Kalama, Washougal and Lewis River Habitat Assessments

Chapter 1: Introduction and Methods

Prepared for:

Lower Columbia Fish Recovery Board
2127 8th Avenue
Longview, Washington 98637

Prepared by:

R2 Resource Consultants, Inc.
15250 NE 95th Street
Redmond, Washington 98052

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Prepared by:

MaryLouise Keefe, Ph.D.
Ron Campbell
Paul DeVries, Ph.D.
Sue Madsen
Dudley Reiser, Ph.D.
R2 Resource Consultants, Inc.
15250 NE 95th Street
Redmond, Washington 98052

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1. INTRODUCTION

1.1 BACKGROUND AND PROBLEM STATEMENT

The Lower Columbia Fish Recovery Board (LCFRB) Watershed Assessment Project was designed to occur in two phases. Phase 1 was completed early in 2004 and provided a description of where and to what extent the watershed processes that impact fish habitat and water quality are functioning properly and where degraded processes are likely to adversely affect fish habitat conditions. Phase 1 of this assessment effort gathered Geographic Information Systems (GIS) data and other information on various indicators of watershed process conditions including sediment, hydrology, and riparian conditions to identify areas where additional assessment activities were needed (LCFRB 2004). This GIS information was attached to subwatersheds (3,000- to 12,000-acre drainages), and an Integrated Watershed Assessment (IWA) analysis of the process conditions was conducted (LCFRB 2004). Along with the identification of subwatershed and watershed process conditions, the LCFRB has also identified populations of fish and habitat reaches that are critical to the recovery of anadromous salmonids in the lower Columbia Evolutionarily Significant Unit (ESU; LCFRB 2004). Watershed summaries for each major watershed in the lower Columbia subbasin that identify and summarize these priority populations and stream reaches are included in Appendix IV in the LCFRB Interim Habitat Strategy on the LCFRB (www.lcfrb.gen.wa.us). These population and habitat priorities, along with watershed process conditions provided the framework for identification of critical assessment needs identified for Phase 2.

Phase 2 of the assessment was conducted by R2 Resource Consultants, Inc. (R2) and S.P. Cramer and Associates. This second phase involved collection of data on stream habitat conditions, riparian conditions, sediment sources, and hydromodifications within priority reaches of the lower Columbia subbasin. Priority reaches were identified in the Kalama, North Fork Lewis, East Fork Lewis, Salmon, and Washougal rivers (Figure 1). The intent of the Watershed Assessment Project was to provide stream-specific data on the current state of aquatic and riparian habitats to help fill data gaps, identify potential enhancement, restoration, or protection projects, and to verify previous Ecosystem Diagnosis and Treatment (EDT) and IWA model results. The information gathered was used to: describe, map and characterize a variety of habitat conditions for salmonids; identify and prioritize specific restoration and protection actions; collect data that will enhance the certainty of Phase 1 assessments (EDT and IWA model inputs and results); and identify additional data needs.

Figure 1. Location map of Kalama, North Fork Lewis, East Fork Lewis, Salmon, and Washougal basins.

1.2 OBJECTIVES

Specific study objectives of the Phase 2 assessment were as follows.

1. Locate hydromodifications that limit fish access to floodplain and off-channel habitat that has been impacted, quantify the extent of habitat lost, and identify potential restoration opportunities.
2. Assess riparian conditions along priority reaches to provide an estimate of species composition, width of riparian corridor, percent canopy cover, and large wood (LW) recruitment potential.
3. Gather the information necessary to better understand fish and habitat conditions within priority reaches of the Kalama, Washougal, and Clark County river basins and identify important protection and restoration actions.
4. Gather the information necessary to better understand fish and habitat conditions within priority reaches of the Kalama, Washougal, and Clark County river basins and identify important protection and restoration actions.
6. Produce a final report that details the findings of the assessment effort, identifies and prioritizes restoration and protection actions, and identifies additional data needs.

This report presents the results of the Watershed Assessment Project. The report is organized into six chapters including Chapter 1 – Introduction and Methods that describes field and analytical procedures used in conducting the assessment; Chapters 2 through 6 that describe data collected, results of analyses, and identifies and prioritizes protection and restoration actions by river basin. The report also contains three appendices including: Appendix A – Aerial Photograph Assessment; Appendix B – Stream Inventory Reach Summaries; Appendix C – Geologic Map Units.

2. METHODS

2.1 EVALUATION OF HYDROMODIFICATIONS

The LCFRB identified four priority areas for evaluation of hydromodifications as part of this study. These areas encompassed the low gradient alluvial reaches of the Kalama, Lewis, East Fork Lewis, and Washougal rivers. Hydromodifications are defined as: 1) structures or activities that change the natural flow regime (e.g., flood control dam or impervious surfaces); 2) interruption of habitat connectivity (e.g., disconnection of side channels or barrier culverts); and 3) direct physical alteration of the stream bank or floodplain (e.g., levees, riprap, stream adjacent roads, bridges and stream crossings; ditches, dams and diversions or gravel extraction). Hydromodifications in each priority area were mapped using Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP) protocols (WDFW 2001). Completion and validation of hydromodification maps and database for priority areas were conducted in a series of six steps as described below.

Step 1 – Reviewed existing data for coverage and completeness.

Existing SSHIAP hydromodification layers were obtained from Washington Department of Fish and Wildlife (WDFW). These GIS coverages were constructed using existing data layers from various federal, state, and local agencies. The SSHIAP hydromodifications layers were reviewed for completeness and accuracy.

Other data sources used to complete the analysis of hydromodifications included recent and historic maps and aerial photos, and reports describing construction and maintenance work conducted to address flood control or navigation concerns. Current digital orthophoto coverage of the study area was provided by Clark County (digital color infrared orthophotos dated 2002) and the LCFRB (digital black and white 4-meter orthophotos dated 2003). Historic photo and map products were obtained from various sources, including the University of Washington map library and U.S. Army Corps of Engineers, Portland District.

Step 2 – Defined the analysis area for each basin and mapped current channel margins.

The SSHIAP protocol(WDFW 2001) calls for delineation of the generalized floodplain to identify the boundaries of the hydromodifications study area. The generalized floodplain represents the area that would be affected by fluvial geomorphic processes in the absence of human intervention, including areas subject to channel migration or inundation during large floods. For this project, we estimated the historic extent of the generalized floodplain by identifying those areas that had either been occupied by the river channel over the past 150 years (based on map and aerial photo analysis), or that were likely to have been inundated during large floods (based on historic gage records).

Delineation of the generalized floodplain was supported by reviewing available maps of regulatory constructs such as the 100-year floodplain (from Federal Emergency Management Agency [FEMA] Federal Insurance Rate Map [FIRM] maps) and the channel migration zone[1] (CMZ). Delineation of the historic generalized floodplain and areas currently accessible to channel migration or inundation during large floods for this study was intended to evaluate the extent to which land use activities in the vicinity of the river may be affecting channel morphology and floodplain processes, and to provide a rough comparison of the probable extent of habitats influenced by fluvial geomorphic processes under both historic and current conditions. It was not intended to quantitatively confirm whether specific structures, property or infrastructure are within the floodplain or CMZ from a regulatory standpoint, and should not be used for that purpose. Such a determination requires an intensive field-based evaluation of channel processes and is beyond the scope of this study.

Step 3 – Prepared preliminary map of hydromodifications.

