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TFW Effectiveness Monitoring Report

ASSESSING THE EFFECTIVENESS OF LARGE WOODY DEBRIS PRESCRIPTIONS IN THE ACME WATERSHED: PHASE 1 - BASELINE DATA COLLECTION

by:

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ABSTRACT

A monitoring project designed to assess the effectiveness of forest practice prescriptions for Large Woody Debris (LWD) was initiated in the Acme Watershed, Whatcom County, Washington. Prescriptions were developed under watershed analysis, a state program to assess aquatic conditions and develop rules for protecting identified Areas of Resource Sensitivity. The watershed assessment found that salmon habitat and water quality conditions in the Acme watershed are severely degraded, largely due to channel manipulations, riparian clearing, and mass wasting. Phase I monitoring conducted in 1998 provides baseline reference conditions for future assessment of prescription effectiveness. Continued data collection under subsequent phases will help establish trends in watershed protection and habitat recovery.

The monitoring effort provides information to help answer the following questions:

- Question LWD1. What are current LWD loading levels in anadromous fish bearing waters and how will they change over time under the watershed analysis prescriptions.
- Question LWD 2. How does riparian harvest on and along Type 5 waters affect LWD recruitment and subsequent loading?
- Question LWD 3. How does the overall wood budget (loading levels) in a basin respond to management under Acme watershed analysis prescriptions as compared with a geomorphically similar basin that has not been recently clearcut?

LWD surveys were conducted in seven fish bearing streams in the Acme Watershed over a total length of 6.3 kilometers. An additional 3.2 kilometers of non fish bearing stream channels were surveyed in three basins. Phase I Monitoring has documented that LWD loading in the Acme watershed appears consistent with that reported in the Acme watershed analysis, that fish bearing creeks are wood impoverished and streamside conifer recruitment potential is low to moderate. Non fish bearing channels in the upper watershed vary in wood loading, with some above and some below targets. Although some moderately healthy riparian stands remain along fish bearing streams, most LWD recruitment in the short-term will be transported, perhaps catastrophically, from upstream. The protection of upland riparian forests will ensure an adequate supply of LWD (including key pieces) to upland and lowland reaches over the short and long term.

LWD prescription effectiveness will take many years to assess (on the order of decades). The effectiveness of prescriptions in protecting riparian leave areas may be a reasonable short-term indicator of long-term recruitment potential. Riparian stand surveys would complement data already available on in-stream wood loading around the watershed. Over time, repeat in-stream LWD surveys will help gage the success of habitat recovery measures in the Acme watershed.

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INTRODUCTION

Acme Watershed Analysis

The Acme Watershed Analysis (AWA, (Crown Pacific, 1999)) aims to assess aquatic resource conditions in the Acme Watershed, Whatcom County, Washington and proposes a set of prescriptions (rules) to protect identified Areas of Resource Sensitivity. WAC 222-22-070(3) states that "These prescriptions shall be reasonably designed to minimize, or to prevent or avoid…the likelihood of adverse change and deliverability that has the potential to cause a material, adverse effect to resource characteristics…" (WFPB, 1995a). This document describes the results of a project designed to assess the effectiveness of Large Woody Debris prescriptions in the Acme Watershed. Phase I monitoring conducted in 1998 provides baseline reference conditions for future assessments of prescription effectiveness. Continued data collection under subsequent phases will help establish trends in watershed protection and habitat recovery.

Description of the Acme Watershed

The lowermost reach of the South Fork Nooksack River flows northerly through the Acme Watershed (Figure 1). Numerous mountain tributaries feed the river, draining the Van Zandt Dike to the east and Stewart Mountain in the west. Land use in the Acme Watershed is a mixture of agriculture, residential, and forestry on the river's floodplain and fans, and forestry at higher elevations. Under unmanaged conditions, Large Woody Debris (LWD) recruitment in the tributaries of the Acme Watershed occurs primarily through mass wasting and streamside mortality. Log placement into cut over streams is also a past method of wood delivery. Rates of loading from each mechanism are unknown.

Fish Use

"The Acme WAU is used by a number of anadromous salmon including chinook, coho, pink and chum salmon, as well as steelhead and sea-run cutthroat trout. Resident cutthroat and rainbow trout are found throughout the WAU…"(AWA Page 1-1). Bull Trout/Dolly Varden are expected to migrate through and rear in the Acme WAU, though recorded spawning occurs higher in the basin (Ned Currence, personal communication).

Fish are found in the mainstem of the river, sloughs along the floodplain, and lower stream reaches of the mountain tributaries (up to waterfalls that block migration). These lower stream reaches, some of which traverse alluvial fans, are typically run-out locations for debris flows initiated at higher elevations.

"Although historically the WAU provided a greater quantity and quality of holding, spawning, and rearing habitat, it remains an important summer and winter rearing area and probably contains a relatively high number of the juvenile salmon and sea-run cutthroat trout over-wintering in the South Fork Nooksack River Basin" (AWA Page 1-2).

Background on Large Woody Debris in the Acme WAU and the LWD Prescriptions

In one of the first written descriptions of the Acme WAU, Morse (1883) wrote of the South Fork Nooksack "We came to a place where the river, during freshets had ground sluiced all the earth away from the roots of the trees, and down some 6 feet to the gravel. This covered a region of country a mile in width by five in length... Immediately below this place, the jams first extend clear across the river, and for the next twenty miles, there is a jam across the river nearly every mile."

Conditions changed over the ensuing century and the lower reaches of the South Fork now contain few accumulations of wood in a constricted channel. In both the mainstem and its fish bearing tributaries, the Acme Watershed Analysis (Page 1-4) reports that "Riparian conditions ...differ greatly between lands devoted to agricultural use (surrounding 89 percent of all fish bearing streams) and lands devoted to forest practices. The majority of riparian stands in agricultural areas are comprised of young and sparse deciduous forests with corresponding low recruitment potential of large woody debris, low amounts of in-stream large woody debris, below-target riparian shade, and peak stream temperatures that exceed the Class A water quality criterion. Riparian stands located in lands devoted to timber production are predominantly forested with mature timber (88%). Prospects for recruitment of large woody debris are good in 57 percent and fair in 29 percent of these stands [using near-term recruitment potential calls (based on stand age, species, and stocking density) found in Table D-5, Riparian Function module (WFPB, 1995b)]."

The Acme Analysis continues: "Under appropriate management, all riparian stands on forested lands appear capable of supporting dense stands of late seral stage riparian forests and therefore good potential for recruitment of large woody debris."

In-stream LWD in fish bearing streams is low for a number of reasons. "Stream cleaning, debris flows and recent large flood events have removed a significant amount of in-channel wood from the streams" (AWA Page 8-17). In the mountain channels, "Debris flows and dam-break floods remove[d] dispersed woody debris from streams thereby lowering pool frequency and depth" (AWA Page 6-26) and reducing storage capacity to store upland-derived sediment. The log jams on the river have been removed for log transport, navigation, and more recently "flood control" purposes. Due to the low near-term recruitment potential along most fish bearing streams, near-term wood recruitment will primarily occur when transported from higher elevations in the Acme WAU.

