engineering new zealand
Institute of Engineering Professionals

WE'RE ASKING THE HARD QUESTIONS. WE'RE SEEKING ADVICE FROM THOSE WHO ARE PASSIONATE. WE'RE EXPLORING ALL THE POSSIBILITIES. WE'RE CREATING MORE RESILIENT AND PROSPEROUS COMMUNITIES. WE'RE DRIVING CHANGE WITHIN OUR INDUSTRY. WE'RE ENGINEERING A BETTER NEW ZEALAND.

Thank you to everyone who helped make *Engineering a Better New Zealand* a reality, including:

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AN ENGINEERING PERSPECTIVE

Engineers are at the coalface of New Zealand's greatest opportunities and most pressing challenges. We also play a pivotal role in responding to, shaping and solving them.

Today's engineers balance society's needs with planning and designing of long-life infrastructure and systems. We create new and innovative solutions to some of the world's most difficult problems and we respond in times of great need and disaster. Engineers create – and use – every imaginable technology to benefit communities. Our perspective and expertise inform and drive change for a better New Zealand.

Sometimes what engineers see keeps us awake at night. We're part of the community and like you we want it to thrive. We see seismic resilience, water quality and climate change as three critical challenges facing New Zealand. The Canterbury and Kaikōura earthquakes have delivered stark lessons on seismic resilience. But those earthquakes are not the most severe that nature can throw at us. Outbreaks of waterborne illness are on the rise.[1] Our rivers are increasingly polluted by run-off, contaminants and sediments. More severe storms are causing more frequent flooding and slips.[2]

These challenges come with huge opportunities to make a difference. To create a future where our cities, towns and rural communities are healthy, productive, resilient and liveable. Where our buildings both protect people and sustain less damage from earthquakes. Where New Zealanders can all rely on the quality of our water, and where storms and flooding have less impact. Where our society has adopted cleaner forms of energy as we adapt to a world where our climate is changing.

Unless we take clear, coordinated action together now, this future is at risk.

Taking action means placing our communities at the heart of everything we do. It means valuing resilience and creating buildings, infrastructure and processes that protect people and property. And it means making sure these are robust and sustainable enough to ride out turbulent events and our changing world.

Realising our vision means committing to change. To get there it will take everyone – communities, iwi, government, land and property owners – getting behind a vision of a healthy, productive, resilient and liveable environment. It also means understanding the consequences of not taking action. If we rely solely on regulation, we won't get there. If we rely on each other, work together in partnership, engage in tough conversations, innovate and have courage, then we will.

Engineers accept responsibility for driving and delivering much of the change that's needed. But we can't do this alone. Engineers can contribute a lot more than fulfilling a brief. Our ability to identify underlying problems and opportunities, and to provide creative solutions, places a large responsibility on us.

Engineers also need to step up and become better communicators of risk, making sure that our unique perspective informs discussions with government, developers, clients and our community on their plans for the future.

"Unless we take clear, coordinated action together now, this future is at risk."

Engineering a Better New Zealand is part of this process. As a profession, engineers have a responsibility to form partnerships and help to drive the change our communities and New Zealand need. To produce this publication, Engineering New Zealand asked engineers to identify the three most critical engineering-related challenges facing our country. We brought together engineers, policy makers and scientists to unpick these challenges and find a way forward. In this publication, we ask decision makers and all New Zealanders to take a hard, fresh look at two of them: seismic resilience and water quality, for the sake of future generations' safety and prosperity. We are continuing our work on clean energy as a response to climate change, for release later this year.

Part One of *Engineering a Better New Zealand* outlines our engineering vision for a resilient New Zealand and our seven recommendations on how to get there. It also examines what we mean by risk and resilience: two critical factors that apply in all these discussions.

Part Two is a detailed look at seismic resilience, for the sake of future generations' safety and prosperity.

Part Three examines the state of our water and looks ahead to a better, safer system.

PART 1
OUR VISION

WHAT DOES A BETTER NEW ZEALAND LOOK LIKE?

OUR VISION FOR A RESILIENT NEW ZEALAND

How would New Zealand's built environment, infrastructure and water management systems look in the future if we take action now? Rather than simply reacting to our seismicity, changing weather, and growing urbanisation, we all need to drive towards a vision of a better, more resilient New Zealand. In our vision, the community is at the heart of New Zealand's resilience.

Resilient communities play their part

People feel more in control of managing their risks because they have information they can engage with. This means they develop a better understanding of risk. They actively help set acceptable risk standards, both in regulation and decision-making about investments in infrastructure and innovation.

New Zealanders at home and work take a broader approach to disruption. They consider how they might be affected by neighbouring buildings, infrastructure outages and storms. Households increase (and regularly refresh) their post-disaster supplies. Businesses and organisations have disaster plans and contingencies that allow them to keep operating through moderate events and evacuate safely after major ones.

We invest in resilient buildings

Our built environment includes buildings either designed or retrofitted to perform well both through and beyond a major earthquake (not just a moderate one).

Our cities think beyond the traditional boundaries of technology. They collect and harness data to provide relevant, meaningful and tailored information, so building owners can make their structures more resilient. We are ready for the earthquake aftermath. Key buildings are instrumented and their data is quickly interpreted after an earthquake, by structural and geotechnical engineers working with seismologists.

Our urban centres benefit from an holistic approach to their buildings that addresses performance of the entire CBD. We set higher performance standards in cities, knowing how a major urban disaster affects the entire country's economy. Our smaller towns benefit from a long-term approach to improving seismic resilience that factors in the fragile nature of regional economies.

Our regulatory pathway defines action for buildings (or parts of buildings) at risk of failing in larger earthquakes, and responds to new learnings from every event. This pathway reflects much closer integration between the design, construction and regulatory sectors on complex issues. We have a clear mechanism for addressing and resolving technical, regulatory and contractual issues, like those concerning non-structural seismic restraints.

"In our vision, the community is at the heart of New Zealand's resilience."

Our consideration of a building's risk is multi-layered. As well as taking into account how neighbouring buildings will perform, we consider access routes to a building and the reliability of infrastructure that supports them. Similarly, we consider economic impact.

Low-damage building design commands a premium that developers and tenants are willing to pay. Our insurance arrangements include standards for assessment and repair, and policy wording is unambiguous.

We plan for and invest in resilient infrastructure

Planning and investment for infrastructure resilience is integrated across organisational and sector boundaries. It creates necessary redundancy in key utility and transportation networks. It's prominent in central government and council long-term plans.

When considering infrastructure investment, we consciously assess resilience. Decisions about future infrastructure factor in ways to reduce risk and increase resilience. For example, an improved alternative public transport link provides a lifeline post-disaster; a more distributed energy or water-storage system reduces vulnerability to outages.

