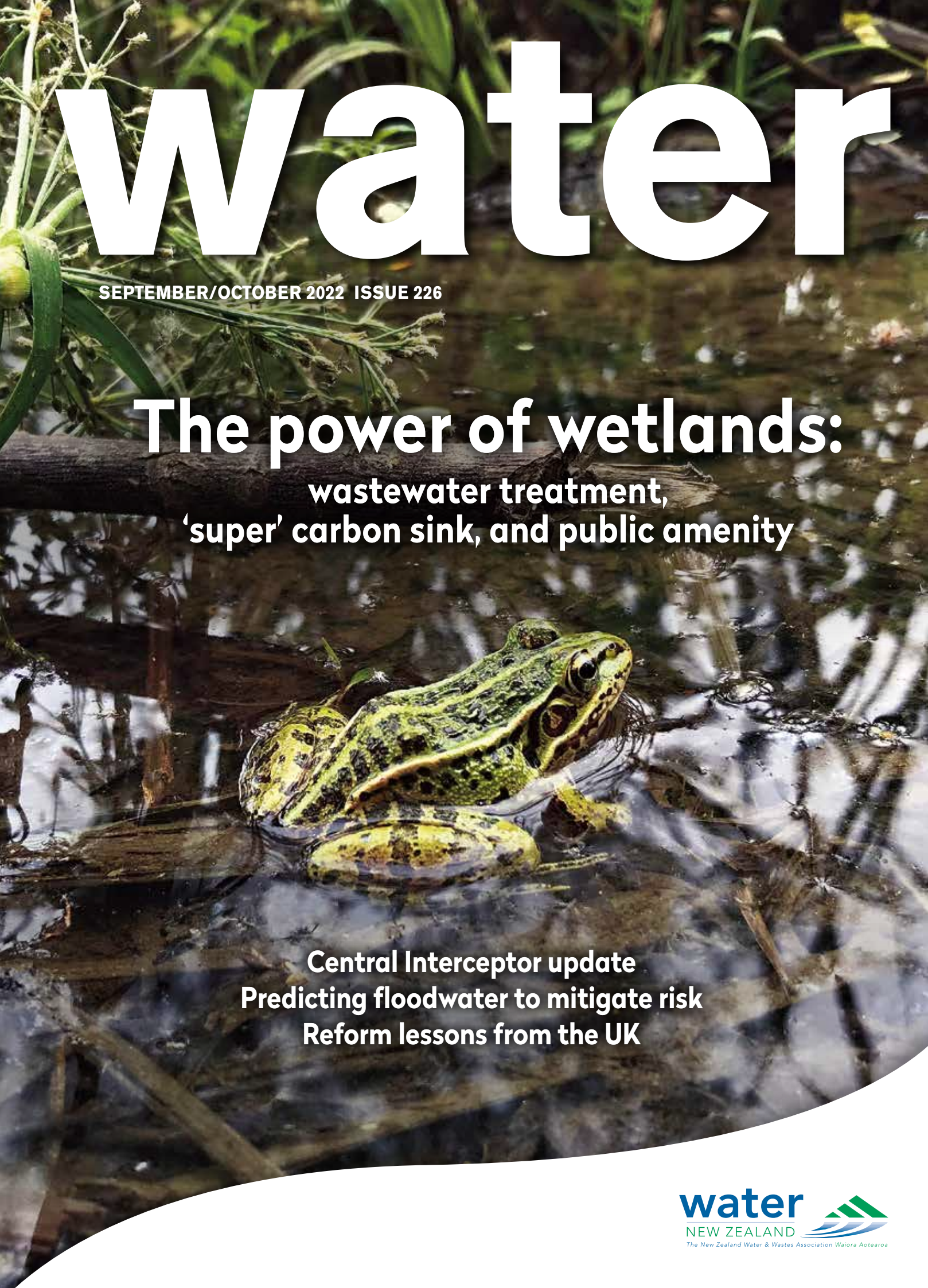
water

SEPTEMBER/OCTOBER 2022 ISSUE 226

The power of wetlands:

wastewater treatment, 'super' carbon sink, and public amenity



Central Interceptor update
Predicting floodwater to mitigate risk
Reform lessons from the UK

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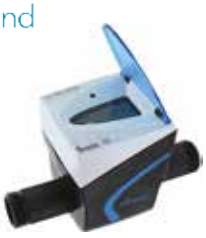
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water

Issue 226 SEPTEMBER/OCTOBER 2022

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'Ka ora te wai, ka ora te whenua, ka ora ngā tāngata'

'If the water is healthy, the land is healthy, the people are healthy'

The official journal of Water New Zealand – New Zealand's only water environment periodical.
Established in 1958, Water New Zealand is a non-profit organisation.

Ka ora te wai, ka ora te whenua, ka ora ngā tāngata

Helen Atkins
President, Water New Zealand

This is my last column as Water New Zealand president and I would like to take the opportunity to thank my board colleagues, staff, and especially you, our members, for your incredible support for our organisation in what we must all agree has been, 'the most interesting of times', in the Three Waters Sector.

I'm very aware of the huge workload that many of our members are under – working through the need to be engaged with the reforms process, the challenges of workforce shortages, as well as what Covid has thrown at us.

While there is a wide range of views about the reforms as they are unfolding – even amongst our members – there is little dispute about the need for reform. Water New Zealand has been working hard to ensure that as a sector, we are well informed, have the opportunity to have our say, and that we are prepared for the changes to come.

Despite the significant degree of misinformation and disinformation in the wider community, I'm heartened that our members have been genuine and very focused on the need to find workable, sustainable solutions to the future challenges.

The recent first report from Taumata Arowai, the Annual Drinking Water Regulation Report, provides a rather sobering snapshot which would have come as no surprise to us in the sector. Of particular note was the comment:

"From 15 November 2021 until the end of the calendar year (31 December 2021), 209 notifications from 127 supplies were received – including 27 boil water notices. Notifications were from across the country, including from 31 councils. Not all notifications indicate that there is unsafe drinking water – notifications are also received for planned and unplanned interruptions or precautionary notices."

However, as many have said before, we have a unique opportunity to turn these sobering statistics around with this once in a generation reform programme we are facing.

I hope that as the Water Services Entities Bill works its way through the Select Committee, we don't lose focus on why we have embarked on this difficult journey and that we use the process to improve the legislation; for the long-term benefit of all.

As part of this, we must also ensure that our regulatory and governance frameworks will support us as a sector and country, to give effect to Te Mana o te Wai through a strong Te Ao Māori strategy. This will be a big win for our communities and for our environment.

This winter could well be a harbinger of what we will increasingly see in the future – unpredictable weather, record rainfall, flooding, not to mention drought, groundwater contamination, sea level rise and so on.

Our sector is going to be significantly impacted by climate change. We need to take every opportunity to reduce our emissions as well as mitigate and build in climate change resilience. There is no doubt it is the biggest challenge facing us.

However, on a lighter note, one of the highlights of my role as Water New Zealand president has been our conferences. Despite the Covid challenges, these conferences continue to go from strength to strength. And while they are always a key event on the water calendar, they are also one of the most enjoyable and informative opportunities during the year to catch up with colleagues and meet new ones.

I hope to see as many of you as possible at Te Pae in October for our Water New Zealand Conference and Expo. If you haven't registered, you can still do so, but be quick. These are conferences that you don't want to miss.

As I step down as president, but stay on the board for one more year as past-president, I am looking forward to the coming year – a year that will continue to see the momentum for change and much of the mahi around reforms getting closer to fruition.

He waka eke noa
Helen Atkins
President

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If you haven't already registered for the Water New Zealand Conference and Expo 2022, there's still time to join us for what promises to be this year's premier water conference.

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Taumata Arowai

Tāwara o te Wai:
Water New Zealand's podcast series

In the latest podcasts in Water New Zealand's recently launched series, Tāwara o te Wai, we looked at the global crisis over plastic pollution in the world's waterways, as well as how we can better tackle climate change by reducing our CO2 emissions in the water sector.

The plastic pandemic

It's estimated that more than 360 billion tonnes of plastic is produced in the world every year. To give an indication of the explosive growth in production, in 1950, the world produced just under two million tonnes.

Unfortunately we haven't developed the infrastructure to deal with it. This means that if we don't do something to curb our plastic addiction, at least 90 million tonnes of plastic will end up in the ocean every year.

Even if we do manage to reduce plastic production, the best case scenario is a further 53 billion tonnes entering the ocean and waterways.

These are the disturbing facts that Canterbury University PhD student Helena Ruffell highlighted in discussion on Water New Zealand's recent Tāwara o te Wai podcast, the Plastic Pandemic.

In her research on microplastics – the plastic pieces smaller than 5mm – Helena found that a significant proportion of microplastics that comes from householders in the form of sponge fragments, fibres from synthetic clothing and furnishings, and so on, eventually escape from wastewater treatment plants and end up in the coastal environments.

She based her findings on measuring influent and effluent from three wastewater treatment plants in Canterbury, where she found that everyday 240,000 microplastics go out to sea from just those three plants alone – that's 87 million every year.

Yet, microplastics are only part of the picture. The more visible signs are seen in the huge volume of plastic debris and litter that gets washed down stormwater systems and out to sea.

Mike Hannah from Stormwater 360 spoke about management opportunities that can prevent plastic from entering the stormwater networks.

He's been working in California where there has been a wide range of regulations and measures introduced to remove plastic from the system before it becomes a stormwater issue. These include reducing and banning plastic bags, targetting factories to ensure they adopt zero pellet loss, and stepping up street cleaning.

Ministry for the Environment policy manager Liz Butcher outlined efforts to reduce plastic consumption here, including the phasing out of plastics over the next three years.

Steps water professionals can take to improve climate outcomes

In our fourth episode of Tāwara o te Wai, we focus on the biggest challenge facing us today – climate change. This episode looks at the role of individuals working across the design, construction, and operation of our infrastructure to reduce emissions from water assets.

Hosted by Water New Zealand insights and sustainability advisor

Lesley Smith in conversation with Andrew Springer, technical principal wastewater engineer at WSP, Quinton Prinsloo, three waters manager for Fulton Hogan's Central Otago operation, and his colleague, executive divisional manager of infrastructure Hayden Miller, this panel is well placed to speak across the water infrastructure project life cycle, from design to build to operate.

We know that the water cycle is on the front line of changes from our climate, and the impacts are happening sooner and with greater severity than many of us expected. After several postponed recordings with Quinton and Hayden who were kept busy assisting communities with flood damage, the session finally went to air, as Andrew's parents were suffering through Britain's record heatwave.

This episode was driven through the Climate Change group who are working to share knowledge that will help us adapt and mitigate against climate change.

Previous initiatives from the group have looked at corporate case studies, tools, and world views that can help the water sector adapt, available as webinar recordings in the knowledge base of our website.

The group saw a need to turn the lens on the role of individuals as change makers. In this episode we hear what has inspired the sustainability journey of our guests, how they work to inspire each other and practical examples of the changes that can follow to shift the dial on our emissions: for example our excavation methods, enhanced pond operations, and knocking back on diesel.

Listen to our podcasts

You can go to waternz.co.nz, to listen to these podcasts. Here you will also find earlier recordings on Te Mana o te Wai, and Making the Invisible Visible – a look at the stress being placed on groundwater.

Training update:
New digital badge launched

Water New Zealand's recently launched digital badge, Small Water Suppliers 101 (up to 100 supplies), is the latest to join a suite of digital badge learning opportunities.

The badge aims to provide a basic understanding of small water suppliers.

The new online learning opportunity has been developed on a similar format to the other successful digital badge programmes where participants have the flexibility to complete the digital badge in their own time over a four-week period or even complete the four to six hours in one sitting.

Training development manager Mumtaz Parker says by the end of the course, participants will have a basic understanding of the governance, legislative and regulatory frameworks, treatment options, best practice, and the people that work on small supplies.

More than 1000 people have enrolled in Water New Zealand's digital badge learning programmes. Other digital badges include Drinking Water 101, Wastewater 101, Stormwater 101 and Backflow 101.

"The exciting news is that there are more digital badges currently in development. They include Drinking Water 201, SCADA 101, and Sampling 101."

Competency Framework

As well as the digital badge progress, the number of roles in the Water New Zealand competency framework is also growing. Mumtaz says the development of the instrumentation technician role is now in the early stages.

"It's important we get feedback from the sector at all stages of the framework development and particularly at the start."

She says anyone who hasn't been in touch yet can still join the review panel by emailing training@waternz.org.nz

The Water New Zealand Competency Framework describes what people should be able to do and what they need to know to competently undertake their work.

The newest role in the framework relates to small rural suppliers and is currently in its final draft stages and awaiting feedback from Taumata Arowai on acceptable solutions.

Other roles already in the framework include drinking water treatment operator, wastewater treatment operator, drinking water distribution operator and wastewater network operator.

Find out more about digital badges and the competency framework by going to waternz.org.nz.

Regional events back on track

Water New Zealand members have finally been enjoying face-to-face gatherings at regional events around the country following more than two years of online meetings.

Water New Zealand's water groups coordinator Katrina Guy says, while Covid restrictions meant that members became very proficient at webinars and zoom meetings, getting back in-person events has been a welcome development.

Canterbury Regional Stormwater Group

In Christchurch, the Canterbury Regional Stormwater Group, together with CIWEM (The Chartered Institution of Water and Environmental Management) met up towards the end of July to discuss all things stormwater.

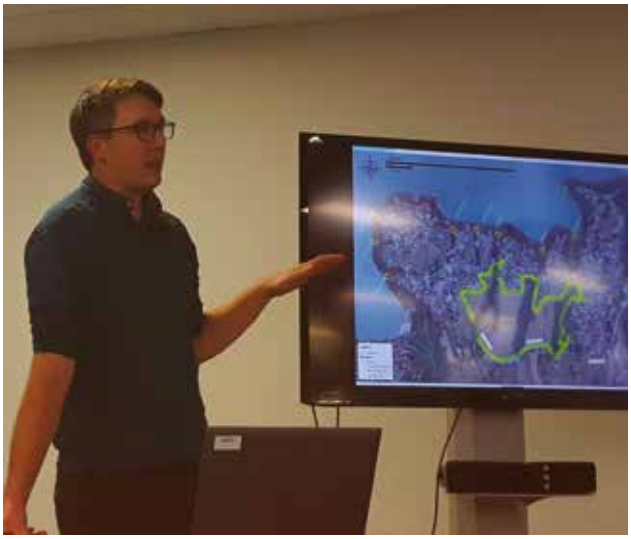
Group chair Peter Christensen shared some insights into the weeks of wet weather in July across the city and Banks Peninsula. It was great to note the reduced impacts of this wet weather due to investment as part of the Land Drainage Recovery Programme. Thanks to Phil Eyles (stormwater lead, National Transition Unit) for engaging with our community of professionals eager to find out more. Phil shared the key elements of the stormwater programme policy framework as well as key transition activities over the next couple of years. Finally, congratulations to Sam Millar for flying solo and presenting on the mahi he has been undertaking for Christchurch City Council. The presentation shared the investigations for understanding and identifying sources of erosion and sediment from the lower reaches of the waterways around Te Waipapa/Diamond Harbour. Sam covered the subject in an engaging and visual way – he even managed to share ideas to support a kete of options to build into future remediation activities across the catchments; a good starting point for the Te Pātaka o Rākaihautū/ Banks Peninsula Settlements Stormwater Management Plan due for lodging in 2023. It was aslo lovely to welcome Water New Zealand's special interest group coordinator Katrina Guy and Allan Leahy, principal – growth planning, Auckland Council Healthy Waters, along with a whole cohort of students from University of Canterbury to this first in-person gathering for quite some time. Roll on November for the next event.

Auckland YWP meeting

The Auckland Young Water Professionals (YWP) committee ran a Q&A panel event for a group of engineering students from the University of Auckland.

The event was designed to develop the students' interest in pursuing a career within the water industry through an open discussion of the pathways and experiences of four panellists from a variety of backgrounds and current positions.

The level of engagement from the students was not only extremely high but the depth of questions and relevance to the current potential effects on the industry around the three waters and reform was a promising glimpse of the future talent coming through.



Far left: Canterbury Regional Stormwater Group event.
Top left: Sam Millar – Christchurch City Council
Lower left: Philip Eyles – Stormwater lead, National Transition Unit

We hope to see the passion for the water industry continue to grow with the students who attended this initial event as the Auckland YWP committee also aims to continue drawing more attention to the industry and the multitude of opportunities it has on offer.

Modelling and Stormwater Group event

Also in Auckland, a great opportunity to catch up with members of the Modelling and Stormwater groups and hear from two great speakers is coming up.

Auckland Council's principal, hydrometric analysis, Kris Fordham, will be speaking on the council's regional rainfall analysis system using gauges, national radar, and vertical profiling radar.

From Stantec, one of the 5S winners for the 2021 Water New Zealand Conference & Expo, Ashleigh Dick, will speak about Young Water Professionals embracing the culture shift in the three waters sector.

This event, sponsored by Hydraulic Analysis, will be held on Thursday 29th September in Parnell. You can register by going to www.waternz.org.nz.

Modelling Symposium – call for abstracts

It's time to start planning and drafting abstracts for the 2023 Modelling Symposium. Next year's symposium will be a long-awaited face-to-face event to be held on 15-16 March at the Copthorne Hotel in Wellington.

Earlier this year, due to Covid, once again the symposium was switched to an online event. So for our modelling members, a 2023 get together will be most welcome.

This symposium is a great opportunity for modellers to meet fellow modellers and keep abreast of the latest developments in this rapidly changing area of water management and design.

Keep an eye on the website, www.waternz.org.nz, for updates.

Conference trade stand winners

Congratulations to the stand winners at the 2021 Water New Zealand Conference and Expo, held in Hamilton in May this year. Winner of the multistand was Pump & Valve; the team pictured above with President-elect Lorraine Kendrick. The team at Techlight, right, took the award for a single stand.

Keeping mum for clean water

We congratulate eight-year-old Sky Wallace for a very impressive fundraising effort to help provide kids growing up in the toughest environments with clean water. Here's her story.

I'm Sky from Oratia District School in Auckland and this is my story of doing the World Vision 40 Hour Famine.

It all started at our school assembly when a teacher went up on stage in an orange t-shirt to tell us about the famine. She said our school was getting involved to raise money for people without water in third world countries. I was so excited!

I asked my mum and dad if I could do it with no eating, but they said no, so I decided to do something even harder – no talking for 40 hours! My challenge started at 8pm Friday and went until 12pm Sunday.

It was really hard not to talk especially when I went to gymnastics and to the ballet with my mum! But I had a whiteboard to write things down.

I slipped up a couple of times but that doesn't change the amazing feeling of making a difference for the kids that need it.

I hope to inspire other kids (and adults) to do this challenge and a big thank you to all the people that sponsored me. I raised $326 – that's enough to give three children long-term clean water from a pump close to their home!

Now it's your turn to get involved: www.worldvision.org.nz/connect/40-hour-famine/

Sky is the granddaughter of long time Water New Zealand member Kevin Healy.

Aurecon team victorious

Aurecon's Young Water Professionals team, 'No Worries Aurie' won this year's Game of Thrones pub quiz held in Wellington recently.

Congratulations to James Johnston, Gabriella Jimenez Rojas, (both pictured), Victoria Ware, Nathan Palairet, Ben McCarroll, Raveen Dias and M Nes for taking the trophy this year.

Thank you to all that took part and we look forward to bringing you the 10th Anniversary event next year.

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Three Waters Reform

Pre-Conference Workshop

Taumata Arowai

One year into the journey – explore the new risk management landscape and find out where the new regulator is heading.

Department of Internal Affairs National Transition Unit

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Interactive discussions at five "watering holes" – asset management, operations, stormwater, people and workforce, data and digital.

Monday 17 October 2022

8.30am – 4.30pm

Te Pae Convention Centre, Ōtautahi Christchurch

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Taumata Arowai

Te Mana o te Wai-hine – **Celebrating Te Wiki o te Reo Māori**

Māori Language Week, 12-18 Mahuru (September) 2022

Nā Troy Brockbank (Water New Zealand Board Member & Pou Ārahi Māori, PDP) rāo ko Aimee Matiu (Pou tokomanawa: Māori Advisory, PDP)

At Waiora Aotearoa Water New Zealand we embrace, promote, and celebrate te reo Māori. This is the fifth year running that we have produced a Te Wiki o te reo Māori poster highlighting the inextricable relationship between Māori and wai.

This year our focus is on 'Te mana o te wai-hine'. We want to help illustrate the important role that wāhine (women) have in Te Ao Māori to ensure the sustained flow of the life-giving waters. It is wāhine who uphold the mana of water, they are the carriers of birth waters, the givers of life, and the kaitiaki of wai.

The poster (pages 15-16) personifies some of the many atua that protect, look after, and empower the transition of water within te hurihanga wai (the water cycle).

The cycle begins high above the sky with the great expanse of waters from Wainuiātea, flowing to the rain clouds of Hine te Kapua, where the sacred teardrop Hine te Ihorangi and the roimata ua (rain) of Hine wai descend to Papatūānuku, our earth mother. She soaks up some of these life-giving waters as rongoa (medicine) and sustenance, infiltrating deep into the whenua (land) to heal her wairua, her wounds and her well-being.

Her remaining waters meander like toto (blood) through her arteries and veins distributing the life-giving waters from upper mountains of Hine tū pari maunga, guided by Parawhenuamea through the flows of Hine wairere across the floodplains to the creeks, streams, and rivers to what is left of the wetlands of Hine te repo prior to discharging to the receiving embrace of the oceans and seas of Hine Moana.

In between it all, is the mist and fog of Hine pūkohurangi, the clutching condensation of Hine wai-tōtā, and the vapour carried back to the sky by Hine wai-etoeto. It is these atua that ensure the connection and relationship of waionuku (the waters of land) and waiorangi (waters of the sky) is maintained.

Wai is taonga tuku iho, a treasured and sacred gift passed down from the atua to us. We must acknowledge and respect the mana of these powerful atua, these powerful wāhine, by protecting and looking after te mauri me te mana o te wai.

Tū wai-Hine! Tū mana!

Ko te wahine kia ora, ko te wai kia rere

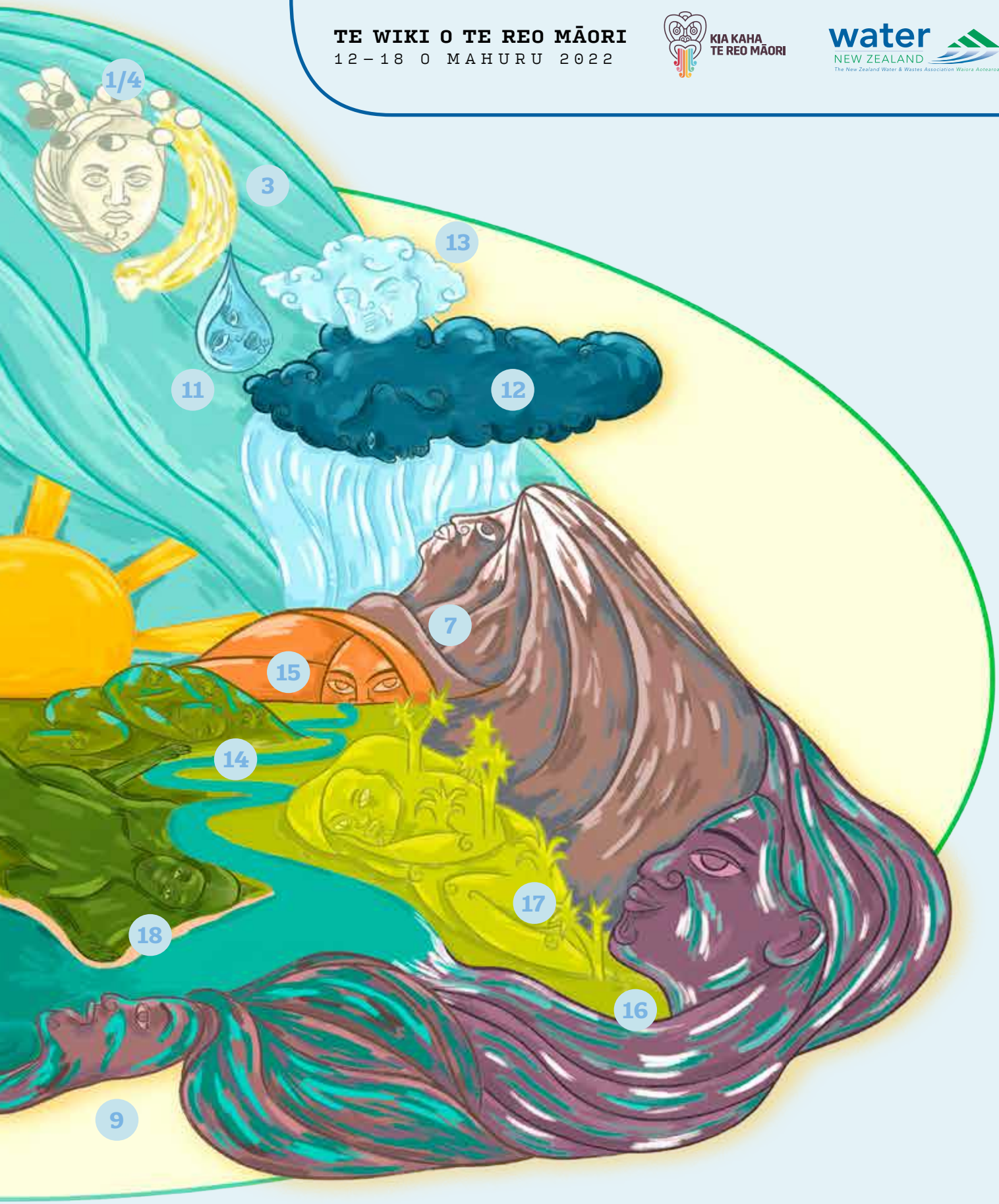
You can find the poster and our earlier ones on our website, waternz.org.nz. Please feel free to download, print, and share.

TE MANA O WAI-HINE

Te waiora o ngā wāhine

THE LIFE-GIVING WATERS OF WĀHINE

1 Hina	*Moon*	**7** Hine-tupari-maunga	*Atua of mountains and cliffs*
2 Hine-pō-ata-rau	*Atua of reflecting moonlight*	**8** Hine moana	*The ocean Atua*
3 Hinekōrako	*Atua of lunar rainbow*	**9** Papatūānuku	*Earth Mother*
4 Rona-whakamau-tai	*Rona the controller of tides*	**10** Hine-te-kapua	*Cloud Atua*
5 Hine-whaitiri	*Atua of thunder*	**11** Hine-te-ihorangi	*The sacred teardrop*
6 Hine-te-uira	*Atua of lightning*	**12** Hine-wai	*Atua of rain*



13 Hine-wai-tōtā	Atua of condensation	**18** Hine-te-repo	Atua of wetlands and swamps
14 Hine-ata haunui	Atua of early morning dew	**19** Hine-huka-a-tai	Atua of seafoam
15 Parawhenuamea	Atua of water that springs forth from the earth	**20** Hine-riko-moana	Atua of sea glare
		21 Hine-wai-etoeto	Atua of evaporation
16 Hine-wairere	Atua of water flow and waterfalls	**22** Hinepūkohurangi	Atua of mist
17 Hine-te-waiora	Atua of life giving waters	**23** Wainuiātea	The great expanse of water

Huge support from membership for submission on reform bill

Expertise and experience from the Water New Zealand membership was a vital ingredient in shaping the industry body's submission on the new Water Services Entities Bill. The new bill sets the framework for the establishment of the four new regional water entities (WSEs) and, as this publication was going into production, Water New Zealand CEO Gillian Blythe and president Helen Atkins presented Water New Zealand's submission at the Finance and Expenditure Select Committee.

In the biggest reform that the water sector has seen in decades, Water New Zealand says safe, efficient, and affordable drinking water and improved environmental performance must remain the cornerstone of the Water Services Entities Bill.

In the submission, Gillian Blythe says the organisation supports the intent of the bill to "ensure effective management of water services delivery and infrastructure so that communities have access to safe, reliable and affordable drinking water and wastewater and stormwater services that meet their environmental and cultural expectations".

Water New Zealand's submission focuses on areas within the current draft legislation that the organisation believes could be improved or adapted to better support and ensure the bill's intent.

For instance, she says the bill needs to be more explicit that water services delivery is retained in public ownership and is not operated for the sole benefit of generating profit.

"The Terms of Reference and scope of the new economic regulator will be important to ensure that the needs of the wider community and environment remains at the forefront of the new delivery system.

"It is also important that the legislation ensures the appropriate level of expertise on the new entities' boards, including knowlege and experience of Te Tiriti o Waitangi and mana whenua perspectives, but also performance monitoring, governance, and appropriate water experience."

However, she says that ensuring more effective and efficient water delivery services will also require a big workforce capability step up within the water entities' workforces.

"Ensuring that Aotearoa New Zealand has the workfore capacity, capability, and skills needed to deliver water services is fundamental and requires greater prominence in the bill.

She says Local Establishment Units and Water Services Entities will need support to build capacity and capability, understand their roles and responsibilities, and ensure they have the tools and resources needed.

The Three Waters sector has suffered from long term under-investment in both infrastructure and workforce capability and there is a risk of a continuing investment hiatus during the transition period.

"We need to ensure that the sector has the confidence and ability to upgrade and innovate during this time."

Looking ahead, the new entity boards will be required to give effect to the council and iwi Regional Representatives Group's strategic and performance expectations as well as any Government Policy Statements.

Gillian says this could lead to conflict over how to manage competing considerations. As it currently stands, there is no guidance on how to reconcile differences between future possible government objectives versus local objectives.

In its submission, Water New Zealand says it is important to ensure that infrastructural innovation and adaptation to climate change and natural hazards be incorporated into the bill's objectives.

As well, collaboration between the four WSEs is fundamental to ensuring that the water services sector operates cohesively across the country.

"Whether a consumer is in a large metro area or a small rural township should not make a difference to the quality of the service and its cost."

She says that although this is referenced in the legislation principles, there ought to be a further requirement that WSEs proactively collaborate with each other.

Water New Zealand would like to thank its many members who gave their time to take part in the discussions and webinars on the submission.

"Our membership represents the biggest pool of technical expertise in the Three Waters sector and it is important that we share that expertise to support improvement across the sector. This reform programme is a critical opportunity to ensure safe effective and efficient water services for decades to come."

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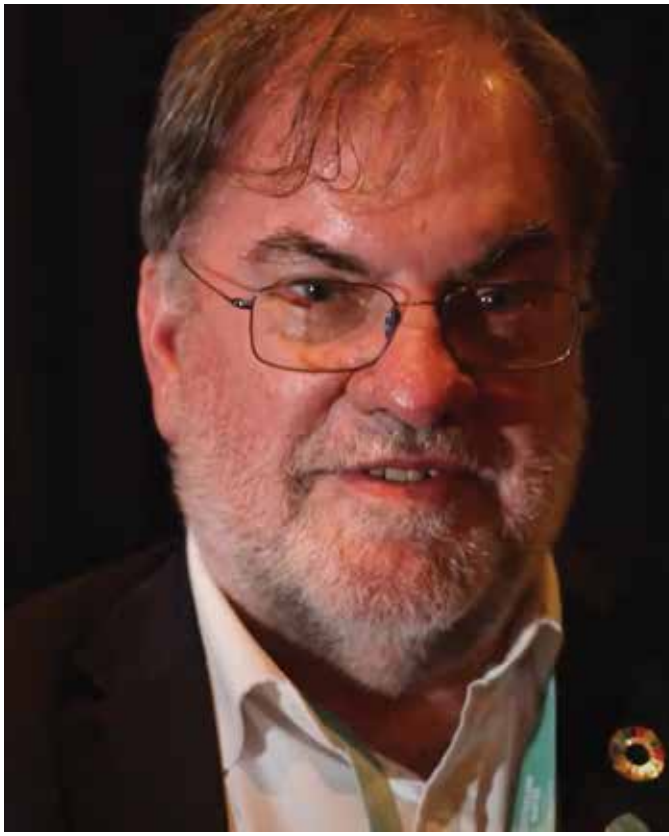

Mark Pascoe

We share the very sad news that Mark Pascoe recently passed away at his Brisbane home. Mark was one of the intellectual giants of the international water industry, and forever a strong advocate of the Australian Water Association and the water industry at large.

His contribution to AWA over the years has been immense but always with great modesty. Mark was a frequent visitor to Water New Zealand events, in both his AWA and International Water Association leadership capacity, and he always made Kiwi visitors to OzWater Conferences and other AWA events feel very welcome.

He was a great mentor for the younger water professionals and always willing to lend a helping hand to those in need.

Mark leaves a significant hole in the water industry both from his physical presence and his intellectual contributions, which were many and varied, and continued right to the end. His life was dedicated to the industry in advocating for it and contributing to bringing new talent into it. He made very significant contributions to the IWA and even more so to AWA.

He will be sorely missed by his family, friends, and colleagues – here in New Zealand, in Australia, and right around the world.

Rest in peace, Mark – your life's work is done and will now be handed over to others.

By Garry Macdonald and Jim Bradley.

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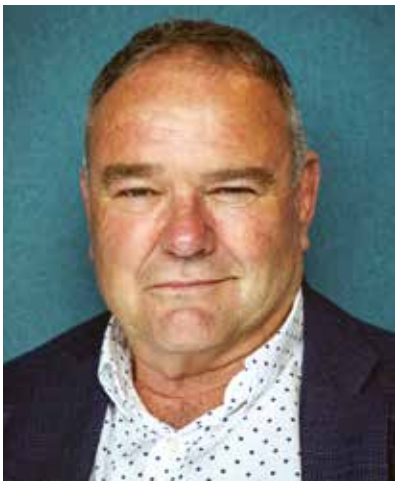
Plenty of time for the registration of **rural drinking water supplies**

Misinformation about the need to register private drinking water supplies is unnecessarily causing stress to rural communities says Bill Bayfield, chief executive, Taumata Arowai. He writes that there is plenty of time for drinking water supplies to be registered and that the system will be simple and affordable.

Many Aucklanders have stories of the summer of 2019/20 when we experienced the worst drought in the region's history.

With water reservoirs running critically low, normally reliable streams drying up, and no rain to fill rainwater tanks, the region was focused on 'looking after' drinking water in a way that it probably never had been before. It really made people think about where their water came from, the reliability of supply, and whether it was safe to drink.

My experience of this drought was at our family bach in Orua Bay on the Manukau Harbour. While most bach owners rely on rainfall or small springs to fill tanks for their drinking water, that summer many of the tanks ran dry!



Bill Bayfield

While we were fortunate enough to be able to draw water from a good spring, other families weren't so lucky, and we ended up making water accessible to other baches that summer.

I recall one woman with young children asking how we knew the water we were supplying was safe to drink, and my gut reaction was to dismiss her concerns. After all, our family had been drinking from the spring for decades and we were 'fine'.

But since becoming the CE of Taumata Arowai, I have re-thought my reaction to our neighbour's query. I realise she had every right to be concerned. She had young children, and it was sensible to seek assurances that the water was safe. I should have taken more care in understanding the health of the water we were providing.

Taumata Arowai was established as the water services regulator in response to the Havelock North incident and inquiry as part of the reform of Three Waters. We are responsible for ensuring New Zealanders who are supplied with water, receive safe and reliable drinking water.

We are committed to Te Mana o te Wai – which is about putting the health and well-being of water first while also providing for the needs of people and communities. In simple terms we think of it as wai ora, tangata ora: healthy water, healthy people.

I am reminded of our story from the summer of 2019/20 because, once again, I am hearing stories about supplying drinking water in New Zealand. But this time the stories are a concern to me because they contain a lot of misinformation and are causing unnecessary alarm in rural communities.

While more than 80 percent of the population gets its drinking water from local councils, there are thousands of smaller supplies on the likes of farms, at marae and papakāinga, schools, baches, and campsites. An estimated 75,000 unregistered drinking water supplies have previously not been included in the regulation of safe drinking water here.

New water safety regulations require many of these supplies to become registered, so we can ensure all drinking water is safe. Something I am sure that woman in Orua Bay would agree with.

Basically, if someone is supplying drinking water to a household other than their own, that supply will need to be registered. Typical examples include farm supply to shearer's accommodation or a staff member's house; an orchardist supplying drinking water to picking gang accommodation, and so on.

Unfortunately, there is rumour and misinformation circulating through rural communities claiming, among other things, that people have to register their water supplies by November 2022, or that they have to install expensive upgrades to their supply to come up to standard. None of this is true.

Unregistered drinking water supplies have until November 2025 to register with Taumata Arowai, with up to three years after that to understand how the rules apply and ensure they are meeting them. Registration won't be a daunting procedure. We'll provide plenty of supporting information.

We are working with rural groups and agricultural sector organisations to create options people can choose from to meet the Drinking Water Standards.

We can use a tool in the Water Services Act that allows us to create an 'acceptable solution'. These provide an alternative option for certain supply types to meet their compliance obligations. This will be a simple, pragmatic list of things people must do that is appropriate for the typically small scale, low complexity and low risks associated with rural supplies.

In the meantime, we simply ask people supplying drinking water to households other than their own to do their best to ensure that water is safe. There is no need to rush to register, or engage consultants or lawyers, or spend lots of money on upgrades to their system.

People and businesses can find out if they are a drinking water supplier and what this means for them at taumataarowai.govt.nz.

Taumata Arowai update

As the water services regulator for Aotearoa New Zealand, we're here to help make sure everyone has access to safe and reliable drinking water every day

The Water Services Act 2021 provides a new regulatory approach for drinking water supplies and introduces some new responsibilities for drinking water suppliers.

Following public consultation, new Drinking Water Standards, Drinking Water Quality Assurance Rules and Drinking Water Aesthetic Values have been published and will come into effect on **14 November 2022**.

Registered suppliers need to submit a Drinking Water Safety Plan to Taumata Arowai by **15 November 2022**. Alternatively, some suppliers may be able to comply with a Drinking Water Acceptable Solution, which are being developed for particular supply types and circumstances.

We're working on finalising the Acceptable Solutions and anticipate publishing these in September 2022.

Me kōrero | Let's talk

Taumata Arowai will be at the Water New Zealand Conference and Expo in October 2022. We welcome your kōrero and questions.

- **Preconference Workshop – Monday 17 October:** Explore the risk management landscape, including Drinking Water Safety Planning.
- **Thought Leadership Session – Tuesday 18 October:** We'll be shining a light on drinking water through data.
- **Keynote Speech – Wednesday 19 October:** Hear from Bill Bayfield, CE of Taumata Arowai.
- **Expo:** Visit our team at the Taumata Arowai Expo stand.

Register for the Water New Zealand Conference and Expo at waternzconference.org.nz.

