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FIELD TRIP GUIDE:

GEOMORPHOLOGY AND HYDROLOGY IN THE H. J. ANDREWS EXPERIMENTAL FOREST, WESTERN CASCADES

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INTRODUCTION

The H. J. Andrews Experimental Forest comprises the entire 6,100 ha Lookout Creek drainage about 60 km east of Eugene in the McKenzie River basin (Figure I). This area was established as an Experimental. Forest in 1948 by the USDA Forest Service. Management of the Forest was carried out jointly by two arms of the U.S. Forest Service--the Willamette National Forest and the Pacific Northwest Forest and Range Experiment Station. Research activities during the first two decades of the Forest focused on problems in applied forestry such as regeneration, design of road networks, logging systems engineering, and management impacts on soil erosion and water quality. During this period about 20 percent of the Forest was clearcut and road right-of-way (20 m width) was developed over about 3 percent of the area. In the past decade, use and management of the Forest have included two aditional areas of emphasis: (1) basic research on the forest and stream ecosystems, and (2) baseline monitoring of key environmental variables and ecosystem properties.

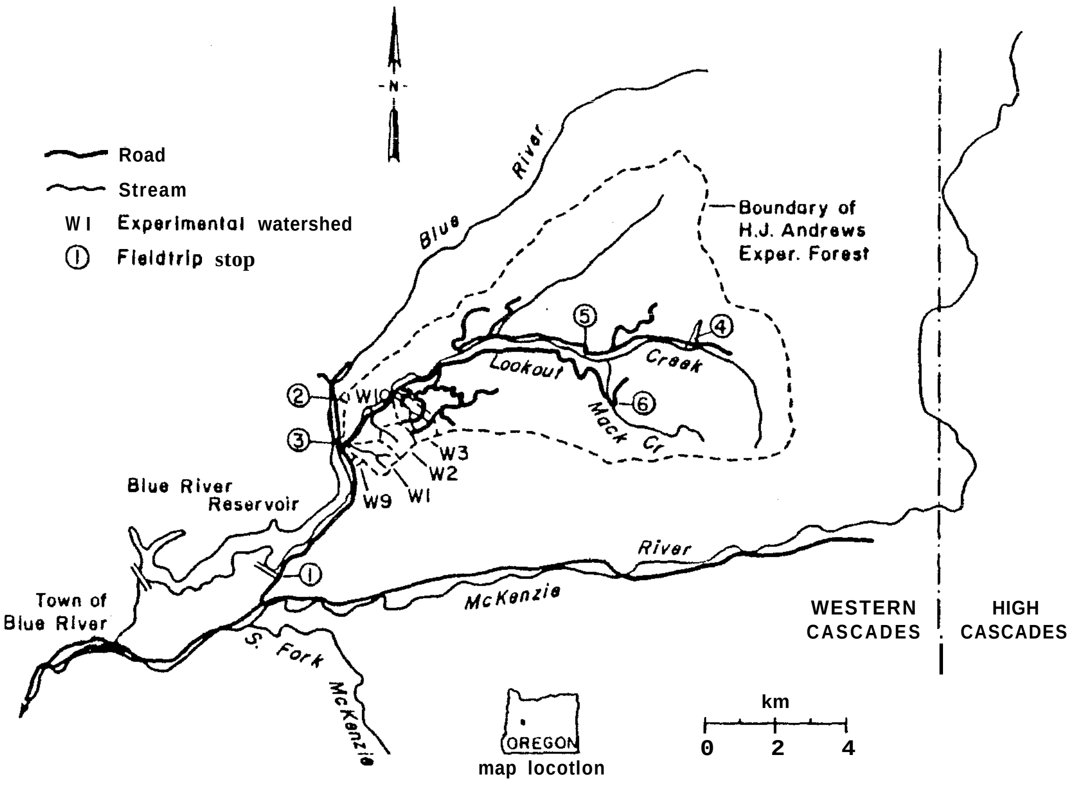

Figure 1. Location map.

Much of the basic ecosystem research has occurred since 1969 when the Forest became a primary slte for research by the Coniferous Forest Blome of the U.S./International Biological Program funded by Natlonal Science Foundation. Many of the studies started under the Blome program led to the numerous ongolng research activities currently supported at a level of more than $1,000,000 per year by U.S. Forest Service, National Science Foundation, Oregon State University, and other organizations. Use of the Forest for long-term monitoring of environmental and ecological parameters has been formallzed by its designation as (1) a site in UNESCO's Biosphere Reserve Program (1974) and (2) the first Experimental Ecological Reserve (1977) established by the National Science Foundatlon. Monitoring activities include standard meteorology observations, stream discharge and water chemistry monitoring, and periodic sampling of vegetation plots, stream organic debris, and channel cross-sections.

Although most of the basic and applied forest ecosystem research and baseline monitoring activities in the Forest are biologlcal ly oriented, geomorphology and soils research have been an important part of the studles since the early 1950's. Steep terrain, mass movement-prone soils, and dense forest vegetation set the stage for many lnteresting lnteractions among vegetation, geomorphic processes, and forest practices. Research on these lnteractions occurs at three scales: (1) forest-wide Inventories of mass movement features, (2) small. watershed studies of sediment sources and yields, and *(3)* measurements of rates of Individual processes (Tables 1 and 2). This field trip exarnlnes geomorphlc features and processes at each of these scales.

GENERAL CHARACTERISTICS OF THE ANDREWS FOREST

The Andrews Forest lies at the east margin of the western Cascade Range In terraln described on an early map as "heavily timbered ridges separated by immense ravines" (Pengra, 1863). The Forest is predominantly timbered with 400 to 500 year-old stands dominated by Douglas-fir (Pseudotsuga menziesii), western hemlock (Tsuga heterophylla), *and* western redcedar (Thuja plicata). Portions of the watershed were burned partially or fully in about 1840, and the headwaters of Mack Creek burned In about 1900. The "immense ravine" of Lookout Creek valley stretches from *420* to 1,615 m in elevation and hill slope gradients over 70 percent are common.