A preliminary map of hydromodifications within the analysis area of each basin was prepared based on review of the most recent available aerial photos. First, a layer depicting the extent of the analysis area (i.e., generalized floodplain) and existing channel margins (including the margins of all off-channel habitat within the analysis area) was constructed using ArcView.

Point, line, and polygon coverages from the existing WDFW SSHIAP database were then overlain on the analysis area and channel margin coverages. Existing hydromodifications codes were checked for accuracy, and additional hydromodification features visible on the orthophotos were added to a separate set of ArcView shapefiles linked to a database created following the SSHIAP database structure and coding standards. Areas where uncertainty existed as to the type or extent of hydromodification present were highlighted for field review. Potential restoration sites were identified on preliminary maps by a geomorphologist and fish biologist with habitat restoration experience.

[1] A channel migration zone is defined as the lateral extent of likely movement along a stream reach with evidence of active movement over the past 100 years (WFPB 2000).

Step 4 – Completed field review.

Field surveys were completed within representative and accessible portions of the analysis areas of each stream to field validate the hydromodification. Field validation of hydromodifications served two objectives: 1) validation of remote sensing based hydromodification data layers; and 2) evaluation of potential restoration sites. Field validation focused on areas of existing map layers where information was lacking or questionable, or sites that were classified as "uncertain." A hydromodifications checklist was developed that included documentation of the characteristics of each hydromodification structure such as bank composition, cover, distance from main channel, and degree of connectivity. We used this checklist to confirm the characteristics of hydromodification features identified in the SSHIAP database and through aerial photo analysis. Field validation of the preliminary hydromodification data was conducted in conjunction with habitat surveys.

Off-channel habitat connectivity and quality and floodplain conditions were assessed in the field by a geomorphologist and fish biologist with experience in the design of habitat restoration projects. It is important to note that all field visits were subject to prior landowner access and approval. Field review focused on sites deemed to have a high potential for future restoration projects.

Step 5 – Finalized maps/database.

Final GIS map coverages and databases were edited using information collected from the field review. GIS was then used to quantify the extent of the various types of hydromodification features by EDT reach.

To provide a context for evaluating and prioritizing projects, the amount of historic floodplain and channel margin habitat that has been "lost" was estimated. For each of the target river basins, the overall amount of floodplain and channel margin habitat that has been lost was estimated by comparing the extent of the historic generalized floodplain and "natural" (i.e., non-hydromodified) channel margin habitat to the amount of existing floodplain and "natural" channel margin habitat identified through field data collection and review or current air photos and floodplain maps.

Historic channel margins and off-channel habitats were delineated from the earliest available map or photo set with a level of detail comparable to the most recent data sources. Mylar overlays or copies of historic maps were scanned and georeferenced to current digital raster graphics (DRGs) of USGS 1:24,000 scale 7.5 minute quadrangle maps based on a series of horizontal control points identifiable on both the DRGs and historic documents. A GIS layer of historic channel margins was developed for each priority area from the georeferenced overlays using ArcView. Channel margin maps were developed that classified margin habitats as bank, bar or off-channel habitat following the system developed by Hayman et al. (1996). Off-channel habitats were further classified as being connected or disconnected from the main channel. Information on the actual map or photo source used for each river basin is provided in the Basin Specific Methods section for that river basin. Current channel margin and off-channel habitat for each basin were delineated in a similar fashion on black and white 4m digital orthophotos dating from 2003.

Step 6 – Prioritized potential restoration sites.

Potential hydromodification restoration opportunities were prioritized based on: a) the nature of the associated hydromodification (e.g., sites disconnected by a major highway or road corridor were assigned a lower priority than those separated from the river by a gravel road); b) the current habitat condition (i.e., sites with intact riparian vegetation were assigned a higher priority than those that have been converted to agriculture); and c) the estimated amount of floodplain habitat that could be restored or preserved. Floodplain and channel margin habitats that could preserve or potentially be reconnected to the mainstem were prioritized as follows: 1) habitats with an intact riparian community that are located within the current floodplain were assigned the highest priority; 2) habitats that do not have an intact riparian community, but that are located within the existing floodplain and do not currently support development or infrastructure were assigned the second highest priority; and 3) habitats within the historic generalized floodplain but outside of the existing floodplain that do not currently support extensive development or infrastructure were assigned the third highest priority. The prioritization of potential hydromodification restoration sites did not consider land ownership or other legal constraints, and was weighed against habitat benefits that could be accrued through restoration opportunities identified in other modules to develop final recommendations regarding restoration.

2.2 AERIAL PHOTOGRAPH ASSESSMENT OF RIPARIAN CONDITIONS ALONG PRIORITY REACHES

The previous riparian assessment, completed as part of the Phase 1 IWA (LCFRB 2004), was conducted at the subbasin scale. For the remote assessment of riparian conditions in Phase 2, we expanded the IWA results by describing in more detail the riparian conditions along each defined EDT reach in the five river basins. The remote assessment provided information for reach-specific riparian habitat quality and the level of impaired and/or healthy components of the riparian corridor within each reach. This information was used to identify reach-specific needs to recommend improvements in riparian function.

For the aerial photographic assessment, 100-ft riparian zones were delineated on both sides of the river. Riparian conditions including categorization of vegetation species type, tree size and density were estimated from the photos and estimates of the riparian LW recruitment potential and shade conditions from the aerial photograph assessment were made in accordance with Washington State Forest Practice Board guidelines for conducting watershed analysis (WFPB 1997).

Riparian condition codes used in evaluating each reach were as follows:

Vegetation Type:

C = Conifer (70% conifer)
D = Deciduous (70% Hardwood)
M = Mixed (all other cases)

Tree Size:

S = Small (< 12 " dbh [diameter at breast height])
M = Medium (12 and < 20 " dbh)
L = Large (20 " dbh)

Tree Density:

S = Sparse (< 1/3rd of ground is visible on aerial photos)
D = Dense (all other cases)

Shade:

> 90% Shade (Stream surface not visible on aerial photos)
70-90% Shade (Stream surface slightly visible or patches)
40-70% Shade (Stream surface visible but banks are not)
20-40% Shade (Stream surface and banks visible at times)
0 - 20% Shade (Stream surface and banks visible)

The remote sensing assessment was coordinated with the SSHIAP protocols for assessing Properly Functioning Conditions (PFC; NMFS 1996) and the Level II stream inventory surveys completed as part of the fish habitat task. Data from these sources were used to refine the aerial riparian assessment. Riparian data collected during habitat surveys included shade, riparian conditions (width, age, density), vegetative cover type, LW recruitment potential, and anthropogenic influences. These data were used to verify the remote assessment and to identify reach-specific riparian habitat needs.

2.3 CONDUCT COMPREHENSIVE STREAM SURVEYS IN PRIORITY REACHES

Stream surveys were conducted to: 1) improve the current state of knowledge of the habitat conditions within the target river basins, 2) identify reach-specific habitat needs that can be addressed by future habitat enhancement projects, and 3) collect data in a fashion that would enhance the certainty of the existing EDT models for the target river basins.

The five targeted rivers (Kalama, North Fork Lewis, East Fork Lewis, Salmon Creek, and Washougal) identified for this project contain approximately 390 miles of river habitat. Because it was not feasible to survey all habitats, a stratified subsampling scheme was used to select reaches representative of overall habitats in these systems. The objective was to select and obtain landowner access to reaches that totaled greater than 10 percent of the total stream miles in the Project area.