Find out more about Taumata Arowai at taumataarowai.govt.nz

Wai ora. Tangata ora.
Healthy water. Healthy people.

TAUMATA AROWAI

Taking a leaf from the best of **overseas' water reform**

Boil water notices, burst mains, and unsafe swimming water are hitting the headlines with alarming frequency. New Zealand is living with the consequences of its ageing water infrastructure. Add in having to future-proof water services for a growing population and uncertain climate future, and it's clear the fixes the country so desperately needs won't be quick, easy, or cheap. By Liam Foster, technical principal for water, WSP NZ, and Mike Woolgar, water strategy director, WSP UK.

Luckily, we can benefit from overseas water reform experiences – including in Europe, Israel, Ireland, and the UK, and apply these to our own unique Three Waters context. WSP water engineers have worked and lived through water reform in several different countries. Here's some of what we've learned along the way.

Communicate for community buy-in

We know from Irish Water's ambitious programme of reform in 2013, and more recently with Aotearoa's own Three Waters programme, that how communities receive, perceive, and respond to information provided is critical to the success or failure of large-scale water reform.

The winning formula needs to take account of local specifics. It hinges on developing and maintaining public trust. This comes about with clear and repeatable messages – tailored for and delivered to diverse audiences with a range of interests.

Doing so in an open and transparent fashion almost always translates into good will from the community. So does being prepared to listen and respond respectfully to comments, questions, and grumbles.

Unfortunately, Aotearoa's Three Waters messaging has hit some speed bumps. Somewhere along the line, the core message of safe and reliable water services for the long term that don't harm people was derailed and interpreted by many in the community as 'asset theft' and 'co-governance lunacy'. This, even as one in five New Zealanders currently lack easy access to clean drinking water.

The position of water as a human right, which some take to mean a right to free water services, can cloud the issue and generate lots of heated argument and confrontational positioning. But we know from overseas experience that it's not too late to turn things around and create more acceptance and understanding.

Scottish Water did this well, with messaging that linked cultural identity and pride with the public good nature of water and good environmental management. The latter message landed well, as there had been significant disquiet about the transfer of water services assets into private ownership – as had happened earlier in England and Wales.

Scottish Water's messaging that the water company would remain fully in public ownership, with ultimate control exerted by the Scottish Government and with access to Scottish Government finance, was identified as a critical success factor in making the transition to a national water company.

Scottish Water has continued to successfully manage public

sentiment, with a strong focus on customer service. It has close relationships with the regulators and Government and emphasises collaborative negotiation for the good of the community. Visible efforts are also being made on things that matter to customers like water quality, a flourishing environment and health and socio-economic benefits.

The Scottish Government has been strongly supportive, having several years ago introduced a vision of 'Scotland the Hydro Nation' where water resources are developed to bring maximum benefit to the Scottish economy.

Consistent messaging about community, economic, environmental and health benefits under the direction of the Scottish Government as a public service delivered with commercial efficiency has resulted in high levels of trust from customers.

A 2021 poll showed that over 66 percent of people trusted Scottish Water to look after customer interests – compared to less than 50 percent for water companies in England and Wales. Trust is a hugely important asset – one that Scottish Water spends time and resource to maintain and improve.

Collaborate and innovate for maximum benefit

Setting up a new nationwide water services model requires an early decision on whether the regional provider entities will compete or collaborate.

In England, the industry is privatised and heavily competitive. The Welsh water company is not-for-profit, which lets it work closely and collaboratively with the Welsh Assembly Government and regulators in taking care of the country's water services.

Scottish Water is publicly owned but funded through customer charges. Irish Water is fully Government owned. Following a failed attempt to introduce metering and charging, Irish Water is funded through general taxation. It's financially regulated by an independent regulator and focuses on achieving outcomes at best value for money rather than setting customer bills.

The fully competitive approach can hold providers back from achieving their greatest potential – although at the start of England and Wales's privatisation journey, some innovation was stimulated.

With a public good as important as water, collaboration is almost always the better course of action – for providers and the public. It's about everyone coming together to deliver world-class water services for the benefit of all – no matter who they are or where they live.

We've seen first-hand that regulating for a fully competitive model can stifle fundamental innovation. After years of effort, it's only been in the last two cycles of water reform in England that innovation has started to be encouraged by the regulator through incentives and risk funding. It could be said that this has been a lost opportunity, as it started so late.

Aotearoa New Zealand can turbo-charge the innovation focus of its reforms by letting the delivery entities work in partnership from

The UK's parks and country houses highlight the beauty of water in nature. Opposite: Blenheim Palace, Oxfordshire.

the outset. Innovations could then be collectively targeted to solve the gnarliest water infrastructure issues – from asset performance to delivering on industry carbon promises.

A useful model can be seen in Israel where each year Mekorot – the national water company – lists the issues it's struggling with and invites parties to offer solutions. Applicants 'sell' their ideas, and if Mekorot accepts these, they commit to embedding it in their system for extended trials.

In this way, companies focus innovation on identified problems, and benefit from a platform to trial and improve their ideas. This also helps them to sell outside of Israel if their idea is successful.

While Israel has a single company, there's an opportunity for Aotearoa New Zealand to take a similar approach – with two or more regional companies working together to innovate their way out of issues.

Thanks to advances in technology such as digital twins, innovations in how water assets are run, maintained, and upgraded are increasingly being seen.

Consider the example of Copenhagen, where highly detailed 2D models of drainage assets, above and below ground, are used to understand flooding risk. In the Danish capital, the water company runs near real-time models of its assets to optimise energy use, pressures, abstractions, etc.

Digital can help with the customer's experience of water services, through apps and widgets. It can even be used to involve communities in the build and development of water assets.

Involving citizens in gathering information (such as reporting leaks, sewage flows, other failures or good news) on their smart phones can help gather data and engage customers. Investigating a Snap Send Solve type of app is one way this could be done – although it would need to be well resourced.

Providers that work together to innovate in these ways are likely to experience more and better continuous improvement.

That's no small benefit in an area like water, where technical engineering and service delivery must keep pace with changing societal trends, customer perception and behaviour.

Focus outcomes on the public experience

Ask an accountant what 'good' looks like in a successful water services entity and they'll likely offer up a laundry list of cost and expenditure KPIs.

While delivering efficient and affordable water services is vital, in our experience it's also critical to evaluate the outcomes of water service delivery using human experience factors – things like 'the water I drink or swim in is clean, fresh and free of contaminants'. It's these real-world, experiential metrics that people connect with and value.

Measuring outcomes in this way takes lots of effort. A quarter to a third of the UK water company business, for example, is monitoring and compliance. That info is fed to regulators and onto the general public – helping boost public trust, support and confidence in water services.

Running a safe and efficient three waters system is a complex undertaking. Technical quality of service is often thought of as the be-all and end-all of delivery. Yes, it's important and is where much of the value of the effort should be concentrated. But so too is an unrelenting focus on end users – the everyday people at the end of the taps, and the human factors they value.

Harness talent from near and far

Workforce issues are a critical topic of discussion in the water industry. With an ageing water engineering workforce, demand for extra investment in our infrastructure to meet enhanced outcomes, post-pandemic border opening and increasing technological demands of water management, the sector is facing staffing challenges on multiple fronts.

The new Three Waters entities will require skilled and capable workforces. Kō Wai Tatou has identified that the sector will see significantly increased workloads. They've pointed out that investment in new skills is needed to attract, train, and retain water engineering know-how.

Reviews of the UK water sector point to the need for Aotearoa New Zealand to foresee and avoid some of the cyclical workforce challenges that the UK has experienced since 1991. The cyclical investment behaviours that drive the delivery of five-yearly Asset Management Planning Programmes put paid to the main delivery of effort in the three central years. The start and end of the cycle leads to periods of uncertainty, loss of productivity, and loss of staff through the period of change.

This is a position that Aotearoa New Zealand can ill afford. Better to prepare, now, to make sure our entities have enough highly trained workers to operate the water utilities of today and tomorrow.

A range of approaches can be taken including working with partners across government, water sector associations, community groups and education providers to make sure the water workforce is strong, diverse, resilient and attracts talented individuals. As much as possible, we should do all we can to attract skilled professionals from overseas.

Put it all together, and we're confident that learning from the experiences of what we've seen work overseas will ease the growing pains of what will be our biggest water shake-up in generations.

The authors would like to thank staff from Dyr Cymru Welsh Water, Severn Trent Water, Thames Water, and the Chartered Institute of Water and Environmental Management (CIWEM) for their opinions shared to support this conversation.

The Chartered Institute of Water and Environmental Management

CIWEM, www.ciwem.org, represents and supports a community of thousands of members and organisations in over 89 countries who are dedicated to improving water and environmental management for the benefit of the public.

Its aim is to work towards a safer, more sustainable world. Its mission is to build a global community of water and environmental professionals dedicated to working for the public benefit.

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Striving for **the best**

At the recent Stormwater Conference, Nick Brown, Auckland Council's regional planning manager, healthy waters, was named as Stormwater Professional of the Year. Mary Searle Bell spoke to Nick about the development of his career and his love of all thing's H_2O.

Growing up on the edge of Lake Taupo helped Nick develop an interest in the environment. He spent many hours cycling beside the lake and enjoying water-based pursuits.

"My parents taught me to swim in the lake. Whenever possible, I was in the water, windsurfing, swimming, and kayaking and, during summer holidays in the Hawke's Bay, we snorkelled, dived, body-surfed, and collected seafood."

These idyllic moments and his ensuing love of nature helped shape his career, which started with him choosing to study earth science at the University of Waikato.

The degree integrated many of Nick's strengths and interests – his love of the practical sciences, the outdoors, and the chance to observe and monitor nature in its ever-changing cycles.

He was awarded a national scholarship to complete a Master's degree, researching techniques for optimal water resource use at a hydro power scheme.

When it came time to find a job, the Asian economic crisis was in full swing, making it difficult for a new graduate. So, Nick got creative and made a video about his thesis topic, shooting it in the field, and submitting it as part of his resume when approaching various businesses.

It worked. He was offered a position as a hydrologist with Kingston Morrison (which became Sinclair Knight Merz (SKM)).

Nick began work on an integrated stormwater and wastewater model for Auckland City's Meola catchment, the area where he happened to live.

"Our main modelling focus was on water quality and flooding outcomes which was a forerunner to the first-generation integrated catchment study (ICS) models.

"I remember walking around my neighbourhood at the weekend, observing the freshwater ecosystem and landscape, and feeling energised because I saw how my efforts would really make a difference."

His work was proof of concept to proceed

with modelling all Auckland City catchments.

It was around this time that Nick attended the inaugural meeting of modelling practitioners who lobbied NZWWA (now Water New Zealand) to recognise the value their work was bringing to engineering. Subsequently, a special interest group was formed to support and develop numerical modelling professionals here.

In 2001, Nick was seconded to Sydney Water Corporation (SWC) as one of five specialists employed to model the performance of the city's wastewater network, in an effort to reduce the detrimental effect wastewater overflows were having on beach and coastal water quality.

"We created and built trunk wastewater models to predict system performance now and in the future."

With the SWC project complete, Nick moved back into the folds of SKM as a senior engineer in the Sydney office. There he became part of a multi-disciplinary team working on the maintenance, operations, and upgrade opportunities for Sydney Water's largest wastewater network.

"This is where I learned all about the mind-blowing costs of infrastructure and managing construction cost escalations and optimisation across networks."

In 2004, he saw a vacancy for a modelling team leader within Auckland's North Shore City Council infrastructure planning unit. It was exactly the position Nick was after, so he headed back across the ditch.

"The council was focused on outcomes for the community and made extraordinary progress. It was all about sharing best practice and there was a real alignment of values from the top down – brilliant people doing brilliant work. It was an exceptional culture to be a part of.

"I lived in the area, and as an added bonus I was able to kayak from the upper East Coast Bays to my workplace in Takapuna and home again."

Nick is proud of the accomplishments of the NSCC team, who significantly reduced wastewater overflows and enhanced the water quality of the North Shore's popular beaches, making them safer for swimming.

"Part of my role was to develop innovative specifications to assess the performance of water, wastewater, and stormwater systems. I pioneered the use of two-dimensional modelling techniques taken from coastal analytics and applied them for the first time on land to calculate rapid flood assessments.

"This method continues to be used nationally and internationally. My team was responsible for creating floodplain maps where there were none before, mitigating flood risk for the community."

When Auckland's eight councils amalgamated in late 2010, Nick chose to move into the stormwater team as the stormwater hydraulic modelling manager.

A significant coastal storm in early 2011, followed by a big rainfall event only a week later, brought the city's flooding weaknesses into sharp focus. The two natural hazards laid the foundation for the development of a LIM programme that clearly identified flooding threats to properties.

"Those events really got the ball rolling. At amalgamation, only 20 percent of the region's people knew their properties were exposed to flood risk. We took this to 100 percent in under three years – a huge achievement."

A restructure in 2014 saw Nick's role evolve into flood planning manager. The creation of Auckland Council's Unitary Plan followed, providing an opportunity to reduce the impact of flood risk within the region.

He provided evidence to the independent unitary plan hearings panel which resulted in the inclusion of objectives and rules to improve the community's resilience to natural hazards. Now, development cannot increase flood risk and all newly developed areas are built outside of flood plains.

"We've made a massive improvement to the rules of the unitary plan, but we have a lot more to do to actively reduce risks from natural hazards, particularly given we are living with a changing climate."

Thanks to monitoring system innovations and greater access to rain gauge and radar data, Nick's team now have comprehensive knowledge of where the region's rainfall hits and whom it is affecting as it occurs. Previously, the analysis of this information took many hours.

"We've gone from understanding rainfall at 84 rain gauge sites across Auckland to 20,000 virtual sites, thanks to radar."

Since 2017, Nick and his team have also focused on water quality issues across the city.

They realised that with the information they held from monthly water samples, they could predict when the water at various Auckland beaches was going to be poor quality. The development of 'Safeswim' got underway, a data-based programme which empowers the community to make risk-based decisions about swimming at their local beach.

Safeswim has since expanded and is now the platform used by Surf Life Saving New Zealand nationally for beach safety information.

In his current role as regional planning manager, healthy waters, Nick is responsible for the on-going development of the Freshwater Management Tool, which predicts current and future water quality, and costs to remediate and improve human and ecosystem health.

"Historically, water quality information has been sparse and available from limited locations.

"My goal is to understand water quality in detail across the entire region, so we can understand the issues and costs to meet the community's aspirations for water quality outcomes.

"I want to know exactly what's in our water – pathogens, metals, nutrients, emerging contaminants – everything."

"The Freshwater Management Tool will allow us to map and understand the existing state of our waterways and lakes, as well as predicting their future state, and will help the region make optimal decisions around investment and planning."

Not only passionate about water, Nick is keen to share his knowledge across the industry and is a driving force in the advancement of stormwater management. He's a member of the NZ Rivers Managers Group, has authored and co-authored over 40 papers, and has given keynote addresses and presentations at many conferences.

On earning the top industry award this year, Nick says he felt humbled to be acknowledged amongst so many talented professionals.

And while there is still plenty of work to do, he believes the future looks bright.

"While some of the existential challenges we face with climate change, pollution, and natural hazards may seem daunting; with tenacity, creativity and collaboration, nothing is unsolvable.

"Looking back, I'm proud of the progress we've made already, and every step forward is a step in the right direction."

Building a career

Battling the odds, Huia Anderson is carving herself a career in the water industry. Her determination and positive attitude were recognised when she was named Water Trainee of the Year at the recent Water Excellence Awards. By Mary Searle Bell.

At 33 years old, Huia is older than most trainees, but perhaps this is why she has proven to be a standout for her employer, the Taupo District Council.

Kevin Sears, who is Three Waters operations manager at the council, nominated her for the Trainee of the Year Award because of her enthusiasm and commitment to her role, and the speed at which she is gaining certification in both water and wastewater.

"Huia is a great example of how you can turn your life around and make something out of it if you commit to it," he wrote in his nomination.

He says that for Huia, life as a solo mother of three young children is a challenging one.

Huia Anderson

After leaving school at 15, Huia tried a variety of different jobs, from admin to hospitality to manual labour, but nothing excited her.

However, things changed dramatically five years ago.

"My youngest had started daycare and it was time to find work," she says. "I didn't want a cleaning job – I wanted a career."

So, she signed on to a course to help her find employment.

"My tutor had a friend in the industry who said there was a cadetship at the council. He thought it would suit me, and it had lots of potential for growth."

The cadetship was a three-year fixed-term contract in the water treatment team. After just two years, Huia had breezed through the NZ Certificate in Water Treatment L4. She is now studying for the NZ Certificate in Wastewater Treatment.

Subsequently, she was offered a full-time position as a relief operator in the council's asset renewals team. Here she did condition assessments on the council's water and wastewater assets, along with its thermally heated swimming pools.

"In 2018, we had a big upgrade to one of our pools when the geothermal bore was changed out. The old bore had reached the end of its life and we had to tweak the plant to run off one bore until the new bore was brought online.

"The pipes were all very old, so it was 'all hands on' adjusting operations to ensure the pools remained open while the bore was being replaced. We learnt a lot about what to do and what not to do!"

Another memorable project for Huia was when a wastewater spill into the lake meant working with others to collect samples twice a day at different points along the lake and river until the issue was resolved.

"Just being part of a big team helping that process was great."

Huia is trained in relieving for both water and wastewater operations, which Kevin says is quite an achievement in itself as Taupo District Council has 20 different water plants, comprising a mixture of UV, membrane, and standard gas chlorination plants, and 10 different wastewater plants, which are a mixture of SAF, MBR, SBR and conventional anaerobic digestion, and trickling filter plants.

Huia says her current challenge is learning the processes of the new treatment plant recently commissioned at Kinloch, as it is different from all the rest.

However, this is just another challenge that Huia will take in

stride – Kevin says she is adaptable and handles everything that is sent her way.

"She has become an outstanding team member and has the potential to take on leadership roles in the future," he wrote in his nomination.

And that future is already here – with Huia moving into a wastewater team leadership role in July.

"I'm getting right into wastewater," she says. "I don't really have a preference between water and wastewater, although at least water is clean. However, wastewater is more of an art – getting the balance of bugs right is essential, whereas with water, you just want to kill them all."

With that in mind, once she finishes her final two units to complete her wastewater ticket, she has plans of achieving a wastewater diploma.

In addition to her study and work, Huia has been the health and safety rep for the water team for the past five years – Kevin says she has been instrumental in reviewing and testing many of its procedures and getting these approved by management.

"She sets a great example in the health and safety space and has stopped a job because the appropriate procedures were not being followed even though she was the junior staff person on site. When she wasn't listened to, she backed off and reported it to the treatment manager who then acted."

Huia credits Frank Allison, a water titan who was with the council for 45 years until his retirement, for his influence on her work, along with her water and wastewater treatment manager Shannon McMillan.

"Frank always took the time to answer anything I asked, and helped fill the knowledge gaps. Shannon has vast knowledge in water and wastewater and is always so helpful."

With a range of experience of her own, Huia now mentors others.

"She regularly helps and guides her fellow trainees with their qualifications and if it wasn't for her guidance and patience, others in the team have said they would really be struggling to complete the qualifications. She encourages others to persist and gives them a gentle nudge when needed to keep them motivated to complete the course," writes Kevin.

"She excelled as a cadet, launching herself into every opportunity she was given with enthusiasm and commitment, and has continued in her current permanent role in the same way. We have seen her confidence grow in all areas and she has become a highly valued member of the team."

Huia has some simple advice for others thinking about starting a new career: "Don't doubt yourself."

And she highly recommends the water and wastewater industry: "It'll never be boring – you'll always be learning as things will always be changing. No two days are the same. I love coming to work."

water
NEW ZEALAND
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KEYNOTE SPEAKERS INCLUDE:

GEORGE HAWKINS,
Founder and Chief Executive,
Moonshot LLC and
Moonshot Missions

George launched his innovation-focused enterprises after stepping down as CEO and General Manager of DC Water, where he served for eleven years. George transformed DC Water into an innovative enterprise while tripling its investment in clean water.

George helps agencies identify and adopt strategies to deliver better service and lower cost.

George serves on the National Infrastructure Advisory Council, which advises the White House. He is an advisor to Xylem, Inc. and is an Executive in Residence for XPV Water Partners. George serves on the Board of the North American Electric Reliability Corporation. He has served as a Senior Lecturer at Princeton University and an Executive in Residence for American University.

BILL BAYFIELD
Chief Executive,
Taumata Arowai

Bill joined Taumata Arowai in May 2020 as Establishment Chief Executive and has guided the organisation through "going live" and the beginnings of establishing their new regulatory system.

Previously he served over a decade as Chief Executive of Environment Canterbury and previously as Chief Executive of Bay of Plenty Regional Council. He was also Group General Manager at the Ministry for the Environment, with responsibilities for climate change and waste policies of Aotearoa and held senior management roles in the Taranaki Regional Council.

HON NANAIA MAHUTA
Minister For
Local Government

As a mother, and a constituent MP with 20 plus years' experience who has come from 'flax-root' politics, Hon Nanaia Mahuta remains connected to the aspirations of people from all walks of life.

In Parliament, Nanaia has supported policies and initiatives that built the capacity of communities, greater investment in education, employment and training opportunities particularly for young people.

Nanaia is a tribal member of Waikato-Tainui, Ngāti Maniapoto and Ngāti Manu and her parliamentary experience has enabled her to contribute to the collective aspirations of Maori and all New Zealanders.

In the 2020 Labour Government, Nanaia became the first woman to hold the Foreign Affairs portfolio. She is also Associate Minister for Māori Development.

KEYNOTE: GAIL TIPA WATER FLOWS AND WHĀNAU PERSPECTIVES

Gail's whakapapa is to Ngāi Tahu, from the South Island of New Zealand, and she is an active member of Te Rūnanga o Moeraki.

She has a master's degree in Resource and Regional Planning and has completed a PhD focusing on environmental co-management of freshwater from an indigenous perspective.

For the last 20-plus years Gail has worked on freshwater projects mainly for the benefit of Māori. Her focus recently has been on developing practical tools for Māori to use to aid freshwater decision-making. More recently she has worked with Māori to undertake cultural flow preference studies to help Māori identify the flows they believe necessary to protect their cultural rights and interests.

She has held governance roles within Ngāi Tahu and Crown organisations and continues to hold responsibilities for resource management on behalf of Te Runanga O Moeraki.

In 2021 Gail received the New Zealand Order of Merit for services to Māori and environmental management.

CONVERSATION WITH SIR TIPENE O'REGAN AND GILLIAN BLYTHE

(Pre-recorded conversation)

Sir Tipene O'Regan is a former long-serving chairman of the Ngāi Tahu Māori Trust Board.

He was a major architect of the Treaty Fisheries settlements of 1989 and 1992. In 1994 he was made a Knights Bachelor.

Sir Tipene led the Iwi's successful land and sea fisheries claims before the Waitangi Tribunal, culminating the Ngāi Tahu Treaty Settlement of 1998.

He co-chaired the Constitutional Advisory Panel (2012-13) which reported on public views on, and aspirations for, constitutional reform in New Zealand.

In addition to his many other roles, he is the Upoko of Te Rūnaka o Awarua and chairman of Te Pae Kōrako, the Ngāi Tahu Archive advisory committee.

In 2022 he received the national accolade as New Zealander of the Year Award – Te Pou Whakarae o Aotearoa, and was appointed a Member of the Order of New Zealand – the nation's highest honour - for services to New Zealand.

KEYNOTE: ZIENA JALIL – BE THE CHANGE YOU WANT TO BE

With a career ranging from diplomat to business leader to entrepreneur across New Zealand and Asia, Ziena draws on a rich experience of many worlds to bring equity and opportunity to those with diverse cultures, abilities and experiences.

A staunch advocate for diversity, equity and inclusion, Ziena regularly speaks and writes about diversity-related issues, including publishing internationally in the book Workforce Diversity: Global Perspectives. As a young(ish) Kiwi Fiji Indian woman, Ziena identifies as much with Asia as she does with the Pacific.

She has helped some of New Zealand's largest businesses build their reputation and revenue, advised Ministers, and supported the growth of Māori and Pacific young people in professional careers.

Ziena is a board member of Manukau Institute of Technology, Unitec, Asia New Zealand Foundation, DNA Design, the Cancer Society Auckland Northland and the board of Education New Zealand.

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TAUMATA ARowai

Major test as Central Interceptor project ramps up

Watercare's giant tunnel boring machine (TBM) building the Central Interceptor tunnel is more than two kilometres into its 14.7 kilometre path from Māngere Wastewater Treatment Plant to Grey Lynn and is currently 35 metres underneath Ambury Regional Park.

It is expected to begin crossing underneath the Manukau Harbour in September. But before then, Watercare's project engineers and Ghella Abergeldie JV (GAJV) construction teams are facing another major test: installation of cascade drop shafts.

The drop shafts will create 'mini waterfalls' which reduce the energy of wastewater as it transfers from the existing surface network into the new deep Central Interceptor tunnel and link sewers. (And at depths of up to 75 metres, they really are deep!) Without them, the tumbling wastewater would damage the sewer tunnel.

The cigar-shaped cascade drop shafts are made from fibreglass reinforced plastic. The first 10 modules arrived in February: each one is 12 metres long, 3.5 metres in diameter and weighs up to 22 tonnes – some of the biggest ever seen in New Zealand.

Watercare Central Interceptor lead engineer link sewers Stephen Grace says the first installation took place at Keith Hay Park, Mt Roskill in July: "It will be a great feeling to get the first one in place. Years of preparation have gone into designing these drop shafts and working out how we're going to install them into position."

Each drop shaft will be built beside existing overflow structures from the combined sewer network. In heavy rain, they discharge into urban streams, such as Meola Creek, which runs between St Lukes and Mt Albert.

The construction of the Central Interceptor will see a massive improvement in water quality in these waterways. But the location of these engineered overflow points (EOPs) in parks and floodplains constrains the shafts' layout.

The shafts range from three to 10.8 metres in diameter, with a special dual-cell 'peanut' shaft within the new pump shaft at the treatment plant. This has a depth of 26.4 metres and is 12.4 metres in diameter.

Overall, shaft construction is progressing well, with eight already excavated to full depth (including the two shafts at Māngere

Watercare's Stephen Grace beside a working model of a cascade drop shaft.

Pump Station), and more to be drilled later this year.

Watercare Central Interceptor executive programme director Shayne Cunis says the shaft design is a critical element to the success of the project.

"While the focus is often on the tunnel, how we convey the wastewater and stormwater into the tunnel is a particularly challenging element, due to the size and scale of the works.

"I'm really proud of the way the team has worked together to develop innovative solutions."

Drop shaft design

Watercare already has several drop shafts, including the Rosedale outfall cascade drop (DN6000) and three vortex drops (DN450, DN900, DN1200) on the Hobson Bay tunnel.

For the Central Interceptor, most of the shafts will be cascades, just two are designed as vortex drops (May Rd B and Western Springs). Both designs have their disadvantages and their benefits.

Vortex drops have limitations at the required depths – beyond 50 metres depth, the vortex core breaks down and wastewater freefalls to the base of the shaft, reaching terminal velocity and potentially causing damage over time.

However for the one site that exceeds this depth, it was decided this was an acceptable risk, given the small flow volumes to be discharged at these two locations, and only one shaft is more than 50 metres deep.

The vortex drop shafts have the additional precaution of a stainless steel, anti-erosion plate at the base slab of the shaft.

The larger shaft volumes at these two locations act as deaeration chambers. Corrosive gases are drawn down the tunnel by mechanical ventilation to be treated at air treatment facilities.

Most of the shafts are designed as cascade drops which have more benefits over vortex drops.

The cascade drop shaft design consists of a cylindrical shaft with an (almost) central dividing wall and multiple shelves


Central Interceptor Tunnel Boring Machine resumes work.

purposefully spaced to ensure unimpeded flow. Under each shelf is a vent port, that equalises pressure within the shaft as the flow rate varies.

The first two Central Interceptor cascade shafts to be installed have a three metre internal diameter and are 69-75 metres deep.

The benefits of a cascade shaft at these depths include:

- Reducing permanent works footprint: no special inlet structure is required at the surface.
- Dissipating influent energy, by spacing shelves no more than 2.5 metres apart.
- Reducing the level of air entrainment (de-aeration chamber and vent shaft are not required).
- Offering opportunities for access for maintenance inspections down a single shaft.
- Catering for a wide range of influent flow rates.
- Largely self-cleaning but will flush clean during storm events.
- Can be installed directly over the tunnel (significantly lower construction costs).
- Reducing surge effects (the shelves are designed for uplift during surge events).

Each shaft has been hydraulically optimised, but in the interests of constructability, sizes have been standardised to allow for manufacturing and construction cost efficiencies.

The wet side transfers the flow from the surface to the deep tunnel via alternating shelves, each occupying a quadrant of the shaft but vertically offset from each other. The capacity of each shaft is determined by the shelf length.

The accumulation of debris and odd shaped objects was considered in the shaft sizing and shelf spacing. The shelves originally had a one percent crossfall, but through design development this was deemed unnecessary.

To minimise air entrainment the lowest shelf is either at right angles to the flow direction or facing upstream.

Innovations include the use of an offset dividing wall and placing the cascade shafts directly over the tunnel or link sewer centre line. The hydraulic performance of these innovations was confirmed by physical modelling at the University of Auckland Fluids Lab in 2015.

Shaft excavation

The preferred method of ground support is secant piles through the soil layers; with rock bolts and shotcrete once into the bedrock (East Coast Bays Formation sandstone).

In some locations, basalt must be removed before the piles are installed and shafts can then be excavated via core drilling using a large piling rig.

Some of the smaller diameter shafts are drilled from the surface, with the excavated hole supported by bentonite slurry.

First, a pilot hole is drilled to the bottom of the shaft using 950mm diameter drilling tools and filled with bentonite. Then five 1200mm diameter holes are drilled around the pilot hole to remove spoil.

Next, the 4.2 metre diameter reamer is installed on the rig to enlarge the shaft to the required diameter. The Liebherr LRB355 is used for the entire drilling process – the largest piling rig in the country.

Two different systems are used during the pilot hole and drilling operations to control the verticality of the shaft to ensure

the permanent liner can be installed smoothly and safely.

The Jean Lutz's PRAD system is used during drilling and is fixed onto the Kelly bar. Every time the auger returns to the surface, the operator receives the information and then makes the adjustments to maintain the hole verticality.

The Shape system is used every five metres to scan the sides and confirm verticality is within the required tolerance, which is to be 1:200 for all the shafts.

Through taking it slowly and carefully the first shaft was well within this tolerance.

Fibreglass Reinforced Plastic (FRP) liner manufacture and installation

Most shafts will be lined with a pre-fabricated FRP liner, manufactured by RPC Technologies, a global leader in the design of fibre reinforced composite materials.

Seven shafts are currently planned to be lined with the FRP system which comes to site virtually complete and only needs to be bolted together as it is inserted into the pre-excavated hole. Liner components are prefabricated at factories in Indonesia and Australia.

The exterior cylinder is composed of polyester fibres impregnated with resin and wound onto a large mandrel, whereas the shelves and dividing wall sections are a composite FRP material with an Armacell PET foam core.

An erosion resistant HDPE layer is bonded to the top surface of the shelves.

The liner is fitted with lifting trunnions to support the modules as they are lowered into the excavation. They will be assembled vertically and progressively lowered into the pre-drilled shaft, supported by bentonite. This not only supports the excavated hole but also helps to make the assembled weight of modules (almost) buoyantly neutral.

Once installed, the FRP shaft will be grouted to full depth.

After the TBM passes under the shaft, the precast segments will be removed from the tunnel crown to access and remove the shaft encasement. Then the temporary FRP domed shaft base can be removed to install a transition piece with O-ring seals to connect the shaft to the tunnel.

Operation and maintenance

Manned entry into the tunnels will be rare, due to the extreme depth of the drop shafts and safety concerns regarding long traverses between shafts.

Hatches have been provided in shaft roof slabs to enable CCTV inspections. Cameras or drones can be lowered down the dry side of the shaft, and the wet side inspected through the DN300 vent port.

Current robotic technology can survey the link sewers, and it's expected to continue to evolve to meet the requirements of the main tunnel.

However, at some stage in the tunnel's 100-year life, it is possible that manned inspections may be required. In this event, most of

the shafts have been designed to permit entry via the dry side of the cascade drop, which is sized to allow a 1500mm x 900mm man-cage to be lowered into the shaft.

At three locations larger hatches will permit inflatable or amphibious vehicles to be inserted, with the maximum spacing between access shafts being four kilometres, but typically only one kilometre.

Where tunnel access isn't required, the minimum size of the dry side is determined by the need to convey air.

Some of the drop shafts are only 30 metres from residential properties, so Watercare engaged Marshall Day and Associates (MDA) to take night-time noise measurements at the existing Rosedale shaft. This shaft is in an industrial zone with an open grille above ground level.

By contrast, the Central Interceptor shafts will be mostly buried or flush with the ground surface and sealed to the outside atmosphere.

After allowing for acoustic loss in the air ducts and dampers, the noise generated was assessed as an average 25 dB(A), with a range from 18 to 37 dB(A). Auckland Council's permitted activity rules require a maximum night-time noise of 40 dB(A).

Watercare acknowledges Jacobs and its subconsultants, AECOM and McMillen Jacobs, who have provided the hydraulic, pneumatic, corrosion and programme management services.

Also, Ghella-Abergeldie JV, whose team includes Arup, RPC Technologies and CLL. They have all played a major part in the design, manufacture, and installation of the FRP drop shafts and we thank them for their expertise and dedication to this project.

Written by Stephen Grace, Antoine Foulon, and Maxine Clayton, Watercare.

Hiwa-i-te-Rangi Tunnel Boring Machine gets going again.

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A hard rain's a'gonna fall

Climate change means more intense storm systems are on their way. Science can't stop it raining, but it can help communities prepare for the worst and plan for the future. NIWA's Jessica Rowley travelled to the West Coast to see what that means when the storms roll in.

Dorothy Burrows is the epitome of 'Westport born and bred'. In her eighties, she's lived in the West Coast town all her life. Her house has been in the family for over a century.

"When I was knee-high to a grasshopper, I can vaguely remember visiting my grandparents here. They inherited it from my great-grandparents. But it was just a small cottage back then."

Like a decades-long game of Lego, the house has had something added to it by each generation.

"When we moved in, we fitted the aluminium windows, built the deck, and put on a new roof. Everybody has contributed."

But on the evening of 15 July 2021, storm clouds rolled in, and Dorothy started to hear an ominous 'pitter-patter' on her roof.

Over the next three days, 690mm of rain plummeted down on the West Coast. The Buller River swelled, and a flood of almost biblical scale descended on Westport.

More than 2000 residents were evacuated, and 127 houses left uninhabitable.

Dorothy's home didn't stand a chance. In a matter of hours, a sanctuary that housed generations was ruined.

"When we came back to the house after the waters receded, I opened my kitchen drawer where our cutlery was kept, and water just poured out of it. We've had weddings here, funerals, anniversaries, birthdays, you name it. That's all gone now. It's not a home anymore."

Like death and taxes, floods are an inevitable part of life in New Zealand.

Floodwaters almost a metre deep swept through Dorothy Burrows' Westport home in July last year.

PHOTO COURTESY OF: STUART MACKAY

They're our most frequent natural hazard.

The power of water can be devastating – just half a metre of water will pick up and carry the largest of vehicles. When moving at 40 kilometres an hour, 15 centimetres of water has the pressure equivalent of wind blowing at 1270 kph.

Insurance Council figures show floods cost a record $248 million last year.

With around two-thirds of the population living in flood-prone areas, the health, homes, and livelihoods of hundreds of thousands are at risk. There are also major implications for infrastructure and the economy.

The people of Westport know this all too well. The same day that Dorothy started to hear rain start to fall, Westport's then Civil Defence controller Bob Dickson had been looking at forecasts from NIWA showing a monumental amount of water was on its way.

The following day he recommended a civil emergency be declared. Next came the agonising decision for mandatory evacuation.

Bob ordered people out of their homes, pushing them to seek higher ground, stay with friends or family, even sleep in their cars if they had to. It was the right thing to do.

The next morning, NIWA environmental monitoring technician Mike O'Driscoll raced up the bulging Buller River in his jetboat.

Using a radar gun, he measured its water

flow. A reading flashed on Mike's screen, and he knew immediately things were bad: 7640 cubic metres per second – the country's largest river flow measurement ever recorded.

That water was plunging down the gorge towards Westport, coinciding head-on with the high tide.

Bob's decision saved lives. But how did he come to it and how do you calculate flood risk?

The process for forecasting a flood hasn't always been exact.

"Down by the Buller Bridge, there's an old swing that we used to use. It's got a couple of markers on it, so when water got to a certain height, we knew we were in trouble. It's unscientific, but it helps," says Bob.

To really help communities during these momentous events, however, we need to throw in the best that science can offer.

Flood risk is a hyper-localised measurement. Even next door neighbours can have different flood risk ratings. Predicting the precise extent, location and potential damage of floodwater takes data; a lot of data. Elevation of the land, soil type, building materials, vegetation, and proximity of people to water sources are just some of the factors that need to be considered.

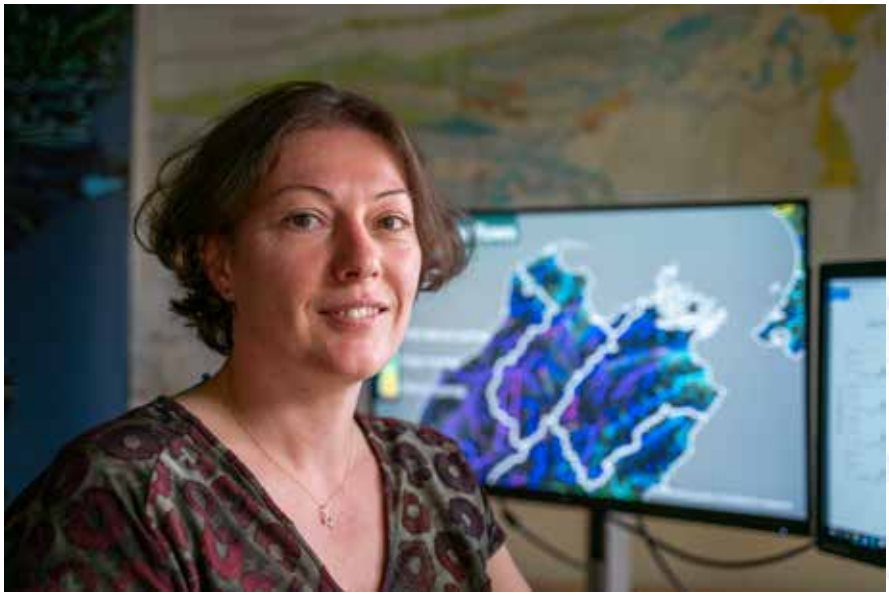
In July last year, this information, amongst a barrage of other data points, advice, warnings, and worries, was being channelled to Bob and the anxious, sleep-deprived team at the West Coast Regional Council.

