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TFW Effectiveness Monitoring Report

THE EFFECTS OF THE INTENTIONAL ADDITION OF LARGE WOODY DEBRIS TO STREAM CHANNELS IN THE UPPER COWEEMAN RIVER BASIN: BASELINE SURVEY RESULTS

by:

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Abstract

Five stream reaches within the Upper Coweeman Watershed Administrative Unit, Cowlitz County, Washington were surveyed where the intentional addition of LWD to the channels had occurred. The surveys were conducted as part of a study effort to evaluate the effectiveness of a watershed prescription process in which LWD is intentionally added to stream channels. Cable yarding, directional felling, and heavy machinery were used to add LWD to the channels. LWD, channel habitat and channel reference point data were collected utilizing Washington State Timber Fish and Wildlife (TFW) Monitoring Program guidelines. Initial surveys were conducted immediately after LWD addition occurred in the summer of 1998. Surveys were repeated in the summer of 1999. Parameters estimated include abundance and quality of natural and added LWD, channel habitat unit quantity and quality and locution. of added LWD relative to established streambank reference points. A total of 43 logs (177 cubic meters of volume) were added to the study sites, at a mean rate of one log for every 9.7 bankfull channel widths. 69% of added logs were transported various distances downstream. Log stability at the jive sites ranged from all volume being exported out of thr established reach to no instability occurring at all. The only alterations to channel morphology quantifiable at the reach scale occurred at a site where added debris was placed in a jam configuration. When logs were yarded into channels, 67% of the volume was placed within the bankfull channel cross section. Directional felling and bridge demolition placed 22% and 31% within the channel, respectively.

Introduction

A Level II watershed analysis (WSA) was iniriated by Weyerhaeuser Company in the Upper Coweeman River Watershed Administrative Unit (WAU) in the fall of 1995. After the analyses and synthesis were completed, the prescription process was started and is now complete. Upper Coweeman WAU riparian prescriptions call for intentional felling of trees and yarding of unmerchantable material (YUM) into stream channels where riparian recruitment potential has been characterized as low to moderate, and/or where in-channel large woody debris (LWD) is lacking. This type of riparian prescription is a departure from typical riparian prescriptions in the State of Washington. Because this riparian prescription is atypical, there is an opportunity to monitor its effectiveness in altering channel morphology and ultimately improving fish habitat.

Although experimental wood addition to streams has been previously evaluated (House and Boehne, 1985; Cederholm, et al. 1997), this effort is unique in that we are examining the effectiveness, of a wood placement effort carried out in an operational setting in Washington. Conventional riparian stand management prescriptions intended to increase LWD recruitment require extended periods of time before any measurable effects, on channel LWD recruitment can be evaluated. The intentional addition of LWD may prove to be a valuable tool in bridging the temporal gap between near-term and long-term effectiveness. An evaluation of the effects of the wood addition prescription on a site-specific scale will provide a basis for modifying and improving the process.

Objectives

The goal of this prescription is to provide one "functional" piece of LWD for every four bankfull channel widths along the length of stream segments adjacent to active harvest units. Functional-piece size criteria were developed during the Coweeman WAU prescription writing process using the results obtained by Bilby and Ward (1989) as a guideline (Table 1). It is important to note that "functional" size should not be confused with "key" size. Key piece size requirements are defined in the WSA Fish Habitat Module (WSFPB, 1995 p. F-261, and differ significantly from the functional piece size as defined in the Upper Coweeman WSA. Both key and functional size categories will be addressed in this study.

Table 1. Guidelines for determining functional piece size of LWD.

CHANNEL SIZE	MINIMUM DIAMETER*
5 to 20 feet	8 inches (20.32 cm)
20 to 35 feet-	1[illegible] [illegible]es (30.48 cm)
35 to 50 feet	1[illegible] [illegible]es (40.64 cm)
50 feet plus	2[illegible] [illegible]es (50.80 cm)

*The minimum lengths for the diameters listed must be at least the width of the channel's ordinary high water mark.

Four specific monitoring questions are being addressed in this study.

1. *How were LWD stocking rates within each study site altered? Was the stated goal of adding one functional piece per 4 channel widths achieved?*

Hypothesis to be tested: LWD stocking rates will increase within the target reach at a rate equal to or greater than one functional piece of LWD per 4 bankfull channel widths.

Relevant parameters being estimated: Quantity and quality of LWD added to each reach will be measured to allow evaluation of changes in the LWD stocking rates at each site.

2. *Did the added LWD remain stable when subjected to peak flow events? What factors influenced stability of the added pieces?*

Hypothesis to be tested: Added LWD will be of a size sufficient to remain within each targeted stream reach.

Relevant parameters being estimated: Migration of added LWD within the reach will be noted and compared to LWD volume, orientation, channel width and channel gradient. We will assume added LWD was transported out of the survey reach if it cannot be located within that reach during follow-up surveys.

3. *Did the udded LWD contribute to pool scour or sediment storage ? What factors influenced the role of the added LWD related to pool scour and sediment storage ?*

Hypothesis to be tested: The addition of LWD to stream channels within the Upper Coweeman WAU will contribute to stream habitat complexity by increasing the rate of pool scour and sediment storage within the target reaches.

Relevant parameters being estimated: Pool quantity and quality data collected during baseline surveys will be compared with data from subsequent surveys. Volume of added LWD will be compared to associated pool surface area and depth, and to the presence of associated sediment accumulations.

4. How did the effectiveness of the treatment methods vary, and why?

Hypothesis to he tested: Treatment methods that cause a greater percentage of LWD volume to be placed within the bankfull channel cross section will enable more enhanced morphologic channel response.

Relevant parameters being estimated: Treatment method, LWD volume, and volume placed within the bankfull channel will be related to associated pool dimensions and sediment storage. Evaluation of the results achieved through use of various techniques to add LWD to channels may provide a basis for suggesting improvements to the process.

