

Sponge Cities

Can they help us survive
more intense rainfall?

A REPORT BY **KALI MERCIER**

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About Mahi Rongo / The Helen Clark Foundation



MAHI A RONGO | THE HELEN CLARK FOUNDATION IS AN INDEPENDENT PUBLIC POLICY THINK TANK BASED IN AUCKLAND, AT THE AUCKLAND UNIVERSITY OF TECHNOLOGY. IT IS FUNDED BY MEMBERS AND DONATIONS. WE ADVOCATE FOR IDEAS AND ENCOURAGE DEBATE; WE DO NOT CAMPAIGN FOR POLITICAL PARTIES OR CANDIDATES. LAUNCHED IN MARCH 2019, THE FOUNDATION ISSUES RESEARCH AND DISCUSSION PAPERS ON A BROAD RANGE OF ECONOMIC, SOCIAL, AND ENVIRONMENTAL ISSUES.

OUR PHILOSOPHY

New problems confront our society and our environment, both in Aotearoa New Zealand and internationally. Unacceptable levels of inequality persist. Women's interests remain underrepresented. Through new technology we are more connected than ever, yet loneliness is increasing, and civic engagement is declining. Environmental neglect continues despite greater awareness. We aim to address these issues in a manner consistent with the values of former New Zealand Prime Minister Helen Clark ONZ, who serves as our patron.

OUR PURPOSE

The Foundation publishes research that aims to contribute to a more just, sustainable, and peaceful society. Our goal is to gather, interpret, and communicate evidence in order to both diagnose the problems we face and propose new solutions to tackle them. We welcome your support. Please see our website www.helenclark.foundation for more information about getting involved.

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Our experts in Aotearoa New Zealand include advisory, planning, architecture, design, engineering, science, and environmental specialists. Leveraging our Future Ready® planning and design methodology, WSP use an evidence-based approach to help clients see the future more clearly so we can take meaningful action and design for it today. With 67,000 talented people globally, including 2,200 in Aotearoa New Zealand located across 36 regional offices, we are uniquely positioned to deliver future-ready solutions, wherever our clients need us. See our website at wsp.com/nz.

He Mihi / Acknowledgements



Kali Mercier
Report author

With flooding in early 2023 leading to tragic loss of life and widespread damage to property, New Zealanders have been profoundly confronted by the realisation that climate change is happening, and our cities and towns need to find ways to adapt.

'Sponge Cities' offer a way to increase resilience to intensifying rainfall. But they also offer us a model for cities that are more beautiful, less polluted, and more hospitable, both to humans and wildlife. The vision that emerged for Aotearoa in writing this report is not one of doom and gloom, but one of green and blue cities and towns that can both survive, and thrive.

To all those who helped shaped my thinking and helped with this report in other ways, ngā mihi nui ki a koutou. I'd like to start by thanking the Helen Clark Foundation staff and board, particularly our Executive Director Murray Bruges and our patron, Rt Hon Helen Clark, for their excellent feedback and support.

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Kali Mercier

WSP Fellow, and Deputy Director of the Helen Clark Foundation

7 August 2023

Glossary

TECHNICAL TERMS AND ACRONYMS

Blue-green infrastructure (BGI)

The use of blue elements such as rivers, ponds and wetlands, and green elements such as parkland and urban forests, for stormwater management.

Brownfield development

Development on land that has already been developed and has existing infrastructure.

Extreme rainfall event

Unusually intense rainfall compared to average rainfall events for a given area or time period.

Flood plain

Areas predicted to be covered by water during heavy rain. Flood plains appear in low-lying areas and next to streams and rivers.

Green infrastructure (GI)

A natural area, feature or process that helps manage floodwater, such as trees, rain gardens, permeable pathways, and planted stream banks.

Greenfield development

Development on land that has not been previously developed, often on the periphery of existing urban areas.

Grey infrastructure

Traditional stormwater infrastructure, generally made of concrete, such as pipes, drains and gutters.

Infill

The construction of buildings on previously unused land within an existing urban area - such as in residential backyards.

LGA

Local Government Act 2002.

Nature-based solutions (NBS)

These aim to address societal challenges such as climate change, threats to human health and food and water security, by protecting, sustainably managing, and restoring natural ecosystems.

