Damned if you do...

They give us green energy but destroy precious river ecosystems. What can we do about dams, asks **Terri Cook**

BETWEEN the still waters of Lake Gruyère, held back by the Rossens dam, and the pretty town of Fribourg, the Sarine river winds lazily through western Switzerland. It's a picture of bucolic tranquility. One day last September, though, it was anything but. Suddenly, great torrents of white water came rushing from the base of the dam. With spectators crowding vantage points and a drone capturing footage from above, it looked for all the world like a catastrophic engineering failure. In fact, it was quite the reverse.

This stretch of the Sarine hadn't run free since it was dammed for hydropower more than half a century ago, restricting its capricious flows to a predictable near-trickle. It is a story repeated around the world, with nearly half of the planet's major river systems choked by dams. They bring important benefits, not least renewable energy, but come with a high ecological cost. Where people once marvelled at these triumphs of engineering, many have come to see dams as an environmental liability. But what if all that concrete could be part of the solution?

That's what the scientists behind the artificial flood released on the Sarine are attempting to find out. They want to unleash regular designer deluges, carefully calibrated to restore the river's natural rhythms. The idea is to give us the best of both worlds: to keep our dams without destroying the ecosystems they exploit. The results are just beginning to dribble in, but they offer hope that dammed rivers may not be damned forever.

We have built a staggering number of dams: on average, a dam 15 metres tall or higher has been constructed each day for the last 130 years. Europe now has about 7000, the US roughly 9200. Counting smaller structures, the total rises to more than 800,000 worldwide.

This dam-building bonanza has delivered on its promise to provide clean energy, a boon as we to try to break our addiction to fossil fuels, plus fresh water for drinking and irrigation. The Hoover dam in the US (pictured right), for example, generates about 4 billion kilowatt-hours of electricity per year – enough to serve 1.3 million people – and can store up to 9.2 trillion gallons of water. But none of this is much good for rivers, or the ecosystems they support.

Dams have helped make riverine ecosystems some of the most vulnerable on the planet. These habitats are losing species much faster than their terrestrial or marine counterparts, and their bellwethers – freshwater fish, including Europe's eight species of sturgeon and the European eel – are disappearing at alarming rates. Some 39 per cent of freshwater fish in North America are now considered imperilled, and the numbers are nearly as high across the countries of the European Union.

That isn't all down to dams, of course, but they are a big part of it. Most obviously, migratory fish can no longer make it up blocked rivers to reach their spawning grounds. There can be few more visceral reminders of the disruption dams cause than the sight of salmon paddling in vain against a looming concrete wall.

But the issues with dams go deeper. Every river has its own personality, defined primarily by the rhythms of its flows – the daily, seasonal and annual shifts in timing and volume as the river thunders or trickles from source to sea. Collectively, these rhythms shape the habitats created by rivers and in turn the flora and fauna that live in and around them, says Julian Olden, an ecologist at the University of Washington in Seattle.

Dams break this natural variability. Depending on the type of hydropower plant, reservoir water is released in a constant flow to produce a steady source of electricity, or at a rate that varies in response to peaks in demand. Either way, dams keep more than just water behind the wall: they trap sand and mud, too. Downstream, this can force the river to scour existing sediment from its bed and banks as it tries to regain its natural equilibrium, transforming the shape and roughness of the channel, and making life tough for fish trying to spawn on the riverbed. The blockage can also drastically reduce the delivery of the organic material and nutrients vital for sustaining the base of any river's food web.

It really is a case of "damned if you do," says Olden. As we have come to understand this dilemma, more and more people have asked whether the renewable energy and other benefits dams bring are really worth it, given the damage they do. Increasingly, in the West at least, the answer is no.

So what can we do? One solution is to ›

JAMEY STILLINGS

“The idea is to recreate the natural rhythms of rivers through controlled deluges”

remove the dams and let the rivers run free again. In the US alone, more than 1000 dams have been demolished in the past 70 years, with half removed in the last decade. Although most were small structures that had outlived their intended purpose, in some cases authorities have seen fit to demolish major dams, including two megastructures on the Elwha river in Washington state. Just days after the second came tumbling down in 2014, native fish, including chinook and coho salmon, ventured back upstream. But although studies show that rivers tend to respond quickly when dams are dismantled, it isn’t often a viable option.

Concrete solution

One problem is that it can be extremely expensive. Taking down the Elwha dams cost $26.9 million, and the restoration project as a whole is expected to exceed $320 million. The US government was prepared to stump up only because it was a special case: the vast majority of the river lies within a national park, and the dam had failed a safety inspection, potentially leaving the Lower Elwha Klallam tribe downstream in harm’s way. Add the fact that people still want the water and renewable power, and you can see why there is precious little political will to decommission most major dams.

