Kalama, Washougal and Lewis River Habitat Assessments

Chapter 3: The North Fork Lewis River Basin

Prepared for:

Lower Columbia Fish Recovery Board
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In association with:

Mobrand Biometrics, Inc.

December 2004

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3. CHAPTER 3 – THE NORTH FORK LEWIS RIVER BASIN

3.1 BASIN SPECIFIC METHODOLOGY

The available information to complete the watershed assessments varied among the targeted river basins, as did the current conditions assessed through field and remote techniques. As such, the methods used were adjusted to match the conditions for each river basin. This section describes all necessary deviations, additions, or deletions to the general methods described in Chapter 1.

3.1.1 Hydromodifications

The hydromodifications analysis area for the North Fork Lewis River consisted of low gradient alluvial and semi-alluvial reaches located at the downstream end of the basin (RM 0.0 to RM 15.5). The analysis area included EDT Reaches 1 through 5. Hydromodification field surveys were completed from September 13-17, 2004.

Generalized Floodplain

The first step in mapping hydromodifications was to identify the lateral extent of the analysis area and map the historic and current channel margins. The Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP) protocol called for delineation of the *generalized floodplain* (Washington Department of fish and Wildlife [WDFW] 2001). The generalized floodplain represented the area that, in the absence of hydromodifications, would have been affected by fluvial geomorphic processes. For this analysis, the historic extent of the generalized flood plain was estimated by identifying areas that occupied by the North Fork Lewis River channel over the past 150 years, or areas likely to have been inundated during large floods.

Historic information on channel condition and configuration for the North Fork Lewis River consisted of cadastral survey maps dating from 1857 (Allied Vaughn, 2000), a 10-foot contour interval topographic map of the Lewis River dated 1938 (USGS, 1938), and 1:20,000 scale aerial photographs flown in 1942 (USACE, 1944). The 1857 cadastral survey map, while providing useful information on gross changes in channel location and pattern between 1857 and 1938, was not sufficiently detailed to represent historic channel margins and off-channel habitats. Historic channel margins, former channel locations and off-channel habitats were therefore delineated by scanning the 1938 contour map and geo-referencing it to digital raster graphics (DRGs) of United States Geological Survey (USGS) 1:24,000 scale 7.5 minute St. Helens, Ridgefield, Deer Island, Woodland and Ariel quadrangles based on a series of horizontal control points identifiable on both the DRGs and historic topographic map (USGS 1938). A geographic information system (GIS) layer of historic channel margins was delineated from the geo-referenced overlays using ArcView.

The historic generalized floodplain was delineated from the geo-referenced 1938 topographic map using ArcView. Where no evidence of past channel migration was documented, the generalized floodplain was estimated to extend across the valley floor to the second contour line (approximately 20-feet above the rivers edge). Gage data from the North Fork Lewis River at Ariel gage indicated that flood stages in excess of 25 feet above the low flow stage were common. As a result, the generalized floodplain delineated up to the 20-ft contour on the historic topographic map was likely a reasonable estimate of the area inundated or affected by large floods.

The current floodplain was delineated based on the location of existing infrastructure (i.e., roads/levees) that affects natural geomorphic processes (e.g., lateral erosion or inundation) and thus constrains the area where those processes function naturally. The current floodplain was assumed to extend from the existing channel margin to the nearest levee, paved road, railroad or developed area on each bank. Although flood flows may inundate or overtop areas beyond these features, such areas are not considered to be functioning naturally.

Hydromodifications

Within the historic generalized floodplain, hydromodifications mapped by SSHIAP were confirmed and additional features, previously identified either on aerial photos or through field surveys were added to the SSHIAP database. The SSHIAP database contained point, line and polygon coverages of hydromodifications for WRIA 27, including the lower North Fork Lewis River area. The SSHIAP map layers provided by WDFW were developed primarily based on existing remote sensing resources (i.e., maps and digital data layers provided by various federal, state and local agencies). New features added to the database for this analysis consisted primarily of armored banks and “developed” areas. Developed areas, identified for this analysis, were polygon features and they were assigned the SSHIAP code for structures (44). These areas represented cleared land and clusters of multiple contiguous dwellings visible on current air photos that were perceived to be of a sufficient density to affect runoff. However, they were outside of the official city limits mapped as “city” in the WDFW SSHIAP coverage. No attempt was made to map individual structures.

Channel Margins

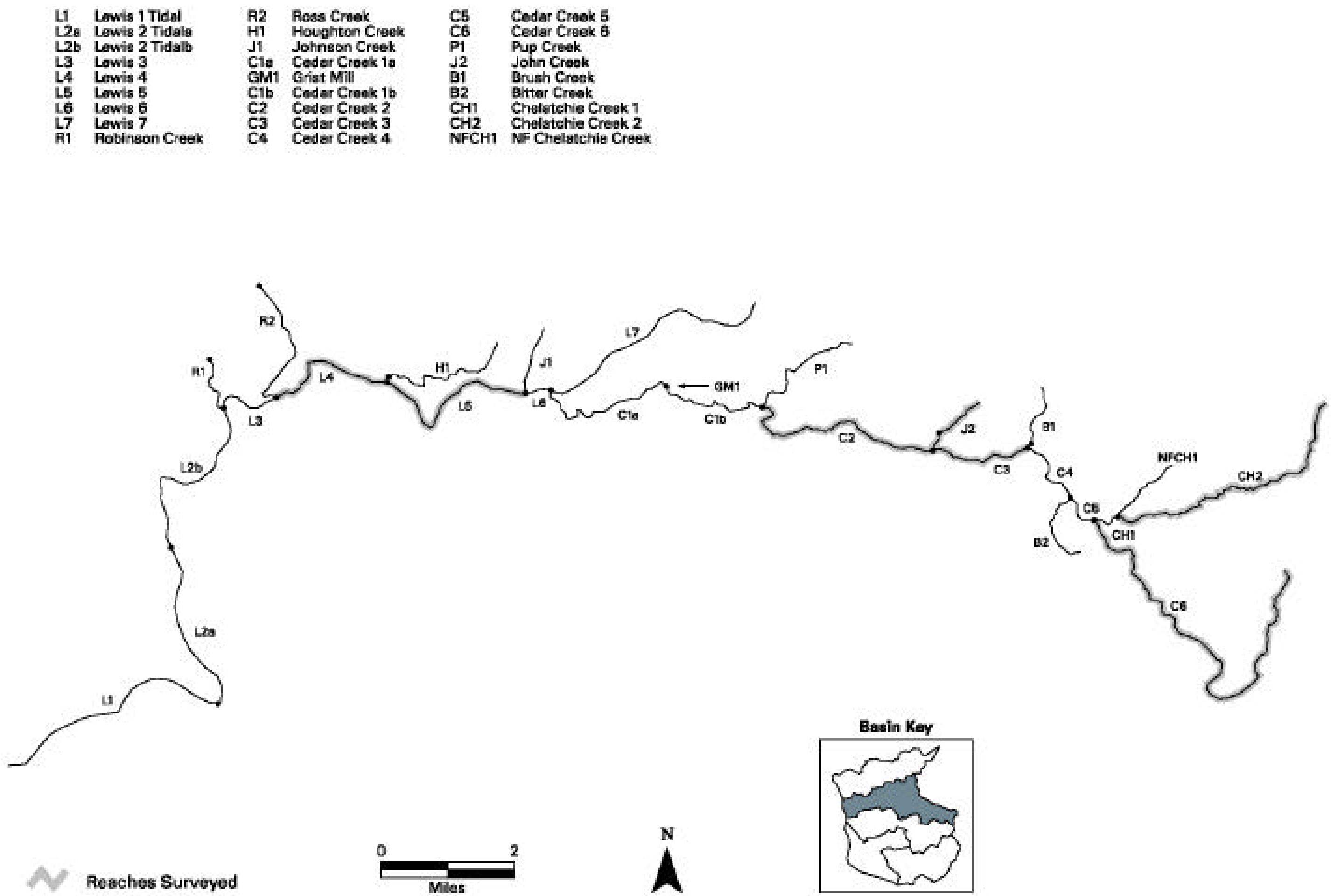
The lateral channel margins of large rivers, including submerged river bank, are areas of high use by juvenile salmonid fishes. Based on Hayman et al. (1996), banks can be classified into three general types: (1) banks, where the shoreline is vertical or nearly vertical and vegetative cover varies from bare to densely vegetated; (2) bars, which have a shallow gradient and are typically unvegetated; and (3) backwaters, enclosed, low velocity areas separated from the main channel. Beamer and Henderson (1998) found that banks without hydromodifications had a higher percentage of cover than non-hydromodified banks. For most species, juvenile fish abundance has been positively correlated to cover, in particular large wood cover. This finding was true for both natural and hydromodified banks, i.e., hydromodified banks that incorporated or had accumulated wood and vegetated cover over time supported higher densities of juvenile salmonids (Beamer and Henderson 1996).

Historic lateral margins habitats were delineated on the 1938 topographic maps and digitized into an ArcView coverage. Current channel margins were digitized from the 2003 black and white digital orthophotos provided by the Lower Columbia Fish Recovery Board (LCFRB). For each coverage, mainstem margins were classified as bank or bar. Backwater habitats generally were not evident on maps or photos used for this analysis. However, side channels and other off-channel habitats connected to the mainstem were delineated and quantified for both historic and current conditions.

3.1.2 Riparian Habitat Conditions

The riparian habitat condition assessment was conducted from aerial photo interpretation of the Washington State Department of Natural Resources 2003 4m orthophoto imagery provided digitally by the LCFRB and from 1m digital color infrared orthophotos dated 2002 provided by Clark County. The aerial photographs at an approximate scale of 1:12,000 were digitally reviewed to assess riparian cover conditions along 27 EDT reaches, representing approximately 58 miles of anadromous fish-bearing streams in the North Fork Lewis River Basin (Map 3-1). The methods for delineating riparian conditions and assessing the large wood (LW) recruitment potential and current shade levels were in accordance with Washington Forest Practices Board (WFPB) guidelines for conducting watershed analysis methodology (Ver. 4.0; WFPB 1997).

Each riparian condition unit was identified using personal computer and ArcInfo computer software to project delineated reaches onto digital aerial photograph images. The riparian stand species composition, relative size, density and percent of stream surface and stream banks visible was estimated from the onscreen image along both banks of the stream reaches as described in



Map 3-1. EDT reaches in NF Lewis River Basin.

Volume I, Methods. These estimates were then converted to LW recruitment potential and incremental shade levels, based on criteria in the Standard Methodology for Conducting Watershed Analysis (WFPB 1997).

Shade levels were determined in the photographic assessment in accordance with shade intervals, based on the degree of the channel visible on the photo. The existing shade categories were compared to target shade levels based on elevation in accordance with the western Washington temperature/elevation screen (WFPB 1997) that was designed to offer sufficient shade to comply with state water temperature standards. This approach is a top down assessment looking through the riparian canopy closure to the channel. It can be compared on a relative basis to the bottom-up approach (stream channel looking skyward) in the View-to-the-Sky assessment discussed in the subsequent section, Chapter 1, Section 2.3.2 Stream Surveys.

3.1.3 Stream Surveys

Stream surveys were conducted on September 14 and 15, 2004 for NF Lewis River mainstem reaches and from October 25-27, 2004 for tributary reaches. Data on habitat conditions were collected in 7 EDT reaches representing approximately 8 miles per the USFS Level II Stream Reach Inventory methods described in Chapter 1 of this report. The locations of seven surveyed reaches are shown in Map 3-2 and are itemized as follows:

EDT Reach	Location (RM)
NF Lewis River Mainstem Reaches	--
Lewis 4	10.5 – 12.6
Lewis 5	12.6 – 15.4
NF Lewis River Tributary Reaches	--
John Creek	0.0 – 1.1
Chelatchie Creek 2	0.5 – 5.1
Cedar Creek 2	4.3 – 7.7
Cedar Creek 3	7.7 – 9.3
Cedar Creek 6	11.1 – 17.9

3.1.4 Sediment Sources

No changes were necessary for the sediment sources methods. Field surveys were conducted from September 13-17, 2004.

3.2 RESULTS

3.2.1 Hydromodifications

The hydromodifications analysis area focused on the lower 15.5 miles of the North Fork Lewis River. The North Fork Lewis River traverses two distinct landforms within the lowermost 15.5 miles (Figure 3-1). From river mile (RM) 0.0 to approximately RM 7.3, the North Fork Lewis River flows across the Columbia River floodplain. The river bisects the Columbia River floodplain from RM 0 to the confluence with the Lewis River at RM 3. At RM 3 the North Fork Lewis River turns abruptly north, flowing along the margin of the Columbia River floodplain until RM 7.3. At RM 7.3, the river turns north and east, occupying a 0.75 mile to 1.0 mile wide alluvial valley that represents its own floodplain. Upstream of RM 15, the river is naturally confined within a bedrock canyon, bordered by narrow, discontinuous floodplain deposits.

Historically, the North Fork Lewis River deposited sediment in a delta that extended into the Columbia River floodplain. The river migrated north and south across that feature as sediment built up in delta distributary channels. East-west trending sloughs identifiable on early maps and photos provided evidence of this process. The area of Columbia River floodplain north of the mouth of the North Fork Lewis River is included in this analysis because channel features identified in that area are related to the North Fork Lewis River.

The disparity in basin size between the Columbia River (>250,000 mi^2) and the North Fork Lewis River (approximately 800 mi^2) gives rise to some important differences in process and timing that affect floodplain dynamics on the North Fork Lewis/Columbia River floodplain. The majority of the Columbia River basin drains interior areas that support a seasonal snowpack, and thus peak flows and sediment loads occur over a prolonged period in spring (May and June). In contrast, the climatic and flow regime of the North Fork Lewis River is dominated by rainfall, with peak flows occurring in response to large rainstorm events in the fall and winter (November through February). Sediments originating in the upper North Fork Lewis basin were carried downstream, settled out in and adjacent to the mouth of the North Fork Lewis River where the North Fork Lewis entered the low gradient Columbia River floodplain. Sediments carried by the Columbia River during spring snowmelt also were deposited on the North Fork Lewis/Columbia

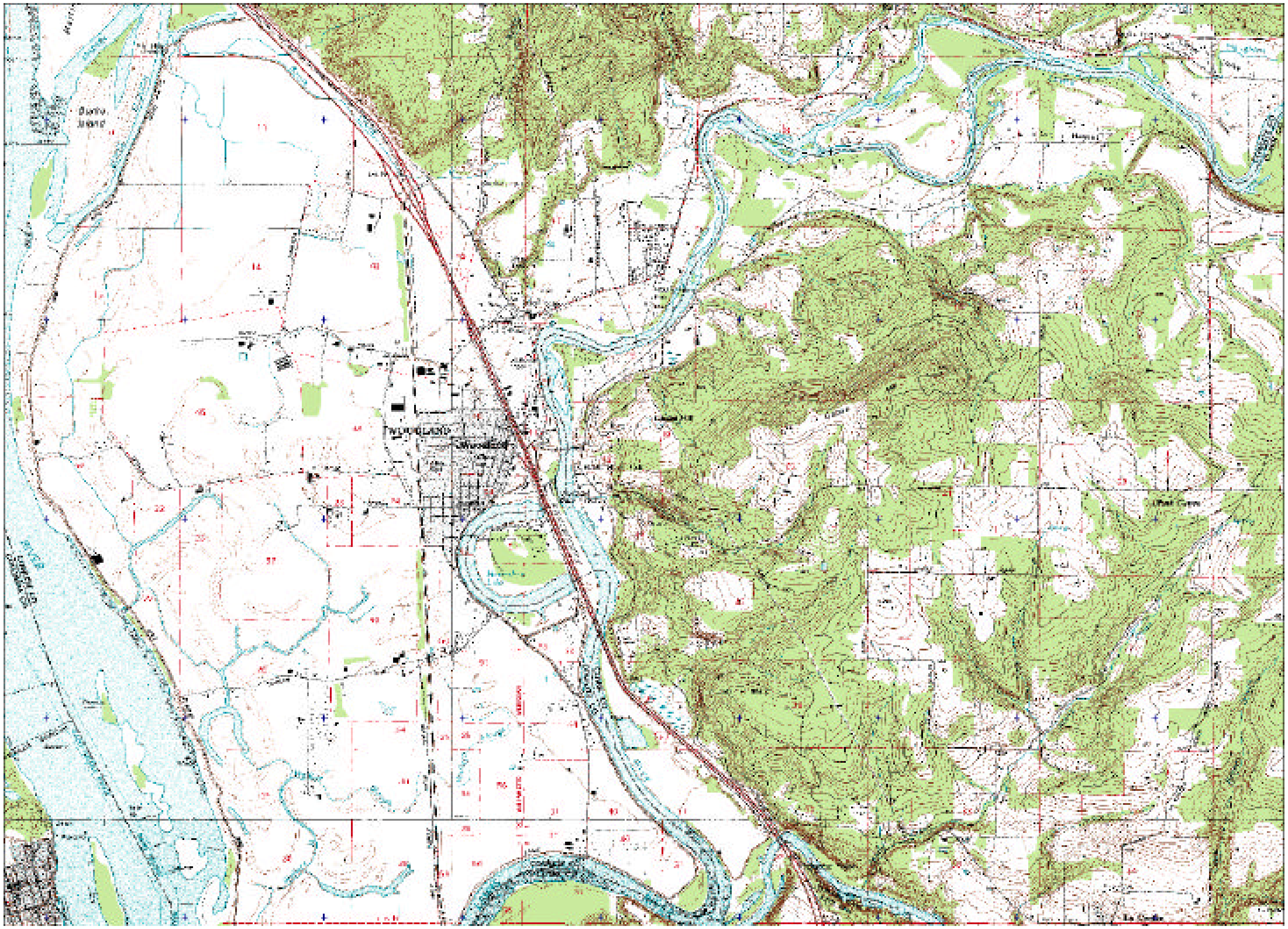


Figure 3-1. USGS 1:24,000 scale topographic map of the hydromodifications study area, (RM 0 to RM 15.5) for the North Fork Lewis basin.

River floodplain. In response to the combined depositional regime of the North Fork Lewis and Columbia rivers, the North Fork Lewis River naturally experienced multiple cycles of aggradation and degradation each year. Historically, the outlet of the North Fork Lewis shifted back and forth across the delta in response to deposition in its lower reaches. This action resulted in a widening of the depositional zone and created a network of former distributary channels represented by east-west trending sloughs. The Columbia and lower North Fork Lewis Rivers also experience daily tidal fluctuations, thus abandoned North Fork Lewis River distributaries persisted on the landscape as marshy tidal sloughs.

Generalized Floodplain

A comparison of the extent of the historic generalized floodplain and the current unconstrained floodplain of the North Fork Lewis River indicated that the area in which natural geomorphic processes (e.g., sediment deposition, bank erosion, channel migration and off-channel habitat development) has been reduced to approximately 12 percent of the area of the former unconstrained floodplain for the lower 15.5 mi of the North Fork Lewis River. Comparisons by reaches previously delineated for an Ecosystem Diagnosis and Treatment model (EDT) are provided in Table 3-1.

Table 3-1. Comparison of the approximate extent of the generalized floodplain associated with the North Fork Lewis River historically and under current conditions, and area of existing disturbed and undisturbed features.

		Current Generalized Floodplain			
EDT Reach	**Historic GF area (acres)**	**Total Area (acres)**	**Percent developed**	**Percent Excavated/ Filled**	**Percent forested**
1 (RM 0 to RM 3)	12,414[1]	430	0%	0.5%	27%
2 (RM 3 to RM 9.05)	2,576	357	20%	1%	3%
3 (RM 9.05 to RM 10.05)	263	147	6%	0%	0%
4 (RM 10.05 to RM 12.25)	867	624	15%	0%	14%
5 (RM 12.25 to RM 15.3)	559	370	9%	0%	15%
6 (RM 15.3 to RM 15.5)	8	4	0%	0%	0%
Total	16,687	1,932	11%	<1%	14%

[1]Includes 6,172 acres of Columbia River floodplain to north and south of Lewis River.

[2]Boundary between Lewis River floodplain and Columbia River floodplain west of the Lewis River indistinct.

Within the combined floodplain of the North Fork Lewis River and the Columbia River, the 1857 cadastral survey maps indicated that vegetation historically consisted of wetlands or tree and shrub species that are tolerant of frequent inundation. Upstream of the influence of the Columbia River, floodplain vegetation most likely would have consisted of a mosaic of forest types and age classes that ranged from young hardwood tree and shrub species on recent flood deposits to old growth conifer forests on older floodplain surfaces. Within the canyon, riparian stands most likely consisted of narrow bands of shrub or deciduous trees in frequently flooded zones, bordered by mixed conifer and hardwood stands. Bedrock outcrops were prominent throughout the canyon, and may have historically limited the density and composition of riparian vegetation. The current status of riparian vegetation throughout the North Fork Lewis River basin is discussed in Section 3.2.2

Currently, floodplain surfaces adjacent to the North Fork Lewis River have been cleared and were either urbanized, utilized for residential development, or used for agriculture. This was most evident in the lower end of the basin on the former Columbia River floodplain. Forest cover represented only 14 percent of the current floodplain area, and forested areas consisted of sparse to medium stocked stands of mixed forest (Section 3.2.2). Within the current floodplain, forested areas were concentrated. At the time of this assessment, less than 5 percent of the historic generalized floodplain supported relatively intact forest stands.

In North Fork Lewis River 1, the Lewis/Columbia River floodplain north of the river historically contained numerous slough and wetland areas that were clearly visible on historic maps and photos. That area has been encircled by levees and currently appears to be used primarily for agriculture. However, remnant slough and wetlands were visible on current maps and photos.

There were extensive urban or developed areas in North Fork Lewis River 2 associated with the city of Woodland, although most of those were separated from the current generalized floodplain by levees. Developed areas accounted for more than 30 percent of the historic generalized floodplain in North Fork Lewis River 2. In other reaches, rural residential development appeared to impact floodplain function. Although structures were not dense enough to be classified as “developed,” paved and gravel roads were extensive within the floodplain, and undeveloped areas were undergoing residential development.

North Fork Lewis River 3 and 4 contained a large undeveloped area known as Eagle Island. This feature represented the last remaining unconstrained section of the lower Lewis River. In 1938, all of the Lewis River flow was transmitted in what is now the north branch of a split section of river. Topographic features indicative of overflow channels were noted on the 1938 map, but the current south branch of the channel was not present. The relatively patchy young forest and extensive bars in the Eagle Island area indicated that this section of the river has continued to be dynamic. Landuse in Reaches 5 and 6 consisted primarily of rural residential development.

Channel Margins

The estimate of historic channel margin length was derived from the digitized, geo-referenced 1938 topographic map. Even at that time portions of the Lewis River were protected by levees or developed, but the overall channel configuration was similar to that depicted in cadastral survey maps dating from 1857, and major side channels were clearly visible in areas that had been cleared for agriculture and development. Unless off-channel habitats appeared to be naturally disconnected from the mainstem river, these features were all classified as connected to better reflect conditions prior to Euroamerican settlement.

Throughout the lower 15.5 miles of the river, the length of mainstem channel bank has actually increased as compared to historic conditions. Comparisons by EDT reach are provided in Table 3-2. This results primarily from the development of a split channel between RM 9.9 and 11.7 (EDT Reaches 3 and 4). Development of the split channel increased the length of channel bank by approximately 4.6 miles. However, channel margin habitat was lost in North Fork Lewis River 2, where construction of the railroad cutoff a 1.5 mile-long meander bend (approximately 3.0 miles of bank habitat). That feature persisted on the landscape as Horseshoe Lake. Bank armoring and levee construction also resulted in slight decreases in margin habitat in North Fork Lewis River 1.

Another important change in mainstem habitat has been the loss of sandbars from the lower 7.0 miles of river. Historically, this area was dredged to facilitate navigation up to the city of Woodland and to maintain flood conveyance. Bar habitat has also been lost in EDT Reach 5, but this appeared to have occurred primarily as a result of terrestrialization of former bar surface and may have been a response to flood control operations at PacifiCorp's Lewis River Project.

Perhaps the most significant hydromodification in the lower Lewis River basin has been the almost complete loss of side channels. East-west trending relict Lewis distributary channels were formerly common on the Columbia River floodplain (mapped as part of EDT Reach 1). Remnants of those features still persist on the landscape, but they have been largely cleared, channelized and cutoff from both the Lewis and Columbia Rivers by levees. Riverine side channel have also been lost in the remainder of the study area, largely as a result of bank

Table 3-2. Comparison of the extent of margin habitat on the lower North Fork Lewis River historically and under current conditions.

EDT Reach	Historic (miles)	Current (miles)
1 (RM 0 to RM 3.0)		
Bank	9.4	9.3
Bar[1]	0.9	0.0
Connected side channel	24.5[2]	0.6
Disconnected side channel/oxbow	0	13.5[3]
2 (RM 3.0 to RM 9.05)		
Bank	15.7	12.4
Bar[1]	0.5	0
Connected side channel	0.9	0
Disconnected side channel/oxbow	0	5.0
3 (RM 9.05 to RM 10.05)		
Bank	2.3	2.7
Bar[1]	0.9	0
Connected side channel	0.2	0
Disconnected side channel/oxbow	0	0
4 (RM 10.05 to RM 12.25)		
Bank	4.4	8.7
Bar[1]	0.1	0
Connected side channel	2.1	0.4
Disconnected side channel/oxbow	0	0
5 (RM 12.25 to RM 15.3)		
Bank	7.5	7.5
Bar[1]	2.8	0
Connected side channel	1.8	0
Disconnected side channel/oxbow	0	0
6 (RM 15.3 to RM 15.5)		
Bank	0.8	0.8
Bar[1]	0	0
Connected side channel	0	0
Disconnected side channel/oxbow	0	0

[1]Flow at time of both photo sets was unknown thus direct comparison of bar area includes differences that result both from river stage and losses due to dredging.

[2]Includes approximately 23 miles of tidal slough habitat on the Columbia River floodplain that were likely relict Lewis River distributary channels.

[3]Represents remnant tidal slough habitats on the Columbia River floodplain that were encircled by levees, but may be periodically connected to the Columbia River via flapgates.

armoring and development in the floodplain. In the Eagle Island area former side channels were captured by the avulsion and split off the main river channel and created mainstem river habitats. However, several new (as compared to 1938) side channels were also noted near Eagle Island.

Hydromodifications

Three primary types of hydromodifications were recognized in this analysis: (1) changes in the hydrologic regime (e.g., flood control or impervious area); (2) activities that alter habitat connectivity (e.g., floodplain land conversion, levees, gravel extraction) and (3) direct alteration of the channel bed and bank (bank armoring, dredging).

Hydrologic Regime

The North Fork Lewis River is regulated by upstream hydropower projects that also provide flood control: the first of these projects was constructed in 1931. Operation of PacifiCorp's Lewis River Project was presumed to affect the connectivity of floodplain habitats; however a detailed assessment of those effects was beyond the scope of this study. The effects of PacifiCorp project operations were currently evaluated as part of Federal Energy Regulatory Commission relicensing activities. Ongoing operations are expected to continue to modify the hydrologic regime, and thus may constrain restoration opportunities in the lower Lewis River.

