HAWKE'S BAY REGIONAL COUNCIL

TE KAUNIHERA Ā-ROHE O TE MATAU-A-MĀUI

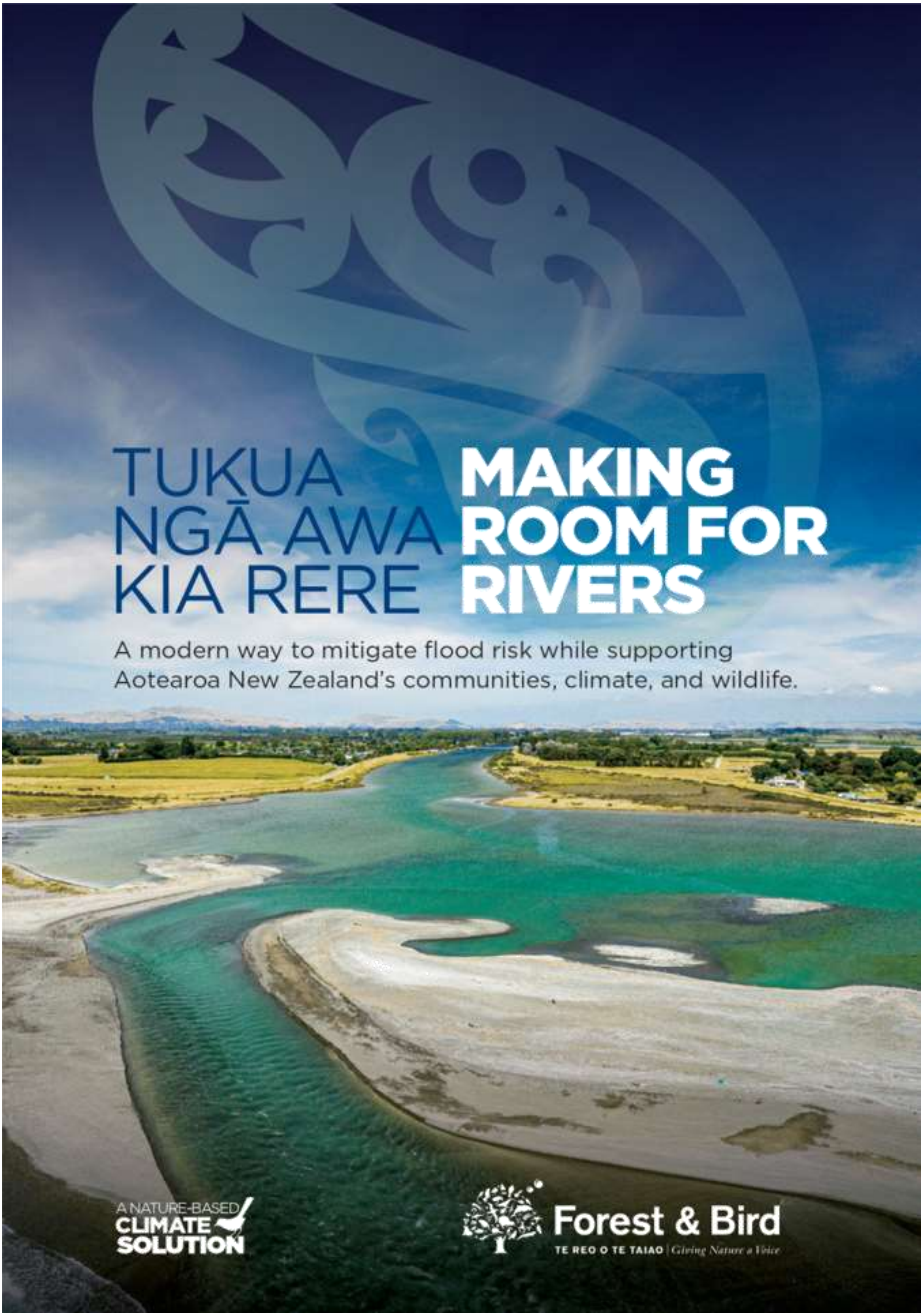
Meeting of the Cyclone Recovery Committee

Date: 21 June 2023

Time: 9.00am

Venue: Council Chamber
Hawke's Bay Regional Council
159 Dalton Street
NAPIER

Attachments excluded from Agenda


TUKUA NGĀ AWA KIA RERE
MAKING ROOM FOR RIVERS
A modern way to mitigate flood risk while supporting Aotearoa New Zealand's communities, climate, and wildlife.
A NATURE-BASED CLIMATE SOLUTION
Forest & Bird
TE REO O TE TAIAO | Giving Nature a Voice

INTRODUCTION

The Dutch revolutionised flood protection with the launch of their nature-based Room for the River programme 15 years ago, completing projects at more than 30 different locations across the Netherlands.

They gave rivers space to flood safely while restoring habitat for plants, fish, and birds. It was popular with local residents, and other countries followed suit, with similar projects in the US, the UK, and Australia, among others.

Here in Aotearoa, we still rely on hard engineering to "control" our rivers. We use diggers and bulldozers to straighten river channels then add stopbanks or rock groynes for stability, degrading our rivers in the process.

The aim is to drain floodwaters out to sea as quickly as possible, keeping them away from people. Although this might work for smaller floods, it can actually increase the risk during a major rainstorm (see illustration below).

Our flood mitigation schemes – covering 5% of the country – have given communities a false sense of security – that it's safe to build homes and businesses right up to the edges of rivers.

But the current approach isn't working. There has been a string of devastating floods across Aotearoa over the past five years, and many existing flood mitigation schemes need expensive upgrading to cope with heavier and more frequent rainstorms.

As the planet warms, more areas will become susceptible to flooding.

Altering the natural course of rivers has destroyed wetlands and habitat for birds, fish, and insects. It has degraded once-wild rivers, reduced te mana o te wai and mahinga kai opportunities, and diminished local swimming holes. However there is another way – a nature-based and climate-friendly way – that can make our communities more resilient to flooding while boosting biodiversity and restoring the mauri of our rivers.

A national conversation is starting about the multiple benefits of adopting the Room for the River approach, and at least one council is already trialling the idea, albeit on a small scale (see right). The government has recognised the value of nature-based solutions like this one in its response to climate change.

Rivers with more room can accommodate bigger floods, naturally recharge groundwater, and provide more habitat for native species. They also become more accessible for people to explore and play.

Room for the River has a proven track record overseas. It's time to give rivers more room to roam in Aotearoa.

Young banded kōkopu. 📷 Nga Manu

Kōtuku, Waitangiroto River, Westland

Flooding is the number one natural hazard in Aotearoa. New Zealand now faces, on average, one major flood event every eight months.

Te Uru Kahika Regional and Unitary Councils Aotearoa

MAKING ROOM FOR TE AWA KAIRANGI

One of the first local authorities in Aotearoa to embrace the room for rivers concept is Greater Wellington. Its RiverLink project combines flood protection, urban revitalisation, and improved transport links.

Te Awa Kairangi Hutt River flows through the heart of many communities and supports the Wellington region's economy and culture. It supplies half the water for Wellington, Hutt Valley, and Porirua, is popular for walking and swimming, and provides important habitat for native insects, fish, and birds.

But during the past century, homes and commercial properties have been built on the river's flood plain, narrowing its natural flow and degrading its health. Urban development has constrained the river, increasing flood risk and destroying natural wetlands.

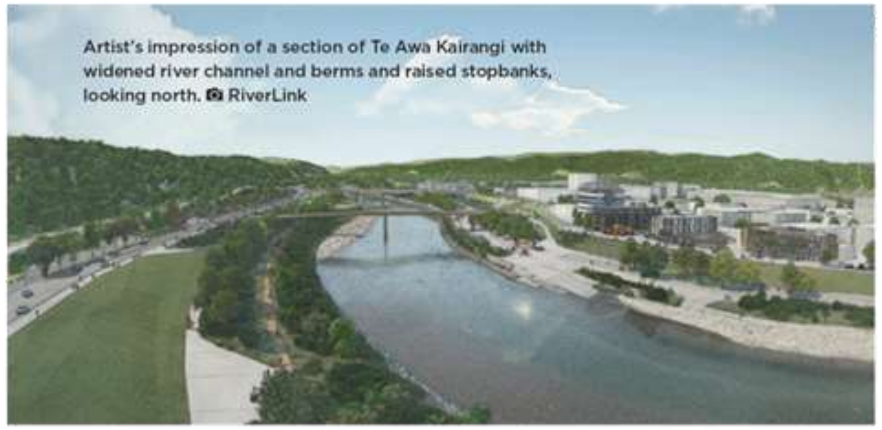
The council estimates a large flood could affect up to 3000 homes, five schools, and 600 businesses, with the potential to cause up to $1.1 billion worth of damage.

In 2023, it plans to widen a section of river that flows through Lower Hutt, giving it room to flow more naturally, reducing flooding risk, and making communities safer.

Widening the river will increase its ecological health by restoring its natural character, creating a mix of pools, riffles, and undercut banks that will provide great habitat for native fish, including tuna eels and īnanga whitebait.

There will also be wetland restoration along parts of the river corridor, providing homes for native species while filtering and slowing stormwater. The improved riverside parks will give more room for people to explore, play, and learn.

For more information about RiverLink, see **https://www.riverlink.co.nz**.



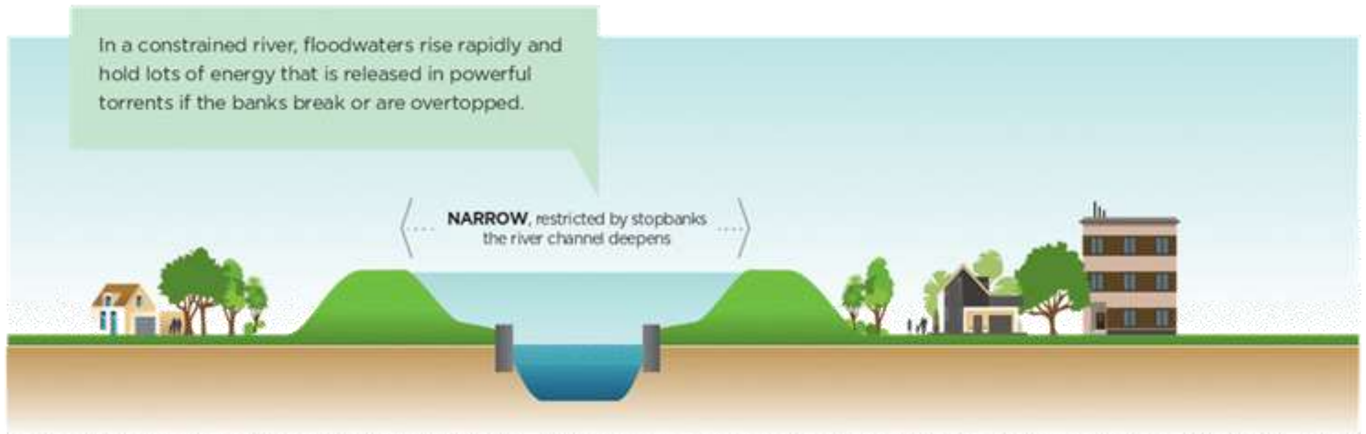
Artist's impression of a section of Te Awa Kairangi with widened river channel and berms and raised stopbanks, looking north. 📷 RiverLink

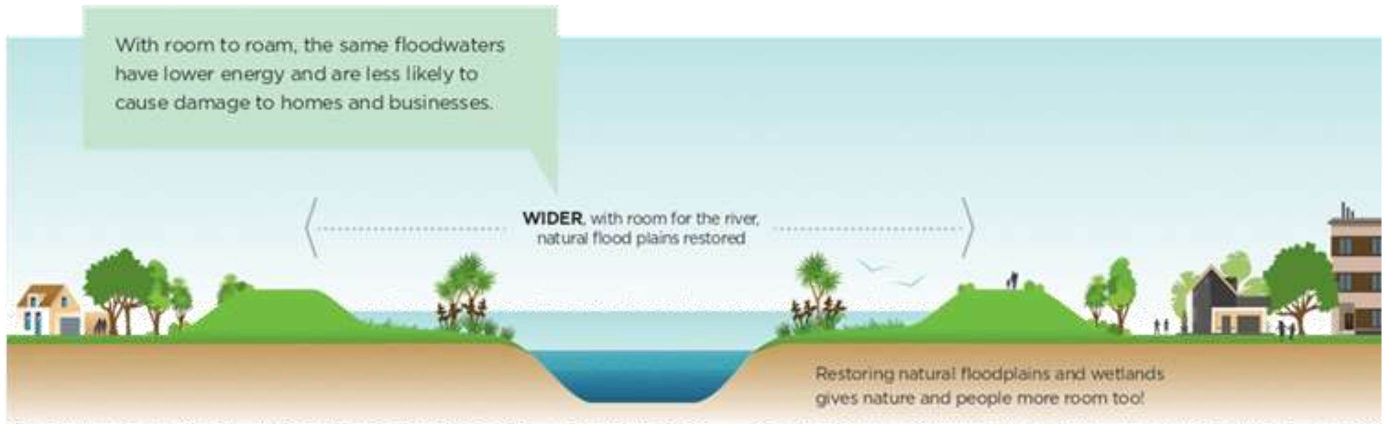
NEXT STEPS

Forest & Bird is calling on the government to work with local councils, iwi, and communities to:

1. **Develop a national Room for Rivers plan**, including strategic managed retreat from high-risk flood plains. **Embed this modern approach to flood management** in resource management and climate legislation.
2. **Appoint an advisory group of experts** to support the development of the Room for Rivers national plan and **create practical guidance for councils** on how to incorporate this and other nature-based solutions into district and regional flood management programmes.
3. **Establish a $500m contestable flood mitigation fund** to support councils to undertake Room for Rivers projects in their communities and **educate the public about the benefits of working with nature** to reduce flooding risks.

