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Science FINDINGS

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"Science affects the way we think together"
Lewis Thomas

LESSONS FROM A FLOODED LANDSCAPE

On the soggy morning of February 6, 1996, Grant, a fluvial geomorphologist at the Corvallis Lab, logged on to the Internet to check the gauging stations in and around the H.J. Andrews Experimental Forest, about 100 miles southeast. When he saw that the McKenzie River was going up 1,000 cubic feet per second every hour, he knew some serious chaos was at hand.

Grant and Fred Swanson, a Forest Service geologist and Andrews Forest project leader, headed immediately for the mountain forest. After all, the last major flood event, in 1964, had predated both their research careers.

Both reacted viscerally to the scene of the flood, once they were literally standing in it during the next two days. "There is a dramatic power to such a huge landscape event, a feel, a smell to it," Grant says. "It was absolutely the high point of my career to date, the field experience you dream about."

Swanson vividly describes the kahwoomp sound of giant boulders rumbling along the streambed, and the "Rip City!" experience of watching whole old-growth trees, with root wads intact, racing down river channels. He recalls standing beside a flooded main channel watching the rapid approach, trunk first, of an old-growth tree captured by floodwaters. "The tip of the trunk lodged in the bank right at my feet. Then the force of the current took the root wad and swung it around to lead downstream. The current yanked the treetop out of the bank, and on it went."

The 1996 flood crystallized scientists' thinking about flood effects and dynamics.

"This is when the physical work of the landscape gets done," says Grant. "More sediment and debris of every kind, from the boulders and the trees to the finest silt, entered the main streams in those 24 hours than will in probably the next 40 or the previous 30 years." And thus more dramatic change was wrought upon the landscape than will occur again until the next "big one."

"One thing the '96 flood has really emphasized," says Swanson, "is the tremendous value of Forest Service watershed research in hanging together through all the decades of boredom. It's a tricky balance between a maniacal persistence in collecting baseline data while very little seems to be happening, and yet responding to the current fashions in science or the latest management-policy issue." For it is precisely those boring baseline data, decades' worth of them, that let researchers truly "measure" the events of the flood. Their patterns through the decades of boredom provide a context for understanding major flood events.

For it is precisely those boring baseline data, decades' worth of them, that let researchers truly "measure" the events of the flood.

Fred Swanson

Decades of boredom punctuated by hours of chaos.

Gordon Grant
("Torrents of Change") on mountain streams

EDITOR'S NOTE

*The **PACIFIC NORTHWEST RESEARCH STATION** serves society by improving the understanding, use, and management of natural resources. This monthly publication presents science findings for people who make and influence decisions about managing land.*

In our first issue, we describe research that reflects our responsiveness to natural events and our ability to address issues over time. Floods can bring tragedy in the wake of their destruction. Floods also are a natural process that has shaped our landscapes. We hope that our scientific information helps people make wise choices that influence floods associated with forest lands.

The next issue of Science Findings will examine another aspect of catastrophic disturbances. We will present findings on how anadromous fish are affected by the dynamics of aquatic ecosystems.

As our first issue of Science Findings, this represents a beginning. We will be making improvements in content and layout as we go along and welcome comments. We also would like to expand our initial distribution. If you have ideas about improving this publication or names to add to our mailing list, please contact:

Cindy Miner
Pacific Northwest Research Station
P.O. Box 3890
Portland, Oregon 97208
(503) 808-2135

United States Department of Agriculture
Forest Service

Floods do the physical work of the landscape.

LEGACY OF KNOWLEDGE BUILDS FROM THE FLOOD OF '96

Rather than dramatically changing existing ideas about flood effects and dynamics, the '96 flood seems to have crystallized many of the hypotheses, according to Swanson. Perhaps its most valuable legacy has been to encourage new ways of thinking.

