ODFW ODOT Fish Passage Banking Pilot

Net Benefit Analysis Tool
Technical Report


Photo credit: USFWS 2013

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By The Nature Conservancy and Willamette Partnership

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Introduction

Oregon's Fish Passage Statute (ORS 509.580 through 910) gives Oregon legal authority to ensure that for a given project, fish passage is addressed wherever fish are currently or were historically present. Under the Habitat Mitigation Policy (OAR 635, Division 415) and the Fish Passage Rules (OAR 635, Division 412), Oregon Department of Fish and Wildlife (ODFW) also has authority to allow for mitigation (i.e. alternatives to providing fish passage at an artificial obstruction). ODFW Fish Passage Program staff has expressed interest in developing tools and methods that would improve the efficiency and transparency of how they implement these rules. Oregon Department of Transportation (ODOT) wants to ensure they meet their obligations for fish passage through efficient and effective use of transportation dollars. A number of entities are interested in developing approaches to advance priority large-scale fish passage conservation and restoration projects.

To address these purposes, Willamette Partnership (Partnership) and The Nature Conservancy (TNC) are working with ODFW, ODOT, and others to create the science, policy, and processes necessary to implement a pilot fish passage mitigation banking program on Oregon's North Coast (Figure 1). The pilot is intended to test the tools and protocols developed for potential future implementation statewide. To our knowledge, no other state has a mitigation program specific to fish passage.

In conversations with ODFW staff, it is understood that fish passage banking will likely be a tool implemented through ODFW's existing waiver process. Currently, ODFW can provide a waiver to projects that trigger fish passage requirements, if adequate mitigation that demonstrates a net benefit to fish and meets other criteria is provided. Fish passage banking will allow ODFW to steer mitigation from multiple waivers toward fish passage banks – locations where high priority barriers are removed and significant benefits for fish are created. Banking will also provide ODFW, waiver applicants, and other stakeholders with a more standardized and transparent process to evaluate whether mitigation is appropriate, adequate, and sustainable in terms of meeting conservation goals for migratory fish habitat in Oregon.

Our goal for this pilot project is to create eligibility criteria for when fish passage mitigation may or may not be appropriate, a net benefit analysis tool to quantify how much mitigation is needed, and the protocols and processes necessary to review and approve waiver applications that request use of a bank.

This report details the development of the Net Benefit Analysis Tool. In addition to this report, the tool includes an Excel spreadsheet (Fish Passage Credit Calculator), a customized Geographic Information System (GIS) interface, and a manual on how to use the interface to input information into the spreadsheet and calculate credits or debits. While the tools described in this report are fully functional, we anticipate they may need minor revisions as they are integrated with the overall mitigation bank protocols and tested through the piloting phase of the project.

Figure 1. North Coast Basin Project Area

Development of the Net Benefit Analysis Tool

One of the objectives of this project is to standardize an approach to net benefit analysis for the quality and quantity of fish habitat in order to meet requirements of the State of Oregon's fish passage provisions. The current approach to passage waiver requests requires ODFW staff to determine if proposed mitigation is adequate to cover the proposed impact to fish passage. A range of methods are used to estimate habitat quantity and quality in order to determine if mitigation provides a benefit greater than the impact. For fish passage banking, where impacts from multiple waivers are likely to use one mitigation bank, there needs to be a standard procedure to quantify how many fish passage credits a waiver site will need from a passage mitigation bank in order to achieve a net benefit (and conversely, how many credits a mitigation site could provide).

To make this determination, a standardized process needed to be established to:

- numerically quantify the amount of habitat(s) impacted by a project and opened up or improved by a fish passage bank; and
- quantify and/or categorize the habitat quality impacted by a project and at a bank site.

This requires analysis of data for both a project/impact site and mitigation site to produce comparable, quantitative assessments of fish passage benefits. In our view, a net benefit analysis tool should be scientifically credible, transparent, standardized, make use of available data, consistent with ODFW policies and, to the extent feasible, compatible with statewide stream mitigation banking approaches being developed.

During this phase of the project, The Nature Conservancy, along with input from the Project Team, developed the Fish Passage Credit Calculator in an Excel spreadsheet format to meet these objectives. It can be used to compile information on key stream and riparian characteristics such as in-stream habitat, functional riparian area, water quality, landscape context of a site, etc. and produce a composite score of habitat quality. This score is then multiplied by a measure of habitat quantity in order to quantify comprehensive fish passage benefits at a site. The same tools, indicators and processes will be used at both a barrier site where the applicant wishes to request a waiver to the fish passage rules as well as at a potential mitigation site.

While we endeavored to take the type of information that ODFW fish passage staff have used to evaluate waiver requests in the past and put it into a consistent and transparent package, we recognize that it is unreasonable to expect the calculator to crunch every potential consideration into a unique and representative set of outputs. There will still be some instances where special features of a given site will need to be taken into consideration during the review process using best professional judgment. We are hopeful that the tools we have developed will facilitate a more streamlined, repeatable and predictable process in most cases.

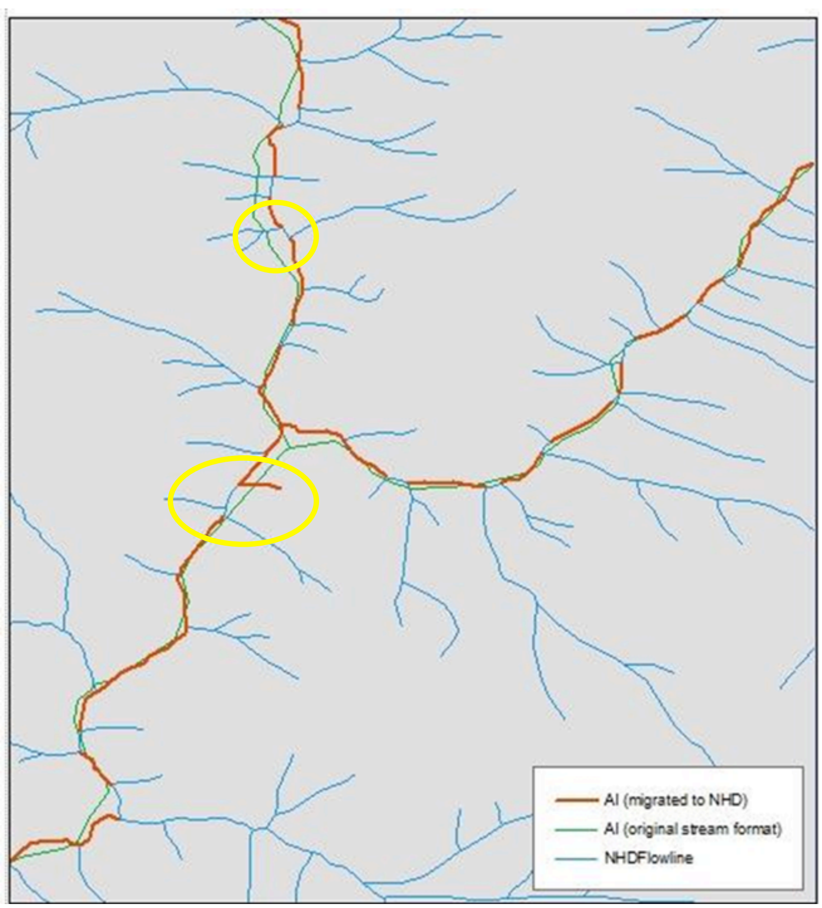
Process and Constraints

Through a combination of group meetings, interviews with ODFW and ODOT GIS staff, a survey of Fish Passage Task Force members, review of waivers, web/literature searches and internal staff knowledge, we identified a number of datasets, prioritization efforts, and other assessment methods that could help inform this project in a number of different ways. A list of these potential sources of information can be found in the Gap Analysis report for this project (Maness & Pickering 2013). Due to differences in scale, purpose, resources, and availability, no one source could fill the needs for this project, but portions of other previous approaches did prove useful. Some, such as the ODFW Aquatic

Inventory Project database provide spatial habitat data useful for characterizing waiver and mitigation sites. Other assessments such as the draft Stream Function Assessment Methodology being built for Oregon provided ideas for habitat components and metrics appropriate for this project. A number of culvert/barrier prioritization projects provided information on databases and potential indicators.