The sampling scheme contained two layers of stratification prior to selecting reaches for subsampling. The targeted watersheds were initially stratified on the basis of river basin and channel morphology (channel width, and gradient). The reach selection process was designed to capture a minimum of 10 percent of the overall reach lengths of each channel type per river basin. A second layer of stratification included grouping the habitat reaches based on Tiers 1-4, previously prioritized during subbasin planning efforts (LCFRB 2004). River reaches throughout the Lower Columbia subbasin were tiered according to their perceived restoration value for assisting with salmon recovery. To maximize the field effort for filling in data gaps and retain valuable ground-truthing of the model inputs, Tier 1 and 2 habitats that had been identified as having the highest restoration value for salmon recovery were sampled proportionally more than other reaches. Subsampling was designed to capture 50 percent of the habitats within Tier 1, 20 percent of the Tier 2 reaches and 10 percent of the Tier 3, Tier 4 habitats.

The stratification scheme resulted in the initial selection of 62 reaches that comprised 77 miles of stream habitat, much of which was bordered by lands in private ownership. In these instances, a formalized process was completed whereby permission to access these areas was solicited from the landowners. When access to an individual reach type was denied, alternative reaches within the same strata were selected and the permission process to inventory habitat was reinitiated. In the end, access constraints limited the extent of the field surveys to a total of 44.5 miles. The planned and actual miles surveyed by stratum are depicted in Table 1.

Table 1. Stream reach lengths (miles) in the Kalama, N.F. Lewis, Salmon, and Washougal rivers, Washington initially planned for field surveys and reaches actually surveyed by tiered habitats

	Tier 1		**Tier 2**		**Tier 3**		**Tier 4**		**Total**	
	Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual
Kalama	11.5	7.8	3.9	2.7	0.5	1.2	3.6	2.2	19.5	13.9
NF Lewis	2.1	1.7	2.7	3.9	1.6	1.1	2.6	1.3	9.0	8.0
Salmon	0.0	0.0	0.0	0.0	0.8	0.8	7.0	5.6	7.8	6.4
Washougal	7.7	8.4	5.6	6.3	0.6	1.0	3.1	1.4	17.0	17.1
Total	21.3	17.9	12.2	12.9	3.5	4.1	16.3	10.5	53.3	45.4
		84%		106%		117%		64%		85%

2.3.1 Stream Survey Protocol

Stream habitat surveys were conducted using a modified USFS Level II protocol (U.S. Forest Service 2001) including natural stream order (NSO) designations. USFS Level II survey protocols were selected for use during this project to provide consistency with USFS and Washington WDFW habitat data previously collected during Phase 1 studies. The USFS protocols were developed originally for long-term monitoring of wadeable stream habitats during low flow conditions. Not all of the components of the USFS protocols were necessary to achieve the specific task objectives and protocols were modified accordingly. Specific modifications were needed for the raft surveys that were conducted in non-wadeable sections of the lower mainstem river reaches. In these river sections, measurements of river depth are highly variable and moreover, impractical to take, and therefore this metric was not included. To collect appropriate data to update current EDT models, the protocols were also modified to use habitat types consistent with EDT. The surveys were also modified to avoid redundancy of data collection necessary for accommodating the hydromodifications, riparian, and sediment sources tasks. Measurements of flood-prone width were derived via remote assessment techniques. In modifying the protocols, variables were only eliminated a) that were covered by other means;

b) that would have provided limited additional value to the surveys, or c) that would have contained an unacceptable level of uncertainty associated with their measurement.

Field data were collected as described in the USFS Level II field manual (U.S. Forest Service 2001). Data were entered into dataloggers, and downloaded to a computer. All field data underwent quality assurance/quality control (QA/QC) checks. The data were then reviewed to: (1) identify areas with nonfunctional habitat, and (2) identify areas that could be considered for restoration.

Field methods for habitat surveys were collected in a manner consistent with Version 2.1 of USFS Level II habitat surveys. We collected habitat data in thirty-four (34) EDT reaches. Within these reaches, the stream lengths surveyed ranged from 0.4 to 3.3 mi long. Data were collected on 7 stream habitat types: pools, beaver ponds, small cobble riffle, large cobble riffle, glide, cascade, and other. For each type, every 10th habitat unit encountered was sampled. Variations from standard protocols are identified in Table 2. Data were collected on different variables during wadeable and raftable surveys (Table 2). In addition, river discharge was measured and a pebble count was obtained at least once in each geographic subwatershed, (Table 3). Culverts that were encountered during the surveys were qualitatively assessed for fish passage and were categorized in accordance with the USFS Level II definitions as passable, impassable, or as needing an additional quantitative estimate.

2.3.2 View-to-Sky Assessment

Data collected during the stream surveys were used in a View-to-the-Sky (VTS) assessment for the targeted watersheds using procedures described by Washington Forest Practices Board (1997). The VTS is the fraction of a hemisphere, centered over the stream that is unobstructed by either vegetation or topography. The VTS methodology is a geometric expression of the relationship between vegetation height and stream channel width. These factors control the relative openness of a channel and hence, the amount of incoming and outgoing solar radiation. A waterbody's openness to the sky, often regarded as the opposite of canopy closure, is a major factor influencing stream temperatures (Sullivan et al. 1990). The proportion of the sky effectively blocked by streamside vegetation and topography determines the relative degree water temperature will be depressed below ambient air temperatures. Coupled with the temperature elevation screen (Sullivan et al. 1990 as adopted by Washington Forest Practices Board rule), VTS calculations can be used to estimate potential stream temperatures per the Washington State DNR Watershed Analysis guidelines (Washington Forest Practices Board 1997). A stream of a given size at a certain elevation should be capable of achieving a reference

Table 2. Data collected during the habitat surveys of the Kalama, N.F. Lewis, Salmon, and Washougal rivers, Washington as modified from USFS Level II stream survey protocols. Italics indicate USFS variables that were not used in the surveys.

USFS Level II Variables	Modified Level II Variables	Wadeable Surveys	Rafting Surveys
Natural stream order	Natural stream order		
Time	Time		
Water Temperature	Water Temperature		
Habitat type	Habitat type		
Habitat length	Habitat length (ft, mi?)		
Habitat width	Habitat width (ft)		
Min/max depth	Min/max depth (ft)		Estimated
Average depth of riffles	--	--	--
Depth at tail pool crest	Depth at tail pool crest (ft)		--
Percent substrate	Percent substrate (%)		--
Large wood count	Large wood count		
Bankfull width	Bankfull width (ft)		
Average bankfull depth	Average bankfull depth (ft)		--
Max bankfull depth	Max bankfull depth (ft)		--
Floodprone depth	--	calculated	Calculated
*Floodprone width**	--	estimated	estimated--
Bank stability	Bank stability		
Innerzone riparian vegetation class (successional)	Riparian vegetation category		
Dominant overstory of innerzone	Bankfull to treeline distance		
Dominant understory of innerzone	View to sky angles		
Outerzone riparian vegetation class (successional)	Inner riparian width	Estimated	Estimated
Dominant overstory of outerzone	Canopy composition, age and density		
Dominant understory of outerzone	Anthropogenic Influences	Descriptive	Descriptive
--	Embeddedness		

*data obtained during other tasks

Table 3. Grain size ranges for substrate size categories used in visual observations and pebble counts, during the habitat surveys conducted in 2004 on the Kalama, N.F. Lewis, Salmon, and Washougal rivers, Washington.