Overland flow path

The route water will naturally take across the ground during heavy rain when the stormwater network is at capacity.

Runoff

Stormwater that drains from the surface of an area of land, or off a building.

Sustainable Urban Drainage Systems (SUDs)

An approach to stormwater management that uses ponds, planters, tanks and other green infrastructure to manage surface water sustainably.

Water sensitive urban design (WSUD)

A design approach that considers stormwater management alongside the ecology of a site. WSUD works with nature, minimises the use of impervious surfaces and uses vegetation to trap sediment and pollutants.

WSE

Water services entities. These new entities will run drinking water, wastewater and stormwater services under the Affordable Water Reform programme.

TE REO MĀORI WORDS AND TERMS

Hapū

Clans or descent groups that sit within iwi, or tribes, in Māori society.

Iwi

The tribes that form the structure of Māori society.

Mana

Prestige, status, authority, spiritual power, charisma.

Mātauranga Māori

The body of knowledge and wisdom originating from Māori ancestors, including the Māori world view and perspectives, Māori creativity and cultural practices.

Mauri

The essence or life force that provides life to all living things and gives water and land the potential to support life.

Papatūānuku

In Māori tradition, Papatūānuku is Mother Earth, who gave birth to all things.

Ranginui

In Māori tradition, Ranginui is the Sky Father / the heavens.

Te Mana o te Wai

The central concept for freshwater management in Aotearoa New Zealand. It translates as mana - or prestige and power - of water.

Wai

Water. Wai has its own (mauri) life force and spirit, and is linked to identity and whakapapa.

Wairua

Spiritual existence or soul.

Whakapapa

Genealogy, ancestry. Whakapapa links people to all other living things, and to the natural and spiritual world, past, present, and future.

Executive Summary

OUR CITIES FACE INCREASING RAINFALL-RELATED RISKS INTO THE FUTURE AS A RESULT OF GLOBAL WARMING, BOTH FROM FLOODING AND FROM DROUGHT. AOTEAROA NEW ZEALAND IS ALREADY EXPERIENCING THE IMPACTS OF A CHANGING CLIMATE, WITH THE FIRST HALF OF 2023 DELIVERING SEVERAL DEVASTATING RAINFALL EVENTS ACROSS MANY PARTS OF THE COUNTRY.



Even if global carbon emissions drop significantly in the coming years, the science indicates we will experience more frequent and more intense rain events for the foreseeable future. This report explores how our urban areas can adapt to the impact of these inevitable changes.

Aotearoa New Zealand's current approach to urban design and flood management is falling short. Our so-called 'grey infrastructure' (pipes and drains) is ageing and in many cases not coping with current requirements, much less up to the task ahead. Meanwhile our urban areas have become less green in recent years, and therefore less able to absorb the large amounts of rain with which they have to deal, now and in the future.

Could 'sponge cities' offer a solution? That approach aims to

protect, enhance and sustainably manage water resources in urban environments by slowing the passage of stormwater. It involves cities working with water rather than against it. This can include building or restoring urban wetlands, 'daylighting' streams and creating space for urban waterways to flood safely – including by moving people and houses out of the way, for example. It also includes relatively new but effective ideas such as pocket parks and tiny urban forests.

Some potential solutions lie in the public domain, and some in the private. Using all the different types of spaces in our urban areas, including parks and school grounds, roads, industrial areas, homes and businesses, helps to spread the water load and the cost, and ensures a better outcome overall.

Adapting Aotearoa New Zealand's cities and towns to a sponge cities model will be expensive. However, there is strong evidence that sponge city approaches provide a compelling cost-benefit ratio, both when compared with conventional stormwater management approaches, and especially when compared with taking no action to prepare for climate change.



For a sponge city approach to be implemented successfully in Aotearoa New Zealand, it will need to reflect the unique national and local context. It would need to be supported in our planning frameworks, and draw on existing knowledge from mātauranga and tikanga Māori in this space.

Incorporating a mātauranga Māori approach, a sponge cities model would be assessed not just by its ability to mitigate flood risk, but also by how well it is able to accelerate ecological restoration in our cities to flourishing levels, rather than to a minimum baseline.