Ecologists aren’t giving up that easily. Instead they have come up with a clever solution: using the dams themselves as conservation tools. Their big idea is to recreate the natural rhythms of free-flowing rivers through controlled deluges – and it is already being put to the test.

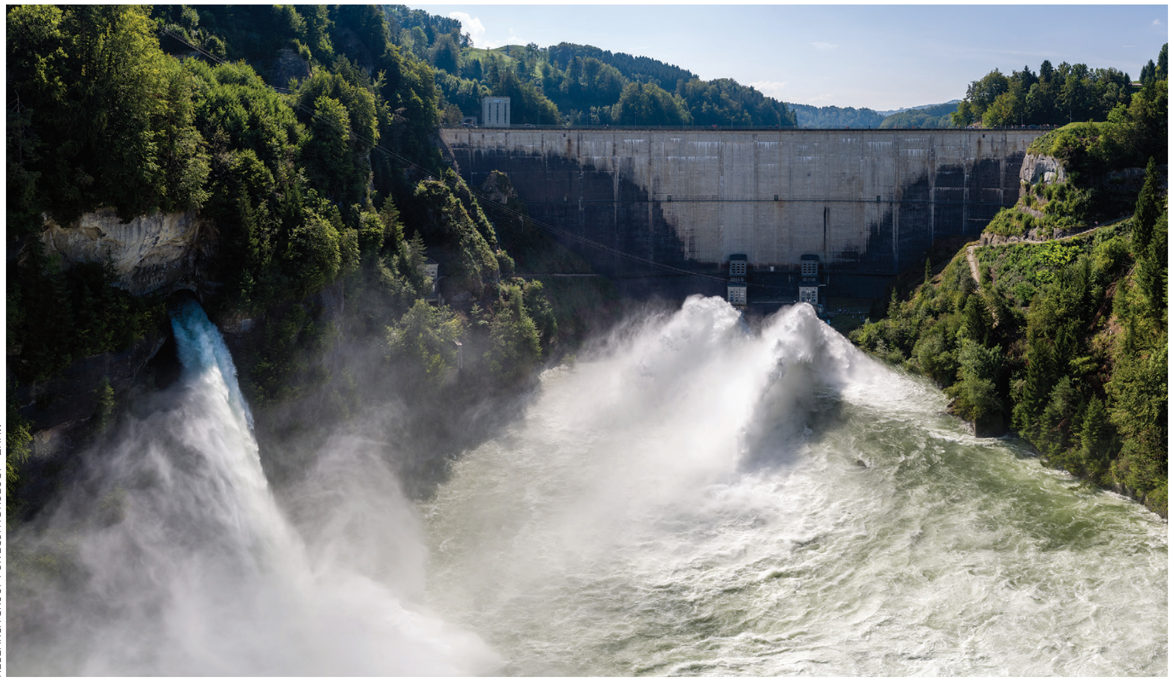
The most spectacular example was the huge pulse of water released in 2014 from the Morelos dam, on the Colorado river at the border between the US and Mexico (see “Just add water”, opposite). But like almost every other artificial flood release so far, it was a one-off. You can’t possibly recreate the myriad differences in flow, temperature and sediment delivery of a free-flowing river with one release, says Olden.

To really figure out whether artificial floods can restore a river’s habitat, we need repeated inundations. Here the challenges run deep. There must be enough water stored in the reservoir, for starters. Then you need to get permission from the dam’s managers to conduct the releases at times that would make sense not economically, but ecologically, according to records of the river before it was dammed or observations of the natural rhythms of similar rivers. All of this explains why, despite ecologists and water managers managing to push through large artificial flooding experiments at more than 100 dams in 20 countries, the vast majority have been one-offs. “Long-term environmental flow programmes are a rare breed,” says Olden.

Switzerland’s Spöl river is the place where the idea of repeated floods was first put to the test. Its sparkling waters flow from the Swiss-Italian border through a deep limestone gorge before joining a tributary of the Danube. But despite its path through the Swiss National Park, the Spöl was dammed at two sites for hydropower in the 1960s – and when the dam gates closed, the ecosystem suffered.

Within a couple of decades, the absence of floods had allowed woody vegetation, including fir trees, to grow in the riverbed, says Chris Robinson, an ecologist at the Swiss Federal Institute of Aquatic Science and Technology. The channel was choked with fine-grained sediment eroded from the river’s steep banks, degrading the spawning grounds of brown trout. The stable, low-flow environment also favoured creatures not normally present in free-flowing Alpine streams, especially a group of crustaceans called *Gammarus*. They basically overran the Spöl, says Robinson, making up a startling 90 per cent of the dammed river’s fauna by the time ecologists started looking closely.