Category	Grain Size Range
Sand	< 2 mm
Gravel	2 – 64 mm
Cobble	64 – 256 mm
Boulder	0.26 – 4.1 m
Bedrock	> 4.1 m

temperature as determined under the assumption of mature timber growing immediately adjacent to the channel's edge. The VTS methodology defines mature timber in western Washington as 150 feet tall.

VTS estimates for potential reference temperatures and estimated present day temperatures were calculated at each of the surveyed EDT reaches in the five river basins. Present day temperatures were estimated using the approximate degree of channel openness as estimated by both: (1) the angle of vegetation height effectively blocking the stream, and (2) estimates of the distance from the channel centerline to the first row of blocking vegetation on either side of the channel, at each of the 10th habitat units conducted during the stream inventory. The lengths of riparian units in Task 3 are typically 2,000 ft or greater depending on specific longitudinal changes in riparian conditions. These units are quite long compared to the every 10th habitat unit riparian transect data collected during the stream surveys. As such, comparisons between these approaches might be somewhat misleading and need to be used with caution. Surface water temperatures generally equilibrate over a long distance of stream channel rather than react to immediate site-specific conditions (Washington Forest Practices Board 1997). Current estimated surface water temperatures determined via VTS calculations were also compared to actual measurements performed during the long-term monitoring surveys where information was available. Deviations from the expected temperature values were evaluated in relation to site-specific variables.

2.3.3 Enhance Existing EDT Model

The EDT methodology uses a standardized set of measurable attributes (Level 2 Environmental Attributes) for characterizing the freshwater environment as it affects the performance of salmonids. As part of a previous Lower Columbia Subbasin Planning effort, EDT attributes were rated and entered into a Stream Reach Editor (SRE) to calculate the capacity, productivity, abundance and life-history diversity potential of each river basin for specific salmonid species. Many of the attribute ratings were based on professional opinion of local managers and not hard data. Thus, to enhance the existing EDT model we used data collected during this watershed assessment to develop new EDT attribute ratings and to create an updated SRE for each of the river basins surveyed. EDT attributes ratings were developed for 13 attributes (Table 4) and 34 of the previously delineated EDT reaches. In addition, we compared the previous EDT ratings to the new ratings developed from the hydromodification analysis and habitat survey data collected in 2004 to begin to understand how the new data might influence the existing EDT model output. A description of the methods used to calculate new ratings for each EDT attribute follows.

During the field surveys, wetted widths were measured or estimated for each habitat unit. Bankfull widths were measured for approximately every tenth habitat unit of each habitat type. The habitat unit measurements were averaged, and weighted by area to estimate the wetted and bankfull widths for each reach. These values were compared to the minimum and maximum widths, respectively, as presented in the SRE dataset used for the EDT analysis for Subbasin Planning. In EDT, stream widths are shaped monthly throughout the year based on average monthly flow. For each reach, the percent change in habitat area was calculated using the channel length and applying the monthly width shape pattern from the SRE to both datasets. The monthly change in habitat area was calculated and then averaged for the year. For reaches without bankfull width measurements, the SRE maximum width was substituted to estimate the percent change in habitat quantity. It is important to note that the percent change in habitat quantity was calculated from the SRE reach lengths, which were not verified as part of this analysis.

Hydromodifications were analyzed for the lower portions of the mainstem Kalama, Lewis, and Washougal rivers. The *connected side channel* referred to in the Hydromodification analysis is analogous to *off-channel habitat factor*, as described in EDT. In EDT, off-channel habitat factor is expressed as a percent of the area of the reach during the high flow month. Off-channel habitat factor was calculated from the estimated lengths of the *bank* and the *connected side channel*, under the assumption that the *connected side channel* was half the width of the mainstem channel. Channel length and maximum width were used to estimate the percent change in habitat quantity. For reaches without bankfull width measurements, the SRE maximum width was substituted.

Table 4. Description of ecosystem diagnosis and treatment level 2 environmental attribute ratings (Lestelle et al. 2004).

CHANNEL WIDTH – MINIMUM	
Feet	Average width of the wetted channel during low flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels.
CHANNEL WIDTH – MAXIMUM	
Feet	Average width of the wetted channel during high flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels.
OFF-CHANNEL HABITAT FACTOR	
Multiplier	A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat. Off-channel habitat consists of oxbows, back swamps, riverine ponds, and the channels that connect them to the main channel or its side channels.
HABITAT TYPES	
Primary Pool	Percentage of the wetted channel surface area comprising pools, excluding beaver ponds.
Backwater Pool	Percentage of the wetted channel surface area comprising backwater pools. Backwater pools are habitat units located along the channel margins but are otherwise enclosed—though still connected to the main channel (or side channel). *Note: backwater pools as defined here include "alcoves" as described by Nickleson and others (1992).*
Beaver Pond	Percentage of the wetted channel surface area comprising beaver ponds. *Note: this includes only those sites associated with the main channel or its side channels. Off-channel sites are addressed through the Off-Channel Habitat Factor.*
Pool Tailout	Percentage of the wetted channel surface area comprising pool tailouts.
Glide	Percentage of the wetted channel surface area comprising glides. *Note: There is a general lack of consensus regarding the definition of glides (Hawkins and others 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore and others 1999): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of < 1% gradient.* Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.
Small Cobble Riffle	Percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts and others (1983) based on information in Gordon and others (1991): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (> 11.9 inch diameter).

Table 4. Description of ecosystem diagnosis and treatment level 2 environmental attribute ratings (Lestelle et al. 2004).

Large Cobble Riffle	Percentage of the wetted channel surface area comprising large cobble/boulder riffles. Particle sizes of substrate modified from Platts and others (1983) based on information in Gordon and others (1991): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (> 11.9 inch diameter).
GRADIENT	
Percent	Average gradient of the main channel of the reach over its entire length.
CONFINEMENT NATURAL	
0	Reach mostly unconfined by natural features **--** Average valley width > 4 channel widths.
1	Reach comprised approximately equally of unconfined and moderately confined sections.
2	Reach mostly moderately confined by natural features **--** Average valley width 2-4 channel widths.
3	Reach comprised approximately equally of moderately confined and unconfined sections.
4	Reach mostly confined by natural features **--** Average valley width < 2 channel widths.
CONFINEMENT HYDROMODIFICATIONS	
0	The stream channel within the reach is essentially fully connected to its floodplain. Very minor structures may exist in the reach that do not result in flow constriction or restriction. Note: this describes both a natural condition within a naturally unconfined channel as well as the natural condition within a canyon.
1	Some portion of the stream channel, though less than 10% (of the sum of lengths of both banks), is disconnected from its floodplain along one or both banks due to man-made structures or ditching.
2	More than 10% and less than 40% of the entire length of the stream channel (sum of lengths of both banks) within the reach is disconnected from its floodplain along one or both banks due to man-made structures or ditching.
3	More than 40% and less than 80% of the entire length of the stream channel (sum of lengths of both banks) within the reach is disconnected from its floodplain along one or both banks due to man-made structures or ditching.
4	Greater than 80% of the entire length of the stream channel (sum of lengths of both banks) within the reach is disconnected from its floodplain along one or both banks due to man-made structures or ditching.
RIPARIAN FUNCTION	
0	Strong linkages with no anthropogenic influences.
1	>75-90% of functional attributes present (overbank flows, vegetated streambanks, groundwater interactions typically present).
2	50-75% functional attribute rating**-** significant loss of riparian functioning**-** minor channel incision, diminished riparian vegetation structure and inputs etc.