Methods

Study Area

The Upper Coweeman Watershed Administrative Unit is located in Cowlitz County, Washington and is divided into nine subbasins draining 44,331 acres. Weyerhaeuser Company is presently the primary landowner in the basin. The watershed was first logged in the late 1800's with many of the stream channels splash dammed in the early 1900's, and has since been subject to intensive forest management. The basin is now dominated by second-growth stands.

The streams in the watershed are generally confined with high stream power. There are only a few alluvial channels. In high stream power channels, sediment and LWD rarely accumulate without obstructions such as LWD (Weyerhaeuser, 1997b; pp. 2-3). Wood and sediment were exported from many stream channels that were splash dammed. Study reaches included high stream power mainstem channels (Geomorphic Map Unit #1) and small channels draining benchy topography (Geomorphic Map Unit #5) (Weyerhaeuser, 1997b).

Riparian areas were also assessed for their potential to contribute LWD to stream channels. Of the 95 miles of stream (4'7.5, both sides) surveyed during watershed analysis roughly half of the riparian areas were characterized as having moderate to low neat-term LWD recruitment potential (Weyerhaeuser, 1997c; pp. 1-2).

Site Selection

As part of the prescription process that is being applied in the upper Coweeman WAU. large woody debris is being intentionally added to stream channels. The additions are made when stream adjacent timber stands are harvested. LWD is being added by felling stems directly into the channel, or by yarding unmerchantable material (YUM) into the channel. One or both of these methods may be used depending on riparian stand characteristics, quality/quantity of unmerchantable material available within harvest units, and use of skyline suspension over the channel. Stream channel reaches are considered candidates for this prescription if the following conditions exist:

1) High LWD recruitment potential; low in-channel LWD volume (Upper Coweeman prescription designation: LWD1)

Rationale: In most channel reaches adjacent to these stands, in-channel wood of a size and quantity to affect channel morphology was found to be lacking.

2) Hardwood–dominated stands (Upper Coweeman prescription designation: LWD2)

Rationale: Hardwoods are often too small or do not last long enough in stream channels to change stream morphology by sorting and storing gravel, increasing pool frequency and depth, and creating cover for anadromous and resident fish species.

Sampling Design

Baseline field data were collected during the summers of 1998 at four sites adjacent to harvest settings soon after felling of trees and/or yarding of material into the channel had occurred. These four sites comprised all of the stream reaches within the upper Coweeman WAU where LWD was added during the 1998 field season. One additional survey was conducted at the site of a log-stringer bridge demolition project. An old bridge was dismantled with heavy equipment and the log stringers were added to the Coweeman River mainstem. Although the bridge project was not described in the prescription process, we obtained valuable information on an alternate method of LWD addition that meshes well with the remainder of the data set. Maps of the study sites are provided in Appendix A.

Initial surveys were conducted during the 1998 summer low flow season, shortly after LWD was added to the channels and logging operations in the areas had ceased. Surveys were repeated approximately one year later at the established sites,, after one winter season had elapsed. Test and control reaches were identified at each location. Test reaches were established, beginning approximately 50 meters below the location of the downstrean-most piece of added debris. This distance was extended in the largest channels. Test reaches extended upstream to the location of the uppermost piece of added debris. For each test reach surveyed, and where conditions allowed, a control reach of similar length was also surveyed. Control reaches were located immediately upstream from the test reach and exhibited similar morphologic and riparian characteristics. At two sites, channel characteristics upstream of the test reach were dissimilar, such that obtaining a reasonably comparable control was not possible (Table 2). In these instances a control reach was not established. Study sites were established at the following locations (Table 2):

The three mainstem sites are utilized by resident and anadromous fish species. The 130 and 134 sites have resident species only. Site 134 contained a field marker indicating the uppermost extent of salmonid usage near the top of our survey reach. The 1738 site has a barrier to fish passage in the form of a large bedrock fall at 441 meters above reference point 0. Only resident species utilize the habitat above the fall (Weyerhaeuser, 1995a).

Data collection

Field data collection involved three general procedures: establishment of streambank reference points, LWD surveys, and channel habitat unit surveys.

TFW Monitoring Program methodology for establishing streambank reference points (Pleus and Schuett-I-fames, 1998) was utilized, with some alterations. This process involved establishing reference markers at regular intervals along survey segments, to allow the segment to be relocated for follow-up surveys,

Data gathered through this process included: reference point location, bankfull channel widths, and channel gradient profiles.

Alterations to the TFW methods included:

A) Only reference points comprising the lower reach boundaries were triangulated with alternate points marked. Additional reference points were marked within survey reaches, but triangulation and alternate points were not established at these locations. Locations of all reference points relative to the downstream end of each reach were documented.
B) Bankfull channel depth data were not collected. Additional bankfull width measurements were taken in place of the depth data. Bankfull widths were measured every 20 m for reaches shorter than 500 m, and every 50 m for reaches longer than 500 m.
C) Shade data was not collected.
D) Channel gradient was measured at 20 to 50 m intervals along the length of all surveyed reaches.

LWD data was collected utilizing TFW Monitoring Program methodology for the LWD Level 2 Survey (Schuett-Hames et al., 1994a). No alterations to the methods were made. Only debris that resided at least partially within the two-year bankfull channel width (Figure 1), was at least 10 cm in diameter and 2 m in length were counted. Data gathered through this process included: length and diameter of pieces, length residing in/out of the bankfull channel, orientation relative to the mean direction of flow, stability factors (rootwad, pinned, buried), pool forming (yes/no), storing sediment (yes/no), species (conifer/deciduous/ unknown). Each piece of added LWD was identified and marked with machine-embossed numbered aluminum tags, and location relative to established streambank reference points was recorded. Added pieces were tallied and measured whether or not a portion resided within bankfull.