It will also be important to adopt a holistic approach. Aotearoa New Zealand is dealing with a biodiversity crisis alongside the increasing impacts of a climate crisis. Thus, the model we adopt should enhance rather than reduce biodiversity in our cities, adopting a 'nature-based solutions' framework. Nature-based solutions aim to address societal challenges such as climate change, threats to human health and food and water security. They also aim to reduce disaster risk, simultaneously providing both human well-being and biodiversity benefits. A sponge city approach therefore should work for the human beings who live in those cities and towns, providing beautiful spaces for rest, recreation, and contemplation.



While sponge cities undoubtedly represent a powerful tool for cities and towns to reduce the damage caused by excess rainfall, it must be recognised that no approach to dealing with that in urban areas can completely eliminate hazards or remove all risks. Sponge city approaches should be seen as reducing the impacts of increasing rainfall in cities, complementing existing grey infrastructure – and not as a silver bullet to all flood risks.

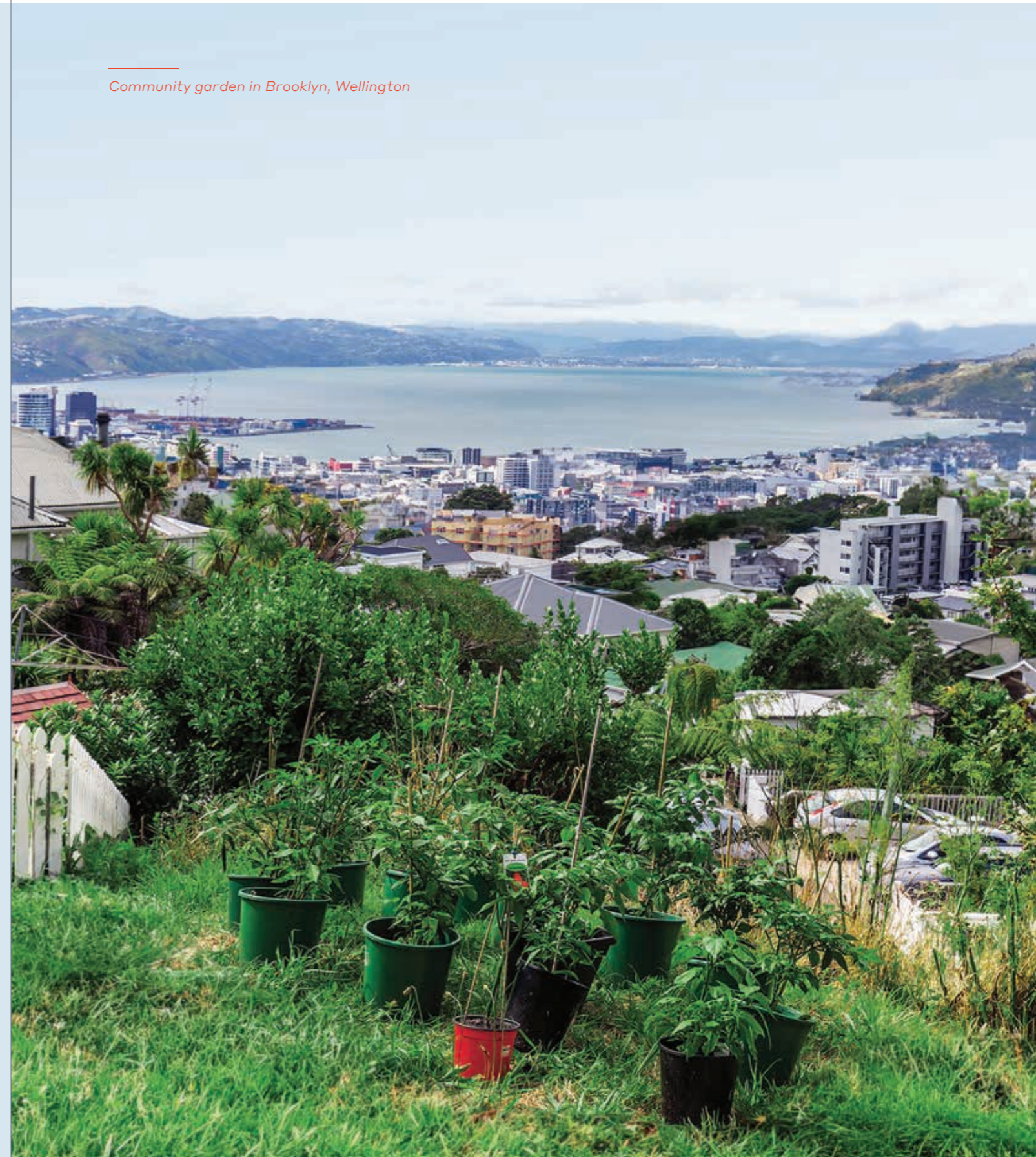
The sponge city approach presents a compelling, and likely essential, pathway if urban areas are to prepare for a much wetter future, a future in which we can be certain that our grey stormwater infrastructure alone will prove to be inadequate again and again. While elements of the approach will be expensive and