First, the news story in the natural forest is that floods are not just about a lot of water. Yes, there's a lot of water, but all the time that story is developing, uncountable diverse processes are happening in stream channels and on hillslopes. Many of them connected. On the hillslopes there are landslides, debris flows, quantities of snow absorbing water or melting at various rates, and interactions between the stream and the road system. In the channels, there is rising water, moving wood, and sediment input ranging in size from silt through gravel to boulders. Everywhere, the transfer of potential to kinetic energy.

The linking of all these processes creates what researchers call a disturbance cascade: some cascades have a snowball effect and get larger as they go, others act more like an unrolling rug, and dissipate their energy and effects quite rapidly. For example, the making of a debris flow starts with saturated soils that begin to liquefy. Some flows never make it into the first small channel, hung up by an old-growth tree, a lack of content, a failure to attract a following. The rug is unrolled, the energy spent.

But if they do gather enough mass, they'll start taking out some streamside shrubs and logs, increasing momentum and power on their way to the main channel. By this time, they're big enough to take on large stands of alder, shift boulders the size of Volkswagen bugs, add their weight to the force of the flow through the channel. The snowball effect.

FOR FURTHER READING

Baker, V.R.; Kochel, R.C.; Patton, P.C. eds. 1988. *Flood geomorphology*. New York: John Wiley and Sons. 503 p.

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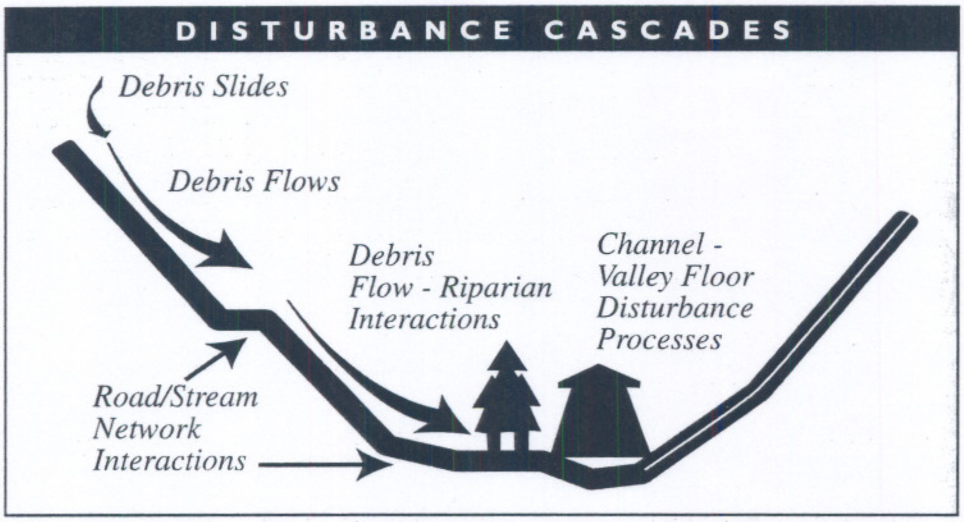
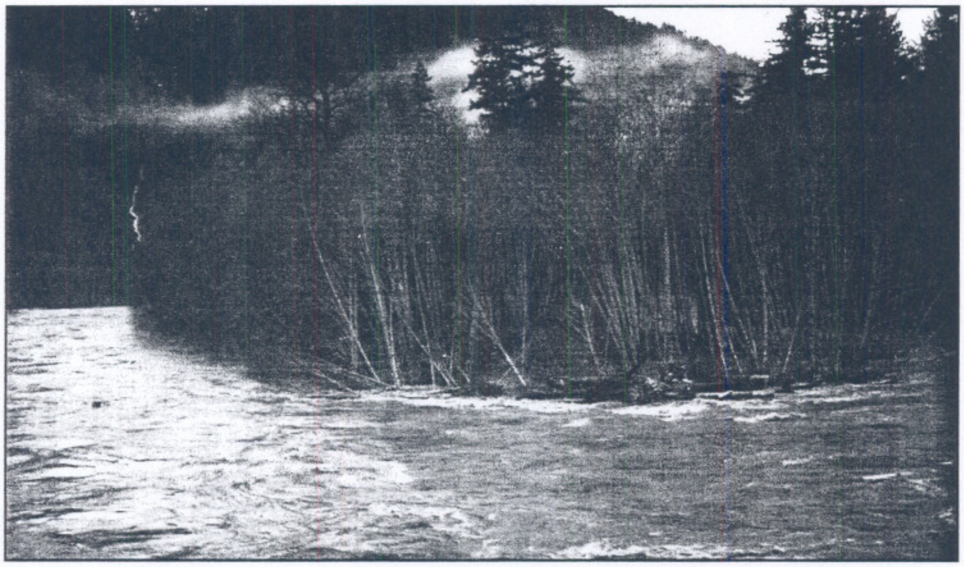
Jones, J.A.; Grant, G.E. 1996. *Long-term stormflow responses to clearcutting and roads in small and large basins, western Cascades, Oregon*. Water Resources Research. 32:959-974.

