Stepping into the river

NIWA discusses this year's most asked question – what is happening to our fresh waterways?

Dave Allen

No one in New Zealand is far from a river. This year, the most asked question is whether those rivers are swimmable.

This question has been part of what the Prime Minister's Chief Science Advisor, Sir Peter Gluckman, calls "a complex and at times confusing public discourse about freshwater."

One problem is that the swimmable quality of water is not the only, nor the best, measure of water quality.

Many of the more than 1000 waterways monitored by NIWA and regional authorities are degraded by human activity in many ways other than water borne pathogens such as strains of *Escherichia coli* (*E. coli*).

The type of degradation varies widely and wildly, depending on how people use land and how water drains to the river. In places, water is contaminated with sediment or nutrients. In others, there's chemical toxins. In still others, the water flow is altered, channel straightened and river routes modified.

Some of these things affect human safety. All of them affect the habitat of hundreds of species of fish, invertebrates and plants.

Gluckman says the "inevitable" human impacts, and the physical, chemical and biological characteristics, of fresh water are so great that "No single measure is sufficient to understand the state of freshwater."

Gluckman says there is no choice but to have "nuanced definitions [of water quality] that take into account what is an acceptable risk, consideration of the seasonal changes, [and] the relationship to extreme weather events."

The challenge to politicians and the public, to scientists and environmental and industry advocates is that the impacts of such complexity must be interpreted and communicated clearly.

This story starts to answer Sir Peter's challenge by identifying the myriad of ways we all contribute to degrading our waterways, and some of the solutions we can be part of.

NIWA's Freshwater and Estuaries team is led by Chief Scientist Dr John Quinn. New Zealand's longest river, the Waikato, flows past his Hamilton home on its journey from the clear upper reaches near Taupo to murky lowland.

Quinn says debate over the Waikato is a microcosm of the nation's struggle with water quality.

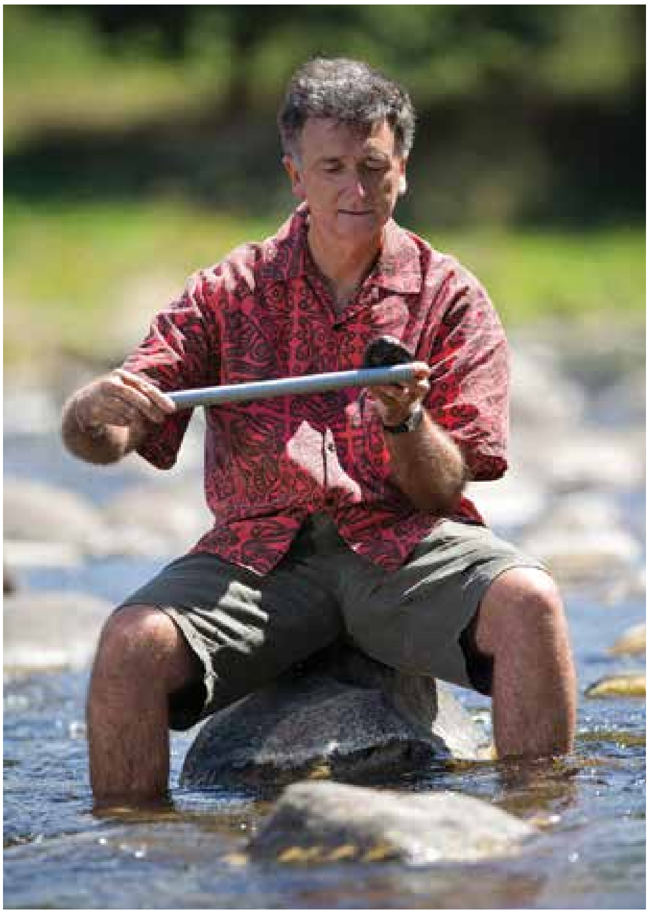
"People want healthy rivers and lakes they can be proud of – where they can swim and fish safely and know that ecological health is good. But many no longer meet the mark because of the way we have used the land and engineered rivers.

"Reversing this is challenging because society also values the things that put pressure on our freshwater.

"No one is removing the hydro-dams that interfere with flow of sediment, fish and water, but also generate clean and renewable energy, help to manage flooding, and provide a world-class rowing lake. We're not removing the roads and paved cities that flood rivers with contaminated storm water. We're not closing down agriculture, but we do expect lower footprint farming systems. Can we really expect to be able to have our cake and eat it too?"