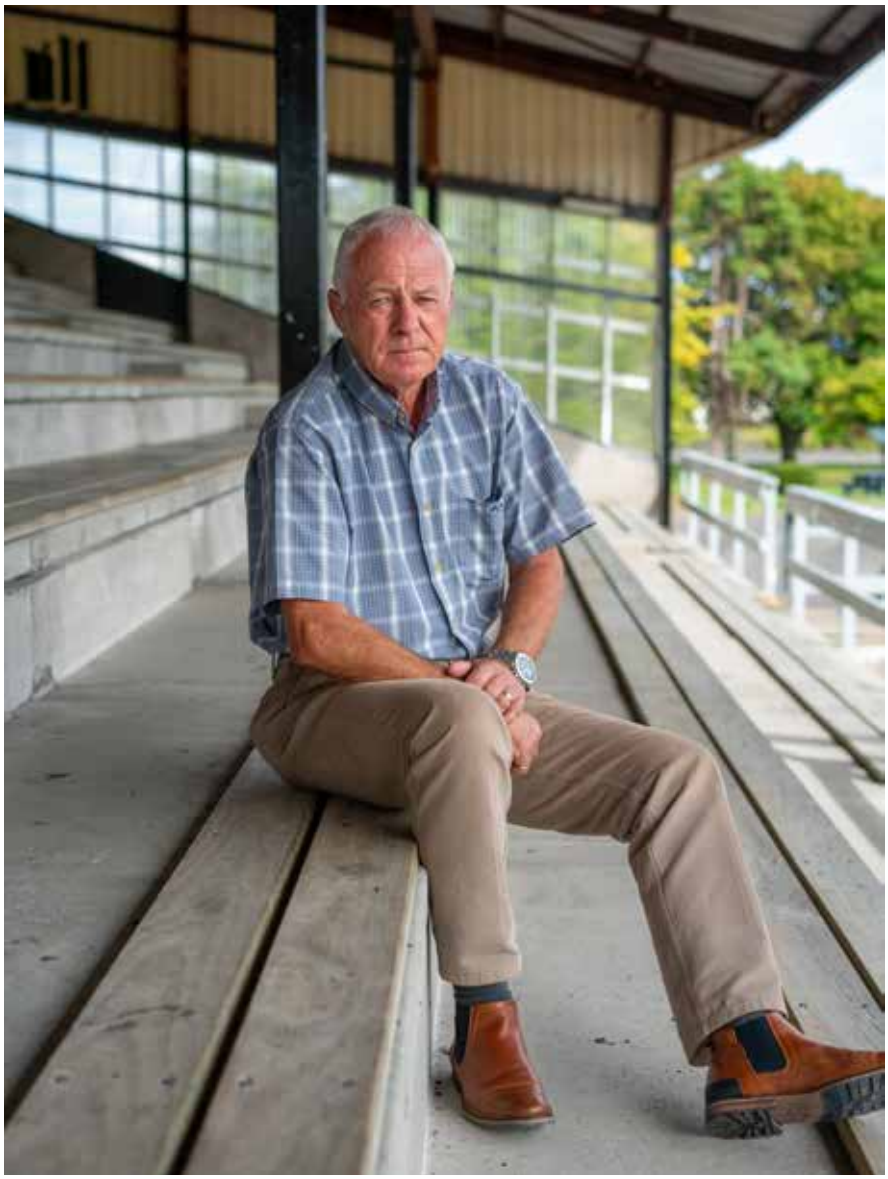
NIWA's national flood awareness system played a key part in helping to decipher that deluge of data.

Dr Céline Cattoën-Gilbert is a hydrological forecasting scientist with NIWA. From her office in Christchurch, Céline and her colleagues were helping Bob and the regional council make calls on how to deal with the events that were unfolding.

Céline is fine-tuning a national river flow tool that combines high-resolution rainfall forecasts with detailed catchment data. The tool models flows for close to 50,000 rivers across the country.

"Luckily, we had been working with the West Coast on river forecasting just a couple of months before last year's flood. When the weather came in, we were able





Top: Dr Céline Cattoën-Gilbert is working to develop an early flood warning system for Westport.
Above: Westport Civil Defence Controller Bob Dickson.

to provide information from real-time data about how, when and where the flood was likely to happen, giving us a high-resolution forecast up to 48 hours in advance.

"Usually, river gauges only give the town 1.5 hours' notice to evacuate. We were able to help with decision making and get people out much earlier," she says.

For Bob and his team, it was invaluable.

"The advice we were receiving around the modelling and predictions matched, almost to the letter, what was happening on the ground. It was great science to have in our back pocket.

"It gave us peace of mind about the decision we made to keep ahead of this event and to get evacuations underway. We have quite an elderly population and people with their own unique medical problems; there is an old people's home that we were ready to evacuate, which would have caused significant difficulties. Luckily, the modelling showed that we didn't have to.

"This town has been through a hell of a lot. That science supporting our decision making is so critical, and working with our colleagues at NIWA and the regional council proved to be an absolute bonus. It's first class."

This flood forecasting work feeds into a much larger five-year, NIWA-led, multi-partner research programme to map flood hazard and risk consistently across the whole country.

Called Mā te Haumaru ō te Wai, the programme will investigate the vulnerability of communities, buildings, and infrastructure networks, along with the long-term sustainability of flood schemes and defences.

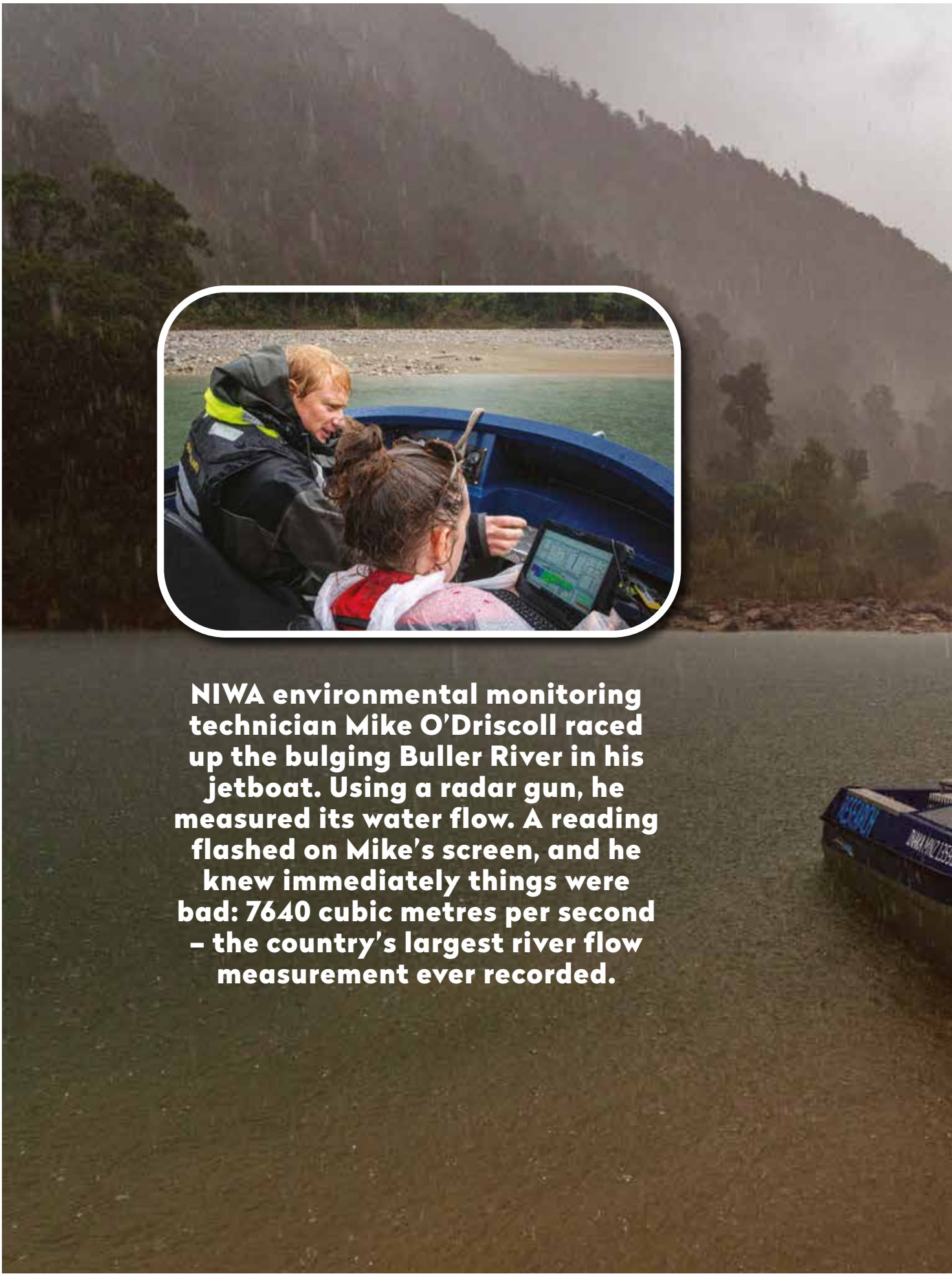
Dr Emily Lane is a hydrodynamic scientist at NIWA who specialises in natural disasters and leads the programme. She says the project will, for the first time, provide a national look at flooding hazards, risks and solutions.

"There are areas that have a fairly clear idea of flooding outcomes, but this isn't the case everywhere. We have an incomplete and inconsistent picture; some places are getting left behind. Having a national-scale lens means that we can start making fair and equitable decisions," she says.

The project is providing a forum for researchers, iwi, stakeholders, and government to investigate flood inundation hazard and risk, and to co-develop strategies for communities to use to become more flood resilient.

An important step is translating hazard into risk. Heavy rain in a flood prone area is a hazard, so at what point does this become a risk to people and places? Where is the water going to go and how bad will it get? How will different types of land, e.g., farms versus forests, impact water depths, and what could the potential damage costs be?

Emily says this kind of information is crucial for emergency responses such as those seen in Westport last year. It helps communities know who to evacuate and when. It also helps with the coordination of sending the right defences and resources to the right places. Who might need sandbags to protect their home?



NIWA environmental monitoring technician Mike O'Driscoll raced up the bulging Buller River in his jetboat. Using a radar gun, he measured its water flow. A reading flashed on Mike's screen, and he knew immediately things were bad: 7640 cubic metres per second – the country's largest river flow measurement ever recorded.

NIWA Environmental technician Mike O'Driscoll checks flows in the lower Buller Gorge. Combining high-resolution rain forecasts with catchment and flow data can give emergency managers up to 48 hours warning of trouble ahead.

Where should temporary shelters be set up? How will supplies get to the people most in need?

In the longer term, it can help planners when creating new developments or changing land use. For example, if you build a new road, how might it impact where water flows during a flood?

The second part of the project is about understanding how people react to flood hazards, particularly over the long term, to assist in developing adaptation strategies.

The team at NIWA is working closely with communities to understand how they react to flood hazards.

Dr Paula Blackett, NIWA's principal scientist of environmental social science, heads this work.

"A lot of our emergency response practices are about the immediate aftermath and saving lives, trying to get back to the original state as quickly as you can.

"However, we don't fully understand how floods affect people's lives over space and time. People can be out of their houses for months, their insurance premiums are higher, they have repair costs. They can be so traumatised by an event that they don't come back," she says.

Emily says flood risk is all about what's important and valuable to people, and individual responses to flooding vary widely.

"We want to understand how communities deal with it, so we are working with them to figure out what's right for them, empowering people to make their own decisions."

Emily says Vision Mātauranga is a major part of the project's framework.

"Māori have spiritual connections with their land and interact with it in different ways to Pākehā. Altering nature by putting in things like stopbanks and seawalls might not fit with their worldview and what's important to them. Including the Māori worldview is an important part of finding solutions."

There's also a giant elephant in the room: climate change.

Temperatures are rising, leading to a warmer atmosphere and more evaporation. The result, says Emily, is more intense storms ahead.

Before the 1970s, New Zealand was hit with just one or two big floods a year. Now, it's about four to seven, according to the Insurance Council.

Human changes to the environment, such as deforestation and building on wetlands, often increase the intensity and frequency of flooding too.

Emily says understanding climate change is fundamental to both the modelling and mitigation.

"We now know a bit more about how climate change is playing out, so we must go back to our old data and models to adapt them. We have built flood defences to a certain level in the past. But now with climate change, the biggest flood we expected has been completely outdone.

"We're already seeing impacts that I thought my children were going to see. Our instincts for what floods might be like may no longer be accurate because it's not a static climate anymore, it's changing, it's getting worse."

Bob Dickson echoes her comments.

"People must adapt. We're in a very changing situation, a fluid situation. Climate change is here. It's real. And Mother Nature always wins."

So, what's next for Dorothy Burrows and her beloved town of Westport? Sadly, for Dorothy, she's lost her family home.

"I'm not coming back here. It would be too unsettling at my age. I don't think I could sleep at night if we got a heavy rain forecast again. I just want to get on with the rest of my life, not that I've got a lot of years ahead."

It's too late for Dorothy Burrows but Emily hopes Mā te Haumaru ō te Wai will help communities like Westport make the right decisions as the climate changes.

After all, flooding may be here to stay, but we don't have to let it drown us.

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Restoring awa health in Ōtaki

The Waitohu and Mangapouri are not healthy awa and tackling this issue is not straight forward. Jamie Peryer, kaitohutohu/land management advisor – western programme leader, Greater Wellington Regional Council explains how the council and Ngā Hapu ō Ōtaki developed Mahi Waiora – a collaborative project aimed at improving the health of the local awa.

Through the Mahi Waiora project a catchment plan was developed that identified actions that we could collaboratively work towards. One such action was to restore inanga (whitebait) habitat.

Inanga as a mahinga kai species are a good indicator of stream health and it was quickly discovered that the habitat for spawning in the Otaki catchment was poor. Whitebait spawn at the top of the salt water wedge, which is the highest point that the salt water comes up to. This location on the Waitohu is where restoration efforts focused.

Before the project started, the site had banks that were vertical and slumping, which was contributing sediment to the stream. For inanga it meant there was limited grass cover which meant little habitat to lay eggs into.

The surrounding land was dominated by weeds, in places the blackberry was two metres high. Large exotic trees shaded out key areas of the stream, and this was also limiting inanga habitat as they require sunlight to warm the areas that eggs are laid.

On the north side of the stream a dedicated landowner, Brent Wootton, had already begun restoration and he was on board with the plan to make the inanga habitat better; he did after all have his own whitebaiting stand. With Greater Wellington Regional Council's support, the exotic trees were removed and large margins were retired to create, as Brent calls it, 'gold standard riparian restoration'.

Through his efforts to restore the various habitats on his property Brent has been rewarded with occasional sightings of Bittern or Matuku. These rare native wetlands birds have not previously been seen on the property.

Once the exotic trees were removed along the north side of the stream, a plan was created for the south side of the stream with landowners Otaki Porirua Trust Board. The plan was to restore the site focusing on both the habitat for inanga and the whenua behind.

Actions included undertaking weed control, getting consent and battering the bank back to a gentle gradient, and then planting appropriate inanga spawning species – plants such as pukio, purei, oioi, wiwi, toetoe, and toetoe upoko-tangata.

The remaining two-hectare margin of dune and wetlands were planted with native species typical of that area and the long term goal is to restore it back to pre-human forest.

Fonterra, which has supported the Otaki Porirua Trust Board in other matters, provided support to this project. The Otaki catchment is a priority catchment for the company to support. Kapiti Coast District Council have also provided support.

The belief is that this project is creating ideal habitat for inanga to spawn. It's hoped that we will see a healthy growing population of inanga and subsequently other species in the awa.

This project is a great example of Greater Wellington Regional Council working in partnership with Ngā Hapū ō Ōtaki. Caleb Royal has been an integral part of this project and the wider work being done in the catchment. He deserves a lot of credit for what has been achieved.

This project is only one small part of what is needed to be done to restore the Waitohu. Greater Wellington Regional Council is undertaking several other projects in the catchment and would encourage any landowners to get in touch and play their part in restoring this stream. Anyone who is interested can get in touch via riparian@gw.govt.nz

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Demand grows for NIWA's Riparian Management Training

NIWA has updated and restarted a course using a riparian planning tool developed by one of its former chief scientists more than 20 years ago

Former Hawke's Bay man John Quinn developed the Riparian Management Classification (RMC) for NIWA in the late 1990s as a 'thinking tool' to help design and manage riparian planting projects. He used the RMC in NIWA's Targeted Riparian Management Course up until 2015 when he became chief scientist for the Freshwater and Estuaries Centre at NIWA.

NIWA land and water scientist Lucy McKergow originally presented the Targeted Riparian Management Course with John and has now restarted the programme, leading it with NIWA freshwater ecologist Elizabeth Graham.

"John developed the RMC as a thought-experiment to help users assess how riparian functions vary across catchments," Lucy says.

"The concept is to provide realistic, science-based expectations of riparian buffer performance for 12 different functions, including fish habitat, shading and water quality."

The first Targeted Riparian Management Course since 2015 was held for Hawke's Bay Regional Council staff in Napier over two days in late February 2022. There were 12 council staff on the course with a background in physical geography, looking to increase their knowledge around stream ecosystems.

"We understand regional council staff are being approached by rural landowners asking how to tell if their stream is healthy.

"This course gives them the tools to increase their knowledge and confidence, to explain and educate landowners about their streams' ecosystems."

Xan Harding is senior catchment adviser (policy implementation) for the Hawke's Bay Regional Council. He says the staff who attended the course enjoyed learning from a great mix of technical, scientific and practical content, delivered by two highly engaging subject matter experts.

"The Riparian Management Classification system at first appeared complex but we were left much more informed and confident to use what is a powerful framework for understanding, assessing, and managing the broad range of elements that make up stream health."

Xan says the course offered key tips which will help staff deliver good advice to landowners.

"For example, if you want to achieve 70 percent shading over a waterway, which is recommended, the rule of thumb is that the maximum height of your trees need to be the same as the width of a stream.

"We also learnt that carbon input from trees which have fallen into streams is an essential part of the health of waterways. Tree trunks provide habitat and leaf litter is a food resource for aquatic life."

Another tip was how to use the EPT Index as an assessment of stream health. The index includes the macroinvertebrate order: Ephemeroptera (mayflies); Plecoptera (stoneflies) and Trichoptera (caddisflies), which are sensitive to water pollution.

Xan says it was a bonus to have regional council staff complete practical work alongside the NIWA researchers.

"It's not often in a course you get that opportunity to benefit from their experience. The course was a very powerful tool and executed well."

Lucy McKergow said the regional council staff will be able to put the course knowledge into action.

"In a way, we have been training the trainers, to provide people with the correct advice to share with rural landowners, iwi and community groups, river care or land care groups."

She said other Government agencies, consultants and university students are also interested in the courses.

Elizabeth with catchment advisers Zoe Harty, Abby Miller and Victoria Anstis.

PHOTO: LUCY MCKERGOW.

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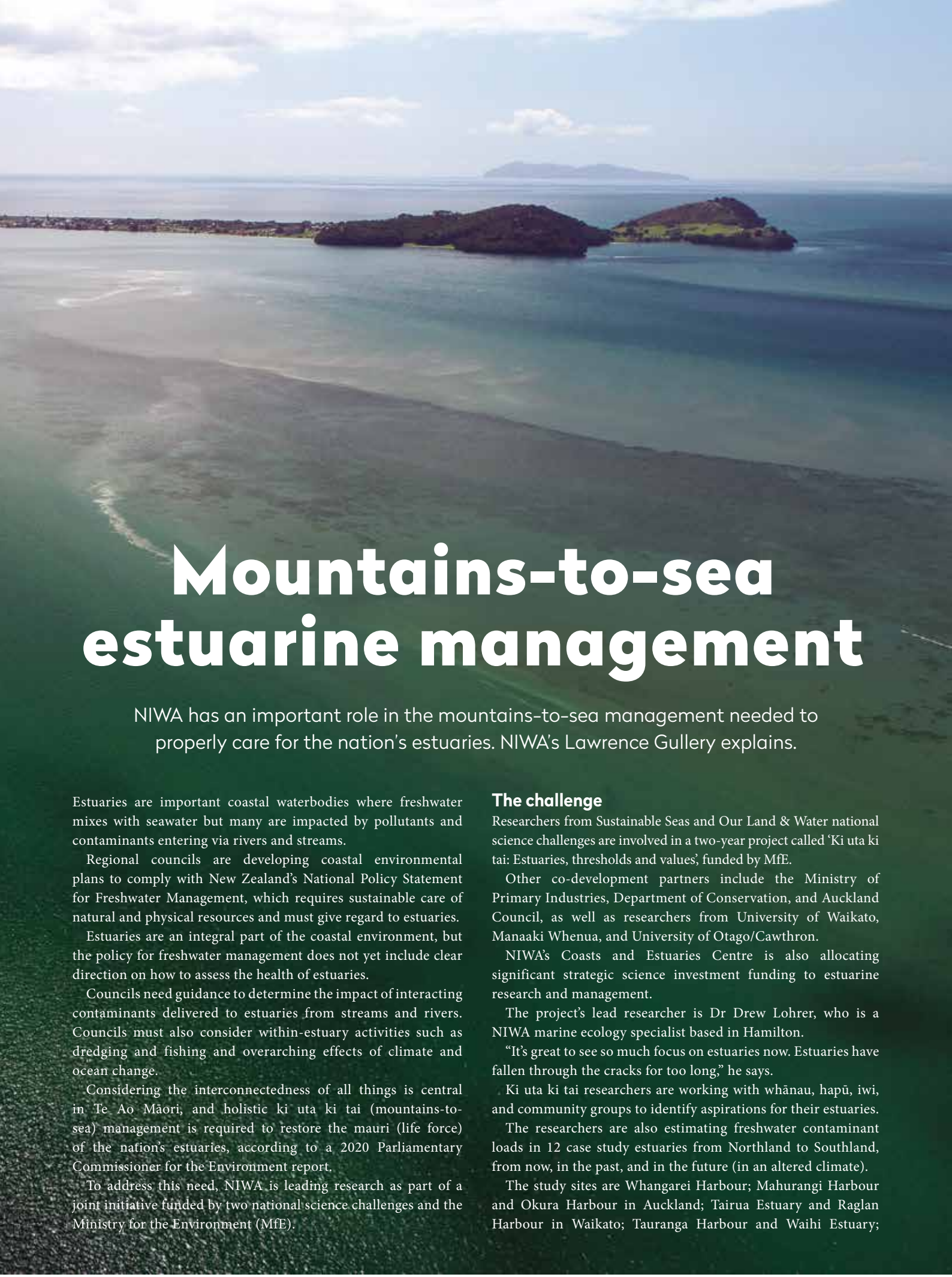

Mountains-to-sea estuarine management

NIWA has an important role in the mountains-to-sea management needed to properly care for the nation's estuaries. NIWA's Lawrence Gullery explains.

Estuaries are important coastal waterbodies where freshwater mixes with seawater but many are impacted by pollutants and contaminants entering via rivers and streams.

Regional councils are developing coastal environmental plans to comply with New Zealand's National Policy Statement for Freshwater Management, which requires sustainable care of natural and physical resources and must give regard to estuaries.

Estuaries are an integral part of the coastal environment, but the policy for freshwater management does not yet include clear direction on how to assess the health of estuaries.

Councils need guidance to determine the impact of interacting contaminants delivered to estuaries from streams and rivers. Councils must also consider within-estuary activities such as dredging and fishing and overarching effects of climate and ocean change.

Considering the interconnectedness of all things is central in Te Ao Māori, and holistic ki uta ki tai (mountains-to-sea) management is required to restore the mauri (life force) of the nation's estuaries, according to a 2020 Parliamentary Commissioner for the Environment report.

To address this need, NIWA is leading research as part of a joint initiative funded by two national science challenges and the Ministry for the Environment (MfE).

The challenge

Researchers from Sustainable Seas and Our Land & Water national science challenges are involved in a two-year project called 'Ki uta ki tai: Estuaries, thresholds and values', funded by MfE.

Other co-development partners include the Ministry of Primary Industries, Department of Conservation, and Auckland Council, as well as researchers from University of Waikato, Manaaki Whenua, and University of Otago/Cawthron.

NIWA's Coasts and Estuaries Centre is also allocating significant strategic science investment funding to estuarine research and management.

The project's lead researcher is Dr Drew Lohrer, who is a NIWA marine ecology specialist based in Hamilton.

"It's great to see so much focus on estuaries now. Estuaries have fallen through the cracks for too long," he says.

Ki uta ki tai researchers are working with whānau, hapū, iwi, and community groups to identify aspirations for their estuaries.

The researchers are also estimating freshwater contaminant loads in 12 case study estuaries from Northland to Southland, from now, in the past, and in the future (in an altered climate).

The study sites are Whangarei Harbour; Mahurangi Harbour and Okura Harbour in Auckland; Tairua Estuary and Raglan Harbour in Waikato; Tauranga Harbour and Waihi Estuary;

Ahuriri Estuary in Napier; Porirua Harbour; Kaipara Harbour; Avon-Heathcote Estuary in Canterbury; and New River Estuary in Southland.

The team will relate those contaminant loads to measures of ecological health in estuaries to determine critical stressor thresholds. Combined, the findings will be used to guide limit-setting for freshwater contaminants in estuaries which the MfE can use to set policy for regional councils to follow.

Estuary types

The 12 study sites being investigated in detail represent different estuary types and sizes with different surrounding land uses and climates. Councils in those areas have supplied data collected from their estuaries, some dating back 10 to 15 years.

"The data will help us calculate the loadings of sediments, nutrients, and *E. coli* to each estuary," Drew says.

"We are also able to use macrofauna assemblages and kaimoana abundance data as indicators of estuary health because we know a lot about how these organisms respond to contaminants."

He says larger councils with more resources can gather data more often, while smaller councils might struggle to provide the same level of detail on their estuaries.

NIWA freshwater modelling experts will help develop tools that all councils can use to determine the exposures of ecological sampling sites to multiple stressors in different parts of their estuaries. These tools can be used to calculate exposures in specific areas of estuaries, rather than averaged across entire estuaries.

Drew says this was important because estuaries came in all shapes and sizes and were complicated, spatially variable environments. For example, large estuaries can have dozens of streams emptying into them, each delivering differing amounts of contaminants. Catchment size, freshwater volume, land use, adjacent ocean characteristics and climate regimes can also play varying roles.

"This research will incorporate mātauranga Māori and western science to take a holistic approach to managing the entire catchment, from the mountains to the sea, in keeping with the ki uta ki tai concept.

"It's about understanding the types and levels of stressors that are most damaging to estuaries, then taking steps, either on land or in the estuaries themselves, to improve their health."

High valued but highly stressed

Drew says there was keen interest in the project among councils, with whom he has been communicating regularly. The joint initiative is expected to be completed in late 2023.

"New Zealanders are very coastally orientated. Coasts and estuaries are where we interact with the marine environment the most.

"Estuaries are highly valued culturally, socially, and environmentally. They have multiple uses but because of that they are also highly stressed.

"They are important because they trap sediment and remove nutrients delivered by freshwater. They benefit us in many ways and so we really need to look after them."

Mahurangi Estuary Benthic Survey

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Providing safe passage for fish

New Zealand's first enclosed Archimedes' screw pump will be tested during the next eel migration to see how successfully it passes native fish species.
By Inger Vos, Waikato District Council.

The testing of the fish-friendly screw pump in the Mangawhero catchment, near Waiuku, is part of Pathways to the Sea, a research and strategy development programme by Waikato Regional Council to help manage flood pump impediments to fish passage and which will lead to the development of a regional fish passage strategy.

The screw pump, which was built in the Netherlands, was commissioned in March. It is the first of up to five fish-friendly upgrades to pump stations in Waikato catchments that will be undertaken as part of the council's 'shovel ready' programme of works, and has a funding contribution of $4.48 million from Kānoa – Regional Economic Development & Investment Unit administered by the Ministry for Business, Innovation and Employment.

Shovel Ready programme manager Julie Beaufill says the current infrastructure is due for replacement and does not enable safe downstream passage of native fish, so the council is installing fish-friendly pumps that are designed to not inflict damage on fish.

Julie says Archimedes' screw pumps, built by FishFlow Innovation, have been proven to be 100 percent fish friendly in Europe.

"We'll be testing the Mangawhero screw pump to see if we get the same results with our significantly large tuna [eels] that can grow up to two metres in length.

"We'll be looking at whether tuna avoid the pump, what size tuna are passing through, and assessing to see if there is any injury or mortality as a result of tuna passing through."

A monitoring programme is being developed with iwi and will take place during the migration season in 2023.

Waikato Regional Council set up the $1.2 million Pathways to the Sea project to develop a regional infrastructure fish passage strategy to

The screw pump, which was built in the Netherlands, was commissioned in March. It is the first of up to five fish-friendly upgrades to pump stations in Waikato catchments.

meet current and future legislative obligations, guide investment and manage downstream fish passage impediments associated with its flood schemes.

Funding partners in the project include government agencies, other councils and organisations from across the country, with the findings and resulting strategy to be available to be used and adapted nationally.

Pathways to the Sea project manager Michelle White says the issue of fish passage is not unique to the Waikato, "but we do have the largest number of flood pumps, and therefore understanding how we can avoid, remedy or mitigate the impact these assets have on our native fish is a priority for our council".

"Our Pathways to the Sea project is about mitigating the unintended consequences of past decisions and protecting our tuna populations."

The trial of the enclosed Archimedes screw pump is just one part of the project.

The council has also been working with MacEwans Pumping Systems and Callaghan Innovation to develop a fish friendly pump to replace existing MacEwans PPF axial pumps – found widely in New Zealand – without the need to make any civil structure modifications to pump stations.

"This project is particularly exciting because we have the potential to have a locally manufactured pump that can be used nationwide to provide safe fish passage specifically for native species," says Michelle.

The project so far has involved developing a concept, building and testing a scale model, designing a full-scale version and the manufacturing of parts. The pump will eventually be installed at the Golf Course pump station, north of Huntly, and it too will be tested for 'fish friendliness' during the following migration season.

Other research to enable safe fish passage includes trialling electrical barriers to deter tuna at pump stations, and trap and transfer methods.

Michelle says fish, notably tuna, are known to be extremely responsive to electric fields.

"The intention of an electrical barrier is to deter tuna from a pump, so they swim away from it rather than into it. This is particularly useful at sites where floodgates are present as another means of passage."

For trap and transfer, a trial undertaken at Okowhao pump station, north of Huntly, showed it to be a feasible option where mortality from pump stations is high and site access is good.

Michele says the recommended approach arising from the trial was to partner with local iwi and employ trap and transfer at priority sites during the lead up to tuna heke.

"The advantage of trap and transfer is it's relatively low-tech, essentially just relying on nets and people. It also has considerable benefits from an iwi perspective, allowing them to build stronger connections with waterways and actively engage in traditional kaitiaki responsibilities.

"However, the disadvantages are it is labour intensive and tuna migration is difficult to predict – you need trained teams on standby, ready to go at short notice."

The council hopes that the ultimate output of all the research and development – the strategy – will be completed by the end of 2023.

A better way to monitor **drinking water wells?**

Modern landfill sites must be monitored for leaks. There are specific regulations on how to do this and a lot of work goes into calculating the optimal layout and number of wells needed.

Inspired by this system, ESR's groundwater scientists asked whether the same logic could be applied to the monitoring of drinking water wells. Usually only the water from the well to be consumed is sampled for contaminants, but by the time this detects anything wrong, it is often too late.

ESR's team asked what would happen if monitoring occurred before (upgradient) the drinking water well – to give water authorities an early warning on potential contamination and a head start for any work that would be required to ensure public safety. If so, how many wells would you need and how often would you need to sample?

The researchers found that even in the most complicated scenario, fewer wells than anticipated are needed as flow converges towards the supply well, and they don't need to be sampled too frequently either.

This had never been analysed before, and as a recently published paper, '*Aquifer Heterogeneity Controls to Quality Monitoring Network Performance for the Protection of Groundwater Production Wells*', shows, the implementation of a sentinel well system is not likely to be as complex or expensive as expected.

Based on this research, water suppliers in New Zealand are now considering including such monitoring systems as a multi barrier approach to maintaining the safety of drinking water.

A groundwater monitoring network surrounding a pumping well (such as a public water supply) allows for early contaminant detection and mitigation where possible contaminant source locations are often unknown.

Paper abstract

A groundwater monitoring network surrounding a pumping well (such as a public water supply) allows for early contaminant detection and mitigation where possible contaminant source locations are often unknown.

This numerical study investigates how the contaminant detection probability of a hypothetical sentinel-well monitoring network consisting of one to four monitoring wells is affected by aquifer spatial heterogeneity and dispersion characteristics, where the contaminant source location is randomised. This is achieved through a stochastic framework using a Monte Carlo approach.

A single production well is considered that results in converging non-uniform flow close to the well. Optimal network arrangements are obtained by maximizing a weighted risk function that considers true and false positive detection rates, sampling frequency, early detection, and contaminant travel time uncertainty.

Aquifer dispersivity is found to be the dominant parameter for the quantification of network performance.

For the range of parameters considered, a single monitoring well screening the full aquifer thickness is expected to correctly and timely identify at least 12 percent of all incidents resulting in contaminants reaching the production well. This proportion increases to a global maximum of 96 percent for a network consisting of four wells and very dispersive transport conditions.

Irrespective of network size and sampling frequency, more dispersive transport conditions result in higher detection rates. Increasing aquifer heterogeneity and decreasing aquifer spatial continuity also lead to higher detection rates, though these effects are diminished for networks of three or more wells. Statistical anisotropy has no effect on the network performance.

Earlier detection, which is critical for remedial action and supply safety, comes with a significant cost in terms of detection rate, and should be carefully considered when a monitoring network is being designed.

To read the full paper, go to: bit.ly/3PYYziw

Effective, chemical-free pest control

The pesky midge fly population on the Māngere foreshore is at its lowest ever thanks to the novel innovation of a Watercare environmental scientist determined to reduce chemicals for pest control. By Hannah Spyksma, Watercare

That environmental scientist is Chris Garton, and his world-first 'lawn mowing' approach to pest control involves a jet ski pulling multiple chains with spikes through the 17-hectare treated wastewater channel near Watercare's Māngere Wastewater Treatment Plant in south Auckland.

After an extensive controlled trial, which Chris completed his master's thesis on, and following the peak of the midge fly season, he's confident the method is a full success.

"It's working wonders – we've now had more than two years with no midge complaints.

"Nobody wants these flies around their homes and in their community, including Watercare. We want to be good neighbours and doing everything we can to reduce the midge population certainly helps with this."

His innovative chain drag method kills the midge fly larvae that live in the shallow water on impact and through burying them with the sediment that is temporarily stirred up.

If left untreated, the flies can create huge clouds that cover houses, washing lines, and swarm neighbourhoods.

The approach has quartered costs for Watercare as it no longer needs to import the expensive chemical methoprene from the USA.

Methoprene is a highly-targeted and environmentally safe chemical that was applied every three weeks using slow-release pellets and cost about $300,000 a year.

By comparison, the chain dragging method is done by a jet ski operator once a week and costs about $75,000 a year.

"It's not that methoprene is a bad technique, but it's very expensive and I knew there must be a better option for pest control that's chemical free.

"Results from the last two seasons have been better than when we were using methoprene and at a fraction of the cost."

The main species that live in the water channel are a native midge fly called *Chironomus zealandicus.*

They look like mosquitos, but don't bite. They are prolific breeders, with females able to lay 1000 eggs at a time. They have a short lifecycle of about three weeks when the weather gets warm in the spring and summer.

World-first 'lawn mowing' approach to pest control involves a jet ski pulling multiple chains with spikes through the 17-hectare treated wastewater channel near Watercare's Māngere Wastewater Treatment Plant.

A very small number can quickly multiply into billions and get out of control if not treated properly.

We originally stopped using methoprene and replaced it with the chain dragging method in August 2017.

"I was blown away by the reduction in population numbers over the first season of 2017/2018."

The midges are monitored every week by an experienced entomologist and the peak numbers received in the traps in the two seasons prior to using the chain method were 6352 and 4852.

But the 2017/2018 season saw this number drop to just 1554.

However, Garton wanted more data to back up his observations and scientifically prove his method.

From August 2018 to August 2019, he ran an experiment on the channel to compare the effectiveness of methoprene and the jet ski chain methods and monitor a 10 percent controlled area that received no treatment at all.

"This experiment provided some excellent data.

"But because some areas were left untreated this, unfortunately, led to higher numbers of midges (about what we experienced when we were treating them with methoprene) around the channel from October 2018 – March 2019.

"Consequently, there was a big spike in population numbers from September 2019 to December 2019."

The following months were spent getting the flies under control, but it's been smooth sailing since then.

"Thanks to the chain dragging method the last two seasons have been the best ever recorded at the Māngere Wastewater Treatment Plant and we've had no midge complaints from the community since 2019."

With two seasons of excellent results, Garton's happy to say the flies are under control and will be writing up an academic paper documenting his findings to date.

His method is such a hit it's now being used at Watercare's Rosedale Wastewater Treatment Plant and was also adopted by Christchurch City Council at the Bromley Wastewater Treatment Plant.

As far as Chris is aware, there are no other wastewater treatment plants around the world that are using his method – yet.

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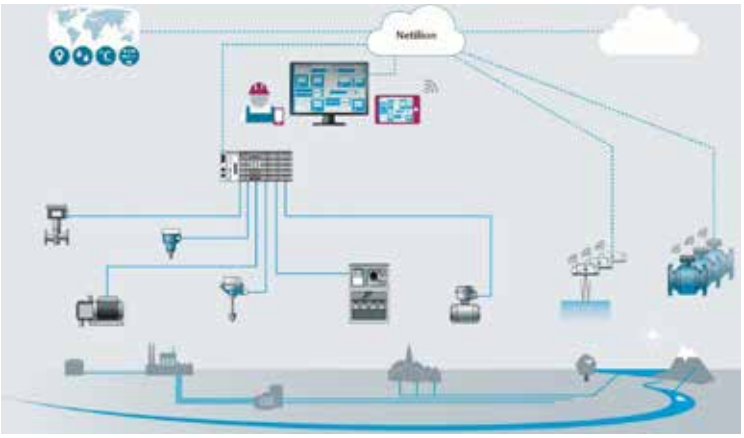

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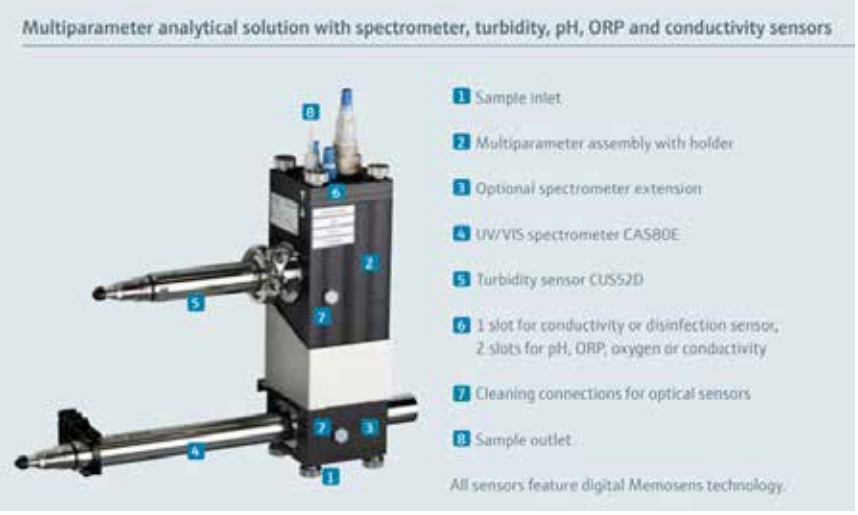

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Will the wastewater reforms improve freshwater outcomes for rural and Māori communities?

