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Caspar Creek Experimental Watersheds

Cumulative Effects of Forest Practices on Downstream Resources

Research at Caspar Creek provides information that helps forest managers assess and predict the environmental effects of forest practices and natural disturbances on downstream resources. Monitoring long-term effects and adapting practices can help protect and restore water quality and fish habitat in Northern California.

A walking stick comes in handy on the switchbacks leading down to the North Fork of Caspar Creek. Starting from broad, rounded ridgetops, the trail descends along steep valley walls to an incised stream gorge deep within a redwood forest.

In the late 1800's, loggers clearcut the canyon of old-growth forest and transported tens of thousands of logs down the creek. After removing or blasting boulders, rocks, trees, debris, and other obstructions in the valley bottom, loggers hauled old growth logs to the Caspar Creek channel. Far upstream of the stacked logs, they constructed a log dam and waited for the reservoir behind it to fill.

Moving the logs downstream required an extraordinarily large flood, so the dam operator would wait until a winter storm to open the spillway gate. Water pouring out of the reservoir combined with high winter flows to carry the logs to a sawmill at the Creek's mouth.

Along the North Fork, second- and third-growth trees, slender by old-growth standards, now replace the logged giants, whose ghostly stumps stand a full story high and up to 10 feet (3 meters) across. Only in dusty photos does the original cathedral-like forest still exist, trees felled long before old-growth redwoods were protected.

Today's managers focus on the younger forests now typical of coastal Northern California. Federal and State legislation currently mandate analyses of cumulative watershed effects, or CWE's, to evaluate forest-management proposals. CWE analysis looks at the combined effects of multiple upstream activities on streamflow, erosion, woody debris, aquatic ecosystems, and other issues that might be of concern in downstream environments. Forty years of research at the Caspar Creek Experimental Watersheds has produced one of the richest sources of information available for assessing cumulative effects in coastal streams and adjacent riparian ecosystems.

The present-day forest in the Caspar Creek watershed consists of coast redwood, Douglas-fir, western hemlock, grand fir, and occasional hardwoods, such as tanoak and red alder. Evergreen huckleberry, Pacific rhododendron, and dense clusters of western sword fern populate the forest floor, and in thickly vegetated valley bottoms, the quiet warble of the winter wren reveals its secretive presence.

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Science Perspectives

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From Science...

Major Themes

Temperate, rain-dominated forests are important sources of both water and wood, and they respond to forest management in ways that cannot be predicted from studies in other environments.

Cumulative watershed effects are poorly understood, yet they cause most of the downstream impacts from forest-management activities.

Research Results

Clearcuts, flooding, and sediment: Logging increased streamflow by decreasing rainfall interception and transpiration, and increased streamflow increased gully erosion.

Legacy effects: The effects that remained from earlier logging increased the sensitivity of watersheds to modern logging practices.

Recovery times: Increased sediment loads took longer to recover after clearcutting than the increased streamflow that caused erosion because sediment sources, once triggered, take decades to heal.

Woody debris, sediment storage, and in-stream habitat: Woody debris contributed by a windstorm improved salmon habitat by storing more spawning gravel and creating deep pools.

Caspar Creek Experimental Watersheds

The Caspar Creek Experimental Watersheds, located within the Jackson Demonstration State Forest near Fort Bragg, California are administered under a long-term cooperative relationship between the USDA Forest Service Pacific Southwest Research Station (PSW) and the California Department of Forestry and Fire Protection (CDF). Researchers from several federal and state agencies, as well as universities, have joined the Forest Service and the Department of Forestry in collaborative research.

As paired watersheds, the forks are similar enough that researchers can use one for experimental treatment and the other as an untreated "control." The control helps investigators determine which effects are actually caused by experimental logging and restoration treatments and which occur through natural variations. Before each experiment, scientists monitor for five years or more to define the natural variation between the two forks. Because the watersheds are managed for research, investigators have control over grazing, logging, and other human-caused disturbances.

Researchers also monitor the effects of natural disturbances, such as floods, drought, wildfire, landslides, windthrow, and insect outbreaks. Monitoring stations along major tributaries record flow rates and suspended sediment. Researchers also track levels of downed wood, ecosystem changes, water temperatures, and other aspects of watersheds that affect stream ecology and downstream rural communities.