<u>Prescriptions</u>

The LWD prescriptions for the AWA are designed to prevent or avoid impacts to vulnerable resources (i.e. protect a riparian stand's ability to supply LWD to waterways over time). Five Areas of Resource Sensitivity (ARS) are identified in the AWA (Figure 1). Each has a separate prescription and represents a distinct area with high vulnerability to fish habitat.

ARS R-1 South Fork Nooksack River and historic meander belt (gradient <0.001)

Input variables: Large Woody Debris
Hazard: Moderate or High

Vulnerability: High (Fish Habitat)
Rule Call: Prevent or Avoid
Prescription: No harvest on or within 100 horizontal feet of the historical meander belt (channel migration zone (CMZ)).

ARS R-2 – Floodplain tributaries (gradient <=0.04) not including alluvial fans
Input variables: Large Woody Debris
Hazard: Moderate or High
Vulnerability: High (Fish Habitat)
Rule Call: Prevent or Avoid
Prescription: No harvest within 100 horizontal feet of the ordinary high water mark.

ARS R-3 – Alluvial fans (gradient >0.04 and <= 0.09)
Input variables: Large Woody Debris
Hazard: Moderate or High
Vulnerability: High (Fish Habitat)
Rule Call: Prevent or Avoid
Prescription:

- No harvest within 100 horizontal feet of the ordinary high water mark on fish bearing streams.
- 300 foot no-harvest region at base of alluvial fan for "barrier tree zone."
- Partial harvest on the remaining portions of alluvial fans.

ARS R-4 – Mountain channels (gradient >0.09) and upland channels below small lakes (gradient = 0.02-0.06)
Input variables: Large Woody Debris
Hazard: Moderate or High
Vulnerability: High (Fish Habitat)
Rule Call: Prevent or Avoid
Prescription:

- No harvest within 100 horizontal feet of the ordinary high water mark on fish bearing streams. Above fish barriers (i.e. waterfalls >12 feet), no harvest within 50 horizontal feet
- Corridors permitted for full-suspension skyline yarding – total corridor width not to exceed 15% of riparian distance in harvest unit.

Objectives of the Large Woody Debris Effectiveness Monitoring Project

The purpose of Phase I monitoring is to establish baseline information with which to assess the effectiveness of LWD prescriptions in representative waters of the Acme Watershed (excluding the South Fork Nooksack River). The information gathered provides a foundation for long-term trend monitoring of resource protection and recovery under forest practice prescriptions. Monitoring results will be useful in the Acme Watershed, and will be applicable to watersheds around the region which, upon further analysis, are found to have similar conditions and prescriptions.

Effectiveness Monitoring Questions

The Acme watershed monitoring project is designed and organized to assist in answering the following three questions:

- Question LWD1. What are current LWD loading levels in anadromous fish bearing waters and how will they change over time under the AWA prescriptions?
- Question LWD 2. How does riparian harvest on and along Type 5 waters affect LWD recruitment and subsequent loading?
- Question LWD 3. How does the overall wood budget (loading levels) in a basin respond to management under AWA prescriptions as compared with a geomorphically similar basin that has not been recently clearcut? Are LWD recruitment mechanisms similarly proportioned in the two basins?

These questions are addressed in the form of hypothesis testing in Section B below.

PHASE I: ACME WATERSHED MONITORING

A Washington Department of Ecology approved Acme Watershed Monitoring Plan (Soicher, 1998) is being implemented to help begin answering the questions posed above. Presented below are hypotheses for each question, followed by discussions of methods used and preliminary results.

Question LWD1. What are current LWD loading levels in anadromous fish bearing waters and how will they change over time under the AWA prescriptions.

- **Hypothesis LWD1:** Current loading levels are generally poor and in-channel volumes will increase under implementation of the prescriptions. Near-term LWD recruitment to fish bearing streams will be transported from higher in the system, as agricultural lands along many fish bearing streams have sparse riparian cover. Riparian/conifer reforestation projects that are underway along some fish bearing reaches will help increase long-term LWD recruitment potential.

> **Note**: The above hypothesis differs from that formulated in the Acme Watershed Monitoring Plan (Soicher, 1998). Changes such as "in-channel volumes will increase" from "conditions will improve" are made for specificity. Other minor edits are made for clarity, with intent unchanged.

- **Monitoring Methods:** Level II LWD surveys (TFW Ambient Monitoring Manual protocol (Schuett-Hames et al., 1994)) were conducted in seven streams in the Acme Watershed by a crew from the Evergreen Land Trust and Western Washington University. 6.3 kilometers of stream length were surveyed (see Figure 2). Stream segments include portions of ARS 2, 3 and 4 and extend from the South Fork Nooksack River upstream through alluvial fans and briefly into mountain channels (until reaching waterfalls). Though forestry is the land use adjacent to most surveyed segments, the predominant land use along most of the fish bearing creeks in the Acme WAU is agricultural.

Evergreen Land Trust staff and the TFW Ambient Monitoring Program (Northwest Indian Fisheries Commission (NWIFC) provided quality assurance for Level II LWD surveys. Field equipment was calibrated against known standards, field crew received training, and data collection methods were independently verified periodically by the Coordinator. Quality Assurance methods outlined in the Acme Monitoring Plan (Soicher, 1998) were consistently followed. The TFW Quality Assurance evaluation is available through NWIFC.

- **Evaluation:** Debris flow runout appears to have occurred along the entire length of most channels surveyed for this project, starting at the base of waterfalls (which block fish migration) and continuing to the lower extent of alluvial fans. The boundary between alluvial fans and lower mountain channels varies, and stream gradients do not appreciably change between reaches (exception: Sygitowicz Creek). The fish bearing alluvial fan and mountain channel reaches were surveyed as one segment. The other segment type surveyed under this project is ARS R-2 – Floodplain tributaries (<=0.04).

Using LWD piece indices from Table F-2 of the Watershed Analysis Manual Version 3.0 (WFPB, 1995b) seven of the fish bearing stream segments surveyed rated poor, two moderate, and one good (<1 LWD piece/channel width (cw), 1-2 pieces/cw, and > 2 pieces/cw, respectively – see Table 1). Key piece per channel width criteria (<.15 = poor, .15-.30 = fair, >.30 = good) yields similar results (see Table 1), though this information is only available for individual pieces and not jams.

