Kathryn Bayliss - Part 1. Statement for CHBDC District Plan, 1. Natural Environment – Natural Features and Landscapes

I, Kathryn Bayliss, thank you for allowing me to table my Statement, Evidence/Representations, and written material in support of my submission. The panel is welcome to contact me if they have any questions or wish to discuss anything.

I uphold my first Submission for the CHBDC Proposed May 2021.

1.
Natural Environment – Natural Features and Landscapes: Policy NFL-P5 (Mākāroro Gorge): NFL-P5 To recognise the regional social and economic significance of water storage within ONF-4 (Mākāroro Gorge). And Principal Reasons of the NFL – Natural Features & Landscapes chapter of the PDP, page NFL-10: The Mākāroro Gorge (ONF-4)....

I disagree with the Council Planners' (s42A) reports Recommendation for my submissions to be rejected.
I agree with the Mākāroro Gorge being recognised as ONF-4, an Outstanding Natural Feature.
I agree with the Mākāroro River being recognised as SAF-1, a significant Amenity Feature.

I seek deletion of both the policy Policy NFL-P5, Mākāroro Gorge, and associated text in the Principal Reasons around water storage in the Mākāroro catchment, (The Mākāroro Gorge, ONF-4, page NFL-10, second sentence). (i.e. delete: "That process confirmed the value of water storage for the District in terms of regional social and economic benefits prior to identification of the area as an Outstanding Natural Feature in the District Plan.")

The main reasons I still oppose NFL-P5 and the main reason given for it in the paragraph: The Mākāroro Gorge (ONF-4), page NFL-10, second sentence, ("That process confirmed the value of water storage for the District in terms of regional social and economic benefits prior to identification of the area as an Outstanding Natural Feature in the District Plan.")" is they are based on false information.

The District Plan can't have a policy based on a false principal reason. The Board of Inquiry did not confirmed the value of water storage for the District in terms of regional social and economic benefits.
The full documents for the Board of Inquiry into the Tukituki Catchment Proposal are available at:
https://www.epa.govt.nz/database-search/rma-applications/view/NSP000028

i.
Extracts:
"Final Report and Decision of the Board of Inquiry into the Tukituki Catchment Proposal Volume 1 of 3: Report and Decisions:
Social
The Board's findings
[1121] In the Board's view there must be an element of conjecture about whether the predicted social effects arising from the development of the RWSS will occur. For example, economic outcomes might not be assured at this stage and there is an element of uncertainty as to the precise extent that the Scheme would lead to intensification and/or transfer of farms.
[1123] On that basis the Board concludes that there will be both positive and negative social effects if the RWSS is

implemented. ......

Economics
The Board’s findings
[1132] While the Board needs to consider the economic impacts on communities and the costs and benefits resulting from the scheme, it is not required (or able) to determine the financial viability of the scheme. Nor can it accurately determine the financial implications for farmers who join the scheme or the business people making consequential decisions. Those are commercial decisions for the parties involved."

Most of the factual findings of the Final Report and Decision of the Board of Inquiry into the Tukituki Catchment Proposal where not included in the District Plan so it seems illogical to include a false finding.
The consents to the Ruataniwha Water Storage Scheme lapse in 2024 so reference to it in the District Plan could become outdated then. Already the reports and research done for the Ruataniwha Water Storage Scheme are outdated as so much as changed worldwide since they were done and the future will be vastly different.

ii.
The majority of reports done for the Board of Inquiry into the Tukituki Catchment Proposal and the Ruataniwha Water Storage Scheme have disclaimers.
Most reports and forecasts, and forward-looking statements come with disclaimers.
e.g."As these forward-looking statements are predictive in nature, they are subject to a number of risks and uncertainties, many of which are beyond the control of us. As a result, actual results and conditions will differ materially from those

expressed or implied in this presentation. Given these uncertainties, no forward-looking statement should be relied upon by the recipient in considering the merits of any particular transaction.
No warranty is given to the achievement of the results expressed or implied by such forward-looking statements or that the assumptions underlying such forward-looking statements will in fact be correct.
Projection of economic benefits from major infrastructure projects can never be an exact science . They required assumptions to be made in relation to factors many years in the future the majority of which are beyond the control of developers and owners. Actual outcomes will vary from those currently assumed."

In 2016 Butcher Partners Ltd did an updated Report for the HBRC. "Ruataniwha Water Storage Scheme. Review of Regional Economic Impacts and Net present Value" March 2016. (The first Butcher Partners Ltd Report for the HBRC. Ruataniwha Water Storage Scheme was done in October 2012)
The original estimated capital costs of dam and infrastructure in October 2012 were $239.7 million. ($246 million including electricity reticulation and mitigation costs). By 2016 total revised capital costs were estimated to have increased to $333 million.
Net extra farm capital investment costs had increased from the original expected $356 million in 2012 to $556 million in 2016.
The above costs did not include development costs incurred by HBRC and HBRIC.

A recent example is the Waimea dam project. The Tasman District Council put out the Waimea Dam project for public consultation in October 2017 with a forecast cost of $75.9m. When the decision to proceed with the dam was finalised in 2018 the estimated cost had risen to $104.5m. A year later there was a further increase of $29 million taking the then expected cost to $158m. The latest estimate of $185 million.

I have also supplied as evidence:
Ansar, A., et al., Should we build more large dams? The actual costs of hydropower megaproject development. Energy Policy (2014), http://dx.doi.org/10.1016/j.enpol.2013.10.069i.
(This includes irrigation and multipurpose dams).

There have been negative impacts since the RWSS was first promoted and years later shelved. These include large financial costs and loses of both public and private money, ongoing social conflicts and negative impacts on the wellbeing of some people. These will continue as long as there is a chance of a large water storage scheme being implemented in Central Hawke's Bay and will increase if any large water storage scheme is developed.

iii.
The Policy NFL-P5 (Mākāroro Gorge) does not follow the National Policy Statement for Freshwater Management 2020 :
(5) There is a hierarchy of obligations in Te Mana o te Wai that prioritises:
(a) first, the health and well-being of water bodies and freshwater ecosystems
(b) second, the health needs of people (such as drinking water)
(c) third, the ability of people and communities to provide for their social, economic, and cultural well-being, now and in the future.

To include a policy on the third of the hierarchy of obligations in Te Mana o te Wai and not the first then second is illogical.

Ruataniwha Water Storage Scheme and Te Mana o te Wai, and the natural environment:
"Actions of people / tangata can diminish the mauri and therefore the mana of a resource."
If the Ruataniwha Water Storage Scheme or similar scheme is developed the affected water bodies and natural, indigenous environments will have their mauri and mana destroyed or diminished by having people destroy them or rule over and control them. The affected water bodies will no longer be consider to have "natural" flows. The water will be impounded in the Makaroro River and the release of the water flow, amount, force, timing and water route will be controlled.
A dam and reservoir on the Makaroro River, (or any other river), will destroy it and some of the surrounding public Ruahine Conservation Forest Park, natural ecosystems and habitats, flora and fauna. 185.18 hectares of ecologically significant indigenous vegetation and habitats would be flooded by the proposed reservoir (or covered over by associated infrastructure, including the dam structure, new access tracks and spoil disposal sites). Some of the flora and fauna in the area include birds, bats, native fish (including whitebait species) and eels are endangered already and will be put in further risk.
Rivers in their natural state are increasing rare in NZ and less than 1% of the world's rivers remain in their natural state.
Wild and scenic rivers are valued for many reasons and their ecosystems are crucial for many of our threatened native species.
The Makaroro and Dutch Creek are probably CHB's most natural, pristine, highest quality rivers.
The Makaroro Storage Scheme could cause an environmental

catastrophe:
Deforestation and use of fossil fuels in construction and running of water storage scheme could cause a greenhouse gas explosion, adding to climate change, environment destruction, loss of biodiversity, natural and indigenous ecosystems.
More wetlands and braided river ecosystems will be destroyed. These also have an important part in absorbing flood waters, without them there will be an increased risk of more severe flooding.
Felling of about 193 hectares of trees and shrubs which absorb greenhouse gases while alive will release greenhouse gases when removed and decaying. Forests also have an important role in absorbing rain and preventing flooding.
Fossil fuels used for dam and distribution infrastructure by machinery and vehicles, increased electricity to run pumps etc will add to green house gases which contribute to climate change.
Increase in fertilisers, herbicides, pesticides, animals used in agricultural intensification will also add to green house gases, and the risk of further polluting the land and water and air. These could have negative consequences for people also.
Many other HB waterbodies will be affected by intensification and won't get any benefits from dam.
We must protect existing forests, restore forests and plant trees to help stop climate change and loss of biodiversity.
The value of intact forests is seldom highlighted.

Extract from the RWSS A5a-Cultural-Values-Assessment-Taiwhenua-o-Tamatea-and-Taiwhenua-o-Heretaunga-June-2012 copy.pdf :
3.6 A river is a living being. It has a mauri life force that weaves itself through the people, connecting the people with the river. Because it nurtures and sustains them it was given

the utmost respect. Any damage done to the river is harm done to the mauri of the river and harm done to the people.

iv.

Many recent studies are advising that we should view rivers differently and "Let them Speak for themselves".

These advise an approach that brings together mätauranga taiao with contemporary sciences to understand rivers as unique, dynamic living systems that include plants, animals and people, and seeks to balance life-enhancing exchanges among them, has the potential to lead to better outcomes for waterways, people and other life forms. This requires a shift from short-term, utilitarian, anthropocentric framings, because if rivers are more ancient and powerful than people, then all waterways have rights to flourish, not just those that are the focus of current human preoccupations.

(Refer to evidence supplied.)

"Let the Rivers Speak thinking about waterways in Aotearoa New Zealand" by Anne Salmond, Gary Brierley and Dan Hikuroa.

"Why we should release New Zealand’s strangled rivers to lessen the impact of future floods." The Conversation. February 23, 2021

"Beware of the Zombie River." James Brasington.pdf

Proposed District Plan submission form

Remember submissions close on Friday 6 August 2021 at 5pm.

Clause 6 of the First Schedule, Resource Management Act 199.

Feel free to add more pages to your submission to provide a fuller response.

To: Central Hawke's Bay District Council

1. Submitter details

Full Name	Last BAYLISS		First KATHRYN		
Company/Organisation (if applicable)					
Contact Person (if different)					
Email Address	Kall@xtra.co.nz				
Address	116 Maharakeke Road RD1 Waipukurau			Postcode 4281	
Phone	Mobile		Home 068589900	Work	

2. This is a submission on the Proposed District Plan for Central Hawke's Bay

3. ☐ I could ☑ I could not – gain an advantage in trade competition through this submission *(Please tick relevant box)*

If you could gain an advantage in trade competition through this submission please complete point 4 below:

4. ☐ I am ☐ I am not – directly affected by an effect of the subject matter of the submission that:

(a) adversely affects the environment; and (b) does not relate to trade competition or the effects of trade competition. *(Please tick relevant box if applicable)*

Note: If you are a person who could gain an advantage in trade competition through the submission, your right to make a submission may be limited by clause 6(4) of Part 1 of Schedule 1 of the Resource Management Act 1991.

5. ☐ I wish ☑ I do not wish – to be heard in support of my submission in person *(Please tick relevant box)*

6. ☐ I will ☑ I will not – consider presenting a joint case with other submitters, who make a similar submission, at a hearing. *(Please tick relevant box)*

7. Do you wish to present your submission via Zoom? ☐ Yes ☑ No

8. Please complete section below *(insert additional boxes per provision you are submitting on)*:

The specific provision of the plan that my submission relates to:

see next pages

Do you: ☐ Support ☐ Oppose ☐ Amend *(Please tick relevant box)*

What decision are you seeking from Council?

Reasons:

see next pages.

Please note: All submissions will be treated as public documents and will be made available on Council's website. However, you may request that your contact details (but not your name) be withheld. If you want your contact details withheld, please let us know by ticking this box. ☑

The specific provision of the plan that my submission relates to:
(1) Pages NFL-4 and NFL 10, Policy NFL-P5 and Principal Reasons about the Mākāroro Gorge (ONF-4) 2nd paragraph on page NFL10

I oppose both the policy NFL-P5 and principal reasons given for the waterstorage within ONF-4 (Mākāroro Gorge). I am seeking Council to delete them both.

My reasons are:
The water storage within ONF-4 Mākāroro Gorge is an illegal dam.
The Board of Inquiry also found "that there was conjecture about whether the predicted social effects arising from the Ruataniwha Water Storage Scheme (RWSS) will occur" and "the economic outcomes might not be assured".
The information for the RWSS is outdated, speculative and conjecture. Much has changed since it was done.
More recent reports have said any smaller legal waterstorage facility on the same site is uneconomical and the site is unsuited to smaller volumes (See August 2020 Tonkin + Taylor CHB Water Security project - Stage 1, Waterstorage Options Assessment)
Costs have increased, it is difficult to get workers, and many people are realising the importance of caring for the natural environment.
In Hawkes Bay it has often been proven when irrigation water supplies are available corporate and industrial farmers take over family farms and there are negative social effects. There has been an increase in migrant labour and seasonal casual workers. School roles have fallen. With the change in farm ownership there can be conflicts with new farmers and their different approaches to farming. Automation for many jobs will increase in future
Most economic reports have not taken into consideration the productivity benefits of conservation, biodiversity and environmental outcomes of not proceeding with the RWSS. Social benefits of improved water quality and quantity, less land use intensification, a ~~most~~ more natural environment to live in could be more benefit compared to a limited number of people who might get a financial benefit from waterstorage in the Mākāroro Gorge.

The specific provision of the plan my submission relates to:

(2) ECO- R2, R3, R4, R5, R6, pages ECO-7, 8, 9, 10, 11 ~~and~~
Clearance of indigenous vegetation.
I ~~do~~ oppose them.
I am seeking Council to prohibit clearance of indigenous vegetation except for ECO-R3,1b. (pages ECO-8, ECO-9). Trimming should be discretionary and limited also to ECO-R3 1b.
The reasons:
Manuka and Kanuka species should be given the same protection and status as other indigenous vegetation species. They are important indigenous colonising and nurse plants that grow quickly and provide ideal conditions for the establishment of other indigenous trees and shrubs.
Indigenous vegetation that has naturally re-grown is usually more adapted to the area than plantings by people. They help increase the biodiversity.
If allowing clearance of a limited area and size each year, the cumulative extent over years can be substantial. As there is only a small amount of remaining indigenous cover in CHB all must be protected.
Small, young sizes of indigenous vegetation needs to be allowed to grow and mature as it will eventually replace older vegetation that naturally dies.
ECO-P4 (page ECO-5) 2. should include all water bodies.
We are encouraged by government, and HBRC, who provide some funding, to plant trees to help control erosion, reduce climate change, enhance our natural environment and help people connect with nature to improve their wellbeing.
It has negative effects to allow any indigenous vegetation to be cleared. It affects the environment in many ways.
Protecting naturally re-grown indigenous vegetation can save time, labour and money.

The provision of the plan that my submission relates to is
② EW P8 - P10,11 Earthworks - hydrocarbon extraction activities, pages EW-1 to EW-19, all references to hydrocarbon activities
The decision I am seeking from Council is to make hydrocarbons, fossil fuels including coal, gas and oil mining activities prohibited.
These produce greenhouse gas emissions and contribute to climate change. Everyone is trying to reduce greenhouse gas emissions and stopping reliance on them.
Oil, gas and coal can have huge negatives on our environment and pose a big risk to our water, soils and air.
Extraction ~~to~~ can increase earthquake risks.
Prospecting, exploration, extraction and use of fossil fuels including hydrocarbons, gas, oil and coal can have a negative effect on human and animal health and wellbeing.

Energy Policy ∎ (∎∎∎∎) ∎∎∎–∎∎∎

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Should we build more large dams? The actual costs of hydropower megaproject development ☆

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HIGHLIGHTS

- We investigate *ex post* outcomes of schedule and cost estimates of hydropower dams.
- We use the "outside view" based on Kahneman and Tversky's research in psychology.
- Estimates are systematically and severely biased below actual values.
- Projects that take longer have greater cost overruns; bigger projects take longer.
- Uplift required to de-bias systematic cost underestimation for large dams is +99%.

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ABSTRACT

A brisk building boom of hydropower mega-dams is underway from China to Brazil. Whether benefits of new dams will outweigh costs remains unresolved despite contentious debates. We investigate this question with the "outside view" or "reference class forecasting" based on literature on decision-making under uncertainty in psychology. We find overwhelming evidence that budgets are systematically biased below actual costs of large hydropower dams—excluding inflation, substantial debt servicing, environmental, and social costs. Using the largest and most reliable reference data of its kind and multilevel statistical techniques applied to large dams for the first time, we were successful in fitting parsimonious models to predict cost and schedule overruns. The outside view suggests that in most countries large hydropower dams will be too costly in absolute terms and take too long to build to deliver a positive risk-adjusted return unless suitable risk management measures outlined in this paper can be affordably provided. Policymakers, particularly in developing countries, are advised to prefer agile energy alternatives that can be built over shorter time horizons to energy megaprojects.

1. Large hydropower dam controversy

The 21st Century faces significant energy challenges on a global scale. Population and economic growth underpin increasing demand for energy from electricity to transport fuels. Social objectives of poverty alleviation, adaptation and mitigation of climate change, and energy security present policy makers and business leaders with difficult decisions and critical trade-offs in implementing sound energy policies. Demand for electricity is, for example, slated to almost double between 2010 and 2035 requiring global electricity capacity to increase from 5.2 terawatt (TW) to 9.3 TW over the same period (IEA, 2011). Currently, the de facto strategic response to these big energy challenges is "big solutions" such as large hydropower dams. Are such big solutions in general and large hydropower dams in particular the most effective strategy, on a risk-adjusted basis, to resolve global energy challenges? Might more numerous small interventions be more prudent from the perspective of risk management and maximizing net present value even when they entail somewhat higher per unit cost of production?

Proponents of large dams envisage multiple benefits. A big step-up in hydropower capacity along with a long and varied list of corollary benefits: reducing fossil fuel consumption, flood control, irrigation, urban water supply, inland water transport, technological progress, and job creation (Billington and Jackson, 2006; ICOLD, 2010). Inspired by the promise of prosperity, there is a robust

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pipeline of new mega-dams being developed globally after a two-decade lull. The Belo Monte dam in Brazil, the Diamer-Bhasha in Pakistan, Jinsha river dams in China, Myitsone dam in Myanmar, or the Gilgel Gibe III dam in Ethiopia, all in various stages of development, are unprecedented in scale.