During the scoping phase of this project, we gathered many datasets that we anticipated would most directly inform the net benefit analysis tool. Many of the most useful datasets are those available from and maintained by ODFW. However, in their current state, several of these key datasets differ in their data standards and formats in accordance with their intended usage and thus presented particular challenges for tool development and implementation. The fish habitat distribution data from ODFW, for example, is based on a derivative stream layer that is driven by StreamNet data standards and not directly transferrable to the National Hydrography Dataset (NHD, 1:24,000 scale) stream data for Oregon. Additionally, other fish habitat-related datasets are built on other stream representations. For example, ODFW aquatic inventory basin-level survey data is based on an earlier customized 1:100,000 scale stream layer, whereas Intrinsic Potential data, which we were initially interested in using, are built using stream information derived directly from a digital elevation model (10m DEM). These differences in base stream data make these datasets incompatible without extensive data manipulation to move biological data between stream representations (see Figure 2 for examples of errors). NHD was accepted as the statewide data standard in 2005 (Oregon Hydrography Data Standard ver. 2.0 2012). Therefore we designed our tool to use the NHD standard.

Figure 2. Aquatic Inventory data migrated to NHD showing missing sections & incorrect tributary



ODFW GIS is in the process of migrating fish distribution and barrier data to the NHD standard in a staged approach. We worked with GIS staff at ODFW to fast-track data migration for one test 5th level watershed (e.g. Tillamook) to support more timely development of the tool. However, after extensive research and efforts, we concluded that migrating all of the data layers to the NHD standard was too prone to error, as well as being beyond the scope of the resources budgeted for this project.

A major question we grappled with during the design phase of the project concerned the platform and which functionality is to be provided to the user base. During interviews with ODFW we learned that GIS proficiency and/or access varies across ODFW districts (as is the case across other state agencies and potential users). Consequently, either a tool built on the ArcGIS Explorer viewer or a web-based mapping solution that integrates a variety of databases in a user-friendly manner would be ideal. In both of those implementation scenarios, significant data manipulation and geo-processing through GIS algorithms would need to be performed to prepare the necessary databases for use by the tool.

Due to the data incompatibility issues discussed above, we determined that we did not have the resources to meet that ideal solution at this time. For this project, we are providing a GIS toolbar and prescribed methods that can be used by GIS staff to interactively populate the Calculator Excel spreadsheet with values for a variety of indicators of fish habitat quality. The resulting spreadsheet values and scores should allow evaluation of the pilot fish passage banking program and be used by ODFW district biologists involved in waiver applications in the North Coast project area. As mentioned above, key datasets are in the process of being migrated by ODFW staff to the NHD standard stream layer, so it may be feasible in the future to develop an enhanced tool tailored to a greater user base and broader geographies.

Glossary of Terms

"Active Channel Width" – means the stream width between the ordinary high water lines, or at the channel bankfull elevation if the ordinary high water lines are indeterminate.

"Bankfull elevation" – means the point on a stream bank at which overflow into a floodplain begins.

"Bankfull Width" – is the active channel width measured at the ordinary high water mark.

"Buffered Upstream Network" – all the streams above the project barrier along with a riparian buffer zone extending 300' on each side of the stream.

"Contributing Area" – contributing watershed, or total upstream watershed, defined by the total upstream drainage area above the subject barrier.

"Entrenchment Ratio" – defined as the flood prone width divided by the bankfull or active channel width.

"Fish-Use Stream Length" or "fish-bearing reaches" – "fish-use" streams as detailed in Oregon Forest Practices Rule guidance (see OAR 629-635-0200) and represented in the Fish Presence GIS data modeled by Oregon Department of Forestry.

"Flood Prone Area" – defined by measuring the width of the channel at twice bankfull depth (AREMP 2005).

"Functional Riparian Area" – the area of fish-use streams along with a riparian zone extending 300' on each side of the stream that is assessed for its degree of functionality based on forest seral class and associated riparian function modifiers (Maher et al. 2005; Beamer et al. 2000).

"HabRate" – a model developed to assess the potential quality of stream habitat using stream survey data for each juvenile life stage of salmon and steelhead (Burke et al. 2010).

"Riparian Buffer" – as defined in the NW Forest Plan Aquatic Conservation Strategy buffer for fish-bearing streams (USDA & USDI 2005) which is 300' slope distance (600' total, including both sides of the stream channel).

"Ordinary high water line" (OHWL) means the line on the bank or shore to which the high water ordinarily rises annually in season. (see OAR 141-085-0010 for physical characteristics that can be used to determine the OHWL in the field.)

"Project Barrier" – the culvert or other type of barrier that is being evaluated in the Fish Passage Credit Calculator either as a waiver request or a potential mitigation site.

"Stream Area" – is defined as bankfull width times length of primary and secondary channels.

"Upstream Network" – all streams above the project barrier as identified on the National Hydrography Dataset (1:24,000 scale) irrespective of stream size or fish presence.

Overview of Tool Components

The Fish Passage Credit Calculator uses a series of indicators with associated threshold levels to rank conditions as good, fair, or poor (see Table 1). These indicators were gleaned from a variety of sources. Our Project Team (see Appendix I) expressed the desire to see how the habitat quality of stream reaches ranked for different fish species and life stages. ODFW's Corvallis Research Laboratory had developed just such a model to assess the potential quality of stream habitat using stream survey data for each juvenile life stage of salmon and steelhead (Burke et al. 2010). The model, called HabRate (see Appendix II), uses information summarized from the literature on salmonid habitat requirements for discrete life history stages (i.e. spawning, egg survival, emergence, summer rearing, and winter rearing). These criteria are used to rate the quality of stream reaches as poor, fair, or good, based on attributes relating to stream substrate, habitat unit type, cover, gradient, temperature, and flow. This model allows us to incorporate the species-specific and life-stage-specific detail the team expressed interest in. The model currently includes only salmonid species and redband trout, but it is flexible enough to add other species as needed (a new cutthroat module is currently being developed by ODFW so we hope to be able to add that in the next iteration of the spreadsheet). As a result, specific in-stream habitat features (e.g. % gravel, % pools) are not needed as individual indicators in the calculator since they are incorporated into the HabRate model results.

The Fish Passage Credit Calculator Excel spreadsheet is organized through a series of tabs. The first two tabs contain basic information about the tool and a cover page to record basic information about the site. Information on the Cover Page does not influence the scoring or calculation of credits for a site. The indicators that are used in the calculation of a score of habitat quality for a site are spread across three tabs based on the type of functional process they represent and how they will be used in the calculations. The first of these is "Instream-HabRate"; this is where the values from the HabRate model are used to rank the in-stream habitat quality as well as the total miles of fish habitat that would be opened up if the project barrier were removed. "Riparian & Floodplain" is next with indicators for riparian functionality and degree of floodplain interaction. Then the influence of the contributing basin's condition is factored in on the "Supporting Landscape" tab. Information from these three tabs is pulled into the "Credit Calculations" tab and used to summarize habitat quality at a number of scales as well as overall credits needed for an impact site, or debits to be used in a mitigation bank. There are also tabs for "References" and a "HabRate Summary".

