Project No. 60406.01
Draft

TIMBER - FISH - WILDLIFE PROJECT

TEST OF CUMULATIVE EFFECTS ANALYSIS METHODOLOGY
TOLT RIVER WATERSHED

Prepared for:

Washington Department of Natural Resources
and the
Timber/Fish/Wildlife
Cumulative Effects Steering Committee

Prepared by:

EA Engineering, Science, and Technology
Northwest Operations
Redmond, Washington

10 June 1992

Project No. 60406.01
Draft

TIMBER - FISH - WILDLIFE PROJECT

TEST OF CUMULATIVE EFFECTS ANALYSIS METHODOLOGY TOLT RIVER WATERSHED

Prepared for:

Washington Department of Natural Resources
and the
Timber/Fish/Wildlife
Cumulative Effects Steering Committee

Prepared by:

EA Engineering, Science, and Technology
Northwest Operations
Redmond, Washington

10 June 1992

DISCLAIMER

The opinions, findings, or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of any participant in, or committee of, the Timber/Fish/Wildlife Agreement, the Washington Forest Practices Board, or the Washington Department of Natural Resources, nor does mention of trade names or commercial products constitute endorsement or recommendation of use.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF MAPS

Note: Maps are provided under separate cover.

INTRODUCTION

As part of its contract with the Washington Department of Natural Resources (DNR), EA Engineering, Science, and Technology (EA) conducted a test of the cumulative effects methods on the Tolt River watershed. This test was conducted on the methods documented in the 26 May 1992 draft version of the Timber, Fish, and Wildlife (TFW) program's Watershed Analysis Manual (TFW 1992). The test was conducted by a multidisciplinary team that included hydrologists, fisheries scientists, and geologists. The methods were conducted primarily in an office setting using existing information. In addition, two separate field visits were conducted on the North and South Forks of the Tolt River to confirm office analyses. During the test of each assessment module, the individuals conducting the test were asked to follow the methods as strictly as possible and to note areas where the methods were confusing, ambiguous, unworkable or incorrect. These comments, as well as overall comments on the method's efficacy, are provided in the individual sections for each module.

Development of the Watershed Analysis Manual was initiated in January 1992, with the initial version issued in March (EA 1992). The current manual (TFW 1992) reflects continued development of these methods plus added many other components of the workbook structure. The manual is still considered in early draft form and will be frequently revised and updated to reflect the experience gained through this test and other planned tests to be conducted during Summer, 1992, and to respond to comments received from TFW cooperators and other individuals participating in the methods development. Because development of many components of the manual are still incomplete, this test of the cumulative effects analysis methodology should not be considered a comprehensive evaluation of the manual. This test primarily concentrates on application of the individual hazard assessment modules because this is the first opportunity for rigorous testing of these methods. The sections contained herein may also not completely follow the method steps as currently published because portions of the Tolt River assessment were performed during earlier method development. These particular assessment components (which include the mass wasting section) were not updated to reflect the current procedures. A section that addresses the final Synthesis step is also included, but less effort was placed on providing a thorough application and critique of this portion of the assessment. It is anticipated that the next test (to be completed in June 1992) and subsequent tests will provide increasing completeness of application of the entire Watershed Analysis Manual.

1. MODULE 1 - MASS WASTING HAZARD ASSESSMENT

The Level 1 mass wasting hazard assessment consists of erosion mapping, landform mapping, and extrapolation to identify sources mass wasting within the watershed and the probable extent of the areas that present a hazard to streams. The method identifies and evaluates sediment contribution from shallow-rapid landslides, deep seated landslides, and debris flows (or undifferentiated debris torrents). The method relies almost entirely on the historical record of aerial photography to identify mass wasting features. Jim Ward of Weyerhaeuser provided most of the mapping effort and interpretation contained in this section.

After each erosion mapping unit is identified and mapped, hazard ratings of low, medium, high, or indeterminate are assigned based on the following:

- High: Moderate or high landslide density and demonstrated delivery to streams;

- Moderate: Low landslide density and demonstrated delivery to streams;

- Low: Very low or no landslide density and no demonstrated delivery to streams; and

- Indeterminate: Unable to assign a rating, for any reason (to be resolved in Level 2).

The distinction between the different hazard ratings is determined largely by regional variability in "natural" background rates as well as the volume and sediment characteristics of the landslides.

This analysis follows assessment procedures contained in Appendix A, Mass Wasting Hazard Module, of the Watershed Analysis Manual. Data are tabulated below and maps are provided as required by the procedure. Exceptions to the procedure are noted.

1.1 Method Steps

<u>1.1.1. Mass Wasting Inventory and Data</u>

Landslides were inventoried from 1964, 1982, and 1990 air photos and plotted on topographic maps. Over 100 road and non-road related failures were tallied. Areas of concentration of <u>non-road</u> related failures were noted and the geology of these areas was determined from published geologic maps and further investigated in the field and with closer scrutiny with air photos. The vast majority of the areas mapped are all areas that have had slope stability problems in the past. Some areas were mapped that are adjacent to areas that have had stability problems and are of similar geology and slope. Landslide features that were mapped are shown on Map 1-1. Data on each mass wasting feature were compiled onto data forms during the inventory mapping and are included in Table 1-1.

Table 1-2 contains a tabulation of failure occurences as related to road related and non-road related activities. Because data were not collected in a consistent fashion (i.e., many mass wasting features were mapped with only minimal information recorded on failure causes and features), this analysis of mass wasting in the Tolt River watershed should be considered very general. However, several observations can be concluded from the data. Of particular interest is the high rate of non-road related landslide and debris flows in harvest units. In fact, there were more non-road related failures than road related failures, indicating that soils within the watershed are particularly unstable when subjected to forest practices. A majority of all failures enter streams due to the steep terrain. Less than 10 percent of all failures are of natural origin (i.e., occuring in mature forests), although an unknown number of landslides in harvest units may pre-date logging activity.

1.1.2. Mass Wasting Mapping Units

The following is a general discussion of slope stability in the Tolt River watershed. The discussion focuses on four dominant landform features:

- Glacial deposits
- Ancient failures
- Hard rock areas
- Forest roads

1.1.2.1. Slope Stability on Glacial Deposits The northeast portion of township 26-8 contains a relatively large gently sloping area covered by impervious glacial till. The slope breaks off abruptly to the west to North Fork Creek, the North Fork of the Tolt to the south and Dry Creek to the east. All the drainages that flow over this break are rapidly cutting down through the glacial material and creating slope stability problems. All these drainages have experienced numerous slope stability problems after harvest and the downslope portions of some of the drainages that were left unharvested have also had failures. The areas mapped should be considered highly unstable, although because of the scale and scope of this

Table 1-1. Tabulation of Mapped Mass Wasting Features

Number	Location			Year First Observed	Assoc.[1]	Failure Type[2]	Stream Delivery?	Landslide Size[3]	Stand Age	Comments
	Sec.	Twn.	Rng.							
1	24	26N	8E	1964	R	Backslope/DS	yes	M	10-25	Road located just below terrace
2	12	26N	8E	1964	NR	Debris flow	yes	M	100+	In timber below 10-25 year old cut
3	12	26N	8E	1964	NR	Debris flow	yes	M	100+	In timber below 10-25 year old cut
4	12	26N	8E	1964	NR	Debris slide	yes	M	100+	Predates harvest above failure
5	14	26N	8E	1964	R	Prism-DS	yes	M	25-100	Whole road failed
6	14	26N	8E	1964	NR	Debris flow	yes	S	10-25	Below break in slope, smaller failures in area
7	14	26N	8E	1964	NR	Slump/stream pond	yes	M	10-25	Old slump predates logging?
8	14	26N	8E	1964	NR	Debris slide	yes	S	10-25	Area below bench came apart along 1000? ft of bank
9	14	26N	8E	1964	NR	Stream bench	yes	S	10-25	Fell into river
10	35	26N	8E	1964	R	Sidecast-DS	no	M	25-100	Landed on river flats
11	22	26N	8E	1964	NR	Debris slide	yes	L	25-100	Old active slide
12	15	26N	8E	1964	R	Debris flow	yes	S	< 10	Sidecast
13	9	26N	8E	1964	NR	Debris flow	yes	M	25-100	Natural failure? Low slope, OG & 30 yr timber
14	32	26N	8E	1964	NR	Debris slide	yes	M	100+	Natural failure? 25 yr old cut above
15	30	26N	8E	1964	NR	Debris slide	no	T	25-100	Small
16	1	25N	7E	1982	NR	Debris slide	no	M	< 10	Terrace edge came apart after harvest
17	1	25N	7E	1982	NR	Debris slide	no	T	< 10	Terrace edge came apart after harvest

Table 1-1. Tabulation of Mapped Mass Wasting Features

Number	Location			Year First Observed	Assoc.[1]	Failure Type[2]	Stream Delivery?	Landslide Size[3]	Stand Age	Comments
	Sec.	Twn.	Rng.							
18	1	25N	7E	1982	NR	Debris slide	no	T	< 10	Lower bench edge came apart after harvest
19	1	25N	7E	1982	NR	Debris slide	no	T	< 10	Lower bench edge came apart after harvest
20	1	25N	7E	1982	NR	Debris slide	yes	T	< 10	Lower bench edge came apart after harvest
21	1	25N	7E	1982	NR	Debris slide	no	T	10-25	Terrace edge came apart after harvest
22	31	26N	8E	1982	NR	Debris slide	no	S	< 10	Terrace edge came apart after harvest
23	32	26N	8E	1982	NR	Debris slide	no	T	< 10	Midslope failure, geologic contact?
24	32	26N	8E	1982	NR	Debris slide	no	T	< 10	Terrace edge came apart after harvest
25	32	26N	8E	1982	NR	Debris slide	no	S	10-25	Bench edge below landing failed
26	32	26N	8E	1982	R	DS/earthflow?	no	M	25-100	Edge of terrace gave way
27	2	26N	8E	1982	NR	Debris slide	yes	T	< 10	Failure of terrace edge
28	1	25N	8E	1982	R	Landing/DS	no	M	10-25	Old landing failure
29	1	25N	8E	1982	NR	Debris slide	yes	M	< 10	Terrace, abrupt break in stream gradient
30	6	26N	8E	1974	R	DS/sidecast	no	S	< 10	Sidecast
31	6	26N	8E	1974	R	Sidecast/DS	no	T	< 10	Sidecast, steep!
32	6	26N	8E	1974	NR	Debris slide	no	T	< 10	Steep! Downslopes yarding
33	6	26N	8E	1974	NR	Debris slide	no	T	< 10	Steep!