Large dams are, however, controversial because they exert substantial financial costs (World Bank, 1996; World Commission on Dams, 2000). Beyond the financial calculus, large dams have profound environmental (McCully, 2001; Scudder, 2005; Stone, 2011), ecological (Nilsson et al., 2005; Ziv et al., 2012), and social (Bakker, 1999; Duflo and Pande, 2007; Richter et al., 2010; Sovacool and Bulan, 2011) impacts. Stone (2011, p. 817) reports in *Science* that the Three Gorges dam in China is an "environmental bane" that will cost over USD 26.45 billion over the next 10 years in environmental "mitigation efforts". Despite their outsized financial and environmental costs, the purported benefits of large hydropower dams prove uncertain. For example, the World Commission of Dams (2000, p. 30) reported that for large hydropower dams "average [hydropower] generation in the first year of commercial operation is 80% of the targeted value"—a trend of which the recently completed Bakun hydroelectric project in Borneo is an alarming example (Sovacool and Bulan, 2011). Similarly, Duflo and Pande (2007) find adverse distributional impacts of large irrigation dams in India. Winners downstream come with losers upstream yielding a more modest, if any, net economic benefit.

The scale of contemporary large dams is so vast that even for a large economy such as China's the negative economic ramifications "could likely hinder the economic viability of the country as a whole" if the risks inherent to these projects are not well managed (Salazar, 2000). Similarly, Merrow et al. (1988, pp. 2–3) warn that "such enormous sums of money ride on the success of megaprojects [such as large dams] that company balance sheets and even government balance-of-payments accounts can be affected for years by the outcomes". Such warnings are not idle alarmism. There is mounting evidence in civil society, academic research, and institutional accounts that large dams have strikingly poor performance records in terms of economy, social and environmental impact, and public support (McCully, 2001; Scudder, 2005; Singh, 2002; Sovacool and Bulan, 2011; WCD, 2000). There are acrimonious, and as yet inconclusive, debates in scientific literature and civil society about whether large dams are a boon or a curse. Should we build more large hydropower dams? How confident can planners be that a large bet on a large dam will pay-off handsomely?

We investigate these questions with the "outside view" or "reference class forecasting" based on the literature on decision-making under uncertainty that won Princeton psychologist Daniel Kahneman the Nobel Prize in economics in 2002 (Kahneman and Tversky, 1979a, 1979b; Kahneman, 1994) extended and applied by Bent Flyvbjerg and colleagues to infrastructure projects (Flyvbjerg et al., 2003; Flyvbjerg, 2009). We present statistical and comparative evidence from the largest reference class to-date of actual costs of large hydropower dam projects (hereafter large dams unless stated otherwise). We find that even before accounting for negative impacts on human society and environment, the actual construction costs of large dams are too high to yield a positive return. Large dams also take inordinately long periods of time to build, making them ineffective in resolving urgent energy crises. Our evidence pertains primarily to large dams and the results cannot be applied either to smaller dams or other large energy solutions such as nuclear power without first building a separate "reference class" for other types of power generation technologies. Our findings, however, point towards the generalizable policy proposition that policymakers should prefer energy alternatives that require less upfront outlays and that can be built very quickly.

There is no doubt that harnessing and managing the power of water is critical for economies but large dams are not the way to do so unless suitable risk management measures outlined in this paper can be affordably provided. Building on literature in decision making under uncertainty in management, psychology, and planning research, this paper further provides public agencies (e.g. national planning and finance ministries, power and water authorities), private entrepreneurs, investors, and civil society a framework to test the reliability of *ex ante* estimates for construction costs and schedules of power generation alternatives. An impartial and rigorous application of the reference class forecasting methods proposed here can improve the selection and implementation of new investments.

2. Delusion and deception in large hydropower dam planning?

Our approach to address the debates about whether or not to build dams is to incorporate an evidence-based perspective that reflects how decisions among alternative options are actually made and on what basis. Theoretical and empirical literature on decision-making under uncertainty proposes two explanations—psychological delusion and political deception—that suggest decision-makers' forecasts, and hence ex ante judgment, are often adversely biased (Tversky and Kahneman, 1974; Kahneman and Lovallo, 1993; Flyvbjerg, 2003; Lovallo and Kahneman, 2003; Kahneman, 2011).

First, experts (e.g., statisticians, engineers, or economists) and laypersons are systematically and predictably too optimistic about the time, costs, and benefits of a decision. This "planning fallacy" (Kahneman and Tversky, 1979b; Buehler et al., 1994) stems from actors taking an "inside view" focusing on the constituents of the specific planned action rather than on the outcomes of similar actions already completed (Kahneman and Lovallo, 1993). Thus, for example, the estimated costs put forward by cities competing to hold the Olympic Games have consistently been underestimated yet every four years these errors are repeated. Biases, such as overconfidence or overreliance on heuristics (rules-of-thumb), underpin these errors.

Second, optimistic judgments are often exacerbated by deception, i.e. strategic misrepresentation by project promoters (Wachs, 1989; Pickrell, 1992; Flyvbjerg et al., 2002, 2005, 2009). Recent literature on infrastructure delivery finds strong evidence that misplaced political incentives and agency problems lead to flawed decision-making (see Flyvbjerg et al., 2009). Flyvbjerg et al. (2009, p. 180) further discuss that delusion and deception are complementary rather than alternative explanations for why megaprojects typically face adverse outcomes. It is, however, "difficult to disentangle" delusion from deception in practice. Using quasi-experimental evidence from China, Ansar et al. (2013) suggest that while better incentive alignment can help to lower the frequency and, to a lesser extent, the magnitude of biases, it does not entirely cure biases.

Be it delusion or deception, is decision-making in large hydropower dams systematically biased by errors in cost, schedule, and benefit forecasts? What is the risk that costs might outweigh benefits for a proposed dam? While the future is unknowable, uncertain outcomes of large investments can still be empirically investigated using "reference class forecasting" (RCF) or the "outside view" techniques (Kahneman and Lovallo, 1993; Flyvbjerg, 2006, 2008). To take an outside view on the outcome of an action (or event) is to place it in the statistical distribution of the outcomes of comparable, already-concluded, actions (or events). The outside view has three advantages: First, it is evidence-based and requires no restrictive assumptions. Second, it helps to test and fit models to explain why the outcomes of a reference class of

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past actions follow the observed distribution. Third, it allows to predict the uncertain outcomes of a planned action by comparing it with the distributional information of the relevant reference class. The theoretical foundations of the outside view were first described by Kahneman and Tversky (1979b) and later by Kahneman and Lovallo (1993) and Lovallo and Kahneman (2003) as means to detect and cure biases in human judgment. The methodology and data needed for employing the outside view, or reference class forecasting, in practice were developed by Flyvbjerg (2006, 2008) in collaboration with first implemented in practice by Flyvbjerg and COWI (2004).

2.1. Three steps to the outside view

The outside view, applied to large dams for the first time here, involves three steps: (i) identify a reference class; (ii) establish an empirical distribution for the selected reference class of the parameter that is being forecasted; (iii) compare the specific case with the reference class distribution. We take a further innovatory step of fitting multivariate multilevel models to the reference data to predict future outcomes. Our technique is an important improvement in the methodology of the outside view that can be generalized and applied to other large-scale and long-term decisions under uncertainty. With de-biased forecasts managers can make empirically and statistically grounded, rather than optimistic, judgments (Dawes et al., 1989; Buehler et al., 1994; Gilovich et al., 2002).

The outside view—as implemented by Flyvbjerg (2006, 2008)—is not without limitations (see Sovacool and Cooper, 2013 for a discussion specifically about energy megaprojects). For example, RCF focuses on generic risk inherent in a reference class rather than specific project-level risk. We rectify against this limitation by fitting regression models in addition to using traditional RCF methods in the result section below. Sovacool and Cooper (2013, p. 63) further suggest that RCF may not provide sufficiently accurate indication of the risks of rare megaprojects the likes of which have never been built before. Such “out of the sample” problems are well noted in probability theory. They do not, however, deny the fundamental usefulness of RCF. If anything our results err towards conservative estimates of actual cost overruns and risks experienced by large dams.

2.2. Measures and data

Following literature on the planning fallacy (Sovacool and Cooper, 2013), the parameters central to our investigation and multilevel regression analysis is the inaccuracy between managers' forecasts and actual outcomes related to construction costs, or the cost overrun, and implementation schedule, or schedule slippage. Following convention, cost overrun is the actual outturn costs expressed as a ratio of estimated costs[1]; cost overruns can also be thought as the underestimation of actual costs (Bacon and Besant-Jones, 1998; Flyvbjerg et al., 2002). Schedule slippage, called schedule overrun, is the ratio of the actual project implementation duration to the estimated project implementation. The start of the implementation period is taken to be the date of project approval by the main financiers and the key decision makers, and the end is the date of full commercial operation.

Inaccuracies between actual outcomes versus planned forecasts are useful proxies for the underlying risk factors that led to the inaccuracies. For example, cost overruns reduce the attractiveness of an investment and if they become large the fundamental economic viability becomes questionable. Bacon and Besant-Jones (1998, p. 317) offer an astute summary:

> The economic impact of a construction cost overrun is the possible loss of the economic justification for the project. A cost overrun can also be critical to policies for pricing electricity on the basis of economic costs, because such overruns would lead to underpricing. The financial impact of a cost overrun is the strain on the power utility and on national financing capacity in terms of foreign borrowings and domestic credit.

Similarly, schedule slippages delay much needed benefits, expose projects to risks such as an increase in finance charges, or creeping inflation, which may all require upward revision in nominal electricity tariffs. Financial costs and implementation schedules, because of their tangibility, are also good proxies for non-pecuniary impacts such as those on the environment or on the society. Projects with a poor cost and schedule performance are also likely to have a poor environmental and social track record. A greater magnitude of cost and schedule overruns is thus a robust indicator of project failure (Flyvbjerg, 2003).

In taking the outside view on the cost and schedule under/overruns, our first step was to establish a valid and reliable reference class of previously built hydropower dams as discussed above. The suggested practice is that a reference class ought to be broad and large enough to be statistically meaningful but narrow enough to be comparable (Kahneman and Tversky, 1979b; Kahneman and Lovallo, 1993; Flyvbjerg, 2006). International standard defines dams with a wall height >15 m as large. The total global population of large dams with a wall height >15 m is 45,000. There are 300 dams in the world of monumental scale; these “major dams” meet one of three criteria on height (>150 m), dam volume (>15 million m^3), or reservoir storage (>25 km^3) (Nilsson et al., 2005).

From this population of large dams, our reference class drew a representative sample of 245 large dams (including 26 major dams) built between 1934 and 2007 on five continents in 65 different countries—the largest and most reliable data set of its kind. The portfolio is worth USD 353 billion in 2010 prices. All large dams for which valid and reliable cost and schedule data could be found were included in the sample. Of the 245 large dams, 186 were hydropower projects (including 25 major dams) and the remaining 59 were irrigation, flood control, or water supply dams. While we are primarily interested in the performance of large dam projects with a hydropower component, we also included non-hydropower dam projects in our reference class to test whether project types significantly differ in cost and schedule overruns or not. Fig. 1 presents an overview of the sample by regional location, wall height, project type, vintage, and actual project cost.

The empirical strategy of this paper relied on documentary evidence on estimated versus actual costs of dams. Primary documents were collected from *ex ante* planning and *ex post* evaluation documents of the

1. Asian Development Bank;
2. World Bank, also see World Bank (1996) and Bacon and Besant-Jones (1998);
3. World Commission of Dams (WCD), also see WCD (2000)[2];
4. U.S. Corps of Engineers;
5. Tennessee Valley Authority;

[1] Cost overruns can also be expressed as the actual outturn costs minus estimated costs in percent of estimated costs.

[2] Note that the World Bank, Asian Development Bank, and the WCD typically report cost data in nominal USD. We, however, converted these data, adapting methods from World Bank (1996: 85), into constant local currencies.

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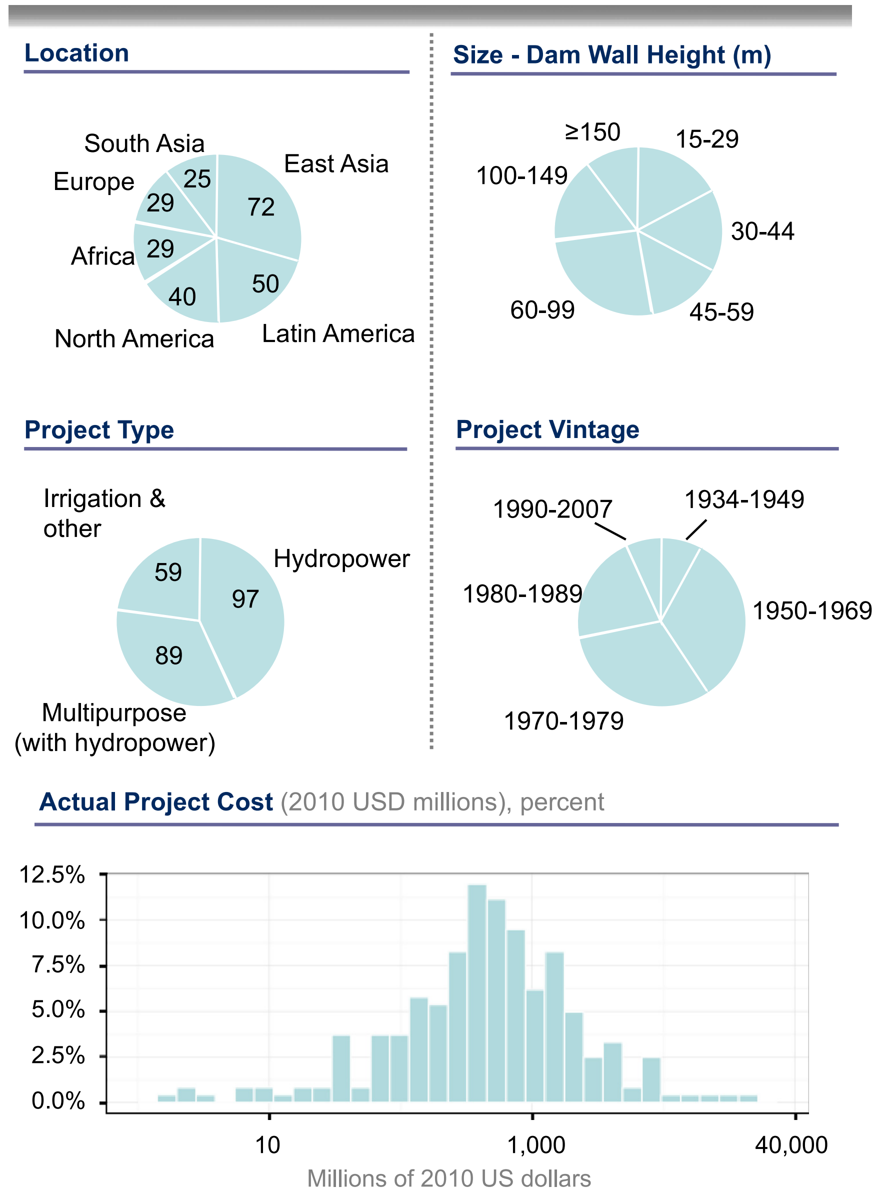

Fig. 1. Sample distribution of 245 large dams (1934–2007), across five continents, worth USD 353B (2010 prices).

6. U.S. Bureau of Reclamation, also see Hufschmidt and Gerin (1970)[3] and Merewitz (1973) on the U.S. water-resource construction agencies.

The procedures applied to the cost and schedule data here are consistent with the gold standard applied in the field—more detailed methodological considerations can be found in Flyvbjerg et al. (2002), Federal Transit Administration (2003), Pickrell (1989, 1992), World Bank (1996) and Bacon and Besant-Jones (1998) with which our data are consistent. All costs are total project costs comprising the following elements: right-of-way acquisition and resettlement; design engineering and project management services; construction of all civil works and facilities; equipment purchases. Actual outturn costs are defined as real, accounted construction costs determined at the time of project completion. Estimated costs are defined as budgeted, or forecasted, construction costs at the time of decision to build. The year of the date of the decision to build a project is the base year of prices in which all estimated and actual constant costs have been expressed in real (i.e. with the effects of inflation removed) local currency terms of the country in which the project is located. We exclude from our calculations debt payments, any *ex post* environmental remedial works, and opportunity cost of submerging land to form reservoirs. This makes comparison of estimated and actual costs of a specific project a like-for-like comparison.

2.3. Analyses

We investigated the magnitude and frequency of cost and schedule forecast (in)accuracies with a combination of simple

[3] Hufschmidt and Gerin (1970) report data on over 100 dams built in the United States between 1933 and 1967. The salient results of the study were that in nominal USD terms dams built by TVA suffered a 22% cost overrun; U.S. Corps of Engineers overrun was 124% for projects built or building prior to 1951, and 36% for projects completed between 1951 and 1964; while U.S. Bureau of Reclamation overrun was 177 per cent for projects built or building prior to 1955 and 72 per cent for all projects built or building in 1960 (Hufschmidt and Gerin, 1970: 277). Despite its large sample, Hufschmidt and Gerin (1970) do not report data broken down project-by-project. The validity and reliability of these data could not thus be established and were consequently excluded.

statistical (parametric and non-parametric) tests and by fitting more sophisticated multilevel regression models sometimes termed Hierarchical Linear Models (HLM).

Multilevel or hierarchically structured data are the norm in the social, medical, or biological sciences. Rasbash et al. (2009, p. 1) explain: "For example, school education provides a clear case of a system in which individuals are subject to the influences of grouping. Pupils or students learn in classes; classes are taught within schools; and schools may be administered within local authorities or school boards. The units in such a system lie at four different levels of a hierarchy. A typical multilevel model of this system would assign pupils to level 1, classes to level 2, schools to level 3 and authorities or boards to level 4. Units at one level are recognized as being grouped, or nested, within units at the next higher level. Such a hierarchy is often described in terms of clusters of level 1 units within each level 2 unit, etc. and the term clustered population is used." Important for a hierarchical linear model is that the dependent variable is at the lowest level of the nested structure. Multilevel models are necessary for research designs where data for observations are organized at more than one level (i.e., nested data) (Gelman and Hill, 2007). Failing to use multilevel models in such instances would result in spurious results (Rasbash et al., 2009).

With respect to our data on dams, projects are nested in the countries of their domicile. Like test scores of pupils from the same school tend exhibit within-school correlation, similarly outcomes of dam projects may exhibit within-country correlation that needs to be properly modeled using a multilevel model. We took this into account by modeling country as a first level random effect in a mixed effects multilevel model. The models were made parsimonious by using stepwise variable selection.

3. Results and interpretation

Our second step was to establish an empirical distribution for the cost forecast errors of large dams. We collected data on 36 possible explanatory variables, listed in Table 1, for the 245 large dams in our reference class.

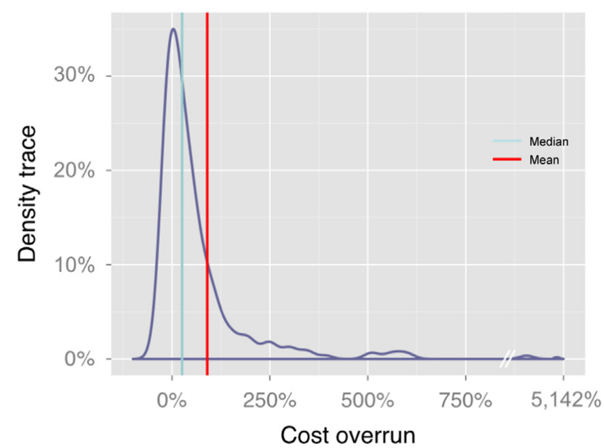

Fig. 2. Density trace of actual/estimated cost (i.e. costs overruns) in constant local currency terms with the median and mean (N=245).