will present complex planning and implementation challenges, investment in sponge city solutions will be less costly to society overall than continual flooding of urban and town infrastructure.

Importantly, the evidence also suggests that even inexpensive sponge city actions would be effective in reducing the impacts of intense rainfall in urban areas if undertaken in the most appropriate locations as part of a strategic long-term vision. As the first half of 2023 has demonstrated, doing nothing will not be free – intense rainfall is already causing major damage in our urban areas and the cost of implementing a sponge city approach will be a fraction of the cost of not preparing. Aotearoa New Zealand must act quickly and decisively.



Community garden in Brooklyn, Wellington



Summary of recommendations



KEY RECOMMENDATIONS:

1. **Retrofit cities and towns to become sponge cities** to help us survive and thrive despite increasing rainfall. Take a holistic, nature-based approach to ensure we also capture benefits for biodiversity and human health and wellbeing.
2. **Act urgently and decisively, and plan strategically** for the long-term at the national, regional, and local levels. Name and prioritise nature-based sponge city approaches as a key climate adaptation approach for Aotearoa New Zealand.
3. **Develop a clear vision for a sponge cities model for Aotearoa New Zealand** that draws on our strengths and unique context, such as mātauranga Māori, and community-led nature-based initiatives.
4. **Have high aspirations.** Aim to revive the mauri (life force) of water by improving its quality, achieve rauora (natural abundance) in the environment, and make beautiful spaces in which to live - rather than simply 'managing stormwater'.

A sponge city model for Aotearoa New Zealand should:

1. At the city and catchment level:

- **Require councils to plan for and provide public green spaces** as they do with other infrastructure, and amend the Local Government Act accordingly.
- **Require councils to set out nature-based sponge city approaches in their long-term plans**, including making space for water along flood plains and flow paths and increasing the provision and connectivity of urban blue and green spaces, both to increase city absorbency and enhance biodiversity.

2. At the neighbourhood and development level:

- **Retrofit existing neighbourhoods, roads and private land to become more absorbent.** Use urban and suburban road corridors and other public places to provide space for green infrastructure; require new buildings in the inner city to include green roofs or equivalent infrastructure; and unseal hard surfaces such as pavements and carparks.
- **Encourage 'upwards' development** in preference to 'outwards' sprawl and 'infilling' back yards, to leave more green space available to absorb water. Develop clear guidance on how to address conflict between housing needs, and the need to provide green spaces.

- ◆ **Raise the national minimum standards for proportion of the total area of new developments that must be left unsealed,** and require more parkland to be zoned as part of new developments. Require new developments to follow sponge city approaches, such as minimising disturbances to topsoil and clustering buildings to retain more green space.

3. **At the local level:**

- ◆ **Incentivise and educate homeowners to make land around private residences more absorbent,** for example by providing free advice such as home audits. Consider rates rebates (including 'treebates') or discounts on materials.

Encourage homeowners to:

- Minimise the use of sealed surfaces.
- Make sure flow paths are not blocked.
- Replace lawns with plants and trees, install rainwater tanks and small-scale rain gardens to collect water and remove pollutants, and recycle rainwater.

4. **Embrace incremental approaches as part of a long-term vision.** Even small investments can have a big impact when strategically implemented.