Resilience includes our cities being prepared for the changes that the digital revolution will bring to our infrastructure, such as fewer cars and public spaces that are used differently.

Our drinking water is reliable and well regulated

Drinking water is safe to drink throughout the country. It's supported by a resilient system that includes both physical infrastructure and a multiple barrier approach to contaminants. Globally benchmarked standards have been set, and these standards are checked and monitored in real time with this information shared with communities.

The regulatory system has been simplified and improved. People know who is accountable for the safety of their drinking water. They have confidence that when standards are breached, action is taken.

We plan better to manage flooding and runoff

Everyone acknowledges that water cannot be controlled, only managed. This shapes our planning. We plan for storm events with increasing rainfall intensities and duration, and for coastal storm surges.

All New Zealand waterways are healthy. We model monitoring results in a way that engages the community, driving advocacy for change.

Central and local government operate from a national decision-making framework for landowners with vulnerable property. The framework helps these landowners make hard decisions about their future. It includes funding mechanisms and can adapt to local circumstances and existing use rights.

We embrace water-sensitive design, which integrates land-use planning and water management. Instead of managing drinking, storm- and wastewater separately, all aspects of water management work together, creating multiple benefits from every dollar spent on water infrastructure.

We prioritise natural courses for water runoff. Flooding and stormwater overflows reduce because natural, porous surfaces help contain water where it falls and slow down the water flow.

HOW DO WE GET THERE?

We recommend seven key steps to build a more resilient New Zealand. They will require commitment and action from engineers, regulators, building and infrastructure owners and communities. Partnerships are vital – everyone has a role to play in building a resilient New Zealand.

Our recommendations

1

Reset the levels of risk we can tolerate and regulate accordingly

In the wake of the Canterbury and Kaikōura earthquakes, we need to recalibrate how we design and construct new buildings. We also need to recalibrate how we evaluate and upgrade existing buildings.

Instead of discussing risk in absolute terms, we should consider what we can tolerate over the range of events we anticipate. This means factoring in likely damage and repair scenarios, the possibility of reduced insurance, and New Zealand's ability to absorb the cost. Then society as a whole can reconsider the risk settings reflected in the Building Code and guidelines for designing and constructing our buildings and infrastructure.

2

Plug the regulatory gap concerning existing buildings

We are limited in the action we can take to protect people living and working in existing buildings that might survive a moderate earthquake but fail in a large one, causing significant loss of life. If this building isn't defined as earthquake prone, then it sits in a regulatory gap. Together we need to develop a regulatory approach to identify, define and remediate building vulnerabilities that present unacceptable risk in severe seismic events.

3

Make infrastructure resilience a collective responsibility

Resilient infrastructure requires everyone (from service providers to regulators) to take collective responsibility for identifying existing system vulnerabilities, improving reliability and redundancy and prioritising upgrading. This requires the crossing of conventional commercial and institutional boundaries, to share information and collaborate for the greater good of all New Zealanders. Engineers must take a central role in driving this systems thinking, given our understanding of the impacts, and expertise in identifying and resolving the challenges.

New Zealanders must also be better prepared for inevitable outages. Engineers can provide information about the realistic consequences of disruption to water, transport, power and other services. But New Zealanders (in both organisations and households) need to use this information to play their parts in planning for and managing those outages.

4

Fix our broken drinking-water system

Following lessons from the Havelock North Inquiry, a revitalised vision for drinking-water infrastructure is emerging. It points to the need for a coherent regulatory system, which engineers strongly endorse, and which the Government is progressing.

We believe the system the Government puts forward should enable affordable water of a consistent minimum standard for all New Zealanders, wherever they live. This requires clear accountability for setting, monitoring and enforcing globally benchmarked minimum standards. It also requires services delivered by competent and regulated water practitioners, and improved effectiveness and efficiency of delivery. A new regulatory system needs to be supported by funding the delivery of the upgrading of existing infrastructure and new infrastructure.

5

Enable the community to value water (in all its forms)

The community must help create a vision for safe water, and understand its role in protecting it. Properly informed, the community will value water, push for investment in its protection and its infrastructure, and take action to conserve it.

To enable this, the community needs government and engineers to provide clear and accessible information – about risks, costs, the benefits of intervention, and incidents that occur, as well as accurate monitoring data. The Government also needs to develop schemes that incentivise communities to conserve water, and fair pricing that reflects the value of clean, healthy water yet safeguards everyone's access to it.

6

Make hard choices now about unsustainable locations

Adapting to the risk presented by climate change means making some hard choices. It means local government stopping new development in locations with existing and increasing risk, and making tough calls about existing developments that are becoming untenable.

7

Commit to real-time monitoring and reporting of water quality

We need water regulators, infrastructure owners and managers to pursue best practice for drinking water, the water we swim in and flood risk. There should be a commitment to real-time monitoring, so that individuals and communities can make informed choices. This means taking collective responsibility in a way that exceeds current regulatory obligations. It should be supplemented by predictive modelling.

Taking this approach would improve water-related infrastructure management, and management of our natural water bodies and systems. It would provide quality information to our communities to enable them to prepare, respond and be more resilient. If we get this right, then we will be able to effectively address national water quality standards as they are implemented.

WHAT DO WE MEAN BY RESILIENCE?

Resilience underpins engineers' vision for the future. Resilience means the ability to withstand and respond to events, whether those events feature earthquakes, pathogens or weather. It means having the capacity to deal with disruption. It's also about what risks we are prepared to accept as a society – and what we are not prepared to accept.

A more resilient New Zealand will cope better with the challenges we face. Resilience creates a buffer that helps insulate us from the worst effects of disaster and disruption so that we can continue to prosper. It safeguards health, people's lives and our livelihoods. Without resilience, each challenge we face can become a major setback.

Resilience has three dimensions: robust buildings and infrastructure, effective relationships within and across sectors, and realistic user expectations with appropriate backup arrangements. Physical assets dominate people's perception of engineering. But effective relationships between service providers are just as important. And the community needs to be effectively prepared. This means making sure people know how much they can rely on their infrastructure, and encouraging them to plan for a realistic level of outage.

What prevents resilience?

We don't value resilience

When something destructive happens, we retrospectively value resilience. We wish we'd paid more for resilient infrastructure or systems. But considerable resilience can come without huge expenditure, if we design carefully and reconsider other priorities.

Perverse incentives reduce resilience

All too often, we're not aiming for a resilient society: we're aiming for one that meets a minimum standard. Setting a regulatory standard can deter people from aiming higher. Unless there are incentives to exceed that standard, the market delivers the lowest-cost solution that meets it.