At the time of this study, approximately 40 percent of the historic North Fork Lewis River floodplain consisted of developed areas with a high proportion of impervious surfaces. Development in the floodplain likely has increased runoff and further reduced floodplain groundwater recharge, particularly in the vicinity of the town of Woodland. As for flood control, an evaluation of specific hydrologic effects was beyond the scope of this study. However, it must be recognized that hydrologic effects associated with urban development may constrain restoration opportunities in the lower Lewis River basin.

Habitat Connectivity

Changes in habitat connectivity within the hydromodifications analysis area consisted primarily of disconnection of off channel habitat and reductions in the amount of functional floodplain habitat as described above. Structures crossing the channel in the North Fork Lewis River generally consisted of bridges and did not interfere with the upstream passage of anadromous fish.

Direct Alteration of Bed and Banks

At the time of this assessment, approximately 11 percent of the river bank in the North Fork Lewis River analysis area was naturally constrained. Natural confinement in North Fork Lewis River 1 through 4 consisted of short areas where the river was impinged by steep side slopes. At RM 15.0 on the Lewis River canyon habitat begins and the river has been constrained by steep sideslopes on both sides.

Numerous activities that have altered the natural channel bed and banks of the North Fork Lewis River were identified within the hydromodifications analysis area in both constrained and naturally unconstrained reaches. Hydromodifications that have affected bank habitat are summarized by EDT Reach in Table 3-3. Almost 70 percent of the length of North Fork Lewis River 1 and 2 has been confined between levees or armoured banks on both sides. Unconstrained areas consisted of a few bars and islands near the confluence with the Columbia River, a small patch of forested land just upstream of Interstate 5, and naturally constrained areas. Midway up North Fork Lewis River 3, the channel split and was generally unconfined for the remainder of that Reach and through most of Reach 4 around Eagle Island. Hydromodifications that were present in this reach consisted mainly of stream adjacent roads that were frequently riprapped to prevent erosion, and discontinuous areas of riprap to protect private residences. Upstream of North Fork Lewis River 4, steep naturally confined banks were more common. Hydromodifications in Reaches 5 and 6 consisted primarily of armored banks that protect streamside residences and stream adjacent roads.

Table 3-3. Summary of the length of mainstem channel banks affected by hydromodification located within 50-feet of the OHWM for the lower 10 miles of the North Fork Lewis River.

EDT Reach	Total margin length (mi)	Naturally constrained[1] (%)	Levee (%)	Bank armoring (%)	Stream adjacent road[1] (%)	Unmodified (%)
1 (RM 0 to RM 3)	9.3	7	58	0	0	42
2 (RM 3 to RM 9.05)	12.4	8	75	0	0	25
3 (RM 9.05 to RM 10.05)	2.7	0	15	7	15	63
4 (RM 10.05 to RM 12.25)	8.7	5	0	11	5	79
5 (RM 12.25 to RM 15.3)	7.5	24	0	8	7	85
6 (RM 15.3 to RM 15.5)	0.8	100	0	5	34	61

[1]Naturally constrained banks may also have been hydromodified.

[2] Areas affected by both stream adjacent roads and armored banks were counted as armored banks. The value in column 5 represents only those areas where stream adjacent roads were present and either no armoring was document during surveys, or no survey data was collected.

[3]Unmodified bank refers to those sites with no hydromodifications located immediately adjacent to the channel, and includes both unconstrained and naturally constrained areas.

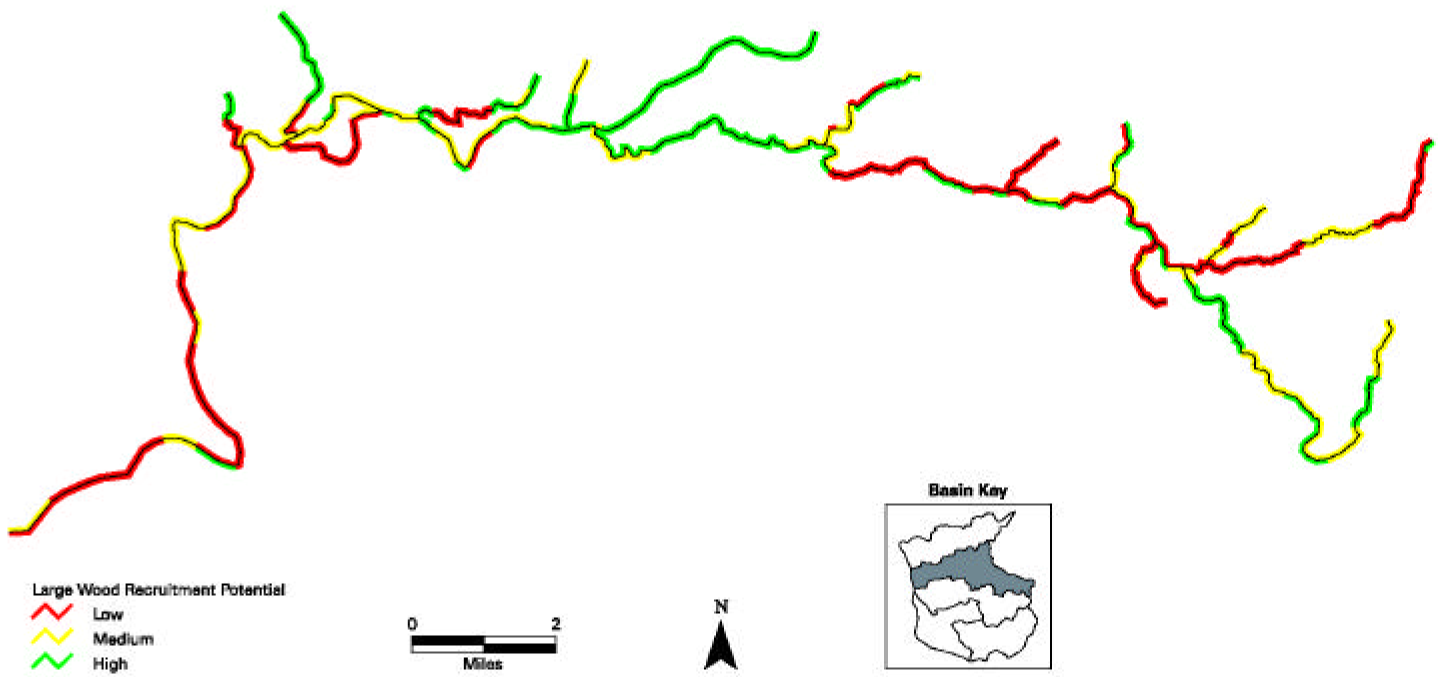
3.2.2 Riparian Habitat Conditions

The intent of the Phase II remote sensing assessment of riparian habitat conditions was to: (1) provide sufficient detail to judge the current level of riparian function related to potential LW recruitment and shade, (2) confirm the Phase I Integrated Watershed Assessment (IWA) results, as well as (3) provide input for refining EDT riparian input factors and for assessing potential restoration opportunities. These assessments are summarized below.

Existing Riparian Function

***Large Wood (LW) Assessment*:** The location and current LW recruitment condition of 27 EDT reaches are shown in Map 3-2. The condition rating for each of the reaches is included in Appendix A.

Aerial photo assessment, along both shorelines of nearly 58 miles of anadromous fish streams, indicated the overall LW condition of riparian stands in the NF Lewis basin represented a moderate level of potential LW recruitment.



Map 3-2. Large wood condition ratings for EDT reaches in the Nf Lewis Basin.

Large Wood Recruitment Potential

Condition	Frequency
Good	32%
Fair	32%
Poor	36%

The riparian recruitment potential of 27 reaches can be divided approximately into equal thirds between good, fair and poor conditions. Portions of Lewis River 5, 6, and 7, Cedar Creek 1a, 1b, and 6, and Houghton, Johnson, Pup, Robinson and Ross creeks offered good current LW recruitment conditions (low recruitment hazard) on both sides of the stream (Map 3-2; Appendix A). Riparian vegetation in these situations consisted of dense stands of either large or medium-sized conifer or mixed species. The existing fair stand conditions were predominately sparse conifer or mixed stands or dense hardwood stands. A second cohort of conifer stand growth will be needed in these areas to support "functional" LW recruitment potential in the future. The poor existing stand situation appeared to be related to both the species composition and size of riparian trees rather than density of the stands. Based on photographic interpretation, approximately 1/3rd of the stands appeared to be dominated by deciduous species, whereas ½ of the stands were dominated by mixed (conifer:hardwood) species. Conifer-dominated stands were low in number. Less than 20 percent of the reaches were conifer-dominated

Riparian Species Composition

Type	Frequency
Conifer	18%
Mixed	50%
Hardwood	32%

The stand density showed equal representation as either sparse or dense tree growth along the streams.

Riparian Stand Density

Condition	Frequency
Sparse	53%
Dense	47%

The relative size of the trees in incremental size classes was on the small side. Only 5 percent of the stands were categorized in the large (> 8 cm; 20” diameter at breast height [dbh]) size class. This result indicated a number of decades of growth (20-40 years) will be needed for the development of a large size class of trees to contribute to future LW recruitment conditions for these streams.

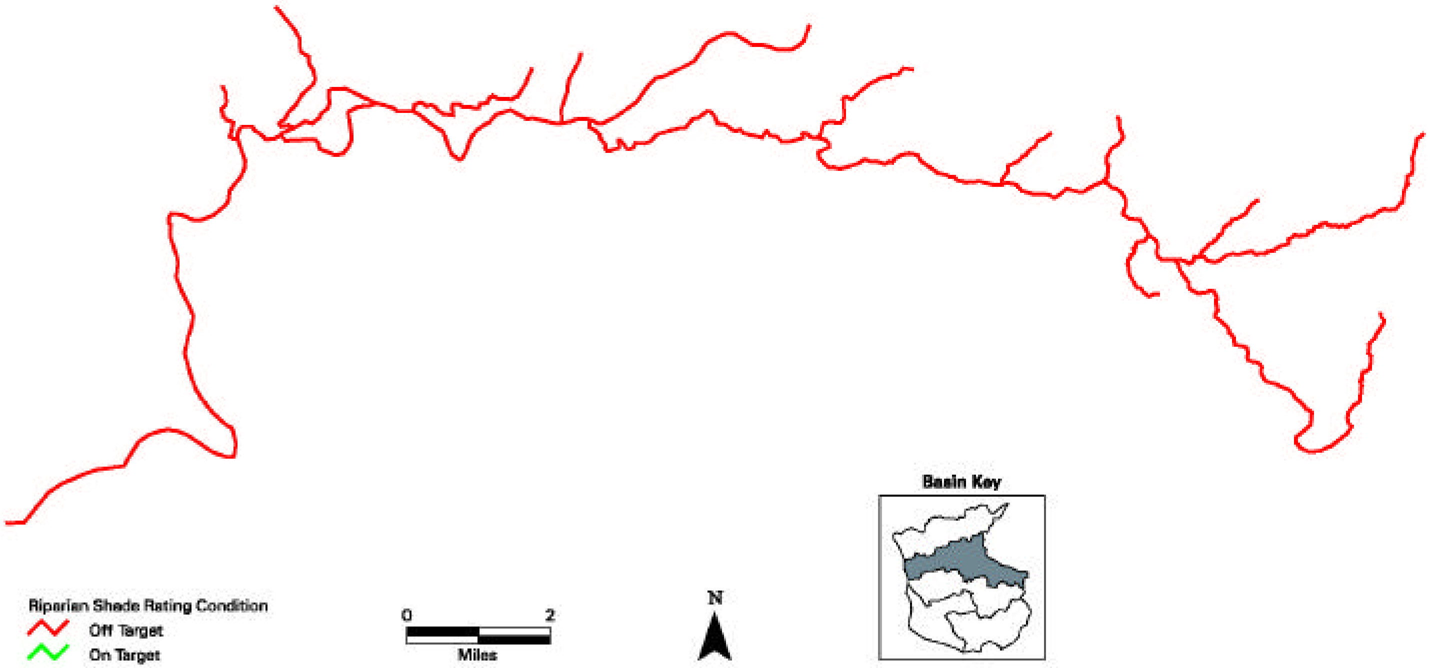
Riparian Stand Size Class

Condition	Size Class	Frequency
	(dbh)	(%)
Small	< 12”	30%
Medium	12 – 20”	65%
Large	> 20”	5%

As described in the Section 3.2.3; *Stream Surveys*, urbanization, roads, railroads, clearcut timber harvesting and thinning along the shorelines have encroached within 30m (100 ft) riparian zones at several places along fish-bearing channels. These activities have adversely influenced the riparian LW recruitment potential.

Riparian Shade Assessment: The location and current shade condition of the 27 EDT reaches is shown in Map 3-3. The condition rating for each of the reaches is included in Appendix A.

Aerial photo assessment indicated, on average, that the existing riparian stands were providing little effective shade. Existing shade levels ranged between 0 and 80 percent shade while the mean level was in the neighborhood of 27 percent shade. According to the State shade/elevation screen, this amount of shade is anticipated to be sufficient to maintain water temperature standards in streams located upstream of approximately the 760m (2,500 ft) msl elevation in the basin.



Map 3-3. Shade condition ratings for EDT reaches in the NF Lewis Basin.

Riparian Shade Condition

Shade Increment	Tally	Frequency
0	1	1%
0 – 20%	39	38%
20 – 40%	46	44%
40 – 70%	15	14%
70 – 90%	3	3%
90 – 100%	0	0%

IWA Verification

The IWA for the NF Lewis River basin provided information related to whether or not indicated riparian conditions were either intact or degraded at the subwatershed level based on total stream length. The proportion of intact versus degraded was then used to assume a level of riparian functionality in three classes; impaired, moderately impaired or functional riparian buffer areas. Subwatersheds were classified according to their existing level of functional riparian conditions. Conditions were rated as moderately impaired in 8 and impaired in 3 of 11 subwatersheds in the NF Lewis basin. None of the subwatersheds was rated as providing functional riparian habitat conditions. Chelatchie Creek (Subwatershed #60406), and the lower NF Lewis River (#60501) were two of the most impaired watersheds with respect to riparian function. Direct verification of IWA results with the reach-level riparian assessment conducted herein, was not possible. However, in general, a review of Maps 3-2 and 3-3 show the reaches with high existing hazards to riparian functions of low potential LW recruitment and off-target shade levels, respectively. Although variable, concentrations of high hazard areas can be found in the lowermost mainstem area and in the Chelatchie Creek subwatershed. Both areas have situations where they may naturally have experienced high hazards to riparian function.

All of the EDT reaches in the basin are currently off-target with respect to the State shade/ elevation screen, representing high shade hazards. Due to the low elevation of lands along the EDT reaches accessible to anadromous fish species, a high level of shade is required to comply with aquatic use temperature criteria. The wide mainstem reaches along the lower NF Lewis River likely offered naturally open riparian canopies and historic warm stream temperature regimes.

Although variable, concentrations of high LW hazard areas can be found in the lower Lewis River basin, and along John, Bitter and Chelatchie creeks. Lewis 1-tidal may have experienced natural high hazards to LW riparian function as a result of the Columbia River floodplain.

The IWA indicated 8 of the subwatershed encompassing EDT reaches in the Kalama basin were “moderately impaired” and 3 were “impaired.” The aerial photo assessment of EDT reaches per WFPB (1997) watershed analysis guidelines suggest the reaches highlighted in red in Map 3-2 represent “impaired” riparian conditions and reaches highlighted in yellow represent “moderately The balance of reaches in green offer current “functional” riparian conditions for LW recruitment, but they remain off-target for shade conditions due in part to the wide nature of these low elevation streams.

3.2.3 Stream Surveys

Habitat inventory data are summarized in this section of the NF Lewis River Basin document per individual EDT reach (Tables 3-4 and 3-5). Habitat conditions for each of the surveyed reaches shown in Map 3-1 are presented in detail in Appendix B.

Channel Morphology

The channel morphologies for the mainstem NF Lewis River reaches surveyed were consistently wide, low gradient, floodplain channels with pool-riffle bedform (Table 3-4). The tributaries surveyed varied from very low gradient palustrine channels with dune-ripple bedform in Chelatchie Creek to 4 to 6 percent moderately confined streams with mixed control features found in John Creek. These type of streams offer pool:riffle bedforms or step pools where channel structure is abundant. However, in the absence of large structure (large wood, boulder clusters, or bedform controls) some sections would likely consist of plane bedded channels.

Habitat Types

The mainstem reaches of the NF Lewis River consisted primarily of glide and riffle habitat types. Pools habitats were infrequent but deep. On average, all of the mainstem pools exceeded 1m (3.3 ft) in depth (Table 3-5). As a consequence, they are considered primary pools and offer good holding habitat for returning adult fish prior to spawning. Riffle habitat was also prevalent in the mainstem reaches. Since gravel and cobbles with low levels of fines dominated the substrate types, the low gradient mainstem reaches of Lewis 4 and 5 offered good spawning conditions.

Table 3-4. Channel Gradient, Confinement and Morphology in the NF Lewis Basin.

Reach	Map gradient (%)	Confinement	Paustian Channel Type	Montgomery-Buffington Bedform	Comments
Lewis-4	1%	Unconfined	Wide, low gradient floodplain	Pool-riffle	Split channel that developed post-1942. Island in center currently a mosaic of bare sediment, shrubs and young Hardwoods. Largely unaffected by Hydromodifications. Would be very responsive to LW jams, need key pieces to form. Floodplain historically forest with mixed species.
Lewis-5	1	Unconfined	Wide, low gradient floodplain	Pool-riffle	Couple of areas where the channel impinges on high Lake Missoula Flood terraces. Otherwise it is generally similar to Lewis-4. Multiple old side/overflow channels likely now disconnected, more as a result of Flood control than Hydromodifications
Cedar 2	0.5%	Moderate	Low gradient FP	Pool-riffle	50m wide channel in 150-m wide valley. Becomes a bit more confined in upper part of reach, but moderate confinement throughout. Expect this channel to be highly responsive to LW in terms of pool-formation, less so for sediment as sediment drops out due to low gradient.
Cedar 3	0.5%	Moderate	Low gradient FP	Pool-riffle	Similar to Cedar-2. Perhaps a bit more confined than Cedar-2 by gently sloping sidewalls.
Cedar 6	1-2%	Moderate to highly confined	Moderate gradient mixed control	Forced pool riffle to plane bed	Gradient and confinement suggest this reach would be highly responsive to LW both for sediment storage and pool-formation.
Johns	4%	Moderate to high	MGM to Moderate gradient contained	Forced pool-riffle to step pool	Narrow valley, but stream is small and there may be areas where it can move around a bit. In locally low gradient areas, plane-bed topography could develop in absence of LW. Sensitive to LW for sediment storage and for side channel formation. Pools moderately responsive to LW (dammed pools in particular), but bed may be resistant to deep scour in many areas.

Table 3-4. Channel Gradient, Confinement and Morphology in the NF Lewis Basin.

Reach	Map gradient (%)	Confinement	Paustian Channel Type	Montgomery-Buffington Bedform	Comments
Chelatchie 2	<0.5%	Low	Palustrine	Dune-ripple to pool-riffle	Small stream underfit in wide valley that appears to be formed by glacial processes. The corridor may even represent the former Lewis River valley? Structural control and volcanic features make this channel a messy one. But it is clear the valley deposits were not laid down by Chelatchie Cr. Bed likely naturally fine, and agriculture does not help the situation. Such areas were commonly meadow with scarcity of trees, which could affect riparian calls. Moderately responsive to LW, but low gradient means in will go around or under rather than storing sediment. Small LW is important here.

Table 3-5. Mean Habitat Inventory data in the NF Lewis Basin.

	Lewis 4	Lewis 5	John	Chelatchie 2	Cedar 2	Cedar 3	Cedar 6
Channel Morphology							
Pool %	18	0	17	52	27	30	35
Pool Tailout	7	0	15	19	37	24	30
Small Riffle	39	48	11	13	68	61	57
Large Riffle	0	0	28	0	0	0	0
Glide	43	52	0	35	6	9	8
Cascade	0	0	45	0	0	0	0
Gradient	1.0	1.0	5.5	<1.0	1.5	1.5	2.0
Channel Type	FP	FP	MGMC	Pal.	FP	FP	MGMC
Bedform	PR	PR	SP	DR	PR	PR	FPR-PB
Wetted channel width	61	95	4.9	6.6	15.3	13.0	10.9
Active channel width	-	-	4.4	7.8	17.8	15.8	9.2
Max. Riffle Depth (m)	-	-	0.4	0.4	0.8	0.8	0.6
Res. Pool Depth (m)	2.0	-	0.5	0.5	0.5	0.6	0.4
Max Pool Depth (m)	2.8	0.0	0.6	0.7	0.9	1.0	0.7
Pools/km	1.1	0.0	11.3	16.8	4.3	3.9	14.0
Primary Pools/km	1.1	0.0	2.1	3.7	3.8	2.6	3.5
LW							
Small Pieces/km	12.4	12.5	24.0	17.0	1.3	0.9	24.4
Medium Pieces/km	10.5	6.8	44.0	29.0	3.9	1.3	23.3
Large Pieces/km	2.1	2.1	8.2	14.0	0.0	2.1	19.8
Jams/km	0.4	0.3	0.0	0.0	0.0	0.0	2.4
Root Wads/km	0.8	0.0	1.0	4.7	0.0	9.4	5.8
Total LW/km	26.7	21.6	77.0	64.5	13.1	13.6	76.0
Substrate							
Sand	-	-	48%	44%	11%	15%	32%
Gravel	55%	41%	17%	50%	34%	39%	48%
Cobble	37%	46%	20%	5%	38%	34%	10%
Boulder	7%	12%	14%	1%	18%	12%	10%
Bedrock	1%	-	1%				
Cover							
LW	3	2	4	6	5	3	3
Undercut Banks	0	0	0	0	0	0	0
Overhanging Cover	0	0	32	31	10	14	9
Depth > 1m	43	35	1	11	7	10	2
Substrate (velocity)	0	0	0	0	0	0	1
Total Cover	45	37	37	48	22	27	15

Table 3-5. Mean Habitat Inventory data in the NF Lewis Basin.

	Lewis 4	**Lewis 5**	**John**	**Chelatchie 2**	**Cedar 2**	**Cedar 3**	**Cedar 6**
Riparian							
Distance to Lf. Bank	200	229	35	42	208	148	38
Angle	26	29	71	67	51	50	78
Distance to Rt. Bank	233	317	39	34	45	39	32
Angle	29	22	74	77	60	64	78
VTS %	69%	72%	20%	20%	39%	37%	13%
Active channel width	61	95	5	8	18	16	9
Elevation	19	26	375	240	190	200	295
Reference Temp ^{o}C	18.6	19.6	15.6	15.9	16.5	16.4	15.8
Current Est. Temp ^{o}C	21.0	20.9	16.8	16.6	18.5	18.3	16.3
Vegetation Community (%)							
LB Hardwood	55%	67%	50%	100%	0%	60%	58%
Mixed	27%	11%	17%	0%	100%	20%	42%
Conifer	18%	22%	33%	0%	0%	20%	0%
RB Hardwood	64%	67%	17%	100%	0%	50%	71%
Mixed	27%	0%	17%	0%	100%	50%	29%
Conifer	9%	33%	67%	0%	0%	0%	0%
Bank Stability							
LB Unstable %	5	7	0.0	0.0	0.0	0.0	0.0
Disturbance %	4	33	1.0	1.0	0.0	32.0	2.0
Disturbance Type	UT	UT	CC	CC		UB	RR
RB Unstable %	1	2	1.0	0.0	1.0	0.0	0.0
Disturbance %	59	33		0.0	0.0	29.0	14.0
Disturbance Type	UR	U				UB	UB, RR

Channel Codes

Pal = Palustrine; Est = Estuarine; FP = Flood Plain; LC = Large, Contained; MGMC = Moderate Gradient, Mixed Control

Bedform Codes

DR = Dune-ripple; PR = Pool-riffle; FPR = Forced pool-riffle; PB = Plain bed; SP = Step Pool

Riparian Disturbance Code

U = Urbanization; R = Road; RR = Railroad; C = Clearcut; T = Thinning; H = Hydromodification

Gravel-cobble riffles dominated the channel habitat types in the Cedar Creek reaches, while pools dominated in Chelatchie Creek and cascade habitat was most prevalent in John Creek. The pools in surveyed tributary reaches ranged from infrequent in the steep gradient of John Creek to prevalent in the low gradient reaches of Chelatchie 2 and Cedar 2, 3, and 6.

Large Wood Structure

On a relative basis, individual instream LW pieces were common in the tributary reaches of John, Chelatchie 2 and Cedar 6 with a full complement of debris piece sizes available. They were less common in the mainstem reaches and in Cedar 2 and 3. The instream wood loading primarily consisted of wood from the small and medium size categories. These piece sizes were too small to properly function in the large mainstem channels. The presence of wood jams and pieces with attached root wads was very low throughout the survey, except where in channel restoration projects had been implemented.

The instream data signal indicated that either the LW recruitment potential to the lower reaches of the NF Lewis mainstem has been low, the stream power has been sufficient to redistribute the LW input, and/or wood was historically removed from the channels. As discussed in the previous section, long-term riparian growth on the order of two to four decades will be needed to offer a high degree of LW recruitment potential to these channels in the future.

Substrate

The prevalence of sand and high embeddedness ratings were only recorded during the habitat inventories in the palustrine reach of Chelatchie 2 and in John Creek and Cedar 6. The balance of the reaches surveyed had low levels of sand and similarly, low embeddedness ratings. See Section 3.2.4 *Sediment Sources* for a more comprehensive view of sediment issues in the basin.

Cover

Cover for fishes in the NF Lewis River mainstem was primarily in the form of water depth. The tributaries offered more diverse cover types. The most frequent cover type in the tributaries was overhanging vegetation, but depth and LW offer additional cover opportunities.

Riparian Condition

The riparian species composition tended to be dominated by deciduous species along the mainstem, Chelatchie 2 and the uppermost reaches of Cedar Creek. Mixed stands predominated in Cedar 2, whereas conifer stands dominated the riparian zone in John Creek. Direct comparison with the riparian conditions collected during the photographic assessment is difficult, since riparian stand composition information is collected during the stream inventory on an occasional (nth unit) basis and summarized over the length of the reach, whereas the photo interpretation was performed continuously along long homogeneous reaches. The field inventory indicated greater presence of deciduous hardwood species than the photo assessment, although the prevalence of mixed and confer species was apparent in both the field surveys and the photo assessment at John and Cedar 2 (Table 3-5).

Encroachment into the 30 m (100 ft) riparian zone along the NF Lewis mainstem has resulted in ratings between 33 and 59 percent of the riparian area disturbed. The greatest frequency of disturbance types included urbanization and roads (Table 3-6).

