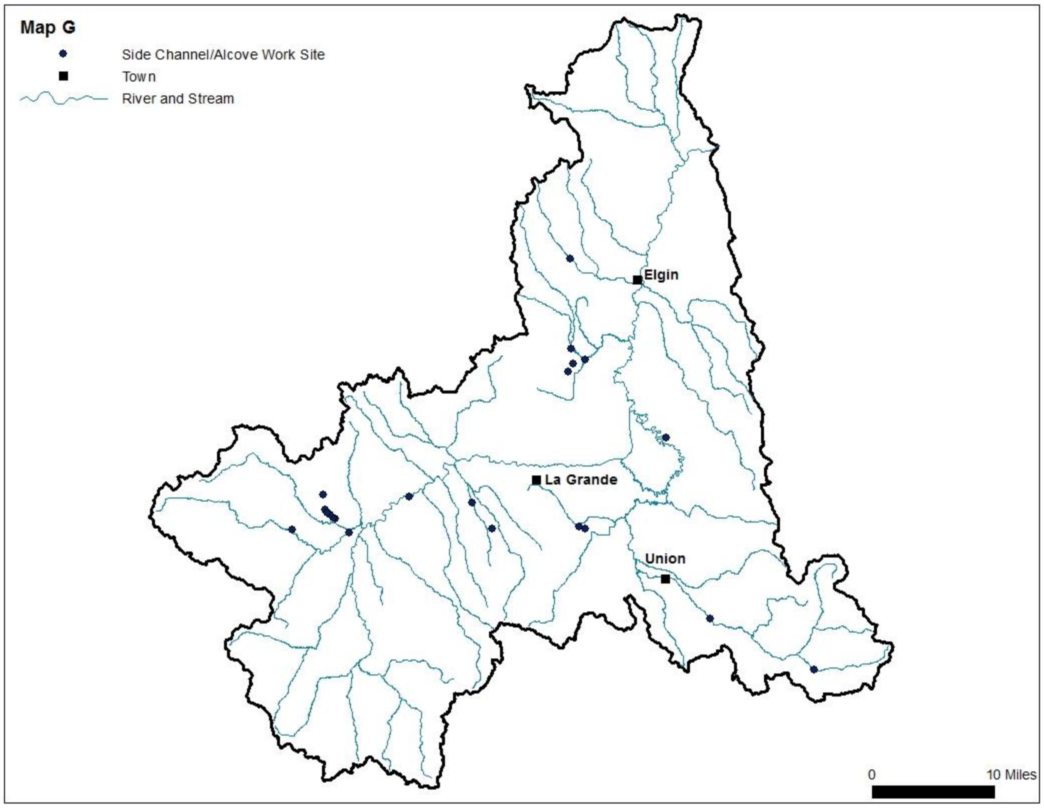

Map D
Irrigation Improvement Work Site
Town
River and Stream
Elgin
La Grande
Union
0
10 Miles

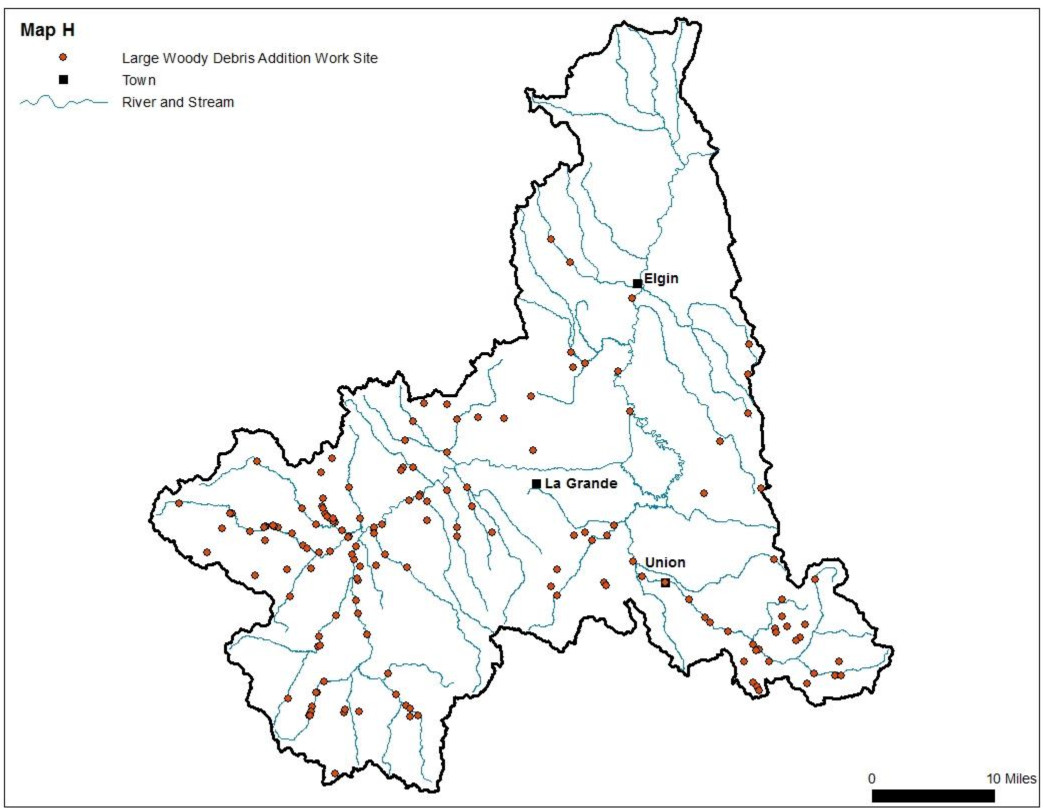


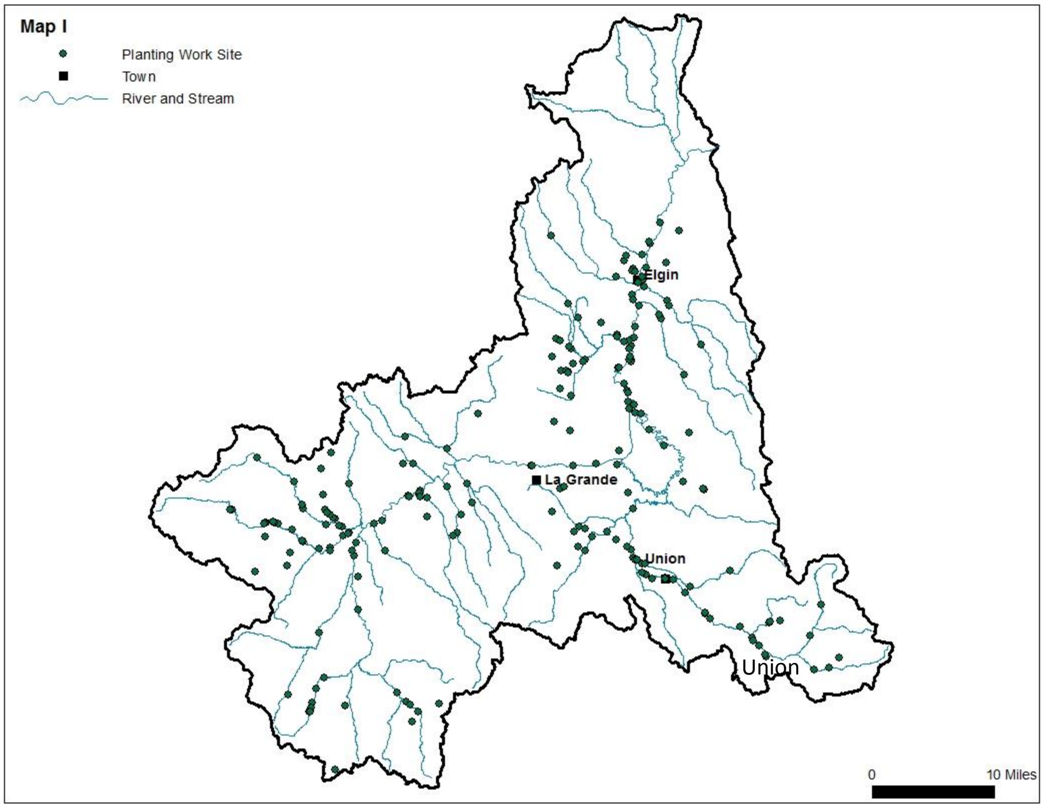
Map E
Road Decommissioning Work Site
Town
River and Stream
Elgin
La Grande
Union
0
10 Miles



Map F
Levee Setback/Removal Work Site
Town
River and Stream
Elgin
La Grande
Union
0
10 Miles


Map G
Side Channel/Alcove Work Site
Town
River and Stream
Elgin
La Grande
Union
0
10 Miles


Map H
Large Woody Debris Addition Work Site
Town
River and Stream
Elgin
La Grande
Union
0
10 Miles



b. Comparison of mapped versus observed restoration

Visits to CHaMP sites allowed for the evaluation of whether field crews could detect restoration work compiled in the data table and mapped in GIS. Actual time spent filling out the restoration assessment sheet was approximately 5-10 minutes per site visit, and therefore did not place a significant burden on field crews. Table 4 shows the results for a sample of sub-categories, indicating restoration sub-categories mapped within 500 meters of CHaMP reaches and restoration sub-categories observed during 2014 field visits. Discrepancies between restoration work mapped in GIS and observed in the field may be due to missing or inaccurate information about the project or its location, restoration activities becoming undetectable to field crews over time, or field crews mistakenly identifying natural features as restoration.

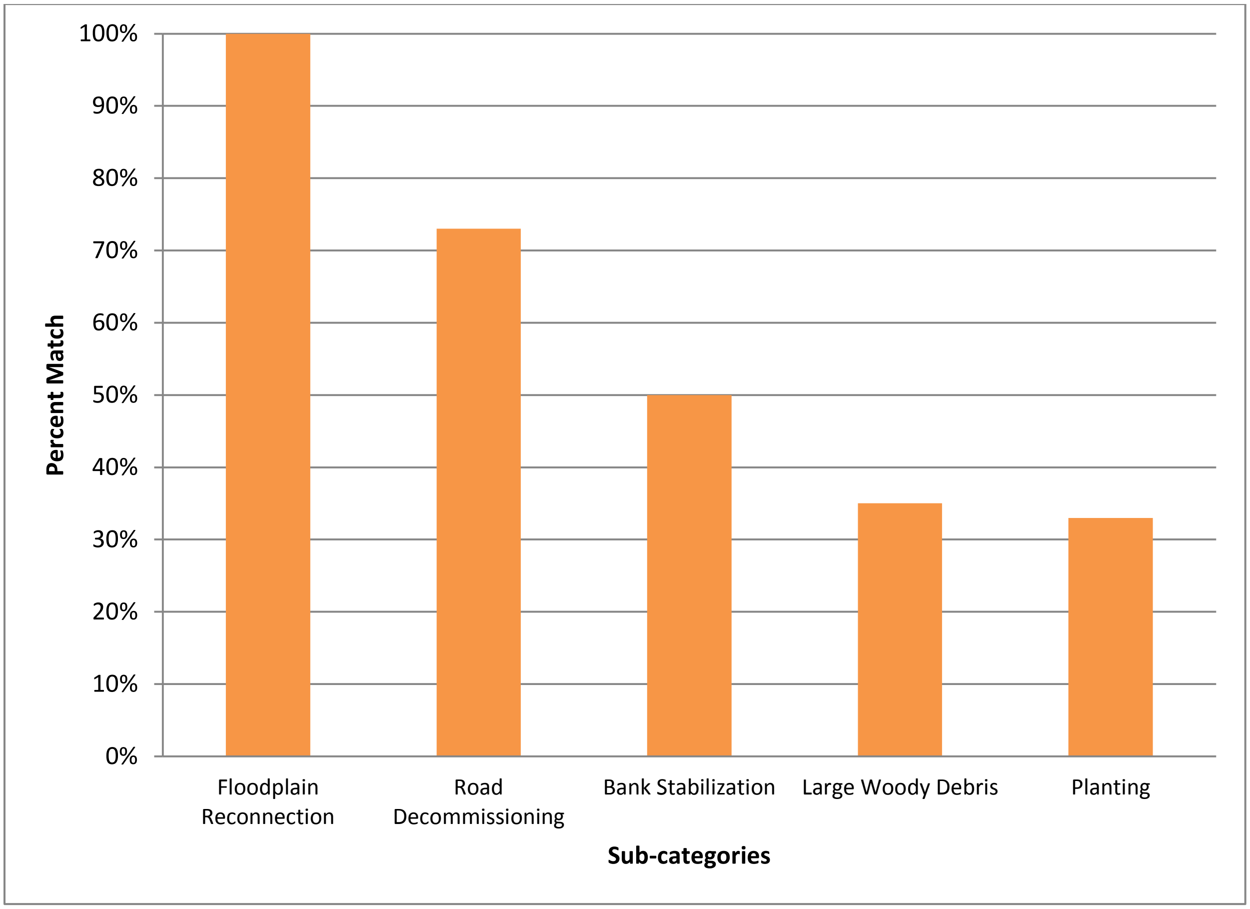
Table 4. Table of indicators showing the presence (1) and absence (0) of five selected sub-categories at mapped restoration work sites within 500 meters of CHaMP reaches and at observed CHaMP reaches during 2014 field visits.

	Floodplain Reconnection		Road Decommissioning		Bank Stabilization		Large Woody Debris		Planting	
SiteID	Mapped	Observed	Mapped	Observed	Mapped	Observed	Mapped	Observed	Mapped	Observed
CBW05583-013882	0	0	0	0	0	0	0	0	0	0
CBW05583-090282	0	0	0	0	0	1	1	0	1	0
CBW05583-092986	0	0	0	1	0	0	0	0	0	0
CBW05583-095642	0	0	0	0	0	0	0	0	0	0
CBW05583-108010	0	0	0	1	0	0	0	0	0	0
CBW05583-135615	0	0	0	0	0	1	0	1	0	0
CBW05583-138554	0	0	1	1	0	0	1	1	0	0
CBW05583-138666	0	0	0	0	0	0	0	0	0	0
CBW05583-142490	0	0	0	0	0	0	0	0	0	0
CBW05583-148970	0	0	0	1	0	0	1	1	1	1
CBW05583-149594	0	0	0	1	0	0	0	0	0	1
CBW05583-155818	0	0	0	0	0	0	0	0	0	1
CBW05583-199103	0	0	0	0	0	1	0	0	0	0
CBW05583-206314	0	0	0	0	0	0	0	0	0	0
CBW05583-217258	0	0	0	0	1	1	0	0	0	0
CBW05583-228666	0	0	0	0	0	0	0	0	0	0
CBW05583-235322	0	0	0	1	0	0	0	0	0	0
CBW05583-240730	0	0	0	0	0	0	0	0	0	0
CBW05583-252730	1	1	1	1	1	1	1	1	0	0
CBW05583-269114	0	0	1	1	0	0	1	0	0	0
CBW05583-275866	0	0	0	1	0	0	0	0	0	1
CBW05583-280042	1	1	1	1	1	0	1	1	1	0
CBW05583-288410	0	0	0	0	0	0	0	0	0	0
CBW05583-316330	0	0	0	0	0	0	1	0	1	1
CBW05583-321338	0	0	1	1	0	1	0	0	0	0
CBW05583-368042	0	0	0	0	0	1	0	0	0	0
CBW05583-382778	0	0	0	0	0	0	0	0	0	0
CBW05583-384154	0	0	0	0	0	0	0	1	0	0
CBW05583-405674	0	0	0	1	1	0	1	0	0	0
CBW05583-420954	0	0	0	0	0	1	0	0	0	1
CBW05583-430250	0	0	0	0	1	1	0	0	0	0
CBW05583-449626	0	0	1	0	0	0	1	1	0	0
CBW05583-456106	0	0	0	0	0	1	1	0	0	0
CBW05583-457530	0	0	1	1	1	0	1	0	0	0
CBW05583-480666	0	0	0	0	0	0	0	0	0	0
CBW05583-489882	0	0	0	0	0	0	0	0	0	1
CBW05583-490810	0	0	1	1	1	0	1	0	0	0
CBW05583-512938	0	0	0	0	0	0	0	1	0	1
CBW05583-514458	0	0	0	0	0	0	0	0	0	0
CBW05583-527786	0	0	1	0	0	1	0	0	0	0

	Floodplain Reconnection		Road Decommissioning		Bank Stabilization		Large Woody Debris		Planting	
SiteID	**Mapped**	**Observed**	**Mapped**	**Observed**	**Mapped**	**Observed**	**Mapped**	**Observed**	**Mapped**	**Observed**
DSGN4-000001	0	0	0	0	0	0	0	0	0	0
DSGN4-000006	0	0	0	1	0	0	0	0	0	0
DSGN4-000009	1	1	1	1	1	1	1	1	1	0
DSGN4-000010	0	0	1	0	0	0	1	0	0	0
DSGN4-000092	0	0	0	0	0	0	0	0	0	0
DSGN4-000094	0	0	1	1	0	0	0	1	0	0
DSGN4-000161	0	0	0	0	0	0	0	0	0	0
DSGN4-000168	0	0	0	0	0	0	0	0	0	0
DSGN4-000202	0	0	1	1	0	0	1	0	0	0
DSGN4-000204	0	0	1	0	0	1	1	0	0	0
DSGN4-000205	0	0	0	0	0	0	0	0	0	0
DSGN4-000213	0	1	0	0	0	0	0	1	0	0
DSGN4-000245	0	0	1	1	0	0	1	0	0	0
DSGN4-000277	0	0	0	1	0	0	0	1	1	0

The proportion of mapped restoration projects that were also observed during field visits was calculated for five selected sub-categories (Figure 3). The highest correspondence between mapped restoration versus observed was noted with floodplain restoration, where all three of the mapped projects were also detected in the field (100% correspondence). The next highest correspondence was noted for road decommissioning (73%), followed by bank stabilization (50%), large woody debris (35%), and plantings (33%). This outcome may be a result of certain types of restoration being more difficult to observe in the field. For example, a floodplain reconnection project is typically large in scope, contains features that are easily recognizable as human activity, and is therefore more likely to be identified as restoration by the field crew. Conversely, a riparian planting project may be more difficult to distinguish from natural vegetation recruitment unless field crews have specific knowledge of the site. The high correspondence for floodplain reconnections could also be the result of the small sample size, with only 3 of the 54 CHaMP sites visited in 2014 having that sub-category mapped. Sample sizes for the selected sub-categories are reported in Figure 3.

Figure 3. Bar graph showing percent of mapped projects also detected in the field. There were a total of 3 floodplain reconnections, 15 road decommissioning projects, 8 bank stabilization projects, 17 large woody debris additions, and 6 planting projects for analysis.



c. Restoration intensity

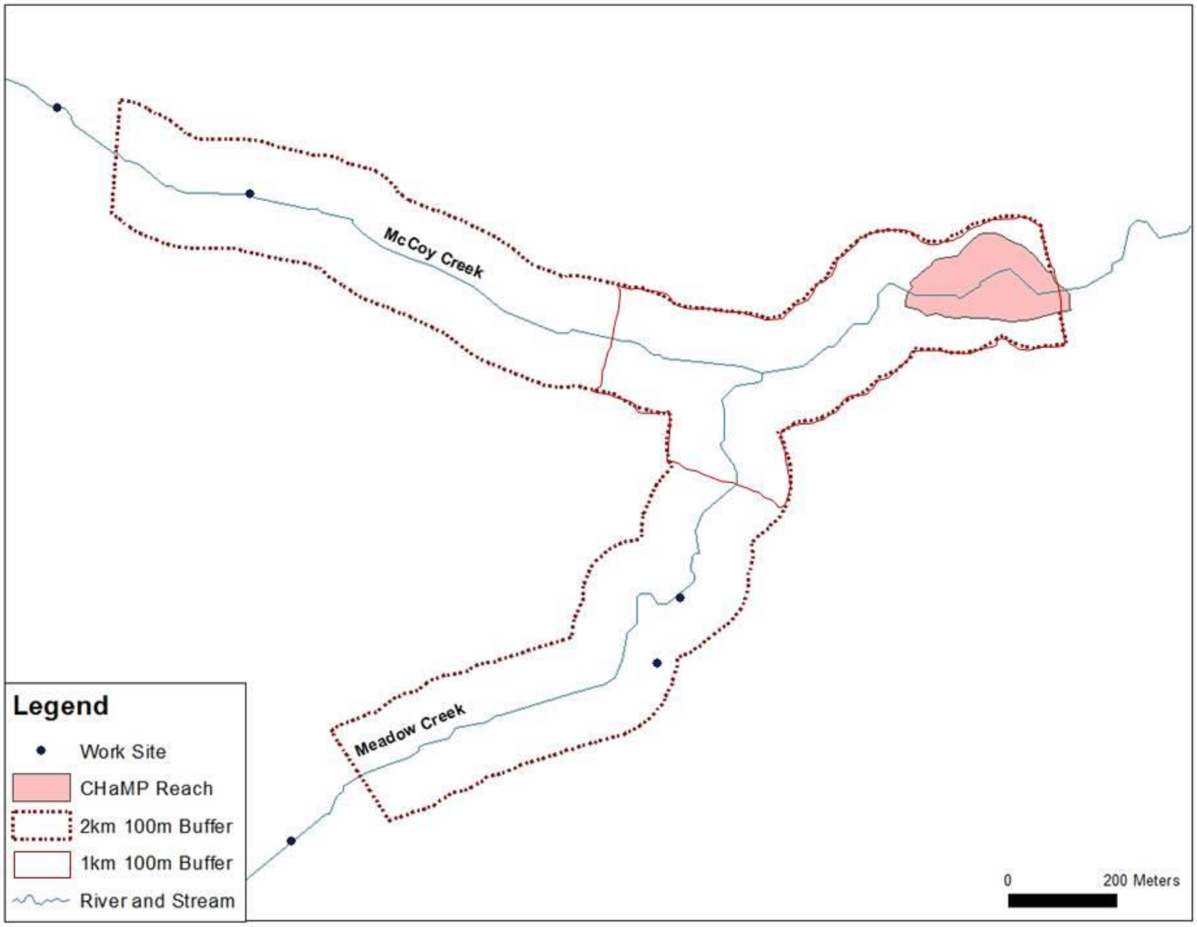
Site length was a metric reported in 95% of the work sites in the final data table. Stream length treated is derived from the reported length metrics for each work site, shown in Table 3 (ex. Miles Unblocked Stream or Miles Channel Reconfiguration). Site length is based on the largest reported length metric per work site, regardless of restoration type, therefore providing one measure of restoration intensity across most work sites. With few metrics reported consistently, this appears to be one of the only ways of assessing restoration intensity across the majority of work sites using the current data (Table 3).

IV. Future Analyses

Using the restoration data table and associated products documented in this report, several future analyses are expected to provide insight on the relationship between restoration actions and fish habitat. In all cases, the goal of further analysis is to demonstrate empirical relationships between restoration intensity, instream and riparian metrics as measured in CHaMP surveys, and biotic indices such as juvenile Chinook rearing capacity or benthic macroinvertebrate indices.

For example, restoration activities are expected to occur in “syndromes,” with certain subcategories—such as large wood additions, riparian plantings, and riparian fencing—occurring simultaneously. Using cluster analysis (Madeira & Oliveira, 2004) of presence-absence of subcategories can help clarify which restoration actions typically co-occur. Work sites can be grouped according to similarity in their syndrome of restoration types and used to rate restoration intensity along with stream length treated, which in the case of intensity refers to the number or diversity of restoration actions at a site. There is also intention to use cluster analysis to help interpolate missing values of stream length treated in cases where those values were not reported.

Figure 4. Map of different buffer lengths above an example CHaMP reach, encompassing restoration work sites upstream.



It is also expected that stream restoration activities conducted nearby will have cumulative downstream effects on fish habitat. At any given CHaMP survey site, restoration activities may occur either immediately upstream or far up into the headwaters, which may in turn affect stream habitat conditions, depending on the intensity and proximity of restoration. Using several different buffer lengths (e.g., 100m, 200m, entire tributary, whole watershed) above each CHaMP site (Figure 4), alternative hypotheses regarding the effect of intensity and proximity of restoration activities on site-specific habitat conditions can be tested. These varying buffer lengths can be evaluated in combination with different restoration assessment methods in a model selection context (Burnham & Anderson, 2002) to help elucidate the effects of restoration on fish habitat.

Additional restoration metrics can be derived using tables of the expected effects of stream restoration sub-categories on stream and habitat function (Table 2) (Beechie, et al., 2013) and their expected relationship to NOAA's ecological concerns (National Oceanic and Admospheric Administration, 2014). By combining a matrix of restoration subcategories by location with matrices of expected stream function or habitat improvement by subcategory—analogous to trait-based analysis in community ecology (Legendre, Galzin, & Mireille, 1997)—restoration intensity can be characterized in terms of its

expected function (e.g., restoration of soil water holding capacity, or actions that provide direct cover for fish), rather than the title it has been given by project sponsors (e.g., large woody debris addition).

V. Relevance of Internship to CRITFC Goals

This work is a starting point to better understand the effects of restoration on stream conditions, and the spatial extent of those effects. This project indirectly addresses CRITFC's first goal of putting fish back in the rivers and protecting watersheds where fish live (Columbia River Inter-Tribal Fish Commission). Table 5 lists the products completed during this project that contributed to CRITFC goals.

Table 5. Value-added products and services of internship. Appendix 4 defines the project task numbers included in the Value Added to Columbia Basin Fish Accords column.

Products	Description	Direct Benefits to Organization	Value Added to Columbia Basin Fish Accords
Project Proposal	Outline of internship, presented to CRITFC staff	-Input on internship outcomes	
Restoration Data Table	Comprehensive data table of restoration work sites in the Upper Grande Ronde River watershed with accompanying project details	-Comprehensive account of restoration project data -Restoration assessment tool for improving salmon habitat	Monitoring Recovery Trends: project tasks 3-6
Restoration Assessment Field Checklist	Tool for assessing the function of different stream restoration project types in the field	-Joint use by CRITFC and ODFW -Form available for CRITC field crews and biologists -Ground truth of reported restoration	Monitoring Recovery Trends: project task 3
Restoration Work Sites Shapefile	Spatial data layer with all identified work site midpoints worked on between 1986-2014	-Analyze and display work sites spatially -Assessing restorations effect on habitat	Monitoring Recovery Trends: project tasks 3-6
Preliminary Analysis	Review of collected data and identification of patterns	-Foundation for trends, outcomes, and further analysis	Monitoring Recovery Trends: project tasks 3 & 4
Project Report	Report outlining the methods and results of this project	-Replicable methods -Interpretation of results -Starting point for restoration from landscape perspective	Monitoring Recovery Trends: project tasks 3-6

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Appendix 1. Metadata on the restoration work sites data table.

	Definition	Data Type	Field Codes	Comments
CRITFCID	Unique CRITFC identifier given to each restoration project site.	text	CRITFC_XXXX, where XXXX is a number between 0001 and 4485	Identifiers ranges from CRITFC_0001 to CRITFC_4485, but are not in complete ascending order.
OneSite	Identifying if the project is comprised of one or multiple sites.	text	Y=yes (or only one site for specific project), N=no (or multiple sites for specific project)	
DataSrc	Data source	text	BLM=Bureau of Land Management, BPA=Bonneville Power Administration, CRITFC=Columbia River Inter-Tribal Fish Commission, CTUIR=Confederated Tribes of the Umatilla Indian Reservation, GRMW=Grande Ronde Model Watershed, ODFW=Oregon Department of Fish and Wildlife, OWEB=Oregon Watershed Enhancement Board, PCSRF=Pacific Coastal Salmon Recovery Fund, PNSHPD=Pacific Northwest Salmon Habitat Project Database, TFT=The Freshwater Trust, USFS=United States Forest Service	Project information coming from a certain data source in our data table doesn't indicate that the project information doesn't exist in another source.
ProjNum	Project number given by data source	text		Numerous project sites may be categorized by one of these project numbers.
OWRIObjID	Unique identifiers for project sites specifically from the Oregon Watershed Restoration Inventory.	text		These project come from OWEB
ProjTitl	Project title, as stated by each restoration project information source.	text		
Year	Year of project milestone	text	Years range from 1986 to 2033	Years can be singular, or within a defined range
YearType	Type of milestone the project year is describing.	text	Completed=year project was completed, Fiscal=year used for yearly financial statements, Initiated=year the project was started, Load=, Primary=year when most work was accomplished on the project, Review Cycle=, Term of Deal=, Treatment=year treatment was administered	
Grantee	Group or agency given grant funds to implement a restoration project.	text	BLM=Bureau of Land Management, Boise Cascades, BPA=Bonneville Power Administration, CBFWA=Columbia Basin Fish and Wildlife Authority, City of La Grande, DU=, ODFW=Oregon Department of Fish and Wildlife, La Grande RD=La Grande Ranger District, City of Union, Contractor= independent contractor, CTUIR= Confederated Tribes of the Umatilla Indian Reservation, DR Johnson, ODF Union Co= Oregon Department of Fish and Wildlife Union County, FSA Union Co= Farm Service Agency Union County, NRCS Union Co= Natural Resource Conservation Service Union County, Union SWCD= Union County Soil and Water Conservation District, FSA Wallowa Co= Farm Service Agency Wallowa County, NRCS Wallowa Co= Natural Resource Conservation Service Wallowa County, Wallowa SWCD= Wallowa County Soil and Water Conservation District, GRMWP= Grande Ronde Model Watershed Project, OWRD= Oregon Water Resource Department, USWCD= Union Soil and Water Conservation District, La Grande HS= La Grande High School, Nez Perce Tribe, NOAA= National Oceanic and Atmospheric Administration, NRCS= Natural Resource Conservation Service, ODA= Oregon Department of Agriculture, ODEQ= Oregon Department of Environmental Quality, ODF Union Co= Oregon Department of Forestry Union County, Private ind/bus= private industry or business, ODOT= Oregon Department of Transportation, OPRD= Oregon Parks and Recreation Department, OR Water Trust, OWHP= Oregon Watershed Health Program, OWRI= Oregon Watershed Restoration Inventory, REO= , TFT= The Freshwater Trust, Union Co NWC= , Union Co PW= Union County Public Works, UPWD= , USBR= United States Bureau of Reclamation, USFS= United States Forest Service, USWCD= Union Soil and Water Conservation District, Walla Walla RD= Walla Walla Ranger District	
ProjDesc	Project description	text		

DownLong	Downstream longitude in decimal degrees	1.0000000		precision varies from 5 to 7 decimal places
DownLat	Downstream latitude in decimal degrees	1.0000000		precision varies from 5 to 8 decimal places
UpLong	Upstream longitude in decimal degrees	1.0000000		precision varies from 5 to 7 decimal places
UpLat	Upstream latitude in decimal degrees	1.0000000		precision varies from 6 to 8 decimal places
Long	Longitude for center point of a restoration project site, in decimal degrees.	1.0000000		precision varies from 4 to 7 decimal places
Lat	Latitude for center point of a restoration project site, in decimal degrees.	1.0000000		precision varies from 4 to 8 decimal places
BPAContr	Bonneville Power Administration's contract numbers for project they fund.	text		
Tribal BiOp		1.0		
CTUIRprojects	Projects executed by the Confederated Tribes of the Umatilla Indian Reservation.	1.0	1= yes, project site completed by CTUIR, 0= no, project site not completed by CTUIR	
Beschta	Projects reported in Beschta, Platts, Kauffman, (1991), which reviewed restoration projects in the Grande Ronde and John Day river basins.	1.0	1= yes, project site in the report, 0= no, project site not in the report	
FPRemBar	FPRemBar= Fish Passage - Remove Barrier. Fish passage restoration activity type, specifically a barrier removal project.	1.0	1= yes, a barrier removal project site, 0= no, not a barrier removal project site	
FPDivScr	FPDivScr= Fish Passage - Diversion Screen. Fish passage restoration activity type, specifically a diversion screening project.	1.0	1= yes, a diversion screening project site, 0= no, not a diversion screening project site	
ISLWDAdd	ISLWDAdd= Instream - Large Woody Debris Addition. Instream restoration activity type, specifically a large woody debris addition project.	1.0	1= yes, a large woody debris addition project site, 0= no, not a large woody debris addition project site	
ISBldrAd	ISBldrAd= Instream - Bolder Addition. Instream restoration activity type, specifically a bolder addition project.	1.0	1= yes, a bolder addition project site, 0= no, not a bolder addition project site	
ISEngPol	ISEngPol= Instream - Engineered Pools. Instream restoration activity type, specifically an engineered pool project.	1.0	1= yes, a engineered pool project site, 0= no, not an engineered pool project site	
ISRmBkAr	ISRmBkAr= Instream - Remove Bank Armoring. Instream restoration activity type, specifically a bank armoring removal project.	1.0	1= yes, a bank armoring removal site, 0= no, not a bank armoring project site	
ISBnkStb	ISBnkStb= Instream - Bank Stabilization. Instream restoration activity type, specifically a bank stabilization project.	1.0	1= yes, a bank stabilization project site, 0= no, not a bank stabilization project site	
ISBvrAct	ISBvrAct= Instream - Beaver Activity. Instream restoration activity type, specifically a project that encourages beaver activity.	1.0	1= yes, a beaver activity project site, 0= no, not a beaver activity project site	
ISNutr	ISNutr= Instream - Nutrient. Instream restoration activity type, specifically a nutrient addition project.	1.0	1= yes, a nutrient addition project site, 0= no, not a nutrient addition project site	
OCFSdCnl	OCFSdCnl= Off Channel/Floodplain - Side Channel/Alcove Construction. Off channel/floodplain restoration activity type, specifically a side channel or alcove creation project.	1.0	1= yes, a side channel/alcove creation project site, 0= no, not a side channel/alcove creation project site	
OCFLvStb	OCFLvStb= Off Channel/Floodplain - Levee Set-Back or Removal. Off channel/floodplain restoration activity type, specifically a levee set-back or removal project.	1.0	1= yes, a levee set-back or removal project site, 0= no, not a levee set-back or removal project site	
OCFFldRn	OCFFldRn= Off Channel/Floodplain - Floodplain Reconnection or Creation. Off channel/floodplain restoration activity type, specifically a floodplain reconnection or creation project.	1.0	1= yes, a floodplain reconnection or creation project site, 0= no, not a floodplain reconnection or creation project site	
OCFWtRst	OCFWtRst= Off Channel/Floodplain - Wetland Restoration. Off channel/floodplain restoration activity type, specifically a wetland restoration project.	1.0	1= yes, a wetland restoration project site, 0= no, not a wetland restoration project site	
OCFRmdr	OCFRmdr= Off Channel/Floodplain - Remeandering. Off channel/floodplain restoration activity type, specifically a channel remeandering project.	1.0	1= yes, a remeandering project site, 0= no, not a remeandering project site	
OCFTrmRf	OCFTrmRf= Off Channel/Floodplain - Thermal Refugia. Off channel/floodplain restoration activity type, specifically a thermal refugia creation project.	1.0	1= yes, a thermal refugia project site, 0= no, not a thermal refugia project site	
RIFnc	RIFnc= Riparian Improvement - Installed Fencing. Riparian improvement restoration activity type, specifically a fencing project.	1.0	1= yes, a fencing project site, 0= no, not a fencing project site	
RIPlnt	RIPlnt= Riparian Improvement - Planting. Riparian improvement restoration activity type, specifically a planting project.	1.0	1= yes, a planting project site, 0= no, not a planting project site	
RIInvsRm	RIInvsRm= Riparian Improvement - Invasive Plant Removal. Riparian improvement restoration activity type, specifically an invasive plant removal project.	1.0	1= yes, an invasive plant removal project site, 0= no, not an invasive plant removal project site	