Recommendations to support implementation include the following:

1. **Be guided by mātauranga Māori** (Māori knowledge) in setting policy and community decision-making around flood adaptation.
2. **Partner with tangata whenua in decision-making around sponge city approaches** at the national, local, and community levels.
3. **Develop and agree a national funding approach** that is coordinated and comprehensive.
4. **Identify cities and towns at the greatest risk,** and prioritise support accordingly.
5. **Rise above policy and operational silos** by providing clear national leadership on sponge city implementation,

supported by a cross-agency work programme and catchment scale working groups at the local level.

6. **Establish a sponge cities and nature-based solutions stormwater expert advisory group** at national level to advise on policy approaches and best practice.
7. **Encourage community involvement** to achieve more equitable outcomes.
8. **Develop an information portal as a one-stop shop for decision-makers.**
9. **Invest in research and development on sponge city solutions** to help communities choose the most appropriate solutions.





CHAPTER 1.

Cities in Aotearoa New Zealand face increasing flood risks

New Zealanders are used to natural hazards, so it is not surprising that the country has been rated the second riskiest in the world for expected annual losses from natural disasters, as a proportion of GDP.¹ Flooding is the most common natural hazard in Aotearoa New Zealand. On average, the country experiences a major flood event every eight months.² Floods cost more than \$160 million dollars in direct economic damages each year, and cause ongoing economic, social, cultural, and environmental impacts.³ Luckily, floods are also one of the most avoidable hazards – they can be planned for and mitigated.⁴

CLIMATE CHANGE BRINGS EXTREMES OF RAINFALL AND DROUGHT

The impacts of climate change are becoming increasingly obvious, even to non-scientists, both globally and in Aotearoa New Zealand. The evidence is now unequivocal that human activities have caused global warming, mostly through emissions of greenhouse gases.⁵ Depending on how successfully emissions can be reduced globally, a person who

is in their early twenties today might experience warming in their lifetime of as much as 2.7°C (under an intermediate scenario), or even 4.4°C (under a high emissions scenario).⁶

As average temperatures rise, more water evaporates, which in turn increases overall precipitation. Globally, the International Panel on Climate Change (IPCC) already reports widespread and substantial impacts from climate change, in terms of both inland and coastal flooding to cities. They attribute these events to global warming “with a high degree of confidence”.⁷

In the short term, every region in the world is projected to face further increases in climate hazards, including an increase in the frequency and intensity of heavy precipitation. In more bad news, as the temperature warms further, the ‘risk drivers’ of climate change (such as changing ocean flows, and ice caps melting) are expected to become increasingly complex and more difficult to manage.^{8,9}

The impacts can already be seen in Aotearoa New Zealand

Aotearoa New Zealand now regularly breaks daily, monthly, and yearly temperature records, and temperature extremes are becoming more common.^{10,11} Most sites around the country have similarly recorded a change in the number and intensity of extreme rainfall events since 1960, whether becoming more, or less, frequent.¹²

Overall increases in annual rainfall in an area will cause stress on existing stormwater infrastructure, but even in those areas where rainfall is going down on average, an increase in extreme rainfall events may pose a risk of flooding.¹³

In the past three years alone, significant, and in some places repeated, flooding has taken place in many cities and towns around the country, with huge sums in damages claimed against insurance.

Marlborough flooding in July 2021



Significant flood events include:

- upper North Island in July 2020 (\$44 million)
- Napier and Greater Wellington in November 2020 (more than \$90 million in combined claims)
- Ashburton and Timaru in May 2021 (\$46 million)
- the West Coast, Tasman, Marlborough and Wellington in July 2021. The West Coast was particularly affected (\$97 million)
- West Auckland in August 2021 (\$62 million)
- Gisborne in November 2021 (over \$3 million) and then again (along with Auckland), in March 2022 (nearly \$120 million)
- widespread flooding at the top of the South Island, on the West Coast, and in Northland, Taranaki and Wellington in August 2022 (nearly \$68 million).¹⁴

The Insurance Council of New Zealand has identified a clear pattern of rising climate-related claims. Insurers reported total claim costs of \$351.26 million in 2022 for damages caused by extreme weather events country-wide – a new record at that time, and the third consecutive year in which a new record was set.¹⁵

In January this year, catastrophic flooding occurred in Auckland, Northland and Waikato after a 1-in-200-year rainfall event.¹⁶ This was followed closely afterwards by Cyclone Gabrielle in mid-

February, which struck the North Island and resulted in tragic loss of life, along with significant flooding and property damage.