The Waikato River drives nine hydro-power stations. It carries waste from 80 direct discharges such as treated town sewage, treated waste from factories, and 1600 smaller discharges into tributaries, and runoff from more than 2000 dairy farms in the Waikato and Waipa catchment.

- 'Swimmable' is a very incomplete measure of water quality.
- 1000 rivers are monitored by NIWA and regional authorities, and most are degraded in some manner at some point in their course.
- New Zealanders have changed rivers in many ways, some have been changed irrevocably.
- The damage is to quantity and quality of water habitats, as well as to water quality.
- Waterway quality is best measured by multiple factors; such as *E. coli*, ecotoxicity, clarity, nitrogen and phosphorus levels, and the health of plant, insect and fish populations.
- There will be hundreds of fixes, implemented by every New Zealander in their working and personal lives, along every stretch of waterway.



NIWA Chief Scientist, Freshwater and Estuaries John Quinn. Quinn's team took on the boldest attempt so far in New Zealand to test how well a river meets everything expected of it. (*Geoff Osborne*)

> "Can we really expect to be able to have our cake and eat it too?"

The quality of the Waikato River has been a concern for many decades. Impetus to do something about it came with the settlement of Waikato-Tainui's claim for the river and the iwi-Crown agreed Vision and Strategy that sets out an aspiration for its improved health.

The river has been witness to a large regional effort to reduce damage to waterways. Direct sewage discharge from Taupo township was stopped in 1995. Two-thirds of dairy farms have switched to land treatment of dairy effluent. It has been estimated that the Waikato River Authority has put $60 million into 170 restoration projects, including a million native trees planted along the river and its tributaries.

Quinn says "The real question is how to fix things so waterways can sustain what we want from them now."

Quinn's team took on the boldest attempt so far in New Zealand to test how well a river meets everything expected of it. Last year, NIWA worked with the Waikato River Raupatu Trust to compile a "report card" on the Waikato River for the Waikato River Authority.

Thirty subject experts from 10 organisations combined science with the views and knowledge of community interests to give the river catchment a C+ grade.

This was the average of the scores given to specific stretches of the river and its tributaries and lakes. The grades reflected measurements across eight different indicators: water quality, water security, economy, kai (food), ecological integrity, experience, effort and sites of significance.

"We regarded this a low grade, because it fell significantly short of people's expectations of a healthy river," Quinn says.

The murky big picture

Quinn believes the recent focus on what is "swimmable" disguises the complexity of the problem and its solution.

"Being swimmable is not a great measure of a river's overall health or quality. You can swim at Lake Ohakuri, for example, but it has lost its koura and has high mercury and arsenic levels in its sediments.

"Pathogens, indicated by *E. coli*, may directly hurt people, but there's a whole lot more human activity that's damaging flora and fauna.

"Aside from water quality, the four biggest pressures on water ecosystems are stress caused by invasive species like hornwort and koi carp, loss of natural connectivity due to

What is water quality?

Water quality refers to the physical, chemical and biological characteristics of a water body.

These determine how and for what purpose water can be used, and the species and ecosystem processes it can support.

Factors measured include pH, dissolved oxygen, suspended sediment, nutrients, heavy metals and pesticides.

Quality measurements can also include key biological and biochemical variables, such as invertebrate and fish composition, the abundance of algae, and oxygen demand. These provide broader measures of ecosystem health.

Multiple measurement variables are used in virtually all assessments of water quality, creating a rich picture of the state of the water.

In an attempt to rank sites and simplify communication, composite indices of water quality have been developed. While these indices can have their uses, they are problematic and can disguise specific problems within a waterbody.

barriers we've built along our rivers, flow and water level changes and riparian habitat damage."

The breadth of NIWA's work on freshwater gives an indication of the complexity and range of human impact.

For example, teams of scientists are working on ways to treat human wastewater in towns and on farms, installing fish passages in channelled waterways, reducing the flood of rain channelled by urban and road stormwater, calculating downstream impacts of water take, building wetlands and riparian strips to stop nutrients washing from farms, and halting the degradation of lakes by invasive exotic plants and fish, nutrients and fine sediment.

Good old days?

Is freshwater quality getting better or worse? The trends are mixed in data published for the period from 2004 to 2013.

"There's general improvement for contaminants like *E. coli* that get into water from surface runoff and stock in streams. There's between one-half and almost two times more sites that have improved over the last decade rather than degraded in *E. coli*, ammonium, clarity and dissolved phosphorus," says Quinn.

