Oregon Department of Forestry

FOREST PRACTICES MONITORING PROGRAM

NOVEMBER 1996 STORM IMPACTS MONITORING PROJECT

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November 1997

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Introduction

This November 1996 Storm Impacts Monitoring Project is an extension of the February1996 Storm Impacts Monitoring Project implemented by the Oregon Department of Forestry (ODF) in the summer of 1996. Preliminary results from this project are inconclusive in terms of determining a link between specific forest management practices and landslide frequency. The November 1996 storm in southwestern Oregon has provided an opportunity to repeat the basic study design from the previous year and attempt to verify and clarify preliminary findings from the 1996 Storm Impacts Monitoring Project.

Preliminary results from the February 1996 project

Landslide frequencies (#/acre) were calculated for the Mapleton and Vida (red zone) sites, using the following age class categories: 0-5, 5-10, 10-30, 30-100, and 100+ years. The "background rate" is assumed to be the landslide frequency associated with unmanaged, mature forests. In terms of the ODF study, the background rate is that of the 100+ year-old age class category (exclusive of road influences). For the Mapleton site, the 5-10 year stands had a landslide frequency that was approximately double the background rate, while the 0-5 year stands were somewhat less than background. In the Vida study area just the opposite occurs. The 0-5-year stands had approximately double the background rate, while the 5-10 year stands were somewhat less than background. Both sites consistently showed landslide frequencies below background levels for those stands between 10 and 100 years in age. In general the pattern supports the following preliminary hypothesis for landslide frequency over time following harvest: There is an increase in landslide frequency at some time during the first 10 years after harvest. This increase is followed by a drop below background levels between 10 and 100 years and a return to background levels sometime after 100 years following harvest.

Specific Objectives

The November 1996 Storm Impacts Monitoring Project will attempt to verify the general long-term pattern that was observed in the February 1996 storm consistent with two red zone sites. This monitoring project will also attempt to clarify contradictory findings in landslide frequencies during the first ten years after a clearcut harvest.

Specific objectives include the following:

1. Determine factors influencing the distance traveled by landslide runout such as debris paths and torrents. Determine high-risk criteria for determining the length of channel impacts by landslide runout.
2. Collect sound information on the specific forest practices applied at the sites of landslides, flood-altered streams, and riparian areas.
3. Link hillslope processes and forest management practices to channel responses or lack of responses.
4. Identify specific forest management practices applied in the sample areas and determine if practices were appropriate for the times of the operations.
5. Develop a comprehensive relational database for detailed ODF monitoring analysis and for subsequent cause and effect type research.

Coordination

Similar to the previous storm-monitoring project, this project will be coordinated in part with the involvement of a Coordination Team and a team of four experts representing different disciplines (the Expert Team). The coordination team is composed of corporate and small private landowners, the USDA Forest Service (USFS), researchers, the Bureau of Land Management (BLM), and the Oregon Department of Forestry State Lands Program. The Expert Team is composed of a hydrologist/riparian specialist, geomechanical engineer, aquatic biologist, and a geomorphologist (see Appendix A for members).

Study Design and Methods

The study design and methods will be very similar to that of the previous storm-monitoring project, with only a few minor changes. Each crew made up of two people is assigned one sub-basin at a time to complete within one of the two study areas. The sub-basins are partitioned into stream segments. Using the stream network to search for only those landslides that deliver to the stream channel and associated debris torrents, the crew walks every stream segment and implements the Channel Impacts Protocol (CHIP) until the gradient is greater than or equal to 40 percent. If at a 40 percent channel gradient no torrent impacts are encountered the crew stops collecting channel impacts and large woody debris (LWD) data and moves on to the next stream segment. When torrent impacts and landslide evidence is encountered up to and beyond a 40 percent channel gradient, the crew continues walking upstream in search of the source using the channel impacts and LWD protocol. When the crew reaches the source landslide(s) they document the landslide characteristics and record the location using a global positioning system (GPS) device and manually on a map. The crew also records the location of and collects data on torrent jams and large deposits that were generated during the November storm. The following sections are detailed descriptions of the Landslide, Channel Impacts, LWD, and Torrent Jam Protocols.

Landslide Investigation Protocol

Introduction

This protocol was developed using the information learned over six years of landslide monitoring by the Oregon Department of Forestry. The development of this protocol was also influenced through the review of other landslide investigation protocols, the February 1996 Flood Monitoring protocol, and in consultation with the Expert Team. The field portion of this protocol is designed for use by persons with science and/or resource management training under the direction of geotechnical and riparian specialists. Additional data on land management history will be collected directly from landowners in the study areas.