During the cyclone, Hawke's Bay and Tairāwhiti recorded particularly high rainfall, with whole towns under water, including some that remained uncontactable and without basic services for days afterwards. One weather station in Gisborne recorded more than half a metre of rain – 621mm – over two days.¹⁷

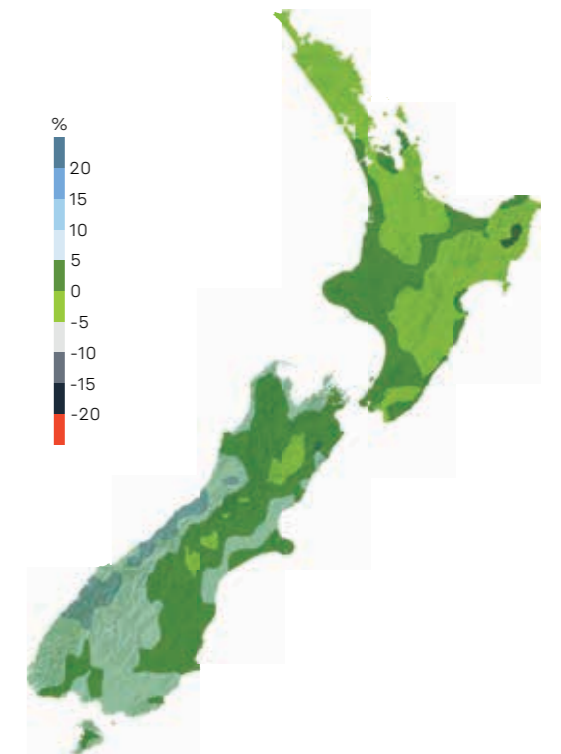
These two events dramatically overtook previous records for insurance claims from flooding, with combined damages estimated at \$2.47 billion.¹⁸ Since then, the North Island has been pummeled by further flooding caused by extreme rainfall, including in Auckland (with lesser impacts in Northland, Waikato and Bay of Plenty) in May, and Tairāwhiti in June.

Extreme rainfall events will continue to intensify

Unfortunately, as global temperatures continue to rise, Aotearoa New Zealand can expect rainfall intensity to keep increasing. Shorter duration rainfall events will increase the most, and rainfall events will become more concentrated, or 'spikier', within smaller areas.¹⁹ What was once a rare, extreme event for us is likely to become common for our children and grandchildren.²⁰

Figure 1.1 shows NIWA's predictions for changes in annual mean rainfall levels. Under a moderate–high temperature increase scenario, Aotearoa New Zealand can expect to see an average increase of mean rainfall of up to fifteen per cent in some areas by 2055, and a reduction of up to five per cent in other areas. Annual rainfall is a different measure to extreme rainfall events, which are harder to model. Even the places that will see less rainfall overall are likely to experience more cases of extreme precipitation.

Figure 1.1. Source: NIWA. Annual Mean Rainfall Change Between 1995 and 2055.⁵⁹



In addition to increases in rainfall, we simultaneously face slow-onset changes, such as rising sea levels and coastal inundation. The National Adaptation Plan refers to this as a “complex adaptation challenge”.²¹ Adaptation for sea level rise is out of scope for this report - although some of the adaptation responses suggested here to deal with pluvial flooding may be similar.

Flooding causes huge impacts, and these will grow

About 675,000 (one in seven) people across Aotearoa New Zealand already live in flood-prone areas, and this number will increase as rainfall increases, storms become more frequent and sea levels rise.²² Recent analysis by NIWA and the University of Auckland found that 441,384 residential buildings are at risk of flooding, most in urban areas, with an estimated value of \$218 billion.²³

Flooding of homes and cultural significant places.