We take a short-term view

The infrastructure we have today was not designed for the future we face, but for a past we have probably surpassed. Patches may be cheaper in the short term. But if our investment timeframe is 50 years, investing in a more resilient option today should pay off over time. More importantly, the more resilient option is far less vulnerable to a disaster – a disaster that is more likely to happen in that longer timeframe.

Planning seldom considers the full consequences of a disaster

Even when people weigh up the cost of buildings and infrastructure in terms of their likely usable life, they don't always fully consider the possibility of a disaster like an earthquake. It's easy to ask, "what is the risk?" instead of, "what if?" We use our perception of a low likelihood to cloud our understanding of consequence. Instead, we should be asking what outcomes we can – and cannot – accept.

We take a simple view of resilience

To be effective, resilience must be developed at all levels at once; from individual, to community, city and nation. None of these can see resilience as someone else's responsibility.

To value resilience we must understand risk better

Risk sits at the intersection of vulnerability, likelihood and consequence. New Zealanders face multiple natural and artificial hazards, some known and some unknown. We can reduce our vulnerability to these hazards. But we will never prepare for every eventuality nor eliminate risk.

For people to value resilience, they must understand the risks they face without it. Engineers have a key role in informing public debate on the understanding of risk. That will help us as a society decide what standards we will collectively accept.

Engineers also know that communities see standards through a different lens from regulators. People don't ask for acceptable levels of contaminants nor for buildings to withstand only one significant earthquake before they need it to be demolished. But the market doesn't necessarily deliver what the community wants. For example, a property developer in New Zealand has little financial incentive to invest upfront in base isolation.

Engineers also know it's hard for humans to think rationally about risk. We all fear earthquakes, which have killed 187 people in New Zealand in the past 10 years. Yet, in the same timeframe, 3,300 people have died on our roads and people continue to drive without fear. But even fear doesn't compel us to mitigate against real risks that we perceive as outside our control or of low probability.

After a major disaster, the community often expresses a sense that it took us all by surprise. But while the timing and impact of disasters can't be predicted, New Zealanders can be relatively sure they will happen. If together we understand, develop and put in place effective risk management, we can avoid or mitigate the worst outcomes.

Another challenge with our thinking about risk is that expecting safety stops us engaging with risk. Safety is relative to risk and is dynamic. "Safe" is not a state that can be permanently attained and retained: what was safe enough in the past may not be acceptable in the future. Engineers need to help communities think about risk, not expect total safety. Conversations about safety prevent more productive conversations about risk and how to manage it.

Being a resilient community means having a realistic understanding of what might happen and what its consequences will be, including how long outages will last. It means being able to recover well. And it means being ready.


JOHN JONES STEEL

PART 2
SEISMIC RESILIENCE

HOW DO WE SURVIVE AND THRIVE IN OUR SEISMICALLY VULNERABLE COUNTRY?

SEISMIC RESILIENCE

The 2010/2011 Canterbury and 2016 Kaikōura earthquakes woke up New Zealanders to earthquake risk. They ended a relatively inactive few decades when large magnitude earthquakes didn't affect population centres and as a nation we became blasé about the risks.

While significant earthquakes will cause loss of life, this shouldn't be concentrated on one building because of engineering and system failures, as happened with the CTV building.[3] Engineers must learn these lessons.

Even after these recent earthquakes, which have increased the public's expectations of safety and resilience, New Zealanders lack an informed understanding of seismic risk. New Zealanders don't have a collective understanding of what our communities can and can't live with, and we don't have a consensus on how to deal with emerging risks in buildings.

For engineers, seismic resilience means protecting lives, reducing damage to buildings and infrastructure, and minimising disruption to everyday life. Knowing what we know today about low probability and high consequence events that have materialised, what can New Zealanders live with and what must we change?

Safety and risk

Communities expect safety

Buildings and infrastructure exist to serve people. Any conversation about seismic resilience must be grounded in the community, and alert to that community's needs and wants. Post Canterbury and Kaikōura, communities want more from their buildings and infrastructure, not less. Their expectations of safety and dependability have rightly increased.

If community expectations don't match what will be delivered, it's because engineers have failed to accurately convey risk. Engineers and scientists have realised seismic risk needs to be explained differently to help people understand what it means, how it should inform their decisions and what they need to do to prepare.

But safety is a difficult concept

The community expects buildings to be "safe", which implies that people will never be harmed, whatever the danger or scenario. It's a concept that works against informed debate about seismic resilience.

Safety can never be guaranteed. New buildings are not designed to be totally earthquake proof because this would require unaffordable levels of strength and resilience. Our Building Code specifies minimum performance standards, like most regulation, rather than setting a gold-standard target. If you ask an engineer whether a building is safe, what you will get is an assessment of whether that building is safe enough for the purpose it was designed, under the conditions that were reasonably anticipated at the time.

Let's talk about risk, not safety

Instead of focusing on safety, engineers need to start conversations about risk. If people understand the components of risk, they can make informed decisions about reducing it. This means regulators and engineers providing information communities can engage with, and understanding what stops people preparing for things that may be unlikely to happen but carry high consequences.

Communicating risk is difficult. It is often mired in complex numerical analysis and expressed in terms that don't connect with people's everyday experience or knowledge. This means we can lose sight of a severe earthquake's horrific outcomes because these earthquakes are so rare. But unlike truly random events, an earthquake will always eventuate on a known fault line, even if its probability of rupturing in any given year is very low. The question is when, not if.

We need to put aside short-term probability in order to plan better. This means communicating seismic risk through event scenarios that explore what happens based on different states of preparedness – and then considering what an acceptable (or unacceptable) outcome looks like.

Buildings

Are we having the right conversation about earthquake-prone buildings?

If a building is earthquake prone, it doesn't have to be immediately emptied. While an earthquake-prone building poses greater risk to people than an equivalent new building, it doesn't necessarily require immediate action. In places where earthquake risk is greatest, the Building Act allows a minimum of 7.5 years for strengthening or demolition. The Act allows longer in areas of lower seismicity.

Many communities struggle with the costs of remediation but still value their built heritage. The local economic impacts of these decisions can be disproportionate to the risk experienced by those in and around the buildings.

What's important is to carefully consider a building's particular risks. Seismic risk should be considered in conjunction with long-term asset management programmes, rather than driving short-term, fear-based actions at unnecessary cost.

It's not one-size-fits-all for cities and towns

Damage and disruption to a major city has a significant negative impact on New Zealand's economy. In contrast, severe damage to a small town, while disastrous for its inhabitants, can be readily absorbed by the country as a whole. The level of absolute risk that New Zealanders accept for any one place must be tempered by how much its recovery would cost – for both those directly affected and us all.