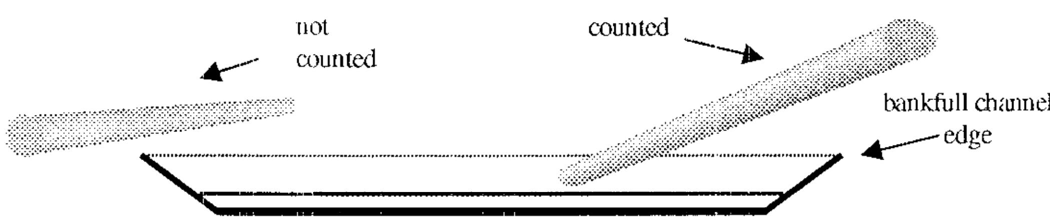

Figure 1. Diagram of bankfull channel cross section with examples of qualifying and non-qualifying pieces.

Channel habitat parameters were estimated utilizing TFW Monitoring Program methods for the Habitat Unit Survey (Schuett-Hames et. al, 1994b). The parameters estimated included unit type (pool/riffle), unit category (primary, secondary, side channel), unit length, mean unit width, residual pool depth, pool formative factor(s), dominant and co-dominant substrate. Photographs were taken to visually demonstrate baseline conditions at the study locations. A photo record of each study site and each added log was constructed so that baseline conditions can be compared with future conditions.

Equipment/Quality Assurance

Field measuring equipment used in these surveys included a hip chain, fiberglass stadia rod, handheld clinometer, fiberglass measuring tape and aluminum tree calipers. The field crew wore chest waders in the Coweeman R. and Mullholland Ck. mainstems to enable access to deeper water.

Survey crew members successfully passed quality assurance checks for the Level 2 LWD survey and Habitat Unit Survey. QA evaluations are conducted by TFW Monitoring Program staff members. Results of the QA were given as pass/fail.

Results

Data collected during the 1998 baseline surveys was used to address monitoring questions 1 and 4. Questions 2 and 3 are addressed using data that was collected when the sites were resurveyed in 1999.

Monitoring Question #1

How were LWD stocking rates within each study site altered? Was the stated goal of adding one functional piece per 4 channel widths achieved? Hypothesis to be tested: LWD stocking rates will increase within the target reach at a rate equal to or greater than one functional piece of LWD per 4 bankfull channel widths.

A total of 43 individual logs were added to the five sites that were surveyed. Directional felling and cable yarding techniques were used to add 32 logs to stream.. adjacent to harvest units. The bridge demolition project resulted in the addition of 11 large diameter logs to the Coweeman River. Those logs were added using heavy machinery and the resulting arrangement of LWD qualifies as a debris jam according to TFW monitoring protocol.

A total of 1'77 cubic meters of debris was added to the sites, with just over a third of that volume (67 m^3) coming to rest within the bankfull channel cross section (zones 1 and/or 2). Average diameter of the added debris was 57.3 cm. The average length was 15 m. 79% of added debris was coniferous and 21% was deciduous. The diameter of coniferous debris averaged 64 cm. and deciduous averaged 31 cm LWD quantities increased a mean of 8% at the five sites (Table 3). The mean stocking rate of natural LWD was 2.14 pieces pet- channel width (CW), increasing to 2.43 pieces per CW after logs were added. Key piece quantity increased 13%, with logs of key size being added to three of the five sites. In channel LWD volume increased by 1% at the 130 and 134 sites and 7% at the 173X site. 14% more in-channel volume was added to the 1652 site. but this was all exported in winter 1998- 1999. In-channel volume at the 168 1 bridge project more than doubled after wood was added.

'The prescription guideline of providing one functional size piece for ever-y four channel widths was met only at the bridge demolition site (Table 4). However, this guideline was intended for use in stream reaches adjacent to harvest units and technically does not apply to the 1681 bridge site. On average, 1 functional piece of LWD was provided for every 19 channel widths within the established treatment reaches.

able 2. Study site locations and wood addition dates.

Stream	legal location	Site Designation (road access)	Drainage area (acres), Channel width (m.)	Watershed stream segments [3]	Prescription Designation, channel type [3]	Treatment type	approx. date of wood addition
Coweeman River mainstem	NE¼ 19, SW¼ 20, 8N 2E	1652	16,832, il.3	300,301,302	LWD2, High Energy Mainstem	Directional felling	7/98
Tributary to Coweeman River	SE ¼ 22, 8N 2E	130	427, 7.3	308	LWD2, Small benchy	YUM	6/98
Tributary to Coweeman River[1]	NW¼ 23, 8N 2E	134	214, 4.2	311	LWD2, Small benchy	Directional felling	6/98
Mullholland Ck. mainstem[1]	SE ¼ 3, 8N 1E	1738	5,873., 10.3	105,106,107	LWD2, High energy mainstem, alluvial	Directional felling YUM	3/98
Coweeman Rv. mainstem[2]	N ½ 27. 8N2E	1681	9,607, 13.6	306	LWD2, High energy mainstem	Bridge demolition	9/9X

[1] control reach not available
[2] not associated with a harvest unit; log-stringer bridge demolition
[3] from Upper Coweeman WSA Riparian and Stream Channel Assessments, 1997

Table 3. Changes in LWD stocking as a result of LWD addition.

Site	LWD Pieces (number, pieces / CW)			Key Pieces (number, pieces / CW)			In-channel volume (all pieces, key pieces)		
	Before	After	% change	Before	After	% change	Before	After	% change
130	55, 3.92	62, 4.42	13	14, 1.00	14, 1.00	0	95.97, 69.96	96.12, 69.96	1, 0
134	69, .68	77, .76	12	25, .25	31, .31	24	66.96, 50.40	67.76, 50.40	1, 0
1738	320, 2.35	332, 2.44	4	67, .49	70, .51	4	488.2, 444.87	521.27, 465.89	7, 5
1652	50, .95	55, 1.05	10	1, .02	1, .02	0	46.41, 3.20	53.04, 3.20	14, 0
1681	45, 2.78	56, 3.46	24	2, .12	7, .42	350	16.02, 2.89	42.12, 15.73	263, 544
Total	**539, 2.14**	**582, 2.43**	**8**	**104, .30**	**118, .38**	**13**	**713.56, 571.32**	**780.31, 605.18**	**9, 6**

Table 4. Functional size LWD addition rate.