Making room for rivers is a nature-based strategy that will reduce flooding, help us adapt to climate change, restore native wildlife, and increase community wellbeing. For a full list of suggested actions to support a Room for Rivers approach, see **www.forestandbird.org.nz/roomforrivers**.





OUR BROKEN RIVERS

Many of our rivers no longer have the space they need to function naturally and flood safely. The result is an ongoing decline in their natural flood capacity, health, and habitat quality. Add in climate change and the picture is worrying, with more intense and record-breaking rain events already happening.

In June 2021, for example, 551mm of rain fell on the Canterbury foothills over three days – the greatest intensity ever recorded in the area. Waters in the Hakatere Ashburton River rapidly rose to a peak of 1794m³/s – the highest flow the river had experienced since 1956.

The resulting floodwaters damaged houses and farms, cut off small towns, closed roads and the rail line, and took out fences, bridges, irrigation equipment, and stock feed. More than 200 households and 300 people were evacuated, and 32 houses were damaged. There were 3800 insurance claims totalling $46.4m, and $5m of damage was done to roads.

It was one of at least eight serious flooding events over the past five years that have caused huge damage and stress to communities in Tairāwhiti Gisborne, Central Hawke's Bay, Westport, Fox River, Franz Joseph, and Canterbury. In 2017, the entire town of Edgecumbe, in the Bay of Plenty, was forced to evacuate.

The Hakatere Ashburton, like New Zealand's other braided rivers, is an extremely high-energy system, carrying gravel and other sediment from the Southern Alps all the way to the coast. Historically, these rivers had room to move, creating wild landscapes and fertile plains.

Over time, however, these rivers have been confined by stopbanks and encroached by farming, hydro, and irrigation schemes.

It's not just braided rivers that have been modified and restricted by hard-engineered structures, including flood mitigation. In fact, more than 100 towns and cities across New Zealand have families and communities living alongside rivers or on flood plains that are protected by flood protection schemes.

Many stopbanks need expensive upgrades to cope with change. Te Uru Kahika Regional and Unitary Councils Aotearoa has asked the government for an additional $150m a year to increase flood resilience across the country.

Tukua ngā awa kia rere

It's not too late for New Zealand's rivers. Letting them flow more freely will restore their mana and health. This nature-based solution can help communities and farmers adapt to climate change. Our special river birds and fish will also benefit and have more space to thrive.

Kōtare Kingfisher. 📷 Harry Haywood

A huge flood covered 70% of Edgecumbe, in the Bay of Plenty, after a stopbank failed in 2017. 📷 Sky View Photography

THE AWA USED TO SING

Arconnehi (Aki) Paipper was born and grew up in a home next to Kohupātiki Marae, on the northern bank of the Ngaruroro River near Clive, in Hawke's Bay.

Kohupātiki is named for the kohu mist that hangs over the river, and for the mud stirred up by pātiki black flounder that used to abound there.

The river was very different during her childhood, she remembers. It was full of kai that could feed the whole community. Her tīpuna and whānau were supported and nourished by the awa.

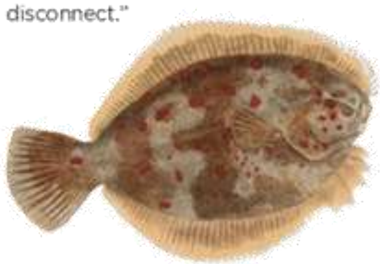
"If we had manuhiri visitors at Kohupātiki marae, it was no problem for our dads and uncles to go out and collect 300 flounders for breakfast, and every person had their own flounder," said Aki, who is Ngāti Hori, a hapū of Ngāti Kahungunu.

"When my dad and them put the hīnaki eel traps in to catch longfin tuna, it took six of his shearers to pull that hīnaki out. That's how important the river was back in my childhood. We never starved. We ate top shelf."

But, in the late 1960s, the Ngaruroro River was diverted away from Kohupātiki Marae into a straightened channel lined with stopbanks. What was left – the river's natural path – suffered a catastrophic decline in health.

The energy of the awa was taken away, and it could no longer cleanse itself. Silt covers what used to be clean gravels, water quality has declined, and the channel is infested with weeds. Migrating fish species, including longfin tuna and pātiki black flounder, have suffered.

"The river is silent. It doesn't sing like it used to," added Aki. "We don't take our children to swim and connect with the river in the same way. For me, it's a cultural disconnect."



Pātiki black flounder. Illustration 1870 by Frank Edward Clark

Aki Paipper remembers how the Ngaruroro River was full of kai before it was modified and diverted away from her marae. 📷 Iain McGregor/Stuff

The natural connection between awa, their flood plains, groundwater, and springs was key to the creation and fertility of the Heretaunga Plains, says Ngaio Tiuka, director of the Environment and Natural Resources Unit at Ngāti Kahungunu.

"People of Kahungunu have lived alongside these rivers and formed connections with them over many generations," he said.

"When rivers are allowed to move more naturally, their waters replenish the land, the groundwater beneath, and in turn the people."

The cultural practices of Kahungunu were – and still are – connected to these waterways, many of which have vanished because of hard-engineered changes. These have disregarded the practices and connections of Māori with their waterways and, in many instances, eroded part of their identity.

"Rivers and streams have been shifted. Communities and marae have lost access to water. Mahinga kai is degraded, affecting the ability to manaaki manuhiri [welcome visitors]," added Ngaio.

"Marae and hapū identify waters of significance in their pepeha. When rivers are diverted or sucked dry, our pepeha becomes theory, practices are lost, captured only in a story, on a path to becoming a myth."

Ngaio says making room for rivers offers a chance to restore connections and te mana o te wai, a concept that refers to the vital importance of water by prioritising its mana, health, and wellbeing.

"Making room for rivers is an opportunity to restore those connections. If our awa have room to be themselves, their health will improve. We can help the awa support us again."

Ngaruroro River, Hawke's Bay. 📷 David Wall

THE NETHERLANDS
ROOM FOR THE RIVER

In the 1990s, the Netherlands experienced unprecedented floods that overwhelmed stopbanks and other flood protections, triggering the evacuation of hundreds of thousands of people and a million livestock.

With the intensity and frequency of flooding increasing, government officials decided that building taller and taller stopbanks was no longer an option – they needed to do something different.

In 2007, they started the Room for the River programme to restore rivers' natural flood plains in strategic places, making room for rivers to flood safely. During the past 15 years, the €2.3 billion programme has proven this modern nature-based approach to flood management works.

Tailor-made solutions were proposed for each of the 34 Room for the River locations, the last of which was completed in 2022. Measures included lowering and widening flood plains, restricting development on flood plains, strengthening and relocating stopbanks, reducing groyne heights, and removing obstacles (such as bridge supports) from river channels.

A key part of the programme was improving riverbank habitats, which benefits nature and offers improved leisure opportunities for residents.

A study of two rivers in the programme, the Rhine and the Meuse, noted that widening the rivers enough to lower water levels by 30cm during floods could reduce the probability of stopbank failure by two to five times. Lowering levels by 50cm could reduce the probability of failure by more than 10 times.

It's a nature-based solution that has placed the Netherlands well ahead of other nations in adapting to the impacts of climate change.

It has also improved quality of life for residents, allowed more space for wildlife and recreation reserves, promoted housing developments in safer spaces, and protected heritage villages and beaches, boosting tourism.

The Dutch government says it has been more cost-effective than constantly repairing or rebuilding flood protection and other infrastructure such as roads, bridges, and towns after large floods.

International engineering consultancy firm Royal HaskoningDHV was involved in the most challenging Room for the River projects in the Netherlands.

George Peters, its global director of climate resilience, said the programme broke with the traditional Dutch reliance on dyke reinforcement as its primary flood risk management tool.

"Instead, we employed nature-based solutions that increased the rivers' water-carrying capacity by opening up more room for the water to naturally flow," he explained.

"As a result, residents are safer, communities are more resilient, and the whole area is more attractive for recreation and tourism opportunities."

> *Climate change will shift the area of geographical risk of floods and make new areas, not presently affected by such events, more susceptible to floods*
>
> **Te Uru Kahika Regional and Unitary Councils Aotearoa**

Deventer, The Netherlands: View across the new channel of the River IJssel, created for the Room for the River project, with the main river channel in the background. 📷 Frans Blok

BRINGING BACK NATURE
MUNICH, GERMANY

Germany's Isar River, which flows through the city of Munich, was engineered into a straight channel in the 1800s. By the 1980s and 1990s, the impact of that engineering was clear: the risk of flooding and damage to property had increased, water quality and the health of the river was poor, and there was limited access to the river for the community. In response, the Isar Plan was launched to make room for the river – and the community – through an 8km stretch within the city. From 2000 to 2011, the riverbed was widened, weirs were removed, gravel banks and islands were created, habitat for fish and birds was restored, and space was made for people to access the river and relax on its banks. The river now flows more naturally, native species have better habitat, the community is more resilient, and Munich has a popular new swimming spot that large numbers of people visit throughout the summer.