Table 1. Components of the Fish Passage Credit Calculator

Tab	Description	Contents
Introduction	Basic information about the spreadsheet	• Abstract • General instructions • Glossary
Cover Page	Contains general information about a site. This information does not influence the scoring or calculation of credits for a site.	• Project name & date • Project type, location & description • Fish species present & essential habitat • Barrier information • Related restoration projects • Special habitat features of note • Land Ownership
In-stream	Contains HabRate ratings for each stream reach upstream of a barrier by species and lifestage. If sufficient HabRate data are not available, then user-generated survey data will be required. Data entered here is automatically transferred to the Credit Calculations Tab.	• Current passage status of project barrier • Total miles of potential fish use • % in-stream data available • Total habitat area and associated HabRate habitat quality scores
Riparian & Floodplain	Contains indicators that describe a stream's riparian condition and interaction with its floodplain. Data entered here is combined to produce a Composite Nearstream score (range 1-3) on the Credit Calculations Tab.	• % functional riparian area above project barrier • % of miles with entrenchment ratio > 2.2 • % of the historical floodplain area that has been excluded from overbank or tidal inundation
Supporting Landscape	Contains indicators that describe landscape level effects on fish habitat. Data entered here is combined to produce a Composite Supporting Landscape score (range 1-3) on the Credit Calculations Tab.	• % of the *buffered upstream network* allocated to management categories of Protection, Preservation, or Retention • % of the *contributing area* allocated to management categories of Protection, Preservation, or Retention • Extent to which non-native aquatic animal species pose a threat to native fish • DEQ 303d list/TMDL for impairment of water quality designation on project fish-use stream • % of the contributing area under agricultural land use • Density of roads & railroads in the contributing area • Density of road & railroad stream crossings in the upstream network
Credit Calculations	Combines HabRate scores for each reach with Composite Scores for Nearstream and Supporting Landscape and the weighting of each composite score to generate a final habitat quality score (range 1-3). Calculations track scoring for each life stage of each species. Credits/Debits are quality-adjusted acres of potential fish habitat.	• Habitat Quality Composite Indicator Sub-scores table • Composite Score by Reach table • Composite Habitat Quality X Quantity by Reach table • Net Benefits by Species • Total Credits/Debits

Description of Indicators and Sources of Threshold Levels

Current Passage Status of Project Barrier

This indicator describes the level of fish passage that is currently available at the barrier. The ODFW Barrier database may provide information regarding passage status; however, it is limited to two categories: fully blocked or partially blocked. The Calculator further divides the partially blocked category into: 1) blocked to both adult and juvenile fish for a portion of the year, and 2) blocking only juvenile fish for all or part of the year. These differences in passage status may occur as a result of differing flow levels throughout the year that inhibit fish passage. For example, low flows that result in shallow sheet flow across a concrete box culvert may not be deep enough to allow adult passage or high flows during the winter being forced through a pipe that is too small may create velocities that are too much for fish passage upstream. An example of a juvenile-only barrier would be a culvert with a downstream end that is perched only a few inches above the streambed allowing adult fish to jump into the pipe but preventing juveniles from traveling upstream on a cool tributary to escape high water temperatures in the mainstem. The applicant should consult with the local district biologist to confirm passage status. In a similar approach to the one employed by Loffink (2013), passage status is used to adjust the overall site score as follows: Fully blocked sites receive 100% of credits; Partially blocked: adult & juvenile receive 80% of credits; Partially blocked: juvenile only receive 60% of credits. This approach to scoring is supported in the fish passage rules that state if partial passage is present, it can be considered during net benefit analysis to reduce the amount of mitigation required.

Total Miles of Potential Fish Use above the Current Barrier

This indicator is used to determine the total potential fish-use stream length (including secondary channels and tributaries) above the barrier. We considered using the ODFW Fish Habitat Distribution database to calculate this since they have records for “historic” presence; however, those records were limited in distribution to streams below barriers blocking fish passage. We also looked into using the NetMap Intrinsic Potential modeling as a way to estimate the portion of stream length above a barrier providing potential fish habitat. This approach was not generally acceptable since there are concerns that it over-estimates potential habitat and the data would have been too costly to acquire. We therefore decided to use the Oregon Department of Forestry Fish Presence Survey database. Rules for determining “fish-use” streams are detailed in Oregon Forest Practices Rule guidance (see OAR 629-635-0200) and are based on physical habitat criteria to determine natural barriers to fish use when actual electro-fishing surveys are not available (Table 2). This database has also been used in recent coastal barrier prioritizations (Bailey 2012; Pilson 2012).

Table 2. Summary of Physical Habitat Criteria Used to Determine Natural Barriers to Fish Use (from OAR 629-635-0200, Page 39 of 71, November 15, 2007)

<table>
<tr><th colspan="2">Type of Barrier</th><th colspan="2">Physical Survey</th><th>Map Survey</th></tr>
<tr><td colspan="2" rowspan="3">Falls & Chutes</td><td>Salmon & Steelhead</td><td>Resident Trout</td><td rowspan="3">Any waterfall marked on a map.</td></tr>
<tr><td>8'+</td><td>4'+</td></tr>
<tr><td colspan="2">2'+ require a jump pool 1.25 times the fall or chute height.</td></tr>
<tr><td rowspan="2">Channel Steepness</td><td>With Pools</td><td>30' or more @ 20%+</td><td>20' or more @ 20%+</td><td rowspan="2">20%+</td></tr>
<tr><td>W/O Pools</td><td>30' or more @ 12%+</td><td>20' or more @ 12%+</td></tr>
<tr><td colspan="2">Lack of Livable Space</td><td colspan="2">No pools approximately 12" or more in depth during spring spawning.</td><td>60 Acres or Less (Coast
80 Acres or Less (South Coast)
100 Acres or Less (Interior)
300 Acres or Less (Siskiyou)
350 Acres or Less (Blue Mountain and East Cascade)</td></tr>
</table>

<u>Percent of Total Miles Available for Fish Use with Suitable Fish Habitat Data</u>

This indicator is designed to ensure there is sufficient data to reliably score the site. The first consideration is what portion of the potential fish use area above the project barrier has adequate data for the in-stream habitat portion of the calculator. ODFW has conducted numerous surveys as part of their Aquatic Inventories Project (http://oregonstate.edu/dept/ODFW/freshwater/inventory/index.htm) and Oregon Plan Monitoring Program. The customized GIS interface developed by The Nature Conservancy for this project contains the most current habitat survey data available for the pilot area as of February 2014. However to make sure new data are not missed and for areas beyond the pilot area, applicants should start this determination by contacting ODFW Corvallis Research Laboratory to request habitat ratings based on surveys done in any portion of the potential fish use area above the project barrier. If the percent of upstream fish use length for which habitat data is available is less than 80%, then the applicant must gather additional field data according to protocols (See Field Data Section below & Appendix III & IV). After field data are gathered, this factor should be recalculated to factor in the new field data.

<u>Habitat Quality and Total Area Available for Different Life Stages and Species</u>

ODFW's HabRate model incorporates all the individual attributes the Project Team initially considered including as separate indicators and the species and life stage specific threshold levels for determining good, fair and poor rankings were well researched and documented in the literature (Burke et al. 2010; Appendix II). We feel this is a robust way to rate in-stream habitat quality at the level of detail requested by the Project Team. As mentioned above, the GIS Interface contains a data layer of the current HabRate rankings derived from ODFW Aquatic Inventory survey information. This can be used as a starting point but the applicant should contact ODFW Corvallis Research Laboratory for the most current habitat survey data and habitat ratings for their project site.

Percent Functional Riparian Area along Fish-Use Streams above the Current Barrier

For this indicator we are using an algorithm described in NOAA Fisheries' Atlas of Salmon and Steelhead Habitat in the Oregon Lower Columbia and Willamette Basins (Maher et al. 2005). They estimate functionality or impairment of riparian vegetation based on the proportion of total buffer area in five GIS-derived forest seral classes. Field observations in Washington State were used to develop a functionality modifier for each vegetation class. To validate the accuracy of this approach, they used field-based riparian inventories to compare the actual riparian condition along a stream channel to the GIS-based forest seral classes. Field inventories at 234 riparian sites showed that riparian condition ratings were predicted reasonably well for most of the seral classes. All of the sampled late seral forest sites and between 85% and 95% of the mid-seral and early-seral sites met their screening criteria for functioning riparian forests, while on the other end of the spectrum, approximately 90% of the areas mapped as non-forest did not meet functioning riparian criteria (Beamer et al. 2000).

One modification we made was to use a database previously developed by Nature Conservancy staff. In this database, the number of vegetation classes is reduced from five to four based on the ability of the modeled data to distinguish between the classes. Our data may or may not have the same accuracy as that of the Atlas. On-the-ground testing of model accuracy has not yet been done for the data that we are using, however field testing is expected during the mitigation banking pilot.

Another difference is that they used a 30 m (~100') buffer and we are using the NW Forest Plan Aquatic Conservation Strategy buffer for fish-bearing streams (USDA & USDI 2005) which is 300' slope distance (600' total, including both sides of the stream channel). The equation and threshold levels for this indicator are from Mayer et al. (2005).

