TAYLOR COMMENTS

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Geomorphic Recovery Processes Following Debris Flow Disturbances in Low-order Channel Systems of the Western Cascades

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Introduction

Sediment discharge rates from low-order stream channels are not constant. Water ~~transports~~ exports some material at regular discharge rates, while a large percentage becomes trapped in the channel. This stored material is then released in mass during infrequent debris flows events. Characterizing how much sediment accumulates in a channel over time is key to understanding debris flow cycles and their impacts on surrounding landscapes and biotic systems. ✓

Debris flow impacts depend on flow frequency and on material volume because both parameters influence geologic and biologic changes in the channel and at the deposition sites. Many studies have examined factors affecting debris flow frequency, including landscape characteristics such as bedrock type and channel slope, as well as hillslope ~~weakness~~ instability due to land management (Snyder 2000, Swanson and Dyrness 1975, Sidel et al. 1985). Few studies have researched the rate at which channels refill with material and factors influencing that rate. Wood volume is expected to significantly influence sediment accumulation in low-order streams by acting as an obstruction where other storage mechanisms are lacking (Keller and Swanson 1978; May and Gresswell 2003).

NEED FIGURE 1 – base map WITH WATERSHEDS & REACH STUDY LOCATIONS IDENTIFIED

NEED TABLE 1 – SUMMARY OF STREAM REACH ~~DATA~~/WATERSHED CHARACTERISTICS

KEY IP'S

INCLUDE LAND USE TYPE, HARVEST HISTORY

This study quantifies ~~begins to quantify~~ fill rates in 1st and 2nd order stream channels that have experienced debris flows in and near the HJ Andrews Experimental Forest (HJA) in the Western Cascades, Oregon. Specific objectives of the study are to:

1) Determine rates of wood and sediment accumulation in debris flow-scoured low-order stream channels, and ✓
2) Identify primary factors influencing accumulation rates, quantitatively and qualitatively. ✓

Project Results ~~were~~ are examined in the ~~In addition, for comparison purposes, study methods were designed for~~ context of a ~~consistency with a~~ similar study in the Oregon Coast Range by May and Gresswell (2003).

Need Figure 1 ↓ location map with channel reach category & ID.

Study Area

The study was conducted along ~~in the~~ lower elevations at HJA ~~of the HJ Andrews Experimental Forest~~ and ~~at~~ two additional sites within two miles of the Forest boundary. The sites were 1st or 2nd order headwater streams as defined by the HJA ~~HJ Andrews~~ Interactive Map and corrected for observed tributaries in the field. Surveys were made in debris-flow scour zones, meaning that the last event ~~debris flow~~ scoured the channel down to bedrock in the study reaches. ~~that reach of the channel.~~

Bedrock ~~The~~ geology of the study area is comprised of lava flow and clastic volcanic bedrock (Swanson and Frederickson 1982). The overstory is primarily Douglass Fir (Pseudotsuga menziesii) — ITALICS, western hemlock (Tsuga heterophylla), and other coniferous and a few deciduous species such as red alder (Alnus rubra) that often recolonize the scoured channels.

use italics

? ? explain

The stream channels in this region experience debris flows with increased frequency relative to higher elevations (Swanson and Dyrness 1975). The dates of their last debris flows have been documented by direct observation or from historical notes and photographs (Snyder 2000). This study included channels with the latest debris flows occurring in 1996 or 1964, the two years accounting for more than 75% of all debris flows in the forest over the last 60 years (Snyder 2000). The abundance of debris flows in these years provided ample channels to study. In addition to those scoured by 1996 and 1964 flows, two channels were included that have not experienced a debris flow during d ~~the record of~~ the last century. The time since the last debris flow at these sites was approximated to 250 years.[1] These three different ages of 11 (1996), 43 (1964), and 250 years since the channels' last flushing event~~s~~, allow the study sites to represent different points in time during the geomorphic a~~long a channel~~'s recovery process.

