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TFW Effectiveness Monitoring Report

ASSESSING THE EFFECTIVENESS OF MASS WASTING PRESCRIPTIONS IN THE ACME WATERSHED: PHASE 1 - BASELINE DATA COLLECTION

by:

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ABSTRACT

This report describes a monitoring project designed to assess the effectiveness of forest practice prescriptions in the Acme Watershed, Whatcom County, Washington. Rule calls of ***Prevent*** or *Avoid* for mass wasting produced a set of prescriptions aimed at protecting identified Areas of Resource Sensitivity in the watershed (Crown Pacific, 1999). Phase I monitoring in 1998 provides baseline reference conditions on mass wasting and prescription implementation, and reveal some preliminary results on prescription effectiveness. Future data collection under subsequent phases will help establish trends in watershed protection.

The Acme Watershed Analysis (AWA) identifies approximately 175 landslides and debris flows from aerial photos covering a period from 1970 and 1994. Roughly 80% of all landslides documented in the AWA are associated with forestry activities such as timber harvest and road construction. The analysis concludes that channel conditions, salmon habitat and water quality *in* the Acme watershed *are* severely degraded. Monitoring aims to assess the improvement of conditions under implementation of these mass wasting prescriptions.

Specifically, this effort helps to answer the following monitoring questions:

- **Question MW1.** Are road construction practices through high hazard mass wasting zones effective at preventing management related mass wasting?
- **Question MW2.** Does windthrow reduce the effectiveness of "no-cut" inner gorge mass wasting prescriptions? (Supplemental: Does buffer orientation, location and edge tree distribution influence windthrow occurrence?)
- Question **MW3.** Are selective harvest techniques in the groundwater recharge zone (GRZ) of deep-seated landslides (RSA MW-3) effective at preventing management related mass wasting?
- **Question MW4.** Are forest management prescriptions in the AWA effective at preventing management-related deliverable mass wasting?
- **Question** MW5. Is the rate of management-related mass wasting decreasing over time on a watershed scale?

These questions are addressed in the form of hypothesis testing, generally assuming that forest practices will not create mass wasting nor impact public resources using AWA prescriptions. Preliminary data show that management related landslides with delivery have been triggered under implementation of AWA prescriptions. From this we conclude that initial data do not fully support the posed hypothesis. Establishing trends in rates of mass wasting and prescription effectiveness will take one to two decades to assess, however, as the maximum loss of root strength after extraction is 5-15 years, and sufficient time must pass to capture large storm events. Over time, repeat surveys will help gage whether forest practice prescriptions are successful at promoting recovery 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 Resource Sensitivity Areas. "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., ." (WAC 222-22-070(3) (WFPB, 1995a)). This document describes the results of a project designed to assess the effectiveness of mass wasting prescriptions in the Acme watershed. Phase I monitoring conducted in 1998 provides baseline reference conditions as well as some preliminary results on prescription effectiveness. Future data collection under subsequent phases will help establish trends in watershed protection.

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 in the east and Stewart Mountain in the west, The majority of the mountain streams occur in the Chuckanut Formation, a late Cretaceous - early Tertiary sandstone, shale and conglomerate (AWA Page 3-1). Tectonic uplift and subsequent downcutting by an extensive stream network has produced a series of wide, steep inner gorges that are prone to shallow rapid landsliding and debris flows. The southern portion of the watershed is comprised of a mechanically weaker phyllite which, because it is more easily fractured and weathered, does not steepen as significantly as the sandstone.

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 l-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 l-2).

Background on Mass Wasting in the Acme WAU and the Mass Wasting Prescriptions

The dominant form of mass wasting in the Acme watershed is shallow rapid landsliding and resulting debris flows. "The majority of shallow landsliding occurs in convergent areas (bedrock hollows) located at the heads of first-order channels and within inner gorges" (AWA Page 3-I). In the AWA, approximately 175 landslides and debris flows were identified from aerial photos, covering a period from 1970 and 1994. Roughly 80% of all landslides documented in the AWA were associated with forestry activities such as timber harvest and road construction.

These mass wasting events have degraded channel conditions over time, resulting in "elevated levels of fine sediment in stream gravels and probably a loss of pools." (AWA Page 6-26). "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 sediment storage capacity. Exacerbated coarse sediment deposition onto alluvial fans and other stream segments has aggraded channels and increased subsurface flow (i.e. water flows through built up sediment rather than on the surface in an open channel). This extends the length of channel and the period of time in which fish bearing creeks run dry in summer.

Prescriptions

The mass wasting prescriptions in the AWA are designed to Prevent *or Avoid* sediment delivery to stream channels from timber harvest and forest road construction. Three mass wasting RSAs were delineated (Figure 1). Each represents a sensitive area with unique conditions contributing to slope instability. A separate prescription was written for each Mass Wasting Map Unit (MWMU):

RSA MW-1 -Shallow Rapid Landsliding and Debris Flows

Input variables:	Debris flow deposition; channel aggradation; coarse and fine sediment (and woody debris)
Hazard:	Moderate or High
Vulnerability:	High (Fish Habitat, Public Works)
Rule Call:	Prevent or avoid

Prescriptions:

- No harvest on convergent topography ≥ 73%, including bedrock hollows and channel heads.
- No harvest in inner gorges ≥ 73%.
- No new roads, except in "rare instances" with geotechnical report and specifications for construction and maintenance.

Additional prescriptions related to logistics and management practices:

- Site specific windthrow strategies are to be developed by the proponent and DNR to reduce high hazard conditions.
- Skyline corridors across riparian areas are allowed for 15% of the stream's length.
- "Trees within these mass wasting units shall not be used as tail-holds."

RSA MW-2 -Devil's Slide

Input variables: Primarily rockfall, possibly debris flows
Hazard: High (with respect to road construction that alters the distribution of surficial bedrock)
Vulnerability: High (Fish Habitat)
Rule Call: Prevent or Avoid
Prescription:

- "No new roads which require bedrock removal are to be built.. ."
  Rationale: This mass wasting map unit "apparently arises because of large topographic stresses in combination with weak rock or by faulting." As such, "Timber harvest probably does not play a role, although road construction that removes bedrock or significantly concentrates runoff may increase the probability of failures."

RSA MW-3 -Deep Seated Landslides in Jones/McCarty Creeks

Input variables: Coarse and tine sediment
Hazard: Moderate (High for small active landsliding areas, characterized by springs, tipped and deformed trees, and recent rotational failures)
Vulnerability: High (Fish Habitat)
Rule Call: Prevent or Avoid
Prescriptions:

- No harvest on active portions of deep-seated landslides.
- Retain a buffer above the active slide area equal to half the acreage of the active slide for Groundwater Recharge Zone (GRZ) protection (or harvest with a geotechnical report "capable of withstanding technical scrutiny").
- No new roads on active portion of slides that deliver sediment to streams.
- No significant increase in surface water inputs to GRZ with roads.

Objectives of the Mass Wasting Effectiveness Monitoring Project

The purpose of Phase I monitoring is to establish a baseline of information with which to assess the effectiveness of mass wasting prescriptions in the Acme watershed. The information gathered provides a foundation for long-term trend monitoring of resource protection under forest practice prescriptions, Draft prescriptions implemented in the two years prior to this monitoring project provide some preliminary data regarding prescription performance, 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 answer the following five questions:

- **Question MW1.** Are road construction practices through high hazard mass wasting zones effective at preventing management related mass wasting?
- **Question MW2.** Does windthrow reduce the effectiveness of "no-cut" inner gorge mass wasting prescriptions? (Supplemental: Does buffer orientation, location and edge tree distribution influence windthrow occurrence?)
- **Question** MW3. Are selective harvest techniques in the groundwater recharge zone (GRZ) of deep-seated landslides (RSA MW-3) effective at preventing management related mass wasting?
- **Question MW4.** Are forest management prescriptions in the AWA effective at preventing management related deliverable mass wasting?
- **Question MW5.** Is the rate of management related mass wasting decreasing over time on a watershed scale?

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

PHASE I: ACME WATERSHED MONITORING

The first phase of monitoring was implemented to help begin answering the questions posed above. All monitoring procedures, including quality assurance measures, were conducted in accordance with methods outlined in the Washington Department of Ecology approved Acme Watershed Monitoring Plan (Soicher, 1998). Presented below are hypotheses for each question, followed by discussions of the methods used and preliminary results. A time span of one to two decades is necessary to conclusively evaluate the effectiveness of these mass wasting prescriptions. Mass wasting inventories were conducted by Alan Soicher, a certified mass wasting analyst in Washington's watershed analysis program

Question MW1. Are road construction practices through high hazard mass wasting zones effective at preventing management related mass wasting?

Hypothesis MW1: Roads constructed under the prescriptions of the AWA will not increase the likelihood or magnitude of mass wasting failures in the watershed.

Monitoring Approach and Methods:
This hypothesis is tested with the following approach:

1. Identify all sites where the prescription was implemented.
2. Visit each site in the field.
3. Photo document the sites to provide reference conditions for future comparison.

4. In cases where mass wasting occurred, use the diagnostic key in Sasich (1998) to determine the triggering mechanism and whether mass wasting resulted from forest management. Estimate the aerial extent of any landslides in the field and estimate sediment volume contributed using a methodology similar to that for measuring bankfull width in a stream (Schuett-Hames et al, 1994).

Preliminary Results:
A total of three road projects were implemented in Mass Wasting Map Units (MWMU) under Acme Watershed Analysis prescriptions:

A. South Todd FPA (Terhorst Creek)
B. East Mainline Crossings of Todd Creek
C. Spar Tree

Site-specific slope stability assessments were prepared by a geotechnical specialist for each project. These roads cross high hazard mass wasting areas that contain streams. Of the 3 projects, one is functioning as designed (Site A). One re-activated unstable slopes and delivered sediment to significantly impact water quality (Site B). The third held up though experienced wind damage in adjacent leave areas and appreciable cutbank erosion (Site C). Locations are shown in Figure 2 and information summarized in Table 1.

