

Using Stream Geomorphic Characteristics as a Long-term Monitoring Tool to Assess Watershed Function

A Workshop

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Channel Processes and Watershed Function

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Introduction

Purpose of this presentation is to put channel monitoring in context of channel processes and dispel the myth of the learned sage walking up the stream channel observing changes in the channel and extrapolating how these changes came about without looking at the rest of the watershed. The message I want to convey is it is not only O.K. to peek at the rest of the watershed, but it is necessary to understand why change has occurred. Many of the other speakers over the next two days will probably reiterate this same point, again and again.

Knowledge of the history and ongoing trends in the contribution of watershed products (water, sediment, woody debris, heat, and nutrients) is essential to effectively monitor and interpret channel condition for adaptive management.

Figure 1: Land-use activities affect downstream resources by changing on-site conditions (e.g., vegetative cover, soil compaction) which change the mobility and availability of watershed products (water, sediment, organic material such as woody debris, nutrients, and heat). The 'watershed product' paradigm simplifies cumulative effects analysis because the effects of a wide variety of activities affecting a wide variety of resources act through the mobilization and transport of only five quantities, and in many cases some of these can be ignored as being unimportant. Effects of land use are transmitted by altered transport and storage of material downstream. Altered inputs of watershed products through the channel system affect channel processes and conditions, and finally, these changes affect downstream resources (e.g., fish populations, water supply). Channel monitoring occurs near the end of this sequence of

cascading processes, and understanding cause-and-effect relations in channels requires an understanding of up-network and up-slope processes as they are arrayed in each watershed.