All landslides (both road and non-road related) that deliver material to channels will be field investigated by the ODF monitoring crews using the channel network to locate the landslides. The crews will collect similar information on landslide characteristics, landform at origin, and soils. Information collected on slope and vegetative alterations from roads and harvesting will be consistent with forest practices requirements.

Methods

Landslide Identification**:** The study area will be inspected for landslides delivering to channels. Landslides include any slope movements where shear failure occurs along a specific surface or combination of surfaces. Some landslides may be less than one cubic yard in total volume, and move less than one-foot down-slope. Other landslides may consist of thousands of cubic yards, moving long distances as subsequent torrents down channels.

All channels within the sample areas will be walked (at least to a 40 percent slope) to identify all points of landslide sediment delivery. Observed landslides will be mapped using a GPS device and manually on a topographic map. Landslides will be found by walking up-slope from the point of sediment delivery and/or debris torrent impacts. Three distinct and separate terms will be used to describe landslide-related impacts in this study. The *landslide* refers to the initial scarp of material on the hillslope or hollow. *Debris path* refers to the subsequent material mobilized by the landslide that is downslope of the initial scarp but upslope of the channel network. *Debris torrent* refers specifically to channel impacts caused by material from the landslide and debris path moving through and being deposited in the channel network.

The principal concerns with the November storm of 1996 impacts are off-site and in-channel effects. Therefore, landslides that enter channels or result in debris paths that enter channels are of principal concern for their effects on water resources. Often a relatively small landslide can have a large effect on the channel down-slope. One of the objectives of this study is to determine what types of slides have the greatest impacts on the channel network and result in adverse effects such as threatening human lives and property and potentially negative impacts on fisheries production.

Efforts will be made to survey only those landslides that occurred during the November storm of 1996. Landslides that are significantly re-vegetated, have consolidated deposits, or which are known through air photos or other means to have moved only in earlier years, will not be included as part of the database for this monitoring project. This past November's landslide scars already have vegetative re-growth on exposed soils, but have less re-growth than older landslides, and can usually be distinguished from older landslides by the presence of unconsolidated landslide or debris torrent deposition. Also, precipitation events occurring in and around the study areas after the November storm were orders of magnitude smaller in intensity, making it unlikely that a significant number of subsequent landslides occurred there.

Terminology**:** Landslides and debris paths will be investigated using the landslide protocol, while debris torrents, torrent jams, and LWD will be investigated with the channel impacts and torrent jam protocol. Debris torrents can usually be traced to the landslide origin. Occasionally, however, there is the appearance of a debris torrent in channels without a landslide origin. Where this occurs the "channel modified" classification will be used (see the Channel Impacts protocol).

A *landslide* is any slope movement where shear failure occurs along a specific surface or combination of surfaces. For this study, landslides are separated from debris paths. Landslides may have a rotational, planar, or irregular failure surface. At the time of landslide initiation, a landslide has a discrete failure surface or surfaces.

A *debris path* occurs if the landslide moves down-slope as a semi-fluid mass scouring, or partially scouring, soil from the slope before reaching a channel. For the purpose of this study, a debris path is the mass soil movement below the initial landslide scarp and up-slope of a channel. Using this definition, debris paths occur only on landforms classified as hillslopes or hollows (i.e. non-channel types of

landforms). Upon entering and continuing down a channel the landslide is considered a *debris torrent*. Debris paths will be sampled within the landslide protocol, while debris torrents will be sampled using the channel impacts protocol. It should be noted that not all landslides will have a debris path, but every debris path will have an associated landslide.

Field Data collection

A GPS device will be used to record the locations of landslides when possible. This, in conjunction with mapping the landslides manually, will allow for the data to be entered into a geographic information system (GIS) and subsequent spatial analysis of the entire data set. Each crew will carry a 35mm camera to record every landslide with a photograph. Each photograph will be recorded on the Photo Record data sheet with a brief description.

Landslide (*LS*): Each landslide will be given a unique number as they are found. One crew will start with 501 and the other with 701.

Stream Segment Number (*Seg*): The segment to which the landslide delivers. (See channel measures protocol.)

Distance (*Dist*): This is the distance along the segment where the landslide or associated debris path enters the channel.

Debris Path Beginning Distance (Bdist): The distance in feet indicated by the hip-chain at the start of the debris path. If the path is in a hollow at the end of a channel segment this distance will be the same as the distance recorded at the last channel cross-section measured. If the path is on a hillslope this distance will be zero (the hip-chain is reset).

Debris Path Average Width (*AveW*): This is the average width of the debris path in feet.

Debris Path Average Depth (*AveD*): This is the average depth of the debris path in feet.

Debris Path Slope (*Slope*): This is the percent slope of the debris path.

Form: There are two general landslide forms evaluated in this protocol, and they are as follows.

1) A *slide (E)* is reasonably close to its point of initiation (materials remain on site).