Table 3-6. Number of habitat units reporting riparian zone disturbance on either shore.

Disturbance Type	Lewis 4	Lewis 5	John Cr.	Chelatchie 2	Cedar 2	Cedar 3	Cedar 6
Urbanization	5	10				18	4
Roads	3						
Railroads							4
Clearcut			1	1			
Thinning	1	2					
Hydro-Modification							
Total	9/22	12/18	1/40	1/30	0/16	18/40	8/40

Estimates of the average distance of trees beyond the bank full stage of the channel along the mainstem Lewis River reaches ranged between 61 and 97 m (200-317 ft) on either side of the river. This zone was wide along the floodplain reaches. The resulting mean view to sky angle (VTS) from mid-channel ranged between 69 and 72 percent (Table 3-5).

These reaches were estimated to remain open to solar radiation even under the unlikely assumption of mature forest stands growing immediately adjacent to the channel, (VTS 69 ^{o}, 39%). As such, these reaches represent areas with naturally low shade levels and they likely offered historically warm surface water temperatures. Assuming mature forest timber stands could develop and grow adjacent to the channel banks, the 7-DADmax reference surface water temperatures were projected to range between 18.6^{o}C and 19.6^{o}C. These temperatures would not be expected to comply with aquatic use criteria for anadromous salmonid fishes or interior resident trout under mature riparian stands simply due to the expanse of channel width and low elevation characteristic of the reaches. The current channel conditions were projected to increase the 7-DADmax on a relative basis between 1.3°C and 2.4°C compared to reference conditions. As a consequence, the anticipated summer 7-DADmax surface water temperature were estimated to range near 21°C at both mainstem reaches under normal summer weather (air temperatures and stream flows) patterns.

Conversely, tree distances from the center of tributary channels ranged between 10-63 m (32-208 ft) with solar radiation blocking angles that allow 13 to 39 percent VTS. Canopy closure over the relatively small channel widths was very near to reference conditions in Cedar 6 and Chelatchie 2 with projected increases in 7-DADmax surface water temperatures of 0.4°C and 0.7°C, respectively (Table 3-7). It is possible the reference conditions in these tributary reaches would comply with state water temperature standards under normal weather conditions. Other tributary reaches remained relatively open to the sky. The current condition exceeded reference temperatures by more than 1 to 2°C, putting these reaches at moderate or high levels of risk for non-compliance with water temperature standards.

Table 3-7. Anticipated Stream Temperature Conditions along EDT Reaches based on Channel View-to-the-Sky (VTS).
(Estimated Hot Spots in the LCFRB basins in sequential order)

NF Lewis River Basin	**EDT Reach**	**Current Change from Reference Temperature[1/]** - (%)	+ T°C	**Hazard[2/]**	**Comment**
Mainstem	Lewis 4	33%	2.4	High	Naturally High
	Lewis 5	18%	1.3	Moderate	Naturally High
Tributaries	Cedar 2	26%	2.0	High	Agri. & Livestock
	Cedar 3	26%	1.9	High	Agri. & Livestock
	John Cr.	16%	1.2	Moderate	
	Chelatchie 2	14%	0.7	Low	Beaver Dams
	Cedar 6	6%	0.4	Low	Preservation

[1]Reference Temperature Condition occurring under the assumption of mature trees (46m; 150 ft high) growing at edge of active channel width.

[2]Water Temperature hazard is the relative degree of risk to complying with aquatic use categories compared to reference condition per reach.

These estimates predicted freshwater surface temperatures only based on elevation, channel width and canopy coverage. They did not consider the cool water influence of groundwater influx or conversely, additional heating due to runoff from wetlands or ponds or the effect of shallow channel cross-sections. Actual water temperatures will vary with NF Lewis Creek discharge, groundwater flux, the relative volume of ponded water runoff and local weather patterns.

Clark County Public Utilities (CPU) and Clark County Public Works (Water Resources) collected continuous surface water temperature recordings of 5 stations in the basin during 2004. Four of those sites overlapped EDT reaches surveyed during this effort including Cedar 2, 3 and 6 and Chelatchie 2. Comparison with VTS modeled results with 2004 temperature data measured by Clark County in the basin indicates actual surface water temperatures are in good agreement with the model in Chelatchie Creek and in certain segments of Cedar 2 but they are warmer than predicted by the VTS model in Cedar 3 and 6 (Appendix B). The data imply site-specific factors other than elevation and the relative degree of open riparian canopy are likely influencing local water temperatures. Cedar 2, 3 and 6 have a high frequency of shallow, small cobble riffles, and a general lack of residual pool depth. These factors have the potential to increase the thermal heating in these reaches. Riparian stand conditions in Cedar 3 consisted predominately of small sparse stands of mixed or hardwood species composition. Cedar 2 and 6 supported a mixture of sparse and dense riparian stand conditions. The VTS model has a optional routine to address sparse riparian stand conditions by adjusting the height of radiation blocking elements to account for various levels of stand opacity. Based on the comparison of measured and predicted temperature levels, the next generation of the VTS model for the NF Lewis River basin should consider an adjustment for stand opacity.

Enhancement of Existing EDT Model

The NF Lewis Basin stream survey data were compared to existing attribute values in the EDT Stream Reach Editor (SRE) in an effort to enhance the current modeling effort with site-specific data. In general, categorical ratings for wood, sediment and embeddedness were relatively consistent between the data in the SRE and the recent field observations. However, measurement data, primarily width and habitat types, occasionally differed between the SRE and the recent field observations. Caution is advised when interpreting wetted or minimum stream width comparisons since the low flow widths are a function of stream flow levels during the surveys and vary between wet and dry years.

Specific comparisons between the SRE and the current stream surveys are itemized in Appendix 2B. In general, the following major items were noted in the NF Lewis basin:

1. Width: The data in the SRE and the recent field measurements show relatively good agreement.

    a. Exceptions related to stream width include: John Creek and Cedar 6. In these reaches the wetted width was greater than active channel width. In these situations it was necessary to compute a revised maximum width for the SRE. For the habitat units where the bankfull width was measured, the average ratio of the bankfull width to the wetted width was computed. The ratio was then applied to the average stream width value for the entire reach to compute a maximum width for the entire reach.

2. Pool Area: In general, the SRE data showed more pool area and less small cobble riffle relative to the more recent field observations.

3. Fine Sediment and Embeddedness: The field observations show higher levels of embeddedness relative to the categorical ratings in the SRE. However, fine sediment levels were more similar in both datasets.

4. The SRE data for large wood consistently included higher estimates of wood levels than the recent field surveys.

The extent of differences between the recent observations and the data in SRE may result in substantial differences in estimated fish performance measures in EDT, depending upon the extent changes permeate through the model. Because the differences appear in both habitat quantity (capacity) and quality (productivity), the EDT is likely to be improved in terms of estimating population capacity and productivity.

3.2.4 Sediment Sources

Lower North Fork Lewis River Basin

Geology and Geomorphology

Between Merwin Dam and the confluence with Cedar Creek, the lower North Fork Lewis River flows through a mix of glacial outwash and Lake Missoula flood sand and silt deposits, and fine grained igneous andesite flows dating from the Oligocene to Eocene (Figure 3-2; Walsh et al. 1987; Foster 1983). Within a short distance downstream of Cedar Creek, the mainstem transitions into thick alluvial deposits of silt, sand and gravel. A recent report documented sand and silt as the dominant soil material (PacifiCorp 2002) in this area.

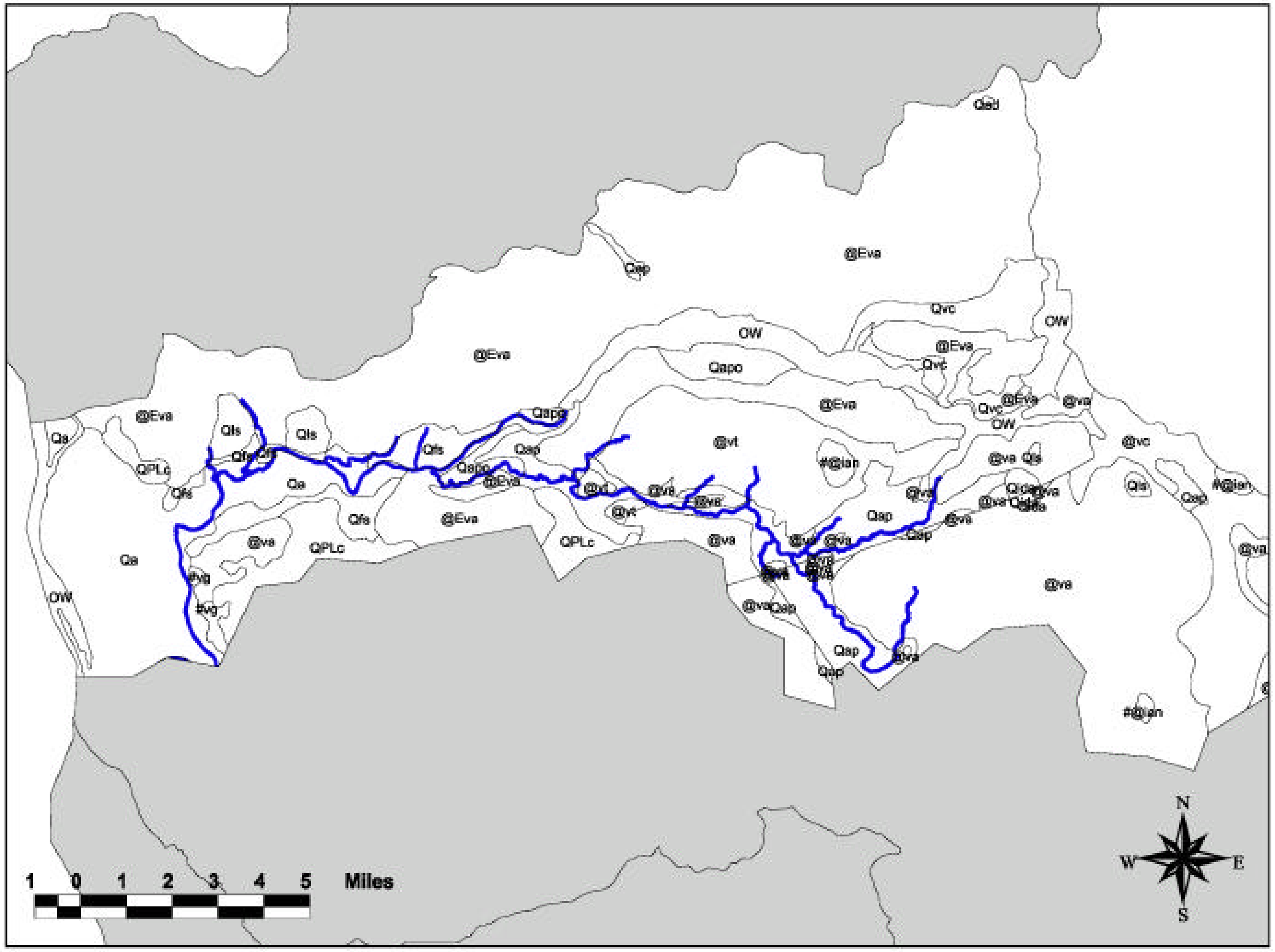


Figure 3-2. Geologic units in the lower North Fork Lewis River basin (Walsh et al. 1987) and EDT reach delineations. See Appendix C for listing of unit symbols.

Robinson Creek flows through a Quaternary landslide debris area with coarser grained fine sediments, whereas Ross, Houghton, and Johnson creeks flow through fine grained igneous andesite flows, similar to Kalama River tributaries. Robinson Creek also flows through a short length of Lake Missoula flood sand and silt deposits. The three lower tributaries flow through mainstem alluvial deposits at their downstream ends before joining with the North Fork Lewis River. At the time of this assessment, Johnson Creek had a much more limited alluvial deposit at its mouth than the other tributaries.

Cedar, Chelatchie, and Bitter creeks flow through predominantly glacial till and outwash sand and gravel, associated with generally medium to coarse grained fine sediments. North bank tributaries to, and the headwaters of, Cedar Creek flow mostly through finer grained igneous tuff and are steeper than the channels flowing through glacial material. Approximately 30 percent of inputs to the Cedar Creek basin are from the Cinnebar/Yacolt soil series located within the glacial till and outwash consists of gravel and larger particles (PacifiCorp 2002).

The lower mainstem North Fork Lewis River has a relatively low gradient, averaging around 0.05-0.06 percent (Figure 3-2). Such channels are categorically considered to be "sediment transport limited" (Montgomery and Buffington 1997), and are sites where sand, gravel and cobble tend to deposit. The four lower, north bank EDT tributaries (Robinson, Ross, Johnson and Houghton creeks) drain steep, small area catchments. Salmon and steelhead spawning habitat in these streams is most likely in segments with average gradients between 1.5-3 percent (Figure 3-4). These segments occur where Robinson, Ross, and Houghton creeks flow out of mountainous terrain onto the wide, flat Lewis River valley and in the low gradient reaches above State Route 503 in Ross, Houghton, and Johnson creeks. Of the four tributaries, Houghton Creek flows most extensively through the mainstem floodplain for approximately a mile, and this channel morphology is reflected in its substrate composition (see below).

Lower Cedar Creek cuts steeply through an underlying andesite flow geologic unit (Figures 3-2, 3-3). Cedar 2, 3, 4, and 5 EDT reaches upstream of Pup Creek have comparable gradients to Chelatchie Creek and lower North Fork Chelatchie Creek (Figures 3-3, 3-4). The Cedar Creek 6 EDT reach steepens to a long segment with a relatively consistent gradient around 1 percent above the confluence with Chelatchie Creek. John Creek is relatively steep throughout, except for short segments near its confluence with Cedar Creek and above and below Cedar Creek Road. Bitter Creek is mostly steep but has about a mile long segment extending above and below State Route 503 with a gradient comparable to the Cedar 6 EDT reach.

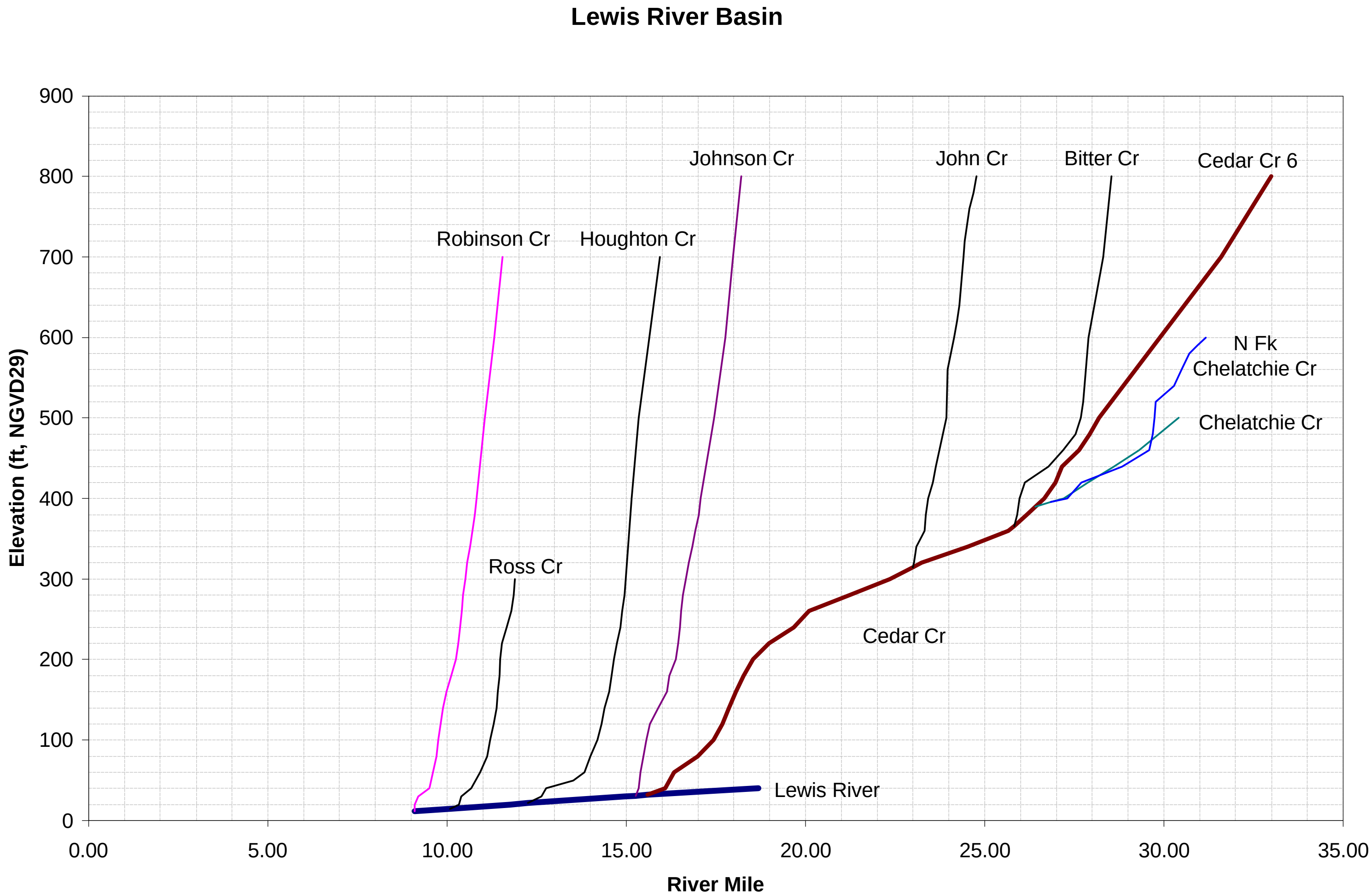


Figure 3-3. Average longitudinal elevation profiles of the mainstem lower North Fork Lewis River and tributaries surveyed for the sediment task.

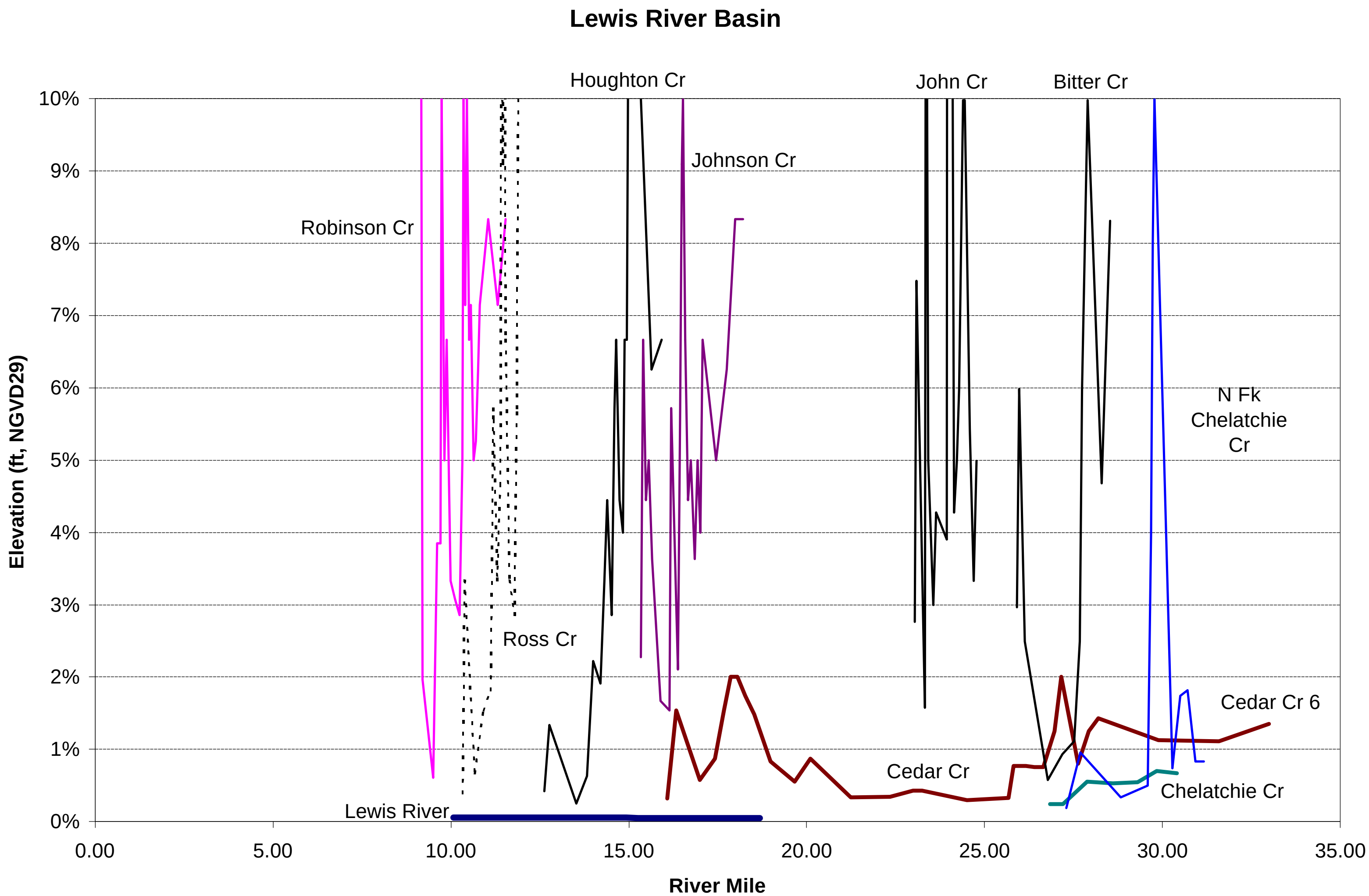


Figure 3-4. Average stream gradients in the mainstem lower North Fork Lewis River and tributaries surveyed for the sediment task.

Effects of Dam Construction on Mainstem North Fork Lewis River Sediment Sources and Transport

The construction of Merwin Dam resulted in holding up a significant source of fine and coarse sediments to the North Fork and lower Lewis River study reach, especially between the dam and the confluence with Cedar Creek. At the same time, flow regulation resulted in reduced magnitude and frequency of peak flows and thus, lower gravel transport capacity. A recent study by PacifiCorp (2002) found gravels were still present on point bars, were not being transported downstream at very high rates annually, and were relatively clean in this reach. Cedar Creek has become by default a significant source of gravel and cobble to the mainstem. Despite dam construction, recent floods have occurred in the lower Lewis River and have transported fine sediments, as evidenced by fresh sand deposits on floodplain terraces. Primary sources of these fine sediments were probably Cedar Creek and the Lake Missoula and alluvial deposits along the Lewis River. Questions remain whether the river morphology and spawning habitat availability changed in response to dam construction. It is generally believed the changes appear in the Lewis River basin have been small relative to other systems that have been dammed (PacifiCorp 2002). Some downstream fining of the streambed was evident in gravel samples collected between Merwin Dam and Eagle Island. The trend may reflect, in part, the transition from a confined to an unconfined reach around RM 15. Median particle sizes were approximately 40 mm and 20 mm in the upper confined reach and in the lower unconfined reach, respectively (PacifiCorp 2002).

Percent Embeddedness and Fine Sediment Levels

Embeddedness levels were generally low in spawning gravels in the mainstem North Fork Lewis River. Relicensing studies indicated percent fines < 2 mm in size comprised typically less than 15 percent of spawning substrates, and often less than 10 percent (Pacificorp 2002). These levels are conducive to high levels of embryo survival to fry emergence (Chapman and McLeod 1987). Sands and much suspended material settle in the series of impoundments upstream of Merwin Dam. Thus, spawning gravels in the lower mainstem remain relatively clean. The amount of fines contributed by Cedar Creek and other tributaries did not appear to significantly influence spawning gravel quality in the mainstem North Fork Lewis River reaches.

Embeddedness and fine sediment levels varied between tributaries draining directly to the North Fork Lewis River. Ross Creek and Robinson Creek were characterized by coarser sands than Houghton Creek and Johnson Creek. This finding reflects the underlying geologic material of each sub-basin (Figure 3-2). Robinson Creek was observed to have the highest level of fines and embeddedness (~75 percent) in habitats that might be used for spawning than the other three tributaries, where embeddedness levels were around 50 percent (Table 3-8). Small increases in fines concentrations above existing levels would be expected to result in measurable decreases in intragravel survival of embryos and alevins (Chapman and McLeod 1987). Specific observations in these tributaries follow.

- Johnson Creek is the largest stream of the four tributaries, and appeared to have the most spawning habitat available upstream of the State Route 503 culvert, which is fitted with fish passage weirs. However, there was notable evidence of livestock impacts leading to increased delivery of fine sediments to the channel in this reach. It is conceivable historic embeddedness levels were close to 25 percent.

- The lowermost mile of Houghton Creek contained high levels of fines such that embeddedness was estimated at 100 percent. The high level of fines reflects both a low gradient and the underlying fine-grained alluvial material the stream flows across. Upstream of State Route 503, the stream was steeper and embeddedness levels (around 50 percent) were lower than observed in downstream reaches (Table 3-8). Houghton Creek fines visually appeared to contain a greater proportion of coarse silt than the other three tributaries, where fine to medium sands were more common.

- Steep habitat units in Ross Creek were characterized by estimates of 25 percent embeddedness.

- Channel encroachment of vegetation, primarily composed of Himalayan blackberry, in lower Robinson Creek appeared to be facilitating more extensive fine sediment deposition in spawning habitat than in the other streams, which may reflect its small channel size.

The Cedar Creek sub-basin was characterized by moderate to high embeddedness levels (Table 3-8). Embeddedness levels appeared to increase in the downstream direction from the Cedar 6 to Cedar 2 EDT reaches. While the visual ratings were similar (50 percent) above and below the confluence with Chelatchie Creek, the Cedar 6 EDT reach was judged to have cleaner substrates than Cedar 5 and other downstream reach. In addition, a fine-sediment “signature” (i.e., visible deposits, streaks, and color of sand, and aquatic vegetation) in the Cedar 5 and other downstream Cedar Creek reaches was more characteristic of Chelatchie Creek than the Cedar 6 reach. The differences reflected in large part the variation in stream gradient, where the gradient in Cedar 6 is steeper than in the Cedar 2 to Cedar 5 reaches. In turn, the downstream Cedar Creek reaches are similar to the gradient in Chelatchie Creek (Figure 3-3).

Table 3-8. Percent embeddedness classes and pebble count percentiles collected in the lower North Fork Lewis River basin for the sediment task.

Basin	EDT River Reach	Geomorphic Location of Pebble Count Sample	Average Stream Gradient [1]	Percent Embeddedness	D50 (mm)	D90 (mm)
N.F. Lewis	Lewis River 5	Point Bar	0.0006	0	32	64
	Lewis River 7	No Sample		0		
	Robinson Creek	No Sample		75		
	Ross Creek	No Sample		50		
	Houghton Creek	No Sample		50		
	Johnson Creek	No Sample		50		
	John Creek	Riffle Thalweg	0.05	50	46	180
	Bitter Creek	No Sample		100		
	Chelatchie Creek 2 (lower)	Riffle Thalweg	0.002	75	17	60
	Chelatchie Creek 2 (upper)	No Sample		100		
	North Fork Chelatchie Creek	No Sample		100		
	Cedar Creek 2	No Sample		75		
	Cedar Creek 3	No Sample		50		
	Cedar Creek 5	No Sample		50		
	Cedar Creek 6 at Amboy	Riffle Thalweg	0.008	50	100	175
	Cedar Creek 6 near Yacolt	Point Bar	0.011	50	17	71

[1] - In sub-reach where pebble count was taken; derived from USGS 1:24,000 topographic maps (approximate).