Table 1-1. Tabulation of Mapped Mass Wasting Features

Number	Location			Year First Observed	Assoc.[1]	Failure Type[2]	Stream Delivery?	Landslide Size[3]	Stand Age	Comments
	Sec.	Twn.	Rng.							
34	6	26N	8E	1974	R	Debris slide	no	S	< 10	Started small on landing and grew
35	29	26N	9E	1974	NR	Debris flow	yes	S	< 10	Headwall below break in slope
36	29	26N	9E	1974	NR	Debris flow	yes	S	10-25	Headwall below break in slope
37	29	26N	9E	1974	R	Debris flow	yes	M	< 10	Sidecast?
38	27	26N	9E	1974	?	Debris flow	yes	M	< 10	May have road influence
39	27	26N	9E	1974	NR	Debris flow	no	S	< 10	Lower edge of new cut
40	27	26N	9E	1974	NR	Debris flow	no	S	< 10	Lower edge of new cut
41	19	26N	9E	1974	R	Debris slide	no	S	10-25	Sidecast over break in slope
42	18	26N	9E	1974	R	DS/sidecast	no	M	10-25	Road located below bench edge
43	18	26N	9E	1974	R	DS/sidecast	no	S	10-25	Road located below bench edge
44	18	26N	9E	1974	R	DS/sidecast	no	M	10-25	Steep
45	17	26N	9E	1974	NR	Debris flow	no	M	< 10	Below contact
46	16	26N	9E	1974	NR	Debris slide	no	S	< 10	Granite failure
47	7	26N	9E	1974	R	DS/landing	yes	S	< 10	2 small NR failure to south
48	8	26N	9E	1974	R	DS/backslope	yes	M	10-25	Big failure area predates area
49	31	26N	9E	1982	NR	Slump	no	L	10-25	Dam failure
49a	32			1991	R		no			
50	30	26N	9E	1982	NR	Debris slide	no	S	10-25	Bench edge coming apart
51	27	26N	9E	1982	R	Debris flow	yes	M	10-25	Fill failure
52	16	26N	9E	1974	R	DS/backslope	no	S	10-25	Backslope in granite?
53	23	26N	9E	1982	R	DF/backslope	yes	L	< 10	

Table 1-1. Tabulation of Mapped Mass Wasting Features

Number	Location: Sec.	Location: Twn.	Location: Rng.	Year First Observed	Assoc.[1]	Failure Type[2]	Stream Delivery?	Landslide Size[3]	Stand Age	Comments
54	24	26N	9E	1982	R	DF/Prism	no	M	< 10	Big wide failures
55	24	26N	9E	1982	?	Debris flow	yes	L	< 10	May have road influence
56	25	26N	9E	1982	R	DF/sidecast	no	M	< 10	Sidecast
57	12	25N	7E	1991	NR	Debris slide	no	T	< 10	Landslide scarp
58	2	25N	7E	1991	NR	Debris flow	no	S	< 10	Top of big glacial terrace, stream entry
59	6	25N	8E	1974	NR	Debris slide	no	S	< 10	Unstable layer again! In terrace edge
60	13	26N	7E	1991	R	Debris slide	no	M	< 10	Landing failure
61	10	26N	8E	1991	NR	Debris flow	no	S	< 10	Downhill yarding, steep edge
62	29	26N	8E	1991	NR	Stream bank	yes	S	10-25	Toe of ancient slide
63	9	26N	8E	1974	NR	Debris flow	yes	L	25-100	In timber below recent cut
64	16	26N	8E	1991	NR	Debris flow	yes	M	25-100	Same slope, younger timber 25-30 yrs old
65	4	26N	8E	1991	R	DS/landing	no	S	10-25	Terrace edge
66				1991	NR					
70a	30			1991	R		no			
71				1991	NR					
72				1991	NR					
73				1991	NR					
74				1991	NR					
75				1991	NR					

Table 1-1. Tabulation of Mapped Mass Wasting Features

Number	Location			Year First Observed	Assoc.[1]	Failure Type[2]	Stream Delivery?	Landslide Size[3]	Stand Age	Comments
	Sec.	Twn.	Rng.							
76				1991	NR					
77				1991	NR					
78				1991	NR					
79				1991	R					
80	4			1976	NR	Debris flow	yes			
81	4			1976	R	Debris slide	no			
82	3			1976	R	Debris slide	no			
83	2			1970	NR	Debris flow	yes			
84	2			1982	R	Debris flow	yes			
85	2			1982	R	Debris flow	yes			
86	2			1958	NR	Debris flow	yes			Timbered
87	1			1970	?	Debris flow	yes			
88	1			1976	R	Debris flow	yes			
89	1			1982	R	Debris flow	yes			
90	1			1958	NR	Debris flow	yes			Timbered
91	1			1976	R	Debris flow	yes			
92	1			1976	R	Debris flow	yes			
93	12			1964	NR	Debris flow	yes			
94	12			1976	R	Debris flow	yes			
95	12			1976	NR	Debris flow	yes			
96	12			1976	R	Debris flow	yes			

Table 1-1. Tabulation of Mapped Mass Wasting Features

Number	Location			Year First Observed	Assoc.[1]	Failure Type[2]	Stream Delivery?	Landslide Size[3]	Stand Age	Comments
	Sec.	Twn.	Rng.							
97	11			1989	R	Debris slide	yes			
98	11			1987	NR	Debris slide	no			
99	20			1982	R	Debris flow	yes			
100	15			1989	R	Debris flow	yes			
101	14			1987	R	Debris slide	no			
102	22			1987	R	Debris flow	yes			
103	22			1987	R	Debris flow	yes			
104	15			1987	NR	Debris flow	yes			
105	15			1976	NR	Slump/earthflow	yes			
106	15			1958	NR	Slump/earthflow	yes			Timbered
107	15			1976	R	Debris slide	yes			
108	15			1987	NR	Slump/earthflow	yes			
109	15			1958	NR	Slump/earthflow	yes			
110	21			1987	NR	Debris flow	yes			
111	16			1970	R	Debris flow	yes			
112	16			1982	NR	Debris slide	yes			
113	16			1970	R	Debris slide	yes			
114	16			1970	R	Debris flow	yes			
115	16			1970	NR	Debris flow	yes			
116	16			1970	R	Debris slide	yes			
117	9			1970	NR	Slump/earthflow	yes			

Table 1-1. Tabulation of Mapped Mass Wasting Features

Number	Location			Year First Observed	Assoc.[1]	Failure Type[2]	Stream Delivery?	Landslide Size[3]	Stand Age	Comments
	Sec.	Twn.	Rng.							
118	1			1987	R	Debris flow	yes			
119	21			1970	NR	Debris slide	no			Talus, timbered
120	14			1990	R	Debris slide	no			
121	12			1991	R	Debris slide	yes			River undercut

[1] Assoc: NR = non-road failure
R = road-related failure

[2] Type: DS = deep seated

[3] Size: S = Small
M = Medium
L = Large

Note: Blank cells indicate data not collected.

Table 1-2. Tabulation of Failure Occurrences and Causative Activities

Activity	Shallow-Rapid Landslide		Debris Flow		Slump-Earthflow		Deep Seated Failure		Unknown Failure Type
	Number of Failures	Percent Entering Stream	Number of Failures	Percent Entering Stream	Number of Failures	Percent Entering Stream	Number of Failures	Percent Entering Stream	
Road-Related (Total number of failures: 52)									
- Landing	2	0%	0	-	0	-	3	66%	-
- Sidecast	1	0%	3	100%	0	-	7	0%	-
- Backslope	0	-	0	-	0	-	4	75%	-
- Prism	0	-	0	-	0	-	2	50%	-
- Other/Unknown	9	55%	17	94%	1	100%	0	-	3
Total	12	42%	20	95%	1	100%	16	31%	3
Non-Road Related (Total number of failures: 65)									
- Harvest Unit	21	29%	10	50%	2	50%	0	-	-
- Mature Forest	3	66%	2	100%	1	100%	0	-	-
- Streambank	0	-	0	-	2	100%	0	-	-
- Other/Unknown	2	50%	9	100%	4	100%	0	-	9
Total	26	31%	21	76%	9	89%	0	-	9

mapping there may be small stable areas incorporated in the areas mapped. Some of the areas mapped do not have the potential to deliver sediment to fish bearing waters. The area of primary concern for the potential to deliver sediment fish bearing waters are the four canyons that drain to the North Fork of Tolt River.

Numerous failures were clustered along the escarpments that border the main Tolt river, up to and a little beyond the confluence of the two forks, following the harvest of that area. There is also a clustering of failure activity in the upper reaches of the south fork, for a few miles just below the dam. Once again, the upslope areas are covered with an impervious layer of till which the rivers have cut down through, creating a steep escarpment. Failures occur at this steep break in slope and are caused by groundwater saturating the overlying sands and gravels causing them to fail over the top of the till. With the exception of the large failure just below the dam, these are shallow failures but can involve quite a bit of material because they spread out laterally along the contact with the till. In some areas, numerous benches (alluvial terraces) or landslide deposits are situated downslope of the main escarpment and serve to prevent the failures from reaching the river. There was also some failures observed off these lower terraces but most originate and occur along the top of the escarpment. Areas of concern for sediment production are those areas where the escarpment or one of the lower benches is near the river and no terraces are present downslope.

<u>1.1.2.2. Slope Stability on Ancient Failures</u> A number of large ancient landslides have been identified on the geologic maps of the area. Smaller ancient failures were also identified through air photos and a number of recent failures were clustered on the sites of the ancient landslides. The primary concern in these areas is on the toes of the failures especially where the streams or rivers are eroding into the mass wasting where the streams or rivers are eroding into the mass wasting deposit. The low strength of the deposit and the rapid erosion as the stream or river attempts to erode down to the pre-landslide landscape results in unstable slopes. Also landslide deposits sometimes extend downstream of the failure site and create unstable stream banks.

<u>1.1.2.3. Slope Stability in the Hard Rock Areas</u> The primary slope stability problems associated with the hard rock areas are shallow soil failures which develop into debris avalanches. The failures are driven more by ground slope than underlying geology and their locations are generally less predictable failures than on the glacial units. Most of the debris avalanches (which deliver the most sediment) originate in the inner gorge area of the steep,

deeply incised channels. Also, some of the debris avalanches have begun in-channel, suggesting that excessive amounts of debris may have been present in the channel.

<u>1.1.2.4. Slope Stability of Forest Roads</u> Slope failures originating at forest roads are a major problem in the hard rock areas. It is less of a problem in the glacial deposits where, in this basin, less than one third of the failures were associated with roads. With most of the roading completed, maintenance is the key to preventing landslides. The maintenance program in place for the North Fork of the Tolt seems to be working well, with only one failure per winter occurring for the last two winters. And in both cases, nothing could have been done to prevent these failures. Continued emphasis should be kept upon road maintenance.

1.1.3. Mass Wasting Hazard Map

The Mass Wasting Hazard map for all areas is included as Map 1-2. This map identifies landforms exhibiting moderate to high failure potential, irrespective of delivery to streams. Map 1-3 includes only those areas that have a potential for delivery to streams.

The following mapping units were determined to be high hazard because of moderate to high landslide density and potential for delivery to streams:

- Shallow, unstable soils (colored brown on Map 1-2)
- Unstable glacial deposits (blue)
- Ancient landslides (green)
- Escarpment above river canyon with high failure rates (double blue line).