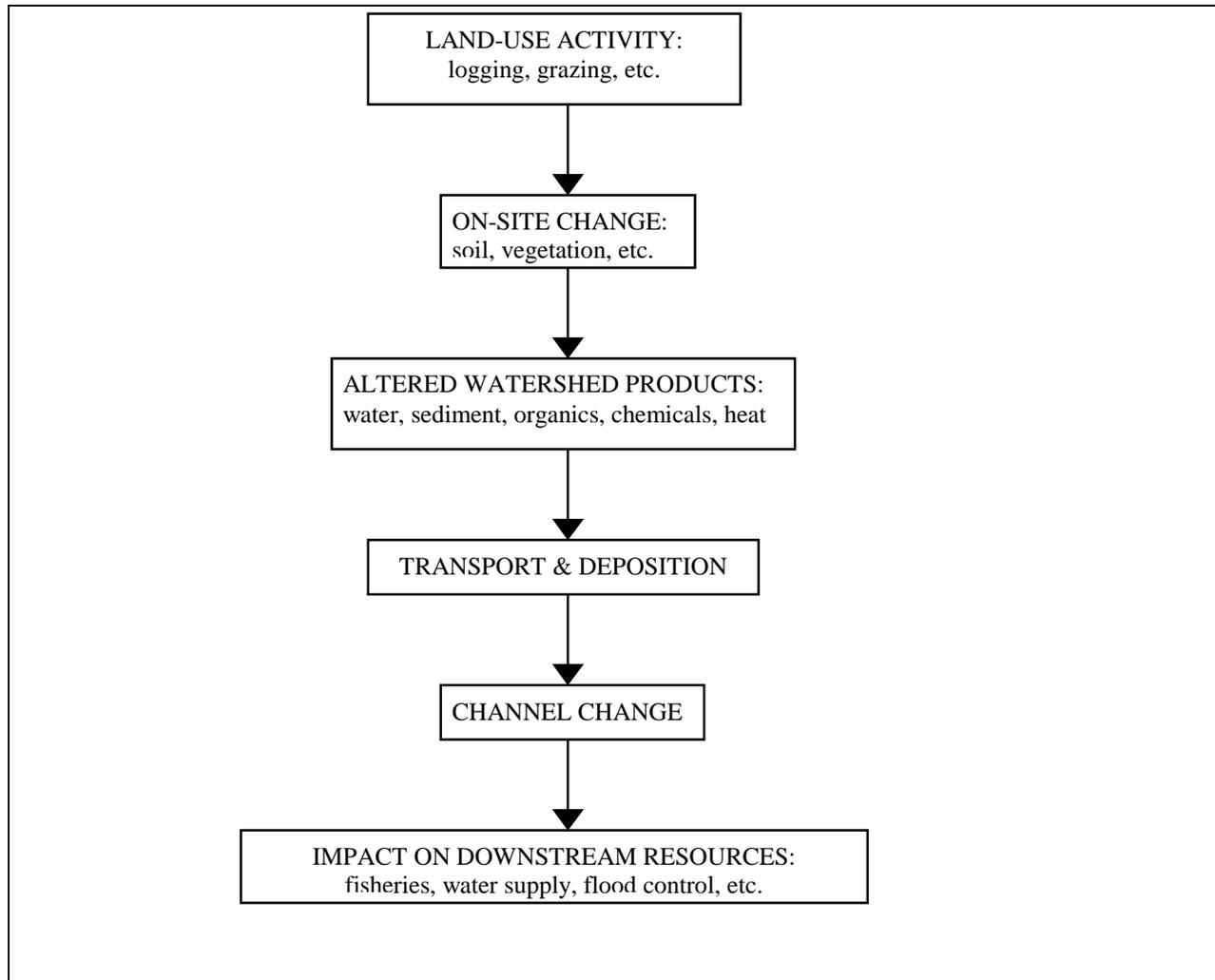


Figure 1. Simplified schematic of the flow of watershed products.

Figure 2: In each watershed, the propagation and ultimate effects of the disturbance of watershed products by land-use practices are uniquely determined by how, when, and where supplies of watershed products are changed, how, when, and where the altered supplies interact and affect channels, and ultimately, how, when, and where downstream resources (e.g., salmon) are affected. Watershed analysis is the process of learning these relations and is the framework for adaptive management. Channel monitoring is just one of the strategies to build more information into an evolving watershed analysis. Therefore, to be useful, any measure of channel condition or process requires putting the channel in context with its watershed. The purpose of this presentation is to further explain why and how this is done.