2) A *slid (D)* has moved completely from the site and may have a debris path and resulted in a debris torrent. It may also be mixed as a torrent jam, eventually residing as channel deposits. A slid that deposits to the channel directly (channel-bank related) will not have an associated debris path.

Type: Landslide type will be evaluated by the following three choices:

1) *Shallow translational (ST)*: Often called debris slides, are slope failures where the failure surface is roughly parallel to the natural ground slope (translational) and the maximum depth to failure surface is usually less than 10 feet. These slides generally move off site (slids).

2) *Rotational (RO)*: Often called slumps, are landslides with a generally rotational failure surface, usually in cohesive material. They have a spoon shape appearance, usually with a pronounced accurate scarp. They generally remain on site (slides).

3) *Other (OT)*: This includes structural translational (block failures), complex slope failure exhibiting several modes of movement, and anything not described above. The geotechnical specialist will investigate these failures. When using this category, detailed notes should be taken to describe the landslide.

Delivery Type (*Torr?*): Record if the landslide resulted in a debris path only (*HO*), a debris path and debris torrent (*HC*), or no debris path or debris torrent (*NO*).

Landslide dimensions: Landslide dimensions will be evaluated by the average landslide width, maximum depth, average depth, and length of the initial landslide, as follows (to the nearest foot):

1) *Begdist* is the distance up the channel segment recorded at the base of the landslide scarp. If the landslide has a debris path this will be the end-distance of the debris path indicated by the hip-chain.

2) *Length* is measured up and down the slope. For length, only the original slide, and not the debris path or other movement is included in this measurement. When length is unknown, as is the case for most slids, the length is estimated based on a change in width or depth of soil.

3) Average *width* is measured across the slope, usually on a contour.

4) *Depth* is a vertical measurement, recorded as maximum (at the center) and the average.

Slope steepness: Measured from the top of the landslide scarp. The "above" measurement is made using a clinometer and sighting to a point at eye height about 100 feet up-slope, while the "below" measurement is made sighting down slope, projected over the hillslope as it existed before the landslide occurred. These are recorded to the nearest 5 percent.

Aspect: Measured in degrees (1-360) using a compass. Stand on the landslide scarp facing down slope.

Drainage Area: Categorize the *plan view (Pview)* shape of the drainage area above the landslide scarp. If there is any hesitation in calling the plan view something other than uniform, it should be called a uniform shape. Only shapes that are obviously concave, convex, or irregular should be classified as such.

1) *Concave (CV)* slopes include *headwall hollows*. This is a concave area in the headwall and most often has an aspect coincident with that of the channel down-slope. This landform is clearly curved inward in plan view and has a valley type appearance. However, there is no defined channel at these locations, as they are often observed close to the ridge-top.

2) *Uniform (UN)* slopes include *hillslopes* adjacent to channels. This is an area high above the channel where the aspect is often perpendicular to the aspect of the channel down-slope. This landform has a relatively uniform slope with no outstanding landform characteristics.

3) *Convex (VX)* slopes are clearly curved outward in plan view. These are often related to old landslide deposits and ridge tops.

4) *Irregular (IR)* slopes are also often related to old landslide deposits, and are evidenced by hummocky, broken terrain with many slope changes.

5) *Other (OT)* includes conditions such as lineaments, contacts, and unusual landforms. When using this classification include specific details in the notes.

Drainage area is determined using a map while at the landslide. Estimate the distance to the drainage divide (*Ridge Dist*) and the average width (*AvgW*) of the area draining to the slide.

Soil Characteristics: Whether or not *bedrock (Y/N)* is exposed is recorded to determine where soil depth and landslide depth is in fact different. The dominant s*oil type* will be identified:

1) *Non-cohesive (N)*: Non cohesive soils include gravel, sand, and fine-grained soils that do not stick together when dry (dry cubes are easily crushed between the fingers).

2) *Cohesive (C):* Cohesive soils are "sticky" and when dry their strength increases greatly (cannot be crushed between the fingers when dry).

Debris Load/Depth: Estimate the amount of organic debris (all sizes) around the perimeter of the landslide scarp using the following categories:

Absent (*AB*)- No visible debris, other than one or two pieces over the entire visible area.

Sparse (*SP*)- A few pieces of debris over the visible area, but no significant clusters.

Non-contiguous (*NC*)- A significant number of pieces, but a majority of the pieces are not touching each other.

Contiguous (*CN*)- Many pieces that are mostly touching each other.

Estimate the depth of debris to the nearest foot in the *Debris depth* column only when using the *contiguous* category.