Table 1
Variables and characteristics used in multilevel regressions on construction cost overrun and schedule slippage.

Project-specific variables
Project features
Hydropower or non-hydropower large dam project (dummy variable)
New power station or station extension (dummy variable)
Size
Generator unit capacity (MW)
Total project generation capacity (MW)
Dam height for new hydropower station (meters)
Hydraulic head for new hydropower station (meters)[a]
Reservoir area created by project (hectares)[a]
Length of tunnels (kilometers)[a]
Cost
Estimated project cost (constant local currency converted to 2010 USD MM)
Actual project cost (constant local currency converted to 2010 USD MM)
Cumulative inflation contingency (percentage)
Time
Year of final decision to build
Estimated implementation schedule (months)
Year of start of full commercial operation
Actual implementation schedule (months)
Procurement
Estimated project foreign exchange costs as a proportion of estimated total project costs (percentage)
Competitiveness of procurement process, international competitive bidding amount as a proportion of estimated total project costs (percentage)[*]
Main contractor is from the host country (dummy variable)
Country variables
Country (second level to control for within country correlation)
Political regime of host country is a democracy (dummy variable)
GDP of host country (current USD)
Per capita income of host country in year of loan approval (constant USD)
Average actual cost growth rate in host country over the implementation period—the GDP deflator (percentage)
MUV Index of actual average cost growth rate for imported project components between year of loan approval and year of project completion
Long-term inflation rate of the host country (percentage)
Actual average exchange rate depreciation or appreciation between year of formal-decision-to-build and year of full commercial operation (percentage)
South Asian projects (dummy variable)
North American projects (dummy variable)

[a] Denotes variables with a large number of missing values not used for regression analysis.

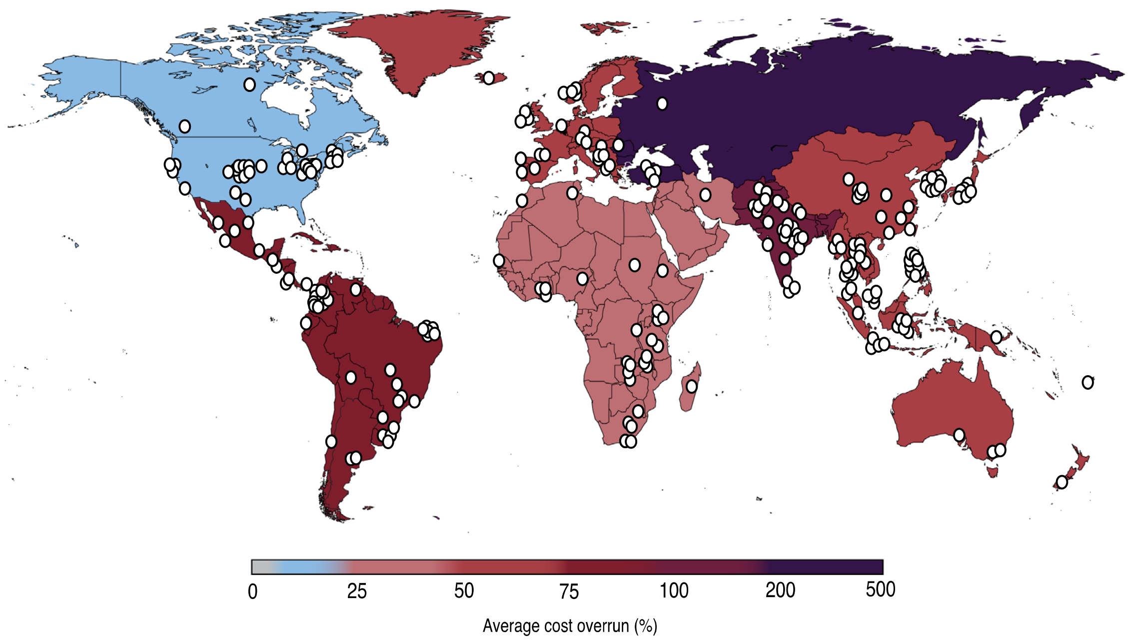

Fig. 3. Location of large dams in the sample and cost overruns by geography.

3.1. Preliminary statistical analysis of cost performance

With respect to cost overruns, we make the following observations:

1. Three out of every four large dams suffered a cost overrun in constant local currency terms.
2. Actual costs were on average 96% higher than estimated costs; the median was 27% (*IQR* 86%). The evidence is overwhelming that costs are systematically biased towards underestimation (Mann–Whitney–Wilcoxon $U=29{,}646$, $p<0.01$); the magnitude of cost underestimation (i.e. cost overrun) is larger than the error of cost overestimation ($p<0.01$). The skew is towards adverse outcomes (i.e. going over budget).
3. Graphing the dams' cost overruns reveals a fat tail as shown in Fig. 2; the actual costs more than double for 2 out of every 10 large dams and more than triple for 1 out of every 10 dams. The fat tail suggests that planners have difficulty in computing probabilities of events that happen far into the future (Taleb, [2007] 2010, p. 284))
4. Large dams built in every region of the world suffer systematic cost overruns. The mean forecasting error is significantly above zero for every region. Fig. 3 shows the geographical spread and cost overruns of large dams in our reference class. Large dams built in North America ($n=40$) have considerably lower cost overrun ($M=11\%$) than large dams built elsewhere ($M=104\%$). Although after controlling for other covariates such as project scale in a multilevel model, reported below, the differences among regions are not significant. We noted, three out of four dams in our reference class had a North American firm advising on the engineering and economic forecasts. Consistent with anchoring theories in psychology, we conjecture that an overreliance on the North American experience with large dams may bias cost estimates downwards in rest of the world. Experts may be "anchoring" their forecasts in familiar cases from North America and applying insufficient "adjustments" (Flyvbjerg et al., 2009; Tversky and Kahneman, 1974), for example to adequately reflect the risk of a local currency depreciation or the quality of local project management teams. Instead of optimistically hoping to replicate the North American cost performance, policymakers elsewhere ought to consider the global distributional information about costs of large dams.
5. The typical forecasted benefit-to-cost ratio was 1.4. In other words, planners expected the net present benefits to exceed the net present costs by about 40%. Nearly half the dams suffered a cost overrun ratio of 1.4 or greater breaching this threshold after which the asset can be considered stranded—i.e. its upfront sunk costs are unlikely to be recovered. This is assuming, of course, that the benefits did not also fall short of targets, even though there is strong evidence that actual benefits of dams are also likely to fall short of targets (WCD, 2000; McCully, 2001; Scudder, 2005).[4]
6. We tested whether forecasting errors differ by project type (e.g., hydropower, irrigation, or multipurpose dam) or wall type (earthfill, rockfill, concrete arch, etc.). Pairwise comparisons of percentage mean cost overrun and standard deviations as well as non-parametric Mann–Whitney tests for each of the parameters show no statistically significant differences. We conclude that irrespective of project or wall type, the probability distribution from our broader reference class of 245 dams applies as in Fig. 2.
7. We analyzed whether cost estimates have become more accurate over time. Statistical analysis suggests that irrespective of the year or decade in which a dam is built there are no significant differences in forecasting errors ($F=0.57$, $p=0.78$). Similarly, there is no linear trend indicating improvement or deterioration of forecasting errors ($F=0.54$, $p=0.46$) as also suggested in Fig. 4. There is little learning from past mistakes. By the same token, forecasts of costs of large dams today are likely to be as wrong as they were between 1934 and 2007.

We also explored the absolute costs of large hydropower dams ($N=186$). A large hydropower dam on average costs 1800 million in 2010 USD with an average installed capacity of 630 MW. One MW installed capacity on average costs 2.8 million in 2010 USD.

[4] A more comprehensive inquiry into planned versus actual benefits of dams is postponed until a future occasion but data available on 84 of the 186 large hydroelectric dam projects thus far suggests that they suffer a mean benefits shortfall of 11%.

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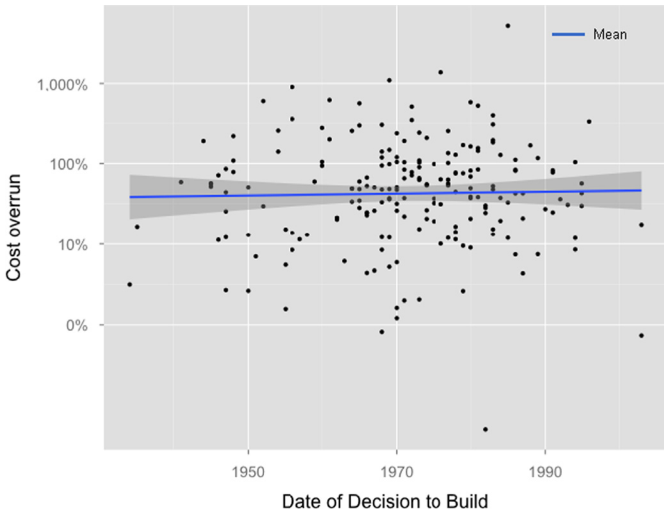

Fig. 4. Inaccuracy of cost estimates (local currencies, constant prices) for large dams over time ($N=245$), 1934–2007.

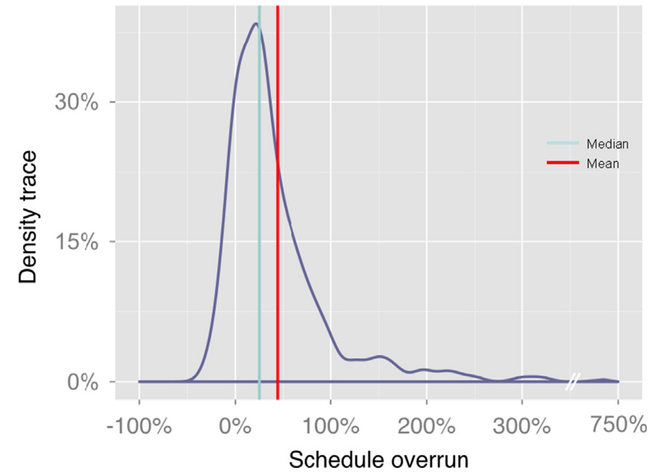

Fig. 5. Density trace of schedule slippage ($N=239$) with the median and mean.

A preliminary univariate analysis, which makes no attempts to take into account any covariates, shows that increase in the scale of a dam, e.g., measured as height of the dam wall, increases the absolute investment required exponentially, e.g. a 100 m high dam wall is four times more costly than a 50 m wall ($R^2=0.27$, $F=92.5$, $p<0.01$). An even stronger relationship can be seen between installed capacity MW and actual costs ($R^2=0.70$, $F=461.1$, $p<0.01$).

Furthermore, the rate of cost overrun outliers increases with increase in dam size either measured in installed hydropower generation ($r=0.24$, $p=0.01$) or wall height ($r=0.13$, $p=0.05$). Since there is a significant correlation between dam height and hydropower installed capacity ($r=0.47$, $p<0.01$), evidence suggests that larger scale in general is prone to outlying cost overruns. We further investigate the effects of scale on cost overruns by fitting multilevel models (Models 1 and 2) reported below.

3.2. Preliminary statistical analysis of schedule performance

Not only are large dams costly and prone to systematic and severe budget overruns, they also take a long time to build. Large dams on average take 8.6 years. With respect to schedule slippage, we make the following observations:

8. Eight out of every 10 large dams suffered a schedule overrun.
9. Actual implementation schedule was on average 44% (or 2.3 years) higher than the estimate with a median of 27% (or 1.7 years) as shown in Fig. 5. Like cost overruns, the evidence is overwhelming that implementation schedules are systematically biased towards underestimation (Mann–Whitney–Wilcoxon $U=29{,}161$, $p<0.01$); the magnitude of schedule underestimation (i.e. schedule slippage) is larger than the error of schedule overestimation ($p<0.01$).
10. Graphing the dams' schedule overruns also reveals a fat tail as shown in Fig. 5, albeit not as fat as the tail of cost overruns. Costs are at a higher risk of spiraling out of control than schedules.
11. There is less variation in schedule overruns across regions than cost overruns. Large dams built everywhere take significantly longer than planners forecast. North America with a 27% mean schedule overrun is the best performer. A non-parametric comparison using a Wilcoxon test ($p=0.01$) suggests that projects in South Asia have significantly greater schedule overruns ($M=83\%$) than rest of the world taken as a whole ($M=42\%$). We investigate this further with a multilevel model below (Model 3).
12. There is no evidence for schedule estimates to have improved over time.

We tested whether implementation schedules and project scale are related. A preliminary univariate analysis, which makes no attempts to take into account any covariates, shows that increase in the scale of a dam, e.g., measured as estimated cost of construction, increases the absolute actual implementation schedule required exponentially ($R^2=0.13$, $F=36.4$, $p<0.01$). Large scale is intimately linked with the long-term (see Model 2 below). The actual implementation schedule, reported here, does not take into the account lengthy lead times in preparing the projects. Dams require extensive technical and economic feasibility analysis, social and environmental impact studies, and political negotiations. The actual implementation cycles are far longer than the average of about 8.6 years, as shown in our data, that it takes to build a dam. These lengthy implementation schedules suggest that the benefits of large dams (even assuming that large dam generate benefits as forecasted) do not come "online" quickly enough. The temporal mismatch between when users need specific benefits and when these benefits come online is not to be downplayed (Ansar et al., 2012). Alternative investments that can bridge needs quickly, without tremendous time lags, are preferable to investments with a long lead-time and hence duration risk (Luehrman, 1998; Copeland and Tufano, 2004).

3.3. Multilevel regression analysis of cost and schedule performance

Means, standard deviations, and correlations of the variables used in the multilevel regressions are shown in Table 2.

We fitted multilevel regression models with projects nested by country as a second level to incorporate within-country correlation. The models were fitted using the "lme" procedure in the "nlme" package in R software. This function fits a linear mixed-effects model in the formulation described in Laird and Ware (1982) but allowing for nested random effects. The within-group errors are allowed to be correlated and/or have unequal variances. We found it necessary to transform variables to remove excessive skewness as noted in Table 2. Using stepwise variable selection, we are not only able to fit explanatory models for cost and overruns and estimated duration but also practicably parsimonious models for predicting them.

Table 3 summarizes the results from multilevel model examining predictors of cost overruns (Model 1). Model 1 identifies

Table 2
Descriptive statistics and correlations ($N=245$).

Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9
1. Cost Overrun[a]	2.0	3.6									
2. Schedule slippage[a]	1.5	0.7	0.17**								
3. Estimated schedule (months)[b]	73.1	33.8	−0.16*	0.23**							
4. Actual schedule (months)[b]	102.7	55.7	−0.27**	−0.43**	0.76**						
5. Year—decision to build	1971.1	13.2	−0.02	0.05	−0.21**	−0.25**					
6. Year—completion	1979.6	12.7	−0.14*	−0.10	0.03	0.08	0.94**				
7. Project type dummy	0.8	0.4	−0.14*	0.08	0.10	0.02	−0.02	−0.02			
8. Democracy dummy	0.4	0.5	0.00	−0.14*	0.16*	0.20**	−0.45**	−0.38**	0.00		
9. Estimated cost (USD MM 2010 constant)[b]	699.6	1215.5	−0.03	0.09	0.48**	0.37**	0.02	0.13*	0.37**	−0.04	
10. Actual cost (USD MM 2010 constant)[b]	1462.2	4032.5	−0.38**	0.02	0.50**	0.43**	0.02	0.17**	0.38**	−0.03	0.93**
11. Height of dam wall (m)[c]	77.3	51.6	−0.10	0.10	0.26**	0.17**	0.10	0.16*	0.34**	−0.03	0.51**
12. Installed hydropower capacity (MW)[b]	487.0	1255.3	−0.16*	0.19**	0.22**	0.08	0.13*	0.16*	0.69**	−0.14*	0.59**
13. Length of dam wall (m)[b]	1364.1	2061.9	−0.12	−0.07	0.25**	0.30**	−0.19**	−0.08	−0.07	0.08	0.37**
14. Tunnel length (m)[b]	3500.0	7869.5	0.13	−0.12	−0.04	0.16	−0.06	−0.01	−0.23	0.05	0.11
15. Manufactures unit value index CAGR[d]	6.0	5.4	−0.01	−0.03	−0.25**	−0.18**	−0.12	−0.18**	0.08	−0.08	−0.13
16. GDP (nominal USD B)[b]	1221.1	253.4	−0.05	0.25**	0.36**	0.17*	0.29**	0.37**	−0.13	0.13	0.19*
17. Per capita income (2000 constant USD)[b]	4132.8	5198.6	0.23**	0.15*	0.11	0.01	−0.37**	−0.40**	−0.07	0.48**	−0.07
18. Long-term inflation (%)[b]	17%	0.2	−0.29**	0.04	−0.09	−0.11	0.22**	0.19**	0.24**	−0.37**	0.13*
19. Forex depreciation (%)[e]	18%	70.3	−0.30**	−0.04	0.03	0.00	0.29**	0.29**	0.16*	−0.20**	0.21**
20. South Asia dummy	0.1	0.3	−0.25**	−0.18**	0.17**	0.26**	−0.04	0.07	−0.06	0.20**	0.11
21. North America dummy	0.2	0.4	0.28**	0.06	0.21**	0.13*	−0.57**	−0.55**	−0.09	0.52**	0.06

Variable	10	11	12	13	14	15	16	17	18	19	20
11. Height of dam wall (m)	0.51**										
12. Installed hydropower capacity (MW)	0.60**	0.47**									
13. Length of dam wall (m)	0.38**	0.03	0.13								
14. Tunnel length (m)	−0.01	0.05	−0.22	−0.18							
15. Manufactures Unit Value Index CAGR	−0.12	−0.08	−0.02	0.02	−0.02						
16. GDP (nominal USD)	0.19*	0.10	0.09	0.04	−0.29	−0.31**					
17. Per capita income (2000 constant USD)	−0.14*	−0.08	−0.11	−0.02	−0.09	−0.01	0.29**				
18. Long-term inflation (%)	0.22**	0.06	0.33**	0.07	−0.41*	0.15*	−0.03	−0.24**			
19. Forex	0.29**	0.09	0.29**	−0.02	−0.37*	−0.16*	0.00	−0.26**	0.64**		
20. South Asia dummy	0.19**	0.08	−0.03	0.20**	NA	−0.09	−0.01	−0.46**	−0.10	0.11	
21. North America dummy	−0.03	−0.10	−0.16*	0.19**	NA	−0.18**	0.33**	0.60**	−0.44**	−0.31**	−0.15*

[a] One over ($1/x$) transformed.
[b] Log transformed.
[c] Sq. rt. ($\sqrt{x}$).
[d] Cb rt. ($\sqrt[3]{x}$).
[e] $x^{0.25}$ transformed to remove excess skewness for regression analysis and to calculate correlations.
** $p<0.01$.
* $p<0.05$.