When Thomas Scheurer at the Swiss Academy of Sciences received a report detailing the sorry state of the river in 1990, he decided something had to be done. “It was obvious that floods could improve the situation, but we had no concept of how to handle it,” says Scheurer, who oversees research within the national park.



RESEARCH GROUP FOR ECOHYDROLOGY – ZHAW

Swollen on purpose: the Sarine river in Switzerland last year

The first step was to engage with the Engadin Hydropower Company, which operates the dams, as well as scientists, park managers and federal and local officials. Without a legal framework or a way of paying for “lost” hydropower revenue, there was always going to be resistance. But after years of negotiations, Scheurer got the nod for regular inundations, which began in 2000.

Flushed out

Dam operators have since unleashed dozens of artificial floods on the Spöl. It took a while to fine-tune them for the optimal timing and volumes required to flush out the crustaceans without losing too much sediment, says Robinson, but the results are encouraging. Twice-yearly torrents seem to be enough to keep the crustacean population sufficiently low to allow native invertebrates such as mayflies and stoneflies to flourish, he says. And brown trout are once again thriving as their spawning grounds are no longer clogged with fine sediment.

The long-term programme on the Spöl has not only paid off in terms of the river’s ecological restoration, says Scheurer; it has also encouraged others to pursue a similar course. The Swiss Federal Office for the Environment, for example, is planning to use artificial floods at 40 Swiss hydropower installations over the next 13 years. It’s one of the ways it hopes to fulfil a promise enshrined in a recent revision to the country’s Water Protection Act, to reduce the ecological impacts of hydropower plants by 2030.

Already the lessons are being applied to the Sarine, which is dammed in five places along its 128-kilometre length. In the section running down to Fribourg, it meanders through floodplains that no longer receive anywhere near as much water as they did before the dams , says Michael Döring, an ecologist at the Zurich University of Applied Sciences (ZHAW).

To mitigate this damage, Robinson, Döring and Diego Tonolla, also at ZHAW, designed a programme of carefully calibrated floods, working alongside hydropower producers, government officials and engineers. Its goals were tailored to the particular challenges along this segment of the Sarine, including the removal of algae and clogging sediment, reconnection with the floodplain, and a reduction in the species that have moved in to take advantage of the unnatural flows. It is still early days, but preliminary results indicate that the flood was large enough to address those problems and restore the river to something much closer to its natural state, says Döring.

Meanwhile, artificial floods are starting to make a splash around the world. The Spöl served as an important model for designing a long-term programme of floods released from Glen Canyon dam on the upper Colorado river, for instance, as well as artificial floods on Australia’s Snowy river and various waterways in Japan. “From an international point of view, the Spöl has been a major impetus for artificial floods,” Robinson says.

The rivers that benefit the most, however, might be those yet to be dammed. There are currently 3700 large dams planned or under construction across the globe, including particularly intensive schemes in South America and Asia. “Although the dam-building era is largely over in developed nations, dam construction is rampant in many developing regions,” says Olden. Decision-makers there are aware of the dilemma dams pose. And although many cannot resist the boons that come with harnessing their rivers, now there is at least a viable strategy for mitigating the ecological costs. ■

Terri Cook is a science writer in Boulder, Colorado. Travel for this article was supported by the European Geoscience Union’s Science Journalism Fellowship

PETE MCBRIDE/NATIONAL GEOGRAPHIC CREATIVE

JUST ADD WATER

The lower portion of North America’s Colorado river, which runs from the mountains of Colorado to the Gulf of California in Mexico, was once a thriving wetland teeming with life. As bobcats stalked their prey, clouds of birds soared above what the conservationist Aldo Leopold described as a “verdant wall of mesquite and willow”. When a series of dams were built upstream in the mid-20th century, however, the delta (pictured above) withered and dried.

A few years ago, the dusty scar left behind was the subject of a spectacular environmental experiment. Following several years of cooperation to help Mexican farmers whose irrigation infrastructure was destroyed by an earthquake, the US and Mexico hashed out a landmark agreement, known as Minute 319, to release a large pulse of water in the hope it would bring the parched delta back to life. The deluge started in March 2014, and a total of 132 million cubic metres of water rushed from the Morelos dam, which straddles the international border.

The flood succeeded in rejuvenating native vegetation, smudging the delta green again. But the restoration didn’t last. Within a year, the greenery began to recede, and according to one analysis the experiment was only “minimally successful” at establishing cottonwood and willow seedlings, its primary goal. There was also an unintended consequence: the release of methane and carbon dioxide from the newly moistened riverbed.

Researchers are still trying to figure out how much greenhouse gas was released, but they don’t think the risks outweigh the benefits, however short-lived. But here’s the rub: the Minute 319 flood was always planned as a one-off experiment. To stand a chance of restoring the delta permanently, you would have to mimic the seasonal floods that came before the dams (see main story).