Open the floodgates!

Hydrologists are gearing up for a second attempt to restore the altered environment of the Grand Canyon, by letting the Colorado River run free. Kendall Powell discovers the lessons learned from the first, fruitless flood.

On 27 March 1996, David Topping woke up at his campsite in the upper Grand Canyon to see a rushing Colorado River that ran three metres higher than the previous day. The flood continued for seven days, as 1,290 cubic metres of water per second flowed through the bypass tubes of the Glen Canyon Dam, more than 160 kilometres upstream.

As the torrent churned up sediment, Topping recalls, the crystal-clear river turned to "the colour of chocolate milk". This was just what Topping, a hydrologist with the US Geological Survey (USGS) Grand Canyon Monitoring and Research Center in Flagstaff, Arizona, wanted to see: the goal was to rebuild sandbars and beaches that had been eroded since the dam was completed in 1963. The flood, Topping and his colleagues reasoned, should liberate years of accumulated sand, silt and clay from the river channel and deposit it onto the eroded beaches.

But David Rubin, a USGS sedimentologist at the Pacific Science Center in Santa Cruz, California, soon began to suspect that something was amiss. From his vantage point 56 kilometres downstream from Topping, the chocolate-milk colour soon faded, although the flood continued to rage. "Every day the water got a little clearer while the flow stayed the same," he says.

Today, Topping, Rubin and their colleagues know that a chronic lack of sediment in the river downstream of the dam doomed the flood to fail in its goal of restoring the Grand Canyon's beaches to a more natural state. Armed with this knowledge, they are now planning to flood the canyon once more, timing the deluge to coincide with an abundance of fresh sediment.

This ambitious hydrological experiment

is part of a wide-ranging plan to preserve the canyon's unique geomorphology and ecology — including a rescue plan for the endangered humpback chub (*Gila cypha*). For the scientists involved, it is also an experiment in stakeholder relations: power companies, tourist operators and Native American tribes all have vested interests in the outcome, and their views must be taken into account.

Grains of hope

With so many people to please, project scientists desperately wanted the 1996 flood to be successful. And at first, optimism ran high. Aerial photos showed wide stretches of sandy beach at more than 50 points down the Grand Canyon. Officials with the federal Bureau of Reclamation, which manages water resources in the western United States, were quick to declare the experiment a success, arguing that the redistribution of sediment would restore fish habitats and make rafting and camping within the canyon more enjoyable.

The day after the floodwaters receded, however, Rubin began analyses that would give the lie to this rosy picture. The first trench he dug through one of the renewed sandbars revealed an odd pattern. As a deposit is built during a flood and its subsequent recession, heavier sand particles would be expected to settle out first, followed by fine silt particles that would settle as the water slowed again. But instead, Rubin found coarse, large-grained sand at the top of the trench, with silt at the bottom.

Two months later, Rubin returned to the canyon with Jack Schmidt, a geomorphologist at Utah State University in Logan, and found the same pattern at several dozen points along a 220-kilometre stretch of the river[1]. In the months that followed, the restored beaches quickly eroded away. By the time of the flood's first anniversary, there was little to show for the exercise.

We now know why. Before the flood, project scientists had asked whether there was enough sediment in the river for the torrent to cause a net benefit. "Our best estimate at the time was that we had enough," says Schmidt. But the experts were sadly mistaken.

What Rubin had spied during the flood was confirmed by analyses of sediment in floodwater samples[2]. These revealed that the sediment supply had diminished rapidly with each passing day, while the average size of the particles increased. This explained the large particle sizes at the surface of Rubin's trenches.

Topographical studies showed that the flood had actually reduced the volume of sandbars in the upper canyon, providing a clue as to where this coarse sand had come

M. COLLIER

Grand plan: Jack Schmidt and his colleagues believe they now have the knowledge to ensure that a second flood project is successful.

J. SCHMIDT

from[3,4]. Floodwater samples also revealed that most of the suspended sand matched the type found in these sandbars. The restored beaches, it transpired, were built not from sediment scoured from the river channel and deposited as the water receded, but from sand scooped up from the sandbars that were the beaches' own foundations — hence the ease with which the recreated beaches were subsequently eroded.