Slope alterations at source area of landslide: *Slope alterations* are also recorded. These include alterations due to management as well as natural alterations such as *windthrow (W)* or *fire (F)*. If there is a linear *gouge (G)* on the slope adjacent to the landslide which when projected intersects the landslide this is also recorded, as is the presence of a *skidroad (S)* located at the landslide or adjacent to the landslide scar. *Road-related* alterations include landslides originating from, or being influenced by, old (*D*) or active (*A*) roads. This includes landslides in close proximity to a road where road drainage or construction is associated with the failure location. *Other (O)* will be recorded for any other type of alteration not discussed above and details will be recorded in the notes. Where no alterations have occurred *none (N)* will be recorded. There can be multiple entries for this item.

Vegetation: The *height* of the *dominant* commercial vegetation immediately about the scarp is recorded, along with an estimate of the *percent cover* that existed at the location of the landslide scarp prior to the occurrence of the landslide.

Picture Number (*Pic#*): The roll and picture number, along with the crew letter (A or B), is recorded.

Notes: Other information is recorded as necessary to describe the landslide and any unusual observations.

Non-field landslide and forest practices information

The following additional information will be collected for each landslide, after the field investigation:

1. Elevation at the slide origin (GPS; GIS)
2. Drainage area (GIS)
3. Most recent timber harvest (year)
4. Geologic map unit
5. Ownership (State, Federal, Industrial Private, Non-industrial private)

Channel Impact Field Protocol

Introduction

The objective of the channel impacts portion of the storm monitoring will be to document storm effects on stream channels. Primarily the monitoring will examine

possible alterations to channel geometry (channel widening, aggradation/degradation), woody debris loading, scour/depositional patterns, and shade. The channel measurements will be taken in three distinct phases:

Channel impact protocol (CHIP): This includes cursory measurements for stream channels. These include channel type, impact type, slope, impact width, length of torrent, shade, woody debris size and distribution, and classification of scour, depositional, and transitional reaches. CHIP will be implemented on all stream channels.

Field measurements for the channel impacts protocol

As described in the overall methods section, the crews will use the channel network as a means of searching for landslides. They will walk up all channels and stop every 150 feet to sample channel characteristics using the following protocol. All measurements will be at a point, or two-dimensional cross-section, at 150-foot intervals. For low impact channels, the crews will stop when coming to a gradient of 40 percent or greater. When the channel gradient becomes 40 percent or greater before reaching the next 150-foot cross-section, the crew will sample an additional cross-section at the end of that segment. At torrent junctions a revised CHIP will be used to sample that cross-section, where only the junction angle measurements and distance will be recorded.

The crews are encouraged to photograph any channel or debris torrent features that are unusual or unique in terms of severity of impacts. Care will be taken to include an adequate description on the Photo Record data sheet.

Stream Segment Number (*Seg*): Segment numbers are assigned as the field crews survey the streams. One crew begins numbering segments with 101 and the other with 301 and labels new segment numbers on the map as the channels are surveyed. New segment numbers are assigned at channel junctions and for all first-order streams.

Distance: The distance (*Dist*) from landmark in feet measured using a hip chain. This is also the *Dist* for the current interval of LWD data collection.

Landmark: The landmark is the start of a new segment at a stream junction. Record the segment and distance up that segment that is the landmark for the beginning of the segment currently being sampled.

Direction (*Updn*): The crew can move from the landmark in an upstream or downstream direction, and the direction of travel will be noted *(U/D)*.

Landform: This is a description of the average valley landform in the immediate vicinity of the cross-section. It is based primarily on the configuration of the valley floor. Descriptions are divided into the following categories:

1) Narrow Valley Floor has a valley floor width < 2.5 times the active channel width. A narrow valley floor is further categorized as one of the following:

a) Steep V-Shaped (*SV*)- valley or bedrock gorge with at least one of the side slopes >60%.

b) Moderate V-Shaped (*MV*)- valley with at least one of the side slopes between 30% and 60%.

c) Open V-Shaped (*OV*)- valley with side slopes <30%.

d) Filled V-Shaped (*FV*)- valley with considerable fill so that the valley width vs. active channel is greater than 2.5 and yet it still has steep side slopes (>60%).

2) Broad Valley Floor has a valley floor width > 2.5 times the active channel width. A broad valley floor is categorized as having one of the following:

a) Constraining Terraces (*CT*). Terraces typically high and close to the active channel. Terrace surface is unlikely to receive flood flows.

b) Multiple Terraces (*MT*). Surfaces with varying height and distance from the channel. High terraces may be present but they are a sufficient distance from the channel that they have little impact.

c) Wide-Active Flood plain (*WF*). Significant portion of valley floor influenced by annual floods. Any terraces present do not impinge on the lateral movement and expansion of the channel.

4) Fan (*FN*)- This is commonly seen when a steep canyon enters into a broader canyon at tributary junctions.