1.2 Problems with Method

Mapping of mass wasting features in sections of the Tolt River watershed was actually performed at different times, once in late 1990 and again in 1992, during early method development. Most of the content of the mapping and this section was provided by Jim Ward of Weyerhaeuser. The time and effort required to produce this product cannot be estimated. Furthermore, data on landslide features were not uniformly collected, resulting in incomplete data forms, and the coverage is probably not uniform. Because the mapping was done before manual development, the method was not specifically followed, and certain tasks were not performed.

An adequate base map is essential for locating mass wasting features in relation to roads, topography, etc. A simple watershed outline with major streams is insufficient. In this Tolt example, the basemap used to show the mapped landslides contains an incomplete and badly segmented road network that provides little added information. It is suggested that an independent task be included in the manual specifically to prepare a single basemap that contains all relevant information (stream network; mainline, secondary, and spur roads; major contours; lakes and water bodies; etc.)

2. MODULE 2 - SURFACE EROSION HAZARD ASSESSMENT

(Note: This section was not completed at the time of report production. It will be sumbitted under separate cover.)

3. MODULE 3 - HYDROLOGY HAZARD ASSESSMENT

This section summarizes data and analyses for the Level 1 peak flow analysis and the low flow and annual water yield analysis. This analysis follows assessment procedures contained in Appendix C, Hydrology Hazard Module, of the Watershed Analysis Manual. All data are tabulated below in the order prescribed by the procedure. Exceptions to the procedure are noted. No maps are provided with this module report.

3.1 Peak Flow Events

3.1.1 Analysis Steps

3.1.1.1 Basin Areas Peak flow events for the Tolt River WAU are assessed in three subwatershed basins, shown below. These subwatersheds were selected as being representative of the Tolt River WAU. These basins include Type III (Titicaca Creek) and Type I (North Fork and mainstem Tolt) streams. The South Fork Tolt is not included because a large dam and reservoir significantly affects flood hydrology in that system.

Table 3-1 data were obtained from USGS maps using a digital planimeter.

Table 3-1. Basin Characteristics

Basin	Name	Drainage Area	
		Acres	Sq Miles
1	Titicaca Creek	900	1.4
2	North Fork Tolt below Titicaca Creek	9,550	14.9
3	Mainstem Tolt below forks	39,500	61.7

Basin 3 excludes the portion of the South Fork Tolt River that lies above the Tolt Reservoir. This excluded area does not contribute peak flows to downstream reaches.

3.1.1.2 Rain-on-Snow Zones To determine the fraction of ROS basin within ROS zone, the DNR rain-on-snow maps were planimetered. Data are summarized in Table 3-2.

Table 3-2. ROS Zones

Basin	Fraction of Basin in each Zone		
	Peak ROS	Snow Dominated	Other
1	.27	.56	.17
2	.26	.46	.28
3	.25	.11	.64

3.1.1.3 Hydrologic Maturity Hydrologic maturity was determined using Weyerhaeuser LANDSAT maps. Data summarized below in Table 3-3 were calculated by Weyerhaeuser using GIS analysis.

Table 3-3. Hydrologic Maturity

Basin	Fraction of Basin in Each Stand Class	
	> 25 years	< 25 years
1	.27	.73
2	.37	.63
3	.62	.38

3.1.1.4 Baseline Floods Baseline flood magnitudes for the 2-year, 5-year, and 10-year flood frequencies were calculated using USGS regression equations (Cummans, et al., 1975). Results are summarized in Table 3-4.

Table 3-4. Flood Frequencies Predicted Using Regression Equations

Basin	Area (sq mi)	Annual Precip (in)	Peak Flow (cfs)		
			Q-2yr	Q-5yr	Q-10yr
1	1.4	105	287	425	497
2	14.9	117	2590	3830	4380
3	61.7	88	5710	8410	9450

Equations:

$$\text{Q-2yr} = 0.191 * A^{0.86} P^{1.51}$$

$$\text{Q-5yr} = 0.257 * A^{0.86} P^{1.53}$$

$$\text{Q-10yr} = 0.288 * A^{0.85} P^{1.54}$$

To check the reasonableness of the regression equation predictions, flood frequencies were calculated (using WATSTORE flood frequency program) for the USGS gauge 12148500, Tolt River near Carnation, and gauge 12147600, South Fork Tolt near Index. The Tolt River gauge is representative of Basin 3 (very similar drainage areas), and the South Fork Tolt River gauge is representative of Basins 1 and 2 (drainage area between that of Basin 1 and 2). As shown below in Table 3-5, the regression equation predictions are close to recorded events and therefore are considered acceptable.

Table 3-5. Flood Frequencies from Local USGS Gauges

Gauge	Area (sq mi)	Recorded Peak Flow (cfs)		
		Q-2yr	Q-5yr	Q-10yr
Tolt River	81.4	5500	7500	8800
S.F. Tolt River	5.34	1200	1600	1900

<u>3.1.1.5 Design Storm Duration</u> The Kirpich Equation and Upland Method were used to calculate design storm duration (i.e., time of concentration). The Upland Method estimates travel time for non-channelized areas, which was assumed to occur at the head of the basins. Results are summarized in Table 3-6. The relatively short times indicate that runoff occurs rapidly in WAU-sized basins.

Table 3-6. Design Storm Duration

Basin	Area	L	H	T_s (hr)
1	Channel	1.6 mi	1200 ft	.5
	Upland	2000 ft	-	.4
	Total			**.9**
2	Channel	6.5 mi	1100 ft	1.5
	Upland	3500 ft	-	.6
	Total			**2.1**
3	Channel	17.3 mi	2300 ft	3.5
	Upland	3500 ft	-	.6
	Total			**4.1**

The Upland Method assumes 1.5 fps velocity (slopes > 45 percent). The Kirpich Equation is $T_s = (11.9*L^3/H)^{0.385}$.

<u>**3.1.1.6 Design Storm Precipitation**</u> Procedures contained in NOAA Atlas 2 were used to derive the two-year precipitation depth for each basin. It is noted that both the basin size and time of concentration determines the magnitude of the two-year precipitation depth (i.e., increasingly larger basins have smaller design depths because of the effects of spatial distribution of storm precipitation and increasing basin sizes, and associated longer times of concentration have greater depths because the basin can receive a longer duration of rainfall before an equilibrium of rainfall inflow equals streamflow outflow is reached). Results are summarized below in Table 3-7.

Table 3-7. Design Storm Precipitation

Basin	Area (sq mi)	Depth-Area Adjust.	T_s (hr)	2-yr Precipitation (in)						
				24-hr	12-hr	6-hr	3-hr	2-hr	1-hr	T_s-hr
1	1.4	.99	.9	4.5	3.2	1.8	1.1	0.83	0.53	0.53
2	14.9	.95	2.1	4.7	3.3	1.9	1.2	0.88	0.56	0.86
3	61.7	.92	4.1	4.0	2.8	1.6	1.0	0.76	0.49	1.1

3.1.1.7 Runoff Efficiency Runoff efficiency was calculated using the equation $E_r = 0.00155 * Q_b * T_s / (P_{2yr} * A)$. See Table 3-8.

Table 3-8. Runoff Efficiency

Basin	Q_b	T_c	P_{2yr}	A	E_r	
					2-yr	5-yr
1	287	.9	.53	1.4	.53	.63
2	2590	2.1	.86	14.9	.66	.87
3	5710	4.1	1.1	61.7	.53	.68

3.1.1.8 Snowmelt Snowmelt calculations using method in Brunengo (1992), Screening for Watershed Analysis. First, snowmelt must be calculated for each stand age class and ROS zone using the ROS equation in Brunengo [$SM_{24} = T_a(0.133 + 0.86V_w + 0.0126P_{24}) + 0.23$], with the results combined for each basin using area-weighing. This step calculates direct snowmelt using the Army snowmelt equation. Results are in Table 3-9.

Table 3-9. Snowmelt for Each ROS Zone

Basin	Stand Age (years)	ROS Zone	Total Snowmelt (inches)	
			ROS Zone	Basin Avg.
1	< 25	Snow Dominated	0.76	
		Peak ROS	1.43	
	> 25	Snow Dominated	0.58	
		Peak ROS	1.06	0.81
2	< 25	Snow Dominated	0.77	
		Peak ROS	1.49	
	> 25	Snow Dominated	0.58	
		Peak ROS	1.08	0.55
3	< 25	Snow Dominated	0.75	
		Peak ROS	1.40	
	> 25	Snow Dominated	0.56	
		Peak ROS	1.03	0.32

Next, the basin-wide water availability is calculated for the 24-hour duration using $WA=m*[P_{24}+(SM_{24}*X/n)]$. This equation relates availability of snowpack, likelihood of melt reaching ground, and hydrologic maturity to the direct snowmelt. Results are in Table 3-10.

Table 3-10. Water Availability

Basin	Water Availability over 24 Hours (inches)			
	Mature	Current	ΔWA	% Inc.
1	4.57	5.00	.34	7.4
2	4.76	5.04	.28	5.9
3	4.23	4.35	.12	2.8

The total water availability (of rainfall and snowmelt) during design storm is summarized in Table 3-11. This calculation assumes that the rate of snowmelt is constant over time.

Therefore, for basins with times-of-concentration less than 24 hours the snowmelt must be proportioned accordingly.

Table 3-11. Water Availability

Basin	Approximate Water Availability During Design Storm (inches)				
	T_s	Rain	Snowmelt	Total	% Inc.
1	0.9	0.53	(0.9/24)*0.34=0.013	0.543	2.4
2	2.1	0.86	(2.1/24)*0.28=0.025	0.885	2.8
3	4.1	1.1	(4.1/24)*0.12=0.021	1.121	1.9

<u>3.1.1.9 Increase in Runoff</u> Increase in runoff is calculated using $Q_s = Q_{sp} * A * (1-H_m) * R_{os} * E_r$. Two cases are considered: 1) using Brunengo's Method for calculating ROS (Table 3-12, below) and 2) assuming 1 inch of ROS (Table 3-13).

Table 3-12. Increase Ii Runoff Using Brunengo Method for ROS:

Basin	ΔWA (in)	Q_{sp} (cfs)	A (sq mi)	$(1-H_m)$	R_{os}	E_r	Q_s (cfs)
1	.34	9.2	1.4	1	1	.53	6.8
2	.28	7.6	14.9	1	1	.66	75
3	.12	3.2	61.7	1	1	.53	105

Note: H_m and R_{os} are incorporated into ΔWA number.

Table 3-13. Increase in Runoff Assuming 1 Inch for ROS (ΔWA)

Basin	ΔWA (in)	Q_{sp} (cfs)	A (sq mi)	$(1-H_m)$	R_{os}	E_r	Q_s (cfs)
1	1	27	1.4	.37	.83	.53	6.2
2	1	27	14.9	.32	.72	.66	61
3	1	27	61.7	.19	.36	.53	60

<u>3.1.1.10 Increased Streamflows</u> The increase in runoff (Table 3-12) is added to the baseline flood to calculate the increase in streamflow for current conditions. In summary, the values are the predicted increases in streamflow that result from forest cover removal. Although the baseline flood may already include effects of logging (because logging occurred during the historical streamflow record that was used to derive the regression equations), its absolute magnitude is not particularly relevant to this analysis except when used here: to determine the percent (or relative) change in streamflows. The important value is the increase in runoff, Q_s.