The majority of the channels surveyed (7 of 9) were in unmanaged forested areas. These forested regions were prioritized because their characteristics would indicate the background rate of accumulation in a natural environment. Two channels surrounded by plantations were also surveyed. These areas were clear cut, burned, and replanted in the 1950's. One such channel's most recent debris flow was in 1964 and the other's was in 1996. Plantations and natural forests may yield different channel refill rates because of varying amounts of wood input. This study focused on channel recovery in natural forests but could be expanded with more plantation sites to compare rates in different management environments.

Refer to (TABLE 1) here ↓ Summary of channel characteristics

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[1] Trees growing along the lower banks of the channel and assumed to have seeded since the last debris flow can be used to assess the time since that event. Using a tree core, a Douglass Fir was estimated at 140 years in one channel, and a cedar was estimated at 95 years in the other. These ages represent minimum time since debris flow, and the last flows could have been as long ago as 1,000 years.

Methods

The study used a space-for-time representation of wood and sediment accumulation in stream channels after debris flow~~s~~. Volumes of wood and sediment were measured by methods specified below to quantify the increase in material over a known number of years.

Multiple channels with the same date of last debris flow were chosen to account for variations among channels ~~of~~ with the ~~same age.~~ recovery time. Three channels from 1996, two from 1964, and two from older flows, all of which exist in natural forest areas were selected from records of debris flow history ~~in the HJ Andrews Forest.~~ at HJA. In addition, two plantation sites, one from a 1996 debris flow and one from a 1964 flow were surveyed.

Refer to Summary TABLE

Once channels were selected, identification of scour zones was made based on channel gradient and exposed bedrock. The bottom of each survey zone was chosen as a location where gradient exceeded 15% or where long exposures of bedrock were observed. In some cases, deposits from the last debris flow remained ~~at intermittent~~ parts sporadic locations ~~of~~ in the scour zone~~s~~. The ~~zones~~ study sites were also located out of range of road influence, ~~(at least 75m from the road).~~ positioned at least 75m from access roads

refers to TIME

Avoid parenthetical statements, use punctuation

Each survey was conducted in 10m sections of channel length in order to observe local variation ~~in the~~ along channel reaches. ~~A sum of~~ ~~total~~ 10 to 15 consecutive sections ~~was~~ were measured, totaling between 100m and 150m per transect, in order to average out local variations and capture channel trends. A minimum of 10 sections were surveyed in each transect. In some cases, high variability along the channel called for extending the survey to improve the sample's representative validity.

— Refer to DATA TABLE —

The following ~~items~~ DATA were measured and recorded in each 10m section of channel.

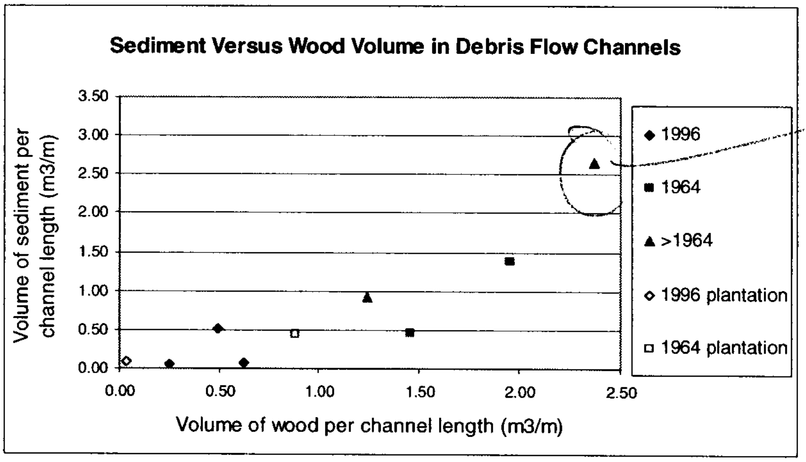
- Channel width: taken as the distance from one side bank to the other at a height of) ? about 5m. above channel grade (?)
- Streambed width: the relatively flat region over which water flowed. (Active channel)
- Channel slope: measured with an Impulse laser.
- Wood vol. in the channel at least 0.2m in diameter and 2m in length: average diameter and average length in the channel were measured to calculate volume as a cylinder; in cases where wood was not cylindrical, a cross-sectional area was measured instead of diameter; wood entirely suspended more than 2m above the channel was not counted.
- Sediment volume accumulations at least 0.5m in length and width and at least 0.1m deep: average length, width, and depth were measured, and volume was calculated as a rectangular solid. When sediment formed terraces with a relatively flat surface but sloping bedrock base, volume of the wedge shape was calculated using the average depth assuming constant bedrock slope. Sediment refers to regolith transported by the stream. It excludes organic material from the sideslopes and boulders larger than 1m across. Sidelsope sp. input or hillslope volume remaining in the channel was approximated separately. Where sediment mixed evenly with organic sideslope material in accumulations, volumes were approximated to be half sediment, half hillslope. Each sediment accumulation was also characterized by the size of its pebbles as observed on the surface. Lastly, the object(s) or feature(s) ~~blocking~~ trapping each sediment accumulation were identified.