The AWA gives a poor rating for near-term LWD recruitment potential in the lower elevation streams surveyed for this project (ARS 2), suggesting that LWD conditions in coming decades will only improve via transport. Riparian stands along most lower watershed reaches have been cleared in past decades, and some now have young deciduous or mixed riparian buffers taking hold. An exception is Standard Creek, where near-term potential recruitment is reported good throughout its fish bearing reach (AWA Figure 7-2). Similarly, using air photo interpretation and site visits with the criteria of the WA Manual (WFPB, 1995b), Oak Park Creek is found with good recruitment potential. In-channel conditions are below target levels in Standard Creek except for a concentrated log jam near the base of the waterfalls. It therefore received a Riparian Function rating of 2 (RF2) for adequate potential recruitment and below target in-channel LWD. The remaining fish bearing channels assessed in the AWA and surveyed in this project received a rating of RF4, or below target in-channel loading and inadequate recruitment potential. Land use on these remaining channels is agricultural and rural residential (with young, establishing riparian buffers).

Fish Bearing Streams	Segment Length (m)	ARS (see Figure 1)	Mean Canopy Cover %	Average Bankfull Width (m)	Average Bankfull Depth (m)	Adjacent Land Use
Todd	268	3, 4~	62.7	6.2	0.38	Forestry
Sygitowicz Segment 1	700	2	90.7	7.1	0.44	Agriculture
Sygitowicz Segment 2	603	3, 4~	72.4	6.4	0.47	Forestry
Hardscrabble	900	3, 4~	81.5	4.8	0.45	Rural Residential/Forestry
Oak-Park	466	3, 4~	80.8	2.8	0.32	Forestry
Standard	587	3, 4~	87.0	9.3	0.52	Forestry
McCarty Segment 1	500	2	83.6	6.1	0.64	Agriculture
McCarty Segment 2	1300	3, 4~	74.7	6.1	0.28	Agriculture and Forestry
Jones Segment 1	700	2	41.6	11.4	0.38	Rural Residential
Jones Segment 2	455	3, 4~	59.4	5.8	0.53	Forestry

~ Mountain channel ARS (#4) in fish bearing reaches are combined with alluvial fans with gradient <0.09.

Fish Bearing Streams	Total Pieces	Percent Pieces in Jams	Total Volume (m^3)	Total In-Channel Volume (m^3)	In-Channel Volume per 100 m (m^3/m)	Average LWD per Ch. Width	Key LWD/ Channel Width (individual pieces only)	% Total Pieces Logs > 50 cm	# Rootwads	Wood Type (% of Total) Conifer	Deciduous	Unknown
Todd	62	0	66.9	57.8	21.6	1.4	0.161	30.6	1	62.9	11.3	25.8
Sygitowicz Segment 1	89	13.6	59.5	46.3	6.6	0.9	0.02	22.5	3	41.3	32	26.7
Sygitowicz Segment 2	76	18.4	45.8	34.0	5.6	0.8	0.021	22.4	1	64.5	23.7	11.8
Hardscrabble	94	0	100.0	73.9	8.2	0.5	0.118	19.1	5	27.7	14.9	57.5
Oak-Park	81	19.8	107.7	47.3	8.0	0.4	0.131	29.2	0	53.9	16.9	29.2
Standard	280	65	221.0	154.3	26.3*	4.4*	1.22	26.8	0	58.2	16.3	25.5
McCarty Segment 1	11	0	1.3	1.0	2.0	0.1	0	0.0	0	0	54.6	45.5
McCarty Segment 2	303	46.2	174.4	108.5	8.3	1.4	0.047	15.2	4	45.1	18.9	36
Jones Segment 1	52	0	27.6	25.2	3.6	0.8	0	17.3	4	34.6	30.8	34.6
Jones Segment 2	60	0	35.1	27.4	4.9	0.6	0.022	12.5	3	33.3	35	31.7

* 63% of LWD found in one log-jam near base of fish blocking waterfall.

Table 1. Summary Statistics from Level II Large Woody Debris Surveys in Acme Watershed Fish-Bearing Streams.

Based on the Manual's Table F-2 (WFPB, 1995b), the surveyed alluvial fan and mountain channel segments of McCarty and Todd Creeks receive moderate habitat quality ratings (1-2 pieces/cw) and the remaining segments low habitat quality (<1 piece/cw - Oak Park, Hardscrabble, Sygitowicz and Jones). From site visits, these higher gradient channels have fair to good near-term LWD recruitment potential and are therefore considered under Situation RF2 in the Manual's Figure D-2: mature mixed stands with below target in-channel wood (no designations were given in the AWA for these channels). Lower reaches have been inundated with debris flows and contain dense, young deciduous stands (Hardscrabble, Oak Park and Jones Creeks). These segments receive designations of RF4 (below target in-channel loading and inadequate recruitment potential).

The Level II LWD data provides insight into wood loading characteristics. Aside from the large jam in Standard Creek and those of McCarty Segment 2, log jams are infrequent in the surveyed streams (see Table 1). Jams are not found in five of the ten surveyed segments, likely because of the recent history of channel scouring debris flows. Average in-channel volumes per hundred meters are higher in Standard Creek and the short mountain channel segment of Todd Creek than in the remaining streams. These two segments, along with Oak-Park have a higher proportion of large wood than the others (Jones and McCarty have the lowest). In-channel rootwads are sparse (<1/150meters) to non-existent in the surveyed segments. Though many LWD pieces are of unknown wood type, the proportion of conifers typically exceeds deciduous, often by as much as 3 and 4:1. Two segments contain more deciduous than conifer.

On average, canopy closure in the floodplain segments (ARS 2) is high (>80%) except for Jones Creek (see Table 1). Canopy cover in the higher gradient fish bearing reaches ranges from 59% (in Jones Creek) to more than 90% in others, with most segments closer to the latter. According to the Shade Requirements in Figure 1.1 of the Forest Practices Board Manual (WFPB, 1995a) canopy cover in these streams (except Jones Creek) is currently at acceptable levels (given as 55-75%, increasing with decreasing elevation). Channel widths vary considerably (from <2m to more than 12m) and channels tend to narrow with elevation in the fish bearing reaches (exception Standard Creek).

In summary, most fish bearing creeks surveyed in this project had in-channel wood conditions below target levels. Near-term LWD recruitment is low in most segments, and tends to increase with elevation and changes in land use (agriculture and residential to forestry).

Question LWD 2: How does riparian harvest on and along Type 5 waters affect LWD recruitment and subsequent loading?

- **Hypothesis LWD 2:** Riparian harvest on and along Type 5 waters decreases potential LWD recruitment and, consequently, loading in streams.

- **Monitoring Methods:** Type 5 streams in the Hardscrabble, Todd and McCarty Creek drainages were surveyed and characterized for wood loading and recruitment potential. Level I data was collected from four Type 5 tributary streams in these three drainages (total length=465m) and LWD recruitment potential assessed according to the methods outlined in

Appendix D of the Watershed Analysis Manual (using aerial photo interpretation and field verification). The Hardscrabble and McCarty segments are within the basins monitored under Question LWD 3 below, and were selected as representative segments of Acme WAU Type 5 streams. The Todd Creek segment was selected for its recent treatment and accessibility. See Figure 2 for survey locations and Table 2 for data summaries.