<u>A. South Todd FPA</u>
A bridge was constructed across the inner gorge of Terhorst Creek in late Fall, 1997. Blasting into inner gorge walls removed materials to allow for the construction of the bridge's gentle approaches. The site visit in the summer of 1998 determined that the bridge over Terhorst Creek is functioning as designed and mass wasting has not occurred.

<u>B. Todd Creek East Mainline FPA</u>
The Todd Creek East Mainline re-construction project occurred in early summer, 1998. Three culvert crossings of high hazard mass wasting areas were proposed in the project. The site specific geotechnical assessment advised that re-construction operations "Must exercise care in removing debris from channels at the head of culverts to prevent destabilization of the upslope channel" (Zander, 1997).

During reconstruction, the three stream crossings were simultaneously exposed without proper armoring of upstream catch basins. During a rain event, each of the upslope channels collapsed and began to cut headward, as much as 30 meters upslope and more than 40 meters laterally along the road (Figure 3). Sediment unraveled into the catch basins and continued to flow through the culverts, which did not plug. These failures are documented in the landslide inventory

The landslide scars extend roughly 600 and 400 square meters, respectively. These would be considered small to medium sized slides using the landslide size chart in the Mass Wasting Module (WFPB, 1995b). Estimates of sediment delivery from the two larger failures are 2,000 and 1,850 cubic meters, though the large rock which has been placed on the failure surface make it difficult to estimate the depth of soil lost. A mile and a half downstream, Todd Creek's fish bearing reaches ran highly turbid for a number of days following the storm. Elevated turbidity levels persist during periods of higher flow.

The landowner has put effort into mitigating the impacts of these failures, including the placement of large rock *on* the exposed surfaces and installation of a concrete wall just up from the culvert intake. These measures may reduce the continued growth of these unstable features.

The Todd Creek failures most resemble Road Management Activity I-C-2 - *Shallow Roadcut Slide Depositing Into Roadbed* **in the Key to Diagnosing Causes of Management-Related Mass Failures** (Sasich, 1998). The probable trigger is given as "Cutslope angle is **not** stable and has oversteepened natural slope." The trigger of the Todd Creek events appears to be toe removal of previously unstable features, causing destabilization, slumping and head-cutting. This type of failure is not specifically referred to in the Sasich key.

C. Spar Tree FPA

The Spar Tree crossing of a tributary to McCarty Creek cuts through a fairly narrow inner gorge (see Figure 4). The geotechnical report prepared for the project focussed mainly on its environmental benetits over the alternative of constructing more road to switchback up the hill on the other side of the stream. A bridge at the site "is considered to be economically infeasible.. ."(Watts, 1996). In the investigation of the channel, Watts found an unconsolidated deposit, estimated 220 cubic yards and less than 20 years old, in a low-gradient reach just upstream from the crossing. Debris flows have not occurred since construction of the crossing.

The inner gorge cutbanks extend more than 30 meters from the creek *on* both approaches and 12-15 meters high. These exposures are unraveling and contributing sediment to the stream. Grass seeding on at least half the surface of these cutbanks has not held. Additional sediment is being contributed as a resultofwindstorms in November, 1998. The wind events brought down doiens of trees in the riparian leave areas above and below the crossing. Some events initiated mass wasting (see landslide inventory below). The culvert did not plug.

Table **1. Road Crossings Constructed Under Implementation of High Hazard Mass Wasting Prescriptions (guided by Sasich, 1998)**

Forest **Practice Name**	**Type of Crossing**	**Waterway**	**Stream Order**	**Bedrock**	**Slope Position**	**Geomorphic Setting**	**Sediment Delivery?**
Sooth Todd	Bridge	Terhorst Creek	4	Chuckanut Formation	Lower 1/3	Low Order Inner Gorge	No
East Mainline	Culvert	Todd Creek	4	Chuckanut Formation	Upper 1/3	Low Order Inner Gorge	Yes
Spar Tree	Culvert	McCarty Creek	4	Chuckanut Formation	Lower 1/3	Low Order Inner Gorge	some

In summary, at least one of the three implemented road projects resulted in a failure of the prescription. Two of the three projects were culvert projects, while one was a bridge. By avoiding in-stream work, the bridge project appears a safer alternative where streams must be crossed. While the potential for failure in Todd Creek was clearly identified in the geotechnical report, implementation of the prescription did not follow the caution advised in the report Particularly important, the three Todd Creek crossings were exposed at one time, allowing for their simultaneous failure and cumulative effect downstream. It is difficult to discern the extent to which this is a compliance issue and how much a prescription effectiveness issue. While the prescription allows for the reconstruction of this historically troubled road, the people implementing the prescription on-the-ground are responsible for the three crossings being exposed all at once.

Insufficient *time* has passed to assess the effectiveness of this prescription under a variety of storm intensities, Sediment delivery to Todd Creek, however, provides data that does not support the hypothesis posed above. Monitoring of these established sites should continue on an annual basis, as well as additional monitoring of all newly constructed roads which implement this prescription across high hazard mass wasting areas.

Question MW2. Does windthrow reduce the effectiveness of "no-cut" inner gorge mass wasting prescriptions? (Additionally: Does buffer orientation, location and edge tree distribution influence windthrow occurrence?)

Hypothesis MW2: Windthrow will not reduce the effectiveness of "no-cut" inner gorge mass wasting prescriptions. Exposure to directional winds, topography and the size of trees along the leave area edge may influence susceptibility.

Note: Hypothesis MW2 differs from that in the Acme Watershed Monitoring Plan (Soicher, 1998). The null hypothesis (i.e. leave areas will not be compromised by wind) replaces the prior hypothesis that landsliding will impact these mass wasting leave areas.

Monitoring Approach and Methods:

Background: High hazard mass wasting prescriptions require retention of all trees in inner gorges with slopes > 36". Above the inner gorge, clearcutting is permitted. These edges often occur as abrupt changes in slope form, with mature trees straddling the boundary Strong winds can blow down trees in leave areas, reducing their effectiveness and potentially triggering mass wasting.

Wind hazard for each treated site in the Acme WAU is to be assessed according to guidelines presented in the Windthrow Handbook for British Columbia Forests (Stathers et al.,1994). Following assessment, "Appropriate windthrow management strategies shall be developed for stands with a high risk of windthrow." Such windthrow management strategies are yet to be implemented in the Acme watershed, suggesting that hazard in already cut buffers has been considered low or perhaps moderate.

Flexibility is written into the prescription for trees located along an inner gorge edge: "If there are numerous mature trees below the edge then the removal of a **portion** of the trees overlapping the boundary should not significantly reduce the rooting strength of the entire potentially unstable feature." (AWA 11-9)

Monitoring: Permanent plots were established along inner gorge buffer boundaries to document post-harvest and pre-windthrow conditions in mass wasting conservation areas Of the forty-eight potential sites identified for monitoring in the Acme WAU, a sub-sample of twenty-five percent, or twelve sites were randomly selected.

Within each site, two monitoring plots were established 100 meters from each other (see Figure 2 for plot locations). Each square plot extends 25 meters along the buffer boundary and 25 meters down the inner gorge (horizontal distance). Tree diameter, class, species and defects were recorded for living and standing dead trees within the plot, as well as geomorphic features. Heights were measured on snags and trees with broken tops. Each tree was numbered and tagged, and located within a grid along the plot.

Evergreen Land Trust staff and the TFW Ambient Monitoring Program (Northwest Indian Fisheries Commission (NWIFC) provided quality assurance support for these surveys. Field equipment was calibrated against NWIFC standards, field crew were adequately trained, and data collection methods were independently verified periodically by the Coordinator. Quality Assurance methods outlined in the Acme Watershed Monitoring Plan (Soicher, 1998) were consistently followed. Field forms and electronically entered data were error checked by the Coordinator.

Preliminary Results:

The purpose of sampling in 1998 was to document buffer strip conditions as they existed soon after their creation. Summary statistics for the monitoring sites are compiled in Table 2 and sample photographs are shown in Figure 5. Appreciable wind damage has been observed during Fall 1998, shown in Figure 6 for some mass wasting buffers in the Acme watershed. Future visits to these monitoring plots will allow for the quantification of damage to these unstable leave areas.

Annual follow-up monitoring is needed to quantify and assess wind damage at these sites and any associated mass wasting. While this information will help express the occurrence of windthrow at the site scale, this effort is neither of sufficient size nor scope to statistically represent wind impacts in all units where prescriptions have been implemented. To better constrain the occurrence of windthrow across the landscape, more treated sites (perhaps another 24) would have to be evaluated as well as some that remain unmanaged. This would provide data to more clearly distinguish between rates of natural windthrow induced mass wasting and those associated with forest management.

Question MW3. Are selective harvest techniques in the groundwater recharge zone (GRZ) of deep-seated landslides (RSA MW-3) effective at preventing management related mass wasting?

Hypothesis MW3: The selective harvest prescription for the GRZ of deep-seated landslides will not increase the magnitude of failure.

Table 2. Summary Statistics for 1998 Mass Wasting Leave Area Monitoring Plots in Inner Gorges, Acme Watershed.