Floodplain Interaction

There are currently two indicators intended to represent how well the project stream interacts with its floodplain: 1) % of miles with entrenchment ratio > 2.2, and 2) % of the historical floodplain area that has been excluded from overbank or tidal inundation. Entrenchment ratios are measured during ODFW Aquatic Inventory surveys; they indicate the potential for the stream to interact with its floodplain. The ratio is defined as the flood prone width divided by the bankfull or active channel width (flood prone area is defined by measuring the width of the channel at twice bankfull depth) (AREMP 2005). Values greater than 2.2 indicate rivers only slightly entrenched in a well-developed floodplain, which encourages development of secondary channels (EPA 2005).

Human alterations such as levees, roads, and railroads can alter a stream's ability to interact with its floodplain. The second indicator attempts to quantify this effect; however, initial field testing of the draft Stream Functional Assessment Method for Oregon, from which this indicator was derived, found it difficult to measure in cases where there are not clear visual cues. The Forest Service Watershed Condition Classification Guide includes an indicator of floodplain connectivity but it is also based on qualitative visual cues (Potyondy & Geier 2011). We feel this indicator is functionally important so we are including it in the calculator, but hope to develop better methods to assess this in the future. The threshold levels for these indicators were derived from the draft Stream Functional Assessment Method and Potyondy & Geier (2011).

Landscape Context

The project team was interested in incorporating condition of the surrounding landscape and potential risk. In order to quantify the relative amount of landscape above the project barrier that may have been modified from natural condition, we are using a database developed by USDA Forest Service, Institute for Natural Resources, and Oregon State University for their Integrated Landscape Assessment Project (http://oregonstate.edu/inr/ilap). The project explores the dynamics of broad-scale, multi-ownership landscapes across all lands in Arizona, New Mexico, Oregon and Washington. For our purposes, we are calculating the percent area allocated to management categories of Protected, Preservation, or Retention. These categories are defined as:

> *Protected & Preservation:* This management category is used to encompass areas that are legally dedicated to protection and preservation of the characteristic of natural landscape (Wilderness, Congressional Reserve, & National Parks). Additionally it contains slightly less restrictive management and may allow for more adjustments in management practices (Regional conservation reserves/preserves, Late Successional Reserves, Wilderness Study Areas, Visual Resource Management Class 1).
>
> *Retention:* This category has more of an emphasis on retention of forested areas or native vegetation for a variety of reasons such as the conservation of endangered species or for maintaining forested corridors along areas of visual or biological importance (Municipal Watersheds, Corridors for visual/riparian/biodiversity, Endangered/threatened species management, Other values of importance, Private conservation areas, Wildlife Refuges, Visual Resource Management Class 2).

The percent of area allocated to these categories is calculated at two scales: within the contributing area, and within the riparian zone represented by the buffered upstream network above the barrier. The riparian zone used in this indicator goes beyond the Functional Riparian Area on the Riparian & Floodplain tab, which is only calculated along the section of stream identified as potential fish-use. The Buffered Upstream Network used in this indicator uses the same buffer width but includes the full stream network above the barrier to better reflect the landscape context and the broader opportunity for large wood and sediment to be delivered to the stream system at natural levels. There was not team consensus regarding the most appropriate scale for measuring this aspect of landscape condition, therefore indicators for both contributing area and buffered upstream network scales are included. The scoring formula in the credit calculator takes the maximum of the two so it is not double counted. The threshold levels for these indicators were derived from the draft Oregon Stream Functional Assessment.

<u>Extent to which Non-Native Aquatic Animal Species Pose a Threat to Native Fish</u>
Project Team members recommended this indicator be included and it was used as an optional factor in the ODFW Fish Passage Priority List (Loffink 2013). We are not aware of a comprehensive database for aquatic animal presence so consulting with the local ODFW District Biologist would be the most reliable method for completing this indicator.

<u>DEQ 303(d) list/TMDL for Impairment of Water Quality Designation on Project Fish-use Stream</u>
Every two years, Oregon Department of Environmental Quality is required to assess water quality and report to EPA on the condition of Oregon's waters. The 303(d) list is developed to identify waters that do not meet water quality standards. The Forest Service Watershed Condition Classification Guide uses the 303(d) list as a measure of impaired water quality (Potyondy & Geier 2011). It is also used in the NOAA Atlas of Salmon and Steelhead maps (Maher et al. 2005). However, in the latter case they point out some of the limitations of the dataset: “Because no watershed is completely censused with regard to all streams, it is incorrect to assume that water bodies not present on the censused list have qualified to pass inspection. In fact, many streams may not have been sampled, in which case those streams will not be present on the list regardless of their status.” (Maher et al. 2005, pg. 5). Regardless of the limitations, we included it as the best data available.

Percent of Contributing Area under Agricultural Land Use

This indicator provides another measure of water quality since agricultural uses, including overgrazing, may result in increased sediment and nutrient runoff as well as chemical inputs toxic to fish. This is an indicator that is used for watershed monitoring under the Northwest Forest Plan (AREMP 2005) so the threshold levels are based on values they used to evaluate watershed condition.

Density of Roads & Railroads in the Contributing Area

This factor affects sedimentation at the local level but also quantity and timing of water flow at the basin level. The density of roads is used in the Forest Service Watershed Condition Classification Guide so we used the threshold levels identified in that guide in the calculator (Potyondy & Geier 2011). For both this and the next indicator, we are using the BLM roads database. We are confident it is the best data available; however, we know it is incomplete (especially for legacy logging roads). This should be taken into consideration as it will likely result in underestimating these indicators.

Density of Road & Railroad Stream Crossings in the Upstream Network

Beyond fish passage, road crossings also affect a number of downstream functions that impact habitat quality through blockage of large wood and natural sediment transport (Pilson 2012). Therefore this indicator, which calculates the number of road and railroad stream crossings, is not restricted to just the fish-use streams in the project area; it includes all streams above the project barrier. The ODFW Fish Passage Barrier database is known to be incomplete (Pilson 2012) so we are using this calculation instead of counting documented upstream barriers. Both the Northwest Forest Plan watershed monitoring (AREMP 2005) and a barrier prioritization conducted by The Nature Conservancy in the Chesapeake Bay watershed (Martin and Apse 2013) also used this indicator. The AREMP report verified this approach with field sampling: "Forty-eight sample watersheds spread across the Plan area were inspected for potential erroneous crossings from digitizing errors. The percentage of suspected false crossings was less than two percent for the total sample." (AREMP 2005, pg. 11). Threshold levels from the AREMP report are used in our calculator.

Relative Importance of Indicators

One of our basic assumptions regarding the relative importance of the indicators was that factors closest to the stream are most important for fish. In-stream processes are the main drivers for creation and maintenance of suitable habitats, which is the most basic need for native migratory fish. Riparian zones on either side of the stream are a major driver not only for materials (e.g. wood) that create in-stream habitats, but they also provide food-web connections, cover for fish to hide from predators, bank stability, and influence water quality factors such as temperature and filtering of sediments and pollutants (Foster et al 2001; Bjornn and Reiser 1991). Naturally-stable stream banks are more likely to develop bank undercut, which provides important cover for fish, and stable banks are less likely to provide fine sediments, which can embed spawning gravels and, in extreme cases, fill in pools (Foster et al 2001). The stream's ability to interact with its floodplain is an important component of habitat complexity since greater floodplain interaction enhances secondary channel formation (important refuge areas for fish during high winter flows), riparian vegetation, and stream bank stability (Foster et al 2001). Improving floodplain connectivity has also been identified as one of the restoration actions most likely to ameliorate effects of climate change on salmon populations (Beechie et al. 2012). Therefore in-stream habitat quality as reflected in the HabRate scores, along with riparian condition and indicators of floodplain interaction were considered of primary importance so they are weighted accordingly in the calculator.

Landscape context and watershed-based perspectives, while less directly related than in-stream and near-stream habitats, are still important considerations because of their influence on in-stream factors (Foster et al 2001; Trombulak and Frissell 2000). Apart from fish passage issues, the density of road/stream crossings has implications for in-stream habitats since inadequate culverts also block large wood and natural sediment transport to the system downstream (Forman and Alexander 1998). These materials are an integral part of hydro-geomorphic processes that result in the formation and maintenance of the complex in-stream fish habitats (Trombulak and Frissell 2000) identified as the top priority above. The surrounding land use of the contributing area influences fish habitat in a variety of ways including the amount of large wood and sediment that can be expected to be delivered to the streams (Cunjak 1996). The percent area in land uses expected to protect the characteristics of a natural landscape can indicate how functional those processes may be (Beechie et al 2003). Beyond crossings, the overall density of roads in the contributing area not only affects sedimentation at the local level but also the quantity and timing of water flow at the basin level (Trombulak and Frissell 2000). Road density has been identified as an important measure of landscape-scale ecological integrity (Forman and Alexander 1998; Potyondy & Geier 2011).