Site	Functional size pieces added	Pieces/C W
130	1	1/14
134	1	1/14
1738	6	1/22
1652	2	ii26
1681	4	1/4

'able 5. Fate of added LWD after one year.

site Number	Number of added LWD pieces (all,key)			In-channel volume of added LWD (all pieces, key pieces)			Total Pieces per channel width (natural and added pieces)		
	Stable	Unstable	% unstable	Stable	Unstable	% change in volume '98 to '99	Immediately after addition	After 1st year	% change
130	7, 0	0, 0	0, 0	.15, 0	0, 0	0	4.42	3.49	-21
134	8. 6	0, 0	0, 0	.80, 0	0, 0	[illegible]	.76	.99	+23
1738	6, 1	"6, 2	50, 67	4.55, .87	26.48, 1X.16	-6, -30	2.44	2.88	+15
1652	'1, 0	4, 0	80, 0	0, 0	0, 0	-100, 0	1.05	.72	-31
1681	5.4	6, I	55, 0	16.10,15.14	6.97, 0	-12, +15	3.46	4.39	+27
Total	**27, 11**	**16, 3**	**59, 27**	**21.6, 16.01**	33.45, 1X.16	-18, +3	2.43	2.49	**+13**

Entire volume of log resides in zone 4.

ii Log # 19 became unstable and broke into three separate pieces. This increase in piece quantity is not reflected in this table, as the net added volume remained unchanged.

Monitoring Question #2

Did the added LWD remain stable when subjected to peak flow events? What factors influenced stability of the added pieces? Hypothesis to be tested: Added LWD will be of a size sufficient to remain within each targeted stream reach.

59% of all added logs were transported downstream from their original locations (Table 5). 27% of key-size added logs were transported. Added logs exhibited various degrees of stability at the three mainstem channel sites, while no instability was observed at the two small-stream sites. Accordingly, small streams and large streams will be treated separately in discussing monitoring question #2.

Mainstem Sites

At the 1652 Coweeman Rv. mainstem site, all of the added volume within zones 1, 2 and 3 was transported out of the established treatment reach. The butt section of one added log remained within the reach, but with all of its volume residing in zone 4 only.

Half of the added LWD at the 173X site was transported downstream some distance, but all pieces remained within the treatment reach. The mean distance those pieces were transported was 3 1 meters (Table 6). Unstable logs at this site had over six times more volume placed in zones 1-2 than stable ones.

At the 1681 bridge demolition site, four of the eleven added logs were unaccounted for in the 1999 survey. It is likely that at least two were transported out of the reach, while the other two may have been buried beneath debris that accumulated against the added logs. One of the logs transported out of the treatment reach was of key size. The remaining logs shifted slightly, but no measurable downstream movement was observed.

Table 6. Mean volumes of stable and unstable added logs at 173X site (volumes from 199X baseline data).

	Quantity	Mean Distance transported (meters)	mean total volume (m^3)	Mean volume in zones 1-2 (m^3)
Transported	6	31	5.23	**4.76**
Remained st	6	0	3.95	**0.76**

Small Stream Sites

No instability of added LWD was observed at the 130 and 134 sites. A small percentage of the total added volume actually intruded into zones 1 or 2 at these sites. Stream power during normal peak flow events is probably not sufficient to cause significant mobilization of LWD in these reaches. Much of the natural LWD was observed covered with thick moss and serving as nurse logs. This suggests lengthy periods of stability, *Monitoring Question #3*

Did the added LWD contribute to pool scour or sediment storage? What factors influenced the role of the added LWD related to pool scour and sediment storage? Hypothesis to be tested: The addition of LWD to stream channels within the Upper Coweeman WAU will contribute to stream habitat complexity by increasing the rate of pool scour and sediment storage within the target reaches.

An increase in pool scour and/or sediment storage rates resulting from the addition of LWD to a site would be best demonstrated by two kinds of evidence: 1) Quaiitative visual observation of scour and/or sediment storage directly associated with added debris; and 2) Quantitative demonstration of an increase in pool quantity, pool surface area and/or increase in the number of logs storing sediment within the treatment reach.

In 1999, added LWD was observed having an apparent influence on pool habitat at the 1738 and 1681 sites only. At the 1738 site two added logs had become incorporated into existing log jams. These jams were forcing pools, and determining the morphological influence of added logs incorporated into existing jams is beyond the scope of this study. One key added piece that had remained stable had apparently forced a small pool. Total pool count was unchanged within this reach between 1998 and 1999 (Table 7). The estimated pool surface area actually decreased in 1999. These data reveal no quantifiable increase in pool scour from 1998 to 1999. Two added logs were observed contributing to sediment storage. These two logs represented 11% of the total number of individual pieces storing sediment at this site. (Table 8). The number of natural logs observed storing sediment increased 1% between surveys. Although we do not have an estimate of surface area of stored sediment, it is unlikely that the amount stored by the two logs would be quantifiable on a reach scale.

The log jam configuration created by the 168 1 bridge demolition forced scouring of a single pool. A large sediment depositional area had also formed immediately upstream from the jam. Habitat unit data indicates an increase in treatment reach pool quantity from 4 in 1998 to 9 in 1999. Total pool surface area also increased from 545 m^2 to 645 m^2. The control reach pool count remained at 3 for both years, yet the estimated pool surface area increased 36%. The pool formed by the bridge logs did not exist in 1998. Prior to the wood addition, no pools were observed that had been formed by individual logs or jams in the treatment reach. The only directly observable alterations to channel morphology occurred adjacent to the jam itself.

Table 7. Changes in pool habitat associated with LWD after 1" winter.