Table 3-14. Increased Streamflows - Current Condition vs. Baseline Flood

Basin	Q_b-Baseline Flood			Q_s	% Inc. over Q-2yr	Revised Q-2yr flood
	Q-2yr	Q-5yr	Q-10yr			
1	287	425	497	6.8	2.4	294
2	2590	3830	4380	75	2.9	2665
3	5710	8410	9500	105	1.8	5815

<u>3.1.1.11 Sensitivity Analyses</u> A sensitivity analysis is performed to determine which variables are important in the analysis. This will indicate if any steps, including assumptions or the level of accuracy of data collection, should be redone to provide greater accuracy. It also provides insight into which combinations of conditions are likely to result in maximum peak flow response.

<u>Effects of Hydrologic Maturity</u>

To assess the effects of the amount of hydrologic maturity in the basin, it is assumed that 100 percent of the basin is open forest (i.e., 0 percent hydrologic maturity). The ROS zones are kept at current levels.

Table 3-15. Sensitivity Analysis - Hydrologic Maturity at 0%

Basin	24-hr Increased Water Availability (in.)			Q_s (cfs)	% Inc. over Q-2yr
	Snow Dom	Peak ROS	Basin Avg		
1	.57	2.08	0.88	17.6	6.1
2	.57	2.18	0.83	220	8.5
3	.56	2.13	0.59	520	9.1

Effect of Storm Duration

This analysis assumes an increase in time of concentration (six times longer). This variable affects total storm precipitation and runoff efficiency. This has the effect of increasing the snowmelt to reflect longer melt times, but also increasing total precipitation because the basin is effectively larger in size which can "absorb" a longer precipitation event. It is noted that in larger basins snowmelt amounts increase at a greater rate than total precipitation (which leads to the conclusion that ROS effects increase with increasing basin size).

Table 3-16. Sensitivity Analysis - Increased Time of Concentration

Basin	T_c	P_{2yr}	24-hr ΔWA (in)	Q_{sp} (cfs)	E_r	Q_s (cfs)	% inc. over 2yr
1	6	1.8	.34	9.2	1.0	12.8	4.5
2	12	3.3	.28	7.6	.97	110	4.2
3	24	4.0	.12	3.2	.86	169	3.0

Effect of Peak ROS Zone

This analysis assumes that the entire basins are within the peak ROS zone. Current stand conditions are retained.

Table 3-17. Sensitivity Analysis - 100% Peak ROS Zones

Basin	24-hr Increased Water Availability (in.)			Q_s (cfs)	% Inc. over Q-2yr
	< 25 yrs	> 25 yrs	Basin Avg		
1	1.09	0	0.79	15.8	5.5
2	1.16	0	0.73	193	7.5
3	1.07	0	0.41	362	6.3

Worst Case Scenario

In the worst case scenario, the above three variables are set to maximum limits: 100 percent peak ROS zones, 100 percent open cut, and five-year storm runoff efficiency.

Table 3-18. Sensitivity Analysis - Worst Case Scenario

Basin	24-hr Increased Water Availability (in.)		E_r	Q, (cfs)	% Inc. over Q-2yr	Revised Flood > 5yr Flood?
	< 25 yrs	Basin Avg				
1	2.08	2.08	0.67	53	18	No
2	2.18	2.18	0.87	763	29	No
3	2.13	2.13	0.68	2410	42	No

3.1.1.12 Conclusion The peak flow analysis indicates that under current forest conditions, runoff from rain-on-snow events are predicted to increase streamflow magnitudes by less than three percent in all three basins analyzed. This increase is far below hazard criteria. Therefore, a low hydrology hazard is concluded.

The sensitivity analysis provides some insight into hydrologic processes. Whereas the effect of independently setting each variable to the maximum limit was relatively small, a very large effect is noted when all three variables are set to maximum. In WAU-sized basins, it is very improbable that a situation will be encountered that even comes close to the worst case scenario. However, this combination would probably be encountered on small sub-basin areas, such as individual or contiguous logging units. Even though runoff from these small areas may impact certain streams (mostly Type IV and V), this analysis is not designed to focus in on these small areas.

3.1.2 Problems with Method

In general, the method can be performed with ease. However, the DNR methods for calculating ROS is meticulous and confusing. It is suggested that, if the DNR approach is acceptable, these additional steps (now contained only in a DNR internal memo) should be written into the manual.

Estimating the time of concentration using Kirpich's Equation has raised some concern. A method that is more appropriate for forested basins should be located.

The sensitivity analyses included above (which are currently not in the manual) should be done by the analyst to verify conclusions and provide insight into the assessment procedure.

3.2 Low Flow and Annual Water Yield

This analysis follows WRENSS assessment procedures contained in Appendix C, Hydrology Hazard Module, of the Watershed Analysis Workbook (26 May 1992 draft). All data are tabulated below in the order prescribed by the WRENSS procedure. Exceptions to the procedure are noted.

3.2.1 Analysis Steps

3.2.1.1 Determination of Rain-Dominated or Snow-Dominated Watershed Streamflow records for the USGS station 12148500, Tolt River near Carnation, were obtained from WATSTORE to determine whether this basin is rain-dominated or snow-dominated. An annual hydrograph was created using flows for the period 1982-1991. A six-day moving average of consecutive daily flows for each of the 10 years was used to create the hydrograph. As is clearly shown, the Tolt basin is rain-dominated. Therefore, the WRENSS procedure for rain-dominated watersheds was selected.

3.2.1.2 Basin Partitioning Partitioning of rain-dominated watersheds by aspect is not required. (Basin partitioning is required only for the snow-dominated portion of WRENSS.) Average hydrologic maturity values for each of the three basins were used (See Table 3-3).

3.2.1.3 Precipitation Data Precipitation data for the NOAA Tolt South Fork Reservoir station was obtained from Climatological Data for Washington (1989). Long-term average precipitation depths for the four seasons were estimated and then adjusted to the three basins using the annual values shown in Table 3-4. These data area summarized in Table 3-19.

Table 3-19. Seasonal Precipitation Data

Period	Average Precipitation (inches)		
	Basin 1	Basin 2	Basin 3
Summer (Jun-Aug)	10.0	11.1	8.4
Fall (Sep-Nov)	30.0	33.4	25.1
Winter (Dec-Feb)	42.2	47.0	35.4
Spring (Mar-May)	22.7	25.3	19.0
Annual Total	105	117	88

3.2.1.4 Water Available for Streamflow The WRENSS procedure uses evapotranspiration (ET) to estimate changes in annual water availability to streamflow. The analysis was performed at the downstream end of the watershed, which corresponds to Basin 3. The method requires values of Leaf Area Index (LAI) for mature and immature (cut) forest conditions. A LAI value of 40 was assumed for the mature condition, based on the H.J. Andrews Experimental Forest example given in WRENSS. This corresponds approximately to the maximum basal area for douglas-fir forests (using the conversion chart in WRENSS). For immature forest conditions, an average LAI value of 10 was assumed for the 0-25 year age class. (For freshly cut areas, the LAI may be as low as 1.0, but since hydrologic maturity recovers rapidly, an average of 10 appears reasonable). Data are summarized below in Table 3-20.

Table 3-20. ET Calculation of Annual Water Availability

Season	Fraction of Basin Area	Precip (cm)	Baseline ET (cm)	LAI	Weighted Adjusted ET (cm)	Water Available for Streamflow (cm)
FORESTED CONDITION						
Summer	1.0	25	26	40	26	-1
Fall	1.0	76	24	40	24	52
Winter	1.0	107	18	40	18	89
Spring	1.0	58	31	40	31	27
Annual Total						167
CURRENT CONDITION						
Summer - Forested - Immature	 0.27 0.73	 25	 26	 40 10	 7.0 18.5	 -0.5
Fall - Forested - Immature	 0.27 0.73	 76	 24	 40 10	 6.5 16.7	 52.8
Winter - Forested - Immature	 0.27 0.73	 107	 18	 40 10	 4.9 8.8	 93.3
Spring - Forested - Immature	 0.27 0.73	 58	 31	 40 10	 8.4 18.1	 31.5
Annual Total						172.6

<u>3.2.1.5 Conclusion</u> The increase in annual water availability is 5.6 cm, or 2.2 inches. This 1.3 percent increase would roughly translate to a similar increase in the average annual stream base flow. No hazard criteria have been proposed for annual water yield.

To assess the sensitivity of the LAI, the value for immature (0 to 25 years) conditions was decreased to 1.0 (e.g., all forests less than 25 years old has essentially no ET demand). This is equal to freshly cut conditions. Under this condition, the increase in water availability is estimated to be 42.5 cm (16.7 inches), or a 10 percent increase. It is very unlikely that an entire watershed would be in this condition, but it would be common in large, individual harvest units.

These increases in annual water availability would not translate to the same percentage increase in peak flows because these are two entirely separate runoff processes. Increased antecedent moisture conditions that would result from decreased ET would, however, probably increase the magnitude of peak flow runoff. Available methods cannot evaluate this particular connection between ET and rainfall runoff.

3.2.2 Change in Timing or Volume of Water Delivered During Spring Snowmelt

The WRENSS procedure for estimating changes to the annual hydrograph in rain-dominated regions was tested. The results of the ET procedure for estimating increased annual water availability, however, is not used in this next step. The WRENSS manual explains that results of the numerical modeling that was used to derive simplified procedures for estimating changes in the hydrograph was best presented using regression equations. Change in ET was estimated using the absolute change in the LAI value (e.g., from 40 to 10). It is noted that only one watershed in the H.J. Andrews experimental forest was used to develop these relationships.

The WRENSS procedure was tested on Basin 3 using the hydrograph developed in Step 1. However, the results of the procedure did not come close to being consistent with the ET estimates on water availability and therefore are considered invalid. For example, for a LAI reduction from 40 to 1 in immature forests in Basin 3, the procedure estimated increases in streamflow ranging from 10 percent to 55 percent (depending on time of year). For a much smaller LAI reduction from 40 to 10 (10 being almost totally hydrologic mature), very large increases in streamflow of 6 percent to 46 percent were still being estimated. In fact, the correlation between LAI and streamflow is flawed because the calculated increase in streamflow does not converge anywhere close to zero when the change in LAI becomes zero.

3.2.3 Problem with Method

The manual states that a personal computer version of WRENSS is available. However, this program applies only to the snow-dominated portions of the procedure. The manual should note this fact. The manual should also state that basin partitioning is required only for snow-dominated watersheds.

The manual has the header INCREASING WATER AVAILABILITY DURING SPRING SNOW MELT (H3). This implies that the method only looks at snow melt basins and the spring time period. It should read INCREASING WATER AVAILABILITY DURING ANNUAL FLOWS (H3) to reference the annual time period and that is in not necessarily limited to snowmelt.