Annual preclpltation averages 230 cm, 80 percent of which falls between October and April durlng long-duration, low-intensity frontal storms. Snow is common at low elevations, but rarely persists longer than 2 weeks and generally melts in several days. Permanent winter snowpack occurs above 1,000 to 1,200 m elevation. Major floods typically occur as a result of rain augmented by snowmelt.

Soils Inthe area have loamy surface hirizons, ranging from silty-clays to sandy and gravelly loams. Because of aggregation of primary soil particles by organic matter and other agents, porosity of surface soils is 60 to 70 percent, over half of which is macropore space (Ranken 1974). Subsoil porosities are also high, ranging from 50 to 60 percent, of which about 20 percent is macropore space. The pore-size distribution of the soil accounts for two important hydrologic properties: (1) all water enters the soil and travels by subsurface flow to streams (Harr, 1977), because soil permeabilities are up to several hundred times greater than rainfall rates, and *(2)* soil is able to retain *30-40* cm of water in Its top 120 cm (Dyrness, 1969) which Is an Lmportant water source for the dense forest vegetation during the dry summers. These conditions of high soil permeability combined with steep slopes cause headwater streams to respond very quickly to changes in rainfall l rate (Harr, 1977).

Bedrock at elevations below about 850 m is composed of a varlety of hydrothermally altered volcaniclastic rocks of the late Oligocene to early Miocene Little Butte Formatlon (Peck et al., 1964, Swanson and James, 1975a). The western end of the Forest is cut by numerous steeply dipping, northwest-trending dikes. Little Butte Formation rocks are overlaln by ash flow and basaltic andesite lava flows of the Miocene Sardine Formation which crop out up to elevations of about 1,220 m. Ridge crests along the eastern and southern boundaries of the Forest are capped with thick andeslte lava flows with K-Ar ages in the range of about *4* to 6 million years.

Table 1. Experimental watersheds in the H. J. Andrews Experimental Forest. Forests in watersheds 1, 2, 3, 9, and 10 were 400 to 500 year old Douglas-fir — western hemlock stands. Watersheds 6, 7, and 8 were 100-130 year old Douglas-fir stands.

Watershed no.	Area (ha)	Elevation (m) Min.	Max.	Management history	Water & sediment yield, start of record W[1/]	C	S	B
1	96	460	990	100 percent clearcut (1962-1966)	1953	1962	1957	1957
2	60	530	1,070	Control	1953	1962	1957	1957
3	101	490	1,070	6 percent roads (1959) 25 percent clearcut (1963)	1973	1962	1957	1957
6	13	880	1,010	100 percent clearcut (1974)	1964	1972	1972	--
7	15	910	1,020	100 percent partial cut (1974)	1964	1972	1972	--
8	21	960	1,130	Control	1964	1972	1972	--
9	9	425	700	Control	1967	1969	1969	1973
10	10	425	700	100 percent clearcut (1975)	1967	1969	1969	1973

1/ W = water discharge; C = water chemistry, typically N, P, K, Ca, Na, Mg; S = suspended sediment, C and S sampled with grab samples and pumping proportional sampler (Fredriksen, 1969); B = bedload sampled in ponding basin.

Table 2. Erosion process studies in the H. J. Andrews Experimental Forest

Erosion process monitoring

Process	Sites	Methods	Duration of record
Creep	Both straight and hummocky slopes	Inclinometer tubes	1969 to present and shorter
Earthflow	One site, upper Lookout Creek	Stake arrays, inclinometer tubes, crackmeter, theodolite survey	1974 to present 1974 to present 1976 to present 1976 to present
Surface erosion	Steep slopes in WS1, WS9, WS10, and other forest sites	Collector boxes, 0.5 and 2.4 m long	1974 to present and shorter
Channel changes	6 sites, small to large streams	Monumented cross-sections	1978 to present

Forest-wide inventories of mass movement processes

Process	Sites	Methods	Duration of record
Debris avalanches	All of Andrews	Ongoing inventory of events 75 m^3	1950 to present
Slump-earthflow	All of Andrews	Field and air photo analysis	Some features 6,700+ yrs.

Holocene deposition of thin tephra units completes the history of accumulation of volcanic material in the Lookout Creek drainage. Mazama ash with fragments up to about 1 cm diameter rained over the Andrews area about 6,700 radlocarbon years ago. Average thickness of lnitlal alrfall deposlts was probably on the order of 1 cm. Fine-grained (<1 mm diameter) basaltic tephra erupting from the Sand Mountain area (Taylor 1968) probably fell on portions of the Forest about 3,000 radlocarbon years ago. The Mazama ash, weathered to a distinctive yellow color, fell in sufficient abundance to be a useful time marker in analysis of some geomorphic surfaces in the area.

Landscapes of the Andrews Forests have been sculptured by glacial, fluvial, mass movement, and other hill slope processes (Swanson and James, 1975a). Details of glaclal history of the area have been obscured by subsequent erosion and redistribution of glacial landforms and deposits. The origin of bouldery deposits In the area is commonly ambiguous. For example, nearly identical bouldery diamictons can be produced by glacial, volcanic, and mass movement processes; and combinations of these three types of processes may all operate on a single batch of earth material. So the glaclal hlstory of these areas of the western Cascades has been poorly kept due to rapid removal of the record by other geomorphic processes and presence of anistropic rock types that do not form neat glacial landforms In the first place.

Despite these difficulties glacial processes have clearly lnfluenced higher elevation, north aspect parts of the Lookout Creek drainage (Crandell, 1965, Swanson and James, 1975a). Cirques were formed by small alpine glaciers on the north slde of ridges higher than about 1,370 m elevation. Valley wall and bottom glaclal deposits derived from headwaters of the Lookout Creek drainage extend as far down valley as about 660 m elevation. The lower end of Lookout Creek dralnage was also influenced by dammlng of lower Blue River by glacial Ice in the main McKenzie Rlver valley (Swanson and James, 1975b). The ice dam backed water up into the mouth of Lookout Creek, causing deposition of fine grained, varved quiet water sediments.