Site #	Number of pools			Pool Surface Area ($m.^2$)			Mean Residual Pool Depth (m.)		
	Before Addition	After 1st year	% change	Before Addition	After 1st year	% change	Before Addition	After 1st year	% change
130	1	4	+400	10.10	26.73	+265	.25	.33	+24
134	2	6	+300	10.80	19.60	+181	.23	.24	+4
1738	40	40	- 0	2846.60	2034.93	-29	.45	.48	+6
1652	16	14	-12	4523.30	3434.55	-24	.55	.68	+19
1681	4	9	+66	545.60	645.19	+15	.55	.50	-10
Total	**63**	**73**	t-14	7936.40	**6161.00**	**-22**	**.41***	**.45***	**+9**

Table 8. Changes in sediment storage rates of natural and added LWD.

	% of natural LWD storing sediment			% of added LWD storing sediment	
Site #	Before Addition	After 1st year	% change	After 1st year	% change
130	9	33	+24	0	0
134	26	37	+11	25	+25
1738	14	15	+1	17	+17
1652	3	8	+5	0	0
1681	0	27	+27	55	+55
Total	**15.2***	**24***	**+8.8**	**19.4**	**+19.4**

The 134 site had two added logs that were observed storing small quantities of sediment (1 m^2 or less). These two logs represented 6% of individual pieces storing sediment at the site.

The 130 and 134 road exhibited an increase in pool quantity and surface area in 1999 (Table 7). 'These increases occurred despite the observation that no added logs directly influenced pool formation. Apparently this increase is the result of natural fluctuations in pool scour at these small stream sites. Pool quantity within the 130 control reach also increased 200% from 1998 to 1999. No control reach was available at the 134 site.

Monitoring Question #4

How did the effectiveness of the treatment methods vary, and why? Hypothesis to be tested: Treatment methods that cause a greater percentage of LWD volume to be placed within the bankfull channel cross section will enable more enhanced morphologic channel response.

LWD was added to stream channels adjacent to harvest units using cable yarding and directional felling techniques. The 1681 bridge was dismantled using power saws and a log loader. Only yarding and felling were addressed in the LWD prescription. The bridge project was executed in addition to the prescription parameters.

When debris was yarded into channels, 67% of the total volume was placed in zones 1-2 (Table 9). The other methods resulted in less than a third of the total volume being placed in zones 1-2. The increased volume within the channel resulted in an increased degree of instability (Tables 5 and 6). Felling and bridge demolition both resulted in a high percentage of total volume remaining stable. This may be a result of the low percentage of volume of felled logs in zones 1-2, and bridge logs with large individual volumes that were inherently stable.

The most obvious alterations to channel morphology occurred at the 168 1 bridge site where 26. I m^3 of LWD volume was placed in zones t-2. More volume was placed in the channel at the 1738 site, however the 1681 logs were all placed within a 12 m segment. The resulting jam structure caused constriction of stream flow, accumulation of additional debris and substantial alteration of channel morphology in the immediate vicinity.

Table 9. Comparison of effectiveness of different methods used to place LWD.

	Number of pieces	Number of key pieces	Mean diameter	Mean volume	Percent of volume		Percent of pieces stable	Percent of volume stable
					In-channel	Suspended		
Yarding	14	3	52.4	3.2	67	13	64	36
Felling	18	7	41.5	2.7	22	29	72	72
Bridge Demolition	11	5	89.5	7.57	31	56	45	75
Total	43	**15**	57.3	**4.11**	**38**	38	65	64

Discussion

Mainstem Sites

Logs added to the Coweeman River 1652 site had no measurable effect on the channel. AU of the added volume in zones 1-3 was transported out of the treatment reach during the winter of 1998-1999. Even the largest added log was transported nearly a kilometer downstream. Individual pieces of natural debris were generally not observed influencing channel morphology in this area. Mainstem channels In the Upper Coweeman WAU are dominated by bedrock substrate, which may be a result of splash damming which occurred early this century, and high stream power (Weyerhaeuser Company, 1995b). It was generally observed during watershed analysis that most inputs of sediment and wood are transported out of these channels. Only jams or accumulations of LWD on the channel margins were observed influencing pool scour and sediment storage. Large jams were historically present, but many were blasted out. Channel response to LWD input was rated as moderate for these segments (Weyerhaeuser Company, 1997b). The logs that were added to this channel may influence channel morphology by becoming incorporated into jams or accumulations below the treatment reach, as log #32 was observed to have done. For future reference, targeting specific reaches in the mainstem Coweeman for LWD addition will likely encounter similar results unless additional efforts are made to stabilize the added pieces.

The 1681 bridge project resulted in the addition of nearly as much volume as the other four sites combined. The added pieces are typical of the quality of debris that was recruited into the channel when mature conifer stands prevailed in the drainage. The effort resulted in the most obvious influence on channel morphology of all the sites. The concentration of such a large volume of debris within a 12 m segment resulted in pool scour and sediment storage. The accumulation of a large volume of additional debris against the added pieces enhanced the overall effect. In a high stream power environment, providin,stability to logs or other enhancement structures requires large log volumes and/or careful engineering and placement of smaller materials. Additional debris will continue to accumulate against the new jam as long as the key supporting pieces remain stable. Considerable widening of the channel may occur in the vicinity of the jam as a result of constricted flow.

All twelve added logs at the Mulholland Ck. 1738 road site remained within the established reach. Logs that remained stable at their original locations tended to have less volume placed within zones 1 and 2. Several added logs became incorporated into existing debris jams and accumulations, which tends to mask the influence of those individual logs. Habitat unit survey data reveal no measurable increase in pool quantity or surface area on a reach scale. One added log was observed functioning as a primary pool formative feature. Of the four sites adjacent to harvest settings, the LWD added to this site is likely to have the greatest potential for influencing channel morphology. Factors contributing to this conclusion are the relatively high percentage of volume placed in zones 1-2, and the existing habitat complexity suggesting a moderate to high degree of channel response to LWD input.