SRARdDcm	SRARdDcm= Sediment Reduction/Addition - Road Decommissioning. Sediment Reduction/Addition restoration activity type, specifically a road decommissioning project.	1.0	1= yes, a road decommissioning project site, 0= no, not a road decommissioning project site	
SRAIprAg	SRAIprAg= Sediment Reduction/Addition - Improving Agricultural/Forestry Practices. Sediment Reduction/Addition restoration activity type, specifically an improved agricultural or forestry practices project.	1.0	1= yes, an improving agricultural/forestry practices project site, 0= no, not an improving agricultural/forestry practices project site	
SRASpnGr	SRASpnGr= Sediment Reduction/Addition - Spawning Gravel Addition. Sediment Reduction/Addition restoration activity type, specifically a spawning gravel addition project.	1.0	1= yes, a spawning gravel addition project site, 0= no, not a spawning gravel addition project site	
APLndAqs	APLndAqs= Acquisition & Protection - Land Acquisition, Lease, or Easement. Acquisition and protection restoration activity type, specifically a land acquisition, lease, or easement project.	1.0	1= yes, a land acquisition, lease, or easement project site, 0= no, not a land acquisition, lease, or easement project site	
FAWtrLs	FAWtrLs= Flow Augmentation - Water Lease or Purchase. Flow augmentation restoration activity type, specifically a water lease or purchase project.	1.0	1= yes, a water lease or purchase project site, 0= no, not a water lease or purchase project site	
FAIrgImp	FAIrgImp= Flow Augmentation - Irrigation Improvements. Flow augmentation restoration activity type, specifically a irrigation improvement project.	1.0	1= yes, an irrigation improvement project site, 0= no, not an irrigation improvement project site	
FAMtgPt	FAMtgPt= Flow Augmentation - Mitigate Point Source Impacts. Flow augmentation restoration activity type, specifically a project that mitigates point source impacts.	1.0	1= yes, a mitigate point source impacts project site, 0= no, not a mitigate point source impacts project site	
Cat_Totl	Total number of sub-categories present at each project site.	1.0	Sub-category totals range from 0 to 12	
RTRemBar	RTRemBar= Response Time - Remove Barrier. A filter displaying barrier removal projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive barrier removal project site, 1= active barrier removal project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RTDivScr	RTDivScr= Response Time - Diversion Screen. A filter displaying diversion screening projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive diversion screening project site, 1= active division screening project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RTLWDAdd	RTLWDAdd= Response Time - Large Woody Debris Addition. A filter displaying large woody debris addition projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive large woody debris addition project site, 1= active large woody debris addition project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RTBldrAd	RTBldrAd= Response Time - Boulder Addition. A filter displaying boulder addition projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive boulder addition project site, 1= active boulder addition project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RTEngPol	RTEngPol= Response Time - Engineered Pools. A filter displaying engineered pool projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive engineered pool project site, 1= active engineered pool project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RTRmBkAr	RTRmBkAr= Response Time - Modification/Removal of Bank Armoring. A filter displaying modification/removal of bank armoring projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive modification/removal of bank armoring project site, 3= active modification/removal of bank armoring project site with a response time of 5-20 years	Response times based on Beechie, et al. (2013)
RTBnkStb	RTBnkStb= Response Time - Bank Stabilization. A filter displaying bank stabilization projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive bank stabilization project site, 1= active bank stabilization project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RTBvrAct	RTBvrAct= Response Time - Beaver Activity. A filter displaying beaver activity promotion projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive beaver activity project site, 1= active beaver activity project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RTNutr	RTNutr= Response Time - Nutrient Addition. A filter displaying nutrient addition projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive nutrient addition project site, 1= active nutrient addition project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RTSdCnl	RTSdCnl= Response Time - Side-Channel/Alcove Construction . A filter displaying side-channel/alcove construction projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive side-channel/alcove construction project site, 1= active side-channel/alcove construction project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RTLvStb	RTLvStb= Response Time - Levee Set-back or Removal. A filter displaying levee set-back or removal projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive levee set-back or removal project site, 3= active levee set-back or removal project site with a response time of 5-20 years	Response times based on Beechie, et al. (2013)
RTFldRn	RTFldRn= Response Time - Floodplain Reconnection or Creation. A filter displaying floodplain reconnection or creation projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive floodplain reconnection or creation project site, 1= active floodplain reconnection or creation project with a response time of 1-5 years	Response times based on Beechie, et al. (2013)

RTWtRst	RTWtRst= Response Time - Wetland Restoration. A filter displaying wetland restoration projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive wetland restoration project site, 3= active wetland restoration project site with a response time of 5-20 years	Response times based on Beechie, et al. (2013)
RTRmdr	RTRmdr= Response Time - Remeandering. A filter displaying remeandering projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive remeandering project site, 1= active remeandering project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RTTrmRf	RTTrmRf= Response Time - Thermal Refugia. A filter displaying thermal refugia projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive thermal refugia project site, 3= active thermal refugia project site with a response time of 5-20 years	Response times based on Beechie, et al. (2013)
RTFnc	RTFnc= Response Time - Installed Fencing. A filter displaying fencing projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive fencing project site, 5= active fencing project site with a response time of >50 years	Response times based on Beechie, et al. (2013)
RTPlnt	RTPlnt= Response Time - Planting. A filter displaying planting projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive planting project site, 5= active planting project site with a response time of >50 years	Response times based on Beechie, et al. (2013)
RTInvsRm	RTInvsRm= Response Time - Invasive Plant Removal. A filter displaying invasive plant removal projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive invasive plant removal project site, 1= active invasive plant removal project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RTRdDcm	RTRdDcm= Response Time - Road Decommissioning. A filter displaying road decommissioning projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive road decommissioning project site, 3= active road decommissioning project site with a response time of 5-20 years	Response times based on Beechie, et al. (2013)
RTIprAg	RTIprAg= Response Time - Improved Agricultural/Forestry Practices. A filter displaying improved agricultural/forestry practices projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive improved agricultural/forestry practice project site, 3= active improved agricultural/forestry practice project site with a response time of 5-20 years	Response times based on Beechie, et al. (2013)
RTSpnGr	RTSpnGr= Response Time - Spawning Gravel Addition. A filter displaying spawning gravel addition projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive spawning gravel addition project site, 1= active spawning gravel addition project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RTLndAqs	RTLndAqs= Response Time - Land Acquisition, Lease, or Easement. A filter displaying land acquisition, lease, or easement projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive land acquisition, lease, or easement project site, 5= active land acquisition, lease, or easement project site with a response time of >50 years	Response times based on Beechie, et al. (2013)
RTWtrLs	RTWtrLs= Response Time - Water Lease or Purchase. A filter displaying water lease or purchase projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive water lease or purchase project site, 1= active water lease or purchase project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RTIrgImp	RTIrgImp= Response Time - Irrigation Improvement. A filter displaying irrigation improvement projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive irrigation improvement project site, 1= active irrigation improvement project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RTMtgPt	RTMtgPt= Response Time - Mitigate Point Source Impacts. A filter displaying mitigation of point source impacts projects having a current effect on ecosystems, based on its response time.	1.0	0= inactive mitigate point source impacts project site, 1= active mitigate point source impacts project site with a response time of 1-5 years	Response times based on Beechie, et al. (2013)
RT_Totl	Total number of active sub-categories present at each project site based on the response time alone.	1.0	Sub-category totals range from 0 to 13	
LGRemBar	LGRemBar= Longevity - Remove Barrier. A filter displaying barrier removal projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive barrier removal project site, 1= active barrier removal project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGDivScr	LGDivScr= Longevity - Diversion Screening. A filter displaying diversion screening projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive diversion screening project site, 1= active diversion screening project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGLWDAdd	LGLWDAdd= Longevity - Large Woody Debris Addition. A filter displaying large woody debris addition projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive large woody debris addition project site, 1= active large woody debris addition project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGBldrAd	LGBldrAd= Longevity - Boulder Addition. A filter displaying boulder addition projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive boulder addition project site, 1= active boulder addition project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGEngPol	LGEngPol= Longevity - Engineered Pools. A filter displaying engineered pool projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive engineered pool project site, 1= active engineered pool project site, based on response time and longevity	Response times based on Beechie, et al. (2013)

LGRmBkAr	LGRmBkAr= Longevity - Modification/Removal of Bank Armoring. A filter displaying modification/removal of bank armoring projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive modified/removal of bank armoring project site, 1= active modified/removal of bank armoring project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGBnkStb	LGBnkStb= Longevity - Bank Stabilization. A filter displaying bank stabilization projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive bank stabilization project site, 1= active bank stabilization project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGBvrAct	LGBvrAct= Longevity - Beaver Activity. A filter displaying beaver activity projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive beaver activity project site, 1= active beaver activity project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGNutr	LGNutr= Longevity - Nutrient Additions. A filter displaying nutrient addition projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive nutrient addition project site, 1= active nutrient addition project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGSdCnl	LGSdCnl= Longevity - Side-Channel/Alcove Construction. A filter displaying side-channel/alcove construction projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive side-channel/alcove construction project site, 1= active side-channel/alcove construction project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGLvStb	LGLvStb= Longevity - Levee Set-Back or Removal. A filter displaying levee set-back or removal projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive levee set-back or removal project site, 1= active levee set-back or removal project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGFldRn	LGFldRn= Longevity - Floodplain Reconnection or Creation. A filter displaying floodplain reconnection or creation projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive floodplain reconnection or creation project site, 1= active floodplain reconnection or creation project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGWtRst	LGWtRst= Longevity - Wetland Restoration. A filter displaying wetland restoration projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive wetland restoration project site, 1= active wetland restoration project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGRmdr	LGRmdr= Longevity - Remeandering. A filter displaying remeandering projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive remeandering project site, 1= active remeandering project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGTrmRf	LGTrmRf= Longevity - Thermal Refugia. A filter displaying thermal refugia projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive thermal refugia project site, 1= active thermal refugia project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGFnc	LGFnc= Longevity - Installed Fencing. A filter displaying fencing projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive fencing project site, 1= active fencing project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGPlnt	LGPlnt= Longevity - Planting. A filter displaying planting projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive planting project site, 1= active planting project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGInvsRm	LGInvsRm= Longevity - Invasive Plant Removal. A filter displaying invasive plant removal projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive invasive plant removal project site, 1= active invasive plant removal project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGRdDcm	LGRdDcm= Longevity - Road Decommissioning. A filter displaying road decommissioning projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive road decommissioning project site, 1= active road decommissioning project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGIprAg	LGIprAg= Longevity - Improved Agricultural/Forestry Practices. A filter displaying improved agriculture/forestry practices projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive improved agricultural/forestry practices project site, 1= active improved agricultural/forestry practices project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGSpnGr	LGSpnGr= Longevity - Spawning Gravel Addition. A filter displaying spawning gravel addition projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive spawing gravel addition project site, 1= active spawning gravel addition project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGLndAqs	LGLndAqs= Longevity - Land Acquisition, Lease, or Easement. A filter displaying land acquisition, lease, or easement projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive land acquisition, lease, or easement project site, 1= active land acquisition, lease, or easement project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGWtrLs	LGWtrLs= Longevity - Water Lease or Purchase. A filter displaying water lease or purchase projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive water lease or purchase project site, 1= active water lease or purchase project site, based on response time and longevity	Response times based on Beechie, et al. (2013)

LGIrgImp	LGIrgImp= Longevity - Irrigation Improvement. A filter displaying irrigation improvement projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive irrigation improvement project site, 1= active irrigation improvement project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LGMtgPt	LGMtgPt= Longevity - Mitigate Point Source Impacts. A filter displaying mitigate point source impacts projects having a current effect on ecosystems, based on its response time and longevity.	1.0	0= inactive mitigate point source impacts project site, 1= active mitigate point source impacts project site, based on response time and longevity	Response times based on Beechie, et al. (2013)
LG_Totl	Total number of active sub-categories present at each project site based on the response time and longevity of the project type.	1.0		
CFSDvrt	Cubic feet per second of water diverted back into a stream.	1.00		precision varies from 0 to 2 decimal places
MlsUnblkSt	Miles of unblocked stream due to the removal of a fish passage barrier.	1.00		precision varies from 0 to 3 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
NPsgImprv	Number of fish passage improvements accomplished.	1.00		a half project is included due to the equal splitting of project metrics when only 1 measurement is reported between multiple sites, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
FishPass	Fish passage notes	1.00		
LogWeirs	The number of installed log weirs.	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
MlsLWD	Miles of large woody debris installed.	1.00		precision varies from 0 to 3 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrsLWD	Acres of large woody debris installed.	1.00		precision varies from 0 to 1 decimal place, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
NLgPcs	The number of log pieces installed.	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
NLgjmStrct	Number of logjam structures.	1.00		partial projects are included due to the equal splitting of project metrics when only 1 measurement is reported between multiple sites, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
MlsStbkStb	Miles of streambank stabilization installed using non-planting methods (ex. rip rap).	1.00		precision varies from 0 to 7 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrStbkStb	Acres of streambank stabilization using non-planting methods (ex. rip rap).	1.00		precision varies from 0 to 2 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement

JtsBrbs	Number of jetties and barbs installed.	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
RckWrsCrsV	Number of rock weirs and/or cross veins installed.	1.00		
BioEngNote	Bioengineering notes, explaining construction taking place at restoration sites.	text		
MlsBldrs	Number of miles of boulders installed.	1.00		precision varies from 1 to 3 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrsBldrs	acres of boulders installed.	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
NBldrStrct	Number of boulder structures installed.	1.00		partial projects are included due to the equal splitting of project metrics when only 1 measurement is reported between multiple sites, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
Bldrs	Number of boulders installed.	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
NPlsCrtd	Number of pools created.	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrsRprnCr	Acres of riparian habitat created.	1.00		
MlsDkRmvl	Miles of dike removal or modification.	1.00		precision varies from 0 to 2 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
MlsFldpln	Miles of floodplain restored.	1.00		precision varies from 0 to 2 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcFldplnRs	Acres of floodplain restored.	1.00		precision varies from 0 to 2 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
FldplnPnds	Number of floodplain ponds installed.	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrsChnlRc	Acres of channel reconfiguration.	1.00		precision varies from 0 to 1 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement

MlsChnlRcn	Miles of channel reconfiguration.	1.00		precision varies from 0 to 3 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
MlsMnCnCrt	Miles of main channel created.	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrsSdChnl	Acres of side channel created.	1.00		precision varies from 0 to 2 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
MlsSdChnl	Miles of side channel created.	1.00		precision varies from 0 to 7 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
BkwtrAlcFt	Backwater alcoves created in feet.	1.00		
NwSpngChFt	New spring/tributary channels in feet.	1.00		
AcrsWtHbRs	Acres of wetland habitat restored	1.00		precision varies from 0 to 2 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
StrmMlsFnc	Stream miles fenced.	1.00		precision varies from 0 to 6 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
PlntMlsFnc	Planting miles fenced.	1.00		precision varies from 0 to 2 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
UplnMlsFnc	Upland miles fenced.	1.00		precision varies from 0 to 1 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AveBfWdtFn	Average buffer width of fencing project.	1.00		
RpAcrPrtFn	Riparian acres protected by fencing project.	1.00		precision varies from 0 to 2 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
UpAcrPrtFn	Upland acres protected by fencing.	1.00		precision varies from 0 to 2 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrWtlPrFn	Acres of wetland habitat protected by fencing project.	1.00		precision varies from 0 to 1 decimal places
X_Fnc	The number of cross fences installed.	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
MlsRpUpXFn	Stream miles riparian/upland benefiting from cross fencing.	1.00		precision varies from 0 to 2 decimal places

AcrRpUpXFn	Acres riparian/upland benefiting from cross fencing	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
NPlntsPlnt	Number of plants planted	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
RprnMlsPln	Riparian miles planted and/or seeded	1.00		precision varies from 0 to 3 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrsRprnPl	Acres riparian planted and/or seeded	1.00		precision varies from 0 to 2 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
UpldMlsPln	Upland miles planted and/or seeded	1.00		precision varies from 0 to 1 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrsUpPlnt	Acres Upland Planted and/or Seeded	1.00		precision varies from 0 to 1 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
WtldAcrPS	Wetland acres planted and/or seeded	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
SdngLBS	Seeding in pounds	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
SdgRshMtFt	Sedge/rush mats in feet	1.00		
MlsUpInvsv	Miles Upland Invasive Control	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
MlsRprnInv	Miles Riparian Invasive Control	1.00		precision varies from 0 to 3 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrsRprnIn	Acres Riparian Invasive Control	1.00		precision varies from 0 to 3 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrsUpInvs	Acres Upland Invasive Control	1.00		precision varies from 0 to 3 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement

FtAvBfWdRd	Feet Average Buffer Width Road Obliteration	1.00		
MlsTrlRctr	Miles of Trail/Road Recontoured/Removed	1.00		precision varies from 0 to 4 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
MlsTrlRcUp	Miles Trail/Road Recontoured/Removed Upland	1.00		
AcrsRdOblt	Acres road obliterated	1.00		precision varies from 0 to 2 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrsImprAg	Acres improved agriculture	1.00		precision varies from 0 to 6 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
MlsTrtSpwn	Miles treated spawning gravel	1.00		precision varies from 2 to 3 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrsAqstLE	Acres of acquisition, lease, or easement	1.00		precision varies from 0 to 1 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
StrmMlsAcq	Stream miles of acquisition, lease, or easement	1.00		precision varies from 0 to 3 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
YrsOutAcq	Years out acquisition, lease, or easement	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
CFSPrchsd	CFS purchased or leased	1.00		precision varies from 1 to 3 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrsAqWtrL	Acres of acquisition, lease, or easement	1.00		precision varies from 0 to 2 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
InstrmDts	Instream dates of water acquisition, lease, or easement	text		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
MlsImprIrg	Miles improved irrigation	1.00		precision varies from 2 to 3 decimal places
AcrImprIrg	Acres improved irrigation	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement

CFSConserv	Cubic feet per second of water flow conserved	1.00		
MlsTxcClnp	Miles toxic cleanup	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AcrsTxcCln	Acres toxic cleanup	1.00		nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement
AltWtrSrcs	Number of alternative water source development	1.00		partial projects are included due to the equal splitting of project metrics when only 1 measurement is reported between multiple sites
AcrsStplRh	Acres stockpile rehabilitation	1.00		flattening of old gold mining dredge piles, constricting the stream channel
StLgthMls	Site length miles	**1.00**		precision varies from 0 to 6 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement, site length is the longest reported metric measurement for a restoration project site
StAcrs	Site acres	**1.00**		precision varies from 0 to 9 decimal places, nulls are included when the sub-category corresponding to this metric was executed without reporting this measurement, site area is the largest reported metric measurement for a restoration project site
TrtmtTyp	Treatment type	text	Treatment Codes: 1 = Upland/Timber Management, 2 = Grazing Management, 3 = Off-Channel Water Developments, 4 = Riparian Exclosure Fences, 5 = Plantings, 6 = Instream Habitat Structures, 7 = Channel Stability-Lateral, 8 = Channel Stability-Vertical, 9 = Meander Reconstruction, Bioengineering, 10 = Floodplain Access, 11 = Floodplain/Wetland Connectivity, 12 = Channel Relocation, 13 = Fish Passage, 14 = Flow	information came from ODFW's Grand Ronde Fish Habitat Database
WtrGps	Number of water gaps	1.00		information came from ODFW's Grand Ronde Fish Habitat Database
ImplmCmnts	Implementation comments	text		information came from ODFW's Grand Ronde Fish Habitat Database
FncMntFt	Fence maintenance in feet	1.00		precision varies from 0 to 1 decimal places, information came from ODFW's Grand Ronde Fish Habitat Database
WgMaint	Number of water gap maintenance projects	1.00		information came from ODFW's Grand Ronde Fish Habitat Database
InstrmMnt	Instream maintenance	text		descriptions of instream project maintenance types, information came from ODFW's Grand Ronde Fish Habitat Database
MntCmts	Maintenance comments	text		information came from ODFW's Grand Ronde Fish Habitat Database

TotlPPT	Number of total photopoints	1.00		information came from ODFW's Grand Ronde Fish Habitat Database
ActvPPT	Number of active photopoints	1.00		information came from ODFW's Grand Ronde Fish Habitat Database
PPTEstbDt	Photopoint establishment date	text		information came from ODFW's Grand Ronde Fish Habitat Database
ShootDate	Shoot date	text		information came from ODFW's Grand Ronde Fish Habitat Database
NmbrThrms	Number of thermographs created	1.00		information came from ODFW's Grand Ronde Fish Habitat Database
RcrdngIntv	Recording interval in hours	text		information came from ODFW's Grand Ronde Fish Habitat Database
DeplmtProd	Deployment period	text		information came from ODFW's Grand Ronde Fish Habitat Database
HabtTrnsN	Habitat transects number	1.00		information came from ODFW's Grand Ronde Fish Habitat Database
HabTrnDtEs	Habitat transects date established	text		information came from ODFW's Grand Ronde Fish Habitat Database
HabTrnDtRe	Habitat transects date repeated	text		information came from ODFW's Grand Ronde Fish Habitat Database
StrmSrvy	Stream surveys notes	text		information came from ODFW's Grand Ronde Fish Habitat Database
RsgnRfrExs	Rosgen reference and existing notes	text		information came from ODFW's Grand Ronde Fish Habitat Database
GPSSurvey	GPS survey notes	text		information came from ODFW's Grand Ronde Fish Habitat Database
BnkStbCvr	Bank stability, cover notes	text		information came from ODFW's Grand Ronde Fish Habitat Database
GrndwtrWls	Groundwater well notes	text		information came from ODFW's Grand Ronde Fish Habitat Database
PlntSrvys	Plant survey notes	text		information came from ODFW's Grand Ronde Fish Habitat Database
LrgWdPlCts	Large wood, pool count notes	text		information came from ODFW's Grand Ronde Fish Habitat Database
RbStSGS	Rainbow steelhead spawning ground survey notes	text		information came from ODFW's Grand Ronde Fish Habitat Database
FshSrvys	Fish survey notes	text		information came from ODFW's Grand Ronde Fish Habitat Database
OtherME	Other monitoring and evaluation notes	text		information came from ODFW's Grand Ronde Fish Habitat Database
MECmnts	Monitoring and evaluation comments	text		information came from ODFW's Grand Ronde Fish Habitat Database
Basin	Stream basin	text	UGR = Upper Grande Ronde	information came from ODFW's Grand Ronde Fish Habitat Database

County	County	text	Union = Union County, Oregon	information came from ODFW's Grand Ronde Fish Habitat Database
ODFWFshDst	Oregon department of fish and wildlife fish district	text	La Grande	information came from ODFW's Grand Ronde Fish Habitat Database
Notes	Additional project site notes	text		

Appendix 2. Workflow outlining steps taken to create restoration work sites data table (pathways from local drive).

- Conducted research on restoration assessment methods prior to data gathering, selecting Bonneville Power Administration's (BPA) Action Effectiveness Monitoring (AEM) program as a framework. AEM uses a variety of restoration actions and sub-categories to describe restoration types, which were to be identified as absent or present in restoration projects having taken place in the Upper Grande Ronde and Catherine Creek watersheds.
- Developed Restoration Project Information Sources document identifying stream restoration project information for the Upper Grande Ronde and Catherine Creek watersheds.
    - Document found here: C:\Users\beng\Documents\Greg's Docs\Restoration Project Information Sources
    - Document logs source/database, # of projects, recorded since date, URL, agency, contact, phone #, email, & notes
    - Presented project to Restoration Atlas group, providing additional sources of restoration project information.
    - Presented proposal to project committee, gaining initial feedback and sources of data.
- Collected all available information pertaining to restoration projects in the study area, including spreadsheets, project layers, and geodatabases and placed C:\Users\beng\Documents\ArcGIS\Layers\Unaltered_Project_Layers
    - Copied data for editing and placed C:\Users\beng\Documents\ArcGIS.
    - Added copied project layers to a working map for data comparison/editing
    - Removed projects outside of AOI.
- Contacted agencies who work/may work in the study area for additional project information not readily available.
- Created project data table C:\Users\beng\Documents\Greg's Docs\Restoration Projects Attributes Table (previous name for restoration work sites data table).
    - Used identify tool in ArcGIS to check for project number repetition if multiple projects appeared in same area. If not applicable, looked for similar project description and year completed to confirm same project displayed multiple times.
    - Used available project reports to confirm multiple displays of same project recorded by different layer sources.
    - Went through projects in order displayed in Restoration Projects Attributes Table, highlighted project on map, clicked point with select feature tool to check for multiple treatments in the same location, removed repeat project reports and combined metrics reported by different agencies, leaving 1 row per site in the project spreadsheet.
    - Combined project data separated by year into 1 row.
    - Recorded info on number of sites, project ID, project name, year, data source, grantee, project description, and location.
    - Identified actions and sub-categories each project addresses, showing if each is addressed by using a 0 for no and a 1 for yes.
    - Recorded all available project metrics into the Restoration Projects Attributes Table, adding additional columns as new metrics were reported.
- Found midpoint locations using visual estimates and the GR Mixed Hydro stream layer for projects not already represented by a single point.
- Saved attribute table C:\Users\beng\Documents\Greg's Docs\Restoration Projects Database\Restoration_Projects_Attributes_Table_17Sep2014

- Updated column headers to accommodate data transfer to ArcGIS.
    - Reduce titles to 10 characters with no symbols or spaces.
- Merged metrics represented in multiple columns
    - Verify new title for metric accurately accounts for what it's representing.
- Saved C:\Users\beng\Documents\Greg's Docs\Restoration Projects Database\Restoration_Projects_Attributes_Table_24Sep2014.
- Added unique CRITFC ID to each project site
- Created new tab in spreadsheet, labeled SubCat_Dictionary
    - List of attribute and sub-category codes used in Restoration_Projects_Attributes_Table with full descriptions of their meaning.
- Created new tab in spreadsheet, labeled Metrics_by_SubCat
    - Starting from the left hand column, Action, Sub-Category, Metric, Data Type, and Code are listed
    - Metrics are sorted first by Action, and then by Sub-Category, showing what measurement represents what restoration Actions and Sub-Categories.
    - Developed metric codes are clarified, listing what each code represents
    - Metrics reported but not representative of a certain Action or Sub-Category are clarified separately
- Saved C:\Users\beng\Documents\Greg's Docs\Restoration Projects Database\ Restoration_Projects_Attributes_Table_25Sep2014
- Recorded nulls into cells not reporting a metric that could have been reported.
- Filled blank cells with 0s
- Saved C:\Users\beng\Documents\Greg's Docs\Restoration Projects Database\ Restoration_Projects_Attributes_Table_29Sep2014.
- Deleted cells with over 255 characters for transfer to ArcGIS, adding the statement "refer to original" to those cells.
- Saved C:\Users\beng\Documents\Greg's Docs\Restoration Projects Database\Restoration_Projects_Attributes_Table_30Sep2014.
- Further combination of metrics for simplification of project data.
    - Created Restoration_Projects_Attributes_Table_6Oct2014 and Restoration_Projects_Attributes_Table_29Oct2014
        - The October 6th document features more original reported metrics left intact, while the October 29th document features a more aggressive simplification and combination of metrics.
    - Meeting with project committee confirmed use of Restoration_Projects_Attributes_Table_29Oct2014 as a better choice moving forward.
    - Miles improved stream complexity combined with miles of large woody debris; rock riprap in feet, root wad revetments in feet, bioengineering in feet, rock grade control structures, shaping and seeding, contour/stabilize/plant, rock vortex weirs, rock barbs, log revetment, repair/reconstruct road, erosion control mats, and sediment trapping were added to miles streambank stabilization; miles main channel remeandered was added to miles channel reconfiguration; riparian miles planted, riparian miles planted and seeded, and riparian miles seeded were added to riparian miles planted and/or seeded; riparian acres planted, riparian acres planted and seeded, and riparian acres seeded were added to riparian acres planted and/or seeded; acres upland planted, acres upland planted and seeded, and acres upland seeded were added to acres upland planted and/or seeded; miles upland planted, miles upland planted and seeded, and

miles upland seeded were added to miles upland planted and/or seeded; dike, road, RR removal in feet was added to miles of trail/road recontoured/removed; acres retired agriculture was added to acres improved agriculture.

- Specified what each project year represents
- Added Response Time and Longevity columns into projects spreadsheet, using time frames from Benefits of Tributary Habitat Improvement in the Columbia River Basin Results of Research, Monitoring and Evaluation, 2007-2012
    - Response times are: 1=1-5 years, 3=5-20 years, 5=>50 years
    - Longevity times are: 1=<10 years, 3=10-50 years, 5=>50 years
    - Each project gets a number for Response and Longevity in connection to its recorded date (ex. project completed in 2013, Response = 1 since it's been between 1 & 5 years from the project date till today, using January 1 2015, and Longevity = 1 since our project is less than 10 years old).
- Formulated Response and Longevity matrices to filter project sub-categories not yet showing a biologic response, or that have become older then the duration that type of project lasts.
    - Starting with a Response matrix, used an If AND OR formula to keep sub-categories at should be showing some response
        - If Response Time (for the project) = 1, then include sub-categories with a 1 rating. If Response Time = 3, then include sub-categories with a 1 or a 3 rating, if Response Time = 5, then include sub-categories with a 1, 3, or 5 rating.
        - Each sub-category has a different formula based on what its Response Time is.
        - Example formula is =IF(AND(U4412=1,OR(I4412=1,I4412=3,I4412=5)),1,0)
            - States that the sub-category needs to be present in the project and if the response time equals 1, 3, or 5, then that cell gets a 1 (sub-category response =1), otherwise it gets a 0
    - Used another IF AND OR formula to further filter project sub-categories based on their Longevity
        - If Longevity (for the project) =1, include all sub-categories, if Longevity = 3, remove sub-categories with a 1 for Longevity, if Longevity =5, remove sub-categories with a 1 or 3 for Longevity.
        - Each sub-category has a different formula based on what its Longevity Time is.
        - Example formula is =IF(AND(AU4425>0,J4425<6),1,0)
            - States that the referenced Response cell must be over 0 and that the Longevity column cell must be something below 6 (so 1, 3, or 5), to get a 1, signifying that this sub-category should be having an effect on the environment, and if these rules aren't met it gets a 0
- Saved C:\Users\beng\Documents\Greg's Docs\Restoration Projects Database\Restoration_Projects_Attributes_Table_4Dec2014
- Distributed reported metrics evenly through projects with multiple sites but only reporting one set of measurements.
- Swapped measurements for primary source information if available, except for USFS information due to their lack of detailed project information.

- Saved C:\Users\beng\Documents\Greg's Docs\Restoration Projects Database\Restoration_Projects_Attributes_Table_11Dec2014
- Removed remaining duplicate project sites leaving 1 row/marker per project site.
- Saved C:\Users\beng\Documents\Greg's Docs\Restoration Projects Database\Restoration_Projects_Attributes_Table_15Jan2015
- Added data from the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), also replacing duplicates with the CTUIR data (using as a primary source).
- Saved C:\Users\beng\Documents\Greg's Docs\Restoration Projects Database\Restoration_Projects_Attributes_Table_6Mar2015
- Given updated tribal project records from David Graves, adding missing project information he obtained from cbfish.org (Taurus database).
- Reviewed updated BPA Taurus database and added additional projects not featured when explored in the past.
    - Accessed database through cbfish.org, opening both the projects section, as well as the interactive map display of projects, both in different windows.
    - Once in the projects section, I scrolled through the table of projects, looking for Grande Ronde subbasin in the Province/Subbasin column.
    - Once a project was found for our project area, I checked the title and project info to see if it was a restoration project.
    - Restoration projects were entered into the interactive map window to check for duplicate projects and to separate projects by site.
        - Entered project numbers were separated by where each restoration activity took place, giving specific sites to be entered into our datasheet.
    - Missing projects were added to our datasheet, while some projects contained limited info and couldn't be added.
        - These project numbers were recorded and sent to Rosemary Mazaika from BPA to check for additional info.
- Given complete list (not only tribal projects) of records David Graves originally downloaded from Taurus database to double check all projects were included and to compare methods for obtaining information.
    - David obtained BPA restoration project information by browsing to cbfish.org and going through the below links.
        - Explore
        - Interactive Data and Reports
        - Show more
        - Habitat Metrics (select All (2005 and later), Expense and Capital, Calculate by Actual Work Location, All, All, Completed and In Progress Work, All, All)
        - View it
    - This will produce a .pdf report. At the very bottom of this report, there is an option to download the data in .xlsx or .txt formats.

  - No additional information was found through this form of obtaining BPA restoration project information, and actually included less projects then what I found through this method.
- **Saved C:\Users\beng\Documents\Greg's Docs\Restoration Projects Database\Restoration_Projects_Attributes_Table_Final**
  - **This table represents the final product to be used for future analysis.**
- Potential additional project information sources were acquired through networking at the River Restoration Northwest Symposium, in which a poster of our work was presented.
  - Obtained CTUIR primary data for projects they have implemented, replacing project data for sites already reported, and adding sites not yet reported.
  - Checked into the Department of State Lands for pending and approved project information, but this appears to not be a useful source for our purposes.
- Replaced other reporting agencies data with USFS project information for potential use, but not moving forward with the data table C:\Users\beng\Documents\Greg's Docs\Restoration Projects Database\Restoration_Projects_Attributes_Table_Final_Primary_Sources
- Added two rows to the top of the data table with words and numbers to make sure all data is properly integrated into ArcGIS, saving as\Restoration_Projects_Attributes_Table_Final_for_ArcGIS
- Created new ArcGIS layer from Restoration_Projects_Attributes_Table_Final_for_ArcGIS, using midpoint latitude and longitude measurements to generate points, and adding the recorded project information into the attributes table.
  - Checked for project overlap and potential errors in location.

Modifications to the AEM program included a merger of the sub-categories “complete barrier removal” and “partial barrier removal”, to the new sub-category “removal of barriers”, and the breaking out of the sub-category “LWD/boulders/pools and complexity”, to “large woody debris additions”, “boulder additions”, and “engineered pools”. “Engineered logjam structures” was removed as a sub-category and instead reflected in “large woody debris additions”, and the “modification/removal of bank armoring” sub-category was added to the “instream structures” action. Sub-categories “side-channel/alcove construction” and “thermal refugia” were added to the action “off-channel/floodplain”, and the “agricultural practices” sub-category was changed to “improved agriculture/forestry practices”.

Appendix 3. Example Restoration Assessment Field Checklist form used for assessing restoration function.

Restoration Assessment Field Checklist

This field sheet is for gathering information regarding the implementation and function of restoration projects while conducting habitat monitoring. Restoration project information will be collected within habitat monitoring reaches, as well as 50 to 100 meters above and below each reach, depending on length of site and accessibility. Scores will be assigned to each sub-category per habitat monitoring site, based on the legend descriptors below. Scores are justified from visual estimates, liable to human error and subjective assessment.

Stream Name: Deer Creek **SITE ID:** CBW05583-123456

Crew: CRITFC **DATE:** 8/5/2014

Legend-Proximity Score		Examples (Large Woody Debris)
Activity absent in and adjacent to site	0	No added LWD present in site
Activity present but with no apparent function	1	A few insignificant pieces of LWD outside active channel
Activity present but with moderate apparent function	3	Moderate amount of LWD in channel
Activity present and having substantial function	5	Large amount of LWD and/or logjams in channel with rootwads intact

Activity Checklist: Circle all that apply

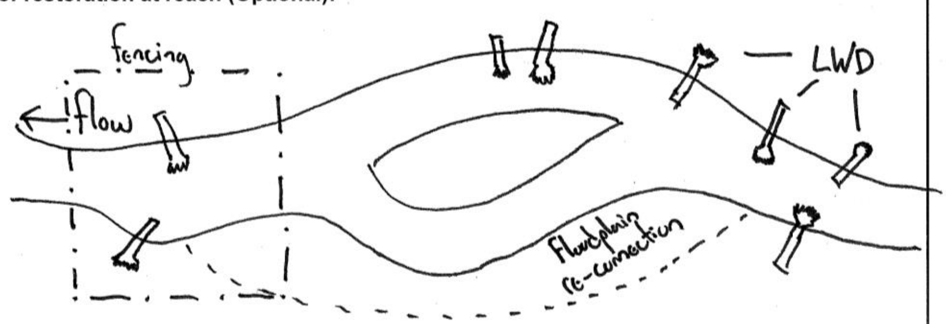
Fish Passage				
Diversion Screening	(0)	1	3	5
Instream Structures				
Large Woody Debris Additions	0	1	3	(5)
Bank Stabilization (ex. rock weir)	(0)	1	3	5
Boulder Addition	(0)	1	3	5
Beaver Activity	(0)	1	3	5
Engineered Pools	(0)	1	3	5
Modification/Removal of Bank Armoring	(0)	1	3	5
Off-Channel/Floodplain				
Levee set-back or removal	(0)	1	3	5
Floodplain Reconnection or Creation	0	1	(3)	5
Remeandering	(0)	1	3	5
Side-Channel/Alcove Construction	(0)	1	3	5
Thermal refugia (spring reconnect, other)	(0)	1	3	5
Riparian Improvements				
Installed Fencing	0	1	(3)	5
Planting	0	(1)	3	5
Sediment Reduction/Addition				
Road Decommissioning	(0)	1	3	5

Activities Requiring Knowledge of Project Area (Circle if Known)				
Removal of Barriers - Complete	0	1	3	5
Removal of Barriers - Partial	0	1	3	5
Nutrient Addition	0	1	3	5
Wetland Restoration	0	1	3	5
Invasive Plant Removal	0	1	3	5
Improved Agricultural/Forestry Practices	0	1	3	5
Spawning Gravel Addition	0	1	3	5
Land Acquisition, Lease, or Easement	0	1	(3)	5
Water Lease or Purchase	0	1	3	5
Irrigation Improvement	0	1	3	5
Mitigate Point Source Impacts	0	1	3	5
OTHER (DESCRIBE):	0	1	3	5

Description of each restoration action in reach:

Substantial LWD added to stream, including rootwads forming scour pools (approx. 20-30 large pieces). Recent grading of mine tailings to allow floodplain re-connection. Fenced from cattle grazing in bottom 1/3 of site (though elk can get in). A few scattered & poorly maintained plantings. Property under easement.

Sketch of restoration at reach (Optional):



Appendix 4. Monitoring Recovery Trends project description, including project tasks referenced in Table 5 (Columbia River Inter-Tribal Fish Commission).

Project Goal

To develop a quantitative means to evaluate current and potential spring Chinook salmon viability factors (productivity, abundance, spatial structure, diversity) for selected listed populations, focusing on key limiting habitat factors.