"Yet there are more streams deteriorating than improving in nitrate levels, which mainly travels via groundwater. There are 55% more sites with rising nitrate levels than those with improvements."

Quinn says people's recollections are often correct, but they sometimes have rose-tinted glasses when they compare rivers of their past with the current situation.

> "people's recollections are often correct, but they sometimes have rose-tinted glasses"

"Forty to 50 years ago a lot of rivers had serious pollution from very poorly treated point source sewage and industrial discharges. These are now largely cleaned up.

"When I studied the Manawatu River in the 1980s it had regular blooms of 'sewage fungus' and fish kills due to very low oxygen levels. The river was polluted by crudely treated sewage, and effluent from dairy and meat works.

"Back then people were not aware of cyanobacterial mats on the river bed, though they existed. Today, those things would generate bathing warnings and newspaper headlines."

Dead eels recovered from traps on the Manawatu River, 1984. (*Manawatu Evening Standard*)

Testing waters

With so many rivers, streams, lakes and wetlands, knowing exactly what is going on is a massive challenge.

Collectively, New Zealand's regional councils, unitary authorities and NIWA monitor more than 1000 river reaches and approximately 80 lakes. Data is periodically aggregated and analysed for national scale assessments of river and lake state and trends.

A river network

NIWA runs the National River Water Quality Network (NRWQN) – a network of 77 sites on 35 rivers that are evenly distributed over the two main islands of New Zealand.

The NRWQN river catchments together drain about half of New Zealand's total land area. Sites were selected so that a national perspective of state and trends of water quality could be developed. On most rivers there are two or more sites representing an upstream "Baseline" site (lightly impacted) and a downstream "Impact" site (reflecting the impacts of humans on water quality).

All the sites are monitored for water quality and biology either monthly, seasonally or annually.

Water quality is notoriously variable. NIWA environmental chemist Dr Neale Hudson says the fact that waterways are not monitored more regularly creates "a lot of holes in our nation's cheese".

"We're missing a lot of what is going on in the waterways between sampling occasions and between sampling locations."

However, Hudson says NIWA has cracked the practical and scientific challenges of continuous water quality monitoring.

Equipment has been converted to battery power and upgraded to communicate data and status by cellphone. Measuring protocols have been created to guide where equipment is placed, and for how long, to ensure accurate readings.

"No stretch of water is the same at any one time – making water measuring a complex business. But we've built systems that provide a lot of confidence in the results," Hudson says.

If it's not feasible to measure water quality everywhere, what do we do about the water quality in places where we aren't sampling?

Linking predictive models, built from national monitoring, and the River Environment Classification has enabled a new approach to filling the spatial gaps in coverage of freshwater information between monitoring points, says NIWA environmental modeller Dr Doug Booker.

NIWA has recently released a free app – NZ River Maps (https://shiny.niwa.co.nz/nzrivermaps/) – that uses these

Neale Hudson analyses water quality using a scan spectrolyser. (*Dave Allen*)