Swanson, F.J.; Dyrness, C.T. 1975. *Impact of clearcutting and road construction on soil erosion by landslides in the western Cascade Range, Oregon. Geology*. 1:393-396.

NOTE: Also see Andrews Flood web page at: http://www.fsl.orst.edu/lter/navigafr.htm; click on Table of Contents; click on Special Reports: Flood 1996.





Each flood sees a different landscape. Where the 1964 flood knocked down old growth, it paved the way for subsequent older stands to fall in 1996.

With sufficient force, and speeds of 20 to 30 miles per hour, even remnant stands of old-growth along the channel cannot always withstand the impact of such a channelized mass. The flood is intractably at work.

And yet here is one of the apparent paradoxes of a big flood event: despite all the drama and the devastation, the landslides, the debris flows, and the channel alterations, some parts of the landscape escape almost unscathed. The effects of the flood were not uniform between basins, streams, or even adjacent reaches of the same stream. Are flood effects completely random?

No. Consider the flood's perspective, Grant suggests: each flood sees a different landscape. In their moments of chaos, previous floods changed the landscape, and in the decades of boredom, land use and vegetation also altered the scene.

For example, if a reach of stream was gouged down to bedrock by a debris flow 30 years ago, it provides less resistance to subsequent debris flows, which therefore have more available energy to transport both wood and sediment downstream. If accumulations of wood remained along the high flow line of a stream, these "wood levees" acted as buffers for the riparian areas behind them. If a stand of old-growth firs got knocked down last time, the alder that succeeded in its place was less likely to withstand the force of a debris flow, and more likely to contribute wood to the gathering mass. Thus the effects of one flood leave their footprints for the next flood.

Overall, the '96 flood produced a pattern of irregular disturbance, with greatest changes in small channels affected by debris flows, and in reaches of the main stem that were unconstricted by bedrock and therefore able to accommodate channel migration. Changes in populations of stream organisms reflected the patchiness, with large changes in some areas and no detectable change in others.

WRITER'S PROFILE

Sally Duncan is a science communications planner and writer specializing in Forest resource issues. She lives in Corvallis, Oregon.