Impacts

This project will provide information to develop more effective habitat restoration strategies by describing the effect of habitat conditions on fish production.

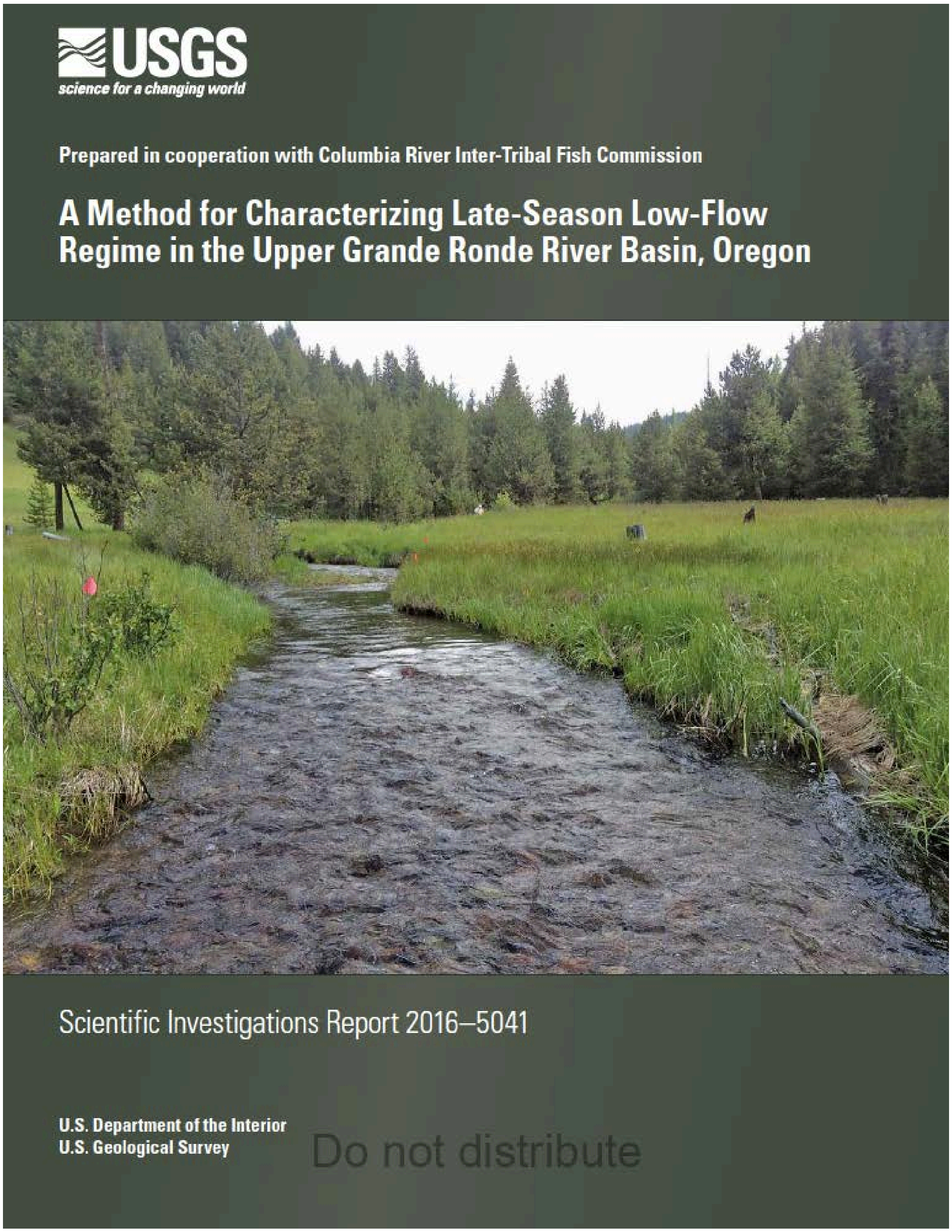
Background

NOAA adopted a method of calculation that simply averages all limiting factors as a means to gauge an overall percentage of potential function (i.e., productivity). This method is not amenable to providing realistic evaluations of habitat condition or restoration trends and their implications to salmon productivity. The tribes need more defensible methods that can provide more accurate assessments so that status and trends in habitat and viability can be meaningfully expressed in the next Accords review.

Project Tasks

1) Collect LIDAR and FLIR data, which will allow us to accurately assess riparian vegetation and stream-side condition by remote sensing.
2) Build a model for predicting longitudinal patterns of water temperature on any day, based on solar radiation, local riparian cover, and other meteorological conditions.
3) Evaluate the spatial distribution of habitat conditions (water temperature, sediment, and flows) in the two test basins in order to integrate overall population productivity.
4) Trends in key habitat conditions and related freshwater survival over time will be viewed as a result of aggregate restoration actions at a basin level.
5) Measure juvenile chinook growth rates in relation to water temperature, food availability, riparian condition, and channel complexity measures.
6) Review and evaluate habitat analysis methods, develop new methods, and examine statistical aspects of sampling.

Appendix E – Hydrology Low-Flow Report Cover (pre-publication copy)



USGS
science for a changing world

Prepared in cooperation with Columbia River Inter-Tribal Fish Commission

A Method for Characterizing Late-Season Low-Flow Regime in the Upper Grande Ronde River Basin, Oregon

Scientific Investigations Report 2016–5041

U.S. Department of the Interior
U.S. Geological Survey

Appendix F – Expanding Snorkel Counts

Developing a Statistical Model for Expanding Snorkel Counts Using Paired Snorkel and Mark-Recapture Data

Casey Justice
Columbia River Inter-Tribal Fish Commission

1/8/2016

Introduction

The objective of this analysis was to develop a statistical model for expanding snorkel counts of juvenile salmonids in the Upper Grande Ronde River basin to account for unobserved fish. Details about the snorkel survey methodology can be found in White *et al*. (2012) (https://www.monitoringmethods.org/Protocol/Details/499). A detailed description of mark-recapture sampling and calculation methods as well as an updated version of the fish abundance data can be obtained from the Oregon Department of Fish and Wildlife (ODFW; contact Chris Horn at La Grande Fish Research office).

Methods

Snorkel surveys are conducted each year by field crews from the Oregon Department of Fish and Wildlife (ODFW) and the Columbia River Inter-Tribal Fish Commission (CRITFC) to estimate the abundance of Chinook Salmon summer parr, juvenile steelhead, and bull trout as well as document presence/absence and relative abundance estimates for other fish species. While snorkel surveys are an efficient method for counting fish in wadeable streams and are less intrusive to the aquatic biota, they do not provide true abundance estimates because an unknown fraction of the population may not be counted by the snorkelers because of poor water clarity, instream cover such as woody debris or undercut banks, or the inherent difficulty in accurately counting a large number of small moving objects. To estimate total abundance from snorkel counts, a correction factor is needed which expands the snorkel counts to account for the unsampled fraction of the population. To develop this correction factor, staff from ODFW, with some assistance from CRITFC, conducted paired snorkel and mark-recapture surveys across a broad range of stream locations during the summers of 2012 and 2015.

Mark-recapture estimates generated from the Chapman estimator (Chapman 1951) were assumed to represent unbiased estimates of true population abundance.

A total of 121 paired snorkel and mark-recapture surveys were conducted in individual channel units, including 62 in 2012 and 59 in 2015. Of these data points, a total of 27 outliers were removed from the original dataset, resulting in a final sample size of 94. Eight data points were identified as outliers by ODFW because of known issues with the sampling methods (e.g., holes in the block nets or net failure), or because the mark-recapture estimates exceeded the snorkel estimates by an order of magnitude or more. In addition, we excluded sites with snorkel counts of zero and two data points that had significantly higher snorkel counts compared to the mark-recapture estimates and were well-outside the 95% confidence bounds of the mark-recapture estimates.

We used a general linear modeling approach to analyze the relationship between the mark-recapture estimates and a set of four explanatory variables including snorkel count, year, channel unit type, and size (Table 1). Population estimates and snorkel counts were log-transformed (natural log) prior to analysis to satisfy model assumptions. Our model selection procedure began by fitting a global model that included all explanatory variables as well as first-order interactions between snorkel count and the other three factor variables (Table 2; model 1) using the lm function in Program R. Next, we examined the summary output from model 1 and removed any variables that were not statistically significant at the $\alpha = 0.05$ level. This resulted in removal of all interaction terms from the global model. Thus, model 2 contained the explanatory variables snorkel count, year, size, and type. The model summary from model 2 indicated that the type effect was also not significant, so it was dropped. The resulting model (model 3) included snorkel count, year, and size. We then examined 4 additional models to explore whether simpler models with fewer variables could provide a reasonably good fit to the data (see models 4-7 in Table 2).

All models were compared using Akaike's Information Criterion (AIC) in addition to other model fit criteria such as R^2 and p-values for model coefficients (Table 3). As a general rule of thumb, models with AIC differences (ΔAIC) values between 0 and 2 have substantial empirical support for selection as the best-fitting model, values between 4 and 7 indicate considerably less empirical support, and values > 10 indicate essentially no empirical support (Burnham and Anderson 2002).

Table 1. Definitions of variables used in the analysis.

Variable Name	Definition
PopEst	Population estimate of juvenile salmonids in a channel unit (Chinook and steelhead combined) as estimated from the Chapman estimator using mark-recapture data.
Count	Number of juvenile salmonids counted in a channel unit (Chinook and steelhead combined) during snorkel surveys.
Year	Factor variable defining the year (2011 or 2015) that the snorkel and mark-recapture surveys were conducted.
Size	Factor variable categorizing the size of the stream ("big" or "small"), where big was defined as ≥ 8 m bankfull width, and small was defined as < 8 m bankfull width.
Type	Factor variable describing the tier-1 channel unit type as defined by the CHaMP program ("fast water", "slow water").

Table 2. Set of candidate linear models used to estimate population abundance.

Model	Model formula
1	*Ln(PopEst) = Year + Size + Type + Ln(Count) + Year*Ln(Count) + Type*Ln(Count) + Size*Ln(Count)*
2	*Ln(PopEst) = Year + Size + Type + Ln(Count)*
3	*Ln(PopEst) = Year + Size + Ln(Count)*
4	*Ln(PopEst) = Size + Ln(Count)*
5	*Ln(PopEst) = Year + Ln(Count)*
6	*Ln(PopEst) = Type + Ln(Count)*
7	*Ln(PopEst) = Ln(Count)*

Results

The best-fitting model in terms of AIC was model 3 ($R^2 = 0.64$, $\Delta AIC = 0$), which contained the explanatory variables snorkel count, year and size. Although all model coefficients were statistically significant, the year effect was only moderately significant ($p = 0.03$) compared with the other model terms which had p-values less than 0.0001. In addition, the relative importance metric (*lmg*) for the year effect, which indicates the proportion of the R^2 contributed by each of the model variables, was only 0.02 compared with relative importance scores of 0.17 and 0.80 for the size and snorkel count variables respectively (Lindeman *et al.* 1980). Moreover, the inclusion of a year effect in a predictive model that is intended for use in years than those in which the data was collected is problematic and may lead to unintended biases in model predictions.

The next best model in terms of AIC was model 2 ($R^2 = 0.64$, $\Delta AIC = 1.04$), which included the variables snorkel count, year, size, and type. Although this model was supported in terms of AIC, the type variable was not statistically significant ($p = 0.28$) and explained essentially none of the variation in fish

abundance (*lmg* = 0.005). For these reasons, we considered this model to be inadequate for predictive purposes.

The only other model considered competitive in terms of AIC was model 4 (R^2 = 0.62, ΔAIC = 3.03). All explanatory variables in this model were highly significant. Relative importance metrics for size and snorkel count were 0.17 and 0.83 respectively. Although this model did not have the lowest AIC score among the candidate models, the R^2 value was very similar to model 3, indicating that the addition of a year effect for model 3 did little to improve model fit. Additionally, the fact that model 4 does not include a year effect makes it more useful for predictive purposes. For these reasons, we considered model 4 to be the best model among the set of models examined.

Diagnostic plots for the final model indicated a slight deviation from normality at the tail ends of the dataset, but model assumptions were generally satisfied. Although the Shapiro-Wilk test still indicated that the residuals from the final model were not normally distributed, these tests are generally regarded as overly conservative.

Examination of the model results from model 4 indicated that population estimates were generally higher relative to snorkel counts in big streams versus little streams (Figure 1). In other words, snorkelers were better able to count fish in small streams versus large streams, which makes intuitive sense. In big streams, the estimated ratio of snorkel counts to population size (i.e., the fraction of total fish observed by snorkelers) ranged from about 0.11 to 0.45 as snorkel counts increased from 1 to 200 (Table 5). Similarly in small streams, the estimated ratio of snorkel counts to population size ranged from 0.20 to 0.84. In addition, the relationship between snorkel counts and population estimates was non-linear with population estimates increasing more rapidly relative to snorkel counts at low abundance and gradually leveling off at higher abundance (Figure 2). The final regression formulas for expanding snorkel counts are given by:

$$Ln(PopEst) = \begin{cases} 0.73351 * Ln(Count) + 1.58159, & if\ Size = small \\ 0.73351 * Ln(Count) + 2.1879, & if\ Size = large \end{cases}$$

Recommendations

Although there is still a relatively large amount of variation in the data that is not explained by the model, we feel that model 4 fits that data reasonably well and should provide a useful means of expanding snorkel counts to account for unobserved fish during snorkel surveys. Additional years of paired snorkel and mark-recapture data could shed some light on potential environmental causes for the apparent year effect observed in the data. We would recommend that previous abundance estimates from 2011-2014 that were generated from the earlier 2012 mark-recapture study in the Upper Grande Ronde basin be updated using the formulas presented in this analysis to ensure consistency in the extrapolation methods across all available years.

Table 3. Model selection summary table. Plus signs indicate factor variables or interactions that were included in the model. Interactions are denoted by a ":".

Model	DF	Log Likelihood	AICc	ΔAICc	Weight	$AdjR^2$
3	5	-93.67	198.06	0.00	0.54	0.64
2	6	-93.04	199.10	1.04	0.32	0.64
4	4	-96.31	201.09	3.03	0.12	0.62
1	9	-92.76	205.76	7.70	0.01	0.63
5	4	-100.58	209.63	11.57	0.00	0.58
7	3	-101.69	209.66	11.60	0.00	0.57
6	4	-100.97	210.40	12.34	0.00	0.58

Table 4. Model coefficients from model 4.

Model coefficients	Estimate	Std. Error	t value	Pr(>|t|)	Signif. codes
(*Intercept*)	2.1879	0.2332	9.384	4.97e-15	***
Size (small)	-0.60631	0.1824	-3.325	0.0013	**
Ln (*Count*)	0.73351	0.0632	11.603	2.00e-16	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.7296 on 91 degrees of freedom
Multiple R-squared: 0.6662, Adjusted R-squared: 0.6589
F-statistic: 90.83 on 2 and 91 DF, p-value: < 2.2e-16

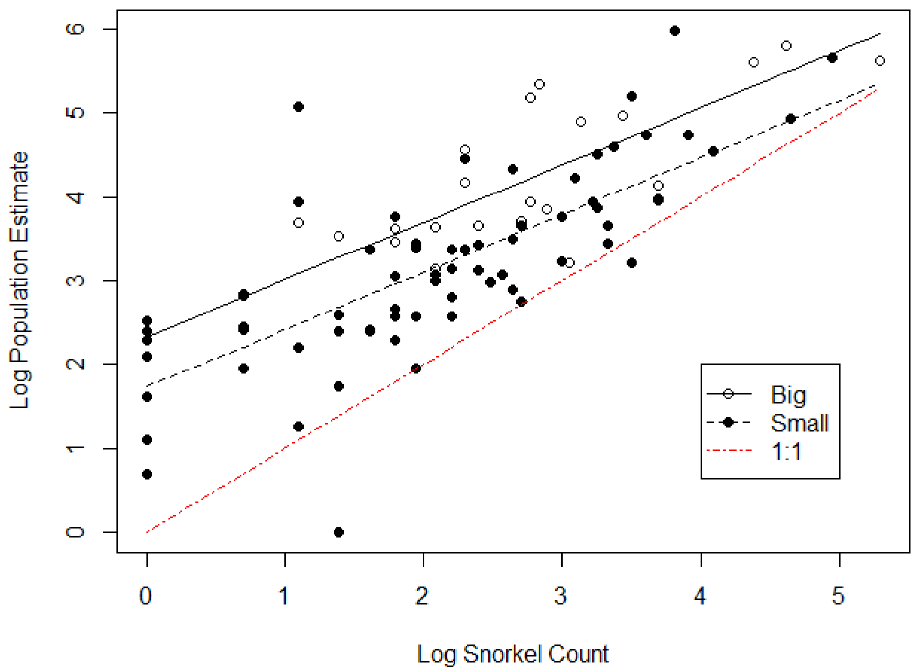


Figure 1. Relationship between log-transformed snorkel counts and log-transformed mark-recapture population estimates showing fitted lines from model 4.

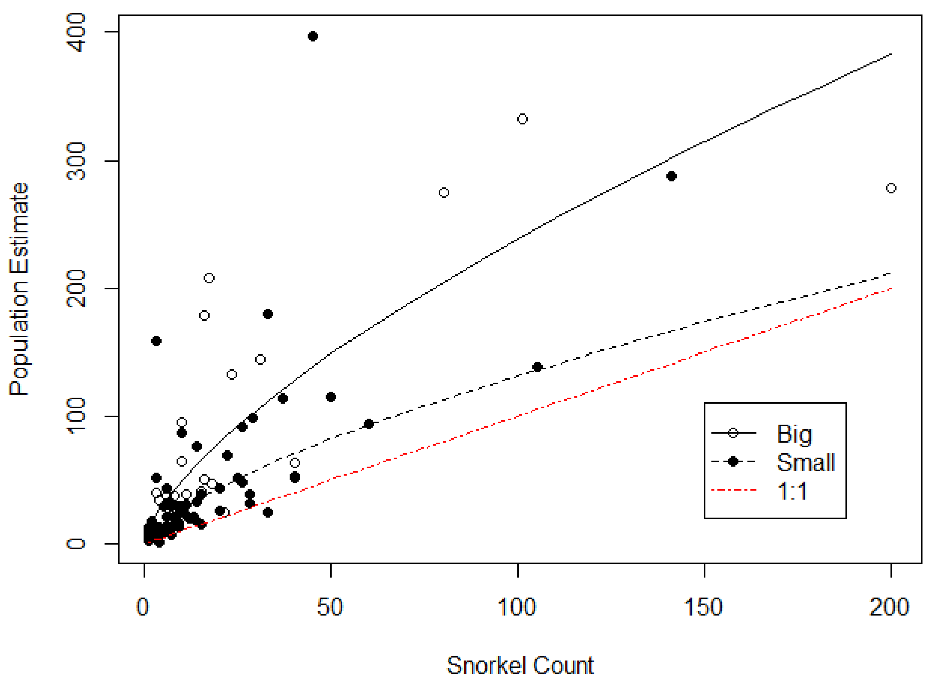


Figure 2. Untransformed relationship between snorkel counts and mark-recapture population estimates showing fitted lines from model 4.

Table 5. Summary table of predicted population estimates for big and small streams for a range of snorkel counts from model 4. Ratios of snorkel counts to population estimates are provided to indicate the average fraction of the total population that was observed by snorkelers at different levels of abundance.

	Big			Small		
Snorkel Count	PopEst	95% CI	Count:PopEst	PopEst	95% CI	Count:PopEst
1	9	[6, 14]	0.11	5	[4, 7]	0.20
2	15	[10, 22]	0.13	8	[6, 10]	0.25
3	20	[14, 29]	0.15	11	[9, 13]	0.27
4	25	[17, 35]	0.16	13	[11, 16]	0.31
5	29	[21, 41]	0.17	16	[13, 19]	0.31
6	33	[24, 46]	0.18	18	[15, 22]	0.33
7	37	[27, 51]	0.19	20	[17, 24]	0.35
8	41	[30, 56]	0.20	22	[19, 27]	0.36
9	45	[33, 61]	0.20	24	[20, 29]	0.38
10	48	[35, 66]	0.21	26	[22, 31]	0.38
15	65	[48, 88]	0.23	35	[29, 43]	0.43
20	80	[59, 109]	0.25	44	[35, 54]	0.45
25	95	[70, 128]	0.26	52	[41, 65]	0.48
30	108	[79, 148]	0.28	59	[46, 75]	0.51
35	121	[88, 166]	0.29	66	[51, 86]	0.53
40	133	[97, 184]	0.30	73	[55, 96]	0.55
45	145	[105, 202]	0.31	79	[60, 106]	0.57
50	157	[113, 219]	0.32	86	[64, 115]	0.58
60	180	[127, 253]	0.33	98	[71, 134]	0.61
70	201	[141, 286]	0.35	110	[79, 153]	0.64
80	222	[155, 319]	0.36	121	[86, 171]	0.66
90	242	[167, 350]	0.37	132	[92, 189]	0.68
100	261	[179, 381]	0.38	143	[98, 207]	0.70
110	280	[191, 412]	0.39	153	[104, 224]	0.72
120	299	[202, 442]	0.40	163	[110, 241]	0.74
130	317	[213, 472]	0.41	173	[116, 258]	0.75
140	335	[223, 501]	0.42	182	[121, 275]	0.77
150	352	[233, 531]	0.43	192	[126, 291]	0.78
160	369	[243, 559]	0.43	201	[132, 308]	0.80
170	386	[253, 588]	0.44	210	[137, 324]	0.81
180	402	[263, 616]	0.45	219	[142, 340]	0.82
190	418	[272, 644]	0.45	228	[146, 356]	0.83
200	435	[281, 672]	0.46	237	[151, 372]	0.84

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Appendix G – Macroinvertebrate Analysis

Benthic Macroinvertebrates

Benthic macroinvertebrate samples were collected at all CHaMP sites in riffles only. Although benthic communities would vary to some degree among major channel unit types, riffles are easier to sample quantitatively and serve as a standardized means of representing the predominant source of drifting food organisms for salmonids. Samples were collected using either a Hess sampler (1 ft^2) or a rectangular-framed kick net (0.5-mm mesh size for both). The Hess sampler was used preferentially when feasible. It was considered to be a more precise delineation of area to be sampled. Conditions that were unsuitable for use of the Hess sampler were water depth greater than about 40 cm, high velocity, or substrate size that was too great (e.g., > 20 cm). When the kick net was used, samples were collected in a manner as similar to the Hess samples as possible. That is, each rock within an estimated 1 ft^2 area in front of the net was carefully moved to the mouth of the net and brushed thoroughly to generate a quantitative sample. The substrate was worked to as low a depth as feasible by moving particles with the hands. Substrate was finally raked with a small garden hand rake and material directed toward the net mouth.

All samples were preserved in 100% ethanol after eliminating as much water from samples as possible. If any sample was highly organic and thereby might contain water within the plant material that could reduce the alcohol strength, alcohol was poured into sample bottles and then poured off to remove excess water and then refilled. Samples were processed by Cole Ecological, Inc. Cole Ecological provided counts of individuals by taxon and size class and dry weight, computed from regression equations for taxa by size.

The benthic samples collected from riffles are expected to be associated highly with CHaMP metrics such as water temperature, Wolman pebble counts, or other fine sediment indices (Huff et al. 2006). Benthic macroinvertebrate communities from riffles would be expected to be somewhat less closely related to ocular fine sediment levels averaged for the entire study site (all channel units combined), pool tail fines or McNeil fines (representing the surface and subsurface substrate, respectively, of pool tails or transition to the head of riffles rather than riffles themselves). Because samples were taken from approximately July through September, it is unclear whether water temperatures representing only a single month, such as August, would represent the density and biomass of macroinvertebrates collected in other months during this summer sampling period. It could be expected that numbers of individuals per taxon would decline due to mortality through the summer, but also that delayed development could replace losses in certain size classes with other individuals that grow and counteract losses. Also, early emerging insects might reproduce in spring to early summer and then be present as eggs or early instars in mid-summer, thereby being small enough to pass through collection nets and not to be represented in mid- to late summer samples.

Taxonomic resolution for sample sorting and identification followed guidelines shown in Table 13.

Table 13. Recommended levels of taxonomic resolution for CRITFC benthic (Hess) samples, derived from taxonomic standards established by the Northwest Biological Assessment Workgroup.

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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

Table 14. Taxa identified in 2013 benthic sample collection.

DENSITY BY TAXON

Note: These calculations represent densities expressed as number of organisms per square meter

Phylum	Class	Order	Family	OR Taxon
ANNELIDA	BRANCHIOBDELLIDA	Miscellaneous		Branchiobdellida
	HIRUDINEA	Miscellaneous	Erpobdellidae	Erpobdellidae
	OLIGOCHAETA	Miscellaneous		Oligochaeta
ARTHROPODA	ARACHNOIDEA	Trombidiformes		Trombidiformes
	CRUSTACEA	Amphipoda	Talitridae	Hyalella
		Decapoda	Astacidae	Pacifastacus
		Isopoda	Asellidae	Caecidotea
		Podocopa		Ostracoda
	INSECTA	Coleoptera	Dytiscidae	Agabus
				Dytiscidae - adult
				Hydroporinae
				Liodessus
				Oreodytes-adult
				Sanfilippodytes-adult
				Stictotarsus
			Elmidae	Cleptelmis addenda
				Cleptelmis addenda-adult
				Heterlimnius
				Heterlimnius-adult
				Lara
				Microcylloepus-adult
				Narpus concolor
				Narpus concolor-adult
				Optioservus
				Optioservus-adult
				Ordobrevia nubifera
				Zaitzevia
				Zaitzevia-adult
			Haliplidae	Brychius
			Hydraenidae	Hydraena-adult
				Ochthebius
			Hydrophilidae	Ametor
				Helophorus-Adult
				Hydrophilidae
			Psephenidae	Psephenus
			Staphylinidae	Staphylinidae-adult

Diptera		Brachycera
	Athericidae	Atherix
	Blephariceridae	Bibiocephala
	Ceratopogonidae	Atrichopogon
		Ceratopogoninae
		Dasyhelea
	Chironomidae	Ablabesmyia
		Boreochlus
		Boreoheptagyia
		Brillia
		Brundiniella
		Cardiocladius
		Chironominae
		Chironomini
		Cladotanytarsus
		Corynoneura
		Cricotopus
		Cricotopus (Nostoc.) nostocicola
		Cricotopus Isocladius
		Cryptochironomus
		Diamesa
		Diamesinae
		Dicrotendipes
		Eukiefferiella
		Eukiefferiella brehmi Gr.
		Eukiefferiella claripennis Gr.
		Eukiefferiella devonica Gr.
		Eukiefferiella gracei Gr.
		Eukiefferiella pseudomontana Gr.
		Heterotrissocladius
		Hydrobaenus
		Krenosmittia
		Labrundinia
		Larsia
		Limnophyes
		Lopescladius
		Metriocnemus
		Micropsectra/Tanytarsus
		Microtendipes
		Nanocladius
		Nilotanypus
		Orthocladiinae

	Orthocladius
	Orthocladius complex
	Pagastia
	Parakiefferiella
	Paramerina
	Parametriocnemus
	Paratanytarsus
	Paratendipes
	Parorthocladius
	Pentaneura
	Phaenopsectra
	Platysmittia
	Polypedilum
	Potthastia gaedii Gr.
	Potthastia longimana Gr.
	Psectrocladius
	Pseudochironomus
	Radotanypus
	Rheocricotopus
	Rheotanytarsus
	Stempellina
	Stempellinella
	Stictochironomus
	Sublettea
	Symposiocladius
	Synorthocladius
	Tanypodinae
	Tanytarsini
	Thienemanniella
	Thienemannimyia Gr.
	Tvetenia
	Tvetenia bavarica Gr.
	Tvetenia discoloripes Gr.
	Zavrelimyia
Dixidae	Dixa
	Meringodixa
Dolichopodidae	Dolichopodidae
Empididae	Clinocera
	Empididae
	Hemerodromia
	Neoplasta
	Oreogeton
	Roederiodes

		Wiedemannia
	Ephydridae	Ephydridae
	Muscidae	Muscidae
	Pelecorhynchidae	Glutops
	Psychodidae	Maruina
		Pericoma/Telmatoscopus
	Ptychopteridae	Ptychoptera
	Simuliidae	Simuliidae
		Simulium
	Tabanidae	Tabanus
	Tipulidae	Antocha monticola
		Cryptolabis
		Dicranota
		Hesperoconopa
		Hexatoma
		Limnophila
		Pedicia
		Rhabdomastix
		Tipula
		Tipulidae
Ephemeroptera	Ameletidae	Ameletus
	Baetidae	Acentrella turbida
		Baetidae
		Baetis
		Baetis bicaudatus
		Baetis flavistriga
		Baetis tricaudatus
		Centroptilum
		Diphetor hageni
		Heterocloeon anoka
		Labiobaetis
		Plauditus
		Procloeon
	Ephemerellidae	Attenella
		Attenella margarita
		Caudatella hystrix
		Drunella coloradensis
		Drunella doddsi
		Drunella flavilinea
		Drunella grandis/spinifera
		Ephemerella
		Ephemerella alleni
		Ephemerella aurivillii

		Ephemerella excrucians/dorothea
		Ephemerella tibialis
		Ephemerellidae
		Matriella teresa
		Timpanoga hecuba
	Heptageniidae	Cinygma
		Cinygmula
		Ecdyonurus criddlei
		Epeorus
		Epeorus albertae Gr.
		Epeorus deceptivus
		Epeorus grandis Gr.
		Epeorus longimanus
		Heptageniidae
		Ironodes
		Rhithrogena
	Leptophlebiidae	Paraleptophlebia
		Paraleptophlebia bicornuta Gr.
	Tricorythidae	Tricorythodes
Hemiptera	Corixidae	Corixidae
	Gerridae	Gerridae
Lepidoptera	Pyralidae	Petrophila
Megaloptera	Sialidae	Sialis
Odonata	Coenagrionidae	Argia
		Coenagrionidae
	Cordulegastridae	Cordulegaster
	Corduliidae	Corduliidae
	Gomphidae	Gomphidae
		Ophiogomphus
Plecoptera	Capniidae	Capniidae
	Chloroperlidae	Chloroperlidae
		Paraperla
		Suwallia
		Sweltsa
	Leuctridae	Despaxia augusta
		Leuctridae
		Paraleuctra
	Nemouridae	Malenka
		Nemouridae
		Visoka cataractae
		Zapada
		Zapada cinctipes

		Zapada columbiana
		Zapada frigida
		Zapada oregonensis Gr.
	Peltoperlidae	Yoraperla
	Perlidae	Calineuria californica
		Claassenia sabulosa
		Doroneuria
		Hesperoperla pacifica
		Paragnetina
		Perlidae
	Perlodidae	Cultus
		Isoperla
		Kogotus/Rickera
		Megarcys
		Perlinodes aurea
		Perlodidae
		Skwala
	Pteronarcyidae	Pteronarcella
		Pteronarcys
	Taeniopterygidae	Taenionema
		Taeniopterygidae
		Taeniopteryx
Trichoptera		Trichoptera
	Apataniidae	Apatania
	Brachycentridae	Amiocentrus aspilus
		Brachycentridae
		Brachycentrus
		Brachycentrus americanus
		Brachycentrus occidentalis
		Micrasema
	Glossosomatidae	Agapetus
		Anagapetus
		Glossosoma
		Glossosomatidae
		Protoptila
	Goeridae	Goera
	Helicopsychidae	Helicopsyche
	Hydropsychidae	Arctopsyche
		Cheumatopsyche
		Hydropsyche
		Hydropsychidae
		Parapsyche
		Parapsyche elsis

			Hydroptilidae	Hydroptila
				Hydroptilidae
				Leucotrichia
				Neotrichia
				Ochrotrichia
			Lepidostomatidae	Lepidostoma
			Leptoceridae	Oecetis
			Limnephilidae	Cryptochia
				Dicosmoecinae
				Dicosmoecus gilvipes
				Hesperophylax
				Limnephilidae
				Onocosmoecus unicolor
				Psychoglypha
			Philopotamidae	Dolophilodes
				Philopotamidae
				Wormaldia
			Psychomiidae	Psychomyia
			Rhyacophilidae	Rhyacophila
				Rhyacophila angelita Gr.
				Rhyacophila atrata Gr.
				Rhyacophila betteni Gr.
				Rhyacophila brunnea Gr.
				Rhyacophila coloradensis Gr.
				Rhyacophila hyalinata Gr.
				Rhyacophila narvae
				Rhyacophila nevadensis Gr.
				Rhyacophila sibirica Gr.
			Uenoidae	Neophylax
				Neophylax rickeri
				Neophylax splendens
MOLLUSCA	GASTROPODA		Lymnaeidae	Lymnaeidae
			Planorbidae	Helisoma
		Basommatophora	Ancylidae	Ferrissia
			Physidae	Physa
			Planorbidae	Gyraulus
				Planorbidae
	Pelecypoda		Pisidiidae	Pisidiidae
			Unionidae	Unionidae
NEMATODA	Miscellaneous	Miscellaneous		Nemata
PLATYHELMINTHES	TURBELLARIA	Miscellaneous		Turbellaria
		Tricladida	Planariidae	Polycelis

A master cumulative list of taxa is continually being developed by Cole Ecological, Inc. with each new year's samples. The current taxa list is shown in Table 14. For each taxon, the spreadsheet reports for all samples the number of individuals per sample and the dry weight. These data were based on processing each sample until 525-550 individuals were recorded. This involved sampling varying percentages of entire samples. In addition to complete identification of subsamples, the total sample was screened for rare and large individuals.

In order to evaluate the distribution of key taxa with water temperature, water temperature data were obtained from champmonitoring.org at the "exports" tab for years 2011-2015. These data were also averaged by CHaMP site using a pivot table in Excel. Annual sites provide data in 2011, 2012, 2013, and 2014. Panel 1 sites have data for 2011 and 2014, provided that data loggers were not lost. Panel 2 sites have data for 2012 and 2015. Panel 3 sites contributed data for 2013 and will be sampled again in 2016.

Because annual data were not available for all sites due to logger loss and the rotating panel process, we also obtained annual data for mean August water temperatures for all sites for years 2011-2013 from the NorWeST database (http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html). Unfortunately, data from 2014 and 2015 are not available yet from this source.

Relationship of benthic community to environmental conditions

Benthic community composition has long been used as a good reflection of overall environmental condition of the aquatic system. The condition of any stream site surveyed is a function of the local conditions (stream channel and associated riparian zone) plus the contributing watershed. The contributing watershed can be considered as the entire watershed upstream of the study reach, or as more specific upstream contributing portions of the watershed, such as the 2-km segment directly upstream, buffered by a 200-m wide riparian zone.

Trends in overall community metrics can be used as indicators of degradation or restoration of the immediate study reach and/or the changes in the contributing portions of the watershed. In addition to trends in overall community metrics, the relationship between individual taxa and local environmental conditions can express unique species adaptations to environment that can be understood with a specific knowledge of species traits and life history.

Community metrics computed for each sample included:

standard BCI indices

functional feeding group composition

Hilsenhoff metrics

tolerant/intolerant species based on fine sediment and temperature (using, in part, indicator taxa by Huff et al. 2006)

PREDATOR (Western Cordillera and Columbia Plateau model)

total taxa densities

biomass/m2

Eastern Oregon multimetric index (Hubler 2006), including component metrics of mayfly, stonefly, and caddisfly richness, number of sensitive taxa, number of sediment-sensitive taxa, modified HBI, percentage of tolerant taxa, percentage of sediment tolerant taxa, and community dominance by the single most abundant taxon.

DEQ temperature and fine sediment stressor models.

Relationship of community biometrics to environmental conditions

Macroinvertebrate summary biometrics are currently available for sample years 2011-2014. In this 4-year time period, there were 247 samples taken in CHaMP sites. Taxonomic composition of these samples was analyzed with Eastern Oregon (Grande Ronde) IBI, with its numerous metrics, functional feeding group composition, Predator (WCCP Model) analysis in terms of observed/expected ratios, Stressor Indicator Taxa, and Stressor Model results by Michael Cole (Cole Ecological, Inc.), who also provided an updated compilation of metrics for all CHaMP samples each year.

The Eastern Oregon IBI provides a variety of biometrics, including sensitive taxa, sediment sensitive taxa, % tolerant taxa, % sediment tolerant taxa. The Stressor Indicator Taxa also provide data on number of temperature sensitive indicator taxa and % temperature tolerant taxa, as well as the number of fine sediment sensitive and tolerant taxa.

Biometrics were plotted against Max7dAM temperature for 2011-2014 and the August mean temperature from NorWeST for 2011-2013. The only drawback of using the Max7dAM temperature data is that temperatures were occasionally missing for CHaMP sites when temperature loggers were missing. Otherwise, these data were the most spatially relevant data available. The NorWeST data for 2011 were based on CRITFC water temperature data and were estimated for nodes distributed throughout the stream networks at 1-km intervals. We matched all CHaMP sites with the nearest NorWeST data estimation site. Unfortunately, years 2012 and 2013 were estimated based on elevation-adjusted air temperature data and 2011 CHaMP data and not from temperature logger data for 2012 and 2013 directly. Data for 2014 were not available for the NorWeST dataset. NorWeST temperature data have the advantage in being available for most sites in the 2011-2013 period.