Site #	Site Name	Wind Exposure	Landforms Within Inner Gorge Plot	# Trees in Plot	Trees Per Zone (Distance from Edge of Leave Area) I (0-5m)	II (5-10m)	III (10-15m)	IV (15-20m)	V (20-25m)	Average DBH (cm)	Size Class Large (>60cm)	Medium (30-60cm)	Small (10-30cm)	# Trees w/ Yarding Damage	# Snags >10cm
1	MCS266ma	south	Planar Slopes	12	5	3	0	2	2	51.0	3	5	4	None	6
2	MCS366mb	south	Bedrock Hollow	10	3	2	0	1	4	42.6	1	6	3	1	2
3	MCS466mc	south	Planar Slopes	9	1	3	0	1	4	43.2	2	4	3	None	2
4	MCS566md	south	Planar Slopes	26	9	1	2	9	5	41.1	8	5	13	1-tailhold	3
5	MCS866ma	south	Bedrock Hollow	19	7	6	1	2	3	40.7	3	8	8	1	2
6	MCS966mb	south	Planar Slopes	29	7	5	7	1	9	27.3	2	5	22	1	7
7	MCTN62ma	north	Planar Slopes	25	8	5	5	4	3	32.6	0	17	8	None	2
8	MCTN162mb	north	Slight Hollow	24	3	6	5	4	6	40.1	2	14	8	None	2
9	STN247ma	north	Planar Slopes	31	12	3	8	5	3	32.6	3	10	18	3	8
10	STN347mb	north	Bedrock Hollow	37	17	11	9	0	0	28.5	2	11	24	None	4
11	STN547ma	north	Bedrock Hollow	48	10	9	10	8	11	28.5	3	11	34	5 (1 tailhold)	4
12	STN647mb	north	2 Bedrock Hollows	48	10	7	10	11	10	31.7	6	7	35	3	2
13	OPN51ma	north	Slight Hollow	26	8	7	5	4	2	33.5	4	5	17	None	8
14	OPN151mb	north	Bedrock Hollow	38	6	7	12	6	7	30.1	4	8	26	None	9
15	OPN251ma	north	Planar Slopes	13	10	2	1	0	0	25.8	1	2	10	3 (1 tailhold)	1
16	OPN351mb	north	Planar Slopes	23	5	10	2	1	5	30.0	2	6	15	2	2
17	OPS71ma	south	Planar Slopes	29	8	9	3	1	8	30.0	1	13	15	2	3
18	OPS171mb	south	Planar Slopes	21	9	7	1	0	4	28.1	1	6	14	8 (1 tailhold)	5
19	OPS271ma	south	Planar Slopes	33	7	13	7	5	1	26.1	1	8	24	1	3
20	OPS371mb	south	Planar Slopes	25	2	3	5	8	7	24.6	1	5	19	2	6
21	THN1ma	north	Planar Slopes	18	10	8	0	0	0	29.2	0	9	9	None	1
22	THN101mb	north	Bedrock Hollow	36	12	2	7	10	5	27.7	3	7	26	3	7
23	TODDS1ma	south	Bedrock Hollow	17	5	4	2	2	4	41.9	5	3	9	4	2
24	ODDS101m	south	Bedrock Hollow	28	9	12	4	3	0	32.9	1	12	15	None	2

Note: Hypothesis MW3 differs from that in the Acme Watershed Monitoring Plan (Soicher, 1998). The word "magnitude" replaces "likelihood" because data requirements for determining increases in the likelihood of failure exceed those available in this project.

Monitoring Approach and Methods:

Background: A number of deep-seated landslides occur in the phyllite bedrock of the southwestern portion of the watershed. The contact between phyllite and the Chuckanut sandstone to the north runs northeast through the watershed and is shown on the geologic map of Figure 7. Eight deep-seated failures were inventoried in the Jones Creek drainage in the AWA (all during 1994-95 surveys). At least one other was located during the preparation of a forest practice in the McCarty Creek drainage. Deep-seated landslides are sometimes difficult to detect using aerial photography, and more are probably scattered throughout the southwest portion of the WAU. Many of these slides continue to deliver sediment and create bulges in the stream profile.

The triggering mechanisms for these deep-seated landslides are not well understood. The location of failure surfaces and the effects of groundwater recharge are uncertain. It is not known what groundwater conditions cause the slides to move (whether near the surface or at great depth), Undercutting of landslide toes by stream action (possibly influenced by increased peak flows) triggers some landslide movement.

Timber extraction on the active landslide is prohibited under prescriptions, and a portion of the GRZ equal to half the area of the active deep seated landslide must be retained. The remaining GRZ is available for clearcutting. Existing roads may be re-opened and new roads may be constructed across portions of the active slide and/or the GRZ. The prescriptions state that "Without clear triggering mechanisms in the active deep-seated landslides in the Acme WAU, we cannot be certain of the effectiveness of any prescriptions." ".. An approach is taken that focuses mitigation (no harvest or partial harvest) on the active portion of the slide area, with a lesser emphasis on the GRZ, until additional site specific information is available on the relationship between harvesting and landslide movement in the Acme WAU."

Monitoring: Deep-seated landslides in Jones and McCarty Creeks were photo documented and visited from land and air (AWA MWMU-3 – See Figure 1). For the purposes of this monitoring effort, all sites were visited where GRZ prescriptions were implemented in 1997/98 (Lower Jones and Lower McCarty Forest Practices). The active portion of deep-seated landslides and their GRZ are delineated by the proponent during preparation of a forest practice and provide documentation of pre-treatment conditions.

Monitoring changes to the size of the active slide area will be conducted to determine the role of forest management in landslide activity (according to the methods of Sasich (1998)). If deemed management influenced, responsibility for the increased landslide activity will be assumed due to tree removal (and increased infiltration) on the GRZ (unless other causes such as road failure or blowdown on the active zone are clearly identifiable as triggers). In this way the above hypothesis can be tested. Photo documentation of current conditions (together with mapping by the proponent) will assist in determining whether changes to these boundaries have occurred over time.

Preliminary Results:

Figure 8 shows aerial photographs of the Jones Creek basin, first in the 1950's and again in 1998. At least one new slide has developed since the 1995 survey conducted for the AWA, in an area not immediately adjacent to forest management activities. This slide may be related to a deep-seated failure on the north bank of the creek whose deposit forced the creek to cut up against the south bank. The undercut toe of this deep seated feature may have caused it to fail.

GRZ prescription implementation is visible in the 1998 forest practice to the right of the photo in Figure 8 (during harvest). Figure 9 shows the Lower Jones unit post-harvest in early December 1998. Wind damage to the protected portion of the Groundwater Recharge Zone occurred during Fall, 1998 storms. A report on this situation (Veldhuisen, 1999), included as an appendix to the AWA, shares modeling estimates that logging on the GRZ increased soil moisture input by 4% and windthrow an additional 2%, or 6% above pre-logging conditions. A map of this forest practice is included as Figure 10.

The purpose of this monitoring project is to determine whether prescriptions for GRZ management are effective at protecting the GRZ (maintaining forest canopy) and limiting contributions to the spread of the active portion of the landslide. Changes to the size of deep seated landslides will be monitored. Time frames perhaps on the order of decades (the AWA suggests using a 30 year history to assess slide movement post-harvest (Page 1 l-14)) may be necessary to assess the effectiveness of these prescriptions.

This monitoring effort does not replace pre-failure hazard monitoring such as that recommended in the AWA (Page 1 l-14): "In an effort to gain a better understanding of the factors which influence its movement, it is recommended that affected landowners adopt and implement a program for monitoring this deep-seated landslide." Such active monitoring may help reduce potential impacts to public resources before they happen, as well as to public safety in the town of Acme at the base of Jones Creek.

Question MW4. Are forest management prescriptions in the AWA effective at preventing management related deliverable mass wasting?

Hypothesis MW4: Mass wasting with delivery to waterways will not occur due to management activities under the prescriptions of the AWA.

Monitoring Approach and Methods: Landslides occurring in the western half of the Acme Watershed (Stewart Mountain) were inventoried using the aerial photography as outlined in the Standard Methodology for Conducting Watershed Analysis (WFPB, 1995b). Most new sites were field verified using a diagnostic key presented in Sasich (1998). This inventory does not include the eastern portion of the watershed, Van Zandt Dike, because of a lack of active management and availability of aerial photos.

Preliminary Results: Table 3 shows the landslides inventoried under this project, and Figure 11 shows slide locations. Aerial photo interpretation reveals at least fifteen previously identified landslides, eleven of which are management initiated, that continue to

Table 3. 1998 Landslide Inventory for Stewart Mountain, west Acme Watershed (based on 1998 aerial photos and site visits)

Slide ID#	Slide Type	Sediment Delivery (None/Stream)	Associated Land-use	Slope Form	Hillslope Gradient (degrees)	T (N)	R (E)	Sec	Field Visit	Comments
Erosion and Growth on Existing Landslides										
19	SR	Standard	clearcut	inner gorge	>36	38	4	25	No	North Side of North Fork.
20	SR	Standard	road	hollow	>36	38	4	25	No	North Side of North Fork
29	SR	None	clearcut	hollow	>36	38	4	22	No	29-31 may be part of
30	SR	None	clearcut	hollow	31-35	38	4	22	No	one deep seated feature
31	SR	None	clearcut	hollow	>36	38	4	23	No	high in Sygitowicz.
46	SR	Sygitowicz	road	hollow	>36	38	4	23	No	Fish hook mad - re-active below x-ing
57	SR	None	road	hollow	>36	38	4	14	Yes	Below the Todd Headwaters Road
61	SR	Standard	mad	hollow	>36	38	4	26	No	South side North Fork Standard Creek.
90	SK	Standard	road	hollow	>36	38	4	26	No	South side North Fork Standard Creek
156	SR	Standard	road	hollow	>36	38	4	26	No	Hairpin on South side of North Fork.
171	DS	Jones	unknown	inner gorge	>36	37	5	7	Yes	Growing toe exposure - clearcut adjacent
173	DS	Jones	unknown	inner gorge	>36	37	4	12	Yes	Growing toe exposure clearcut adjacent
174	DS	Jones	unknown	inner gorge	>36	37	4	12	Yes	Deformed trees
178	SR	South Fork	road	hollow	>36	38	5	30	Yes	Continuing to widen
182	DS	Jones	unknown	inner gorge	>36	37	5	7	No	Exposed area expanding
New or Re-newed Landslides										
192	SR	Todd	mad	hollow	>36	38	4	14	Yes	Below the Todd Headwaters Road (formerly # 115)
193	SR	Todd	mad	hollow	>36	38	4	14	Yes	Below tie Todd Headwaters Rood (formerly #123)
194	SK	Todd	road	hollow	>36	38	4	14	Yes	Below the Todd Headwaters Road (formerly # 122)
195	SR	Sygitowicz	mad	hollow	>36	38	4	23	No	Fish hook mad - re-active below x-ing (formerly #39)
196	SR	N branch-Oak Park	clearcut	hollow	>36	38	4	25	YCS	Blowdown of at least 100 trees, large exposed scarp
197	SR/DF	Standard	unknown	inner gorge	>36	38	4	26	No	Begins high w/ clearcut above, failed road crossing low
198	SR	Standard	clearcut	hollow	>36	38	4	36	Yes	Wind triggered event
199	SR	Trib 1 N of McCarty	clearcut	hollow	>36	38	4	36	Yes	Blowdown from S along buffer edge
200	SR	Trih I N of McCarty	unknown	hollow	>36	38	4	36	Yes	Not clear if management related
201	SR	McCarty	unknown	hollow	>36	37	4	1	Yes	Along Spar Tree buffer - wind assisted?
202	SR	McCarty	unknown	hollow	>36	37	5	6	Yes	Along Spar Tree buffer - wind assisted?
203	SR	McCarty	clearcut	hollow	>36	37	5	6	Yes	Along Spar Tree buffer: N exposed - wind effects likely
204	DS	Jones	unknown	inner gorge	>36	37	5	7	Yes	Slide on north bank may have helped trigger