Quality assurance (QA) measures, as described under Question LWD 1 above, were implemented for the work associated with Question LWD 2 (though Level I LWD data were collected).

- **Evaluation:** Wood loading in visited streams is moderate to high, with most pieces buried, well decayed and some bucked (a result of past harvest). The partially buried key pieces in the three untreated segments function to create steps, store sediment and dissipate hydraulic energy. These functions tend to provide stability for the stream channel.

Grizzel and Wolff (1998), in their study of non fish bearing streams found that "Large woody debris was the primary component of 93% of in-stream obstructions which stored sediment." This is greater than the 60% reported by Potts and Anderson (1990) for a set of low order streams studied in Montana. Grizzel and Wolff (1998) explain that "Debris dams usually consisted of several pieces of woody debris anchored by larger key pieces of wood, boulders or bedrock."

The Type 5 streams visited have poor short-term LWD recruitment potential (dense young conifer or no vegetation, providing moderate to high riparian LWD recruitment impact calls (Table D-5 (WFPB, 1995b))). We hypothesize that LWD loading will decrease over time since little or no new LWD is available for recruitment to replace LWD that rots or is transported out of the reach.

Visited upper watershed Type 5 streams have moderate to steep gradients, ranging from 5 to 60%. Future downstream LWD transport is possible, though not certain. Clearcutting on Type 5 streams will reduce the supply of key and smaller pieces to fish bearing channels over time.

Future surveys in these and additional Type 5 streams should occur at least once every 5 years, prior to each review of the Acme Watershed Analysis. Pre- and post-treatment water quality monitoring (temperature, turbidity) in select Type 5 streams could provide information on the effectiveness of prescriptions (or lack thereof) in protecting water quality. Establishment of soil horizon monitoring sites in Type 5 riparian areas could help assess the role of forest treatment in reducing sediment retention and storage, and contributing erosion to waterways.

TABLE 2. Type 5 Stream Surveys in the Acme Watershed (Level I surveys).

Surveyed Stream	Survey Length (m)	Surface Flow Length (m)	Wet Channel Width (m)	Riparian Stand Age Class (years)	% Canopy Closure	Slope Aspect (%)
Hardscrabble Trib. 1	100	Min.	0.6	15-20	84	5-10
Hardscrabble Trib. 2	65	Min.	0.46	15-20	96	5-40*
McCarty Tributary	200	200	.2-.7	30-35	92	9-15
Todd Tributary	100	100	0.65	0	0	50-60

*steepens upstream

TABLE 2 (continued). Type 5 Stream Surveys in the Acme Watershed (Level I surveys).

Surveyed Stream	RTWD Dia. >20 cm	Key Pieces	SMALL LOG >10cm - <20cm	Key Pieces	MEDIUM LOG >20cm - <50cm	Key Pieces	LARGE LOGS >50cm	Key Pieces	Total Pieces
Hardscrabble Trib. 1	0	0	25	0	24	0	12	5	66
Hardscrabble Trib. 2	1	0	6	0	5	2	0	3	12
McCarty Tributary	1	0	19	0	14	2	1	7	44
Todd Tributary	3	0	41	0	24	0	6	0	74

Question LWD 3: How does the overall wood budget (loading levels) in a basin respond to management under AWA prescriptions as compared with a geomorphically similar basin that has not been recently clearcut? Are LWD recruitment mechanisms similarly proportioned in the two basins?

- **Hypothesis LWD3:** Short-term LWD recruitment in a basin managed under AWA prescriptions may be similar if not greater to those in an unmanaged basin. Blowdown and management related mass wasting may contribute wood in excess of natural rates.

  Note: The above hypothesis differs slightly from the hypothesis formulated in the Acme Watershed Monitoring Plan (Soicher, 1998). The sentence beginning with "Blowdown" above replaces the prior hypothesis: "Mass wasting wood delivery is expected to be of a historically higher proportion in the managed versus unmanaged basins." The new language represents a more pertinent and readily testable hypothesis.

• **Monitoring Methods**: Level II LWD surveys (under TFW Ambient Monitoring Manual protocol (Schuett-Hames et al., 1994)) were conducted in the main channels of the McCarty and Hardscrabble basins (5.3 kilometers, including 2.7 km of non-fish bearing channels) from the South Fork Nooksack River to the upper extent of perennial flow. Figure 2 shows survey locations. The Hardscrabble drainage was selected as the most recently undisturbed basin in the WAU. McCarty Creek, undergoing more active clearcut management, has a similar geology, geomorphology and size to Hardscrabble Creek. Since site selection in 1998, active management has been pursued in the Hardscrabble drainage as well. Uneven age strategies are being employed, however, in contrast to those in McCarty Creek. This paired basin analysis may evolve into an assessment of differing management strategies rather than a comparison of managed vs. unmanaged basins. As the effectiveness of buffer prescriptions may be related to management techniques (i.e. buffers with adjacent forests vs. clearcuts), this paired basin analysis provides a comparative tool for prescription effectiveness.

The quality assurance (QA) measures described under Question LWD 1 above were implemented for the work associated with Question LWD 3.

Initial 1998 surveys establish baseline conditions for future assessment. Future surveys will document both changes in LWD loading within each basin and, comparatively, the effects on short-term LWD loading of differing management techniques.

• **Evaluation:** The fish bearing reaches of both McCarty and Hardscrabble creeks have young, deciduous riparian forests near their mouths. McCarty Creek flows as a low gradient floodplain channel (<.1% gradient) that is separated from an alluvial fan by agricultural fields (where the channel is not discernable). Above the fields, McCarty Creek climbs onto an alluvial fan followed by a mountain channel (defined by an inner gorge). In contrast, Hardscrabble Creek flows across its alluvial fan directly into the South Fork Nooksack, having no floodplain channel and an average gradient of 6%.

McCarty Creek's lowest segment contains virtually no in-channel wood. The fish bearing reaches above the agricultural fields contain considerably more wood, but are still of only fair habitat potential (see Monitoring Question #1 above). Hardscrabble Creek is similarly below in-channel wood targets. On average, these lower gradient channels are areas of deposition and are moderately confined according to Table E-2 of the Manual (WFPB, 1995b).

Above the fish bearing reaches, McCarty Creek flows perennially for roughly 1.2 kilometers and Hardscrabble 1.8 km. Both streams flow through steep, deep and wide inner gorges. Waterfalls greater than 5 meters (with most being much higher) define the boundaries of the stream segments. While average bankfull widths in these segments of Hardscrabble Creek remain similar, the equivalent segments of McCarty Creek show more variation (see Table 3). All channels are clearly confined in their respective inner gorges, though some contain reaches where a slightly broader valley floor has multiple parallel channels running through it. Other areas are quite narrow and scoured to bedrock. Due to the steep, inner gorge topography these non fish bearing reaches were rated as confined under the definitions of the Manual (WFPB, 1995b).