- Other notes: the percent of streambed covered by large wood (>0.2m diameter and >2m length), small wood (wood less than measurable threshold size), sediment, exposed bedrock, reaches and other material was approximated ? ? ? ? Finally, Qualitative observations were noted ~~that helped~~ to further characterize the channel environment, including size of the largest trees in the channel, evidence of sideslope failures after the last debris flow, and ~~descriptions of the~~ sideslope ~~makeup~~ composition.

Results

~~As expected,~~ Volumes of both wood and sediment are lowest in the channels that were most recently scoured (1996) and highest in channels with the longest time since a debris flow (before 1964). Because older scour zones exhibit more of both wood and sediment than ~~newer~~ younger ones, there is an observable correlation between the volume of sediment in a channel and the volume of wood in the channel (See Figure 1). While the sample number is too small to allow credible statistical analysis, there does appear to be a non-linear relationship between wood and sediment volume: doubling wood volume corresponds to more than a doubling of sediment volume.

Figure 1.



Label marker ID's

The rate of wood and sediment accumulation in the study area can be calculated by relating the amount of wood and sediment to the time since the channel was scoured. Figures 2 and 3 display these two relationships. The amount of material found in 1996-scoured channels represents the accumulation over the first 11 years of recovery. The average wood from the three such sampled channels was 0.46m^3/m. The average sediment volume was 0.22m^3/m. The average amount of wood found in 1964-scoured channels, representing the accumulation during the first 43 years of recovery, was 1.7m^3/m. Sediment volume from these channels averaged 0.92m^3/m.

Figure 2. Laser pts.

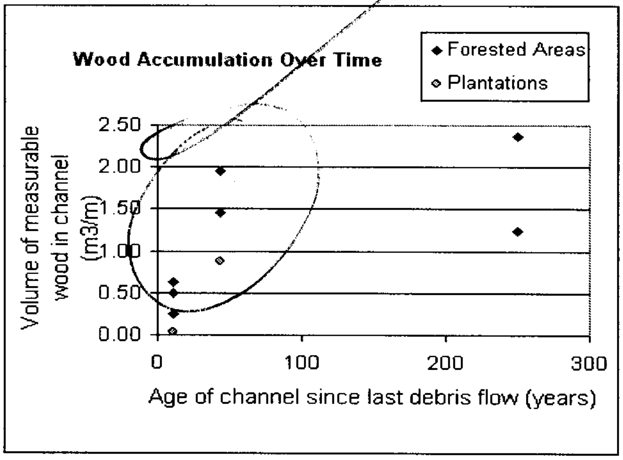
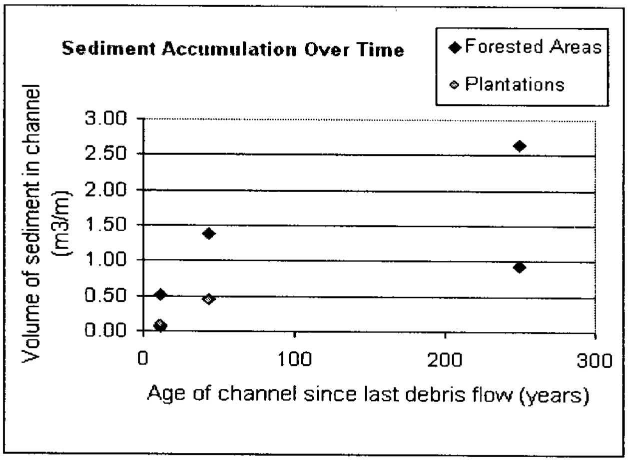