Higher rents and occupancy rates in cities can fund the expenditure required to make existing buildings more resilient. But older buildings in smaller communities are in the opposite position. For those communities, a national approach to strengthening buildings can have a highly destructive impact on their local economy, with outcomes that could, over time, be worse than the effect of a natural disaster.

People don't understand %NBS

Often mangled by the media, the New Building Standard seismic rating system doesn't paint a full picture. Simply defined, a %NBS score evaluates the performance of a particular building over a range of earthquakes, in terms of protecting life. It's calculated as part of a seismic assessment of a building.

%NBS does not measure compliance with the current Building Code. If a building scores 100%, it doesn't mean it fulfils all the requirements of the Building Code. It means that the building should perform in a way that meets the minimum seismic performance objectives of the Code in terms of protecting people.

A %NBS rating doesn't measure a building's ability to function after an earthquake. It says nothing about the damage that building could be expected to sustain or whether it will be able to be used again. %NBS ratings also don't factor in the expected performance of adjacent buildings, which could damage or collapse on the building concerned or block access to it.

***Engineering New Zealand* acknowledges and remembers the 185 people who died in the February 2011 Christchurch earthquake, the two people who died in the November 2016 Kaikōura earthquake, and the ongoing loss suffered by their families and loved ones.**

BUILDINGS AND INFRASTRUCTURE EXIST TO SERVE PEOPLE. ANY CONVERSATION ABOUT SEISMIC RESILIENCE MUST BE GROUNDED IN THE COMMUNITY.

Mind the regulatory gap

Our Building Act and Code focus mainly on protecting life, not on damage that affects a building's usability or accessibility following an event. Since the Building Act 2004, the regulatory system has targeted the "worst of the worst" buildings because remediating them will prevent deaths in moderate earthquakes. The major regulatory changes made in 2016 did not alter this focus. However, the work required to lift a building just above the earthquake-prone building threshold (that is, make it greater than 34% NBS) might not effectively mitigate the impact of a severe earthquake.

All new building work must comply with the Building Code. But once a building is consented and constructed, it sits in a regulatory hole. There is no regulatory requirement to address any shortcoming that potentially poses a risk to people, unless the building is defined as earthquake prone. The dangerous buildings provisions of the Building Act only require action if there is an imminent risk to life – and these provisions specifically exclude earthquakes.

The Canterbury and Kaikōura earthquakes shook many buildings harder than the moderate levels prescribed by the Building Code.

This stronger shaking showed that some features of more modern and larger buildings, such as precast flooring systems and non-structural elements, pose a risk to occupants in a way that our design codes and the regulatory environment hadn't anticipated. Buildings with these flooring systems may not be earthquake prone. However, studies[4] have suggested that in a severe earthquake, these systems are highly vulnerable. In a severe earthquake, it's possible that our larger mid-to-late 1900s buildings with these features might cause more death and injury than masonry buildings, because more people live and work in them.

The CTV building in Christchurch and Statistics House in Wellington[5] respectively caused, or had the potential to cause, multiple deaths that everyone considers unacceptable for modern buildings. In both cases, flaws or vulnerabilities had been identified before the earthquakes that damaged them, and Statistics House was in the process of being upgraded. Neither had been assessed as earthquake prone, so neither was captured by any regulatory imperatives.

To better protect people, engineers and regulators need to develop different approaches that address the vulnerabilities of classes of building, rather than focus only on %NBS as an indicator of overall performance.

Are engineers designing for the event or the recovery?

Our focus on protecting lives has created a Building Code that only requires building designers to ensure people can evacuate after a moderate earthquake. When seismic design was in its infancy, this made sense. It kept building costs affordable and made sure building inhabitants were reasonably protected.

But as seen in Christchurch, that approach has unanticipated consequences in a larger earthquake. Buildings that were expected to be repairable turned out to be impractical to repair. Large areas of the city were closed during the demolition and rebuilding that followed, as were large residential areas where inadequate consideration had been given to liquefaction impacts of earthquakes. Although insurance generally insulated us from the worst economic impacts, the long-term disruption will be felt for decades to come.

Another unanticipated impact was the elevated levels of earthquake risk following the initial event. This meant that even buildings that survived the earthquakes with minimal damage were downgraded in assessed capacity, relative to the increased risk.

If engineers approached design differently, rather than being "single-use" structures, our new buildings would have the capacity to be repaired after a major event. Our experience shows that well-configured, regular buildings can perform to a very high standard without costing the earth. Our current approach to risk and cost means that base isolation, which was developed in New Zealand and provides a high level of protection to buildings, their contents and users, is ironically rarely used in this country. The same challenge applies to land development more generally.

Seismic restraint of non-structural elements is messy

Non-structural elements like overhead ceilings can cause great harm if they come loose in an earthquake. Non-structural damage has contributed to more than 60 percent of all earthquake-related injuries in commercial buildings.[6] These elements need to be securely fixed in ways that allow the building to move.

But there's a lack of clear roles, responsibilities and processes in this space. The expectations and responsibilities of engineers involved in their design and installation can vary from project to project. Price-based procurement of services and use of fit-out subcontractors blur the line of engineering responsibility. There is inconsistency in design standards, codes don't cover everything that needs to be considered and uncertainty surrounds regulatory signoff, including the extent of input by the building consent authority. The current building consent and procurement process needs an overhaul that clarifies these uncertainties.

Timely data speeds up and improves the response

When buildings are fitted with instruments that measure their performance in an earthquake, the data from these instruments speeds up engineers' diagnoses, gives greater confidence about decisions to re-occupy, and informs the scope of repairs. But instrumentation is not a regulatory requirement and is seldom installed in new buildings.

Individual building data also serves the greater good. Early data from instrumented buildings can be aggregated and analysed by an operational network of structural and geotechnical engineers working with seismologists. This helps Emergency Operations Centres communicate what to look for in rapid building assessments, which are the quick visual assessments that engineers do immediately following an earthquake. Councils then more quickly understand which types of buildings are most affected and how to act.

The Canterbury earthquakes have shaken our insurance environment

Before 2010, our earthquake insurance model had not been stress tested. The Canterbury earthquakes continue to teach hard lessons about assessment and repair. Policy wording was imprecise: "as when new" has no accepted definition, despite seeming intuitively clear. There are no established standards of how to assess damage and, similarly, there are no standards of repair. Engineers have sometimes been caught in the middle, with different engineers acting to different briefs from homeowners and insurers.

Insurance shifts the consequences of risk – for a price. Insurers, having learned the lessons from Canterbury, are looking differently at the New Zealand market. When risks are too high, insurers may either withdraw from the market or increase the cost of insurance to unaffordable levels, particularly for the most vulnerable. We can't take it for granted that we will see the same level of insurance cover for future events. Assumptions that are made now, when insurance is widely available and reasonably priced, may not hold true in the future. This means that we should make long-term decisions on risk and building performance without the expectation of insurance cover hardwired into our thinking.