Room for the River Isar. 📷 iStock

Grantham flood aftermath. 📷 Dean Saffron

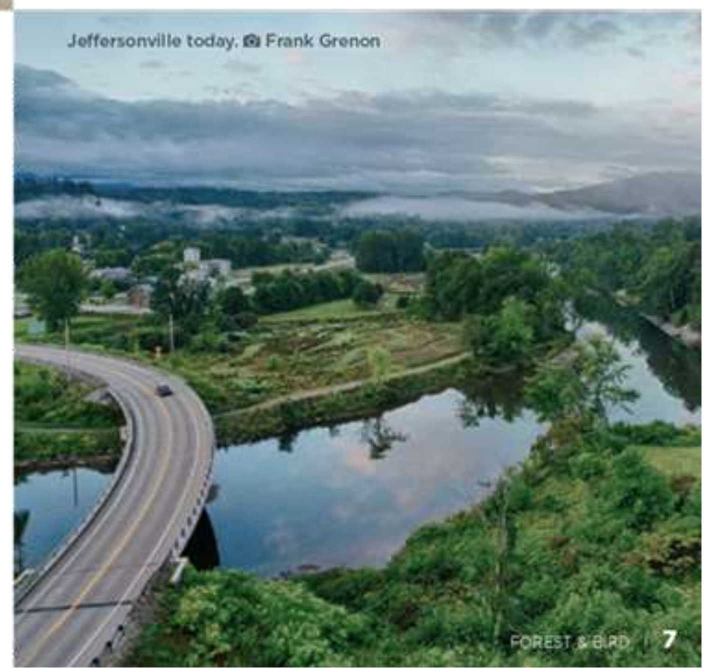
MOVING A TOWN
GRANTHAM, AUSTRALIA

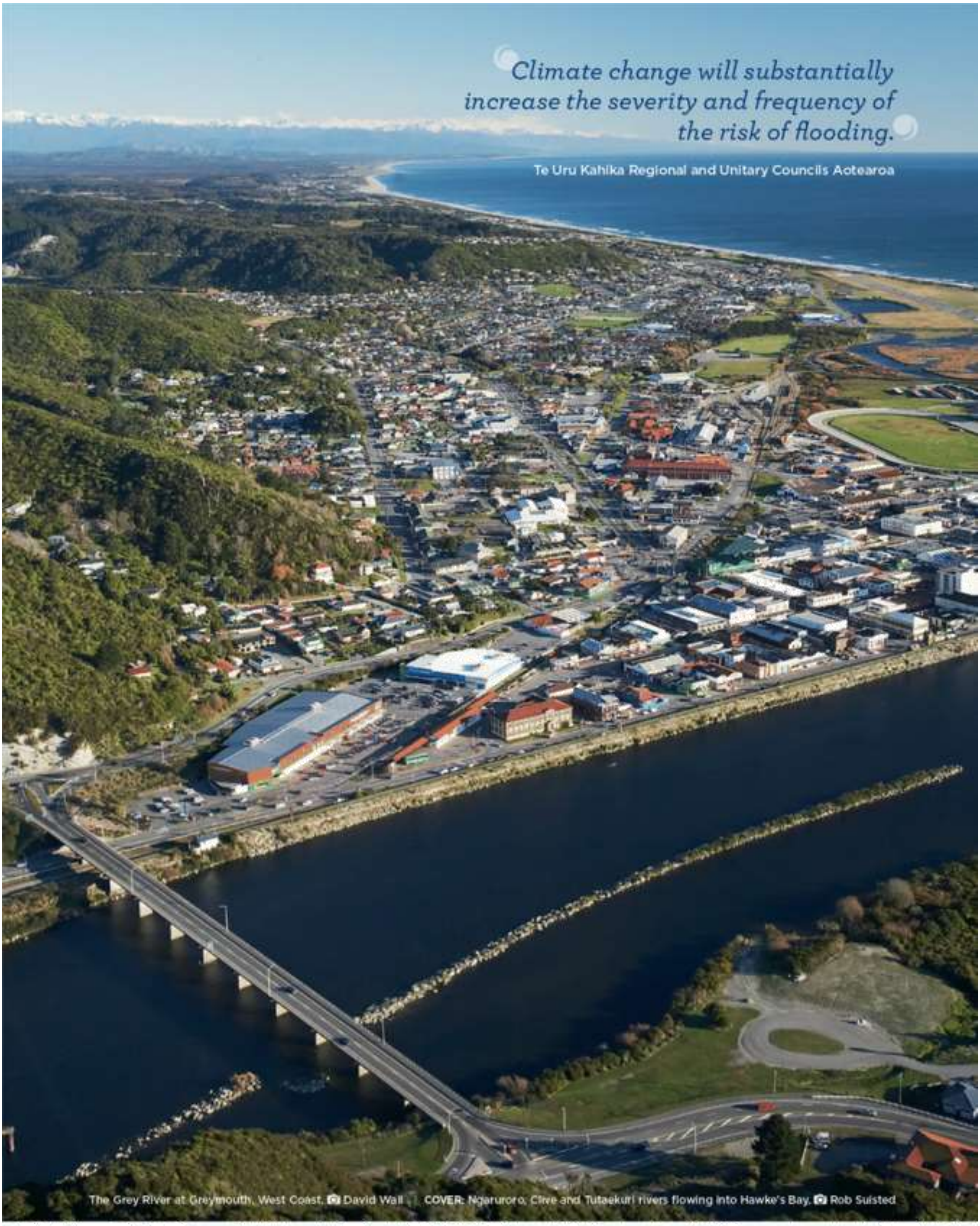
In 2011, the area around Grantham, a small town on a flood plain in Queensland, Australia, was hit by one of the strongest rainstorms since records began. Rain fell so heavily and fast that a flash flood – an inland tsunami – hit the town, killing 12 people and destroying most of the town centre. Rather than rebuild in the same dangerous location, a plan called Strengthening Grantham was developed to move the town uphill. Land on a nearby farm was purchased for the new development. With leadership from a small project team, including the mayor and residents, it took just 11 months to move the first families off the flood plain and into their new homes. Since then, around 120 families have moved uphill. Today, the council continues to help people move off the flood plain, taking them away from potential harm and making room for the river to flood safely.

SOMETHING HAD TO CHANGE
JEFFERSONVILLE, USA

Flooding was a regular occurrence in the small village of Jeffersonville, Vermont, which sits on a flood plain at the confluence of the Brewster and Lamoille Rivers. During heavy rain, the Lamoille filled up, causing the Brewster to flood the village. In 2011, Jeffersonville experienced four floods in less than 11 months, and the community decided something had to change. Residents worked with council planners and engineers to develop a master plan to reduce flooding risks. An old rail bridge over the Brewster River was raised and widened, making room for the river to move and preventing floodwaters backing up under the bridge. Plans to develop low-lying land in the path of floodwaters were shelved, and the development moved to a higher location, with the flood-prone area turned into a park. Jeffersonville is now a more resilient community, able to withstand future floods as the climate changes.

Jeffersonville today. 📷 Frank Grenon





The Grey River at Greymouth, West Coast. David Wall | COVER: Ngaruroro, Clive and Tutaekuri rivers flowing into Hawke's Bay. Rob Suisted

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FOCUS ARTICLE

WIREs WATER WILEY

Reanimating the strangled rivers of Aotearoa New Zealand

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Abstract

Contemporary management practices have artificially confined (strangled) river systems in Aotearoa New Zealand to support intensified land use in riparian areas. These practices work against nature, diminishing the functionality and biodiversity values of living rivers, and associated socio-cultural relations with rivers. River confinement can accentuate flood risk by promoting development in vulnerable locations and limiting the flexibility to adapt to changing climate, prospectively accentuating future disasters. To date, uptake of space-to-move management interventions that seek to address such shortcomings is yet to happen in Aotearoa New Zealand. This is despite the fact that such practices directly align with Māori (indigenous) conceptualizations of rivers as indivisible, living entities. Treaty of Waitangi obligations that assert Māori rights alongside colonial rights of a settler society provide an additional driver for uptake of space-to-move initiatives. This article outlines a biophysical prioritization framework to support the development and roll out of space-to-move interventions in ways that work with the character, behavior, condition, and evolutionary trajectory (recovery potential) of each river system in Aotearoa.

This article is categorized under:

Water and Life > Conservation, Management, and Awareness
Science of Water > Water and Environmental Change

KEYWORDS

geomorphology, Mātauranga Māori, restoration, river management

1 | INTRODUCTION: THE STRANGLED RIVERS OF AOTEAROA NEW ZEALAND

Command-and-control management practices seek to tame dynamic rivers (Holling & Meffe, 1996), but in so doing they restrict the capacity of a river to adjust, regenerate and recover (Brierley & Fryirs, 2022; Florsheim et al., 2008; Fryirs & Brierley, 2016; Kondolf, 2011; Piégay et al., 2005). Just as dams *silence* rivers (McCully, 1996), confinement between engineered flood and erosion defenses *strangles* rivers, locking channels in place and freezing them in time

(Brierley et al., 2021; Kondolf, 2011). Removal of meander bends narrows and simplifies river morphology, increasing the slope and energy of flow within the channel. Such practices, and the outcomes they engender, create path dependencies as they lock-in future management options as economic development and overcapitalization of the defended valley corridor skews the balance of costs-and-benefits in favor of maintaining and upgrading control practices over deteriorating ecological and cultural values (Holling & Meffe, 1996; Hutton et al., 2019; Tobin, 1995).

Across the world, this orthodox logic and the underpinning social construction of values (Chan et al., 2016) is increasingly being challenged and tipped in favor of environmental rehabilitation. Innovative solutions that move beyond this pathology embrace proactive, precautionary, and preventative plans and restorative actions that address concerns for environmental protection and repair (Brierley & Fryirs, 2022). This is showcased, for example, by high-profile dam removal interventions in the USA (e.g., Foley et al., 2017; Poff & Hart, 2002) and the advent of space-to-move river management programs in Europe (Buijse et al., 2002; Piégay et al., 2005) and North America (Biron et al., 2014). This nascent paradigm shift reflects a growing consensus that confining dynamic rivers has negative and lasting ecosystem-scale impacts on biodiversity and may actually accentuate channel instability and elevate the risk of catastrophic flooding (e.g., Roni & Beechie, 2012).

Recognizing that change is underway as part of Aotearoa New Zealand's first national adaptation plan (Ministry for the Environment, 2022), in this article we explore why contemporary river management practices in Aotearoa New Zealand continue to emphasize engineering solutions that prioritize flood protection to the detriment of more inclusive practices that address concerns for ecosystem and cultural values. In large measure, this situation reflects the funding of flood protection schemes through targeted rates levied on the adjacent landowners, who in turn benefit through developing the protected land and raising its economic value. This creates a feedback mechanism that is resistant to change and innovation. Associated with this "development", the cost of breaches to flood defenses has also increased. We contend that this approach to river management has promoted socially inequitable and environmentally and economically unsustainable outcomes. In relation to these concerns, we highlight two emerging transformations in Aotearoa New Zealand. The first lies in an urgent and deliberate reframing of perspectives and priorities that proactively asserts indigenous (Māori) values and conceptions of rivers as living, indivisible entities that have assured rights under a foundational national document, Te Tiriti o Waitangi|The Treaty of Waitangi (Hikuroa et al., 2021; Parsons et al., 2019; Ruru, 2018; Stewart-Harawira, 2020; Te Aho, 2019). Intriguingly and generatively, Māori notions of rivers as dynamic continua resonate with hydrogeomorphic perspectives that emphasize longitudinal and lateral connectivity (Brennan et al., 2019; Ward et al., 1999; Wohl et al., 2005, 2015, 2019) and disturbance (Richards et al., 2002; Stanford et al., 2005) as fundamental determinants of the ecological health and integrity of river systems (Brierley et al., 2019; Wilkinson et al., 2020).

The second transformation recognizes growing awareness of an emerging crisis wherein attempts to stabilize high-energy rivers through confinement may inadvertently be manufacturing future disasters by accelerating aggradation and enhancing the risk of catastrophic breakout flooding (Brierley et al., 2021). Rivers in Aotearoa New Zealand have some of the highest sediment yields per unit area in the world (e.g., Hicks et al., 2011; Walling & Webb, 1996). Increases in the frequency and magnitude of high flows under climate change will likely increase sediment delivery through confined reaches, accentuating management problems associated with elevated bed levels in bedload-dominated systems. This is especially evident on active alluvial fans that are sites of productive agricultural land and some urban settlements (Davies & McSaveney, 2006, 2008, 2011). This sets in train a race to the bottom that pitches increasingly unsustainable upgrades to defenses against rising river bed levels, amplifying elevation differences between the confined river corridor and its surrounding floodplain (Figure 1a).

In this article, we present a simple biophysical prioritization framework that can be used to assess options for the uptake of space-to-move interventions under different physical, ecological, and social contexts. We contextualize this study with a brief overview of circumstances that created the strangled rivers of Aotearoa New Zealand and approaches to space-to-move interventions that have been developed and applied in other parts of the world.