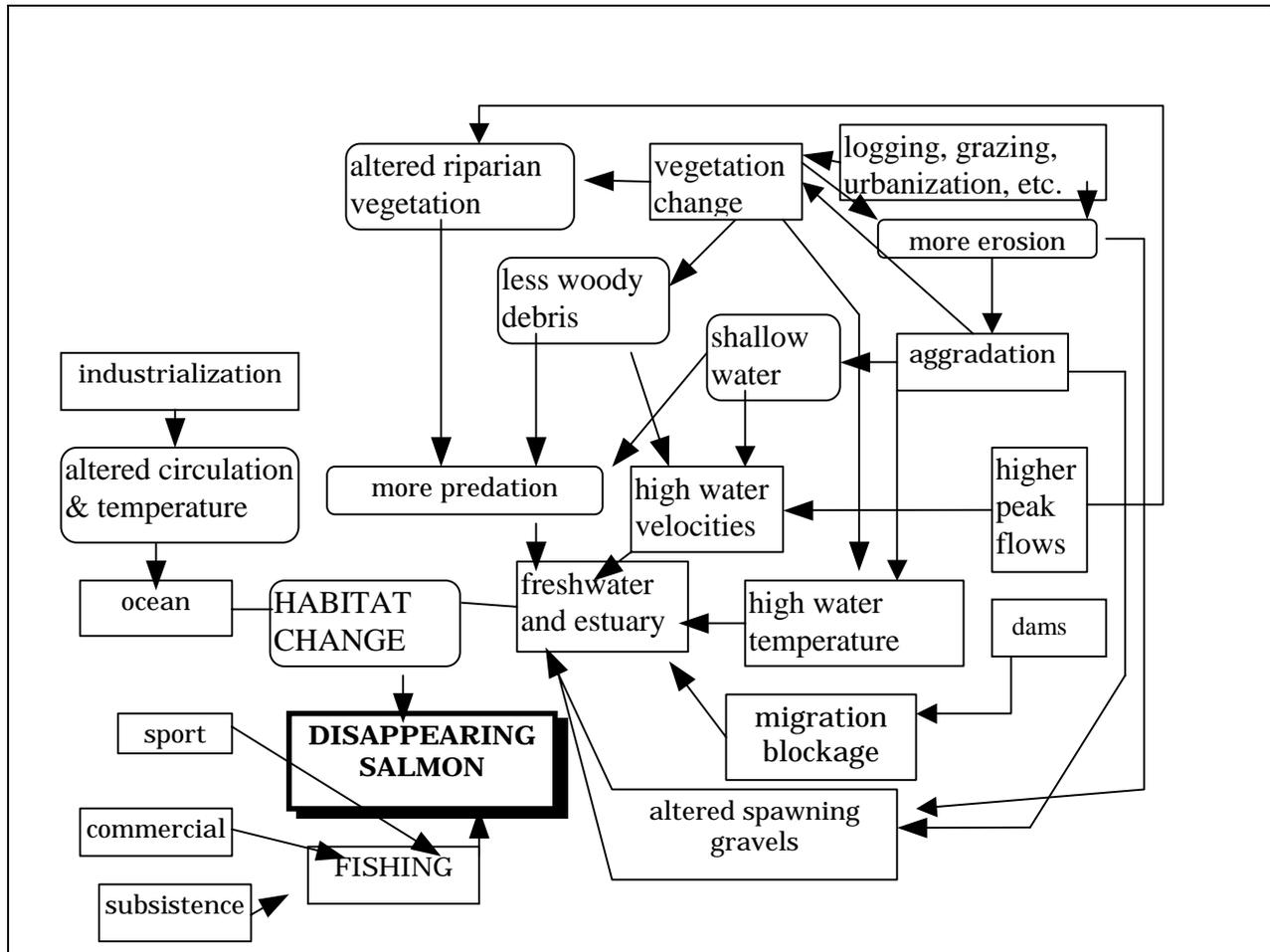


Figure 2. Disappearing salmon, detailed pathway of the flow of watershed products (courtesy of Leslie Reid).

Lags

There are long lags between hillslope disturbance, mobilization and routing of watershed products (particularly sediment and woody debris), and channel response. Climatic events that trigger processes with high thresholds (e.g., landslides, wind throw) may recur only once a decade or so, on average. Therefore, land-use practices that accelerate these processes could accumulate over a long period before their effects become suddenly evident. Other processes (e.g., downstream movement of bed load) occur annually but slowly, producing a long lag

between mobilization of watershed products and their appearance far downstream. Monitoring hillslopes and headwaters provides a proactive strategy to correct damaging land-use practices before they impact downstream resources.

Some of the watershed products with the smallest lags between up-slope or up-network disturbance and appearance in the channel include fine sediment (clay to sand), water temperature, and runoff. Channel monitoring of these products can yield timely information.

Indeterminacy of Channel Changes

Knowledge of watershed processes is necessary to determine causes for channel change. Conclusive evidence cannot be found on the victim alone; the same channel change can result from a number of causes related to changes in the supply of watershed products.

In the following two examples, I examine some common linkages between logging and road building and pool habitat, realizing that other activities can ultimately affect pools, and that other factors besides pools are important to fish populations. Logging commonly increases the supply of sediment which can fill pools. However, logging can also increase or decrease the supply of large woody debris, which is commonly responsible for forming many of the pools in forest channels. An interesting interaction occurs between sediment and wood: besides promoting local scour (and forming pools), large wood and other obstructions extract energy from the flow and thereby increase deposition of bed material. Given opposite and interacting effects of wood and sediment, if you increase or decrease supplies of both sediment and large wood in a channel, how does pool volume respond? Two examples are provided:

Figure 3: North Fork Caspar Creek

In an ongoing watershed experiment (Ziemer, 1998), modest increases of sediment and large increases of large wood have affected sediment storage and pool volume in the main stem of North Caspar Creek, Mendocino County, California. Following clear-cut logging of 50% of the watershed and minimal road building in 1989-1991, suspended sediment yield increased by approximately 90%, but no major landslides have occurred (Lewis, 1998). Approximately 1000 Mg of sediment has accumulated in the channel, but this is most likely due not to an over-supply of sediment, but from an increase in storage potential created by a 50% increase in woody debris volume in the lower 600 m of the channel (Lisle, 1998). The new wood came from extensive wind throw from a buffer strip that was left from the logging (Reid and Hilton, 1998). Measured changes in bed elevation at surveyed cross sections was highly variable. Most of the aggradation occurred upstream of new log jams. The increase in wood (along with the increased sediment storage) resulted in a doubling of pool volume.