Note: All deep seated landslides **(DS)** occur in the phyllite while shallow rapid landslides (SR) occur in the Chuckanut Formation.

deliver sediment to waterways on Stewart Mountain, Thirteen new or re-activated slides were documented in the Acme WAU. The photos in Figure 12 show some of the recent events on Stewart Mountain.

Of the thirteen new or renewed slides documented in the watershed since 1995, at least eight slides are management related and delivering sediment (determined through aerial photo interpretation and field verification). The hypothesis that management related mass wasting will not occur due to forest management activities under the AWA is not supported by the data collected thus far.

Using a diagnostic key as in Sasich (1998), field verification provided greater certainty on the triggering mechanisms for each slide. Four of the slides were initiated by roads (three under re-construction (Todd Creek (previously #115, 122, 123, now #192-194) and one re-activated on an inactive road (previously #39, now #195)). The triggering mechanisms for these failures are discussed under Question MWI. The Todd Creek crossings appear to have been constructed in compliance with AWA mass wasting prescriptions (e.g. full bench end haul construction, keyed rock fill, etc.). The failures occurred when warnings from the geotechnical investigation were not implemented on the ground. (see discussion of Todd Creek failures in Question MW1).

Clearcut harvest adjacent to unstable features was responsible for four new landslides identified on Stewart Mountain. Slides #196, 198, 199 and 203 were identified on aerial photos and field verified. All appear to be associated with windthrow initiated along clearcut boundaries, all with sediment delivery to waterways. These forest practices were conducted using Acme watershed analysis mass wasting prescriptions. From field visits to these sites and conversations with DNR personnel, each appears to be implemented in compliance with the prescriptions (though measures were not implemented to protect from windthrow). Using the Sasich diagnostic key, the triggering mechanism for these slides most closely resembles "root strength reduced in "leave area" from windthrow after harvest."

The role of forest management in triggering the remaining five inventoried landslides is not certain. Hydrologic changes may have influenced triggers (such as increases in peak flow cutting the toe of the deep seated landslide in Jones Creek (#204), or increased pore pressure from infiltration in a clearing above slide #197). Slides #200-202 begin near clearcut boundaries, though triggers for these bedrock hollow slides are uncertain.

With the maximum loss of root strength occurring within twenty years of tree removal, a time frame of this magnitude is needed to comprehensively assess the effectiveness of prescriptions in preventing mass wasting. Similarly, the practice must have sufficient time to experience a wide variety of climatic conditions and storm intensities, perhaps on the order of decades.

Preliminary results show that mass wasting with sediment delivery continues to occur in the Acme watershed from implementation of AWA mass wasting prescriptions.

Question MW5. Is the rate of management related mass wasting decreasing over time on a watershed scale?

Hypothesis MW5: Since the Acme Watershed has experienced higher than natural rates of mass wasting in the last half century, management-related mass wasting will decrease over time under the AWA prescriptions.

Monitoring Approach and Methods: Using data collected in MW4, rates of landsliding are calculated and compared with those determined in the Acme watershed analysis.

Preliminary Results: Based on the nearly 30 year landslide inventory, rates of mass wasting do not appear to be declining in the Acme Watershed. Table 4 shows the number of mass wasting events on Stewart Mountain as reported in the AWA Landslide Inventory, and those documented in this project. Summertime photos for 1970, 1978, 1983, 1987, 1991, 1995 and 1998 were used for this analysis. A mass wasting event occurring in the latter portion of 1998 was also included in the inventory.

Table 4. Summary Landslide Rates for Stewart Mountain, western Acme Watershed

Sampling Interval	# Years Between Sampling	# Landslides	Average Rate of Landsliding (Slides/Year)
1970-1974	4	18.5	4.6
1974-1978	4	18.5	4.6
1978-1983	5	20	4.0
1983-1987	4	43	10.8
1987-1991	4	15	3.8
1991-1995	4	18	4.5
1995-1998	3	13	4.3

Mass wasting events tend to occur episodically, affected by weather patterns and storm intensities. Storm events during the winters of 1996-1998 (both rain and wind) have been significant but not of an unusual magnitude. Based on conversations with DNR personnel, Veldhuisen *(1999) concluded* that "the intensity of the fall 1998 windstorms was substantial, though apparently not of an exceptional or catastrophic magnitude." Storm events such as those occurring in 1983 (which produced debris flows throughout the WAU) have not been realized in the past few years. More time must pass to adequately gage the effectiveness of these mass wasting prescriptions under various climatic conditions.

SUMMARY AND RECOMMENDATIONS

Phase I of this Acme watershed analysis monitoring effort provides a snapshot of watershed conditions in 1998. A number of new landslides have been documented in the watershed, including those caused by forest management. Permanent monitoring plots have been established to consider wind and its effects on mass wasting leave areas. Continued monitoring will allow us to gage the effectiveness of prescriptions and the success of resource recovery measures in the Acme watershed.

Long term trends in resource-protection can only be established through the continuation of monitoring in coming years. Additional monitoring should be implemented for future forest practices in the Acme watershed that use mass wasting prescriptions. This will provide a more statistically meaningful dataset for analyzing trends. The particular needs of repeat surveys, as well as specific suggestions for improvements to this monitoring project are outlined in Section B, Preliminary Results. Expansion of this monitoring effort is needed to improve the certainty (or rather quantify the uncertainty) with which we draw conclusions regarding the effectiveness of mass wasting prescriptions in the Acme WAU.

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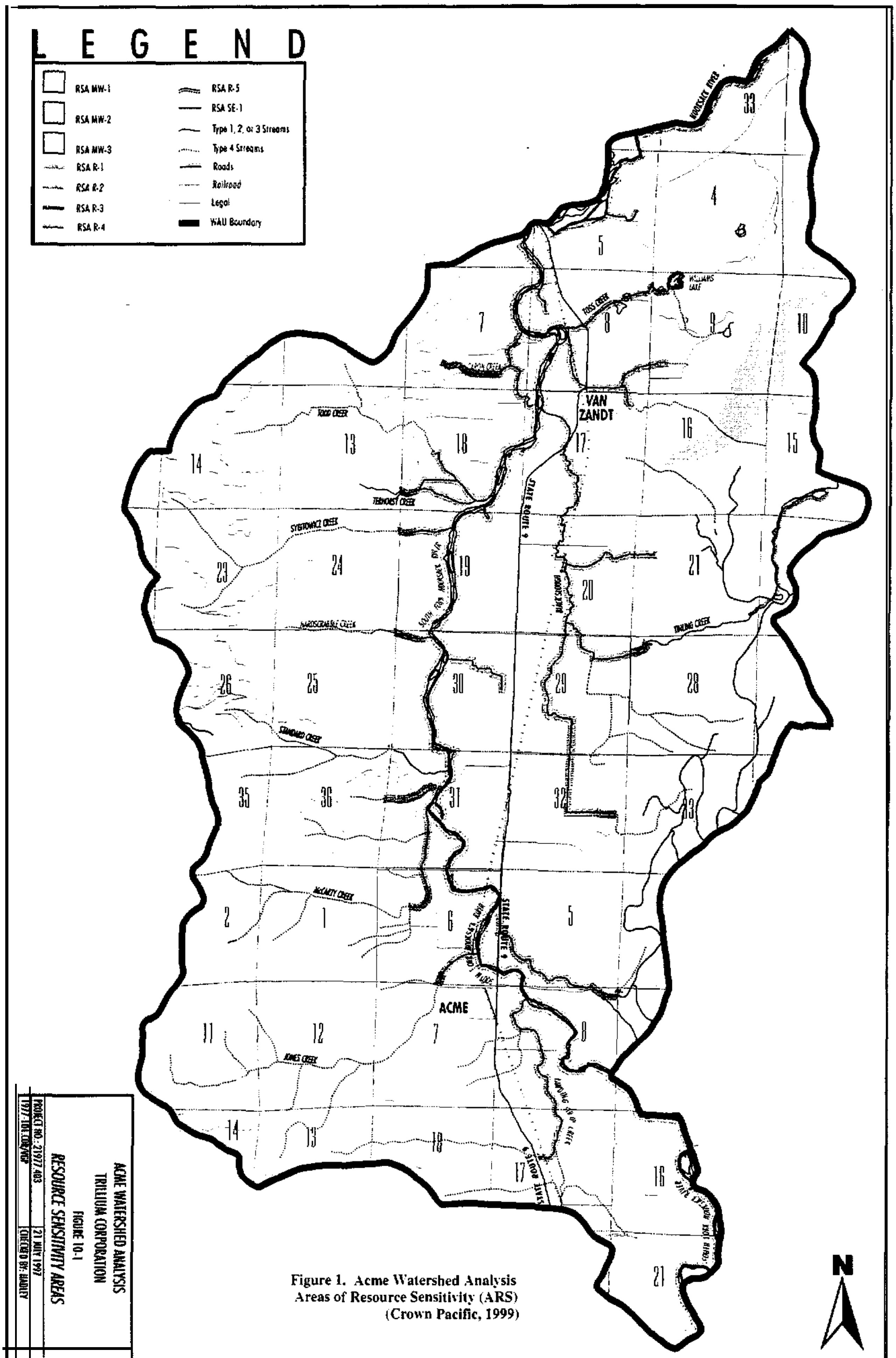