5) Hillslope (*HS*)- Used only for high impact types, this will indicate the end of the channel impacts and the start of a debris path and/or landslide. The debris flow path occurs on a hollow or hillslope with no defined channel bed and bank.

6) Hollow (*HO*)- Used only for high impact types, this will indicate the end of the channel impacts and the start of a debris path and/or landslide. This can be a transition area between a "steep-valley" channel-type landform and a hillslope. The debris flow path occurs in a hollow or hillslope with no defined channel bed and bank landform.

Impact Type: Each cross-section and the reach immediately about the cross-section will be classified by impact type. Evidence of high water is usually indicated by minor alterations to the riparian area and minimal channel changes. Torrent scour is when the stream is typically scoured to bedrock and there is evidence of a torrent moving through such as severe alterations to the riparian area or wood stored high out of the channel. Torrent deposition reaches typically are widened and aggraded. Torrent jam reaches are distinctive, as they are jammed with wood and sediment. (Be careful to check for jam removal around road crossings). Dambreak flood reaches are identified by a possible breached roadfill or evidence of a breached debris deposit followed by high-water damage much greater than what is normally seen in other nearby stream reaches. See categories below.

1) Low Impact Group (no torrent impacts)

a) No (*NO*) perceivable impact from high water, flood or torrent. Winter flows appear to be contained within the active channel.

b) High Water (*HW*) impacts only. Indications of high flow, such as bird nests (i.e., twigs gathered in brush above stream) in streamside vegetation and cleaning of litter from low terraces and flood plains.

c) Scour and deposition patches (*SD*). Localized channel, bank, and floodplain scour or deposition of fines, gravel, or cobble. Scale: patch size generally less than a few channel widths long.

2) Moderate Impact Group (no torrent impacts)

a) Channel modified (*CM*). Larger scale (multiple channel widths long) channel relocation, deposition of new gravel bars, or scour of new side channels. These areas may appear to be torrent-impacted reaches. Look for the impact width extending up to, but not beyond, the channel bank-full height. A torrented reach will have impacts relatively high above the channel bank, where as *channel modified* impacts do not extend very far beyond the bank-full width/height, if at all.

3) High Impact Group (torrent impacts)

a) Torrent scour impacted (*TS*). Greater then 75 percent of the reach is scoured. Massive lengths of channel are scoured deeply and often to bedrock. Often times a depositional reach is downstream where gradient moderates or the valley widens.

b) Torrent transitional (*TT*) Greater than 25 percent of the reach consists of scour and deposition. There are definitive torrent impacts but scour and deposition roughly balance out.

c) Torrent deposition reach (*TD*). Greater then 75 percent of the reach is deposition. Consists of massive lengths of channel with deposits of generally poorly sorted material. Generally the deposition is wider than you would expect the channel to be.

d) Torrent jam (*TJ*). This is a plug in the channel that backs up wood and other debris, ranging in depth from three to 30 feet. The active channel is unable to form a new path around this feature and appears to disappear at some point and re-emerge downstream. When encountering this feature, measurements will be recorded on the Torrent Jam data sheet. Care is taken not to mistake large deposits as torrent jams, where the active channel is still present off to one side or down the center of the feature.

e) Dambreak torrent scour (*DS*). This is a dambreak scour combination caused by a dambreak flood. Dambreak flood effects are evident by unusually high water and evidence of a roadfill or torrent deposition breaching upstream. Dambreak floods are much less frequent than debris torrents and can be very difficult to identify. When encountering this feature it is important to record it with photograph.

f) Dambreak torrent deposition (*DD*). A dambreak and deposition combination.

g) Dambreak torrent jam (*DJ*). A dambreak-jam combination.

Channel Type: Channel types are categorized using a variation on ODF&W's small stream protocol. The channel type is categorized as one of the following:

1) Meadow Trench (*MT*). Low gradient, low energy system with meandering channel flowing through meadow soils and peat. Typical of low gradient headwater meadow and wetland reaches. Poorly defined pool-riffle sequences may be present, but the scour pools are not much deeper than the riffles or glides.

2) Braided (*BR*). Multiple channels with poorly defined riffles and few pools.

3) Pool-Riffle (*PR*). Low to moderate gradient. Sequence of full channel width pools

4) Pool-Step-Pool (*PS*). Moderate to high gradient. Full-channel-width pools separated by steps, riffles, rapids, or cascades. Easily identified pools with a mix of habitat types in between.

5) Cascade (*CA*). High gradient. Rapids, boulder strewn chutes falls, and very small pools.

6) Colluvial Debris (*CD*). Channel filled with unsorted material from the adjacent hillslopes (boulders, smaller sediments, and/or large wood).