Further analyses have shown that the flood formed the majority of beaches within its first two days[5]. Indeed, as the flood reached its end, it was eroding the beaches rather than building them up. Subsequent studies have revealed why the supply of sediment was so limited: most of the sand pumped in from the river's tributaries after seasonal rains is transported downstream in a matter of weeks or months, rather than being retained for several years, as researchers had thought[6,7].

Armed with this knowledge, Rubin, Topping, Schmidt and their colleagues have devised a new approach for future flooding experiments[8]. To rebuild beaches properly, the scientists believe, floods should ideally be timed to coincide with fresh sediment input from the Colorado's tributaries. Seasonal rains in late summer and autumn transport roughly three million tonnes of sediment each year down the Paria River, the main tributary that enters the Colorado upstream of the Grand Canyon (see map, opposite). If a flood were to be let loose from the Glen Canyon Dam after this input of sediment, just 60 hours of flooding, rather than the seven days tried previously, should be sufficient to build beaches that will be much more resilient.

Using these recommendations, the Bureau of Reclamation, the USGS and the National Park Service have crafted a new set of experiments for the Grand Canyon under the watchful eye of the Glen Canyon Dam Adaptive Management Workgroup — a diverse group of stakeholders that represents the companies that supply power generated by the dam, the governments of the states along the Colorado River, park managers, Native American tribes, recreational interests and environmental groups.

Getting all these factions to back the project is no easy task, particularly given that the 1996 flood cost the hydroelectric companies that use the Glen Canyon Dam's power some $2.5 million in lost generation. This, together with the experiment's disappointing results, prompted complaints from some workgroup members. But the scientists involved argue that the first flood yielded valuable lessons. "As an experiment, it was a tremendous success," says Schmidt. "We learned important things we could not have known had the experiment not been run — that much less sediment than we thought can be stored on the river bed, and that the sediment budget used prior to 1996 had been calculated in error."

What a blast: the Glen Canyon Dam during the 1996 effort to restore the Colorado River's beaches.

T. SMART/DESERET NEWS

Don't rock the boat

The Glen Canyon Adaptive Management Workgroup has to balance a diverse range of interests. Rafting guides and National Park rangers want the best experience for boaters and campers without having fluctuations in flow disrupt their activities. The Western Area Power Administration, which sells the dam's hydroelectric power to companies in 15 states, must meet the power demands of its customers. Archaeological sites, plants of tribal cultural importance, and threatened species must also all be protected.

These goals often conflict with the aim of restoring the canyon to its natural state, and any management plan will contain inherent uncertainties. But through regular meetings and reviews of the scientific evidence, the stakeholders represented in the programme have recommended to the Secretary of the Interior, Gale Norton, that the next round of experimental flooding should go ahead. Norton has the final say for the dam's operations and the management of the Grand Canyon National Park, and her decision on how to proceed is expected any day now.

Although the various stakeholders have diverging priorities, everyone agrees that, since the Glen Canyon Dam became the Grand Canyon's gatekeeper almost four decades ago, the canyon and its river have undergone a detrimental transformation.

Before 1963, the Colorado's flows varied seasonally and carried an average of 57 million tonnes of sediment each year, giving its waters a muddy reddish colour. In the spring, snowmelt from the Rocky Mountains would bring a rush of near-freezing water. But as summer wore on, the river would slow to a lazy creek and warm to as much as 32 °C. The spring snowmelt floods, which could reach heights more than twice that of the 1996 experimental torrent, scoured sediment from the channel and renewed the Grand Canyon's beaches.

Today, flows remain relatively low all year round. With more than 90% of the river's incoming sediment trapped behind the dam in Lake Powell, the water flowing through the


US BUREAU RECLAMATION

Coming out in the wash: the 1996 flood restored the Colorado River's eroded beaches (left, before; right, after), but the benefits were sadly short-lived.

Grand Canyon is unnaturally clear. Deprived of its regular floods, the river has lost the ability to regenerate its shores. And because water flows from the dam through valves near its base, insulated from the Sun's rays, the river's temperature remains a chilly 9 °C throughout the year.

These changes have been bad news for the Grand Canyon's native fish populations. Three species have already disappeared from its waters. The humpback chub, which evolved in the Colorado River basin in the past two million years, and is found nowhere else, has declined from an estimated population of 8,000 to around 2,000 over the past 20 years.