[2]The habitat crew was working in Cedar Creek at a higher flow than when the sediment/hydromod team was in the field. Embeddedness ratings of the two teams were similar for the Cedar 6 reach, where the channel and flow depth are small enough to be able to characterize embeddedness. However, embeddedness ratings diverged the most for the Cedar 2 and 3 reaches: the habitat crew estimated a substantially lower embeddedness (around 25 percent) for both reaches than the sediment/hydromod team (75-100 percent embedded). Values in Table LS1 were weighted more to the latter team's estimates, which were made when flows were low and visibility good; the habitat crew estimates likely reflected active entrainment of surface fines ("Phase I" transport, Beschta and Jackson 1979) and more opaque water during what appeared to be near-bankfull flow in photographs. Ratings were more consistent between the two crews in other sites.

Unpaved road crossing densities were low in the Cedar Creek sub-basin compared with other sub-basins in the three watersheds surveyed. Tributary embeddedness levels reflected variation in geology, stream gradient, and land use:

- John Creek had the lowest embeddedness rating (Table 3-8), which appeared to most strongly reflect differences in geologic units and channel gradient (Figure 3-8).

- Bitter Creek had a heavy fine sediment load, which likely reflects a combination of geology and livestock/rural residential impacts.
- Chelatchie Creek and North Fork Chelatchie Creek flow through a low gradient valley that has experienced agriculture/livestock and low density residential development. The streams appeared to provide good quality rearing habitat but spawning habitat quality was severely limited by high fine sediment levels. However, fine sediment levels in these channels would be expected to be naturally high given the low stream gradients and relatively small drainage area compared with the glacial outwash valley size.

Comparison of Data With the EDT Model's Hypothesized Embeddedness Ratings

The EDT model defined percent embeddedness as the extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. In this assessment, embeddedness was determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface were buried by fine sediments. The embeddedness attribute only applies in the EDT model to values in riffle and tailout habitat units, and only where cobble or gravel substrates occur. The ratings applied in the model are as follows:

Percent Embeddedness	EDT Rating
0-9 %	0
10-24 %	1
25-49 %	2
50-89 %	3
90-100 %	4

In the EDT model, the pristine (template) conditions were assumed to be associated with a rating 0.5 for embeddedness (i.e., generally less than 10%) throughout the North Fork Lewis basin, based on an assumption between fines and embeddedness. Current conditions were estimated indirectly assuming that embeddedness levels correlate with percent fines levels. It was assumed further that percent fines (and thus embeddedness) increased by 1.3% (assumed here to be absolute) as road density increased by 1 mile per square mile of drainage area. This factor was reported in the EDT database as having been determined by Rawding (unpublished citation) in the nearby Wind River basin. A scale was developed relating road density to percent fines and embeddedness.

Comparison of the data collected in this study with the assigned EDT ratings indicated that modeled embeddedness levels were under-estimated throughout the basin. If the EDT ratings were accurate, the points depicted in Figure 3-5 would have been expected to fall within the diagonal range defining the EDT ratings. The EDT model should be revised accordingly to more accurately reflect current conditions.

Pebble Count Data and Spawning Gravel Distributions

Spawning gravels were present in usable amounts throughout the lower North Fork Lewis River basin mainstem and tributaries. Of the tributary sub-basins surveyed, coho salmon and steelhead trout were either known or presumed to spawn in all four of the smaller mainstem tributaries (Ross, Robinson, Houghton and Johnson), and in Cedar Creek, Chelatchie Creek, North Fork Chelatchie Creek, and John Creek. Chinook salmon reportedly spawn primarily in the mainstem Lewis River between ~ RM 4.0 and Merwin Dam, and in Cedar Creek. Chum salmon historically spawned in the lower Lewis River and Cedar Creek (LCFRB 2004). Tributary sub-basins appeared to be limited less in terms of spawning habitat quantity than in terms of quality as influenced by fine sediment levels.

Of the reaches sampled for pebble counts, the mainstem North Fork Lewis River and John Creek appeared to have deposits that are best suited for spawning Chinook salmon and steelhead trout (Figure 3-6). The following observations were also made based on the pebble counts and field visit.

- Johnson Creek appeared to possess a relatively large amount of spawning habitat upstream of the State Route 503 culvert, which is fitted with fish passage weirs. There was notable evidence of bedload transport of gravel and cobble suggesting a steady supply to the reach from upstream.

- Gravel and cobble bedload was deposited over a short reach in Houghton Creek between Abel Road and State Route 503, where the gradient decreases rapidly in the downstream direction. Spawning habitat was located above this slope break, but the substrate was cemented by coarse silt compared to substrates in Johnson Creek and Ross Creek, that appeared unconsolidated and mobile.

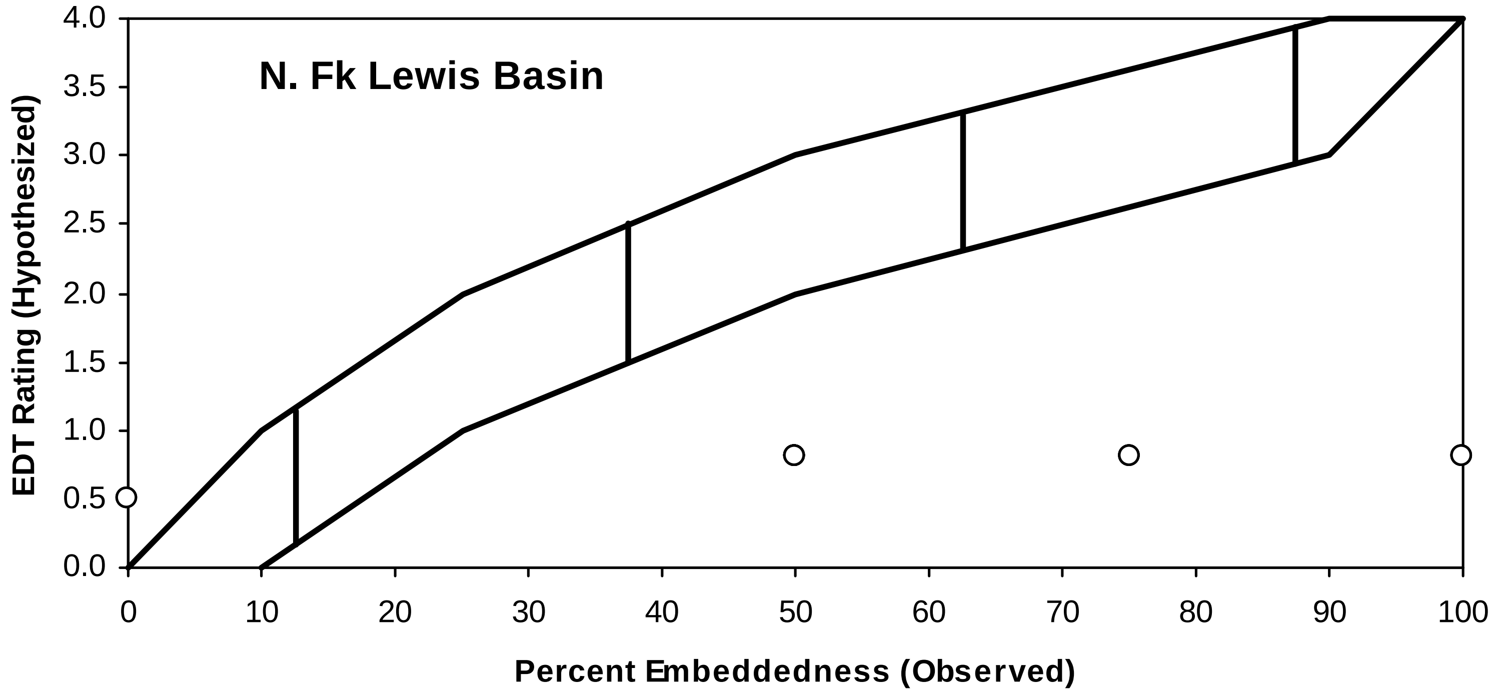


Figure 3-5. Comparison of embeddedness data collected in the lower North Fork Lewis basin for the sediment task (horizontal axis) with ratings assigned to the respective EDT reach (and represented in LCFRB 2004). The hypothesized EDT ratings are accurate when the observed data points fall within the respective diagonal ranges (which define the range of embeddedness values assigned to each EDT rating).

- Ross Creek had sections with good spawning substrates, although shallow depths associated with relatively low stream discharge may limit the salmon and steelhead spawning.

- Chelatchie Creek had suitable spawning substrates, but they were generally embedded heavily with fines.

- Substrates in the lower Cedar 6 reach channel appeared to be of a suitable size for use by spawning Chinook and steelhead, but riffle bed material may be too coarse in many locations (Figure 3-6).

3.3 SYSTEM WEAKNESS, STRENGTHS AND OPPORTUNITIES

The primary goal of the enhancement strategy for the Lower Columbia Watershed Assessment was to identify system strengths and weaknesses and where appropriate identify restoration opportunities. Restoration was focused on re-establishing natural watershed processes that formed and maintained fish habitat prior to changes resulting from historic and current land-use practices. Restoration thus includes three main components: 1) restoration of habitat connectivity; 2) restoration of upslope and riparian geomorphic processes; and 3) rehabilitation of degraded habitats. This restoration approach is consistent with that outlined by NMFS scientists in their NWFSC Watershed Program (Roni et al. 2002).

3.3.1 Identification of System Weaknesses

Habitat weaknesses identified during the assessment are summarized below.

- At the time of this assessment forest covered only 14 percent of the current floodplain and less than 5 percent of the historic generalized floodplain for the lower 15.5 miles of the NF Lewis River.

- The lower 15.5 miles of the NF Lewis River was associated with an unconstrained floodplain that was reduced to only 12 percent of its historic condition.

- Current levels of urban and rural residential development impact floodplain function in the lower 15.5 miles of the NF Lewis River.

- There has been a loss of connectivity in the Columbia/North Fork Lewis rivers floodplain.

- There has been a severe loss of side channel habitat throughout the lower 15.5 mi of the river.

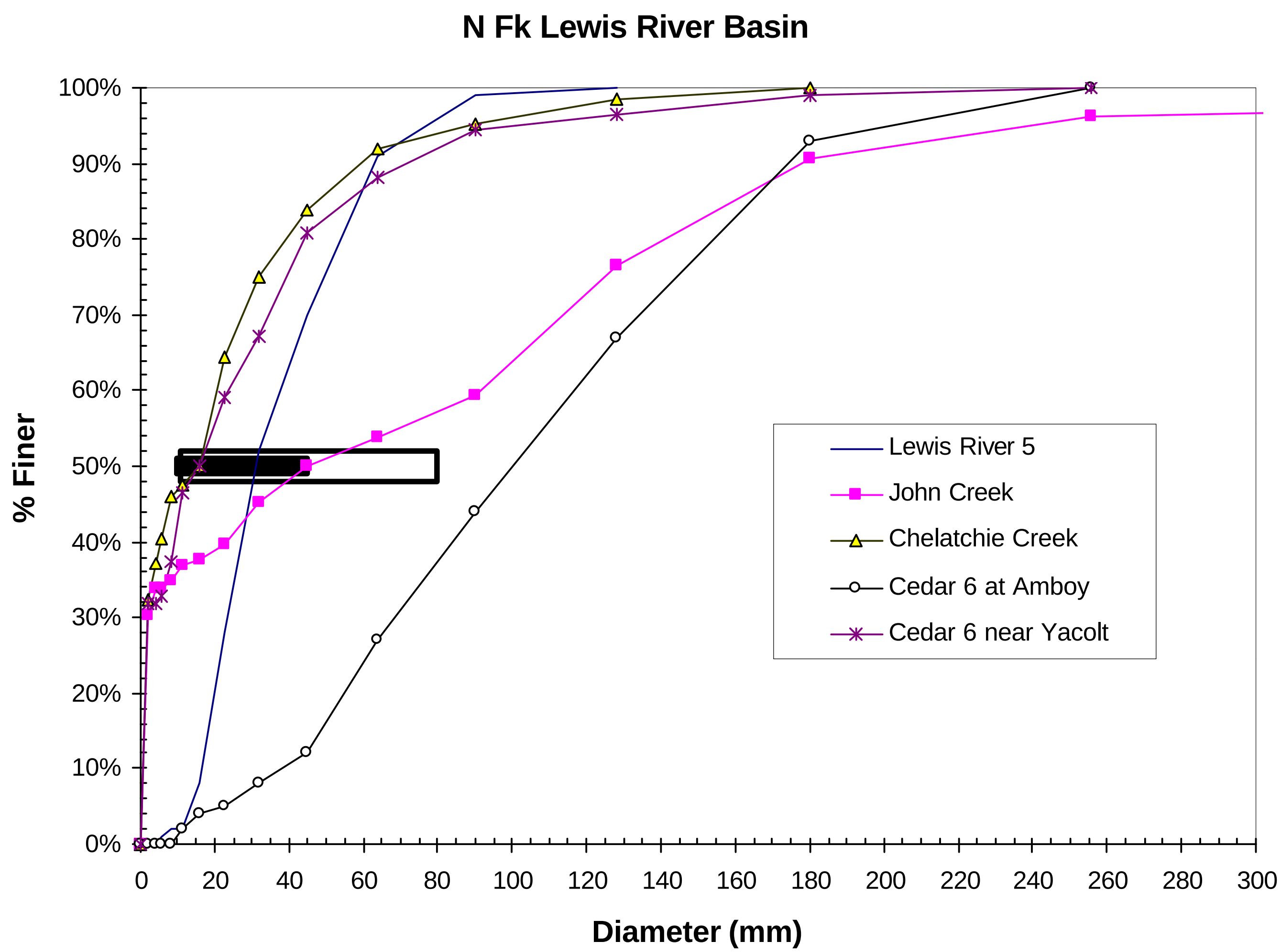


Figure 3-6. Grain size distributions of pebble counts collected in the lower North Fork Lewis River basin for the sediment task. The horizontal bars represent the range of D_{50}s reported by Kondolf and Wolman (1993) as suitable for steelhead trout (filled bar) and Chinook salmon (open bar) spawning.

- Large sections of the river are confined by levees, armored banks and roads
- Fair to poor riparian stand conditions were found in over 68 percent of the riparian corridor assessed and a high proportion of the stands were dominated by deciduous species for the entire river basin.
- Encroachment resulted in 33-59 percent disturbance to riparian habitat and has adversely impacted LW recruitment.
- In-channel loading of LW was lacking in the mainstem NF Lewis River and in the lower reaches of Cedar Creek.
- A high proportion of invasive plant species were found in Robinson, Ross, and Johnson creeks.
- VTS model indicated that current riparian conditions are likely to result in exceedances of water temperature standards in NF Lewis River tributaries.
- VTS model indicated that current riparian conditions are likely to result in exceedances of water temperature standards in tributaries.
- High water temperatures in Cedar Creek are associated with land use practices that have impacted riparian habitats.
- Embeddedness was high in Johnson, Houghton, Robinson, and Ross creeks and in the Cedar Creek subbasin including the Chelatchie Creek subbasin.

3.3.2 Identification of System Strengths

Habitat strengths identified during the watershed assessment are summarized below.

- The Eagle Island area is the last unconstrained section of the lower NF Lewis River.
- In the lower 15.5 mi, the length of mainstem NF Lewis River channel bank has increased from historic conditions.
- Although infrequent pools in the mainstem of the NF Lewis River were deep and clear and provide good adult holding habitat.
- Mainstem NF Lewis River reaches with spawning gravels had low embeddedness.
- Spawning gravels were distributed throughout the entire basin in useable amounts.

- Cedar Creek has potential for increased salmonid production with implementation of appropriate enhancement restoration actions.

3.3.3 Protection/Restoration Opportunities

The habitat conditions for the North Fork Lewis River basin were reviewed and the data from subdisciplines were synthesized into appropriate opportunities for preservation and or protection throughout the basin. Potential restoration opportunities were prioritized by: (1) emphasizing preservation and protection of areas that currently function normally, (2) considering actions that help to restore overall system function, and (3) considering the distribution of and likely habitat use by anadromous salmonid fishes.

The majority of floodplain and off channel habitats in the lower Lewis River basin have been cut-off from the river and are now developed. Because undeveloped areas are concentrated within the current floodplain, future restoration of hydromodified habitats in the lower North Fork Lewis River basin should focus on preserving natural channel margins and areas with existing functional floodplain habitats.

Recommended categories of management actions for the improvement of riparian conditions in the NF Lewis River Basin, include protecting existing riparian vegetation and promoting recovery were possible. Efforts to preclude future human-induced encroachment into the riparian zone or reversal of prior encroachment should be considered. Riparian improvements are limited in lower NF Lewis River mainstem since these reaches likely offered naturally low levels of shade and wood recruitment. The reaches lying in the existing and historic floodplain likely experienced a frequent disturbance history in the riparian zone. Riparian plantings and protections along both banks and around the mid-channel island in Lewis 5 offer the best opportunity to provide much needed shade to the mainstem reaches.

With respect to in-channel habitat restoration opportunities, the large contained mainstem reaches offer a good level of stream power. Wood placement opportunities may be restricted to massive engineered log-jams in the unconstrained portions of the lower NF Lewis River. Wood placement is occurring in the tributary reaches and should be encouraged at sites where the structures have a good likelihood of remaining during storm events. The low gradient portions of Cedar 6 offer good opportunities for further wood placement. Wood will remain readily in Chelatchie Creek, but the palustrine channel habitat does not offer much room for improved fish production with additional wood inputs.

Streams in the lower North Fork Lewis River basin currently have a lower road crossing density compared to streams in the Kalama River and Washougal River basins. Hence, measures addressing road-generated sediments would not be expected to have a large effect on reducing fine sediment levels in the basin. Highest levels of embeddedness in the surveys generally match reach slopes and the geologic units in the basin. Thus, measures to reduce sediment loading must consider first and foremost the geologic backdrop in the lower North Fork Lewis River basin. Measures to reduce fine sediment levels in small to mid-size channels are expected to lead to limited to negligible benefits to salmon and trout reproductive success in Ross Creek, Robinson Creek, Bitter Creek, Chelatchie Creek, and North Fork Chelatchie Creek. These streams cut through parent geologies associated with high levels of instream fines, and/or have relatively low slopes and channel forms that do not facilitate high downstream transport rates of fine sediment. Cedar Creek, presents a special case that may benefit in the near future from fine sediment source control, particularly below the confluence with Chelatchie Creek in Cedar 2 – 5. Cedar 6 upstream of the Chelatchie Creek confluence would also benefit from fine sediment source control.

Restoration opportunities in the mainstem North Fork Lewis River have been the subject of relicensing studies for Merwin Dam (PacifiCorp 2002). Substantial resources have been expended in assessing spawning gravel availability, quality, and restoration potential. Gravel augmentation has been considered feasible to mitigate for upstream reductions in supply caused by dam construction. Annual transport rates have been estimated to be relatively low, and fine sediment infiltration would also be limited because of the upstream impoundments. High quality spawning gravel deposits consequently remain present in relatively large quantities below Merwin Dam. Spawning gravels are generally cleanest in the NF Lewis River between Merwin Dam and the confluence Cedar Creek. It would make sense from a gravel quality perspective to augment gravel supplies in the NF Lewis River upstream of the confluence of Cedar Creek

The following prioritized list of conceptual opportunities, based on the data and field observations, have the greatest potential for success and benefits to salmonid fish production (Table 3-9). However, it is strongly recommended additional, detailed studies be conducted to determine feasibility of the potential opportunities.

1. Preservation: Eagle Island, RM 9.9 to 11.9

This area consists of an island located in the center of a split mainstem channel, and a small backwater slough on the north bank at the mouth of Houghton Creek. It currently supports a mosaic of bar, shrub and forest, although the timber there is not mature. This mainstem section of Lewis 4 appears to be the only area within existing floodplain where fluvial geomorphic processes (erosion, sedimentation, channel avulsion and side channel development) are currently functioning properly.

2. Preservation/restoration: north and south banks, RM 2.0 to 3.1

There are two small areas of intact forest within this portion of the Lewis River, one on the south bank between RM 2.0 and 2.7, and the other along the margin of a point bar located on the inside of a tight meander bend at RM 2.9 to 3.1. Historic maps suggest both of these areas may have supported overflow channels. As a consequence, they represent sites with some potential for development of off-channel habitat. In addition, although there are residences behind the levee near the north bank point bar, this area represents one of the few locations where a relatively limited levee setback projects could restore functional floodplain habitat. Preservation/restoration of floodplain habitats in this area is given a relatively high priority due to the scarcity of functional habitat throughout the first 7.3 miles of Lewis River mainstem channel.

3. Preservation/restoration: south bank, RM 13.3 to 15.0

The floodplain area located on the south bank between RM 13.3 and RM 15.0 historically supported a number of side channels and backwater habitat features. For the most part the floodplain in this area has not been cut off from the river, and remnant off-channel features persist on the landscape today. The area appears to be currently undergoing residential development. Preservation of remaining undeveloped areas and prevention of additional bank armoring will maintain existing off-channel habitat features.

4. Preservation of Cedar Creek spawning habitats. The Cedar 6 EDT reach currently exhibits a relatively low development impact on instream fine sediment levels. At a little below 50 percent embeddedness, however, relatively small increases in fines concentrations would be expected to result in measurable decreases in intragravel survival. This reach should be the focus of preservation efforts to prevent further degradation. The upper Cedar Creek basin appears subject to future development pressure, so it will be important to ensure development occurs without adversely affecting fine sediment levels. In addition, restoration efforts are needed to provide a safety factor to maintain fines below the threshold condition. The Cedar 6 EDT reach appears to have greatest potential for restoring or enhancing spawning habitat in the Cedar Creek sub-basin, based on the embeddedness, pebble count sampling and riparian function. It is important to ensure future development does not result in increasing fine sediment levels above present day

values or encroach upon riparian areas along this reach. Given the great potential in this reach, it makes sense to focus fine sediment abatement and control efforts in this sub-basin first.

5. Enhancement of Cedar Creek spawning habitats.
   a. Spawning gravel enhancement measures are recommended first in the Cedar 6 EDT reach rather than downstream where fine sediment problems appear to a concern. Efforts in other reaches should be given secondary priority to efforts in the Cedar 6 reach. Channel gradient, pebble counts, and visual observations of bed material and gravel deposit composition suggest gravel transport in this stream reach is sufficient for successful implementation of instream structures to reduce local gradients or provide roughness with the goal of trapping and creating local in-channel deposits of spawning gravel. Based on data and observations made in this study, such efforts are expected to be most successful in the Cedar 6 reach compared with the other reaches surveyed in the North Fork Lewis River basin.

   b. The Cedar 2, 3, and 5 reaches had greater width:depth ratios than Cedar 6, which may reflect, in part, a loss of riparian vegetation compared with pre-settlement conditions. It is conceivable riparian restoration efforts, including fencing to keep livestock out of the riparian zone, could eventually lead to narrowing and deepening of the channel in Cedar 2, 3, and 5 over the long term. This effort could increase fine sediment transport capacity sufficiently with potential improvements in spawning riffle embeddedness and salmonid fish reproductive success. This measure would require more detailed bedload transport analyses to better determine feasibility and expected success.

   c. While it may not be feasible to reduce fine sediment levels in Chelatchie Creek to values associated with good reproductive survival, it may be feasible to reduce sediment delivery sufficiently from Chelatchie Creek to improve substrates in Cedar Creek. Riffles in the Cedar 2, 3 and 5 EDT reaches had observed embeddedness levels around 25-50 percent, whereas higher levels were observed in glide and run habitats. The embeddedness levels reported in Cedar Creek below the confluence with Chelatchie Creek appear to be sensitive to changes in supply. Thus, the middle reaches of Cedar Creek may respond positively to source control both locally and upstream in Chelatchie Creek. Specifically, livestock access and riparian re-vegetation measures would need to be considered throughout the Chelatchie sub-basin, as well as in selected locations in Cedar Creek. While the scale of effort needed to be effective is large, it appears feasible with sufficient local community support. In addition, depending on community willingness, (re)introduction of beaver to Chelatchie Creek would be expected to decrease the delivery of fine sediments to Cedar Creek. The extent such measures would be successful in reducing fine sediment levels downstream in Chelatchie Creek will require additional, detailed sediment budgeting and transport analyses.

6. Johnson and Houghton creeks also have some potential to benefit from fine sediment abatement measures. These two streams: (1) run through less erodible geologic units than Ross and Robinson creeks, (2) have reaches with relatively abundant spawning gravels, and (3) are relatively undeveloped upstream. Collaborative efforts with landowners to keep livestock out of the riparian corridor, and allow riparian vegetation stands to establish or become more dense would be associated with a probability of measurable benefits to salmonid fish reproductive success.

7. Riparian plantings. Surveyed areas in John Cr, Cedar 2, Cedar 3, and Cedar 6 have specific opportunities for riparian plantings or other techniques to narrow the current VTS and to offer future potential increases in LW recruitment potential.

8. Explore the potential for conifer enhancement in riparian stands. Potential enhancement of riparian stands could occur by either: (1) hardwood conversion where soil conditions are conducive to conifer growth or (2) releasing conifers in mixed or overstocked stands for enhance conifer growth rates at appropriate sites.

9. Invasive plant removal. An abundance of invasive plant species were identified in Robinson, Ross and Johnson creeks. Cooperation with landowners and Clark County Weed Management Department to remove these invasive and plant native riparian species enhance riparian function in these tributaries.

10. Incorporation of LW into existing armored banks during maintenance. Additional bank hardening should be limited throughout the river basin. If future maintenance or reconstruction projects are required, incorporation of woody debris into existing armored banks would improve habitat conditions for juvenile salmonid rearing along the stream margins (Beamer and Henderson 1996).

11. Restoration of tidal slough and floodplain habitats, RM 0.0 to RM 5.0 NF Lewis River. Remnant slough, wetland and floodplain surfaces associated with the combined Lewis and Columbia River floodplains persist in the area north and west of the Lewis River between RM 0.0 and RM 5.0. A small amount of undeveloped floodplain also exists east of the river between

RM 3.3 and RM 5.0. While these areas currently support relatively limited infrastructure, they are used extensively for agriculture and are separated from the river by a major levee system. Thus, restoration to fully functioning condition would be difficult and expensive. However, there may be opportunities for limited restoration of tidal slough habitat or possibly future conversion of agricultural lands to floodplain forest in this area. This restoration opportunity is given a low priority because of the high cost, degree of difficulty and extensive use of the area in question for agriculture. Similar functional habitats also exist south of the Lewis River in the Ridgefield National Wildlife refuge.