Mass movement processes have created distinctive wide spread landforms. Slump-earthflow features, produced by slow, deep-seated mass movements, cover over 25 percent of the landscape In the lower elevation half of the forest underlain by volcaniclastlc rocks (Swanston and Swanson, 1976). The heads of most large earthflow features are located at geologic contacts where hard lava flow bedrock caps softer volcaniclastlc rock. About a third of the slump-earthflow areas has been active In the past century based on disrupted growth of trees; and some areas are currently active during each wet season. Even the most active earthflows in the area are heavily forested.

Slump-earthflow areas typically have subdued relief, hummocky ground and deranged drainage systems. Active features have open tension and shear cracks, split and tilted trees, and very lrregular drainage patterns and channel cross-section geometry. At low flow stream water goes undergound where crack systems lntersect stream channels. On flows that have been dormant for progresslvely longer periods of time there is less evidence of disrupted vegetation and drainage systems. Some earthflows in the Forest have deposfts of Mazama ash in poorly drained depressions, suggesting that the hummocky ground existed 6,700 years ago.

Steep terrain in areas of volcaniclastic bedrock and associated soils has been sculptured largely by debris avalanches. These rapid soll mass movements are Initiated from the headward tips of incipient drainage depressions ("hollows" of Dietrich and Dunne, 1978), from streamside areas, and infrequently from smooth slopes. Events are commonly triggered as a result of high precipitation on wet soil conditions, and multiple windthrow of trees may also be a contributing factor on forested sites. Debris avalanches are a major mechanism for transfer of soil from slump-earthflow features to streams. Slump-earthflow movement oversteepens the toes of deep-seated failures and causes them to encroach on streams, thus aggravating bank cutting and debris avalanche potential (Swanson and Swanston, 1977). Debris avalanches also take place on the steep headwall areas of some slump-earthflow features.

Small, steep channels in the lower elevation half of the Forest area are also subject to mass movements termed debris torrents. Most debris torrents (82 percent of 38 inventoried events) are initiated as debris avalanches from hillslopes which enter channels and maintain their momentum downstream until they are stopped by obstructions or bends in the channel or simply by decreasing channel gradient (Swanston and Swanson, 1976). Some debris torrents start in channels as a result of flotation of organic debris. Many torrents move through first–order channels and can travel up to a kilometer downstream into lower second– and upper third–order channels, The scouring and exposure of bedrock by debris torrents probably contributes to the incised appearance of many first– through third–order channels in the area. Many small streams are flanked by 2 to 8 m high steep banks of colluvium and bedrock.

Other hillslope processes transport soil from slopes to channels in the Forest, but do not create large scale landforms. Sheetwash and rill erosion are trivial on all but severely disturbed sites due to low precipitation intensities and high lnfil tratlon rates. Surface erosion by dry ravel, throughfall and rain drop impact, and freeze–thaw processes is significant on steep slopes. Root throw is also an important soil transport process which does create distinctive, though small scale, landforms. Soil mantle creep and transport of material in solution are subtle, but important, pervasive processes in this terrain.

Fluvial processes, of course, have played important roles in shaping the landscape of Lookout Creek basin. Streams are steep and development of fluvial landforms has been constrained by influences of bedrock, hillslope mass movement processes, and large organic debris derived from adjacent forests. Significant development of flood plains and terraces occurs along streams larger than third–order. Remnants of alluvial fans are located at junctions of smaller streams with fourth– and fifth–order streams (Swanson and James, 1975b). The coarse scale of jointing in the volcanic bedrock produces large clasts that become the boulders and cobbles covering much of the streambed area.

Sediment yield from forested parts of this landscape are at the low end of the range for mountainous terrain. Anderson (1954) estimates *48* T/km2/yr of suspended sediment yield for the McKenzie River basin, based on samples collected In 1949 and 1950 before much development had occurred. Sediment yield from small forested watersheds in the Forest ***is*** about *40* T/km^2/yr composed of dissolved, suspended, and bedload sediment In order ***of*** decreasing contribution to total yield (Fredriksen and Harr, 1979, Swanson et al., in press). Removal of vegetation by wildfire and logging results in increased soil erosion and sediment yield (Fredriksen and Harr, 1979, and others).

STOP 1. SADDLE DAM OF BLUE RIVER RESERVOIR

This stop provides an overview of the geographic, geologic, and geomorphic setting of the field trip area and environs (Figure 1). To the north we look across the Blue River Reservoir and into the Blue River drainage. We are on a low divide with the westward flowing McKenzie River south of **us.** The Lookout Creek drainage and the Andrews Experimental Forest meet Blue River at the head of the reservoir.

We are in the western Cascade geologic and physiographic provinces. Bedrock is comprised entirely of Pliocene and older volcanic and subvolcanic intrusive material , and landforms have been shaped by erosional processes. The boundary with the High Cascades lies about 20 km east of this spot. Steeply dipping, north–trending, normal faults which are down–dropped on the east form the boundary. The High Cascades are predominantly a constructional volcanic landscape formed during the past two million years.

During the Pleistocene, Blue River drained directly into the McKenzie River through this saddle dam area (Swanson and James, 1975b). Pre–latest Wisconsin glaciers from the High Cascade platform and from the South Fork McKenzie River basin flowed down the main McKenzie River valley and blocked the mouth of Blue River. This ice dam formed a lake 30+ m higher than maximum reservoir level and diverted the lower Blue River to its present course. Drilling in the saddle dam area by the Corps of Engineers revealed more than 60 m of glacial deposits forming a natural saddle dam below the man-made saddle dam.