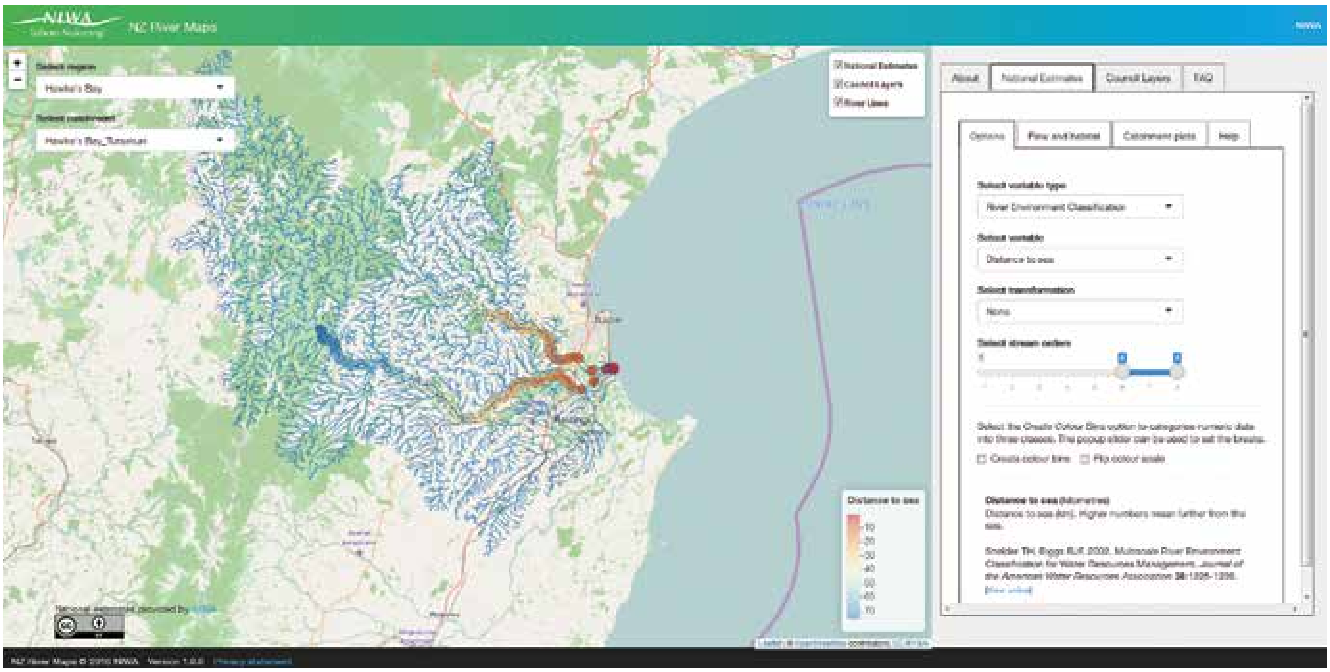
model predictions to show patterns across New Zealand's rivers in about 100 attributes covering hydrology, water quality, fish distributions, invertebrate metrics, suspended and deposited sediment and fish and bird habitat.

No more assumptions

Dr Scott Larned, NIWA's Manager of Freshwater Research, is looking even further ahead to understand the ecological processes that muddy the picture of our human impact.

"You can't fit a river inside a test tube. We can't yet run tests that replicate everything that happens in a river, and how that changes moment to moment."

A recent paper by NIWA scientists analysed streams from which dairy stock were excluded by fencing. Even where stock had been excluded for years, positive responses in aquatic communities were generally weak.



An example of NZ River Maps display of predicted median Total Nitrogen concentrations across third order and larger REC river reaches in the Ahuriri, Ngaruroro and Karamū catchments. (*NIWA*)

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"It's common sense that exclusion stops direct waste input and habitat destruction by livestock. However, some sediment and nutrients still get into rivers in other ways.

"The legacy of decades of erosion, fertiliser and pesticide use, urban development and other activities may take decades to clear. The sensitive species that have been lost need to recolonise and compete with the tolerant, weedy species that have moved in – so ecological recovery can lag behind improvements in water quality and habitat.

"The links between specific activities and ecological conditions in freshwater are often unclear. There's a shortage of cause-and-effect relationships. Those relationships are needed to predict effects of future activities, including restoration. They provide evidence for making land management recommendations."

Larned thinks timeframes for improving water quality can be shortened by moving from assumptions about human impact on land cover (bush, plantation forest, pastoral and urban) to measurement of specific activities on each block of land.

"When we link what we see in the water to exactly what we're doing on land we will get much better at understanding water quality problems and how to reduce and prevent them."

A new measure of water

Quinn thinks the "swimmable" test is the first in a series of measurements that will become familiar to the public.

Scott Larned, Manager Freshwater Research says the ecological timescale of water defies human demand for quick answers. (*Dave Allen*)

"Water is too critical to our lives to be satisfied by superficial questions and simplistic answers. You cannot use one measure to determine the state of a very complex system.

"It's all connected. That creates deep issues we're just unravelling. But it means that every action we take can have multiple benefits, if we are strategic.

"We've got to consider multiple things in the water, and the habitat around it."

He says this more holistic view of the health of our freshwaters needs to include measurements of ecotoxicity, clarity, nitrogen and phosphorus levels, flow regimes, economic uses, ecosystem services, cultural values and the health of plant, insect and fish populations.

Some of NIWA's Hamilton freshwater scientists (from left) – Andrew Swales (Estuarine Physical Processes); Fleur Matheson (Aquatic Biogeochemist); Neale Hudson (Environmental Chemist); Cindy Baker (Freshwater Fish); Mary de Winton (Freshwater Ecologist); Rupert Craggs (Aquatic Pollution); Brian Smith (Freshwater Biologist). (*Dave Allen*)

> “We all impact on fresh water. There will be hundreds of fixes required, and each of us will need to be involved”

He predicts the measurements will be used by communities doing their own versions of the Waikato River report card.