Table 4. Description of ecosystem diagnosis and treatment level 2 environmental attribute ratings (Lestelle et al. 2004).

3	25-50% similarity to natural conditions in functional attributes- many linkages between the stream and its floodplain are severed.
4	< 25% functional attribute rating: complete severing of floodplain-stream linkages.
WOOD	
0	A complex mixture of single large pieces and accumulations consisting of all sizes, decay classes, and species origins; cross-channel jams are present where appropriate vegetation and channel conditions facilitate their existence; large wood pieces are a dominant influence on channel diversity (e.g., pools, gravel bars, and mid-channel islands) where channel gradient and flow allow such influences. Density of LW (pieces per channel width [CW]) consistent with the following: channel width <25 ft -- 3-10 pieces/CW, 25-50 ft -- 3-10 pieces/CW, 50-150 ft -- 7-30 pieces/CW, 150-400 ft -- 20-50 pieces/CW in conjunction with large jams in areas where accumulations might occur, >400 ft -- 15-37 pieces/CW in conjunction with large jams in areas where accumulations might occur.
1	Complex array of large wood pieces but fewer cross channel bars and fewer pieces of sound large wood due to less recruitment than index level 1; influences of large wood and jams are a prevalent influence on channel morphology where channel gradient and flow allow such influences. Density of LW (pieces per channel width CW) consistent with the following: channel width <25 ft -- 2-3 pieces/CW, 25-50 ft -- 2-4 pieces/CW, 50-150 ft -- 3-7 pieces/CW, 150-400 ft -- 10-20 pieces/CW (excluding large jams) in conjunction with large jams in areas where accumulations might occur, >400 ft -- 8-15 pieces/CW (excluding large jams) in conjunction with large jams in areas where accumulations might occur.
2	Few pieces of large wood and their lengths are reduced and decay classes older due to less recruitment than in index level 1; small debris jams poorly anchored in place; large wood habitat and channel features of large wood origin are uncommon where channel gradient and flow allow such influences. Density of LW (pieces per channel width CW) consistent with the following: channel width <25 ft -- 1-2 pieces/CW, 25-50 ft -- 1-2 pieces/CW, 50-150 ft -- 1-3 pieces/CW, 150-400 ft -- 10-20 pieces/CW without large jams in areas where accumulations might occur, >400 ft -- 8-15 pieces/CW without large jams in areas where accumulations might occur.
3	Large pieces of wood rare and the natural function of wood pieces limited due to diminished quantities, sizes, decay classes and the capacity of the riparian streambank vegetation to retain pieces where channel gradient and flow allow such influences. Density of LW (pieces per channel width CW) consistent with the following: channel width <25 ft -- 0.33-1 pieces/CW, 25-50 ft -- 0.33-1 pieces/CW, 50-150 ft -- 0.33-1 pieces/CW, 150-400 ft -- 3-10 pieces/CW without large jams in areas where accumulations might occur, >400 ft -- 2-8 pieces/CW without large jams in areas where accumulations might occur.
4	Pieces of LW rare. Density of LW (pieces per channel width CW) consistent with the following: channel width <25 ft -- <0.33 pieces/CW, 25-50 ft -- <0.33 pieces/CW, 50-150 ft -- <0.33 pieces/CW, 150-400 ft -- <3 pieces/CW with accumulations where they might occur, >400 ft -- <2 pieces/CW with no accumulations where they might occur.

Table 4. Description of ecosystem diagnosis and treatment level 2 environmental attribute ratings (Lestelle et al. 2004).

EMBEDDEDNESS (APPLIES TO POOL TAILOUTS AND SMALL COBBLE RIFFLES)	
0	< 10% of surface covered by fine sediment
1	> 10 and < 25% covered by fine sediment
2	> 25 and < 50% covered by fine sediment
3	> 50 and < 90% covered by fine sediment
4	> 90% covered by fine sediment
FINE SEDIMENT (APPLIES TO POOL TAILOUTS AND SMALL COBBLE RIFFLES)	
0	Particle sizes <0.85 mm: < 6% OR Particle sizes <6.3 mm: <10%
1	Particle sizes <0.85 mm: > 6% and < 11% OR Particle sizes <6.3 mm: >10% and <25%
2	Particle sizes <0.85 mm: > 11% and < 18% OR Particle sizes <6.3 mm: >25% and <40%
3	Particle sizes <0.85 mm: > 18% and < 30% OR Particle sizes <6.3 mm: >40% and <60%
4	Particle sizes <0.85 mm: > 30% fines OR Particle sizes <6.3 mm: >60%

Habitat diversity data (number of pool, riffles, glides) collected during the field surveys was compared to the SRE dataset. For the most part, the habitat survey data was synonymous with the EDT habitat type definitions. The exception being that in EDT, cascades are included in the definition of large cobble riffles. The habitat unit measurements were averaged, weighted by area, to estimate the percent of the reach comprised of each EDT habitat type.

For each reach surveyed, natural confinement was expressed in terms of confined, moderately confined, or unconfined and was attributed to a Paustian Process Group. These terms were categorized into an EDT rating or range of ratings. Confinement due to hydromodifications (man-caused) was estimated by subtracting the proportion of unmodified channel from the total channel, as determined from the hydromodification analysis previously described.

Riparian function ratings were determined from the percent of disturbance recorded for approximately every tenth habitat unit of each habitat type. The riparian disturbance was averaged, and then weighted by area to develop the EDT ratings for each reach. Pieces of small, medium and large wood present in the stream channel were documented during the habitat surveys. The number of pieces was summed for each reach and divided by the reach channel width. EDT ratings were derived from the total number of pieces per channel width.

The substrate attributes of Embeddedness and fine sediment ratings were compared to the habitat survey data. Embeddedness refers to the extent that larger cobbles or gravel are surrounded by or covered by fine sediment. During the habitat surveys, percent embeddedness and substrate composition were visually estimated for each habitat unit but were not collected for pool tailout habitats. In EDT, both embeddedness and fine sediment ratings only apply to spawning habitat types (i.e., small cobble riffles, pool tailouts, and to a lesser extent, glides). Glides were excluded from the substrate comparison because in EDT glides are not considered spawning habitat. Percent embeddedness survey data was averaged, and then weighted by area, for small cobble riffle habitat types and converted to an EDT rating, as defined in Table 4. Fine sediment ratings were developed for each reach from the percent sand and smaller particles substrate category for small cobble riffles, which were then averaged and weighted by area. Definitions of fine sediment ratings appear in Table 4.

2.4 IDENTIFY SEDIMENT SOURCES

An important goal of this task was to identify streams where restoration actions addressing fine sediment inputs and spawning gravel availability could be implemented effectively, or alternatively, where fine sediment levels or sediment transport characteristics may adversely affect the successful implementation and benefits of different types of restoration projects.