Till, outwash, and varved lake sediments are exposed In the dam area. A wood sample from these deposits is more than 40,000 radiocarbon years old. Along the drive up the east side of the reservoir we pass kame terrace deposits on the valley wall above the road. Bedrock exposed in road cuts is predomicantly propylitical ly altered, green, laharic breccias cut by numerous vertical, northwest-trending dikes.

STOP 2. WATERSHED 10

Watershed 10 (WSIO) has been the principal study site of the Oregon phase of the Coniferous Forest Biome research. This 10 ha watershed is probably the most intensively studied piece of ground of this scale in the western hemisphere. Research since 1969 has examined hydrology, vegetation, nutrient cycling, aquatic biology, and geomorphology under both forested and recovering clearcut conditions. The *400* to 500 year-old stand of Douglas-fir, western hemlock, western redcedar, and other tree species (Crier and Logan, 1978) was clearcut with directional falling with jacks and yarded with a skyline system in the summer of 1975. Heavy residues were yarded to the landing and hauled away or burned there. Limb-sized material was hand-cleaned from the channel and piled above high flow line. The overall logging operation was designed to follow practices used in standard Forest Service operations at that time. Companion WS9 about 1.5 km south is maintained in the forested condition as a control.

Geomorphology research in WSIO is comparing erosion under forested and clearcut recovery conditions. We do this by developing erosion budgets, comprehensive assessments of soil and sediment movement by al 1 significant erosion processes. The soil/sediment routing system is viewed as movement of material down slopes and channels from one temporary storage slte to another. Storage sites include shallow depressions on slopes that ultimately fall by debris avalanching (Dietrich and Dunne, 1978) and wedges of sediment stored behind logs In streams. Transfer processes between storage sites range from debris avalanches that typically occur on a few percent of the watershed once every few centuries to watershed-wide persistent processes such as surface erosion and solutlon transfer (Table 3).

Table 3. Process characteristics and transfer rates of organic and lnorganic material to the channel by hil l slope processes (T/yr) and export from the channel by channel processes (T/yr) for Watershed 10.

Process	Frequency	Area influenced (% of watershed)	Material tranefer: Inorganic	Material tranefer: Organic
Hillslope processes				
Solution transfer	Continuous	99	3	0.3
Litterfall	Continuous, seasonal.	100	0	0.3
Surface erosion	Continuous	99	0.5	0.3
Creep	Seasonal.	99	1.1	0.04
Root throw	1/yr	0.1**	0.1	0.1
Debris avalanche	1/370 yr	1-2**	6	0.4
Slump/earthflow	Seasonal*	5-8%	0	0
TOTAL			10.7	1.4
Channel processes				
Solution transfer	Continuous	1	3.0	0.3
Suspended sediment	Continuous, storm	1	0.7	0.1
Bedload	storm	1	0.6	0.3
Debris torrent	1/580 yr	1	4.6	0.3
TOTAL			8.9	1.0

*Inactive in past century in Watershed 10
**Area influenced by one event.

An erosion budget has been prepared for Watershed 10 in old-growth forest conditions (Table 3). Methods of generating these estimates are described by Swanson et al. (in press). Such a budget provides a basis for comparing processes. For inorganic matter transport the mass movement processes are very important, although they are estimated to occur less frequently than 1 per 300 years under forest conditions, (Note: there are many difficulties in making these estimates, including the dominance of the 30 year record by events triggered in a single storm of a probable return period much greater than 30 years.) The most persistent process, solution transfer, is also very important.

We are now observing changes in the rate of each erosion process during the post-clearcut recovery period. Each transfer process and storage site in the soil/sediment routing system is regulated by a different combination of vegetative factors. Root strength, for example, affects debris avalanche potential, and presence of an organic litter layer moderates surface erosion. Consequently each erosion process has a different response to clearcutting and revegetation.

Substantial increases in suspended and bedload export occurred following logging. Sediment yield is limited by (1) availability of sediment for transport and (2) availability of flowing water, the transporting medium. Snowmelt peak flows from WS10 were actually delayed and smaller the first winter after logging, but rain generated peak flows were not affected significantiy (Harr and McCorison, 1979). Changes were attributed to differences in short term snow accumulation and melt. Increased sediment yield has come from increased availability of material from three sources: (1) material input to the channel during the logging operation itself, predominantly fine organics, (2) sediment that entered the channel and was stored behind large debris before logging, but was released from storage when logs were removed in the yarding operation, and (3) soil from post-logging accelerated hillslope erosion.

Erosion monitoring facilities on the watershed include inclinometer tubes, 0.5 m wide surface erosion collectors along the stream perimeter, 2.4 m wide surface erosion collectors on upslope sites, monumented channel cross-sections, sediment ponding basin, and stream gaging facility with proportional pumping sampler (Fredriksen, 1969) for water chemistry and suspended sediment sampling.

STOP 3. EXPERIMENTAL WATERSHEDS 1, 2, AND 3

These watersheds have long, documented histories of land use, research activities, and erosion (Fredriksen 1963, 1965, 1970, Fredriksen and Harr 1979). WS1 was clearcut between 1962 and 1966 using a skyline yarding system and slash was broadcast burned in a hot fire in 1966. WS3 had clearcuts of 5, 9, and 11 ha logged with high lead cable systems and slash was broadcast burned. Roads totalling 2.66 km were built at three levels in the watershed in 1959. Water and sediment yield, precipitation, and vegetation have been monitored since before logging (Table 1, Fredriksen and Harr, 1979, Dyrness, 1973). WS2 has been maintained as a control.

Vegetation removal caused several changes in streamflow characteristics. Removal of forest vegetation reduced both interception and transpiration, allowing more precipitation to leave the watershed by streamflow rather than evaporation. At WS1 initial increases in annual water yields were 45-50 cm, about 75 percent of which occurred during the winter rainy season (Rothacher 1970). Yield increases are diminishing as revegetation proceeds. Summer flows were increased 3-5 times the first few years after logging, but owing to rapid growth of riparian vegetation, such increases have disappeared (Rothacher, 1971). Changes at WS3 have been smaller because of less extensive logging in that watershed.