7) Bedrock (*BD*). The channel bottom is more that 50 percent bedrock, typical of "sluiced out" sections of headwater tributaries. It is important to continue the survey

far enough to identify the source of the channel failure (road, landslide, or other source).

Aspect: Measured in degrees (1-360) using a compass. This is measured facing down stream. If the channel is meandering try to visualize the straight-line general direction of the channel 150 feet down stream.

Slope: Measured facing upstream with a clinometer in percent. Sight to a point at eye height about 100 feet up slope, or as far as you can see, which ever is shorter.

Thalweg: Maximum wetted depth of the channel cross-section in feet. A dry channel has a zero depth. If flow present but immeasurable (trace amounts) use 0.01 feet.

Active Width: Width of the active channel, and not the over-bank areas where excess water may have run.

Sediment Type: Channel bed substrates will be sampled using three general categories:

Boulders to Bedrock (B): > 250mm (basketball size and greater)

Coarse Gravel and Cobbles (C): 16mm – 250mm (marble to basketball size)

Fines, Sand, and Fine Gravel (F): < 16mm (silt to pea size)

At each cross-section along the channel segment observe the substrates on the stream bottom. For the area bound by the active width and a one-foot unit length, estimate the percent that falls in the three categories defined above. Estimate to the nearest five or ten percent for each and record these values on the channel impacts data sheet. To avoid a bias towards larger particles that are easier to see, be sure to look carefully for the smaller gravel, sand, and fines.

Impact Width: Impact width in feet. This is the area impacted by debris torrents and flood flows during the November 1996 storm. May extend over floodplains, terraces and side slopes. The impact can be seen in the form of scour and depositional features on the side slopes. For those cross sections classified as a high impact type, this measurement will be an estimate of the width of impacts related to the debris torrent.

Impact Height: Impact height above channel. This is measured vertically from the low point of channel cross section in feet to the height of the top marks of flood/torrent related impacts. Use the surveyor rod to get the height. For those cross-sections classified as a high impact type, this measurement will be an estimate of the depth of impacts related to the debris torrent.

Debris Load/Depth (reach): Estimate the amount of organic debris (all sizes) using the following categories:

Absent (*AB*)- No visible debris, other than one or two pieces over the entire visible area.

Sparse (*SP*)- A few pieces of debris over the visible area, but no significant clusters.

Non-contiguous (*NC*)- A significant number of pieces, but a majority of the pieces are not touching each other.

Contiguous (*CN*)- Many pieces that are mostly touching each other.

The visible area is 75 feet up and down stream of the cross-section, or as far as you can see, which ever is shorter. When surveying a high impact channel, look just beyond the impact width to assess the debris load. For a low impact channel, look in and around the active channel itself. When using *contiguous*, estimate the depth of debris to the nearest foot in the *Debris depth* column.

Shade: Shade is measured with a convex densiometer. Take measurement facing upstream, downstream, left direction and right direction from the center of the channel at each station. Record the count of intersections covered by vegetation (maximum is 17). For details on how to use the densiometer see Kaufmann and Robison, 1994.

Channel Junctions: Along those channels with torrent impacts, all of the channel junction angles that the torrent moved through will be recorded. The angle is determined by finding the acute angle between the incoming tributary and the main channel. This is determined by taking two aspect measurements. One aspect is taken facing downstream of the channel that is being traversed. The other aspect is taken looking upstream at the entering tributary with torrent impacts. (At a later time the difference between these two aspects will be subtracted from 180 degrees to determine the acute angle.) An additional observation will be recorded that answers the following question: Is there evidence of a torrent riding high up over the channel bank opposite the incoming torrented channel? In other words, does it appear that the torrent from the tributary channel moved through the junction? (*Opim, Y/N*)

Notes: It is very important to note any comments about a measurement point. Especially important are any comments about possible dambreak areas or debris torrent particulars.

Method for large woody debris

The measurement protocol is simplified from the one used in ODF&W habitat surveys (Moore et. al, 1995 p. 23-24). Two matrices of wood diameter versus wood length are used (Appendix B). One matrix is for wood stored partially or wholly within the active channel. The other is for wood stored outside the active channel but within the impact zone or potential impact zone. The impact zone is the area that is encompassed by the impact width measurement. For low impact reaches this is the estimated width that would be impacted had a torrent occurred. For each channel segment, a continuous tally is kept of LWD based on diameter, length and location (150-foot intervals). LWD tally intervals correspond with channel sampling intervals to allow for an analysis of the spatial distribution of LWD.