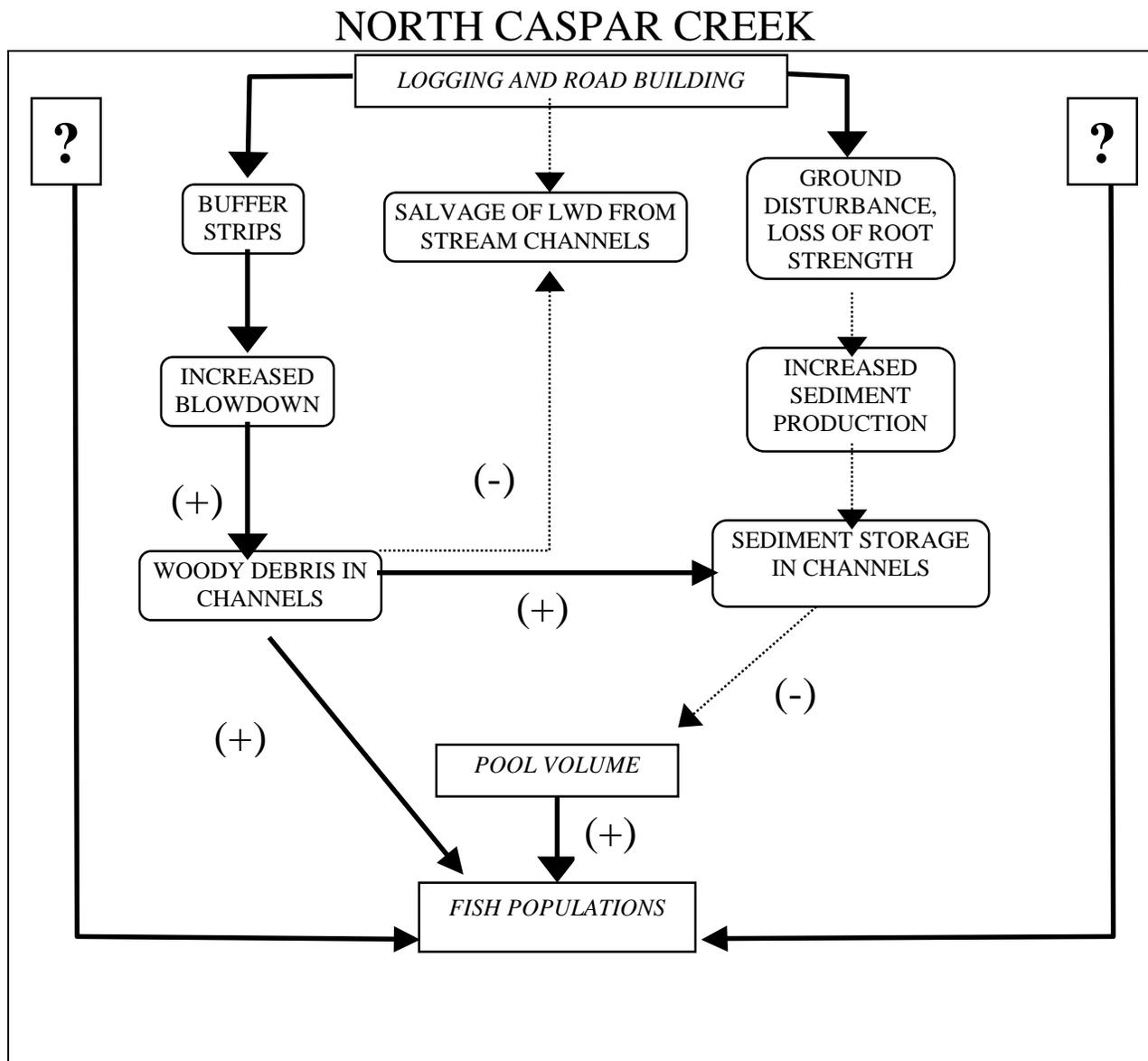


Figure 3. Simplified schematic of the effects of logging and road building on pool volume and fish populations in North Fork Caspar Creek, California.