After logging, peak flows in fall and spring increased up to 2 times because soil water storage remalned high due to reduced evapotranspiration (Rothacher, 1973). Large peak flows in winter were largely unchanged because (1) soils in logged and unlogged areas are both recharged by this time and respond similarly to Precipitation, and (2) the hydrologic properties of soil were not altered to the extent that surface runoff became slgnlflcant. On other experimental watersheds in western Oregon, where soil disturbance and compaction by roadbuilding and tractor yarding were much greater than on WSI, size of peak flows has been increased (Harr et al., 1975, Harr et a1., 1979).

Variation of annual suspended and bedload (material trapped in sediment basln) sediment yields among watersheds has been great. In the flrst 14 years following cutting and burning WS1 has yielded 12 times as much particulate matter as WS2. Much of thls lncrease has come from accelerated debris avalanche eroslon after clearcuttlng. Seven debris avalanches (>75 m^3 each) moved soll down slope between 1964 and 1972. About 75 percent of the volume of soil moved by debris avalanches came from sites of current or past slump–earthflow activity, emphasizing the importance of lnteractions between these two types of processes, Surface eroslon processes, particularly dry ravel, also ln-creased substantial ly (Mersereau and Dyrness, 1972), but most sites of accelerated surface erosion have returned to rates more typical of forested areas. Soil whlch has entered the channel systems after logging has been routed slowly downstream through the numerous large logs and alder (Alnus rubra) and willow (Salix spp.) riparian vegetatlon. Despite burnlng and some physical removal of sediment–trapping organic matter from the main channel, much cf the soil eroded from slopes after logging is stil I stored In the channel system.

WS3, on the other hand, experienced very rapid release of sediment. Most debrls avalanche activity in the watershed was related to roads, principally fill slope fallures (Fredriksen, 1963, 1965, 1970). The masses of fill material entered steep headwater channels and moved rapidly downstream sweeping up a1luvlum, colluvlum, and streamslde vegetatlon along the way. Thls series of debris torrents in the major December 1964 storm moved about two–rhlrds of the total particulate matter export from **WS3** over the first 17 years after logging and road construction. About 80 percent of export for the perlod occurred in two days. Total post–logging yield has been about 90 times that of control WS2.

The debris torrent hlstorles of WS1 and WS3 have determined the contrasts in thelr sediment yield histories. The road fill failures at the heads of long, steep, stralght channels initiated debris torrents which flushed the WS3 channel system. **No** torrents have flushed the WS1 channels because of a variety of factors, including debris avalanche location in the watershed. WS1 debris avalanches have not had sufflclent velocity, volume, and stralght down–channel trajectory to trigger debris torrents. Annual sediment yield from **WS** 1 now exceeds yield from WS3 as sediment **1s** slowly released from storage in the lower WS1 main channel and as soil is eroded from an actlve earthflow in the upper part of the watershed.

STOP 4. LOOKOUT CREEK EARTHFLOW

Thls 900 m long and 150 m wide earthflow **1s** moving south into Lookout Creek at an average rate of about 10 cm/yr (Flgure 2, Swanson and Swanston, 1977). Bedrock **is** a variety of volcanlclastlc materials capped by a basalt flow whlch **is** the source of blocks formlng the talus slope at the headscarp. Except for two small clearcut areas, the earthflow ***is*** forested, mainly with *400* to 500 year–old trees in the lower half while most trees on the upper half were established following a wildfire In the mid–1800's.

The earthflow landscape **is** irregular with scattered steep (>60%) slopes, whlch probably represent vegetated scarps, and many low relief areas, including poorly drained depressions, Drainage pattern and channel cross-sectional geometry are very Irregular. The earthf low can be dlvided into three active blocks In the lower half of the whole earthflow. Each block **is** bounded by open, lateral shear cracks and a tenslon crack system across the head (Figure 2). The upper half of the earthflow does not appear to have been actlve in the last century or so, based on stralght growth of trees in that area.

Earthflow movement **is** monltored wlth (1) stake arrays (strain rhombs) across actlve cracks to measure relative surface movement between blocks, (2) lnclinometer tubes for

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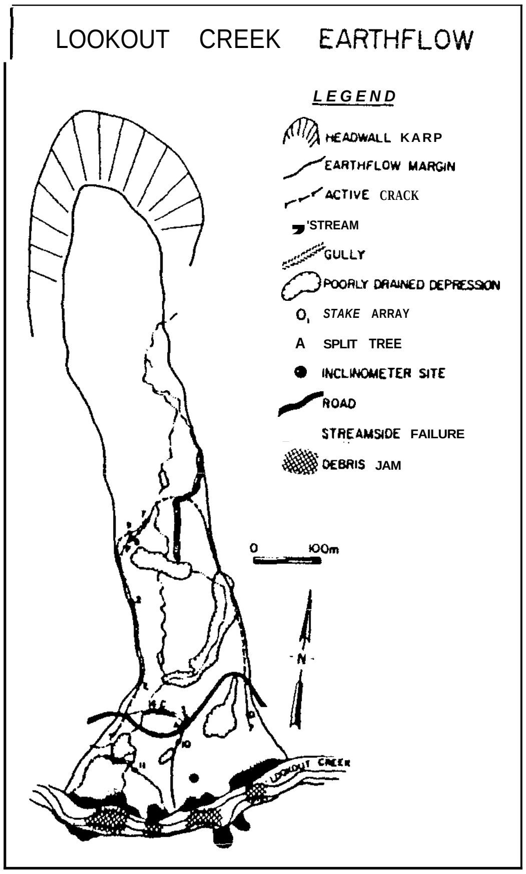

Figure 2. Map of Lookout Creek earth-Plow. Mapped by G. W. Lienkaemper (from Swanson and Swanston, 1977).

monltoring vertical velocity proflles, (3) crackmeters to record contlnuously the opening of crack systems, (4) theodolite surveys of points on the earthflow from stable reference points off the earthflow, and (5) analysis of tree rings in scar tissue on live trees being split up the middle because they straddle an active crack (Swanson and Swanston, 1977). Water lnputs in rain and snowmelt and groundwater levels are also contlnuously recorded, so that movement–water input relations can be examined. The purpose of the work is to gain a basic understanding of earthflow behavior so we can better assess impacts of management actlvitles on this erosion process.