Figure 1. Acme Watershed Analysis
Areas of Resource Sensitivity (ARS)
(Crown Pacific, 1999)

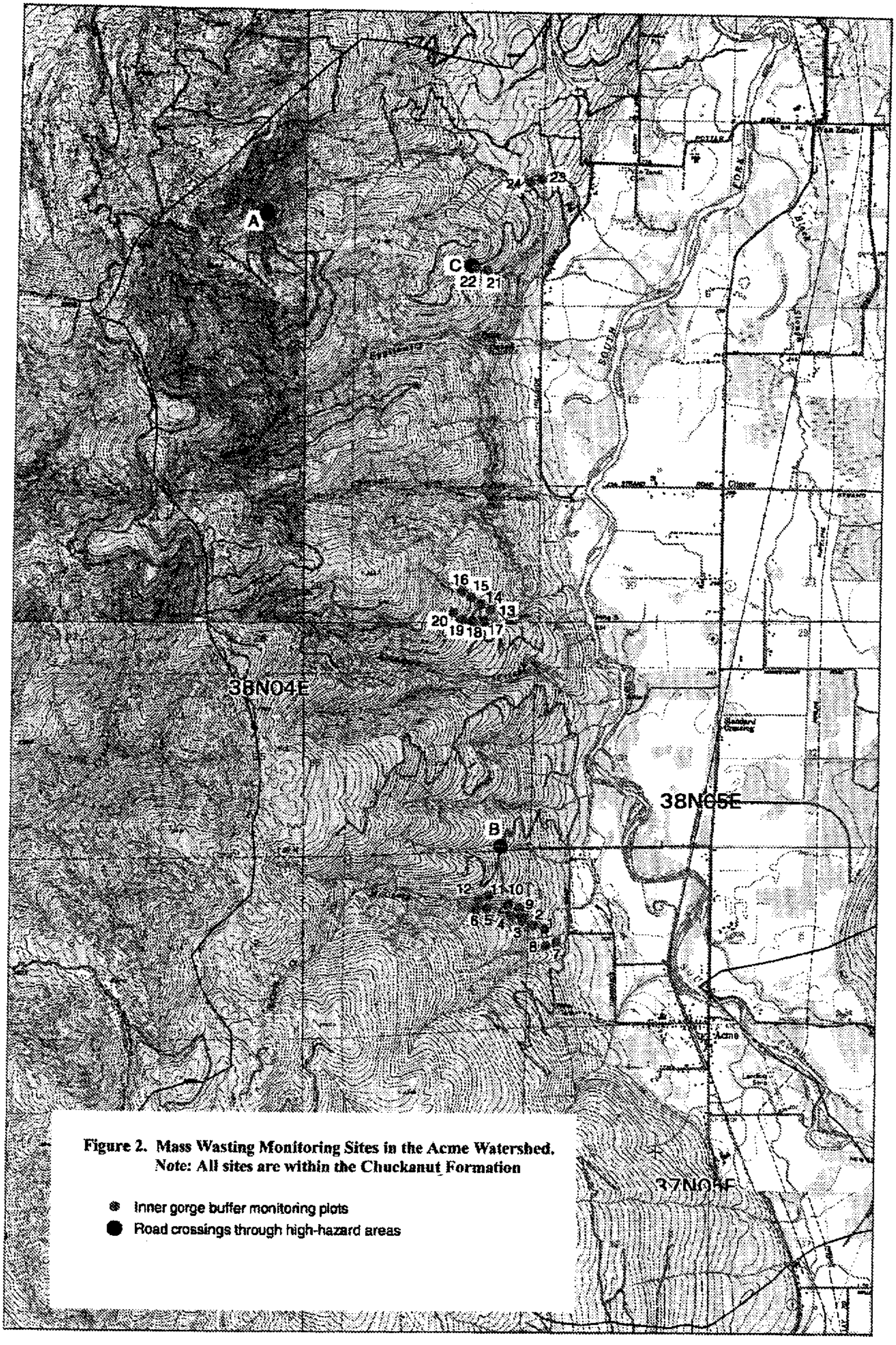
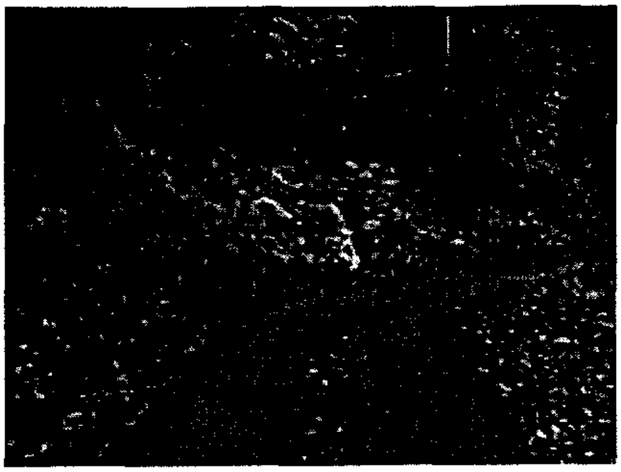
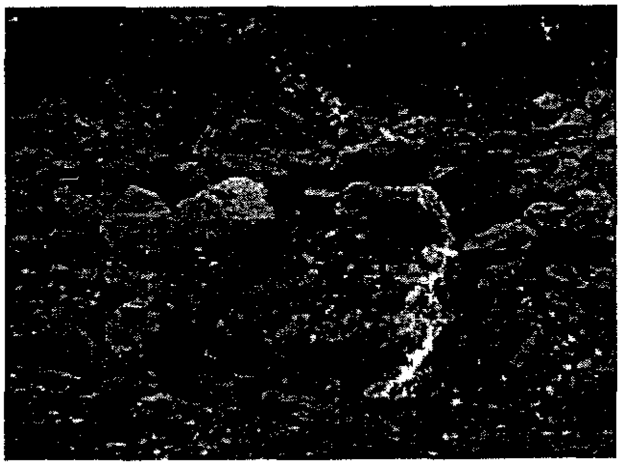


Figure 2. Mass Wasting Monitoring Sites in the Acme Watershed.
Note: All sites are within the Chuckanut Formation

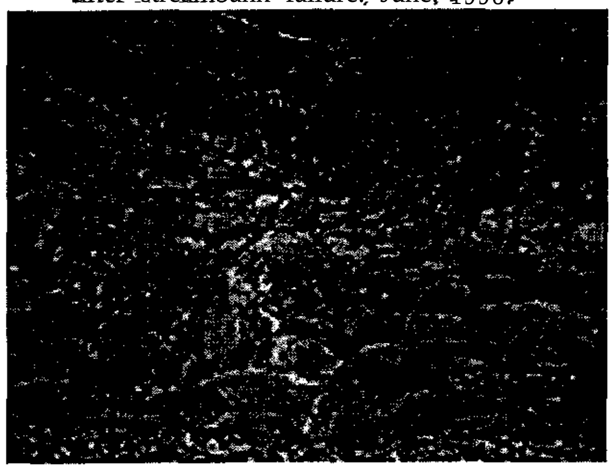


Approach from South (Landslide #193).

Upstream from crossing #193. Note forester for scale. Photo taken shortly after streambank failure., June, 1998.



Same shot as top right after importing rock to place along the failure surface



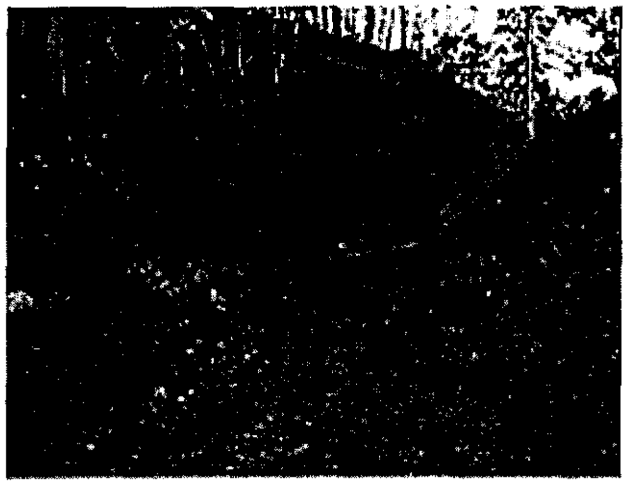
Looking upstream from crossing #194.

Approach from south (crossing #194). Note wall and rock imported for erosion control.

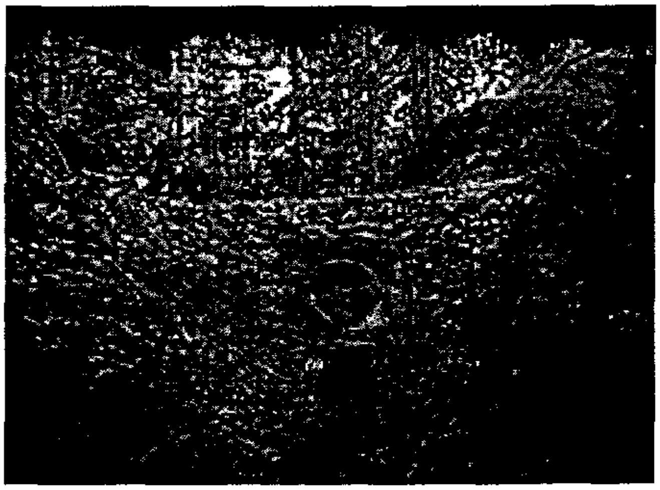
Approach from north (crossing #194).