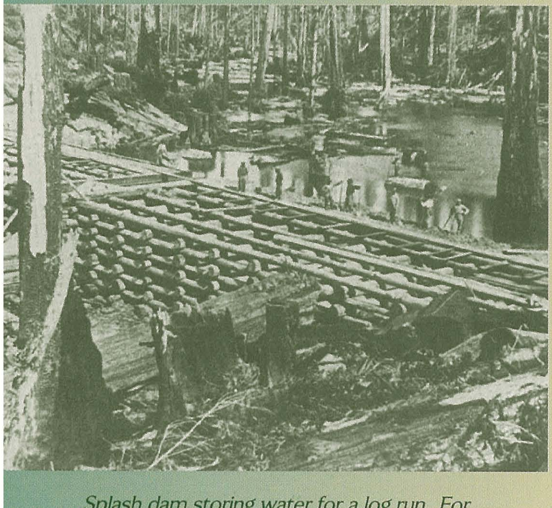
Two aspects of Caspar Creek studies make them especially valuable for planning and understanding forest management activities. First, the studies are large-scale, providing data relevant to entire watersheds. Second, the data are long-term and continuous, so they show how the effects of various management practices change as watersheds recover.

Road Building and Logging

Two major experiments that explore how logging and road building affect forest hydrology took place at Caspar Creek over the past 40 years. Scientists are currently planning a third experiment, focusing partly on forest restoration (see What's Next).

The South Fork Experiment (1967-1985) was designed to measure the effects of extensive road building, as well as selective logging with log extraction by tractor yarding. Soils on about 15 percent of the watershed were compacted during this process, and 65 percent of the timber volume was removed from throughout the watershed. The North Fork watershed, left untouched, served as a control.

Scientists found that high flows occurring only one percent of the time carried over 80 percent of the South Fork sediment. Roadbuilding resulted in a 275 percent initial increase in stream sediment, while logging itself caused a 350 percent



Splash dam storing water for a log run. For scale, note the men silhouetted by the water

Old-growth logging at the turn of the 20th century

Caspar Lumber Company mill at the mouth of Caspar Creek, 1910 increase. Increases in peak streamflow due to forest canopy loss and watershed soil compaction were detected during autumn storms, and peak flows peaked sooner after heavy rains.

The North Fork Experiment (1985-2005) examined the effects of clearcut logging combined with log extraction by cable yarding, a process that minimizes road construction. Scientists used the recovered South Fork and some North Fork tributaries as controls. Approximately 50 percent of the North Fork watershed was clearcut, with unlogged buffer strips left along creeks in the clearcut blocks.

Logging caused a 90 percent increase in sediment yield during the six years after logging began, less than that observed during the earlier South Fork study where tractor yarding had extensively disturbed the hillsides. Clearcutting also resulted in increased peak flows, and this time the increases were also detected during major winter storms. Increased peak flows raise sediment yields by causing more gully erosion.

PSW hydrologist Elizabeth Keppeler analyzed summer low-flow measurements and found that selective logging caused a 38 percent increase in South Fork minimum flows and clearcutting caused a 148 percent increase in North Fork minimum flows. She also found that, despite the important role played by fog drip in redwood forest ecosystems, reductions in fog drip after logging did not affect creek flows in the watersheds.

Cumulative Effects Downstream

Focused Process Experiments

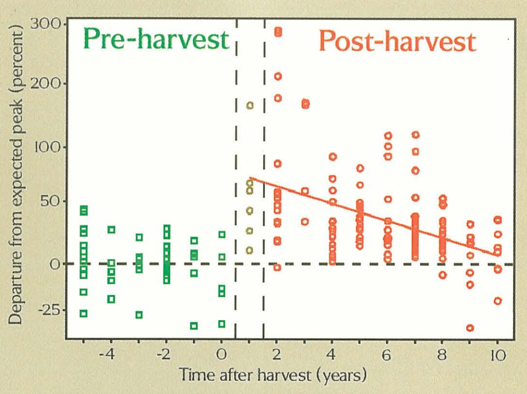
The North Fork experiment was designed to shed light on how the cumulative effects of disturbances change from the top of the watershed to the bottom. Nested within the larger North Fork Experiment, a series of smaller studies focused on how logging affects individual watershed processes. Scientists also evaluated how the effects of various disturbances interact downstream.

Rainfall Interception and Pipe Flow

A raindrop's journey begins as it falls to earth—but its landing site may not be on the soil surface. In forests, foliage intercepts rain, allowing some to evaporate. PSW geomorphologist Leslie Reid and colleagues compared the amount of rainfall reaching the ground under second-growth redwoods and in adjacent clearcuts. Results show that interception plays a major role in reducing flows—about one quarter of the rainfall in second-growth redwood forests never hits the ground. In fact, the decrease in interception, together with a reduction in water uptake by trees after logging, explained the rise in peak flows observed in the North Fork experiment.