The five year record of annual movement from repeat surveys of stake arrays reveals large year–to–year differences in movement, determlned by water lnputs durlng current and previous years (Table 4). Very little movement occurred in the 1976–1977 drought year, and this dry period appears to have also caused low total movement rate in the next year. Movement in 1978–1979 was twice that in 1977-1978, although the more recent perlod had 20 percent less preclpitatlon.

Table 4. Stake array measurements of movement of Lookout Creek earthflow. Stake array 2 measures movement relative to stable ground. Arrays 3 and 6 measure relative movement between two movlng blocks. Preclpltatlon data are from WS2 meteorology statlon.

Stake array	Earthflow Movement (cm/yr) 1974–1975	1975–1976	1976–1977	1977–1978	1978–1979**
2	9.6	14.2	0.2	6.1	13.1.
3	5.0	8.6	0.7	3.9	9.2
6	no data	5.9	0.7	2.8	5.9
Total precipitation (mm) Oct. I–June 1.	2225	236 1.	'1.049	2125	1707

*Located on Fig. 3
**Movement data for this year are preliminary

Comparison of crackmeter and precipitation records indicates tlght control of movement rate by water availability (Figure 3). Movement at this slte does not begin in the fall until nearly 90 cm of raln has fallen, Once the system is primed with water, movement continues at a slow rate until spring except for periods of accelerated movement in response to storm periods of water input in excess of about 12 cm/24 hr.

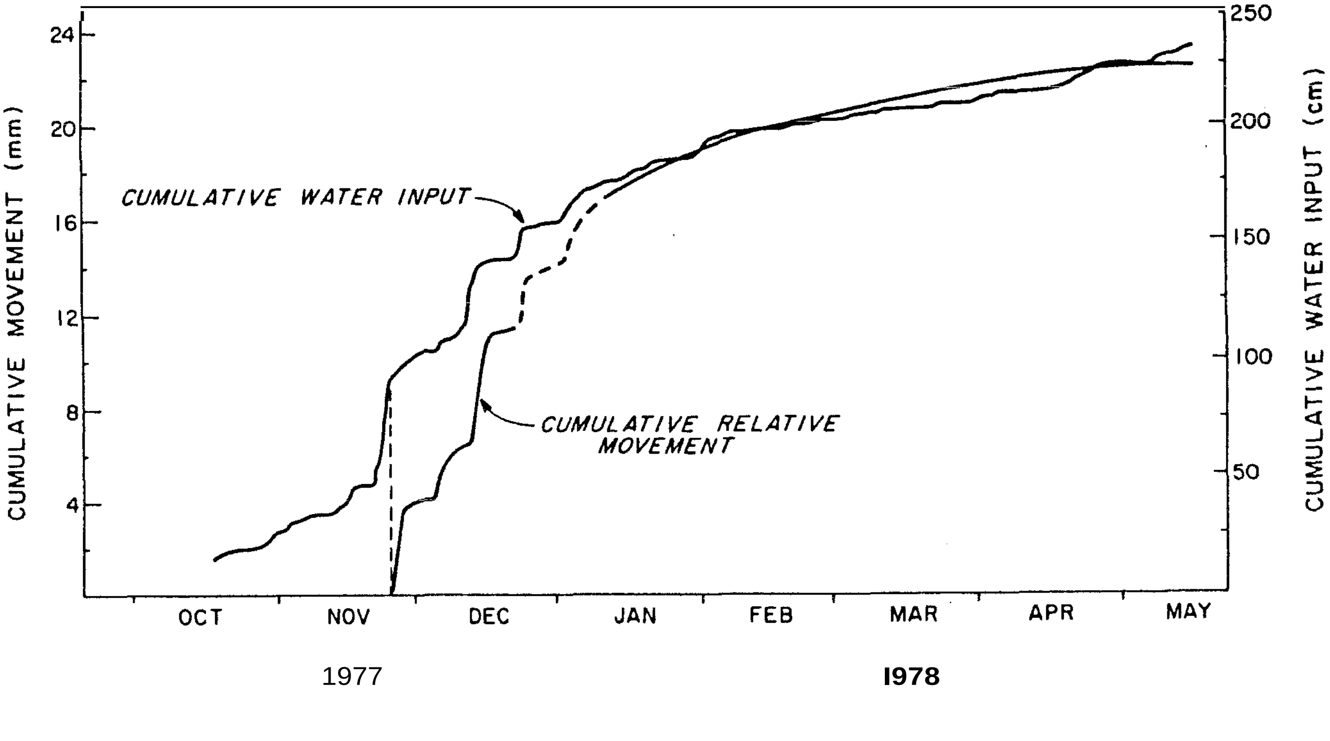

Figure 3. Cumulative water input and relative movement at crackmeter located at slte 6 (Fig. 2). Movement curve is dashed for period when only total movement is known.

Sediment delivery to Lookout Creek occurs by bank cutting and streamside slides after long periods of earthflow movement constricting the channel.. The last major episode of sediment input to Lookout Creek from this earthflow was during the December 1964 and January 1965 floods.

Earthflow movements can affect the structure and species composition of forest esosystems. For example, differential movement near stake arrays 7, 8, and 9 (Figure 2) has tipped and split trees, leading to much windthrow, many holes in the canopy, and a multileveled forest with abundant understory vegetation. Close upslope, in areas of no recent earthflow movement, the canopy of Douglas-fir and western hemlock is complete, heavily shading lower levels of the forest and, thereby, greatly limiting understory development.