Despite the different strengths of the temperature data available between CHaMP and NorWeST, a comparison of the two showed a high level of correlation (Figure 54). Max7dAM temperatures are the highest running average of the 7-day maximum temperatures for each year from 2011-2014. For years 2011-2013, where NorWeST temperature data were available for average August temperatures, a plot of Max7dAM vs. NorWeST temperature data for the same years yielded a linear regression with $R^2 = 0.78$ (Figure 55).

Regressions of water temperature (either Max7dAM water temperature or NorWeST mean August temperatures) showed a significant negative relationship with number of temperature sensitive or sensitive taxa (Figure 56 and Figure 57). As Max7dAM water temperature increased from 12 to 27°C, numbers of temperature sensitive taxa declined from a high of about 8 to 0 (Figure 56). Sensitive taxa

declined from a high of 13 to 0 over the same temperature range (Figure 57). The same temperature increase produced a decline in total IBI score from 50 to 30 (Figure 58).

The NorWeST temperature range (mean August temperatures) was about 8 to 21°C. Temperature increase within this range was associated with a decline in sensitive taxa from about 16 to 0 (Figure 59) and a decline in temperature sensitive species from about 12 to 0 (Figure 60). Tolerant species increased from approximately 0 to 30 over the temperature increase range (Figure 61).

Over a temperature range of about 12 to 29°C Max7dAM the number of tolerant taxa increased from about 0 to 35 (Figure 61).

It was more difficult to find sediment indices from CHaMP monitoring that corresponded with taxa known from the literature as being sensitive to fine sediment. CHaMP metrics available to represent substrate characteristics and fine sediment in particular were:

pool tail fines measured with grids for counting number of particles <2 mm and <6 mm

ocular sediment composition, which was based on visual estimates made in each channel unit. Sediment size classes that were visually distinguished were bedrock, boulders (>256 mm), cobbles (64-256), coarse gravel (16-64 mm), fine gravel (2-16 mm), sand (0.06-2 mm), and fines <0.06 mm. Particles of sand-size or smaller in diameter were <2 mm.

Wolman pebble counts from 110 or 220 pebbles collected on 10 transects across riffles or fast non-turbulent habitats when insufficient riffles were present produced 14 size categories (depending upon year in CHaMP monitoring history). Fine sediment particles included particles that were retained on a 5.7 mm sieve (i.e., 5.7-8 mm), 4 mm, 2 mm, 0.06 mm, and <0.06 m. The sand size fraction to the silt/clay fraction was <2 mm. Wolman pebble counts also generated statistics such as D_{16}, D_{50}, and D_{84}, where D16 would be that size that 16% of all particles is less than by dry weight.

In addition to CHaMP fine sediment metrics, we have CRITFC-based metrics:

McNeil fine sediment cores. Our McNeil sediment analysis provided percentages of fines that were <0.83 mm, <2 mm, and <6.3 mm.

Among the sediment metrics available, only the Wolman pebble counts were taken in riffles, the same channel unit as targeted for sampling macroinvertebrates. However, Wolman pebble counts are known to be insensitive to fine sediment (Bunte and Abt 2001). It is still possible that statistics such as D_{16} or D_{50} would be related to the amount of fine sediment. That is, if the median particle size declines, one might expect an increase in percentage of particles at the bottom of the distribution. The full range of D_{50} for all Wolman pebble count estimates made was about 0.11 to 175 mm (n = 247).

Pool tail fines estimates include particles <2 mm, which is a particle size class also available in the ocular estimate as well as the Wolman pebble counts. However, pool tail fines estimates are made on pool tails rather than in riffles.

Ocular estimates of fines were collected on a channel unit basis, and were then computed as a weighted average (weighted by channel unit area) for entire CHaMP sites and also computed as an average for all riffles. Plots were made for ocular substrate estimates (<2 mm) against macroinvertebrate community

summary metrics, such as fine sediment tolerant taxa (Figure 63). The regression of fine sediment tolerant indicator taxa vs. ocular fines (<2 mm) was not significant ($y = 0.0334X + 3.7684$, $R^2 = 0.0366$). A somewhat better relationship was expressed between number of fine sediment indicator taxa and the D_{50} substrate size in riffles measured with the Wolman pebble counts. This regression was $y = 0.0539X + 1.701$, $R^2 = 0.265$ (Figure 64). Regressions of fine sediment sensitivity revealed greater significance in relation to stream gradient. The number of fine sediment sensitive indicator taxa regressed on gradient was highly significant (Figure 65), as was the regression of fine sediment tolerant indicator taxa (Figure 66). The higher the gradient (up to 8%) the higher the numbers of sediment sensitive taxa and the lower the number of tolerant taxa. It is interesting that fine sediment tolerant taxa decline with gradient. It seems likely that competition from fine sediment sensitive taxa that would have higher survival in this environment might limit the use of habitat by tolerant taxa that otherwise would do well in the colder water typical of higher gradient environments. The exact taxa involved in these contrasts should be examined to assess the environmental requirements of competing species.

All macroinvertebrate samples taken from CHaMP sites from 2011-2014 were grouped by stream name (Table 15). Because there were 35 unique streams and 247 samples, streams had multiple sites that were averaged. The average of modified HBI (HBI and HBI2), Total Score (Oregon IBI), O/E ($P > 0.5$), and average number of temperature sensitive indicator species revealed differences among streams. O/E scores for 181 stream sites monitored where average August water temperature values (°C) were available from NorWeST datasets revealed a negative relationship with water temperature ranging from about 8 to 20.5°C (Figure 67). O/E ratios were near 1.0 at average August water temperatures of 11°C and declined to about 0.8 at 19°C.

The Catherine Creek sites had HBI indices ranging from 1.71 to 2.56, the Minam sites from 2.95 to 3.03, while the mainstem Grande Ronde was 3.39 (Table 15). HBI values for Grande Ronde tributaries were higher that the Grande Ronde mainstem average. Chicken and West Chicken were 3.34 and 3.48, respectively, Dark Canyon, 3.88, Sheep Creek, 3.92; Burnt Corral, 3.97; Fly Creek 3.99, Waucup, 4.14; Limber Jim, 4.31, Meadow Creek 4.36, and McCoy, 4.61.

Meadow and McCoy Creeks visually appear to be the most disturbed among the Grande Ronde sites and their high HBI scores seem to reflect this difference from Catherine Creek and the Minam sites.

When viewed in terms of Total Score, the Catherine Creek sites ranged from 43.89 to 46, while the Minam sites ranged from 47.33 to 49.71 (Table 15). The mainstem Grande Ronde presents conditions that range from relatively high quality spawning habitat in headwaters to heavily disturbed, warm sites downstream. Its average Total Score was 41.10, which reflect a wide range of conditions. The more heavily disturbed sites among Grande Ronde tributaries, Meadow Creek and McCoy Creek had scores of 32.00 and 30.50, respectively.

Average total taxa richness for streams in the study basins from 2011-2014 ranged from 28.00 (E. Phillips Creek) to 57.50 (Limber Jim Creek). Catherine, NF Catherine, SF Catherine, and MF Catherine, respectively, had taxa richness of 45.63, 50.00, 46.50, and 46.00 (Table 16). Taxa richness on the Minam and Little Minam were 45.67 and 52.71, respectively. Taxa richness on the mainstem Grande Ronde was 48.59.

The percentage of all taxa that were EPT taxa (i.e., Ephemeroptera, Plecoptera, or Trichoptera) in samples taken in 2011-2014 were 56.6% in the mainstem Catherine Creek and 70.7%, 62.9%, and 63.9% in the Middle Fork, North Fork, and South Fork, respectively (Table 16). For 20 sites distributed along the mainstem Grande Ronde, the mean % EPT/total taxa was 53.1%. Sheep Creek had five sites surveyed from 2011-2014 and had 54.6% EPT/total taxa. The Minam, by contrast, had 55.8% and the Little Minam had 59.3%.

Values of % EPT/total taxa increased with elevation in both the Grande Ronde mainstem (Figure 72; $y = 0.0002x + 0.2862$, $R^2 = 0.258$, $P = 0.019$, $n = 20$) and in the Catherine Creek drainage network (Figure 73, $y = 0.0002x = 0.4315$, $R^2 = 0.2452$, $P = 0.0021$, $n = 35$). However, the environmental status of the stream in general also appears to control % EPT/total taxa. McCoy and Meadow Creeks had relatively low values of % EPT/total taxa (i.e., 38.1 and 41.0%, respectively). This index taken by itself does not reveal all aspects of quality of the macroinvertebrate community. For example, East Phillips Creek has a % EPT/total taxa of 57.1%, yet has only an average taxa richness of 28.0 compared with the richness of Catherine Creek (45.6) and the Minam River (45.7).

Composition of the macroinvertebrate communities among the major river systems was evaluated from samples taken in 2014 by comparing the percentage presence of taxa in samples. Presence was compared between the Grande Ronde mainstem (13 sites) and Catherine Creek (mainstem—10 sites, North Fork— 3 sites, and South Fork—3 sites), and between the Grande Ronde mainstem and the Minam River (mainstem—6 sites, and Little Minam—3 sites). Of the 291 total species observed in all 66 samples from the study areas in 2014, there were 47 taxa that were 25% more (absolute percentage difference) common in Catherine Creek than the Grande Ronde mainstem (Table 17), and 41 that were 25% more common in the Minam than the Grande Ronde mainstem (Table 18). Based on the assumption that the Grande Ronde mainstem provides, on average, lower quality habitat than the other two streams, this difference in percentage presence would indicate that taxa such as *Arctopsyche*, *Drunella, Cinygmula, Glossosoma, Epeorus, Glutops, Lara, Zapada*, and *Rhyacophila* tend to be indicators of higher quality habitat. On the other hand, species that are 25% more common in the Grande Ronde than in both Catherine Creek and the Minam, such as *Brachycentrus occidentalis*, *Hydropsyche*, *Paraleptophlebia*, *Psephenus*, *Pteronarcys californica*, *Tricorythodes*, and *Zaitzevia* would be presumed to be indicators of lower habitat quality and more tolerant taxa.

When examined at a critical difference of 50% (absolute percentage difference) in percentage presence between the Grande Ronde and the other two streams, one finds that taxa indicative of higher habitat quality in both Catherine Creek and the Minam include *Cinygmula*, Capniidae, *Epeorus deceptivus*, *Eukiefferiella* (Table 19). Taxa that are 50% more common in the Grande Ronde than the other two streams included *Brachycentrus occidentalis*, *Calineuria californica*, *Cardiocladius, Microtendipes, Ochrotrichia, Paraleptophlebia*, and *Petrophila*. We hypothesize that these species would indicate greater levels of disturbance which might be indicative of higher water temperature or preference for higher levels of detritus. These hypotheses are based on the assumption that rivers of the Blue Mountains are all able to draw species from the same species pool and that the predominance of taxa in our reference stream (Minam River) or our minimally damaged stream (Catherine Creek above Union) reflects the influence of higher quality habitat than is found in the Upper Grande Ronde basin.

Certain taxa are relatively ubiquitous across all three basins. The taxa specified were the lowest level resolution identified for each. Taxonomic constancy was calculated as the frequency of taxa collected in all 66 CHaMP sites in 2014 in the Upper Grande Ronde, Catherine Creek, and the Minam River, where all sites within each basin sampled by both CRITFC and ODFW were considered. There were 11 taxa present in all three basins at 70% frequency, 7 at 80% frequency, and 3 at 90% frequency (Table 20). *Baetis tricaudatus, Micropsectra/Tanytarsus*, and Trombidiformes were the taxa found in greater than 90% of all sites.

When taxa were grouped at the family level, the percentage occurrence in all sites sampled in 2014 across the Upper Grande Ronde, Catherine Creek, and the Minam River were calculated (Table 21). Baetidae and Chironomidae were found in 100% of all sites. Additional families that were found with a frequency greater than 90% included Elmidae, Ephemerellidae, Heptageniidae, Trombidiformes (order level was lowest OUT), Chloroperlidae, and Perlodidae, among a total of 73 families. There were 25 families that had a frequency of less than 10% among the 73 total families.

Taxa richness for EPT taxa tended to follow water temperature. Average values of the total taxa richness, and mayfly, stonefly, and caddisfly richness of all samples taken at each CHaMP station were calculated for samples taken between 2011 and 2014. The mean August water temperature for years 2011-2013 from NorWeST data calculated for these CHaMP sites were placed in 2°C bins from 8 to 10°C, 10 to 12°C, up to 20 to 22°C. Average EPT richness arrayed according to the same temperature bins (Table 22) revealed that maximum mayfly richness occurred in the temperature range 12 to 14°C, while maximum stonefly and caddisfly richness occurred at 10 to 12°C and 8 to 10°C, respectively. From the optimum taxa richness of mayflies, stoneflies, and caddisflies, the average richness for samples taken across all stream sites in 2011-2014 represented a maximum decline of 32.2, 60.9, and 56.7%, respectively (Table 22). This information shows that stonefly and caddisfly richness is about twice as responsive as mayfly richness to a change in temperature from the optimum to 20 to 22°C average August temperature.

Macroinvertebrate taxa from collections made between 2011 and 2014 were sorted by functional feeding group and average densities of these groups were placed into the same temperature bins as for EPT richness (Table 23). Bins were 2°C increments from 8 to 22°C. Highest densities of collector-filterers, collector-gatherers, parasites, predators, scrapers, and shredders were found in the 8-10°C bin. Aside from the 8-10°C bin, the distribution of feeding group densities were very uniform between 10 and 20°C for collector-gatherers, omnivores, predators, scrapers, and shredders. Collector-filterers appeared to be at higher densities at temperatures above 14°C. This is apt to be a function of increasing trends in fine particulate matter suspended in the water column with distance down the river continuum in each drainage (Vannote et al. 1980). Shredders may have declined at 20-22°C due to lack of leaf litter in lower stream reaches, but this result may only be coincidentally related to river continuum theory.

Total Score in the Eastern Oregon (Grande Ronde) IBI is calculated as the sum of scores for (1) taxa richness, (2) mayfly richness, (3) stonefly richness, (4) caddisfly richness, (5) sensitive taxa, (6) sediment sensitive taxa, (7) modified HBI (Hilsenhoff Biotic Index), (8) % tolerant taxa, (9) % sediment tolerant taxa, and (10) % dominant taxa. Scores assigned to each of these 10 metrics were either 1, 3, or 5. The maximum IBI score (sum of all 10 individual metrics) is 50 and the minimum is 10. Ratings were assigned

categories of Severe impairment (<27), High impairment (27-34), Moderate impairment (35-41), and No impairment (>41) (Hubler (2006).

The range in Total Scores for sites on the Grande Ronde mainstem was 22 to 48.9. Total Scores were significantly related to elevation (y = 0.0303 x + 5.9447, R^2=0.6724) (Figure 68). Temperature sensitive taxa were also significantly related to elevation (m), as shown by the regression y = 0.012 x – 10.993, R^2 = 0.7857 (Figure 69). This relationship was expected because there is a general downstream increase in temperature on the mainstem, although there are many other key habitat factors that vary on this same longitudinal continuum. It is interesting that fine sediment sensitive taxa also declined on this same elevational continuum (y = 0.0086 x – 5.6186, R^2 = 0.7823) (Figure 70). At the same time, the distribution of fine sediment tolerant species is not highly related to our measured indices of fine sediment. Because we expect that fines would increase downstream, it may be that our methods of measuring fines are not adequate to capture the actual environmental status.

The range in Total Scores for sites on the Catherine Creek mainstem, North, South, and Middle Forks was 32 to 50.0. Total Scores were somewhat related to elevation (y = 0.0087 x + 35.212, R^2=0.191) (Figure 71). The lack of a significant trend relative to the Grande Ronde mainstem might be caused by a variety of factors, which will require more exploration. The Total Score has a maximum limit of 50.0; the temperature range in Catherine Creek within the geographic range monitored was less than that for the Upper Grande Ronde mainstem; it is likely that increased percentage of EPT taxa would not continue to produce an increase in Total Score based on the way that the rating is formed.

One would expect that at higher elevations in the drainages where water temperatures are colder that EPT taxa would comprise a greater percentage of total taxa. This appears to be the case, although the relationship with elevation is not exceptionally strong. The regressions of % EPT taxa/total taxa richness vs elevation for the Grande Ronde mainstem is very similar to that for Catherine Creek and the three forks. Grande Ronde mainstem: y = 0.0002 x + 0.286, R^2 = 0.258, P = 0.018 (Figure 72); Catherine Creek and three forks: y = 0.0002 x + 0.4315, R^2 = 0.245, P = 0.0021, Figure 73).

It would be assumed that the metric % EPT/total taxa would increase with elevation because water temperature would decline with elevation and EPT taxa are more predominant with colder temperatures. However, for the Upper Grande Ronde mainstem, where there is a strong water temperature longitudinal gradient, the effect of water temperature was not pronounced. The regression of % EPT/total taxa (based on 2011-2014 benthic community summaries) against water temperature (NorWeST average 2011-2013) was not strong (y = -0.0029 x + 0.5756, R^2 = 0.0105, P = 0.67, Figure 74).

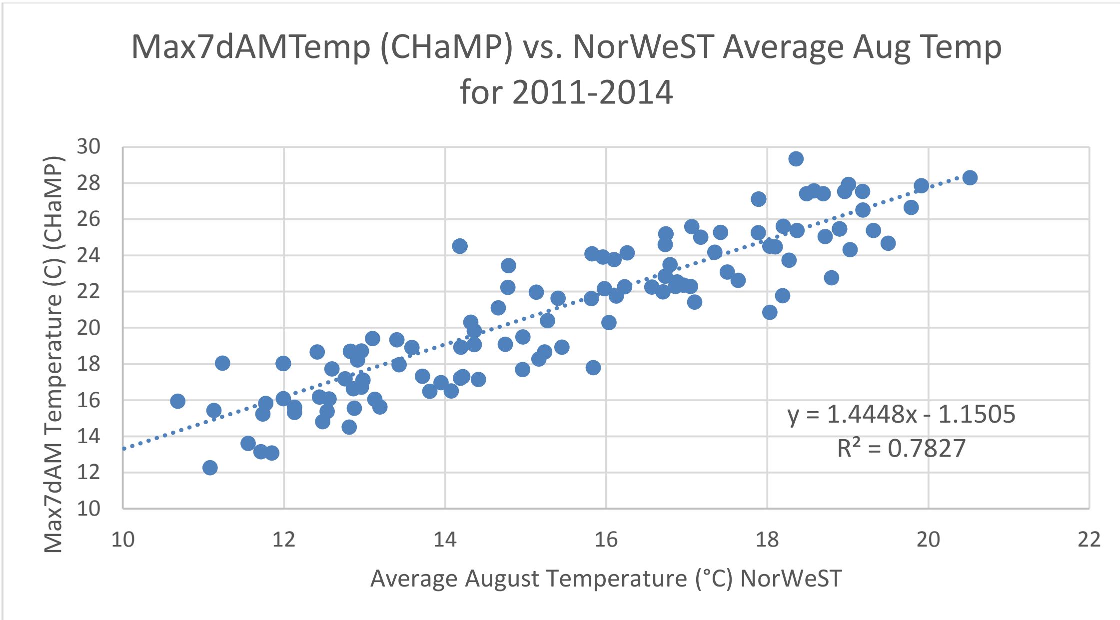

Figure 55. Max7dAM temperatures (2011-2014) regressed against NorWeST average August water temperatures for matching years.

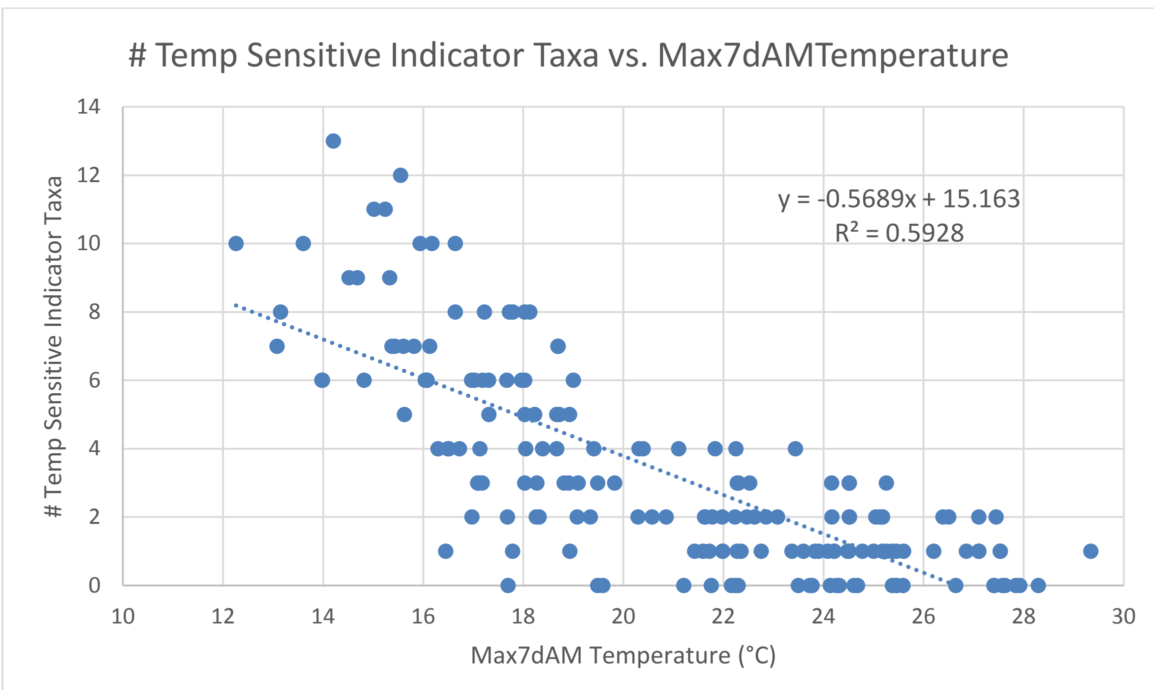

Figure 56. Number of temperature sensitive indicator taxa vs. Max7dAM temperatures.

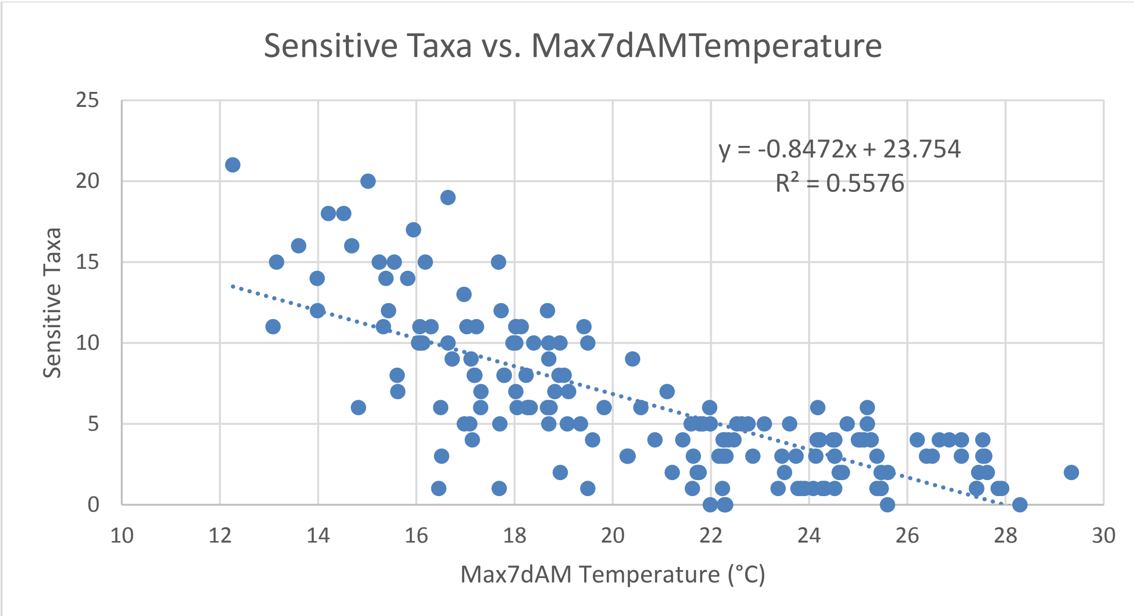

Figure 57. Number of sensitive taxa (Eastern Oregon IBI) regressed against Max7dAM water temperatures.

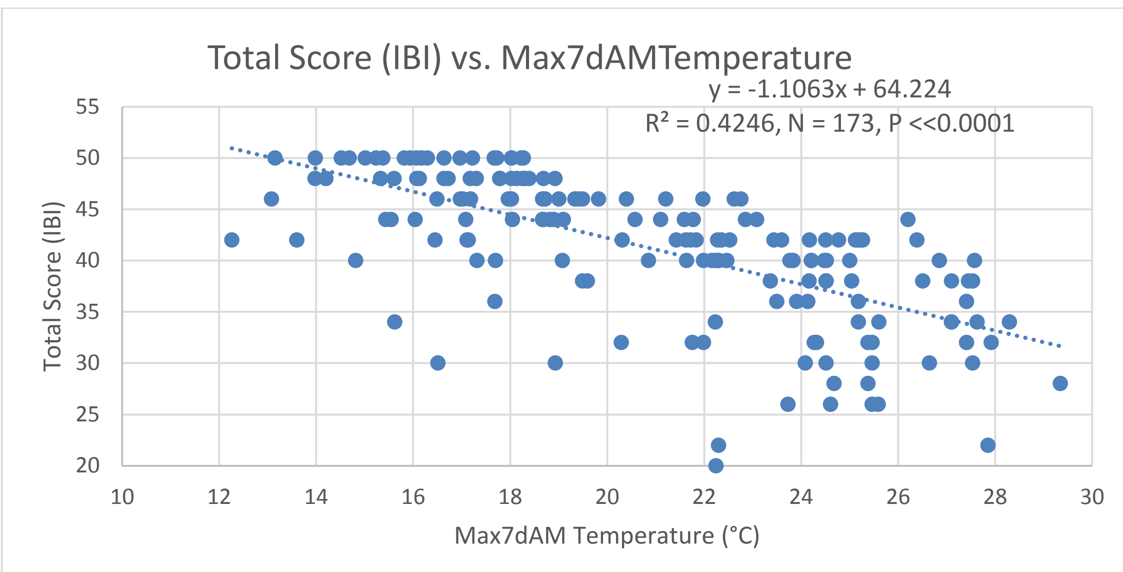

Figure 58. Total score (IBI) vs. Max 7dAM temperatures.

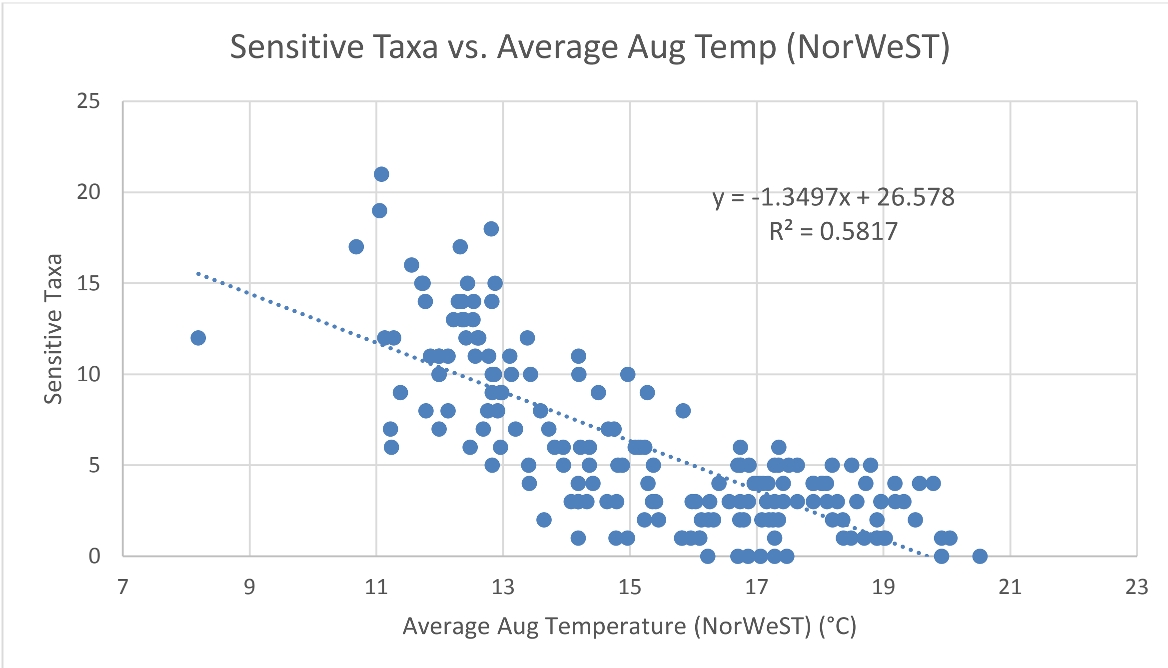

Figure 59. Number of sensitive taxa (Eastern Oregon IBI) regressed against NorWeST average August water temperatures for matching years.

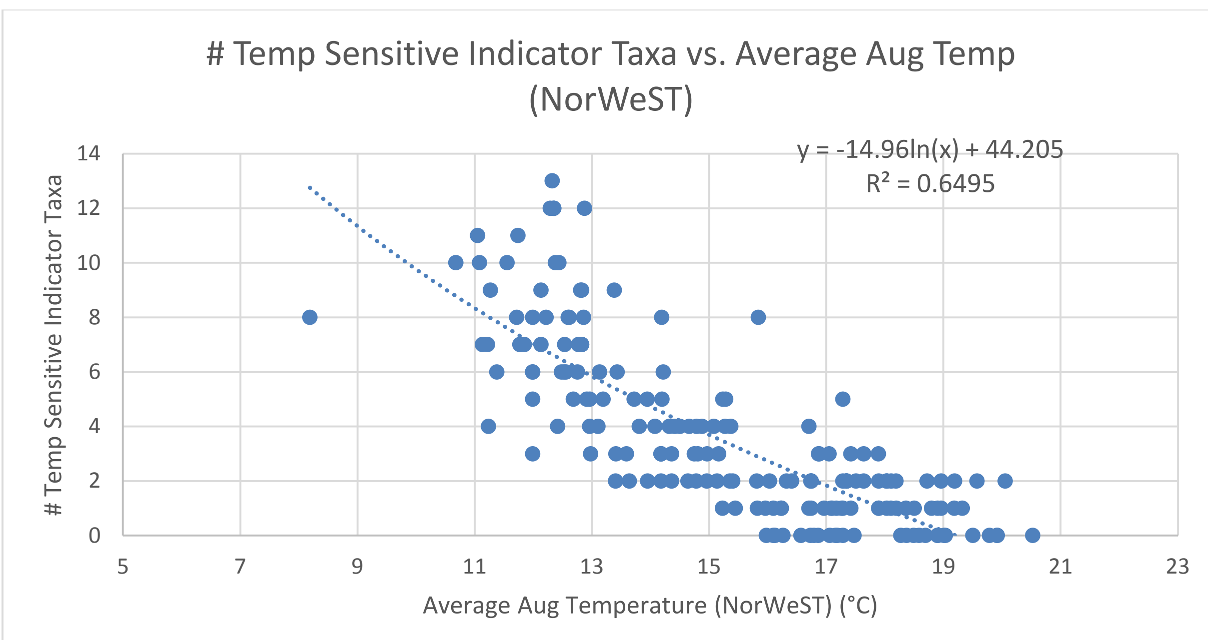

Figure 60. Number of temperature sensitive indicator taxa (Stress Indicator Taxa) regressed against NorWeST average August water temperatures for matching years.

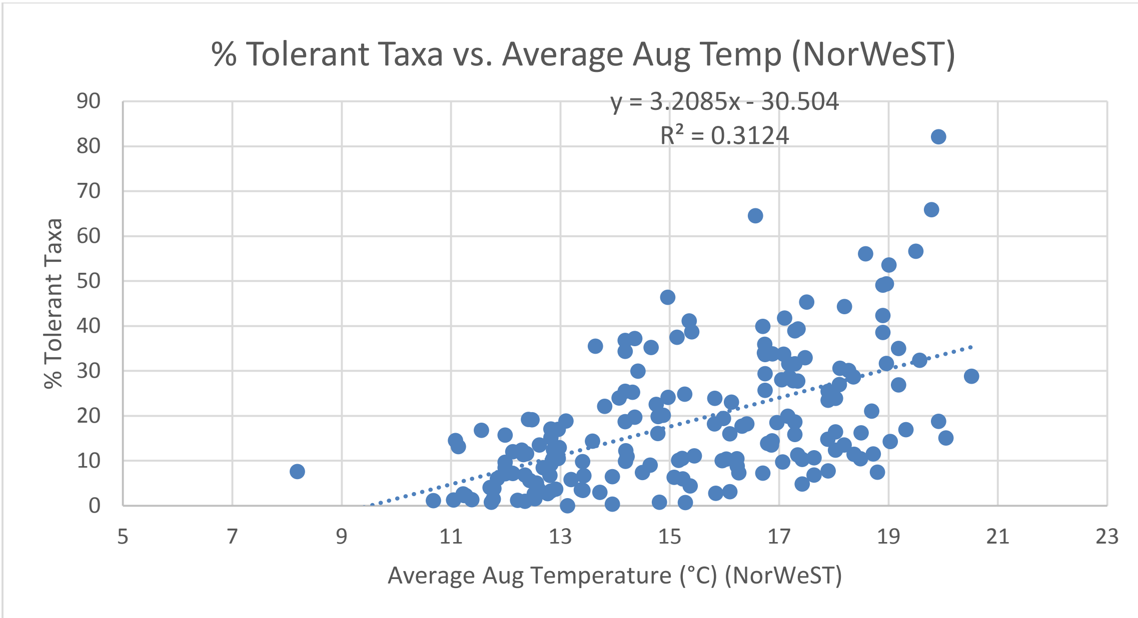

Figure 61. Percentage tolerant taxa (Eastern Oregon IBI) regressed against NorWeST average August water temperatures for matching years.

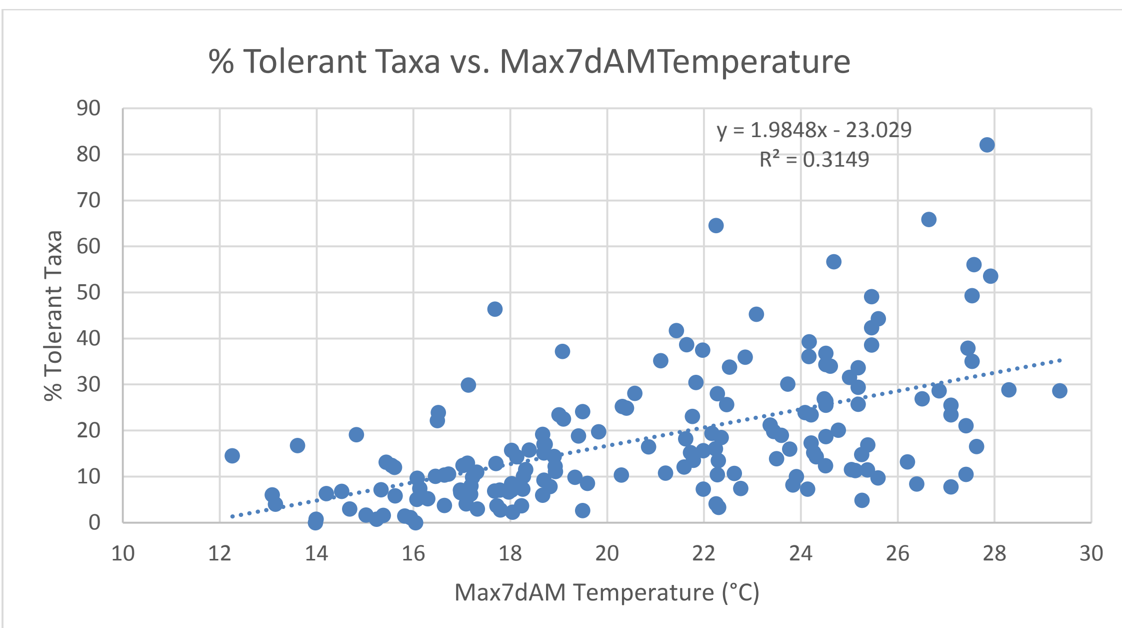

Figure 62. Percentage tolerant taxa (Eastern Oregon IBI) regressed against Max7dAM water temperatures.