With respect to average LWD pieces per channel width, non fish bearing segments of McCarty Creek tend to contain higher levels than those found in Hardscrabble Creek. All but one segment in McCarty Creek contains levels greater than the 2.0 threshold of the Manual, while the same segments in Hardscrabble Creek are near 2.0 or are appreciably below target (Table 3). When expressed as the volume of in-channel wood per 100 meters, both streams show considerable fluctuation. Surveys in McCarty Creek above the fish bearing reaches begins with high wood volumes, then decreases in its mid section and again increases near the upper reaches of perennial flow. At this upper end, the stream gradient climbs appreciably, flows across a boulder field, and the channel loses definition.

A similar pattern of wood distribution is found just above the first set of waterfalls on Hardscrabble Creek, though volumes remain steadier until approaching the upper extent of flow (where it decreases). The start of perennial flow appears to be the initiation point of a large debris flow that ran out onto the alluvial fan. Channel scour is evident and large log jams above the area suggest that the jams extended further downstream and broke off, probably initiating a debris flow (last event was in 1983). As with McCarty Creek, the stream gradient here jumps significantly. In all the surveyed mountain channels, the percent of wood pieces considered large (logs >50cm) ranges from just above 6% to a maximum of 20% with no clear pattern.

Using pieces per channel width as measure, the non fish bearing reaches of both McCarty and Hardscrabble Creeks contain higher amounts than their fish bearing counterparts. This may be due to renewed loading since the early 1980's debris flows, as well as the history of stream clearing in some fish bearing reaches. With respect to in-channel volumes this pattern does not hold, and the upper fish bearing reaches contain greater volumes, on average than some of the higher segments (see Table 3).

In recent years, management trends in these two basins appear to favor McCarty Creek for more extensive clearcut management and thus implementation of watershed analysis prescriptions (see aerial photos in Figure 4). The continuation of this trend will allow for the comparison of wood distributions in basins treated under different management schemes and differing levels of activity and implementation of prescriptions. Additional surveys every 3 years or following catastrophic events will allow for the establishment of trends in wood loading and comparisons between these basins.

	Segment Length (m)	Area of Resource Sensitivity	Map Grad (%)	Confinement (moderate/ confined)	Elevation at end of segment (ft)	Mean Canopy Cover %	Average Bankfull Width (m)	Average Bankfull Depth (m)	Ave. LWD Pieces/ Channel Width	% Pieces Logs > 50 cm	In-Channel Wood Vol per 100 m (m^3/m)	Adjacent Land Use
McCarty Creek												
1	500	2	<0.1	m	275	83.6	6.1	0.64	0.1	0.0	2.0	Ag
2	1300	3, 4~	6	m	560	74.7	6.1	0.28	1.4	15.2	8.3	Ag and Forestry
3	200	4	12	c	680	64.8	10.3	0.45	21.1	15.1	19.4	Forestry
5	100	4	5	c	740	78.7	6.0	0.22	13.4	10.7	29.4	Forestry
8	131	4	12	c	900	63.6	5.7	0.23	1.8	14.3	2.7	Forestry
9	79	4	6	c	940	52.4	4.4	0.29	6.6	18.5	7.3	Forestry
10	25	4	18	c	985	70.4	2.6	0.32	5.2	14.0	2.7	Forestry
12	118	4	10	c	1080	56.3	5.2	0.16	7.2	6.7	2.4	Forestry
13	203	4	10	c	1210	60.0	5.8	0.33	4.6	6.6	9.1	Forestry
14	200	4	26	c	1410	71.1	2.3	0.11	2.8	12.2	14.1	Forestry
Hardscrabble Creek												
1	900	3, 4~	6	m	440	81.5	4.8	0.45	0.5	19.2	8.2	Ag and Forestry
3	190	4	19	c	960	70.4	3.5	0.17	2.8	8.6	13.7	Forestry
4	306	4	12	c	1080	68.9	3.50	0.13	2.0	9.4	7.2	Forestry
6	229	4	12	c	1190	69.7	3.10	0.66	2.3	20.0	8.1	Forestry
7	180	4	12	c	1260	68.5	3.75	0.15	1.3	12.9	14.5	Forestry
8	186	4	20	c	1380	73.8	3.10	0.17	0.8	10.4	4.7	Forestry
10	500	4	34	c	2080	74.6	4.13	0.21	1.2	9.8	2.4	Forestry

NOTE:
Beginning with Segment 3 in McCarty Creek and 2 in Hardscrabble, boundaries are distinguished by waterfalls. Inaccessible segments include the following:

McCarty Segments 4, 6, 7, and 11, roughly 65, 50, 30, and 20 meters, respectively in length.
Hardscrabble Segments 2, 5, and 9, roughly 25, 30 and 120 meters in length, respectively.

Table 3. Stream Segment Characteristics and Large Woody Debris Data for the Paired-Basin Monitoring of Hardscrabble and McCarty Creeks.

DISCUSSION, SUMMARY AND RECOMMENDATIONS

LWD loading in the Acme Watershed appears consistent with that reported in the Acme Watershed Analysis, namely that fish bearing creeks are wood impoverished and streamside conifer recruitment potential is poor to fair (using near-term recruitment potential calls in Table D-5, Riparian Function module (WFPB, 1995b). Although some relatively healthy, recovering riparian stands remain along fish bearing streams (most notably on lower Standard, Hardscrabble, and Oak Park Creeks), most LWD recruitment in the short-term will be transported, likely catastrophically, from upstream.

Many of the trees in the upper watershed available for short-term LWD recruitment are second growth. In a number of the difficult access areas, riparian stands still contain large diameter trees that survived the first rotation. Under natural conditions, these trees will eventually fall, individually or in a group, and some will supply the stream network with key LWD pieces. As McHenry et al (1998) report for streams on the Olympic Peninsula, these key pieces are less prone to rapid transport and/or decay than second growth LWD and will function in the system for decades beyond those of smaller size. As noted in the Type 5 stream section above, Grizzel and Wolff (1998) find that key pieces are a critical component for starting and maintaining upland debris jams that store sediment.

Downstream habitat conditions warrant protection and recovery of upland late seral riparian forests to maintain a continual supply of LWD for short and long term channel improvement. Recovery of impacted riparian stands to late seral conditions is also desirable. Buffer strategies are being implemented to preserve this source of LWD, though not always successfully. Grizzel and Wolff (1998), in their study of 40 non fish bearing stream buffer sites on 1-3 year old clearcuts in Northwest Washington, found that windthrow, on average, caused 33% loss of stand density following adjacent harvest. This loss of standing riparian trees reduces the overall number of trees having the potential to mature to key piece size and reduces shade. In some of the more extreme cases, entire riparian leave areas blow down in the wind (see Soicher, 1999b). This type of impact shares similar effect on LWD recruitment as harvest on Type 5 streams, and centuries will pass before key pieces are available to recruit naturally to the channel network.