COMPARING RESPONSES TO TWO FLOODS

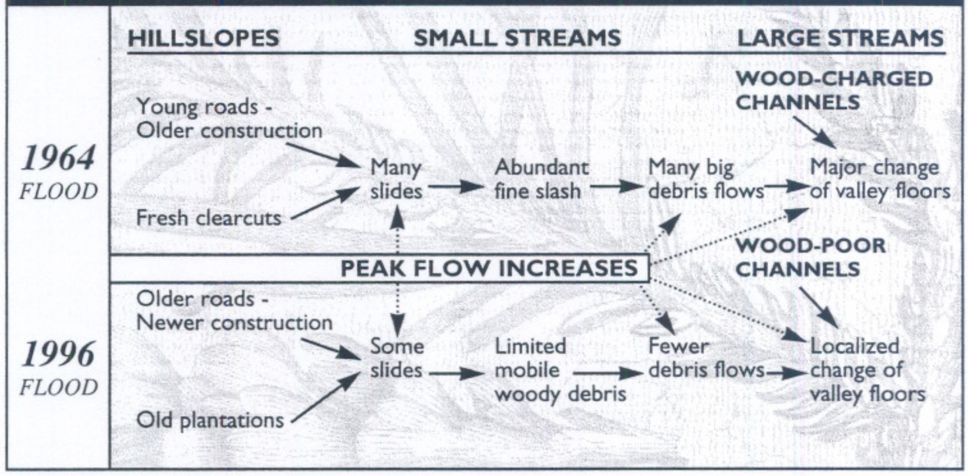
Land management activities do affect how a flood plays out across the landscape, in a sense because they intensify natural instabilities in the system. As the two activities with the greatest impact on the landscape, logging and road building come under particularly close scrutiny. Both affect the quantity of woody debris in small channels, the frequency of mass movements from hillslopes, and the interaction between streams and roads or bridges.

How do we accurately track the effects of management? By comparisons over time. Witness the differences between the '64 and the '96 floods.

"In 1964, there had been 15 years of fairly constant logging, the road system had been built into the watershed from lower elevations, on the flood plains and midslope," explains Swanson, "and its objective was to move logs efficiently, not to consider landscape effects." Furthermore, there had been no big flood events in the previous 20 years to thoroughly "clean" the system, thus leaving a lot of big trees and logging debris to work major change in the stream system.

But by 1996, there had been 25 years without much logging or road construction, and that big flood just 32 years before. Specifically, in 1964 as much as 15 percent of the basin area had clearcuts younger than 15 years, and about 80 km of roads the same age, whereas in 1996 there were only 2 percent of the clearcuts and less than 20 km of roads less than 15 years old.

HYPOTHESIZED DIFFERENCES IN FLOOD RESPONSE, 1964 & 1996



"Younger plantations are thought to have a higher susceptibility to sliding because of reduced root strength and possible effects on soil-water movement," says Swanson, so slide numbers from plantations were lower in the '96 flood. In addition, road building methods had been modified substantially because of lessons from the '64 flood; road related slides were reduced by about half in 1996.

There was simply less large woody debris and fewer unstable slopes and roads to contribute to massive structural change.

Another player that differs between flood scenes is snow pack. The timescale of snow pack registers in days and weeks, rather than years and decades like landslides. By affecting the timing and height of peak flows, the amount of water stored in the snow pack can significantly exacerbate or diminish flood effects. The February 1996 flood came on the heels of high snowfall, as much as 112 percent of average. As the flood progressed, three zones of snow effect were apparent: a lower zone from 400m to 800m elevation where melting from a thin, wet snow cover added its volume to high rainfall; a middle zone from 800m to 1200m where a deeper snow pack first stored then released water; and an upper zone above 1200m where a very deep pack stored much of the precipitation and buffered the intensity of the storm in the upper elevations.

> *Road building methods had been modified substantially because of lessons from the '64 flood: road related slides were reduced by about half in 1996.*
>
> Fred Swanson

K E Y   F I N D I N G S

- **The overall pattern of landslides and streamflows was very strongly influenced by precipitation intensities, and in some areas by snowpack dynamics.**
- **All floods are strongly affected by preexisting conditions and by the legacies of human actions and natural events.**
- **Floods have a wide variety of unpredictable consequences and different effects even in neighboring stream reaches.**

INTEGRATION IS THE NEW WAVE OF SCIENCE

Any flood leaves behind lasting teaching materials. But the lessons from this flood have a significant new aspect to them: integration.

"In studies of the '64 flood, the focus was mostly on a limited set of questions in smaller watersheds, but we're now looking at larger basins, and how material is routed through the whole system," Swanson explains. There is less focus on just counting landslides, counting road failures, and inventorying channel change. Instead, the emphasis is on "How do these pieces connect and so what?" And it ain't easy.