Improved management of point source wastewater discharges will be critical in helping give effect to Te Mana o te Wai and achieving the improvements in freshwater quality directed by the National Policy Statement for Freshwater Management 2020 (NPS-FM). While Te Mana o te Wai is also a key operating principle of both the Water Services Regulator Act that established Taumata Arowai and the Water Services Act under which it now operates, Taumata Arowai's regulatory oversight is limited to reticulated wastewater networks. Does this limit the potential to improve environmental outcomes associated with wastewater treatment in unreticulated rural areas? By Juliet Milne, resource management scientist, NIWA.

NIWA has been examining existing regulatory provisions and guidance for wastewater discharges as part of its five-year MBIE-funded Ecocultural Wastewater Treatment Research Programme. The programme is focused on co-development of culturally appropriate upgrades of wastewater systems servicing small reticulated rural towns, unreticulated settlements, and facilities such as papakāinga and marae.

Juliet Milne

Why rural wastewater treatment might need to be looked at

While recent media attention has focused on repeated failures of reticulated wastewater networks in our larger cities such as Wellington, it is well established that wastewater infrastructure in rural areas is often aged, failing, or not able to achieve desired environmental and public health outcomes.

Discharge of treated wastewater into or onto land may also adversely impact groundwater and surface water quality, including drinking water sources (current national estimates put the number of unregistered small water supplies at 75,000, and many are likely to be located in areas where they may be at risk of intercepting contaminants discharged from on-site wastewater systems).

Risks of adverse environmental impacts are exacerbated in small towns that experience significant peaks in wastewater inflows over summer and other holiday periods.

Similarly, many rural industries or facilities serviced by unreticulated 'on-site' treatment systems experience significantly higher seasonal wastewater inflows arising from tourism or increased workforces (e.g., ski fields, orchards, campgrounds, and motels). In the case of marae, large events such as tangi can potentially overload systems that may be designed for a smaller 'base' population load.

Among the many challenges Taumata Arowai will have to address through the new water entities is improving the performance of existing treatment systems. Taumata Arowai has the ability to introduce wastewater performance standards for reticulated rural towns under section 138 of the Water Services Act.

For around 200 rural communities across the country, wastewater treatment systems are based on one or more oxidation ponds (now typically called waste stabilisation ponds), followed by discharge to land, surface water, or a combination of both. One of the many advantages of these systems is their ability to cope with seasonal or short-term hydraulic and organic loading peaks. They are also relatively simple and inexpensive to operate and maintain.

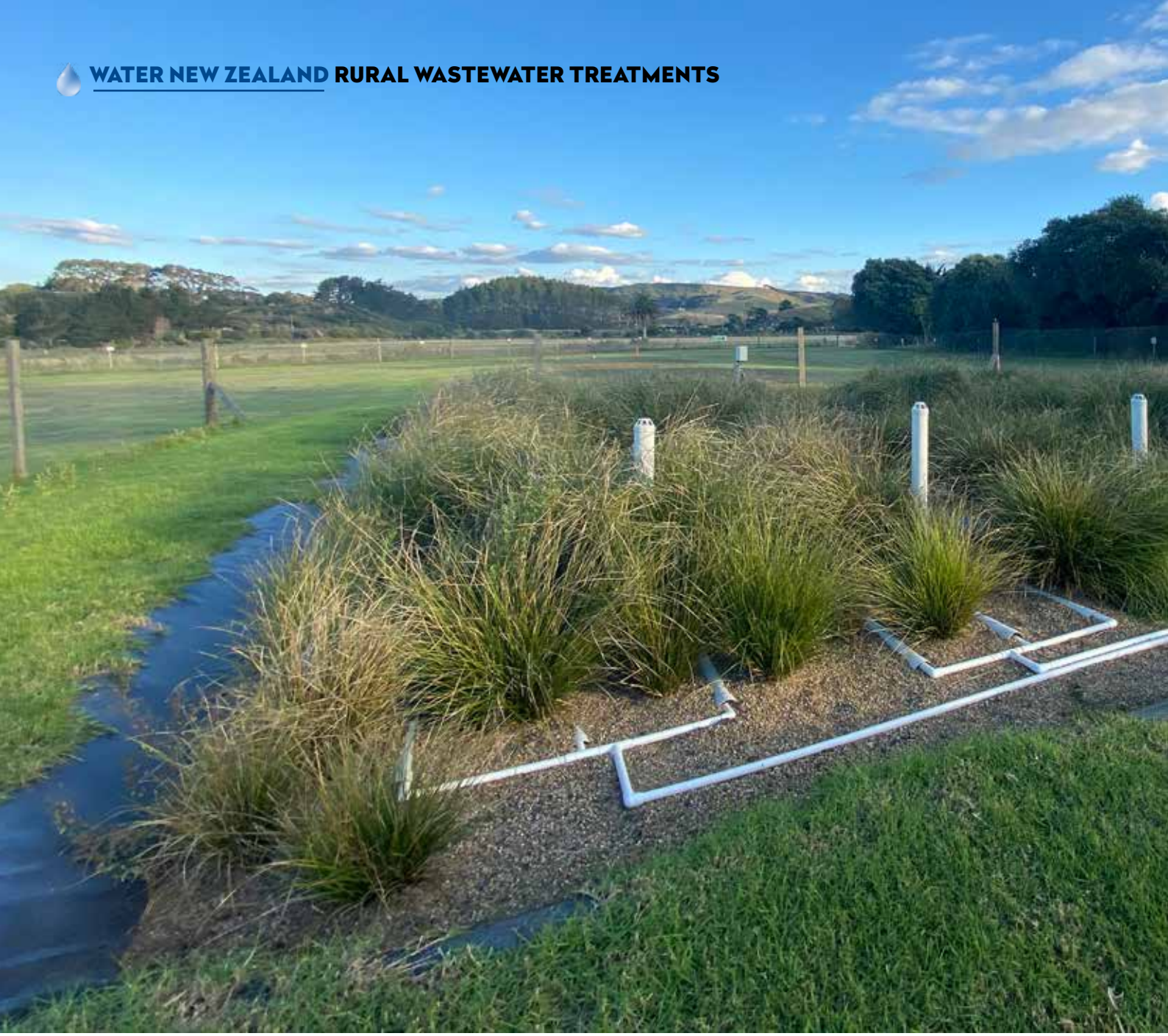
On the flip side, removal of nutrients (nitrogen and phosphorus) and pathogens is modest at best, with additional treatment increasingly being implemented to improve effluent quality.

With Taumata Arowai's regulatory remit limited to establishing performance standards for reticulated wastewater networks, will the status quo remain for managing and improving the discharges to water or land from non-reticulated wastewater systems?

That regulatory responsibility lies nationally with the Ministry for the Environment under the RMA and regionally with the 16 regional or unitary councils through their regional plans.

A review of a cross-section of operative regional plans identified a strong reliance on the joint AS/NZS 1547 standard (or a precursor or regional adaption of this) to manage the potential effects on public health and the environment from small on-site domestic wastewater discharges. However, this standard targets systems designed for domestic wastewater flows up to 14,000 litres per week (i.e., a population equivalent of up to 10 persons).

While nothing limits application of the principles and practices of the standard to systems treating larger volumes, many rural



settlements, industries and facilities generate volumes of wastewater more than 10 times greater than what the standard was specifically designed for.

So, given the potential mis-match between the Standard and the wastewater volumes requiring treatment, and the focus of the Three Waters Reform Programme on the performance of reticulated wastewater systems, it appears that it will be up to individual regional and unitary councils to drive any improvements needed in the performance of mid to large-sized on-site wastewater treatment systems.

There appears to be a need for national guidance to assist councils with this.

What national direction or guidance is required?

One of the common themes across current regional plan policies addressing wastewater discharges is that wastewater storage, treatment, and discharge should occur in accordance with nationally or industry recognised good management practices or guidance.

As established above, the provisions of AS/NZS 1547 appear inadequate to meet these needs when it comes to medium to large-sized on-site wastewater treatment systems. Moreover, the scope of the land treatment and application systems in the Standard is limited to conventional trenches, beds, evapotranspiration areas, mounds, drip irrigation, and spray irrigation.

The sorts of ecocultural treatment systems NIWA is investigating (suited to discharge volumes covered by the current standard, or which can be much larger than those covered by the standard), including multi-layered vertical wetland filters and high rate filamentous algae ponds, do not feature.

New Zealand currently lacks national guidance or standards addressing municipal wastewater treatment performance (current guidance is limited to application of wastewater and biosolids to land). Taumata Arowai has the mandate to remedy this deficiency and, in so doing, has an opportunity to ensure that a range of treatment systems are considered.

However, prescribing a one-size-fits all approach, particularly for small rural communities that have existing pond-based systems (often with some capacity to buffer variable inflows), may be costly if entirely new mechanically-based systems are required.

Moreover, if overly prescribed solutions are proposed, they

An intensified multi-layered wetland filter that was recently constructed to treat wastewater at Te Kopua campground, Whāingaroa. Local kaumatua of Tainui Awhiro selected the plant species which had previously been abundant in the area. This kind of wetland has no open water and requires less land for effluent infiltration than more traditional horizontal and vertical-flow wetlands.

PHOTOS COURTESY OF: CHRIS TANNER, NIWA.

will likely reduce the potential to develop creative, locally-based treatment solutions that may better meet the needs of Māori and the wider community, or may deliver equivalent or better treatment performance at lower capital and operating cost.

Guidance is also required regarding the new RMA climate change provisions that will come into force later this year. Existing RMA provisions direct councils to disregard the climate change effects of greenhouse gas (GHG) emissions from any activity other than where the use and development of renewable energy enables an overall reduction in the discharge of GHGs.

However, once the amendments come into force in November, considering the effects of a wastewater discharge on climate change will no longer be out of bounds for councils when deciding whether or not to grant consent, or to adopt new policies and rules governing consents.

It is unclear how or if this regulatory opportunity will be used by councils given the likely replacement of the RMA with the Natural and Built Environments Act (NBA) and other legislation in 2023.

Regardless, with non-reticulated wastewater systems outside of the remit of the current Three Waters Reform Programme, the question remains: what guidance will be provided for small rural communities, business owners and Māori settlements on suitable, affordable systems to achieve improved effluent quality and minimise GHG emissions?

Advantages arising from use of standardised terminology

New national guidance or standards would also provide an opportunity to rationalise and standardise the wide array of wastewater-related terms in use across existing guidance, standards and regional plans. For example, NIWA found nine of 16 regional plans defined an on-site wastewater system but there were eight variations on this term across these nine plans.

While standardised terminology isn't essential for managing wastewater discharges, it could facilitate an improved understanding of wastewater and make it easier for industry practitioners who work across different regions and hence regional plan policy and rule provisions.

The current version of the National Planning Standards, introduced by Ministry for the Environment in 2019 to improve, amongst other things, the consistency of the format and content

of RMA planning documents, only defines three terms: greywater, sewage, and wastewater.

A much wider array of terms, including definitions for sludge, septage, and various types of wastewater treatment system, could be provided in new national guidance and, from there, be incorporated into future regional natural and built environment plans prepared under the NBA.

An opportunity exists now

The Government's current three waters and resource management regulatory reforms provide an opportunity to establish new national guidance for wastewater treatment systems that better service both reticulated and unreticulated communities.

Ecocultural wastewater treatment technologies should be included in this guidance, recognising that they can provide cost-effective, 'natural' alternatives when considering technologies required to upgrade substandard or failing rural wastewater infrastructure. These systems focus on beneficial reuse of wastewater resources, including nutrients in the wastewater and recovery of methane produced during treatment. Informed by Matāuranga Māori through co-design with Māori, correctly implemented ecocultural wastewater systems will help give effect to the principles of Te Mana o te Wai.

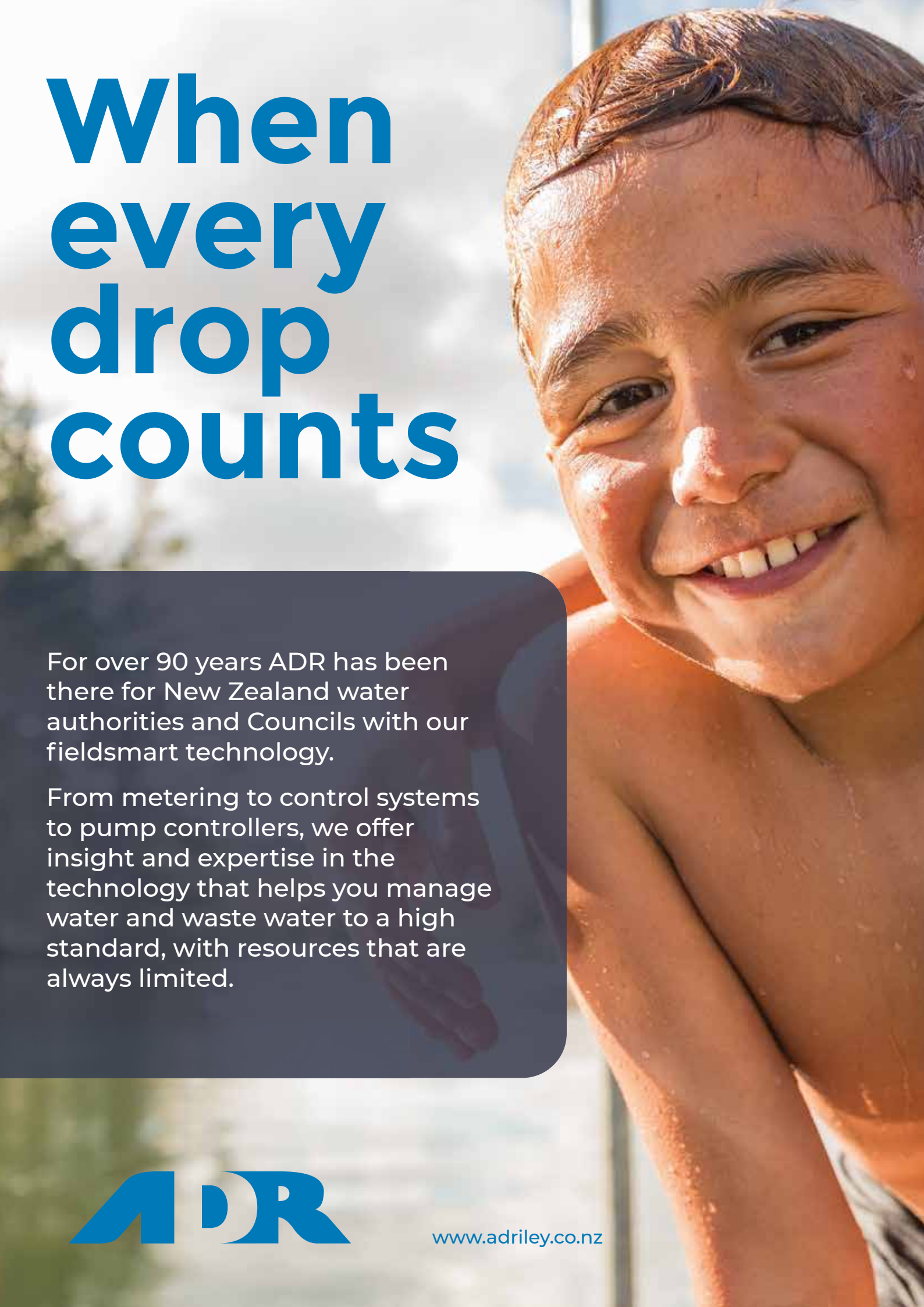
As directed by the NPS-FM, by December 2024 new regional freshwater plans will be publicly notified across the country. Regional and unitary councils therefore have a window of opportunity now to explicitly recognise the advantages ecocultural wastewater technologies can provide in giving effect to Te Mana o te Wai and achieving freshwater outcomes.

While all regional plans include objectives or policies that promote the discharge of treated wastewater to land rather than to water, only on-site wastewater discharges from individual dwellings of up to 2000 litres per day are permitted activities. Other wastewater discharges to land are almost universally classified as a discretionary activity, regardless of the nature or degree of treatment.

Is there not a case to at least explore the potential for a restricted discretionary – or even controlled – activity classification for larger wastewater discharges to land (e.g., those averaging in the order of 2000-8000 litres/day) that can meet some well-defined, ecocultural-based criteria?

Juliet Milne is a resource management scientist with a focus on water quality, based at NIWA's Wellington campus. She has previous regional council experience in consenting, monitoring and assessing the effects of wastewater discharges. Juliet is currently investigating implementation pathways for ecocultural wastewater treatment technologies being developed by NIWA. Comments are welcome, email juliet.milne@niwa.co.nz.

When every drop counts



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Global exposure to flood risk and poverty

Flooding is a pervasive natural hazard, with new research demonstrating that more than one in five people around the world live in areas directly exposed to 1-in-100-year flood risk. Exposure to such flood risk is particularly concentrated amongst lower income households worldwide. By Thomas K. J. McDermott, J.E. Cairnes School of Business and Economics, National University of Ireland Galway.

Among climate hazards, flooding is by far the most pervasive risk globally. Tens of millions of people around the world are displaced from their homes by flooding each year, while damages from flood events run into the hundreds of billions of US dollars in direct asset losses annually.

The human impacts of flooding tend to be concentrated disproportionately among low-income households, with vulnerability linked to poverty. Alongside immediate impacts on people and their assets, floods may impose longer-term effects on welfare, constraining development opportunities of affected communities, particularly where coping capacity is limited and risks are not fully insured.

Flood risk is expected to worsen in the coming decades, as rainfall intensifies and sea levels rise due to climate change. A perhaps less well-recognised driver of increasingly costly flooding is the increase in exposure over time.

Economic and population growth means there are more people and assets in harm's way. Global development trends are also such that the fastest rates of economic development and population growth are often in places such as large coastal cities, where flood risks are particularly concentrated and getting progressively worse.

This all means that the global economic costs and human impacts of flooding are likely to rise, perhaps substantially, over the coming decades.

Development planning needs to account for these rising risks. This underscores the need to develop a better understanding of current exposure and vulnerability to climate hazards, as a prerequisite for informing sustainable and climate-resilient forms of development.

New findings highlight the scale of the challenge

New research by Jun Rentschler of the World Bank, and colleagues, documents global exposure to flood risk at a very high spatial resolution.

The authors combine state-of-the-art information on flood risk with high-resolution population maps to estimate exposure to flood risk on a global grid at three arc-seconds resolution (roughly 90m × 90m at the equator). The paper also adds subnational information on poverty rates and incomes, enabling Rentschler and colleagues to present the first global estimates of the interaction between exposure to flood risk, and poverty.

The data show that 1.81 billion people (23 percent of the world population) are directly exposed to 1-in-100-year floods. The vast majority (89 percent) of these people live in low – and middle-income countries.

In terms of regional distribution, Rentschler et al.'s results show that flooding is a near-universal global phenomenon; of the more than 2000 subnational regions analysed, only nine have less than one percent of their population exposed to flood risks.

Rentschler and colleagues also estimate that some US$9.8 trillion of economic activity globally, equivalent to 12 percent of the gross global product in 2020, is located in areas directly exposed to flooding.

In contrast to population estimates, exposure of economic activity – at least in absolute terms – is found to be heavily concentrated in higher-income countries. However, as the authors point out, these exposure estimates do not account for flood protection measures. Typically when floods occur, a greater fraction of exposed economic activity is lost in lower-income settings.

In terms of the interaction of flood risk and poverty, Rentschler and colleagues estimate that over 780 million people living on under US$5.50 per day face high flood risk. In other words, the data suggest that four out of every 10 people exposed to flood risk globally live on low incomes.

This study represents an important contribution to our understanding of the scale and distribution of flood risk around the world, as well as the significant overlap between areas at risk of flooding and the concentration of poverty.

Rentschler and colleagues have also contributed to the literature by providing comprehensive estimates of exposure to flood risk that account for all sources of flood risk – fluvial, pluvial, and coastal – with global coverage.

Importantly, the state-of-the-art data employed here – comprising of 38 billion data points, covering 7.9 billion people in 189 countries – has resulted in substantial updates on previous estimates of flood exposure.

Moreover, the evidence presented suggests that the number of people living with the dual challenges of flood risk and poverty is substantially higher than previously thought.

Why does it matter to be exposed to flood risk?

Why does it matter to be exposed to flood risk? A hard-nosed economics response might be that it does not. At least in theory, if the costs of living with flood risk are balanced against the benefits of living in these riskier locations (for example, better access to job markets in urban areas) then flood risk may not always represent an important public policy concern.

However, there are various reasons to suspect over-exposure to flood risk due to, for example, taxpayers bearing some of the costs leading to a form of moral hazard, or outdated, costly or otherwise missing information on flood risk.

Rentschler and colleagues' findings also underline the additional concern that exposure to flood risk is unevenly distributed across income groups. But unequal exposure is only one part of the inequality of flood risk.

The consequences of living with flood risk are radically different depending on household income; frequency of occurrence, losses relative to household income, and mortality rates are all dramatically higher in low-income settings.

Moreover, households with low incomes tend to have difficulty coping with risk, resulting in potentially longer-term consequences for development prospects.

The estimates of people living in poverty exposed to flood risk quoted in this study may well represent a lower bound on the true figures. By applying subnational income data to headcount estimates of exposure, Rentschler et al.'s study implicitly assume that flood risk exposure is distributed evenly amongst richer and poorer households within regions.

In reality, it's likely that flood risk exposure varies systematically with incomes at a local level. For example, if housing markets price flood risk, even to a limited extent, then households will sort over flood risk by incomes.

Similarly, there may be institutional or political reasons for systematic local variation in exposure to flood risk by incomes; for example, if certain neighbourhoods benefit more from investments in infrastructure that help to mitigate flood risk, including but not limited to flood defences, basic sewerage and drainage systems.

Further research is required to better understand how local context, including institutions and policies, affects the distribution and scale of flood exposure, how this exposure evolves over time, and how it might be expected to vary under different climate scenarios.

Future prospects for flood mitigation

Rentschler and colleagues point to the need for investment in flood mitigation, including flood defences, and identify hotspots where flood risk and poverty (or more generally vulnerability) coincide, and which might be considered priorities for investment.

However, flood defence systems are costly, take a long time to build, and come with additional challenges given uncertainty about the scale of future flood risk in the context of climate change.

Defensive systems will work better in some places than others, with some locations requiring more creative solutions such as green infrastructure or complementary investments in people, communities, and their capacity to cope with risk.

For some locations and threats, the optimal response may involve restricting the development of risky areas, allowing space for flood waters, and in some cases managed retreat.

Thinking about the threat of climate change more broadly, there is an expectation that as climate change alters risk profiles, people and economies will adapt to minimise the costs of these changes; including by relocating away from areas where risks are increasing.

For example, it has been shown that with free mobility, expected climate damages can be reduced dramatically. However, various barriers and frictions constrain human (and economic) mobility; aside from political and legal restrictions on mobility, an equally significant constraint for many vulnerable households may be the financial cost of migration and associated risk.

It has been well documented that often the poorest and most vulnerable, or those directly affected by climate shocks, do not migrate. The findings presented in Rentschler et al.'s research highlight that those most exposed to climate risk – in this case in the form of flood risk – are precisely those who may have the least capacity to adapt or move.

This paper was first published in Nature Communication. To read the original paper (includes references), go to doi.org/10.1038/s41467-022-30725-6

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TINY TECHNOLOGY **BIG POSSIBILITIES**

A new wastewater technology is available that will drastically reduce the sludge output, with a smaller footprint.

Particularly suited for municipal and industrial use, Aqua-K NZ Limited has harnessed cutting edge biotechnology to design a range of wastewater treatment systems. The Aqua-K system is a more effective treatment system with a smaller footprint - with cleaner outputs and less sludge. The Aqua-K systems can be built as containerised systems for smaller applications, and either purpose-built or retrofitted to existing plants for larger systems. The core technology behind the Aqua-K systems is the PVA gel, a revolutionary poly-vinyl alcohol gel bead that acts as a bio-carrier to protect and encourage the growth of the bacteria that breakdown the wastewater, especially the BOD, COD and nitrogen components. This technology is exclusively supplied by Aqua-K across the New Zealand, Australian and South Pacific markets. The PVA gel combines well with other treatment technologies to improve the overall outcome.

Early testing results show incredible promise:

- 70-80% sludge reduction.
- Increased capacity of existing systems by up to 5 times without increasing footprint.
- 80% - 90% reduction in BOD & COD levels.
- Conversion of ammoniacal nitrogen to nitrogen gas.
- Concentration of phosphorus in the sludge allowing for its removal from the wastewater.

The PVA gel beads, which were initially developed and patented in Japan, have proven to be a game-changer for wastewater treatment across markets like Japan, Singapore, China, Canada and Ireland, UK, India and other Southeast Asian countries.

PVA GEL magnified

Toray MBR Flatsheet module

Pilot test results

	Inlet	MBR Outlet
Ammoniacal Nitrogen (as N)	19.7 mg/L	0.557 mg/L
CBOD5	200 mg/L	8.5 mg/L
COD (as O2)	540 mg/L	49 mg/L
pH (at room temp c. 20 °C)	8.4 ph unit	8.5 mg/L
Total Dissolved Solids	1500 mg/L	1100 mg/L
Total Kjeldahl Nirtogen (as N)	31.8 mg/L	2.92 mg/L
Total Phosphorus (as P)	3.87 mg/L	0.194 mg/L
Turbidity	55 NTU	2.6 NTU
Volalite Solids	85.0 mg/L	7.6 mg/L

So how does it work?

The PVA gel beads contain a network of tiny pores, about 20 microns in diameter. The pores support the growth of up to 1 billion bacteria inside each bead. The small pore size excludes metazoa or protozoa which consume and reduce the effectiveness of the active bacteria. The pores in the PVA gel allow easy entry for oxygen and nutrients to feed the bacteria colonised inside the beads. After the bacteria die, they stay inside the beads where they are consumed by the next generation of bacteria, rather than dropping to the bottom of the tank and becoming sludge.

Aqua-K can also provide other wastewater treatment components, including:

- Toray MBR modules
- Mitsubishi MBR modules
- Reverse Osmosis filtration systems
- UV filtration systems

The combination of the oxygenation of wastewater in the PVA gel tank and the anoxic conditions in the following tank works to remove most of the ammoniacal nitrogen from the wastewater as nitrogen gas.

With the introduction of PVA gel, existing systems can be modified to treat 2-5 times the existing BOD and COD loading using the same footprint. They offer both containerised and non-containerised systems using PVA gel technology. The capacity of the systems can range from a minimum of 10 KLD to 2 MLD.

"Aqua-K typically expects a 70-80% reduction in sludge production over an existing system by using the PVA gel as part of the treatment process. We've seen a particular interest in this feature, with various councils and industries facing huge sludge transportation and disposal costs."

- Peter McLeod, Director, Aqua-K NZ Ltd.

Aqua-K are based in Paerata, South Auckland, where they are operating a 30 KLD containerised wastewater treatment demonstration plant showcasing their treatment capability. Their system is currently treating the waste from a mix of industrial and domestic sources. They have recently begun building a containerised system with a capacity of 150 KLD to demonstrate the system's capabilities treating municipal sewage and wastewater.

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Recent developments in relation to the National Policy Statement on Freshwater Management and the Government's reform agenda.

By Helen Atkins, director, and Amelia Scharting, solicitor, Atkins Holm Majurey.

Left: Helen Atkins and Amelia Scharting.

In this article we provide an update on recent case law in the water management space, as well as a status report on the three waters reforms and latest policy documents, and a review of a recent consenting fast track process for a proposed dam.

Judicial review of vegetable exemption in NPS-FM

Muaūpoko Tribal Authority Inc v Minister for Environment [2022] NZHC 883 was a judicial review case dealing with the Minister's decision to include an exemption to mandated bottom lines within the NPS-FM.

Known as the 'Vegetable Exemption', the relevant clause allows local authorities in Horowhenua and Pukekohe to set target attribute states of local freshwater bodies that are below national bottom lines. This so-called exclusion or exemption (called an exemption in this article) attempts to find a compromise between the needs to improve freshwater body health across the country, and the intense vegetable farming that occurs within those areas.

Given that these areas of farming are a vital component of domestic fresh vegetable supply, the Minister sought to allow for a more bespoke approach to applying targets in those regions.

The exemption is time bound and will expire at the earlier of 10 years or the introduction of new national policies on this matter. This is intended to allow mana whenua, local authorities, and the Ministry for Environment to continue discussions about these regions, to find more bespoke solutions to the contrasting needs.

Following the release of the NPS-FM 2020, two iwi in the Horowhenua region brought a judicial review proceeding against the decision of the Minister to include the vegetable exemption.

Muaūpoko Tribal Authority Incorporated (Muaūpoko), who was then joined by Te Rūnanga o Raukawa Incorporated (Raukawa), argued that the exemption breaches components of the RMA, it runs against Te Tiriti o Waitangi and relevant principles, and is an unlawful exemption.

The High Court considered their arguments, and ultimately found that the decision-making process of the Minister had been lawful, and that the exemption itself was not in any way unlawful. Consequently, the decision by the Minister to approve the NPS-FM with the exemption included was not unlawful.

Of particular relevance in the Court's decision were features of the exemption which showed care and consideration for iwi groups, and which acknowledged that the exemption was not an ideal solution, but rather an interim measure intended to allow more time for bespoke alternatives in those regions.

Given the strong national interests to allow vegetable farming to continue, the Court was satisfied that the Minister had met his duty to consult, and to consider the relevant principles of the Treaty of Waitangi.

The decision was released in June and has been appealed to the Court of Appeal by both iwi.

Three Waters Reform

The latest phase of the Three Waters Reform was public consultation on the Water Services Entities Bill (WSEB). Written submissions, including from Water New Zealand, on the Bill closed in mid-July, and the Select Committee will now hear oral presentations from submitters, before making their recommendations to Parliament.

Taumata Arowai has now released the final Drinking Water Standards, Drinking Water Quality Assurance Rules, and Aesthetic Values, which are to take effect from 14 November 2022.

Compliance with the reporting requirements of the Standards and Rules will be expected from suppliers from 1 January 2023. A summary of these can be found on Taumata Arowai's website.

Other water policy updates

Submissions on the proposed changes to the National Policy Statement on Freshwater Management (NPS-FM 2020) and the National Environmental Standards on Freshwater (NES-F), and on the National Policy Statement on Indigenous Biodiversity (NPS-IB) exposure draft have now closed. Members will have seen our draft submissions circulated on these pieces of policy, which were finalised and lodged with the Ministry for the Environment for review.

Generally, in its submissions, Water New Zealand supported

the policy documents, but sought greater provision for, and enabling of, water services and infrastructure, and clarity around activities in the relevant freshwater zones (in the case of the NPS-FM and NES-F 2020) and significant natural areas (SNA) zones (in the case of the NPS-IB).

Wetland case

In relatively recent breaking news the High Court's decision in *Minister of Conservation v Mangawhai Harbour Restoration Society Incorporated* [2021] NZHC 3113, that held the NES-F applies to natural wetlands in the coastal marine area (CMA).

MfE and DOC are considering how to respond to concerns raised by some councils and resource users that the NES-F's application in the CMA is uncertain. The following approaches are being consulted on:

- Retain the status quo: The NES-F continues to apply to the CMA (unchanged);
- Amend the NES-F to clarify where and how it applies to the CMA;
- Amend the NES-F so its wetland provisions do not apply to the CMA (this is MFE's recommended option).

Public consultation has begun and will be open for six weeks. The Discussion Document can be found on the website for the Ministry for the Environment, www.consult.environment.govt.nz/freshwater/managing-our-wetlands-in-the-coastal-marine-area/

Northland dam

Lastly, on the topic of the NPS-FM, a second dam has been approved for the Northland Region under the fast-track resource consent process.

In October 2020, the region saw the Matawii Project, a proposal for a dam for drinking water, be the first project approved under the Covid-19 Recovery (Fast-Tracking Consenting) Act 2020.

The dam is now under construction about four kilometres north-west of Kaikohe. This first consent paved the way for the recent decision on the Otawere Project, a second drinking water dam which is around five times larger than the Matawii project.

The fast-track consenting process allowed the Otawere application to be heard by a special expert hearing panel convened by the Environmental Protection Authority. In making their decision, the panel was required to consider NPS-FM policies relating to natural wetlands.

Once constructed, the dam will affect around 4.5 hectares of natural wetlands in the area, and hence policies six and seven of the NPS-FM were relevant.

The panel was satisfied that the construction of riparian buffers, as well as the restoration and protection of a greater amount of wetland, satisfied the requirements under these policies.

Additional factors in the project's favour were the regional significance of the infrastructure, the provision of a lifeline utility, and the consistency of the project with The Treaty of Waitangi principles.

Drinking water treatment planning in a climate of change

Drought, bushfires, floods, high temperatures; the unprecedented events that are a result of climate change are becoming more frequent. Regardless of climatic changes and/or instantaneous weather events, there is a critical requirement for the provision of safe and reliable supplies of drinking water during these times of increased risk to public health.

By Sally Williamson, lead engineer, Aurecon

Historically, drinking water treatment has remained relatively static with respect to technology. Thus, many drinking water treatment and supply schemes have been in operation for decades, often with only minimal operational issues and augmentation driven by growth/capacity.

Outcomes of research and investigative projects have confirmed the impacts of climate change and extreme weather events on raw drinking water quality. Drought, wildfires/bushfires and extreme wet weather are the key events that have been observed globally, not just in Australia and New Zealand.

Such events have left some drinking water treatment systems, which have historically operated well, in a position where they cannot produce a safe supply of water; some in the short-term, others for longer periods of time.

The uncertainty around climate change and the unprecedented events it causes brings challenges in planning for future drinking water treatment needs.

Climate change impacts

A range of impacts on drinking water treatment and supply caused by climate change have been observed globally, but with varying risk profiles depending on location.

Usually quantity is the first aspect that is thought of with respect to the impacts of climate change on drinking water supplies, with reports of many communities approaching 'day zero' caused by the combination of increased temperatures and reduced rainfall frequency that is commonly associated with severe and long-lasting drought.

However, the quality of raw drinking water can have an equally significant impact on communities.

Effects linked to climate change have the potential to impact the quality of raw drinking water sources and/or the ability to treat raw water. These include:

- Increases in high temperatures and increases in occurrences of heatwave conditions;
- Decreasing frequency but increasing intensity of wet weather events;
- Increased duration of bushfire/wildfire seasons and increased intensity due to the combination of increased temperatures and dry conditions;
- Combinations of the above resulting in the compounding of impacts.

The specific impacts on raw water quality that are a direct result of effects of climate change are presented in Table 1.

Other risks to drinking water quality caused by climate change that are more relevant to the distribution network, but which also require risk mitigation, include:

- High temperatures of treated water increasing the likelihood of occurrence of Naegleria fowleri, putting pressure on the operation and maintenance of network chlorination systems.
- Increased formation of disinfection by-products observed at higher water temperatures and increasing trends in raw water organic carbon concentrations.

As an example of a poor water quality event that represents a long period without rain followed by an extreme wet weather event, Figure 1 shows the concentrations of dissolved organic carbon (DOC) and total organic carbon (TOC) during drought.

This event started with available storage in a surface water reservoir that went as low as 35 percent followed by an extreme wet weather event that occurred in February 2020 which resulted in the fast filling of the reservoir.

The inflows that entered the reservoir were high in DOC and TOC and caused the entire water column to be mixed.

The figure shows that the pre-2020 maximum TOC/DOC concentrations, that occurred at the last significant wet weather event in 2017 was around three milligrams per litre lower and that during the drought that occurred between the two events TOC and DOC gradually decreased.

Figure 2 provides a higher resolution snapshot of the behaviour of three key contaminants in raw water: turbidity, true colour, and DOC after the 2020 extreme wet weather event.

The figure shows the difference between the behaviour of turbidity, which reduces to less than 50 percent of the peak after seven days and to around 10 percent of the peak in 20 days, whereas the concentration of DOC and true colour decreases at a much slower rate.