Fine sediments affect fish habitat quality and survival at broader scales than hydromodifications, riparian habitat, and physical habitat characterized at the site level. The scale of analysis is important because sediments are transported downstream. Hence, while a specific point source of fine sediments can be identified and controlled in the upper segments of a stream, the effects of reducing the input rate on downstream segments will be highly variable. Cumulative effects typically increase in the downstream direction because the contributing area for fine sediments increases. In general, correction of fine sediment impacts in the mainstem river of each of the major basins studied here would require a more concerted, strategic effort at the watershed scale, than correction of impacts within individual subbasins. For this study, we focused on identifying restoration opportunities linked to reducing or ameliorating fine sediment impacts in tributaries habitats (source control). In addition, we identified reaches where substrates suitable for spawning use are in short supply, and reaches where it is plentiful. Such information was critical to identifying feasible and effective projects that can help increase reproductive success of salmonid fishes, and the physical processes that influence project effectiveness.

In addition to evaluating restoration options, we also evaluated the accuracy of the EDT model input data and resulting conclusions regarding degree of impairment and restoration potential. This assessment was an important step toward validating (or determining additional data needs of) the EDT model. By comparing the model inputs with data collected in the field, we were able to determine if the current condition was accurately represented in the model. This approach was accomplished by comparing data collected at the EDT reach scale with the data input into the model. The null hypothesis was that relative differences in fine sediment levels determined through the field sampling were similar to differences postulated by the model.

2.4.1 Office-Based Analyses

2.4.1.1 Study Site Selection

Subwatersheds were first identified where fine sediment had been identified in the IHS watershed summary and subsequent subbasin planning reports as a major limiting factor, through either EDT or IWA determinations. Efforts were concentrated in these basins and downstream. The results of the EDT and IWA efforts were used to prioritize and strategically select sampling locations for assessing fine sediment conditions and impacts. All EDT reaches were first classified according to the following five conditions:

I. The reach was identified as a "High" impact reach in the EDT sediment column (presented in the "Reach-Level Habitat Factor Analysis" section of the respective basin summaries;

II. The reach was located within a subwatershed identified by the IWA as being "impaired" at the local level with respect to sediment;

III. The reach was a tributary within a subwatershed identified by the IWA as being "moderately impaired" at the local level with respect to sediment;

IV. The reach was identified as a Tier A reach in the "Integration" section of the respective basin summaries;

V. The reach was specifically identified in conjunction with a High Impact Habitat Factor in any tier in the "Integration" section of the respective basin summaries.

A reach was identified for pebble count and embeddedness sampling if either condition I or II was true, or if conditions III and V were both true. A reach was identified for embeddedness sampling only if both conditions III and IV were true and the reach was not selected for pebble count sampling. Some reaches originally selected for pebble counting were subsequently relegated to embeddedness sampling only when it was a mainstem reach with adjacent reaches also slated for sampling (i.e., the more laborious pebble counting data would have been redundant), or did not have a priority species associated with it. The resulting sampling effort allocation and reasons for re-considering the sampling data to be collected are presented in Tables 5 through 7.

2.4.1.2 Aerial Photograph and Map Interpretation

Aerial photo interpretation was conducted in basins where sediment impacts were estimated to be highest (see site selection methods described below). Available aerial photographs provided by the LCFRB and Clark County, and 1980 DNR orthophotographs at the University of Washington Library, were reviewed to see if major anthropogenic and natural sediment sources could be identified sufficiently and consistently in each basin. Mass wasting locations were identifiable only if they were severe and unvegetated. Similarly, it was not possible to assess likely road and streambank point sources from the photographs without using a stereoscope. After review of the photographs, it was concluded to sufficient resolution sediment sources could not be discerned in a cost-effective manner. The photographs were thus reviewed primarily with respect to discerning major land use types (e.g., forestry vs. rural vs. agricultural, etc.), assuming that each type has a characteristic mechanism for sediment delivery to stream channels.

GIS overlays of mapped geologic types and EDT stream reach locations were reviewed to identify the likely grain sizes (i.e., fine vs. coarse) of fine sediments delivered to each reach, both from local inputs and from upstream. The primary geologic map used was the DNR coverage for the southwestern quadrant of Washington State (Walsh et al. 1987), which was sufficient for assessing fine and coarse sediment sources and characteristics at the subbasins/EDT reach scale.

2.4.2 Field Data Collection

Field efforts focused on subbasins where instream fine sediment levels were relatively high. Field data collection included broad scale data on fine sediment levels and grain size distributions of substrates suitable for salmonid spawning. We assumed that subbasins with high instream fine sediment levels were subject to large inputs of fine sediment, although it was not possible to identify and partition specific sources.

Table 5. Sediment impact characteristics of EDT reaches in the Kalama River basin, Washington and resulting sample site selection for pebble count and embeddedness determinations.

	EDT/IWA Analysis Conclusions					Sample Site Selection Details		
Reach Name	**High Impact (EDT)**	**Impaired (IWA)**	**Moderately Impaired (IWA): Tributaries**	**Tier A**	**High Impact Priority Reach by Species**	**Pebble Count, Embeddedness Sampling?**	**Embeddedness Sampling Only?**	**Reason For No Pebble Count**
Arnold Creek		Y		Y		Y		
Bear Creek			Y					
Bush Creek	Y		Y	Y		Y		
Cedar Creek			Y	Y			Y	
Dee Creek			Y					
Elk Creek			Y					
Gobar Creek			Y					
Hatchery Creek								
Indian Creek				Y				
Jacks Creek			Y	Y			Y	
Kalama 1 tidal				Y				
Kalama 2	Y			Y	Y	Y		
Kalama 3	Y			Y	Y	Y		
Kalama 4				Y				
Kalama 5	Y			Y		Y		
Kalama 6	Y			Y	Y		Y	Redundant
Kalama 7	Y			Y		Y		
Kalama 8	Y			Y	Y		Y	Redundant
Kalama 9	Y			Y	Y	Y		
Kalama 10	Y			Y	Y		Y	Redundant
Kalama 11	Y			Y	Y	Y		
Kalama 12	Y			Y	Y		Y	Redundant

Table 5. Sediment impact characteristics of EDT reaches in the Kalama River basin, Washington and resulting sample site selection for pebble count and embeddedness determinations.

	EDT/IWA Analysis Conclusions					Sample Site Selection Details		
Reach Name	**High Impact (EDT)**	**Impaired (IWA)**	**Moderately Impaired (IWA): Tributaries**	**Tier A**	**High Impact Priority Reach by Species**	**Pebble Count, Embeddedness Sampling?**	**Embeddedness Sampling Only?**	**Reason For No Pebble Count**
Kalama 13	Y			Y		Y		
Kalama 14	Y			Y			Y	Redundant
Kalama 15	Y			Y	Y	Y		
Kalama 16	Y			Y			Y	Redundant
Kalama 17	Y			Y	Y	Y		
Kalama 18	Y			Y	Y		Y	Redundant
Kalama 19	Y			Y	Y	Y		
Kalama 20	Y			Y	Y		Y	Redundant
Kalama 21	Y			Y		Y		
Knowlton Creek				Y				
Lakeview Peak Creek			Y	Y			Y	
Langdon Creek	Y		Y	Y		Y		
Little Kalama River			Y					
Lost Creek			Y	Y			Y	
Lower Falls				Y				
NF Kalama River			Y					
Spencer Creek			Y	Y			Y	
Summers Creek	Y			Y		Y		
Unnamed Creek (27.0087)			Y	Y			Y	
Wildhorse Cr				Y				
Wolf Creek			Y	Y			Y	

Table 6. Sediment impact characteristics of EDT reaches in the lower North Fork Lewis River basin, Washington, and resulting sample site selection for pebble count and embeddedness determinations.