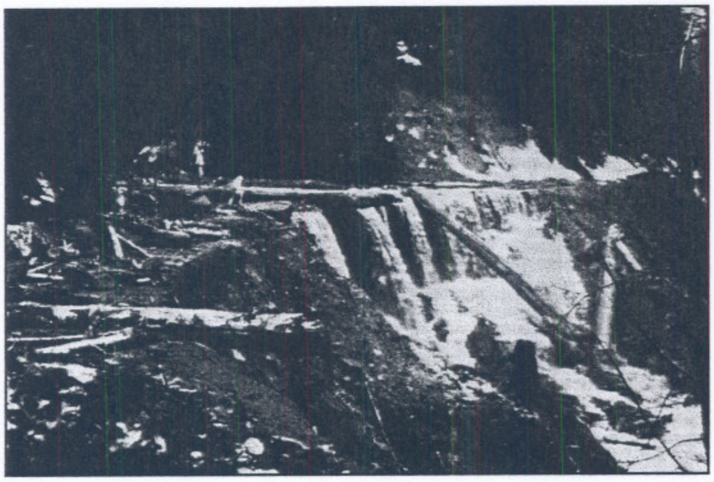
"We still fall into the trap of having some people look just at a horizontal view of the landscape via roads, and the people right beside them taking just the vertical view via landslides."

In fact, as Grant says, "When you try to build an integrated study so that you can understand floods as systems, the connectivity of all these events becomes a kind of tyranny. Far from the old days when we dealt separately with roads, channels, slides, water, or wood, we now "get it" that the flood doesn't care. It moves through a whole landscape, so if we want to understand it, we'd better have a good grasp of the whole landscape. And that takes a huge effort."

Integrated research, in a sense, tries not to care more about one landscape response than another, tries to "treat" the whole landscape at once. After all, that's what the flood does.

Swanson notes that the focus even of an integrated research effort can change within the span of studying a single flood. In '96, their original focus was, of course, ecosystem and watershed processes, but it rapidly turned to public safety and policy after the five southern Oregon deaths. Ongoing municipal water supply issues, particularly out of Salem, kept the pot boiling. "We're seeing floods become an urban interface issue, linking people with wildland hazards like fire, wild animals, and landslides," he says.

Remember, although researchers must respond to the information needs of policymakers, someone has to be collecting the baseline data. Hence although the '96 flood triggered new studies, it also reinforced the value of long-term monitoring of such variables as climate, stream flow, channel conditions, and biota.



Scientists are focusing less on simply counting landslides and road failures, instead they are asking, "How do these pieces connect and so what?"

LAND MANAGEMENT IMPLICATIONS

- *Land use practices and policies have changed dramatically since 1964 and appear to be reducing certain kinds of flood hazards.*
- *New policies under the State Forest Practices rules and the Federal Northwest Forest Plan are barely evident yet on the landscape, so we don't know if they will meet their stated objectives.*
- *Clearcuts are more susceptible to sliding during the first two decades after harvest; roads' susceptibility may diminish over time as well, but slide rates from roads remain substantially higher than they are in forested areas.*

BIOLOGICAL DYNAMICS OF FLOODS

Generalities first. "We need to remember these are dynamic systems whether we cut trees or build roads or not," says Swanson. "We've uncovered countless ways in which ecosystems are attuned to floods and their effects." He refers to the flood pulse concept as an example. The idea is that land based inputs pulsed into a river during a flood may actually improve the productivity of the river in terms of vegetation, fisheries, and wildlife.

What was the biological story in the flood? "Survival of species is a direct function of whether and where they can hide, such as relatively undisturbed side channels and flood plains, and an organism's ability to get to the refuges," says Swanson.