Figure 4: Mt. St. Helens

The 1980 eruption of Mt. St. Helens, Washington, contributed vast quantities of fine sediment and large wood to channels draining the blast area. Timber companies and Gifford Pinchot National Forest responded by salvaging downed wood from stream channels and hillslopes. The logic of removing wood from channels was that it would hasten recovery of aquatic ecosystems by increasing transport of fine sediment. A group of Forest Service researchers tested this strategy with an experiment whereby wood was left in some reaches of Clearwater Creek and

removed from others. Channel cross sections and thalweg profiles surveyed from 1982-1990 show that land managers correctly predicted that removal of wood would reduce storage of fine sediment (Lisle, 1995). However, it also decreased pool volume: Deep and frequent pools

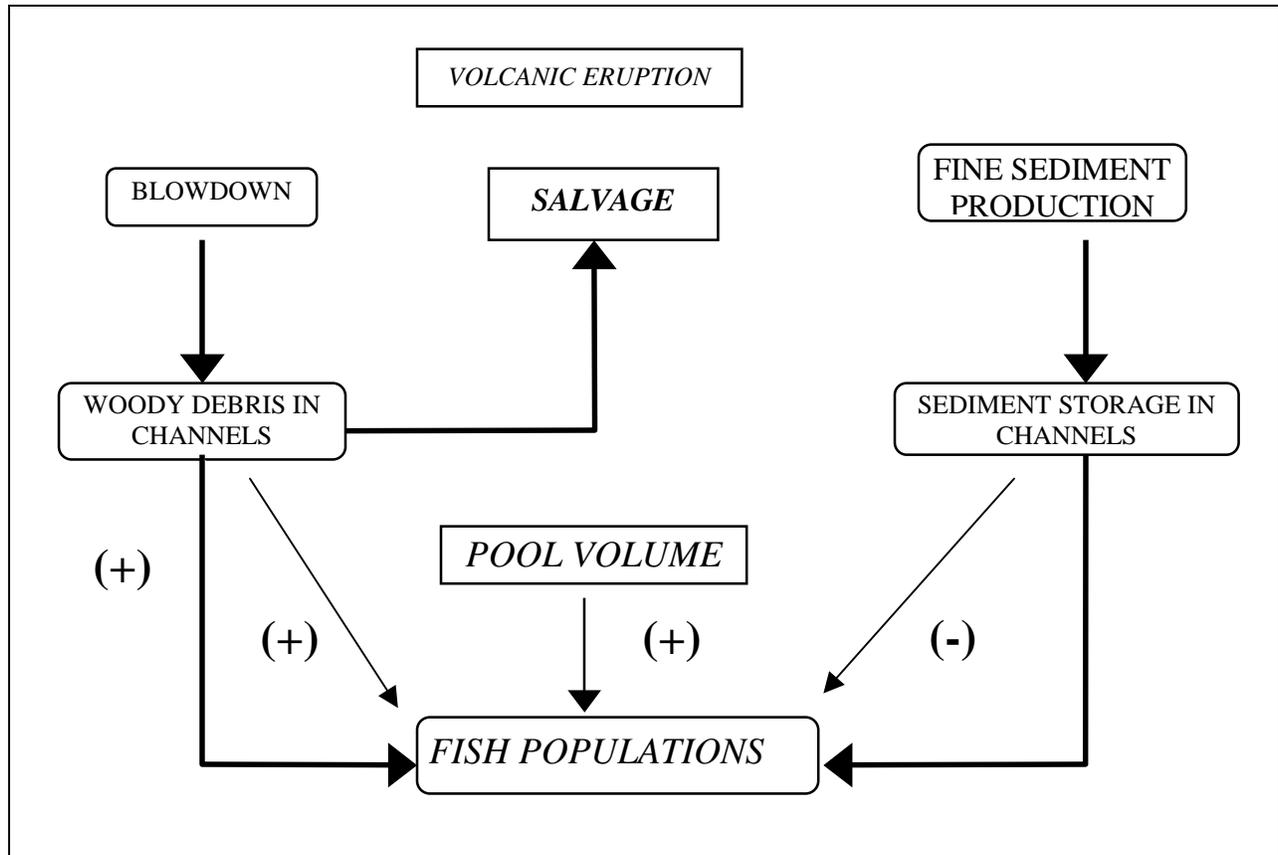


Figure 4. Simplified schematic of the effects of volcanic eruption and salvage logging on pool volume and fish populations following Mount Saint Helen's eruption in Washington.