Table 3
Model 1—Significant variables for cost accuracy for large dam projects (constant local currency).

Variable	Regression coefficient	Standard error	*t*-Stat	2-Tailed significance
Intercept	1.402	0.185	7.560	0.000
Log estimated duration (months)	−0.100	0.041	−2.424	0.016
Log of country's long-term inflation rate (%)	−0.085	0.029	−2.930	0.005

Note: Dependent variable is cost forecast accuracy, which is the estimated/actual cost ratio (i.e. $1/x$ of the cost overrun to remove excessive skewness), based on 239 observations. Since the dependent variable in Model 1 is the inverse of the cost overrun a negative sign on the coefficients of both significant variables suggests that an increase in the estimated duration or long-term inflation rate increases the cost overrun.

the estimated implementation schedule and the long-term inflation rate in the country in which the project is built as highly significant variables. An increase in estimated duration of one year contributes to an increase in cost overrun of approx. 5–6 percentage points depending on the country whilst holding the inflation rate constant (see Fig. A1). Note that an R-squared measure, which is customary to report for single-level regressions as explained proportion of variance, cannot be applied to multilevel models (Recchia, 2010).[5] The usual diagnostics, based upon the model residuals, were satisfactory.

The first finding in Model 1 is that the larger the estimated implementation schedule the higher the cost overrun ($p=0.016$), with all other things being equal, is particularly noteworthy for two reasons.

First, Model 1 suggests that planners' forecasting skills decay the longer in the future they are asked to project the risks facing a large dam. Material information about risks, for example, related to geology, prices of imports, exchange rates, wages, interest rates, sovereign debt, environment, only reveal in future shaping episode to which decision-makers are "blind" ex ante (Flyvbjerg and Budzier, 2011). We discuss some qualitative case examples to illustrate this statistical result and its broader implications in the next section.

Second, preliminary analysis had suggested that estimated implementation schedules depend on the scale of a planned

[5] Recchia (2010, p. 2) explains further why a *R*-squared measure cannot be used for a multilevel model. A single-level model "includes an underlying assumption of residuals that are independent and identically distributed. Such an assumption could easily be inappropriate in the two[or multi]-level case since there is likely to be dependence among the individuals that belong to a given group. For instance, it would be difficult to imagine that the academic achievements of students in the same class were not somehow related to one another". Also see Kreft and Leeuw (1998) and Goldstein (2010).

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investment—i.e. bigger projects take longer to build. Support of this preliminary result was found by fitting a multilevel model (Model 2) that examines the predictors of estimated implementation schedule. Model 2 shows that height ($p=0.02$), installed capacity (MW) ($p=0.02$), and length ($p=0.04$) of the dam wall are significant variables associated with the estimated implementation schedule. The effect of these covariates can be seen from the coefficients in Table 4: a greater height, installed capacity, or length contribute to longer implementation schedules. We interpret Model 2 as follows. Estimated implementation schedule acts not only as a temporal variable but also as a surrogate for scalar variables such as wall height (which is also highly correlated with installed capacity). The larger the dam, the longer the estimated implementation schedule, and the higher the cost overrun.

Taken together, the multilevel models for cost overruns and estimated schedule suggest that longer time horizons and increasing scale are underlying causes of risk in investments in large hydropower dam projects.

The second finding in Model 1 is that higher the long-term inflation rate of the host country the higher the cost overrun suffered by a dam ($p=0.02$). The long-term inflation rate was calculated by fitting a linear model to the log of the time series of the GDP deflator index of each country. The slope of this fitted line can be interpreted as the annual average growth rate of the log inflation for each country. This slope is a different constant for each country with some countries such as Brazil with a considerably higher long-term inflation rate, and hence greater propensity to cost overruns, than China or the United States. Moreover, this slope is stable in the short-run (it takes years of high or low inflation to change this slope) and hence our estimate can be assumed to be reliable predictor. Recall that the cost overrun is being measured in constant terms (i.e. with the effects of inflation removed); yet Model 1 suggests that the inflation trajectory of a country, which we interpret as a surrogate of the overall macroeconomic management, is an important risk when making durable investments. The multilevel model finally suggests that once country specific factors have been taken into account the factor that drives cost overrun is the planning horizon.

Finally, we fit a multilevel model (Model 3) to examine predictors of schedule overruns. Model 3 identifies the following significant variables: whether or not a country is a democracy; the per capita income of the country in 2000 constant USD in the year of the decision to build; the planned installed capacity (MW); and planned length of the dam wall (meters). Avid dam building countries in South Asia, at various stages of democratic maturity, have also one of the poorest schedule performances in building dams. We controlled for this fact by including a dummy variable for South Asia in the model as a covariate with an interaction effect with the democracy dummy. Democracy in South Asia is significant in explaining schedule overruns. The South Asia dummy, however, does not come out to be significant. The effect of these covariates and the interaction effect can be seen in Table 5.

First, democracies' forecasts about implementation schedules of large dams are systematically more optimistic than autocracies even after controlling for systematically higher schedule overruns in India and Pakistan. The size of the coefficient is large suggesting that political process has profound impact on the schedule slippage. We tested whether democracies take longer than autocracies to build large dams by fitting a model to explain the actual implementation schedule (Model 4). Model 4, summarized in Table 6, shows that effects of political regime on the actual schedule are not significant. In other words, while democracies do not take longer to build large dams than autocracies in absolute terms, democracies appear to be more optimistic. Given its vast scope, we defer a further investigation of this important result to a future inquiry. We note, however, that theories of delusion and deception in the planning of large infrastructure projects (Flyvbjerg et al., 2009) would interpret this as evidence of ex ante political intent among democratically elected politicians to present a rosier picture about large dams than they know the case to be.

Second, countries with a higher per capita income in constant 2000 USD in the year of decision to build tend to have lower

Table 4
Model 2—Significant variables for estimated construction schedule for large dam projects (months).

Variable	Regression coefficient	Standard error	*t*-Stat	2-Tailed significance
Intercept	3.444	0.197	17.464	0.000
Sq rt of dam wall height (m)	0.029	0.012	2.414	0.017
Log of dam wall length (m)	0.058	0.027	2.153	0.033
Log of hydropower installed capacity (MW)	0.016	0.007	2.141	0.034

Note: Dependent variable is log of the estimated construction schedule, based on 239 observations.

Table 6
Model 4—Significant variables for estimated construction schedule for large dam projects (months).

Variable	Regression coefficient	Standard error	*t*-Stat	2-Tailed significance
Intercept	−17.712	6.401	−2.767	0.007
Log of dam wall length (m)	0.105	0.029	3.567	0.001
Year of actual project completion	0.011	0.003	3.358	0.001

Note: Dependent variable is log of the actual construction schedule, based on 239 observations.

Table 5
Model 3—Significant variables for schedule slippage for large dam projects.

Variable	Regression coefficient	Standard error	*t*-Stat	2-Tailed significance
Intercept	0.405	0.163	2.483	0.014
Democracy dummy[a]	−0.134	0.055	−2.439	0.016
Log of country's per capita income in year of decision to build (constant USD)	0.065	0.019	3.334	0.001
Log of dam wall length (m)	−0.027	0.013	−2.081	0.039
Log of hydropower installed capacity (MW)	0.018	0.006	3.207	0.002
South Asia dummy	0.211	0.113	1.874	0.066
Democracy in South Asia interaction effect	−0.239	0.113	−2.114	0.036

Note: Dependent variable is $1/x$ of the actual/estimated schedule ratio, based on 239 observations.

[a] Dummy based on the Polity2 variably of Polity IV regime index. Score of +10 to +6=democracy; score of +5 to −10=autocracy.

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schedule overruns than countries with lower per capita income. We concur with the interpretation of Bacon and Besant-Jones (1998, p. 325) that "the best available proxy for most countries is [the] country-per-capita income…[for] the general level of economic support that a country can provide for the construction of complex facilities". This result suggests that developing countries in particular, despite seemingly the most in need of complex facilities such as large dams, ought to stay away from bites bigger than they can chew.

Third, the evidence appears to be contradictory with respect to scale. While a greater dam wall length contributes to a higher schedule overrun, a higher MW installed capacity has the opposite effect. Model 3 in Table 5 shows that the size of coefficients for the two significant variables related to physical scale—i.e. Log of dam wall length (m) and Log of hydropower installed capacity (MW)—is approximately the same but with the opposite sign.[6]

In attempting to interpret this result our conjecture is as follows. Dam walls are bespoke constructions tied to the geological and other site-specific characteristics. In contrast, installed capacity is manufactured off-site in a modular fashion. For example, the 690 MW installed capacity of the recently completed Kárahnjúkar project in Iceland was delivered with six generating units of identical design (6×115 MW). We propose that project components that require onsite construction, e.g. dam wall, are more prone to schedule errors than components manufactured off-site, e.g. generation turbines. Project designs that seek to reduce the bespoke and onsite components in favor of greater modular and manufactured components may reduce schedule uncertainty.

This conjecture is supported by Model 4 in Table 6, which shows that the actual construction schedule, in absolute terms, is significantly increased with an increase in the length of dam wall. In contrast, MW installed capacity does not have an effect on the absolute actual construction schedule suggesting that construction schedules are more sensitive to on-site construction than to components manufactured in factories. Note that lower installed capacity does not necessarily equate with a smaller dam. For example, it is not rare for a large multipurpose dam to have a low MW installed capacity when, for instance, the dam is primarily being used for irrigation or flood management purposes.

4. Qualitative case examples and policy propositions

The statistical results reported in the preceding sections show that cost and schedule estimates of large dams are severely and systematically biased below their actual values. While it is beyond the scope of this paper to discuss wider theoretical implications, the evidence presented here is consistent with previous findings that point to twin problems that cause adverse outcomes in the planning and construction of large and complex facilities such as large hydropower dams: (1) biases inherent in human judgment (delusion) and (2) misaligned principal-agent relationships or political incentives (deception) that underlie systematic forecasting errors. In the context of large dams, we argue that large scale and longer planning time horizons exacerbate the impact of these twin problems. We now present a few qualitative examples of risks large dams typically face to illustrate the statistical results reported above. We jointly draw on the statistical analyses and qualitative analyses to distill propositions of immediate relevance to policy.

Globally, experts' optimism about several risk factors contribute to cost overruns in large dams. For example, the planning documents for the Itumbiara hydroelectric project in Brazil recognized that the site chosen for the project was geologically unfavorable. The plan optimistically declared, "the cost estimates provide ample physical contingencies [20% of base cost] to provide for the removal of larger amounts [of compressible, weak, rock] if further investigations show the need" (World Bank, 1973). This weak geology ended up costing +96% of the base cost in real terms. Itumbiara's case is illustrative of a broader problem. Even though geological risks are anticipatable there is little planners can do to hedge against it. For example, exhaustive geological investigation for a large dam can cost as much as a third of the total cost (Hoek and Palmieri, 1998); at which point still remains a considerable chance of encountering unfavorable conditions that go undetected during the *ex ante* tests (Goel et al., 2012).

Policy proposition 1. *Energy alternatives that rely on fewer site-specific characteristics such as unfavorable geology are preferable.*

Similarly, in the Chivor hydroelectric project in Colombia, the planning document was upbeat that there will be no changes in the exchange rate between the Colombian Peso and the U.S. dollar during the construction period (1970–1977) stating, "No allowance has been made for possible future fluctuations of the exchange rate. This approach is justified by recent experience in Colombia where the Government has been pursuing the enlightened policy of adjusting [policy] quickly to changing conditions in the economy" (World Bank, 1970). In fact, the Colombian currency depreciated nearly 90% against the U.S. dollar as shown in Fig. 6.

Since over half the project's costs covers imported inputs, this currency depreciation caused a 32% cost overrun in real Colombian Peso terms. Currency exposure arises when the inputs required to build a project are denominated in one currency but the outputs in another, or vice versa. The outputs of dams, such as electricity, are denominated in the local currency. Similarly, any increases in tax receipts a dam may enable for the host government also accrue in local currency. A large portion of inputs to build a dam, particularly in developing countries, however, constitute imports paid for in USD. Since the USD liabilities also have to eventually be

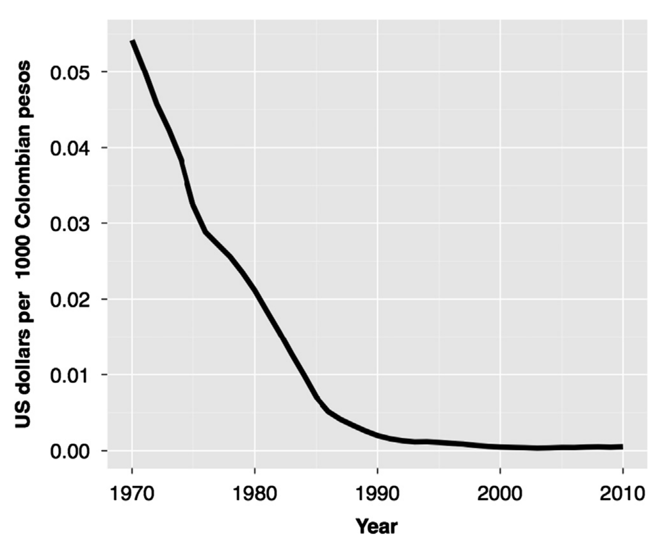

Fig. 6. Depreciation of the Colombian Peso 1970–2010.

[6] Note that the dependent variable in Model 3 is forcast accuracy, the inverse of schedule overrun (i.e. $1/x$ of the schedule overrun or Estimated/Actual schedule). Thus a negative sign on the Log of dam wall length (m) suggests that an increase in wall length decreases the inverse of the schedule overrun. In other words, increase in wall length increases schedule overrun.

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paid in local currency, currency exposure consistently proves to be a fiscal hemorrhage for large projects.

Policy proposition 2. *Energy alternatives that rely on fewer imports or match the currency of liabilities with the currency of future revenue are preferable.*

Although, following convention, our cost analysis excludes the effects of inflation, planners ought not to ignore the risks of "unanticipated inflation" (Pickrell, 1992, p. 164). Episodes of hyperinflation in Argentina, Brazil, Turkey, and Yugoslavia caused staggering nominal cost overruns, e.g. 7-times initial budget for Brazil's Estreito dam (1965–1974), or 110-times initial budget for Yugoslavia's Visegrad dam (1985–1990), which had to be financed with additional debt. Effects of unanticipated inflation magnify the longer it takes to complete a project. For example, during the planning phase of Pakistan's Tarbela dam, it was assumed that inflation would not have a signification impact on the project's costs. The appraisal report wrote: "A general contingency of 7½% has been added in accordance with normal practice for works of this size and duration" (World Bank, 1968). The project, launched in 1968, was meant to start full commercial operation in 1976, but the opening was delayed until 1984. Actual cumulative inflation in Pakistan during 1968–1984 was 380%; the actual cost of the dam in nominal terms nearly four times the initial budget. In the case of Tarbela, unanticipated inflation was "a product of delays in a project's construction timetable and a higher-than expected inflation rate" (Pickrell, 1992, p. 164). For our reference class, 8 out of 10 large dams came in late with an average delay of 2.3 years. Moreover, forecasters expected the annual inflation rate to be 2.5% but it turned out to be 18.9% (averages for the entire sample). Large dams have a high propensity to face unanticipated inflation.

Policy proposition 3. *The best insurance against creeping inflation is to reduce the implementation schedule to as short a horizon as possible. Energy alternatives that can be built sooner and with lower risk of schedule overruns, e.g. through modular design, are preferable.*

Large dams are typically financed from public borrowing. While our calculations exclude debt-servicing, cost overruns increase the stock of debt but also the recurring financing costs that can further escalate if interest rates go up. The optimistic risk assessments of the costs of large dams are consistent with "explosive growth of Third World debt" (Bulow and Rogoff, 1990; Mold, 2012). For example, the actual cost of Tarbela dam, the majority of which was borrowed from external sources, amounted to 23% of the increase in Pakistan's external public debt stock between 1968 and 1984; or 12% for Colombia's Chivor dam (1970–1977) as shown in Table 7.

These case examples reinforce the essential message of our statistical results: bigger projects entail uncontrollable risks, which even when anticipatable cannot be adequately hedged. We do not directly negate the presence of economies of scale or learning curves—i.e. declining average cost per unit as output increases. Instead our argument is that any economies of scale embedded in large scale are being acquired for a disproportionately increased exposure to risk that can cause financial impairment. Companies and countries with insufficient capacity to absorb adverse outcomes of big bets gone awry often face financial ruin.

Policy proposition 4. *Energy alternatives that do not constitute a large proportion of the balance sheet of a country or a company are preferable. Similarly, policymakers, particularly in countries at lower levels of economic development, ought to avoid highly leveraged investments denominated in a mix of currencies.*

Table 7
Total stock of public net external debt (USD current, MM).

Year	Colombia	Pakistan
1968		3252.4
1970	1296.6	
1977	2699.6	
1984		9692.8
Debt increase over the implementation schedule	1403.0	6440.5
Cost of mega-dam over the relevant period (USD current MM)	Chivor dam	Tarbela dam
	168.7	1497.90
Cost of dam as percentage of debt increase	12.0%	23.2%

5. Forecasting the actual costs and schedules using reference class forecasting (RCF)

As discussed in the method section, the third step of the "outside view" or RCF techniques is to compare a specific venture with the reference class distribution, in order to establish the most likely outcome for the specific venture. Thus if systematic errors in the forecasts generated using the "inside view" of previous ventures are found, decision-makers should apply an uplift or downlift to the "inside view" forecast in order to generated a de-biased "outside view" forecast. For example, empirical literature has established that rail projects suffer a cost overrun of 45% on average (Flyvbjerg, 2008; also see Table 8). The 50th percentile cost overrun for rail projects is 40% and the 80th percentile is 57%. Based on these findings, RCF techniques suggest that decision-makers ought to apply a 57% uplift to the initial estimated budget in order to obtain 80% certainty that the final cost of the project would stay within budget (Flyvbjerg, 2008, p. 16). If decision-makers were more risk tolerant then they could apply a 40% uplift to the initial estimated budget but then there will remain a 50% chance that the proposed project might exceed its budget.

In line with the RCF techniques, the third and final step of our investigation on dams was to derive a good predictor of cost and schedule overruns for proposed large dams based on the distributional information of the reference class. This predictor serves to "correct" the systematically biased *ex ante* cost and schedule estimates by adjusting them upwards by the average cost or schedule overrun (see Kahneman and Tversky, 1979b; Flyvbjerg, 2006, 2008).