“The report card method identifies and balances all our uses – economic, environmental and cultural,” Quinn says.

“We cannot pin blame and remedial work on just one section of society. We all impact on fresh water. There will be hundreds of fixes required, and each of us will need to be involved.”

For further study

- The river monitoring network: https://www.niwa.co.nz/freshwater/water-quality-monitoring-and-advice/national-river-water-quality-network-nrwqn
- Map on swimmable locations: https://www.lawa.org.nz/explore-data/swimming

Water everywhere

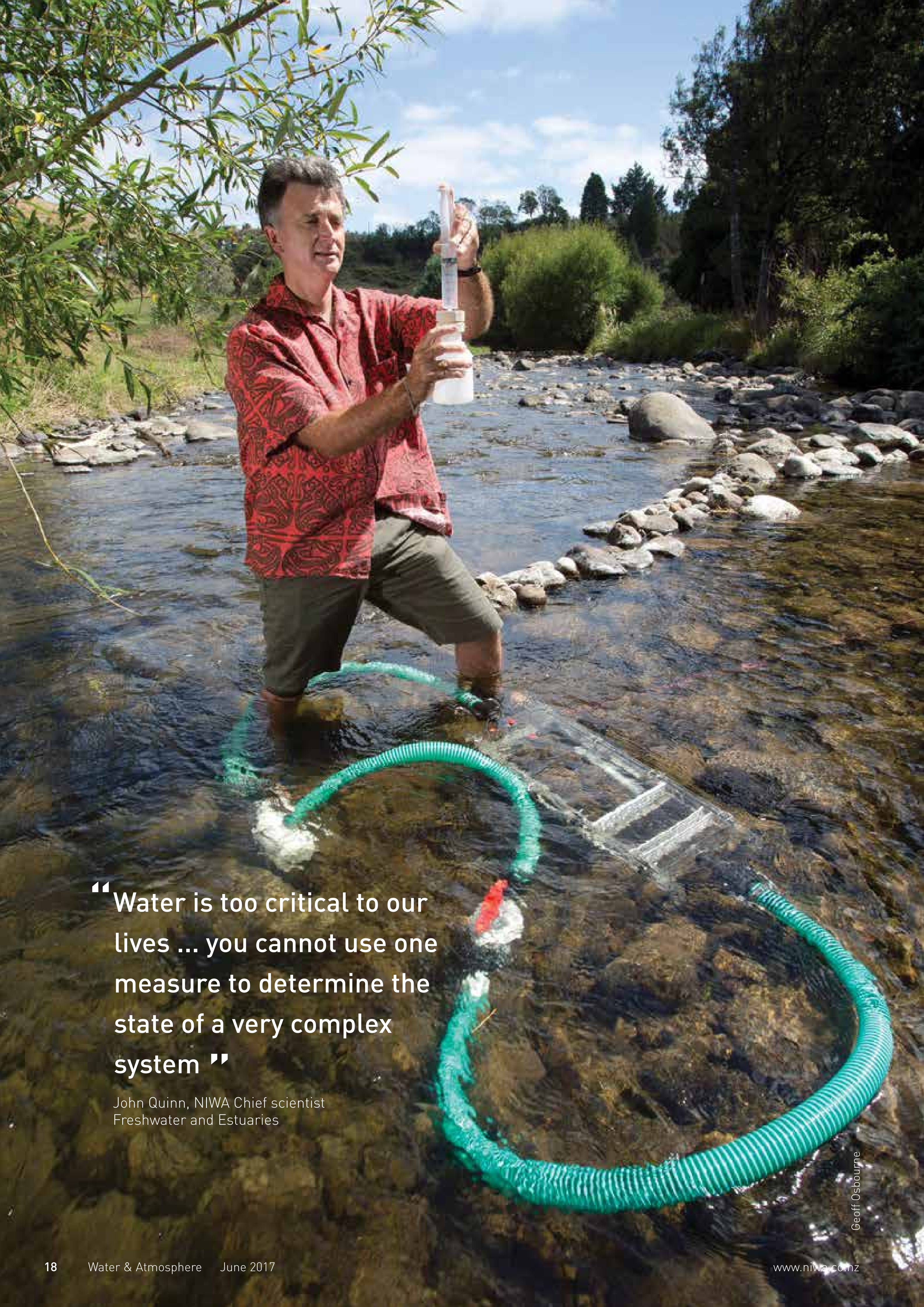
New Zealand has one of the highest volumes of water per capita flowing to the sea through some of the shortest waterways in the world, over the course of days rather than months (unless dammed).