persisted in channels where wood was retained, and filled where wood was salvaged. The protected reaches contained more sediment and more pool habitat. Salvaging wood defeated the purpose of recovering habitat by removing the predominant factor forming pools, and new supplies of wood to replace that produced by the eruption will not be standing along streambanks for many decades.

Therefore, as in Caspar Creek, pool volume was affected more by changes in the supply of large wood than by changes in the supply of sediment. In order to understand the effects of land use on pool volume and channel elevation, you needed to know changes in the supply of large wood and sediment and to understand their interaction.

Variability of Channel Parameters

Watershed history is necessary to evaluate the departure of channel condition parameters from pristine or reference values. I illustrate this by comparing regional variations in large woody debris volumes in channels.

Figure 5: Cumulative frequency curves of large woody debris volumes (m^3 per ha of channel area) in channels in unmanaged basins are used to show variation within and between forested regions of California and Oregon (Keller and Tally, 1979; Harmon et al., 1986; Berg et al., 1998). Each point along these lines shows the fraction of channels that have less than the wood loading for that point; the median value has a cumulative fraction of 0.5. There are wide differences between regions. For example, median loading for old-growth redwood is about $1000 \text{ m}^3/\text{ha}$, while median loading in the northern Sierra Nevada is only $30 \text{ m}^3/\text{ha}$. There are also wide variations with regions; the difference between maximum and minimum loadings are well over ten-fold. This indicates that reference (or pristine) loadings for one region cannot be applied to another.