2 | FLOOD PROTECTION AND THE SETTLER MINDSET

Flood protection schemes in Aotearoa New Zealand use a range of approaches to control flooding and erosion hazards. Construction of stopbanks (levees, embankments) to control the spread of floodwater is often combined with bank armoring, wing groynes, planted willow buffers, or other means of erosion protection. Alongside this, gravel extraction is used frequently to control bed levels and maintain a design flood capacity. Official records indicate that the stopbank network in Aotearoa is 5284 km long (Crawford-Flett et al., 2022). Various relict and often derelict features, such as bunds, embankments, levees, and stopbanks are also constructed by local landowners, sometimes without statutory

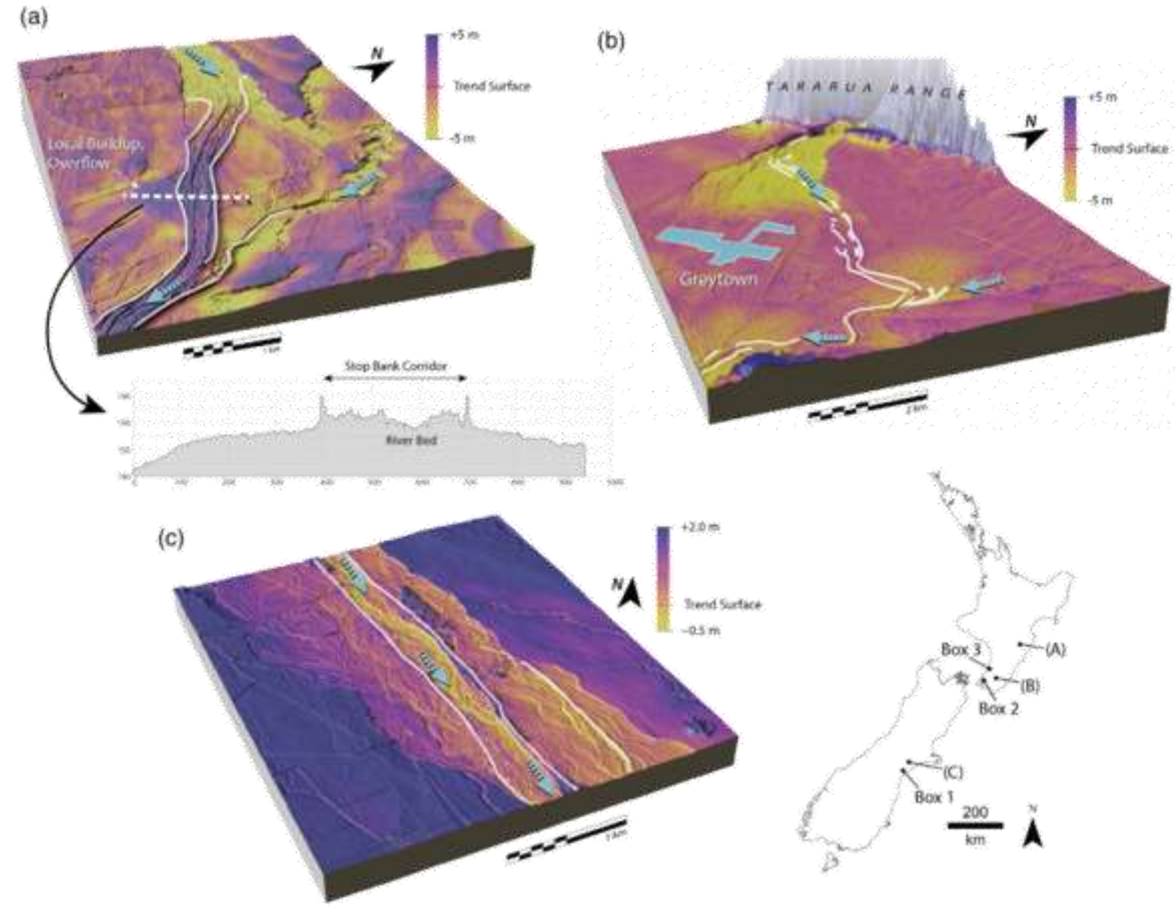


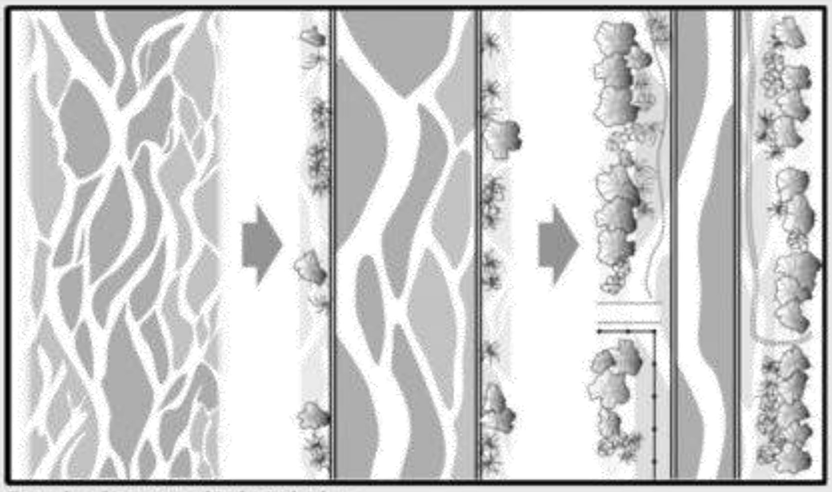
FIGURE 1 Photomosaic showing geographic variability in anthropogenic river confinement for various strangled rivers of Aotearoa. The Tukituki River (image a and cross-section) siphons sediment from a large distributary system as part of a flood protection scheme. Bed aggradation between confining stopbanks leaves the river several meters above the surrounding floodplain. Image b shows the location of Greytown on the fan of the Waiohine River, highlighting the vulnerability to aggradation-induced stopbank breach. Stopbanks along the Ashburton River (image c) divorce the river from its ancestral floodplain, restricting the contemporary channel to a narrow fairway. The color scale on these images indicates the departure from a trend surface based on LiDAR data. Ashburton and Waiohine have a 10 m range (± 5 m) and Tukituki has a 2.5 m range (+2 m, −0.5 m). White lines indicate stopbank locations

consent, and are not reflected in this total. These practices have differing impacts upon different types of river across the country, with variable consequences and prospects for recovery (discussed later; see Figure 1).

The strangled rivers of Aotearoa New Zealand reflect institutional legacies and assertions of fixity of a colonial settler society that sought to control fluvial hazards, conceptualizing rivers in the service of society through measures that impose expectations of a familiar, liveable world in ways that reflect nostalgic memories of the mother country (Beattie & Morgan, 2017; Goodin, 2012). Engineers demonstrated considerable technical prowess in their efforts to train rivers into stable, hydraulically efficient conduits that are conceived to be more predictable and manageable (Knight, 2016). Short-term successes in this regard, however, led to long-term unsustainable outcomes in biophysical, socioeconomic, and cultural terms (Table 1; Arnaud et al., 2015; Bravard, 2010; Frings et al., 2019; Knox et al., 2022; Tena et al., 2020). Impacted systems have been referred to as zombie rivers (Mitchell & Williams, 2021)—rivers that are increasingly devoid of life and diversity.

In many instances, managed channel forms and corridor width are out of balance with prevailing catchment conditions. Active and continuous intervention is required to maintain flood capacity, yet equivalent outcomes could be achieved by simply giving the river more space, and allowing channels to adjust. As disturbance-driven entities, naturally unconfined and free-flowing rivers continuously adjust their form to variations in the flow of water and sediment, and changes in local

TABLE 1 A geomorphic perspective upon compromised values of a strangled river



Examples of impacts on biophysical values

- *Biodiversity*—aquatic and terrestrial habitat; ecosystem (life-cycle) functionality—the *mauri* (life force) of the river
- *Geomorphic processes*: Flooding, sediment transport, erosion and deposition, interacting with riparian vegetation and wood—the *mauri* (life force) of the river
- *Altered connectivity*—Increase longitudinal, reduced lateral, +/−vertical (dependent on circumstance; From the Mountains to the Sea; *ki uta ki tai*)
- Flood conveyance (peakedness, maintenance of base flow)

Examples of impacts on socioeconomic issues

- Flood risk, disaster management
- Opportunity costs
- Repair/maintenance costs (infrastructure protection)

Examples of impacts on sociocultural values, connections, and relations

- Aesthetic values; emotional relations (psychological wellbeing, *ora*); recreational activities (walking, swimming, fishing, water sports, etc.)
- Spiritual connections (reinstigating the *mauri* and *mana* of the river)

or regional base level (Brierley & Fryirs, 2022). Working against nature does not work (Fryirs & Brierley, 2021; Newson, 2021). Nature always reasserts itself, as channels seek to recapture the space that has been taken from them.

Semantics matter in these deliberations. Floods—or any "hazards" for that matter—generate anthropocentric concern for the management of "risk" (e.g., protection of values pertaining to people, places, properties, etc.; see Weir et al., 2021). Yet the river is simply being a river. Despite the inherent logic, this thinking is largely absent in management responses to recent flood events in Aotearoa that resulted in significant damage to infrastructure, severing critical communication links and impacting heavily on riparian agricultural land (Mitchell & Williams, 2021; Williams, 2022). Subsequent calls to "put the river back" and reinstate and elevate protection measures reflect the dominant mindset which seeks to place rivers out of sight, out of mind (Knight, 2016). Such framings separate human societies from rivers, promoting a perception that rivers are *over there*—something to be managed by someone else.

Prevailing socioeconomic relations to rivers that assert human authority and the imperative to maintain assets and infrastructure in the interests of "protecting" society limit the scope of future management options. Legacy effects and locked-in path dependencies are difficult and expensive to revoke, creating inequities for subsequent generations (Winter, 2020; Wohl, 2019). For at least three generations, confined and defended rivers have constituted an accepted baseline state (e.g., Pauly, 1995; Soga & Gaston, 2018). Over time, the assumption that this state is normal creates a perceptual, cognitive, and infrastructural lock-in that is self-reinforcing. Problems that ensue are likely to increase in response to climate change and further land use intensification on valley floors.

The quest to reanimate the strangled rivers of Aotearoa New Zealand seeks a radical repositioning of conventional thinking and a rejuvenation of sociocultural connections to rivers. Embracing the environmental values of dynamically adjusting rivers acknowledges the need to understand hazards and mitigate associated risks. We contend, however, that solutions lie not in pinning channels in place, but rather by adapting societal uses of river corridors and, where possible, keeping assets out of harm's way.

3 | THE GENERATIVE POTENTIAL OF SPACE-TO-MOVE PROGRAMS

In various parts of the world, space-to-move and similar interventions address concerns for river health and flood risk by returning parts of the valley floor to rivers, even where anthropogenically enforced separation has endured for hundreds of years (e.g., Buijse et al., 2002; Formann et al., 2014; Formann & Habersack, 2007; Habersack & Piégay, 2007; Jungwirth et al., 2002; Piégay et al., 2005; Schmutz et al., 2016; Smith et al., 2017). These initiatives reconnect severed socio-cultural linkages with rivers, restoring psychological, and recreational associations (e.g., walking, fishing, swimming, boating) as well as biophysical connections (e.g., channel-floodplain linkages, riparian wetland function, soil regeneration, and ecological enhancement; Table 1).

The concept of allowing space for flooding and movement of river channels, including initiatives to re-wild or re-nature rivers, is practiced under different auspices and names in different parts of the world [e.g., channel migration zone (Rapp & Abbe, 2003); erodible corridor (Piégay et al., 2005); fluvial territory (Ollero, 2010); river corridor (Kline & Cahoon, 2010); freedom space (Biron et al., 2014; Buffin-Bélanger et al., 2015)]. Such interventions seek to achieve a balance between the environmental benefits derived from allowing the river to flow freely and self-adjust within the river corridor, while maximizing public security and economic benefits by protecting property and infrastructure outside of the river corridor.

Major engineering interventions as part of a Room for the River program have achieved considerable success in countries such as the Netherlands. For example, recent activities celebrated a comprehensive program of initiatives on the lower reaches of the Meuse River over the last 30 years (Van Looy & Kurstjens, 2021), and extensive redesign of a major bend of the Waal River at Nijmegen (e.g., Edelenbos et al., 2017; Schouten, 2016; Verweij et al., 2021; see Room for the River Programme|Dutch Water Sector). Essentially, these nature-based solutions work with the river and allow for its variability (Albert et al., 2021; Fryirs & Brierley, 2021; Nesshöver et al., 2017; Newson, 2021). Sometimes these programs incorporate managed retreats, removing assets, and infrastructure from threatened areas (e.g., Mach & Siders, 2021; Moss et al., 2021; Wible, 2021). Opening up the river can have considerable on-site and off-site benefits, relieving the impacts of inundation in downstream reaches. Despite the long-standing recognition of the multiplicity of benefits of space-to-move interventions (Table 1), the uptake of such practices has, so far, been very limited in Aotearoa New Zealand.

4 | CONTEMPORARY RIVER MANAGEMENT PRACTICES IN AOTEAROA NEW ZEALAND

Although the history of systematic direct human manipulation of river systems in Aotearoa New Zealand is relatively short (Knight, 2016), profound anthropogenic impacts are evident across most of the country (Fuller & Rutherfurd, 2021). Given the late stage of the colonial settlement of Aotearoa New Zealand relative to other parts of the world, there are relatively few instances in which urban and industrial developments are located immediately adjacent to major rivers. Comprehensive river management schemes, undertaken under the auspices of Total Catchment Management, only started in the middle of the twentieth century (Memon & Kirk, 2012). Over time, however, land-use practices have sought to optimize agricultural expansion across lowland environments and ever higher into the catchment. Realignment of the drainage network through subsurface drains, drainage canals, and ditches has reduced natural attenuation and retention of storm flows, thereby generating exceedingly high peak flows to the mainstem channel. Enhanced continuity of flow to the lower system has altered the timing and intensity (thus inundation and erosivity) of flooding downstream. Alongside this, forest clearance and management practices in steepland terrain have increased delivery of debris flow and landslide materials into river systems (cf., work by Jakob et al. (2020) in British Columbia). Although flooding impacts are primarily restricted to local urban areas and agricultural lands, given the influence of primary industries upon the export-driven economy of Aotearoa New Zealand, these are significant socioeconomic and political concerns. Despite long-standing awareness of these impacts, pressures for land-use intensification on valley floors continue to further restrict rivers to this day (Mitchell & Williams, 2021).