For rain-dominated regions, the portion of the WRENSS method that estimates changes in the streamflow hydrograph should be deleted. Until a new method is proposed, estimation of changes to annual flows would have to rely on the change in annual water availability, presented in Step 4, above. The WRENSS procedure for developing annual hydrographs for rain-dominated regions is concluded to be flawed and should not be used. Delete bullet that starts with "Develop an annual streamflow hydrograph", pg C-8, and modify bullet that starts with "Distribute change in water availability onto annual hydrograph" by adding (snow dominated regions only) and deleting first three lines and two equations, pg C-10.

The hydrograph procedure for snow-dominated regions will be evaluated in the next field test and therefore comments on it are not provided here.

4. MODULE 4 - RIPARIAN FUNCTION HAZARD ASSESSMENT

Riparian function hazard includes two components, large organic debris (LOD) recruitment hazard, and stream water temperature or energy hazard. The two analyses are related because both are concerned with the size and density of trees within the riparian zone. However, the specific methods used to judge each hazard differ. Both of these methodologies were developed largely by Weyerhaeuser Corp. based on field studies within the Tolt River watershed. Jeff Light of Weyerhaeuser provided copies of test results using these methodologies. These results were reviewed by EA and incorporated directly into this cumulative effects test. Consequently, the discussion below focuses only on the interpretation and field verification of these results.

This analysis follows assessment procedures contained in Appendix D, Riparian Function Hazard Module, of the Watershed Analysis Manual. All data are tabulated below in the order prescribed by the procedure. Exceptions to the procedure are noted.

4.1 LOD Recruitment

4.1.1 Analysis Steps

Map 4-1 identifies the LOD hazard units for the Tolt River watershed. Study reaches were located on both forks, on the mainstem and on Stossel, North Fork, Yellow, Titicaca, Titicaed, Phelps, Lynch and 16 unnamed creeks within the watershed. Moderate to high hazard areas were located throughout the upper North Fork and its tributaries, along the upper South Fork, including the Tolt Reservoir, the lower South Fork, the upper mainstem Tolt River, and in Stossel, Lynch and Phelps Creeks. Of the total hazard area, a majority was of the moderate hazard dense conifer less than 40 year old category (approximately 60 percent). This hazard category was found in the upper North Fork, along the north and SW portions of Tolt Reservoir, along the upper mainstem, in Stossel Creek, and along several unnamed tributaries. This class indicates high potential for mitigation over the next 20 to 40 years as these trees increase in size. This hazard class is due predominantly to management related activities, especially harvest of mature trees within the immediate channel area followed by replanting of conifers.

The second most abundant LOD hazard category is the high hazard, mixed deciduous/conifer less than 40 years old category (approximately 20 percent). This hazard type was located in the middle portion of the North Fork, along the lower South Fork and in several patches along the mainstem and middle South Fork and its tributaries. As above, this hazard category has the potential for significant mitigation over the next 20 to 40 years as these stands mature. This hazard category is largely due to harvest within the immediate channel area followed by natural revegetation of the area.

The third most abundant LOD hazard category is the high hazard, dense deciduous less than 40 years old (approximately 10 percent). This category is limited to the SE portion of the Tolt Reservoir and adjacent South Fork, and a small area on the South Fork below the reservoir. Because deciduous trees decompose quickly relative to conifers, areas with this category are likely to remain high to moderate hazard areas regardless of stand age until significant conifer colonization occurs. This hazard category also occurs largely because of harvest within the immediate channel area followed by natural revegetation.

On 27 June, a field visit was conducted to confirm the LOD hazard rating at sites on the North Fork. Site NF1 was located just below Dry Creek near the Weyerhaeuser Mainline Road (see Map 4-1). The field team found very little LOD within the channel (approximately .3 pieces/30 feet). The riparian vegetation in this area was young, with trees approximately 20 to 40 feet tall. Alders comprised 60 percent of the stand with the remainder composed of conifers. Stand density was dense. Using these observations, the study site would be classified as high hazard, deciduous/conifer less than 40 years old. This classification agrees with that determined previously using office based methods.

Site NF2 was located between Titicaca and Titicaed Creeks (see Map 4-1). Conditions in the immediate study area were very similar to those in the first site: young, short trees, alder dominated (approx. 60 percent) with .6 pieces LOD/30 feet within the channel. In this case the classification indicated by the field reconnaissance, high hazard, deciduous/conifer less than 40 years old does not agree with the office identification of high hazard, conifer dominated less than 40 years old. A review of the riparian zone above and below the study area indicated that conifers do dominate the riparian zone in adjacent locations.

Site NF3 was located just above Yellow Creek (see map 4-1). Little LOD was present within the channel. However, the riparian vegetation in this area was older, averaging 60 to 80 feet in height, a mature stand. In addition, the riparian zone was dominated by conifers which comprised 70 percent of the stand. Stand density was dense. These conditions lead to a low hazard call which is in agreement with the office based classification.

Site NF4 was located just NW of the City of Seattle re-regulation reservoir (see map 4-1). In this area the forest has never been cut (i.e., old growth conditions). The stand density was dense and was dominated by conifers (80 percent). These conditions also lead to a low hazard call which is in accordance with the office based classification.

4.1.2 Problems with Method

Problems with this analysis were limited to a single inconsistency in the hazard classification from office and field analyses. This inconsistency was due to the limited length of the study site investigated. A study site length of 10 times the channel width may be insufficient when the channels are narrow.

4.2 Temperature

4.2.1 Analysis Steps

The Level 1 temperature assessment relies on topographic maps and the TFW Temperature Screen to identify approximate shading values needed to meet state water quality criteria for maximum stream temperatures. Analysis of aerial photographs plus field checks provides an estimate of whether current conditions meet target shade values.

4.2.1.1 Target Shade Values Map 4-2 indicates the target shade values given the elevation and distance from the basin divide that are required for a low stream temperature hazard. These values were compared to levels indicated in aerial photos and site visits to determine actual hazard.

4.2.1.2. Existing Shade Levels High temperature hazards exist when existing riparian shading, averaged over the target zone, is less than the target shade values shown on Map 4-2. For the Tolt River watershed, a map of existing shade values was not compiled because it was not practical to collect these data all reaches for the assessment. It is impractical to field survey each stream reach in the watershed for existing shade values, and no office methods exist that can derive these data. Therefore, only spot measurements can be used.

To determine if temperature hazard areas do exist in the watershed, data for individual sites were collected during a field survey conducted on 11-17 October, 1991, and again on 27 June 1992. A total of 12 sites were visited: 8 on the North Fork and 4 on the South Fork. Sites are shown on Map 4-2. Data for these sites are summarized in Table 4-1.

__4.2.1.3. Temperature Hazards__ For the reasons stated above, a watershed-wide temperature hazard map cannot be developed. The above data for 12 visited sites provides a general insight into existing conditions within the watershed; however, this information generally cannot be extrapolated to other areas.

For Sites NF1 to NF4, the following observations are made. At Site NF1, (see Map 4-2) canopy closure was approximately 20 percent. Riparian vegetation at this site was short (20 to 40 feet) but dense, and approximately 20 percent shade is present. The target shade value for this site is 50 percent, which gives this site a high hazard rating. At Site NF2, canopy closure was approximately 60 percent, which is close to the target shade value of 50 percent for this reach but within the low hazard rating. At Site NF3, canopy closure averaged 40 to 50 percent, which is considered high hazard but is close to the 50 percent target for this site. At Site NF4, a combination of trees and a tall, narrow canyon provide 80 percent shade. The target for this reach is 70 percent so this is a low hazard area.

For Sites NF5 to NF8 and SF1 to SF4, all are predicted to have high temperature hazards (although shade values for these sites are maximum values for these reaches). A few of these determinations are inconsistent with Sites NF1 to NF4, and may be caused by different measurement techniques. Thus, high variability may characterize a temperature hazard map.

Based on the spot field measurements, it appears that most reaches within the Tolt River watershed have high temperature hazards. Temperature hazard on the North Fork is due to a combination of past riparian zone harvest and, in the upper North Fork, channel widening due to sediment deposition. Temperature hazards on the South Fork are primarily due to past riparian zone harvest. All temperature hazard areas have the potential for significant impact mitigation of the next 20 to 40 years as the riparian vegetation increases in height.

Table 4-1. Field Data for Temperature Assessment

Site and Location	Reach Length (m)	Mean Bankfull Width (m)	Mean Wetted Width (m)	Mean Depth (m)	Shade Values and Predicted Hazard		
					Existing Shade	Target Shade	Hazard?
North Fork Tolt River - June 1992 field visit							
Site NF1: Just below Dry Creek near the Weyerhaeuser Mainline Road	NR	NR	NR	NR	20%	50%	Yes
Site NF2: Between Titicaca and Titicaed Creeks	NR	NR	NR	NR	60%	40%	No
Site NF3: Just above Yellow Creek	NR	NR	NR	NR	40-50%	50%	Yes
Site NF4: Just NW of the City of Seattle re-regulation reservoir in canyon area	NR	NR	NR	NR	80%	70%	No
North Fork Tolt River - October 1991 field visit							
Site NF5: Begins 150m above confluence with S. Fork, upstream to canyon)	566	32.3	~21	0.35	36%	80%	Yes
Site NF6: Between confluence of North Fork Creek and the bridge (RM 10.4-10.7)	580	53	~16	0.52	24%	70%	Yes
Site NF7: First major widened, alluvial stream reach just below bridge at RM 14.8	462	105	~13	0.22	26%	50%	Yes
Site NF8: Upstream of the last bridge crossing on the North Fork (above RM 23). Wide braided stream.	386	66	~6	0.24	15%	40%	Yes
South Fork Tolt River - October 1991 field visit							
Site SF1: Just above confluence with North Fork (RM 0)	610	29.5	17	0.42	47%	90%	Yes
Site SF2: Upstream of canyon (RM 3-4.1)	841	30	12	0.40	51%	80%	Yes

Table 4-1. Field Data for Temperature Assessment

Site and Location	Reach Length (m)	Mean Bankfull Width (m)	Mean Wetted Width (m)	Mean Depth (m)	Shade Values and Predicted Hazard		
					Existing Shade	Target Shade	Hazard?
Site SF3: Upstream of the mainline bridge and downstream of the landslide (RM 7.2-7.8)	469	42	22	0.38	18%	70%	Yes
Site SF4: Between landslide (RM 7.8) and base of falls	233	21	NR	0.50	16%	70%	Yes

NR - not recorded

4.2.2 Problems with Method

Determining existing shade values must be done before a watershed temperature hazard map can be created. However, shade values cannot be determined using aerial photographs, and therefore no office method exists to perform the temperature hazard assessment. Given the time allotted for field visits in the Level 1 analysis limits, only spot measurements of shade values can be collected, which means that hazard ratings can be developed only for very limited areas of the watershed. Therefore, because of the impracticality of determining watershed-wide existing shade values, developing a temperature hazard map at this stage of the assessment (i.e., prior to FPAs) may not be appropriate.