12. There is an active salmon carcass placement program underway in the Cedar Creek basin, including in the Chelatchie Creek sub-basin. Given the prominent algal growth and other signs of eutrophication seen in Chelatchie Creek and downstream in Cedar Creek that seems to reflect agricultural and rural land use practices, those portions of the basin as a whole do not appear to be nutrient limited. Therefore it is not clear if carcass placement to provide marine-derived nutrients will achieve the desired results. It may be more cost effective to focus predominantly on adding carcasses to the Cedar 6 EDT reach, which does not show similar signs of eutrophication.

13. The Cedar Creek culvert under the Amboy-Yacolt Road was replaced recently with an oversized, countersunk, no-slope culvert, reflecting WDFW design guidelines. However, a riprap rock weir potentially constructed to provide downstream grade control for the culvert also appears to make upstream passage difficult over a range of low- to middle-stream flows because there is no low flow passage lane. Water is distributed widely to flow through and among a jumble of rock. Salmon and steelhead passage may be delayed as a result until a freshet or large storm event occurs. Minor rearrangement of the rock structure could be accomplished to effectively provide unfettered passage to upstream spawning habitat, while still providing grade control.

Table 3-9. Prioritized protection/enhancement opportunities for the North Fork Lewis River basin by geographic area. Detailed project descriptions are found in section 3.3 of the report. NA indicates no corresponding EDT reach.

Location	EDT Reach/ RM	Opportunity	Short Description	Priority
Mainstem N. Fork Lewis	NA -basin wide	Riparian Enhancement	Enhancement of conifer species in riparian habitat by hardwood conversion or releasing conifers in mixed stands.	8
Mainstem N. Fork Lewis	Lewis 1, 2/ RM 0 to 5.	Restore tidal slough and floodplain.	Remnant slough, wetland and floodplain surfaces still exist but are used for agriculture and are protected by levees. Restoration of the tidal slough and floodplain forest are recommended.	11
Mainstem N. Fork Lewis	Lewis 1/ RM 2.0 to 3.1	Preservation of North and South banks.	Preserve to small areas of intact forest (south bank RM 2.0 to 2.7 and north bank RM 2.9 to 3.1). Both sites have potential for off channel habitat restoration. Floodplain function could be restored near north bank point bar.	2
Mainstem N. Fork Lewis	Lewis 3, 4/ RM 9.9 to 11.9	Preserve Eagle Island	Eagle Island appears to be the only existing floodplain where fluvial geomorphic processes are functioning. Includes backwater habitat in slough near the mouth of Houghton Creek.	1
Mainstem N. Fork Lewis	Lewis 5 / RM 13.3 to 15	Preservation and restoration of South bank.	Maintain floodplain, side channels and backwater habitats. Preserve undeveloped land from future development.	3
Mainstem N. Fork Lewis	Lewis 1,2,3,4,5/ RM 0.0 to 15.4	Add large wood to existing armored banks.	Take opportunities to add large wood into armored banks during future maintenance or repair activities.	10
Robinson, Ross and Johnson Creeks	Robinson Creek, Ross Creek, Johnson Creek/ Tributary-wide	Invasive plant removal	Cooperate with landowners to remove invasive species and replant with native riparian species.	9
Houghton and Johnson Creeks	Houghton Creek, Johnson Creek/ Tributary-wide	Fine sediment reduction.	The tributaries have abundant spawning gravels and are relatively undeveloped upstream. Work with landowners to keep livestock out of the streams and all riparian stands to establish or increase in density.	7

Table 3-9. Prioritized protection/enhancement opportunities for the North Fork Lewis River basin by geographic area. Detailed project descriptions are found in section 3.3 of the report. NA indicates no corresponding EDT reach.

Location	EDT Reach/ RM	Opportunity	Short Description	Priority
John	John Creek/ RM 0.0 to 1.1	Riparian Plantings.	Work with landowners to make riparian habitat improvements.	6
Cedar Creek	Cedar 2,3,5/ RM 4.3 to 11.1	Riparian Plantings.	Work with landowners to make riparian habitat improvements.	6
Cedar Creek	Cedar 2, 3, 5, 6/ RM 4.3 to 17.9	Enhancement of spawning habitats	Spawning gravel enhancement measures are recommended with Cedar 6 being priority. Gravel supply and transport appear sufficient for instream structures that can reduce local gradients or provide roughness and can trap local in-channel gravels. Riparian restoration could also improve the stream channel.	5
Cedar Creek	Cedar Creek/ Tributary-wide	Refocus of carcass placement program.	Based on eutrophication evident in Chelatchie Creek and downstream Cedar Creek we suggest reducing effort for carcass placement with the exception of the Cedar 6 reach.	12
Cedar Creek	Cedar 6/ RM 11.1 to 17.9.	Preservation of spawning habitat.	Spawning substrate is good in this reach but further degradation is likely with future developmental pressure. Sediment abatement and control measures are recommended.	4
Cedar Creek	Cedar 6/ RM 11.1 to 17.9	Passage enhancement at Amboy-Yacolt Rd. culvert	The rock weir appears to make passage difficult over low- to mid-range flows. Minor rearrangement of the rock structure could be done to enhance passage while still providing grade control.	13
Chelatchie Creek	Chelatchie Creek/ Tributary-wide	Enhancement of spawning habitats.	Reduce fine sediments transported into Cedar Creek. Livestock control and riparian revegetation would be needed throughout the tributary.	5

3.4 REFERENCES

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APPENDIX 3A

Large Wood Recruitment Potential and Shade Ratings for Each EDT Reach in North Fork Basin

Based on Aerial Photograph Assessment Data (2002/2003 Photo Data Sets)

NF LEWIS RIVER BASIN

Case	EDT Reach Name	RIPARIAN							LW Recruitment Potential					
		lb		rb		Shade		Length						
		Code	Hazard	Code	Hazard	Code	(%)	(ft)	Good		Fair		Poor	
1	Bitter Creek	CSS	Poor	CMS	Fair	1	10	1973				1973	1973	
2	Bitter Creek	HSD	Poor	HSD	Poor	3	55	1828					1828	1828
3	Bitter Creek	HSS	Poor	HSD	Poor	2	30	756					756	756
4	Bitter Creek	HSS	Poor	HSS	Poor	1	10	1512					1512	1512
5	Bitter Creek	MSD	Poor	MSD	Poor	2	30	1316					1316	1316
6	Brush Creek	CMD	Good	CMS	Fair	2	30	656	656			656		
7	Brush Creek	CMD	Good	MMS	Fair	2	30	1267	1267			1267		
8	Brush Creek	CMS	Fair	CMS	Fair	1	10	1742			1742	1742		
9	Brush Creek	MMD	Good	MSS	Fair	2	30	2214	2214			2214		
10	Cedar Creek 1a	CLD	Good	CLD	Good	3	55	3164	3164	3164				
11	Cedar Creek 1a	MMD	Good	CMD	Good	3	55	2969	2969	2969				
12	Cedar Creek 1a	MMS	Fair	CMD	Good	2	30	2025		2025	2025			
13	Cedar Creek 1a	MMS	Fair	MMD	Good	2	30	4963		4963	4963			
14	Cedar Creek 1b	MMD	Good	CMS	Fair	2	30	3247	3247			3247		
15	Cedar Creek 1b	MMD	Good	MMD	Good	2	30	5925	5925	5925				
16	Cedar Creek 1b	MMD	Good	MMS	Fair	2	30	498	498			498		
17	Cedar Creek 2	CMD	Good	CMS	Fair	1	10	1034	1034			1034		
18	Cedar Creek 2	CMD	Good	CMS	Fair	2	30	1660	1660			1660		
19	Cedar Creek 2	HSS	Poor	HSS	Poor	1	10	8168					8168	8168
20	Cedar Creek 2	MMD	Good	CMS	Fair	2	30	565	565			565		
21	Cedar Creek 2	MMD	Good	CSD	Poor	2	30	1132	1132					1132
22	Cedar Creek 2	MMD	Good	HSS	Poor	1	10	3943	3943					3943

NF LEWIS RIVER BASIN

Case	EDT Reach Name	RIPARIAN							LW Recruitment Potential					
		lb		rb		Shade		Length						
		Code	Hazard	Code	Hazard	Code	(%)	(ft)	Good		Fair		Poor	
23	Cedar Creek 2	MSS	Poor	CSD	Poor	1	10	916					916	916
24	Cedar Creek 2	MSS	Poor	HSS	Poor	1	10	607					607	607
25	Cedar Creek 3	HSS	Poor	HSS	Poor	2	30	3874					3874	3874
26	Cedar Creek 3	MMD	Good	MMS	Fair	2	30	2719	2719			2719		
27	Cedar Creek 3	MSS	Poor	HSS	Poor	1	10	1751					1751	1751
28	Cedar Creek 4	HSS	Poor	MMS	Fair	1	10	3047				3047	3047	
29	Cedar Creek 4	MMD	Good	HSS	Poor	1	10	469	469					469
30	Cedar Creek 4	MMD	Good	MSD	Poor	2	30	2622	2622					2622
31	Cedar Creek 5	MMD	Good	HSS	Poor	1	10	995	995					995
32	Cedar Creek 5	MMD	Good	MSD	Poor	2	30	1269	1269					1269
33	Cedar Creek 5	MMS	Fair	MSD	Poor	2	30	999			999			999
34	Cedar Creek 6	CMS	Fair	CMS	Fair	1	10	1924			1924	1924		
35	Cedar Creek 6	CMS	Fair	CMS	Fair	2	30	5225			5225	5225		
36	Cedar Creek 6	HMD	Fair	HMD	Fair	2	30	3668			3668	3668		
37	Cedar Creek 6	MMD	Good	HMD	Fair	3	55	2286	2286			2286		
38	Cedar Creek 6	MMD	Good	MMD	Good	2	30	4851	4851	4851				
39	Cedar Creek 6	MMD	Good	MMD	Good	3	55	7574	7574	7574				
40	Cedar Creek 6	MMD	Good	MMS	Fair	2	30	6819	6819			6819		
41	Cedar Creek 6	MMS	Fair	CMS	Fair	1	10	2930			2930	2930		
42	Cedar Creek 6	MMS	Fair	MMS	Fair	2	30	882			882	882		
43	Chelatchie Cr 1	HSD	Poor	HSD	Poor	2	30	1293					1293	
44	Chelatchie Cr 1	MMS	Fair	HSD	Poor	2	30	1209			1209			1209

NF LEWIS RIVER BASIN

Case	EDT Reach Name	RIPARIAN							LW Recruitment Potential					
		lb		rb		Shade		Length						
		Code	Hazard	Code	Hazard	Code	(%)	(ft)	Good		Fair		Poor	
45	Chelatchie Cr 2	CMS	Fair	CMS	Fair	1	10	5510			5510	5510		
46	Chelatchie Cr 2	HMD	Fair	HMD	Fair	3	55	1284			1284	1284		
47	Chelatchie Cr 2	HSD	Poor	HSD	Poor	2	30	1801					1801	1801
48	Chelatchie Cr 2	HSS	Poor	HSS	Poor	1	10	4304					4304	4304
49	Chelatchie Cr 2	MMD	Good	MSS	Poor	2	30	1141	1141					1141
50	Chelatchie Cr 2	MSS	Poor	HSS	Poor	2	30	2513					2513	2513
51	Chelatchie Cr 2	MSS	Poor	MSS	Poor	1	10	7881					7881	7881
52	Grist Mill					0	0	5						
53	Houghton Cr	MLD	Good	MLD	Good	4	80	1282	1282	1282				
54	Houghton Cr	MLD	Good	MMS	Fair	2	30	1125	1125			1125		
55	Houghton Cr	MMD	Good	MMD	Good	2	30	456	456	456				
56	Houghton Cr	MMD	Good	MMD	Good	3	55	3291	3291	3291				
57	Houghton Cr	MMD	Good	MMS	Fair	2	30	774	774			774		
58	Houghton Cr	MSS	Poor	MSS	Poor	2	30	5736					5736	5736
59	John Creek	MSS	Poor	MSS	Poor	2	30	5828					5828	5828
60	Johnson Cr	CMD	Good	CMD	Good	4	80	2818	2818	2818				
61	Johnson Cr	MMS	Fair	MMS	Fair	3	55	2675			2675	2675		
62	Lewis 1 tidal	HLS	Poor	HMD	Fair	2	30	4145				4145	4145	
63	Lewis 1 tidal	HLS	Poor	HSS	Poor	1	10	3052					3052	3052
64	Lewis 1 tidal	HMD	Fair	HMD	Fair	1	10	2641			2641	2641		
65	Lewis 1 tidal	HSS	Poor	HSS	Poor	1	10	6745					6745	6745
66	Lewis 1 tidal	MMD	Good	HSD	Poor	1	10	1110	1110					1110

NF LEWIS RIVER BASIN

Case	EDT Reach Name	RIPARIAN							LW Recruitment Potential					
		lb		rb		Shade		Length						
		Code	Hazard	Code	Hazard	Code	(%)	(ft)	Good		Fair		Poor	
67	Lewis 1 tidal	MMD	Good	HSS	Poor	1	10	2192	2192					2192
68	Lewis 2 tidal_A	HLD	Fair	HSS	Poor	1	10	2618			2618			2618
69	Lewis 2 tidal_A	HLS	Poor	HSS	Poor	1	10	1134					1134	1134
70	Lewis 2 tidal_A	HMS	Poor	HSD	Poor	1	10	2044					2044	2044
71	Lewis 2 tidal_A	HMS	Poor	HSS	Poor	1	10	8320					8320	8320
72	Lewis 2 tidal_B	HLS	Poor	HSS	Poor	1	10	641					641	641
73	Lewis 2 tidal_B	HMS	Poor	MMS	Fair	1	10	5853				5853	5853	
74	Lewis 2 tidal_B	HSS	Poor	HMS	Poor	1	10	1284					1284	1284
75	Lewis 2 tidal_B	HSS	Poor	MMS	Fair	1	10	1739				1739	1739	
76	Lewis 2 tidal_B	MMS	Fair	MMS	Fair	1	10	6162			6162	6162		
77	Lewis 3	MMS	Fair	MMS	Fair	1	10	5556			5556	5556		
78	Lewis 4	CMD	Good	MMS	Fair	2	30	1075	1075			1075		
79	Lewis 4	MMS	Fair	MMD	Good	1	10	1658		1658	1658			
80	Lewis 4	MMS	Fair	MMS	Fair	1	10	8387			8387	8387		
81	Lewis 5	CLD	Good	MMD	Good	2	30	1371	1371	1371				
82	Lewis 5	HSS	Poor	MMS	Fair	1	10	3102				3102	3102	
83	Lewis 5	MMD	Good	MMD	Good	2	30	1052	1052	1052				
84	Lewis 5	MMD	Good	MMS	Fair	1	10	985	985			985		
85	Lewis 5	MMD	Good	MMS	Fair	2	30	5702	5702			5702		
86	Lewis 5	MMS	Fair	MMS	Fair	1	10	2687			2687	2687		
87	Lewis 6	CLD	Good	CMD	Good	2	30	1039	1039	1039				
88	Lewis 6	MMD	Good	CMD	Good	2	30	1067	1067	1067				

NF LEWIS RIVER BASIN

Case	EDT Reach Name	RIPARIAN							LW Recruitment Potential					
		lb		rb		Shade		Length						
		Code	Hazard	Code	Hazard	Code	(%)	(ft)	Good		Fair		Poor	
89	Lewis 7	MMD	Good	MMD	Good	3	55	19734	19734	19734				
90	Lewis 7	MMD	Good	MMS	Fair	2	30	335	335			335		
91	NF Chelatchie Cr	HMD	Fair	HMD	Fair	3	55	5509			5509	5509		
92	NF Chelatchie Cr	HMS	Poor	HMS	Poor	2	30	1172					1172	1172
93	Pup Creek	HMD	Fair	HMD	Fair	4	80	1228			1228	1228		
94	Pup Creek	HMD	Fair	HMS	Poor	3	55	502			502			502
95	Pup Creek	MMD	Good	CMD	Good	3	55	1605	1605	1605				
96	Pup Creek	MMD	Good	CMS	Fair	2	30	1376	1376			1376		
97	Pup Creek	MMD	Good	CSD	Poor	3	55	3312	3312					3312
98	Pup Creek	MMS	Fair	MMS	Fair	2	30	2717			2717	2717		
99	R4 Secndry Ch	HMS	Poor	CMS	Fair	2	30	2138				2138	2138	
100	R4 Secndry Ch	HMS	Poor	HSS	Poor	1	10	8648					8648	8648
101	Robinson Cr	MMD	Good	MMD	Good	3	55	2282	2282	2282				
102	Robinson Cr	MSS	Poor	MSS	Poor	2	30	2988					2988	2988
103	Ross Cr	MMD	Good	MMD	Good	3	55	8008	8008	8008				
104	Ross Cr	MSS	Poor	MMS	Fair	1	10	4136				4136	4136	
						1.8	27							
	27 Reaches					104	Ft	307968	121013	77133	74701	121202	112250	108335
							Mi	58	23	15	14	23	21	21
							Km	94	37	24	23	37	34	33

NF LEWIS RIVER BASIN

Case	EDT Reach Name	RIPARIAN							LW Recruitment Potential					
		lb		rb		Shade		Length						
		Code	Hazard	Code	Hazard	Code	(%)	(ft)	Good		Fair		Poor	
								Miles		38		37		42
										32%		32%		36%
			LB	RB	TOT	(%)								
	Conifer	C	14	23	37	18%				GOOD		FAIR		POOR
	Mixed	M	59	45	104	50%								
	Hardwood	H	30	35	65	32%			NF LEWIS LW Recruitment Potential					
			103	103	206	100%								
	Small	S	24	38	62	30%								
	Med	M	69	64	133	65%								
	Large	L	10	2	12	6%								
			103	104	207	100%								
	Sparse	S	47	62	109	53%								
	Dense	D	56	41	97	47%								
			103	103	206	100%								

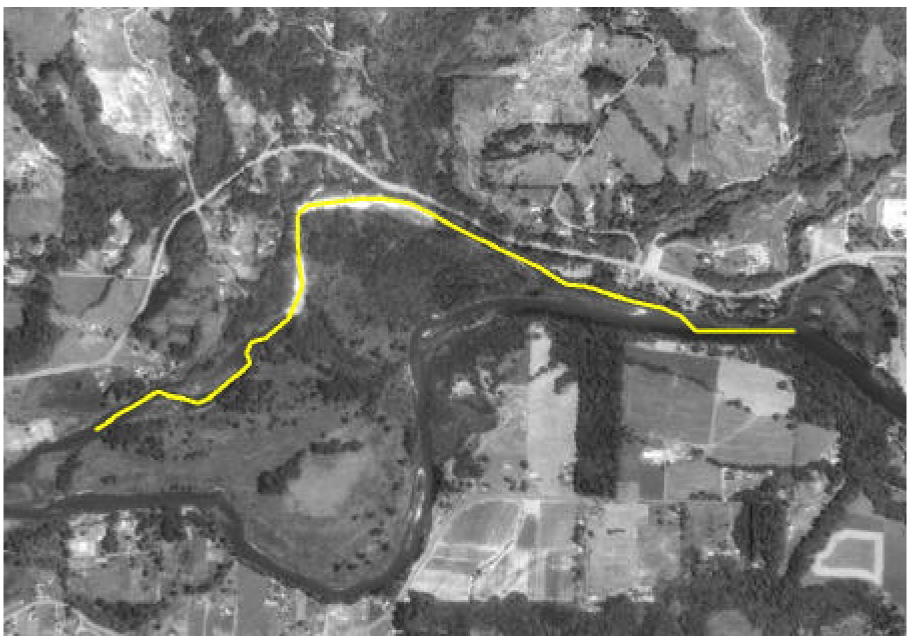
APPENDIX 3B

Stream Inventory
Reach Summaries
for NF Lewis Basin

NORTH FORK LEWIS RIVER 4

INTRODUCTION

North Fork Lewis River 4 is a mainstem reach between Ross Creek (RM 10.05) and Houghton Creek (RM 12.25). This reach is a free-flowing, freshwater reach that is not influenced by tidal action in the Columbia River. This section of the North Fork Lewis River is unconfined, occupying a 0.5 to 0.75 mile wide valley formed by the Lewis River where it cut through glacial outwash and Lake Missoula Flood deposits dating from the Quaternary. Reach 4 consists of a split mainstem channel that developed sometime between 1942 and 1990. Approximately 50 percent of the mainstem flow is transmitted by each channel. The entire length of the north channel was floated during the 2004 survey (Map B-1).



Map B-1. Portion of Lewis 4 surveyed.

CHANNEL MORPHOLOGY

North Fork Lewis 4 is a wide low gradient floodplain channel. The map gradient was 1 percent, and the reach was characterized by pool-riffle bedforms throughout its length. The reach is one of the few remaining sections of the river that support relatively natural fluvial processes. North Fork Lewis River 4 consists predominantly of glide habitat, but includes relatively large pool and riffle components as well (Figure B-1).

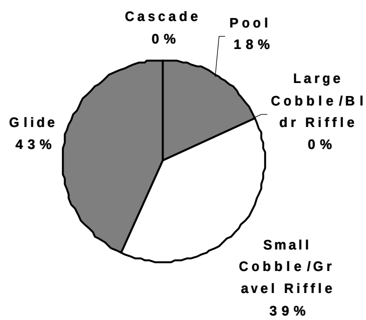


Figure B-1. Unit composition by percent surface area of the surveyed section of North Fork Lewis 4.

The wetted width of North Fork Lewis 4 during the survey averaged 61 m (200 ft). The maximum depth of pools averaged 2.7m (8.9 ft) with residual pool depths of 2.0m (6.6 ft) [Table B-1].

Table B-1. Average channel morphology characteristics of surveyed sections of North Fork Lewis 4

Parameter	Reach Value
Mean gradient	1.0 %
Mean wetted width (m)	61.0 m
Mean active channel width (m)	NA
Mean of the maximum riffle depths (m)	NA
Mean residual Pool depth (m)	2.0 m
Mean of the maximum pool depths (m)	2.8 m
Pools per kilometer (p/km)	1.1
Primary pools (>1.0m deep) per kilometer	1.1

WOOD

There were 26.7 pieces of large woody debris per kilometer (LW/km) recorded in North Fork Lewis 4 during the summer of 2004, but most (> 85%) were of the small or medium size class of woody debris pieces (Table B-2). Few jams and or root wads were observed during the survey.

Table B-2. Size and density of wood, jams and root wads in surveyed section of North Fork Lewis 4

Wood Category	Definition	# per kilometer
Small Pieces	10-20 cm diameter; > 2 m long	12.4
Medium Pieces	20-50 cm diameter; > 2 m long	10.5
Large Pieces	> 50 cm diameter; > 2 m long	2.1
Jams	> 10 pieces in accumulation	0.4
Root wads	> 2 m long	0.8

SUBSTRATE

Characterization of substrate based on visual observation showed the dominant and sub-dominant substrate classes were gravel and cobble, respectively (Table B-3).

Table B-3. Substrate grain size composition in surveyed section of North Fork Lewis 4.

Category	Mean Frequency
Sand	0%
Gravel	57%
Cobble	37%
Boulder	7%
Bedrock	1%

COVER

Cover provided in North Fork Lewis 4 was classified using the five different cover forms recognized by the protocol including: LW, undercut banks, overhanging cover, depth and substrate velocity breaks. The dominant cover form in the mainstem remains as water depth with the balance of cover in the reach coming from LW (Table B-4)

Table B-4. Presence of cover within the surveyed portion of North Fork Lewis 4. Measured as percent of surface area of stream unit covered.

Cover Type	Average Percent Cover
Large Woody Debris	3%
Undercut Banks	0%
Overhanging Vegetation	0%
Water Depth > 1 m	43%
Substrate (Velocity Cover)	0%

RIPARIAN

North Fork Lewis 4 is a wide floodplain channel that is open to the sky. Riparian vegetation on both banks is provided in the inner zone by grasses, forbs, small shrubs and saplings. The vegetation stands along the outer riparian zone primarily consist hardwoods, but some mixed conifer/hardwood stands and conifer dominated stands were present (Figure B-2). The distance of trees beyond the bank full stage of the channel averaged around 66 m (217 ft). Much of this zone represents an area of frequent flood disturbance where tree growth is difficult to establish. As such the open channel width to the sky averages 61 m (200 ft) of channel width plus an additional 71 m (233 ft) of open bank or a total of 132 m wide zone without vegetative cover. The mean view to sky is 69 percent open (Table B-5).

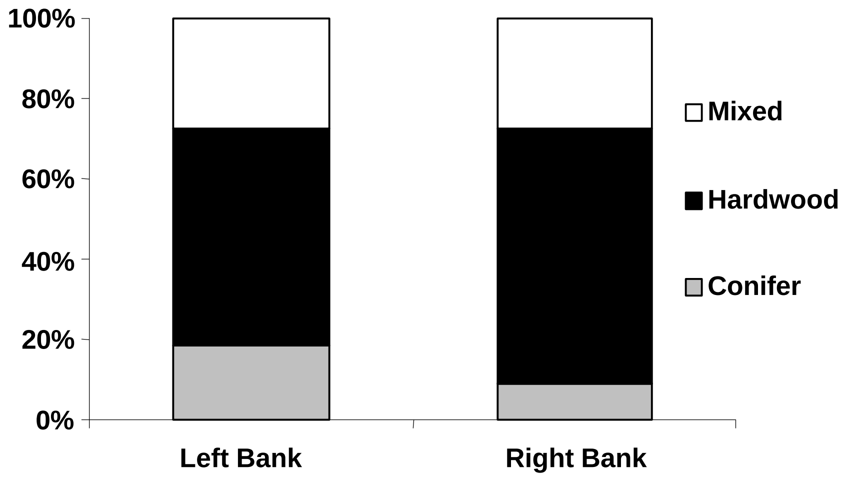


Figure B-2. Vegetation type by percent of units observed. Data presented as proceeding downstream.

Table B-5. Riparian shading characteristics in survey section of North Fork Lewis 4. Data oriented in downstream direction.

Parameter	Result
Active Channel Width (m)	61 m
Mean distance to blocking vegetation – left bank (m)	61 m
Mean left bank canopy angle (degrees)	26^{o}
Mean distance to blocking vegetation – right bank (m)	71 m
Mean right bank canopy angle (degrees)	29^{o}
Mean view to sky (percent)	69 %
Elevation (msl)	19’
Reference Temperature ($T^{o}C$)	$18.6^{o}C$
Estimated Current Temperature ($T^{o}C$)	$21^{o}C$

Even with mature forest stands growing immediately adjacent to the channel, this reach would be expected to remain open to solar radiation (VTS 39%). As such, it represents an area that has a naturally high hazard to shade and it likely offered historically warm surface water temperatures. Assuming mature forest timber stands could develop and grow adjacent to the channel banks, the 7-DADmax reference temperature would be anticipated to approach 18.6^{o}C. This temperature is greater than aquatic use criteria for salmon and trout spawning and rearing. The current channel condition (VTS 69%) is anticipated to increase the 7-DADmax on a relative basis approximately 2.4 ^{o}C compared to reference conditions or peak at 21.0^{o}C.