Benda and Sias (1998) present the main processes at work in recruiting wood to stream systems (shown reproduced as Figure 5). Following a review of the literature, Pollock and Kennard (1998) find "these studies suggest that up to half of LWD in lower gradient (e.g. fish bearing) streams may come from upstream sources. This is an excellent example of longitudinal connectivity in riparian networks and lends support to the argument that salmonid habitat can only be protected in the context of the entire watershed." Benda and Sias (1998) conclude "However, because of the low frequency of debris flows (about one every 3 to 6 centuries in first- and second- order channels) compared to the relatively short lifespans of wood because of decay, the overall contribution to the long-term wood mass balance is low, about 10% - 15%."

Due in part to the extensive riparian clearing and historic wood removal along and within fish bearing streams, existing wood in lowland channel segments likely came in on recent debris flows from higher in the system. Until riparian forests of the lowland Acme WAU can recover to ecological maturity, transport from above will continue to be the dominant source of natural, long-lived wood recruitment. Lest haste be added, the infrequency suggested by Benda and Sias (1998) for events in low order channels makes significant wood recruitment to fish bearing reaches unlikely for years to come.

Large Woody Debris surveys in the western Acme Watershed have been conducted to provide a 1998 snapshot for Phase I Acme Watershed Analysis Monitoring. Some baseline LWD conditions are further established, including those in fish and non-fish bearing streams. With current conditions documented, future surveys will allow a reasonable evaluation of trends toward watershed protection and resource recovery in the Acme WAU.

LWD prescription effectiveness will take many years to assess (on the order of decades). The effectiveness of prescriptions in protecting riparian leave areas appears to be a reasonable short-term indicator of long-term recruitment potential. Accompanying riparian stand surveys would complement data already collected on in-stream wood loading around the watershed. Over time, repeat in-stream LWD surveys will help gage the success of habitat protection measures in the Acme Watershed.

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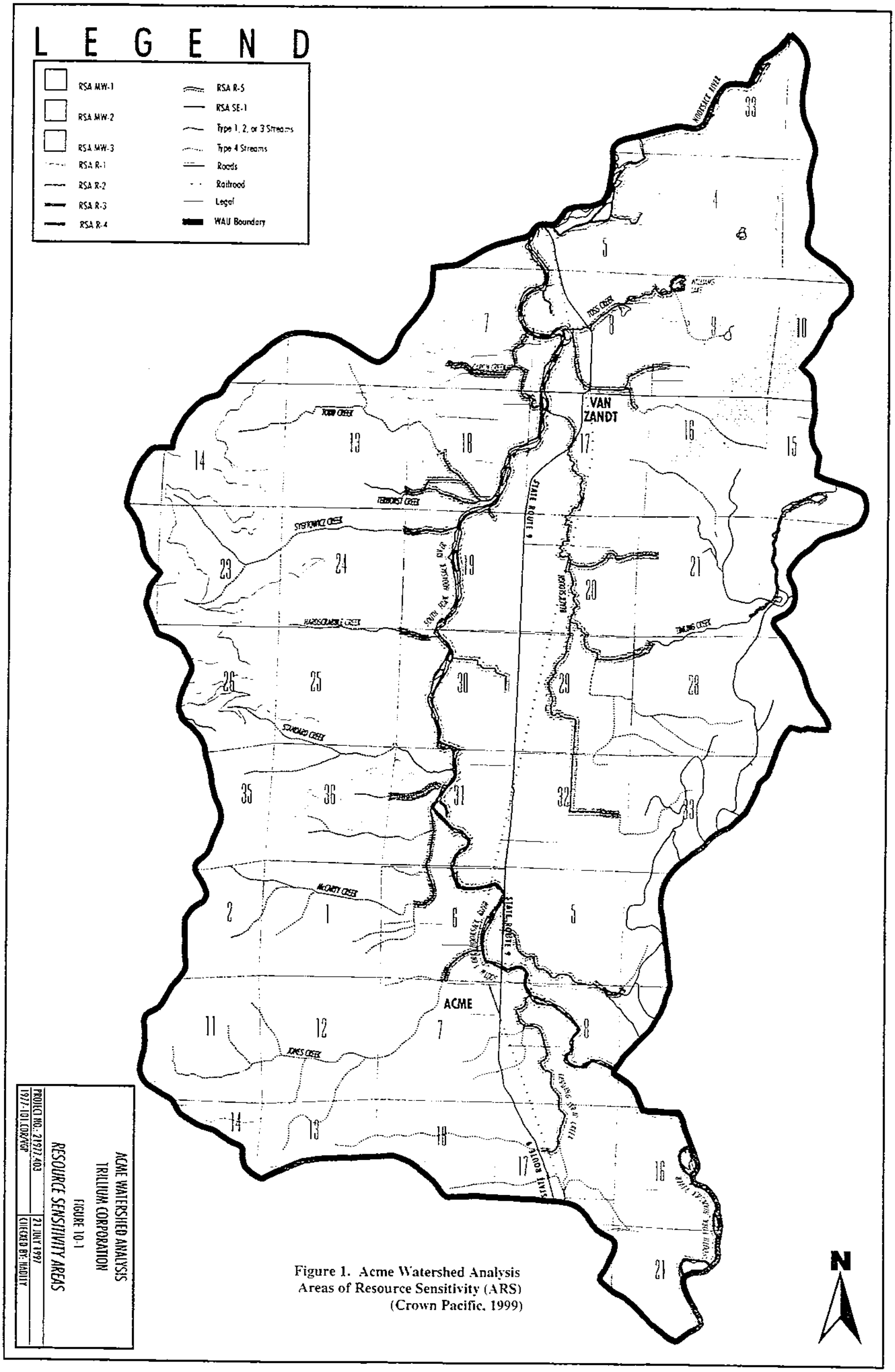

Figure 1. Acme Watershed Analysis
Areas of Resource Sensitivity (ARS)
(Crown Pacific, 1999)

