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# Science

FINDINGS

*“Science affects the way we think together.”*

Lewis Thomas

## SEEN ONE DAM, SEEN ‘EM ALL?: THE SURPRISING STORY OF THE DESCHUTES RIVER

Photo credit: Portland General Electric



▲ *Deschutes River just downstream of Whitehorse Rapids. The landslide dam that formed at Whitehorse Rapids breached and released floodwaters over the terrain shown in the area about in the right center of the photo.*

*“You can’t step twice  
into the same river.”*

Heraclitus 513 B.C.

**I**n the heated debate about removal of dams from the Columbia and Snake Rivers, an interesting twist emerges from the rapids of another famous river. It turns out that not all dams are created equal.

“We’ve learned that dams must be evaluated on a case-by-case basis, with peer-reviewed science as a primary tool,” says Gordon Grant, a research hydrologist with the PNW Research Station in Corvallis, Oregon. “It is scientifically unsound simply to tar them all with the same brush.”

Dams differ widely, he notes, in their influence on downstream resources, depending on their geologic—and ecologic—setting and the degree to which their operation modifies predam flow and sediment regimes.

The Deschutes River of central Oregon spills into the Columbia River between The Dalles and John Day Dams and is home to the Pelton-Round Butte Hydroelectric Project. A geomorphological study of the privately owned three-dam complex was commissioned by current license-holder Portland General Electric (PGE). The U.S. Geological Survey, PNW Research Station, and Oregon State University contributed to a scientific review of the downstream physical effects of the dam.

### IN SUMMARY

*In the next few decades, hundreds of private dams will be relicensed by the Federal Energy Regulatory Commission. Many of them are on or influence Forest Service lands. Relicensing requires rigorous technical assessments of the effects of dams on critical resources, including channels, aquatic habitat, water quality, and recreation. Dams differ widely in their influence on these resources, and predicting their consequences is critical. Researchers at the Pacific Northwest Research Station examined the effects of the Pelton-Round Butte Dam complex on the geomorphology of the Deschutes River in central Oregon. The purpose was partly to study the effects of this particular dam on this particular river, but also to develop and test theory, concepts, and tools that would apply to dam assessments anywhere. The results—minimal impacts on the channel downstream—surprised researchers and revealed how close are the lines between geomorphology and hydrology in this river system.*

"This study yielded some of the biggest research surprises I have encountered," says Grant, who led the Deschutes study. "We didn't know going in where the Deschutes was in the spectrum of downstream effects. But we found that the change in flow and sediment regimes before and after the dam complex was built were minor. Consequently, changes to the channel itself were almost undetectable."

After more than 40 years, he says, there are few obvious effects to channel and valley morphology that are traceable to the dam complex. Researchers attributed this to the fact that the dam did not substantially change the flow of the river, and although it trapped sediment, the background supply from the surrounding area upstream of the dam had always been so small anyway that the effects brought about by the dam are only minor.


KEY FINDINGS


- The Deschutes is a remarkably stable river, and was so before dam construction, based on analyses of bed-load transport, historical channel changes, and longitudinal patterns of sediment size. Thus channel position is largely fixed; islands, bars, and flood plains are well vegetated; and record floods cause only minor physical changes.

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- Because of the intrinsic stability of the Deschutes basin, the dam complex studied has had virtually no detectable effects on the physical structure of the downstream channel. No evidence of increased channel erosion, changes in grain size, or other channel changes could be found.

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- These results, surprising in comparison with other rivers, are consistent with the magnitude of changes predicted by a conceptual model, which relates the type and extent of geomorphic change downstream of a dam to the relation between the predam and postdam flow and sediment regimes.

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- In spite of decadal stability, the Deschutes has experienced previously unrecognized gargantuan floods many times during the past 100,000 years from events including volcanic eruption, collapse of glacial dams, and large landslides from the canyon walls that temporarily dammed the river.

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- Related fisheries work suggests that the islands and surrounding back channels created by large and rare floods provide core habitats for diverse fish populations.

## RELICENSING SCRUTINY

**N**on-Federal dams are licensed—and relicensed, or not—by the Federal Energy Regulatory Commission (FERC), usually for 30 to 50 years. Relicensing thus requires a long-term view and rigorous technical assessments of the effects of dams on critical resources, including channels, aquatic habitat, water quality, and recreation.

In the next few decades, hundreds of private dams face relicensing; many of these are on or influence Forest Service lands, which gives the Forest Service "conditioning authority;" that is, it can specify some of the conditions of the licensing process.