It is this behaviour that needs to be well understood when planning for treatment upgrades, as it could be the difference to system demand being met with respect to,

CLIMATE CHANGE IMPACTS ON RAW WATER QUALITY			
Climate change effect	**Event type**	**Impacts to raw water quality**	**Typical trend**
Increased average and maximum temperature Reduced rainfall frequency Reduction in volumes available for environmental flows and groundwater replenishment	Drought	Settling of turbidity and other particulate contaminants Concentration of contaminants – organic carbon, salinity Drawing feed from new depths/sources Saltwater intrusion into raw drinking water supplies	Slow improvement or slow deterioration depending on the contaminant Unknown water quality risk profiles
Increased average and maximum temperature Consecutive days at high temperatures	Heatwave	Increased temperature resulting in a chain of linked events: Nutrients → algae/cyanobacteria → low dissolved oxygen levels → leeching of metals (iron and manganese) from sediments and/or blackwater events resulting in fish kills	Slow deterioration (site specific)
Increased average and maximum temperature Reduced rainfall frequency – increased dryness	Bushfire	Increase in: • Solids/turbidity (and potentially pathogens from deceased wildlife) • Organic carbon • Nutrients Magnitude of effect linked to subsequent timing and intensity of wet weather event.	Slow deterioration (site specific)
Decreased rainfall frequency, but increased rainfall intensity	Wet weather and flooding	Increase in: • Solids/turbidity (and potentially pathogens from deceased wildlife) • Organic carbon • Nutrients Dependent on time since last wet weather event and spatial occurrence of rain.	Fast peaks followed by gradual decrease. *Note that different contaminants will decrease at different rates.*

Table 1

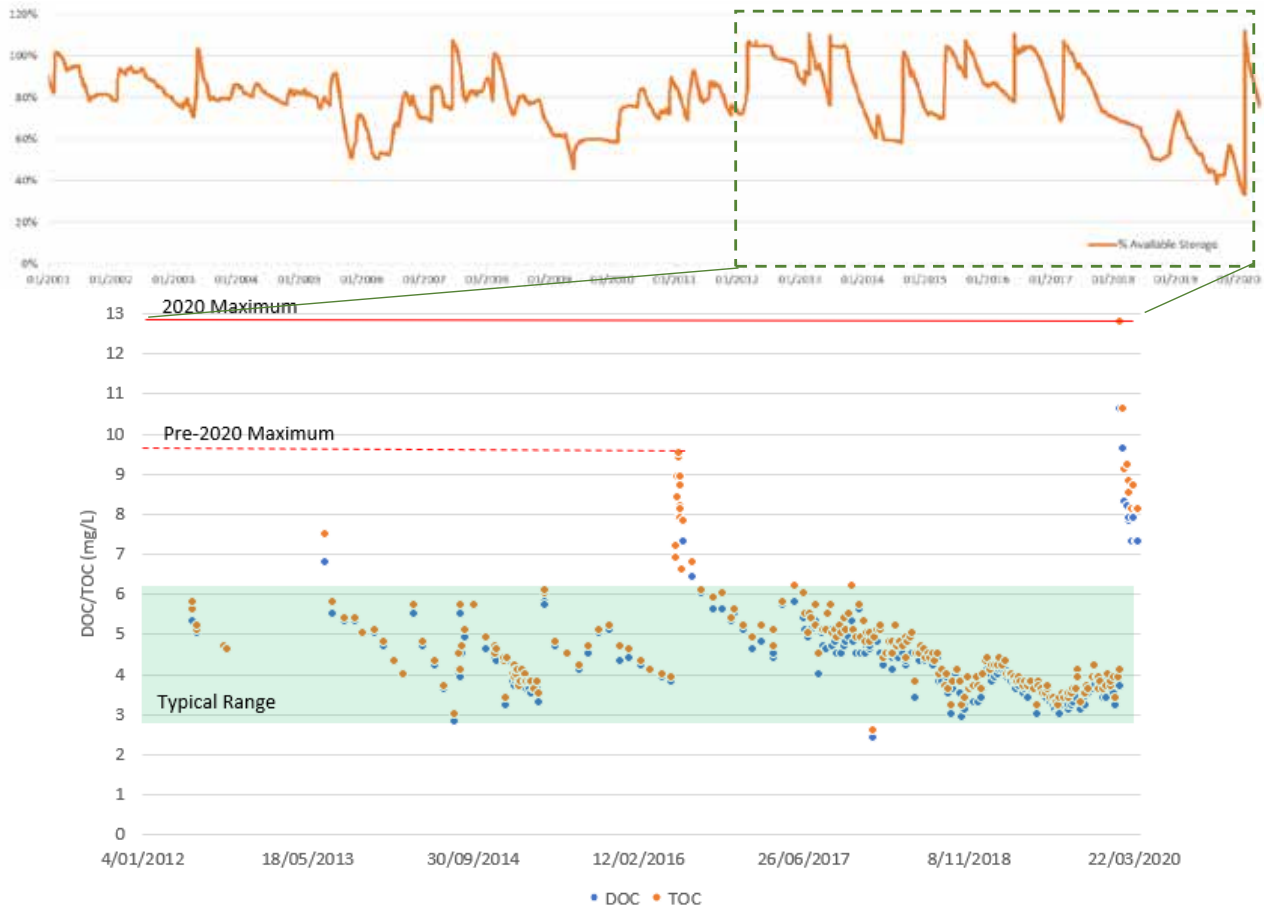

Figure 1: % Available Storage and Raw Water DOC/TOC Concentrations

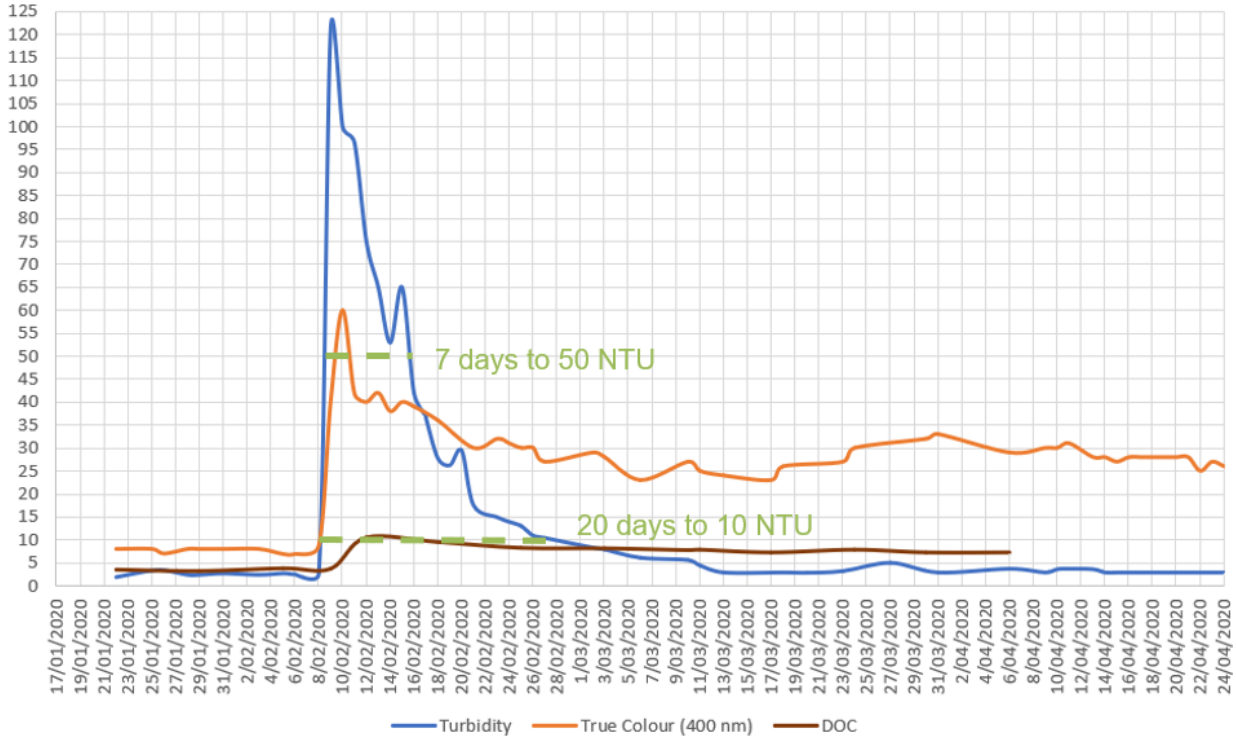

Figure 2: Raw Water Turbidity, Colour and DOC Trends After Wet Weather Event

on the one hand, being able to treat water of sustained poor quality or, on the other hand, a reduction in plant production capacity and the accompanying reliance on sufficient treated water stored in the network.

Drinking water treatment

Technology selection for drinking water treatment has always been specific to the type and characteristics of the raw water source.

In the absence of climate change impacts, the most complex drinking water treatment for surface water reservoir sources has typically been conventional treatment of flocculation/coagulation followed by settling (or flotation) and filtration, with many schemes having a direct filtration plant or even less depending on the raw water quality and/or catchment-related risk.

With relatively stable feed water quality, these types of treatment plants can operate with minimal operator intervention.

However, with the increased intensity of extreme weather events as well as the compounding of risk when multiple events happen simultaneously or in quick succession, conventional treatments designed without climate change in mind are unlikely to be appropriate.

Treatment criteria

There are two main categories of drivers with respect to water quality requirements and the treatment of drinking water:

1. Safe drinking water, which is a non-negotiable requirement and comprises both health-based limits and maximum acceptable values (MAVs); and utility/site-specific operating targets/key performance indicators (KPIs).
2. Drinking water that is aesthetically drinkable, which is an important requirement that involves meeting aesthetic guidelines values/limits to supply water that has minimal colour and no offensive taste or odour.

These drivers need to be considered in conjunction with the requirement to produce sufficient drinking water to meet demands in the community and the potential impact that water quality has on the production capability of drinking water treatment plants.

Planning considerations

There is no 'one size fits all' approach for drinking water treatment planning due to the variability in water supply system configurations as well as the nature of climate change impacts resulting in variable risk profiles for each raw water source.

The following sections look at three considerations that should be made in the process of planning for drinking water treatment upgrades when developing an approach to climate change adaptation and risk mitigation.

Acceptable level of service

The first consideration that needs to be made in the planning process is the acceptable level of service to the community. That is, what is the minimum quality and quantity of supply that the treatment system must meet to be acceptable to the community.

As described previously, there are non-negotiable (health) water quality criteria that are regulated and represent the acceptable level of service for production quality.

The acceptable level of service for aesthetic water quality criteria/limits is lower than for health criteria, in that the maximum duration they are exceeded is higher than for health limits and thus could potentially be exceeded if there is no alternative, but they are still an important consideration for designing treatment upgrade capability. In other words, water that is entirely healthy to drink may not meet aesthetic water quality criteria/limits.

A key deciding factor in determining the minimum level of service for production

quantity is the level of connectivity between systems.

Where a treatment plant has a single source and supplies water to an isolated system the risk of not meeting demand is higher than for a system that can be supplied by multiple treatment plants and/or sources. Thus, for an isolated system, emphasis needs to be placed on planning for a treatment process that can meet the demand under all raw water quality scenarios.

Managing variability with storage

Planning to manage variability can be approached in two ways: management using storage or management using treatment.

For the hypothetical raw water quality event represented by a sudden peak followed by gradual decrease of one or more contaminants as described previously, management using storage uses either existing or new storage to store raw (System B in Figure 3, over the page) or treated (System C in Figure 3,) water before or after treatment, respectively.

This is compared to the configuration (System A in Figure 3) where the only option during a poor water quality event is to attempt to treat the available raw water (or turn the plant off) and if demands can't be met, the potential reliance on tankering or community boil water alerts, which incur a cost both in terms of finance and in terms of reputation.

The premise behind the approach to utilise storage is as follows:

- Offline storage of good quality raw water (pre-event) that can be used as the plant feed until the raw water quality event has passed (System B);
- Storage of treated water in network storages to allow the plant to be shut down during raw water quality events (System C).

Both approaches require operating the system (feed or network) above demand when raw water quality is good so that storages are as close to full as possible just prior to the event that can impact water quality in other ways.

The key considerations that should be made when utilising system storage for mitigating the impacts of poor feed water quality events include the following:

- The duration of the poor raw feed water quality event during which the treatment plant would be unable to perform to meet the required water quality and/or quantity targets. That the types of events can be managed using this approach are limited by the available storage volumes. For example, if the event results in elevated turbidity only, the duration of the event is likely to be lower than if the event results in elevated colour (refer to Figure 2) or if the event results in elevated salinity caused by ongoing drought conditions with an unknown event end.
- The timing of the poor water quality scenario versus demand trends. That is, the likelihood of a poor water quality event (which are often triggered by an extreme wet weather event) occurring at the same time as a high

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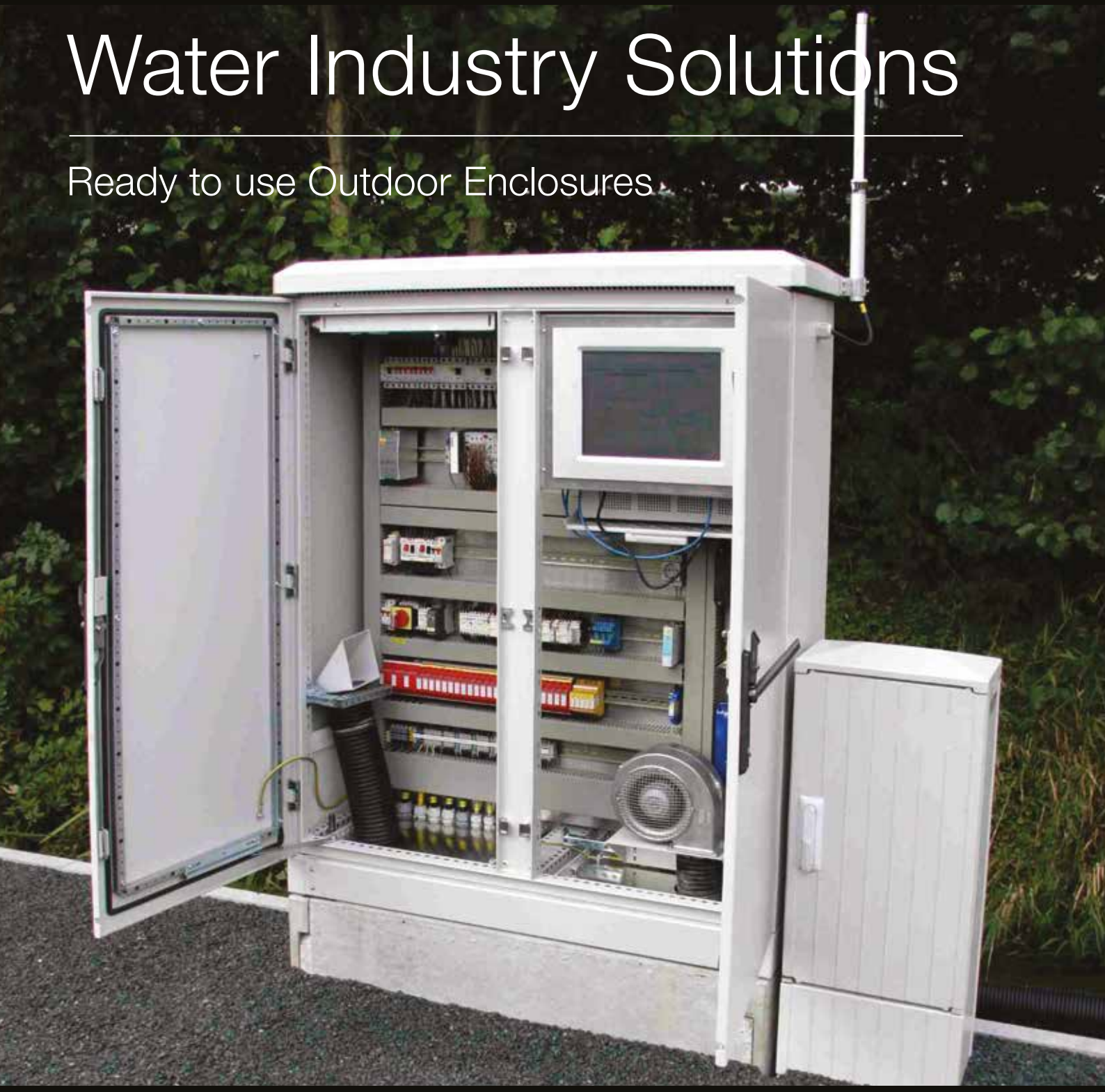

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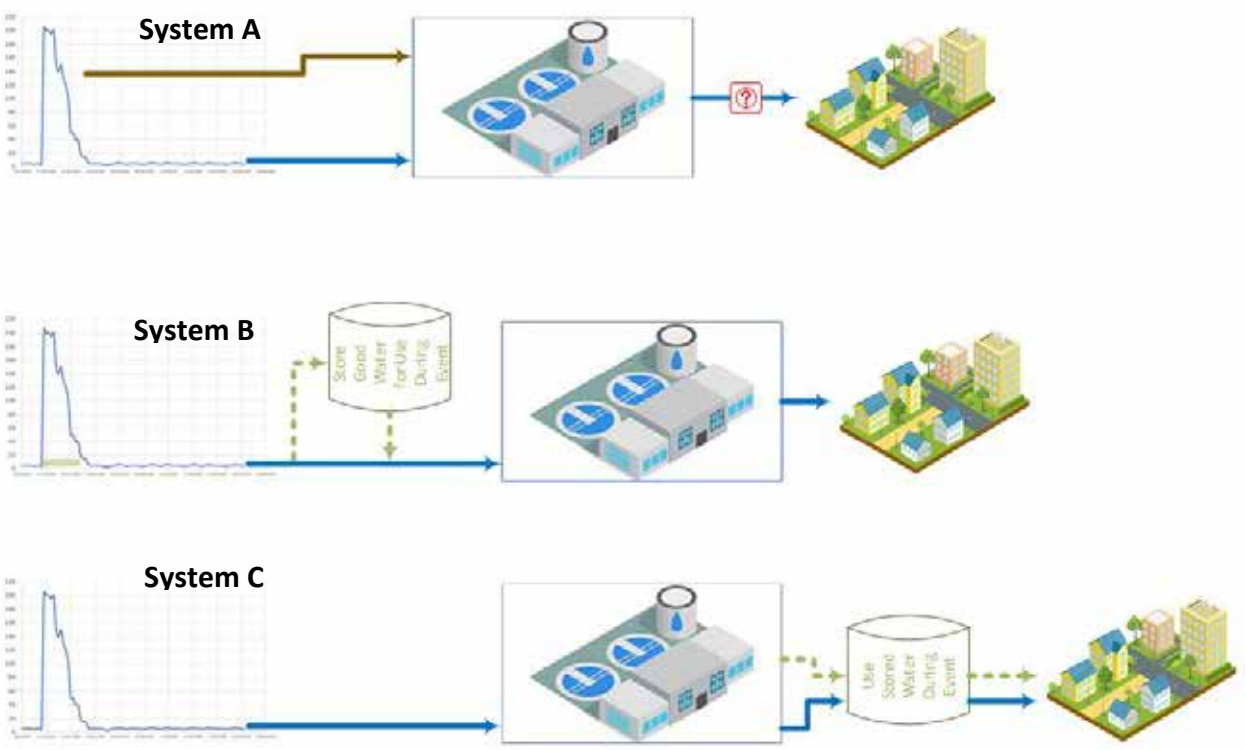

Figure 3: Storage Scenarios: System A – No storage, System B – Raw Water Offline Storage, and System C – Treated Water/Network Storage

customer demand and whether demand management needs to be employed.
- The limitations to available footprint to construct new storages that are sufficient in size to be able to buffer against the full duration of water quality events as well as operational issues around water age that could be introduced.

For the same hypothetical raw water quality event, managing using treatment relies solely on designing and operating a water treatment plant to continuously meet the acceptable levels of service to the community. That is, the treatment plant must be designed for not only the historic worst quality raw water event: due to climate change, we need to consider the potential future worst quality raw water event.

To accomplish this, the full suite of process risks in the system, including those introduced by climate change, need to be considered. This is discussed in the following section.

Process risk

Process risk relates directly to the ability of the treatment plant to mitigate the water quality hazards that are caused by the impacts of climate change.

As summarised in Table 1, different impacts of climate change increase the risk of different water quality hazards. However, the impacts of climate change on water quality don't present themselves uniformly in different locations let alone from one event to another.

Typically, water treatment schemes are designed based on a review of historical data, then a selection is made of a set of design values based on a tolerable level of risk of having to address peak poor water quality operationally.

However, when a reliable supply of safe water is a key driver for a system and there is a non-zero probability that an unprecedented water quality event will occur in the future, simply selecting a design value based on percentiles of historic data is inappropriate.

This brings about the question of how to select a set of appropriate design values to ensure future reliability and/or adaptability to cover raw water quality conditions that may never happen.

The first step in mitigating process risk is developing a broad understanding of the raw water catchment and the behaviour of the raw water source (reservoir, groundwater, or river) under the various climate change related events.

Specifically, understanding of the types of events that could occur, the frequency and magnitude of those events (including the occurrence of multiple events types simultaneously or in quick succession), and the resulting water quality impacts that would arise with each event.

Once the process risks are understood, in addition to utilising available storage to mitigate the variability of raw water quality change, there are two approaches that could be taken with respect to mitigation. They are as follows:
- Increased treatment flexibility through the addition of new treatment processes to target specific hazards (System A in Figure 4, over the page).
- Increased monitoring at operational and critical control points (OCPs and CCPs) along the treatment train with targeted operational changes to mitigate risks in real time (System B in Figure 4).

The key differences between these two approaches come down to capital versus operational expenditure.

The upgrades required for System A would require capital investment in treatment infrastructure to allow flexibility in treatment approaches and could be described as a proactive approach, whereas System B requires a finer resolution of monitoring and development of operational procedures (corrective actions) that could be

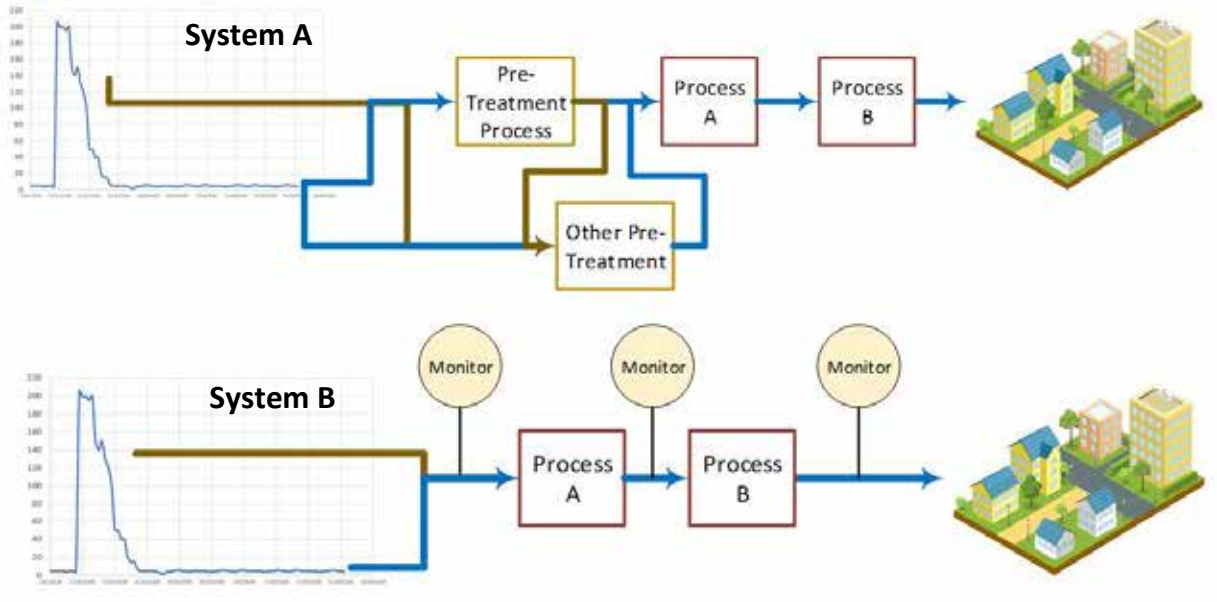

Figure 4: Treatment Configuration and/or Operational Scenarios: System A – Flexible Configuration, and System B – Optimised Monitoring

implemented quickly and could be seen as a reactive approach that puts significant pressure on operations teams.

However, the limitation that applies to both systems is the uncertainty around the magnitude of raw water quality degradation and the ability to mitigate this risk through additional treatment or targeted operational changes.

For System A, the uncertainty relates to the raw water quality feed design envelope that is selected, which will be able to cover a future scenario of unknown severity. This uncertainty could result in a treatment process that is not capable of meeting treatment targets, or in a treatment process that sits idle for long periods, or both.

Typically, water treatment plants are designed based on a review of historical data, then selection is made of a set of design values based on a tolerable level of risk of having to address peak poor water quality operationally, however with the increased frequency of unprecedented events leading to previously unseen poor water quality this approach is no longer suitable.

Thus, to minimise uncertainty when designing new or upgrades for water treatment the following should be employed in addition to the standard historic source water quality assessment:

- A detailed risk assessment looking at the behaviour of key water quality parameters in the catchment.
- An assessment of the existing system (if applicable) and its historical performance under adverse water quality scenarios.
- Application of climate forecasting and water quality modelling to historical peak contaminant levels, to develop future worst-case peak contaminant levels under a range of defined events.

For System B the uncertainty relates to the rate that raw feed water quality changes and the overall limitations on the operations team and the process.

That is, even if there is a robust corrective action plan for a poor feed water quality scenario, can it be implemented quickly enough to mitigate risk, and what happens if the magnitude of raw water quality degradation exceeds the treatment capability of the plant. In other words, the plant will have a limit at which poor water quality can't be treated with the available infrastructure and may eventually require capital expenditure.

It should also be noted that whilst this approach can defer the need for capital investment, it puts significant pressure on the operations team, which requires the team to be highly trained and able to make key decisions quickly.

Conclusions

When assessing the overall risk of adopting an approach for mitigating process risk caused by climate change, there are multiple aspects that need to be considered.

Selecting the approach for the mitigation of impacts of climate change inevitably comes back to the acceptable level of service with respect to quality and quantity of drinking water to the community.

In selecting the most appropriate approach for a specific drinking water system, the key considerations are as follows:

- The configuration of the system and the ability to service the community with drinking water that meets the non-negotiable (health-based) water quality criteria.
- The ability to operate the system to avoid poor water quality events through utilisation of available storage and demand management.
- The level of investment (capital and/or operational) that is suitable for that system to mitigate process risks given the system configuration and its treatment limitations.

Whilst there is no 'one size fits all' solution, through an increased understanding of the frequency and magnitude of climate change related events, the process risks relating to different events and the limitations of the system, planning to mitigate the risks to water quality caused by climate change impacts is feasible and necessary to maintaining an acceptable level of service to the community.

This paper was presented at the Water New Zealand Conference & Expo 2021. This version has been edited for style. To see the full paper, go to: bit.ly/3ATEXbf

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Optimisation of wastewater irrigation

Tools such as OverseerFM are currently widely used and accepted for assessments of nutrient leaching. However, OverseerFM is designed to model agricultural land use for farming rather than for wastewater treatment. This paper discusses an integrated water balance model that can be used to assess the performance of land treatment systems. By Neeraj Pratap, environmental engineer, and Hilary Lough, technical director – water resources, Pattle Delamore Partners

The health and well-being of our water bodies are of high priority. With the implementation of the National Policy Statement for Freshwater Management 2020 (NPS-FM), regional councils are required to give effect to Te Mana o te Wai. Requirements for certain activities, such as the discharge of nitrogen, are set out in the National Environmental Standards for Freshwater 2020 (NES-F). These documents aim to protect and prevent further degradation of our freshwater environments.

Irrigation of wastewater to land is a common practice in New Zealand for both municipal and industrial wastewater. Irrigation to land typically provides significant environmental benefits over other discharge to land techniques and direct discharge to surface water.

Discharges following treatment at a wastewater treatment plant (WWTP) often contain elevated levels of nitrogen, which can be both difficult and expensive to remove. Elevated nitrogen concentrations can result in adverse effects on public health and aquatic life.

The Drinking Water Standards (Ministry of Health, 2018) provide a maximum acceptable value (MAV) for nitrate-nitrogen, a highly mobile form of nitrogen which can be easily leached through soils into groundwater. The NPS-FM provides attribute states for nitrate-nitrogen for ecosystem health protection and sets national bottom lines.

Discharges of wastewater to land via irrigation following treatment in a WWTP can provide additional nitrogen removal prior to the water entering the receiving freshwater environment.

This paper outlines a soil moisture balance (SMB) model developed by Pattle Delamore Partners (PDP). The tool is useful for assessing and optimising wastewater applications to land, including to maximise nitrogen removal. It can provide a better understanding of potential discharges to the receiving freshwater environment through drainage and/or overflow during extreme events.

The model was originally designed as a demand-based soil moisture model, focusing on determining clean water irrigation requirements. It was further developed to model wastewater irrigation, including modules for estimating nutrient leaching.

The advantage of the model is that it works on a daily timestep and can incorporate various components of a wastewater treatment system, such as storage ponds, and wetlands to assess the full irrigation system. This provides the capability to evaluate and optimise a wastewater system's ability to achieve the desired environmental outcomes.

Flexibility to include any number of irrigation areas, each with its own soil and climate inputs is available. The soil moisture for each area is assessed at a daily timestep. The previous soil moisture content is used to establish priorities for the next timestep.

Priorities can be set to a wide array of options. This includes the highest soil moisture deficit in an area or the number of days since the last irrigation. A daily resolution provides a fine level of detail for optimisation and can assist in reducing the total seasonal drainage to groundwater arising from the wastewater discharge.

This paper describes the soil moisture balance component of the model, and then describes how the model can be used to estimate nutrient leaching. The model has the capabilities to be run in real-time to optimise wastewater management and minimise adverse effects.

Soil moisture balance model

The general principle of a soil moisture balance is to track the mass of water entering and leaving the soils over a fixed depth profile. The model can be extended to allow for nutrient leaching. This illustrates the conceptual soil moisture balance model.

The key components available in the model are described in detail below.

Irrigation

Different irrigation systems use different methods to apply water to the land treatment area. These include spray, drip, or border dyke irrigation.

A spray irrigation system such as a centre-pivot system is commonly used to irrigate wastewater for larger scale discharges. In areas where the terrain is a limiting factor or spray irrigation may not be as effective (for example some forestry) or for smaller scale systems, drip irrigation may be specified.

Deficit irrigation is ideal to minimise nutrient leaching, but not always practical for wastewater discharges given the year-round nature of most wastewater generating activities and common limitations on storage.

Deficit irrigation models set a maximum threshold for soil moisture levels below which irrigation can occur (often below field capacity). When the water level in the soil profile drops below the threshold, the depth required to reach the threshold is the soil moisture deficit.

The maximum irrigation applied for the day can then be set as either the soil moisture deficit or a maximum irrigation rate as determined by the soil characteristics and specified irrigation system.

As part of reconsenting or upgrades to a system, modelling the status quo and comparing it to new systems or alternative

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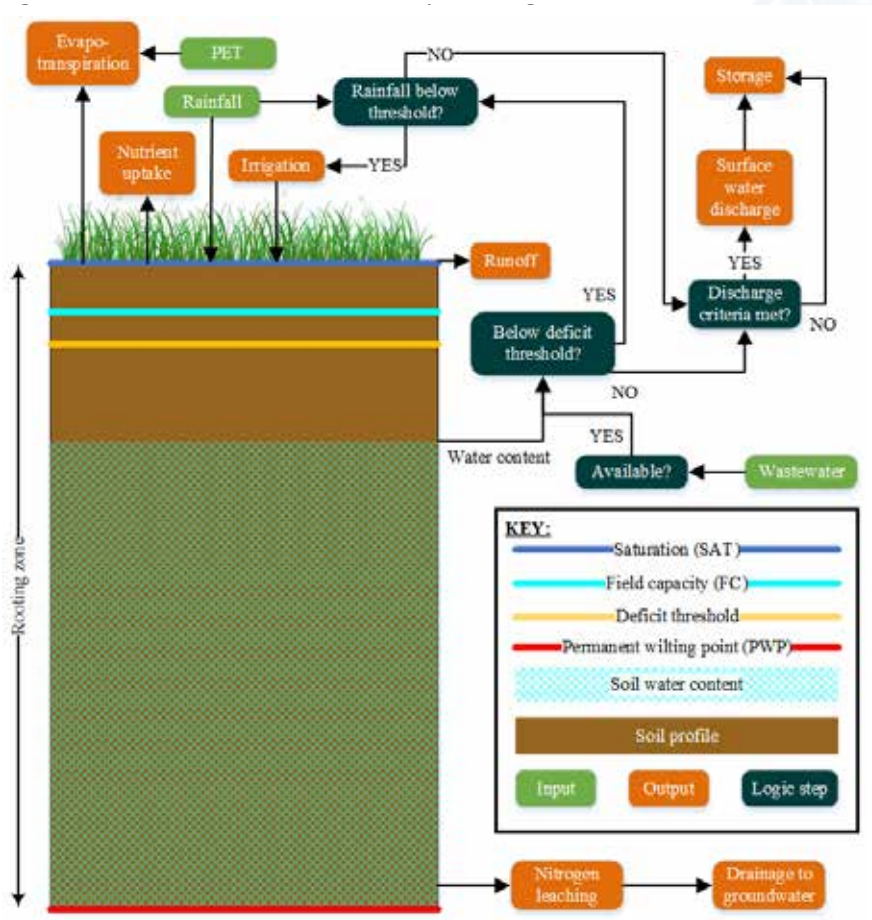

Figure 1: Soil water balance conceptual diagram.

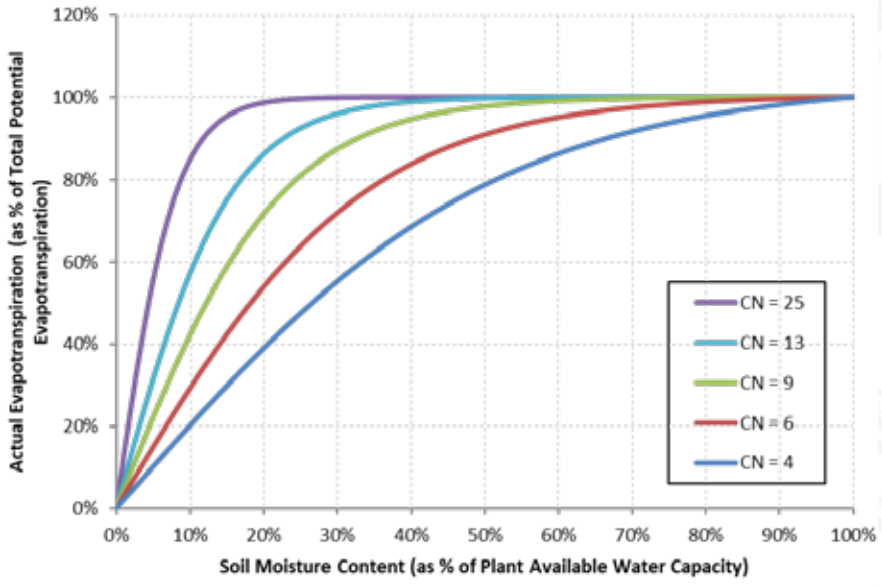

Figure 2: Evapotranspiration soil moisture content adjusted by a curve number.

management practices can provide valuable information to optimise improvements.

An existing scenario can be modelled using recorded application depths and other data, where available, to set the existing baseline for comparison.

Assessing the soil moisture balance for each irrigable area using a daily time step, the model can select which area to irrigate based on the prioritisation of demand parameters. The demand parameters can include soil moisture deficit, time since last application (after any minimum rest periods), and/or a specific irrigation sequence.

By optimising the application of wastewater available based on the required prioritisation, the drainage and consequent leaching of nutrients can be better managed.

Evapotranspiration

Evapotranspiration (ET) is a key mechanism for non-draining moisture loss from the soil profile. The amount of ET losses from the soil is a function of the soil moisture content.

The model assumes that actual ET from the soil is given by the relationship with potential evapotranspiration (PET) shown in Figure 2. As the soil becomes drier, water is more difficult for plants to draw from the soil.

The curves shown in Figure 2 are based on a mathematical approximation of experimental data. The approximation does not account for variances with soil type. The curve numbers allow for adjustment of the relationship for various climates.

Rainfall and runoff

Rainfall is the key factor for producing drainage through the soil profile for deficit irrigation. The rainfall series selected is site specific and chosen to best represent the modelling period.

The most ideal record would be a complete long-term dataset from a rainfall gauge near to the irrigation site. This is often not the case and judgement is required to produce a reasonable estimate of the rainfall at the site.

Wastewater is typically irrigated on flat or gently sloped areas. Therefore, rainfall losses due to overland flow runoff are generally minimal. This assumption is hydraulically conservative provided that the application rates are low enough not to cause runoff during irrigation.

Runoff coefficients can be used if the irrigation site includes areas where runoff generation can be expected. The model reduces the rainfall applied to the area by a calculated proportion to estimate the runoff losses.

Drainage

Drainage occurs when the soil water content exceeds field capacity.

The model assumes drainage continues at an increasing rate as the water content approaches saturation. At this point, water from the soil profile is assumed to drain at the saturated drainage rate, which can be measured in-situ for different soils.

The model assumes the drainage rate relationship is either linear or exponential.

Interaction with system components

During larger rainfall events, if the soil water content is above the deficit threshold, the ability for the soil to receive additional wastewater without resulting in drainage is limited.

For WWTPs servicing larger catchments (for example municipal wastewater), inflow and infiltration during these larger events also tend to increase the flows through the WWTP and increase the volume to be irrigated.

Possible options for excess wastewater above the daily irrigable volume are storage or an alternate disposal, such as discharge to a nearby waterbody where appropriate. In practice, a combination of the two is often implemented and designed based on site restrictions and the characteristics of any receiving water body.

A design event can be used as a threshold for when excess volumes may be discharged outside of the irrigation system. Non-deficit irrigation may be a preferable option to other discharge methods.

The two key variables when designing a new wastewater disposal system are the land available for irrigation and any storage volume available.

For reconsenting existing systems these parameters may not always be easy to accommodate without investigating alternative areas for discharging. Optimising the full system in an integrated manner can identify where the most effective adjustments could be made.

Nutrient assumptions

The key nutrient typically modelled is nitrogen. Nitrogen is commonly the main nutrient of concern for leaching associated with wastewater discharges. Excess nitrogen entering the environment can have adverse effects on the receiving environment and may pose a risk to human health.

The nitrogen cycle has been conservatively simplified in the model. The complex transformation processes such as nitrification, denitrification, and mineralisation have not been included in the model at this point in time.

It has been reasonable to assume for the wastewater discharges modelled to date that all applied nitrogen is readily available for conversion into nitrate that can be lost to groundwater via leaching during a drainage event.

Plant uptake is the only mechanism for nitrogen removal in the model. All nitrogen which is not taken up by plants is assumed to leach during drainage events. This results in a conservative estimate of leaching output.

While the modelled nitrogen entering the receiving environment is conservatively estimated in the current model, meaning the nitrogen leached may be over-estimated compared to models that allow for more complex processes, the model is able to provide a useful comparison of potential leaching between different irrigation systems and management approaches.

Comparison against OverseerFM

OverseerFM is a widely used and accepted software package for consenting and modelling the impact of farm management on the flow of nutrients. The core model has been developed around informing strategic farming decisions with a focus on agricultural production.

OverseerFM provides capability for modelling the nutrient cycle, working on a monthly timestep. The nutrient component of OverseerFM incorporates the nitrogen cycle and natural processes such as nitrification and denitrification. The nitrogen leached is calculated at a monthly timestep and based on the monthly drainage.

A NIWA 30 year average climate model is used where the climate information (rainfall, average temperature, and annual PET) is selected based on the site location and is gridded at a 500m scale. The monthly rainfall figures are not available to the user nor is there an ability to enter or edit blocks manually.

Irrigation applications are entered monthly as either a fixed return period and fixed depth, or as a soil moisture strategy with triggers and application depths based on the soil moisture deficit.