Contemporary river management practices lie in stark contrast to the world-leading emphasis on the importance of sustainability that underpinned the legal framework for the management of natural resources in Aotearoa New Zealand. The Resource Management Act (RMA), established in the early 1990s, defines the bed of a river as: "the space of land which the waters of the river cover at its fullest flow without overtopping its banks" (Resource Management Act 1991 No. 69 (as at 21 December 2021), Public Act 2 Interpretation—New Zealand Legislation). Associated assertions of river channels as "static, clearly, and cleanly delimited" entities are clearly inconsistent with both western-science and Māori ontologies that acknowledge rivers as dynamically adjusting continua and in many cases, inherently messy. Doubling down on this paradox, the braided rivers of Aotearoa New Zealand, characterized by multiple, continuously shifting channels, and distinctive ecosystem values (Gray & Harding, 2007; Hicks et al., 2021), remain important as beacons of a wild, untamed landscape in the psyche of many New Zealanders, yet all-too-often they are managed in a narrow straight-jacket between stopbanks and engineered banks of willows (Brierley et al., 2022).

More problematically, this policy framing establishes and perpetuates undue confidence in the totality of flood protection. This, in turn, encourages further development, thereby raising land and property values and initiating an unending cycle that necessitates on-going investment in flood protection at all costs (cf., Donaldson, 2021). Ultimately, all flood defenses have limits, and incentivizing development on naturally vulnerable land serves only to engineer disasters into the future (Tobin, 1995). Eventually, regulating structures will fail or require prohibitively expensive maintenance.

Commenting on a parallel situation in response to recent floods in British Columbia, Canada, geomorphologist Brett Eaton noted: *This wasn't a natural disaster, this was an infrastructure disaster* (Globe and Mail, 2021). Meanwhile to the indigenous people on whose land the flood occurred, the real disaster took place a hundred years ago when Sumas Lake was drained by settlers to create the agricultural Sumas "Prairie" (https://globalnews.ca/news/8385289/sumas-lake-reflection-first-nations/). Legacy effects and the memory of what is gone before constrain contemporary and future options. Such realities exemplify the importance of long-term indigenous knowledge as an integral part of climate change adaptation programs (Caretta et al., 2022).

We contend that contemporary management practices in Aotearoa New Zealand put people and infrastructure on a collision course with rivers. Unfortunately, the contemporary governance system that uses targeted rates to fund the costs of land drainage and flood protection neglects the wider value that is provided by rivers and their riparian corridors, including ecosystem and cultural services (Table 1). Strangled rivers that create the conditions for future disasters reflect a lack of proactive and precautionary planning, limiting prospects to adapt to a changing climate that will include more frequent and more severe high flows (Arnell & Gosling, 2016; Slater et al., 2021; Tellman et al., 2021; Winsemius et al., 2016). Reliance on conventional approaches to flood management, and associated instruments that leverage the past as a guide to future behavior, are hazardous ways to prepare for increasingly uncertain futures (e.g., Sofia & Nikolopoulos, 2020; Tonkin et al., 2019). Today's "extreme" events will become the new normal while new levels of severity loom in the future. As more assets and infrastructure lie within harm's way, the potential for disastrous effects can only increase. How effectively can existing infrastructure handle multiple hazards, or concatenations of events? Crawford-Flett et al. (2022), for example, estimate that up to 80% of stopbanks in the Christchurch area may be prone to liquefaction following seismic events.

Despite increasingly acknowledged obligations under the Te Tiriti o Waitangi|The Treaty of Waitangi, consecutive governments in Aotearoa New Zealand have consistently failed to change management mindsets and practices that conflict directly with Indigenous (Māori) relations to rivers. In light of prospects for reframed management practices, what do just and equitable approaches to adaptation look like, and how do they work?

5 | CULTURE CLASH: MĀORI CONCEPTUALIZATIONS OF RIVERS AS LIVING ENTITIES

Historically, legal conceptualizations of rivers in Aotearoa New Zealand have failed to incorporate indigenous (Māori) relations to river systems (Harmsworth et al., 2016; Hikuroa et al., 2021; McAllister et al., 2019; Stewart-Harawira, 2020; Te Aho, 2019). Colonization and industrialization ruptured traditional Māori relationships to freshwater bodies and overlooked customary practices tied to Māori knowledge, values, and ethics (Stewart-Harawira, 2020). Parsons et al. (2019) show how successive generations of government policies and actions directed with a specific goal and underpinned by dominant social values created a profoundly path-dependent system of managing rivers. For example, Coombes (2000) noted that evidence presented in both the Tribunal hearings and the earlier compensation court cases for the Waipaoa River flood scheme near Gisborne documents Māori alienation from use of river systems, referring to stopbanks as boundaries and obstacles. Dispossession of lands and waters also deprived Māori of their rights and inherent responsibilities to enact traditional customary practices of *kaitiakitanga* or stewardship of the natural environment, disrupting long-standing expressions of deep relationality through genealogical connection (Stewart-Harawira, 2020).

Notions of management have a very different meaning when framed in relation to Māori ways of knowing and living with (being a part of) rivers (*Ko au te awa, ko te awa ko au*; I am the river and the river is me; Rangiwaiata Rangitihi Tahuparae in Wilson, 2010). Rather than envisaging and striving to achieve a particular state over a given timeframe through particular management goals, ancestral connections to rivers emphasize an ongoing commitment to a duty of care, living sustainably with, and as a part of, the river (Hikuroa et al., 2021). Resonant scientific themes that emphasize complexity, connectivity, contingency, and emergence are remarkably consonant with Indigenous knowledge or *mātauranga Māori* (Brierley et al., 2019; Hikuroa, 2017; Wilkinson et al., 2020).

Māori value rivers as holistic entities that are more ancient and more powerful than people, with lives and rights of their own (Ruru, 2018; Te Aho, 2019). In these relational ways of knowing and being, land, forests, rivers, and oceans are simultaneously considered ancient kin, revered elders, and living entities (Salmond, 2014). Such relationships are expressed as *whakapapa*, a noun or verb that expresses a complex web of privileges and obligations that incorporate ancestral relations through concerns for descent, lineage, connections, identity, and so forth in space, through time. Rights, and the obligations that come with them, are derived from collective relationships, inherited from ancestors, including direct relationships and responsibilities to land and waterways. Claims for *mana tupuna*—authority deriving from ancestors—are expressed through discharging obligations to care for land and waterways. This can, in turn, confer the privileges of *mana whenua*—the authority to make collective decisions in the use and care of land—and *mana moana*—the authority to make collective decisions in the use and care of water. Concerns for *tikanga*—the customary system of values and practices that have developed over time and are deeply embedded in their social context—reflect and express a respectful, relational and emergent lens—an ethical way of being that openly acknowledges the rights of nature and the rights of the river (Ruru, 2018).

In these framings, an holistic lens incorporates respect for the *mauri* (lifeforce) and the *mana* (authority) of each river, innately conceptualized as indivisible entities at the catchment scale—*Ki Uta Ki Tai* (From the Mountains to the Sea). Concerns for *ora* (collective health and wellbeing, for the river, the society, and the environment), embrace respectful ways of living with the diversity, morphodynamics, and evolutionary traits of every river (cf., a state of *mate*, disrepair; Hikuroa et al., 2021). Understandings of and concerns for reciprocity, interdependence, and co-evolutionary relations recognize that what's good for the river is good for society, and vice versa, as inherently these are parts of the same thing (Salmond, 2017). In the parlance of management, this can perhaps be expressed as managing for, and managing with, giving primacy to integrity and societal relationships to rivers, not the rivers themselves. How can we assume to manage rivers that are more ancient and powerful than us?

Viewed through a Māori lens, separating humans from rivers through stopbank construction severs deep-seated ancestral relations to rivers, disrespecting regard for *taniwha* (supernatural beings that may be considered highly respected *kaitiaki* (protective guardians) of people) and *taonga* (often translated as treasure, but better understood in the active sense, that is to be treasured or relational, what do you treasure?). A Māori lens reframes the managerial and engineering question "how much space does a river need?" into a much deeper relational question, "how can we live with the river as a living, indivisible entity?" Seeing ourselves as part of the river recognizes that damaging it inescapably damages us.

It is only in recent years, largely associated with the Treaty of Waitangi tribunal processes (Harmsworth et al., 2016), that the quest to redress indigenous dispossession and marginalization of Māori values has gathered momentum in Aotearoa New Zealand (Memon & Kirk, 2012; Parsons & Fisher, 2020; Paterson-Shallard et al., 2020). Increasingly, efforts to break path dependencies incorporate formal recognition of Māori governance, values, and knowledge within policies, translating Māori values into tangible actions that seek to destabilize Western command-and-control approaches to flood risk management (Harmsworth et al., 2016; Parsons et al., 2019). Biophysical imperatives to reanimate the strangled rivers of Aotearoa New Zealand synchronize directly with Māori conceptualization of rivers as living entities. In this regard, the pan-tribal flora and fauna claim (WAI 262) is pivotal to any discussions pertaining to the impacts of stopbanks. Responding to this claim, The Waitangi Tribunal in its report, *Ko Aotearoa Tenei* (This is New Zealand; Waitangi Tribunal, 2011) states that "Kaitiakitanga is the obligation, arising from the kin relationship, to nurture or care for a person or thing... Kaitiaki can be spiritual guardians existing in nonhuman form... But people can (indeed, must) also be kaitiaki... Mana and kaitiakitanga go together as right and responsibility, and that kaitiaki responsibility can be understood not only as cultural principle but as a system of law."

Failure to embrace the potential of space-to-move interventions as a basis to address concerns for strangled rivers reflects an abjuration of guarantees made in *Te Tiriti o Waitangi*. In accordance with Treaty obligations, Māori are rightsholders rather than stakeholders. Implementation of policies and plans by local authorities in Aotearoa New Zealand, under the auspices of the RMA, are required to give effect to the National Policy Statement for Freshwater Management 2020 (NPSFM; building on previous manifestations in 2014 and 2017). This policy document explicitly recognizes the need to acknowledge *Te Mana o te Wai*, expressed as the innate relationship between the health and well-being of the water and the wider environment and their ability to support each other while sustaining the health and well-being of people (Te Aho, 2019).

Conceptualizations of rivers as living entities to whom society has distinct (shared) responsibilities provide a ready-built interpretive framework for catchment-specific applications (Brierley et al., 2019). As formally acknowledged in the Engineering NZ Climate Change Position Paper (2021), working in alignment with the principles of *te ao Māori* and *mātauranga Māori* is required to proactively support a just transition in climate change adaptation programs and to embrace a sustainability lens. Such practices "work in harmony with the environment, actively enhancing the *mana of te taiao* as well as mitigating and minimising harm" (p. 5).

Perhaps inevitably, the management perspective is the real laggard, entrenching historic power relationships and in so doing, failing to deliver proactive and precautionary practices that meet obligations to Māori under the terms of the Treaty of Waitangi. Here we ask: What will it take to give effect to *Te Mana o te Wai*, enhancing our collective role as guardians (*kaitiakitanga*) in efforts to revitalize, reanimate and resuscitate the strangled rivers of Aotearoa? We specifically consider two aspects of this aspiration. First, we develop a biophysical prioritization framework that appraises prospects to design and implement space-to-move interventions in differing situations. Second, we assess various policy implications of such programs, highlighting some of the issues to be addressed in scoping prospects to bring about a transformation in practice.

6 | A GEOMORPHIC PERSPECTIVE ON SPACE-TO-MOVE INTERVENTIONS IN AOTEAROA NEW ZEALAND

Geomorphologists have established clear understanding of the factors that affect the ways rivers appear, work, and evolve (Kasprak et al., 2016). Geomorphology is not a linear, cause-and-effect science (Grant et al., 2013). Inherent uncertainties accompany understandings of rivers as nonlinear, contingent, and emergent entities, wherein universal principles play out in distinctive ways in any given catchment (e.g., Brierley et al., 2013; Phillips, 2007). While such complexity poses challenges to conventional management approaches, it sits comfortably alongside Māori interpretations of relationships to rivers and the importance of catchment-specific knowledge. In the deeply contextual relationships that underpin *whakapapa*, assertions of generic understandings and seeking universal truths have no place.