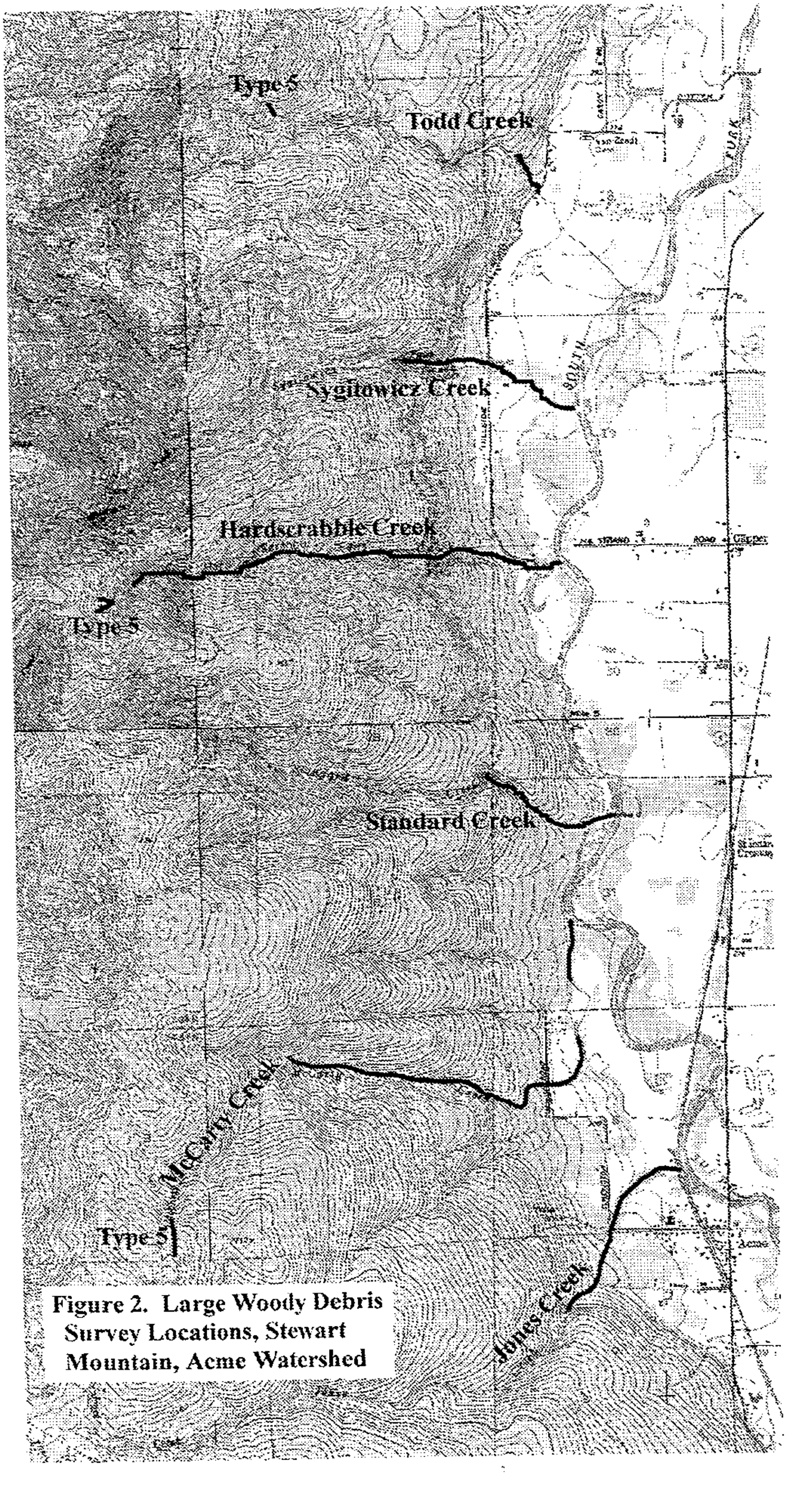

Figure 2. Large Woody Debris Survey Locations, Stewart Mountain, Acme Watershed

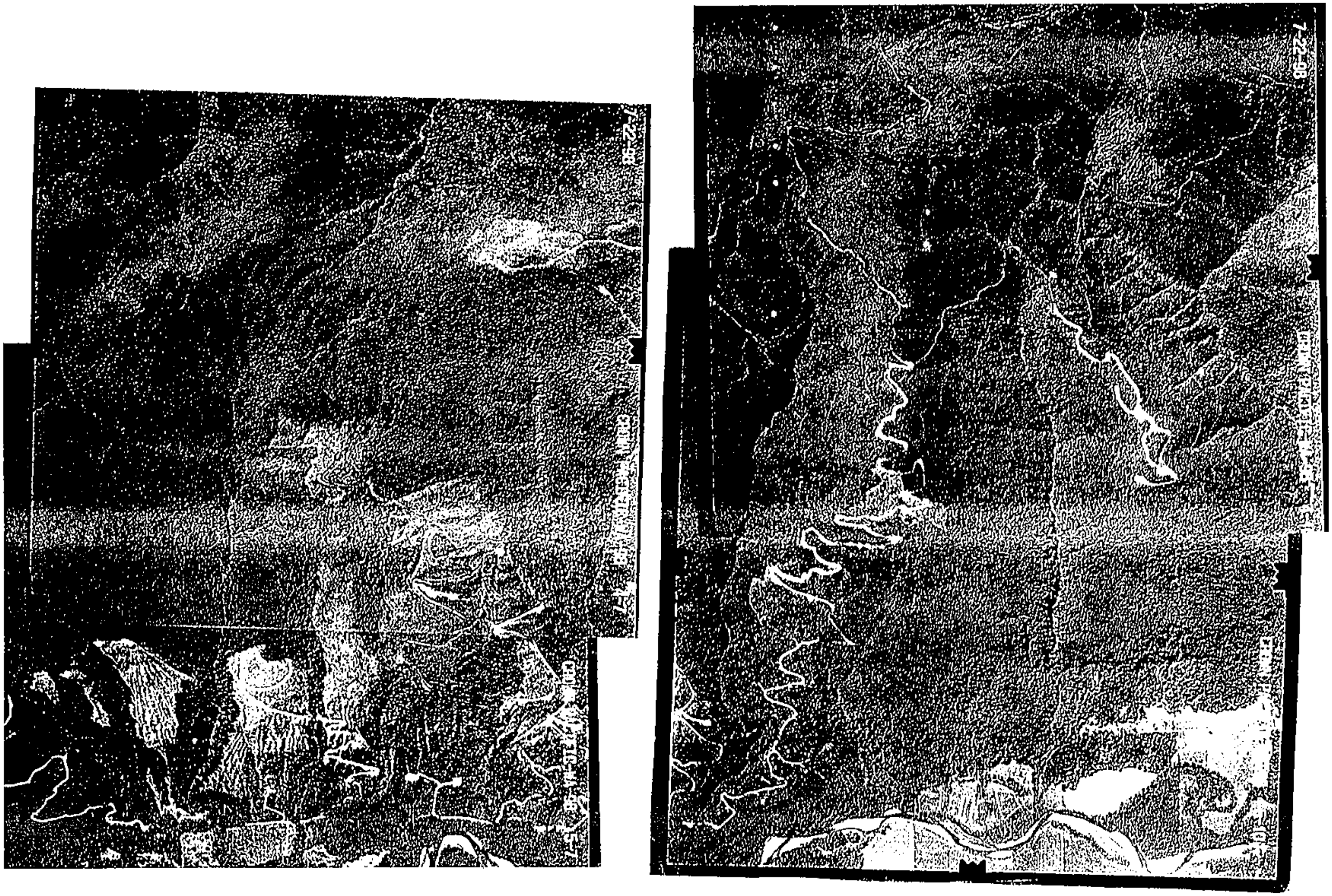

Figure 3. McCarty and Hardscrabble Creeks, Acme Watershed.