There are nine different size classes for LWD that are a combination of diameter and length categories. The small, medium, and large diameter categories are 10-18, 18-36 and greater than 36 inches, respectively. The small, medium, and large lengths categories are 6-15, 15-35, and greater than 35 feet, respectively. The following diagram is a matrix of the nine size classes:

Length —— Diameter |	**S** (6-15 ft)	**M** (15-35ft)	**L** (> 35 ft)
S (10-18 in)	**SS**	**SM**	**SL**
M (18-36 in)	**MS**	**MM**	**ML**
L (>36 in)	**LS**	**LM**	**LL**

Torrent jam/deposit measures

The Torrent Jam protocol (Appendix B) is used to map the occurrence and volumes of torrent jams and very large depositional features in the field to understand in a

gross sense the sediment budget of the landslides, torrents and channel impacts. This form should be used whenever a torrent jam is encountered, or if a large sediment deposit greater than 10,000 cubic feet is encountered. This is equivalent to a deposit that is 10 feet deep, 10 feet wide, and 100 feet long. A torrent jam is defined as a large deposit that plugs the entire channel width and causes a distinct drop off. This is often, but not always, the end-point of a debris torrent.

Crew, date, major basin name, and segment number are described under the channel measures protocol. The following categories are unique to the torrent jam form:

TJ: This is the number assigned to the jam (or deposit) by the crew. One crew will start with 901 and the other with 951.

Type: This is the feature type. It will be either a torrent jam (*J*) or a large deposit (*D*)

Beginning Distance: The distance to the down stream end of the depositional feature from the landmark in feet.

Beg Width: Width of feature measured at the point furthest down stream.

Beg Height: Height of feature measured at the point furthest down stream.

Slope Down: Take a slope measurement, facing downstream, standing just below the feature.

Frontal Textures: The percentage of material that is visible at the front (downstream end) of the feature. This includes any pieces that appear to have played a role in stopping the torrent and causing the jam. Wood refers to large wood over 10" in diameter and six feet in length (LWD). Anything smaller should be placed in the organic category (*O*). Everything else should go in the inorganic category (*IO*). The three columns should add up to 100%. The predominant diameter *size* of the LWD will also be recorded (*S = 10”-18”; M=18”-36”; L=36”+*).

Ending Distance: The distance to the up stream end of the depositional feature from the landmark in feet.

End Width: Width of feature measured at the point furthest up stream.

Slope Up: Take a slope measurement, facing upstream, at the upstream end of the feature.

Surface textures: The same measurements taken for frontal textures but applied to the surface of the feature instead. This includes any pieces that do not appear to have played a role in stopping the torrent and causing the jam.

Channel Junction *(Y/N)*: Is feature within 100 feet downstream of the junction of an incoming landslide?

Aspect Down: *If at a channel junction* the junction angle must be determined. This is done by finding the acute angle between the incoming landslide and the main channel, and is described in the channel impact measures protocol. Measure the aspect facing downstream while standing at the channel junction.

Aspect Up: *If at a channel junction*, measure the aspect facing up the torrented tributary while standing at the channel junction.

Notes: Record any additional notes here.

Hypotheses for Testing

Landslide related hypotheses

A. The time distribution of landslides following timber harvest does not have a simple single modal distribution, but rather a bimodal distribution with the highest landslide rates occurring some time between zero to ten years after harvest. This is followed by a decrease between 10 and 100 years after harvest and a return to background rates following 100 years after harvest.

B. The distance traveled by debris flows is related to slope steepness; drainage area; volume of the initial landslide; distance to channel; channel junction angles;

landform along the total distance traveled; stand age/LWD along the total distance traveled.

C. Storm intensity had a great impact on landslide frequency, and will be apparent in changes in landslide density with elevation, aspect, and especially space within similar landforms.

D. The highest frequency of landslides will be found on slopes between 80 and 90 percent steepness.

E. Most landslides will occur on landforms that meet the ODF guidance for high-risk sites.

F. Of those lands meeting the ODF criteria for a high-risk site within the study areas, landslides directly affect only a small portion of that land.

Channel impacts related hypotheses

A. "Standardized" stream width will increase with delivering landslide density. Channel width will be standardized by watershed area.

B. "Standardized" shading will decrease with increases in delivering landslide density. Standardization will be done by watershed area and possibly other factors like location and geology.

C. In paired comparisons, sunlight entering the stream and active stream width increases with increasing channel impact groups (see protocol).

D. Wood loading (volume per surface area) is significantly greater and more variable in torrent-impacted reaches and especially torrent depositional reaches.

E. In terms of volume, the ratio between initiating landslide volume and stream scour and fill volume is relatively small.

Analysis

The analysis will generally be limited to examination of the associations between landslides, landform characteristics, slope disturbance, and condition of vegetation (as described in the hypothesis section). Both landslide occurrence and landslide sediment delivery will be evaluated for associations with landform and forest management practices.