Figure 3. "East Mainline" Road Reconstruction Project Across Todd Creek Headwaters (photos taken 11/98 unless otherwise noted).

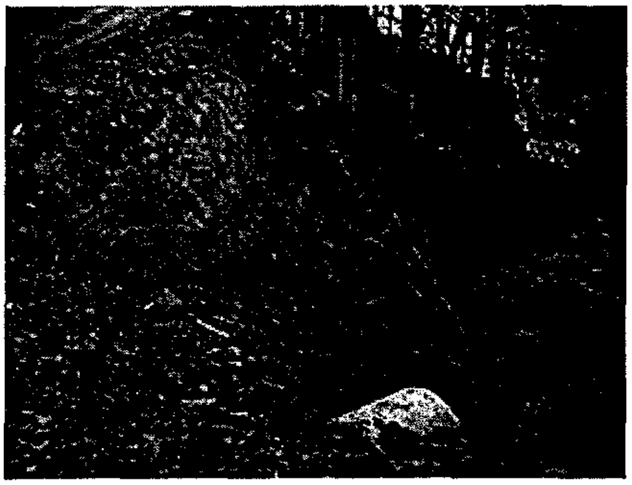
Approach from North.



Approach from South.



Upstream Looking Downstream



From Center of Crossing Looking Downstream.

From Center of Crossing Looking Upstream.

Looking Upstream at Culvert

Figure 4. Inner Gorge Road Crossing in spar Tree Unit - Tributary to McCarty Creek.

Plot A from within the clearcut unit.

Into Buffer Plot A at the lower comer.

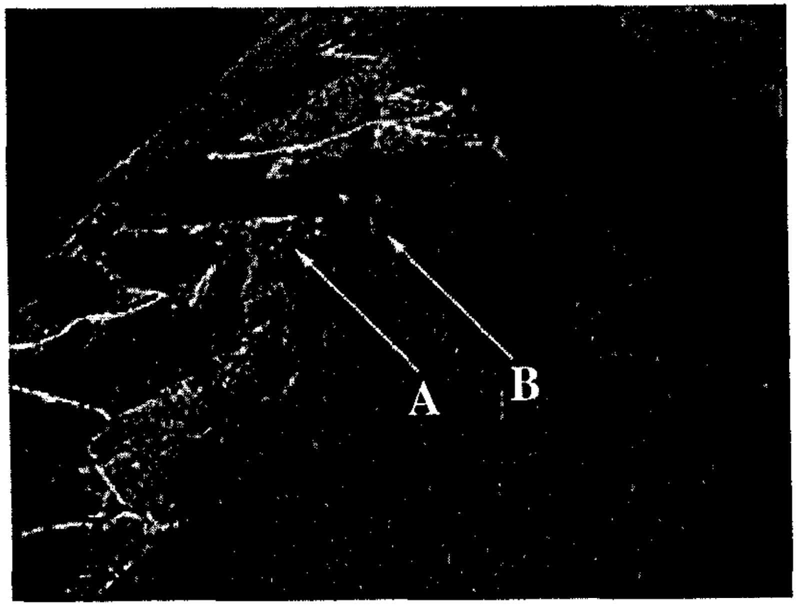
Along the edge of Buffer Plot A from the lower comer.

Plot B from within the clearcut unit.

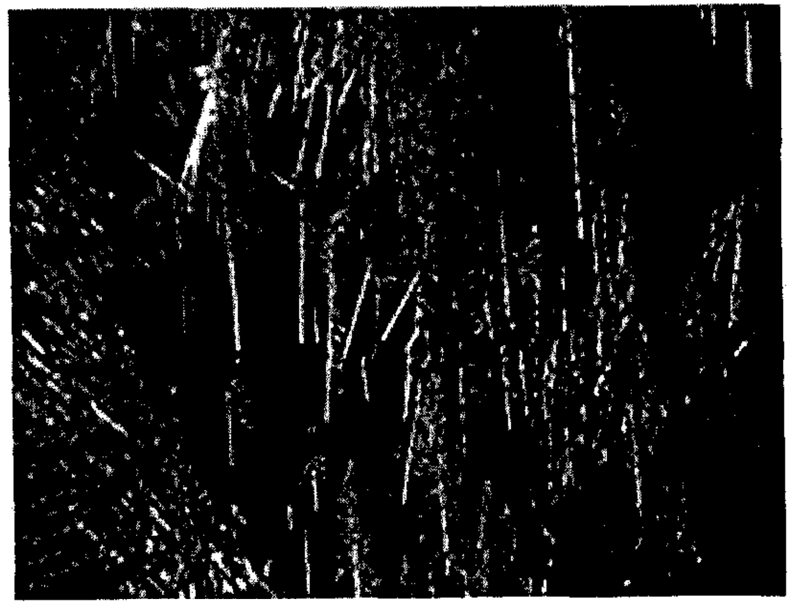
Along the edge of Buffer Plot B from the upper comer.

Into Buffer Plot B at the upper comer.

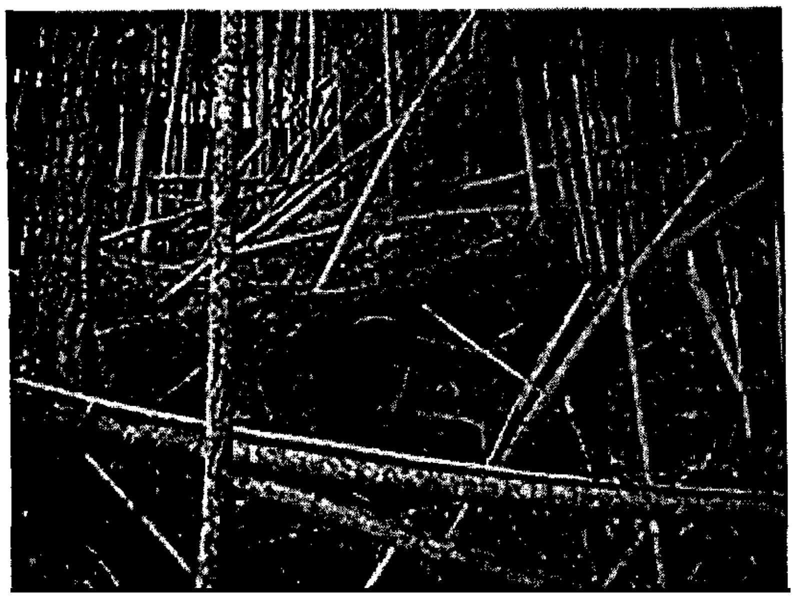
Figure 5. Lower McCarty Mass Wasting Buffer Monitoring Plots S and 6 (A and B, 866-966m).



"Hardscrabble" Unit - Headwaters of Oak Park Creek.



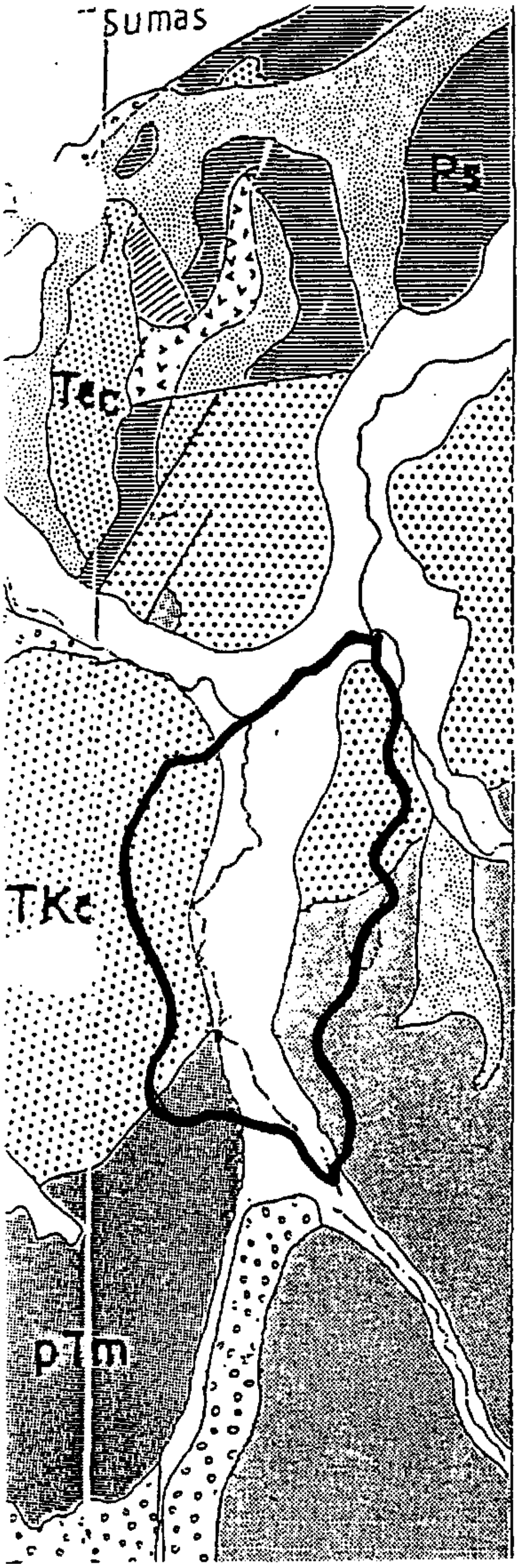
Zone A: Wind triggered failure on a protected bedrock hollow.



Zone B: Stream protected with a mass wasting buffer bit by the wind.

Down in Zone A looking up the hollow axis at the failure surface.

Figure 6. 1998 Wind Damage to Areas of Resource Sensitivity Protected Under Acme WA Mass Wasting Prescriptions.



Qr — Recent alluvium of streams, spits, and deltas

Qs — Outwash deposits of Late Pleistocene Sumas Stade; terrace deposits

Qe — Glaciomarine drift of Late Pleistocene Everson Interstade; also minor till, ice-contact deposits, and outwash.