The flow rate changes dramatically due to rain, and the water often passes through an extreme range of geography – from mountain, bush, forest, pasture and towns.

And there are other complications – water is not uniformly spread and much of it is in places where people are few (like the West Coast), flows are highly variable over time and predicted to get more so with climate change, and water that is available for use after allowing for environmental values is often fully-allocated (sometimes over-allocated) in the drier regions of the east coasts of both islands and Northland.

About half of New Zealand’s river length is fed by water coming from largely indigenous land cover, while 45.7% comes from pasture land, 5.1% by exotic forest and 0.8% by urban land cover.

Some of NIWA’s Christchurch freshwater scientists (from left) – Doug Booker (Hydro-ecological Modeller); James Griffiths (Hydrologist); Mandy Home (Te Kūwaha); Phil Jellyman (Freshwater Ecology); Murray Hicks (River Geomorphology); Amy Whitehead (Quantitative Freshwater Ecologist); MS Srinivasan (Hydrologist). (*Dave Allen*)



"Water is too critical to our lives ... you cannot use one measure to determine the state of a very complex system"

John Quinn, NIWA Chief scientist
Freshwater and Estuaries

Geoff Osbourne

Dairy turns the corner

John Quinn believes the dairy industry has been responsive in the tools it has adopted to reduce its impact on waterways.

"There has been a lot of improvement in dairy industry practice in the last 15 years.

"Dairy shed effluent management has improved and is more professional, and the majority of streams on dairy farms are now fenced to exclude cows.

"Things like the Farm Enviro Walk Toolkit and Sustainable Dairying Water Accord have increased adoption of a range of good environmental practices. These advances have been industry-led, rather than driven by government rules."

Quinn notes, however, that the reduction in impact per farm has been offset by the expansion of dairying into areas that used to be dominated by drystock farming, which generally has a smaller footprint.

That is why Quinn still thinks the single biggest thing that can be done to improve our environment is to reduce the footprint of agriculture to both meet the nation's greenhouse gas reduction commitments and improve freshwater quality and ecosystem health. And to incentivise this by finding high value markets that will pay for the value of advanced environmental practices and associated healthy food.

"It's a big 'single thing' to complete, but without that level of strategy the little things any of us do won't really matter," he says.

Dave Allen


Kaniwhaniwha riparian buffer, Waikato region. (*John Quinn*)

In the shade

More than 97% of streams running through dairy farms are now fenced, so cows are out of waterways.

Waterways are still receiving *E. coli* and *Campylobacter* from other unfenced stock and wild animals. They're also getting microbial pathogens from land runoff when it rains. A 2005 NIWA study found that rain can wash a million to a billion *E. coli* bacterium per square metre of hillside into streams.

Riparian strips can help. These are the areas where plants grow alongside streams. They trap and absorb nutrients and microbes, including *E. coli*, in surface water. In the best conditions, riparian strips can remove at least 60% of nitrogen and 65% of phosphorus from runoff and groundwater.

There's even more to riparian strips than the benefits to water quality.

Trees holds together river banks, which stabilises them as habitats for insects and prevents silting and cloudy water that disturbs fish. The shade of trees creates cooler and more humid conditions, which insects need, and prevents over-growth of plants in the stream. Their branches and leaf litter provides direct habitat and food for many of the insects that like riverside conditions for only parts of their life stages, particularly larval, before moving to other habitats.

NIWA has recently started two new programmes looking at riparian management.

One project will work with highly trained and supported citizen scientists to use existing riparian restoration projects as a "natural experiment" to identify design features that result in success over the next four years.

The other will develop riparian and constructed wetland design methods that achieve better water quality outcomes while minimising implementation costs. It will focus on the known hotspots of runoff and transport of contaminants.

Mawaihakona Stream Restoration group, Upper Hutt. (*Allan Sheppard*)

Citizen swim test

People are becoming alarmed to find water quality warnings in largely populated spots where councils conduct regular microbial testing.

Resource limitations mean that not all spots on a river can be checked, and it's often up to the public to use their own judgment as to water quality.

"This is particularly a problem for rivers where potentially toxic algae (cyanobacteria) can be present in numerous places," says NIWA Resource Management Scientist Juliet Milne.

"Public concern about the quality of our rivers and lakes has led to increasing interest in water management and monitoring – there is a growing move towards 'citizen science', with community groups wanting to do their own monitoring," says Milne.