The chub is a strange-looking fish. Before the arrival of the dam, its prominent hump probably stabilized its swimming through the river's turbulent, fluctuating flows. Eyes were fairly useless in the canyon's muddy waters, so they shrank to two small dots. But this evolutionary oddball has done poorly in today's cool, clear waters. "The chub has done such an amazing job of surviving in the naturally harsh desert river system," says Nikolai Ramsey, a programme manager at the Grand Canyon Trust, a conservation group in Flagstaff. "The irony is that it can't survive in these really stable conditions."

In part, the chub's decline is due to the loss of beaches and sandbars, which provided sheltered backwaters for its fry. At the same time, populations of brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) in the canyon have exploded to 250,000 or more, constituting a predatory threat. In a 1997 study, biologists retrieved partially digested chub from the stomachs of trout and channel catfish (*Ictalurus punctatus*), another non-native species[9]. Some researchers suspect that the trout are also feeding on chub eggs and fry. "Even if there were suitable backwater habitats for chub, they wouldn't stand a chance," says Steven Gloss, a biologist at the USGS Grand Canyon Monitoring and Research Center in Flagstaff. "We've got to get the numbers of trout down."

To do so, the USGS will take a two-pronged approach over the next two years. First, it will remove non-native fish from a 16-kilometre stretch of the Colorado River in the canyon, near chub spawning grounds, by electrofishing. Wildlife managers will collect the stunned fish and kill the non-natives with an overdose of anaesthetic. The native fish will be allowed to recover in river water before being returned.

The second part of the plan is to disrupt trout breeding by varying the flow from the Glen Canyon Dam during the spawning season, from January to March. Because mating occurs in the shallows of the river, alternating between high and low flows should leave trout eggs and fry stranded.

Local fishing guides say that it is inevitable that some adult trout will also be left high and dry. The government acknowledges that this is a risk, but argues that the plan will nevertheless benefit anglers. Today, the fishery is clogged with many small trout, which compete with each other. Thinning the population will result in larger trophy fish, argues Gloss.

Fishing for compromise

The local Hopi and Hualapai tribes are also anxious about the trout-control plan. "We have an ancient belief that the fish are our ancestors and they are very important, regardless of whether they are an exotic species," says Loretta Jackson, cultural resource manager for the Hualapai. But the tribes are willing to consider a compromise plan in which the killed fish won't simply be discarded, but will be put to beneficial use, such as for pet food or fertilizer.

So far, the Glen Canyon Adaptive Management Workgroup has avoided show-stopping controversies. In general, most participants agree that the compromises reached, although laborious, are a better alternative than a courtroom standoff. But litigation remains a possibility, particularly from environmental groups, which remain frustrated by the slow progress in protecting the humpback chub. "We'll stay in the group and work sincerely within it — as long as it's our best option," says Ramsey.

Getting the hump: the humpback chub is under threat from habitat change and predatory fish.

In this strained atmosphere, scientists are awaiting the green light for the next set of experiments. The revised plan calls for a flood of similar magnitude to 1996, but only after a significant influx of sediment from the Paria River and only for two and a half days. Even if Norton were to give the go-ahead tomorrow, however, another necessary compromise means that the next flood can't take place until after 1 January, because of laws that govern the dam's operations. To compensate for this, the plan calls for low flows from the Glen Canyon Dam following a large sediment input, to try to retain as much of it as possible in the river channel. Scientifically, it's a tenuous position; realistically, it's the only current option.

Mother Nature has not played her part this year — not enough sediment has entered the river to put the flood plans into motion even if they are approved, because 2002 has been one of the driest years on record. But another bad drought year is historically unlikely, and the plans will carry over to next year. The removal of non-native fish will proceed regardless.

In the meantime, the scientists advising the adaptive management process face a heavy responsibility. "We have river guides, power customers and environmentalists looking over our shoulders. It's a pain in the neck, time-consuming; collecting data is difficult and expensive," says Schmidt. "But it's one of the most beautiful places on Earth. I would hope people would care about it." ■

Kendall Powell is an intern with *Nature* in Washington.

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