Besides temperature (which can be factored into the HabRate model if stream temperature data is available), water quality is generally of lower importance. Salmonids are documented to be sensitive to high water temperatures and have well-defined limits regarding temperatures within which they can survive and be productive (Bjornn and Reiser 1991). The HabRate model can use temperature data to modify the ratings, therefore we did not include a separate indicator for temperature per se but it could also be reflected in the DEQ 303(d) indicator. Excessive sediment levels in streams can also be harmful if they cover or surround spawning gravels or prevent juvenile salmon from using the interstitial spaces between boulders, cobble, and gravel for cover (Foster et al 2001; Bjornn and Reiser 1991; Cunjak 1996). However, this issue is addressed in the HabRate assessment of spawning habitats so additional indicators were not deemed necessary. Other water quality issues may be a concern in some areas so the Project Team recommended indicators for agricultural inputs and DEQ 303(d) list. However, the team recommended that the 303(d) list be rated of lower importance because of uneven sampling statewide and resulting data limitations cited above. The non-native species indicator may be difficult to determine but where they are known to have a significant impact on fish, it should be a consideration.

Credit Calculations

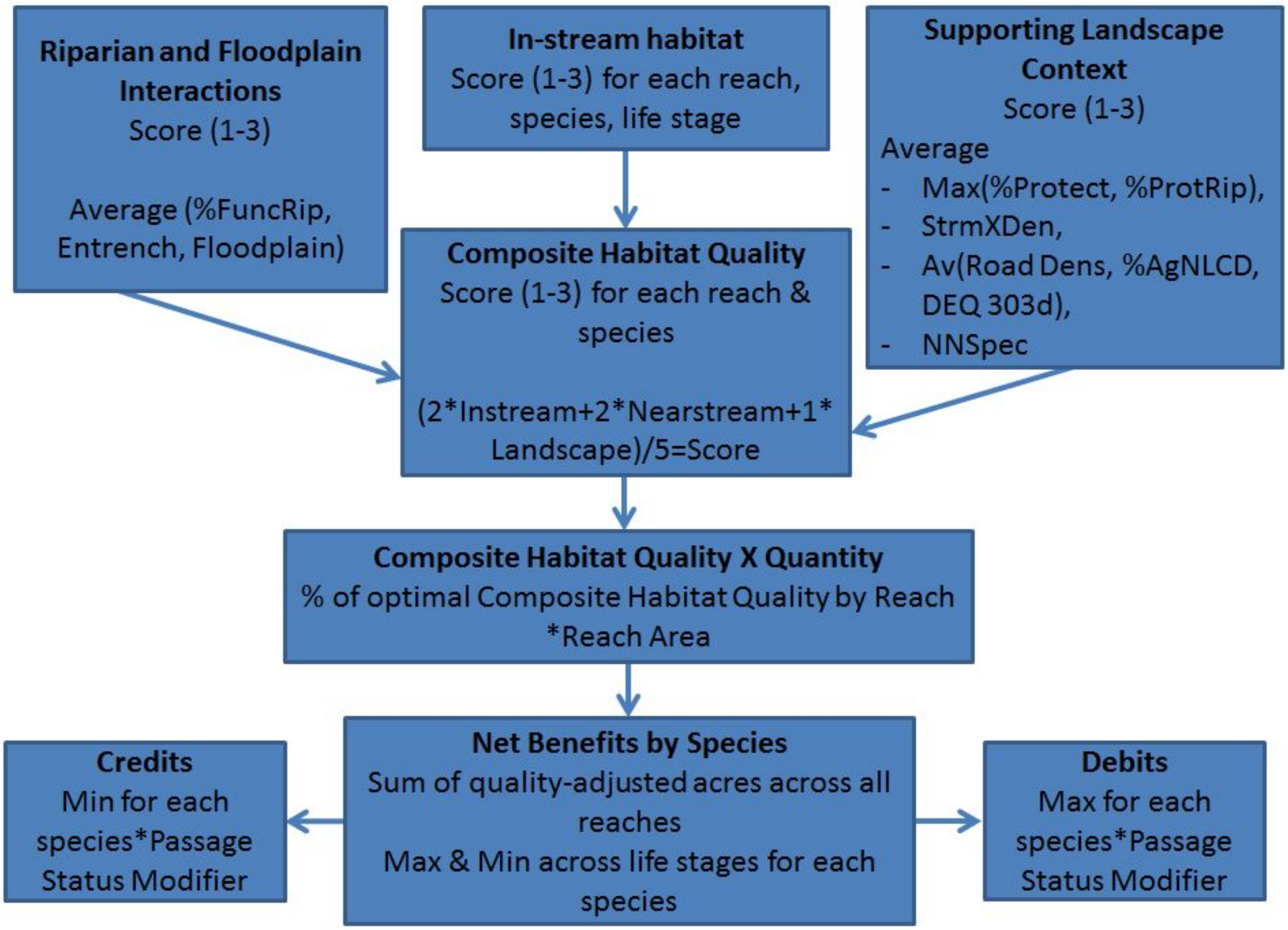
The value entered for each indicator (e.g. >50%, 15-34%, >1 crossings/mi) is converted to a percent of the total possible functional value for that indicator (e.g. 100% for the best possible score; 30% for the worst score of 3 options). These scores are used in the formulas on the Credit Calculations tab.

In general, it is assumed that all the indicators will have values entered. But we recognize there may be instances where that is not feasible. However, some indicators are considered essential to return a meaningful result and must have a value entered for the calculator to return a credit/debit calculation. These are:

- HabRate results
- % Functional Riparian Area
- At least 1 of the floodplain interaction indicators (entrenchment or % floodplain excluded from inundation)
- At least 1 of the Protected Management status indicators (% Protected contributing area or % Protected buffered upstream network)
- Density of road & stream crossings in the upstream network

On the Credit Calculations tab, data from the previous tabs are combined at a variety of levels (see Fish Passage Credit Calculator Excel spreadsheet). The Riparian Condition and Floodplain Interaction indicators are combined into a Near-stream Composite Score by averaging the three individual indicator scores. The Supporting Landscape indicators are combined into a Landscape Composite Score by averaging the maximum score of the Protected Management indicators, the Road-Stream Crossing Density, the average of the Water Quality indicators, and the Non-Native Species indicator (Figure 3). The resulting Composite Values are converted to Composite Sub-score ranks of 1, 2, or 3 corresponding to poor, fair, or good respectively to match the ranks used in the HabRate model results.

Figure 3. Diagram Illustrating Fish Passage Credit Calculator Formulas



As discussed above, the In-stream and Near-stream indicators are considered to be more important than the Landscape indicators. Therefore, they are given a weighting factor of 2 while the Landscape Composite Score has a weight of 1.

The HabRate scores for each reach are copied from the Instream-HabRate tab, however if a fish species is not checked as being present in a particular reach, the corresponding HabRate scores for that reach are left blank in the table on the Credit Calculations tab. The Composite Score by Reach table combines all three indicator groupings into a weighted average habitat quality score by species and life stage. And finally, the Composite Habitat Quality X Quantity by Reach table brings in the stream area of each reach and multiplies it by the habitat quality ranking for each species and life stage converted to the percent of the optimal score (i.e. a rank of 3 [good] habitat quality is the best so if a reach is ranked 2.4 for the Chinook spawning/emergence life stage 2.4/3=0.8 or 80% of optimal so the stream area for that reach is multiplied by 0.8). All the reaches for a particular species and life stage are totaled for a quality adjusted habitat area for that species and life stage (bottom center box in Figure 3 above).