What happens to raindrops that do reach the ground? Most seep into the soil; hillsides shed little surface water during storms, even in shallow valleys known or swales. Rainfall percolating into the ground flows through the soil and some concentrates in natural underground conduits called "soil pipes." Pipes range from about 1 in. (2.5 cm) to several feet (about a meter) in diameter and can occur from just beneath the surface to as much as 6 feet deep (about 2 meters).

PSW hydrologist Robert Ziemer and Humboldt State University graduate student Jeff Albright excavated soil pipes in three swales to capture their flow and transported sediment. The scientists found that pipe networks collected nearly all of the flow in each of the swales studied. But compaction during logging processes, as well as increased flow volumes following logging, led to eventual collapse of some pipes. Collapse transformed them into rapidly eroding gullies, which are large sources of sediment.



Peak flows in North Fork Caspar Creek increased after logging and recovered in the next ten years

Gully Erosion in Tributaries

The first channels that pipeflow is likely to encounter are gullies formed by collapsed pipes or headcuts in swales. Data collected by Nick Dewey, a Humboldt State University graduate student, indicate that gullies enlarged after the initial clearcut logging of the old-growth forest over 100 years ago. Renewed gully erosion is a large contributor to increased sediment yields that typically follow second-growth logging.

Woody Debris

Water encounters numerous detours as it continues downstream. For example, according to detailed channel surveys by PSW hydrologist Sue Hilton, windstorms during the 1990's toppled many trees into the North Fork channel, forming small dams that trap sediment and deflect flow. In this way, much of the sediment eroding off hillsides or gullies ended up stored in the creek bed and floodplain, rather than continuing downstream.

A Joint Venture with the California Department of Forestry and Fire Protection (CDF)

The long-term research and management venture between the Forest Service and CDF has resulted in a scientific heritage for future generations, a heritage that becomes more valuable with each year that research continues. Consequently, CDF and PSW have agreed in principle to continue cooperative research at the Caspar Creek Experimental Watersheds for the next 100 years. This long-term commitment represents a realistic time-frame for forest research that accounts for forest maturation. The newly established Jackson Demonstration State Forest Learning Center provides facilities for visiting students and scientists carrying out studies at Caspar Creek and promotes educational use of Caspar Creek and the Jackson Demonstration State Forest.

...To Management

A Conversation with Tom Lisle

Q ***How do Caspar Creek studies help forest managers understand cumulative effects and plan effectively for watershed protection?***

Cumulative effects have been a thorny issue for forest managers, regulators, and the public because these effects are very important to downstream users of high-quality streamflow, yet they can be hard to measure or predict. We provide the only data available for California's North Coast region on the full suite of processes linking forest practices to downstream effects. We provide the kinds of information needed by forest managers to predict the environmental effects of modern forest practices, to monitor cumulative watershed effects, and to redesign practices to more effectively meet environmental needs.

Q ***What are some of the ways Caspar Creek studies have influenced development of better forest management?***

Information from Caspar Creek is widely cited in documents supporting management decisions in California and elsewhere, and has helped guide development of California's Forest Practice Rules. As a result, forest managers are developing new broad-scale strategies to reduce downstream impacts. We also have invented new approaches to in-stream sediment monitoring that decrease cost and increase accuracy. The improved feedback on sediment inputs is allowing new forest practices to be evaluated and adapted more quickly to meet management goals. This is an example of "adaptive management" -- a concept central to the federal Northwest Forest Plan.

Q ***Could you describe these new monitoring methods?***

We have developed automated technologies for sampling sediment and other constituents carried by water. Our method continuously monitors turbidity, a measurement of water opacity that correlates with sediment concentration; when turbidity reaches a critical level, it triggers an automatic water sampler. This provides the calibration needed to interpret the turbidity record as a continuous record of suspended sediment. Jack Lewis and Rand Eads, both of PSW, developed the new instrumentation, computer software, and analytical procedures that make up our "turbidity threshold sampling" (TTS) method. PSW hydrologist Elizabeth Keppeler took the lead in running the gauging stations, gathering turbidity data, and testing the technology. Use of TTS is expanding rapidly among forest managers, researchers, and regulators.