Community groups want to measure real-time changes in a waterway's appearance such as rubbish present, odour, deposited sediment, and nuisance plant growth, which all influence perceptions of water quality and "swimmability".

"Ultimately, monitoring will better reflect what people care about," says Milne.

NIWA is educating community groups and local residents on how to monitor waterways in the regions. Since the 1990s, NIWA has provided environmental community groups and farmers with the NIWA-designed Stream Health Monitoring and Assessment Kit (SHMAK) to self-monitor waterways.

NIWA recently updated the kits to include an *E. coli* test for use in a study testing the efficacy of community monitoring. The results from community monitoring efforts in nine regions were then compared with regional council-collected data.

> "... there is a real role for citizen science in New Zealand"

"The results matched well enough to show there is a real role for citizen science in New Zealand," said NIWA Freshwater Ecologist Dr Richard Storey, who has conducted extensive research into community-based monitoring of New Zealand streams.

"Councils can only afford to monitor waterways on a limited basis. There are more than 600 volunteer environmental care groups in New Zealand and there is an increasing desire to take positive action, including monitoring. By empowering community groups to undertake testing themselves, and providing them with testing equipment, we can increase the amount of accurate monitoring around the country."

NIWA is now working on an app that will allow users to upload monitoring data from mobile devices to a purpose-built public website providing real-time, user-friendly information about water safety and swimmability.

Nature knows best?

Returning water to our waterways after we've used it in our homes, on farms and in industry is a complex and challenging process.

Large centres have traditionally employed mechanical treatment systems to clean up wastewater. These systems are able to process large volumes, but the flipside is that they are expensive to build and have high operational costs.

For smaller centres, that's a problem. Oxidation ponds have been the go-to solution for small and medium-sized communities for the past 30 years. Relatively cheap to build and easier to maintain, these work well at removing suspended solids and lessening biochemical oxygen demand. But the problem is they're highly inconsistent when it comes to removing pathogens and nutrients.

NIWA has been working to take the pond concept to the next level, with work on developing and improving smaller scale, eco-tech wastewater treatments.

"Oxidation ponds have been a great workhorse for New Zealand," says Dr Rupert Craggs, Principal Scientist - Aquatic Pollution. "But now our aspirations for water quality are so much higher."

NIWA and the Waipa District Council are working together to demonstrate the use of enhanced pond systems to achieve cost-effective, efficient wastewater treatment. At the Cambridge wastewater treatment plant, the use of two one hectare shallow ponds has been shown to maximise algal productivity and nutrient removal.

Given the system requires a comparatively large land area to work, smaller communities with land available stand to gain most. And, as well as the land requirement, there's another variable – the sunlight that fuels the processes involved in cleaning up wastewater.

"Because it's a natural system reliant on sun-driven power, the caveat is that there can be variation with seasonal conditions," says Craggs. "Our focus is now on designs to take this into account, and considering additional treatment elements."

But what of water quality? Can a natural wastewater treatment system trump a mechanised plant?

"A natural system can be designed to perform as well as a mechanised system, and better in some cases. There's also the co-benefit of recovering resources from the wastewater (such as bio-gas) as well as providing treatment."

The Cambridge Wastewater Treatment Plant uses NIWA-developed technology to cost-effectively treat, and recover energy and nutrients from, wastewater. (*Jason Park*)

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Toxic mix

In the early 20th century, coal miners used canaries in mines as an early-warning signal for the dangerous build-up of toxic gases.

The birds, being more sensitive to toxic gases than humans, would develop symptoms of carbon monoxide poisoning well before the miners, who would then have a chance to take action to protect themselves.

Technology has advanced a long way since then, but bioassays – measures of how potent a substance is by its effect on living cells or tissues – continue to be a critical measure of the impact of contaminants on various environments.

> "Coal miners used canaries in mines as an early warning signal ... technology has advanced a long way since then"

In NIWA's freshwater ecotoxicity testing work, a range of organisms including invertebrates, fish and algae, are exposed to different concentrations and combinations of contaminants in laboratory conditions to gauge response.

"This allows us to establish thresholds for short-term lethal exposure, for example, to longer term sub-lethal impacts on lifecycles," says Dr Chris Hickey, NIWA Principal Scientist - Ecotoxicology and Environmental Chemistry.

"The key thing is that it provides solid numeric data on how much (contamination) is too much and the diagnostic tools needed for toxicity identification."