These estimates predict surface water temperatures only based on elevation, channel width and canopy coverage. They do not consider the influence of cool groundwater influx or warm wetland runoff. Actual water temperatures will vary with discharge, local weather patterns and the volume of groundwater contribution.

INSTABILITY AND DISTURBANCE

There was little observed signs of bank instability recorded in the surveyed section of North Fork Lewis 4 (Table B-6). Bank erosion occurs naturally in low gradient floodplain channels on the outside of meander beds or at the location of recent channel avulsions. Some rip-rap was mapped along the right bank of North Fork Lewis 4, protecting roads or residences from erosion.

The left bank riparian zone consisted primarily of the undeveloped Eagle Island, the land area located between the split mainstem channels. Little disturbance was noted there. On the right bank man-made disturbances included the urbanizing presence of residential development and roads. Almost 60 percent of the 35m (100 ft) riparian zone influenced to some degree or another on the right bank.

Table B-6. Bank instability and disturbance of surveyed section of North Fork Lewis 4. Data oriented in downstream direction.

Parameter	Result
Left bank instability (%)	5
Right bank instability (%)	1
Left bank disturbance (%)	4
Right bank disturbance (%)	59

COMPARISON TO EDT VALUES

EDT patient scores were generally similar to scores assigned based on the 2004 survey results. Important differences include: (1) channel morphology adjustments based on less minimum channel widths and existing off-channel habitat and more small cobble/gravel riffle habitat and historic off-channel habitat than previously estimated in the SRE (Tables B-7 – B-9). Other minor differences include categorical estimates of more hydromodifications and less in-channel wood than reported in the SRE.

Table B-7. Comparison of EDT Level 2 attribute ratings assigned to Lewis 4, and EDT ratings based on 2004 stream survey and hydromodification analysis results for habitat quantity attributes.

Attribute	SRE Rating	Rating from Survey	% Change in Habitat Quantity
Channel width – minimum (ft)	230	200	-5.8%
Channel width – maximum (ft)	410	NA	
Habitat Type – off-channel habitat factor (patient)	15.0%	2.3%	-12.7%
Habitat Type – off-channel habitat factor (template)	15.0%	23.9%	8.9%

Table B-8. Comparison of EDT Level 2 attribute ratings assigned to Lewis 4, and EDT ratings based on 2004 stream survey results for habitat diversity attributes.

Attribute	SRE Rating	Rating from Survey	
Habitat Type – primary pools	10.0%	15.9%	
Habitat Type – backwater pools	15.0%	0.0%	
Habitat Type – beaver ponds	0.0%	0.0%	
Habitat Type – pool tailouts	3.0%	1.1%	
Habitat Type – glides	50.0%	43.6%	
Habitat Type – small cobble/gravel riffles	16.0%	39.5%	
Habitat Type – large cobble/boulder riffles	6.0%	0.0%	

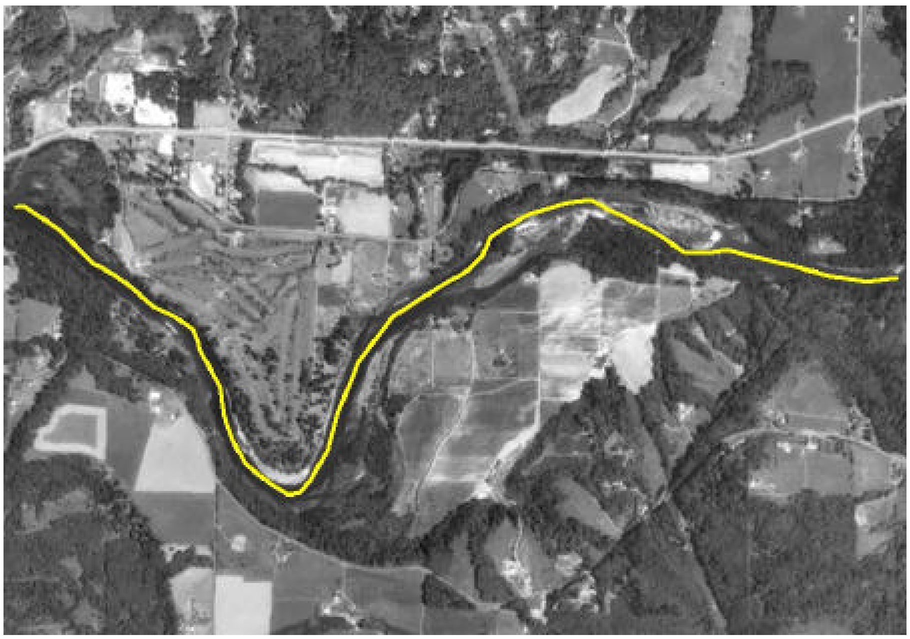
Table B-9. Comparison of EDT Level 2 attribute ratings assigned to Lewis 4, and EDT ratings based on 2004 stream survey and hydromodification analysis results for attributes relevant to data collected.

Attribute	SRE Rating	Rating from Survey	
Gradient (%)	0.0%	1.0%	
Confinement – natural	1	0-1	
Confinement – hydromodifications	1	1.9	
In-channel wood	3	3.8	
Embeddedness	0.5	0	
Fine sediment	1	NA	

NORTH FORK LEWIS RIVER 5

INTRODUCTION

North Fork Lewis River 5 is a mainstem reach between Houghton Creek (RM 12.25) and Johnson Creek (RM 15.3). This section of the North Fork Lewis River is unconfined, occupying a 500- to 1,000-meter (0.3 to 0.6 mile) wide valley formed by the Lewis River where it cut through glacial outwash and Lake Missoula Flood deposits dating from the Quaternary. Reach 5 consists of an unconfined single thread channel. The channel flows along the base of high, eroding bluffs consisting of the outwash and flood deposits at some sites. The entire length of the reach was floated during the 2004 survey (Map B-2).



Map B-2. Portion of Lewis 5 surveyed.

CHANNEL MORPHOLOGY

North Fork Lewis 5 is a wide low gradient floodplain channel. The map gradient was 1 percent, and the reach was characterized by pool-riffle bedforms throughout its length. North Fork Lewis River 5 consisted predominantly of glide and riffle habitat types (Figure B-3).

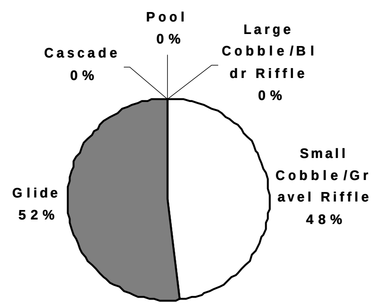


Figure B-3. Unit composition by percent surface area of the surveyed section of North Fork Lewis 5.

The wetted width of North Fork Lewis 4 during the survey averaged 61 m (200 ft). The maximum depth of pools averaged 2.7m (8.9 ft) with residual pool depths of 2.0m (6.6 ft) [Table B-10].

Table B-10. Average channel morphology characteristics of surveyed sections of North Fork Lewis 5

Parameter	Reach Value
Mean gradient	1.0 %
Mean wetted width (m)	95.0 m
Mean active channel width (m)	NA
Mean of the maximum riffle depths (m)	NA
Mean residual Pool depth (m)	NA
Mean of the maximum pool depths (m)	NA
Pools per kilometer (p/km)	0.0
Primary pools (>1.0m deep) per kilometer	0.0

WOOD

There were 21.6 pieces of large woody debris per kilometer (LW/km) recorded in North Fork Lewis 5 during the summer of 2004, but most (> 57%) were of the small size class of woody debris pieces (Table B-11). Few jams and no root wads were observed during the survey.

Table B-11. Size and density of wood, jams and root wads in surveyed section of North Fork Lewis 5

Wood Category	Definition	# per kilometer
Small Pieces	10-20 cm diameter; > 2 m long	12.5
Medium Pieces	20-50 cm diameter; > 2 m long	6.8
Large Pieces	> 50 cm diameter; > 2 m long	2.1
Jams	> 10 pieces in accumulation	0.3
Root wads	> 2 m long	0.0

SUBSTRATE

Characterization of substrate based on visual observation showed the dominant and sub-dominant substrate classes were cobble and gravel, respectively (Table B-12).

Table B-12. Substrate grain size composition in surveyed section of North Fork Lewis 5.

Category	Mean Frequency
Sand	0%
Gravel	41%
Cobble	46%
Boulder	12%
Bedrock	0%

Embeddedness was rated in each habitat unit according to four categories (0-25%, 25-50%, 50-75% and 75-100%). Embeddedness was 6 percent.

A pebble count was performed in North Fork Lewis 5. The D50 and D90 particle sizes were 32 mm and 64 mm respectively. Refer to report section 3.2.4 for a more complete discussion of pebble count results.

COVER

Cover provided in North Fork Lewis 5 was classified using the five different cover forms recognized by the protocol including: LW, undercut banks, overhanging cover, depth and substrate velocity breaks. The dominant cover form in the mainstem was water depth with the balance of cover in the reach coming from LW (Table B-13)

Table B-13. Presence of cover within the surveyed portion of North Fork Lewis 5. Measured as percent of surface area of stream unit covered.

Cover Type	Average Percent Cover
Large Woody Debris	3%
Undercut Banks	0%
Overhanging Vegetation	0%
Water Depth > 1 m	35%
Substrate (Velocity Cover)	0%

RIPARIAN

North Fork Lewis 5 is a wide channel that is open to the sky. Riparian vegetation on both banks is provided in the inner zone by grasses, forbs, small shrubs and saplings. The vegetation stands along the outer riparian zone primarily consist hardwoods, but some mixed conifer/hardwood stands and conifer dominated stands were present (Figure B-4). The distance of trees beyond the bank full stage of the channel averaged around 35 m (115 ft). Much of this zone represents an area of frequent flood disturbance where tree growth is difficult to establish. As such the open channel width to the sky averages 95 m (312 ft) of channel width plus an additional 72 m (236 ft) of open bank or a total of 167 m wide zone without vegetative cover. The mean view to sky is 69 percent open (Table B-14).

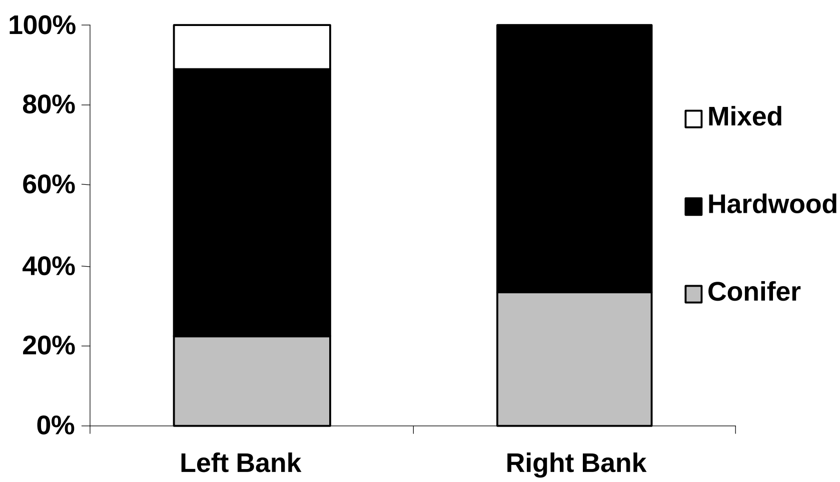


Figure B-4. Vegetation type by percent of units observed. Data presented as proceeding downstream.

Table B-14. Riparian shading characteristics in survey section of North Fork Lewis 5. Data oriented in downstream direction.

Parameter	Result
Active Channel Width (m)	95 m
Mean distance to blocking vegetation – left bank (m)	70 m
Mean left bank canopy angle (degrees)	29 ^{o}
Mean distance to blocking vegetation – right bank (m)	97 m
Mean right bank canopy angle (degrees)	22 ^{o}
Mean view to sky (percent)	72 %
Elevation (msl)	26'
Reference Temperature ($T^{o}C$)	19.6^{o}C
Estimated Current Temperature ($T^{o}C$)	20.9^{o}C

Even with mature forest stands growing immediately adjacent to the channel, this reach would be expected to remain open to solar radiation (VTS 39%). As such, it represents an area that has a naturally high hazard to shade and it likely offered historically warm surface water temperatures. Assuming mature forest timber stands could develop and grow adjacent to the channel banks, the 7-DADmax reference temperature would be anticipated to approach 19.6^{o}C. This temperature is greater than aquatic use criteria for salmon and trout spawning and rearing. The current channel condition (VTS 72%) is anticipated to increase the 7-DADmax on a relative basis approximately 1.3^{o}C compared to reference conditions or peak at 20.9^{o}C.

These estimates predict surface water temperatures only based on elevation, channel width and canopy coverage. They do not consider the influence of cool groundwater influx or warm wetland runoff. Actual water temperatures will vary with discharge, local weather patterns and the volume of groundwater contribution.

INSTABILITY AND DISTURBANCE

There was little observed sign of bank instability recorded in the surveyed section of North Fork Lewis 5 (Table B-15). Bank erosion occurs naturally in low gradient floodplain channels on the outside of meander beds or at the location of recent channel avulsions.

Approximately 33 percent of the of the 35m (100 ft) riparian zone on each bank was classified as disturbed. Man-made disturbances included residential development and roads.

Table B-15. Bank instability and disturbance of surveyed section of North Fork Lewis 5. Data oriented in downstream direction.

Parameter	Result
Left bank instability (%)	7
Right bank instability (%)	2
Left bank disturbance (%)	33
Right bank disturbance (%)	33

COMPARISON TO EDT VALUES

EDT patient scores were generally similar to scores assigned based on the 2004 survey results. Important differences include: (1) channel morphology adjustments based on less confined channel nature, amount of existing off-channel habitat, primary pool and large cobble/boulder riffle habitat and more stream gradient, channel width and small cobble/gravel riffle habitat than previously estimated in the SRE (Tables B-16 – B-18).

Table B-16. Comparison of EDT Level 2 attribute ratings assigned to Lewis 5, and EDT ratings based on 2004 stream survey and hydromodification analysis results for habitat quantity attributes.

Attribute	SRE Rating	Rating from Survey	% Change in Habitat Quantity
Channel width – minimum (ft)	230	312	15.9%
Channel width – maximum (ft)	410	NA	
Habitat Type – off-channel habitat factor (patient)	15.0%	0.0%	-15.0%
Habitat Type – off-channel habitat factor (template)	15.0%	12.0%	-3.0%

Table B-17. Comparison of EDT Level 2 attribute ratings assigned to Lewis 5, and EDT ratings based on 2004 stream survey results for habitat diversity attributes.

Attribute	SRE Rating	Rating from Survey	
Habitat Type – primary pools	10.0%	0.0%	
Habitat Type – backwater pools	15.0%	0.0%	
Habitat Type – beaver ponds	0.0%	0.0%	
Habitat Type – pool tailouts	3.0%	0.0%	
Habitat Type – glides	50.0%	45.2%	
Habitat Type – small cobble/gravel riffles	16.0%	54.8%	
Habitat Type – large cobble/boulder riffles	6.0%	0.0%	

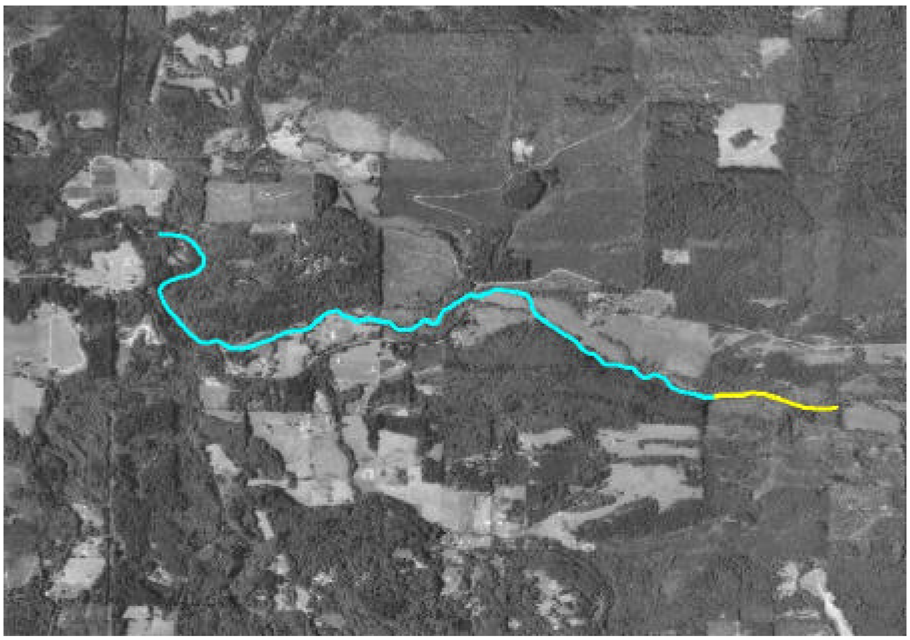
Table B-18. Comparison of EDT Level 2 attribute ratings assigned to Lewis 5, and EDT ratings based on 2004 stream survey and hydromodification analysis results for attributes relevant to data collected.

Attribute	SRE Rating	Rating from Survey	
Gradient (%)	0.0%	1.0%	
Confinement – natural	4	0-1	
Confinement – hydromodifications	1	1.7	
In-channel wood	3	3.7	
Embeddedness	0.5	0.5	
Fine sediment	0.5	NA	

CEDAR CREEK 2

INTRODUCTION

Cedar Creek is the major tributary to the North Fork Lewis River downstream of Merwin Dam. Reach 2 of Cedar Creek extends from Pup Creek at RM 4.3 to John Creek at RM 7.7. This portion on Cedar Creek flows through a 100 to 150 meter (0.3 to 0.6 mile) wide valley cut through glacial outwash and is generally unconfined. The uppermost 0.8 km (0.5 mile) segment of the reach was surveyed as highlighted in yellow in Map B-3.



Map B-3. Portion of Cedar 2 surveyed.

CHANNEL MORPHOLOGY

Cedar Creek 2 is a narrow low gradient floodplain channel. This channel type is expected to be highly responsive to LW, which would play an important role pool and off-channel habitat formation.

The wetted width of Cedar 2 during the survey averaged 15.3 m (50 ft). The map gradient was 0.5 percent, and the reach was characterized by pool-riffle bedforms throughout its length. Cedar 2 consisted predominantly of riffle habitat types (Figure B-5). Pools represented 27 percent of the habitat by length. The maximum depth of pools averaged 0.9 m (3 ft) with residual pool depths of 0.5m (1.5 ft) [Table B-19].

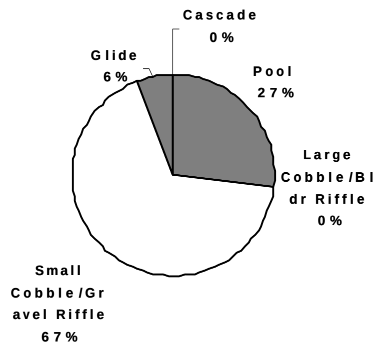


Figure B-5. Unit composition by percent surface area of the surveyed section of Cedar 2.

Table B-19. Average channel morphology characteristics of surveyed sections of Cedar 2

Parameter	Reach Value
Mean gradient	1.5 %
Mean wetted width (m)	15.3 m
Mean active channel width (m)	17.8 m
Mean of the maximum riffle depths (m)	0.8
Mean residual Pool depth (m)	0.5
Mean of the maximum pool depths (m)	0.9
Pools per kilometer (p/km)	4.3
Primary pools (>1.0m deep) per kilometer	3.8

WOOD

There were 13.1 pieces of large woody debris per kilometer (LW/km) recorded in Cedar 2 during the summer of 2004, but most (> 57%) were of the small size class of woody debris pieces (Table B-20). Few jams and no root wads were observed during the survey.

Table B-20. Size and density of wood, jams and root wads in surveyed section of Cedar 2

Wood Category	Definition	# per kilometer
Small Pieces	10-20 cm diameter; > 2 m long	1.3
Medium Pieces	20-50 cm diameter; > 2 m long	3.9
Large Pieces	> 50 cm diameter; > 2 m long	0.0
Jams	> 10 pieces in accumulation	0.0
Root wads	> 2 m long	0.0

SUBSTRATE

Characterization of substrate based on visual observation showed the dominant and sub-dominant substrate classes were cobble and gravel, respectively (Table B-21).

Table B-21. Substrate grain size composition in surveyed section of Cedar 2.

Category	Mean Frequency
Sand	11%
Gravel	34%
Cobble	38%
Boulder	13%
Bedrock	0%

Embeddedness was rated in each habitat unit according to four categories (0-25%, 25-50%, 50-75% and 75-100%). Embeddedness was 28 percent. No pebble count was performed in Cedar 2.

COVER

Cover was classified using the five different cover forms recognized by the protocol including: LW, undercut banks, overhanging cover, depth and substrate velocity breaks. Overhanging vegetation, LW and water depth all provided cover in Cedar 2 (Table B-22)

Table B-22. Presence of cover within the surveyed portion of Cedar 2. Measured as percent of surface area of stream unit covered.

Cover Type	Average Percent Cover
Large Woody Debris	5%
Undercut Banks	0%
Overhanging Vegetation	10%
Water Depth > 1 m	7%
Substrate (Velocity Cover)	0%

RIPARIAN

Cedar 2 is a relatively narrow channel that is largely open to the sky. Riparian vegetation consisted of mixed conifer/hardwood stands (Figure B-6). The open channel width to the sky averages 18 m (59 ft) of channel width plus an additional 45 m (148 ft) of open bank or a total of 63 m wide zone without vegetative cover. The mean view to sky is 41 percent open (Table B-23).

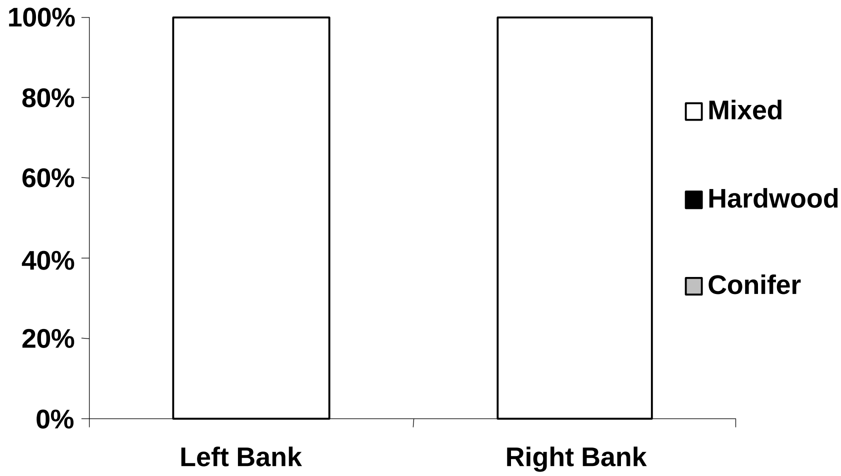


Figure B-6. Vegetation type by percent of units observed. Data presented as proceeding downstream.

Table B-23. Riparian shading characteristics in survey section of Cedar 2. Data oriented in downstream direction.

Parameter	Result
Active Channel Width (m)	18 m
Mean distance to blocking vegetation – left bank (m)	45 m
Mean left bank canopy angle (degrees)	49 ^{o}
Mean distance to blocking vegetation – right bank (m)	18 m
Mean right bank canopy angle (degrees)	57 ^{o}
Mean view to sky (percent)	41 %
Elevation (msl)	190’
Reference Temperature ($T^{o}C$) 7-DADmax	16.5^{o}C
Estimated Current Temperature ($T^{o}C$) 7-DADmax	18.5^{o}C
Measured Temperature ($T^{o}C$) 7-DADmax	23.3^{o}C

Mature forest stands growing immediately adjacent to the channel in Cedar Creek 2 would be expected to provide sufficient shade for temperatures to meet aquatic use criteria for salmon and trout spawning and rearing. Assuming mature forest timber stands could develop and grow adjacent to the channel banks, the 7-DADmax reference temperature would be anticipated to approach 16.5^{o}C. The current channel condition (VTS 41%) is anticipated to increase the 7-DADmax on a relative basis approximately 2.0^{o}C compared to reference conditions or peak at 18.5^{o}C. Actual surface water measurements performed by Clark County Department of Public Utilities, Water Resources during the summer of 2004 were substantially higher at 23.3^{o}C.

The VTS estimates predict surface water temperatures only based on elevation, channel width and canopy coverage. They do not consider the influence of cool groundwater influx or warm wetland runoff. Actual water temperatures will vary with stream discharge, local weather patterns and the volume of groundwater contribution and pond runoff.

INSTABILITY AND DISTURBANCE

No bank instability or riparian disturbance was recorded in the surveyed section of Cedar 2 (Table B-24). Bank erosion occurs naturally in low gradient floodplain channels on the outside of meander beds or at the location of recent channel avulsions. In addition, landuses in the area (livestock grazing and agriculture) would be expected to exacerbate bank erosion. It is not known if the surveyed section of Cedar 2 is typical of the reach as a whole.

Table B-24. Bank instability and disturbance of surveyed section of Cedar 2. Data oriented in downstream direction.

Parameter	Result
Left bank instability (%)	0
Right bank instability (%)	0
Left bank disturbance (%)	0
Right bank disturbance (%)	0

COMPARISON TO EDT VALUES

EDT patient scores were generally similar to scores assigned based on the 2004 survey results. Important differences include: (1) channel morphology adjustments based on less glides and large cobble/boulder riffle habitat and more stream gradient, and small cobble/gravel riffle habitat; and (2) less substrate loading of fine sediment than previously estimated in the SRE (Tables B-25 to B-27).

Table B-25. Comparison of EDT Level 2 attribute ratings assigned to Cedar 2, and EDT ratings based on 2004 stream survey and hydromodification analysis results for habitat quantity attributes.

Attribute	SRE Rating	Rating from Survey	% Change in Habitat Quantity
Channel width – minimum (ft)	43	50	7.3%
Channel width – maximum (ft)	60	60	
Habitat Type – off-channel habitat factor (patient)	0.0%	NA	NA
Habitat Type – off-channel habitat factor (template)	3.0%	NA	NA

Table B-26. Comparison of EDT Level 2 attribute ratings assigned to Cedar 2, and EDT ratings based on 2004 stream survey results for habitat diversity attributes.