OverseerFM supports seven irrigation systems: fixed pivot, spray lines, border dyke, controlled flood, micro irrigation, travelling, and solid set. The type of irrigator has an impact on losses to the atmosphere or drainage. The selected irrigator also has set defaults for application depth and irrigation start/stop triggers.

The soil moisture strategy is based on how much water is required by plants rather than a required volume to be discharged, as is required for wastewater discharges. There is no ability in OverseerFM to model volumes in excess of the soil capacity going to storage or an alternative disposal system.

Irrigating pasture typically increases dry matter (DM) production and so allows more animals to graze the same area of pasture or greater production of grass/silage (cut and carry). Commonly, the discharge of wastewater is coupled with cut and carry operations.

OverseerFM estimates pasture DM production based on the metabolisable energy (ME) requirements of grazing (or cut and carry fed) animals on a farm less the ME supplied as crops and/or supplements. This is determined by animal management and production information that the user enters.

As OverseerFM is designed to assess agricultural production, parameters such as storage volume and required area for wastewater irrigation are not provided for. There are assumptions associated with the OverseerFM model to ensure ease of use.

The PDP model is not considered to be a replacement for OverseerFM, rather it is complementary and provides an additional level of detail focused on the discharge of wastewater.

The optimised irrigation results from the PDP model can be used for comparison with OverseerFM and to develop OverseerFM inputs to provide additional assessment of the nutrient cycle and transformation.

Example case study

The following case study involves the discharge of treated meat processing wastewater to land. The study presented here is to assess the transition from existing travelling irrigators to centre pivots. The site includes five main irrigation blocks and contains a diverse range of underlying soil types. Figure 3(see page 87) shows the soil types, and Figure 4 (see page 87) shows the existing and proposed irrigation layouts. It is noted that Ruat_7a.1 is restricted by clay horizon which limits the rooting depth, and therefore, the profile available water capacity.

For this study, the two irrigation layouts were compared using the same input

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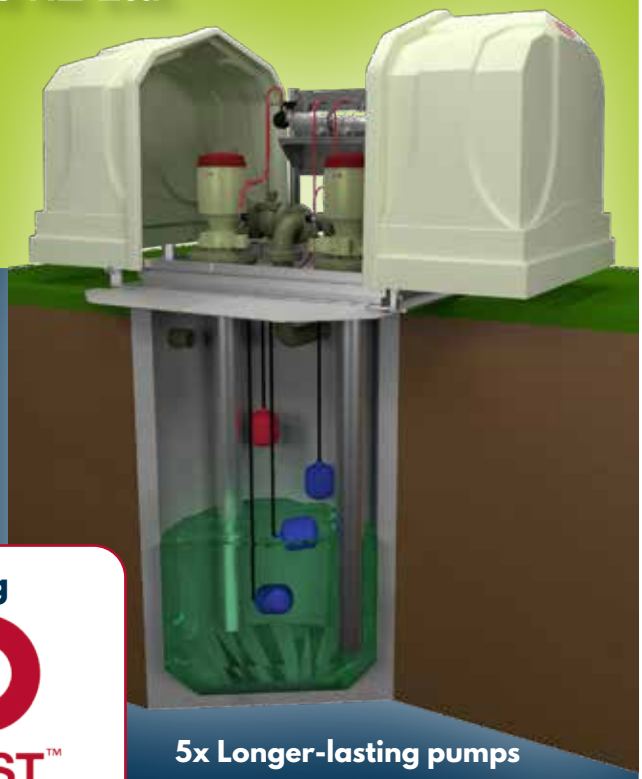

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Figure 3: Case-Study Soil Map.

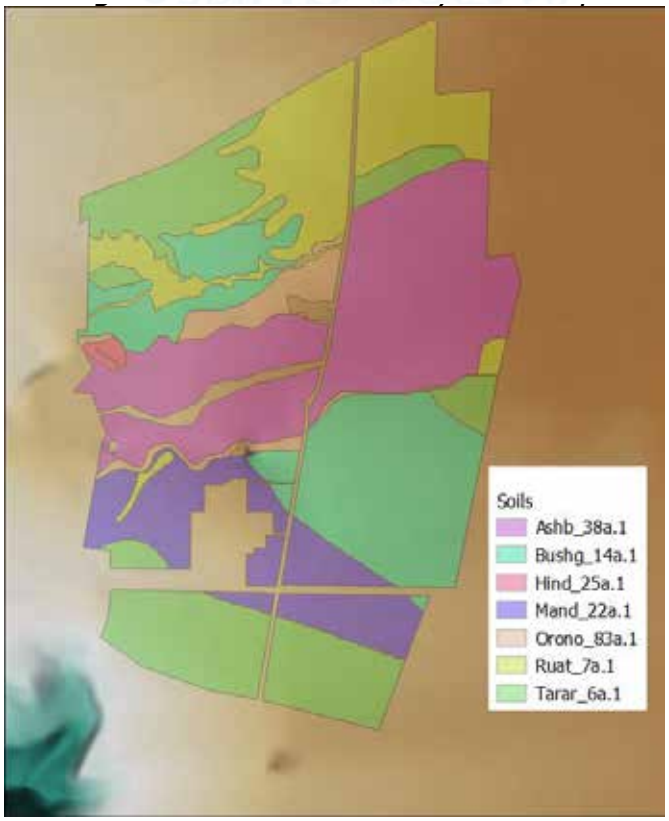
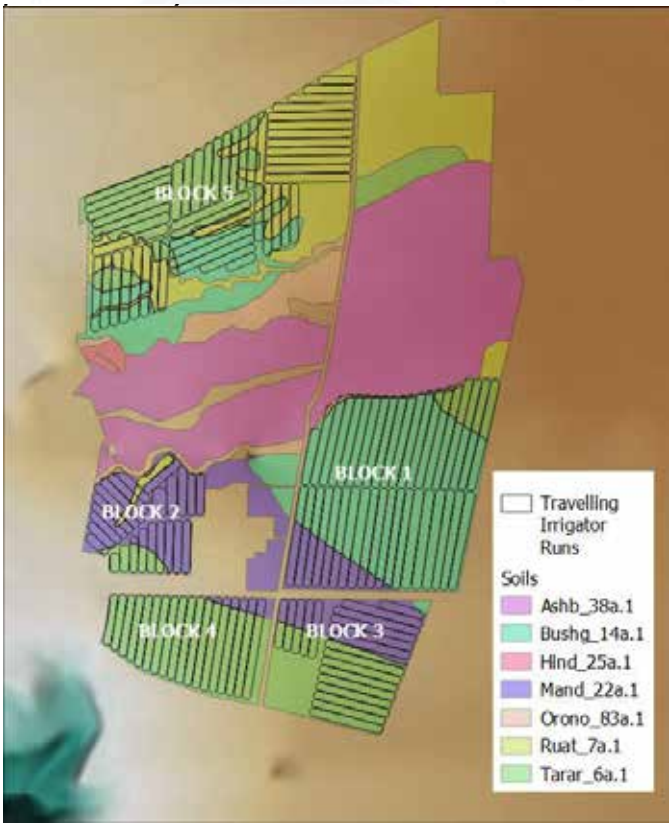
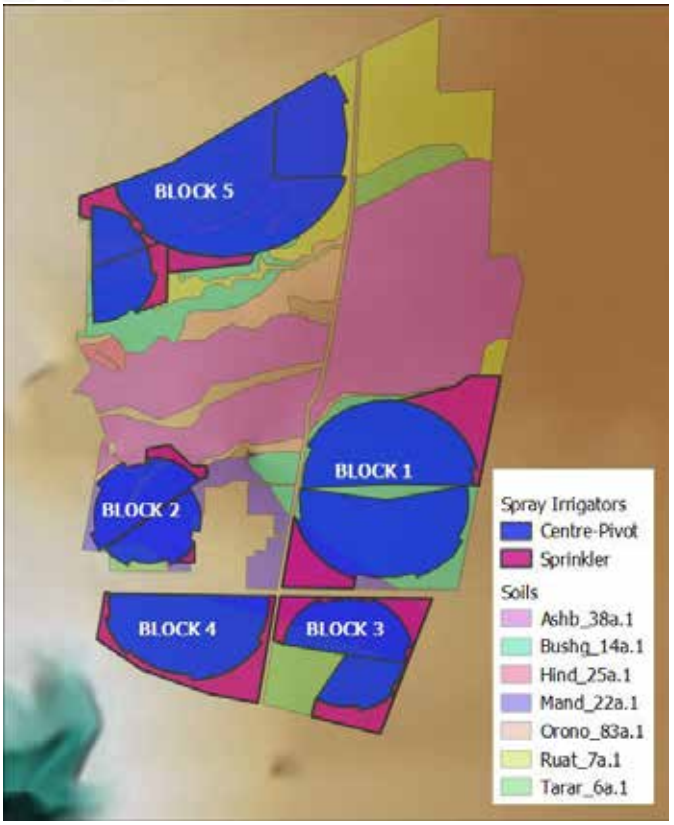


Figure 4: Existing travelling irrigator runs and proposed centre-pivots with sprinkler layout





wastewater flow series for a year with sufficient data. The wastewater flows were recorded over the entire year and applied using the existing travelling irrigators.

An optimised irrigation scenario using centre-pivots and sprinklers was then modelled and compared for the same study year.

Figures 5-7 (See Page 88) compare the modelled irrigation applied, modelled drainage, and modelled nitrogen leaching over the model year, respectively.

Figure 5 shows the average of the total irrigation applied over each of the blocks is greater in the centre-pivot scenario.

The travelling irrigators can be seen to underutilise two of the sub-blocks in Block 5 (5b and 5d). These areas have a clay horizon limiting their soil water capacity. With the higher application rates of the travelling irrigator, these areas were not well draining and therefore not preferred.

With the centre-pivot scenario, the irrigation is applied more evenly over all the areas available for that scenario. This results in the average of the total irrigation applied over the site being greater even though the same wastewater volume was applied. The modelled drainage and nitrogen leached however, are lower.

As all the blocks were utilised effectively using a centre-pivot with soil moisture optimised irrigation, the average application depth over many areas increased.

Assessing the drainage and consequent leaching, the centre-pivot irrigation system has been optimised to irrigate with the objective of reducing the drainage. The areas with the highest soil moisture deficit were prioritised to ensure that the wastewater was applied based on the water holding capacity of the soil types.

Forecasting and real time modelling

Capabilities in future versions of the model, which are currently in development, include forecasting and the inclusion of real time modelling. Additional nitrogen processes are also being considered.

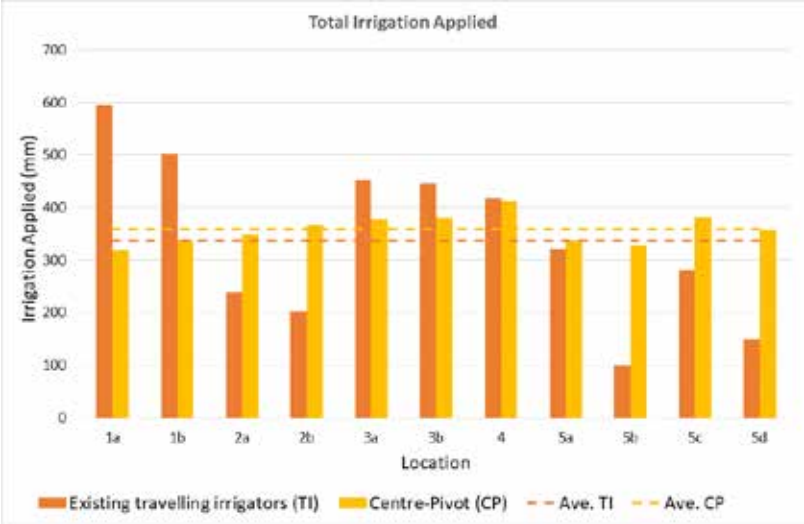


Figure 5: Irrigation applied over a single year. The dashed lines represent the average irrigation over all blocks.

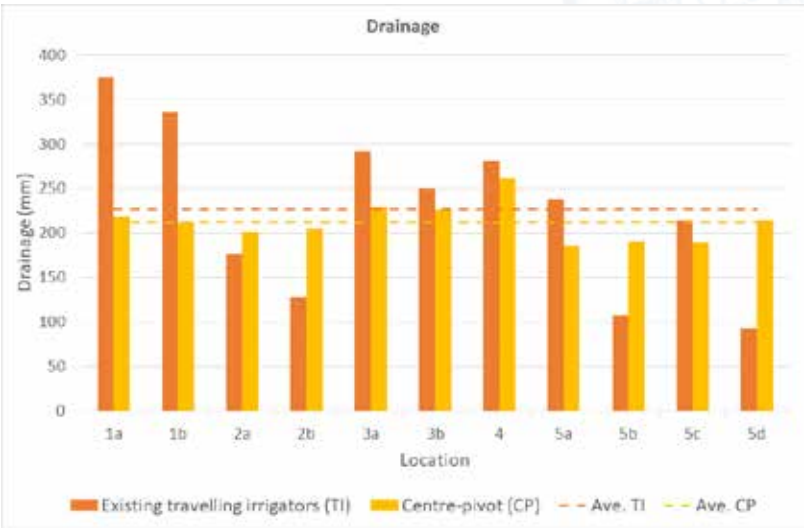


Figure 6: Modelled drainage for each block. The dashed lines represent the average drainage over all blocks.

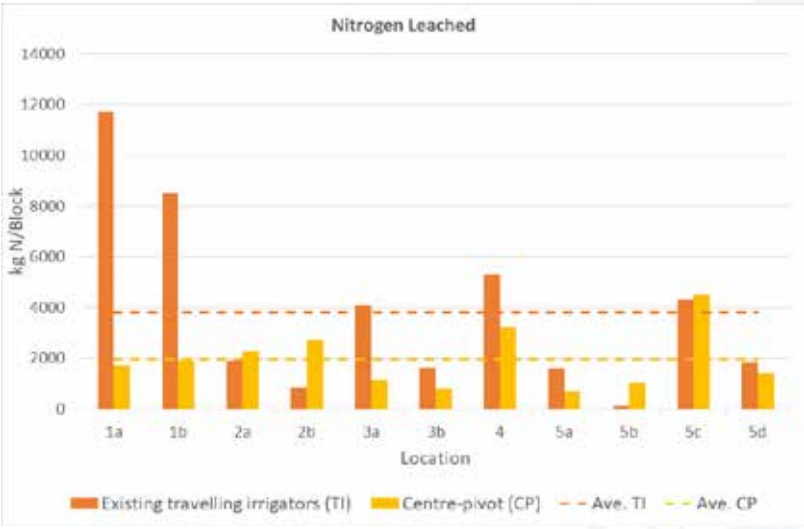


Figure 7: Modelled nitrogen leaching for each block. The dashed lines represent the average nitrogen leaching over all blocks.

The forecasting module estimates future conditions based on rainfall predictions. As the key driver for drainage events is rainfall exceeding the field capacity of soil, forecasting wet weather events and limiting the application of irrigation prior can provide additional strategies for managing potential leaching into the freshwater environment.

The real time modelling can occur in conjunction with site monitoring equipment such as soil moisture meters and lysimeters. The model can be run with updates to the dataset and frequently be calibrated and reviewed against the in-situ modelling.

Conclusions

The protection of our freshwater environment is at the forefront of our engineering decisions. The discharge of treated wastewater from a wastewater treatment plant is often high in nutrients, and nitrogen is often difficult and expensive to remove, so discharge of wastewater to land via irrigation is often used as part of the treatment process to increase nitrogen removal.

As the discharge is part of the treatment process, it is important to understand the soil moisture balance and, as with any environmental engineering design, to optimise the system to achieve the best environmental results.

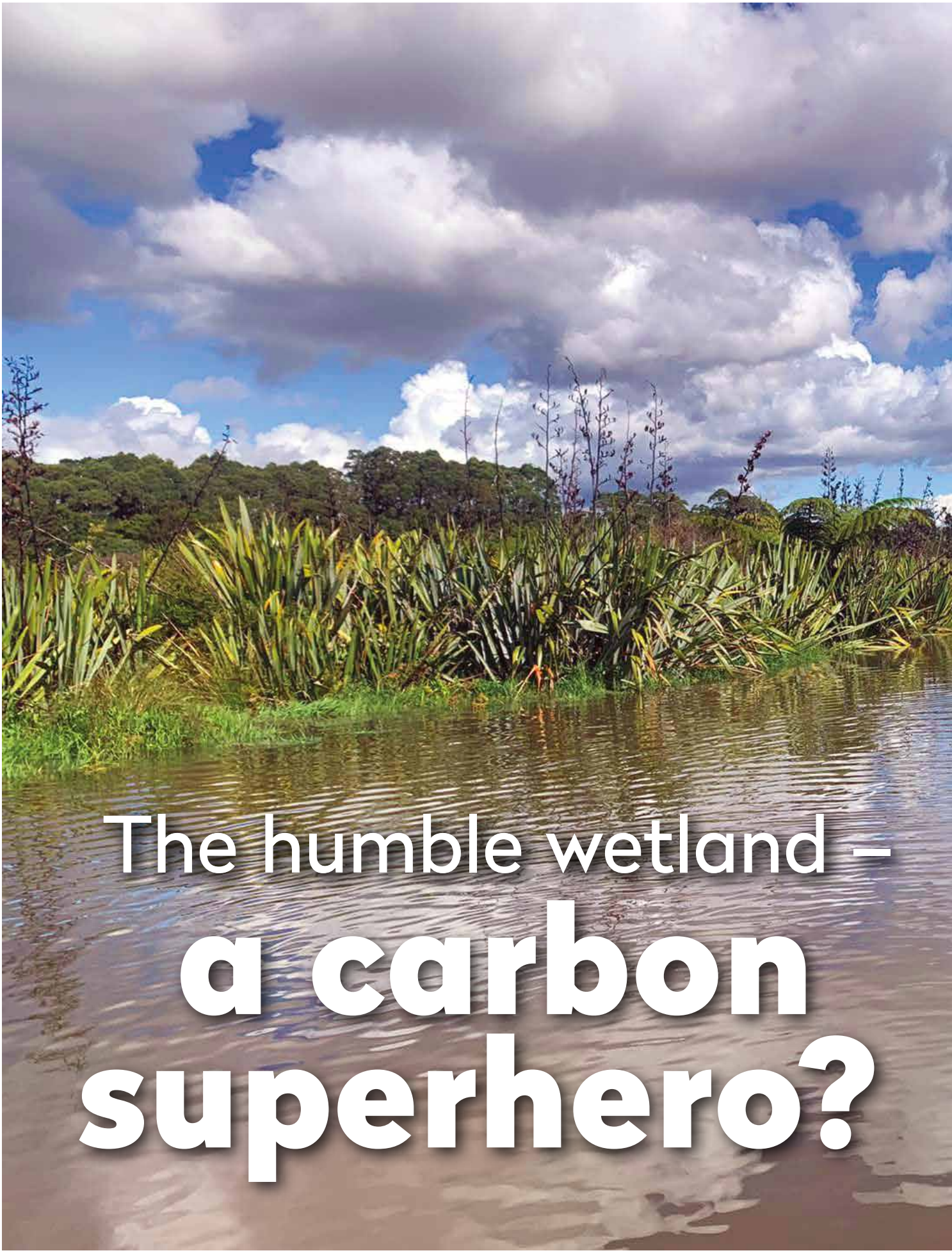
This paper has outlined a soil moisture model developed by PDP. The particular model described has been designed specifically for modelling and assessing the discharge of treated wastewater to land. The model can be used to optimise a wastewater irrigation system and provide valuable information on irrigation management.

A case study assessed the difference between two irrigation methods, an existing travelling irrigator and an optimised centre-pivot system. The modelled results showed better utilisation of the irrigable areas available and a reduction in modelled drainage and leaching.

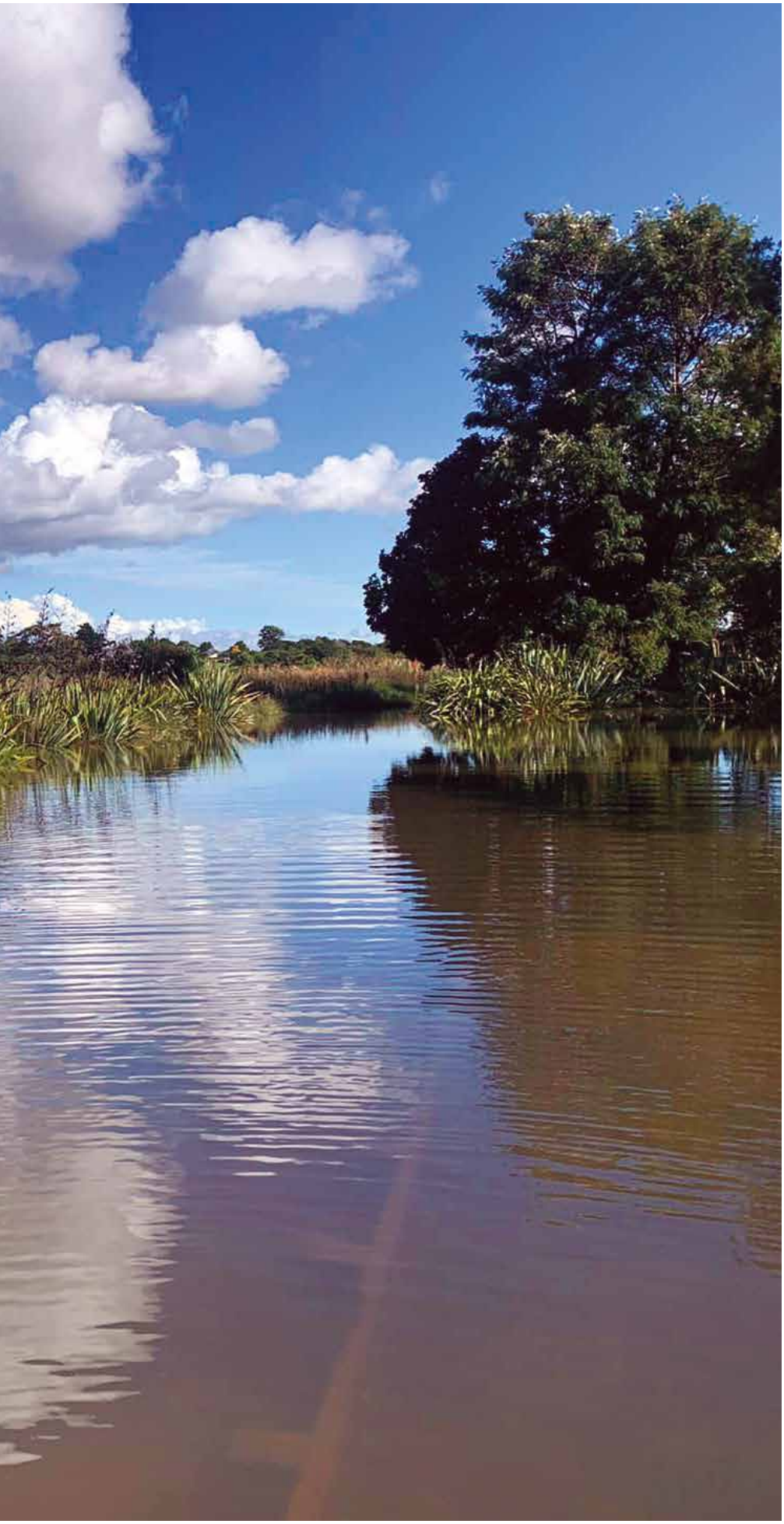
The model has capacity to include forecasting modules in future developments as well as real-time modelling to assist in monitoring and adherence to consent conditions. Further nitrogen processes will be included as required.

Overall, the model is a useful tool to aid in the understanding of the potential impacts from wastewater irrigation. It is versatile in its capabilities and can be used for the design and management of new systems as well as assessing and comparing upgrades to existing systems.

This paper was presented at the Water New Zealand Conference & Expo 2021. This version has been edited for style. To see the full paper, go to: bit.ly/3ASbU7N



The humble wetland – a carbon superhero?



Wetlands can play a role in the strategies to mitigate climate change and could be called a 'carbon superhero'. A paper presented at the Water New Zealand Conference and Expo 2021 Part 2 by Kate Simmonds and Lucy Ferris of Jacobs New Zealand shows that wetlands could be reinvigorated as a critical piece of wastewater infrastructure with multi-faceted benefits.

It is well understood that the climate is changing at an extraordinary rate. It is predicted that these changes will result in intensifying storm activity, rising sea levels and more frequent floods and droughts.

Strategies to mitigate climate change and adapt to its changing conditions are needed now, more than ever. Wetlands can play a vital role in this strategy and the humble wetland might even be called a 'carbon superhero'.

In New Zealand, in a municipal wastewater context, wetlands are a common process in the overall wastewater treatment train. Wetlands as part of the treatment process are particularly evident in smaller and more rural wastewater treatment plants (WWTPs).

Wetlands, particularly peatlands and coastal systems (i.e., mangroves), store significant volumes of carbon in plant biomass and especially in the soil. Peat wetlands are considered 'super' carbon sinks, holding twice as much carbon as all of the world's forests combined, estimated at between 180 and 450 gigatonnes globally, yet covering less than three percent of the earth's surface.

This poses the question – is the wetland a carbon superhero – and could strategic use of wetlands in WWTP treatment trains result in improved overall environmental outcomes for wastewater management and treatment?

The 4G Wetlands comprises 176 acres of created wetland habitat.
Located on the 4G Ranch, near Tampa, Florida, it takes excess reclaimed water from five wastewater treatment plants.

Current New Zealand situation

The numerous values and uses of wetlands have been well documented. Healthy wetlands are part of a healthy environment; yet wetlands continue to be lost, degraded, undervalued, ignored, and destroyed both deliberately and through lack of understanding of their importance. It is estimated that we have lost approximately 90 percent of our wetlands following European settlement.

Constructed wetlands (CWs) are an established technology for secondary or tertiary treatment of wastewater, with over 80 systems in operation here. Wetlands as part of the treatment process are particularly evident in smaller and more rural wastewater treatment plants.

Wetlands in wastewater treatment

Wetlands can be used for wastewater polishing as an alternative for small communities that are either situated near an existing wetland or in a position to construct one.

(CWs) are engineered systems that have been designed and constructed to utilise the natural processes involving wetland vegetation, soils, and their associated microbial assemblages to assist in treating wastewater. CWs are designed to take advantage of many of the processes that occur in natural wetlands, but do so within a more controlled environment.

To evaluate the efficiency of CWs, Environmental Waikato requested NIWA to undertake an assessment of the performance of seven CWs that treat domestic wastewater in the Waikato Region. Sukias and Tanner (2004) found that the wetlands had good rates of removal of BOD and suspended solids, moderate rates (17-33 percent) of total kjeldahl nitrogen removal and negligible phosphorus removal. However, low removal rates of phosphorus are typical in all types of well-established CWs.

A study by Kadlec and Wallace (2009) spanning a number of sites around the world, shows median removal rates of 36 percent for total phosphorus, and examples in New Zealand of –76 to +80 percent phosphorus removal. These removal rates demonstrate that CWs can be an efficient step in a wastewater treatment train.

Wetland restoration

It is noted that the majority of the drained wetlands (peatland) in New Zealand have been reclaimed and are used for intensive farming. Dried peatland emits carbon and is responsible for up to six percent of agricultural emissions in New Zealand. A number of studies globally have recommended that natural and coastal wetlands be restored all around the world.

Restoration of wetlands can lead to a reversal of the carbon oxidation that came about as a result of drainage of peatlands, which would then make restored wetlands a sink of atmospheric carbon dioxide (CO2) again. However, there is a time lag after the restoration until processes in restored wetlands become similar to those of natural wetlands.

With restored wetlands, a minimum of 55 percent vegetation cover is needed to become a net carbon sink, which most wetlands can achieve once vegetation is established, sometimes as early as two years after restoration.

Bathymetry design and water depth are the key factors of vegetation establishment after restoration. A reduction in bathymetry variations can lead to higher vegetation to water ratios, which is key when designing wetlands for carbon sequestration.

A global net carbon sink by 2100 could be achieved through peatland protection and restoration policies, if around 60 percent of present-day degraded peatlands could be restored in the coming decades, along with the protection of existing peatlands.

Peatland restoration may become more attractive to policy makers in the near future as it provides a new opportunity for investing in ecosystem-based mitigation through the development of carbon markets due to peatland restoration's cost effective climate mitigation and abatement potential, comparable to other measures.

An example of a wetland restoration project undertaken by Jacobs, is the 4G Wetlands in southwest Florida, USA. The 4G Wetlands consisted of a 176-acre groundwater recharge wetland system built on wet pastures with the aim of reversing groundwater drawdowns in areas affected by public water supply wellfields in the region.

Flow to the wetland is 18.9 million litres per day (MLD) of nitrified, secondary effluent. The natural design of the wetland cells blended in with the natural environment, creating biological diversity and providing significant additional acreage of wildlife habitat.

Benefits achieved from the wetland restoration included water quality improvement, such as the removal of nitrate-nitrogen inherent in the reclaimed water to protect groundwater and adjacent surface water quality.

For restoration of peatlands, the wider scale hydrological effects of the 4G wetlands are of special interest. The zone of rehydration, restoring the previously existing state of affairs of wet meadows, is well over 10 times the area of the wetland itself.

Thus, design of similar wetlands in areas of former peat wetlands have the potential to rewet peatlands at similar scales in which one hectare of treatment wetland may restore over 10 hectares of peatlands.

Wetlands for decarbonisation

Inundated wetlands can potentially sequester substantial amounts of soil carbon long-term due to slow decomposition and high primary productivity, particularly in climates with long growing seasons.

Peatlands are wetlands with an organic soil layer of at least 30cm, which may extend up to 15-20 metres depth.

The habitat requirements for peat initiation and accumulation are similar in every geographical location, those being waterlogging, low pH, low nutrient availability, low oxygen supply and reduced decomposition rate. However, the physical and chemical characteristics differ according to specific site characteristics of landscape area and topography, climate, water depth and flow, nutrient availability and biogeographical availability of plant species.

Peat formation is the result of incomplete decomposition of the remains of plants growing in waterlogged conditions. Peat accumulation occurs when plant production exceeds organic losses from a site. This usually occurs in wetlands where very cold or anaerobic sediments inhibit soil respiration, resulting in mean long-term rates of peat accumulation being higher in boreal and temperate peat deposits.

Ovenden (1990) found that the mean long-term rate of carbon accumulation in a peat deposit (g $C/m^2/yr$) is the product of the peat accumulation rate (cm/yr) and its carbon concentration (g C/cm^3 x 104).

This rate depends on the productivity of the aquatic vegetation that in turn is determined by the nutrient content of the water and, initially, the mineral substrate.

Long-term carbon sequestration is a function explicitly restricted to actively peat accumulating systems. Peat accumulation is only possible when the water level in the peatland is – on average in the long-term – near the surface. The exact level depends on the peatland type.

Both too low and too high-water levels are detrimental to peat accumulation and the associated functions.

Ability of wastewater wetlands to sequester carbon

Considerable information is available on treatment wetland (TW) design and greenhouse gas (GHG) issues associated with natural wetlands, but much less information is available on GHG emissions from TWs, where nutrient and carbon loading tend to be considerably greater than in nature.

The release of GHG, especially methane, is the inevitable result of inundating land rich in organic matter with water. These conditions support microbial carbon processing reactions, and are characteristic of all constructed wetlands, including TWs. Releases of GHG from TWs have been found to be comparable to natural wetlands.

It is clear that, in general, the creation of wetlands will sequester large amounts of carbon in living vegetation and detritus, but there will be a release of CO2, N2O, and CH4 that will vary with climate, season of the year, wetland type, and loading rate.

There is a rapidly growing demand for developing detailed carbon footprints for all human activities. CO2 release from water treatment facilities may be considered entirely biogenic, in that CO2 from degradation of plant tissue represents a cyclic return to the atmosphere.

The degradation of the organic load in wastewater to CO2 also represents no net increase in GHG emission unless there is an increase in CH4/N2O as compared to other treatment processes.

The CO2 captured by wetland plants through photosynthesis that is subsequently degraded and released as CO2 provides no net contribution of GHG.

Degradation of carbonaceous compounds from wastewater in a TW eventually leads to CO2 release to the environment, and mineralisation within the wetland to CO2 again does yield a net contribution of GHG.

On the other hand, conversion of organic compounds in wastewater or wetland biomass to CH4, and conversion of organic and mineralised N to N2O, represent the major potential negative impacts of TW on GHG that need to be understood.

Some studies have shown that vegetated zones in free water surface and horizontal sub-surface flow (HSSF) TWs have reduced emission of CH4 compared to unvegetated zones. As a percentage of carbon loading, approximately two to four percent of the carbon in wastewater applied to vegetated wetlands is released as CH4, as compared to seven to eight percent for unvegetated areas.

Plant roots can introduce oxygen into the root zone through arenchyma (specialised tissues in wetland plants that facilitate the

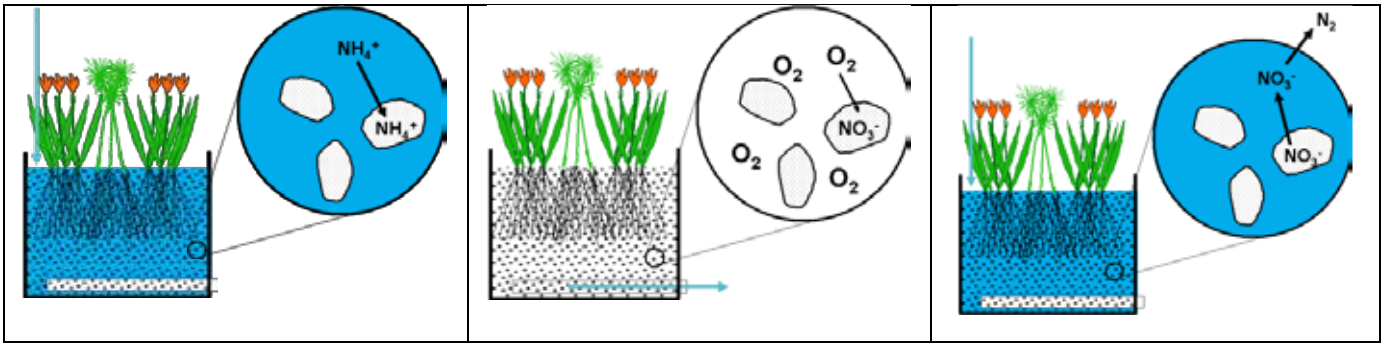


Figure 2: Flood and Drain (Tidal) Flow Wetland Schematic. Tidal flow wetlands use cation exchange for oxygen transfer. Positively charged ammonium ions (NH4 +) adsorb to negatively charged aggregate surfaces when wetland is flooded. When drained, ammonium ions oxidise to nitrate (NO3 -) in the presence of atmospheric oxygen (O2). When flooded again, the negatively charge nitrate ions desorb from aggregate surfaces and denitrify if organic carbon is present.

exchange of gases between the root zone and the atmosphere), shifting the balance toward methanotrophy.

The data on GHG emissions from TWs under various conditions suggests a number of design options that could be explored to reduce emissions. However, some of the measures to mitigate GHG emissions come at the cost of a reduction in other types of environmental benefits, the efficiency treatment, or cost-effectiveness.

Flood and drain wetlands

Operating the wetlands with variable water levels, including lowering the water table below the soil surface during the growing season, can help reduce CH4 emissions, but will significantly reduce treatment capacity for wastewater constituents such as nitrate, and may increase releases of phosphorus and metals accumulated in wetland sediments. However, for seasonally discharging wetlands, this technique could be considered.

Flood and drain (tidal) designs (Figure 2), with regular and frequent fluctuations in water level, can still provide high levels of treatment for a number of constituents and would likely have very low emission of CH4 relative to more common constant-flow designs. They also have the benefit of a significantly reduced footprint.

Amendments

The addition of amendments could be considered to help regulate microbial processes that impact GHG emissions.

Acidic conditions tend to reduce the ratio of N2O/N2 produced, so pH adjustments could be considered as a means to decrease emissions of N2O.

Molybdenum is an essential cofactor for

the enzymes that perform nitrate and sulfate reduction, and micromolar additions to some wastewaters could potentially help favour growth of denitrifiers and sulfate reducers over methanogens.

Substantial quantities of amendments would reduce the operations and maintenance cost advantages of TW over conventional treatment however, which may limit this approach in comparatively large systems.

Gypsum or other sources of sulfate also have the potential to limit methane generation by favouring utilisation of organic substrates by sulfate reducers.

Aeration of inlet zones

Especially for HSSF designs, the CH4 emissions could likely be reduced by increasing the redox potential of the inlet zone. This may be accomplished through recirculation of nitrified effluent, aeration, or intermittent loading to favour aerobic degradative processes.

Emissions – treatment wetlands versus conventional technologies

The most common use of wetlands in wastewater treatment in New Zealand is polishing to supplement secondary treated wastewater rather than raw wastewater treatment, particularly for surface flow wetlands.

However, globally there are over 4000 treatment wetlands in France that receive coarsely screened, raw influent, and more than 10,000 wetlands in Europe that treat septic tank effluent.

In terms of total area of wetland, by far

PHOTO COURTESY OF: JACOBS.COM

The 4G Wetlands is the largest man-made groundwater recharge wetland in the world.

the largest area is devoted to stormwater treatment (e.g. more than 16,000 hectares in Florida).

To allow comparison of emissions from wetlands versus conventional advanced wastewater treatment in treating typical municipal wastewater, calculations of infrastructure and carbon footprints are required.

Treatment wetlands typically use less energy comparative to conventional treatment technologies. A typical wetland system at a WWTP may require pumping of wastewater to its inlet works, but under normal design circumstances, water inside the wetlands will flow entirely by gravity. Typical energy requirements are therefore limited to an inflow pump station and powering of automated control systems.

The nature of plant growth that drives microbial and physical pollutant removal processes in the wetland means no further energy or chemical inputs are generally required.

A study by Jacobs assessed the emissions from typical surface flow wetlands treating varying qualities of secondary effluent to a tertiary level. The estimated footprint to achieve the target water quality from each of the three influent waters was found to require significant footprint (assuming treatment of 38 megalitres per day of flow). However, it should be noted that emerging wetland technology can significantly reduce the required area (more than 90 percent) needed for nitrification.

The estimated carbon dioxide equivalents required for conventional tertiary treatment for the same flows and loads were also calculated, to allow comparison. The results factor GHG emissions due to power demand (excluding decarbonized power sources) and chemical usage. The numbers also include direct N2O emissions in the tertiary treatment process. For the analysis, direct CH4 and CO2 emissions were considered biogenic and omitted.

The assessment concluded that while there are emissions of greenhouse gases from treatment wetland facilities, they are less than conventional treatment facilities, and these releases must be weighed against the ecosystem function and environmental services provided by treatment wetlands that conventional advanced water treatment facilities lack. Therefore it is important to assess the net environmental benefit.