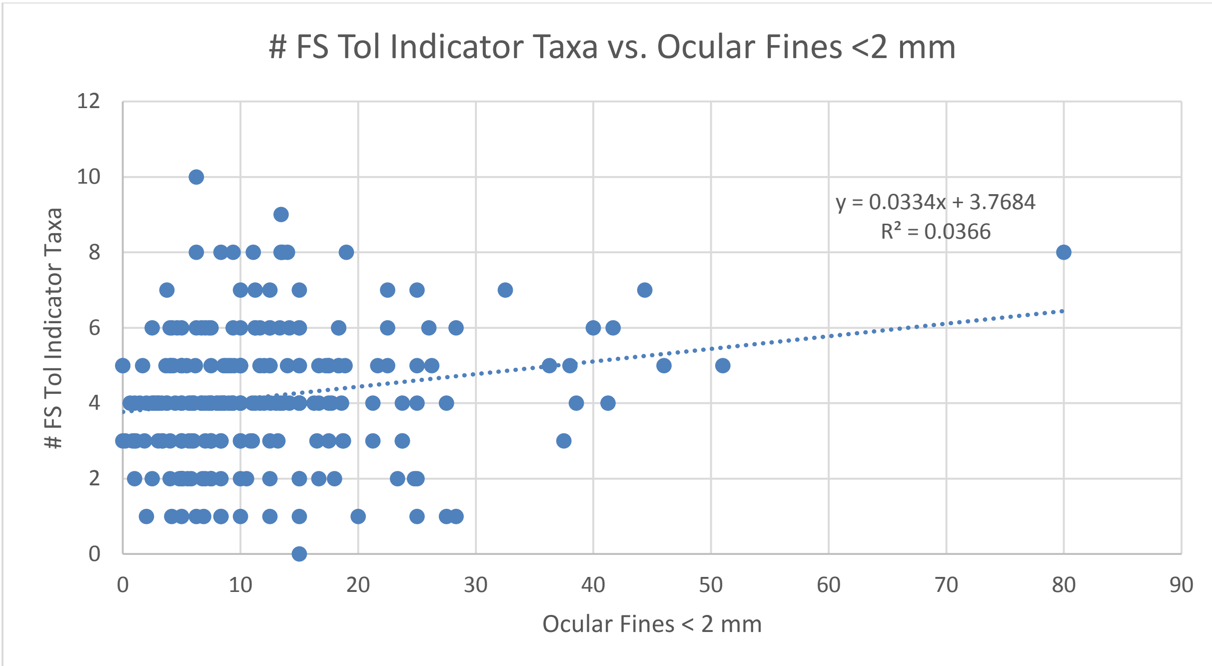

Figure 63. Number of fine sediment tolerant indicator taxa vs. ocular fines (<2 mm) estimated for riffle channel units.

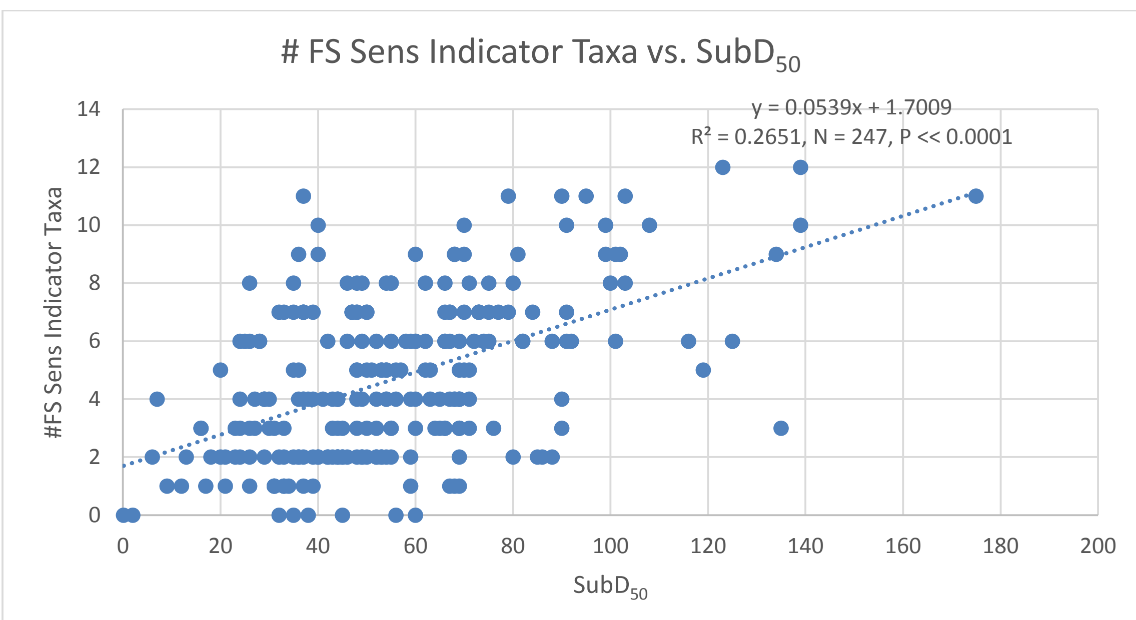

Figure 64. Number of fine sediment sensitive indicator taxa vs. substrate median particle size (D_{50} mm) estimated by Wolman pebble counts for riffle channel units.

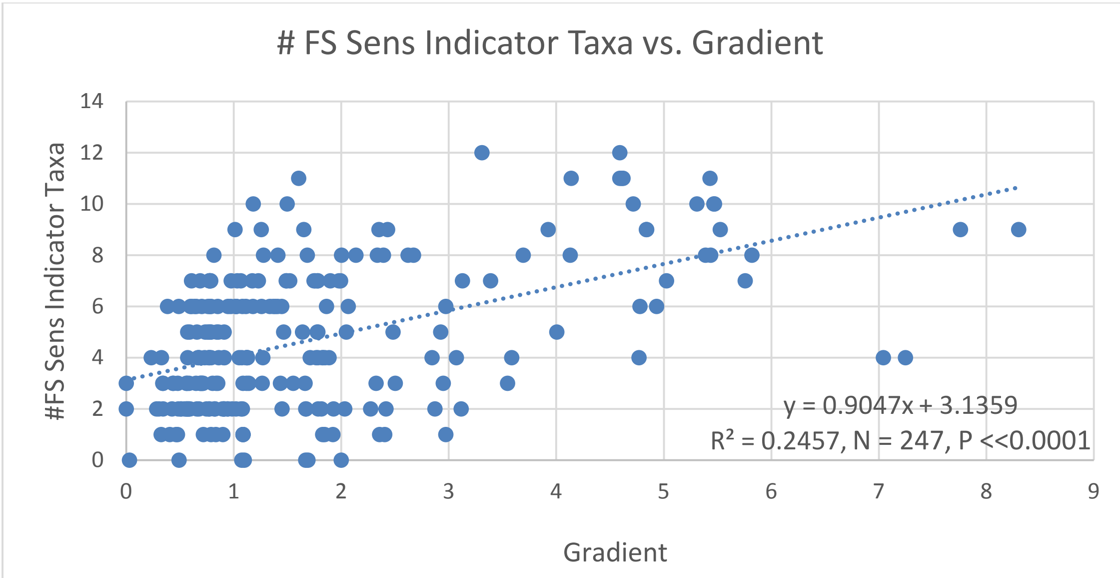

Figure 65. Linear regression of number of fine sediment indicator taxa vs. stream channel gradient.

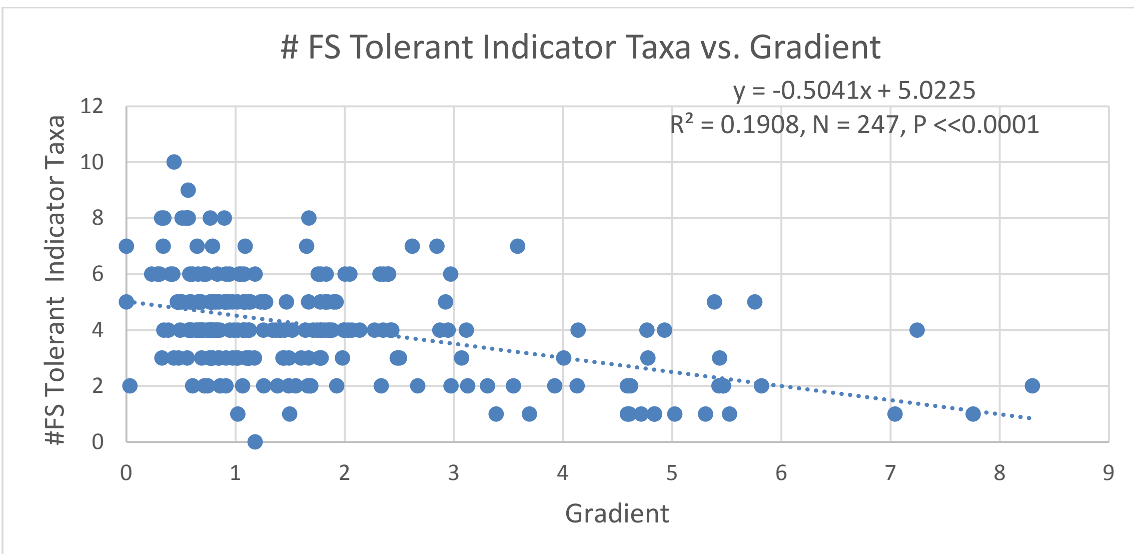

Figure 66. Linear regression of number of fine sediment tolerant indicator taxa vs. stream channel gradient.

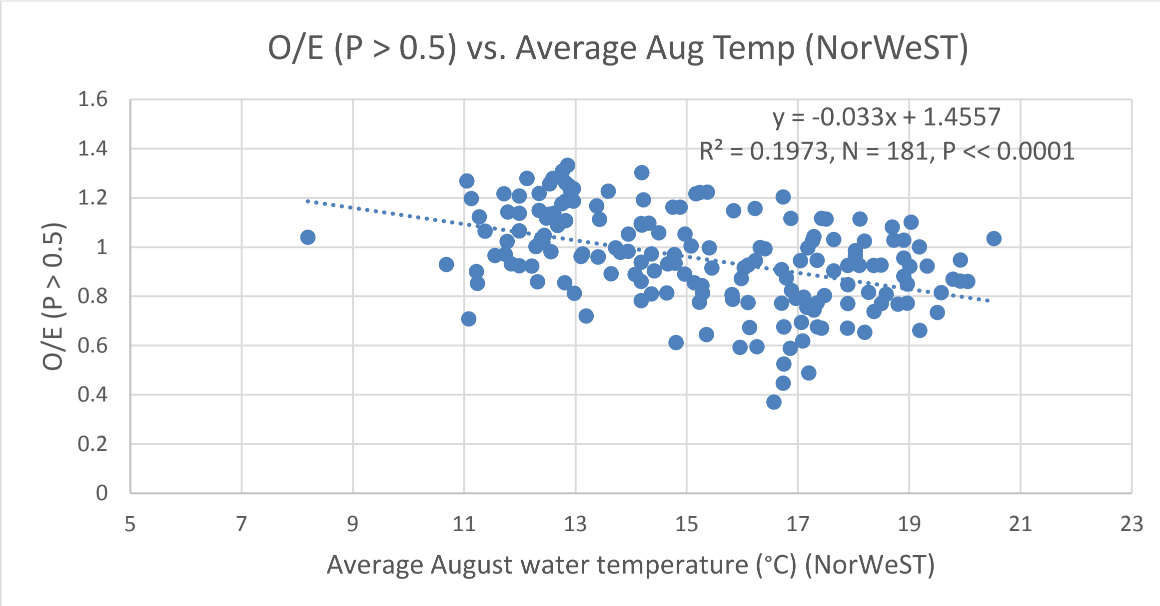

Figure 67. Linear regression of observed to expected ratios (RIVPACS model) with a probability > 0.5 vs. average August water temperature (°C) (NorWeST data).

Table 15. Community metrics for all samples taken from streams in the Upper Grande River, Catherine Creek, and the Minam River (2011-2014).

Stream name	Average of Modified HBI	Average of Modified HBI2	Average of TOTAL SCORE	Average of Whole Sample Dry Mass (mg)2	Average of O/E (P > 0.5)	Average of # Temp Sens Indicator Taxa
Burnt Corral Creek	3.97	4.33	42.3	404.5	0.95	2.83
California Gulch	3.59	5.00	34.0	299.3	1.09	4.00
Catherine Creek	2.73	5.00	43.9	2499.8	1.01	2.95
Chicken Creek	3.34	5.00	42.0	357.1	1.09	5.00
Clark Creek	3.43	4.71	39.1	2123.3	0.97	2.43
Dark Canyon Creek	3.88	5.00	42.0	685.9	0.77	1.00
E Phillips Creek	4.00	3.00	34.0	76.0	0.72	5.00
Fly Creek	3.99	4.09	38.2	5191.4	0.81	1.64
Gordon Creek	3.36	5.00	46.0	697.0	1.17	5.00
Grande Ronde River	3.39	4.55	41.1	1003.0	0.94	2.90
Grande Ronde/Horn Cr	3.70	5.00	38.0	1001.0	1.00	1.00
Limber Jim Creek	4.31	3.00	44.0	1025.2	1.08	6.50
Little Catherine Creek	3.67	4.00	48.0	19912.7	1.14	4.00
Little Indian Creek	2.91	3.00	42.0	349.2	0.92	3.00

Little Minam River	3.03	5.00	49.7	886.8	1.24	5.57
Little Phillips Creek	3.12	5.00	39.0	742.5	0.94	6.00
Little Whiskey	4.89	1.00	26.0	122.8	0.78	1.00
Lookingglass Creek	4.17	3.00	44.0	1158.0	0.85	4.00
McCoy Creek	4.61	3.00	30.5	1402.2	0.69	1.25
Meadow Creek	4.36	2.60	32.0	944.4	0.81	0.40
MF Catherine Creek	1.71	5.00	46.0	1643.2	0.99	10.50
Milk Creek	3.78	5.00	35.0	2542.7	0.89	2.00
Minam River	2.95	5.00	47.3	1032.5	0.88	4.33
NF Catherine Creek	2.20	5.00	48.8	860.7	1.09	9.46
Peet Creek	3.35	5.00	45.0	308.5	0.96	2.50
Phillips Creek	4.81	2.00	31.0	441.3	0.71	4.00
Rock Creek	4.81	1.67	29.7	967.5	0.83	0.50
SF Catherine Creek	2.56	5.00	45.9	811.8	1.02	9.50
Sheep Creek	3.93	4.50	45.5	1404.7	1.10	4.67
Spring Creek	3.53	3.50	35.3	299.5	0.91	1.38
Summer Creek	3.21	5.00	46.0	358.9	1.04	8.00
W Chicken Creek	3.48	4.25	39.8	282.1	0.94	3.63
Waucup Creek	4.14	3.00	36.0	47.7	0.86	1.00
WF Ladd	6.20	1.00	16.0	515.2	0.85	2.00
Willow Creek	6.54	1.00	22.0	322.5	0.61	0.00

Table 16. EPT community metrics for all samples taken from streams in the Upper Grande River, Catherine Creek, and the Minam River (2011-2014).

Stream name	Average of Taxa Richness	Average of Mayfly Richness	Average of Stonefly Richness	Average of Caddisfly Richness	Average of % Tolerant Taxa	Sum Average EPT	EPT/Taxa Richness
Burnt Corral Creek	48.00	10.83	8.50	6.83	17.56	26.17	54.5%
California Gulch	34.00	10.00	4.00	4.00	5.02	18.00	52.9%
Catherine Creek	45.63	10.55	7.47	7.82	17.77	25.84	56.6%
Chicken Creek	45.00	12.00	4.00	9.00	8.44	25.00	55.6%
Clark Creek	42.14	10.00	7.14	5.43	18.66	22.57	53.6%
Dark Canyon Creek	49.00	7.00	7.00	6.00	10.04	20.00	40.8%
E Phillips Creek	28.00	5.00	5.00	6.00	5.84	16.00	57.1%
Fly Creek	45.64	11.82	5.73	6.45	18.22	24.00	52.6%
Gordon Creek	50.00	12.25	7.00	9.50	4.30	28.75	57.5%
Grande Ronde River	48.59	10.41	6.04	8.92	23.66	25.37	52.2%
Grande Ronde/Horn Cr	43.00	9.00	4.00	10.00	35.01	23.00	53.5%
Limber Jim Creek	57.50	11.00	8.50	7.50	13.29	27.00	47.0%
Little Catherine Creek	51.00	11.00	9.00	9.00	9.11	29.00	56.9%

Little Indian Creek	43.00	8.50	6.00	7.50	3.09	22.00	51.2%
Little Minam River	52.71	11.86	9.57	9.86	2.65	31.29	59.3%
Little Phillips Creek	37.00	9.00	5.50	4.50	1.47	19.00	51.4%
Little Whiskey	33.00	7.00	4.00	1.00	10.55	12.00	36.4%
Lookingglass Creek	47.00	9.00	6.00	14.00	2.27	29.00	61.7%
McCoy Creek	42.00	9.25	3.75	3.00	27.18	16.00	38.1%
Meadow Creek	44.52	9.20	3.88	5.16	24.55	18.24	41.0%
MF Catherine Creek	46.00	9.00	11.50	12.00	7.88	32.50	70.7%
Milk Creek	35.50	8.00	3.50	7.50	40.92	19.00	53.5%
Minam River	45.67	10.00	7.33	8.17	4.96	25.50	55.8%
NF Catherine Creek	50.00	11.77	9.62	10.08	3.66	31.46	62.9%
Peet Creek	47.00	11.50	5.00	5.50	8.81	22.00	46.8%
Phillips Creek	31.00	13.50	4.00	4.00	0.74	21.50	69.4%
Rock Creek	41.17	9.00	3.00	4.33	15.38	16.33	39.7%
SF Catherine Creek	46.50	9.93	8.93	10.86	8.04	29.71	63.9%
Sheep Creek	54.17	11.67	8.00	9.92	18.82	29.58	54.6%
Spring Creek	38.13	9.25	4.50	4.88	10.78	18.63	0.49
Summer Creek	46.00	9.00	7.00	13.00	7.59	29.00	63.0%
W Chicken Creek	40.50	10.13	5.88	6.00	20.95	22.00	54.3%
Waucup Creek	45.50	11.50	4.50	4.00	9.33	20.00	44.0%
WF Ladd	31.00	4.00	2.00	3.00	31.63	9.00	29.0%
Willow Creek	41.00	2.50	0.00	2.00	24.89	4.50	11.0%

Table 17. Taxa found to differ by more than 25% (absolute percentage) in frequency of occurrence between upper Grande Ronde sites and all Catherine Creek (Catherine Creek mainstem, NF Catherine Creek, and SF Catherine Creek) sites.

Taxa that are 25% (abs. diff.) more sensitive than those in GR based on CC % presence	Taxa that are 25% (abs. diff.) more tolerant in GR based on CC % presence
Arctopsyche	Agapetus
Baetis bicaudatus	Amiocentrus aspilus
Brillia	Atherix
Capniidae	Baetis flavistriga
Caudatella hystrix	Brachycentrus occidentalis
Chloroperlidae	Calineuria californica
Cinygmula	Cardiocladius
Clinocera	Centroptilum
Corynoneura	Cheumatopsyche
Dicranota	Cricotopus (Nostoc.) nostocicola
Dolophilodes	Cricotopus Isocladius

Doroneuria	Diphetor hageni
Drunella coloradensis	Ecdyonurus criddlei
Epeorus deceptivus	Epeorus albertae Gr.
Epeorus grandis Gr.	Ferrissia
Epeorus longimanus	Hydropsyche
Ephemerella excrucians/dorothea	Microtendipes
Ephemerella tibialis	Nanocladius
Eukiefferiella	Nilotanypus
Eukiefferiella claripennis Gr.	Ochrotrichia
Eukiefferiella devonica Gr.	Ophiogomphus
Eukiefferiella gracei Gr.	Optioservus
Glossosoma	Paraleptophlebia
Glutops	Paraleptophlebia bicornuta Gr.
Heterlimnius	Perlidae
Krenosmittia	Petrophila
Lara	Potthastia Gaedii Gr.
Megarcys	Psephenus
Narpus concolor	Pteronarcys californica
Oligochaeta	Rheotanytarsus
Orthocladiinae	Skwala
Orthocladius	Sublettea
Pagastia	Thienemannimyia Gr.
Parapsyche elsis	Tricorythodes
Pericoma/Telmatoscopus	Wormaldia
Polycelis	Zaitzevia
Rheocricotopus	Zaitzevia-adult
Rhyacophila atrata Gr.	
Rhyacophila brunnea/Vemna Gr.	
Rhyacophila hyalinata Gr.	
Stempellinella	
Taeniopterygidae	
Tvetenia bavarica Gr.	
Visoka cataractae	
Zapada	
Zapada cinctipes	
Zapada columbiana	

Table 18. Taxa found to differ by more than 25% (absolute percentage) in frequency of occurrence between upper Grande Ronde sites and all Minam sites (i.e., Minam River and Little Minam).

Taxa that are 25% (abs. diff.) more sensitive than those in GR based on Minam % presence	Taxa that are 25% (abs. diff) more tolerant in GR based on Minam % presence
Arctopsyche	Agapetus
Baetis alius/moqui	Antocha monticola
Brachycentrus americanus	Atherix
Capniidae	Attenella margarita
Caudatella hystrix	Baetis
Chironominae	Brachycentrus occidentalis
Cinygmula	Calineuria californica
Clinocera	Cardiocladius
Dicranota	Centroptilum
Dolophilodes	Cheumatopsyche
Drunella grandis	Cladotanytarsus
Drunella spinifera	Cricotopus (Nostoc.) nostocicola
Epeorus	Cricotopus Isocladius
Epeorus deceptivus	Cryptolabis
Epeorus grandis Gr.	Diphetor hageni
Epeorus longimanus	Drunella grandis/spinifera
Ephemerellidae	Ecdyonurus criddlei
Eukiefferiella	Epeorus albertae Gr.
Eukiefferiella brehmi Gr.	Eukiefferiella pseudomontana Gr.
Eukiefferiella devonica Gr.	Ferrissia
Glossosoma	Heterlimnius-adult
Glutops	Hexatoma
Heleniella	Hydropsyche
Hesperoperla pacifica	Microtendipes
Lara	Nanocladius
Micrasema	Nilotanypus
Narpus concolor	Ochrotrichia
Orthocladiinae	Oligochaeta
Orthocladius	Ophiogomphus
Pagastia	Optioservus
Paraleuctra	Paraleptophlebia
Parametriocnemus	Paraleptophlebia bicornuta Gr.
Perlodidae	Petrophila
Rhyacophila brunnea/Vemna Gr.	Polypedilum
Rhyacophila narvae	Potthastia Gaedii Gr.
Stempellinella	Psephenus
Taeniopterygidae	Pteronarcys californica

Tanytarsini	Skwala
Tvetenia bavarica Gr.	Sublettea
Visoka cataractae	Tricorythodes
Zapada	Wormaldia
	Zaitzevia-adult

Table 19. Taxa found to differ by more than 50% (absolute percentage) in frequency of occurrence among upper Grande Ronde sites, all Catherine Creek (Catherine Creek mainstem, NF Catherine Creek, and SF Catherine Creek) sites, and all Minam sites (i.e., Minam River and Little Minam).

Taxa that are 50% (abs. diff.) more sensitive than those in GR based on CC % presence	Taxa that are 50% (abs. diff.) more tolerant in GR based on CC % presence	Taxa that are 50% (abs. diff.) more sensitive than those in GR based on Minam % presence	Taxa that are 50% (abs. diff) more tolerant in GR based on Minam % presence
Arctopsyche	Brachycentrus occidentalis	Baetis alius/moqui	Antocha monticola
Baetis bicaudatus	Calineuria californica	Brachycentrus americanus	Brachycentrus occidentalis
Capniidae	Cardiocladius	Capniidae	Calineuria californica
Cinygmula	Microtendipes	Cinygmula	Cardiocladius
Dicranota	Ochrotrichia	Clinocera	Drunella grandis/spinifera
Dolophilodes	Paraleptophlebia	Drunella spinifera	Epeorus albertae Gr.
Drunella coloradensis	Petrophila	Epeorus deceptivus	Hydropsyche
Epeorus deceptivus		Epeorus longimanus	Microtendipes
Eukiefferiella claripennis Gr.		Eukiefferiella	Ochrotrichia
Polycelis		Micrasema	Optioservus
Rhyacophila hyalinata Gr.		Narpus concolor	Paraleptophlebia
Zapada columbiana		Orthocladiinae	Petrophila
		Parametriocnemus	Polypedilum
		Tvetenia bavarica Gr.	Pteronarcys californica
			Skwala
			Sublettea

Table 20. Taxonomic constancy among all 66 samples taken from CHaMP sites in 2014 across the Grande Ronde River, Catherine Creek, and the Minam River.

Constancy Among All 66 Samples from CRITFC Sites		
>70%	**>80%**	**>90%**
Antocha monticola	Baetis tricaudatus	Baetis tricaudatus
Baetis tricaudatus	Micropsectra/Tanytarsus	Micropsectra/Tanytarsus
Ephemerella tibialis	Optioservus-adult	Trombidiformes

Micropsectra/Tanytarsus	Orthocladius complex
Optioservus	Simulium
Optioservus-adult	Sweltsa
Orthocladius complex	Trombidiformes
Rhithrogena	Zaitzevia
Simulium	Zaitzevia-adult
Sweltsa	
Trombidiformes	
Zaitzevia	
Zaitzevia-adult	

Table 21. Constancy ranking among macroinvertebrate family groups indicating the percentage presence of any taxon representing each family or higher grouping among all 66 samples taken from CHaMP sites in 2014 across the Grande Ronde River, Catherine Creek, and the Minam River.

Family	Constancy	Family	Constancy
Baetidae	100.0%	Psephenidae	18.2%
Chironomidae	100.0%	Tricorythidae	18.2%
Elmidae	97.0%	Blephariceridae	16.7%
Ephemerellidae	97.0%	Tabanidae	15.2%
Heptageniidae	97.0%	Psychodidae	13.6%
Trombidiformes	97.0%	Pyralidae	13.6%
Chloroperlidae	90.9%	Ostracoda	12.1%
Perlodidae	90.9%	Astacidae	10.6%
Perlidae	87.9%	Hydrophilidae	10.6%
Tipulidae	86.4%	Taeniopterygidae	10.6%
Hydropsychidae	83.3%	Uenoidae	10.6%
Simuliidae	81.8%	Physidae	9.1%
Brachycentridae	80.3%	Dixidae	7.6%
Nemouridae	77.3%	Hydraenidae	7.6%
Oligochaeta	66.7%	Peltoperlidae	7.6%
Glossosomatidae	59.1%	Psychomiidae	7.6%
Philopotamidae	57.6%	Leptoceridae	6.1%
Rhyacophilidae	56.1%	Ephydridae	4.5%
Leptophlebiidae	54.5%	Thaumaleidae	4.5%
Lepidostomatidae	53.0%	Haliplidae	3.0%
Nemata	53.0%	Polycentropodidae	3.0%
Pteronarcyidae	50.0%	Sialidae	3.0%
Ceratopogonidae	47.0%	Staphylinidae	3.0%
Hydroptilidae	45.5%	Coenagrionidae	1.5%

Ameletidae	37.9%	Corixidae	1.5%
Limnephilidae	37.9%	Deuterophlebiidae	1.5%
Athericidae	34.8%	Dolichopodidae	1.5%
Pelecorhynchidae	31.8%	Erpobdellidae	1.5%
Empididae	30.3%	Glossiphoniidae	1.5%
Capniidae	27.3%	Gyrinidae	1.5%
Pisidiidae	24.2%	Hirudinea	1.5%
Leuctridae	22.7%	Lymnaeidae	1.5%
Apataniidae	21.2%	Margaritiferidae	1.5%
Dytiscidae	21.2%	Planorbidae	1.5%
Gomphidae	19.7%	Talitridae	1.5%
Planariidae	19.7%	Valvatidae	1.5%
Ancylidae	18.2%		

Table 22. Overall taxa richness and EPT richness found in all macroinvertebrate samples collected between 2011-2014, distributed into temperature bins (NorWeST) where the sites were characterized by the average water temperature estimated for 2011-2013.

	Average percentage richness of species groups			
Temperature Bins (°C)	Taxa Richness	Mayfly Richness	Stonefly Richness	Caddisfly Richness
8 to 10	46.0	9.0	7.0	13.0
10 to 12	45.4	10.0	9.6	9.9
12 to 14	48.1	10.9	8.0	9.3
14 to 16	42.9	9.6	6.5	6.5
16 to 18	44.2	9.4	5.1	6.2
18 to 20	44.5	9.4	4.6	6.6
20 to 22	35.0	7.4	3.8	5.6
Grand Total	45.1	9.9	6.6	7.6

Table 23. Average density (no./m²) of functional feeding groups found in macroinvertebrate samples collected between 2011-2014, distributed into temperature bins (NorWeST) where the sites were characterized by the average water temperature estimated for 2011-2013.

	Average functional feeding group density (no./m²)								
Temperature Bins (°C)	Collector-Filterer	Collector-Gatherer	Macrophyte Herbivore	Omnivore	Parasite	Piercing Herbivore	Predator	Scraper	Shredder
8 to 10	44.00	207.00	2.00	4.00	16.00	0.00	54.00	125.00	33.00
10 to 12	8.48	65.48	0.16	8.19	3.12	0.07	15.99	43.86	17.51
12 to 14	9.54	62.51	3.18	9.20	4.08	4.07	16.33	34.74	8.91
14 to 16	20.58	54.60	0.46	8.65	4.14	2.08	14.72	31.12	10.53
16 to 18	26.28	60.20	0.13	9.16	7.84	2.90	13.12	24.10	20.04
18 to 20	32.10	67.20	0.06	18.32	9.55	1.33	15.20	25.88	16.56
20 to 22	21.21	47.67	0.00	4.71	11.93	1.11	8.18	46.21	7.45
Grand Total	19.12	61.81	1.19	9.95	5.80	2.66	15.20	31.83	13.64

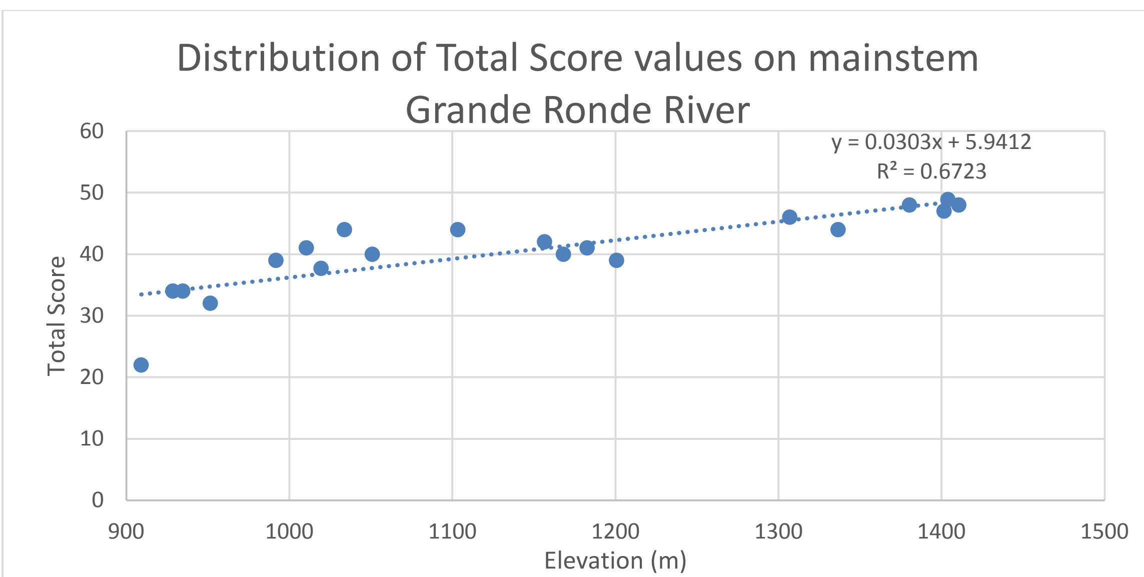

Figure 68. Distribution of Total Score values with elevation (m) on the mainstem Grande Ronde River for benthic macroinvertebrate samples taken during 2011-2014 at a total of 20 sites. Total Scores were averaged by site to account for some sites being annual sites (sampled in all four years) and other sites being rotating panel sites (i.e., sampled in 2011 and 2014, or in 2012, or 2013).

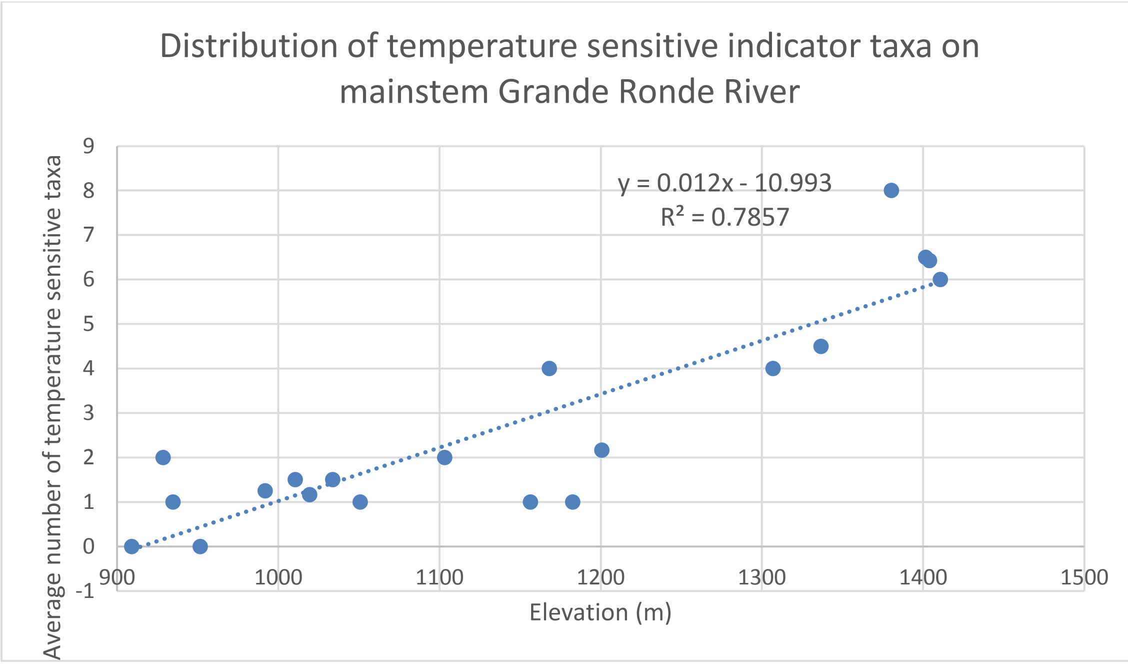

Figure 69. Distribution of average number of temperature sensitive taxa with elevation (m) on the mainstem Grande Ronde River for benthic macroinvertebrate samples taken during 2011-2014. Temperature sensitive taxa numbers were averaged by site to account for some sites being annual sites (sampled in all four years) and other sites being rotating panel sites (i.e., sampled in 2011 and 2014, or in 2012, or 2013).

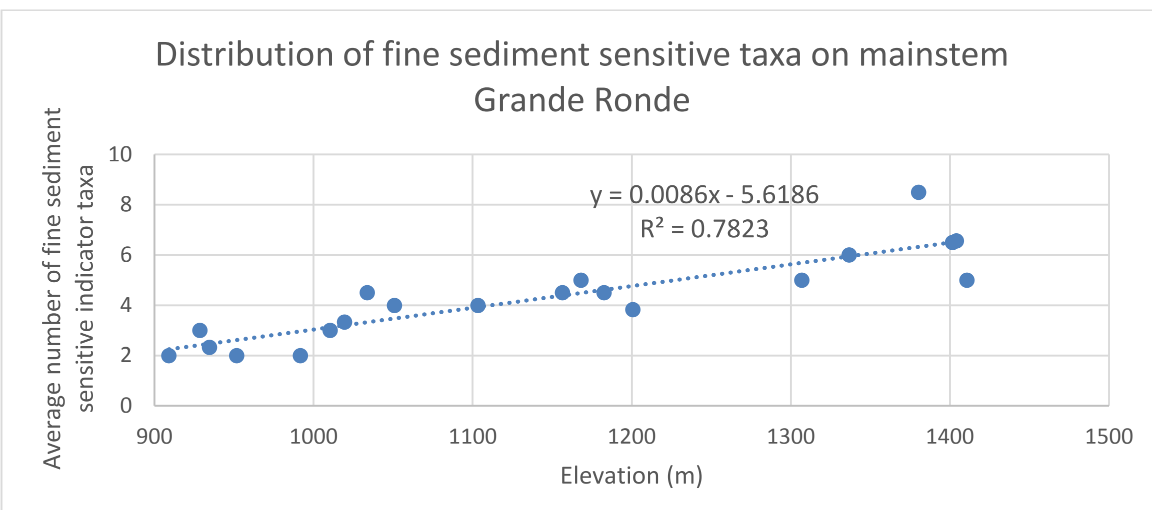

Figure 70. Distribution of fine sediment indicator taxa with elevation (m) on the mainstem Grande Ronde River for benthic macroinvertebrate samples taken during 2011-2014. Fine sediment sensitive taxa numbers were averaged by site to account for some sites being annual sites (sampled in all four years) and other sites being rotating panel sites (i.e., sampled in 2011 and 2014, or in 2012, or 2013).