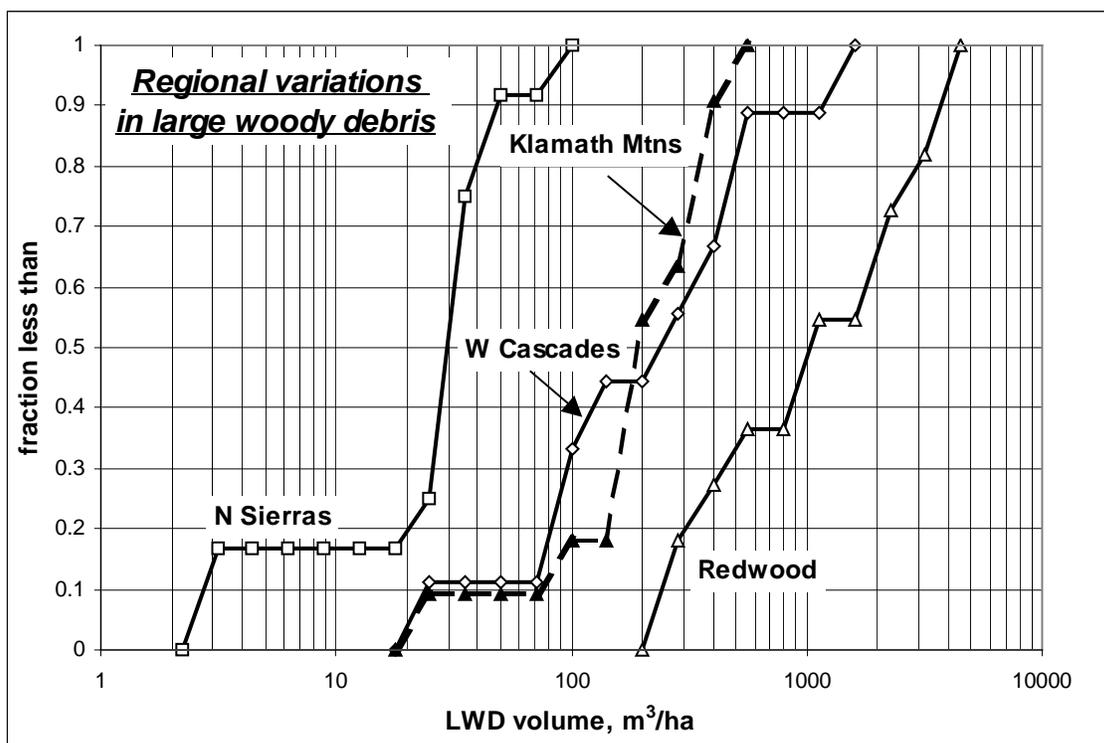


Figure 5. Regional variations in LWD loading in streams within unmanaged watersheds

Figure 6: Second-growth redwood channels contain three to five times less, on average, than old-growth channels (second-growth data from Knoll, 1993). A history of logging, salvage, and stream cleaning has apparently created a deficit of wood in second-growth channels (as well as a decrease in size of pieces). However, as is common with environmental parameters, the

enough can be learned to evaluate important historic trends and thus inform managers to intelligently evaluate how projected trends would be affected by alternative land use plans. For example, if there has been a history of wood depletion from log runs in the 19th century, followed by aggressive stream cleaning in the 1970's, then there would be added incentive to maintain recovering supplies in intact second-growth riparian stands. In this case, wind throw from narrow buffer strips might provide short-term increases in wood, but early cashing in of remaining wood supplies could perpetuate the deficit in decades hence.