Q ***How do ecosystem studies at Caspar Creek contribute to protecting and restoring creeks for fisheries?***

Turbidity increases are pervasive in logged forests, but the potential impact on salmonids has not been well understood. Turbidity can limit the ability of fish to find food. PSW aquatic ecologist Bret Harvey is using turbidity monitoring, laboratory experiments, and computer modeling to evaluate the effects of increased turbidity on salmonid populations. Caspar studies also explore relations between logging, long-term supplies of woody debris in streams, and aquatic habitats such as pools. Taken together, the Caspar Creek studies help scientists understand how logging affects water, sediment, and wood—vital information for designing land use plans that protect and restore stream habitats.

Interception is measured by collecting precipitation inside and outside the forest canopy

Large-scale, long-term studies: Caspar Creek study results are widely quoted because they provide information at a scale relevant to today's concerns.

Cumulative watershed effects: Management activities can be more easily planned to improve forest health and maintain public safety if the causes of cumulative impacts are understood.

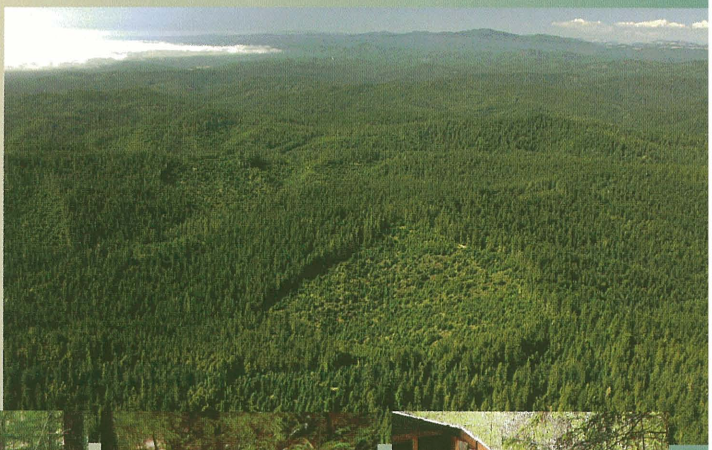
Managing increased peakflows: By understanding how logging affects peak streamflows, foresters can plan management to help avoid downstream impacts from flooding.

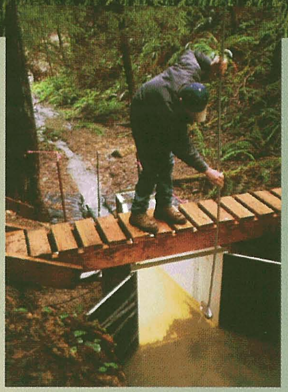
Water quality monitoring: The automated monitoring methods developed at Caspar Creek are now being used widely by forest managers, researchers, and regulatory agencies.

Interactions: Physical and biological processes affect each other, and both must be understood if we are to understand how watersheds are influenced by forest-management.

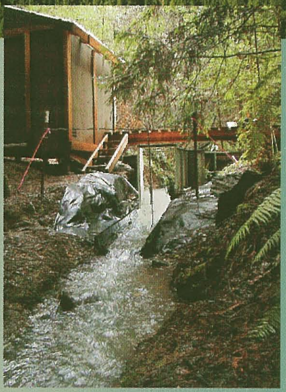
Fisheries restoration: Forests can be managed to protect and restore fish habitat by influencing runoff, sediment, and woody debris.

Photo below: New forest growth on clearcut blocks in North Fork Caspar





Manually collecting a suspended sediment sample



Fully instrumented gauging station

Science Team Profile

From left to right and back to front: Leslie Reid, Tom Lisle, Jack Lewis, Sue Hilton, Rand Eads, Rodney Nakamoto, and Debbie Visser

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The science team based in Arcata, California, is building on a long and rich tradition of carefully crafted watershed research begun in 1962. Ray Rice (1962-1989) and Robert Ziemer (1989-2001) were team leaders during the South Fork and North Fork experiments. Ziemer is responsible for greatly expanding the gauging network and setting the stage for the new South Fork experiment. The Caspar team, now led by Tom Lisle (Research Hydrologist), includes Bret Harvey (Aquatic Ecologist), Leslie Reid (Research Geomorphologist), Elizabeth Keppeler (Hydrologist), Jack Lewis (Mathematical Statistician), Rand Eads (Hydrologic Technician), Sue Hilton (Hydrologist), Rod Nakamoto (Fisheries Biologist), and Deb Visser (Hydrologic Technician). Based in Fort Bragg, Liz Keppeler maintains instrumentation and supervises data collection in Caspar Creek. Jack Lewis and Rand Eads designed automatic sediment sampling and streamflow measurements at gauging stations. Lewis is also responsible for most data analysis, and Deb Visser analyzes sediment samples and manages new data.