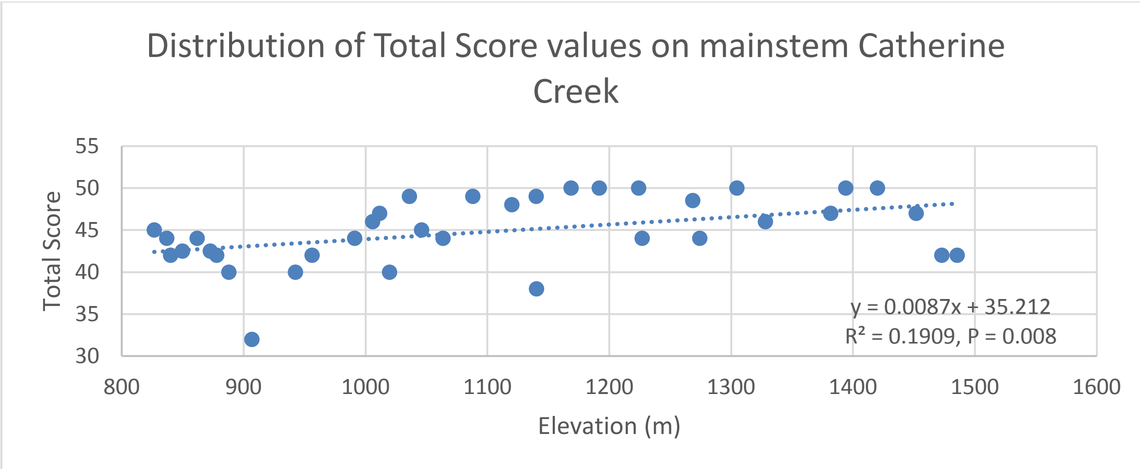

Figure 71. Distribution of Total Score values with elevation (m) on the mainstem Catherine Creek for benthic macroinvertebrate samples taken during 2011-2014.

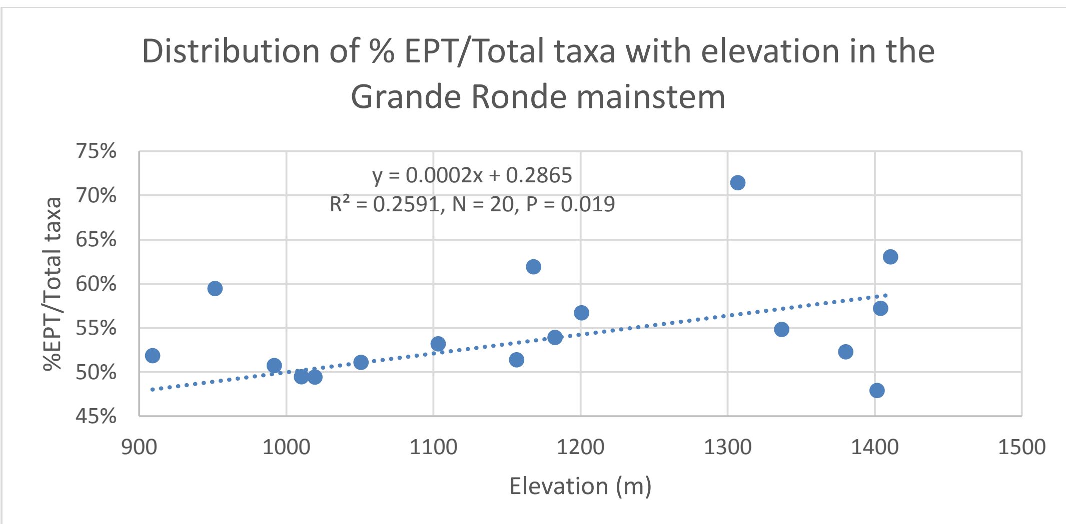

Figure 72. Distribution of % EPT/Total taxa values with elevation (m) on the mainstem Grande Ronde River for benthic macroinvertebrate samples taken during 2011-2014.

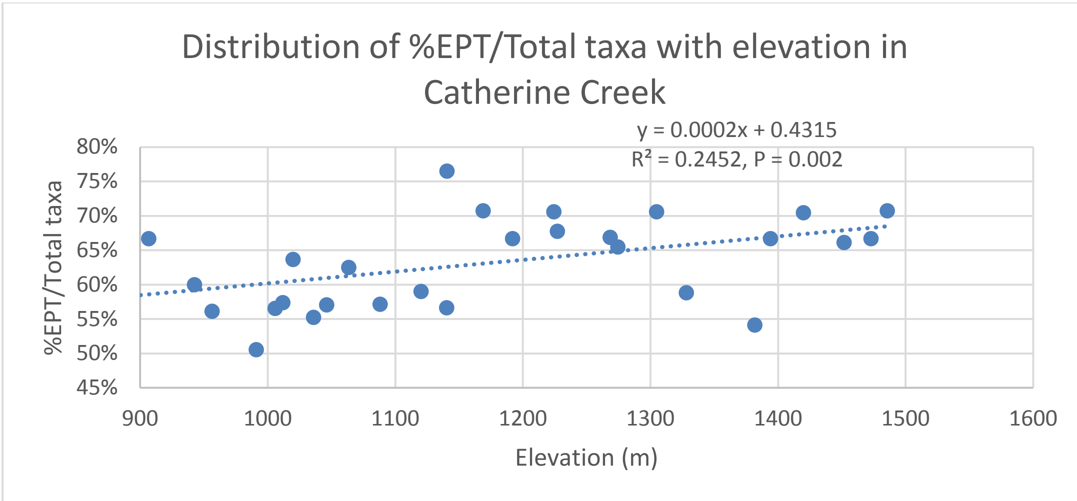

Figure 73. Distribution of % EPT/Total taxa values with elevation (m) on the Catherine Creek (mainstem and forks) for benthic macroinvertebrate samples taken during 2011-2014.

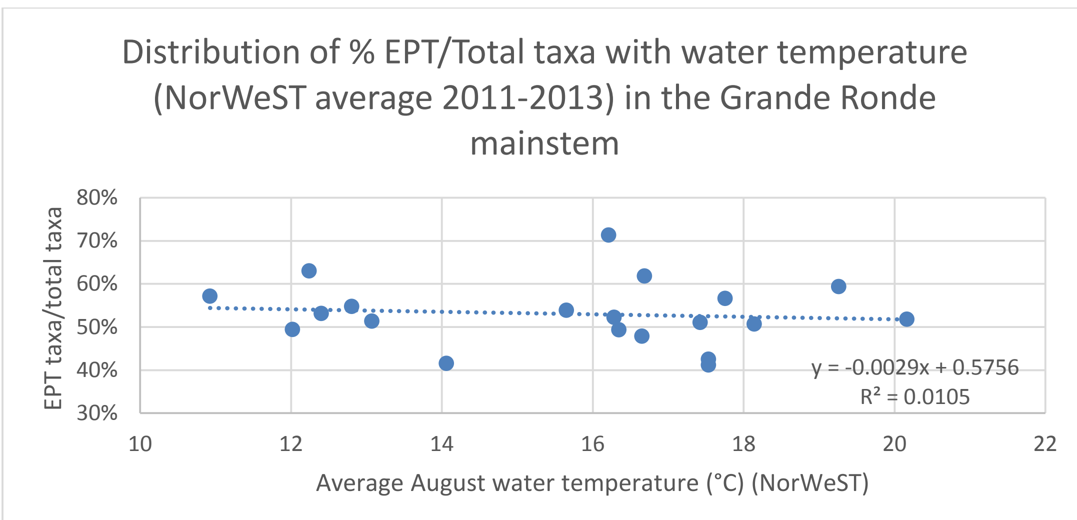

Figure 74. Distribution of % EPT/Total taxa (2011-2014 macroinvertebrate sample summaries) with water temperature (NorWeST, average of 2011-2013 for CHaMP sites) in the Grande Ronde mainstem.

Analysis of water temperature indices and fine sediment indices for benthic communities

The taxa for 2013 benthic samples taken at all CHaMP sites (that also had drift samples taken there) had optimum water temperature data tabulated for many of them (Huff et al. 2006, Cole Ecological, Inc. Excel file stressor coding.xlsx). The optimum water temperature values for as many taxa as data were available for from regional macroinvertebrate studies were weighted by $\log_{10}$ abundance in samples to generate a total water temperature index. This value was plotted against NorWest mean August water temperature data for 2013 (Figure 75). These NorWest water temperature data were developed by

Isaak from CRITFC data collected at those sites. The community optimum water temperature index was the sum of all the weighted values for taxa having optimum indices. The benthic community can be used effectively to indicate the actual water temperature regime experienced at each site where the community was sampled. Standard tabled values of weighted average optimum temperatures (method from Huff et al. 2006) developed in the region appear to give a good indicator of the water temperatures recorded at the sites described by these macroinvertebrate communities. Figure 75 also indicates that, even though all macroinvertebrate taxa are distributed along a river continuum and have a fixed value for optimum that might best be reflected in a limited number of CHaMP sites, the shifts in abundances of other species having different geographic distribution patterns in relation to water temperature create trends in overall community water temperature optimum indices that are accurately reflected in the water temperature regimes of the sites.

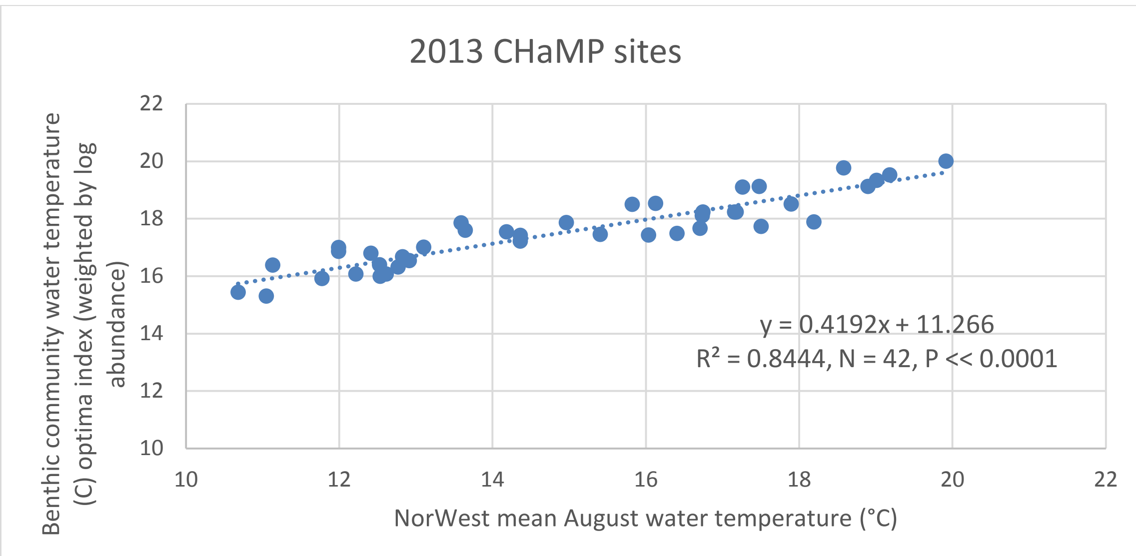

Figure 75. Regression of benthic community water temperature (°C) optimum index for CHaMP sites of 2013 (having matching drift samples) vs. NorWest mean August water temperature (°C at each site.

The benthic community water temperature optimum index (log_{10}-weighted by abundance) was computed for all 2013 benthic samples having matching drift samples. The purpose of this was to confirm the computation of average WA_inv (Temp C) done by Cole Ecological, Inc. The regression of these two indices for all CHaMP sites for samples from 2011-2014 (Figure 76) revealed a very statistically significant level of correspondence (N=173, P<<0.001). The differences that exist may be attributed to the fact that we applied a tabulated optimum temperature value to a taxon only when there was a perfect match to the taxonomic resolution provided in tabled values in Huff et al. (2006). Cole Ecological used temperature optima for all taxa found in the sample, resorting to operational taxonomic units when necessary, using the closest temperature optima values that were available. It is possible that using only the temperature optima for which exact matches existed between the taxonomic resolution

of the sample identification and that for the tabulated optimum values provided a more accurate estimate of actual water temperature regime experienced by the macroinvertebrate communities. It is clear that there is not a 1:1 relationship between the benthic community water temperature index calculated from a partial set of taxa (having exact matches at the resolution level for tabulated values) and that computed by Cole Ecological for all taxa, where tabulated values from closest OUT's were applied. The application of the partial list of taxa tends to generate lower average community temperature tolerance values than does the Cole Ecological method. Regardless, there is a close correspondence between the community optimum temperature metric computed in CRITFC work and the NorWest mean August water temperatures (Figure 75).

The WA_inv (Temp C) computation for the benthic communities of all 2013 CHaMP sites provided by Cole Ecological was based on all taxa present in the samples and this was highly related to the benthic community index (partial community) for optimum water temperature computed by CRITFC. It is unclear why this significant regression was not perfectly 1:1. It is possible that WA_inv (Temp C) was not based on optimum temperature, or the $\log_{10}$ weighting procedure influenced the result. It was determined that this index for all samples from 2011-2014 across the three major study basins was highly related to Max7dAM water temperature (Figure 77). This result provides good confirmation that the known thermal response of a wide range of macroinvertebrates is so consistent across environments that their distribution can be used in a predictive sense to express Max7dAM values. One would conclude that because the Max7dAM values range from 11 to 29°C that small changes in thermal regime would result in substantial changes in benthic community composition that can be linked to shifts in overall benthic community thermal index that spans the same range of water temperatures.

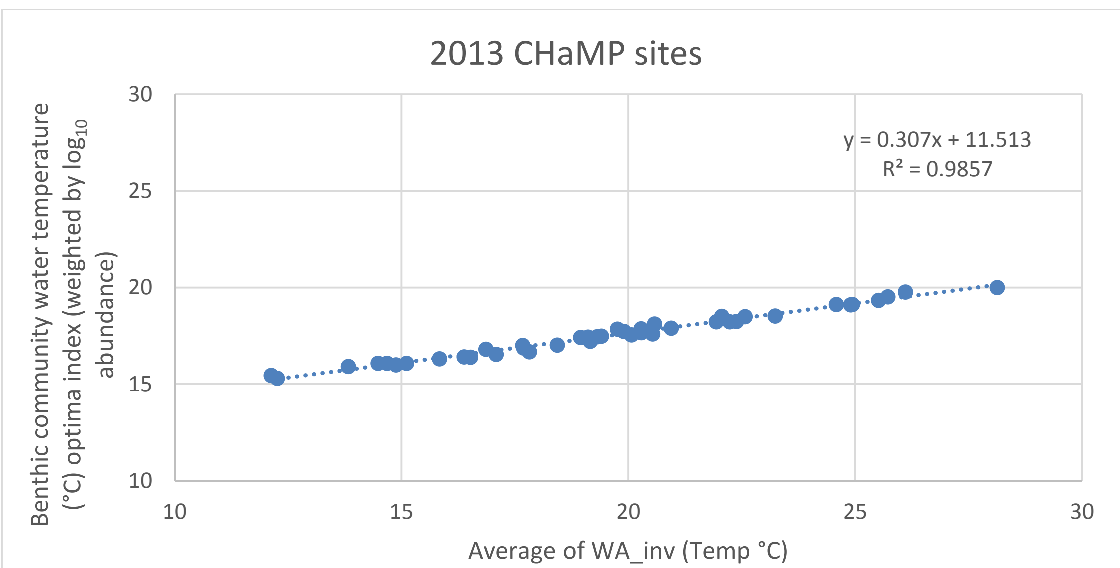

Figure 76. Regression of benthic community water temperature optimum index (weighted by $\log_{10}$ abundance) vs. average of WA_inv (Temp °C) computed by Cole Ecological, Inc.

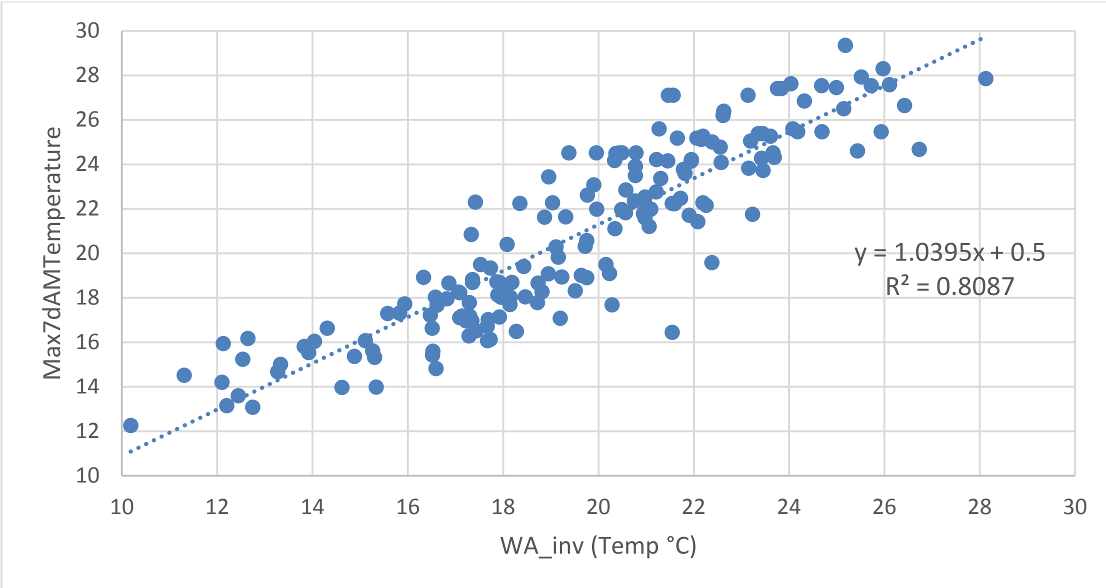

Figure 77. Regression of Max 7dAM temperatures vs. WA_inv (temp C). (see 2011-2014_Summary metrics_dm.xlsx, Tab Ocular <2mm)].

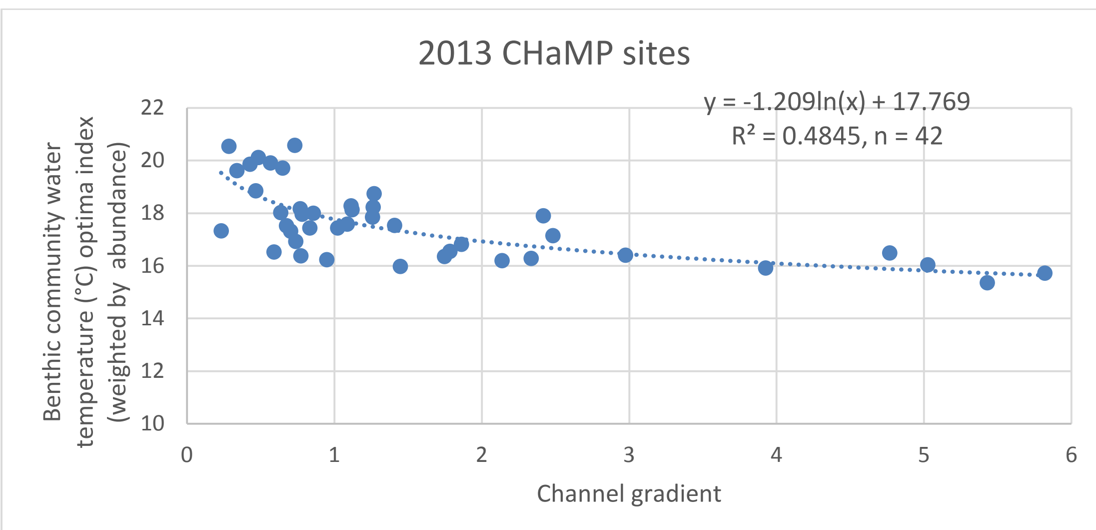

Figure 78. Regression of benthic community water temperature optimum index (weighted by log_{10} abundance) vs. channel gradient of CHaMP sites from 2013 (having matching drift samples).

It is expected that water temperature and channel gradient both generally increase in a downstream direction. This relationship between water temperature and channel gradient is the environmental template that can also be expressed in biological terms as a relationship between the benthic community mean water temperature optimum (which is based on the community composition and is weighted by log_{10} abundance of each taxon) and channel gradient ($y = -1.209 \ln(x) + 17.769$, $R^2 = 0.4845$, N = 42). That is, the community composition expresses definite trends in temperature optima relative to channel gradient and August mean temperatures (Figure 75 and Figure 78).

By using tabulated values of fine sediment upper tolerance values, we computed the community average upper tolerance value for each CHaMP site sampled in 2013 (for which matching drift samples existed). Just as for the water temperature optimum calculations, the community average was derived for only those taxa in each sample that had exact taxonomic identification matches to tabulated values for regional taxa. The regression on channel gradient (Figure 79) indicates a logical correspondence. With increasing gradient, the benthic community upper fine sediment tolerance average declined. It is logical to expect that at higher channel gradients, there would be lower levels of tolerance of fine sediment, given that typically fine sediments (percentage surface area covered) are lower at higher gradients. However, since there is also a correspondence between the community composition and water temperature optima, and water temperatures tend to decrease as gradient increases (i.e., upstream), it is likely that gradient is essentially a surrogate for water temperature.

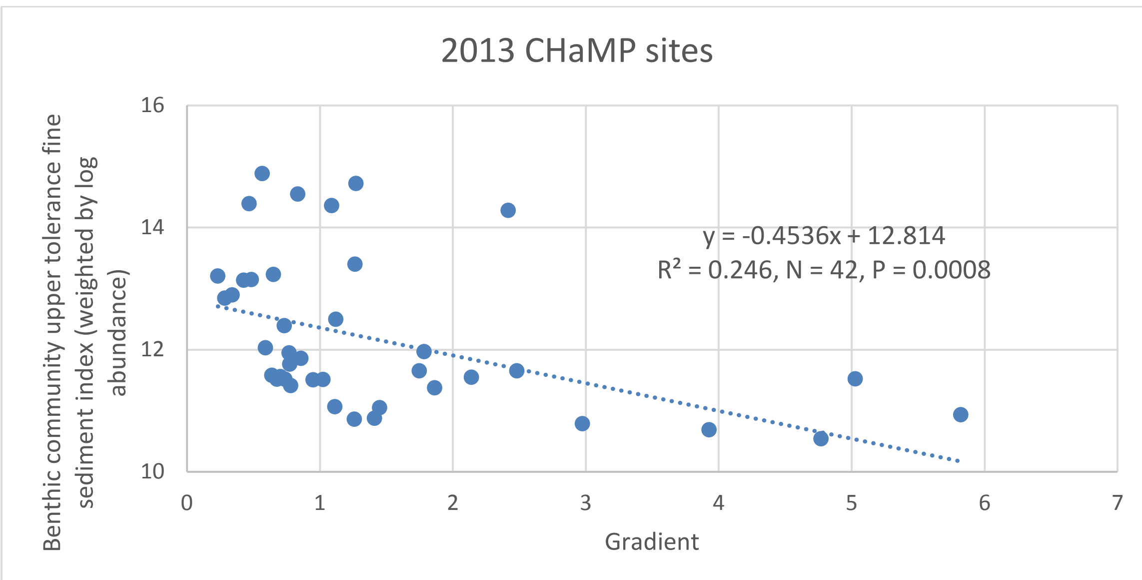

Figure 79. Regression of benthic community upper fine sediment tolerance index (weighted by $\log_{10}$ abundance) vs. channel gradient at 2013 CHaMP sites (having matching drift samples).

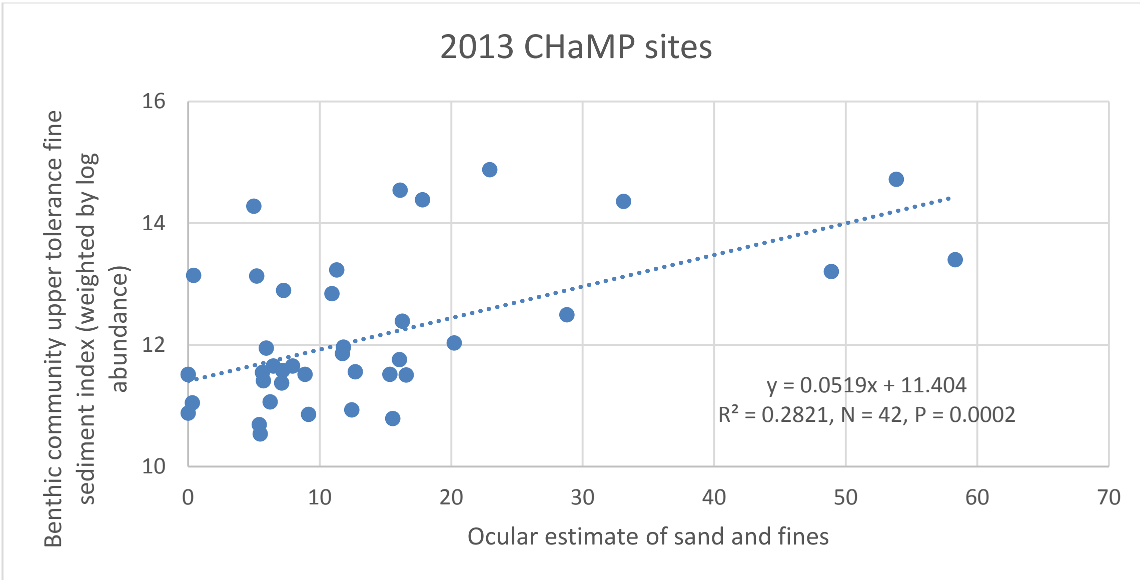

Figure 80. Regression of benthic community upper fine sediment tolerance index (weighted by $\log_{10}$ abundance) vs. ocular estimate of sand and fine sediment percentage.

It is strange that benthic community upper tolerance for fine sediment index (weighted by log10 abundance) is not better related to CHaMP multiple measures of fines or substrate composition. However, the benthic macroinvertebrate fine sediment community index was significantly related to ocular sand and fines percentage (Figure 80) based on the tabulated values for fines (< 0.06 mm, Huff et al. 2006), although the R2 was relatively low. The < 0.06-mm size fraction is silt/clay in the CHaMP program, while the sand category includes particles less than 2 mm diameter. The moderate relationship between the community sediment tolerance value and ocular sand and fines might be due to fines in the Huff et al. (2006) compilation being based on particles less than 0.06 mm diameter. But general methodological difficulties in measuring fines, using Woman pebble counts (i.e., bias against fine sediment), ocular estimates (i.e., qualitative, visually-based method), and pool-tail fines estimated with grid devices (i.e., interference with flocculent algal mats during extreme low flow and in late summer) make this a difficult metric to use consistently.

In the same way that benthic community water temperature index was related to WA_Inv (temp C) (Figure 76), there is a close relationship between benthic community upper fine sediment tolerance index (weighted by log10 abundance) and Untransformed WA_inv (% Fine Sediment) (Figure 81). While the benthic community upper fine sediment tolerance index was based only on those taxa having an exact taxonomic match to tabulated sediment indices for macroinvertebrates from the region (Huff et al. 2006), and the Untrans WA_Inv (% Fine Sediment) index provided by Cole Ecological and calculated using C2 software hosted by Oregon DEQ and originated by Juggins (2003) (see Huff et al. 2006), there is a significant regression. Again, this relationship is not 1:1, but it appears to indicate the same thing. An even stronger regression relationship exists between benthic community optimum sediment index and the Untransformed WA_inv (% Fine Sediment) (Figure 82). It is probably easier in sampling to ascertain

the optimum sediment concentration level than the tolerance level, given the higher abundances associated with the optimum than with the extremes. The tolerance value for each taxon is one standard deviation from the mean, weighted by each taxon's log transformed abundance.

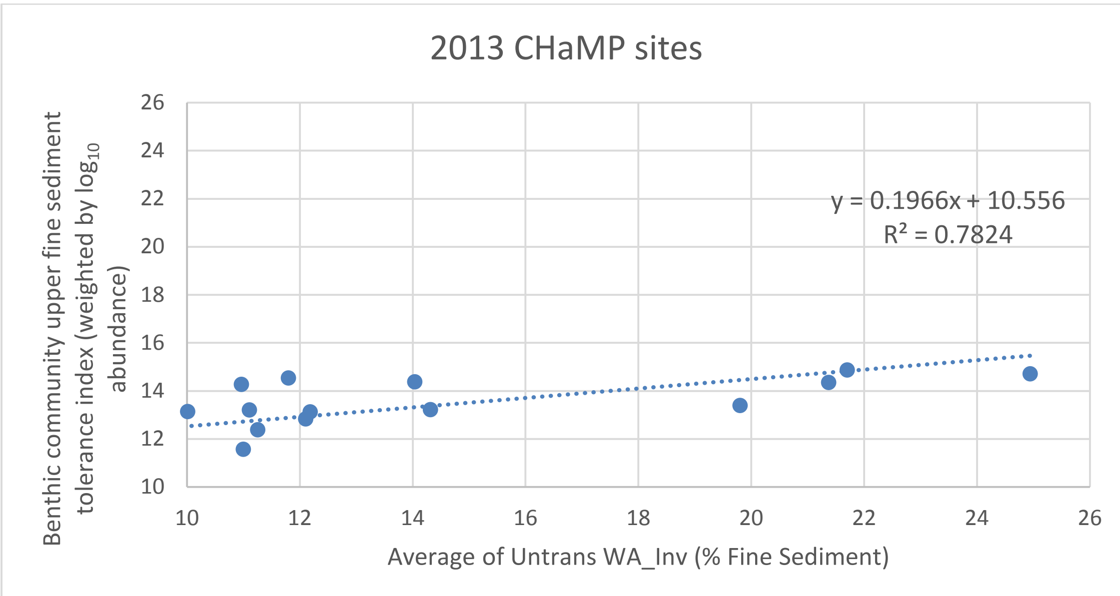

Figure 81. Regression of the benthic community upper fine sediment tolerance index (weighted by log_{10} abundance for partial taxonomic list) vs. average untransformed weighted average inverse percentage fine sediment index computed by Cole Ecological, Inc.

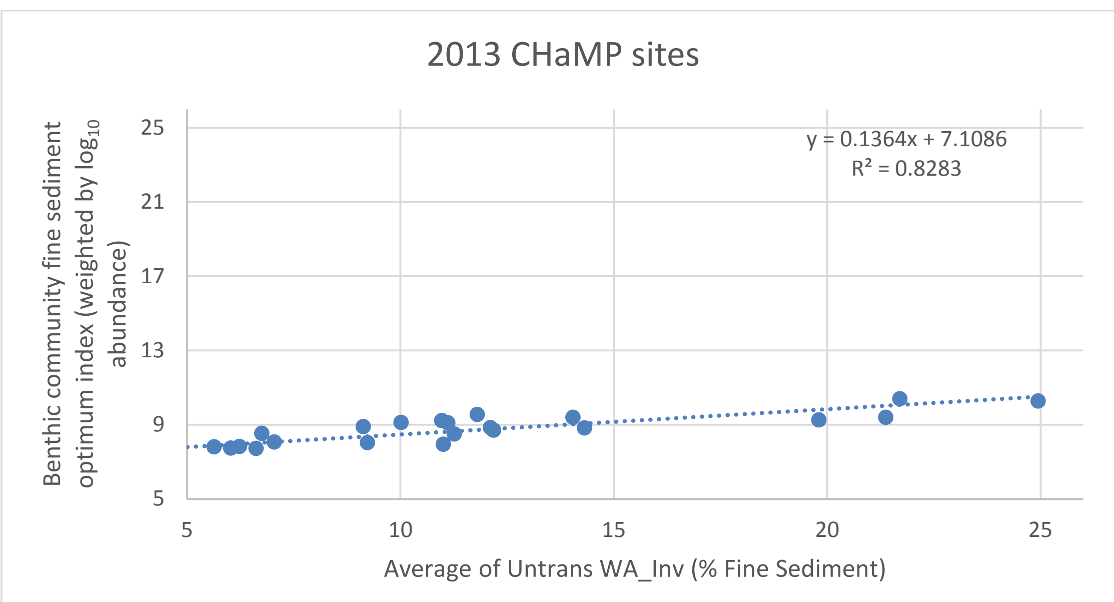

Figure 82. Regression of the benthic community fine sediment optimum index (weighted by log_{10} abundance for partial taxonomic list) vs. average untransformed weighted average inverse percentage fine sediment index computed by Cole Ecological, Inc.

Relationship of individual benthic taxa to environmental conditions

Plotting *Hydropsyche* density (no./m^2) against maximum of the 7-day average of the daily maximum temperature (Max7dAM) reveals a distribution with a maximum density at about 23°C, and a range from about 13 to 29°C (Figure 43).

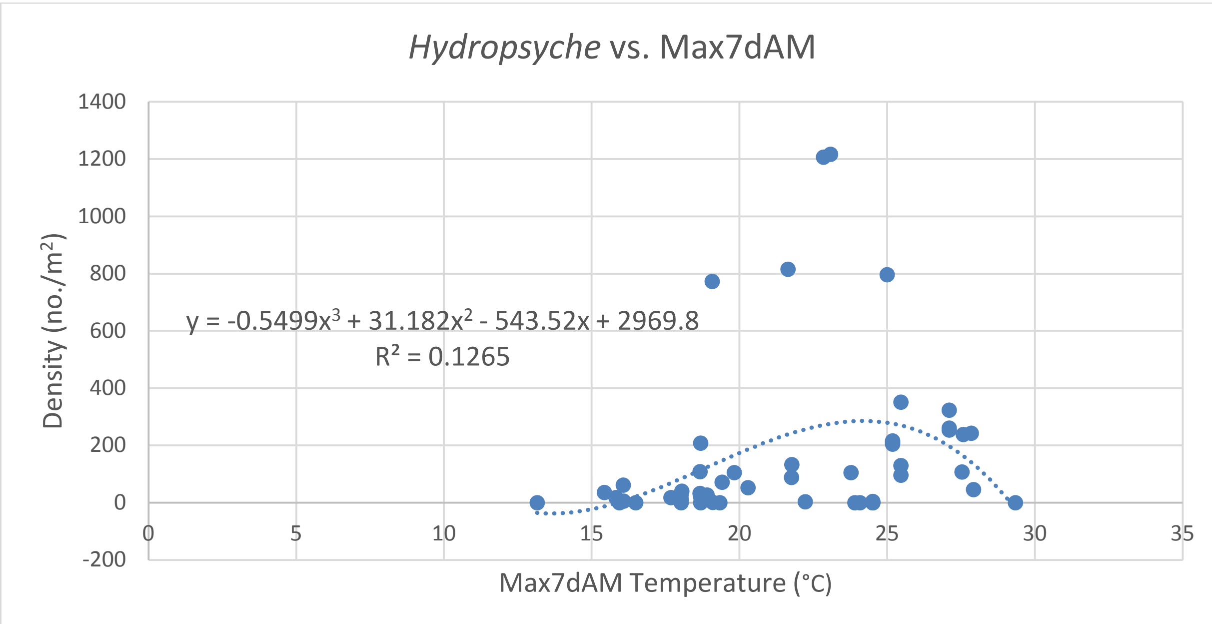

Figure 83. Distribution of *Hydropsyche* against 7-day average of the daily maximum temperature (2013 data).

A similar distribution curve was plotted for Ephemerellidae in which the maximum density occurred at about 19°C (Figure 84). However, the temperature optimum listed by Oregon DEQ for *Ephemerella* was 14.4 °C and an upper tolerance level of 18.1°C. The upper tolerance level seems to correspond most closely to the temperature having the highest density. This relationship needs to be explored in greater detail using 2011-2015 data rather than simply a single year.

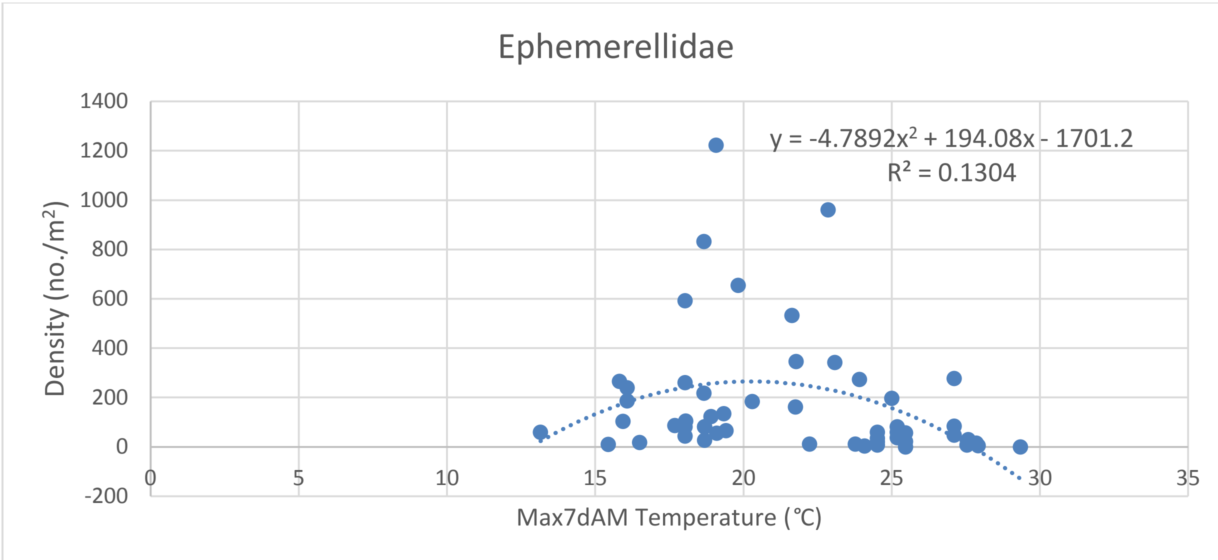

Figure 84. ***Distribution of Ephemerellidae against 7-day average of the daily maximum temperature (2013 data).***

Chloroperlidae had a distribution and optimum very similar to Ephemerellidae (Figure 85).