In the licensing process, aggressive efforts to supplement sediment loads and possibly design floods to restore channel and flood-

plain habitats will be considered by FERC or by Forest Service land managers, says Grant. Whether restoration is needed, however, is largely based on what the effects of the dam actually are. Clearly, he says, science-based assessments of dam-imposed regimes on downstream resources are critical to managers, power companies, and all users of regulated, or dammed, rivers.

What puts this famous river into a category that allows a dam to block its normal flow and yet produce virtually no detectable effects on the physical structure of the downstream channel?

### *Purpose of PNW Science Findings*

To provide scientific information to people who make and influence decisions about managing land.

*PNW Science Findings* is published monthly by:

Pacific Northwest Research Station  
 USDA Forest Service  
 P.O. Box 3890  
 Portland, Oregon 97208  
 (503) 808-2137

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United States  
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## CONTEXT IS EVERYTHING

**T**he Deschutes River is fed by a large hydrologic sponge, otherwise known as the Cascade mountains, a porous environment that makes the river behave much like a big spring-fed creek," Grant explains. Thus most precipitation enters the ground-water system, rather than flowing through well-defined channels.

The geology of the Deschutes basin has dictated its sediment and water regimes. Key attributes of the basin include a remarkably stable hydrologic system, a muted response to weather events, and little sediment production from vast areas of the basin. Together, these factors—as well as climate, vegetation, and land use—control the quantity, timing, and type of sediment transport through the basin.

The links between the overarching geology and hydrology, which are fundamental controls, and local channel and habitat conditions, operate through a set of hierarchical relations from the basin scale and the millennial timeframe, down to instream habitats and the most recent high-water event.

"This is a remarkable system in that the geology plays right through to the river that the fish see. Understanding these links allows us to understand how any changes to the system may ripple through it and



### LAND MANAGEMENT IMPLICATIONS



- Only by examining historical and modern changes to and processes operating in the physical channel and riparian environment can the true effects of a dam be evaluated, and mitigating measures put in place.
- The conceptual model may provide managers with a diagnostic tool for distinguishing different types of dam effects. Specific resources likely altered by dam operations can be targeted for more intensive studies.
- Rivers and dams are complicated, each requiring its own close scrutiny.
- Independent scientific investigations are an important part of relicensing and should be designed to pass rigorous standards of technical scrutiny and review.

ultimately affect critical resources such as aquatic habitat," Grant says.

As early as 1923, the U.S. Geological Survey recognized the Deschutes River as having one of the most stable hydrologic regimes anywhere in the country, as reflected in the magnitude and limited variation of the flows throughout the year. The flow regime in turn affects sediment transport from the river's surroundings—the boulders, rocks, gravel, and sand that are routinely carried downstream by streams and rivers. Because the flows are so stable and generally remain at levels below what would be required to move much sediment, the amount of sediment moved also stays low.

To give the basin's hydrologic stability meaning, consider that the average maximum flow for a given year in the Deschutes, both before and after the dam complex was installed, is reached when the river carries only about three times as much water as it does at low flow. In other rivers, this factor can be closer to 100 times; in other words, a winter peak flow might be 100 times higher than a summer low flow.

One result is that this river responds to what we humans quaintly call "historic floods" with something of a geomorphic shrug.

## SCALING UP THE FLOOD EVENT

**M**ost of the building activity of a river normally occurs during floods. Boulders are moved, woody debris piles up or changes position, gravel bars are made and unmade and moved, and sand is carried from one reach to another. Grant has previously characterized the flow of rivers and their defining flood events as "decades of boredom punctuated by hours of chaos."

"For the Deschutes, however, it's more like millennia of boredom punctuated by all hell breaking loose," he laughs. "You see, I flew over that river after the 1996 flood, one of our historic, so-called 100-year events. When the game of musical chairs was over, and everybody sat down, there was really very little change to the river."

Subsequent research of archives, and also first and incomplete observations of the geologic record of flood deposits in the Deschutes River canyon, revealed that at least 8 to 10 floods of comparable size to the 1996 flood have occurred in the last 1,000 years. If the river's response to these floods was similar to that in 1996, there would be some small changes to islands and channel banks, erosion of riparian zones, and deposits of wood and fine sediment on low surfaces adjacent to the channel.