Small Stream Sites

LWD additions to the 130 and 134 road sites were not observed influencing channel morphology. This is due, in part, to the lack of added volume intruding into zones 1 and 2, and also due to the low level of channel response to LWD in this small stream draining benchy topography (Upper Coweeman WSA Stream Channel Assessment, 1997). Pool habitat was lacking in these reaches, even though key-size LWD was abundant in the channel. Key piece abundance was 1 piece per 4 channel widths at the 134 site, and 1 piece per 1.6 channel widths at the 130 site. Many of the large pieces present in these reaches were remnant cull logs from past logging operations. Both segments were located on the same unnamed stream. This stream drains a relatively small area (Appendix A, stream segment maps) and exhibited many of the characteristics described for this Geomorphic Map Unit during WSA. It was hypothesized that the tumbling flow developing within these cascade-type reaches limits the increase in scour potential during high flow events. (Weyerhaeuser Company, 1997b; pp. 60-61). Bedrock dominated substrate is also a likely contributor to the lack of pools being forced. Stability of added pieces in these low-energy channels is not an issue. The influence of the added logs may increase in the future, if channel migration processes begin to incorporate them into the system. However, in 1999 no significant channel modifying influence was observed and it is doubtful whether any future influence would be quantifiable on a reach scale.

Suggestions for Prescription Process Improvement

Our observations revealed several ways the LWD addition prescription could be improved in the future. Attempts should be made to add pieces at greater rates to targeted reaches with the intent of achieving the goal of I piece per 4 channel widths. When cable yarding techniques are used, extra effort should be made to place a greater percentage of log volume within zones 1 and 2. In mainstem channels, especially the Coweeman Rv., attempts should be made to increase stability of added pieces by selecting logs with larger volumes, or by pinning the added logs against stable objects. Felling and yarding techniques should be modified to reduce the number of logs that are channel spanning.

Future monitoring

No further opportunity exists to monitor the 1652 treatment site since all of the volume added to zones 1, 2 and 3 was transported out of the treatment reach. Considering the low degree of channel response to existing large diameter LWD in the 130 and 134 channels, and the relatively small percentage of volume added to these sites, the likelihood that any channel response would be quantifiable on a reach scale is low. The 199X and 1999 survey data suggest that natural year to year fluctuations in the amount of pool scour and sediment storage would probably mask any effects of the added debris.

Although some direct evidence of channel influence was observed at the 173X site, the likelihood that effects at this site would be quantifiable on a reach scale utilizing TFW survey methods is remote. This is due to the relatively small percentage of LWD volume that was added, and the incorporation of added debris into existing jams. Also, since an adequate control reach was not available, any observed alterations would not be discernible from natural fluctuations. Gathering of descriptive information associated with the added logs in the future may be warranted, but in depth quantitative analysis is not.

An increase in pool quantity and surface area was detected at the 1681 bridge demolition. The added logs contributed visibly and quantifiably to pool scour. Sediment storage was also evident at a depositional area above the jam. Persistence of these pieces over time may be of interest to resource managers attempting similar projects. If continued monitoring of this site is desired, parameters should include descriptive and photographic records of the fate of these logs over time. Channel response to the added bridge timbers was substantial, and occurred after only one winter season. Although opportunities to duplicate this LWD addition effort are rare, its effectiveness should be noted if near-term habitat rehabilitation in high power mainstem channels is desired.

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References

Bilby, R.E. and James W. Ward. 1989. Changes in Characteristics and Function of Woody Debris with Increasing Size of Streams in Western Washington. Transactions of the American Fisheries Society 11 8:368-378.

Cederholm, C.J. et. al. 1997. Response of juvenile coho salmon and steelhead to placement of large woody debris in a coastal Washington stream. North American Journal of Fisheries Management vol. 17 no. 4.

House, R.A.,, and P.L. Boehne. 1985. Evaluation of instream enhancement strauctures for salmonid spawning and rearing in a coastal Oregon stream. North American Journal of Fisheries Management 5:283-295.

Pleus, A.E. and D. Schuett-Hames. 1998. TFW Monitoring Program methods manual for the reference point survey. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish and Wildlife Agreement. TFW-AM9-98-002. DNR #104. May.

Schuett-Hames, D., A. Pleus, and L. Bullchild. 1994b. TFW Amhient Monitoring Program Habitat Unit Survey Module. IN: Schuett-Hames, D., A Pleus, L. Bullchild and S. Hall (eds.). TFW Ambient Monitoring Program Manual. TFW-AM9-94-001. Northwest Indian Fisheries Commission. Olympia

Schuett-Hames, D; J. Ward, M. Fox, A. Pleus and J. Light. 1994a. TFW Ambient Monitoring Program Large Woody Debris Survey Module. IN: Schuett-Hames, D., A. Pleus, L. Bullchild and S. Hall (eds.). TFW Ambient Monitoring Program Manual. TFW-AM9-94-001. Northwest Indian Fisheries Commission, Olympia