Land area in different age classes will be determined for each study site. A generalized sediment budget will be developed for the landslides and debris flows, and compared with the volume in torrent jams and other sediment deposition reaches within and, where traceable, outside the study areas. Gross differences within different land classifications will be identified if they are apparent.

It is likely that there will be insufficient data for rigorous cause and effect testing of some of the hypotheses. It is more likely that in many cases only general associations will become apparent, and may lead to better research priorities.

References

Kaufmann P.R. and E.G. Robison. 1994. Physical habitat assessment. Section 6, 36 p. IN: D.J. Klemm and J.M. Lazorchak (Eds.). EMAP Surface Water and Reg. 3; Regional 1994 Pilot Operations Manual for Streams. U.S. EPA Env. Sys. Lab. Cincinnati OH.

Appendix A: Forest Practices Monitoring Staff

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Appendix B: ODF field forms for the Landslide and Channel Impacts Protocols

- Landslide Measures
- Channel Impacts & LWD Measures
- Torrent Jam Measures
- Photo Record
- Cheat-sheet

Landslide Measures

Crew	Study Area

LANDSLIDE				Debris Path (pre-channel)														
													Avg	Max	Avg	Abv	Blw	Asp
Date	LS	Seg	Dist	Bdist	AveW	AveD	Slope	Form	Type	Torr?	Bdist	L	W	D	D	(%)	(%)	(deg)
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Landslide Measures (continued)

Drain Area			Bed	Soil	Slash		Slop	Dom	Cov	Pic
Pview	Rdist	Avew	rock	Type	Load	D	Alt	Ht	%	#

Channel Impacts & LWD Measures

Crew	Date	Study Area

CHANNEL		Landmark										Sedtype			Imp	Imp	Slash		Shade				(ChJct, If Torrent)		
Seg	Dist	Jseg	Jdist	Updn	Lform	Imptyp	Chtyp	Asp	Slope	Thalweg	Actwid	B	C	F	Wid	Ht	Load	D	1	2	3	4	Asp Dn	Asp Up	Opp imp?
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Notes																									

LWD		(In)									(Out)								
Seg	Dist	SS	SM	SL	MS	MM	ML	LS	LM	LL	SS	SM	SL	MS	MM	ML	LS	LM	LL

Torrent Jam Measures

Crew	Study Area

TORRENT JAM/DEP				Beg	Beg	Beg	Slope	Front Texture				End	End	Slope	Surface Texture				Ch	(Asp	(Asp
Date	Seg	TJ	Type	Dist	Wid	Ht	Down	% LWD	Size	% Org	% Inorg	Dist	Wid	Up	% LWD	Size	% Org	% Inorg	Jct?	Dn)	Up)
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Photo Record

PHOTO RECORD

Crew	Study Area	Roll #

Photo	Seg/LS	Date	Description
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
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23			
24			
25			
26			

Cheat-sheet

Channel

SedType

B = Boulders to Bedrock
C = Coarse Gravels and Cobbles
F = Fines, Sand and Fine Gravel

Landform

Narrow Valley:
SV >60%
MV >30%, <60%
OV <30%
FV '= SV w/Fill, Valley vs. Channel >2.5

Broad Valley:
CT = Constraining Terrace
MT = Multiple Terrace
WF = Wide-active Floodplain

Other:
FN = Fan
HS = Hillslope
HO = Hollow

Slash

AB = Absent SP = Sparse
NC = Non-contiguous CO = Contiguous

Impact Type

Low:
NO = no impacts
HW = high water only
SD = minor scour & deposition

Medium:
CM = channel modified

High:
TS = Torrent Scour
TT = Torrent Transition
TD = Torrent Deposition
TJ = Torrent Jam
DS = Dambreak/TS combo
DD = Dambreak/TD combo
DJ = Dambreak/TJ combo

Channel Type

MT = Meadow trench
BR = Braided
PR = Pool-riffle
PS = Pool-step-pool
CA = Cascade
CD = Colluvial debris
BD = Bedrock

Landslide

Form:
E = slide
D = slid

Type:
ST = Shallow-trans
RO = Rotational
OT = Other

Drain Area:
Pview
CV = Concave
UN = Uniform
VX = Convex
IR = Irregular
OT = Other

Slope Alterations:
W = Windthrow
F = Fire (recent)
G = Gouging
S = Skidroad
D = Old road
A = Active Road
N = None
O = Other

Torrent?:
HO = Hillslope only
HC = Hillslope & Channel
NO = None

Soil Type
N = Non-co.
C = Cohesive

Torrent Jam

Type:
J = Jam
D = Large deposit

Front Texture:
Size (diameter)
S = 10-18 in
M = 18-36 in
L >36 in

LWD

Diameter
S = 10-18 in
M = 18-36 in
L = >36 in

Length
S = 6-15 ft
M = 15-35 ft
L = >35 ft