STOI 5. REVEGETATING DEBRIS AVALANCHES AND TOI S TES

This road backslope failed in 1957, entered the channel below the road, and this material moved as a debris torrent downstream to Lookout Creek. The slide scar was planted. with Douglas-fir seedlings many of which survived; but they have stunted growth and a chlorotic condition from growing in the nutrient deficient subsoil. The torrent track is now a lush stand of alder overtopped by a few black cottonwood (Populus trihcocarpa).

More than 140 such debris avalanches moving greater than 75 m3 of soil have occurred from forested, clearcut, and road right-of-way sites since 1950 (Dyrness, 1967, Swanson and Dyrness, 1975). Al I but two events began in soil derived from volcaniclastic bedrock, indicating the strong control of bedrock and soil types on slope stability. In the debris avalanche-prone part of the Forest, rates of debris avalanche erosion from clearcuts and road right-of-way exceed the forest rate by 2.8 and 31 times respectively, based on rates calculated by dividing soil volume moved by 28 years and by the area in each land status at the end of the record. This estimate of management impact on debris avalanche erosion is similar to results of other studies in the Pacific Northwest (Swanston and Swanson, 1976).

This method of measuring management impacts can result in substantial under- or overestimates. Management impacrs may be overestimated because (a) forest rates are used as the natural debris avalanche erosion rate, but the actual natural rate should include periods of accelerated erosion following natural disturbances such as wildfire, (b) in the case of roads, analysis on this time scale assesses impacts of some road construction, site location, and maintenance practices no longer employed, and (c) management impacts are only temporary and there may be a one to two decade period of accelerated erosion followed by a long interval of debris avalanche erosion at rates lower than in older forested areas. If (c) is true, cutting may affect the timing of debris avalanche erosion more than the overall long term rate. On the other hand, management impacts for general National Forest land may be underestimated by Andrews Forest data, because logging and roading have generally been conducted with the highest contemporary standards. Furthermore, intensity of timber harvest activities Ln the Forest has declined markedly since the mid-1960's. These estimates of impact are also conservative because the calculation method uses area in each land status at the end of the inventory period. This is the time of smallest forested area and largest clearcut and road right-of-way areas. Since we divide total volume of soil moved by debris avalanches for the period by these area terms, the forest debris avalanche erosion rate is overestimated and road and clearcut rates are underestimated.

There is need for assessment of debris avalanche impact on long term timber productivity. This involves determining both landscape area impacted by debris avalanches and the recovery of productivity on these sites. General observations suggest that area affected is less than a few percent of the landscape, even in debris avalanche-prone areas; but recovery rate may be so slow that at least one rotation of timber production may be lost.

STOP 6. MACK CREEK

The adjacent clearcut and forested reaches of Mack Creek have been sites of intensive stream ecosystem research since the early 1970's, including studies of conditions and roles of large organic debris in streams. Large woody debris derived from the adjacent forest shapes aquatic habitats, provides nutrients, cover, and substrate for aquatic organisms, and regulates movement of sediment, particulate organic matter, and water through the stream system. Consequently, natural or man-imposed changes in debris conditions affect physical and biological functions of streams,

Debris conditions vary with stream size. Concentrations of coarse woody debris (>10 cm diameter) generally decrease downstream where wider channels have greater transport capability and the canopy is open over the stream, so input of large woody debris is lower. Large debris in first- and second-order streams is randomly distributed along streams, and is generally located where it initially fell, because the stream is too small to move it. Intermediate-sized streams, such as this third-order section of Mack Creek, can move some large pieces of debris at flood flows, but not whole down trees. Therefore, these streams have scattered, distinct acciumulations, many of them affecting the full channel width. Large rivers can transport all debris that enters them and they deposit this material high on the banks and on upstream ends of islands. This material then affects the stream only at high flow.

We have studied the history of large debris in Mack Creek by dating log input to the stream with tree-ring analysis (Swanson et al., 1976) and by following changes in debris conditions through time. Generally we have observed scattered inputs during wind storms and this material moves and accumulates on the large, stable debris jams during very high flow events. Maps made in 1975 of Mack Creek above the road crossing (Figures 4 and 5) can be compared with the distribution of logs today to get a measure of variability of debris conditions. Much of the change occurred during a high flow event in November 1977. The main accumulations which were keyed on large, down, old growth trees (MA-13 and MA-16) have remained intact with minor modification. Accumulation MA-I4 appears to have washed out because the main piece had decayed and partially collapsed under its own weight. It was, therefore, hit directly, broken up, and washed downstream by the high flow. So in streams of this size, debris conditions change as a result of new inputs, redistribution during high flows, and the slow, continual process of wood decomposition.

Monitoring of this site will continue on a long term basis. Changes are observed by annually mapping any new or moved pieces and by repeat surveys of monumented channel cross-sections. Changes in the adjacent forest will be followed by annual checks of a map showing standing and down live and dead trees in a 2-ha area straddling the creek. Debris conditions in streams of other sizes of the saiie forest type, and some flowing through younger stands, are being monitored at other sites in the area.

Reprints of cited papers and other literature on research in the H. J. Andrews Experimental Forest are available through the authors or the Resident Manager, H. J. Andrews Experimental Forest, P.O. Box 300, Blue River, Oregon 97413.