First, using traditional RCF (Flyvbjerg, 2006, 2008), we traced the empirical distribution of cost and schedule overruns of large dams. Second, we use multilevel Models 1 and 3, described above, for predicting cost and schedule overruns. Models 1 and 3 prove to be practicably parsimonious models for two reasons: First both models are fitted with variables known *ex ante*. Second, both models were successfully fitted with only a few significant variables making it practicable to collect the data needed to make a prediction. For example, Model 1 on cost overruns has only two significant variables—estimate schedule and the long-term inflation rate of the host country. Data on both these variables is readily available for any proposed large dam making it possible to predict the cost overrun before construction begins. We illustrate the usefulness of our predictive models with an example below.

With respect to cost overruns, using traditional RCF (Flyvbjerg, 2006, 2008), we find that if planners are willing to accept a 20% risk of a cost overrun, the uplift required for large dams is +99% (i.e. ~double experts' estimates) as seen in Fig. 7; and +176%

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Table 8
Comparing large dams with other infrastructure asset classes.

Category	Types of projects	Mean cost overrun	Applicable capital expenditure optimism bias uplifts (constant prices)	
			50th percentile	**80th percentile**
Roads	Motorway, trunk roads, local road, bicycle facilities, pedestrian facilities, park and ride, bus lane schemes, guided buses	20%	15%	32%
Rail	Metro, light rail, guided buses on tracks, conventional rail, high speed rail	45%	40%	57%
Fixed links	Bridges, tunnels	34%	23%	55%
Building projects	Stations, terminal buildings		4–51%[a]	
Standard civil engineering			3–44%[a]	
Non-standard civil engineering			6–66%[a]	
Mining projects		14%[b]		
Thermal power plants		6%[c]		
Large dam projects	Large hydropower, large irrigation, flood control, multipurpose dams	**90%**	26%	**99%**
Nuclear power plants		207%[d]		109–281%[d]

[a] Based on Mott MacDonald (2002).
[b] Based on Bertisen and Davis (2008).
[c] Based on Bacon and Besant-Jones (1998, p.321), included for an approximate comparison purposes only, reference class probability distribution not available.
[d] Based on Schlissel and Biewald (2008, p.8) review of the U.S. Congressional Budget Office (CBO) data from Energy Information Administration, Technical Report DOE/EIA-0485 (January 1, 1986).

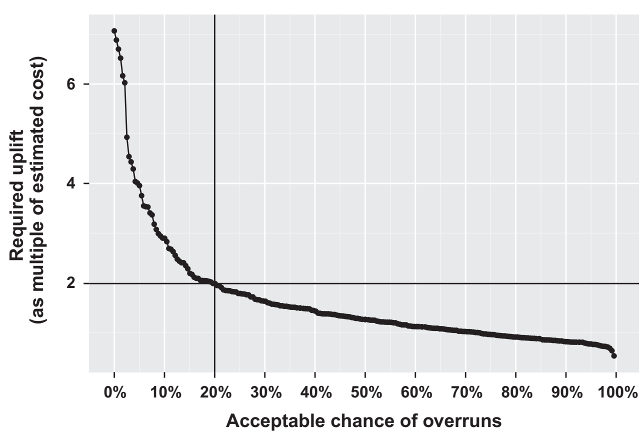

Fig. 7. Required uplift for large dam projects as function of the maximum acceptable level of risk for cost overrun, constant local currency terms ($N=245$).

including unanticipated inflation. If planners are willing to accept a 50–50 chance of a cost overrun, the uplift required is 26% (32% outside North America).

In terms of cost overruns, Fig. 7 also illustrates that large dams are one of the riskiest asset classes for which valid and reliable data are available. Compare, for example, Fig. 7 with reference class forecasts previously conducted for rail, road, tunnel, or bridge projects (Flyvbjerg, 2006, 2008) also summarized in Table 8.

Second, using our multilevel Model 1 we were able to derive predictions for cost overrun (in constant local currency) and schedule overrun respectively.

Experts estimate, for instance, that Pakistan's Diamer-Bhasha dam, whose construction began shortly after the 2010 floods, will cost PKR 894 billion (~USD12.7B in 2008 prices and exchange rates and about 9% of Pakistan's 2008 GDP) (WAPDA, 2011). The dam is forecasted to take 10 years from 2011 and become operational in 2021. Using our first approach, the reference class forecast for cost overruns suggests that planners need to budget PKR 1,788B (USD25.4B) in real terms to obtain 80% certainty of not exceeding the revised budget. Including the effects of unanticipated inflation the required budget is PKR 2,467B (USD35.0B) or about 25% of Pakistan's 2008 GDP. A future sovereign default in Pakistan owing to this one mega-dam is not a remote possibility.

Using our second approach, our multilevel Model 1 predicts that given the 10 year estimated duration and a long-term inflation rate of about 8% the expected (average) cost overrun of a large dam in Pakistan will be 44% (PKR 1,288B or USD 18.3B). Combining the two methods, a conservative estimate for the cost overrun on the Diamer-Bhasha dam is 44% at which point there remains a 4 in 10 chance of the revised budget being exceeded. Note, however, that if a dam of dimensions similar to Diamer-Bhasha were being built in the US, Model 1 predicts that it would only suffer a cost overrun of 16%, which the much larger US economy could absorb without any lasting damage.

We applied a similar two-pronged forecast of schedule slippage. Using our first approach, the reference class forecast for schedule slippage suggests that planners for large dams around the world need to allow for a 66% schedule overrun to achieve 80% certainty that the project will be completed within the revised implementation schedule. Since Diamer-Bhasha is expected to take 10 years to build (2011–2021), planners need to adjust their schedule estimate upwards to nearly 17 years (i.e. an actual opening date of 2028). Using our second approach, our multilevel Model 3 predicts that given that the dam's final decision to build was made in Pakistan by a democratically elected government, when the per capita income was USD 497 in 2000 constant dollars, a dam wall length of 998 m, and an installed capacity of 4500 MW, the expected outcome is a 60% schedule overrun. Thus, using either approach, Diamer-Bhasha can be expected to only open in 2027 when there remains a 20% risk of further delay. Pakistan is facing an energy crisis today (Kessides, 2011). A dam that brings electricity is 2027 will be a little late in coming.

Note, however, that if a dam of dimensions similar to Diamer-Bhasha were being built in the US (with its high per capita income of approximately USD 38,000), Model 3 predicts that it would face a schedule slippage of a mere 0.05%. Recall that per capita income is a useful proxy for the economic support that a country can provide for the construction of complex facilities. This suggests that rich and not developing countries best attempt very large energy projects, such as large dams. Even so, richer countries should also consider alternatives and should adopt the risk management measures of the outside view illustrated here to choose prudently among energy alternatives.

Using their "inside" cost estimates, the net present benefits to cost ratio of the dam according to experts is 1.43 (WAPDA, 2011). Even assuming experts' calculations about potential benefits are accurate, although this is a doubtful assumption, the de-biased cost forecasts require an uplift of 44–99% in constant prices suggest that the benefits to cost ratio will be below one. The Diamer-Bhasha dam is a non-starter in Pakistan. This is without even discussing potential effects of inflation and interest rates, potential social and environmental costs, and opportunity cost Pakistan could earn by committing such vast amount of capital to more prudent investments.

Our reference class forecasting techniques suggests that other proposed large dam projects such as Belo Monte, Myitsone, or the Gilgel Gibe III among many others in early planning stages are likely to face large cost and schedule overruns seriously undermining their economic viability. Large dams also exert an opportunity cost by consuming scarce resources that could be deployed to better uses, sinking vast amounts of land that could have yielded cash flows and jobs from agricultural, timber, or mineral resources. Risks related to dam safety, environment, and society further undermine viability of large dams. Decision-makers are advised to carefully stress test their proposed projects using the risk management techniques of the outside view proposed here before committing resources to them.

The outside view techniques applied to large dams above have broader application in energy policy by helping public agencies (e.g. national planning and finance ministries, power and water authorities), private entrepreneurs and investors a framework to improve upfront selection among alternatives. The problems of cost and schedule overrun are not unique to large hydropower dams. Preliminary research suggests that other large-scale power projects using nuclear, thermal, or wind production technologies face similar issues. Our research of large hydropower projects reveals that there is a serious dearth of valid and reliable data on the risk profiles of actually completed energy projects across the board. Much of the data in existing literature are drawn from surveys and interviews of dubious validity. At times, interest groups, seeking to promote a particular kind of scale or technology, also report distorted data. There is thus an urgent need to empirically document, in a comprehensive global database, the risk profiles of energy infrastructure assets of large, medium, and small scales across production technologies. For example, comparing the likely actual cost, schedule, and production volumes of a large hydropower dam project versus an on-site combined heat and power generator.

We propose that prior to making any energy investment, policy makers consult a valid and reliable "outside view" or "reference class forecast" (RCF) that can predict the outcome of a planned investment of a particular scale or production technology based on actual outcomes in a reference class of similar, previously completed, cases. Rigorously applying reference class forecasting to energy investments at various scales and production technologies will yield the following contributions:

- Create transparency on risk profiles of various energy alternatives, from not only the perspective of financial cost and benefit but also environmental and social impact—hard evidence is a counter-point to experts' and promoters' oft-biased inside view.

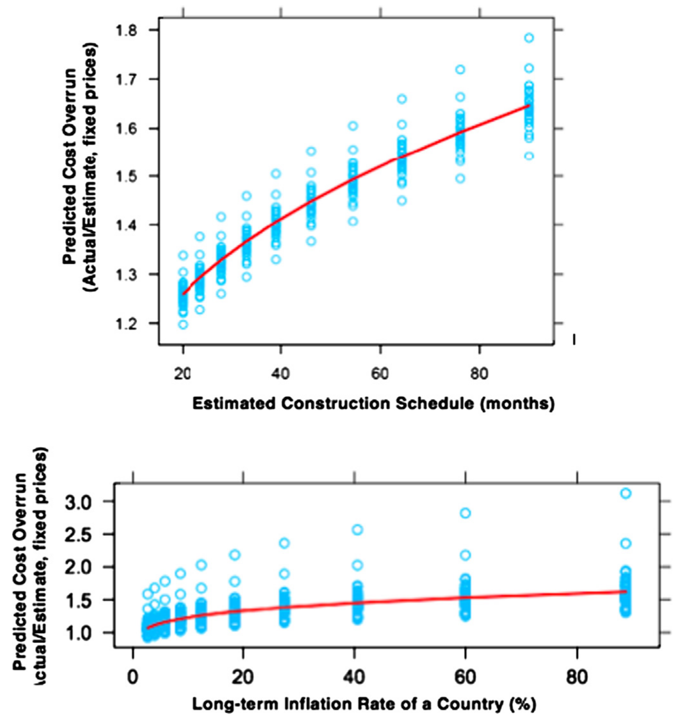

Fig. A1. .

- Improve resource allocation through outside-in view to estimate costs, benefits, time, and broader impacts such as greenhouse gas emissions incurred in building a project and emission created or averted once a project becomes operational.

A comprehensive global dataset that can create such transparency on risk profiles of energy alternatives does not yet exist. We have sought to bridge this precise gap by providing impartial evidence on large hydropower dam projects. As a venue for further research we hope valid and reliable data on the actual cost, schedules, benefits, and impacts of other production technologies will become available to enable comparative analysis with novel implications for theory and practice.

Appendix A. Visual representation of Model 1 (reported in Table 3)

See Fig. A1.

References

Ansar, A., Flyvbjerg, B., Budzier, A., 2013. Do "Hard States" Make Better Decisions? Incentives versus Biases. Working paper. Saïd Business School, University of Oxford, 42 pp.

Ansar, A., Flyvbjerg, B., Budzier, A., 2012. Big is Fragile: The Effects of Temporal Uncertainty and Sunk Costs on the Outcomes of Big Ventures. Working paper. Saïd Business School, University of Oxford, 58 pp.

Bacon, R.W., Besant-Jones, J.E., 1998. Estimating construction costs and schedules: experience with power generation projects in developing countries. Energy Policy 26, 317–333.

Bakker, K., 1999. The politics of hydropower: developing the Mekong. Political Geogr. 18, 209–232.

Bertisen, Jasper, Davis, Graham A., 2008. Bias and Error in Mine Project Capital Cost Estimation. The Eng. Economist 53 (2), 118–139.

Billington, D.P., Jackson, D.C., 2006. Big Dams of the New Deal Era: A Confluence of Engineering and Politics. University of Oklahoma Press.

Buehler, R., Griffin, D., Ross, M., 1994. Exploring the" planning fallacy": Why people underestimate their task completion times. J. Pers. Soc. Psychol. 67, 366.

Bulow, J., Rogoff, K., 1990. Cleaning up third world debt without getting taken to the cleaners. J. Econ. Perspect. 4, 31–42.

Copeland, T., Tufano, P., 2004. A real-world way to manage real options. Harv. Bus. Rev. 82, 90–99.

Please cite this article as: Ansar, A., et al., Should we build more large dams? The actual costs of hydropower megaproject development. Energy Policy (2014), http://dx.doi.org/10.1016/j.enpol.2013.10.069

Dawes, R.M., Faust, D., Meehl, P.E., 1989. Clinical versus actuarial judgment. Science 243, 1668–1674.
Duflo, E., Pande, R., 2007. Dams. Q. J. Econ. 122, 601–646.
Federal Transit Administration (FTA), 2003. Predicted and Actual Impacts of New Starts Projects: Capital Cost, Operating Cost and Ridership Data. U.S. Department of Transportation, Washington, DC.
Flyvbjerg, B., 2003. Delusions of success: comment on Dan Lovallo and Daniel Kahneman. Harv. Bus. Rev. 81, 121–122.
Flyvbjerg, B., 2006. From Nobel Prize to project management: getting risks right. Project Manage. J. 37, 5.
Flyvbjerg, B., 2008. Curbing optimism bias and strategic misrepresentation in planning: reference class forecasting in practice. Eur. Plann. Stud. 16, 3–21.
Flyvbjerg, B., 2009. Survival of the unfittest: why the worst infrastructure gets built—and what we can do about it. Oxford Rev. Econ. Policy 25, 344.
Flyvbjerg, B., Bruzelius, N., Rothengatter, W., 2003. Megaprojects and Risk: An Anatomy of Ambition. Cambridge Univ Press, Cambridge.
Flyvbjerg, B., Budzier, A., 2011. Why your IT project may be riskier than you think. Harv. Bus. Rev. 89, 23–25.
Flyvbjerg, B., COWI, 2004. Procedures for dealing with optimism bias in transport planning: Guidance document 2006–09 [WWW Document]. URL goo.gl/lLiNj.
Flyvbjerg, B., Holm, M., Buhl, S., 2005. How (in) accurate are demand forecasts in public works projects. J. Am. Plann. Assoc. 71, 131–146.
Flyvbjerg, B., Holm, M.S., Buhl, S., 2002. Underestimating costs in public works projects: error or lie? J. Am. Plann. Assoc. 68, 279–295.
Flyvbjerg, B., Garbuio, M., Lovallo, D., 2009. Delusion and deception in large infrastructure projects. Calif. Manage. Rev., 51.
Gelman, A., Hill, J., 2007. Data Analysis Using Regression and Multilevel/Hierarchical Models. Cambridge University Press, Cambridge.
Gilovich, T., Griffin, D., Kahneman, D., 2002. Heuristics and Biases: The Psychology of Intuitive Judgment. Cambridge University Press.
Goel, R.K., Singh, B., Zhao, J., 2012. Underground Infrastructures: Planning, Design, and Construction. Butterworth-Heinemann, Waltham, MA.
Goldstein, H., 2010. Multilevel Statistical Models, 4th ed. Wiley.
Hoek, E., Palmieri, A., 1998. Geotechnical risks on large civil engineering projects. In: Proceedings of the 8th Congres IAEG, pp. 79–88.
Hufschmidt, M.M., Gerin, J., 1970. Systematic errors in cost estimates for public investment projects. In: Margolis, J. (Ed.), The Analysis of Public Output. Columbia University Press, New York.
ICOLD, 2010. International. Commission on Large Dams [WWW Document]. URL 〈http://www.icold-cigb.org/〉.
IEA, 2011. Policies and Scenarios [WWW Document]. URL 〈http://www.iea.org/publications/scenariosandprojections/〉.
Kahneman, D., 1994. New challenges to the rationality assumption. J. Inst. Theor. Econ. 150, 18–36.
Kahneman, D., 2011. Thinking, Fast and Slow, 1st ed. Farrar, Straus and Giroux, New York.
Kahneman, D., Lovallo, D., 1993. Timid choices and bold forecasts: a cognitive perspective on risk taking. Manage. Sci., 17–31.
Kahneman, D., Tversky, A., 1979a. Prospect theory: an analysis of decision under risk. Econometrica, 263–291.
Kahneman, D., Tversky, A., 1979b. Intuitive prediction: biases and corrective procedures. In: Makridakis, S., Wheelwright, S.C. (Eds.), Studies in the Management Sciences: Forecasting. North Holland, Amsterdam.
Kessides, I.N., 2011. Chaos in Power: Pakistan's Electricity Crisis.
Kreft, I.G.G., Leeuw, J.d.e., 1998. Introducing Multilevel Modeling. Sage Publications Ltd.
Laird, N.M., Ware, J.H., 1982. Random-effects models for longitudinal data. Biometrics, 963–974.
Lovallo, D., Kahneman, D., 2003. Delusions of success. Harv. Bus. Rev. 81, 56–63.
Luehrman, T.A., 1998. Strategy as a portfolio of real options. Harv. Bus. Rev. 76, 89–101.
McCully, P., 2001. Silenced Rivers: the Ecology and Politics of Large Dams. Zed Books, London.
Merewitz, L., 1973. How do Urban Rapid Transit Projects Compare in Cost Estimating Experience. Institute of Urban & Regional Development, University of California.
Merrow, E.W., McDonnell, L., Argüden, R.Y., Corporation, R., 1988. Understanding the Outcomes of Megaprojects: A Quantitative Analysis of Very Large Civilian Projects. Rand Corp.
Mold, A., 2012. Will it all end in tears? Infrastructure spending and African development in historical perspective. J. Int. Dev. 24, 237–254.
Mott MacDonald, 2002. Review of Large Public Procurement in the UK, Study for HM Treasury. HM Treasury, London. www.hm-treasury.gov.uk/d/7(3).pdf.
Nilsson, C., Reidy, C.A., Dynesius, M., Revenga, C., 2005. Fragmentation and flow regulation of the world's large river systems. Science 308, 405–408.
Pickrell, D.H., 1989. Urban Rail Transit Projects: Forecast Versus Actual Ridership and Costs (No. PB90148693), Office of Grants Management, Urban Mass Transportation Administration. Transportation System Center, U.S. Department of Transportation, Cambridge, MA.
Pickrell, D.H., 1992. A desire named streetcar: fantasy and fact in rail transit planning. American Planning Association. J. Am. Plann. Assoc. 58, 158–176.
Rasbash, J., Browne, W., Goldstein, H., Yang, M., Plewis, I., Healy, M., Woodhouse, G., Draper, D., Langford, I., Lewis, T., 2009. A User's Guide to MLwiN. University of London, Institute of Education, Centre for Multilevel Modelling.
Recchia, A., 2010. R-squared measures for two-level hierarchical linear models using SAS. J. Stat. Softw., 32.
Richter, B.D.a., Postel, S.b., Revenga, C.c., Scudder, T.d., Lehner, B.e., Churchill, A.f., Chow, M., 2010. Lost in development's shadow: the downstream human consequences of dams. Water Alternatives 3, 14–42.
Salazar, J.G., 2000. Damming the child of the ocean: the Three Gorges project. J. Environ. Dev. 9, 160–174.
Scudder, T., 2005. The Future of Large Dams: Dealing with Social, Environmental, Institutional and Political Costs. Earthscan, London.
Schlissel, D., Biewald, B., 2008. Nuclear Power Plant Construction Costs. Synapse Energy Economics, Inc.
Singh, S., 2002. Taming the Waters: The Political Economy of Large Dams in India. Oxford University Press, New Delhi.
Sovacool, B.K., Bulan, L.C., 2011. Behind an ambitious megaproject in Asia: the history and implications of the Bakun hydroelectric dam in Borneo. Energy Policy 39, 4842–4859.
Sovacool, B.K., Cooper, C., 2013. The Governance of Energy Megaprojects: Politics, Hubris and Energy Security. Edward Elgar, Cheltenham, UK.
Stone, R., 2011. Hydropower. The legacy of the Three Gorges Dam. Science 333, 817.
Taleb, N.N., 2010. The Black Swan: The Impact of the Highly Improbable with a new section: “On Robustness and Fragility”, 2nd ed. Random House Trade Paperbacks.
Tversky, A., Kahneman, D., 1974. Judgment under uncertainty: heuristics and biases. Science 185, 1124–1131.
Wachs, M., 1989. When planners lie with numbers. J. Am. Planning Assoc. 55, 476–479.
WAPDA, 2011. Diamer-Basha Dam Project Status as on 20 June 2011.
World Bank, 1968. Report and Recommendation of the President to the Executive Directors on a Proposed Loan for the Tarbela Project and on Proposed Extension of Closing Dates of Loan 266-PAK (Indus Basin Project), Pakistan (No. P-616). The World Bank, Washington, DC.
World Bank, 1970. Staff Appraisal Report (pu-31a) of the Chivor Hydroelectric Project, Interconexion Electrico S.A., Colombia (No. PU-31a). The World Bank, Washington, DC.
World Bank, 1973. Staff Appraisal Report (150a-BR) of the Itumbiara Hydroelectric Power Project, FURNAS, Brazil (No. 150a-BR). The World Bank, Washington, DC.
World Bank, 1996. Estimating Construction Costs and Schedules: Experience with Power Generation Projects in Developing Countries (No. WTP325). The World Bank, Washington, DC.
World Commission on Dams (WCD), 2000. Cross-Check Survey: Final Report. Cape Town, South Africa.
Ziv, G., Baran, E., Nam, S., Rodríguez-Iturbe, I., Levin, S.A., 2012. Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin. Proc. Natl Acad. Sci. 109, 5609.