In the interest of ensuring the mitigation bank results in replacement by life stage, one project team member suggested using the maximum value for each species at the impact site but the minimum at the mitigation site. This is reflected in the Net Benefits by Species and Credits/Debits tables. Credits/Debits are quality-adjusted acres of potential fish habitat that have been adjusted for current passage status of the project barrier (i.e. 100% for full barriers, 80% partial: adult & juveniles, 60% partial: juveniles only). The Mitigation Banking Instrument document will define any trading ratios that might further modify the credits and/or debits.

Field Data

The processes described above take advantage of a variety of GIS datasets to populate the credit calculator whenever feasible. However there will be instances when additional on-the-ground data gathering will be required. If the percent of upstream fish-use length for which in-stream habitat data is available is less than 80%, then it will be necessary to gather field data. There may also be instances where the ODFW District Biologist requests additional survey data (as authorized in OAR 635-412-0040(9)(k)) including re-survey of previously surveyed stream segments if the data are out of date due to situations such as a major storm or a restoration project that occurred since the last sample date. Alternatively, the applicant might choose to assume the full section of fish-use stream length without data had the best conditions possible and determine mitigation based on that.

In instances where additional data are required, it is preferable to survey the full fish-use stream length above the project barrier if that can be accomplished by two surveyors in one day. If that is not feasible for a given site, sampling can be employed as long as it is designed to be representative of the overall fish-use area at the site and is unbiased in site selection. The following recommendations are based in part on ODFW Oregon Plan sampling as described in Moore et al. 2006).

Site Set-up

- Determine what portion of the site needs additional field data to meet the 80% data coverage standard
- If the total distance is more than can be sampled in one day, identify the number of reaches within the fish-use stream segments lacking habitat data
- Randomly select enough reaches to fulfill 80% criteria assuming 1-500m survey section per reach
- Randomly select a starting point for a survey site within each selected reach
- Each survey site must encompass the point identified for the site
- Each survey site must be 500 meters in length
- Include only one homogenous reach in each survey site
- When possible start and end surveys at obvious recognizable points (e.g. sharp bends, tributaries, bridges, etc…).

Data gathering at the sample sites should use standard protocols used by ODFW as modified for Oregon Plan Habitat-only Monitoring Surveys (Moore et al. 2006; pgs. 54-56) for the attributes used in the HabRate model. These are excerpted in Appendix III & IV along with sample data sheets.

Future Testing

In developing the Net Benefit Analysis Tool set, we have drawn on a diversity of sources in both approach and content. We encountered a number of constraints and set-backs due to inconsistencies among datasets and varying levels of completeness within datasets. As a result, we only had resources available for very limited field testing of the tool during the first phase of the project. We anticipate more extensive field testing will be conducted in the next phase of the pilot to test accuracy, sensitivity, repeatability, and usability of the tool. The results of this testing, along with feedback from additional peer review, may result in refinements to the Net Benefit Analysis Tool presented here.

Considerations for Statewide Use & Future Upgrades

The Fish Passage Net Benefit Analysis Tool and processes described in this report were developed for the North Coast Basin pilot study area. If fish passage mitigation banking is ultimately approved for state-wide use, a number of modifications will need to be made to ensure maximum applicability in other areas of the state. Weighting factors could also be tailored to different regions of the state.

There are a number of places in the calculator spreadsheet where specific fish species are listed. The species checklist on the cover page and the list of species with HabRate scores are currently specific to the pilot study area. If the calculator is used in other areas of the state, these should be modified to include the local species and remove inapplicable ones. As mentioned earlier, the suite of species for which input criteria have been developed for use in the HabRate model is limited. If there are additional native migratory fish species of special concern in other areas of the state, ODFW staff can request the Corvallis Research Lab customize inputs for those species and add them to the HabRate model.

The significantly different climatic conditions in areas of the state east of the Cascades will require some additional considerations if the credit calculator is to be used there. In degraded systems, water temperatures may be more likely to reach lethal levels and some stream reaches may be de-watered to the point of going dry at certain times of the year. The HabRate model does have the ability to factor these conditions into the model and override habitat scores in reaches where these conditions would prevent fish use. Extra attention should be paid to making sure the temperature and flow data required for that feature are provided as part of the request to the Corvallis Research Lab for HabRate results in places where this is applicable.

Another consideration for eastside streams is the Functional Riparian indicator. This indicator is currently most suitable for use in stream systems where forested plant communities would naturally be dominant. Other vegetation cover classes and associated riparian functionality modifiers may need to be identified for parts of the state not normally dominated by forests such as sagebrush steppe and native bunchgrass prairie found in Eastern Oregon.

When we embarked on this effort, we were hopeful that we would be able to design a calculator to determine debits and credits not only for culvert projects but also for other types of barriers such as dams, dikes/levees and tidegates. For the most part, the overall process and a number of the indicators probably can be used in these situations but some adjustments will be necessary. An additional consideration in the case of new proposed dams might include an assessment of potential downstream effect from the dam. In the case of dikes/levees and tidegates, a supplemental estuarine habitat quality module will need to be developed to replace the HabRate habitat quality rankings since the attributes used in HabRate are specific to stream systems. In some cases, where a project affects both estuarine and stream habitats, quality adjusted acres using both rankings could be used.

Service Area

Defining service areas for a statewide fish passage mitigation banking program will require consideration of both ecological/biological issues and potential supply and demand of fish passage mitigation credits.

OAR 635-412-0040 states:
"(9) Mitigation:

> (a) shall be conducted in-proximity to the artificial obstruction, with respect to geographic scope;
> (b) shall have habitat type and quality which is more beneficial than that affected by the artificial obstruction, if mitigation is passage into, restoration of, or enhancement of habitat;
> (c) shall at least benefit the same native migratory fish species affected at the artificial obstruction;…"

OAR 635-412-0005 defines "in-proximity" as being within the same watershed or water basin, as defined by the Oregon Water Resources Department, and having the highest likelihood of benefiting the native migratory fish populations, as defined by the Oregon Department of Fish and Wildlife, directly affected by an artificial obstruction.

According to OAR 635-415-0005, " 'Watershed' means a drainage basin encompassing a stream, its tributaries, and associated uplands at the USGS 4th Field Hydrologic Unit level."

As such, our current recommendation is to use the 4th level HUC watershed as the geographic definition of a service area.

Refinement of this definition may be required in subsequent stages of the fish passage banking project as more information becomes available through lessons learned in the pilot application of the banking approach in the North Coast.

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Appendices

Appendix I. Project Team Members

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Appendix II. HabRate Overview

Habrate: A Limiting Factors Model for Assessing Stream Habitat Quality

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Abstract:
Fishery managers are commonly tasked with the basic question "Will the contemporary habitat above a barrier support the fish populations that historically resided in the watershed?" Managers in central Oregon were confronted with that question in an effort to reestablish fish populations in 375 kilometers of stream above the Round Butte-Pelton Dam complex (Rkm 161) on the Deschutes River. Stream surveys had been conducted in most of the available stream habitat, but had not been synthesized in a form that allowed managers to view the quality and complexity of stream habitat in an easily-understandable fashion. In response, we developed a limiting factors model (HabRate) that assessed the potential quality of stream habitat using stream survey data for each juvenile life stage of salmon and steelhead. The model was developed for a specific application to the middle Deschutes River basin in Oregon, but was intended for general application to Pacific Northwest basins. To paramatize the model, we summarized available literature on salmonid habitat requirements. Habitat criteria were developed for discrete life history stages (i.e. spawning, egg survival, emergence, summer rearing, and winter rearing) and used to rate the quality of stream reaches as poor, fair, or good, based on attributes relating to stream substrate, habitat unit type, cover, gradient, temperature, and flow. Reach level summaries of stream habitat data were entered into MS Excel, and interpreted by a series of algorithms to provide a limiting factor assessment of potential egg-to-fry and fry-to-parr survival for each reach. Model output lists habitat quality by species and life stage for each reach of stream. The model is a decision making tool that is intended to provide a qualitative assessment of the habitat potential of stream reaches within a basin context. Design criteria for the model were simplicity, flexibility, and transparency. While HabRate was based on our interpretations of the published literature, specific criteria for habitat quality were structured to be easily adjusted where interpretations differ from ours. Information not common to standard stream survey designs, such as seasonal flow or temperature extremes can be included as input from professional judgment. The results were integrated into a GIS coverage coupled with the stream network and habitat data to provide a comprehensive map-based perspective of habitat quality in a watershed.