In scientific terms, generating catchment-specific geomorphic knowledge is now a relatively straightforward task, facilitated by readily available high-precision topographic and Earth observational data and a wide range of analytical tools (e.g., automated machine learning applications and modeling toolkits; see Boothroyd et al., 2021; Fryirs et al., 2019; Piégay et al., 2020; Reichstein et al., 2019). In a New Zealand context, this is supported by impressive long-term national-scale datasets and toolkits such as the River Environment Classification (REC) and Freshwater Environments of New Zealand (FRENZ) (Snelder et al., 2004). However, to date, remarkably few studies document systematic catchment-wide appraisals of river evolution, explaining forms, and rates of adjustment to inform predictions of prospective river futures (Downs & Piégay, 2019; cf., Walley et al., 2020). Carefully selected archetypal histories conducted in different landscape settings for rivers subject to differing forms of anthropogenic disturbance would be very helpful in efforts to address this shortcoming. Much work remains to be done in developing a shared understanding of each river's story, appraising what efforts to work with the river look like and how to operationalize such understandings. In scientific terms, regional LiDAR coverage (LINZ, local councils) and capacity to systematically characterize and explain the recent history of local/reach scale river adjustments in relation to catchment-specific attributes and connectivity relationships highlights the potential to "change the game". Introduction of bathymetric LiDAR will further enhance these prospects, supporting monitoring programs that will increasingly reveal catchment-specific relations between headwater change and downstream responses, as well as links to land-use change, storm (cyclonic) events, tectonics, riparian vegetation change, and so forth.

In Table 2, we present a geomorphologically informed approach to support the development and implementation of space-to-move interventions in Aotearoa New Zealand. Biophysical considerations underpin prospects to reanimate strangled rivers as they help to determine what is realistically achievable in any given instance. Context is everything (Kondolf & Yang, 2008). In large part, this reflects the extent to which anthropogenic activities have modified and constrained a reach (and associated use of the land that has been set aside), and catchment-scale considerations that determine recovery potential (Fryirs & Brierley, 2016).

Geographic and historical considerations such as geomorphic setting and anthropogenic imprint (settlement, assets, infrastructure, and critical lifelines) fashion the vulnerability of a given river system. The uneven distribution of stopbanks across the country (Crawford-Flett et al., 2022) reflects different types and severity of problems (Figure 1). In regions such as Southland, for example, extensive use has been made of stopbanks that are offset some distance from

TABLE 2 A geomorphologically informed pathway to support the development and uptake of space-to-move interventions in Aotearoa New Zealand

Articulate distinctive values in light of catchment-specific contextual considerations
Develop and share understandings of each river's story, compiling and disseminating technical (geomorphic, ecological, hydrological, etc.), mātauranga, and social understandings of the meanings of a living river at a given location—its character and behavior, distinctive values, contemporary condition, relationships to (interdependence upon) other reaches (i.e., pattern of reaches, reach-reach connectivity, and tributary-trunk stream relations).
↓
Articulate what constitutes success in proactive, precautionary, and realistic catchment-scale visions, carefully contextualizing opportunities relative to limitations and risks of inaction (unsustainable practices that maintain the status quo). Determine what is desirable/achievable, assessing sense of loss induced by stopbanks (e.g., cultural values, fishing, swimming, habitat, etc.). Assess what needs to be done to protect and/or enhance distinctive values/attributes (things that matter), including concerns for *taonga* (treasures), taniwha, and ancestral relations. Communicate aims, aspirations, and benefits of the proposed plan of action, clearly identifying its purpose/rationale and the supporting evidence base.
↓
Appraise evolutionary trajectory to interpret future prospects
Interpret evolutionary trajectory to determine controls upon forms and rates of river adjustment, unraveling cumulative impacts and path dependencies set by legacy effects. Interpret how changing boundary conditions and connectivity relationships, and associated stressors and limiting factors, impact upon flow/sediment regimes, and the recovery potential of the system (Fryirs & Brierley, 2016).
↓
Scope the future to assess what is realistically achievable (what is manageable). Assess how differing forms of anthropogenic modifications and riparian vegetation and wood impact upon river form and flow/sediment conveyance.
↓
Co-develop a pathway to implementation
Identify and seek to address challenges, obstacles, impediments, roadblocks, and pinch points to implementation. Strategically address threatening processes, pressures, and stressors, giving particular attention to thresholds of potential concern. Minimize prospects for catastrophic change wherever and whenever possible. Manage land use problems at source and at scale (Wheaton et al., 2019), striving to ensure that management practices "do not fight the site" (Brierley & Fryirs, 2009, 2016; Fryirs & Brierley, 2021). Negotiate trade-offs and prioritize actions at the catchment scale, carefully considering treatment responses that minimize negative off-site impacts and legacy effects (i.e., do not transfer problems elsewhere; Schmidt et al., 1998).
↓
Co-develop risk maps and assess impacts of differing management strategies upon biophysical, socioeconomic, and cultural attributes, guiding interpretations of where differing forms of managed retreat may be possible. Differentiate reaches to retain as is (to protect assets/infrastructure) from reaches in which local measures are possible (e.g., reoccupation of abandoned secondary channels and ox-bow lakes) and reaches that have genuine prospect for managed retreat and/or stopbank removal.
↓
Carefully consider use of archetypes for differing types of interventions in differing situations/circumstances. Prioritize trial applications, working first in instances with high recovery potential to demonstrate proof of concept in situations that have high likelihood of success.
↓
Monitor the effectiveness of trial applications, including concerns for local values (e.g., *tohu*; sentinels, signals, acute observations of change; appropriate measures of the physical habitat mosaic and morphodynamics (functionality)), remembering that pretreatment data are vital. Modify practices and adapt behaviors based on learnings along the way.
↓
Communicate findings. Roll out and scale-up applications appropriately.

the contemporary channel, allowing the river sufficient space-to-move such that it retains a good degree of geo–eco–hydrological functionality. As outlined below, this is not the typical situation, and contextual considerations vary markedly across the country.

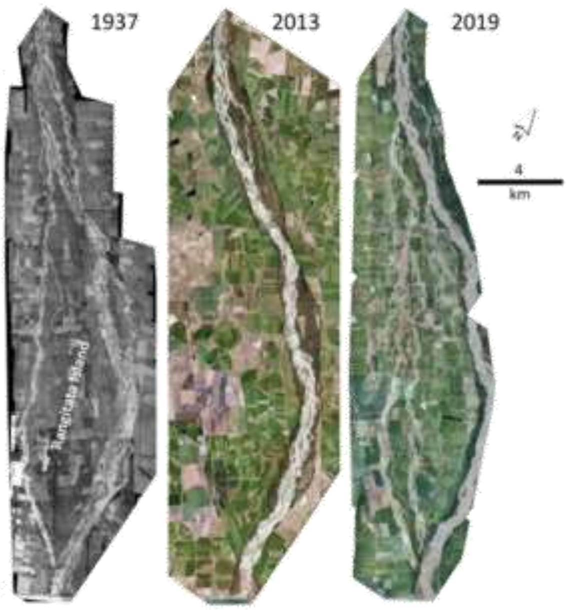
Effective management practices and associated policy framings recognize explicitly distinctive river morphologies and associated behavioral and evolutionary traits. Threats presented by geo–eco–hydrological impacts of strangled rivers, and prospects to address them, vary markedly for different types of river and with scale (Figure 1, Boxes 1–3).

BOX 1 An example of high-priority prospects for space-to-move interventions in biophysical terms

High-priority reaches for uptake of space-to-move interventions in biophysical terms have good potential to achieve tangible, clearly identified, and measurable benefits over a definable timeframe. In order for a river to self-heal, it must have sufficient room to move and sufficient energy (stream power) to rework available sediments, such that an appropriate sediment load is able to establish a suitable level of heterogeneity (i.e., channel complexity, and morphodynamic links to floodplains that shape the physical habitat mosaic of the river; Choné & Biron, 2016; Kondolf, 2011). Kondolf (2011) contends that habitat diversity is reduced if rivers are too dynamic, while low-energy, low-sediment load rivers may have limited prospects for self-recovery following channelization.

We consider the Rangitata River on the Canterbury Plains as an example of a high-priority prospect for uptake of space-to-move interventions in biophysical terms. Iconic braided rivers in Aotearoa New Zealand are cherished for their aesthetic beauty and dynamics. Sediment reworking and recurrent channel adjustment regenerate rich, complex river habitats that support a high biodiversity (Gray et al., 2006; O'Donnell et al., 2016).

Rangitata River, Canterbury Plains



1937 imagery credited to Orianne Etter, for Forest & Bird, imagery sourced from http://retrolens and licensed by LINZ; 2013 imagery was captured for "Environment Canterbury" by Aerial Surveys Ltd, Unit A1, 8 Saturn Place, Albany, 0632, New Zealand. 2019 imagery contains data sourced from Canterbury Maps and partners licensed for reuse under CC BY 4.0. Reach location is indicated in Figure 1.

Geomorphic setting

The glacially fed Rangitata River drains the eastern Southern Alps (2865 m). Its catchment area as it exits from gorges onto the floodplain is around 1500 km^2. Frequent freshes and floods generated by headwater rainfall combine with abundant sediment derived from alpine processes to create one of New Zealand's iconic braided rivers. Floods tend to occur in December or January. The mean annual flood is 1350 m^3/s. The river is largely naturally unconfined across the lower Canterbury Plains, with some Late Pleistocene terrace and bedrock confinement across the upper plains. The bed gradient of the Rangitata across its alluvial plain (below Arundel) is

6.2 m/km which is steeper than the nearby Rakaia and Waimakariri floodplains. The Rangitata River is competent to convey gravel all the way to the coast.

Reach-scale anthropogenic constraints

Between Arundel and State Highway 1, the river naturally bifurcated into two main channels, the North and South Branches, separated by Rangitata Island. The 1937 image indicates the complex and diverse assemblage of bars, islands, and channels associated with the large range in river dynamics. Exotic riparian plantings in buffer strips, combined with some stopbanks and rock groynes, artificially constrain the river, allowing agricultural intensification along much of the river's length across the Canterbury Plains. Stopbanks constructed on the true right bank of the channel are designed to prevent any flow in the South Branch except under severe flood conditions. The former active channel bed of the South Branch has been converted into agricultural use (notably dairy intensification). Although the river maintains an active braided form (2013 image), this modification has reduced the capacity of the river to adjust and occupy channel anabranches, re-work bars and form or maintain islands. Incorporation of former islands into the adjacent floodplain (2013 image) has removed important refugia for ground-nesting birds (O'Donnell et al., 2016).

Despite imposition of hard and soft management infrastructure, a flood with a peak discharge of 2270 m^3s^{-1} on 7 December 2019 breached flood defenses in several places on the south bank, occupying the South Branch and other former braids (2019 image). This damaged roads, powerlines, the railway line, irrigation machines, and farmland. The peak discharge was close to a 1/10 AEP event. Impacts were accentuated as this event closely followed double peaks of around 1000 m^3s^{-1} on 3 and 5 December which already overtopped the banks in places.

Catchment-scale recovery potential

The artificially constrained portion of the river has a high recovery potential. Allowing the river to permanently occupy the south branch, and/or setting back willow buffers to allow more room for the main stem, would support natural braided river processes and allow island refugia to re-form (O'Donnell et al., 2016). An abundant supply of bedload-caliber material from the Southern Alps, coupled with frequent flows competent to mobilize bed material, provides a good prospect for rapid reoccupation of former channel courses and a widening of the braidplain. This would facilitate geo-ecological recovery of river functionality, reinvigorating the diversity of geomorphic units, and habitats.