Increasing rainfall is likely to cause more floods, slips, landslides, pollution of stream water, and impacts on biodiversity, infrastructure, buildings, and homes, as well as culturally significant places such as urupā (burial grounds).²⁴ Heavy rain and floods also affect wastewater services, road networks, and power and water supplies. These effects impact the safety of individuals as well as their quality of life and mental and physical health.²⁵

Māori face particular challenges

Indigenous peoples worldwide are more likely to be negatively affected than other groups by the impacts of climate change,²⁶ and Māori face many challenges ahead. For example, of nearly 800 marae situated across Aotearoa New Zealand, eighty per cent are built on low-lying coastal land or flood-prone rivers.²⁷

Māori land, including burial sites and traditional food sources are at risk from a changing climate, imposing increasing social, economic, health, cultural and spiritual pressures.²⁸

United Nations agreements such as the Sendai Framework for Disaster Risk Reduction²⁹ acknowledge that progress in addressing disaster risk reduction priorities is hindered by insufficient attention to Indigenous Peoples and emphasise the importance of strengthening Indigenous governance, workforce capacity, and capabilities as a climate change adaptation response.³⁰



As the climate continues to change, seasonal tohu become less reliable, places of special significance are affected, taonga species face increased risk of extinction, te mātauranga me ngā tikanga (knowledge and customs) are lost, and risks to the unique Māori values at the heart of our society grow. Ministry for the Environment.⁶¹

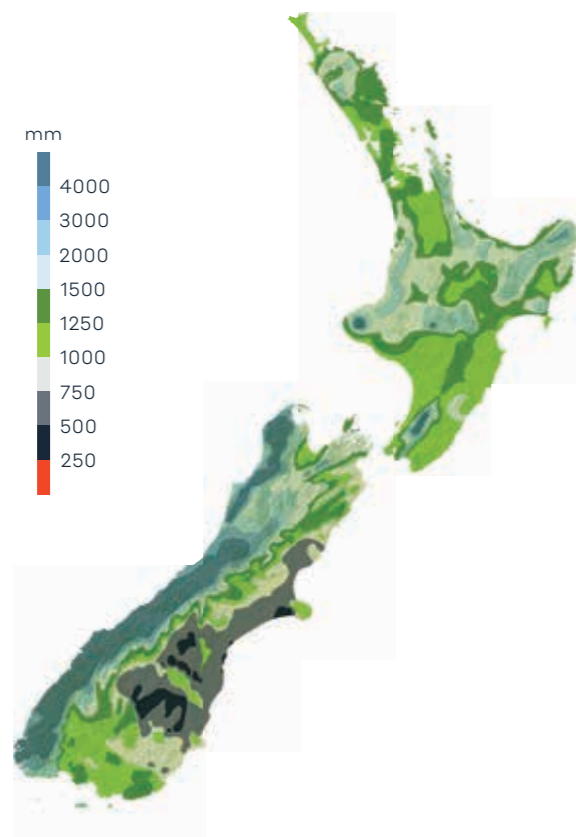


Aotearoa New Zealand is not yet tracking risk comprehensively or consistently

NIWA carries out regional-level modelling for annual average rainfall, and number of wet days,³¹ and can run reports for individual weather station sites predicting high-intensity rainfall levels under different climate change scenarios.³²

Modelling of current and future flood hazards has been done by regional and unitary councils in some of Aotearoa New Zealand's bigger cities. Auckland's GIS1 can show flood hazards and risks down to the level of flow paths through neighbourhoods, for example. This

Figure 1.2. Source: NIWA. Median Annual Rainfall NZ, 1981 - 2010 ⁵⁹



level of modelling, however, is not yet standard.

The lack of consistent regional plans, and the absence of a national database that can measure relative risks in different urban areas makes it very difficult to prioritise accurately which areas are most in need of attention, nationwide.

An MBIE Endeavour project is aiming to remedy that by producing an updateable and nationally-consistent flood hazard and risk assessment database. It will cover both current conditions and future scenarios under climate change³³ and will be able to compare risks across different urban locations. While the tool will help to identify the neighbourhoods most at risk, so councils will know where to best focus their efforts, it won't give information down to the granular level that cities may need, nor take into account existing stormwater networks and other relevant information. The database is still some way from being completed, and will need ongoing funding to be a viable tool for the future.