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Anne Salmond, Gary Brierley and Dan Hikuroa

Let the Rivers Speak

thinking about waterways in Aotearoa New Zealand

Abstract

This article explores deep underlying assumptions about relationships between people and the planet, and how these translate into very different ways of relating to waterways in Aotearoa New Zealand. In te ao Māori – ancestral Māori ways of living – rivers and lakes are the tears of Ranginui, the sky father, mourning his separation from Papatūānuku, the earth mother, and people are their descendants, joined in complex whakapapa that link all forms of life together. In modern ways of thinking, on the other hand, ideas such as private property, resource management and ecosystem services can be traced back to the Genesis story of God's gift of 'dominion' to Adam and Eve over fish, birds, plants and the earth itself, including waterways, in which all other life forms are created for human purposes.

In successive Waitangi Tribunal claims, iwi have disputed these assumptions in relation to fisheries, tribal lands and rivers, and, in world-leading legislation, the Whanganui River has been declared a legal person with its own rights. In this article, the authors discuss different ways in which the rights of rivers *as rivers* might be understood in scientific terms, investigating the 'geomorphic rights' of the Whanganui River, for instance, and how rivers as living communities of land, water, plants, animals and people might be understood through 'river ethnography', an approach that aligns a wide range of natural and social sciences with mātauranga taiao – ancestral knowledge of other living systems. They also consider how current policy discussions might be informed by such framings, so that river communities across Aotearoa New Zealand may be restored to a state of ora – life, health, abundance and prosperity.

Keywords water rights, whakapapa, Waitangi Tribunal, awa tupua, mātauranga taiao, commodification, reciprocity, Te Awa Tupua Act, the commons

In Aotearoa New Zealand, since first European settlement in the early 19th century differing assumptions about the relationships among land, sea and ancestors have collided and been contested.

Before the first Europeans arrived, accounts taught in the whare wānanga or ancestral schools of learning traced the origins of the cosmos to a primal surge of energy:

Nā te kune te pupuke
Nā te pupuke te hihiri
Nā te hihiri te mahara
Nā te mahara te hinengaro
Nā te hinengaro te manako
Ka hua te wānanga
Ka noho i a rikoriko
Ka puta ki waho ko te pō Nā te kore i ai
Te kore te whiwhia
Te kore te rawea
Ko hau tupu, ko hau ora Ka noho i te atea
Ka puta ki waho ko te rangi e tū nei
Te ata rapa, te ata ka mahina
Ka mahina te ata i hikurangi!

From the source of growth the rising
From rising the thought
From rising thought the memory
From memory the mind-heart
From the mind-heart, desire
Knowledge becomes conscious
It dwells in dim light
And Pō (darkness) emerges ...
From nothingness came the first cause
Unpossessed nothingness
Unbound nothingness
The hau of growth, the hau of life
Stays in clear space
And the sky emerges that stands here.
The early dawn, the early day, the mid-day
The blaze of day from the sky!
(Te Kohuora of Rongoroa, in Taylor, 1855)

From that first surge of energy, thought, memory, the mind-heart, desire and knowledge emerged. As knowledge became conscious, the world took shape in te kore, nothingness, and te pō, darkness, through

> ... the introduction of ideas of land as 'property' owned by individuals or corporations ... cut through the intricate, entangled strands of whakapapa (ancestral connection) that wove people, land, waterways and the sea together.

aeons of ancestral space-time. When the winds of life and growth began to blow, the sky and the earth emerged. At first Ranginui the sky father and Papatūānuku the earth mother were one being, locked together, and as their children were born they lay cramped between them, living in darkness. Frustrated and constricted, they decided to separate their parents, and one after another they tried until at last Tāne, the ancestor of forests, lay on his back and pushed them apart. As Rangi wept for his wife, Papatūānuku sent up mists to greet him, and Rangi's tears became rivers and lakes, bringing life to the land (Te Rangikaheke, 1849).

In this cosmological account, water is a source of ora (well-being and abundance). The water cycle is placed at the heart of the relationship between sky father and earth mother,[1] who eternally exchange mist and rain, giving life to their children – the ancestors of forests (Tāne-mahuta), wild food plants (Haumia-tiketike), cultivated food plants (Rongo-mā-tāne), the ocean and waterways (Tangaroa), winds (Tāwhiri-matea) and people (Tū-matauenga). When Tāwhiri-matea, enraged by his brothers' violence against their parents, attacks his brothers, only Tū-matauenga stands strong. Because of Tū's courage his descendants, human beings, inherit the mana (ancestral power) to harvest the offspring of his brothers – birds and forest foods, wild and cultivated plants, fish and other creatures. Because they are kinfolk, though, they must ask permission from Tū's brothers in the seasonal rituals of fishing, birding, agriculture and other forms of harvest. The aim is to keep these exchanges in balance, so that the life force of birds, fish, plants and people remains strong and healthy (mauri ora). If particular species became depleted (mauri noho), those who have the right to conduct such rituals placed a rāhui or ritual restriction on them until their life force had recovered.

In this way of living, kin groups moved across land, waterways and the coast in seasonal cycles, harvesting particular foods as they became abundant. Rights to take particular species were passed down genealogical lines and through relationships of alliance and friendship, tangling across the landscape in overlapping patterns of seasonal residence and harvest. Only by staying close to land and sea and lighting one's fires (ahi kā) could these relationships (which involved both rights and responsibilities to care for other life forms) be kept 'warm', instead of lapsing and going 'cold' (ahi mātaotao).

Since the first Europeans settled in Aotearoa, these kin-based ways of living have been radically disrupted. Most fundamentally, the introduction of ideas of land as 'property' owned by individuals or corporations, fragmented into measured, bounded areas by survey and

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mapping, in which almost all rights can be exchanged with strangers for a price, cut through the intricate, entangled strands of whakapapa (ancestral connection) that wove people, land, waterways and the sea together.

This way of understanding was first enacted by the first explorers and surveyors who were sent to Aotearoa to grid the land by latitude and longitude, quantify it and cut it into 'blocks', irrespective of mountains, rivers and valleys; abstract it and empty it of life and people. The notion of land as a commodity was authorised by the Old Land Claims Commission following the signing of the Treaty of Waitangi between Māori kin group leaders and the British Crown in 1840; enforced by acts of confiscation following the New Zealand Wars in the early 1860s and by the establishment in 1865 and operation of the Native Land Court; and enacted by the incremental assumption of the rights of the nation state to 'manage' all 'resources' in Aotearoa, most recently in the Resource Management Act 1991. These ideas about the rights of human beings, in particular 'civilised' people, to control land, waterways and the ocean were also underpinned by ancient cosmological framings, including the origin story recounted in the Book of Genesis, in which God creates Adam and Eve in his own image, telling them to be 'fruitful, and multiply, and replenish the earth, and subdue it: and have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moveth upon the earth' (King James Bible, Genesis 1:28).

If one examines the emergence of modern ideas about private property, their cosmological underpinnings are obvious. In *Two Treatises of Government,* for instance, John Locke devotes the first treatise to arguing about Adam's rights over land, sea and people, based on this biblical passage. While he does not dispute that God granted Adam and Eve dominion over fish, plants and animals (a unilateral, 'command and control' relationship), Locke contends that this did not extend to other human beings. Dominion over land and sea could not thus be claimed by absolute monarchs as Adam's inheritors, but rests in humankind in general. In Locke's framing, the origin of private property can be traced back to the act of an individual investing his own labour in improving and cultivating the land and 'enclosing it from the common' (Locke, 1821).[2]

Likewise in his *Commentaries on the Laws of England,* William Blackstone, the influential 18th-century British jurist, cites the Genesis story:

> In the beginning of the world, we are informed by holy writ, the all-bountiful Creator gave to man 'dominion over all the earth, and over the fish of the sea, and over the fowl of the air, and over every living thing that moveth upon the earth.' This is the only true and solid foundation of man's dominion over external things. (Blackstone, 1770, book 2, p.18)

At the same time, Blackstone expands on Locke's account of how private property and 'civil society' developed:

> It was clear that the earth would not produce her fruits in sufficient quantities without the assistance of tillage; but who would be at the pains of tilling it, if another might watch an opportunity to seize upon and enjoy the product of his industry, art, and labour?
>
> Had not therefore a separate property in lands as well as movables been vested in some individuals, the world must have continued a forest, and men have been mere animals of prey, which, according to some philosophers, is the genuine state of nature …
>
> Necessity begat property; and, in order to insure that property, recourse was had to civil society, which brought along with it a long train of inseparable concomitants, – states, government, laws, punishments, and the public exercise of religious duties.

In the Treaty of Waitangi Act 1975, the Waitangi Tribunal was specifically prohibited from recommending the return or purchase of private land, or from inquiring into historical breaches of the Treaty relating to commercial fisheries …

Ideas of ancestry are still significant here, tracing the origins of human 'dominion' over land, sea and other species back to God's gift to Adam and Eve, and 'sovereignty' to those who share God's attributes of judgement and wisdom (ibid., introduction, p.48).[3] Land, sea and other life forms are not seen as kinfolk, however. Rather, these are understood as the passive recipients of human labour, which 'improves' and encloses the land, converting it into private property which can be traded on a market.

At the same time, in Blackstone's formulation, waterways largely escaped this framing. Like light and air, water was in a 'state of nature' and part of 'the commons' (ibid., book 2, p.13):[4] 'For water is a movable, wandering thing, and must of necessity continue common by the law of nature; so that I can only have a temporary, transient, usufructuary, property therein' (ibid., p.18).[5] Nevetheless, according to Blackstone, if a man fouls a waterway shared with his neighbour, or diverts it so that this neighbour loses the use of that water, this is an injury to be redressed under the law. Interestingly, this restraint upon the use of fresh water was not given legal force when British law was introduced to Aotearoa New Zealand. Rather, the freedom of a person to use their own land (understood as private property) overrode Blackstone's framing of their responsibility to protect the rights of their neighbours to the use of fresh, free-flowing streams and rivers.[6]

This powerful emphasis on private property was also evident in the processes established to give Māori kin groups redress against the Crown for breaches of the Treaty of Waitangi. In the Treaty of Waitangi Act 1975, the Waitangi Tribunal was specifically prohibited from recommending the return or purchase of private land, or from inquiring into historical breaches of the Treaty relating to commercial fisheries (s6(4A) and (7)). Only Crown land, forests or other properties, as well as taxpayer funding, could be recommended as remedies for these breaches.

Nor was the Tribunal given powers to inquire into historical breaches of the Treaty until 1985, hot on the heels of the election of a Labour government. At the same time, however, the government embraced neo-liberal economics, including an extensive programme of privatising state properties, including forests, fisheries and lands. Almost immediately there was a series of clashes with Māori. In June 1985, for instance, Matiu Rata, then the minister of Māori affairs, wrote a letter to the Tribunal claiming that the Treaty rights of his Muriwhenua people had been breached by the Crown's presumption that their rights to their ancestral fisheries had been extinguished. A quota management system for Aotearoa New Zealand fisheries had been proposed which assumed that fish stocks in New Zealand's territorial waters were 'owned' by the Crown, quantifying the stocks of particular species and turning them into quotas to be traded on the market. In 1987 the Muriwhenua kin groups lodged a claim with the Waitangi Tribunal that succeeded in establishing that their rights to their ancestral fisheries, guaranteed under the Treaty, had never been legally extinguished (Waitangi Tribunal, 1988). As a result, a significant proportion of quotas in the new quota management system was awarded to Māori kin groups around the country.

While this Waitangi claim was fought on the grounds that the Crown's claim to 'own' New Zealand fisheries was unfounded, the remedy was still framed in terms of property rights, including both cash and quotas. These gave only partial

In successive Treaty claims against the Crown, iwi challenges against modern framings of relations among land, waterways and people have become increasingly fundamental.

compensation and did little to restore fish stocks to a state of ora. In the case of rivers, in keeping with Blackstone's dictum that water is part of the commons, however, the Crown did not claim to 'own' these waterways, but to govern them on behalf of the people of New Zealand. In the case of the Waikato River, the longest river in Aotearoa, when the government proposed to build a power station at Huntly adjacent to the Māori Queen's marae in the early 1970s (Whittle, 2013), this assumption was also contested. As Robert Mahuta, the Māori Queen's brother, declared in 1975, 'Noo taatou te awa. Noo te awa taatou. E kore e taea te wehe te iwi o Waikato me te awa. He taonga tuku iho naa ngaa tuupuna. E whakapono ana maatou ko taa maatou, he tiaki i taua taonga moo ngaa uri whakatupu' (The river belongs to us. We belong to the river. The Waikato people and the river cannot be divided. It is a treasure handed down from the ancestors. We believe it is our role to take care of this treasure for future generations) (Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010, preamble).

This idea of the river as a treasure, the lifeblood of the earth mother from whom the ariki (high chiefs) of Waikato-Tainui descend, was powerfully expressed in a waiata composed by Tāwhiao, the second Māori King, farewelling his ancestral lands, confiscated (raupatu) by the Crown after the wars of the 1860s:

> I look down on the valley of Waikato
> As though to hold it in the hollow of my hand …
> See how it bursts through
> The full bosoms of Maungatautari and Mangakawa,
> Hills of my inheritance:
> The river of life, each curve
> More beautiful than the last,
> Across the smooth belly of Kirikiriroa,
> Its gardens bursting with the fullness of good things,
> Towards the meeting place at Ngāruawahia
> There on the fertile mound I would rest my head
> And look through the thighs of Taupiri.
> There at the place of all creation
> Let the King come forth.
> (quoted in Muru-Lanning, 2010, p.45)

In the event, when the Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act was passed in 2010 as partial reparation for the confiscations, it was agreed that authority over the river should be shared between Waikato-Tainui kin groups and the Crown. In the preamble to the act, the ancestral relationship between these kin groups and the river was legally recognised: 'To Waikato-Tainui, the Waikato River is a tupuna (ancestor) which has mana (prestige) and in turn represents the mana and mauri (life force) of the tribe. Respect for te mana o te awa (the spiritual authority, protective power and prestige of the Waikato River) is at the heart of the relationship between the tribe and their ancestral river.' The history of the disruption of this relationship was also recorded in the act's preamble, from the decision of Governor Grey to send an iron steamer down the river in 1862 to invade the Waikato and the confiscations that followed, to the Crown's assumption of jurisdiction over the river and the harm done to the Waikato by 'farming, coal mining, power generation schemes, the discharge of waste, and domestic and industrial abstraction'.

In this case, the remedies included a recognition of 'te mana o te awa' (the mana of the river), along with an agreement that the Crown would work with the Waikato-Tainui kin groups to restore their 'mana whakahaere' (governance, authority, jurisdiction) over the Waikato River and bring these groups together to protect te mana o te awa.

In successive Treaty claims against the Crown, iwi challenges against modern framings of relations among land, waterways and people have become increasingly fundamental. In the case of the Te Urewera Act 2014, for instance, the mana of Tūhoe's ancestral lands in the former Te Urewera National Park, including waterways, was given a higher priority than the mana of people. In this act, Te Urewera is declared to be a legal entity, inalienable and independent. As Tamati Kruger, a leader of the Tūhoe people, has declared, 'The Urewera owns itself'. This understanding is elaborated in the background section of the act:

> Te Urewera is ancient and enduring, a fortress of nature, alive with history; its scenery is abundant with mystery, adventure, and remote beauty. Te Urewera is a place of spiritual value, with its own mana and mauri. Te Urewera has an identity in and of itself, inspiring people to commit to its care …
>
> Te Urewera expresses and gives meaning to Tūhoe culture, language, customs, and identity. There Tūhoe hold mana by ahikāroa [long having their fires alight on the land]; they are tangata whenua [land people] and kaitiaki [guardians] of Te Urewera. (Te Urewera Act 2014, s3)

In their guardianship of Te Urewera, Tūhoe kin groups have rejected ideas of human dominion over land and waterways as reflected in the doctrines of sovereignty, property rights and possessive individualism. Historically, although Tūhoe were promised considerable autonomy by the Crown, these promises were broken. Their territory is relatively remote, mountainous and forested, and a heartland for the preservation of tikanga (ancestral customs) and te reo, and their expressed ambition is to govern their own affairs in their own way on their own lands. Decisions about the future and uses of Te Urewera are made by consensus at hui on marae, rather than by voting, for instance.