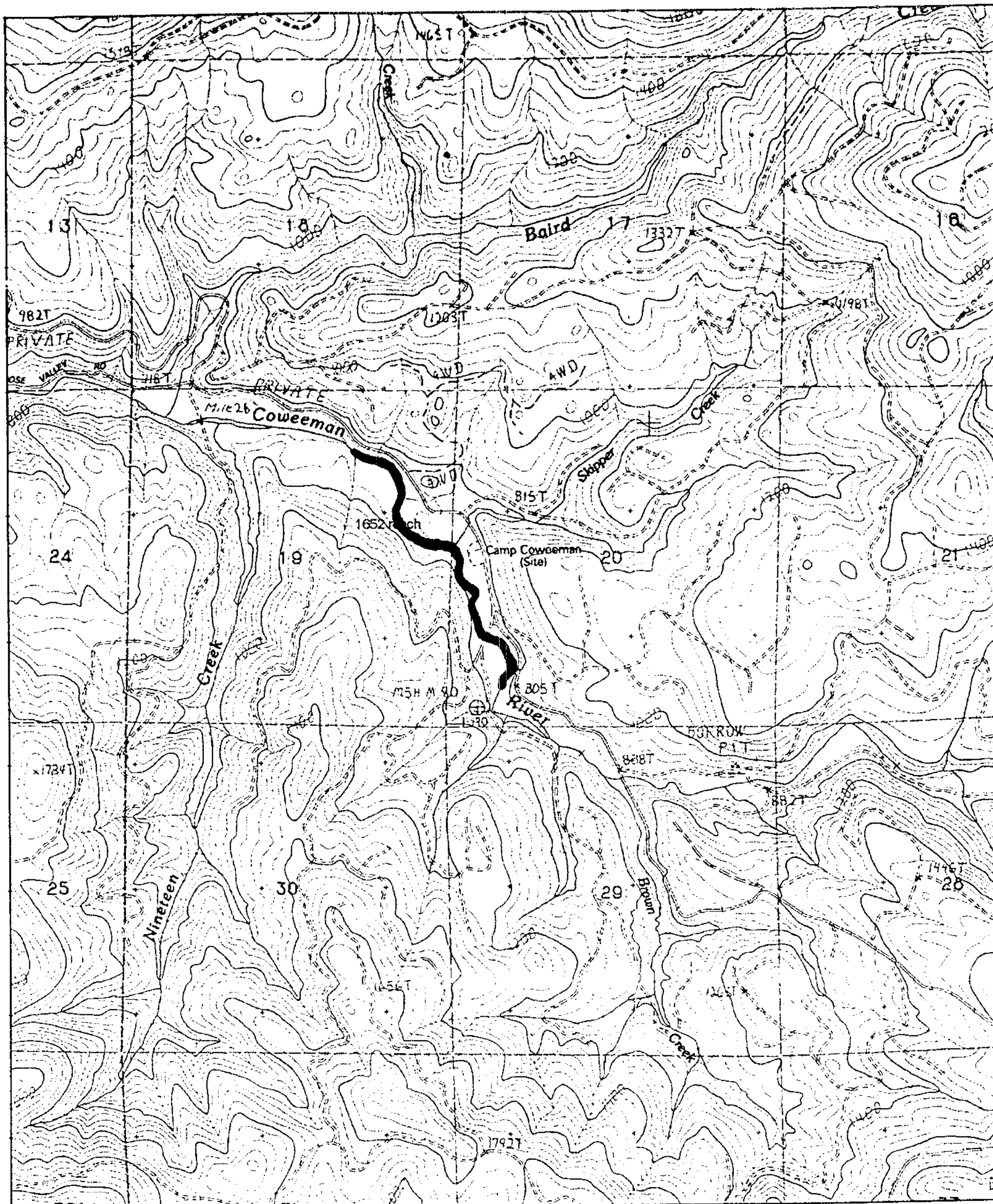
Weyerhaeuser Company. 1997a. Upper Coweeman Watershed Analysis. Fish Habitat Module. Washington Department of Natural Resources. Central Region. Chehalis.

Weyerhaeuser Company. 1997b. Upper Coweeman Watershed Analysis. Stream Channel Assessment. Washington Department of Natural Resources. Central Region. Chehalis.

Weyerhaeuser Company. 1997c. Upper Coweeman Watershed Analysis. Riparian Function Assessment. Washington Depanment of Natural Resources. Central Region. Chehalis.

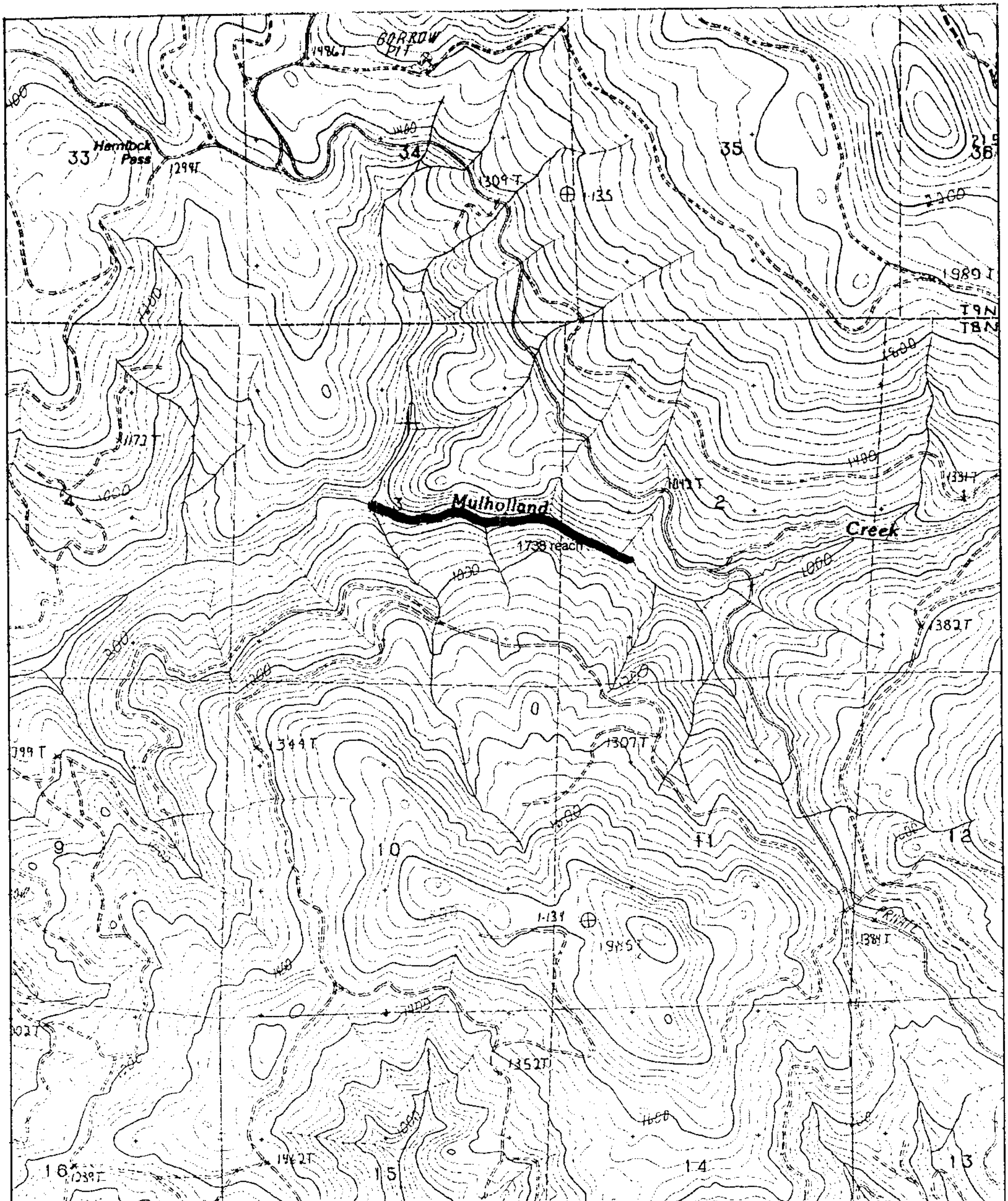
WSFPB. 1995. Washington State Forest Practice Board Manual: Standard Methodology for Conducting Watershed Analysis. Version 3.0.