Tec — Eocene continental rocks; Huntingdon Fm. sandstone and shale

TKc — Late Cretaceous-early Tertiary continental rocks: Chuckanut Fm. sandstone, shale, and conglomerate

Ms — Mesozoic sedimentary rocks; mostly graywacke and shale

Ps — Late Paleozoic sedimentary rocks; mostly graywacke, limestone, chert, and shale

pTm — Pre-Tertiary metamorphic rocks; mostly phyllite with some greenschist, serpentine, and metagraywacke

pTu — Pre-Tertiary serpentine and peridotite

Figure 1 Geologic map of the Acme WAU (from Easterbrook, 1971).

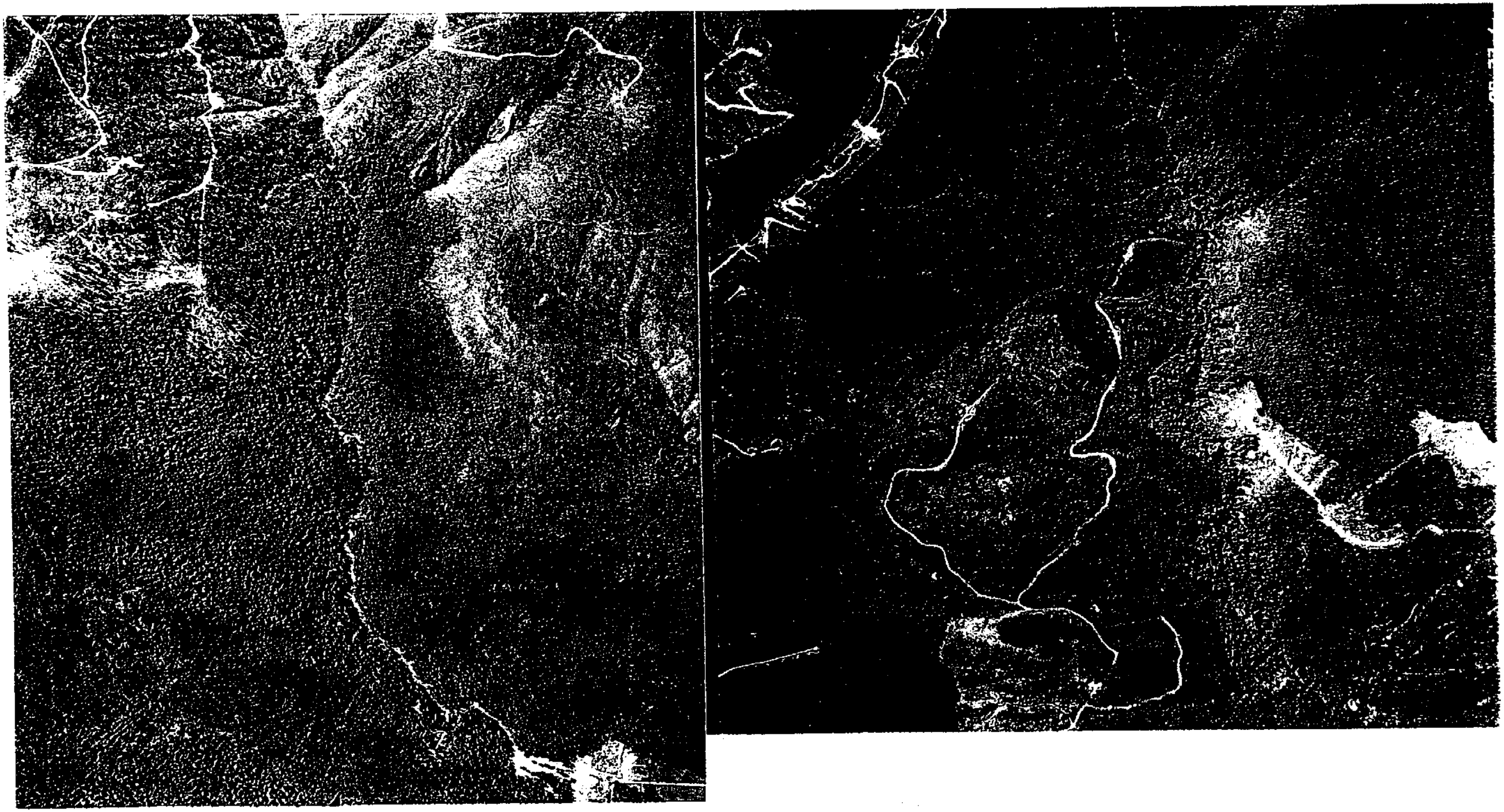
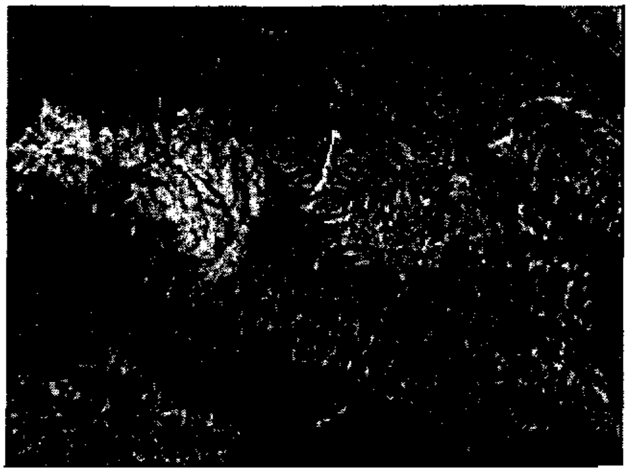
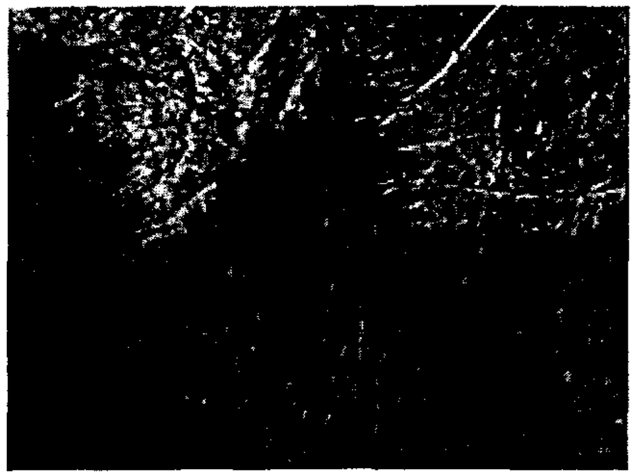


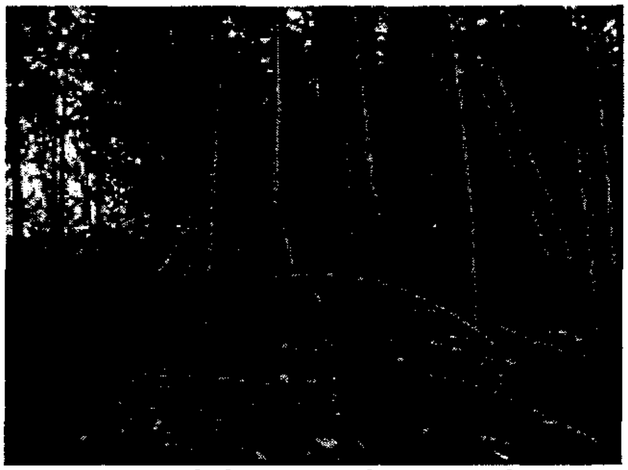
Figure 8. 1950's (left) and 1998 photos of the Jones Creek Basin. Note the town of Acme in the right corner. The creek flows west to east, and north is to the right.



Looking North at Jones Creek in the foreground and McCarty in the distance. Lower Jones Forest Practice in center.



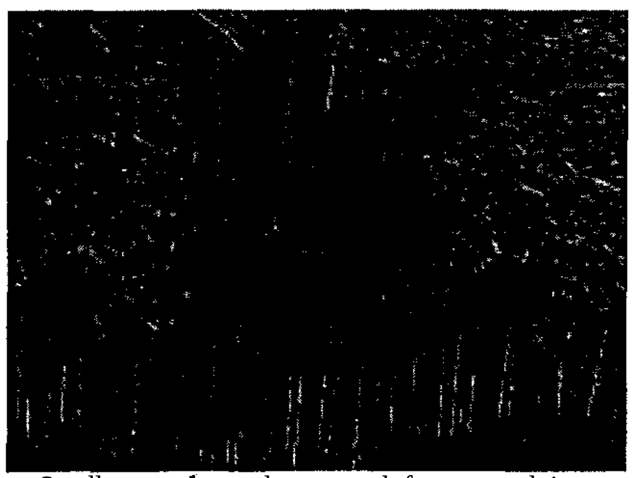
Close up of the larger deep-seated feature and its protected Groundwater Recharge Zone (GRZ) in Lower Jones FPA.



Wind damage to the protected GRZ onto the road crossing, Lower Jones FPA, Dec-1998.

Looking up at the wind thinned GRZ protection area from the road.

Active toe of the larger deep-seated landslide in the Lower Jones FPA.



Smaller, upslope deep-seated feature and its protected GRZ in the Lower Jones FPA.

Figure 9. Deep-seated Landslides in Jones Creek Treated Under AWA Prescriptions.