5. MODULE 5 - CHANNEL CONDITION HAZARD ASSESSMENT

This module attempts to determine the sensitivity of different channel segments to inputs of wood, water and energy by reviewing geomorphic parameters such as slope, substrate, width, depth, etc. Both this module, and the following habitat module, require the delineation of study reaches based on breaks in slope, channel confinement and obvious changes in channel form. Within each reach, a series of measurements and characteristics are determined in the office using remote sensing and other data. Field verification is used on one or more segments. Finally, both field and office analyses are combined to determine overall sensitivity of each reach.

This analysis follows assessment procedures contained in Appendix E, Channel Condition Assessment Module, of the Watershed Analysis Manual. All data are tabulated below in the order prescribed by the procedure. Exceptions to the procedure are noted.

5.1 Analysis Steps

In this test, a total of 21 segments were defined using breaks in gradient and confinement determined from USGS topographic maps (Map 5-1). Of these 21 reaches, 3 were located on the mainstem, 8 on the North Fork, 8 on the South Fork and 2 on Stossel Creek. The USGS maps were used to estimate valley and channel widths and gradient for each segment. These values were then used to determine the dominant inputs that each segment would respond to using Table 5-1. Widths, slopes and response variables are listed for each segment on Map 5-1.

Results for the above mapping indicates that most segments are sensitive to coarse or mixed sediment deposition and LOD loss. Several sections on the lower portions of the North and South Forks were additionally sensitive to scour frequency and/or depth. Fine sediment deposition was identified as a sensitivity on the North Fork above Yellow Creek, and in two of the three mainstem segments. Finally, bank erosion was indicated as a potential problem on two of the three lowest segments on the North Fork.

Aerial photos were then reviewed to determine channel widths, patterns, shade and overall condition. Results for this analysis are shown on Table 5-1 and a blank copy of the data form used is shown on Table 5-1A. Aerial photos indicated extreme channel widening on two portions of the North Fork, the channel below Titcaed Creek extending to within

Table 5.1 Geomorphic Channel Assessment Worksheet

Segment	Channel Width	Stream Condition	Channel Pattern	Shade	Landslides	Other Disturbance
N12	365.3'	Open canopy	Braided	< 10%	No	Extreme channel widening
N11	71.8'	Closed canopy	Non-braided	70%	No	
N9	397.3'	Open	Braided	< 10%	No	Extreme channel widening
N8	476.8'	Open	Braided	20%	No	Extreme channel widening
N7	76.9'	Closed, narrow	Non-braided	80%	No	
N6	97.4'	Mixed, open and closed	Non-braided	50%	No	Some with deposits on side stream
N2	188.4'	All closed except downstream end	Non-braided	60%	No	Downstream end with extensive channel widening
N1	115.4'	Mixed, open and closed	Non-braided	40%	No	In canyon - no obvious widening
S9	128.2'	Open	Braided	20%	No	Some channel widening
S8	76.9'	Mixed	Non-braided	40%	No	Narrow channel
S5	76.9'	Mixed	Non-braided	50%	No	
S2	76.9'	Mixed	Non-braided	50%	No	Goes through deep, bowl-shaped canyon
S1	76.9'	Closed	Non-braided	60%	No	No evidence disturbance
3	173.0'	Open	Non-braided	20%	No	Channel open but no evidence channel widening from excess sediment

Table 5.1A. Geomorphic Channel Assessment Worksheet

Segment	Channel Width	Stream Condition	Channel Pattern	Shade	Landslides	Other Disturbance

approximately one mile of Titicaca Creek, and from approximately one mile below Titicaca Creek to just above Yellow Creek. Areas of channel widening were indicated by the absence of riparian vegetation, extensive light colored deposits, and, frequently, a braided channel. Extensive channel widening was not observed in any other portion of the channel network. Landslides were not observed in any of the segments examined. Percent shade varied from < 10 percent to 80 percent with the highest levels generally on the South Fork and the lowest in portions of the North Fork with channel widening.

On 27 May, field studies were conducted on two segments of the North Fork to verify results determined in the office. Results for segment N12, located below Titicaed Creek (see Map 5-1), are listed on Table 5-2 and a blank copy of the data form used in shown on Table 5-2A. Segment N12 had a bankfull width of 67.5 feet and a valley width of approximately 250 feet. Estimates of width from the USGS topographic map and aerial photographs were 15.4 feet and 365.3 feet, respectively. Both of the remotes estimates were inaccurate, leading to an incorrect classification for this reach as unconstrained. The channel at N12 was composed of coarse gravel, cobbles and boulders. No pools were present within the study area. Instead the channel was composed of riffles and runs in a roughly 60%:40% proportion. Habitat composition could not be determined from the USGS maps or aerial photographs. LOD was sparse and the riparian vegetation was immature indicating sensitivity to LOD loss, as predicted by the office based analysis.

Field studies were also conducted at segment N8, which is located below Dry Creek (see Table 5-3). The channel width in this area was 131 feet. Estimates of width from the USGS topographic map and aerial photographs were 15.4 feet and 476.8 feet, respectively. Again, both of the remotes estimates were inaccurate, leading to an incorrect classification for this reach as unconstrained. The channel was composed of coarse gravel, cobbles and boulders. Extensive banks of coarse cobbles and gravel were located on both banks forming a wide, sparsely vegetated floodplain. No pools were present within the study area. The channel was composed of riffles and runs in a roughly 73.4%:26.6% proportion. Habitat composition could not be determined from the USGS maps or aerial photographs. LOD was totally absent except for some root wads located up out of the active channel. The distance of the riparian vegetation from the channel and its immature status indicate a sensitivity to LOD loss, as predicted by the office based analysis.

The office and field analyses were combined for an overall, integrated assessment of channel condition. Results for this analysis are shown on Table 5-4 and a blank copy of the form used is shown on Table 5-4A. The overall interpretation indicated coarse and mixed

GEOMORPHIC CHANNEL ASSESSMENT
FIELD FORM

Segment N12 Date 5/27 Time 1004 Observer MG, JB

Dominant Bed Material cobbles

Channel Length 350' Channel Width 67.5'

Valley Width 200' (est.) Pieces LOD/100' 2

Channel Architecture loss in riffles

Bank Material cobbles Bank Slope < 30%

Bank Eroding? Left? N Right? N Canopy % 50%

Channel Pattern straight Riparian Veg. Type Alder/Conifer

% Pools 0% % Riffles 60% % Runs 40%

Max Pool Depth (1) - Pool Lip Depth (1) -

Max Pool Depth (2) - Pool Lip Depth (1) -

Max Pool Depth (3) - Pool Lip Depth (1) -

Surface Pebble Count ( ) __________

Subsurface Pebble Count ( ) __________

Table 5-2. Geomorphic Channel Assessment Field Form

GEOMORPHIC CHANNEL ASSESSMENT FIELD FORM

Segment ________ Date ___________ Time ________ Observer ________________

Dominant Bed Material ____

Channel Length ______________ Channel Width ______________

Valley Width _________ Pieces LOD/100' __________

Channel Architecture ____

Bank Material ____________________________ Bank Slope ______________

Bank Eroding? Left? _________ Right? _________ Canopy % __________________

Channel Pattern ______________________ Riparian Veg. Type ____________________

% Pools _____________ % Riffles _________________ % Runs _________________

Max Pool Depth (1) __________________ Pool Lip Depth (1) ____________________

Max Pool Depth (2) __________________ Pool Lip Depth (1) ____________________

Max Pool Depth (3) __________________ Pool Lip Depth (1) ____________________

Surface Pebble Count ( ) ____

____

____

____

Subsurface Pebble Count ( ) ____

____

____

____

Table 5-2A. Geomorphic Channel Assessment Field Form

GEOMORPHIC CHANNEL ASSESSMENT
FIELD FORM

Segment N8 Date 5/27 Time 0901 Observer MG, JB

Dominant Bed Material cobbles

Channel Length 1080' Channel Width 131'

Valley Width 250' (est.) Pieces LOD/100' 3

Channel Architecture elevation loss in riffles

Bank Material cobbles Bank Slope < 30%

Bank Eroding? Left? N Right? Y Canopy % 20%

Channel Pattern straight-braided Riparian Veg. Type Alder/Conifer

% Pools 0% % Riffles 73.4% % Runs 26.6%

Max Pool Depth (1) - Pool Lip Depth (1) -

Max Pool Depth (2) - Pool Lip Depth (1) -

Max Pool Depth (3) - Pool Lip Depth (1) -

Surface Pebble Count (cm) 12, 8, 9, 6, 5, 3, 5, 5, 7, 7, 5, 8, 12, 5, 7, 5, 6, 4, 3, 15, 3, 8, 3, 4, 5, 5, 5, 6, 11, 4, 3, 2, 3, 2, 3, 3, 3, 5, 4, 2, 2, 3, 3, 3, 3, 2, 2, 3, 1.5, 1.5, 1.5, 3, 3, 6, 8, 6, 4, 5, 8, 6, 7, 8, 8, 6, 7, 7, 8, 5, 6, 20, 6, 10, 8, 5, 8, 5, 5, 7, 7, 8, 6, 3, 3, 1.5, 2, 2, 3, 3, 8, 3, 2, 1.5, 3, 6, 8, 5, 6, 8, 12

Subsurface Pebble Count (mm) 10, 12, 15, 20, 13, 10, 14, 20, 22, 13, 12, 11, 10, 15, 22, 15, 17, 15, 15, 14, 18, 12, 18, 14, 16, 8, 12, 11, 9, 12, 9, 10, 11, 12, 12, 7, 7, 14, 11, 11, 8, 5, 7, 6, 7, 8, 12, 14, 16, 11, 12, 21, 18, 13, 11, 13, 20, 15, 15, 12, 16, 16, 18, 10, 15, 15, 17, 14, 20, 18, 17, 15, 6, 7, 15, 14, 7, 14, 5, 10, 17, 8, 12, 20, 13, 12, 18, 13, 22, 11, 15, 21, 16, 17, 15, 10, 18, 15, 14, 20

Table 5-3. Geomorphic Channel Assessment Field Form

Table 5-4. Geomorphic Channel Assessment - Channel Interpretation

Segment	Coarse/Mixed Sediments	Fine Sediment	Flow	LOD	Energy	Riparian
N12	Coarse substrate sediment bars; widening indicates excess sediment.			LOD levels low, riparian veg. young = high hazard.	Open canopy suggests problems.	
N11	Lack widening, bars suggest no excess sediments.			unknown		
N9	Coarse substrate sediment bars; widening indicates excess sediment.			LOD levels low, riparian veg. young = high hazard.	Open canopy suggests problems.	
N8	Coarse substrate sediment bars; widening indicates excess sediment.			LOD levels low, riparian veg. young = high hazard.	Open canopy suggests problems.	
N7		Lack widening suggests no excess sediments.	Lack channel indicators suggests no problems.	unknown	Closed, tight canopy suggests no problems.	
N6	Some sediment bars and widening suggest at or just over capacity.			unknown	unknown	
N2	Except downstream end, no excess sediment. Downstream end with excess sediment.		Lack channel indicators suggests no problems.	Extensive canopy closure suggests no problems.	Closed, tight canopy suggests no problems.	
S9	Some sediment bars and widening suggest at or just over capacity.			Low canopy closure suggests problems.	Open canopy suggests problems.	
S8	Lack widening, bars suggest no excess sediments.			Low canopy closure suggests problems.	Open canopy suggests problems.	