But nowhere after the 1996 flood, Grant emphasizes, was there substantial channel migration or alteration of the valley bottom geometry. When he had ridden down the river at other times, however, he had seen much evidence of flood action, such as large

boulders, islands, and very big gravel bars. "What on earth must it take, I wondered, to get this river to respond?"

Well, the answer is, REAL floods. Gargantuan ones, beyond our imagining, and over scales of tens of thousands of years, not mere centuries.

Grant called in Jim O'Connor of the U.S. Geological Survey, a world authority on large floods, and together they took another look at the area. What happened, he says, is that they began to adjust their eyes to what they were seeing.

## WRITER'S PROFILE

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# FLOODS, FLOODS, AND FLOODS

The Deschutes River has historically experienced floods caused by literally every mechanism known to man, Grant says. This includes volcanic eruption, collapse of glacial dams, and large landslides from the canyon walls.

"It turns out that the well-known rapids on the river, such as Whitehorse and Boxcar Rapids, lie at the base of what were once huge landslides. Huge landslides, that blocked the river and backed it up as much as 20 miles," Grant says. Dams formed by landslides are intrinsically unstable and typically fail rapidly and catastrophically soon after formation, thereby resulting in large discharges immediately downstream from the breach.

"On the Deschutes River, several such dam-break floods have occurred—the landslide at Whitehorse Rapids is one where the landslide, upstream aggradation

(buildup) features, and downstream flood features all can be reasonably linked," says O'Connor. "Boxcar Rapids also may be part of an accumulation of huge, 20- to 30-foot diameter boulders, deposited during the breach of the nearby channel blockage."

The size of materials transported along the Deschutes and their elevation above the present river level seem to require discharges several orders of magnitude greater than historical discharges, the researchers agree. This indicates either the type of catastrophic release suggested or a significantly different climactic regime.

Compared with other, more "normal" rivers, the Deschutes has experienced so-called sediment-moving flows—flows capable of moving riverbed materials—only once every 5 to 10 years, Grant says. A typical alluvial river might do this two or three times per year.

Analyses of movement of materials along the riverbed, historical channel changes, and longitudinal patterns of sediment size were completed by former Oregon State University graduate students Ellen McClure and Heidi Fassnacht. These studies underscore the remarkable stability of the Deschutes: channel position is largely fixed; islands, bars, and flood plains are well vegetated; and floods such as the one that occurred in 1996 cause only minor physical changes.

"A meteorological flood like in 1996 does not have the energy to make a mark on a channel that has been sculpted by huge events," says O'Connor. "The geometry has been set by the large-scale floods, and these smaller events just dress it up a little."

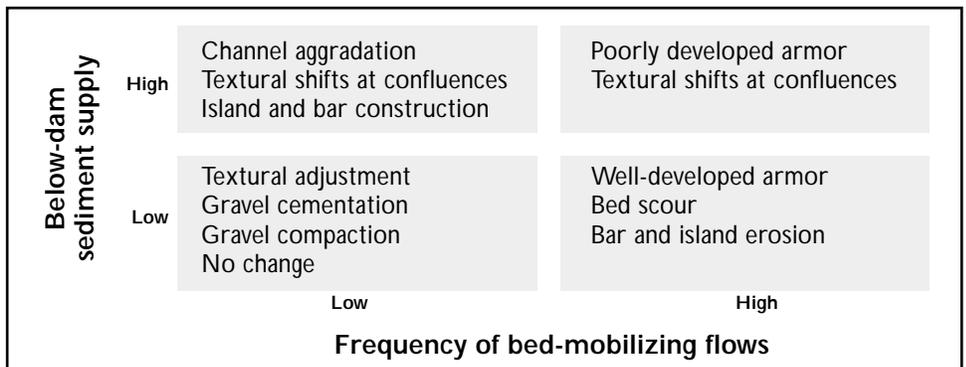
## IS THIS PREDICTABLE?

The mild reaction of the Deschutes River to most flood events, and to the flow constraints imposed by a dam complex, contrast sharply to downstream effects of dams on other large rivers, such as the Snake or Colorado. There, ample documentation shows extensive erosion of beaches and sandbars downstream of dams caused by reduced sediment supply and transport.

Given that this river's history has so clearly dictated its current sediment-transport responses, is there a way to predict a river's reactions to interference? Remember, all those private dams on all those rivers await similar relicensing analysis.

"While these results are surprising when compared with other rivers, they are consistent with the magnitude of changes predicted by the model we developed as part of this research," Grant says. The model relates the type and extent of geomorphic change downstream of a dam to the relation between the predam and postdam flow and sediment regimes.