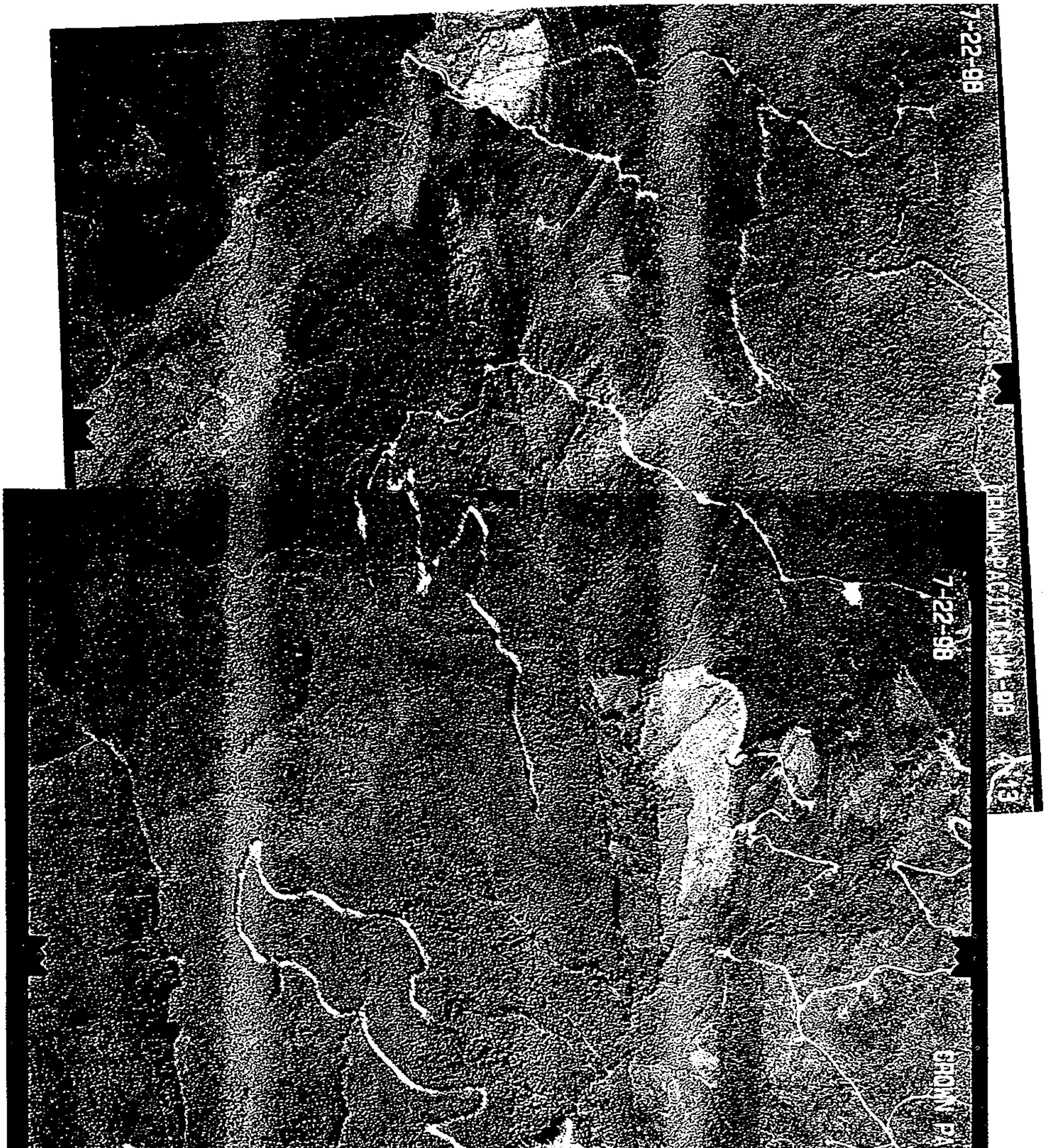

Figure 4. Treated Type 5 stream in Todd Creek, Acme Watershed.

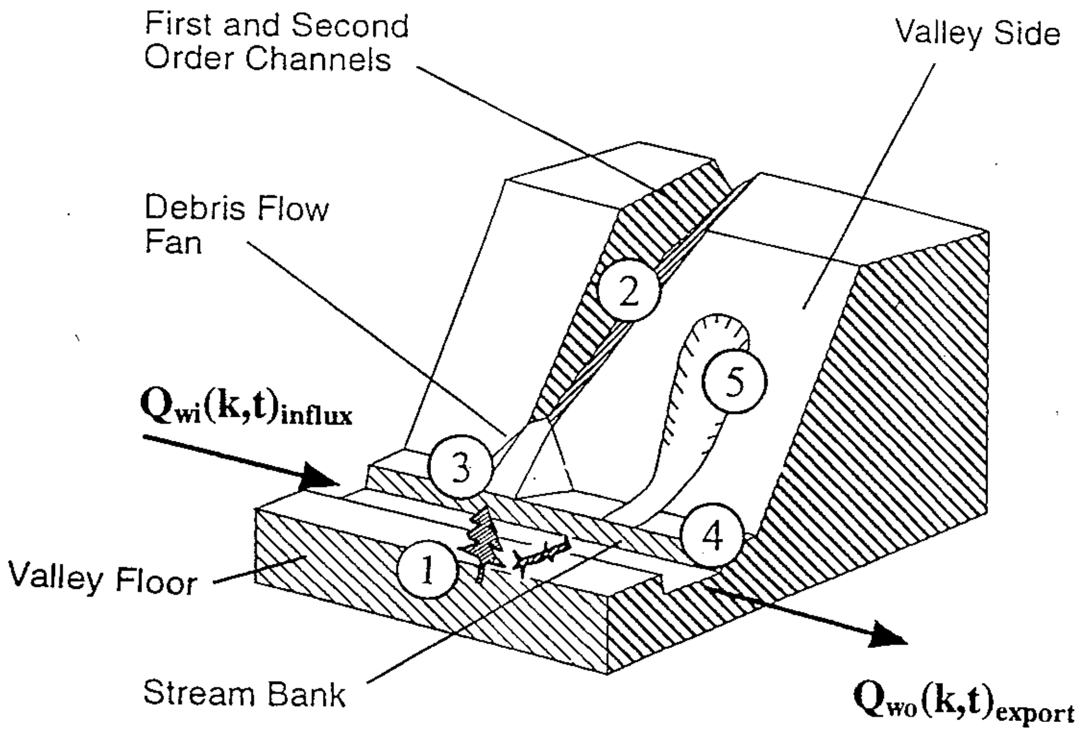

Figure 1. Illustration of the wood mass balance governed by the universal landscape processes of (1) stand mortality and fire-pulsed wood, (2 & 5) debris flows and streamside landslides, and (3 & 4) bank erosion along terrace and fan margins,. Stream influx and export of wood is shown as Q_{WI} and Q_{WO}, respectively.

Figure 5. Large Woody Debris Recruitment Mechanisms (from Benda et al., 1998).