Attribute	SRE Rating	Rating from Survey	
Habitat Type – primary pools	27.0%	14.5%	
Habitat Type – backwater pools	1.0%	0.0%	
Habitat Type – beaver ponds	0.0%	0.0%	
Habitat Type – pool tailouts	8.0%	11.1%	
Habitat Type – glides	16.0%	6.5%	
Habitat Type – small cobble/gravel riffles	17.0%	67.9%	
Habitat Type – large cobble/boulder riffles	31.0%	0.0%	

Table B-27. Comparison of EDT Level 2 attribute ratings assigned to Cedar 2, and EDT ratings based on 2004 stream survey and hydromodification analysis results for attributes relevant to data collected.

Attribute	SRE Rating	Rating from Survey	
Gradient (%)	0.4%	1.5%	
Confinement – natural	1	0-1	
Confinement – hydromodifications	0	NA	
In-channel wood	3	3.8	
Embeddedness	0.8	1.8	
Fine sediment	2.1	0.6	

CEDAR CREEK 3

INTRODUCTION

Cedar Creek is the major tributary to the North Fork Lewis River downstream of Merwin Dam. Reach 3 of Cedar Creek extends from John Creek at RM 7.7 to Brush Creek at RM 9.3. This portion on Cedar Creek flows through a 100-meter (330 ft.) wide valley cut through glacial outwash. Topographic features suggest large quaternary earthflows may have filled the valley from the north east, pushing Cedar Creek to the south edge of the valley, where it currently flows along a step sideslope. The channel is generally moderately confined and had a map gradient of 0.5 percent. The entire reach of Cedar 3 was surveyed (Map B-4).

Map B-4. Portion of Cedar 3 surveyed.

CHANNEL MORPHOLOGY

Cedar Creek 3 is a narrow low gradient floodplain channel. This channel type is expected to be highly responsive to LW, which would play an important role pool and off-channel habitat formation.

The wetted width of Cedar 3 during the survey averaged 13 m (43 ft). The map gradient was 0.5 percent, and the reach was characterized by pool-riffle bedforms throughout its length. Cedar 3 consisted predominantly of riffle habitat types (Figure B-7). Pools represented 30 percent of the habitat by length. The maximum depth of pools averaged 1.0 m (3.3 ft) with residual pool depths of 0.6m (2.0 ft) [Table B-28].

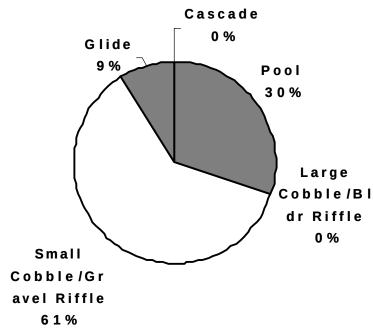


Figure B-7. Unit composition by percent surface area of the surveyed section of Cedar 3.

Table B-28. Average channel morphology characteristics of surveyed sections of Cedar 3

Parameter	Reach Value
Mean gradient	1.5 %
Mean wetted width (m)	13.0 m
Mean active channel width (m)	15.8 m
Mean of the maximum riffle depths (m)	0.8
Mean residual Pool depth (m)	0.6
Mean of the maximum pool depths (m)	1.0
Pools per kilometer (p/km)	3.9
Primary pools (>1.0m deep) per kilometer	2.6

WOOD

There were 13.6 pieces of large woody debris per kilometer (LW/km) recorded in Cedar 3 during the summer of 2004. Most LW was in the medium and large size classes of woody debris pieces (Table B-29). No jams, but numerous root wads were observed during the survey.

Table B-29. Size and density of wood, jams and root wads in surveyed section of Cedar 3

Wood Category	Definition	# per kilometer
Small Pieces	10-20 cm diameter; > 2 m long	0.9
Medium Pieces	20-50 cm diameter; > 2 m long	1.3
Large Pieces	> 50 cm diameter; > 2 m long	2.0
Jams	> 10 pieces in accumulation	0.0
Root wads	> 2 m long	9.4

SUBSTRATE

Characterization of substrate based on visual observation showed the dominant and sub-dominant substrate classes were gravel and cobble, respectively (Table B-30).

Table B-30. Substrate grain size composition in surveyed section of Cedar 3.

Category	Mean Frequency
Sand	15%
Gravel	39%
Cobble	34%
Boulder	12%
Bedrock	0%

Embeddedness was rated in each habitat unit according to four categories (0-25%, 25-50%, 50-75% and 75-100%). Embeddedness was 29 percent. No pebble count was performed in Cedar 3.

COVER

Cover was classified using the five different cover forms recognized by the protocol including: LW, undercut banks, overhanging cover, depth and substrate velocity breaks. Overhanging vegetation, LW and water depth all provided cover in Cedar 3 (Table B-31)

Table B-31. Presence of cover within the surveyed portion of Cedar 3. Measured as percent of surface area of stream unit covered.

Cover Type	Average Percent Cover
Large Woody Debris	3%
Undercut Banks	0%
Overhanging Vegetation	14%
Water Depth > 1 m	10%
Substrate (Velocity Cover)	0%

RIPARIAN

Cedar 3 is a relatively narrow channel that was largely open to the sky. Riparian vegetation consisted of primarily of hardwood or mixed conifer/hardwood stands (Figure B-8). The open channel width to the sky averages 16 m (52 ft) of channel width plus an additional 40 m (131 ft) of open bank or a total of 56 m wide zone without vegetative cover. The mean view to sky is 41 percent open (Table B-32).

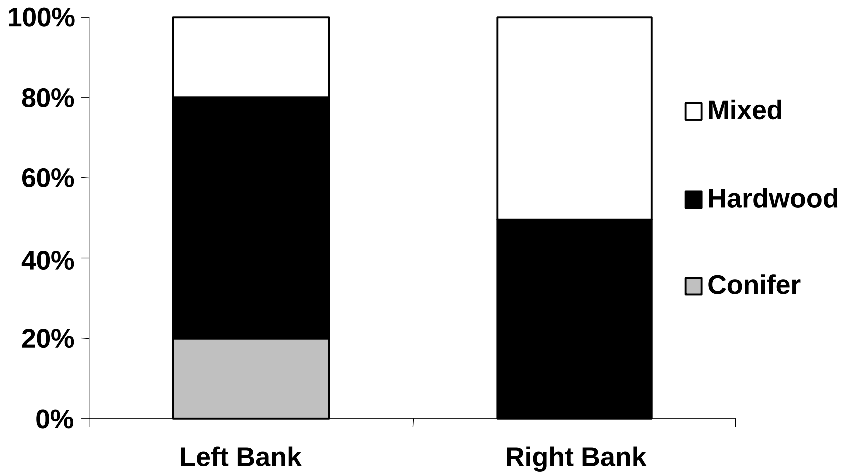


Figure B-8. Vegetation type by percent of units observed. Data presented as proceeding downstream.

Table B-32. Riparian shading characteristics in survey section of Cedar 3. Data oriented in downstream direction.

Parameter	Result
Active Channel Width (m)	16 m
Mean distance to blocking vegetation – left bank (m)	44 m
Mean left bank canopy angle (degrees)	53^{o}
Mean distance to blocking vegetation – right bank (m)	12 m
Mean right bank canopy angle (degrees)	64^{o}
Mean view to sky (percent)	34 %
Elevation (msl)	200’
Reference Temperature ($T^{o}C$) 7-DADmax	$16.4^{o}C$
Estimated Current Temperature ($T^{o}C$) 7-DADmax	$18.3^{o}C$
Measured Temperature ($T^{o}C$) 7-DADmax	$23.3^{o}C$

Mature forest stands growing immediately adjacent to the channel in Cedar Creek 3 would be expected to provide sufficient shade for temperatures to meet aquatic use criteria for salmon and trout spawning and rearing. Assuming mature forest timber stands could develop and grow adjacent to the channel banks, the 7-DADmax reference temperature would be anticipated to approach 16.4°C. The current channel condition (VTS 34%) is anticipated to increase the 7-DADmax on a relative basis approximately 1.9°C compared to reference conditions or peak at 18.3°C. Actual surface water measurements performed by Clark County Department of Public Works, Water Resources during the summer of 2004 were substantially higher at 23.3°C.

The VTS estimates predict surface water temperatures only based on elevation, channel width and canopy coverage. They do not consider the influence of cool groundwater influx or warm wetland runoff. Actual water temperatures will vary with stream discharge, local weather patterns and the relative volume of either groundwater or ponded water contribution.

INSTABILITY AND DISTURBANCE

No bank instability was recorded in the surveyed section of Cedar 3 (Table B-33). Bank erosion occurs naturally in low gradient floodplain channels on the outside of meander beds or at the location of recent channel avulsions. In addition, landuses in the area (livestock grazing and agriculture) would be expected to exacerbate bank erosion. It is not known if the surveyed section of Cedar 3 is typical of the reach as a whole.

The riparian zone was noted to be highly disturbed by residential development. Over 60 percent of the of the 35m (100 ft) riparian zone on the right bank, and 73 percent of the riparian zone on the left bank were influenced to some degree or another.

Table B-33. Bank instability and disturbance of surveyed section of Cedar 3. Data oriented in downstream direction.

Parameter	Result
Left bank instability (%)	0
Right bank instability (%)	0
Left bank disturbance (%)	72
Right bank disturbance (%)	63

COMPARISON TO EDT VALUES

EDT patient scores were generally similar to scores assigned based on the 2004 survey results. Minor differences include slightly more stream gradient and higher embeddedness ratings but lower fine sediment levels and large wood in-channel loading levels recorded during the 2004 stream surveys than previously estimated in the SRE database (Tables B-34 to B-36).

Table B-34. Comparison of EDT Level 2 attribute ratings assigned to Cedar 3, and EDT ratings based on 2004 stream survey and hydromodification analysis results for habitat quantity attributes.

Attribute	SRE Rating	Rating from Survey	% Change in Habitat Quantity
Channel width – minimum (ft)	36	43	2.9%
Channel width – maximum (ft)	57	52	
Habitat Type – off-channel habitat factor (patient)	0.0%	NA	NA
Habitat Type – off-channel habitat factor (template)	0.0%	0.0%	0.0%

Table B-35. Comparison of EDT Level 2 attribute ratings assigned to Cedar 3, and EDT ratings based on 2004 stream survey results for habitat diversity attributes.

Attribute	SRE Rating	Rating from Survey	
Habitat Type – primary pools	21.0%	22.2%	
Habitat Type – backwater pools	0.0%	0.0%	
Habitat Type – beaver ponds	0.0%	0.0%	
Habitat Type – pool tailouts	6.0%	8.2%	
Habitat Type – glides	12.0%	6.3%	
Habitat Type – small cobble/gravel riffles	56.0%	63.2%	
Habitat Type – large cobble/boulder riffles	5.0%	0.0%	

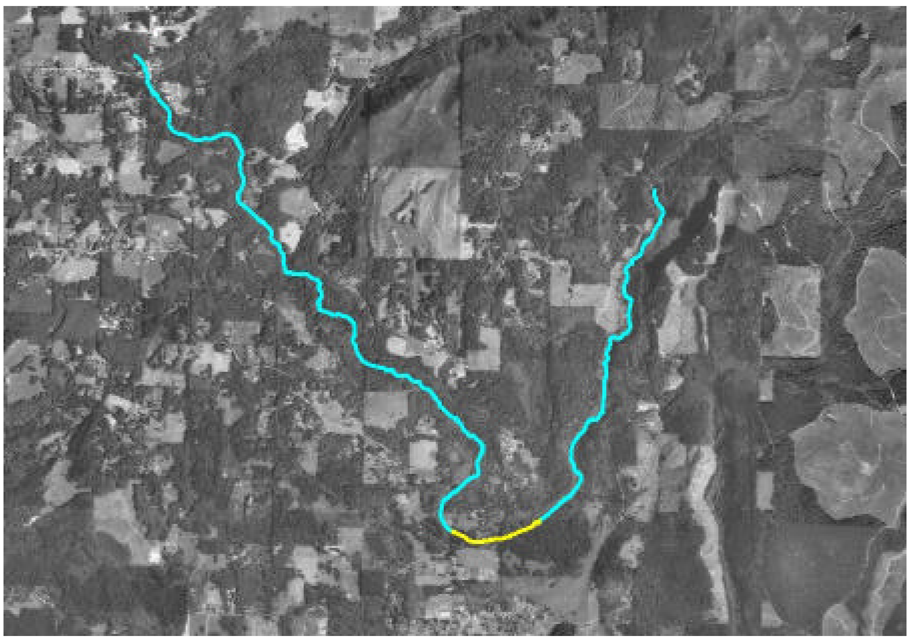
Table B-36. Comparison of EDT Level 2 attribute ratings assigned to Cedar 3, and EDT ratings based on 2004 stream survey and hydromodification analysis results for attributes relevant to data collected.

Attribute	SRE Rating	Rating from Survey	
Gradient (%)	0.3%	1.5%	
Confinement – natural	1	1	
Confinement – hydromodifications	0	NA	
In-channel wood	3	3.8	
Embeddedness	0.8	1.8	
Fine sediment	2	1	

CEDAR CREEK 6

INTRODUCTION

Cedar Creek is the major tributary to the North Fork Lewis River downstream of Merwin Dam. Reach 6 of Cedar Creek extends from Chelatchie Creek at RM 11.1 to Brush Creek at RM 17.9. This portion on Cedar Creek flows through a narrow valley. Only 0.5 mile of the 6.8 mile reach was surveyed as highlighted in yellow in Map B-5.



Map B-5. Portion of Cedar 6 surveyed.

CHANNEL MORPHOLOGY

Cedar Creek 6 is a moderate gradient mixed control channel. Confinement varies from moderate to high throughout the reach, and the map gradient is 1 to 2 percent.
This channel type is expected to be highly responsive to LW, which would play an important role pool formation and sediment storage. With abundant wood, bedforms would be expected to consist of forced pool-riffle morphology. In the absence of wood, plane-bed morphology would be expected to develop.

The wetted width of Cedar 6 during the survey averaged 9.2 m (30 ft). Habitat in Cedar 6 consisted predominantly of riffles (Figure B-9). Pools represented 35 percent of the habitat by length. The maximum depth of pools averaged 0.7 m (2.3 ft) with residual pool depths of 0.4 m (1.3 ft) [Table B-37].

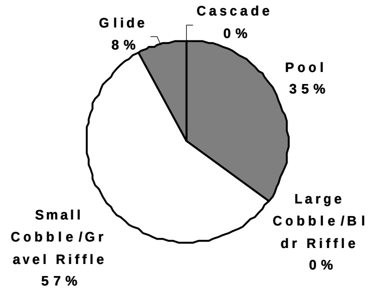


Figure B-9. Unit composition by percent surface area of the surveyed section of Cedar 6.

Table B-37. Average channel morphology characteristics of surveyed sections of Cedar 6

Parameter	Reach Value
Mean gradient	2.0 %
Mean wetted width (m)	9.2 m
Mean active channel width (m)	10.9 m
Mean of the maximum riffle depths (m)	0.6
Mean residual Pool depth (m)	0.4
Mean of the maximum pool depths (m)	0.7
Pools per kilometer (p/km)	14.0
Primary pools (>1.0m deep) per kilometer	3.5

WOOD

There were 76 pieces of large woody debris per kilometer (LW/km) recorded in Cedar 6 during the summer of 2004. All size classes of LW were present (Table B-38). Debris jams and root wads were also observed during the survey.

Table B-38. Size and density of wood, jams and root wads in surveyed section of Cedar 6

Wood Category	Definition	# per kilometer
Small Pieces	10-20 cm diameter; > 2 m long	24.4
Medium Pieces	20-50 cm diameter; > 2 m long	23.3
Large Pieces	> 50 cm diameter; > 2 m long	19.8
Jams	> 10 pieces in accumulation	2.4
Root wads	> 2 m long	5.8

SUBSTRATE

Characterization of substrate based on visual observation showed the dominant and sub-dominant substrate classes were gravel and sand, respectively (Table B-39).

Table B-39. Substrate grain size composition in surveyed section of Cedar 6.

Category	Mean Frequency
Sand	32%
Gravel	48%
Cobble	10%
Boulder	10%
Bedrock	0%

Embeddedness was rated in each habitat unit according to four categories (0-25%, 25-50%, 50-75% and 75-100%). Embeddedness was 42 percent.

A pebble count was performed in Cedar 6. The D50 and D90 particle sizes were 17 mm and 71 mm respectively. Refer to report section 3.2.4 for a more complete discussion of pebble count results.

COVER

Cover was classified using the five different cover forms recognized by the protocol including: LW, undercut banks, overhanging cover, depth and substrate velocity breaks. Overhanging vegetation, LW and water depth all provided cover in Cedar 6 (Table B-40)

Table B-40. Presence of cover within the surveyed portion of Cedar 6. Measured as percent of surface area of stream unit covered.

Cover Type	Average Percent Cover
Large Woody Debris	3%
Undercut Banks	0%
Overhanging Vegetation	9%
Water Depth > 1 m	2%
Substrate (Velocity Cover)	1%

RIPARIAN

Cedar 6 is a narrow channel that was well shaded at the time of the survey in 2004. Riparian vegetation consisted of primarily of hardwood or mixed conifer/hardwood stands (Figure B-10). The open channel width to the sky averages 9 m (30 ft) of channel width plus an additional 13 m (43 ft) of open bank or a total of 22 m wide zone without vegetative cover. The mean view to sky is 13 percent open (Table B-41).

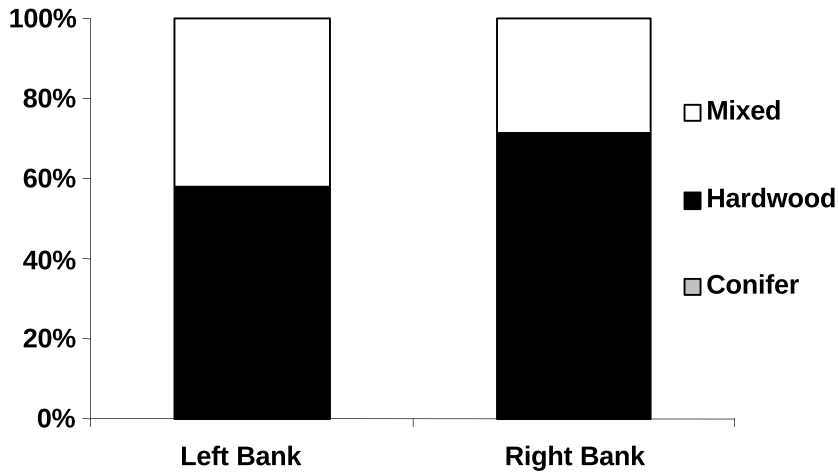


Figure B-10. Vegetation type by percent of units observed. Data presented as proceeding downstream.

Table B-41. Riparian shading characteristics in survey section of Cedar 6. Data oriented in downstream direction.

Parameter	Result
Active Channel Width (m)	9 m
Mean distance to blocking vegetation – left bank (m)	12 m
Mean left bank canopy angle (degrees)	78 ^{o}
Mean distance to blocking vegetation – right bank (m)	10 m
Mean right bank canopy angle (degrees)	78^{o}
Mean view to sky (percent)	13%
Elevation (msl)	295’
Reference Temperature (T^{o}C) 7-DADmax	15.8^{o}C
Estimated Current Temperature (T^{o}C) 7-DADmax	16.3^{o}C
Measured Temperature (T^{o}C) 7-DADmax	19.5^{o}C

Mature forest stands growing immediately adjacent to the channel in Cedar Creek 6 would be expected to provide sufficient shade for temperatures to meet aquatic use criteria for salmon and trout spawning and rearing. Assuming mature forest timber stands could develop and grow adjacent to the channel banks, the 7-DADmax reference temperature would be anticipated to approach 16.3^{o}C. The current channel condition (VTS 13%) is anticipated to increase the 7-DADmax on a relative basis approximately 0.5^{o}C compared to reference conditions or peak at 16.3^{o}C. Actual surface water measurements performed by Clark County Department of Public Works, Water Resources during the summer of 2004 were substantially higher at 19.5^{o}C. The temperature monitoring site was more than a mile downstream of the surveyed reach.

The VTS estimates predict surface water temperatures only based on elevation, channel width and canopy coverage. They do not consider the influence of cool groundwater influx or warm wetland runoff. Actual water temperatures will vary with stream discharge, local weather patterns and the relative volume of either groundwater or ponded water contribution to the channel.

INSTABILITY AND DISTURBANCE

No bank instability was recorded in the surveyed section of Cedar 6 (Table B-42). The riparian zone was noted to be disturbed by residential development and a railroad. Approximately 45 percent of the of the 35m (100 ft) riparian zone on the right bank, and 20 percent of the riparian zone on the left bank were influenced to some degree or another.

Table B-42. Bank instability and disturbance of surveyed section of Cedar 6. Data oriented in downstream direction.

Parameter	Result
Left bank instability (%)	0
Right bank instability (%)	0
Left bank disturbance (%)	20
Right bank disturbance (%)	45

COMPARISON TO EDT VALUES

EDT patient scores were generally similar to scores assigned based on the 2004 survey results. Important differences include: (1) channel morphology adjustments based on more small cobble/gravel riffle habitat and less glide and large cobble/boulder riffle habitat; and (2) higher embeddedness ratings but lower fine sediment levels recorded during the 2004 stream surveys than previously estimated in the SRE database (Tables B-43 to B-44).

Table B-43. Comparison of EDT Level 2 attribute ratings assigned to Cedar 6, and EDT ratings based on 2004 stream survey and hydromodification analysis results for habitat quantity attributes.

Attribute	SRE Rating	Rating from Survey	% Change in Habitat Quantity
Channel width – minimum (ft)	21	36	NA
Channel width – maximum (ft)	33	35	
Habitat Type – off-channel habitat factor (patient)	0.0%	NA	NA
Habitat Type – off-channel habitat factor (template)	0.0%	NA	NA

Table B-44. Comparison of EDT Level 2 attribute ratings assigned to Cedar 6, and EDT ratings based on 2004 stream survey results for habitat diversity attributes.

Attribute	SRE Rating	Rating from Survey	
Habitat Type – primary pools	22.0%	17.0%	
Habitat Type – backwater pools	1.0%	0.0%	
Habitat Type – beaver ponds	0.0%	2.3%	
Habitat Type – pool tailouts	6.0%	8.5%	
Habitat Type – glides	16.0%	7.1%	
Habitat Type – small cobble/gravel riffles	35.0%	65.1%	
Habitat Type – large cobble/boulder riffles	20.0%	0.0%	

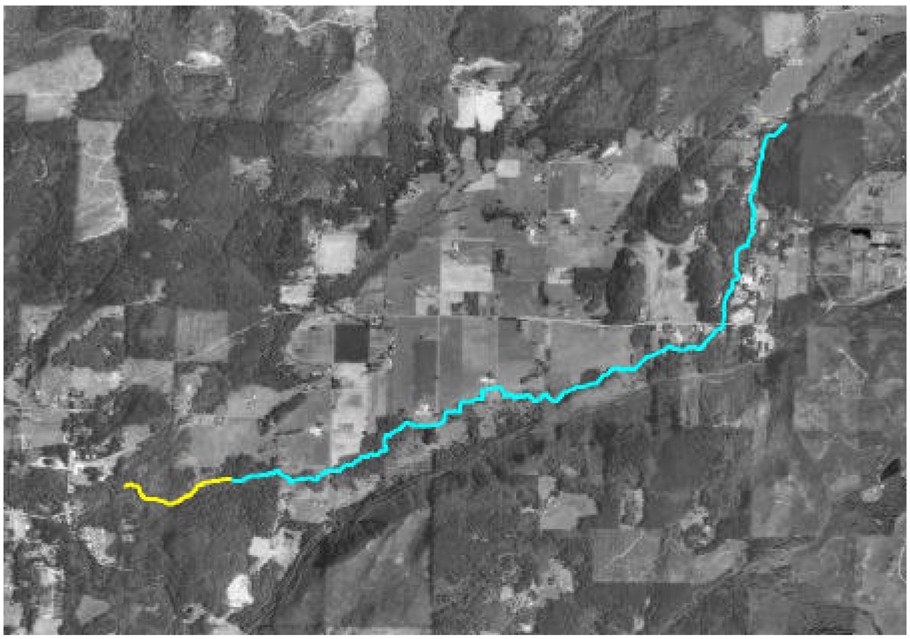
Table B-45. Comparison of EDT Level 2 attribute ratings assigned to Cedar 6, and EDT ratings based on 2004 stream survey and hydromodification analysis results for attributes relevant to data collected.

Attribute	SRE Rating	Rating from Survey	
Gradient (%)	1.3%	2.0%	
Confinement – natural	3	3-4	
Confinement – hydromodifications	1	NA	
In-channel wood	3	3.1	
Embeddedness	0.8	2.2	
Fine sediment	2.1	1.5	

CHELATCHIE CREEK 2

INTRODUCTION

Chelatchie Creek is a tributary to the Cedar Creek that flows across a landform known as the Chelatchie Prairie before joining Cedar Creek near RM 11. The present Chelatchie Creek is underfit in this wide open valley formed of glacial outwash. As a result the stream energy is low, and the channel meanders back and forth across sediments laid down in a previous climatic regime. Reach 2 of Chelatchie Creek extends from North Fork Chelatchie Creek at RM 0.5 to RM 4.8, the upstream end of fish distribution. The lowermost 0.75 miles were surveyed (Map B-6).



Map B-6. Portion of Chelatchie 2 surveyed.

CHANNEL MORPHOLOGY

Chelatchie 2 is a very low gradient, unconfined Palustrine channel. Historically, it is likely that beaver activity was widespread in this valley. This channel type typically responds to LW by shifting laterally or undercutting rather than forming pools or storing sediment. However, LW may be important for channel complexity and cover, particularly in the absence of beaver. Bedforms associated with Palustrine channels are vertically oscillating dune-ripple sequences formed of sand and small gravel, or weakly developed pool-riffle sequences in higher gradient areas. Extensive glide habitats with undercut banks are common under unmanaged conditions.

The wetted width of Chelatchie 2 during the survey averaged 9.2 m (30 ft). Habitat consisted predominantly of pools and glides (Figure B-11). Pools represented 52 percent of the habitat by length. The maximum depth of pools averaged 0.7 m (2.3 ft) with residual pool depths of 0.5 m (1.6 ft) [Table B-46].

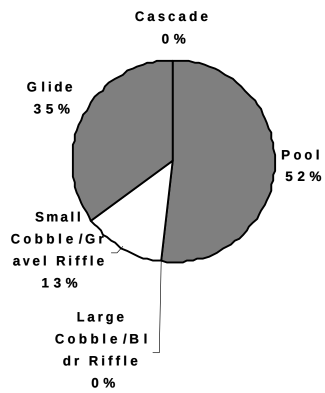


Figure B-11. Unit composition by percent surface area of the surveyed section of Chelatchie 2.

Table B-46. Average channel morphology characteristics of surveyed sections of Chelatchie 2

Parameter	Reach Value
Mean gradient	<1 %
Mean wetted width (m)	6.6 m
Mean active channel width (m)	7.8 m
Mean of the maximum riffle depths (m)	0.4
Mean residual Pool depth (m)	0.5
Mean of the maximum pool depths (m)	0.7
Pools per kilometer (p/km)	16.8
Primary pools (>1.0m deep) per kilometer	3.7

WOOD

There were 64.5 pieces of large woody debris per kilometer (LW/km) recorded in Chelatchie 2 during the summer of 2004. All size classes of LW were present (Table B-47). Debris jams and root wads were also observed during the survey.