Infrastructure

Our lifelines are vulnerable

Our roads, rails, cables and pipes are vulnerable to ground movements, including faulting, liquefaction and landslides. They also depend on each other. Phone and data networks need electric power and repairs often require road access. We often call these utilities "lifelines" because they provide such essential services.

Infrastructure providers face challenges that make resilience difficult. Many of our urban areas sit on problematic geology, including coastal flats and the mouths of alluvial rivers. And our infrastructure sector comprises many independent service providers that are generally commercially independent of the communities they serve. They may be caretakers of aging infrastructure that needs replacing.

We need to be ready

People need greater awareness of the outages they are likely to face, and to have plans and physical arrangements in place to deal with these. For example, recent weather events have illustrated that residential facilities such as rest homes don't often have backup power arrangements. The New Zealand Lifelines Council has highlighted the lack of a New Zealand-wide view of nationally significant customers for utility services and their need for effective backup arrangements.

To increase the resilience of utility and transportation networks, the network needs more redundancy. This can mean the creation of alternative routes: for example, the high level of redundancy in Christchurch's road network helped reduce the impact of the February 2011 earthquake. Similarly, Orion's 20 years of investment in the electricity network's resilience, including key linkages between sectors, avoided much greater disruption (including to telecommunications networks).

This kind of resilience requires greater emphasis on the consequence of a major event occurring, rather than focusing on its likelihood. It also means presuming that adverse events like earthquakes will occur, rather than hoping they won't.

Together we're stronger

Working together is critical. For almost three decades, regional lifelines projects and groups have been actively encouraging providers to take a collective approach. This means understanding lifelines' regional vulnerabilities and working together to mitigate these risks. They have identified regionally significant critical areas; for example, locations where several services run through a vulnerable feature, like a bridge. The recent National Vulnerability Assessment report by the New Zealand Lifelines Council helpfully defines the characteristics of nationally significant infrastructure vulnerabilities to earthquakes and other hazards, and provides a platform for future resilience investment.[7]

With this information at hand, the responsibility to act and prioritise investment is unavoidable. Engineers take responsibility for providing this advice. And we challenge the various government and utility operators to do likewise, and for them to then act with prioritised investment, to ensure redundancy and resilience of these networks.

CASE STUDY **WELLINGTON LIFELINES GROUP RESILIENCE PROJECT**

Wellington is vital to New Zealand's economy and government but its infrastructure is vulnerable to large seismic events.

The Wellington Lifelines Group Resilience Project is a powerful – and currently unique – collaboration across local and central government and the private sector, taking a new, collective approach to reducing risk. It looks for the best sequencing of projects from a regional and national perspective, and commitment from the various agencies to provide funding to accelerate infrastructure mitigation investment. The project looks at the potential impact on the community and economy, how big and difficult those impacts will be, and what can proactively be done about them.

Recommendations for seismic resilience

1

Reset the levels of risk we can tolerate and regulate accordingly

In the wake of the Canterbury and Kaikōura earthquakes, we need to recalibrate how we design and construct new buildings. We also need to recalibrate how we evaluate and upgrade existing buildings.

Instead of discussing risk in absolute terms, we should consider what we can tolerate over the range of events we anticipate. This means factoring in likely damage and repair scenarios, the possibility of reduced insurance, and New Zealand's ability to absorb the cost. Then society as a whole can reconsider the risk settings reflected in the Building Code and guidelines for designing and constructing our buildings and infrastructure.

2

Plug the regulatory gap concerning existing buildings

We are limited in the action we can take to protect people living and working in existing buildings that might survive a moderate earthquake but fail in a large one, causing significant loss of life. If this building isn't defined as earthquake prone, then it sits in a regulatory gap. Together we need to develop a regulatory approach to identify, define and remediate building vulnerabilities that present unacceptable risk in severe seismic events.

3

Make infrastructure resilience a collective responsibility

Resilient infrastructure requires everyone (from service providers to regulators) to take collective responsibility for identifying existing system vulnerabilities, improving reliability and redundancy and prioritising upgrading. This requires the crossing of conventional commercial and institutional boundaries, to share information and collaborate for the greater good of all New Zealanders. Engineers must take a central role in driving this systems thinking, given our understanding of the impacts, and expertise in identifying and resolving the challenges.

New Zealanders must also be better prepared for inevitable outages. Engineers can provide information about the realistic consequences of disruption to water, transport, power and other services. But New Zealanders (in both institutions and households) need to use this information to play their parts in planning for and managing those outages.


Ko te wai te ora ngā mea katoa
Water is the life giver of all things

HOW DO WE ENSURE THAT SUFFICIENT AND SAFE WATER IS AVAILABLE TO EVERY PERSON?

WATER MANAGEMENT

New Zealanders are placing increasing demands on water and our water-related infrastructure. Our population has grown, along with water use and discharge. We face changing and heavier rainfall because of climate change. We're less tolerant of contaminant discharge into our environment, and more sensitive to its cultural impact.

The upshot is our natural water environment is deteriorating. Intensified agriculture and horticulture, forestry and urbanisation are degrading our marine, freshwater and groundwater systems. As New Zealand's climate continues to change, our population grows and our land use patterns change, the problem is exacerbated.

The Havelock North drinking-water contamination in 2016 and the Edgecumbe flood in 2017 highlighted critical weaknesses in water infrastructure[8] and the way in which we think about natural water systems. As a result, the Government is reviewing the management of drinking water, stormwater and wastewater to better support New Zealand's prosperity, health, safety and environment. Managing all water systems well is vital for human health. But much of the infrastructure inside these systems is due (or overdue) for significant renewal or replacement.[9]

In 2015, Treasury estimated the cost to renew the three-waters network over the next 15 years would range from $30 billion to $50 billion. It's a significant challenge to understand what the true costs are and when they will be incurred. The Office of the Auditor General has found local authorities often don't have reliable information about their stormwater, water supply and wastewater assets, and that they are more likely to reinvest in their roading assets than their water assets.[10] Local authorities also have varying abilities to cope with the significant bills that lie ahead.

If water services are provided at a district or city level simply because that's how it's always been done, then we should challenge this. Sharing upfront investment costs and pooling expertise means resources can go where they're most needed – and engineers can avoid designing a costly bespoke system for every area. Getting the degree of aggregation right is crucial: this is something engineers should help define.