Research at Caspar Creek is truly a collaborative effort requiring the contributions of many team members. Hundreds of scientists have worked in Caspar over the past four decades, and many researchers and forest managers got their training here as students or temporary field crew. Additionally, in a unique relationship, the USDA Forest Service Pacific Southwest Research Station (PSW) and the California Department of Forestry and Fire Protection (CDF) jointly established and manage the Experimental Watersheds. Such teamwork and collaboration have resulted in over 150 scientific publications, all available from the Caspar Creek Experimental Watersheds web site.

www.fs.fed.us/psw/topics/water/caspar/

Continued from front page

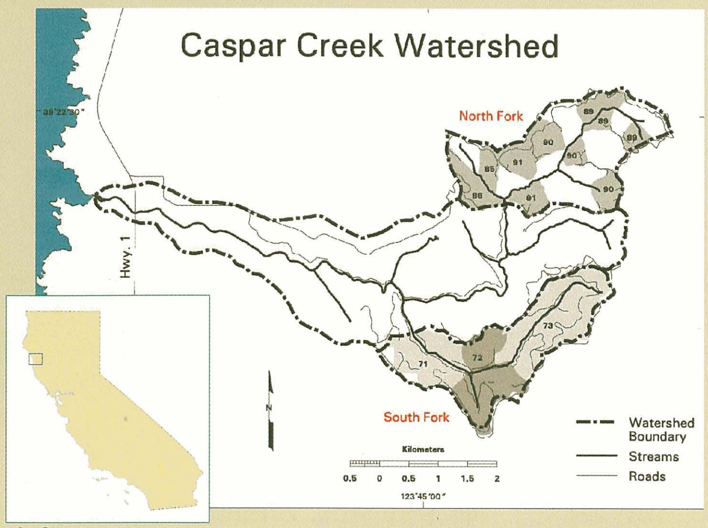
Hatched in Caspar Creek gravels, steelhead trout and coho salmon feed and grow, preparing for their challenging ocean-bound journey and subsequent sojourn. For its size, Caspar Creek is now one of the most productive coastal streams for coho salmon in Northern California. After 100 years, many components of the original forest ecosystem have returned.

From the upper reaches of Caspar's North Fork to its junction with the Middle and South Forks, the forest on either side changes little, except for occasional stands of alders along the banks. The creek itself, however, changes shape and character extensively.

Above the location where the dam once stood, Caspar Creek still bears the marks of logging over a century ago. Since large downed wood was removed and no longer buttresses valley soil deposits, gullies tend to incise upstream. A nearly vertical step (or "headcut") forms at the head of each gully, and down-stream of the headcut the creek flows through a deep, gullied channel before eventually spreading across the valley floor downstream. Smaller tributaries throughout the watershed exhibit similar flow patterns.

Below the dam site, the North Fork, once scoured and smoothed by log running, is regaining complexity as trees topple into the channel and disrupt water flow. Caspar continues for 7 miles (12 km) downstream of the dam site as a perennial stream, growing in size and eventually merging into an estuary that reaches the Pacific.

Liz Keppeler (center) and field crew



What's Next?

As forest management issues evolve and science progresses, new studies will be initiated at Caspar Creek. These will be interdisciplinary in nature and broad in scope, and will focus on how the physical and biological components of the ecosystem interact to affect forest and watershed functions. The long-term monitoring will continue, using the extensive system of gauging stations now in place. Only through continued monitoring can variations over longer timescales be detected and the effects of rare disturbances such as floods, earthquakes, landslides, and drought be understood.

In the third major watershed experiment, planned for 2007-2015, the South Fork watershed will again be logged. Even though sediment loads and flow have largely recovered, the South Fork landscape still shows effects of two episodes of logging, as is typical for lands throughout the redwood region. The next experiment will address issues relevant to management of coastal forests in the 21 st century by evaluating the effects of modern selective logging, quantifying the effectiveness of various approaches to repairing legacy disturbances from past logging, and measuring how reestablishing old-growth forest characteristics affects hydrologic functions and aquatic ecosystems.

Coho salmon returning to spawn

For Further Reading

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Web Resources

www.fs.fed.us/psw.topics/water/caspar/

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