Other studies of dammed rivers tend to support this model, he notes. Most dams have such a marked effect on sediment loads or on flows capable of moving sediment that their effects are widely known



▲ *Conceptual model of the channel below dams in relation to the predam and postdam flow regime and frequency of bed-load transport.*

and written about. The most common effect of a dam is to dramatically reduce both the peak flows and the sediment load of the river, thereby resulting in coarsening, and degradation of the channel bed in the reaches closest to dams. The Deschutes River represents an unusual case among the four general quadrants of river response (see figure), but its geomorphic dynamics were adequately captured by the model.

"The results from the Deschutes River increase our confidence in the model and its ability to predict downstream changes in other rivers, and emphasize how different rivers respond quite differently to the presence of dams," he says. "This model may ulti-

mately provide managers with a diagnostic tool for distinguishing different types of dam effects." But, he adds, the model can only serve this purpose if used in conjunction with rigorous technical studies conducted to the accepted high standards of science.

By knowing the degree to which a dam has altered the water and sediment transport regimes, he points out, managers could target for more intensive study those specific resources likely to have been affected by dam operation. For example, dams that dramatically reduce sediment loads without changing peak flows are likely to degrade, and thus potentially change fish habitat.

Grant points out, however, that what is really needed to strengthen the potential of the model as a diagnostic tool is the type of “case lore” that helps in medical diagnosis: if you get enough unusual cases around the country, you become gradually aware of patterns, then increasingly able to diagnose effectively.

## FACING THE RELICENSING PROCESS

**B**ecause one of the issues usually addressed during the FERC relicensing process is the maintenance of the downstream channel environment, findings from analyses like these provide the data against which the proposed operating regime for the dam can be evaluated, according to Grant.

He notes that these geomorphological findings are just one small part of the data required by FERC of operators of dams. Under the FERC process, the effects of various factors such as fish habitat, water quality, recreation effects, aesthetics, and wildlife are studied.

Related fisheries work in the lower Deschutes by Chris Zimmerman of Oregon State University and Gordon Reeves of the Pacific Northwest Research Station is showing that the islands and surrounding back channels created by the extremely large and rare floods provide core habitats for diverse fish populations.

“Fish in the Deschutes system have different habitat opportunities than fish in a more active alluvial system. Nonetheless, it’s

In other words, the model in its current crude form could be used to predict where more empirical evidence needs to be collected from the broad universe of dams, and the growing body of empirical evidence would provide a database on which to build an increasingly robust tool.

a blue ribbon trout fishery,” Grant says. “It’s amazing how the legacy of past geologic events is strongly influencing the quality of today’s fish habitat.” This does not, of course, mean that building the dam has had no effect on migrating fish. It simply shows that the physical workings of the downstream channel are little changed.

“The model as yet offers just a way of thinking about these kinds of relations. We’re at the edge of what we know, and the time to start building up case lore is now,” he says. “The relicensing process could provide a worthwhile opportunity for real adaptive management, with close and constant communication between the people who think they know how the system works—the scientists—and the people on the ground at a particular dam.”

Independent science such as this research requires that all data be made public, all results and conclusions subject to scrutiny by peer review. “The relicensing process is intended to ensure that the past, present, and potential future impacts and benefits of dams are fairly and honestly evaluated. Independent science conducted in an open



**A** Map of three dams in the lower Deschutes River basin: Round Butte Dam impounds Lake Billy Chinook, which holds over 40 percent of the water stored in the Deschutes basin. Just downstream is Pelton Dam, responsible for daily peaking power production, then the Reregulating Dam, which provides constant discharge to the lower Deschutes River, evening flow on a daily basis.

process to high standards is crucial to having our rivers managed for a wide range of purposes.” To that end, results from the Deschutes study now are being prepared for a book.

Given the long-term nature of dam licenses, the Deschutes findings also might serve as the basis for developing a long-term monitoring strategy, he says, which includes measurement of bed-load transport and channel change to confirm study results.

Thus a dam could be watched for bad behavior and monitored to ensure that possible future effects are detected early and incorporated into ongoing management decisions.

*“I’ll have the current in  
this place dammed up,  
And here the smug and  
silver (river) shall run  
In a new channel,  
fair and evenly.”*

Henry IV, Part 1 (William Shakespeare)

## FOR FURTHER READING

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**SCIENTIST PROFILE**



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