Drinking water

Our water can make us sick

Clean drinking water is a basic human right[11] that New Zealand strives for but doesn't always deliver. Water can contain microorganisms that make people sick or die but that we can't taste or see. Sometimes people attribute their sickness to another cause, not realising it's the water they drink. According to the Havelock North Drinking Water Inquiry, up to 100,000 people are getting sick every year in New Zealand because of their drinking water. Campylobacteriosis, which can be caused by contaminated water as well as food, is the most commonly notified disease in New Zealand.[12]

We take safe, clean water for granted

Despite this, New Zealanders take clean drinking water for granted. People assume that because their water has previously seemed safe, this is a natural state that will continue. This complacency makes it hard to communicate the risks that contaminated drinking water poses. And as a result, New Zealanders often fail to place sufficient value on our tap water. With almost "free"[13] tap water (outside metered areas) being taken for granted, people don't see the need to advocate for investment in drinking water treatment to safeguard our health.

One result of New Zealanders' complacency is that treatment of drinking water is not mandatory. Decisions about whether to treat water, and how, are made on a local basis by political decision makers rather than by experts.

If water isn't treated, local authorities generally monitor water quality by testing samples. We rely on E. coli monitoring to indicate water is free from viruses, protozoa or bacteria. However, it takes 24 hours (at best) before results are known, which means people have already been drinking that water for a day. Otago Regional Council found E. coli levels 150 times higher than Ministry of Health drinking water maximums during routine checks earlier this year.[14]

Our regulation has been lax

Too often compliance with standards is unacceptably low. The array of regulators involved in drinking water also means dispersed accountability and obfuscated transparency. Even when standards are breached, action isn't always taken. No formal enforcement action has been taken by district health boards since the current drinking water regime was introduced in 2007.[15]

For those working in the field, there are no statutory requirements for licensing, certification, or competency to practise. This applies whether people are technicians, operators, supervisors or managers, or whether they work on urban or rural supplies. These practitioners play a critical public heath role. They make the day-to-day decisions that keep our water safe.

While the likelihood of contaminated water killing people may be low, the impact on public heath can be high, as the Havelock North Inquiry noted. The consequences of serious contamination of a city's water supply are unacceptably severe.

***Engineering New Zealand* acknowledges and remembers the four people who lost their lives and the 5,500 people who were made sick (some permanently) by the Havelock Water contamination incident, and the grief and suffering this incident caused their community.**

CASE STUDY
THE TIP OF THE ICEBERG?

The Havelock North Inquiry found the town's drinking water contamination in August 2016 was far from an isolated incident. It estimated New Zealand experiences as many as 100,000 cases a year of sporadic illness from drinking water contamination. It found that about 20 percent of people on town supply are drinking water that is "not demonstrably safe". In June 2018, the Ministry of Health released its own report confirming that nearly 20 percent of New Zealanders were receiving reticulated water that failed to meet drinking water standards.

But the effects of contamination are often masked. As the Inquiry discussed, people may not realise unclean drinking water caused their illness. Sporadic incidents may not be detected by authorities or come to public attention. The Inquiry revealed that monitoring and reporting has been inadequate, maintenance neglected, accountability dispersed and regulation not fully effective.

The short-term response to the Havelock North contamination has been to recommend adding residual disinfectant to all reticulated supplies.

Treatment is a start

The Havelock North Inquiry acknowledged the risk New Zealanders currently face from drinking water. It also recognised that while the system needs to be fixed, this will take time. As an urgent measure, the Inquiry urged the Director-General of Health to persuade all water suppliers to treat water without delay.

Even though using chlorine to treat water isn't harmful, communities can react negatively, as Christchurch and Hastings have recently demonstrated.[16] This misinterpretation shows a lack of understanding of the real risk to human health of not treating water, despite the lessons from Havelock North.

But just treating water with a residual disinfectant like chlorine is not enough. New Zealand needs a system with multiple barriers, to prevent waterborne illness and its cumulative impacts on human health. For example, contaminants must be prevented from entering drinking water at source. This is achievable through considered catchment planning and engineering design of water collection and treatment systems. With the risks to human health, it needs to be a priority.

Help the community to value water

Service providers and government invest in improvements when the community demands them. If people value clean, healthy water, they are more likely to protect it and be willing to pay a fair price for it. This requires engineers and regulators to engage with the community, and develop a common understanding of the risks, costs and the benefits of interventions. Increased public understanding makes a shared vision for water possible. It also means giving people accurate monitoring data and an understanding of incidents that do occur, and how they can best respond. Engineers can help inform communities about the value of water, the risks we face, and options to deal with the growing challenges.

Creating the right incentives

Engineering New Zealand recommends incentivising people to conserve water. For example, through the introduction of a fair charging system, with smart meters at point of use to encourage conservation and to prevent waste.

Charging regimes could also be extended to wastewater and possibly stormwater. Some of these systems are already in place across New Zealand – it is time to extend them. A charging system is also more likely to result in better performance from drinking water providers and greater accountability. It will enable them to borrow, based on future income, which will result in faster infrastructure development.

One caveat to a charging system is that however we price water, it must safeguard people's access to drinking water.

Flooding

More flooding, more often

The combination of increasing urbanisation, intensification of land use (for example, agriculture) and climate change (heavier rainfall and rising sea levels) has increased the likelihood of floods. And floods are already New Zealand's number one hazard in terms of frequency, loss and declared civil defence emergencies.[17]

As well as this combination of factors leading to increased frequency of flooding, many of our older flood protection structures were not designed to today's standards. In some cases, they were constructed by rural landowners without expert input or risk assessment. This means that flood defences that were adequate in the past could fail today – and will almost certainly fail in the future.

In cities, stormwater infrastructure is designed to handle the level of rainfall events that statistically occur once every 10 years. This means that in larger storms, not all the water is intended to go underground via the piped system. Some will go overland. When these larger rainfall events combine with high winds and king tides, it exacerbates flooding, particularly in coastal regions. For example, the Tasman Tempest of March 2017 showed the effect of system blockages on urban flooding, with significant flooding in New Lynn, Auckland. It also significantly affected Auckland's water supply through damage to the Ardmore Dam catchments.

Let's change how we think about flooding

We can expect local failures to continue, so there needs to be a greater emphasis on protecting affected communities. This starts with creating an awareness that failures might happen, and that our infrastructure will not provide absolute protection. We want New Zealanders to better understand the risks of flooding in their environment so they can make informed decisions about the level of protection they want for their own homes and community, and what they want to fund collectively. Flood management and response plans also needs to specifically include how to prepare for, and respond to, breaches of flood protection and overland flow.

New Zealand must move away from total reliance on structures and infrastructure for protection. This means changing planning and development policies to take a more integrated and adaptive approach to flooding. This includes managed retreat, minimising (or eliminating) development in vulnerable areas, greater use of overland flow and flood ponding and redefining land available for development. Many professions, including engineers, are battling these challenges.