Citation:
Burke, J. L, K. K. Jones, and J. M. Dambacher. 2010. Habrate: A Limiting Factors Model for Assessing Stream Habitat Quality for Salmon and Steelhead in the Deschutes River Basin. Information Report 2010-03, Oregon Department of Fish and Wildlife, Corvallis.
http://oregonstate.edu/dept/ODFW/freshwater/inventory/habratereg.htm

Aquatic Inventory Attributes used in the HabRate Calculations:
% gradient, unit width, active channel width, floodprone width, % pools, scour pool depth, riffle depth, large boulders/100m, % fines, % gravel, % cobble, % boulder, pieces of large woody debris (LWD)/100m, % undercut, residual pool depth, average pieces LWD in pools, average keypieces LWD in pools, and average % sheltered pools

Appendix III. Field Data Methods from Moore et al. 2006

The following are sections taken from the methods used by ODFW for Aquatic Inventory surveys; these only include the attributes that are necessary for the HabRate model. Consult Moore et al. 2006 for complete methods and pointers about conducting these types of surveys.

UNIT FORM

Crews work upstream, identifying and characterizing the sequence of habitat units. They enter the following information into the data sheet:

Reach #. The numbered sequence of reaches as they are encountered. A **reach** is a length of stream defined by some functional characteristic. A reach may be simply the distance surveyed. More frequently, reaches are defined as: stream segments between named tributaries, changes in valley and channel form, major changes in vegetation type, or changes in land use or ownership. Each reach is comprised of variable number of channel units.

Unit #. The sequential number describing the order of channel habitat units starting with the first unit recorded. A reach is comprised of many channel units.

Unit Type. The concept of a channel habitat unit is the basic level of notation for our survey methodology. We subdivide the stream into two general classes of unit types: channel geomorphic units and special case units.

Channel geomorphic units are relatively homogeneous lengths of the stream that are classified by channel bed form, flow characteristics, and water surface slope. With some exceptions, channel geomorphic units are defined to be at least as long as the active channel is wide. Individual units are formed by the interaction of discharge and sediment load with the channel resistance (roughness characteristics such as bedrock, boulders, and large woody debris). Channel units are defined (in priority order) based on characteristics of (1) bedform, (2) gradient, and (3) substrate.

Special case units describe situations where, because of stream flow level or a road crossing, the usual channel geomorphic unit types do not occur. Special case units include dry or partly dry channels, and culverts.

GEOMORPHIC CHANNEL UNITS
Characteristic water surface slopes are given for each group of habitat unit types. However, channel bed form and flow characteristics are the primary determinant of unit classification. Use the unit's slope to help make determinations when the other characteristics are ambiguous.

POOLS (water surface slope always zero)

PP **P**lunge **P**ool: Formed by scour below a complete or nearly complete channel obstruction (logs, boulders, or bedrock). Substrate is highly variable. Frequently, but not always, shorter than the active channel width

SP **S**traight scour **P**ool: Formed by mid-channel scour. Generally with a broad scour hole and symmetrical cross section.

LP **L**ateral scour **P**ool: Formed by flow impinging against one stream bank or partial obstruction (logs, root wad, or bedrock). Asymmetrical cross section. Includes corner pools in meandering lowland or valley bottom streams.

TP **T**rench **P**ool: Slow flow with U or V-shaped cross section typically flanked by bedrock walls. Often very long and narrow with at least half of the substrate comprised of bedrock.

DP **D**ammed **P**ool: Water impounded upstream of channel blockage (debris jams, rock landslides).

BP **B**eaver dam **P**ool: Dammed pool formed by beaver activity. In most cases this will be preceded by a SD (step over beaver dam).

SUBUNIT POOLS
Alcoves, backwaters, and isolated pools are types of habitat subunits; generally not as long as the full channel width. They are, however, generally easy to identify and are important habitat types. Alcoves, backwaters, and isolated pools are formed by eddy scour flow near lateral obstructions.

AL **AL**cove: Most protected type of subunit pool. Alcoves are laterally displaced from the general bounds of the active channel. Substrate is typically sand and organic matter. Formed during extreme flow events or by beaver activity; not scoured during typical high flows.
BW **B**ackwater **P**ool: Found along channel margins; created by eddies around obstructions such as boulders, root wads, or woody debris. Part of active channel at most flows; scoured at high flow. Substrate typically sand, gravel, and cobble.
IP **I**solated **P**ool: Pools formed outside the primary wetted channel, but within the active channel. Isolated pools are usually associated with gravel bars and may dry up or be dependent on inter-gravel flow during late summer. Substrate is highly variable. Isolated pool subunits do not include pools of ponded or perched water found in bedrock depressions.

GLIDES

GL **GL**ide: An area with generally uniform depth and flow with no surface turbulence. Low gradient; 0-1 % slope. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. Generally deeper than riffles with few major flow obstructions and low habitat complexity. There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993).

RIFFLES

RI **RI**ffle: Fast, turbulent, shallow flow over submerged or partially submerged gravel and cobble substrates. Generally broad, uniform cross section. Low gradient; usually 0.5-2.0% slope, rarely up to 6%.
RP **R**iffle with **P**ockets: Same flow and gradient as Riffle but with numerous sub-unit sized pools or pocket water created by scour associated with small boulders, wood, or stream bed dunes and ridges. Sub-unit sized pools comprise 20% or more of the total unit area.

RAPIDS

RB **R**apid with protruding **B**oulders: Swift, turbulent flow including chutes and some hydraulic jumps swirling around boulders. Exposed substrate composed of individual boulders, boulder clusters, and partial bars. Moderate gradient; usually 2.0-4.0% slope, occasionally 7.0-8.0%.
RR **R**apid over Bed**R**ock: Swift, turbulent, "sheeting" flow over smooth bedrock. Sometimes called chutes. Little or no exposed substrate. Moderate to steep gradient; 2.0-30.0% slope. Low gradient bedrock, similar to a riffle, is considered “RR”.

CASCADES

CB **C**ascade over **B**oulders: Much of the exposed substrate composed of boulders organized into clusters, partial bars, or step-pool sequences. Fast, turbulent, flow; many hydraulic jumps, strong chutes, and eddies; 30-80% white water. High gradient; usually 3.5-10.0% slope, sometimes greater.
CR **C**ascade over Bed**R**ock: Same flow characteristics as Cascade over Boulders but structure is derived from sequence of bedrock steps. Slope 3.5% or greater.

STEPS

Steps are abrupt, discrete breaks in channel gradient. Steps are usually much shorter than the channel width. However, they are important, discrete breaks in channel gradient with gradients. Steps can separate sequential units of the same type. For example, small steps (<0.3m high) that separate pools may be important features in very low gradient reaches and should be recorded as individual habitat units. Low steps (<0.3m high) in moderate to high gradient reaches formed by gravel and small cobbles on the face of transverse bars can usually be included in the next fast water unit upstream.

Steps are classified by the type of structure forming the step.

SR **S**tep over Bed**R**ock (include hardpan and clay steps)
SB **S**tep over **B**oulders
SC **S**tep over face of **C**obble bar
SL **S**tep over **L**og(s), branches
SS **S**tep created by **S**tructure (culvert, weir, artificial dams)
SD **S**tep created by Beaver **D**am

<u>SPECIAL CASE UNIT TYPES</u>

DU **D**ry **U**nit: Dry section of stream separating wetted channel units. Typical examples are riffles with subsurface flow or portions of side channels separated by large isolated pools. Record the length, active channel width (acw), and unit data. Count boulders w/in acw.
PD **P**u**D**dled: Nearly dry channel but with sequence of small isolated pools less than one channel width in length or width. Record all unit data. Record the average wetted width and modal depth. Note the acw and any deep pockets in the NOTE field.
DC **D**ry **C**hannel. Section of the main channel or side channel that is completely dry at time of survey. Record all unit data, use active channel width for width. Count boulders w/in acw. Depth = zero.
CC **C**ulvert **C**rossing. Stream flowing through a culvert. Record all data for metal bottom culverts. However, record the substrate of the surrounding fill material when estimating the composition of substrate material.