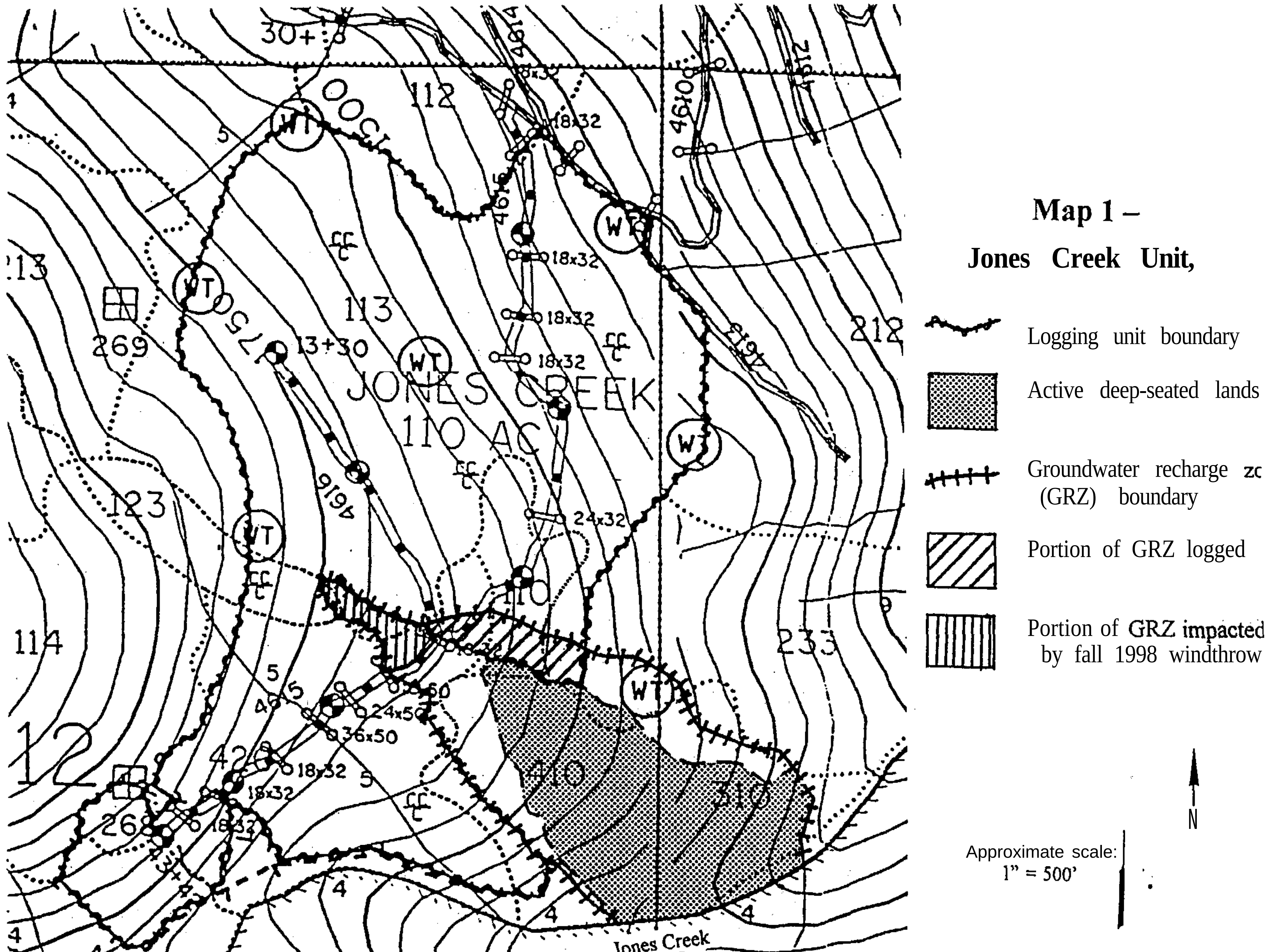


Figure 10. Lower Jones FPA.

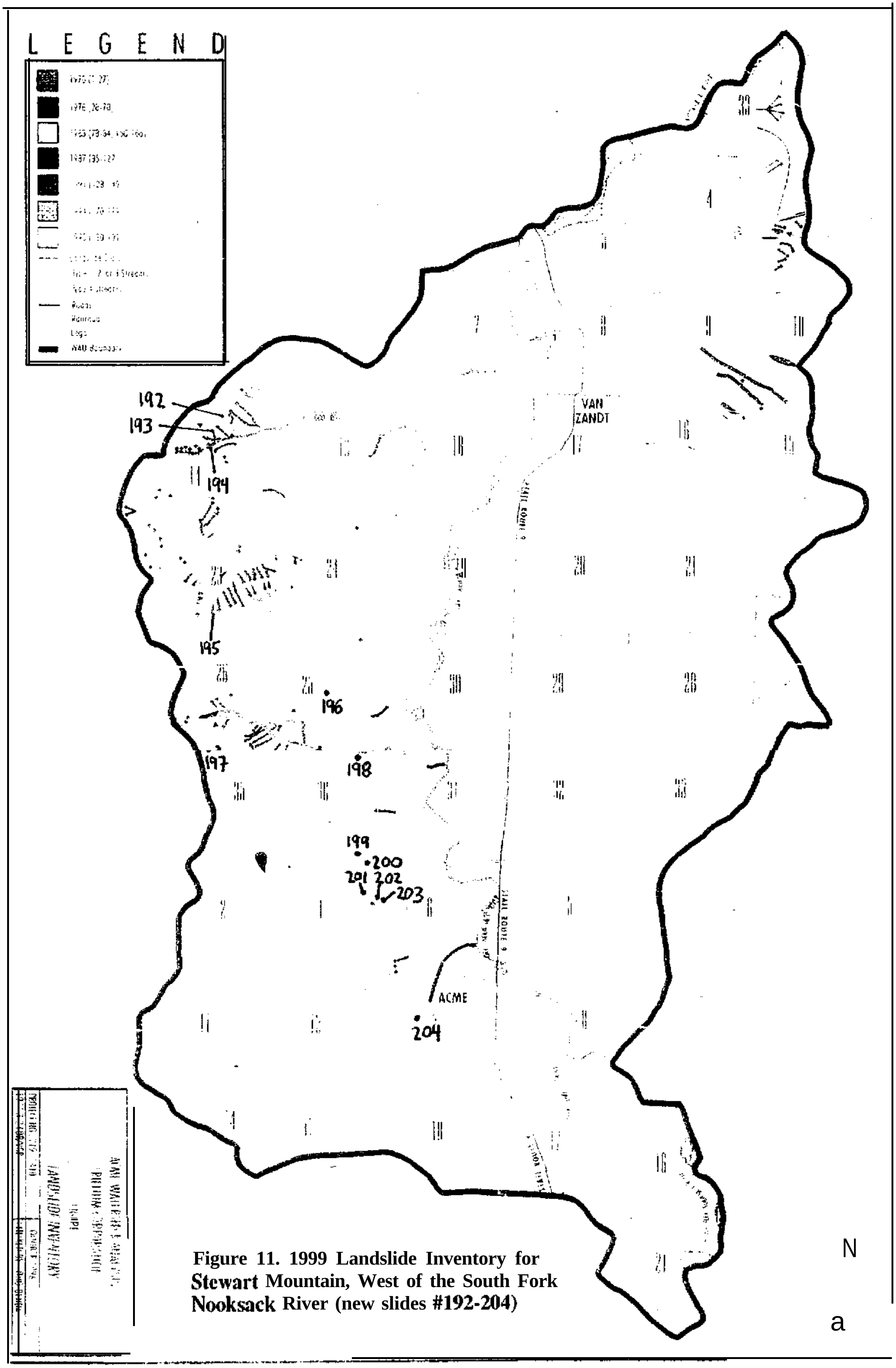
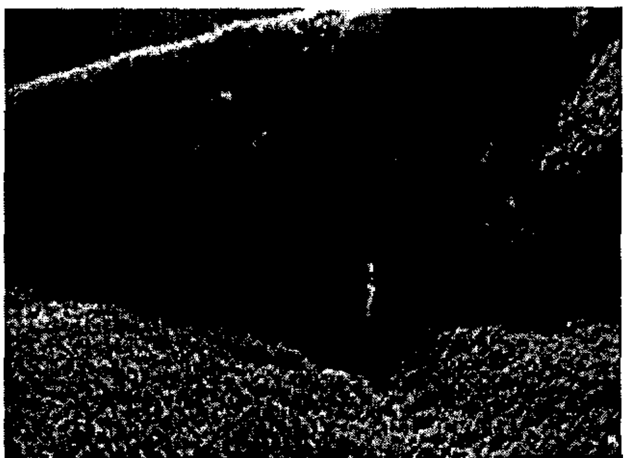


Figure 11. 1999 Landslide Inventory for Stewart Mountain, West of the South Fork Nooksack River (new slides #192-204)

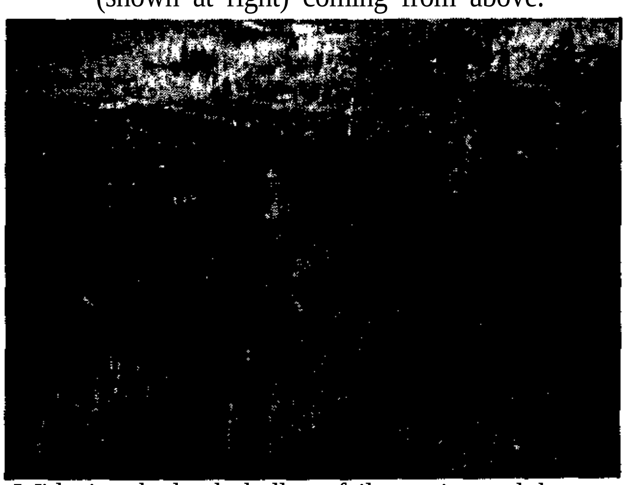
Wind triggered failure on a mass wasting buffer. State lands on Standard Creek (Landslide #198).

Looking down into the landslide shown at left, with delivery into Standard Creek.



South face, north fork Standard Creek. Old road failures as well as a new slide (shown at right) coming from above.

Initiation point of recent debris flow into Standard Creek (Landslide # 197). Note clearing, top right.



Widening bedrock hollow failure triggered by excessive drainage off a 5 year old spur. Direct delivery to the S.F. Nooksack (Landslide #178).

Re-activation of a slide off the inactive "Fish Hook" road, south side Sygitowicz Creek (Landslide *#195)*.

Figure 12. Landslide Activity on Stewart Mountain (photographed in late 1998).