We need to work together to better inform the public and present long-term, holistic approaches to decision makers.

CASE STUDY THE FORCE OF WATER HAS TO GO SOMEWHERE

Water breached the flood wall in Edgecumbe in April 2017, causing the destruction of 15 homes and extensive damage to a further 250.

This was not an isolated event. The area has a 150-year history of frequent floods and many different perspectives on how to control or mitigate water's flow. When European settlers arrived, two different philosophies clashed on the Rangitāiki Plains. Engineers drained the plains to create usable agricultural and horticultural lands; the river was channelled to the sea and hydroelectric dams were engineered. But to local Māori, the river has its own mauri, or life force, that must be allowed to express itself through its flow.

However, even though the 2017 flood was not an isolated event, many residents didn't know about the likelihood or potential consequences of floods. They were caught by surprise and weren't prepared enough. People evacuated just in time to avoid loss of life.

This situation showed how the mauri cannot be reduced. If water is contained, then that energy is stored or displaced, not removed. Engineering works can only divert, hold back or pump that much water for so long.

CASE STUDY
MONITORING THAT MAKES A DIFFERENCE

Auckland's Safeswim model went live in 2017, in response to intensive monitoring that had shown contaminants regularly exceeding safe limits.

Safeswim is a predictive model, based on actual monitoring results, that provides water-quality forecasts and up-to-date information on risks to health and safety for 84 beaches and eight freshwater locations around Auckland. Real-time information is available to anyone online.

Safeswim led to more frequent alerts, which drove media coverage and increased public awareness. The community demanded cleaner water even if this meant increasing rates to pay for it.

As a result, Auckland Council created a new vision to dramatically improve water quality at beaches and streams. A step change in investment is planned.

"Improving our water quality means proactively preventing contamination, rather than cleaning it up."

Water quality in our lakes and waterways

The quality of water in our lakes, rivers, streams, and aquifers varies massively. It's often good in areas with indigenous vegetation and less intensive use of land, but typically poor when under pressure from urban and agricultural land use.[18]

When it rains, stormwater flows from our roofs, roads and drains into our streams, rivers and beaches. It can also combine with overflows from wastewater systems. This means that faecal matter and urban contaminants including copper and zinc, flow into our lakes, waterways and aquifers, making water unsafe to swim in or kaimoana unsafe to eat. But contamination isn't restricted to wet weather. In dry weather, illegal cross connections and leaking wastewater pipes result in human faecal contaminants entering our natural water bodies.[19]

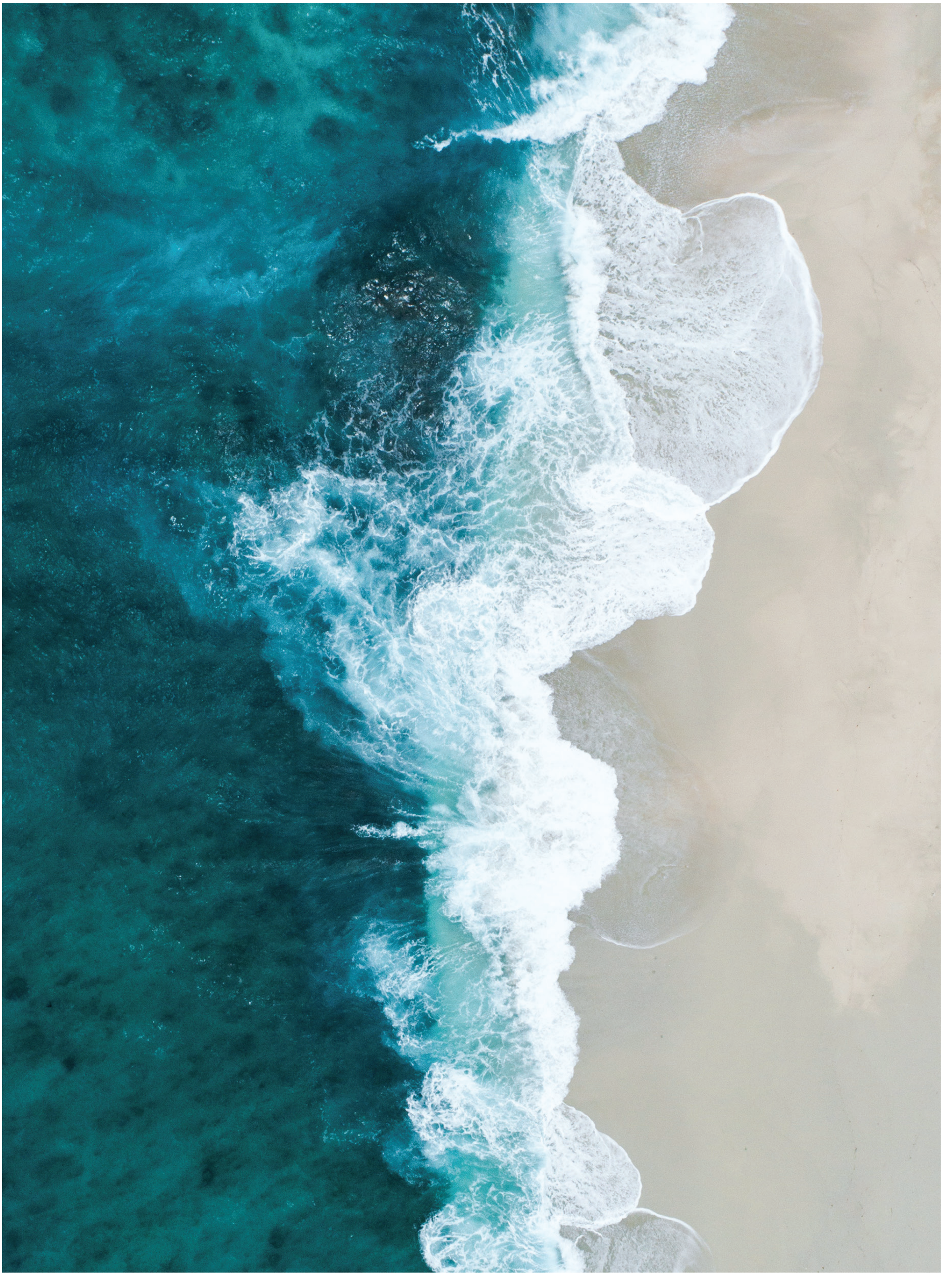
We need smarter monitoring

Sometimes the quality of this water is monitored, often in places where people swim, to protect public health. National regulation for rivers was introduced in 2017, under a Freshwater Policy Statement. This included retrospective monitoring of water quality for swimming.