Channel Type. Channel ordering code based on channel by size and location. Orders the sequence of single, multiple, and side channels. The inventory considers the stream as the system of all channels that transport water down the drainage. The intention is to survey and quantify all aquatic habitats located within the valley floor. All active channels and unit types will be classified with one of the following channel codes.

00 No Multiple Channels (all flow in one channel)
01 Primary Channel (of multiple channel reach or in the unit where a tributary enters the channel)
02 Secondary Channel (of multiple channel reach)
03 Tertiary Channel (of multiple channel reach)
Continue pattern for 04, 05, 06 level channels.
10 Isolated Pools, Alcoves, or Backwater Pools.
11 Primary channel of valley floor tributary. If the tributary has a name, write it in the note column.
12 Secondary channel of valley floor tributary.

Unit Length. Length of each unit in meters. Unit length will be measured up the center of the channel or following the thalwag in pools. The thalwag is defined as the portion of the stream carrying the most flow. In lateral pools this may be to the right or left of the center of the stream.

In order to ensure an adequate number of habitat units, maximum lengths are:

- *The maximum length of fast-water units is 25m (+5m).*
- *There is no maximum length for slow water units (pools).*

If a unit will naturally end within 5 m of the maximum unit length the unit may be extended to the natural end.

Unit Width. Width of wetted channel. Unit width will be measured at the point of average unit width. In highly variable or long units, multiple widths will be measured and averaged together.

Slope. Gradient of water surface in the unit. Expressed as the **percent** change in elevation over the length of the unit. Estimated with a clinometer using the scale on the right side in the viewfinder.

Active Channel Height. Vertical distance from the streambed to the top of the active channel. Determined by averaging the cross-section measurements of the water depth of fast water units or at pool tail crest of pools and adding it to the distance from water surface to the top of the active channel.

Active Channel Width. Distance across channel at "bank full" flow. Bankfull flow is the level the stream flow attains every 1.5 years on average. The boundary of the active channel can be difficult to determine; use changes in vegetation, slope breaks, or high water marks as clues. Sum the width of all active channels in multichannel situations.

The key indicator of bankfull stage (active channel) is the floodplain: a flat depositional surface adjacent to the channel and at the top of point bars.

Floodprone Height. The floodprone height is determined by doubling the active channel height. The floodprone height is the maximum depth in the channel during a flood event occurring approximately every 50 years. Record twice the active channel height as the floodprone height to the nearest 0.1 meter.

Floodprone Width. Distance across the stream channel and/or unconstraining terraces at floodprone height. The floodprone width is the width of the valley floor inundated during a flood event occurring approximately every 50 years. If the floodprone width is greater than 4 times the active channel width at that location, simply estimate the floodprone width. The ratio of floodprone width to active channel width is necessary to determine the reach type and entrenchment ratio.

Flood Prone Width, Flood Prone Height, Active Channel Width, and Active Channel Height will be measured 5 times per survey at 0, 125, 250, 375 and 500m. It is not necessary to break a unit at exactly these distances if it does not happen naturally. Instead, conduct these measurements at the beginning (or end) of the unit closest to the desired distance.

Depth. Maximum depth in pools, modal or typical depth in glides and fast water units. Measure to the nearest 0.05 meter as accurately as possible in pools. Probe the bottom with the depth staff to find the deepest point. Small differences in pool depth are significant.

Depth at Pool Tail Crest: Measure the maximum depth to the nearest 0.01 meter at the pool tail crest (PTC) for every pool habitat unit. For subunit pools (BW, AL, IP), a PTC does not need to be measured or recorded. The PTC location is where the water surface slope breaks into the downstream habitat unit. Measure the deepest point along the hydraulic control feature that forms the pools. For beaver ponds unit type (**BP**) that have no water flowing over the top of the dam yet there is subsurface flow through the sticks and logs of the dam, record the PTC depth as 0.01 meter.

Substrate. Percent distribution by streambed area of substrate material in six size classes: silt and fine organic matter, sand, gravel (pea to baseball; 2-64mm), cobble (baseball to bowling ball; 64-256mm), boulders, and bedrock. Estimate distribution relative to the total area of the habitat unit (wetted area). Round off each class to nearest 5 percent.

Do not worry about totaling your estimates to 100 percent; this will be done during analysis. Be sensitive to the difference between surface flocculants and other fine sediment. Fine sediment that covers and embeds gravel and cobble should be part of your estimate. A thin layer of low density fine material over bedrock or boulders should not be included. Hardpan clay or conglomerate substrate has bedrock characteristics and is therefore classified as bedrock when estimating percent composition. Estimate the distribution of the surrounding and/or supporting substrate to the best of your ability at SL (step over log) and CC (culvert crossing) units. For open bottom culverts, estimate the substrate as you would a normal habitat unit.

Boulder Count. Count of boulders greater than 0.5 m in average diameter. Within this size class, include only the boulders that have any portion protruding above the water surface and those at the margin of the wetted channel. In dry units and dry channels, estimate the boulder count within the active channel.

Percent Undercut Bank. An estimate of the percent of the perimeter of the habitat unit composed of undercut banks. Estimate at the margins of the wetted channel as an index of cover habitat.

Look for areas that provide good hiding cover for fish. Typically, if the undercut portion extends along the bank for a meter or more, include it in your estimate. Include areas undercut beneath root wads.

WOOD FORM

Objective of this effort is to apply a standardized and consistent methodology to obtain quantitative estimates of wood volume and distribution within stream reaches. Information will be used to evaluate effects on fish habitat and channel structure and to make quantitative comparisons between streams.

- Minimum size to consider is 15 cm (0.15m) diameter by 3 m length. Exception: root wads less than 3 m long; these are included and counted on the wood form in a specific column.
- Collect data for all wood that meets the minimum size criteria. Do not attempt to evaluate its effectiveness as fish habitat.
- Count all dead pieces that are within, partially within, or suspended over the active channel, regardless of height above channel. Any live woody material is not counted.
- **Measure** the entire length and diameter of all pieces; include portion outside the active channel (do not estimate).
- Use additional lines for each unit when more than one configuration, type, or size class of wood is present.
- Indicate grouping of pieces in individual accumulations and jams by drawing brackets around the appropriate rows in the note column.
- Location of all wood pieces within a jam is identified by the primary location or function of the jam. A jam on the wood sheet does not necessarily mean a DJ comment is necessary
- Make no entry for units where woody debris is absent.

Reach #. Same as on Unit Form

Unit #. Same as on Unit Form

Unit Type. Same as on Unit Form

Debris Configuration.

S **S**ingle piece.
A **A**ccumulation. Two to four pieces.
J **J**am. More than four pieces.

Diameter Class. Estimate diameter of each piece at 2 meters above the base of the stem. Assign each piece or group of pieces to the closest size class (ex. 0.15, 0.30, 0.45). For pieces greater than 0.60 diameter be as accurate as possible when determining diameter and length. Measure diameter in meters.

Length Classes. Count and tally the number of pieces within each length class. Root wad less than three meters long (frequently with a cut end) is a special case and has its own column, (RW<3). Wood >3m goes in the 3-6m column; wood >6m goes in the 6-9m column, etc.

When measuring very large amounts of wood in debris jams assign all jams to one unit number. Indicate in the note column if the jam spans more than one unit. ***Record and tally*** *all countable pieces.*

Appendix IV. Field Data Sheets (modeled on Moore et al. 2006)

UNIT Field Data Sheet Page: ______ of _______

Stream: ____ Date: _________________ Data Gatherer(s): ___________________________________

Reach #	Unit #	Unit Type	Depth	Depth PTC	Channel Type	Unit Length	Unit Width	Slope %	Active Channel		Flood Prone		Percent Substrate						Boulder Count	% Under Cut
									Ht.	Width	Ht.	Width	S/O	Sand	Grvl	Cble	Bldr	Bdrck		

Appendix IV. cont. Field Data Sheets (modeled on Moore et al. 2006)

WOOD Field Data Sheet

Page: ______ of _______

Stream: ____ Date: _________________ Data Gatherer(s): ____________________________________

Reach #	Unit #	Unit Type	Debris Config.	DBH Class (m)	Length Class (m)												Wood Notes
					RW < 3	3	6	9	12	15	18	21	24	28	32	36+	