Table B-47. Size and density of wood, jams and root wads in surveyed section of Chelatchie 2

Wood Category	Definition	# per kilometer
Small Pieces	10-20 cm diameter; > 2 m long	17.0
Medium Pieces	20-50 cm diameter; > 2 m long	29.0
Large Pieces	> 50 cm diameter; > 2 m long	14.0
Jams	> 10 pieces in accumulation	0.0
Root wads	> 2 m long	4.7

SUBSTRATE

Characterization of substrate based on visual observation showed the dominant and sub-dominant substrate classes were gravel and sand, respectively (Table B-48).

Table B-48. Substrate grain size composition in surveyed section of Chelatchie 2

Category	Mean Frequency
Sand	44%
Gravel	50%
Cobble	5%
Boulder	1%
Bedrock	0%

Embeddedness was rated in each habitat unit according to four categories (0-25%, 25-50%, 50-75% and 75-100%). Embeddedness was 66 percent.

A pebble count was performed in Chelatchie 2. The D50 and D90 particle sizes were 17 mm and 60 mm respectively. Refer to report section 3.2.4 for a more complete discussion of pebble count results.

COVER

Cover was classified using the five different cover forms recognized by the protocol including: LW, undercut banks, overhanging cover, depth and substrate velocity breaks. Overhanging vegetation, LW and water depth all provided cover in Chelatchie 2 (Table B-49)

Table B-49. Presence of cover within the surveyed portion of Chelatchie 2. Measured as percent of surface area of stream unit covered.

Cover Type	Average Percent Cover
Large Woody Debris	6%
Undercut Banks	0%
Overhanging Vegetation	31%
Water Depth > 1 m	11%
Substrate (Velocity Cover)	0%

RIPARIAN

Chelatchie 2 is a narrow channel that was relatively well shaded at the time of the survey in 2004. Riparian vegetation consisted solely of hardwood (Figure B-12). The open channel width to the sky averages 8 m (26 ft) of channel width plus an additional 15 m (49 ft) of open bank or a total of 23 m wide zone without vegetative cover. The mean view to sky is 20 percent open (Table B-50). Long stretches of Chelatchie Creek were observed to flow through agricultural areas or rural residences with little riparian vegetation, thus the surveyed segment may overestimate existing riparian shade for this reach.

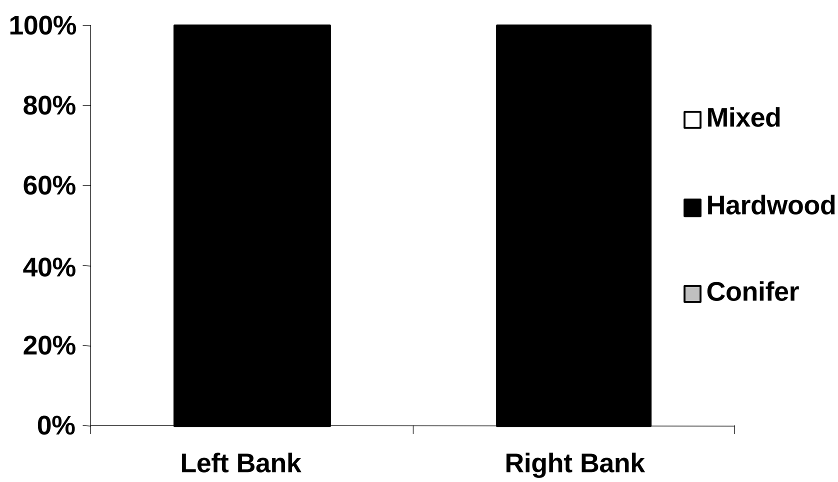


Figure B-12. Vegetation type by percent of units observed. Data presented as proceeding downstream.

Table B-50. Riparian shading characteristics in survey section of Chelatchie 2. Data oriented in downstream direction.

Parameter	Result
Active Channel Width (m)	8 m
Mean distance to blocking vegetation – left bank (m)	13 m
Mean left bank canopy angle (degrees)	67 ^{o}
Mean distance to blocking vegetation – right bank (m)	10 m
Mean right bank canopy angle (degrees)	77^{o}
Mean view to sky (percent)	20%
Elevation (msl)	240'
Reference Temperature (T^{o}C) 7-DADmax	15.9^{o}C
Estimated Current Temperature (T^{o}C) 7-DADmax	16.6^{o}C
Measured Temperature (T^{o}C) 7-DADmax	17.0^{o}C

Mature forest stands growing immediately adjacent to the channel in Chelatchie 2 would be expected to provide sufficient shade for temperatures to meet aquatic use criteria for salmon and trout spawning and rearing. Assuming mature forest timber stands could develop and grow adjacent to the channel banks, the 7-DADmax reference temperature would be anticipated to approach 15.9^{o}C. The current channel condition (VTS 20%) is anticipated to increase the reference condition 7-DADmax on a relative basis approximately 0.7^{o}C or peak at 16.6^{o}C. Actual surface water measurements performed by Clark County Department of Public Works, Water Resources during the summer of 2004 were slightly higher at 17.0^{o}C.

The VTS estimates predict surface water temperatures only based on elevation, channel width and canopy coverage. They do not consider the influence of cool groundwater influx or warm wetland runoff. Actual water temperatures will vary with stream discharge, local weather patterns and the relative volume of groundwater or ponded water contribution to the channel.

INSTABILITY AND DISTURBANCE

No bank instability was recorded in the surveyed section of Chelatchie 2 (Table B-51). Extensive areas of disturbed bank were observed elsewhere in Chelatchie Reach 2, thus conditions in the survey segment are not representative of the reach as a whole.

The riparian zone was noted to be disturbed by residential development and a railroad. Approximately 20 percent of the of the 35m (100 ft) riparian zone on the left bank was disturbed by clearcutting, but no riparian disturbance was noted on the right bank.

Table B-51. Bank instability and disturbance of surveyed section of Chelatchie 2. Data oriented in downstream direction.

Parameter	Result
Left bank instability (%)	0
Right bank instability (%)	0
Left bank disturbance (%)	20
Right bank disturbance (%)	0

COMPARISON TO EDT VALUES

EDT patient scores were generally similar to scores assigned based on the 2004 survey results. Important differences include: (1) channel morphology adjustments based on more small cobble/gravel riffle habitat and less glide and large cobble/boulder riffle habitat; and (2) higher embeddedness ratings but lower fine sediment levels recorded during the 2004 stream surveys than previously estimated in the SRE database (Tables B-52 to B-54).

Table B-52. Comparison of EDT Level 2 attribute ratings assigned to Chelatchie 2, and EDT ratings based on 2004 stream survey and hydromodification analysis results for habitat quantity attributes.

Attribute	SRE Rating	Rating from Survey	% Change in Habitat Quantity
Channel width – minimum (ft)	13	22	41.9%
Channel width – maximum (ft)	21	26	
Habitat Type – off-channel habitat factor (patient)	0.0%	NA	NA
Habitat Type – off-channel habitat factor (template)	3.0%	NA	NA

Table B-53. Comparison of EDT Level 2 attribute ratings assigned to Chelatchie 2, and EDT ratings based on 2004 stream survey results for habitat diversity attributes.

Attribute	SRE Rating	Rating from Survey	
Habitat Type – primary pools	27.0%	19.3%	
Habitat Type – backwater pools	0.0%	0.0%	
Habitat Type – beaver ponds	0.0%	27.5%	
Habitat Type – pool tailouts	8.0%	8.2%	
Habitat Type – glides	15.0%	28.6%	
Habitat Type – small cobble/gravel riffles	20.0%	16.4%	
Habitat Type – large cobble/boulder riffles	31.0%	0.0%	

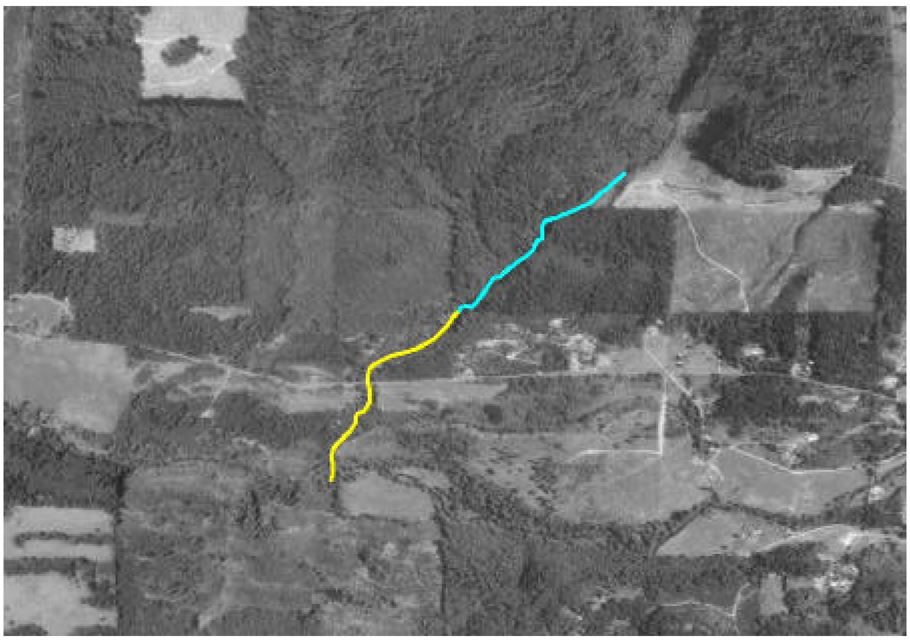
Table B-54. Comparison of EDT Level 2 attribute ratings assigned to Chelatchie 2, and EDT ratings based on 2004 stream survey and hydromodification analysis results for attributes relevant to data collected.

Attribute	SRE Rating	Rating from Survey	
Gradient (%)	0.2%	<1.0%	
Confinement – natural	0	0	
Confinement – hydromodifications	1	NA	
In-channel wood	3	3.2	
Embeddedness	0.8	2.7	
Fine sediment	2.1	2.5	

JOHN CREEK

INTRODUCTION

John Creek is a small tributary that enters Cedar Creek near RM 7.7. John Creek flows through a narrow, v-shaped valley and has an overall map gradient of approximately 4 percent. As a result the stream energy is relatively high, and the channel would be expected to be supply limited. The lowermost half of the reach (1.0 km; 0.6 mile) was surveyed as highlighted in yellow in Map B-7.



Map B-7. Portion of John Creek surveyed.

CHANNEL MORPHOLOGY

John Creek is classified as a moderate gradient contained channel, but is steep enough that bedforms likely consist primarily of step-pool sequences. Large woody debris in this channel type is important for storing sediment and forming bed-step sequences. In low gradient areas the channel would be expected to revert to plane-bed topography in the absence of wood. Accumulations of small wood may also force localized channel avulsions in less confined areas, forming and maintaining small pockets of off-channel habitat.

The wetted width of John Creek during the survey averaged 4.4m (14 ft). Habitat consisted predominantly of cascades and riffles (Figure B-13). Pools represented 17 percent of the habitat by length. The maximum depth of pools averaged 0.6 m (2.0 ft) with residual pool depths of 0.5 m (1.6 ft) [Table B-58].

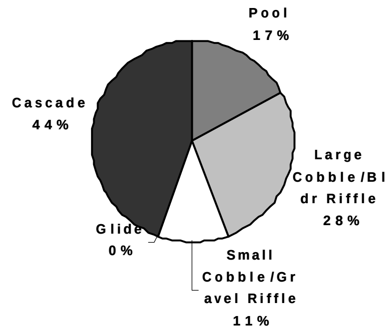


Figure B-13. Unit composition by percent surface area of the surveyed section of John Creek.

Table B-55. Average channel morphology characteristics of surveyed sections of John Creek

Parameter	Reach Value
Mean gradient	<1 %
Mean wetted width (m)	4.4 m
Mean active channel width (m)	4.9 m
Mean of the maximum riffle depths (m)	0.4
Mean residual Pool depth (m)	0.5
Mean of the maximum pool depths (m)	0.6
Pools per kilometer (p/km)	11.3
Primary pools (>1.0m deep) per kilometer	2.1

WOOD

There were 77 pieces of large woody debris per kilometer (LW/km) recorded in John Creek during the summer of 2004. The majority of LW observed consisted of medium size pieces (Table B-56). No debris jams, and few rootwads were observed during the survey.

Table B-56. Size and density of wood, jams and root wads in surveyed section of John Creek

Wood Category	Definition	# per kilometer
Small Pieces	10-20 cm diameter; > 2 m long	24.0
Medium Pieces	20-50 cm diameter; > 2 m long	44.0
Large Pieces	> 50 cm diameter; > 2 m long	8.2
Jams	> 10 pieces in accumulation	0.0
Root wads	> 2 m long	1.0

SUBSTRATE

Characterization of substrate based on visual observation showed the dominant and sub-dominant substrate classes were sand and cobble, respectively (Table B-57). The predominance of mobile sediments (sand, gravel and small cobble) in this channel suggests wood is functioning to store LW. More extensive bedrock was observed elsewhere in John Creek where wood was less common.

Table B-57. Substrate grain size composition in surveyed section of John Creek

Category	Mean Frequency
Sand	48%
Gravel	17%
Cobble	20%
Boulder	14%
Bedrock	1%

Embeddedness was rated in each habitat unit according to four categories (0-25%, 25-50%, 50-75% and 75-100%). The mean embeddedness level was 56 percent.

A pebble count was performed in John Creek. The D50 and D90 particle sizes were 48 mm and 180 mm, respectively. Refer to report section 3.2.4 for a more complete discussion of pebble count results.

COVER

Cover was classified using the five different cover forms recognized by the protocol including: LW, undercut banks, overhanging cover, depth and substrate velocity breaks. Overhanging vegetation provided the most cover, with lesser amounts provided by LW and water depth (Table B-58)

Table B-58. Presence of cover within the surveyed portion of John Creek. Measured as percent of surface area of stream unit covered.

Cover Type	Average Percent Cover
Large Woody Debris	4%
Undercut Banks	0%
Overhanging Vegetation	32%
Water Depth > 1 m	1%
Substrate (Velocity Cover)	0%

RIPARIAN

John 2 is a narrow channel that was relatively open to the sky at the time of the survey in 2004. A variety of riparian stand types were observed, but conifer stands were common on both banks (Figure B-14). The open channel width to the sky averages 4 m (13 ft) of channel width plus an additional 23 m (75 ft) of open bank or a total of 27 m (89 ft)wide zone without vegetative cover. The mean view to sky is 29 percent open (Table B-62).

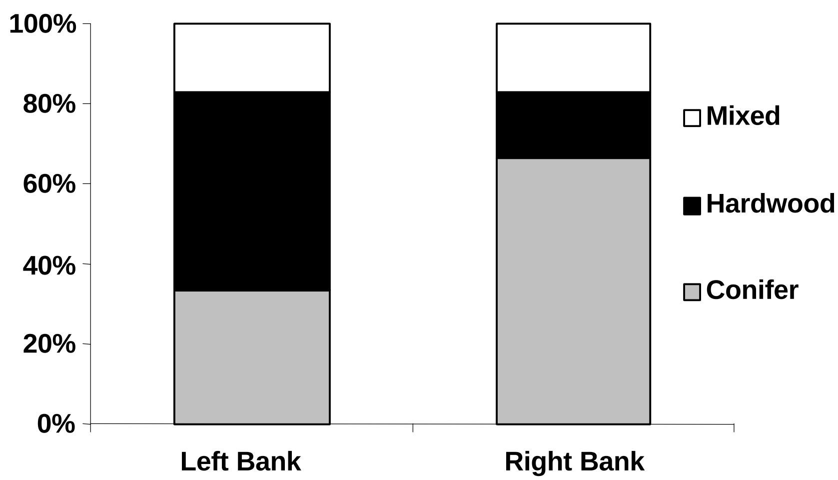


Figure B-14. Vegetation type by percent of units observed. Data presented as proceeding downstream.

Table B-59. Riparian shading characteristics in survey section of John Creek. Data oriented in downstream direction.

Parameter	Result
Active Channel Width (m)	4 m
Mean distance to blocking vegetation – left bank (m)	13 m
Mean left bank canopy angle (degrees)	63 ^{o}
Mean distance to blocking vegetation – right bank (m)	14 m
Mean right bank canopy angle (degrees)	64 ^{o}
Mean view to sky (percent)	29%
Elevation (msl)	375’
Reference Temperature (T^{o}C)	15.6^{o}C
Estimated Current Temperature (T^{o}C)	16.8^{o}C

Mature forest stands growing immediately adjacent to the channel in John Creek would be expected to provide sufficient shade for temperatures to meet aquatic use criteria for salmon and trout spawning and rearing. Assuming mature forest timber stands could develop and grow adjacent to the channel banks, the 7-DADmax reference temperature would be anticipated to approach 15.6^{o}C. The current channel condition (VTS 29%) is anticipated to increase the 7-DADmax on a relative basis approximately 1.2^{o}C compared to reference conditions or peak at 16.8^{o}C.

These estimates predict surface water temperatures only based on elevation, channel width and canopy coverage. They do not consider the influence of cool groundwater influx or warm wetland runoff. Actual water temperatures will vary with stream discharge, local weather patterns and the relative volume of groundwater or ponded water contribution to the channel.

INSTABILITY AND DISTURBANCE

Only minor bank instability was recorded in the surveyed section of John (Table B-60). Banks in this channel type would be expected to be fairy stable given the colluvial sideslopes and coarse bank material.

Approximately 20 percent of the of the 35m (100 ft) riparian zone on the left bank was disturbed by clearcutting. No data on the level of riparian zone disturbance within the survey segment was noted for the right bank.

Table B-60. Bank instability and disturbance of surveyed section of John Creek. Data oriented in downstream direction.

Parameter	Result
Left bank instability (%)	0
Right bank instability (%)	1
Left bank disturbance (%)	20
Right bank disturbance (%)	ND

ND=No data

COMPARISON TO EDT VALUES

EDT patient scores were generally similar to scores assigned based on the 2004 survey results. Important differences include: (1) channel morphology adjustments based on more small cobble/gravel riffle habitat and less glide and large cobble/boulder riffle habitat; and (2) higher embeddedness ratings but lower fine sediment levels recorded during the 2004 stream surveys than previously estimated in the SRE database (Tables B-61 to B-63).

Table B-61. Comparison of EDT Level 2 attribute ratings assigned to John Cr., and EDT ratings based on 2004 stream survey and hydromodification analysis results for habitat quantity attributes.

Attribute	SRE Rating	Rating from Survey	% Change in Habitat Quantity
Channel width – minimum (ft)	17	16	NA
Channel width – maximum (ft)	27	15	
Habitat Type – off-channel habitat factor (patient)	0.0%	NA	NA
Habitat Type – off-channel habitat factor (template)	0.0%	NA	NA

Table B-62. Comparison of EDT Level 2 attribute ratings assigned to John Cr., and EDT ratings based on 2004 stream survey results for habitat diversity attributes.

Attribute	SRE Rating	Rating from Survey	
Habitat Type – primary pools	27.0%	0.6%	
Habitat Type – backwater pools	0.0%	0.0%	
Habitat Type – beaver ponds	0.0%	17.8%	
Habitat Type – pool tailouts	8.0%	2.7%	
Habitat Type – glides	15.0%	0.0%	
Habitat Type – small cobble/gravel riffles	20.0%	10.8%	
Habitat Type – large cobble/boulder riffles	30.0%	68.1%	

Table B-63. Comparison of EDT Level 2 attribute ratings assigned to John Cr., and EDT ratings based on 2004 stream survey and hydromodification analysis results for attributes relevant to data collected.

Attribute	SRE Rating	Rating from Survey	
Gradient (%)	5.3%	5.5%	
Confinement – natural	4	3-4	
Confinement – hydromodifications	0	NA	
In-channel wood	3	3.4	
Embeddedness	0.8	2.5	
Fine sediment	2	2.5	

APPENDIX 3C

Geologic Map Units

Table C-1. Definition of geologic map units found in Kalama, lower North Fork Lewis, and Washougal basins (edited from Walsh et al. 1987).

Database Symbol	Unit Name	Description
Qa	Alluvium	Silt, sand, and gravel deposited in streambeds and fans; surface relatively undissected
Qls	Landslide debris	Clay, silt, sand, gravel, and larger blocks; unstratified and poorly sorted; surface commonly hummocky. Includes the 1980 debris avalanche of Mt St Helens, talus, and all other mass wasting deposits
Qt	Terraced sediments	Silt, sand, and gravel of diverse compositions and origins, such as proglacial outwash, glacial outburst deposits, older alluvium, lahars, and uplifted coastal marine and estuarine deposits.
Qfs	Flood sand and silt (Glacial Lake Missoula Outburst deposits)	Silt, sand, and clay, commonly grading into unit Qfg; contains slackwater deposits and cross-bedded fine grained surge deposits, and some interbedded gravels
Qfg	Flood gravel (Glacial Lake Missoula Outburst deposits)	Boulder to cobble gravel with sandy matrix and minor silt interbeds
Qap	Undifferentiated drift	Glacial till and outwash sand and gravel.
QPlc	Continental sediments	Gravel, sand, silt and clay; deposits of ancestral Columbia River contain distinctive orange quartzite clasts thought to be derived from northeast Washington
Qvb	Quaternary basalt flows	Light gray to black, microphyric to coarsely phyric olivine basalt and olivine-clinopyroxene basalt
Qvc	Quaternary volcaniclastic deposits, undivided	Ash- to block-sized lithic and pumice-rich pyroclastic deposits, debris flows, laharic deposits, pumice lapilli, and ash tephra, and fluvial gravels, sand, and silt; deposited by pyroclastic flows, lahars, and debris avalanches; at Mt St Helens, lithic clasts consist of gray to pink hornblende-hypersthene dacite and andesite and lesser black andesite and basalt, locally interbedded with glacial till
Qvl	Quaternary lahars	Unsorted to poorly sorted, generally unstratified mixtures of cobbles and boulders supported by a matrix of sand or mud; also contains lesser stratified fluvial deposits
Qplva	Pleistocene-Pliocene andesite flows	Gray olivine-hypersthene, pyroxene, hornblende, and hypersthene-hornblende andesite flows and associated breccias; erupted from vents
QPlvb	Pleistocene-Pliocene basalt flows	Gray to gray-black, aphyric and plagioclase-olivine-phyric and pyroxene-olivine-phyric basalt; commonly trachytic; platy, blocky, and columnar jointed; commonly scoriaceous; erupted from multiple vents distinguished by cinder cones
@va	Oligocene andesite flows	Aphyric to porphyritic andesite flows and flow breccia; in southwest Skamania County, thick flows of clinopyroxene basaltic andesite.
@vc	Oligocene volcaniclastic rocks	Greenish to brown and maroon, andesitic to basaltic lithic breccia, tuff, and tuff breccia, and volcanic siltstone, sandstone, and conglomerate; interbedded with basalt and andesite flows and rare dacite to rhyolite flows and tuffs; breccias typically unstratified, crudely graded, or very thickly bedded, poorly sorted, with clasts of pyroclastic rock, porphyritic basaltic andesite to dacite, aphyric to glassy lava, in a matrix of altered plagioclase, devitrified glass ahards and clay; sandstone and ash to lapilli tuff commonly form well-bedded, graded, parallel laminated, poorly to well sorted sequences

Table C-1. Definition of geologic map units found in Kalama, lower North Fork Lewis, and Washougal basins (edited from Walsh et al. 1987).

Database Symbol	Unit Name	Description
@vt	Oligocene tuff	Crystal-lithic and pumice-lithic tuff and tuff-breccia; in the Mt St Helens area, dominantly pyroxene- and plagioclase-phyric with lesser quartz-phyric, block to lapilli tuffs, commonly unstratified and poorly sorted; interbedded with volcanic sedimentary rocks and dacitic to andesitic flows or plugs
@Eva	Lower Oligocene to upper Eocene andesitic flows	Platy to massive, vesicular to dense, porphyritic basaltic andesite flows and flow breccia, with lesser andesite, basalt, and dacite; flows commonly have oxidized, wavy bases and thin interbeds of shale, tuff, or volcanic sandstone and conglomerate; forms complexes of numerous thin, irregularly shaped flows of limited areal extent; most flows are plagioclase-clinopyroxene phyric; two-pyroxene or olivine-phyric flows also present; zeolites and calcite common in amygdules and fractures
#igd	Miocene granodiorite	Porphyritic to equigranular, Fine- to medium-grained, hornblende-biotie or pyroxene granodiorite and lesser quartz monzonite and quartz diorite
#iq	Miocene quartz diorite	Equigranular to porphyritic quartz diorite
#ian / #@ian	Miocene / Miocene-Oligocene intrusive andesite	Aphanitic to porphyritic pyroxene and hornblende andesite and basaltic andesite / aphyric to porphyritic hornblende-, pyroxene-, and hornblende-pyroxene andesite; forms dikes, dike swarms, sills, small plugs, and stocks
#id / #@id	Miocene / Miocene-Oligocene diorite	Fine- to medium-grained and commonly porphryitic pyroxene diorite, pyroxene-hornblende diorite, and hornblende diorite; occurs as sills, dikes, small stocks, and cupulas of major plutons; contains lesser quartz diorite
#vt / #@vt	Miocene / Miocene-Oligocene tuff	Welded to non-welded, vitric to crystalline, lithic and pumiceous dacite and rhyolite tuffs and tuff breccias; commonly quartz phyric; contains pyroclastci flows and airfall tuff with minor silic lava flows and volcaniclastic sedimentary rocks,
#va	Miocene andesite flows	Pyroxene andesite and two-pyroxene andesite and balsatic andesite flows and flow breccia; also contains minor hornblende-pyroxene andesite and clinopyroxene basalt flows interbedded with volcaniclastic breccia, tuff, and volcanic sandstone; lavas commonly porphryitic
#vc	Miocene volcaniclastic rocks	Massive to well-bedded volcaniclastic breccias and conglomerates, tuffs, tuff breccias, and volcanic sandstones and siltstones
#vg	Middle Miocene Grande Ronde basalt	Fine grained, aphyric to very sparsely phyric flood-basalt with basaltic andesite chemistry, forms broad sheet flows with sedimentary interbeds of tuffaceous sandstone, siltstone, and conglomerate
#vw	Middle Miocene Wanapum basalt	Fine- to coarse-grained, sparsely phyric to abundantly phyric theoleiitic basalts, forming sheet flows that have thin sedimentary interbed and a few intracanyon flows
#cg	Miocene continental sedimentary rocks, conglomerate	Conglomerate with abundant dark-colored porphyritic andesite clasts, debris flow breccia, pebbly volcaniclastic sandstone, siltstone, and minor airfall tuff; commonly thick bedded