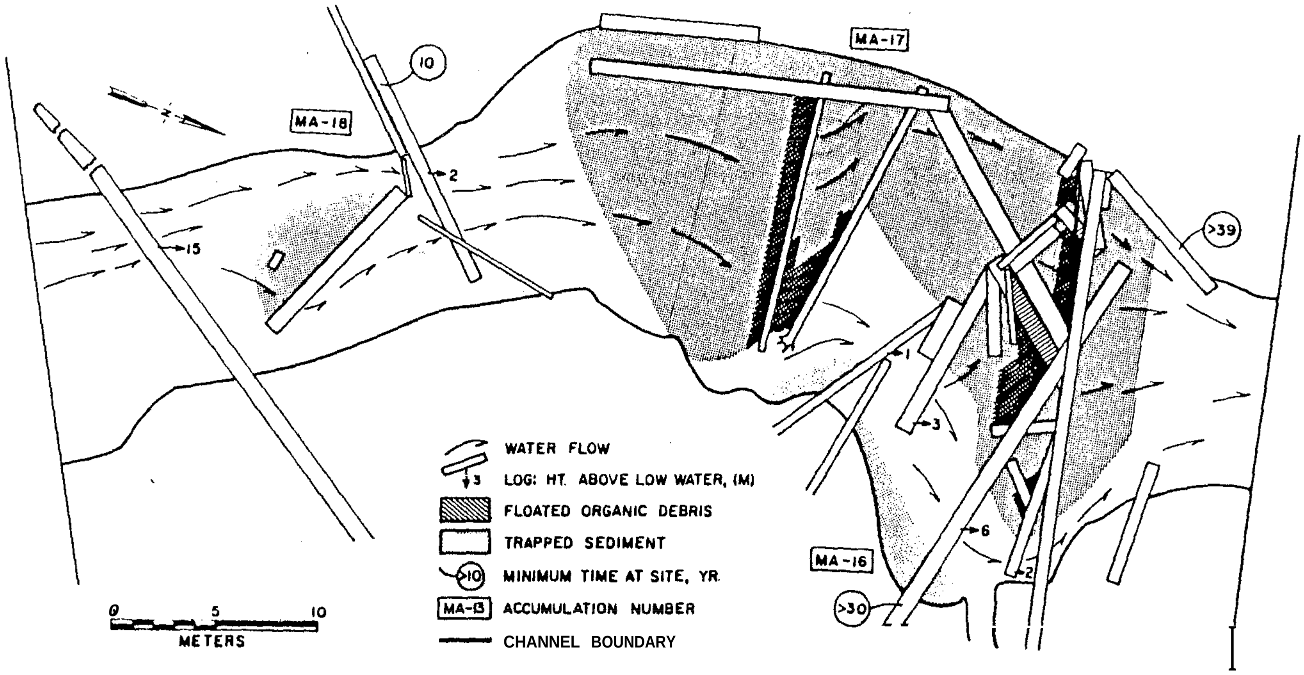

Figure 4. Map of large organic debris and other material. in 1975 in section of Mack Creek upstream from section in Figure 5.

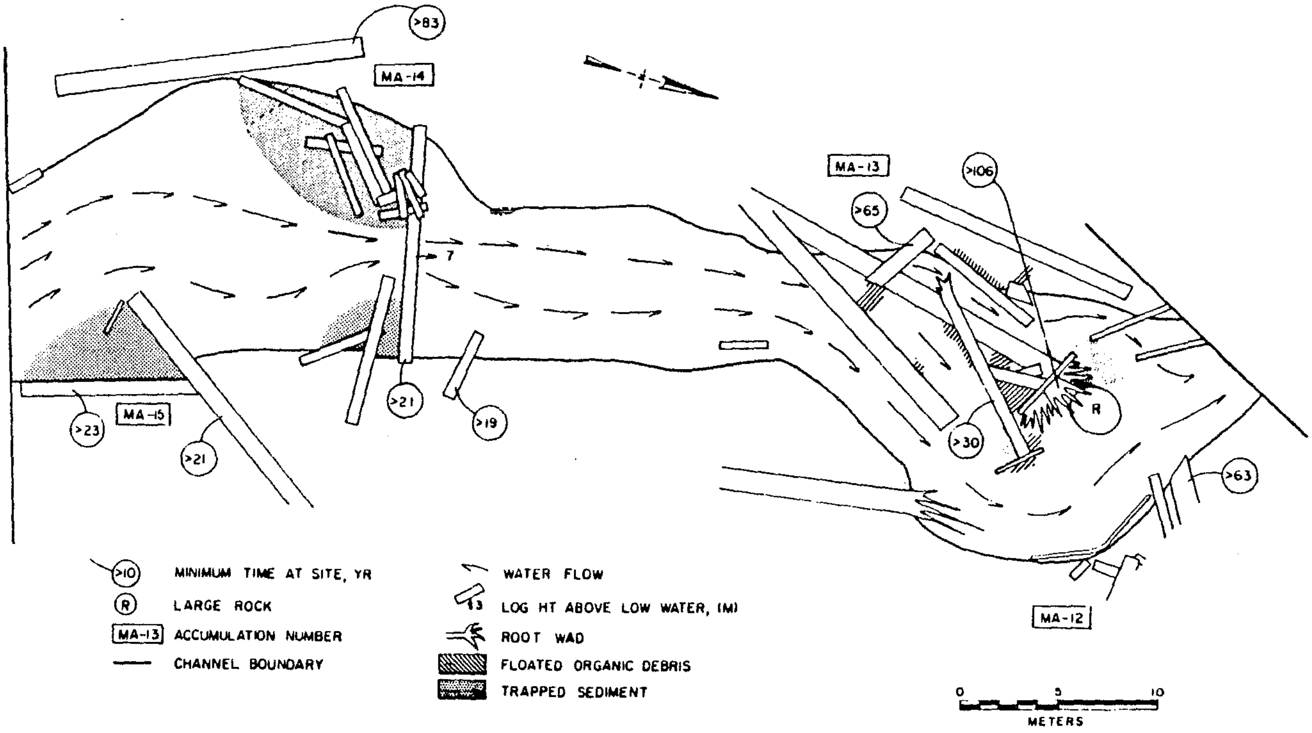

Figure 5. Map of stream section downstream of section in Figure 4. Maps by G. W. Lienkaemper (from Swanson et al., 1.976).

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