Table 5-4. Geomorphic Channel Assessment - Channel Interpretation

Segment	Coarse/Mixed Sediments	Fine Sediment	Flow	LOD	Energy	Riparian
S5	Lack braiding, widening suggests no problem.		Lack channel indicators suggests no problems.	Moderate canopy closure suggests potential problems.	Moderate canopy suggests potential for problems.	
S2	Lack braiding, widening suggests no problem.		Lack channel indicators suggests no problems.	Deep bowl canyon with trees suggests no problems.	Closed, tight canopy suggests no problems.	
S1	Lack widening, bars suggest no excess sediments.			Extensive canopy closure suggests no problems.	Closed, tight canopy suggests no problems.	
3	Lack braiding, widening suggests no problem.	Lack widening suggests no excess sediments.		Extensive canopy closure suggests no problems.	Closed, tight canopy suggests no problems.	

Table 5-4A. Geomorphic Channel Assessment - Channel Interpretation

Segment	Coarse/Mixed Sediments	Fine Sediment	Flow	LOD	Energy	Riparian

Table 5-4A. Geomorphic Channel Assessment - Channel Interpretation Page 2

Segment	Coarse/Mixed Sediments	Fine Sediment	Flow	LOD	Energy	Riparian

sediment deposit problems along the upper North Fork. LOD and energy inputs were also identified as significant factors in this area. Overall, no other portion of the Tolt River drainage was identified as having significant problems that were consistently found along reaches.

5.2 Problems with Method

Problems with this method module related to the remote assessment of channel conditions and the confusing write-up for the integration step. First, USGS topographic maps are not sufficiently detailed for the measurement of channel or valley width, although they were sufficient for measurement of gradient. USGS quadrangles for the study area have a 40 foot contour interval (except the Lake Joy quadrangle where 20 foot intervals were available. However, to be consistent, valley widths were measured between 40 foot contours). Consequently, the valley widths were always overestimated because the actual valley boundary is less than 40 foot above the channel. This led to misidentifying segments as unconstrained because the valley widths were so large. Similarly, the USGS maps underestimated channel widths, especially in headwater areas. This exacerbated the tendency to classify channels as unconstrained.

The aerial photos, by contrast, overestimated channel width. Because the active channel could not be seen in most photographs, the channel width was estimated as something between the valley width and actual channel width, that is, the area between dense vegetation on either side of the channel. The aerial photographs provide perhaps a better estimate of valley width, but even this boundary was often indeterminate.

Another problem concerns the field testing portion of the module. As currently stated, this testing is very time intensive, both to collect the field data and to assess this data in the office. The time required suggests that most of this work is Level 2. One suggestion would be to measure channel and valley widths in a Level 1 study and leave detailed analyses like D*, V* and Q* to a level two study.

As noted above, the interpretation portion of the module is very confusing. Coarse, mixed and fine sediment have elaborate assessment tables but these tables are not really explained. What does a "low" mean, that conditions currently suggest limited transport, or that additional transport capability is low? In addition, other variables lack sufficient documentation to evaluate except subjectively. The LOD and energy analyses duplicate work done as part of the Riparian Hazard analysis and should be eliminated.

Finally, Table 5-1 (the gradient/confinement matrix) needs to be cleaned up and factors listed in those blanks that are currently blank. In the current test, two segments on the upper South Fork were undefined on this matrix.

6. MODULE 6 - FISH HABITAT CONDITION ASSESSMENT

The fish habitat module is designed to delineate the limits of anadromous populations, to identify the salmonid species present within a watershed, and to identify segments that are representative of the major habitat uses within the basin, namely spawning, summer rearing and winter rearing. Conditions within each of these segments are then evaluated to determine the potential habitat value based on slope and gradient, and the actual habitat condition based on interviews, literature searches and field visits. Potential and actual conditions are then compared to make calls on habitat condition.

At the time of this test, Timber/Fish/Wildlife has not decided which of two rating systems would be used to make these final calls on condition. One system would use a good/fair/poor system similar to that used in other modules. Alternately, a target, off-target natural and off-target management system has been proposed. The latter system uses conditions in unmanaged systems to set target goals. Habitat conditions equal or better than these levels rate a call of on-target. Conditions less than these levels must be further analyzed to determine if the cause is due to natural causes or to the consequences of current or past management activities. Depending on the cause, these conditions lead to calls of off-target natural and off-target management, respectively. The current test uses both rating systems for the determination of final habitat calls.

This analysis follows assessment procedures contained in Appendix F, Fish Habitat Condition Assessment Module, of the Watershed Analysis Manual. All data are tabulated below in the order prescribed by the procedure. Exceptions to the procedure are noted.

6.1 Analysis Steps

Table 6-1 summarizes the interviews with individuals familiar with the Tolt River system. The questionnaire was designed to cover all aspects of the fisheries within the Tolt system including distribution, habitat types, life history use by location, habitat conditions, and perceived impacts to the system.

Several studies were reviewed to assess the distribution of fishes within the river system, and current and historic habitat conditions. These studies are listed in the reference section at the end of this report.

Table 6-1. **Interview Forms - Fish Habitat Assessment**

INTERVIEW FORM

Fish Habitat Assessment

Person Interviewed Kurt Beardslee Representing Washington Trout

Address P.O. 402 Duvall, WA 98019 Date Interviewed

Phone #

Educational/Professional Experience

Specific experience with fisheries in watershed being analyzed? (Y/N) Y

If yes, detail Fished Tolt 20 years, Assistance w/ Pfeiffer 1990 Study

What species are found in watershed? Chum, Pinks, Chinook, Sockeye, Sum. & Win. Steelhead, Cutthroat, Brook

Where are the species located? Chums & Pinks 1st couple miles, Cohos to Stossel Ck, Chinook [illegible], up North Fork [illegible]

What are boundaries anadromous and resident waters? Mile 3.6 for North Fork, below Tolt Reservoir dam for South Fork

Are there fish passage barriers? (Y/N) Y If yes describe type/location See above - Falls in both cases

What areas are used for spawning? Both forks to limit passage barriers, actual locations different [illegible] Stossel Ck for Cohos. S. Fork above mile 3.2 for S. Steelhead

What areas are used for summer rearing?

What areas are used for winter rearing? Beaver Ponds on Stossel Ck for Cohos

What is general habitat condition in watershed? Bedload high, especially on the North Fork

Is there enough flow and holding water for upstream migration of spawning adults? Lack freshets: Not getting migration signal

Are summer water temperatures within legal limits? S. Fork = Took grab samples above & below reservoir - Found ≈ 11.5°F ↑ (mid-hi 60's), No diel shift downstream, [illegible] upstream

Is there evidence of poaching on spawning adults? Poaching on both forks, most at N. Fork at First Falls ≈ R.M. 2.8

Is there enough spawning gravel in streams? Gravels on S Fork embedded, N. Fork also embedded, ↑ in embedd[illegible] in last 6 years

Is there evidence of reduced egg survival due to fine sediments? N/A

(Do you have any data on) the percentage of fine sediments in spawning gravels?

Is egg pocket scour a problem in system? ______

Is there sufficient summer rearing habitat? ______

Do you have any data on the percentage of habitat composed of pools? ______

Are there enough deep pools and off-channel areas for winter rearing needs? ______

Is there enough coarse substrate for winter hiding habitat? ______

How has habitat changed over time? Riparian zone invasion, Holes filling up,

To what extent are these changes due to management activities? Flow Regulations by Reservoir, landslides etc.

if flow barrier winter run not working would worry about total habitat avail on S. Fork

Harvest Regs ↑ # spawners x 300%

6-3

INTERVIEW FORM

Fish ~~Channel~~ Habitat Assessment

Person Interviewed Bruce Stoker, EbAsco Env. Representing ____
Address Bellevue, WA Date Interviewed ____
Phone # ____
Educational/Professional Experience Fisheries Background
Specific experience with fisheries in watershed being analyzed? (Y/N) Y
If yes, detail Study on South Fork for Seattle Water Dept.
What species are found in watershed? Summer Steelhead
Where are the species located? ____

What are boundaries anadromous and resident waters? ____

Are there fish passage barriers? (Y/N) ____ If yes describe type/location ____

What areas are used for spawning? ____

What areas are used for summer rearing? ____

What areas are used for winter rearing? ____

What is general habitat condition in watershed? Overall habitat in good condition, not viewed as limiting populations
Is there enough flow and holding water for upstream migration of spawning adults? Y
Are summer water temperatures within legal limits? ____
Is there evidence of poaching on spawning adults? ____
Is there enough spawning gravel in streams? Y
Is there evidence of reduced egg survival due to fine sediments? N
(Do you have any data on) the percentage of fine sediments in spawning gravels? Y
Is egg pocket scour a problem in system? ____
Is there sufficient summer rearing habitat? Y
Do you have any data on the percentage of habitat composed of pools? Y
Are there enough deep pools and off-channel areas for winter rearing needs? Y

Is there enough coarse substrate for winter hiding habitat? N/A
How has habitat changed over time? ____

To what extent are these changes due to management activities? ____

USGS topographic maps and aerial photographs were reviewed to assess channel conditions along the North and South Forks, along the mainstem, and in Stossel Creek. These sources were used especially to determine slopes, channel widths, valley widths, and the condition of the riparian zone.

All three sources of information were used to compile Map 6-1. First, the upstream boundary of anadromous waters was determined from Pfeiffer (1990) and the Department of Fisheries stream catalog. Anadromous waters extend up the North Fork to a fall located due north of the City of Seattle re-regulation reservoir (approx. two miles below Yellow Creek). Stossel Creek is passable but North Fork Creek, located just above Stossel is not. On the South Fork, the limit of anadromous fishes is a fall located about 1.5 miles below the Tolt Reservoir (see Table 6-1). Lynch Creek, the only major tributary entering the South Fork below this point has an impassable cascade near its mouth. All upstream areas to the limit of type 3 waters was assumed to contain resident fishes.

The next step was to define segments. In total 33 segments were selected. This pool of 33 contained all 21 of the segments used in module 5 (geomorphic channel assessment) as well as 12 more segments. A total of 3 segments were identified on the mainstem, 14 on the South Fork, 12 on the North Fork and 4 on Stossel Creek (see Table 6-1). The channel width, valley width, gradient and confinement of each segment was then determined. Values for the 21 module 5 segments were taken from that analysis. Values for the remaining 12 segments were determined using methods outlined in module 5.