	EDT/IWA Analysis Conclusions					Sample Site Selection Details		
Reach Name	**High Impact (EDT)**	**Impaired (IWA)**	**Moderately Impaired (IWA): Tributaries**	**Tier A**	**High Impact Priority Reach by Species**	**Pebble Count, Embeddedness Sampling?**	**Embeddedness Sampling Only?**	**Reason For No Pebble Count**
Bitter Creek	Y		Y			Y		
Brush Creek			Y					
Cedar Creek 1a			Y	Y			Y	
Cedar Creek 1b			Y					
Cedar Creek 2								
Cedar Creek 3			Y					
Cedar Creek 4			Y					
Cedar Creek 5			Y					
Cedar Creek 6	Y		Y			Y		
Chelatchie Cr 1			Y					
Chelatchie Cr 2			Y					
Grist Mill			Y					
Houghton Cr			Y	Y			Y	
John Creek	Y		Y			Y		
Johnson Cr	Y		Y	Y		Y		
Lewis 1 tidal			Y					
Lewis 2 tidal_A			Y					
Lewis 2 tidal_B			Y	Y			Y	
Lewis 3	Y		Y	Y	Y	Y		
Lewis 4			Y	Y	Y	Y		
Lewis 5			Y	Y			Y	
Lewis 6			Y	Y			Y	

Table 6. Sediment impact characteristics of EDT reaches in the lower North Fork Lewis River basin, Washington, and resulting sample site selection for pebble count and embeddedness determinations.

	EDT/IWA Analysis Conclusions					Sample Site Selection Details		
Reach Name	**High Impact (EDT)**	**Impaired (IWA)**	**Moderately Impaired (IWA): Tributaries**	**Tier A**	**High Impact Priority Reach by Species**	**Pebble Count, Embeddedness Sampling?**	**Embeddedness Sampling Only?**	**Reason For No Pebble Count**
Lewis 7			Y					
NF Chelatchie Cr	Y		Y			Y		
Pup Creek			Y					
Robinson Cr			Y	Y			Y	
Ross Cr			Y	Y			Y	

Table 7. Sediment impact characteristics of EDT reaches in the Washougal River basin, Washington and resulting sample site selection for pebble count and embeddedness determinations.

	EDT/IWA Analysis Conclusions					Sample Site Selection Details		
Reach Name	**High Impact (EDT)**	**Impaired (IWA)**	**Moderately Impaired (IWA): Tributaries**	**Tier A**	**High Impact Priority Reach by Species**	**Pebble Count, Embeddedness Sampling?**	**Embeddedness Sampling Only?**	**Reason For No Pebble Count**
Bear Cr			Y					
Bluebird Cr								
Boulder Cr								
Boulder Creek 1B	Y					Y		
Boulder Creek 1C	Y						Y	Redundant data
Boulder Creek Culv1								
Boulder Creek Falls1								
Cougar Cr			Y					
Deer Cr			Y	Y			Y	
Degraded								
Dougan Cr			Y					
Dougan Creek 1B			Y					
Dougan Creek Culv 1			Y					
Dougan Falls			Y	Y			Y	
Jones Cr	Y		Y			Y		
Jones Creek 1B			Y					
Jones Creek Culv 1			Y					
Lacamas	Y						Y	Not important gravel source to mainstem
LB tribA (28.0211)								
Little Washougal 1			Y		Y	Y		
Little Washougal 1B	Y		Y		Y		Y	Redundant data

Table 7. Sediment impact characteristics of EDT reaches in the Washougal River basin, Washington and resulting sample site selection for pebble count and embeddedness determinations.

	EDT/IWA Analysis Conclusions					Sample Site Selection Details		
Reach Name	**High Impact (EDT)**	**Impaired (IWA)**	**Moderately Impaired (IWA): Tributaries**	**Tier A**	**High Impact Priority Reach by Species**	**Pebble Count, Embeddedness Sampling?**	**Embeddedness Sampling Only?**	**Reason For No Pebble Count**
Little Washougal 1C			Y					
Little Washougal 2			Y		Y	Y		
Little Washougal 2 Culv1			Y					
Little Washougal 2B	Y		Y		Y	Y		
Little Washougal 2C	Y		Y		Y		Y	Redundant data
Little Washougal 2D	Y		Y		Y	Y		
Little Washougal 2E	Y		Y		Y		Y	
Little Washougal 3			Y					
Little Washougal 4			Y					
Little Washougal Culv 1			Y					
Little Washougal Culv 2			Y					
Lookout Cr			Y					
Meander Cr			Y	Y			Y	
Prospector Cr 1			Y	Y			Y	
Prospector Cr 2			Y	Y			Y	
Prospector Creek 1B			Y	Y			Y	
Prospector Creek Culv 1			Y	Y			Y	
RB trib 1A								
RB trib 1B								
RB trib 1C			Y					
RB trib 2			Y					
RB trib1 Barrier 1								

Table 7. Sediment impact characteristics of EDT reaches in the Washougal River basin, Washington and resulting sample site selection for pebble count and embeddedness determinations.

	EDT/IWA Analysis Conclusions					Sample Site Selection Details		
Reach Name	**High Impact (EDT)**	**Impaired (IWA)**	**Moderately Impaired (IWA): Tributaries**	**Tier A**	**High Impact Priority Reach by Species**	**Pebble Count, Embeddedness Sampling?**	**Embeddedness Sampling Only?**	**Reason For No Pebble Count**
Salmon Falls								
Silver Cr								
Stebbins C			Y					
Texas Cr	Y		Y	Y		Y		
Timber Cr			Y	Y			Y	
Timber Creek 2			Y	Y			Y	
Timber Creek Culv 1			Y	Y			Y	
Washougal 1 tidal			Y	Y			Y	
Washougal 2 tidal			Y	Y			Y	
Washougal 3	Y		Y	Y	Y	Y		
Washougal 4			Y		Y	Y		
Washougal 5			Y					
Washougal 6			Y					
Washougal 7			Y					
Washougal 8	Y		Y		Y	Y		
Washougal 9	Y		Y		Y	Y		
Washougal 10			Y					
Washougal 10A			Y					
Washougal 11			Y					
Washougal 12			Y	Y			Y	
Washougal 13			Y	Y			Y	
Washougal 14			Y	Y			Y	

Table 7. Sediment impact characteristics of EDT reaches in the Washougal River basin, Washington and resulting sample site selection for pebble count and embeddedness determinations.