Appendix A.. Site Maps.



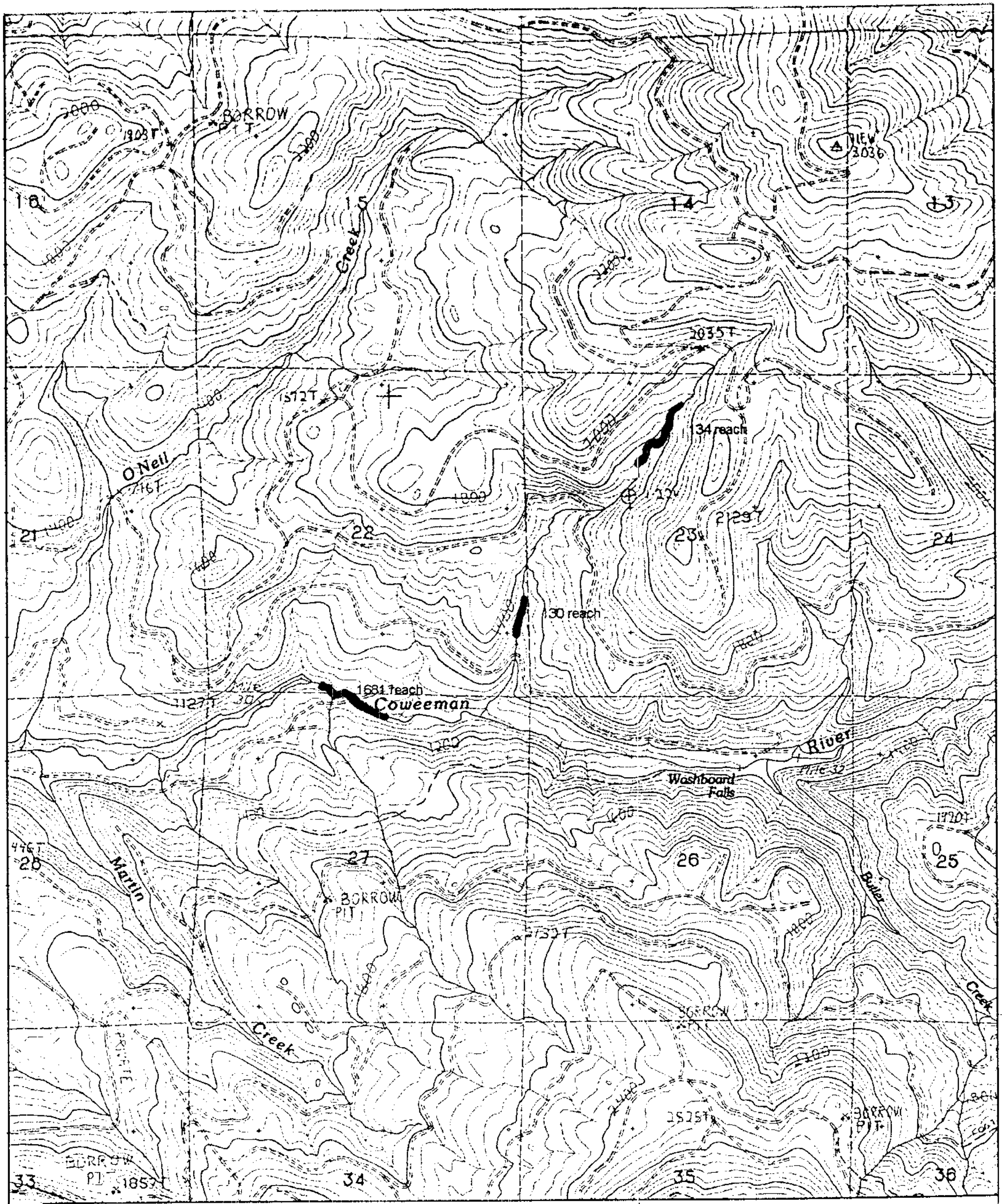
Name: WOLF POINT
Date: 7/28/99
Scale: 1 inch equals 2000 feet

Location: 046" 09' 30.3" N 122" 35' 33.8" W
Caption: 1652 road site: coweeman Rv. mainstem



Name: HEMLOCK PASS
Date: 7/28/99
Scale: 1 inch equals 2000 feet

Location: 046" 11' 59.7 N 122" 39' 38.4" W
Caption: 1738 road site: Mulholland Ck. mainstem



Name: WOLF POINT
Date: 7/28/99
Scale: 1 inch equals 2000 feet

Location: 046" 09' 26.4" N 122" 32' 04.1" W
Caption: 1661, 130 and 134 road sites: Coweeman Rv. mainstem and unnamed trib to Coweeman Rv.