The gradient and confinement estimates were then used to derive potential habitat value for spawning, summer rearing, and winter rearing using tables FH-1 - FH-3 of module 6. These values are shown for each segment on Map 6-1. Overall, potential spawning and rearing habitat was rated as good for all segments except those located in steep areas with greater than an 8 percent gradient (segments S4, N4). In addition, three segments on the South Fork (S10, S13, S14) and one on Stossel Creek (SC1) were not definable using the existing tables (i.e., confinement/slope characters not defined on tables).

Actual habitat conditions were then assessed. Habitat conditions are listed on Table 6-2. A review of habitat conditions indicates that poaching of summer steelhead in the mainstem and both forks is a significant concern, especially because the targeted population, summer steelhead, has shown a pattern of decreasing escapement numbers in the last decade (Pfeifer 1990). In addition, summer rearing habitat may be lacking due to cover in the North Fork

Table 6-2. Record of Evidence Supporting Salmonid Habitat Sensitivities

Question	Response				Locations
	Y/N	Description	Meas.	Call	(reach numbers)
Upstream migration					
IV.2.b (passage)	N	No evidence Temp. or culvert blockage, Hydro blockage above Falls		/	All
IV.2.c (holding areas)	N	Much evidence lacking - overall appears sufficient in anadromous zone	/	/	All
IV.2.d (poaching)	Y	Poaching of Summer Steelhead Thought Significant		/	1-3, S1-S9, N1-N3
Spawning and Incuabtion					
IV.3.b (availability)	N	Available evidence is That Spawning gravels sufficient		/	All
IV.3.c (Scour)	N	No evidence Significantly increased freq. Scour			All
IV.3.d (dewatering)	N	No evidence dewatering			All
IV.3.e (fines)	N	Much evidence lacking, Segments examined in field OK	/	/	All
Summer Rearing					
IV.4.a (area or depth)	Y	Some concern over % pools, esp. in North Fork and Mainstem		/	1-3, N1-N2
IV.4.b (cover)	Y	Cover lacking in N. Fork resident zone, insufficient evident Anadro.	/	/	N8-N12
IV.4.c (temperature)	N	Some evidence high temperatures on South Fork in steelhead area		/	S1-S9
IV.4.d (dewatering)	N	No evidence dewatering		/	All
IV.4.e (percent pools)	Y	See IVA			1-3, N1-N12
Winter Rearing					
IV.5.a (pools)	Y	Lack cover in N. Fork Resident Zone		/	N8-N12
IV.5.b (off-channel)	N	No significant evidence of Reduction in This parameter		/	All
IV.5.c (embeddedness)	N/A				

resident zone, pools may be deficient in number and areal extent in the mainstem, and temperatures may limit populations in the South Fork. Winter rearing habitat may be impacted in the North Fork resident zone because of insufficient cover.

Finally, calls on overall sensitivity were made. These calls and a summary of the information used to make them is listed on Table 6-3. This analysis shows that the two steepest segments, N1 and S4 had generally low sensitivity. All segments showed a moderate sensitivity to coarse sediment and to wood except those located on the upper North Fork, which were highly sensitive. All but N1 and S4 had high sensitivity to water and heat.

6.2 Problems with Method

Problems with this module involve the complexity of the sensitivity analysis and some measurement problems. The final step, part 5 is confusing. Part of this derives from having two value systems, poor, fair, good and target/non-target. However, part derives from an effort to generate conclusions even when data do not exist to do so. For example, several sensitivities are set by habitat potentials, not by any analysis that directly examines those variables (e.g., sensitivity to water). Results for the two value systems are identical indicating one should be dropped from future tests.

Problems identified in module 5 relative to measurement of channel and valley widths apply here as well. The consequence to this analysis is that potential habitat value was rated as good in every section except one.

Minor problems include: empty spaces in the matrices of Tables FH-1 - FH-3 and several typographical errors in the text.

Table 6-3. Record of Information Supporting Fish Habitat Sensitivity Calls

SEGMENT NUMBER	1-3	S1-S3	S4	S5	S6	S7-S9	S11	S12	N1	N2	N3	N4	N5	N6-N12
GRADIENT/CONFINEMENT CATEGORY	UNCON.	UN	MOD CONS	UNCON	MOD CONS	UNCON.	UNCON	UNCON	MOD CONS	UNCON	MOD CONST.	MOD CONST.	MOD CONST.	UNCON
SPAWNING POTENTIAL	G	G	P	G	G	G	G	G	G	G	G	P	G	G
SUMMER REARING POTENTIAL	G	G	P	G	G	G	G	G	G	G	G	P	G	G
WINTER REARING POTENTIAL	G	G	P	G	G	G	G	G	G	G	G	P	G	G
SELECTED SAMPLE REACHES														
CONDITION CALL - COARSE SEDIMENT	G/T	G/T	G/T	G/T	→	→	→	G/T	G/T	→	→	G/T	P/OTM	→
CONDITION CALL - FINE SEDIMENT	G/T	G/T	G/T	G/T	→	→	→	G/T	G/T	→	→	G/T	G/T	→
CONDITION CALL - WOOD	G/T	G/T	G/T	G/T	→	→	→	G/T	G/T	→	→	P	P/OTM	→
CONDITION CALL - WATER	G	G	F	G	→	→	→	G	G	→	→	G	G	→
CONDITION CALL - TEMPERATURE	G	G	F	F	F	F	F	G	G	→	→	G	G	→
HABITAT SENSITIVITY CALL - COARSE SEDIMENT	M/M	M/M	M/M	→	→	→	→	M/M	M/M	→	→	M/M	H/H	→
HABITAT SENSITIVITY CALL - FINE SEDIMENT	M	M	L	H	H	→	→	M	M	→	→	L	M/M	→
HABITAT SENSITIVITY CALL - WOOD	M/M	M/M	M/M	→	→	→	→	M/M	M/M	→	→	M/M	H/H	→
HABITAT SENSITIVITY CALL - WATER	H	H	L	H	→	→	→	H	H	→	→	L	H	→
HABITAT SENSITIVITY CALL - HEAT ENERGY	H	H	L	H	H	→	→	H	H	→	→	L	H	→
COMMENTS														

G=Good P=Poor M=moderate, H=high, L=low / Where two values are listed in the same space, the upper was derived using a Good, Fair, Poor value system and the lower using a target/off target system. (OTM=off target management)

SC1	SC2-SC3	SC4												SEGMENT NUMBER
unCon.	UnCon.	mod Const												GRADIENT/CONFINEMENT CATEGORY
?	G	G												SPAWNING POTENTIAL
?	G	G												SUMMER REARING POTENTIAL
?	G	G												WINTER REARING POTENTIAL
														SELECTED SAMPLE REACHES
G/T	→													CONDITION CALL - COARSE SEDIMENT
G/T	→													CONDITION CALL - FINE SEDIMENT
G/T	→													CONDITION CALL - WOOD
G	→													CONDITION CALL - WATER
G	→													CONDITION CALL - TEMPERATURE
M/M	→													HABITAT SENSITIVITY CALL - COARSE SEDIMENT
M	→													HABITAT SENSITIVITY CALL - FINE SEDIMENT
M/M	→													HABITAT SENSITIVITY CALL - WOOD
H	→													HABITAT SENSITIVITY CALL - WATER
H	→													HABITAT SENSITIVITY CALL - HEAT ENERGY
														COMMENTS

7. SYNTHESIS

The synthesis portion of the watershed assessment links the independent assessments completed under each of the individual hazard assessments by integrating data on a segment and input variable basis. This integration process develops segment-specific problem statements, or *situation sentences*. These sentences define existing or prospective changes to the watershed and specific linkages to forest practices for each of five input variables: coarse sediment, fine sediment, wood, water, and heat energy. A completed sentence for a given segment establishes the following:

- Activities are altering (or may alter) inputs related to the process under consideration (e.g., logging road failure generating coarse materials)

- The input in question is reaching the stream system (or is likely to)

- Public resources sensitive to the input are present in the reach under consideration (i.e., rearing habitat is sensitive to inputs of coarse sediment)

- Resource conditions in a response reach can be adversely affected, or the current rate of inputs is such that an already affected or degraded condition will not improve (i.e., the coarse material that is generated is likely to accumulate in pools with expected reduction in pool volume).

In addition to situation sentences, the assessment method produces ratings of resource vulnerability, resource condition, delivered hazard, and management response, as called for under the Cumulative Effects Rule (WAC 222-12-046). Delivered hazard and vulnerability determinations are combined in a matrix to produce prescribed management responses. The rule matrix produces three possible management responses: standard rules, minimize, and prevent or avoid.

At present, under the current version of watershed analysis *delivered hazard* is the same as *hazard* because delivery criteria have not been developed. Furthermore, the management response terms *minimize* and *prevent or avoid* have not been defined.

7.1 Fine Sediment

The following situation sentence applies to fine sediment:

"(to be added)"

7.2 Coarse Sediment

The following situation sentence applies to coarse sediment:

"Coarse sediment from road related landslides is leading to channel widening that affects pool depth on the upper North Fork Tolt River. This leads to a prevent call for coarse sediment".

7.3 Hydrology

No situation sentences for the Tolt Watershed result from the hydrology assessment.

7.4 LOD Recruitment

The following situation sentence applies to LOD recruitment:

"LOD hazard from past riparian harvest has resulted in insufficient LOD for fish habitat on the North Fork Tolt River. This leads to a prevent call for LOD."

7.5 Shade and Stream Temperature

The following situation sentences apply to shade and stream temperature:

"Young riparian trees from past riparian harvest causes insufficient shade leading to temperature hazards on the North Fork Tolt River. This leads to a prevent call for temperature."

"Warm water releases from South Fork Tolt Reservoir has resulted in elevated water temperatures on the South Fork Tolt River below the reservoir. This leads to a prevent call for temperature".

REFERENCES

Brunengo, M.J. 1992. Draft screening for watershed analysis. Unpublished memo. Washington Department of Natural Resources.

Cummans, J.E., M.R. Collins, and E.G. Nassar. 1975. Magnitude and frequency of floods in Washington. U.S. Department of the Interior. Geological Survey, Tacoma, WA. Open-File Report 74-336 pp.

EA. 1992. Level 1 and Level 2 Cumulative Effects Analysis Methods, Summary Report and Draft Methods Manual. EA Engineering, Science, and Technology. 3 March 1992.

Pfeifer, Bob. 1990. Tolt River Summer - Run Steelhead Stock Assessment. Unpublished Manuscript. Washington State Department of Wildlife, District Two.

TFW. 1992. Watershed Analysis Manual, Comment Draft Version 0.1. Edited by Cumulative Effects Steering Committee of the Washington State Timber, Fish, and Wildlife Program. 26 May 1992.

PERSONAL COMMUNICATION

Beardslee, Kurt. Washington Trout.

Johnson, Rich. Washington Department of Wildlife.

Light, Jeff. Weyerhaeuser Corporation.

Stoker, Bruce. Ebasco Environmental.

Ward, Jim. Weyerhaeuser Corporation.