While testing informs the development of water quality guidelines, one of ecotoxicology's greatest values is in its application to monitor the impact of specific stressors in site-specific situations. It is increasingly being used to provide reliable information to industries trying to meet their resource consent requirements under the Resource Management Act.

That is no surprise given how New Zealand's vast network of waterways are subject to a wide range of usages and resulting stressors. Freshwater is used in commercial, industrial, residential and recreational situations, and waterways can be affected by multiple contaminants from many different sources.

"There isn't a one-size-fits-all (test) for all environments," says Hickey. "Bioassays using both standard and native species tests complement other biological monitoring techniques used to establish the health of New Zealand's aquatic ecosystems".

Bankwood (Kukutaruhe) Stream fish pass, Hamilton. (*Jacques Boubée*)

Free passage

Tide gates stop fish from accessing 1100km of waterways in the Waikato River catchment. Thousands more kilometres are made inaccessible by other structures such as culverts, weirs and dams.

Nationwide, there are likely tens of thousands of structures in our rivers, with between 30% and 50% of these structures impeding migration of fish in some way. The result is fewer fish in our rivers.

NIWA Freshwater Ecologist Dr Paul Franklin sees the problem first-hand in his work.

"We see fish massing by human barriers, trying to continue their upstream movements. A few make it past, but many do not. Some will find alternative habitats, but many are eaten. You often see shags collecting fish below the barriers."

Some native fish are more affected by migration barriers than others. Inanga (*Galaxias maculatus*), the main whitebait species, are weak swimmers and cannot climb. They are highly susceptible to being blocked by in-stream structures. However, koaro (*G. brevipinnis*) and juvenile eels (*Anguilla australis* and *A. dieffenbachii*) are very good climbers and can even make their way past waterfalls.

Franklin says the good news is that there is almost always a way of building new structures in a more fish-friendly way, and to retrofit existing structures to allow more fish past.

"We helped design and install a rock fish ramp and baffles where the Bankwood (Kukutaruhe) Stream was piped into the Waikato River in Hamilton. Within a year, the number of fish species upstream of the culvert had doubled and there are now many more fish in the stream."

Providing fish passage is required by law and many regional regulations. The Tasman District Council has recently made it mandatory to fix fish passage at all existing culverts.

"We've known the importance of providing fish passage for decades, but designing effective fish passes for our native fish has been challenging," Franklin says.

"A big problem has been the gap between ecologists and engineers, but we're now doing a better job of speaking the same language."

NIWA and DOC are currently drafting fish passage guidelines that will help policymakers and engineers with the best methods of constructing fish-friendly structures.

NIWA is part of a national advisory group leading the development of new resources to improve management of fish passage.

A new research project just underway will improve understanding of how and why fish behave at structures. This will help us do an even better job of building fish-friendly structures in the future.

Flipping lakes

As freshwater storage and supply sources, New Zealand's lakes serve as critical gauges of the overall health of many water catchments and ecologies.

There's good news and bad news in what these gauges are revealing, says NIWA Chief Science Advisor Dr Clive Howard-Williams.

"While about one-third of our monitored lakes are ranked good or very good, and one-third are ranked moderate in terms of ecosystem health, we have a long way to go to restore the one-third that are ranked poor or very poor. Most of these are in lowland areas.

"There are some grounds for optimism in that over the past 10 years of monitoring, more lakes have shown improvements than have worsened."

The introduction of pest fish species, aquatic weeds and nuisance algae had seriously undermined the ecological health of lakes.

"Aquatic weeds have impacted on the native vegetation of lakes in the high country as well as lowland New Zealand, and the lake edges, or littoral zones, have been most impacted," says Howard-Williams.

"Pest fish such as koi carp and catfish prey on native species and in some cases have markedly contributed to declines in ecosystem health."

Coastal lakes and the shallow lakes of the Waikato were in particularly bad shape.

"Lakes reflect land use in a catchment and can also modify downstream aquatic systems. The shallow lakes of the Waikato, for example, have suffered from excessive nutrient inflows from farming in their catchments and, in particular, from pest plants and fish that have significantly altered lake habitats."

NIWA is working with a range of partners on a series of research programmes aimed at improving the health of New Zealand lakes, says Howard-Williams.

"NIWA is looking at improved catchment management where lakes are receiving waters in the catchment. Some of this is directly funded through the National Science Challenge 'Our Land and Water', which seeks to minimise environmental effects in an improving agricultural economy."

Monitoring lake ecosystem health. (*Rohan Wells*)