Conclusions

It is clear that wetlands, in particular peat accumulating wetlands, can act as a carbon sink, sequestering significant volumes of carbon. Restoration of 60 percent of the degraded peat wetlands could achieve a global net carbon sink by 2100, provided existing peat wetlands are protected.

The use of wetlands in the wastewater treatment process, designed to achieve peat accumulation, can further support this. The concern being whether the emissions from the wetlands outweigh the ability for carbon sequestration.

In the end, some form of wastewater treatment is required, so the more fundamental question is whether wetlands can achieve tertiary treatment of municipal wastewater, and how the emissions footprint compares to a more conventional treatment process.

Other benefits of wetlands include replacement of lost habitat, aesthetics, recreational facilities, and the role wetlands can play as environmental buffers in indirect potable reuse, which will likely be increasingly needed as global climate change and increasing water demands put increasing pressure on fresh water supplies.

Use of wetlands in the treatment process should be encouraged due to the significant potential to sequester carbon, and the low emissions footprint when compared to more conventional approaches, as well as the technology advancements which are seeing improvements in the effluent quality and reduction in required footprint.

An additional benefit of treatment wetlands for wastewater treatment is that they set the community on a path towards restoring lost wetlands and perseverance of large tracts of green space near urban areas.

The value of the land will increase over time and the net environmental benefits will become a community asset that improves the value of adjacent neighbourhoods relative to building a conventional tertiary treatment plant.

This paper was presented at the Water New Zealand Conference & Expo. This version has been abridged and edited for style. To see the full paper, go to: bit.ly/3e6oGXz

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For peat's sake

The Awakeri Wetlands Stage One Project is a signature project for Auckland Council and the first large-scale open stormwater channel in New Zealand. The result will not only solve the issue of flooding in the area, enabling it to be safely developed for thousands of new homes, but it also provides a real community asset and an environment that supports the ecology.

Completed in July 2020, Stage 1A of the Awakeri Wetlands Project comprised a new 2.3 kilometre stormwater channel to improve flood-prone areas in Takanini and enable thousands more homes to be built in this growing community.

Part of a bigger $100 million investment by Auckland Council in the Takanini Integrated Stormwater Solution, the project has created healthy and connected waterways, boardwalks, shared cycleways and pathways, and open green spaces to support restored natural habitats and resolve the dangers of flooding and stormwater problems in the area.

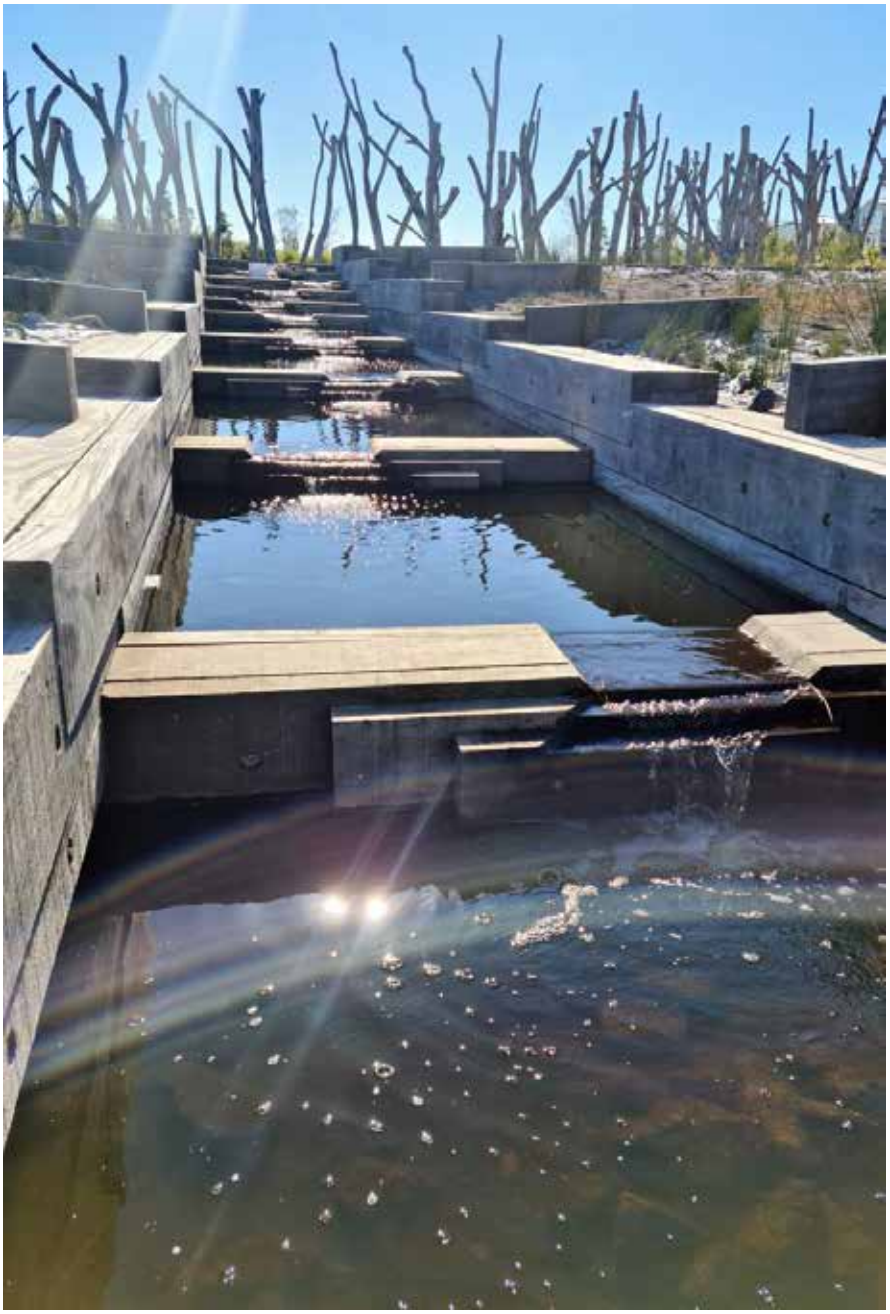
The channel forms a natural stream and wetland, surrounded by public recreation areas and enhanced by extensive native plantings and specimen trees.

Originally a historic kauri swamp, many large and ancient swamp kauri logs were uncovered during construction, many of which have been left in place to celebrate the history of the area.

Along with the open stormwater wetland channel, the project saw contractor McKenzie & Parma undertake large scale earthworks in a waterlogged peat swamp, construction of a seven-metre-deep impervious curtain wall, the building of road culverts, weirs, and fish passages, stormwater connections for neighbouring land development, and construction of 3.3 kilometres of footpaths and seven boardwalks. The team also eco-sourced and planted 200,000 native plants.

This was a highly complex project and involved earthworks, soft materials, drainage, numerous structures, along with robust erosion and sediment control.

McKenzie & Parma describe it as a collaborative project that required



The Awakeri Wetlands Stage One Project is a signature project for Auckland Council and the first large-scale open stormwater channel in New Zealand.

a problem-solving approach to find solutions that were sustainable, environmentally sensitive, and deliver value for money to the client.

As well as being a large development, this project was unique in the site being almost entirely composed of peat material and prone to waterlogged conditions.

Being the first open stormwater channel in the country meant there were no projects to base ideas and methodologies from. Added to which, it was to be built in an environment comprising extensive peat and sodden ground conditions, which presented a further set of challenges with regards to environmental and health and safety risks.

In addition, recognition of the historical importance of the ancient kauri to the area was also vital, with the contractors working with the council to recover, tag, and weigh over 200 swamp kauri logs, then placing them as a decorative feature in the channel.

McKenzie & Parma faced many different and complex challenges, from tight timeframes to the ever-present battle against peat, to the real risk of project shutdown and damaged reputation to council if stringent environmental controls were not followed to the letter.

Despite these risks, the team embraced the challenges and went the extra mile, completing the project within budget and three months ahead of programme.

This was achieved through a combination of detailed planning and preparation, specialist experience in working in difficult ground conditions, an enthusiasm for innovation, and an unceasing commitment to health and safety and the environment.

Detailed planning up front meant the two earthworks seasons for bulk excavation were maximised, while making the most of the winter seasons to construct the weirs and boardwalks, which were enabled by bunding these areas off and keeping ground water out with the use of six-inch pumps.

Understanding and recognising the complexities of peat from the outset meant the team allowed for settlement of structures and heightened health and safety measures in what were hazardous conditions due to constant water and peat that behaved like quicksand.

Ground conditions

McKenzie & Parma say the biggest challenge was working with the peat. It required ingenious problem solving and combined expertise to develop engineered solutions to overcome the obstacles this environment presented.

"We set up a permanent dewatering line

Procedures were undertaken to strengthen the haul roads and work areas before any works could be done. This included laying geogrids, geocloth, and adding metal to form working platforms.

along the entire length of the channel, which reduced the number of pumps required on site.

"We also created excavator work platforms to transfer the weight of the machinery when working above unstable peat areas, reducing the risk of sinking into the peat, and constructed a six-metre-wide haul road which ran along both channels to maximise productivity during the removal of 80,000 cubic metres of peat from site. This allowed adequate access to the entire site, with enough space for trucks to pass each other while being loaded.

"Our GPS diggers were then able to cut the design channel and load material directly into the trucks, without interrupting operations further down the channel. GPS control meant one pass cut to design, with no re-trafficking over soft ground for rework."

Settlement also added to the complexity of the project.

Since peat mimics the behaviour of water, any material or structure that has a small surface area tends to settle more than a heavier material or structure that has a large surface area. This is similar to the behaviour of large boats' ability to float, whereas small objects sink in water.

Considering this, the team had to calculate the exact height they needed to install a structure so that after settlement, it would still be within the design tolerance of the finished level. For example, one staircase with a smaller surface area was installed 50mm higher than the design as, after one month, it had settled to the exact level.

"When it came to the structure piles, we allowed two months for them to settle before proceeding. Similarly with the sheet piles for the weirs – we continued to check the heights until we were able to confirm the peat had stopped settling."

Health and safety

Health and safety measures also needed extra consideration thanks to the peat. The risk of injury caused in operating

machinery in these conditions was especially high. And manoeuvring around slippery ground surfaces and working in knee-deep water at all times was particularly hazardous.

"This had a significant impact on how quickly the team could move as they needed to take greater care when doing so. It also required extra attention when handling materials on the ground as their potential lack of stability was a hazard."

The detailed Health and Safety Management Plan included special safety considerations, including not operating machinery directly above any noticeably unstable material, as this would not hold the weight of even a small excavator.

"We were pre-warned of an incident in 2017 where another contractor had lost equipment, having got stuck in the peat."

Additionally, no one was to walk directly above any wet peat surface as it behaves like quicksand.

Procedures were undertaken to strengthen the haul roads and work areas before any works could be done. This included laying geogrids, geocloth, and adding metal to form working platforms.

Environmental

In line with council's goal to apply environmentally sensitive solutions to this project, McKenzie & Parma set its own goal to not only meet regulatory compliance, but to go beyond.

A set of Sensitive Area Plans (SAPs) were prepared to aid in the identification and protection of significant environmental features. These plans were considered prior to starting any work activity that may require ground disturbance and were updated throughout construction as required.

In addition, progressive Erosion and Sediment Control Plan (ESCP) drawings were prepared to manage soil and water through the various project phases.

"We placed firm emphasis on making sure that any planned sediment controls were fully functioning at all times as the culvert at the end of our channel was

Giant kauri logs that were uncovered now feature in the wetland.

connected to the Pahurehure Inlet. This meant any poor quality water discharge would have an immediate detrimental effect on the lake.

"We worked closely with the client's engineering consultants to determine the height of the water table on the site. We then used this information to set up our erosion and sediment controls and made sure that all our water stops would always be higher than the 100-year flood line level."

During construction however, McKenzie & Parma says it became evident these erosion and sediment controls were not enough.

"Though the controls were as per the GDO5 standard, the clarity of peat laden water was still low.

"We elected therefore to introduce a double layer of controls consisting of bidim cloth and mulching. In addition we installed a series of 'turkey nests', into and out of which we pumped the water and finally through the culvert which discharged into the inlet."

Supporting social outcomes

McKenzie & Parma is a strong supporter of the Te Whangai Trust, and the Awakeri Wetlands project is an excellent example (and one of the first) that demonstrates how people who are struggling to find employment can take a step towards doing so.

"We took on several candidates, trained them, and supervised them during the project.

"The reward and sense of purpose that one of those employed on the project felt means that she is still working for us now."

Additionally, the Kauri Flats school collaborated with Auckland Council to undertake some planting activities on site. McKenzie & Parma provided safe access to site and an isolated area for the students to plant.

Auckland Council also asked McKenzie & Parma to assist with the selection and delivery of a few handpicked kauri logs to the University of Auckland for carbon dating. This was to provide further information about the history of the wetlands and how it came to be.

From the 350-plus different sized kauri logs and stumps excavated during the job, seven large logs ranging from five to eight tonnes were gifted to local iwi to use for decorative carvings.

This article was taken from McKenzie & Parma's entry into the 2021 Civil Contractors New Zealand (CCNZ) National Awards, where it won Category D (medium), projects with a value greater than $5 million.

Running repairs to Silverstream

While the project appears to be a simple earthwork and rock rip-rap construction contract, the client requirements and site restrictions meant that innovative thinking was needed for successful site access and management.

Left: Supervisor Barry Ravenwood, doing a site walkover.
Below: A view south showing erosion prior to works.
Bottom: The temporary bridge bracing was designed by the internal temporary works team.

The Silverstream, known to Māori as Whakaehu, runs from the Silver Peaks north of Dunedin, discharging into the Taieri River south of Dunedin. In 2017 and 2018, significant flood events scoured large amounts of material (an estimated 2000 cubic metres) out of the stream embankment.

This resulted in flooding of residential housing and erosion of the embankments and the Taieri Aerodrome land adjacent to the river. Erosion affected water supply pipes along with the banks supporting the pipe bridge.

Therefore, a fundamental aspect of this project was to reinstate and improve the embankment to ensure the security of supply to critical water infrastructure.

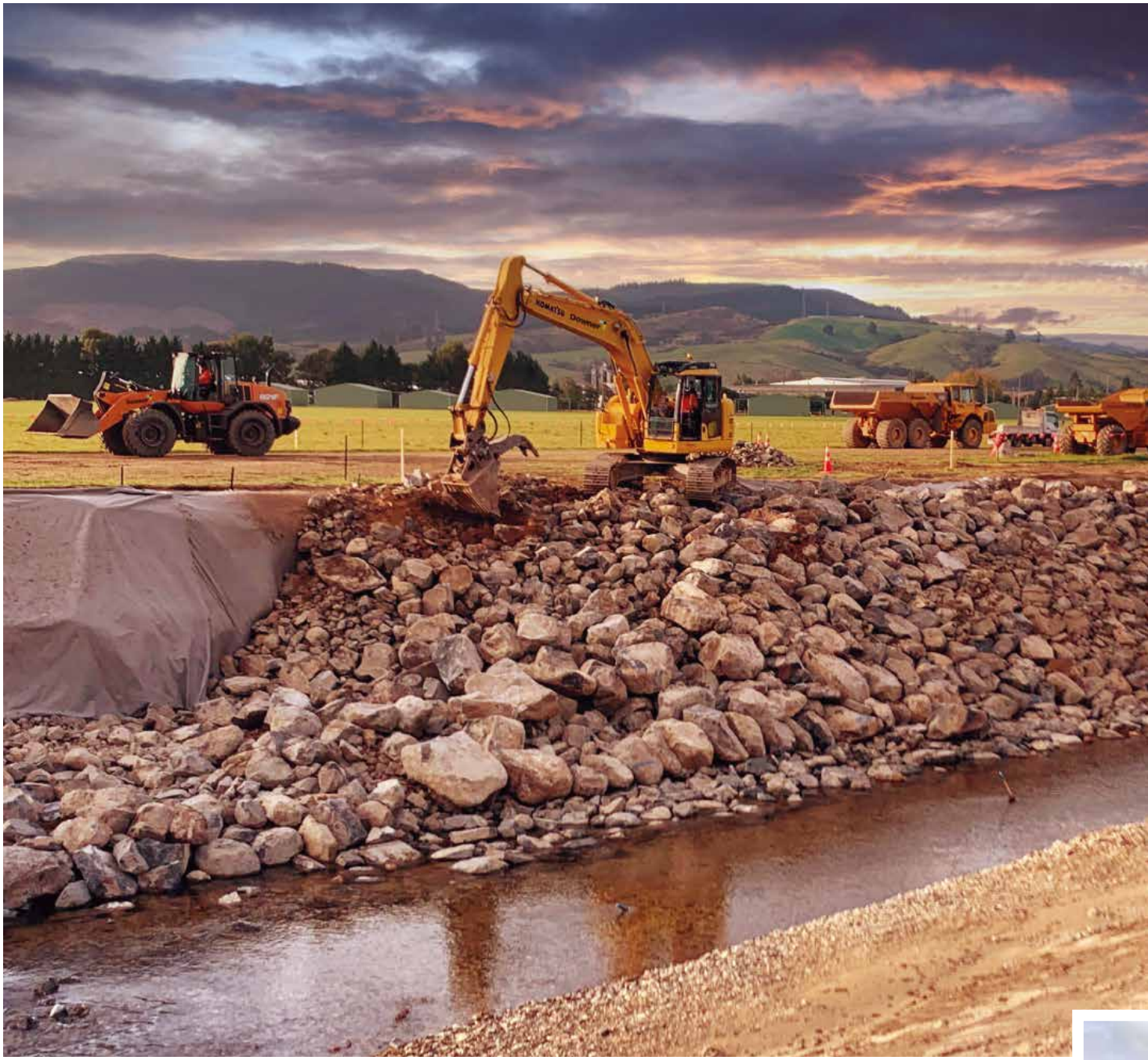
In addition, the embankment wall erosion caused by this flood event increased the erosion rate of the stream walls over the past several years and has caused excessive damage to the natural habitat.

The contractor, Downer, identified two key risks with the Silverstream Bank Reinstatement (SBR) project in the tender phase – working in an active airfield and temporary work to the pipe bridge. However, when the project received essential work status, the third risk of Covid-19 restrictions required additional planning.

To get approval, and then set-up and manage the project work area in operational airspace, Downer surveyed the Taieri airfield, plotting safety zones, taxiways, and zones of influence, including vertical clearance for trucks when tipping next to the runway.

The Otago Airfield car park was the only access point to the site along the river's boundary. Downer identified that truck height would breach the Civil Aviation Authority (CAA) regulations, but there were no alternative access options because of residential housing and a popular walkway on the river's left bank.

After consulting with Taieri Aerodrome occupants, Otago Aero Club and Heli



Otago, an understanding of the safety requirements and end-user needs was established.

Strict CAA rules did not allow for runway closures. So, the Downer construction team collaborated with its automation team (which specialise in electrical/radio equipment and Intelligent Transport Systems) to develop a solution that met the required safety specification.

Equally, the risks associated with the temporary pipe bridge construction were under review right from the tender phase.

Supporting the pipe bridge during construction work was a challenge because excavations were required below the pipe bridge foundation levels in-stream. If the pipe bridge sustained any damage or movement, it could cause the water pipeline's failure.

Downer engaged its internal Temporary Works Team (TWT) to evaluate the risk and provide a preliminary design structure for the pipe bridge's temporary bracing during the tender phase.

The armouring repair (rip-rap) of the true right bank to protect the overhead pipeline bridge and the subterrestrial pipeline was the most complex endeavour on the project, according to Downer.

An extra consideration for the pipe bridge area was the unknown location of buried asbestos pipes that feed into the pipe bridge. Site investigations helped define the risks, and a site layout and vehicle movement plan was created to ensure adequate protection.

Repair of the erosion-damaged embankment wall repairs required extensive environmental management, since the work was performed in-stream. Otago Fish and Game Council provided guidelines to Downer on the successful management of ecology and habitats, and extensive planning ensured the team had

Top: This photo shows the scope of the rock placement required.
Above: Erosion of the embankment exposed the pipe bridge foundation.

an understanding of the site's erosion and sediment control requirements.

With the toe excavation required below the stream bed, staged works allowed effective diversion of the wet stream bed to ensure that sedimentation was captured and/or reduced. Silt fences and booms were installed directly downstream from the works.

No discolouration of water samples were permitted within 50 metres of site, and the team had no breaches of consent conditions reported for the entire project works.

Indigenous vegetation, such as grass, and debris needed to be cleared from the existing banks. While this process was reasonably straight-forward, Downer needed to ensure aquatic life and freshwater habitats weren't disturbed.

Of concern was small fish and eels that seek refuge in the edges of banks, along with the organisms they feed on. The site team performed ground and stream clearance work, encouraging aquatic life to vacate before excavation to reduce impacts on the native species in the stream.

Using small hand tools, such as shovels and picks, areas were gently agitated before excavation, with crews observing fish exiting the grasses and moving downstream. As an added precaution, a spotter was used to watch for any aquatic life getting stranded in pooled water.

Cut-to-waste materials were transferred across the stream to allow the walkway to remain open.

A further challenge to the project came in the form of Covid-19 lockdown restrictions.

However, since the Dunedin City Council deemed the SBR project essential work, the increase of risk to its asset was the primary concern, should repairs be delayed until after winter.

So, once the SBR project received its essential work permit, health and safety plans were re-written and work proceeded throughout the alert level 4 lockdown.

However, thanks to the lockdown, the site was inundated with bystanders. The community watched the project progress during their daily walks and the site crews became accustomed to families stopping to watch the machinery and the construction process.

Consequently, the team revised the methodology to allow the walkway to remain open throughout the project.

"This increase in attention scrutinised our safety and environmental controls, and our team is proud to have delivered a project without any safety, security or environmental incidents."

With these key challenges overcome, the community encountered zero water supply disruptions during the project and no lingering effects on the environment.

This article comes from Downer NZ's (Christchurch branch) submission to the 2021 Civil Contractors New Zealand (CCNZ) National Awards.

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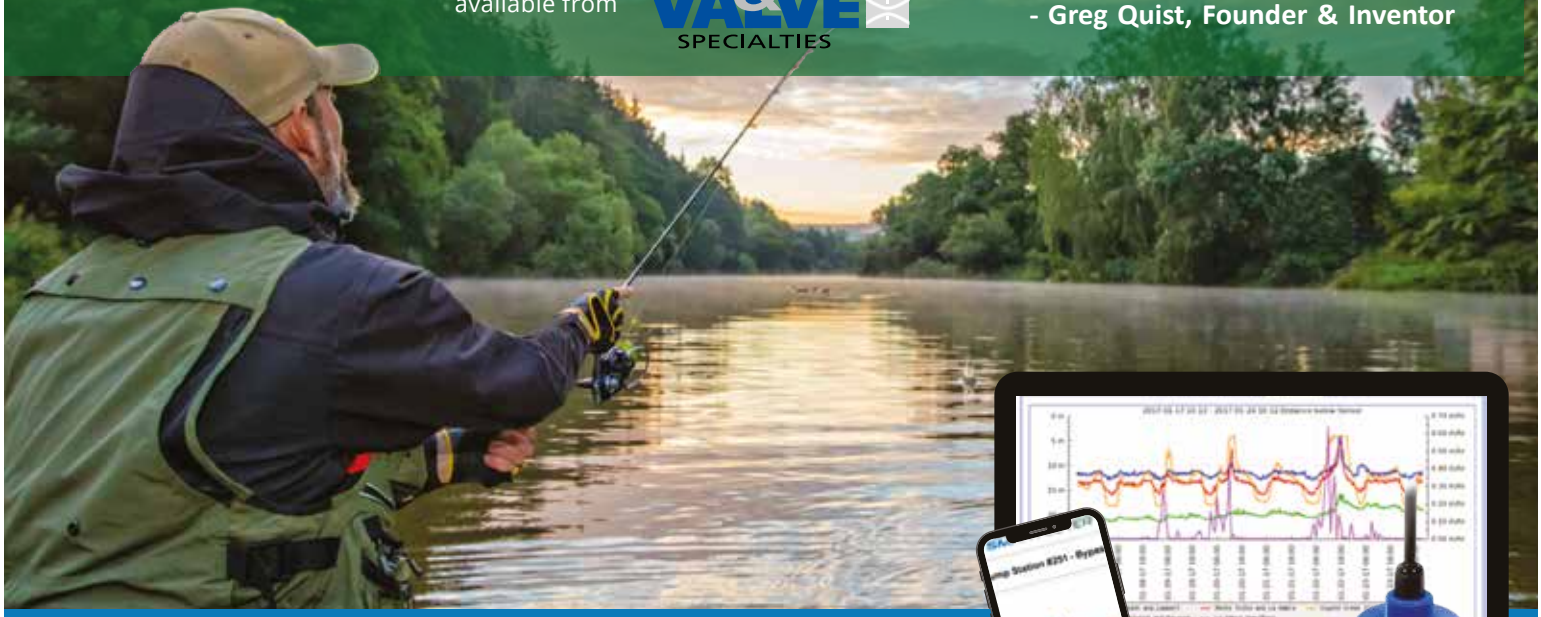

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Urgently rebuilding a sludge tunnel in the capital

Two critical sludge pipes collapsed deep in a Wellington tunnel in January 2020. Brian Perry Civil (BPC) provided an $8 million world-leading solution, during a Covid lockdown, to repair the Mt Albert Sludge Pipeline for Wellington Water.

When two critical sludge pipes collapsed deep in a Wellington tunnel in January 2020, Brian Perry Civil (BPC) came to the capital's rescue with a world leading solution and delivered it during the challenges of a Covid lockdown.

A critical asset on Wellington Water's network, the 1.85 kilometre Mount Albert tunnel runs from Dover Street in Island Bay (west) to Queens Drive in Lyall Bay (east). The tunnel is a gravity pipe carrying wastewater from Brooklyn, Owhiro Bay, Island Bay and Berhampore to the city's water treatment plant at Moa Point.

Wastewater from the catchment area is pumped via a rising main from Island Bay to the mouth of the tunnel. A secondary flow gravity feeds wastewater from the Berhampore catchment flows which merges with the rising main flows before entering the tunnel.

Although this is a wastewater tunnel, there are infiltrations from the stormwater network and during periods of heavy rainfall, the Island Bay pump station pumps wastewater at a powerful 600 litres per second to the Mount Albert tunnel.

Once the wastewater goes through the treatment process at Moa Point, a by-product of the treatment process known as sludge is created. This sludge is effectively waste and is sent to the Happy Valley landfill for further treatment and disposal.

The sludge is pumped in liquid form from Moa Point to Happy Valley via two 180mm diameter buried ductile iron pipelines. Only one of the two pipes operate at a time, with the second pipe acting as a backup. The pipes run through the Mount Albert tunnel, where they are encased in the concrete benching in the floor of the tunnel.

The Mount Albert Tunnel and the sludge pipelines were constructed in the late 1980s through to the early 1990s and were designed to last at least 80 years.

At the height of summer 2020, one of the lines lost pressure and failed. Switching on the secondary pipe also failed, signalling a major issue somewhere on the pipeline route. Investigations by Wellington Water revealed the pipe burst 250 metres inside the Mt Albert tunnel, inaccessibly buried deep under the city's town belt. An earthquake probably caused the concrete benching encasing the two pipes to break, allowing water infiltration to corrode the iron pipes and lead to their failure.

With both pipes out of action, Wellington Water resorted to trucking millions of litres of sludge every day to Happy Valley landfill. Running the trucks 24/7 in shifts worked, but at a cost of $600,000 a week it was financially unsustainable as well as being unacceptable to residents along the trucks' route.

Wellington Water needed a swift solution to get at least one of the pipes operational. Turning to their trusted team, they appointed Brian Perry Civil as the lead contractor and consulting engineers Stantec to develop a solution.

"We recognised early on that the repair work was technically challenging and risky to the crew, as there was no way to excavate the pipes at the rupture site," says BPC. "Further compounding

The repairs to the concrete benching around the pipes in the tunnel had to be done while the tunnel pumped raw sewage from Island Bay to Moa Point. This required working at nights in the tunnel as there was a 90 minute window to be in the tunnel between sewage flows.

this, shutting down the Island Bay pump station for longer than 45 minutes was not possible, making remote repairs the only option."

The solution

The plan was to use expanding stents at the failures and then line the full 1.85 kilometres length of each pipe.

The repairs to the concrete benching around the pipes in the tunnel had to be done while the tunnel pumped raw sewage from Island Bay to Moa Point. This required working at nights in the tunnel as there was a 90 minute window to be in the tunnel between sewage flows. This risk was successfully managed through an isolation plan at the Island Bay Pump Station.

Suffice to say most of project challenges were huge. To complicate things further, the tunnel had only one access shaft.

During peak rain conditions up to 600 litres a second of wastewater enters the tunnel. Shutting down the feeding pump station for longer than an hour was impossible, so the repairs needed to be done remotely.

The team investigated several pipe-repair expanding patch options, but research revealed current market patches were incapable of withstanding the pipeline's 22 Bar pressure.

The team also identified a new risk, the possibility the ageing pipeline had ruptured both lines meaning a patch could cause the pipeline to rupture again at the next weak point.

To avoid this, the project team and Wellington Water agreed the safest and most practical method was Hadlee and Brunton's (H&B) design which incorporated Quicklock mechanical pressure patches to repair the pipe ruptures and install two 1.8 kilometre pipeline liners manufactured by German company, Amex Sanivar.

This cure-free pull in pipe method, Sanitube, would line the full length of both pipelines with a superior 35 Bar operating pressure liner. It offered quick installation, value for money, a 50-year design life and a 10-year warranty.

As this was the first installation of Sanitube of this size in the world, Amex offered five German technicians to assist H&B to carry out the challenging install.

Once the method was decided, the project management plans and construction programme were quickly prepared.

At this stage there were still several unknowns, making the scope unclear until they were confirmed on site. However, as the liner and Quicklock patches had to be procured from Germany these fell on the critical path.

The manufacture, air freight, and technicians to assist were estimated to arrive in seven weeks. The tight programme ensured one of the pipelines would be operational by the end of May 2020. A budget was set, but the uncertainty and urgency of the works meant cost reimbursable terms were agreed.

Environmental and health risks

The potential for wastewater overflow to enter the ocean was a major risk identified during the planning stages.

The Island Bay pump station has a wastewater holding tank that automatically pumps to the rising main as it fills up. If not carefully planned and managed, turning off the pumps risks the holding tank overflowing to a pipe running out to sea and causing a detrimental effect to the environment.

As the pump station's shutdown periods were unknown, BPC carried out trials to identify the best opportunity for workers to enter the tunnel. The trials revealed a shutdown period of only 45 minutes during the day and 90 minutes at night.

Flagged as a critical risk, controlling the isolations was imperative.

From a health and safety risk perspective, if uncontrolled the pump station could automatically start pumping wastewater into the tunnel and engulfing workers. A shutdown and isolation plan was devised, with an appointed BPC person stationed at the pump station for every work shift, manually controlling the isolation process and communicating regularly with the site controller to control access to the tunnel.

With the tunnel open at either end, a stench would escape into the surrounding area. This was unavoidable as it provided essential positive air movement for the safety of the team working inside the confined space. To mitigate it, BPC mobilised odour neutraliser sprayers to both ends of the tunnel to spray a fine mist into the air at the tunnel openings.

Initial challenges

Getting the Amex team from Germany to the site was a huge challenge. Due to the critical nature of the work, H&B worked closely with MBIE and Wellington Water to get the necessary approvals to bring the technicians to the country while the borders were closed and the country still in level four lockdown. The flights were being cancelled faster than one could book them, and the travel guidelines changed every day.

During the initial investigation stage, CCTV footage showed the concrete benching within the tunnel was damaged at the pipe burst locations needing repair. To plan the works, a better understanding of the inside of the tunnel was required.

Accessing the damaged locations 250 metres inside the tunnel was a difficult and dangerous confined space operation, with the potential for explosive gas in the atmosphere. To assess the risk, the team flew a drone fitted with a camera down the tunnel in advance of any personnel entry.

Before flying the drone, the team ventilated the tunnel and floated a small boat fitted with a gas detector. The results showed there was no issue with the lower explosive limit provided the

same ventilation was used, but there were high levels of hydrogen sulphide.

The drone provided useful footage to the team, which now understood some of the constraints inside the tunnel but not the size of the defects. This meant it could not remove the need for personnel entry.

Having conducted the trial shutdowns in stage one, the project team decided to complete the confined space inspection of the tunnel at night when it could shut-down the pump station for the longest period. This occurred from 2-4am with two entrants wearing breathing apparatus as an added precaution. They were closely followed by a tractor CCTV camera, so the safety observer could always see them.

They completed the inspection and reviewed the footage with Stantec to develop the repair methodology for each section of damaged concrete.

The biggest challenge was accessing the damaged areas 250 metres from the tunnel access point within the short 45-minute work periods.

One of the greatest concerns was how the safety observer would keep in contact with the confined space entrants in the tunnel. This risk was mitigated by installing a 'leaky feeder' communications cable enabling the tunnel

entrants to communicate with the safety observer via radio.

The crew faced a significant risk – the potential of being engulfed by the highly toxic hydrogen sulphide gas while in the tunnel.

As with the earlier works, the tunnel was ventilated. Each tunnel entrant was also issued with a positive air mask, a personal gas detector, and an emergency oxygen breather kit to use in the event of a gas alarm, to provide them with 40 minutes of oxygen to walk out of the tunnel.

To deal with the inevitable foul air impacts on residents in lockdown in Lyall Bay, an overground duct was installed to divert the foul air into a separate wastewater network adjacent the site.

With this arranged, the team turned to managing the wastewater flows, diverting them to gain safe access to the area.

BPC designed and installed an over-pumping system made up of a new over-pumping manhole on the gravity line that feeds the tunnel and three eight-inch pumps to over-pump the wastewater.

A single 250-metre-long polyurethane lay-flat hose was dragged through the tunnel and used as a bypass line...

A single 250-metre-long polyurethane lay-flat hose was dragged through the tunnel and used as a bypass line, while the team installed two 250-metre-long pipelines of 225mm diameter PVC pipes on brackets to the tunnel wall.

Once the wall pipes were installed the flows were diverted through them, and the layflat hose was maintained as a spare pipe and a visual means of triggering an evacuation.

The system was designed to run automatically – two pumps would maintain the over-pumping under normal conditions, and the third pump connected to the lay-flat as a precaution. If this pump kicked in, it signalled that the system was working at full capacity, and triggered an emergency evacuation of the tunnel.

A job well-done

Despite the lockdown BPC delivered the project in the agreed timeframe, delivering the first pipeline three days ahead of schedule.

On May 21, 2020 the first pipeline was switched back on, putting a halt to the 24/7 trucking operation, with the second pipeline repaired in June.

The BPC project team completed over 1000 working hours in confined space and unsanitary conditions without anyone falling ill, something very uncommon in these types of environments.

From start to finish this would have been a complex, logistically challenging project at the best of times, but the restrictions of the Covid lockdown and residents' understandable anger at having to endure the constant noise and odours while at home all day added extraordinary challenges.

Homes were within a metre of the site boundaries and many residents had been unaware the tunnel entrances were even there. Normally most people would have been away at work all day, but the lockdown meant they had nowhere to escape the construction noise, smell and vibration.

This generated significant frustration and stress, and at times, hostility. Predicting this, BPC's stakeholder engagement manager ensured she had met with the most affected residents and made herself available 24/7 to listen and respond to the frequent phone calls and emails received.

"We gathered a list of email addresses so that we could keep everyone informed of upcoming work when the usual letterbox drops were not permitted. We engaged with individuals and families to understand their particular needs, and concerns so we could be proactive in determining what mitigations and support would be most helpful.

"We developed prompt, practical responses. Every call, query and concern was quickly acknowledged and addressed.

"All site staff were also alert to the impact their work was having and the high scrutiny they were facing from the local community. By being proactive, empathetic and responsive, the project team built trust with the affected residents and ensured they did not feel the need to go to the media or online platforms to have their concerns heard and addressed."

This article was taken from Brian Perry Civil's submission to the 2021 Hirepool/Civil Contractors New Zealand (CCNZ) National Awards, where it received a Highly Commended.

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Smart research to ensure employee safety

Health and safety in the water sector may soon enter a new era thanks to an innovative study using wearable technology to track employees' physiological data for greater insight into workplace health and well-being. By Cecilia Harris

SA Water has teamed up with researchers from the University of South Australia to pilot the new study, which involves 15 of the utility's field-based staff wearing smart devices, which collect data that will be analysed to identify opportunities for early detection and intervention of potential safety issues.

Wristband sensors and smart shirts are among the devices now being tested by staff from SA Water's Kadina Depot, along with trade waste and water sampling teams. In-sole sensors are also on the horizon.

SA Water general manager of people and safety Kylie Johnson says the safety initiative could have broad application across the utility's state-wide workforce, and potentially the broader water community too.

"With a vast water network, our people are often performing challenging physical tasks in a range of weather conditions and our trial will explore how technology can improve their health and well-being..

"Working together with the University of South Australia, our people will undertake specific work activities, such as driving prolonged distances and pipe maintenance to explore how their bodies respond, measure their vital signs, and monitor the effect of heat, fatigue and sleep.

"Excitingly, the wearable devices provide the opportunity to capture mental and physical well-being. insights we haven't been able to in the past."

The wristband sensors worn by the utility's Kadina staff quantify sleep deprivation and the resulting effect on alertness, focus and mental health, while the biometric smart shirts monitor the cardiac and respiratory system to capture greater knowledge about physical strain.

"All of these collective insights can lead to improved situational awareness and allow certain work activities to be altered, postponed or optimised, creating better safety outcomes for our people."

Filling the research gap

Project lead, University of South Australia research professor Jill Dorrian says findings from the study could set a new precedent for proactive safety practices in the water sector.

"Our research continues to find that issues such as fatigue and sleep are prevalent across industries and can often increase the risk of workplace incidents, but our trial could open the door for the use of innovative technologies that support an even more proactive approach to safety and well-being..

"Literature from researchers overseas demonstrates the use of wearable devices can increase employee satisfaction, while providing early detection and intervention for improved decision-making around how physical tasks are performed or managing individual workload to avoid burnout."

SA Water media, communications and strategic engagement senior manager Joshua Zugajev says that while there have been early explorations in the UK into how wearable devices could deliver useful health and safety data, there's still work to do in translating data into practical outcomes for water professionals working in Australia.

"We want to take this area of research to the next level and translate it into practical guidance around how work practices could be enhanced. But also, there is a need to explore the data within our own local context."

The South Australian climate and geography is diverse, as is the range of tasks SA Water staff complete, so the trial will be collecting data from staff engaged in a broad range of in-field tasks within different environmental contexts.