Flood responses of cutthroat trout, sculpins, and Pacific giant salamanders, the most abundant vertebrates in Andrews streams, tell the story. Trout are strong swimmers capable of moving quickly in the stream, even at high velocity, and take cover along edges or in woody debris during high flows. Sculpins move with considerably less speed and agility, and move into the streambed during high winter flows. Pacific giant salamanders are also bottom dwellers, move mostly by crawling, and are not strong swimmers.

"Trout survival was very similar to winters without major floods," Swanson says. "But sculpin and salamander were hammered hard, declining by about 65 percent. When flood discharge is sufficient to cause movement of gravel and boulders along the streambed, organisms limited to that habitat may be killed by moving particles."

Grant adds, "The consequences of floods are not easily summarized as good or bad for humans or organisms. Much depends on the life cycles and strategies of the various critters."

Most management questions, then, need to be framed openly. What might help or harm particular species? How did the wild system work, and how did the management overlay affect it?

ROADBUILDING AND LOGGING

Aspects of the road story were already known in sketchy fashion: ridgetop, midslope, and valley floor roads have different impacts on the landscape under flood conditions. Roads can fail in a variety of ways. Roads in different landscape positions have different capacities to become a sediment source or a sediment sink.

The '96 flood brought roads under the research spotlight as landscape elements with distinct characteristics, rather than individual "case studies" of failure. It also provided more numbers to solidify the story. But what really came clear about roads was how to ask better questions.

Swanson takes some stabs. "How can we reconfigure roads to do tomorrow's job, not yesterday's? Now that road maintenance budgets are severely reduced because of less logging, how can we get roads to take better care of themselves?"

Likewise, logging practices are key players in flood times, and the details of their effects are coming to be better understood through the combination of flood data, baseline data, and integrated research. It does appear that younger plantations play a larger role than established stands in landslide activity during floods. The question becomes a complex study of ecological effects playing out beside risk and hazard management.

For men may come and men may go, but I go on forever

Tennyson
("The Brook") on rivers

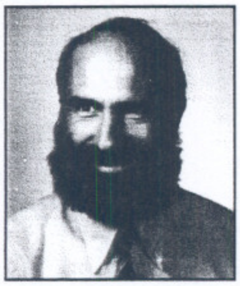
"While no models are perfect, results from flood studies can contribute directly to our mapping of high hazard areas aimed at reducing risks to public safety," Grant says. Swanson, too, feels that while they cannot claim complete accuracy on causes and effects of each slide, existing data can offer extremely useful predictions of high hazard sites.

"What we have going in management," Grant concludes, "is a grand experiment with no possibility of replication. Surely we are required therefore to learn from events like floods that are episodic. Most importantly, we need to take some Zen moments, learnable moments, before we rush back in to 'restore' things. Our actions have consequences in time as well as space."

Science
FINDINGS

U.S. Department of Agriculture
Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, Oregon 97208-3890

SCIENTIST'S PROFILES



FRED SWANSON, A Research Geologist with the PNW Research Station, has been studying landslides and other erosion processes in western Oregon for more than 25 years. Swanson is also a leader of the National Science Foundation sponsored Long-Term Ecological Research program at the H.J. Andrews Experimental Forest. He is also leader of the Cascade Center of Ecosystem Management, a research-management partnership involving Forest Service Research, the Willamette National Forest, and Oregon State University.

GORDON GRANT, a Research Hydrologist with the PNW Research Station, has been studying rivers for more than 15 years. Before that, his interest in fluvial processes was sparked by a decade-long career as a whitewater river guide. His research now focuses on the structure and behavior of mountain streams, and the effects of forest land use, dams, floods, and other disturbances on rivers and watersheds in the Pacific Northwest and elsewhere. He is also a Courtesy Associate Professor of Geosciences at Oregon State University.

SWANSON and GRANT can be reached at:

Pacific Northwest Research Station/USDA Forest Service
Corvallis Forest Science Laboratory
3200 S.W. Jefferson Way
Corvallis, Oregon 97331

E-MAIL ADDRESSES are:

swansonf@fsl.orst.edu
grantg@fsl.orst.edu.