Figure 3.



Sediment obstructions were divided into 8 categories, and the total volume of sediment stored by each type are displayed in Figure 4. The same data is shown as percentages in Figure 5. Large wood alone accounted for 45% of all sediment storage. In conjunction with small wood and boulders, large wood played an ~~obstruction~~ trapping role for 87% of the total sediment volume. Boulders alone blocked 9% of the sediment, while small wood alone, hill slump/bank, and a shallow channel slope (no obstruction) each ~~blocked~~ trapped less than 2% of sediment.

Figure 4.

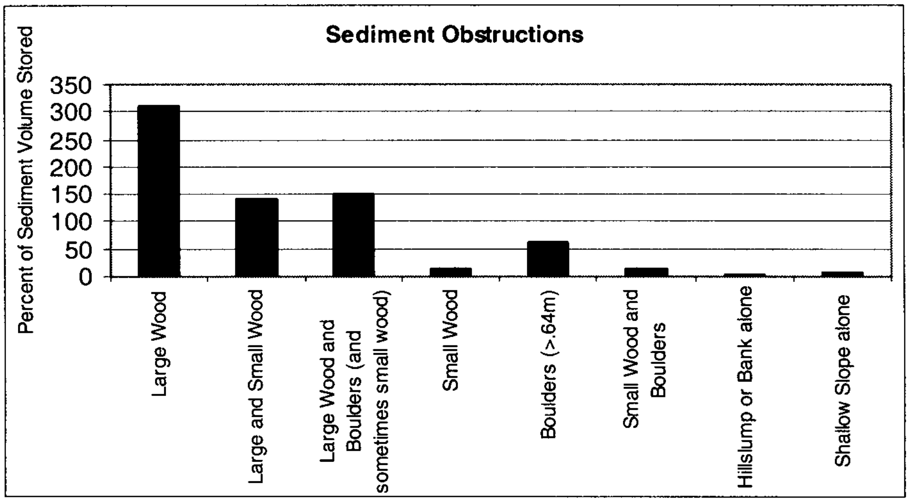
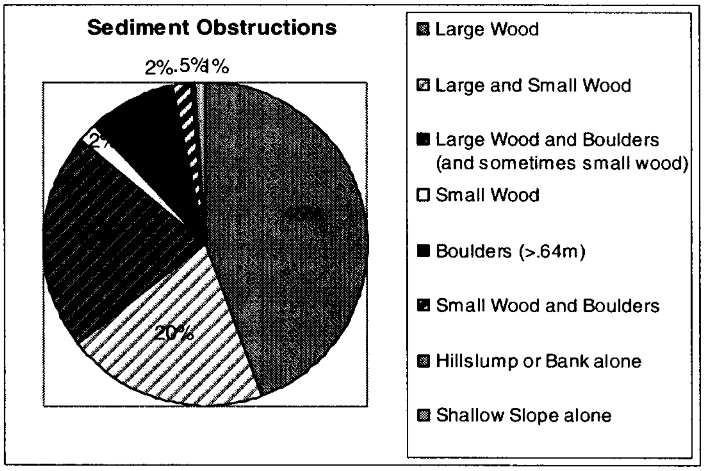


Figure 5.