"We now have a team of people across three different business units, including field operations, pipelines maintenance, and trade waste, who are helping us test this wearable technology.

"All of these activities are different, and will be testing different scenarios and work activities. It also means we are testing different types of geography and climate as well."

Next level safety

Joshua says that SA Water staff have a great safety mindset and the utility is aware that getting ahead of emerging hazards requires thinking about safety from a design perspective.

"When we design assets and processes, designing out hazards from the start is very effective. It delivers really tangible results. Our people have seen for themselves that avoiding hazards and incidents in the first place is the best approach to ensuring safety.

"The really cool outcome from collecting this kind of data is that it may help us prevent exposure to risk at an individual level. Getting extra insights into the physiological reactions our staff have within different circumstances may help us detect people at risk of danger due to fatigue.

"There's the potential that we could intervene to prevent any harm from occurring."

Furthermore, Joshua says using all of the data sets could result in more predictive works planning to increase safety and productivity.

"Knowing how people's bodies react at certain times of the day, in certain temperatures and doing certain activities can help us schedule works based on those insights to achieve peak outcomes, while keeping people safe.

"But there is also potential for intervention as well. There is the potential to generate alerts or warning mechanisms that ensure staff are aware of emerging risks, or potentially detect when an employee might need assistance."

Joshua says the trial is important to SA Water due to the utility's commitment to ensuring the safety of its employees and the development of better safety and well-being. measures.

"Our business is very large and integrated. We provide services within all the water sector scenarios. The study is a great testing ground to see what data all the possible scenarios produce.

"We have people that need to complete work out in environments with very variable factors. There are often other people present, as well as machinery and equipment, animals, and of course the weather. There are lots of different types of hazards."

He says that while the whole water sector is very much focused on designing out, reducing or controlling hazards as much as possible, it's important to continue to pursue more sophisticated and beneficial work safety outcomes for staff.

"The fact is that many of our staff are still exposed to hazards and many of them are hazards we will never be able to fully design out or prevent.

"We need to continually stay on top of the ways we can improve, learn more and reduce and help manage risks that are there."

This article is reprinted with the permission of the Australian Water Association.

Exploring water careers with virtual reality

If you've ever had the satisfaction of seeing water restored to a residential street or read a report giving a clean bill of health to a town's supply system, you'll know there's a lot to be proud of working in the water industry. A new digital promotion tool is now giving job seekers a chance to see and experience a little of that, and maybe find a role for themselves in the water sector.

SkillsVR is a digital learning company committed to helping people create better futures for themselves and the world around them. They are on the cutting edge of virtual reality training and education, and recently took on the challenge of promoting the water industry.

"We wanted people to understand that this is a vital part of our community infrastructure," says Paul Dunn, one of the design team that brought the experiences to life. "We take drinking, wastewater, and stormwater systems for granted until something goes wrong.

"The people that keep those structures functioning are invisible heroes, so we wanted to bring them into the light, and let people have a little fun while they explored what the water industry is about."

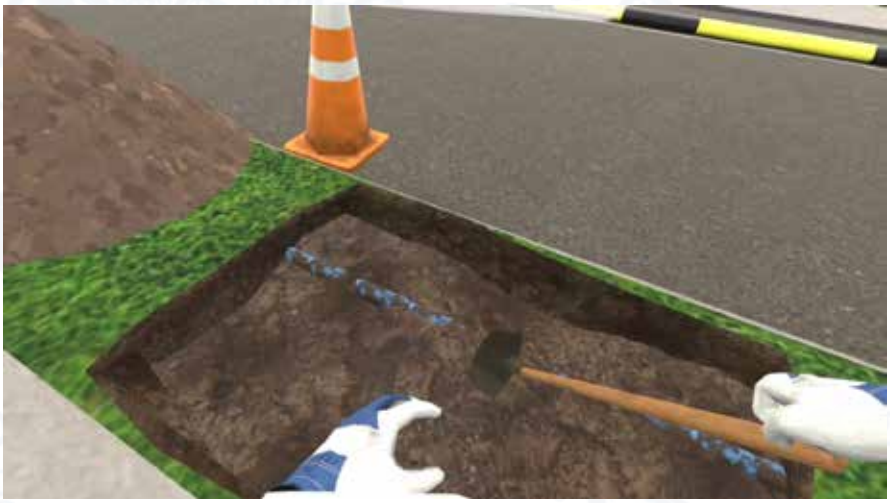
SkillsVR, in conjunction with several water service providers, has developed two virtual reality (VR) experiences that highlight what a career in water services could entail.

The first experience provides an overview of the water cycle and lets people drop into different parts of that process to meet people who keep it functioning.

Interactive games within the module provide insight into what those roles contribute to our water networks, while keeping the learning light and fun. From 'zapping' microbes in a lab to clearing a stormwater garden, learners experience some of the employment variety the industry provides while developing an awareness of what it takes to keep water flowing in communities.

The second experience places learners on a worksite with an experienced water supply engineer to conduct a water main repair.

Learners are given a chance to help, being guided step by step through everything from isolating the water supply to dealing with the public. Even digging up the water pipe is included, though significantly easier with a digital shovel! The participant is then given the chance to go through the process themselves and prove they've got what it takes to support our water network.



The experience offers some insight into what a water engineer's role might involve and the breadth of factors that need to be considered to maintain our water infrastructure.

Virtual reality allows people to experience immersive learning and offers them the chance to experience real-world working environments while remaining safe. It caters to a range of learning styles – especially for those people who learn by doing or who may have difficulties with literacy. And gives employers an opportunity to assess skills that are difficult to showcase on a CV and aren't typically tested in a formal interview, like communication and teamwork.

These VR experiences have been developed in conjunction with Ministry of Social Development (MSD) industry partnerships, and job seekers will be able to experience the scenarios at upcoming VR job expos held nationwide. Touch base with a local Work and Income contact for more information about an event near you.

Amanda Nicolle, director industry partnerships at MSD says, "It's an important part of our role to help our job seekers explore the employment opportunities that are available to them now, and those that offer a career pathway within their community.

"VR is an immersive experience. You can see yourself in a job, interacting with others, completing tasks, facing challenges. VR is a great icebreaker for conversations about employment and a very effective way for employers to engage job seeker interest.

"MSD has supported employment in the water sector for many years through our engagement with key partners. We are investing in VR because it's the future of learning and training."

Article supplied by Ministry of Social Development and SkillsVR.

Water-tech can be a catalyst for peace in the Middle East

By Josh Brown and Vanessa O'Brien, directors, New Zealand Israel Innovation Hub

The Middle East has always been dry and salty and access to water is critical. It can bring unpredictable and sharp geopolitical shifts. It can serve peace or conflict, trade or war, be a weapon or a tool.

Renewable water resources there are scarce at best. As much as 90 percent of Middle East and North Africa (MENA) live in areas of high-water stress with serious consequences on health, nutrition and development.

The Waterproject.org describes several countries including Yemen, the United Arab Emirates, Saudi Arabia and Iraq, as facing unique problems that require global, immediate attention.

Israel is an outlier in its parched neighbourhood. It produces 20 percent more water than it needs through desalination plants. It plans to pump this water into natural water reservoirs to support environmental ecosystems during drier years.

It wasn't always this way. In previous decades, water demand from Israel's rapidly growing population outpaced the supply and natural replenishment of potable water – so much so that by 2015, the gap between demand and available natural water supplies reached 1 billion cubic meters (BCM).

Necessity – the mother of invention and creator of new friends

Right from the beginning, water shortages demanded creative solutions. Perhaps it all started with Simcha Blass, an Israeli water engineer who established Netafim in the 1960s to commercialise water-saving drip and micro-irrigation technology. Israel has since become a major food exporter by using this technology to grow crops in the desert.

Israel's water technology is now helping to bring about an era of peace as well.

Israeli organisations and institutions such as Ben Gurion University's Zuckerberg Institute for Water Research, MASHAV, KKL-JNF, Start-Up Nation Central and the Arava Institute actively disseminate Israel's expertise, technologies, and policy strategies with geographic neighbours and distant communities suffering from endemic water crises.

There are some 150 early-stage start-ups and established companies dedicated to eco-efficient water infrastructure development in Israel.

Many Middle Eastern countries are recipients of these technologies and former enemies such as Morocco and the UAE now heavily invest in, and work with Israelis to develop world-leading water tech.

Water for peace?

The ongoing Israeli-Palestinian conflict is arguably the most complex, intractable, and sensitive geopolitical impasse in the world today.

Entrenched positions across the political spectrum have become barriers to pragmatic and centrist dialogue. Thus, acknowledging the lack of space amongst many in the conflict to reach a concession, trade now has a critical role to play in creating an environment of trust, communication, and cooperation.

Solving water disparity at a political level is tenuous and fraught with ideological agendas. At a grassroots level, there is more hope.

NGOs such as EcoPeace bring teams of Palestinians, Jordanians, and Israelis together to improve infrastructure and develop innovations that enable a more efficient usage of available water resources. An interesting project is the development of new treatment plants along the Jordan river to halt and reverse years of degradation.

The diversion of 96 percent of its fresh water, in addition to the discharge of large quantities of untreated sewage, threatens to irreversibly damage the River Valley. The Center for Transboundary Water Management at the Arava institute provides a platform for regional water professionals and policy makers to cooperate in water conservation, desalination, wastewater treatment and education. The Center facilitates direct communication between Arabs and Jews in the Arava desert.

These initiatives recognise that those who are threatened by water scarcity need to be empowered to develop the solutions that best meet their communities' needs.

At a corporate level, many Israeli start-ups actively seek to employ Palestinian engineers and scientists to develop capability, others voluntarily impart knowledge on how to develop ideas for commercialisation.

Companies such as Laguna Innovation export their wastewater tech to regional Arab communities at a low cost and work with them to integrate that tech into existing infrastructure. Socially responsible Israeli start-ups such as Watergen choose to install atmospheric drinking water devices in Gaza

Water New Zealand comment:

We acknowledge that the report of the United Nations High Commissioner for Human Rights (Sept 2021) has found that the Government of Israel is likely to be in breach of its obligations in relation to the allocation and administration of water resources in the occupied Palestinian territories and that, as such, the High Commissioner has recommended a series of actions to address the humanitarian crisis.

These include the lifting of the blockade of Gaza to allow for the repair and rebuilding of water infrastructure, reducing water exploitation and environmental degradation, immediately ending the practice of demolitions including the destruction of water tanks and water infrastructure, halting the extraction of natural resources including water undertaken for the benefit of Israel, address lack of sufficient access for Palestinians to important natural resources such as water and ensure that hazardous waste is disposed of in compliance with international standards. bit.ly/3AWTbYS

and Syria to improve access to portable water.

This demonstrates that below the political level, there is another at which corporate stakeholders in water tech can build trust and prepare the ground for peaceful dialogue.

Kiwis – what does this mean for us?

New Zealand's water problem isn't so much resource as infrastructure.

The good news is that there are many cost-effective Israeli water tech solutions that can help. We have profiled a few at the end of this article.

As with any other country in the world, working with Israeli start-ups and NGOs in the water tech space is not necessarily endorsing a political point of view. Having said that, if you would like to support those working towards peace and/or initiatives that help Arab communities maximise existing resources and improve water infrastructure, we suggest getting behind responsible Israeli companies and institutions working towards this end.

In doing so, you will be endorsing initiatives that build trust, dialogue and collaboration between the peoples and it will raise the Palestinians' standard of living by allowing them to access better paying tech jobs that foster egalitarianism and diversity.

NZIIH's role in fostering relationships

The New Zealand Israel Innovation Hub (NZIIH or The Hub) is an apolitical NGO established in 2021 to facilitate collaboration, communication, and enterprise between the two countries' tech ecosystems. It also takes on the role of a business council by advocating for trade in both directions.

The NZIIH supports peace between Israelis and Palestinians and works to improve the Palestinian socio-economic situation through innovative tech partnerships.

Additional examples of cutting-edge Israeli water technology:

Kando is a wastewater intelligence big data solution provider that uses original algorithms and artificial intelligence to enable utilities and municipalities to protect public health and the environment. The technology allows departments to gain insights and control over the wastewater networks by detecting anomalies and public health threats, track to their source and communicating their impact in real-time. Keeping the world's sewage systems hygienic and high-functioning, Kando helps save economic and environmental resources while bolstering public health.

Water Flow Tech offers a cost-effective leak-detecting solution that revolutionises flow-metering functionality at low water flows, detects low-flow leaks via alerts in real time, and solves non-revenue water issues. WTF works closely with local councils within Morocco, UAE, Bahrain, Oman and Saudi Arabia and other Arab countries to make every drop count.

Ayala Water & Ecology are sustainability experts who have developed a natural technology for treating sewage and waste streams, rehabilitating affected water bodies and rebalancing watersheds. Ayala is a member of BRIGAID, an initiative that works to bridge the gap for innovations in disaster resilience.

Asterra locates leaks across entire water systems at once using satellite imagery. This technology was the winner of the inaugural AWWA Innovation Award in 2021, moving it from an innovation to an industry standard. Asterra works with customers in the potable and wastewater industries to meet their Sustainable Development Goals.

Blue Green Water Technologies uses cutting-edge technologies to selectively target and eliminate harmful cyanobacteria/algae without harming other life forms or leaving any chemical trace in the water. Treatments rehabilitate vast tracts of water within days, restoring environmental balance and biodiversity. BG Technologies has just completed a large pro-bono project at Setumo Dam South Africa to provide safe water for local underprivileged communities.

Plucking drinking water from desert air

More than a third of the world's population lives in drylands; areas that experience significant water shortages. Scientists and engineers at The University of Texas at Austin have developed a solution that could help people in these areas access clean drinking water.

The team developed a low-cost gel film made of abundant materials that can pull water from the air in even the driest climates. The materials that facilitate this reaction cost a mere $2 per kilogram, and a single kilogram can produce more than six litres of water per day in areas with less than 15 percent relative humidity and 13 litres in areas with up to 30 percent relative humidity.

The research builds on previous breakthroughs from the team, including the ability to pull water out of the atmosphere and the application of that technology to create self-watering soil. However, these technologies were designed for relatively high-humidity environments.

"This new work is about practical solutions that people can use to get water in the hottest, driest places on Earth," says Guihua Yu, professor of materials science and mechanical engineering in the Cockrell School of Engineering's Walker Department of Mechanical Engineering. "This could allow millions of people without consistent access to drinking water to have simple, water generating devices at home that they can easily operate."

The researchers used renewable cellulose and a common kitchen ingredient, konjac gum, as a main hydrophilic (attracted to water) skeleton. The open-pore structure of gum speeds the moisture-capturing process.

Another designed component, thermo-responsive cellulose with hydrophobic (resistant to water) interaction when heated, helps release the collected water immediately so that overall energy input to produce water is minimised.

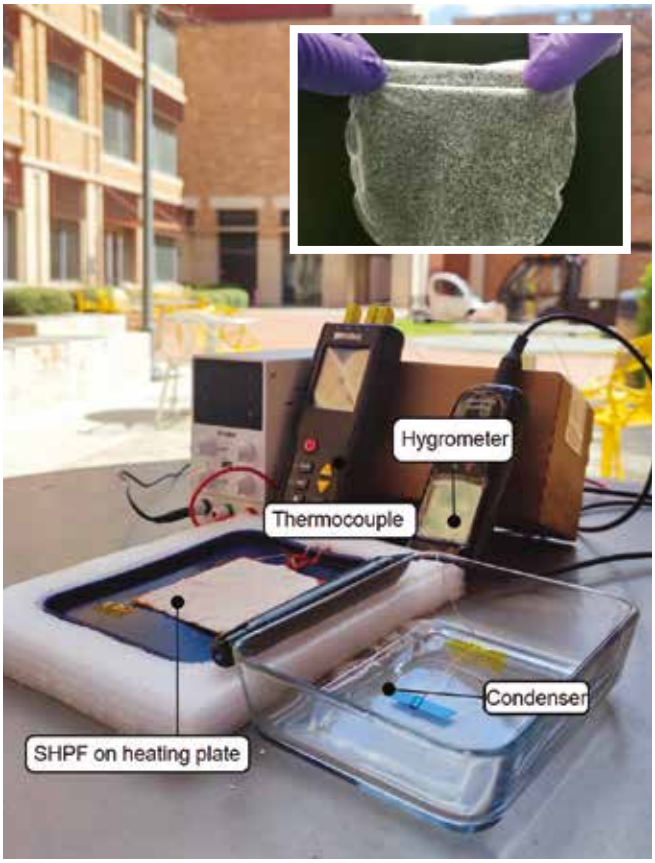
Other attempts at pulling water from desert air are typically energy-intensive and do not produce much. And although six litres does not sound like much, the researchers say that creating thicker films or absorbent beds or arrays with optimisation could drastically increase the amount of water they yield.

The reaction itself is a simple one, the researchers say, which reduces the challenges of scaling it up and achieving mass usage.

"This is not something you need an advanced degree to use," says Youhong 'Nancy' Guo, the lead author on the paper and a former doctoral student in Yu's lab, now a postdoctoral researcher at the Massachusetts Institute of Technology.

"It's straightforward enough that anyone can make it at home if they have the materials."

The film is flexible and can be moulded into a variety of shapes and sizes, depending on the need of the user. Making the film requires only the gel precursor, which includes all the relevant ingredients poured into a mould.



A prototype device for capturing water from the air using the new film. Insert: An example of a different shape the water-capturing film can take.

"The gel takes two minutes to set simply. Then, it just needs to be freeze-dried, and it can be peeled off the mould and used immediately after that," says Weixin Guan, a doctoral student on Yu's team and a lead researcher of the work.

The research was funded by the U.S. Department of Defense's Defense Advanced Research Projects Agency (DARPA), and drinking water for soldiers in arid climates is a big part of the project. However, the researchers also envision this as something that people could someday buy at a hardware store and use in their homes because of the simplicity.

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Australia-first wastewater gas-to-grid trial to support energy demands

Australia's first wastewater gas-to-grid trial has kicked off at Sydney Water's Malabar Wastewater Resource Recovery Plant with 95,000 gigajoules of renewable biomethane soon to support the energy demands of thousands of Sydney homes. By Cecilia Harris

The A$16 million project is a joint partnership between Sydney Water, energy infrastructure company Jemena, and the Australian Government's Australian Renewable Energy Agency (ARENA), which is contributing a A$5.9 million grant.

NSW Minister for Lands and Water Kevin Anderson says the trial is an exciting and significant milestone that will supply renewable gas to about 6300 homes by the end of the year, with the capacity to double production by 2030.

"This five-year pilot will put gas directly into the supply network and will also help industries across NSW meet their net-zero emissions targets, with the facility able to turn waste material into a new clean energy source."

Sydney Water asset lifecycle general manager Paul Plowman says the trial is part of Sydney Water's long term plan to increase the circularity of all of its products and services.

"We are increasing the reuse of water and recycling of water. We have a long history of recycling our biosolids into soil conditioning products and using the gas produced by the wastewater treatment process to generate electricity, which helps us run our treatment plant.

"But at Malabar, we have the opportunity to produce more gas and we are seeking to put this extra resource to good use, rather than letting it go to waste. With the help of Jemena, we can put that gas into the grid."

Partnering for success

As Greater Sydney grows and the volume through Sydney Water's network increases, Plowman says innovation-based partnerships will be crucial to unlocking the potential of wastewater to help power the city.

"We couldn't do this without our partner. We are not a gas company and we don't have licences to trade gas to the network. So when Jemena approached us, it was really a win:win scenario.

"We worked together to develop the business case and put our submissions to Arena, which is supporting the project financially to help with the capital cost of completing this trial. Arena believe the trial is an excellent opportunity to think about how this might play out across Australia.

"If we can make it work and use this trial to demonstrate that we can do it efficiently, then it's something that could be adopted industry wide."

Sydney Water's responsibility under the trial is to produce the gas to go into the purification plant, which Jemena is building on the utility's land.

"There is no cost to Sydney Water customers to do this. The facility will be built within the boundary of the Malabar facility, about 40 meters away from our digesters," Plowman says.

"The biosolids in our digester produce a combination of methane, hydrogen sulfide, and carbon dioxide. We use that gas to make electricity to run the plant, but the remainder will go into the purification plant to create pure methane, which will then be put into the gas network."

Plowman says the trial will allow Sydney Water to learn about the technology, and also running costs and how the market works.

"It's a trial because we are learning about the Australian context, but many of these projects are already underway in Europe.

"Furthermore, Jemena will be assessing how this supply interplays with the demand of the

local gas market, considering when to produce it and supply the gas to the grid."

Planning and adapting

Plowman says getting the trial off the ground has required a lot of work between the partnering organisations, particularly in terms of drawing up the agreements.

"There was an awful lot of work that went into the agreement between Arena, Jemena, and Sydney Water, to make sure that all organisations were comfortable with the risks they were taking on and the likely returns that they were going to get out of the project.

"We had three executive boards to get over the line, which is always a challenging thing with any partnering agreement, particularly when something is new."

Furthermore, Plowman says that while similar wastewater gas-to-grid works are underway in Europe, adapting the technology for Australian standards and regulations was another hurdle.

"You can't simply take a piece of European technology and pop it down in Australia. The rules are different, the laws are different, the statutory and safety requirements are different.

"Jemena completed a lot of technical work to modify the purification plant, which is actually being built in Brisbane. It's a European design that's been manufactured and modified in accordance with Australian standards."

Despite this, Plowman says Malabar presents as an excellent site to run the trial, as it has enough gas from its bioreactors and is positioned relatively close to the gas grid.

"There is a short pipeline that needs to go from the Malabar purification plant to the gas grid. And that is in an urban area, so we've had to do a fair amount of planning approvals associated with that."

Long term benefits

While positive outcomes of the trial include contributing to the circular economy and helping supply renewable energy for Sydney communities, Plowman says the real value the utility will derive is in how this type of operation might be expanded in future.

"The value for us is all about the long game. We expect to benefit hugely from learning about how to get these types of projects up and running, and see where it can be applied elsewhere in our network.

"The return we get from this is about knowledge. It will give us more options in terms of how we utilise the gas resources from our treatment plants in future."

Sydney Water has already done trials in the past looking at adding additional food waste, which multiplies gas production during the digestion process.

"The gas we produce at Malabar is derived completely from our treatment process. But we know from trials in the past that adding food waste can significantly increase our gas production.

"There are exciting opportunities to consider in terms of partnering with companies who can manage more waste input into our digesters.

"We could potentially multiply our gas production, which means more renewable electricity, potentially more gas to grid, but it also means less waste going into landfill."

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Water utilities targeted by hackers

Cybersecurity specialists Alex Ladur and Benjamin Guy of First Watch look at recent cyber-attacks on water utilities around the world, how they played out, and what actions can be taken to reduce risk.

Cyber-attacks targeting critical infrastructure have become increasingly common in Western countries, including in the water sector.

Water utilities are particularly vulnerable to ageing infrastructure, budgetary limitations, and cyber skills shortages. They are also, like electricity, the lifeblood of industry and the urban environments that support them. Consequently, they have become an attractive target for nation-states, professional hacking groups, and disgruntled insiders in an increasingly polarised world.

By reviewing a couple of recent cyber-attacks on water utilities and seeing how these attacks were carried out, we can understand how perpetrators can take advantage of systemic issues in the water sector and the potential outcomes of attacks, from data theft through to loss of water supply.

We also cover various steps engineers can take to harden the security of their organisation, with a particular focus on addressing some of the more commonly seen insecure practices.

Security incident at Oldsmar Water Treatment Plant

On February 5, 2021, an unknown person gained unauthorised access to change the lye concentrations of the water supply for nearly 15,000 people at the Bruce T. Haddock Water Treatment Plant in Oldsmar, Florida.

The intruder accessed the plant's HMI system via TeamViewer, used widely in the industrial environment for remote support and maintenance.

The cyber incident was detected by an operator on duty on two occasions, approximately five hours apart. On a first occasion, around 8am, an operator found the mouse cruising on the HMI's screen. It didn't raise any concerns due to the usual practice in the plant when a remote engineer checks the process's parameters remotely.

Later in the day, around 1.30pm, an operator saw the moving mouse on the screen again, but this time an unknown person tried different software and jumped to the HMI screen where they changed the setpoint of lye from 100ppm to 11,100ppm.

An operator quickly returned the setpoint of the chemical to its original value, raised a call to the supervisor, and remote access via TeamViewer was disabled.

According to city officials for Oldsmar, it would have taken approximately 24 hours for the changes in lye level to affect the public water supply adversely. Nevertheless, the process control system has built-in redundancies to alert them of high pH conditions.

Since the plant operator observed the cyber intrusion in progress, the setpoint change was reversed quickly, and Oldsmar's population of 15,000 was never in danger.

However, if the cyber intrusion was not detected, the outcome of the potential drinking water damage would bring hundreds of people to hospitals for treatment. When lye is introduced into the water supply in elevated concentrations, it can cause rashes, burns to the body, and other adverse effects. There would also be extra costs to decontaminate the water.

A detailed analysis of the existing practices at the Oldsmar treatment plant shows that cyber security practices were widely overlooked.

The potential intrusion happened because account credentials were leaked in the days before the unauthorised setpoint change. The compilation of usernames and passwords of all previously known attacks were leaked to the internet, including Oldsmar accounts. A responsible cyber security specialist would check the compromised account at www.cybernews.com/personal-data-leak-check/ and change passwords immediately.

In addition, remote access was not configured to use VPN with 2FA (Two-Factor-Authentication) and with individual accounts. The shared account gave an attacker a privilege to traverse software on the HMI machine and understand the software structure.

Also, data restriction mechanisms were not implemented on the HMI system. A cyber monitoring system would be able to

detect an unauthorised setpoint value in the network traffic and disallow sending it further.

In addition, the Oldsmar's engineering practice of connecting remotely to the HMI machine without notifying an operator on duty led to the situation when an operator didn't raise an alert as early as possible.

Finally, risk assessment of the cyber security posture was not conducted in the past.

Ransomware attack on Riviera Beach, Florida

Starting on May 29, 2019, the computer systems and network of the Riviera Beach city services were subject to a ransomware attack, which encrypted their data and took their computers offline.

It stemmed from a successful phishing email, which started in the police department, which traversed the network and infected almost all the systems, including the water utility, taking down pumping stations, water quality testing, and payment systems. This resulted in the water utility staff having to run the pumps, test water quality, and process payments manually.

With no suitable backups available, the city had a meeting after a few days and decided to pay the attackers fee of 65 Bitcoins (BTC), roughly US$600,000 at the time.

The city's insurance paid the attackers' fee causing the town to incur a US$25,000 insurance deductible from the city's budget.

Even after paying the price, for two weeks the water utility systems were only partially operational.

As a councilperson relayed, all the hardware was outdated and scheduled to be updated in the next year or so.

While there was no impact on the water services offered because the city had a manual operation plan, there was a significant financial burden, both in paying the ransom and prompting a planned upgrade to be brought forward and expanded, rising from US$300,000 to US$900,000.

Being forced to use a manual payment system also meant slower service for customers paying their bills.

In addition, while the water utility could still operate manually, the plant was a lot more fragile and could have easily been disrupted in another way.

When we look at what could have helped prevent this attack, simply keeping all system hardware and software updated is a good starting point. However, implementing as many layers of security as reasonably possible is advised. With that in mind, the following points jump out.

Systems need to be appropriately compartmentalised – if the water utility was behind a Demilitarized Zone (DMZ) and each subsystem (e.g., pumps, monitoring, and payments) on monitored subnets, then the attack would have been a lot less likely to spread to all of them.

Just as important is ensuring there are proper backups. These would have resolved most of the significant consequences of this attack. Having an offline weekly/nightly backup would mean that the affected systems could have been restored in a matter of hours, with little data lost.

While it worked somewhat on this occasion, paying ransoms is ill-advised, as there is no guarantee of receiving the unlock key in a prompt manner, if at all. It also encourages other cyber attacks – if not on the same victim again, but on others in a similar position.

Staff training should be regular and people should be encouraged to ask their IT department to check anything suspicious – be it an email, a dropped USB stick, or someone asking for access without notice or written permission.

Overall, system security should be regularly audited, especially regarding access between systems and credentials sharing.

This should also be backed up by running 'white hat' intrusion attempts (a white hat hacker is an ethical information security developer or engineer who tests security configurations on behalf of an organisation, aiming to identify any vulnerabilities in the current system). This will ensure there are no known back doors into the systems and that staff, for the most part, will respond correctly to social engineering attempts.

With the number of cyber-attacks increasing worldwide, all critical infrastructure providers should be looking at their current layers of security, ensuring they firm up things like like network infrastructure and data policies, and add new layers of protection, such as process monitoring and traffic sniffing.

A year in paradise: Achieving safe drinking Water in Vanuatu

As international borders re-open, new opportunities for volunteering are also unfolding. Water New Zealand spoke with Dane Hart, CEO of Engineers Without Borders New Zealand, about the drinking water challenges facing communities in Vanuatu and the work EWBNZ is doing to help resolve this.

WNZ: Can you tell us a bit about what EWBNZ are hoping to achieve in Vanuatu?

Dane: The Vanuatu government set themselves a goal to ensure all people have reliable access to safe drinking water and sanitation infrastructure by 2030. This means the Department of Water Resources (DoWR) is tasked with working with more than 2000 communities across 83 islands to develop drinking water safety and security plans, and then supporting these communities with the investment required to achieve these plans.

EWBNZ, along with Volunteer Services Abroad (VSA), is supporting DoWR to build the technical capabilities of their staff in each of the provincial offices. Increasing the technical capabilities of the department's staff is considered to be one of the more sustainable ways of providing support – the intention is that those learned skills stay with the provincial office staff and are used again and again.

WNZ: So how exactly do these volunteers achieve this?

Dane: VSA and EWB recruit volunteers for placements typically between one and two years. These placements involve being integrated into the DoWR teams in the provincial offices.

However, it is important to be clear that these volunteers are not there to just provide additional design capability, they are really there to help their teammates learn new skills. This means understanding what they need to know, working out any gaps in their existing knowledge, and then working with the team to create a learning and development plan to fill those gaps.

It is likely that most of this plan will involve on-the-job learning, but it may be supported by a few workshops or online courses too.

As success to us means an increase in relevant skills and knowledge, we make sure we stop to assess the learning at regular intervals, and work with the volunteers to adjust those learning and development plans as needed.

WNZ: It sounds like a very worthwhile way for someone to use their skills. Can you tell us a bit about what it is like to live and work in Vanuatu?

Dane: I lived in Vanuatu myself many years ago and absolutely loved it. There was always something new to learn, and the locals were always happy to share their knowledge and include me in experiences. I never dreamed that I would find myself learning how to catch prawns in mountain streams with a homemade Hawaiian sling.

Many of the volunteers who undertake an assignment request to extend their stay. Some of the feedback that we get is that they really enjoy the relationships they have built with their team. They learn how to be a more well-rounded engineer, and person.

Many enjoy living in a place with a much slower pace of life, and where the beach is never far away.

WNZ: We understand that you are currently recruiting for volunteers in these roles. Can you tell us some of the details?

Dane: Yes, we are looking for four more volunteers.

As borders have now re-opened, we have the all-clear to field volunteers again. Applicants will go through a recruitment process with VSA to ensure they have both the technical (professional) skills and personal attributes to be a volunteer with DoWR.

The volunteers need to have enough technical knowledge to be able to coach others who are designing small rural water supply systems – that does not necessarily mean a professional engineering background, there are plenty of technicians or operators in New Zealand who would fit that bill too.

We are particularly interested in skilled individuals who are nearing the end of their career and have a desire to give back to the profession.

When the selection process is complete, selected volunteers will go through a pre-deployment briefing with both VSA and EWBNZ to help provide context around working and living in Vanuatu as a volunteer. EWB will provide ongoing support with learning and development planning and monitoring.

VSA makes sure each volunteer is well looked after and have the support they need to live and work in this unfamiliar environment.

WNZ: So where do people sign up?

Dane: If you are interested, and want to find out more, contact me at dane.hart@ewb.org.nz for a no obligations chat about how you can be involved.

This programme is funded by the Ministry of Foreign Affairs and Trade, and is run in partnership with VSA.

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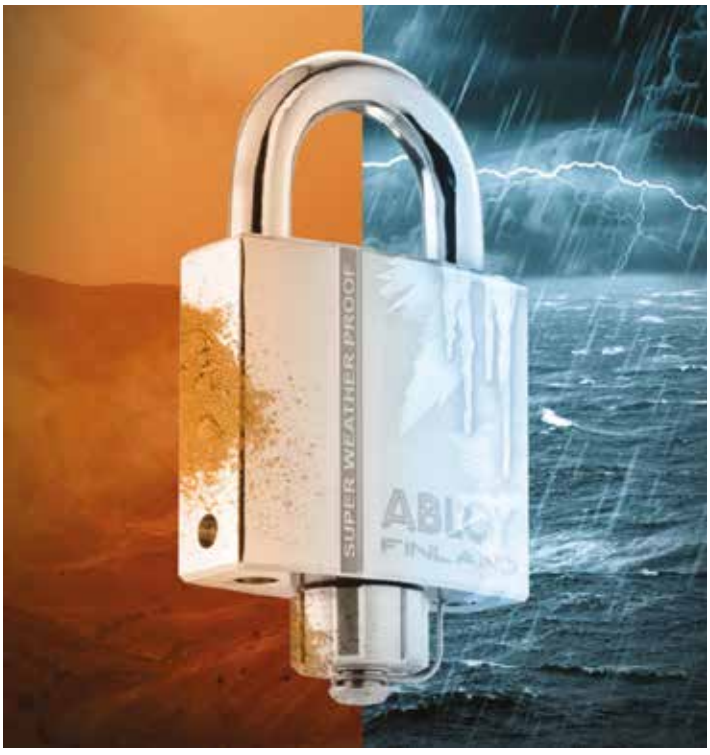

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Boosting access to safe water in the Democratic Republic of Congo

By 2026, the ICRC's (International Committee of the Red Cross) Goma West Resilient Water Project, in the Democratic Republic of Congo, will help over 330,000 people have access to safe and affordable drinking water.

Developing long-term sustainable solutions takes time and money. The success of such projects lies in the trust and confidence of key partners and innovative public-private financing solutions.

There's no shortage of water in Goma, eastern Democratic Republic of Congo (DRC). The city sits on Lake Kivu, plus it rains a lot.

The problem is you wouldn't want to drink it untreated. You might get diarrhoea, cholera, or other water-borne diseases.

Unfortunately, this isn't an option for over half the population who don't have access to clean water.

People either fetch untreated water directly from the lake, carrying heavy 20 litre jerrycans long distances, or they pay high prices at distribution points for water that is not available every day due to decaying water infrastructure.

Time is of the essence, as the city's population is expected to rise to 1.1 million people by the end of the decade. The situation is particularly dire in west Goma where many of the city's most vulnerable communities live amid dire sanitary conditions.

Above: Street vendors get water directly from the lake. Over page: A woman draws water from the lake, four times a day to fill her two 25L jerry cans.

The Goma West Resilient Water Project aims to bring clean water to 330,000 city residents by 2026. Building on the ICRC's

extensive knowledge and decades-long presence in Goma, the project will provide long-term access to safe and affordable drinking water. It will transform lives in a region that has faced multiple crises in recent decades, including conflict, violence and natural disasters.

"This project will have a positive and sustainable impact on the lives of hundreds of thousands of people," says ICRC president Peter Maurer. "Its implementation shows how important local partnerships and those across the humanitarian, development and private sectors have become. These partnerships bring complementary skills and expertise, ensure local ownership and deliver new ways of funding and financing."

Initiated in 2019, the GWWP is the ICRC's third New Financial Model (NFM), following in the footsteps of the Humanitarian Impact Bond and the ICRC Climate and Environment Transition Fund. The NZ$66.8 million project brings together humanitarian and development funding with private sector participation and investment.

Around NZ$28 million has been raised as of May 2022, including a NZ$25 million foreseen from the World Bank through combined grant and credit financing to the DRC government (under the Access, Governance, and Reform for Water and Electricity Sectors Project).

Axel van Trotsenburg, managing director of the World Bank, says he was pleased to be partnering with the ICRC on such an "innovative and much-needed" project:

"Strong and effective partnerships such as this, are a crucial part of the World Bank's approach to successfully working in fragile, conflict and violence affected environments, where leveraging the comparative advantages of both organisations will provide a safe and more reliable water supply for the citizens of Goma."

Other contributions to the ICRC have come from the Swiss Agency for Development and Cooperation (SDC), the Swedish International Development Cooperation Agency and the Fondation Lombard Odier. In addition to financial support, the SDC deploys technical experts to the project.

"Switzerland supports the strengthening of Goma's water infrastructure to improve the well-being of its population, its health and prevent the spread of water-related diseases such as cholera outbreaks," says Patricia Danzi, director general of the SDC.

"To face the complexity of a crisis, we all need to think short and long term, and adapt our approaches to the humanitarian challenges we meet."

An additional NZ$13 million funding is being sought in 2022/23 for the ICRC to finalise preparation and continue essential emergency works.

ICRC water engineers have been working closely with local partners for the past 25 years to ensure that the city's existing water infrastructure continues to provide water to a large part of the city. The GWWP is an example of working towards sustainable solutions to recurrent emergencies, ultimately saving lives and using funding more effectively.

According to the World Health Organization, investments in water supply and sanitation generate an economic return of up to US$4.3 for every dollar spent.

This would translate to US$175 million in economic benefits for Goma and the surrounding region.

The project includes the construction of a drinking water supply system composed of water treatment plants, pumping stations and reservoirs.

Once built, the new water infrastructure will need maintaining to ensure sustainability. To that end, the ICRC is also supporting the establishment of the Régie Provinciale, a body that will monitor the quality of the service provided by the water operator.

Partnerships within the International Red Cross and Red Crescent Movement allow the ICRC to connect deeply with communities benefitting from the project and ensure it is affordable and relevant.

"This project is not just about preventing disease, major epidemics and improving public health; it will boost living standards and foster economic growth, as people spend less on water and medical bills, and more on other necessities such as housing and education," says ICRC water and habitat engineer Jérôme Guillaumot, who's managing the Goma project.

"New approaches and partnerships are an essential component to increase the long-term stability of a region that has endured successive conflicts and crises for far too long."

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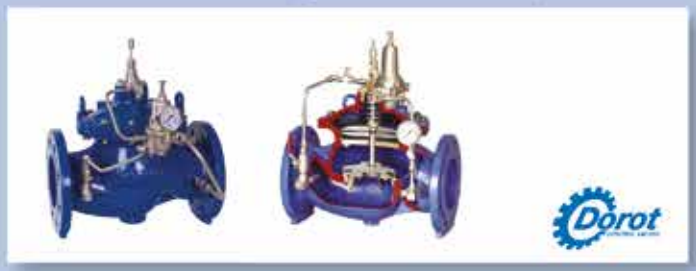

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