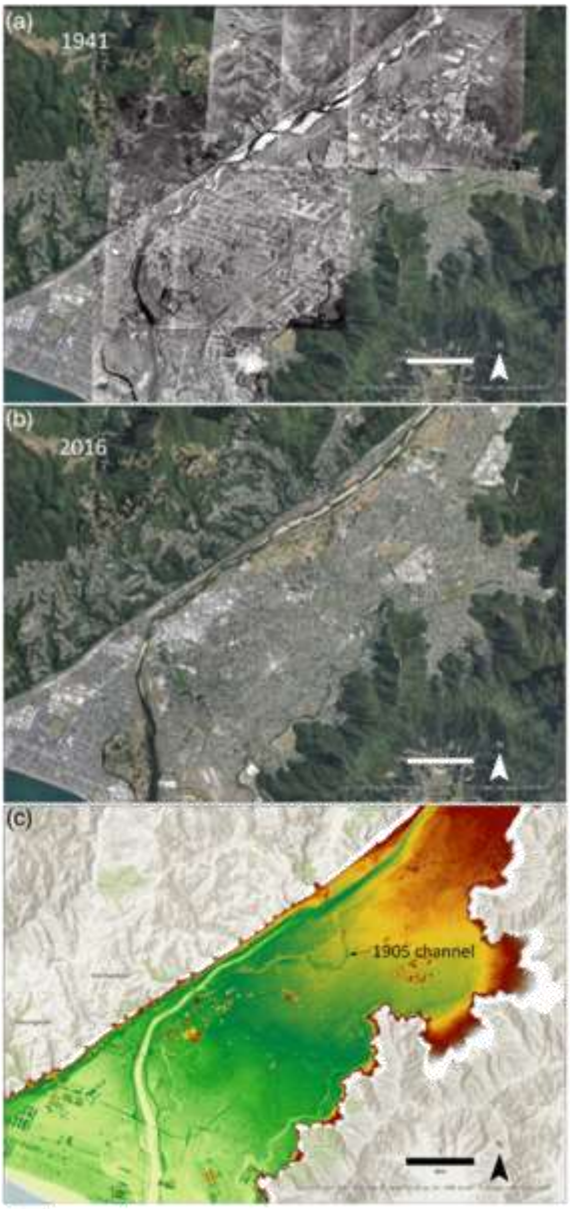
The high value of intensive agricultural land presents a barrier to allowing the Rangitata more space to move. However, changing the funding mechanism for river management away from one reliant on adjacent landowners, and including ecological and cultural values in any cost–benefit analysis, could help to facilitate the uptake of space to move interventions. Opportunity costs associated with climate change adaptation include expenses that can be avoided through reduced impacts of future disasters while minimizing maintenance costs of path dependencies. Cost-effective programs minimize prospects that destructive and expensive pathways are set in train for rivers that presently remain relatively unrestrained. The cost of repair far outweighs the costs of proactive, preventative approaches in the management of these remnants (high conservation value) reaches. Collective socioeconomic and cultural gains would be achieved if the river is seen as less of a threat, restoring its *mauri*, *mana*, and *ora*.

Sophisticated understandings of biophysical process interactions, alongside readily available datasets in Aotearoa, make explanation of the capacity for river adjustment and likely range of variability, and prediction of prospective river futures, a relatively straightforward task, at least in conceptual terms and in a statistical sense. Key differences are evident, for example, when considering braided rivers relative to wandering gravel-bed, active meandering or passive meandering rivers (see, e.g., Brierley & Fryirs, 2022). Alongside this, appropriate measures for each and every river carefully consider the problem of scale. Larger rivers typically adjust over longer timescales, often with a significant memory of past river adjustments. Accordingly, impacts of past management practices, and prospects to address them, vary with position (and scale) along a given river.

BOX 2 **An example of low-priority prospects for space-to-move interventions**

Highly impacted reaches, sometimes referred to as sacrificial rivers (Bouleau, 2014), typically have limited prospects for uptake of space-to-move interventions as they have been subjected to irreversible change. Concerns for protection of high-priority assets over-ride all else. Implicitly, once infrastructure is in place, it becomes increasingly expensive to implement space-to-move programs as path dependencies limit the range of viable options in the future.

Lower Hutt



Geomorphic setting

Hutt River (655 km^2) drains the southern Tararua Ranges (1376 m; located in Figure 1). The short, steep catchment is set within a tectonically controlled valley in which Late Pleistocene terraces, fault scarps, and valley margins exert considerable confinement. The river is less confined in its most distal (downstream) reach where it flows through Lower Hutt City, although the northern valley margin and Wellington Fault scarp confine the right bank. The Hutt River is a short, steep river that is cobbly for most of its length and is competent to convey gravel within ~2 km of the coast.

Reach-scale anthropogenic constraints

The LiDAR-derived DEM indicates that historically the Lower Hutt River was a dynamically adjusting system with a significant range of habitat diversity. Pool-riffle sequences, point bar assemblages, and channel-floodplain connectivity would have been characteristic attributes of the sinuous 1905 channel—most likely a wandering gravel-bed river. Distinct cut-offs and palaeochannels would have supported wetland habitats in former times. The greatly suppressed range of river behavior indicated in the 1941 image is accentuated to an even greater degree in the 2016 image. Profound habitat loss accompanied imposition of a laterally constrained low sinuosity channel that now operates as a series of alternating bars, disconnected from its floodplain. The narrow channel corridor is marked by truncated lateral bars as the channel bounces from side to side between armored banks. Bends are unable to develop, let alone form cutoffs. Channel rationalization and simplification have reduced resistance and improved conveyance of sediment and discharge through the urbanized reach, amplifying stream power, and propensity for erosion. Rigorous maintenance of the riparian margin is required to ensure security of flood protection infrastructure to protect urban development (Lower Hutt and Upper Hutt cities). Recurrent repairs to substantial stopbanks, rock lining, tied tree groynes, and willow-planting are needed to fix every minor breach.

Catchment-scale recovery potential

Pronounced path dependencies present little choice but to leave the river in its current location, pinned between urban development and the valley margin. However, future developments on adjacent lands are considered unwise, as disasters are inevitable in the future. In biophysical terms, efforts to improve river conditions are now limited to minor habitat enhancement.

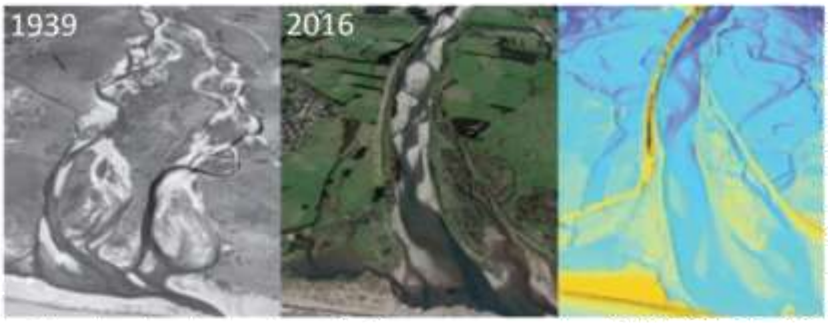
A disregard for the ancestral *whakapapa* connection has resulted in an overwhelming sense of loss, often expressed in terms of degraded *mauri* (cf., Hikuroa et al., 2018). However, interventions that reconnect urban areas to their rivers as parkland corridors can enhance aesthetic and sociocultural relationships. Prospectively, the aim of *kaitiakitanga* (guardianship) will restore *mauri*, revitalizing ancestral connections, enhancing amenity values, and the vibrancy of a living river system. RiverLink (https://www.riverlink.co.nz/) is a partnership between Hutt City Council, Greater Wellington Regional Council, and Waka Kotahi NZ Transport Agency working together with Ngāti Toa Rangatira and Taranaki Whānui ki te Upoko o te Ika to deliver flood protection, revitalize urban areas as a river city and enhance community connectivity via cycleways and pathways. Some managed retreats may be feasible to improve flood capacity and reduce risk of catastrophic infrastructure failure. This section of river is specifically included as a case study in the National Adaptation Plan (Ministry for the Environment, 2022, p. 130).

In geomorphic terms, optimal prospects to reanimate strangled rivers are situations that have been subject to a lesser degree of anthropogenic constraint and have high recovery potential (see Box 1). Reaches that are subject to low-intensity land uses (e.g., no urban development or vineyards or horticulture) and low-impact (older or patchy) stopbanks are considered as high-priority situations for space-to-move interventions. In these instances, relatively small initiatives may engender significant and sustained improvement in river conditions. Trial applications of space to move interventions in carefully targeted locations offer the greatest prospect for successful interventions, building confidence in the effectiveness and benefits of low-cost passive restoration practices that leave the river alone as far as practicable (e.g., Fryirs et al., 2018; Fryirs & Brierley, 2016; Kondolf, 2011; Poeppl et al., 2020).

BOX 3 **Moderate (often highly contested) prospects for space-to-move interventions**

Instances between examples shown in Boxes 1 and 2 have notable potential for rehabilitation, but question marks remain over either prospects or approach. Typically, existing land uses and infrastructure, and associated land ownership issues inhibit the availability of space to support managed retreat initiatives.

Ōtaki River, Greater Wellington



Geomorphic setting

The short, steep catchment of the Ōtaki River (348 km^2) drains the western Tararua Ranges (1529 m) prior to the river crossing a narrow coastal plain (reach is located in Figure 1). The channel is largely naturally unconfined in its most distal (downstream) reach, but upper reaches of the coastal plain where the river exits the range-front are laterally confined by Late Pleistocene river terraces (Brierley et al., 2022). Within the ranges, the river is bedrock confined, comprising gorges, and pockets of alluvium. The Ōtaki River is competent to convey gravel to the coast where a mixed sand-gravel bar forms across the river mouth.

Reach-scale anthropogenic constraints

Historically, the Ōtaki River had a high dynamic range of variability. Multiple channel anabranches and dynamic, migrating bends created a rich assemblage of geomorphic units, including medial, lateral and point bars, islands, and oxbows (see Brierley et al., 2022). Channel rationalization and simplification have reduced resistance and improved conveyance of sediment and discharge to the coast, enhancing flood protection for Ōtaki township and development of areas previously occupied by the active channel bed and floodplain. These economic benefits have come at significant social–ecological cost. Loss of river diversity and geo-ecological functionality has been accompanied by environmental loss (solastalgia) that has impacted iwi connections to their river (Brierley et al., 2022; Moore, 2004). Maintenance of the riparian margin is required to ensure security of flood protection infrastructure. This includes substantial stopbanks, rock lining, tied tree groynes, and willow-planting.

Catchment-scale recovery potential

Although the downstream portion of the Ōtaki River has been highly modified, it has significant recovery potential. An abundant supply of bedload-caliber material from the ranges, coupled with frequent flows competent to mobilize this material, provides a good prospect for rapid reoccupation of the Ōtaki's former channel courses. The river has a high propensity for lateral change and reworking of its bed and adjacent gravelly floodplain. Although maintenance and enhancement of north bank stopbanks is required to protect Ōtaki township, removal of the south bank infrastructure would allow substantial recovery of the river and sufficient room to accommodate an enhanced range of flows and channel mobility. This strategy would improve floodplain connection, enhancing river habitat in wetlands and abandoned channels. Reanimating the Ōtaki as a living river would enhance its *ora* and further improve its *mauri* (life force) and *mana* (authority).

Successful first steps could encourage and promote more ambitious initiatives in the future. A progressive sequence of actions can be envisaged, starting with initiatives to enhance riparian functionality (the geoecohydrological template of the river). Building on this, local allocation of additional space-to-move along the river corridor could enhance lateral (re)connection, reduce hydraulic efficiency (longitudinal connectivity) and ensure that vertical connectivity is not significantly altered (unless it is desirable to do so in a given instance; e.g., Wöhling et al., 2020). Thankfully, design criteria are increasingly in-hand to support such rewilding ventures (e.g., Ciotti et al., 2021; Wheaton et al., 2019). Appropriate management practices are fit-for-purpose, working with the river both individually and collectively (Brierley & Fryirs, 2022). Carefully targeted interventions for larger braided rivers, with their characteristic heterogeneity and biodiversity, are likely to have a high payoff for all the measures of impact/success indicated in Table 1. Alongside this, multiple measures that address issues at source, typically in riparian areas of small upland streams, enhance prospects to achieve a high payoff in downstream areas.

Barriers to uptake of space-to-move interventions are especially pronounced in highly impacted areas, such as modified streams and rivers in towns and cities. Legacy effects set by past anthropogenic disturbance determine the degree of strangulation and the extent to which path dependencies are set-in-stone (or rip-rap/rock armor, or pipes!). It is extremely difficult to envisage a return to former circumstances in instances where significant land use development now occupies that space that has been put-aside. In these low-priority situations in terms of prospective uptake of high-cost space-to-move interventions, the best must be made of prevailing conditions (Box 2). Ongoing expenditure to increase flood protection in line with the changing climate is easily justified in these instances.

For in-between, mid-priority instances, space-to-move interventions may have significant prospect to facilitate environmental repair, but these sites are likely to be the most contested sites in terms of land use relationships (Box 3). What some may see as options to reserve or retreat may be seen by others as land that is available for development. Proactive approaches to river management recognize the importance of diminishing returns in step-by-step approaches to the prioritization, design, and implementation of space-to-move interventions. Non-linear relations may become evident in negotiating compromise solutions between infrastructure protection and allowing a river space to move. Local allocations of small additional spaces for a river to adjust (say, a fraction of the active channel width) may achieve limited outcomes in terms of environmental benefits and hazard reduction relative to systematically allowing for half to full additional active width (or more) over a substantive length of river. Smaller, incremental additions may also engender limited socio-cultural benefits, continuing to perceive the river "over there, to be managed by someone else".