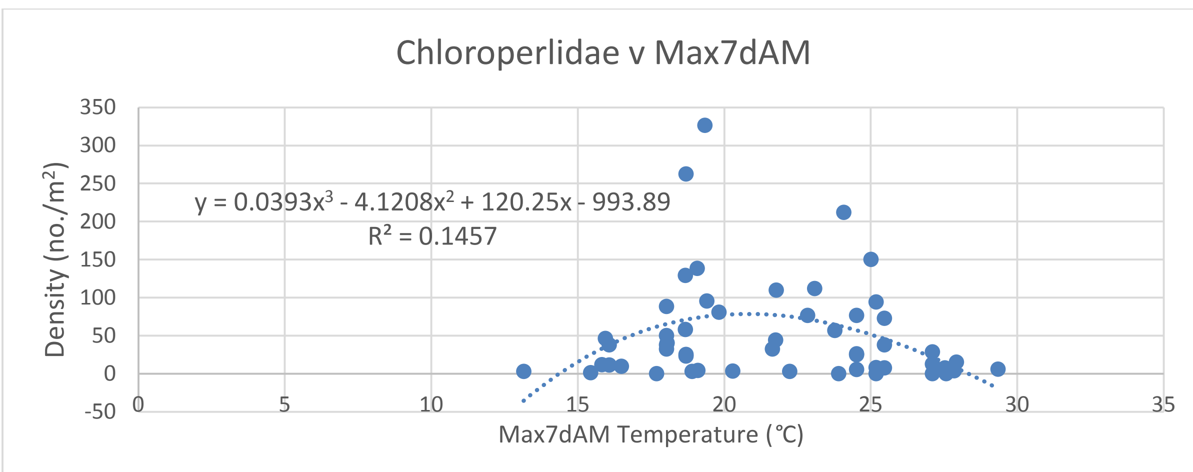

Figure 85. Distribution of Chloroperlidae against 7-day average of the daily maximum temperature (2013 data).

The distribution of Leuctridae with maximum water temperature reveals an optimum that is near 16°C (Figure 86). This species is highly temperature sensitive. The Leuctridae are represented in the ODEQ list of temperature and fine sediment optima by only two genera, *Despaxia* and *Moselia*. These have temperature optima of 14.5 and 13.9 °C, respectively, which seems to be reflected in the geographic distribution of max7DAM values.

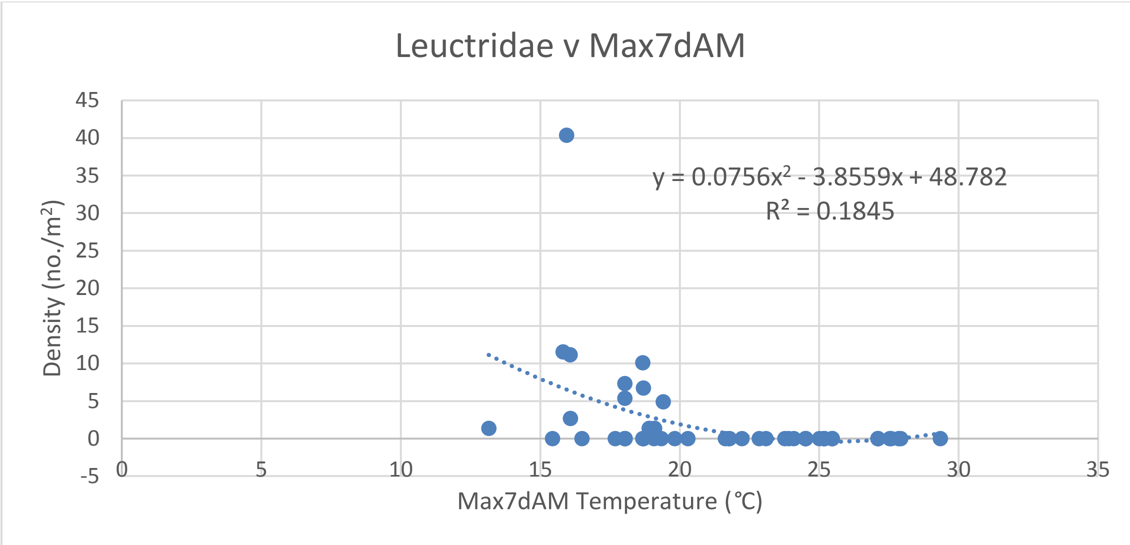

Figure 86. ***Distribution of Leuctridae against 7-day average of the daily maximum temperature (2013 data).***

For each of a number of key taxa (i.e., having significant numbers of individuals found in samples), the average densities by each taxon found in samples having Max7dAM values in various temperature bins were tabulated. An example of this process is shown in Table 24. Temperature bins were in 2.5°C bin increments: 12-14.5°C, 14.5-17°C, up to 27-29.5°C. The taxa selected for illustration were those with plots of density per sample against Max7dAM. In addition, the maximum number of individuals/m^2 found in each temperature bin for all sites surveyed in a year was also compiled, using all samples from 2013 and 2014 (Table 24 and Table 25). This showed a bit more clearly the optimum temperatures for each taxon. This corresponded to what was inferred from plotting all sample densities vs. temperature. The average and maximum taxa densities were also converted to percentage of the total bin averages and maxima to show in a standardized manner the temperature bin corresponding to the optimum.

In 2013, percentage of the average and maximum temperatures revealed an optimum for *Hydropsyche* of 22-24.5°C and 24.5-29.5°C in 2014. For Ephemerellidae the optimum water temperature in 2013 was in the range 17-24.5°C, but appeared to be centered more at 14.5-17°C in 2014. For Chloroperlidae, the optimum appeared to be in the range 17-24.5°C in 2013, but was distributed from 12-27°C relatively uniformly in 2014. Leuctridae was strongly associated with a temperature range of 14.5-17°C in 2013, and 12-17°C in 2014.

Notes: There are a variety of additional things to explore with these data.

Plot the distribution of all families or genera with respect to temperature bins to look for associations structured by water temperature.

Include the influence of gradient or substrate characteristics in riffles in addition to water temperature to assess multiple factors that control macroinvertebrate distribution

Use D_{16} or D_{50} as an index of riffle substrate characteristics since Wolman pebble counts are restricted to riffles, the channel unit in which macroinvertebrates are sampled.

Calculate riffle gradient for CHaMP sites by calculating the elevation difference between BOS and TOS and dividing by the in-stream distance between bottom and top minus the length of slow-water habitat. Because the elevation change due to pool habitat is very small, the gradient based on channel length without pool length would approximate the gradient of the fast water areas. This might provide a better relationship between macroinvertebrate distribution in riffles (1-4% gradient) or rapids (4-8% gradient) and gradient. Preferably, CHaMP database specialists can make water surface gradient available for these calculations.

Table 24. Distribution of selected taxa relative to Max7dAM water temperature bins in 2013.

	Distribution of taxa (average no/m2) relative to temperature (Max7dAM)			
T_bin (°C)	*Hydropsyche*	Ephemerellidae	Chloroperlidae	Leuctridae
12-14.5	0.0	59.2	2.7	1.3
14.5-17	19.8	136.8	19.6	11.0
17-19.5	84.3	250.3	82.1	2.3
19.5-22.0	238.8	375.5	53.9	0.0
22.0-24.5	421.9	266.8	76.6	0.0
24.5-27	182.4	52.1	45.7	0.0
27-29.5	183.9	58.1	9.1	0.0

T_bin (°C)	Distribution of taxa (maximum no/m2) relative to temperature (Max7dAM)			
12-14.5	0.0	59.2	2.7	1.3
14.5-17	61.2	265.3	46.1	40.4
17-19.5	772.7	1222.5	326.3	10.1
19.5-22.0	815.4	653.9	109.6	0.0
22.0-24.5	1217.1	960.2	211.9	0.0
24.5-27	795.8	196.1	149.9	0.0
27-29.5	322.9	276.8	28.5	0.0

T_bin (°C)	Distribution of taxa (% of average no/m2) relative to temperature (Max7dAM)			
	Hydropsyche	Ephemerellidae	Chloroperlidae	Leuctridae
12-14.5	0.00%	4.94%	0.93%	9.20%
14.5-17	1.75%	11.41%	6.76%	74.93%
17-19.5	7.45%	20.88%	28.33%	15.87%
19.5-22.0	21.11%	31.32%	18.62%	0.00%
22.0-24.5	37.30%	22.25%	26.44%	0.00%

24.5-27	16.12%	4.35%	15.77%	0.00%
27-29.5	16.26%	4.85%	3.16%	0.00%

T_bin (°C)	Distribution of taxa (% of maximum no/m2) relative to temperature (Max7dAM)			
12-14.5	0.00%	1.63%	0.31%	2.60%
14.5-17	1.54%	7.30%	5.27%	77.92%
17-19.5	19.39%	33.64%	37.29%	19.48%
19.5-22.0	20.46%	17.99%	12.52%	0.00%
22.0-24.5	30.54%	26.42%	24.22%	0.00%
24.5-27	19.97%	5.40%	17.13%	0.00%
27-29.5	8.10%	7.62%	3.26%	0.00%

Table 25. Distribution of selected taxa relative to Max7dAM water temperatures in 2014.

T_bin (°C)	Distribution of taxa (average no/m2) relative to temperature (Max7dAM)			
	Hydropsyche	Ephemerellidae	Chloroperlidae	Leuctridae
12-14.5	0.00	217.46	88.68	11.57
14.5-17	4.56	295.20	79.26	10.99
17-19.5	13.24	127.93	85.53	3.25
19.5-22.0	73.88	138.84	45.28	0.00
22.0-24.5	97.83	140.51	59.57	0.00
24.5-27	230.29	74.42	44.45	0.00
27-29.5	266.21	3.36	10.81	0.00

T_bin (°C)	Distribution of taxa (maximum no/m2) relative to temperature (Max7dAM)			
12-14.5	0.00	310.49	161.46	31.05
14.5-17	20.18	788.29	191.73	23.07
17-19.5	48.44	403.64	314.84	16.15
19.5-22.0	272.46	259.49	114.37	0.00
22.0-24.5	592.01	383.46	282.55	0.00
24.5-27	699.65	150.69	86.50	0.00
27-29.5	518.01	6.73	20.18	0.00

T_bin (°C)	Distribution of taxa (% of average no/m^2) relative to temperature (Max7dAM)			
	Hydropsyche	Ephemerellidae	Chloroperlidae	Leuctridae
12-14.5	0.00%	21.80%	21.44%	44.83%
14.5-17	0.67%	29.59%	19.16%	42.59%
17-19.5	1.93%	12.82%	20.68%	12.58%

19.5-22.0	10.77%	13.92%	10.95%	0.00%
22.0-24.5	14.26%	14.08%	14.40%	0.00%
24.5-27	33.57%	7.46%	10.75%	0.00%
27-29.5	38.81%	0.34%	2.61%	0.00%

T_bin (°C)	Distribution of taxa (% of maximum no/m^2) relative to temperature (Max7dAM)			
12-14.5	0.00%	13.48%	13.78%	44.19%
14.5-17	0.94%	34.23%	16.36%	32.83%
17-19.5	2.25%	17.53%	26.87%	22.98%
19.5-22.0	12.67%	11.27%	9.76%	0.00%
22.0-24.5	27.53%	16.65%	24.12%	0.00%
24.5-27	32.53%	6.54%	7.38%	0.00%
27-29.5	24.09%	0.29%	1.72%	0.00%

Analysis of Benthic and Drift Samples

Benthic as well as drift samples were collected in each CHaMP site surveyed each year. Benthic samples per site were a composite of 8-1 ft^2 collections using a Hess sampler (500 *u*m) in low to moderate-sized substrate with low to moderate gradient and depths less than about 40 cm. Under other conditions of substrate size, gradient, and depth a dipnet (500 *u*m) was used. Drift samples were collected with two 40-cm wide and 60-cm tall drift nets (500 *u*m mesh). Comparisons of benthic and drift samples were done to address a variety of questions: (1) Can benthic sampling provide useful data for inferring drift composition and abundance, (2) Do some species found in the benthos drift preferentially, while others are rarely found in the drift, (3) Are there species found in the drift that are not found in the benthos, implying that they originated from upstream of the study site, or from channel units other than the riffles sampled for benthos?

In order to display the relationship between taxa in the benthos vs. the drift, taxa identified in benthic and drift samples from 2013 were plotted against one another. These points were distributed in zones created to reveal tendencies to drift. Zone 1 has taxa with a benthic frequency of >30%. Zone 2 has taxa with a benthic frequency of <30% (Figure 87). Zone 1H and Zone 2H have drift frequency that is higher than the upper limit of deviation from the benthic sample frequency. Zone 1L and Zone 2L have drift frequency that is lower than the lower limit of deviation from the benthic sample frequency. The upper and lower limits of deviation from the 1:1 line representing equal frequency of occurrence of benthic and drift taxa were +35% and -35%, respectively, of the benthic frequency.

All points in Figure 75 represent the average frequency of occurrence of benthos and drift taxa based on 42 sites. There are some sites that have zero frequency of occurrence of a taxon in the benthos, but have positive occurrence of the taxon in the drift. Benthic samples were taken in riffles distributed throughout the study reaches, while the drift samples were taken at the upstream end of the study

reach for practical reasons. Drift was collected at the same time that the site was being surveyed. We assumed that the reach entering the study reach had characteristics similar to the study reach and consequently similar benthic community although there are cases where this was probably not accurate. It may also be that a taxon occurred in a clumped distribution and was missed in riffles sampled, or the taxon in the drift originated wholly or largely from channel units other than riffles (e.g., pools) where the benthos was sampled.

Zone 1 benthic taxa have a relatively high frequency of occurrence (i.e., >30% across sites in the Upper Grande Ronde, Catherine Creek, and the Minam River). Among the 42 CHaMP sample sites for 2013, when a taxon occurred in a benthic sample, it was found very seldom at a frequency in drift samples significantly exceeding the benthic frequency (i.e., above the upper limit of deviation in Zone 1). Only *Tanytarsini* and *Narpus concolor* had drift frequencies greatly exceeding the benthic frequencies in Zone 1 (Table 26). Many taxa with benthic frequency >30% had drift in Zone 1L. It is expected that some taxa would drift at a lower rate than they are found in the benthos. However, this would mean that the ability to find certain taxa at a site, even when they generally are found in >30% of all sites can be hard enough that these taxa are not found in the drift at certain sites. Possibly this means that at some sites a given taxon is rare enough by density that the probability of finding it in the drift is low. This argues for assessing the combination of density in sites where the taxon is present as well as frequency of occurrence among sites. A taxon found at most sites in the benthos could always occur at low densities. This could lead to low observation in the drift because drift community composition is based on only 600 individuals (Rhithron) and the occurrence in the drift might be lower than the taxon's relative abundance in the benthos. The frequency of occurrence of macroinvertebrates in the benthos has been based on only 525-550 individuals.

Although we have not computed statistical probabilities of finding taxa that are present in benthic samples when they are collected in benthic samples, this is a task that should be addressed so that we can estimate confidence in benthic community trends. In the 42 benthic samples from 2013, it was determined that there were from 31 to 92 taxa identified per sample. Individual samples were each 1 ft^2 and eight samples were composited to make the composite sample that was sorted and identified for each site. Average number of individuals per taxon per individual Hess sample ranged from 0.64 to 14.8. The minimum number of individuals per taxon per Hess sample ranged from 0.03 to 1.36. Because 8 Hess samples were taken, there would be 8 times this minimum number of individuals collected per taxon as a minimum.

It is interesting that *Baetis tricaudatus*, a species found in all sites in the benthos, was located in Zone 1L (Table 26). That is, it was found in the drift at a frequency >35% less than the benthic frequency. *Zaitzevia* was found in >80% of all benthic samples and was located in Zone 1, indicating that the drift frequency did not deviate significantly from the benthic frequency (note: > 35% deviation was taken as the level for significant deviation). Simuliidae had an 81.8% frequency among all sites and *Simulium* fell into Zone 1. It is, therefore, found in drift at approximately the same rate as the benthos.

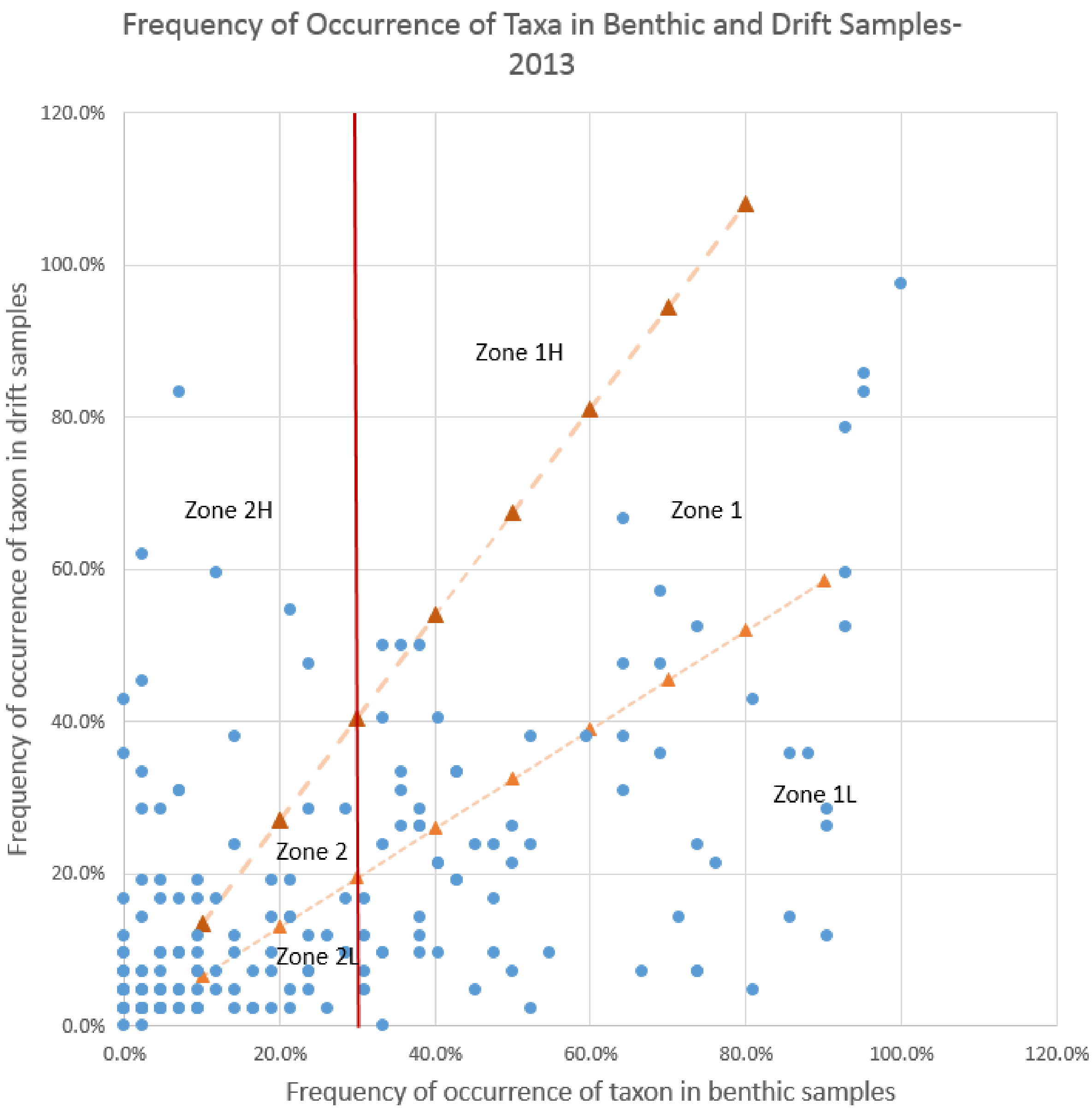

Figure 87. Zonation of frequency of occurrence of taxa in benthic vs. drift samples for all sites surveyed in 2013.

Table 26. Taxa from benthic and drift sampling in 2013 that were found in various zones depicted in Figure 87. Zonation was created to display differences in frequency of taxa in benthos as well as level of deviation from the 1:1 line for benthic vs. drift frequencies.

Zone 1	Zone 1H	Zone 1L	Zone 1L
Epeorus grandis Gr.	Narpus concolor	Amiocentrus aspilus	Lepidostoma
Brachycentrus americanus	Tanytarsini	Acentrella	Micropsectra/Tanytarsus
Cardiocladius		Ameletus	Microtendipes
Caudatella		Antocha monticola	Nemata
Cleptelmis addenda		Arctopsyche grandis	Oligochaeta
Drunella doddsii		Atherix	Pagastia
Drunella grandis/spinifera		Baetis tricaudatus	Paraleptophlebia bicornuta Gr.
Ephemerella tibialis		Brachycentrus occidentalis	Perlidae
Eukiefferiella		Calineuria californica	Perlinodes aurea
Ferrissia		Capniidae	Perlodidae
Heterlimnius		Cheumatopsyche	Petrophila
Hydroptilidae		Cinygmula	Psephenus
Micrasema		Cricotopus (Isocladius)	Pteronarcys
Optioservus		Dicranota	Rheocricotopus
Orthocladiinae		Diphetor hageni	Rheotanytarsus
Polypedilum		Epeorus	Rhithrogena
Potthastia gaedii Gr.		Ephemerella excrucians/dorothea	Rhyacophila
Rhyacophila brunnea Gr.		Eukiefferiella devonica Gr.	Skwala
Simulium		Glossosoma	Sweltsa
Tricorythodes		Glutops	Thienemanniella
Trombidiformes		Hesperoperla pacifica	Thienemannimyia Gr.
Zaitzevia		Hexatoma	Tvetenia
		Hydropsyche	Zapada cinctipes

Zone 2	Zone 2H	Zone 2H
Brundiniella	Boreoheptagyia	Larsia
Apatania	Baetidae	Liodessus
Brychius	Baetis	Lymnaeidae
Ceratopogonidae	Brachycentridae	Nanocladius
Dasyhelea	Brillia	Nemouridae
Dicrotendipes	Chironomini	Neophylax
Dixidae	Chloroperlidae	Ochthebius
Epeorus deceptivus	Corixidae	Onocosmoecus unicolor
Glossosomatidae	Cricotopus	Oreodytes
Helicopsyche	Cryptochia	Ostracoda
Hydropsychidae	Cryptochironomus	Parapsyche
Labrundinia	Diamesinae	Procloeon

Limnophyes	Dolichopodidae	Psychoglypha
Maruina	Drunella coloradensis	Simuliidae
Matriella teresa	Drunella flavilinea	Stictochironomus
Megarcys	Dytiscidae	Suwallia
Meringodixa	Empididae	Timpanoga hecuba
Oecetis	Epeorus longimanus	Tipulidae
Parakiefferiella	Ephemerellidae	Trichoptera
Paratanytarsus	Ephydridae	Zapada columbiana
Parorthocladius	Gerridae	
Pentaneura	Gyraulus	
Phaenopsectra	Heptageniidae	
Psectrocladius	Heterotrissocladius	
Pseudochironomus	Hydraenidae	
Pteronarcella	Hydrobaenus	
Ptychoptera	Hydrophilidae	
Roederiodes	Kogotus/Rickera	
Sialis	Lara	
Tanypodinae		

Zone 2L	**Zone 2L**
Ametor	Limnophila
Ablabesmyia	Malenka
Anagapetus	Neoplasta
Attenella	Nilotanypus
Baetis bicaudatus	Pacifastacus
Baetis flavistriga	Parametriocnemus
Bibiocephala	Parapsyche elsis
Centroptilum	Pisidiidae
Cladotanytarsus	Psychomyia
Coenagrionidae	Sublettea
Corynoneura	Taeniopterygidae
Dicosmoecus gilvipes	Tipula
Dolophilodes	Visoka cataractae
Ecdyonurus criddlei	Wormaldia
Gomphidae	Yoraperla
Hemerodromia	Zapada
Hyalella	Zapada oregonensis Gr.
Limnephilidae	

Table 27.Taxa found exclusively in Catherine Creek in 2013.

Taxon	Catherine Creek or tribuary
Anagapetus	
Baetis bicaudatus	MF, NF, SF
Boreoheptagyia	1 site
Caecidotea	only Ladd Cr.
Chironomini	only Ladd Cr.
Cryptochironomus	only Ladd Cr.
Cultus	1 site
Diamesinae	1 site
Drunella coloradensis	1 site in NF, 1 site in SF
Dytiscidae	only Ladd Cr.
Epeorus grandis Gr.	common, abundant
Ephemerella alleni	
Erpobdellidae	
Eukiefferiella gracei	1 site in MF
Eukiefferiella claripennis Gr.	
Goera	only Milk Cr.
Hydrobaenus	1 site, SF
Helophorus	only Ladd Cr.
Maruina	1 site in CC, 1 site in Milk
Muscidae	only Ladd Cr.
Nemouridae	1 site
Ochthebius	only Ladd Cr.
Paragnetina	2 sites
Paraperla	4 sites
Parapsyche elsis	MF, NF, SF
Parorthocladius	1 site, NF
Pedicia	only Milk Cr.
Protoptila	1 site-main CC
Ptychoptera	only Milk Cr.
Radotanypus	only Ladd Cr. (abundant)
Rhyacophila betteni	
Rhyacophila hyalinata	
Symposiocladius	1 site, NF
Taenionema	1 site-NF (abundant)
Turbellaria	
Wiedemannia	1 site, NF
Zapada columbiana	
Zapada frigida	1 site, MF

Table 28. Taxa found only in the Upper Grande Ronde basin in 2013.

Taxon	Grande Ronde or tributary	Taxon	Grande Ronde or tributary
Agapetus			
Argia	mostly Meadow	Microcylloepus	1 site, Fly
Atrichopogon	1 site, Sheep	Nanocladius	
Attenella	several sites in GR; also Milk	Neophylax	
Baetidae	1 site	Nilotanypus	
Baetis flavistriga		Oecetis	abundant
Brachycentridae	1 site	Onocosmoecus unicolor	1 site, Spring
Brachycera	1 site, Meadow	Ophiogomphus	common
Branchiobdellida	1 site, Fly	Ordobrevia nubifera	common, esp. Meadow
Brundiniella	1 site, Sheep	Oreogeton	1 site, W. Chicken
Centroptilum	common	Parakiefferiella	
Coenagrionidae	only Meadow	Paraleptophlebia bicornuta Gr.	
Cordulegaster	1 site, W. Chicken	Paramerina	
Corduliidae	1 site, W. Chicken	Pentaneura	
Corixidae	1 site, Meadow	Phaenopsectra	
Cryptochia	1 site, Meadow	Plauditus	
Dasyhelea	1 site, Meadow	Potthastia longimana Gr.	1 site, Meadow
Dicosmoecinae		Procloeon	1 site, Meadow
Dicosmoecus gilvipes		Psectrocladius	
Dicrotendipes		Pseudochironomus	1 site, Meadow
Dolichopodidae	2 sites, Meadow	Psychoglypha	1 site, UG mainstem
Ephemerella aurivillii	1 site, W. Chicken	Rhyacophila sibirica	
Helisoma	1 site, Meadow	Sanfilippodytes	1 site, McCoy
Heptageniidae	1 site, Rock	Simuliidae	1 site, Meadow; Simulium common to all
Hesperoconopa		Stempellina	1 site, UG mainstem
Heterocloeon anoka	2 sites	Stictochironomus	1 site, Waucup
Hydrophilidae	1 site, Sheep	Stictotarsus	1 site, McCoy
Hydroptila		Sublettea	
Ochiotrichia		Tabanus	
Leuchotrichia		Taeniopteryx	
Neotrichia		Timpanoga hecuba	
Ironodes		Tvetenia discoloripes Gr.	

Labrundinia	2 sites, Meadow	Unionidae	1 site, Fly
Larsia		Zavrelimyia	1 site, Spring
Leuctridae	1 site, Sheep		
Matriella teresa	1 site, McCoy		
Meringodixa	1 site, Sheep		
Metriocnemus	1 site, Sheep		

There were 19 samples from Catherine Creek, 19 from the Upper Grande Ronde, and 4 from the Minam in 2013 that provided both benthic and drift samples. Given this small a number of samples per basin and only a single year of sampling, the frequency of certain taxa expressed in a chart that encompasses the entire three-basin area would make it appear that taxa relatively confined to one of the basins had a low frequency of occurrence, especially if a unique taxon was found in the Minam, which had limited sampling. Sampling that was done in 2011, 2012, 2014, and 2015 will help assess whether the three basins have some taxa that are confined to one or two basins, or missing from a basin. To the extent that this is true, stating that a taxon is rare in the benthos or drift based on taxa that are confined to a certain basin can be misleading.

A comparison of Catherine Creek with the Upper Grande Ronde from 2013 sampling indicated that there were a variety of taxa that were found in Catherine Creek that were not found in the Upper Grande Ronde, and vice versa (Table 27 and Table 28).

It was interesting that *Baetis bicaudatus* was found in the Middle Fork, North Fork, and South Fork Catherine Creek but not in the Upper Grande Ronde, whereas *B. tricaudatus* was found in both. *B. flavistriga* was found only in the UGR in 2013.

Within the Catherine Creek basin, Ladd Creek contributed several taxa that were unique to samples taken in this basin (Table 27). Also, Milk Creek contributed several taxa not found elsewhere in the Catherine Creek basin or in the UGR. The North Fork, South Fork, and Middle Fork individually each contributed taxa that were unique among the 19 samples taken in Catherine Creek basin in 2013, but the apparent similarity in these tributaries makes it less certain that these community composition differences were related to physical differences among them.

In the UGR, it appeared that unique taxa frequently were found in West Chicken Creek (Table 28). In addition, Meadow Creek and McCoy Creek (tributary to Meadow Creek) were frequent contributors of unique UGR taxa. In some cases, these unique species were a result of the slow velocity, warm water, high filamentous algae growth, and pond-like conditions present in Meadow Creek and McCoy Creek that resulted in dragonfly species and Corixidae. Sheep Creek was also frequently highlighted as a species having unique taxa within the UGR.

Comparison of drift between watersheds on the basis of frequency of occurrence

There were 19 sites sampled in 2013 for benthos and drift in the upper Grande Ronde and Catherine Creek, respectively. The average frequency of occurrence of taxa in the drift was computed for every taxon found in the benthos for these 38 sites. A plot of drift frequencies for all samples having each

taxon revealed that the two basins are different in their frequencies of occurrence of taxa in the drift when they are present in the benthos (Figure 48). There were several taxa that had zero occurrence in CC when found in GR and vice versa (not depicted in Figure 48). For the 50 taxa included in the regression, some had significantly higher frequency in the drift in CC than in GR. The converse also occurred. There were 50 taxa in common in the two basins where they had drift occurring in sites where the taxa were found in the benthos for both CC and GR.

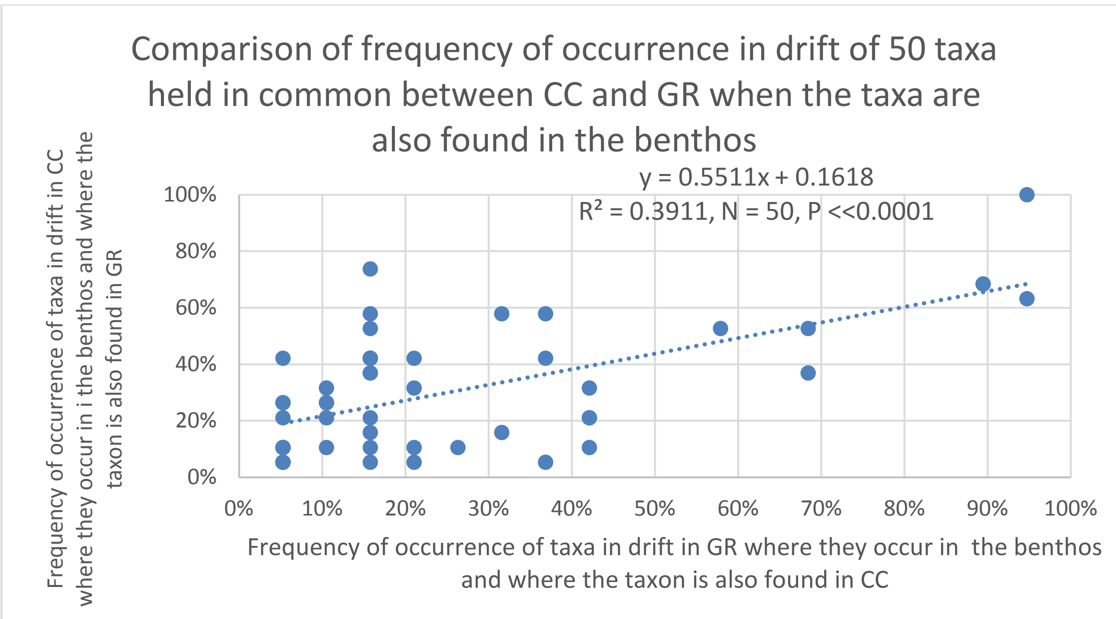

Figure 88. Comparison of frequency of occurrence in the drift of 50 taxa in Catherine Creek and the Upper Grande Ronde River when these taxa are held in common as determined from benthic samples.

Comparison of drift vs. benthos for watersheds on the basis of frequency of occurrence

Taxa that occurred with greater than 30% frequency in the drift in both GR and CC included Trombidiformes, *Zaitzevia*, *Optioservus*, Orthocladiinae, Lepidostoma, *Polypedilium, Antocha monticola*, *Hydropsyche, Eukiefferiella, Simulium,* and *Drunella grandis/spinifera*. Sites having greater than 30% frequency in drift in the GR where they occurred in the benthos that had no presence in CC included Hydroptilidae, *Tricorythodes, Cardiocladius, and Thienemannimyia* Gr.

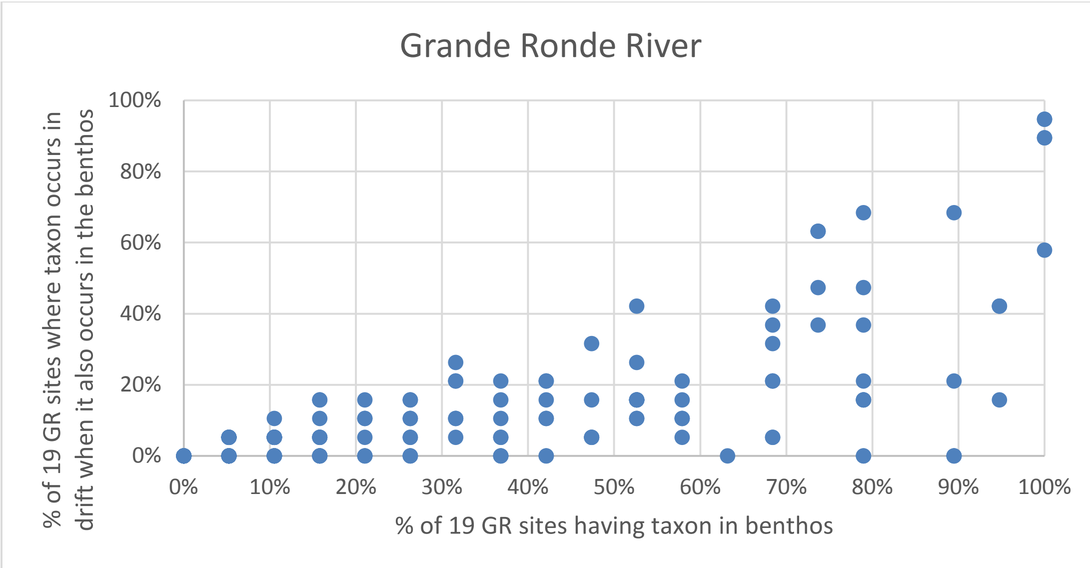

Figure 89. Frequency of occurrence of taxa in the drift in the Upper Grande Ronde River vs. the frequency of occurrence in the benthos based on 19 sites.