	EDT/IWA Analysis Conclusions					Sample Site Selection Details		
Reach Name	**High Impact (EDT)**	**Impaired (IWA)**	**Moderately Impaired (IWA): Tributaries**	**Tier A**	**High Impact Priority Reach by Species**	**Pebble Count, Embeddedness Sampling?**	**Embeddedness Sampling Only?**	**Reason For No Pebble Count**
Washougal 15			Y	Y			Y	
Washougal 16			Y	Y			Y	
Washougal 17			Y	Y			Y	
Washougal 18			Y	Y			Y	
Washougal 19			Y	Y			Y	
Washougal 20			Y					
Washougal Falls 1			Y					
WF Washougal 1	Y		Y	Y	Y	Y		
WF Washougal 1B	Y		Y	Y	Y		Y	Redundant data
WF Washougal 2			Y	Y	Y	Y		
WF Washougal 3	Y		Y	Y		Y	Y	Redundant data
WF Washougal Falls 1			Y	Y			Y	
WF Washougal Weir			Y	Y			Y	
Wildboy Cr 1	Y		Y	Y		Y		
Wildboy Cr 2	Y		Y	Y			Y	Redundant data
Winkler Cr			Y					

Field visits were made to as many of the subbasins in Tables 4 through 6 as possible based on accessibility. In the interest of efficiency, the visits were conducted over a 4-day period during the week of September 20, 2004, by a water resource engineer/fish biologist and a fluvial geomorphologist. The surveys served to identify where fine sediments were a problem, whether the problem could be addressed directly, and where fine sediments could influence success of various restoration projects. In addition, differences between basins were evaluated regarding the quantity and rates at which spawning-sized substrates are transported as bedload in each subbasin.

The stream survey habitat crews collected pebble count and embeddedness data in subbasins sampled for the habitat task.

2.4.2.1 Pebble Count Procedure

Pebble count data were collected to document watershed scale variability in supply of gravel and cobble for spawning habitat, and also to evaluate EDT model input and output data. For this, we compared field-derived pebble counts collected from areas representing commonly transported bedload, with observations on grain size distribution (percentiles) by reach slope and overall channel size. We assumed that channels with the same general size and slope can differ in grain size distributions reflective of watershed scale variation in supply of substrates suitable for spawning.

Pebble counts were conducted in select EDT reaches identified as having high sediment impacts (Tables 4 to 6), and in other reaches upstream and downstream of impacted tributaries identified in the EDT analysis. In small channels, the count was conducted over either:

(I) The middle of a depositional point bar to reflect deposition of finer gravel and cobble that is more commonly transported as bedload;

(II) A patch near the thalweg of a representative riffle when such bars are generally absent; or

(III) From localized deposits behind larger flow obstructions present, depending on the sediment supply and transport balance, or "net supply."

These three classes are presented in order from generally high to low net supply. In the main channel, pebble counts were most frequently performed over the downstream half of a depositional point bar, or from localized deposits in gravel poor streams. The counts were performed to characterize the texture of the bedload deposit, not the texture of the entire channel. Particles were selected while walking randomly over the sample location (Wolman 1964).

2.4.2.2 Embeddedness Procedure

For this study, we used a rapid visual assessment method to determine embeddedness (Platts et al. 1983). This method is repeatable and provides information at a level sufficient to evaluate fine sediment impacts and sources. The degree of surface embeddedness was characterized over riffle and run areas, and classified to 0%, 25%, 50%, 75%, and 100% levels (class splits at roughly one-half way intervals between the specified percentages). These levels were selected to discern watershed scale effects of fine sediments. For example, salmonid embryo survival to emergence is generally good when embeddedness levels are below 50 percent, and poor when above 75 percent (cf. Chapman and McLeod 1987). Streams with high fine sediment loads tend to have the streambed pore spaces completely filled or embedded (>75%). Streams with low loads tend to have relatively clean pore spaces; given that porosity of gravel and cobble mixtures is on the order of 30 to 35 percent, it may be assumed that embeddedness levels <37.5 percent (break between 25 percent and 50 percent ratings) are characteristic of a low fine sediment supply (or alternatively, cases where transport capacity exceeds supply). We used these criteria to evaluate fine sediment impacts and restoration potential.

We determined embeddedness values after first walking upstream and downstream from a given access point in smaller channels, or after making multiple stops in mainstem reaches of the major study basins. One of the five categories above was assigned to the reach based on the integrated visual assessment, by consensus of the sediment and hydromodification analysts. In contrast, the habitat teams first determined embeddedness values for each habitat unit to the nearest 5 percent level, and then computed a single average value that was assigned to one of the five categories.

2.4.3 Sediment Data Analysis

Longitudinal profiles of stream elevation were derived from USGS 1:24,000 scale maps and plotted for each subbasin and major mainstem identified as having fine sediment impacts in the EDT and IWA analyses. The information was compared against the pebble count grain size distribution quantiles (e.g., D_{50}, D_{90}), which were also plotted against slope in each basin. The longitudinal profiles were used to interpret the grain size and spawning gravel distributions. Information presented in the subbasin plans regarding known important spawning areas was also used to infer gravel availability at the basin scale.

Percent embeddedness levels were reviewed and compared between basins and against the geology map. Fine sediment size (i.e., clay vs. silt vs. fine sand vs. coarse sand) observed in the field was corroborated against the geology maps. The embeddedness values were compared with values used in the original EDT analysis to compare how well the initial EDT effort characterized fine sediment levels.

The collective information was interpreted with respect to identifying subbasins where:

- Fine sediment levels might be reduced to provide relatively greater benefit to spawning habitat;
- Fine sediment levels would or would not overwhelm efforts to improve spawning habitat-related projects;
- Direct and/or indirect spawning gravel enhancement projects should be avoided; and
- Specific gravel- or fine sediment-related projects might have a greater certainty of success and be more likely to lead to benefits to salmon.

3. REFERENCES

Chapman, D.W., and K.P. McLeod. 1987. Development of criteria for fine sediment in the northern Rockies ecoregion. Final report prepared for EPA Region 10, Work assignment 2-73. Battelle Columbus Laboratories. EPA 910/9-87-162. 279 p.

LCFRB. 2004. 2004 Interim Habitat Strategy. Appendix VII: Integrated Watershed Assessment (IWA) description and methods. Document prepared by the Lower Columbia Fish Recovery Board, Longview, Washington, 26 p. www lcfrb.gen.wa.us \Habitat Strategy\Final Docs\Appendix VII IWA Description and Methods.doc.

NMFS. 1996. Making Endangered Species Act determinations of effect for individual or grouped actions at the watershed scale. Prepared by: National Marine Fisheries Service, Environmental and Technical Services Division, Habitat Conservation Branch. August 1996, 19p.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden UT. Gen. Tech. Rep. INT-138.

Sullivan, K., J. Tooley, K. Doughty, J.E. Caldwell and P. Knudsen. 1990. Evaluation of prediction models and characterization of stream temperature regimes in Washington. Timber/Fish/Wildlife Rep. No. TFW-WQ3-90-006. Washington Department of Natural Resources, Olympia, WA.

U.S. Forest Service. 2001. Stream Inventory Handbook; Level I and II. Version 2.1. U.S. Department of Agriculture, Pacific Northwest Region 6, U.S. Forest Service. 76 p + app.

Walsh, T.J., M.A. Korosec, W.M. Phillips, R.L. Logan, and H.W. Schasse. 1987. Geologic map of Washington – Southwest quadrant. Geologic Map GM-34. WA State Dept. Natural Resources, Olympia WA.

Washington Department of Fish and Wildlife (WDFW). 2001. Methods for assessing hydromodifications – overview and data dictionary. Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP). Washington Department of Fish and Wildlife, Olympia, Washington. Version dated December 28, 2001.

Washington Forest Practices Board. 1997. Standard methodology for conducting watershed analysis, Version 4.0. Washington Department of Natural Resources, Olympia, WA. November 1997.

Wolman, M.G. 1964. A method of sampling coarse river-bed material. Trans. Am. Geophys. Union 35: 951-956.