Small wood and boulders commonly rested on flat reaches of bedrock along the channel. The ~~slope~~ gradient of the bedrock streambed varied considerably between 10m sections of most channels. ~~Slope~~ GRADIENT changes from one section to the next varied by an average of 6% ~~percentage gradients~~. Dramatic slope changes were also apparent within sections, usually in the form of a 2-5m bedrock ~~cliff waterfall~~ KNICK POINT followed by a flat scour pool. Small wood, boulders, hillslump, and no obstructions were more common sediment storage mechanisms in flatter sections than on steeper stretches. The two examples of remnant debris flow

explain?

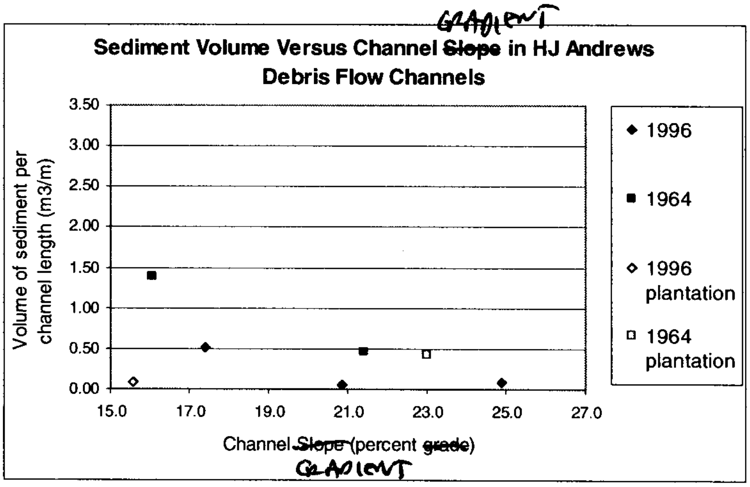
NOT A TERM

deposit~~ions~~s in the otherwise scoured channel reaches rested on flat bedrock sections. Large wood that entered the channel since the last debris flow, by contrast, exhibited no significant preference for shallow or steep channel ~~slopes~~ gradients.

While channel ~~slope~~ gradient alone plays present tense a negligible direct role in sediment storage, it was past tense related to total sediment volume in the 1964 and 1996 channels. Channel reaches with higher average ~~slopes~~ gradients exhibited lower sediment volumes (See Figure 6).

use parallel verb tense

Figure 6.



The above graph also shows the influence of time since debris flow on sediment volume, as the trend line of 1964 channels lies consistently above the 1996 trend line. The 250 year-old channels were ~~left off this graph~~ omitted because they do not show any relationship between channel ~~slope~~ gradient and sediment volume, ~~but only~~ however do emphasize the observation that sediment increases with time.

In the ~~younger channels~~ more recently scoured reaches, the interacting influence of channel ~~slope~~ gradient and large wood on sediment accumulation can be observed by profiling ~~the channels by~~ reaches in 10m ~~sections.~~ increments (fig. 7) Figure 7 shows measurements of sediment volume, wood volume, and channel ~~slope~~ gradient in each section of channel WS 2-3, ~~which was~~ last scoured in 1996. Section 1 is downstream, and section 10 is at the top of the study reach. By following the green and blue lines from right to left, one observes that an increase in ~~slope~~ gradient corresponds to or is closely followed by a decrease in sediment volume ~~; likewise, decreases in slope correspond to increases in sediment.~~ and vice versa. Spikes in wood volume have some effect on sediment ~~volume~~ accumulation as well. The 1964 channels also displayed a link between slope and sediment volume. One example is profiled in Figure 8 with channel WS 1-2. In these channels, increases in wood correspond strongly to increases in sediment. Shallow ~~slope~~ gradient and corresponding small wood, boulders, and hillslope accounted for only 10-15% of sediment storage in 1964 or older channels, while the same features ~~blocked~~ trapped 45% of sediment in 1996 channels.