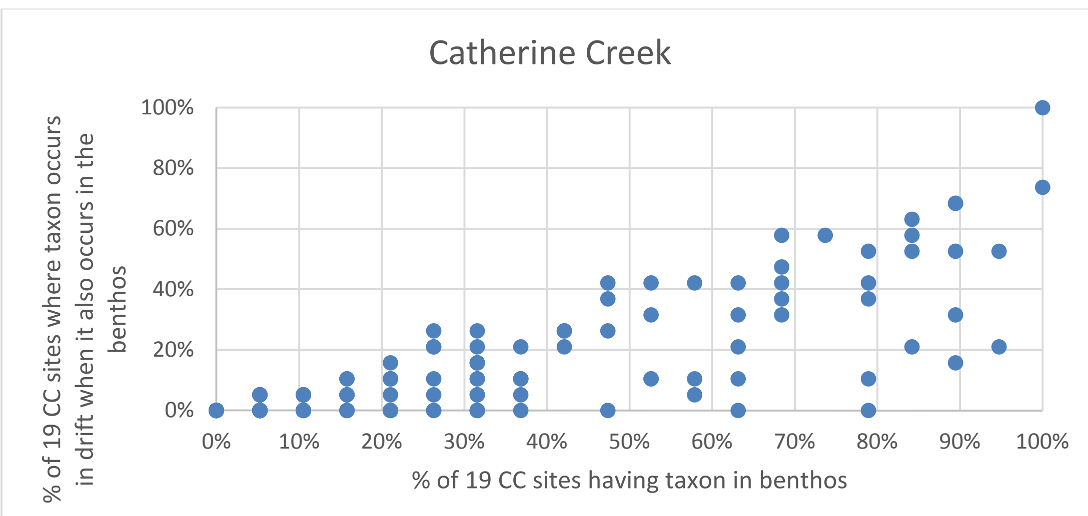

Figure 90. Frequency of occurrence of taxa in the drift in Catherine Creek vs. the frequency of occurrence in the benthos based on 19 sites.

The GR and CC basins were also evaluated independently for occurrence in the drift and the benthos (Figure 49 and Figure 90). The percentage occurrence in the benthos of each taxon was computed for the 19 GR sites and 19 CC sites. There were 101 taxa in the GR and 80 taxa in CC having occurrence in one or more of the 19 sites each. The percentage occurrence in the drift of each taxon was also computed for each taxon having presence in the benthos at each site. Consequently, some sites having the taxon present in the benthos had no presence in the drift. When evaluated for all 19 sites, taxa were

able to have, for example, greater than 0 up to 100% frequency of occurrence in the benthos, but the corresponding percentage occurrence in the drift was always less than or equal to that for the benthos. It was not possible to have a greater percentage presence in the drift because the frequency of occurrence in the drift was computed only for sites having the taxon in the benthos. The highest frequency possible for the drift in this case would be the same frequency as the benthos. These graphs demonstrate that across the range of percentage occurrence in the benthos of taxa from >0 to 100%, there were some taxa that occurred with nearly the same frequency in the drift, considering only taxa having positive occurrence in both drift and benthos in one or more of the 19 sites. There were also some sites that had much smaller presence in drift than in the benthos. For example, a site that has occurrence in 15 of 19 sites for a given taxon in its basin might have drift of that taxon occurring in only 10 of 19 sites. Most likely, when density is low in the benthos, the ability to detect presence in drift will be reduced.

Comparison of relative densities of taxa in the drift vs. benthos

Relative density of *Eukiefferiella* in each of the 42 samples that had matching benthic and drift samples was calculated by dividing the density of *Eukiefferiella* in the benthos or drift by the total density of all taxa in the benthos or drift, respectively, at each site independently. There was a general positive relationship between these values for each sample (Figure 91). However, there were a number of sites in which there was presence of *Eukiefferiella* in the benthos but not the drift. It was also occasionally found in the drift but not the benthos.

The exercise of regressing drift relative densities of a taxon against benthic relative densities indicates that it might be more meaningful to contrast absolute density of taxa in the drift vs. benthos rather than relative densities given that if certain other taxa present in the benthos do not appear in the drift or are highly variable, the relative densities of that taxon in the drift are affected. Only when the total numbers of all other taxa in drift and benthos maintain a consistent relative abundance ratio would it be possible to use relative abundance of a target taxon to compare drift vs. benthos.

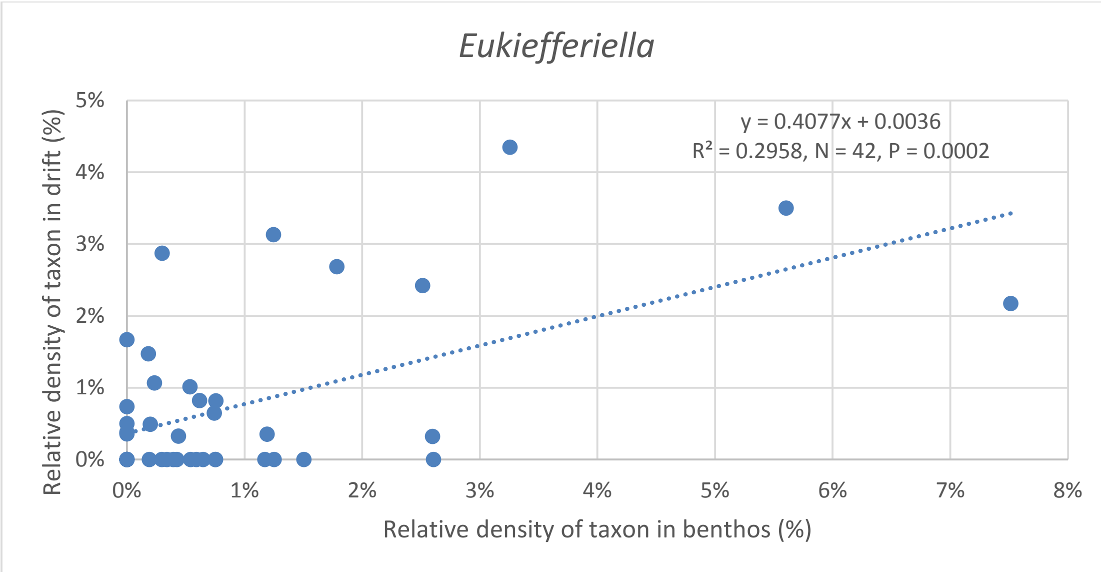

Figure 91. Relative density of *Eukiefferiella* in the drift vs. relative density in the benthos for 42 sites in the GR, CC, and MN in 2013.

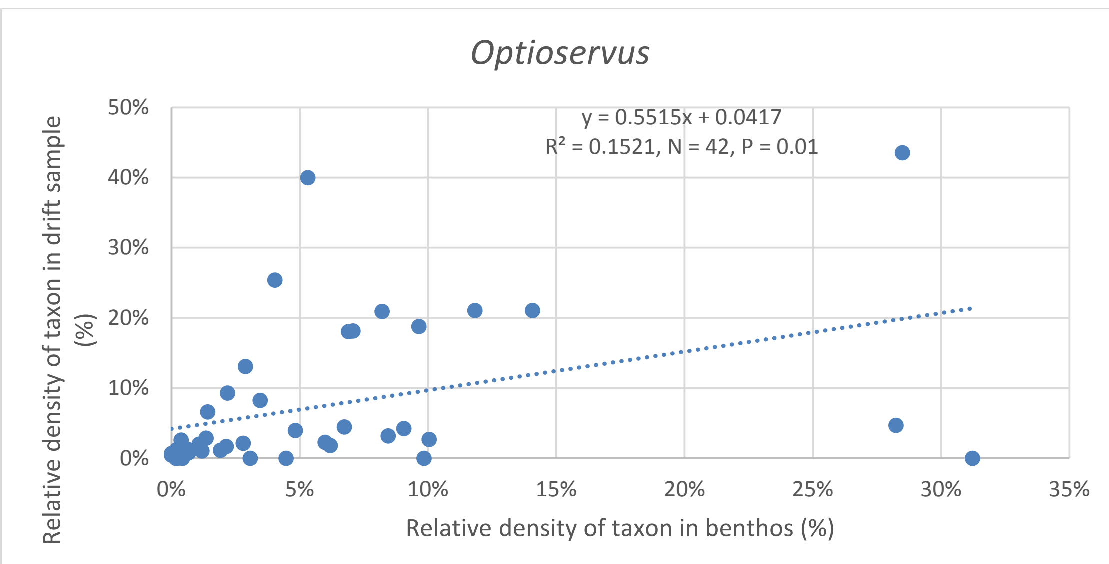

Figure 92. Relative density of *Optioservus* in the drift vs. relative density in the benthos for 42 sites in the GR, CC, and MN.

Optioservus similarly had several sites across the GR, CC, and MN where this taxon comprised up to 32% of the relative density in the benthos, but had no presence in the drift (Figure 92). It is possible that the habitat conditions contributing drift to the upper end of the site were different than the site itself. Also, there were many sites having a higher relative density in the drift than in the benthos, but it appears that there were about as many sites having lower relative density in the drift as higher in the drift vs. the benthos relative densities.

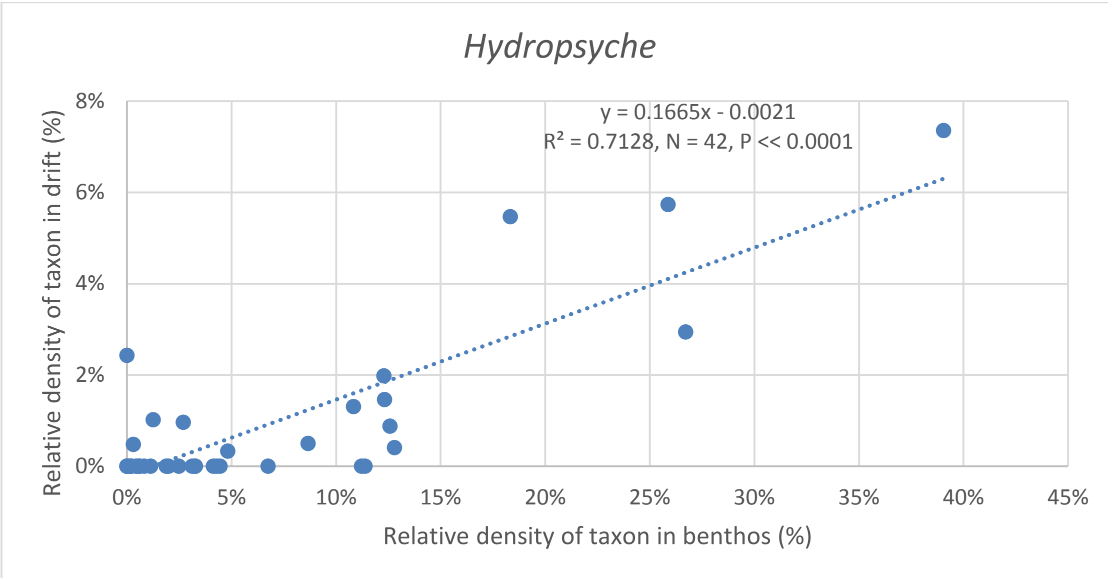

Figure 93. Relative density of *Hydropsyche* in the drift vs. relative density in the benthos for 42 sites in the GR, CC, and MN.

Hydropsyche drift and benthic relative densities revealed a significant regression exists between drift and the benthic community that supports the drift, but one in which the relative density of this taxon in the drift was about 17% of the relative density in the benthos (Figure 45). As relative density in the benthos increases, the relative density in the drift increased.

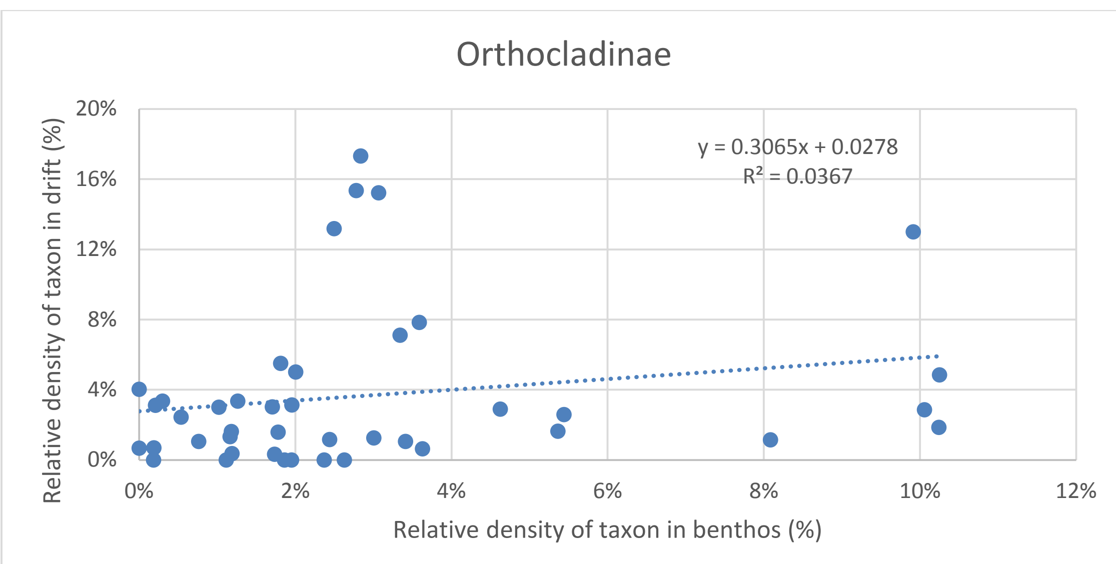

Figure 94. Relative density of Orthocladinae in the drift vs. relative density in the benthos for 42 sites in the GR, CC, and MN.

The slope of the regression of relative density in the drift of Orthocladinae vs. relative density in the benthos indicates that there is a relative density in the drift that is about 28% of that in the benthos (Figure 94). However, because of the scatter of points representing all 42 sites surveyed, there are many sites in which the relative density in the drift was up to about 6 times greater than the benthos.

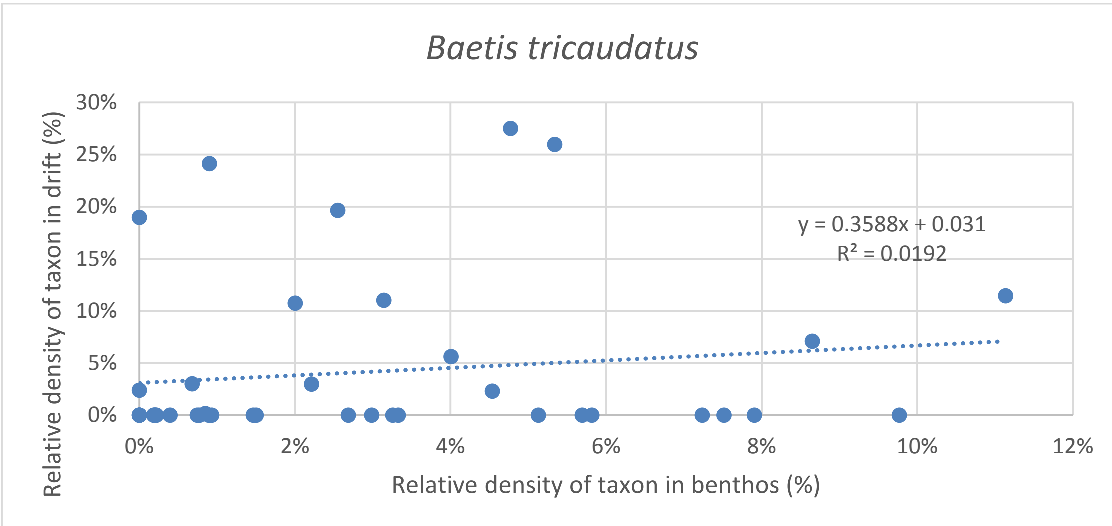

Figure 95. Relative density of *Baetis tricaudatus* in the drift vs. relative density in the benthos for 42 sites in the GR, CC, and MN.

Baetis tricaudatus is a species that is known to be a common taxon in drift supporting the food web for salmonids. *B. tricaudatus* had a relative density in benthic samples of 3.2%, but had a relative density of 11.7% in the drift, based on 42 sites distributed in the GR, CC, and MN drainages. *B. tricaudatus* was found in 85.7% of all sites surveyed in 2013. In many of these sites the species was found in relative percentages ranging up to about 10% for all individuals in the benthos, yet were not found in the drift. However, considering all samples, the relative density of *B. tricaudatus* in the drift was approximately an average of 35.9% of the relative density found in the benthos based on slope of the regression of drift on benthos (Figure 95).

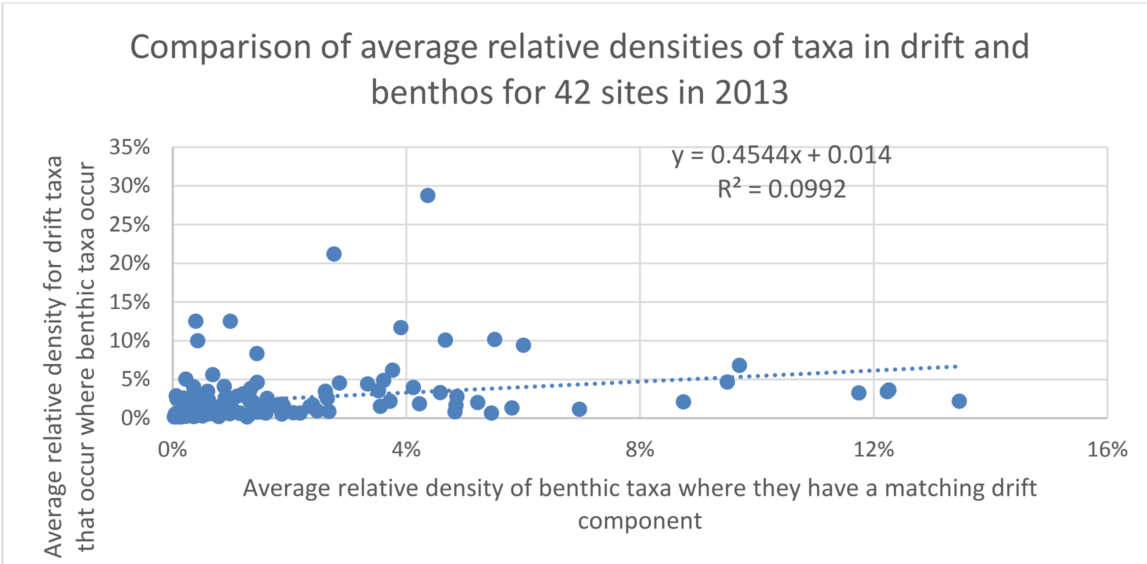

Figure 96. Comparison of average relative densities of taxa in the drift vs. the benthos for 42 sites in 2013.

There were a total of 132 taxa, where some were aggregated into lower resolution taxonomic classification that had each taxon represented in the drift as a whole when it was found in the benthos. That is, because benthos was identified by Cole Ecological and drift by Rhithron, taxonomic identification was adjusted so that there was correspondence at the finest resolution feasible. It was reasoned that finding a taxon in the drift when it was not found in the benthos represented mostly a signal from other sites upstream. A plot of the relative abundance of drift for these 132 taxa against relative abundance in the benthos reveals that on average, the relative density in the drift is about 45% of that in the benthos (Figure 96). The taxa that comprised greater than 4% of the benthos were *Hydropsyche, Cheumatopsyche, Brachcentrus occidentalis, Glossosoma, Ephemeralla excrucians/dorothea, Crictopus (Isocladius), Lepidostoma, Cinygmula, Optioservus, Micropsectra/Tanytarsus, Tricorythodes, Anagapetus, Rhithrogena, Epeorus grandis Gr., Zapada cinctipes, Diphetor hageni, Baetis bicaudatus, Oecetis, Helicopsyche, Drunella doddsii,* and *Brachycentrus americanus*. It is interesting that *Hydropsyche* and *Cheumatopsyche* together comprised about 25.8% of the benthic density across these 42 sites. The two *Brachycentrus* species comprised 16.3%. *Baetis tricaudatus* comprised 3.9%, and with *B. bicaudatus*, the total for these species was 8.6%.

Taxa with a relative abundance in the drift that was greater than 5 times that in the benthos when their relative abundance in the benthos was greater than 1% were *Helicopsyche*, Trombidiformes, *Ferrisia*, *Limnophila*, Ceratopogonidae, *Narpus concolor*, and Gomphidae.

Those taxa that comprised greater than 4% of the drift when they comprised greater than 1% of the benthos included *Helicopsyche*, Trombidiformes, *Baetis tricaudatus, Tricorythodes, Baetis bicaudatus, Optioservus*, *Ferrissia*, *Ephemerella excrucians/dorothea*, *Parapsyche elsis*, *Paratanytarsus*, *Cricotopus* (*Isocladius*), *Micrasema*, *Cleptelmis addenda*, Orthocladiinae, and *Brachycentrus americanus*. Among these taxa, the only ones to be present at a relative density greater than 5 times that of the benthos

were *Helicopsyche*, Trombidiformes, and *Ferrissia*. The two Baetis species comprised on average 22.8% of the drift in sites where they occurred in the benthos.

Comparison of drift vs. benthic density for individual taxa

Drift was also compared with benthos in terms of density of each at the level of individual taxa. For example, for *Baetis tricaudatus* the density of this taxon in the drift (numbers/m^3) was contrasted with the density in the benthos, using only those sites in all three study basins that had presence in both the drift and the benthos. The regression for this taxon was y = 0.0987 X + 37.38, R^2 = 0.047, n = 13, P = 0.48 (Figure 97).

All Hydropsychidae taxa were combined (e.g., *Hydropsyche*, *Cheumatopsyche*) so that density in the drift could be contrasted with that in the benthos for sites having occurrence in both benthos and drift. This regression was not significant (Figure 46). This regression was based on 18 sites out of a total of 42 sites in the GR, CC, and MN that had non-zero values for absolute density for both benthic and drift at each site. It is unclear why Hydropsyche had a positive relationship between relative drift and benthic densities, while the at the family level, which would include greater presence of the family at all sites, there was no relationship at all in terms of regression of absolute densities. It may be that behavioral drift could be highly variable during the day or with variations in environmental characteristics that may change during the summer season when CHaMP surveys are conducted. Environmental characteristics that could lead to variations in drift rates (drift density) are water temperature and density of particulate matter suspended in the drift that these net-spinners filter from the water.

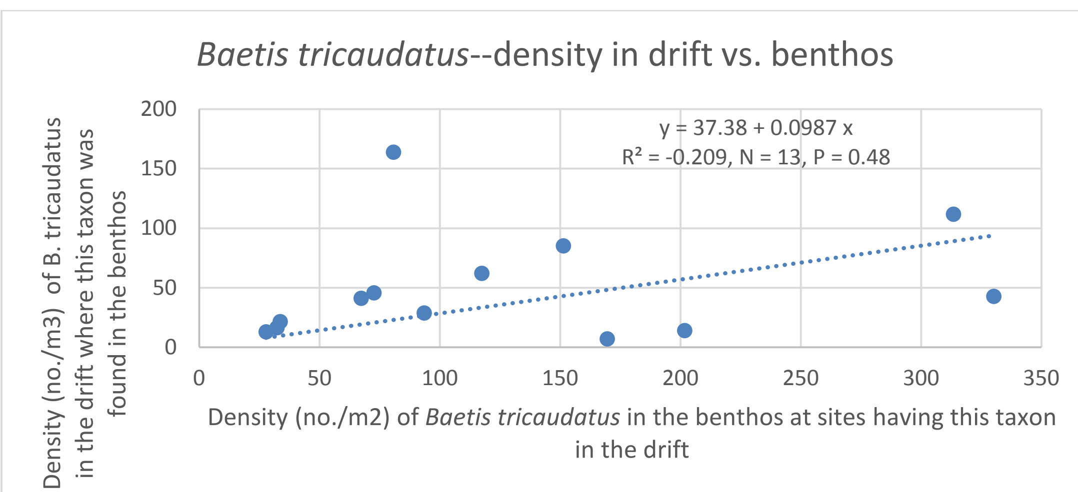

Figure 97. Comparison of density (no./m^3) of *Baetis tricaudatus* in the drift vs. density (no./m^2) in the benthos based on sites that had this taxon in both the drift and the benthos.

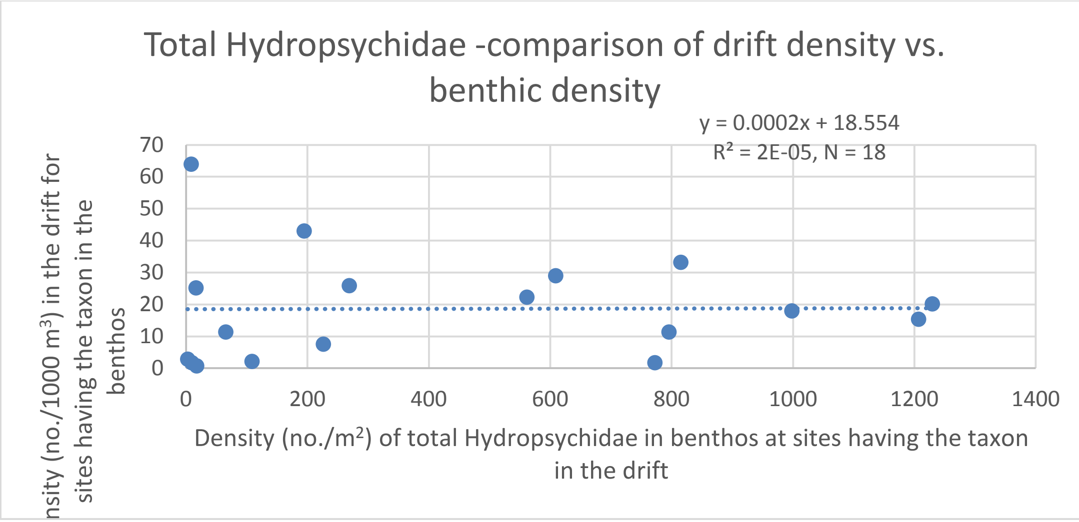

Figure 98. Comparison of density (no./m^3) of Hydropsychidae in the drift vs. density (no./m^2) in the benthos based on sites that had this taxon in both the drift and the benthos.

The beetle larva *Optioservus* showed a positive relationship between absolute density in the drift vs. the benthic density (y = 0.1166X + 45.465, R^2 = 0.1283, n = 32, P=0.04) (Figure 47). There were 32 sites out of 42 that had positive values for absolute density for both drift and benthos at individual sites. In contrast to the Hydropsychidae, it is possible that *Optioservus* may drift with less temporal variability, creating a greater similarity between drift and benthic density.

Orthocladiinae, a sub-family of midges in the family Chironomidae, is comprised by many 13 genera in the three study basins. The relationship between drift density and benthic density of the total Orthocladiinae is positive (y = 0.93x - 23.382, R^2 = 0.277, n = 39, P = 0.0005). The general pattern of the upper level of the drift density is to increase with an increase in the density in the benthos (Figure 100). This seems to fit the general concept that increasing densities of Orthocladiinae in the benthos can generate greater densities in the drift. However, this relationship is also quite variable.

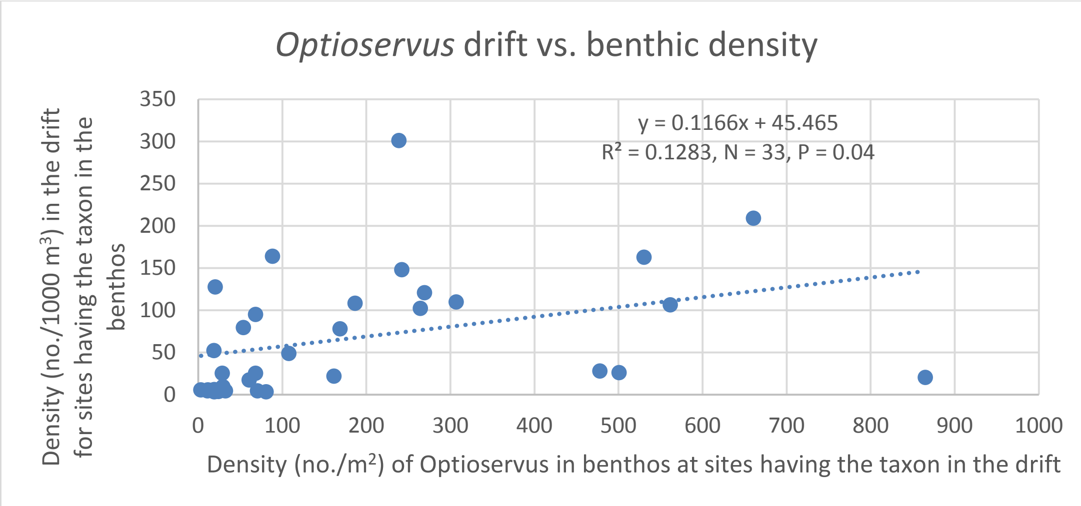

Figure 99. Comparison of density (no./m³) of *Optioservus* in the drift vs. density (no./m²) in the benthos based on sites that had this taxon in both the drift and the benthos.

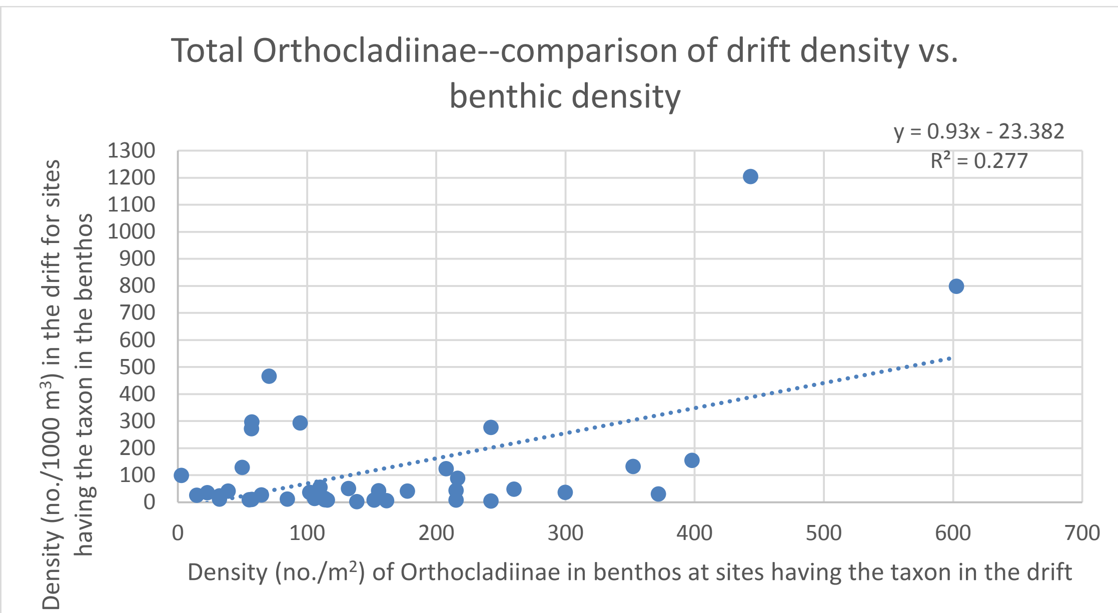

Figure 100. Comparison of density (no./m³) of total Orthocladiinae in the drift vs. density (no./m²) in the benthos based on sites that had this taxon in both the drift and the benthos.

Comparison of drift vs. benthic communities in relation to water temperature and fine sediment indices

We used the tabulated values of water temperature optima and fine sediment upper tolerance levels by taxon for drift and benthic communities (Huff et al. 2006) sampled in 2013 to assess the degree of correspondence between these communities. Regressions for the water temperature optima for drift vs. benthic showed a high level correspondence ($y = 1.135x - 2.231$, $R^2 = 0.8705$) (Figure 50). This

relationship is also very close to 1:1, indicating that the composition of the drift community is a good reflection of the water temperature optima of the benthic community. This relationship also suggests that the organisms collected in the drift originated from the vicinity of the proximal benthic community rather than being an assortment of organisms that had drifted for many kilometers in the stream. This indicates that drift communities are derived from spatially linked benthic communities and that differences in relative abundances are attributable to either diel variations in drift periodicity or different propensities to drift.

A similar result was demonstrated between drift and benthic communities in the 2013 CHaMP samples when the tabulated fine sediment upper tolerance values were applied to the taxa in drift and benthic samples. The tolerance values were weighted by log10 abundance. Again, there was a close relationship between the fine sediment tolerance characteristics of the drift communities and benthic communities (Figure 102).

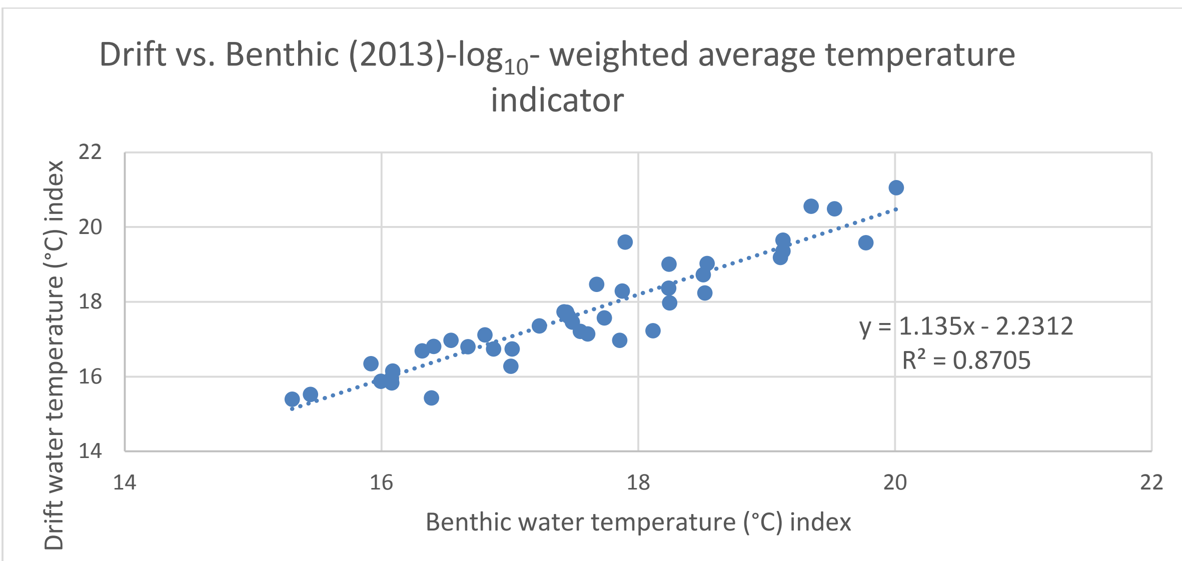

Figure 101. Regression of the drift community water temperature optimum index (log_{10}-weighted by abundance) vs. benthic community water temperature optimum index (log_{10}-weighted by abundance) for 2013 CHaMP sites having both drift and benthic samples.

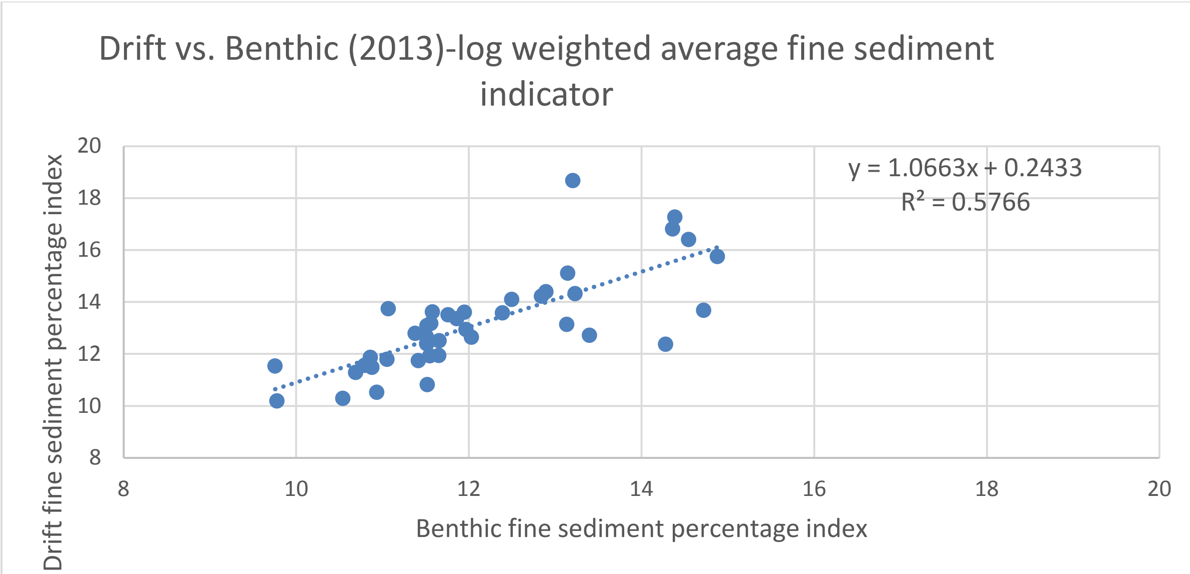

Figure 102. Regression of the drift community fine sediment upper tolerance index (log_{10}-weighted by abundance) vs. benthic community fine sediment upper tolerance index (log_{10}-weighted by abundance) for 2013 CHaMP sites having both drift and benthic samples.

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Hubler, S. 2008. PREDATOR: Development and use of RIVPACS-type macroinvertebrate models to assess the biotic condition of wadeable Oregon streams (November 2005 models). Oregon Department of Environmental Quality. Laboratory and Environmental Assessment Division, Watershed Assessment Section. Hillsboro, Oregon. DEQ08-LAB-0048-TR Version 1.1

Huff DH, Hubler SL, Yangdog P, Drake DL. 2006. Detecting shifts in macroinvertebrate assemblage requirements: Implicating causes of impairment in streams. DEQ06-LAB-0068-TR Version 1.1, Oregon Department of Environmental Quality.