In their guardianship of Te Urewera, Tūhoe kin groups have rejected ideas of human dominion over land and waterways as reflected in the doctrines of sovereignty, property rights and possessive individualism.

This same kind of thinking is also evident in the Te Awa Tupua (Whanganui River Claims Settlement) Act 2017. Like Waikato-Tainui, the Whanganui iwi have kept their 'fires alight' by maintaining marae along the length of their ancestral river, the third longest in New Zealand. Like the Waikato, too, there is extensive non-Māori settlement on the river, with the city of Whanganui around the river mouth. In their Tribunal hearings, Whanganui kin groups have demonstrated their ongoing relationship with the Whanganui River, arguing that their life and well-being and that of the river are inextricably entangled. As a Whanganui elder, Turama Thomas Hawira, lamented:

> It was with huge sadness that we observed dead tuna [eels] and trout along the banks of our awa tupua [ancestral river]. The only thing that is in a state of growth is the algae and slime. Our river is stagnant and dying. The great river flows from the gathering of mountains to the sea. I am the river, the river is me. If I am the river and the river is me – then emphatically, I am dying.[7]

In their Treaty settlement, the Whanganui kin groups insisted on honouring the rights and life of the river. In the event, their relationship with the river was recognised in the act, which declared that 'Te Awa Tupua [literally, a river from the ancestral realm] is a legal person and has all the rights, powers, duties, and liabilities of a legal person' (s14(1)). In this act, two individuals, one appointed by the Crown and one by the Whanganui iwi, were established as Te Pou Tupua, the human face of Te Awa Tupua, authorised to act in the name of the river to protect its health and well-being, using funding dedicated for this purpose.

Like the Te Urewera Act, this act was world-leading in acknowledging the legal rights and responsibilities of a territory in the first instance, and a river in the second, in relation to those of people. The framing of it is still anthropocentric, however, since it defines the river as a legal person. In effect, this diminishes the mana of the Whanganui, since, in ancestral understandings, waterways emerge from the exchange of rain and mist between sky and earth, and are more ancient and powerful than people. At the same time, setting up Te Pou Tupua as its 'human face' limits the river's agency, its independent power to act, by providing the river, like children or those who are incapacitated, with guardians who speak and act in its name. Likewise, framing the mana of the river as 'rights' fails to respect the principle of reciprocity (utu), which aims to generate ora through balanced exchange. When this balance fails, this leads to a state of mate (illness, failure, death), which is arguably what has happened to waterways across Aotearoa New Zealand.

This limited legal framing has inspired attempts in New Zealand to explore what it might mean for a river (or a territory) to have its own life, in its own terms, with its own rights to health and well-being. In the case of the Whanganui River, for instance, a recent article arising from the Te Awaroa: Voice of the River project (Salmond, Tadaki and Gregory, 2014) has explored the rights of the river by juxtaposing 'geomorphic understandings of a river's agency' with 'ancestral Māori relations to the river based upon mutual co-dependence (reciprocity)'. The aim of this exercise is to bring together ancestral insights with the findings of contemporary geomorphological science to assist in restoring the health, well-being and life force of the Whanganui river, along with other waterways across the country.

In this article, the authors give a bleak view of the impact of utilitarian and 'command and control' framings of rivers as introduced to Aotearoa through colonial processes:

> Notions of progress and improvement brought about the wholesale clearance of native vegetation, the drainage of wetlands, and the creation of large grassland areas for pastoral farming. Rivers were treated as drains or sewers, conduits for the disposal of waste with a seemingly limitless capacity for self-cleansing and self-renewal.
>
> Impacts on rivers from mining, forestry, sawmilling, pastoral farming, flax milling and the operation of tanneries, dairy factories, and meat works were accentuated in the 20th century by the implementation of a 'command and control' management ethos.
>
> Major hydroelectricity schemes, irrigation projects, and artificial stop banks (levees) transformed virtually all alluvial rivers in the country. Civil engineers were tasked with harnessing the powers of nature for human benefit, straightening, diverting, and culverting rivers to separate them from people. Catastrophic biodiversity losses ensued. Channels and harbours filled with sediment, pollutants and contaminants, and aquifers and waterways were depleted beyond sustainable limits. (Brierley et al., 2018, p.2)

Drawing on ancestral Māori framings, the [Te Awaroa] team focused on hearing 'the voice of the river', the behaviour and health of the river over time, as reflected in 'river stories'.

Extractive approaches, one-way relationships and radical failures of reciprocity have resulted in fundamental ecological damage to many waterways across New Zealand. After exploring Māori ideas about relations between rivers and people, seven geomorphic 'rights' are described that a river *as a river* might enjoy in its quest for ora: a right to flowing water; a right to transport sediment; a right to be diverse; a right to adjust; a right to evolve; a right to operate at the catchment scale; and a right to be healthy (ibid., p.4), and these rights are applied to the Whanganui River in a case study.

In the 1960s, as the authors note, the headwaters of the Whanganui River were diverted by the Tongariro Power Scheme, without consultation with Whanganui kin groups and in spite of their protests:

> The turbulent, glacial-blue flows of the Whakapapa River were reduced to a trickle, transferring 97% of its water. An iwi representative, Gerrard Albert, later described it: '… the head of our river has been cut off, and it no longer exists as a whole river … and so we continue to bleed as a people, as it bleeds as a river.' (ibid.)

This scheme has had powerful impacts on the river, diminishing its rights to flowing water, to transport sediment, to operate at catchment scale and to be healthy. This river, with its deeply incised headwaters and confined valleys, has little room to move, and this has been further constrained by stopbanks, the drainage of wetlands and the clearance of riparian vegetation. Further downstream, the impacts of flooding have become increasingly severe, with residents in parts of Whanganui city having to be relocated.

In the article, the authors trace powerful resonances between the insights of mātauranga taiao (ancestral knowledge of the living world) and contemporary geomorphological science, and argue that by working together, these can enrich understandings of rivers as living systems with unique properties, and assist in devising better ways of handling the relations between people and waterways. What happens, however, if rivers are not regarded by Māori as ancestors, or if the relationships between kin groups and waterways have been radically disrupted?

In the case of another river studied by the Te Awaroa team, the Waimatā River on the east coast of the North Island, Māori occupation of its upper reaches largely ceased soon after European settlement. In order to understand the long-run life of the river, its geomorphological character, the arrival of Māori and European settlers, their uses of and impacts on the river system, and its ecological history were investigated. This approach, styled 'river ethnography', aims to bring together a wide range of disciplines (including history and the social sciences) with mātauranga taiao (ancestral knowledge of living systems) in an attempt to explore the Waimatā River as a living community through time, with its land, water, plants, animals and people. Drawing on ancestral Māori framings, the team focused on hearing 'the voice of the river', the behaviour and health of the river over time, as reflected in 'river stories'.

The inquiry began by exploring the relationship between land and the river. Like the Whanganui River, the channel of the Waimatā is confined and acts as a flume, transporting sediment and waste materials from source to the ocean. From its headwaters the river runs through highly erodible, steep country, through forests, pastoral farmland and suburbs, where it joins the Taruheru River to become the Tūranganui River, the shortest river in Aotearoa New Zealand, which runs through Gisborne city and the port (Cullum, Brierley and Marden, 2016).

Unlike the Whanganui and Waikato rivers, in ancestral Māori times the upper reaches of the Waimatā were largely used as a highway to the east coast and for access to forest resources, and were not permanently settled (Phillips and Salmond, 2017). During the early phase of European settlement the land around the river passed into European control and then ownership, and Māori occupation of the upper and mid catchment largely ceased (Gundry, 2017). No doubt for this reason, the Waimatā has not been subject to a specific Treaty claim, although several kin groups have submitted statements of their ancestral relationships with the river as part of the Treaty claim process. Occupation continued on the northern banks of the Tūranganui, however, where the Waimatā joins the Taruheru and flows into the sea. Both the local hapū, Ngāti Oneone, and their ancestral river experienced major impacts, including the development of the port along with other industrial uses; the relocation of their marae, Te Poho-o-Rāwiri; the blasting of Te Toka-ā-Taiau, a sacred rock near the mouth of the river; and the loss of Te Wai o Hīharore, a place set aside in ancestral times so that inland kin groups could go fishing, declared an inalienable fishing reserve by the Native Land Court in 1875 (Phillips and Salmond, 2017, pp.4, 21).[8]

The introduction of pastoral farming by European settlers in the mid and upper reaches of the Waimatā catchment led to the clearance of hill and riparian vegetation, severe erosion, and major flooding in the lower reaches of the river and Gisborne city, so that major engineering works were carried out to divert the mouth of the river into a separate channel from the port.

The kin networks that bind people with other living systems resonate with the science of complex networks, key to understanding many ‘wicked problems’ of our time, in which the exchanges between people, land, rivers, plants, animals, the sea and the atmosphere are inextricably entangled and mutually implicated.

Nevertheless, the lower Waimatā has been heavily used for recreational purposes, with rowing, kayaking and more recently waka ama paddling as major activities. With the introduction of plantation forestry in the headwaters and mid reaches of the river in the late 1960s to deal with severe erosion, followed by recent clear-felling, the lower reaches of the river have been affected by aggradation and flooding, putting these activities at risk.

Finally, the team examined the ecological history of the river, and the impacts of these activities over time upon plants, animals and people, many of which have been devastating (Salmond, 2017). The research process, which involved interviews with many individuals with different kinds of knowledge about the life of the river, from local residents to iwi members, foresters, farmers, scientists, local body engineers, and waka ama and kayak paddlers and rowers, was a way of empowering different voices to speak *from* as well as *about* the life of the river. Once the reports were written, meetings to share their findings with local communities were held. With no formal Treaty process to draw specific attention to the degradation of the river and the associated risks to local people, and a short-term utilitarian approach that largely ignores the downstream impacts of upstream activities, the Waimatā River had been relatively neglected. This is despite a close relationship between local residents and the lower reaches of the river, and the fact that it runs through Gisborne city and port. The public meetings were very well attended, including by those who had participated in the research process, and many of those present expressed a strong desire to play an active role in ensuring a healthy future for the river.

Here, too, an approach that brings together mātauranga taiao with contemporary sciences to understand rivers as unique, dynamic living systems that include plants, animals and people, and to seek balanced, life-enhancing exchanges among them, has the potential to lead to better outcomes for waterways, people and other life forms. This requires a shift from short-term, utilitarian, anthropocentric framings, because if rivers are more ancient and powerful than people, then all waterways have rights to flourish, not just those that are the focus of current human preoccupations.

Here one can begin to glimpse the strength of ecological perspectives based on ancestral Māori insights as well as contemporary sciences. In Aotearoa New Zealand, after perhaps 80 million years of independent evolution[9] – aeons of ancestral space-time – the first human beings arrived. Human occupation is brief, beginning about 800 years ago. As the saying goes, ‘Toi tū te whenua, whatungarongaro te tangata’ – the land stands, while people come and go; the land, with its rivers, mountains and forests, is indeed more ancient and powerful than people. Just as the tears of Ranginui and the mists of Papatūānuku bring life to the world, Tangaroa, the ancestor of the sea, is also the ancestor of waterways and their creatures, confounding the division between the marine and river sciences, since water itself and so many life forms move between them. The kin networks that bind people with other living systems resonate with the science of complex networks, key to understanding many 'wicked problems' of our time, in which the exchanges between people, land, rivers, plants, animals, the sea and the atmosphere are inextricably entangled and mutually implicated. When waterways become ill and polluted, people also fall ill, with very high rates of water-borne diseases in parts of Aotearoa. As Whanganui people say, 'If the river is dying, so am I'. In such a situation, the fragmentation of disciplines and radical divisions between the 'natural' and 'social' sciences make little sense, since human activities have profound impacts on all the other life forms, including losses of biodiversity, the degradation of rivers and the ocean, and climate change; and these transformations in turn have profound implications for human communities.

At present, freshwater policy is under active debate in Aotearoa New Zealand. It will be fascinating to see how far the challenge to possessive individualism, property rights and short-term profits proceeds in practice. The framing that defines human interests in terms of 'fresh water' rather than waterways is already laden with utilitarian assumptions, since it is precisely the process of abstracting, enclosing, quantifying and pricing that leads to the commodification of 'the commons', whether this is applied to land, fish stocks or water. Likewise, talk of 'ecosystem services' is underpinned by the idea that springs, wetlands, streams and rivers were created to serve human purposes, denying the need for reciprocity and life-enhancing exchanges. The emphasis on waterways as living systems or communities, more ancient and powerful than people, on the other hand, resonates with mātauranga taiao and the findings of contemporary science, and is more likely to lead to healthy, sustainable relations between people, waterways and other life forms into the future.

Te Hauora o te Wai is understood as the fundamental right of a river to flourish *as a river*, with clean water, plentiful flows and flourishing ecosystems.

A move towards these kinds of perspectives should be possible in Aotearoa New Zealand. This will require some conceptual shifts, for instance in the Resource Management Act (RMA), which aims to promote the 'sustainable management' of 'resources' in Aotearoa by:

> managing the use, development, and protection of natural and physical resources in such a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well-being and for their health and safety while –
> (a) sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and
> (b) safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and
> (c) avoiding, remedying, or mitigating any adverse effects of activities on the environment. (s5(1), (2))

Here the emphasis is still on the 'management' of 'resources' for human uses.

One key instrument in the RMA, the national policy statements, state objectives and policies for matters of national importance, such as coastlines, forests and water. These national policy statements must be given effect in regional policy statements, and regional and district plans. In 2014 the National Policy Statement for Freshwater Management was released. In the 23 years since the RMA was first enacted, reliance on it to protect waterways had clearly failed. Assertions that the 'market' would drive positive change in the management of waterways proved misguided, and faith that technology would provide solutions had yet to deliver.

Predictably, the National Policy Statement for Freshwater Management provided direction to manage water quality and quantity, using techno-scientific rationales. Nevertheless, this national policy statement took a significant step by acknowledging the Treaty of Waitangi as the underlying foundation of Crown and Māori relationships, and recognising 'Te Mana o te Wai' in setting freshwater objectives. Te Mana o te Wai, inspired by precedents in the Waikato and Whanganui River acts, recognises a range of tāngata whenua values, including the kin relationship through whakapapa between iwi and hapū and the natural environment, including fresh water, and that as kaitiaki, iwi and hapū have a reciprocal obligation to ensure that freshwater ecosystems are healthy (including human health).

In an appendix to the national policy statement, Te Mana o te Wai is further elaborated by defining these relationships in terms of Te Hauora o te Wai – the health and mauri of the water; Te Hauora o te Tangata – the health and mauri of the people; and Te Hauora o te Taiao – the health and mauri of the environment. Te Hauora o te Wai is understood as the fundamental right of a river to flourish *as a river*, with clean water, plentiful flows and flourishing ecosystems. Once that is secured, people can derive health and sustenance from the waterway (Te Hauora o te Tangata), in ways that ensure Te Hauora o te Taiao, wider ecosystem and environmental health.

In the 2017 amendment of the policy statement, Te Mana o te Wai was further defined as 'the integrated and holistic well-being of a freshwater body' and as an integral part of freshwater management (Ministry for the Environment, 2017, p.7).[10] This was a major step towards placing particular waterways at the heart of freshwater management approaches in Aotearoa. When the current coalition government comprising Labour, the Greens and New Zealand First was formed in late 2017, fresh water was identified as an issue of urgent public concern. As a result, the minister for the environment, David Parker, initiated an Essential Freshwater reform programme, which included a critical reappraisal of the National Policy Statement for Freshwater Management.

This review included the establishment of Kāhui Wai Māori – the Māori Freshwater Forum – who in their April 2019 report to the minister argued that Te Mana o te Wai offers a positive way forward in realising better outcomes for waterways in Aotearoa New Zealand. They framed the kaupapa (issue) in terms of mana atua–mana tangata–mana whenua, the relationships between the mana of creator ancestors, people and the land. They proposed that obligations are first 'to the water, to protect its health and its mauri'; second, 'providing essential human health needs such as drinking water'; and third, 'for other consumption provided that such use does not adversely impact the mauri of freshwater'. The first obligation aligns with Te Hauora o te Wai, the second with Te Hauora o te Tangata, and the third with Te Hauora o te Taiao.

Although the relative order of particular hauora may vary in different formulations, the mauri and mana of the waterways always comes first. If the values articulated in Te Mana o te Wai can be effectively integrated with practical objectives for the care of waterways across Aotearoa New Zealand, there is a real chance that degraded waterways can be returned to a state of health, prosperity and abundance.

Although it is never explicitly stated, and indeed has been vehemently denied by successive governments, the underlying assumption is that a form of ownership rights to water exists in Aotearoa New Zealand. In contrast, ancestral Māori philosophies take it for granted that humans belong to Papatūānuku, earth mother, not the other way round, and that waterways arise from the living relationship between earth and sky. So, although recognition of Te Mana o te Wai in the National Policy Statement for Freshwater Management is a significant step forward, incorporating a Māori approach and privileging the use of Māori knowledge, the policy statement is still linked with legislative instruments based upon ancient Western ideas about a divine gift to Adam and Eve of command and control over 'nature', which also underpin 19th-century definitions of 'property rights' and 20th-century ideas about 'resource management' and 'ecosystem services'. It tries to reconcile two different ways of framing reality, with no guidance about how to negotiate the contradictions between them, or the significant power imbalances that have marginalised Māori understandings of relationships between people and waterways over time.

Indeed, conceptual framings are key to the future of waterways in Aotearoa and elsewhere. While notions of a 'holistic' ecological lens are often envisaged, they have proved exceptionally difficult to meaningfully capture, let alone apply (Capra, 1983). Fragmentation continues to reign supreme, satisfying vested interests while marginalising more generative and inclusive prospects. Working across worlds, on the other hand, enhances our capacity to envisage and create new ones. In Aotearoa, where lived realities already inform legislative, scientific and technical endeavours, there is an opportunity to recognise that each and every river is a living community with its own hauora, mauri and mana, where water, land, plants, animals and people are inextricably entangled, shaping each other across the generations in kin-based exchanges. At the same time, automated monitoring and measurement procedures, alongside ethnographic inquiries, present unprecedented capacities to tell the stories of each river, recorded through system-specific forms, rates and patterns of adjustment, and the study of long-run relationships and interactions of these life forms at the catchment scale (Brierley et al., 2013; Fryirs et al., 2019).

Such convergent place-based framings highlight the potential to generate insights into the emergent properties of each waterway, fostering a genuine prospect to live with rivers in ways that respect bonds of mutual interdependence, reciprocity and co-evolution. Exciting legislative and scientific endeavours are increasingly in hand as we envisage encounters that weave across laws, narratives and data sets, between people, plants, animals and rivers, letting the rivers speak, restoring vitality to the lifeblood of the land.