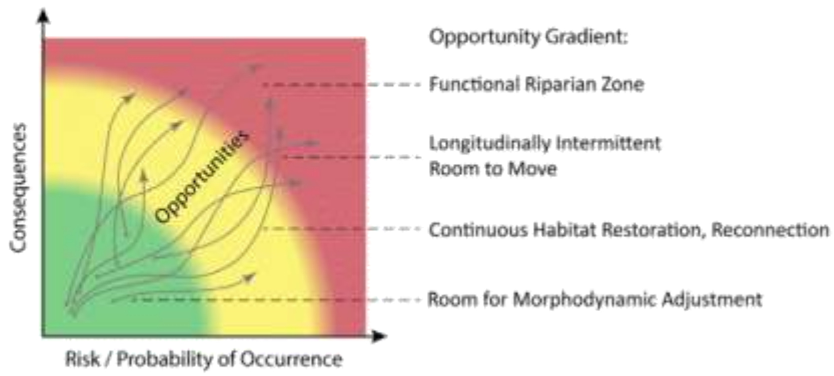


FIGURE 2 Schematic representation of risks and consequences associated with the uptake of space-to-move interventions in differing situations. Contextual circumstances determine opportunities for different forms of space-to-move intervention, reflecting what is achievable on the one hand, and associated consequences and risks on the other (Boxes 1–3). Highly constrained situations, typically associated with concerns for asset and infrastructure protection, have limited scope for uptake of space-to-move practices, although riparian zone enhancement and local improvement to the availability and viability of physical habitat may be possible (shown in red). The yellow zone refers to situations where a staged, incremental approach enhances space/capacity for adjustment and longitudinal/lateral reconnection of biophysical processes (and habitat linkages). These instances are often subject to contested land use pressures. The green zone represents situations with considerable prospect for uptake of space-to-move interventions, facilitating morphodynamic adjustment with low risk and low consequence in economic terms, but significant benefit in biophysical and socio-cultural terms (i.e., re-instigation of the *mauri*, *mana*, and *ora* of a living river).

Pushing issues aside will make it even harder to address key issues in the future, perpetuating further reactive responses as part of disaster management practices.

Further work is required to systematically appraise prospects for uptake of space-to-move interventions in light of contrasting circumstances exemplified in Boxes 1, 2, and 3. Management of risk varies markedly for these different situations (Figure 2). Risks and severity of consequences increase in highly developed situations. Accordingly, maintenance of the *status quo* and perhaps even accentuation of existing practices (e.g., enlarged and reinforced stopbanks) may be required to cope with future challenges. In less developed situations, space-to-move interventions may alleviate and mitigate various risks, but they cannot be eliminated. Conversely, without sufficient space-to-move, progressive deterioration in river conditions is likely. In intermediary situations, an engaged, informed, deliberative approach to negotiation of trade-offs is recommended (see next section). Prospects for uptake of space-to-move interventions are inherently fashioned by the policy context in which they are designed and applied.

7 | PROSPECTS TO REANIMATE THE STRANGLED RIVERS OF AOTEAROA: SITUATING SCIENTIFIC INTERVENTIONS IN THEIR POLICY CONTEXT

> *So as the image of tomorrow becomes clearer and more certain, a purely reactive approach to climate impacts becomes ever less credible. Instead, we need to plan and we need to prepare. For too long we have pushed climate adaptation to the back of the cupboard. Now is the time for a real step-change in our approach. Because the sooner we start, the more effective our efforts will be.*—Hon James Shaw, Message from the Minister of Climate Change, August 2022, Urutau, ka taurikura: Kia tū pakari a Aotearoa i ngā huringa āhuarangi. Adapt and thrive: Building a climate-resilient New Zealand. Aotearoa New Zealand's First National Adaptation Plan, p. 6.
>
> *Sooner or later the conversation (about managed retreat) will have to happen.*—Jamie Cleine, Buller District Council Mayor, commenting on the recommendation that an extensive system of stopbanks and floodwalls be built to ringfence Westport on the South Island following devastating impacts of flooding in mid-July, 2021 (cited in Donaldson, 2021, p. 23).

As highlighted by Castree (2019), the public authority of scientists lies in their ability to generate answers to cognitive questions, not normative ones, while politicians, businesses, and citizens select solutions to address what are perceived to be environmental problems (see Bluwstein et al., 2021; Lahsen & Turnhout, 2021). While river management is largely a response to political expedience and societal acceptability, science does play a fundamental role in helping to set the parameters and forecasting the impacts of socially acceptable actions in a given river system, as well as planning cost-effective ways to go about it. Researchers are not passive agents in this process.

Recognizing that uptake of science is enhanced when it can point to publicly acceptable and feasible solutions, there is cause for optimism in considering prospects to address concerns for the strangled rivers of Aotearoa New Zealand (Williams, 2022). Recurrent flood disasters and concerns for the health of freshwater systems keep issues high on the public radar (Gluckman et al., 2017; State of Environment reports; Joy & Canning, 2020; Richards et al., 2021). The need for enhanced adaptive capacity to cope with extreme events in the face of climate and land use change already has immediacy and high salience, resonating across society (Mitchell & Williams, 2021).

Unfortunately, the perceived flood protection provided to rate payers by stopbanks and associated infrastructure may not reflect reality, and risk will increase with climate change. Furthermore, the funding of flood defense through targeted rates and the focus this puts on purely economic cost–benefit considerations needs further analysis as a cause of the problem, highlighting the inability of such measures to fix it. Ultimately, the cost of repair far outweighs the costs of preventative approaches.

Recognizing the imperative for economically viable options, from a landowner perspective much depends upon what the initial cost would be and whether such expenditure is viable at the time. In many instances, opportunities to avoid the cost and pain of reactive measures are still in-hand: Allow some productive land to rewild and rethink transport planning, even if it means selected road and rail routes will no longer take the most efficient (and cheapest) path. Costs for uptake of space-to-move interventions, or profits foregone as the case may be, must be weighed against the future losses of land taken from the river and the assets built upon it. Further case studies are required to quantify implications of managed retreat, appraising benefit–cost analyses of allowing a river to self-adjust relative to alternative interventions, clearly articulating prospects to reduce impacts of future disasters (cf., Buffin-Bélanger et al., 2015; Hanna et al., 2020, 2021).

A strong collective will to do something about these problems recognizes that unless the current trajectory is changed, the situation is only going to get worse into the future. This awareness enhances prospects to socialize the problem before contemplating solutions, sharing perspectives to clearly articulate the full range of perspectives on the issue. Facilitation of deliberative fora and workshops to inform planning options will further enhance public recognition and ownership of the problem, identifying what needs to change and how practitioners and publics might work together to tackle it.

Identifying who has the mandate and who needs to be involved in the process of change through institutional and stakeholder mapping and engagement are critical starting points for such endeavors. A coalition of aligned practitioners and engaged citizens who want to do something about it could identify tangible ways to collectively drive change through formal partnerships to identify points of intervention with policy- and decision-makers. In such endeavors, it pays to make it as easy as possible to take action, maximizing the political incentive to do so. To this end, a well-planned deliberative process is required to support collaborative problem structuring, joint fact-finding, and iterating solutions, building public understanding to motivate action. For the science community, this means using clear messaging to make the issue as readily comprehensible as possible, making every effort to reduce inherent complexities such that solutions to address problems are practicable and tractable.

Uptake of managed retreat and space-to-move interventions entails much more than scientific rationales and benefit–cost analyses. Ultimately, it is a question of political will. Transformative change in the face of prevailing path dependencies is highly contingent and requires social catalysis (Acevedo Guerrero, 2018). While moving out of harm's way saves lives and ultimately, money, it remains a politically unpalatable solution (cf., Goodell, 2018). This is despite scientifically robust concerns for proactive and precautionary plans that emphasize the imperative for adaptation *before* the crisis hits.

Pre-emptive interventions require enabling statutes. At present, the statutory system in Aotearoa New Zealand fails to readily enable space-to-move initiatives. A forthcoming overhaul of the Resource Management Act and its replacement with new legislation that includes a Climate Change Adaptation Act creates opportunities to incorporate space-to-move interventions and strategic (managed) retreat from land at risk of catastrophic and outbreak flooding within the planning framework (Donaldson, 2021, p. 22). Although these policy advances are encouraging, as yet no clear guidance has been provided to indicate what role compensations will play and how any work/compensations will be paid. Inevitably, the insurance industry will reposition itself too, as flood risk maps are revised and reappraised. A new generation of policy tools and legal instruments such as conservation covenants will be required to expropriate lands in the built environment, whether by consensus or decree. It is likely that escalating costs driven by climate change will place increasing strain on targeted rate models in the future. Ultimately, these costs can only be met by central (or a wider form of regional) government, rather than local authorities. Potentially, concern for management of river hazards could be incorporated within a well-resourced (rates-based) body such as the Earthquake Commission.

In alignment with the recently announced national adaptation plan (Ministry for the Environment, 2022), we contend that this article provides initial guidance into some of the considerations to be addressed in taking steps to prioritize rivers and types of response in assessing prospects to design and implement space-to-move interventions to reanimate the strangled rivers of Aotearoa. In stark contrast to the emphasis upon fixity of a colonizing settler society (Goodin, 2012), space-to-move interventions promote adaptivity, envisaging rivers as living, adjusting, and emergent entities. In situations where managed retreat is the only viable long-term option, how can a flexible and dynamic adaptive pathways approach to negotiate the planned withdrawal of communities and infrastructure away from threatened areas be developed and applied (Donaldson, 2021; see Ministry for the Environment, 2022, p. 143)? A policy logic that frames the problem and possible solutions in a different way requires public support to facilitate a transformation in river management practices. Moving beyond undue reliance upon technological solutions to fix rivers, regenerative approaches emphasize concerns for how society lives with (as a part of) living rivers, rather than the increasingly futile quest to control them (Salmond et al., 2019).

Collaborative co-design processes that work with community stakeholders from across the social, political, and economic spectrum offer the greatest prospect for transformative change. Prospectively, the principles outlined in Table 2 and the examples shown in Boxes 1–3 could support initial steps in an incremental, staged approach to interventions that evaluate and perhaps classify priorities in a given catchment and region. More broadly, however, how can leadership be envisaged and enacted as a distributed, collaborative process that incorporates collective engagement and ownership through catchment guardianship?

Conducted effectively, river rehabilitation is a socially and culturally regenerative process that enhances collective wellbeing (*ora*). Outwardly, constructive alignment of scientific principles with *Te Mana o te Wai* (Brierley et al., 2019; Hikuroa et al., 2021; Te Aho, 2019) indicates a genuine prospect to design and implement space-to-move interventions that will reanimate the strangled rivers of Aotearoa New Zealand. Such programs would express and realize a different interpretation of the public values of river systems. Prospects to steer a different and potentially difficult course, while maintaining social consensus, require the establishment of a common or shared understanding of the problem from a wide range of perspectives (Harmsworth et al., 2016; Parsons et al., 2021). Development and use of Living Databases is required to facilitate, promote and use such understandings to support transformed approaches to the management of living rivers. Integrating plural perspectives in programs that work with nature and embrace ancestral connections are policy imperatives in enhanced approaches to sustainability and biodiversity management across the world (e.g., Díaz et al., 2015; Hill et al., 2020; cf., Smith et al., 2016). Ultimately, it pays to listen and learn from the river itself in effort to live generatively with it (Salmond et al., 2019).

AUTHOR CONTRIBUTIONS

Gary Brierley: Conceptualization (equal); investigation (equal); project administration (lead); writing – original draft (lead); writing – review and editing (equal). **Daniel Hikuroa:** Conceptualization (equal); writing – original draft (supporting); writing – review and editing (supporting). **Ian Fuller:** Conceptualization (equal); project administration (supporting); visualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **Jon Tunnicliffe:** Conceptualization (supporting); visualization (equal); writing – original draft (supporting); writing – review and editing (supporting). **Kristiann Allen:** Conceptualization (equal); writing – original draft (supporting); writing – review and editing (supporting). **James Brasington:** Conceptualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **Heide Friedrich:** Conceptualization (equal); writing – review and editing (supporting). **Jo Hoyle:** Conceptualization (equal); visualization (supporting); writing – review and editing (supporting). **Richard Measures:** Conceptualization (equal); writing – review and editing (supporting).

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