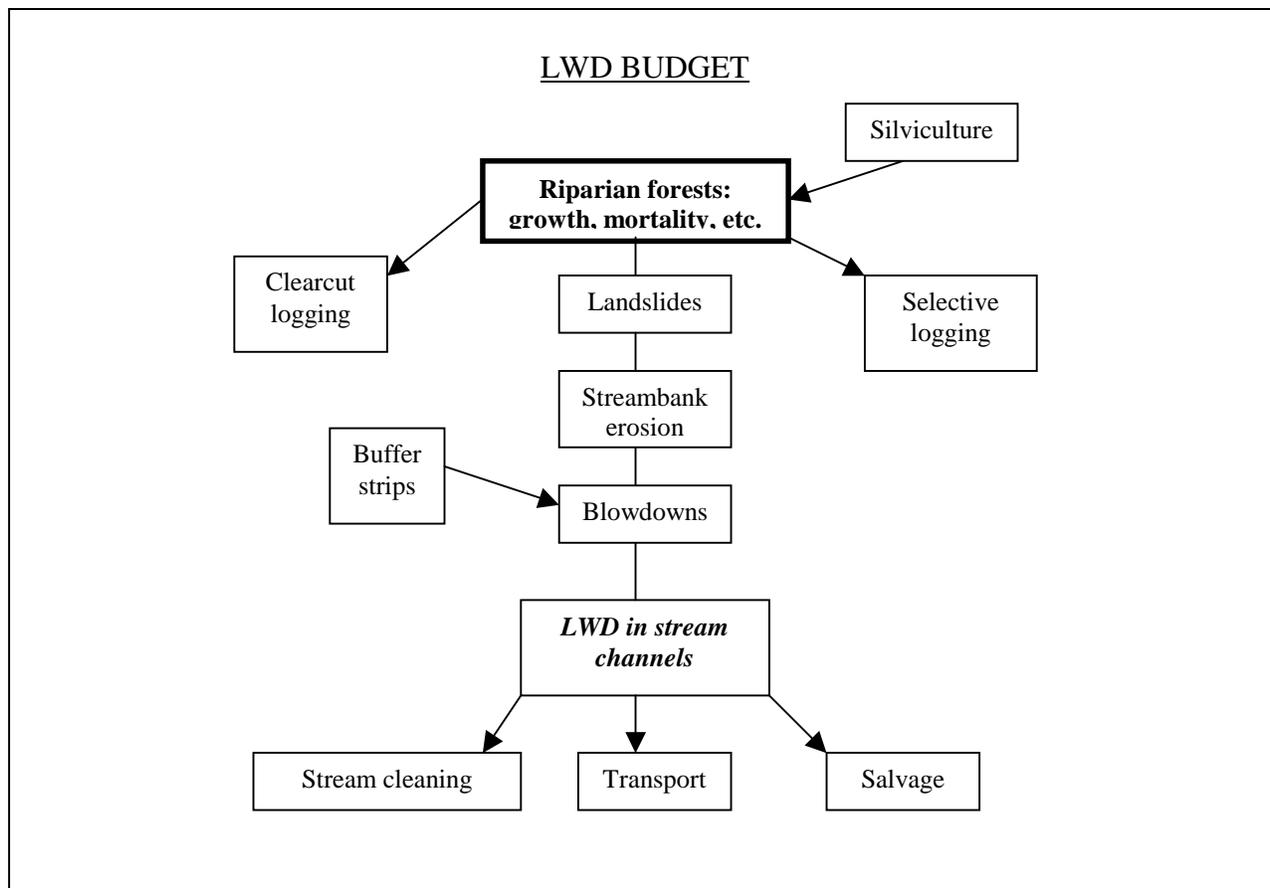


Figure 7. Schematic of LWD budget, as related to timber management practices.

Many other channel parameters (e.g., fine sediment concentration, water temperature) could be substituted for wood in this comparison and the results would be essentially the same. Strong regional differences would indicate that reference values would be appropriate only within the same 'litho-topographic' or 'geo-hydrologic' area. Depending on the parameter, the distribution of values for the population of affected channels would be greater or less than those for pristine channels. However, overlap in these distributions would invalidate the use of single threshold values to regulate management of individual channels. Instead, appropriate target conditions would need to be evaluated by putting the channel in context with its watershed: determining how past and projected production and routing of watershed products interacting within the

setting of the watershed, land use, and climatic events have created current trends as monitored by the appropriate parameters linking land use to downstream resources.

Concluding Statement:

Basic point is that channel monitoring is just one of many strategies to gather information to facilitate adaptive management. Need to regard the whole set of links of watershed processes to understand the results of channel monitoring to be pro-active in managing the resources. Sometimes when you examine the whole picture and strategize where you need to collect information you will be led to channel monitoring in some cases, but in many cases not. Must not monitor channels in isolation of other processes occurring across the entire landscape of the watershed.

Clarification Questions:

1. *In Mount Saint Helen's example the conclusion was "wood trumps sediment", is it possible to predict in which settings this is true? Probably in lower gradient channels where the sediment moving through the system is annually transported bedload. Where (and when) this probably does not hold true is during debris flows, which will often wipe-out the pools from the sheer volume and force of water, wood, and sediment pulsing down the channel. But after the debris flow (which often scours the channel clear of obstructions) new inputs of LWD occur when trees are recruited from bank scour caused by the passing debris flow.*
2. *One graph in which you showed old-growth versus second-growth LWD in terms of cubic meters per hectare, you said you could substitute fine sediment for LWD, however wouldn't the relationship (for fine sediment) be opposite of the LWD relationship? Yes, that is right, that is a good point. I was only referring that any parameter of interest could be substituted for LWD, not that the relationship was the same.*
3. *Also, regarding the same graph, you mentioned that LWD is inefficient in creating habitat, wouldn't an even better graph compare the number of pools and pool volume to LWD volume in those two types of channels (old-growth versus second-growth), and to account for that inefficiency and show that it will be hard (or take a long time) to achieve old-growth levels of LWD volume? Yes, you could probably develop that relationship. I would anticipate lots of variation. There would probably be a positive relationship of pool volume and pool number versus LWD volume, but lots of scatter of the data points.*
4. *Regarding Caspar Creek, what was the source of the sediment seen in North Fork Caspar Creek? Not sure of the source, but the point I was trying to make was that the sediment accumulated there because of the LWD, maybe from upstream (inchannel) sources, but the sediment slowed its passage where the LWD was located, and accumulated. There were no big landslides upstream that obviously contributed sediment to the channel during the study period.*
5. *You mentioned there were three factors regarding why channel monitoring wasn't the best tool for adaptive management purposes, the first two were time lags and variability in*

watersheds, what was the third factor? The impossibility in deciphering what was going in the watershed by just looking at the channel.

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