Figure 7.

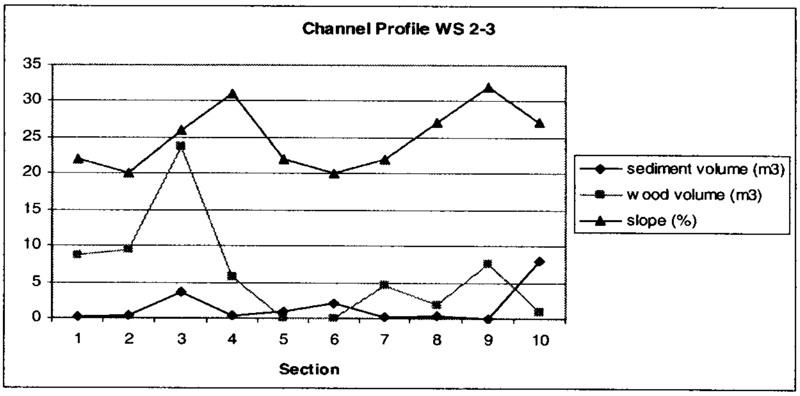
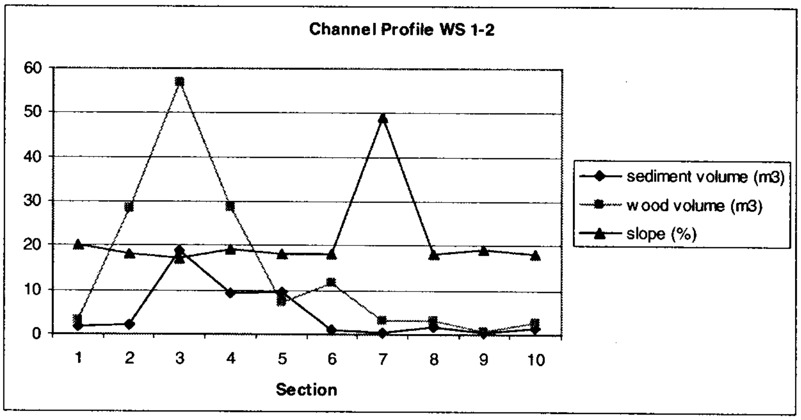


Figure 8.



Discussion

The results of this study provide preliminary estimates of sediment and wood accumulation rates in low-order channels of unmanaged regions at HJA ~~in HJ Andrews Forest~~. The reliability of fitting a trend line to the data points is limited because only three time intervals were sampled, and the longest one is not known. Nevertheless, the average accumulation volumes in the first 11 (1996) and first 43 (1964 event) years indicate initial accumulation patterns in the study area, and these values can be compared to accumulation rates determined for ~~calculated in~~ other geographic regions.

May and Gresswell's (2003) study of wood and sediment accumulation rates in headwater streams of the Oregon Coast Range provides one basis of comparison. The two figures below (fig 6 x 8x??) compare the trends in wood accumulation between these two studies. Figure 9 is derived from ~~the same as~~ Figure 2 above, and Figure 10 is from May and Gresswell (2003).

Debris flow channels at HJA ~~in the HJ Andrews Forest~~ exhibited higher initial rates of wood accumulation than did the channels in the Coast Range. ~~In the HJ Andrews Forest,~~ low-order channels in the study area accumulated an average $0.46m^3/m$ of wood in the first 11 years and $1.7m^3/m$ in the first 43 years. IN ~~By~~ contrast, the equation that May and Gresswell derived to describe wood accumulation based on their measurements (see Figure 10) indicate accumulation volumes of $0.16m^3/m$ in the first 11 years and $0.25m^3/m$ in the first 43 years. These differences in wood volumes between the two study areas could be due to older forests and thus larger trees inputting wood to HJA ~~the HJ Andrews~~ streams compared to those in the Coast Range. ~~channels.~~