But retrospective monitoring, as currently required, doesn't necessarily protect public health, especially if it's infrequent. If weekly monitoring delivers a poor result, it could mean people shouldn't have been swimming for the past seven days. Weekly monitoring is also likely to underestimate the frequency of issues, given it captures only one out of every seven days. Real-time monitoring or predictive modelling is a better option.

Prevention is better than cure

Improving our water quality means proactively preventing contamination, rather than cleaning it up. It means engineers working alongside other professions to better inform policy, including how we respond to development pressures. For example, once land is converted to intensive farming, it's an uphill battle to prevent contamination.



Recommendations for water management

1

Fix our broken drinking-water system

Following lessons from the Havelock North Inquiry, a revitalised vision for drinking-water infrastructure is emerging. It points to the need for a coherent regulatory system, which engineers strongly endorse, and which the Government is progressing.

We believe the system the Government puts forward should enable affordable water of a consistent minimum standard for all New Zealanders, wherever they live. This requires clear accountability for setting, monitoring and enforcing globally benchmarked minimum standards. It also requires services delivered by competent and regulated water practitioners, and improved effectiveness and efficiency of delivery. A new regulatory system needs to be supported by funding the delivery of the upgrading of existing infrastructure and new infrastructure.

2

Enable the community to value water (in all its forms)

The community must help create a vision for safe water, and understand its role in protecting it. Properly informed, the community will value water, push for investment in its protection and its infrastructure, and take action to conserve it.

To enable this, the community needs government and engineers to provide clear and accessible information – about risks, costs, the benefits of intervention, and incidents that occur, as well as accurate monitoring data. The Government also needs to develop schemes that incentivise communities to conserve water, and fair pricing that reflects the value of clean, healthy water yet safeguards everyone's access to it.

3

Make hard choices now about unsustainable locations

Adapting to the risk presented by climate change means making some hard choices. It means local government stopping new development in locations with existing and increasing risk, and making tough calls about existing developments that are becoming untenable.

4

Commit to real-time monitoring and reporting of water quality

We need water regulators, infrastructure owners and managers to pursue best practice for drinking water, the water we swim in and flood risk. There should be a commitment to real-time monitoring, so that individuals and communities can make informed choices. This means taking collective responsibility in a way that exceeds current regulatory obligations. It should be supplemented by predictive modelling.

Taking this approach would improve water-related infrastructure management, and management of our natural water bodies and systems. It would provide quality information to our communities to enable them to prepare, respond and be more resilient. If we get this right, then we will be able to effectively address national water quality standards as they are implemented.

LOOKING FORWARD

The engineering profession's unique perspective on New Zealand's challenges and opportunities comes from being immersed in identifying and solving them.

This publication has focused on what engineers believe needs to happen for New Zealand to become a more resilient country, particularly in the areas of seismic risk and water management. We know many New Zealanders are thinking about these topical issues, and we believe the profession's voice is central to this debate.

Engineering a Better New Zealand calls us all to action – engineers, communities and regulators – to better understand risk, to be better informed, to be more proactive, and to prepare and plan for the individual, community and national consequences of disruption. It stresses that the time to act is now, if we want to remain productive, stay healthy and ensure our cities and rural areas are places where New Zealanders can thrive.

This publication also calls on the engineering profession – to raise its voice, take responsibility for driving change, and understand the importance of its role in facing into and sorting out what's ahead.

But this is just the start of the conversation. We want this document to generate discussion and, even more importantly, action in the areas we have discussed and made recommendations on. Engineering New Zealand is committed to working hard to make sure this happens.

This is the first in a series of thought leadership papers. Alongside the work you see here, we have been working on clean energy. This is another topical area and a critical part of New Zealand's focus on mitigating and adapting to climate change. The areas we have been focusing on include the value of a smart, resilient energy grid and the need for a holistic transport strategy. Both areas will enable us to maximise the convergence of new technology, engineering adaptation and our dreams for the future.

And beyond that, we will continue to engage on issues and opportunities that affect us all. Our mission at Engineering New Zealand is to engineer better lives for New Zealanders. We take that responsibility seriously.

References

1 Ministry for the Environment, *Environment Aotearoa 2015*

2 mfe.govt.nz/climate-change/likely-impacts-of-climate-change/overview-of-likely-climate-change-impacts

3 Canterbury Earthquakes Royal Commission Final Report, Vol 6, Section 9

4 Various research reports from University of Canterbury, 2000 and onwards; and University of Auckland, 2014 and onwards

5 MBIE, *Investigation into the performance of Statistics House in the 14 November 2016 Kaikōura Earthquake*, March 2017

6 Beca report to MBIE, *Estimating the Risk to Life Safety during Earthquakes from Non-structural Elements in Commercial Buildings in New Zealand*, October 2016

7 New Zealand Lifelines Council, New Zealand Lifelines Infrastructure. Vulnerability Assessment: Stage 1, September 2017

8 *Report of the Havelock North Drinking Water Inquiry: Stage 1*, May 2017; *Report of the Havelock North Drinking Water Inquiry: Stage 2*, December 2017; *Rangitāiki River Scheme Review – April 2017 Flood Event Final Report,* 18 September 2017

9 According to the Department of Internal Affairs, combined local government assets have a $51.4 billion replacement value, with $12.8 billion planned expenditure from 2016–2025

10 Controller and Auditor General, *Water and roads: Funding and management challenges*, November 2014

11 On 28 July 2010, through Resolution 64/292, the United Nations General Assembly explicitly recognised the human right to water and sanitation and acknowledged that clean drinking water and sanitation are essential to the realisation of all human rights

12 7,456 cases were notified in 2016, compared with 6,218 cases in 2015, according to ESR's 2016 Notifiable diseases commentary

13 Tap water is paid for via general household rates or water metering charges

14 Otago Regional Council, Media release: E-Coli found in Lower Waitaki Plains Aquifer bores, 15 June 2018

15 Department of Internal Affairs presentation, 2018

16 Stuff, *Christchurch mayor wants chlorination levels reduced after public outcry over taste, smell,* 22 May 2018; *Christchurch water's chlorine levels to be reduced*, Stuff, 28 May 2018; *Chlorine protest at Hastings council drinking-water pop-up*, Hawkes Bay Today, 13 March 2018

17 getthru.govt.nz/disasters/flood

18 Rivers in these areas have reduced water clarity and aquatic insect life, and higher levels of nutrients and Escherichia coli (E.coli) bacteria, according to Ministry for the Environment's *Environment Aotearoa 15*

19 Ministry for the Environment & Stats NZ, *New Zealand's Environmental Reporting Series: Our fresh water 2017*

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