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1 For an elegant account of the fundamental role of the water cycle in making the planet habitable for people, plants and animals, see Mauser, 2012.
2 Book 2, chapter 5, section 32: 'As much land as a man tills, plants, improves, cultivates, and can use the product of, so much is his property. He by his labour does, as it were, enclose it from the common.'
3 'In general, all mankind will agree that government should be reposed in such persons, in whom those qualities are most likely to be found, the perfection of which is among the attributes of Him who is emphatically styled the Supreme Being; the three grand requisites, I mean, of wisdom, of goodness, and of power: wisdom, to discern the real interest of the community; goodness, to endeavour always to pursue that real interest; and strength, or power, to carry this knowledge and intention into action.'
4 'But, after all, there are some few things, which, notwithstanding the general introduction and continuance of property, must still unavoidably remain in common; being such wherein nothing but an usufructuary property is capable of being had; and therefore they still belong to the first occupant, during the time he holds possession of them, and no longer. Such (among others) are the elements of light, air, and water.'
5 'The proprietor of each bank of a stream is the proprietor of half the land covered by the stream; but there is no property in the water. Every proprietor has an equal right to use the water which flows in the stream; and, consequently, no proprietor can have the right to use the water to the prejudice of any other proprietor.'
6 For a discussion of Blackstone's dictum and the doctrine of 'public trust' in relation to the governance of waterways in Aotearoa, see Salmond, 2018.
7 Turama Thomas Hawira, brief of evidence for the Whanganui District Inquiry (do B28), 11.
8 Many of these wider impacts are documented in Coombes, 2000; Waitangi Tribunal, n.d.; Spedding, 2006.
9 Zealandia separated from Gondwanaland in the late Cretaceous period: Mortimer et al., 2017.
10 'Upholding Te Mana o te Wai acknowledges and protects the mauri of the water. This requires that in using water you must also provide for Te Hauora o te Taiao (the health of the environment), Te Hauora o te Wai (the health of the waterbody) and Te Hauora o te Tangata (the health of the people)' (p.7).

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References

Blackstone, W. (1770) *Commentaries on the Laws of England, in four books,* Oxford: Clarendon Press

Brierley, G., K. Fryirs, C. Cullum, M. Tadaki, H.Q. Huang and B. Blue (2013) 'Reading the landscape: integrating the theory and practice of geomorphology to develop place-based understandings of river systems', *Progress in Physical Geography*, 37 (5), pp.601–21

Brierley, G., M. Tadaki, D. Hikuroa, B. Blue, C. Sunde, J. Tunnicliffe and A. Salmond (2018) 'A geomorphic perspective on the rights of the river in Aotearoa New Zealand', *River Research and Applications*

Capra, F. (1983) *The Turning Point: science, society, and the rising culture,* Bantam

Coombes, B. (2000) *Ecological Impacts and Planning History: an environmental history of the Turanganui casebook area,* Wai 814, #20, Waitangi Tribunal

Cullum, C., G. Brierley and M. Marden (2016) *Landscapes and Rivers of the Waimatā and Taruheru,* Te Awaroa Project Report 1, University of Auckland, https://www.waikereru.org/assets/documents/WaimataReport1.pdf

Fryirs, K.A., J. Wheaton, S. Bizzi, R. Williams and G.J. Brierley (2019) 'To plug-in or not to plug-in? Geomorphic analysis of rivers using the River Styles Framework in an era of big-data acquisition and automation', *WIREs Water*

Gundry, S. (2017) *The Waimatā River: settler history post 1880,* Te Awaroa Project Report 3, University of Auckland, https://www.waikereru.org/assets/documents/WaimataReport3.pdf

Locke, J. (1821) *Two Treatises of Government,* London: Whitmore and Fenn

Mauser, W. (2012) 'Sustainable water', in A. Kneitz and M. Landry (eds), *On Water: perceptions, politics, perils,* Munich: Rachel Carson Center

Ministry for the Environment (2017) *National Policy Statement for Freshwater Management 2014 (amended 2017)*, Wellington: New Zealand Government

Mortimer, N., H.J. Campbell, A.J. Tulloch, P.R. King, V.M. Stagpoole, R.A. Wood, M.S. Rattenbury, R. Sutherland, C.J. Adams, J. Collot and M. Seton (2017) 'Zealandia: Earth's hidden continent', *GSA Today,* 27 (3), pp.27–35

Muru-Lanning, M. (2010) 'Tupuna Awa and Awa Tupuna: an anthropological study of competing discourse and claims of ownership to the Tainui River', PhD thesis, University of Auckland

Phillips, C. and A. Salmond (2017) *Native Land Court Blocks on the Waimata River, Gisborne, Te Awaroa Project Report 2*, University of Auckland https://www.waikereru.org/assets/documents/WaimataReport2.pdf

Salmond, A. (2017) *Biodiversity in the Waimatā River Catchment, Gisborne,* Te Awaroa Project Report 4, University of Auckland, https://www.waikereru.org/assets/documents/BiodiversityInTheWaimataCatchmentReport.pdf

Salmond, A. (2018) 'Rivers as ancestors and other realities: governance of waterways in Aotearoa/New Zealand', in L. Te Aho, M. Humphries and B. Martin (eds), *ResponsAbility, Law and Governance for Living Well with the Earth,* Routledge

Salmond, A., M. Tadaki and T. Gregory (2014) 'Enacting new freshwater geographies: Te Awaroa and the transformative imagination', *New Zealand Geographer,* 70 (10), pp.47–55

Spedding, M. (2006) *The Turanganui River: a brief history,* Gisborne: New Zealand Historic Places Trust

Taylor, R. (1855) *Te Ika a Maui, or, New Zealand and its inhabitants,* London: Wertheim and Macintosh

Te Rangikaheke, W. (1849) 'Nga tama a Rangi (the sons of Rangi)', GNZMMSS 43, Auckland Public Library

Waitangi Tribunal (1988) *Report of the Waitangi Tribunal on the Muriwhenua Fishing Claim,* Wellington: Waitangi Tribunal

Waitangi Tribunal (n.d.) *Te Aitanga-a-Hauiti and Ngati Oneone*, Claim Wai 1000, Waitangi Tribunal

Whittle, J. (2013) 'Into the backyard: Huntly Power Station and the history of environmentalism In New Zealand', *ENNZ: Environment and Nature in New Zealand,* 8 (1), http://www.environmentalhistory-au-nz.org/2013/11/into-the-backyard-huntly-power-station-and-the-history-of-environmentalism-in-new-zealand/

Why we should release New Zealand's strangled rivers to lessen the impact of future floods

February 23, 2021 7.57am NZDT

Shutterstock/Tracey McNamara

When two West Coast rivers flooded on the same day in 2019, the Waiho tore down a bridge and cut off local communities for 18 days, and the Fox eroded a landfill, exposing 135 tonnes of rubbish that contaminated beaches more than 100km away.

A flood on the Rangitata River during the same year severed road, rail and power connections along the east coast of the South Island and cut a 25km path to the sea through prime dairy country.

We shouldn't be surprised when our rivers break their banks — that's just a river being a river. Current management practices in Aotearoa treat rivers as static, in the hope of making them more predictable.

But this can lead to disasters.

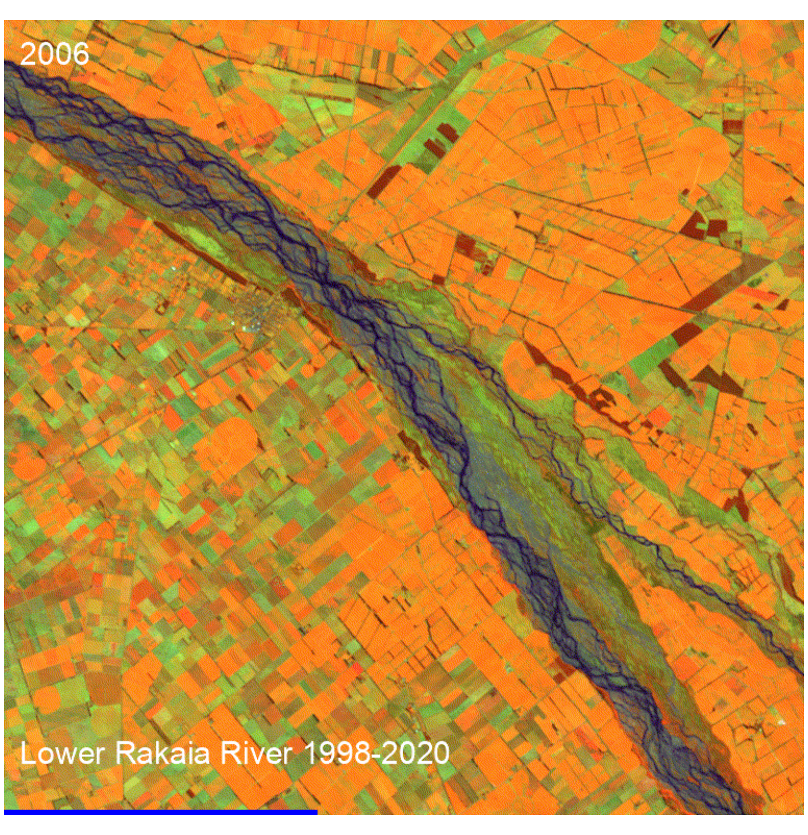
The recently announced reform of the Resource Management Act (RMA) is an opportunity to address river confinement, but it isn't enough. We need to change the way we think about rivers.

By forcing rivers into confined channels, we are strangling the life out of them and creating "zombie rivers".

Unless we change management practices to work with a river, giving it space to move and allowing channels to adjust, we will continue to put people and rivers on a collision course.

When flood risk is managed poorly, disadvantaged groups of the population are often disproportionately impacted. Given climate change predictions of more extreme floods and drought, the problem will only get worse.

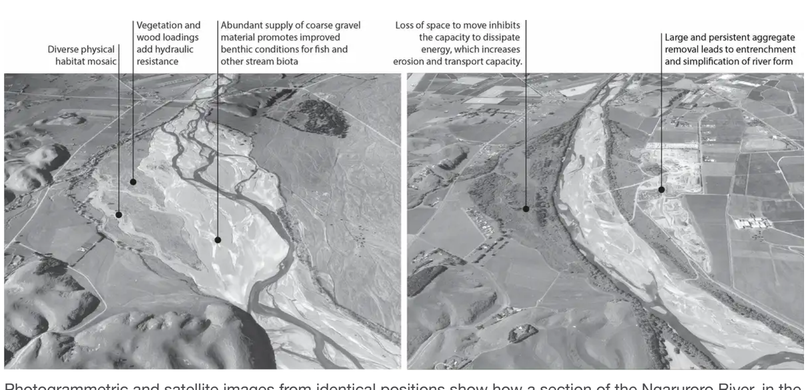
Read more: Letting rivers run wild could reduce UK flooding – new research



Working with a river, not against it

A healthy river is resilient, constantly adjusting its path and regenerating habitats, with significant capacity to self-heal and recover from disturbance.

Although New Zealanders associate with the ecological and cultural values of living rivers, such as ancestral connections and places of food gathering (mahingai kai), our management practices continue to treat rivers as unchanging. This reflects a colonial approach that tries to confine rivers within defined corridors to maximise the availability of land and manage flood risk.



Photogrammetric and satellite images from identical positions show how a section of the Ngaruroro River, in the Hawkes Bay, changed between 1950 (left) and 2020 (right). NZ Aerial Photography (via Retrolens), SN541 (1950) and Google Earth/Digital Globe (2000)., Author provided

River confinement in New Zealand is the result of both engineering works such as stop banks, intentionally focused on flood defence, and the slow creep of agricultural encroachment. Current river management practices are funded by targeted rates paid by landowners. Their goal is to protect as much land as possible as cheaply as possible.

This has arguably been very effective to date and is understandable, but ignores other river values. It also misses the point that when design limits are exceeded, disaster usually follows.

Effective river management

There are always trade-offs. For example, planting introduced willows along river banks is a cost-effective way of trying to control the river in the short term. But willows spread aggressively and choke the river, diminishing habitat diversity and reducing the river's capacity to transport flood waters and gravel. This exacerbates risk in the medium to long term.

In scientific terms, effective approaches to river management look after the geomorphology of river systems — the interactions that shape the changing mosaic of river habitats — alongside concerns for water quality and aquatic ecology. This requires analysis of flows and sediment deposition to assess how a river uses its energy.

Read more: When dams cause more problems than they solve, removing them can pay off for people and nature

When a river has space to move, it dissipates its energy. This builds its capacity to recover from disturbances and maintain a dynamic but stable state. Constraining a river's flow into a restricted space concentrates flow energy, increases flood magnitude and accentuates problems downstream.

Rather than forcing a river into a defined place (which also often limits people's access to it), more responsive and low-impact practices would embrace a harmonious relationship with dynamic, living and adjusting rivers.

Reframing environmental law

Just as landowners often perceive wetlands as potential farm land once drained, planted river margins are sometimes considered "wasted" land. Agricultural encroachment removed more than 11,000 hectares of braided river bed on the Canterbury Plains between 1990 and 2012.

Changing flows of the braided Waimakariri river between 1942 and 2020. Author provided

The current wording of the Resource Management Act (RMA) allows this, as its definition of river bed assumes a static river channel. This is clearly inappropriate for braided rivers, which have multiple shifting channels.

That said, we are cautiously optimistic about reframing the RMA to promote more judicious choices of land for development.

Reducing the impacts of future disaster

International studies show that allowing a river to self-adjust is cheaper and more effective than active interventions that force a river into a particular place.

Europe and Japan have a long history of confining rivers. Once management practices start on this path, they become locked into progressively building more and more expensive hard engineering structures. Many rivers in Aotearoa New Zealand are less modified than those in other parts of the world. Changing management practices now can have a significant positive effect.

Contemporary scientifically-informed approaches to river management directly align with te ao Māori, wherein practices respect ancestral connections, living with rivers rather than seeking to control them. This presents an opportunity for regenerative relations to living rivers, recognising and enhancing their mana so they can function unimpeded.

Although rivers in Aotearoa are well described and we have some of the best databases and monitoring practices, this does not mean we are giving effect to the principle of Te Mana o te Wai, which aims to respect the natural need of a river to adjust as a living entity.

Working with the processes that create and rework a river channel and its floodplain will reduce the impacts of future disasters. Recognising the links between sections of a river and the whole catchment will help us assess how likely it is that the river will adjust to accommodate larger and more frequent future floods.

An honest discussion now could save us the direct and indirect costs of future clean-up and repair. Reanimating rivers seeks to respect the rights of healthy, living rivers that erode and flood in the right place and at the right rate.

This article is part of a series The Conversation is running on the nexus between disaster, disadvantage and resilience. It is supported by a philanthropic grant from the Paul Ramsay foundation. You can read the rest of the series here.

Flood protection | New Zealand stories | te ao Māori | Disaster & Resilience series

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James Brasington receives funding from multiple regional councils in Aotearoa New Zealand, the Ministry for Business Innovation and Employment (MBIE) as well as overseas research funding agencies.

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Jon Tunnicliffe works for The University of Auckland (School of Environment) and receives research funding from regional councils and the Ministry of Business, Innovation and Employment (MBIE). He is affiliated with the New Zealand Rivers Group, a joint technical interest group of Engineering New Zealand and Water New Zealand.

Kristiann Allen receives funding from the International Development Research Centre for globally connected research and capacity building on systems and practices for evidence-informed public policy and science advice to governments in relation to the Sustainable Development Goals. She is Associate Director (Policy and International engagement) of Koi Tū: The Centre for Informed Futures at the University of Auckland, and directs the secretariat of the International Network for Government Science Advice (INGSA), which is hosted by Koi Tū.

Richard Measures works for NIWA and receives research funding from NIWA and the Ministry of Business, Innovation and Employment (MBIE). He is a committee member of the New Zealand Rivers Group, a joint technical interest group of Engineering New Zealand and Water New Zealand.

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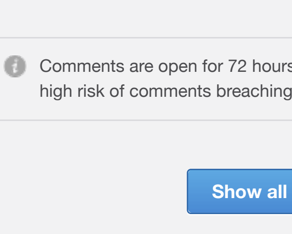

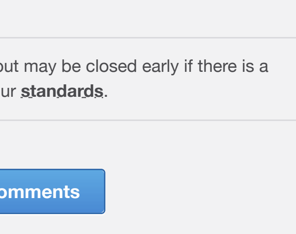

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Beware the zombie river

18 July 2019

James Brasington

New Zealanders are in danger of creating "zombie" rivers, not because of nutrient overloading, but because we're locking our waterways into position between stopbanks and impounding their headwaters.

Professor James Brasington, inaugural holder of the Waikato Regional Council Chair of River Science at the University of Waikato, says we risk the creation of zombie rivers because too often we prevent them from finding their own course and treat them as a means to simply to get excess water out to sea as fast as possible.

He'll be talking about his research as part of the University of Waikato Hamilton Public Lecture Series, on Tuesday 6 August. Professor Brasington is a geomorphologist who researches the processes that control the form, structure and function of rivers and their catchments. "If we put our rivers into straight-jackets, they lose the diversity of form and process that are fundamental to the creation of thriving ecosystems," he says. "Instead we should make space for rivers to erode their corridors, flood naturally in areas that are of less value which will in turn, reduce risks in more sensitive areas. We must work with natural processes to reduce the flood risk and support healthy river ecosystems."

The river scientist is a pioneer of new technologies that are enabling him and his colleagues to collect novel datasets to better understand how rivers are formed and change over time. "We now can use remote sensing to capture the complex 3D structure of rivers. We use aerial surveys and satellites to create detailed models of rivers that capture the sand and gravel particles that shift and form them through time. This information helps us understand what drives the evolution of rivers through floods and how they create the complex mosaic of habitats within their floodplains."

Professor Brasington's research seeks to synthesise these technological advances with numerical models to shed light on how rivers might behave in a future shaped by a changing climate and shifting patterns of land use.

He joined the University of Waikato in late 2017 from Queen Mary University of London and has previously worked at the University of Canterbury in New Zealand, and the universities of Hull, Cambridge and Wales before that. His PhD focussed on catchment modelling in the Nepal Himalaya and since then he has worked on rivers in many mountain environments, including the European Alps and Pyrenees, the high Himalaya, the US Rockies and New Zealand's Southern Alps.

His research has attracted competitive funding from a wide range of sponsors, including the UK Natural Environmental Research Council, the Leverhulme Trust, the US Department of Defence, UK and New Zealand government departments and their executive agencies, and a broad range of industrial partners. He recently returned from the Tibetan plateau where he and other scientists in an international team were studying the effects of overgrazing on soil erosion and river dynamics.

Professor Brasington's lecture, Tales from the Riverbank: shining new light on riverscapes, takes place on Tuesday 6 August at 5.45pm in the Academy of Performing Arts at the University of Waikato.