THE COUNTRY'S CURRENT APPROACH TO URBAN DESIGN AND FLOOD MANAGEMENT WILL NOT CARRY US THROUGH

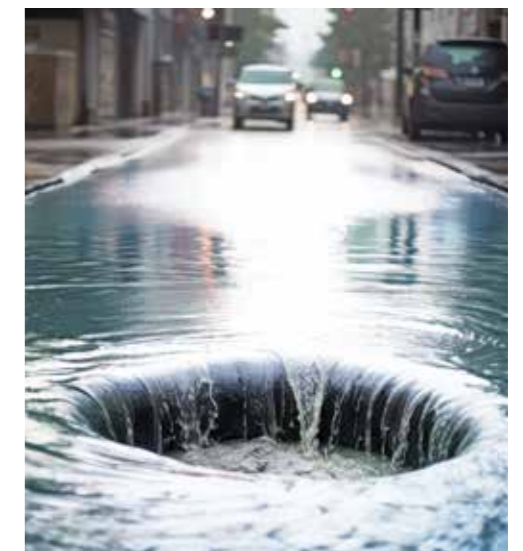
The conventional approach has been to rely on 'grey infrastructure' to take stormwater away

The conventional approach to flood water management in western societies originated more than 2,000 years ago in ancient Greece, and is more about defending people from nature than working with it. The approach stems from a perception that water in an urban environment is a hazard that needs to be moved as quickly as possible away from the hard surface on which it lands, into our drains, and then away out of sight.³⁴

Typical approaches to stormwater management include above- and below-ground drainage and

diversion systems such as pipes and culverts, and physical barriers such as stop banks and dams. These approaches are called 'grey' solutions because they typically require large amounts of concrete.³⁵

Conventional grey, engineered, infrastructure often routes runoff to the sewerage system, which may overflow during extreme rainfall events, or sends it directly to streams or into the ocean, where it can pollute and degrade the ecosystem.



This approach is no longer fit for purpose

The pipes and other infrastructure in which cities place such faith are ageing, and increasingly creaking under the strain even at current rainfall levels. Aotearoa New Zealand's \$20 billion water network infrastructure – including 17,000km of storm systems – was not designed for the huge volumes of rainfall which they will have to manage with rising seas and increasing extreme rainfall events.³⁶

Bringing all the country's water networks (including stormwater) up to scratch is expected to cost as much as \$120–\$185 billion over the next 30 years.³⁷ Meanwhile, councils only spend around \$1.5 billion on water pipes each year – a significant shortfall on what is likely to be required.³⁸

Houses and other developments continue to be built on flood plains and across flow paths, raising risks further. Where urban areas were once seen as a place of safety, with technical solutions as the answer to all society's problems, White refers to cities now as "the hub of modern risks"³⁹.



"The perception that risk can be effectively managed and that engineering can remove environmental constraints is now being questioned in the face of a rising incidence of 'natural' disasters." Iain White, author of *The Absorbent City*.³⁹

Traditional city design favours covering natural surfaces with concrete and asphalt

Meanwhile, the traditional approach to city-building leads most available ground to be covered over with roads, buildings, pavements, and other infrastructure. Part of that development often includes draining and removing lakes, and diverting or covering over streams – many cities in Aotearoa New Zealand have dozens of streams buried beneath them.⁴⁰

When buildings and roads replace natural ground cover, the flow of water is severely modified. Water cannot be absorbed into soil, and instead runoff flows on the surface. This increases the chance of erosion and flooding of urban streams, causing damage to natural habitats, properties, and infrastructure and increasing the chance of overflows of untreated sewage in some cities.⁴¹

The more impervious the surfaces in a city, the greater the volume of water that needs to be artificially managed, the faster it flows, and the more often it becomes a problem for residents. Calculations made by the Parliamentary Commissioner for the Environment using online stormwater tools suggest that should urban green coverage in a typical Aotearoa New Zealand city block drop from 45 per cent to 35 per cent of the total area, this would increase rainfall runoff

volume approximately eighteen per cent from a single rainfall event.⁴²

Where impervious surfaces increase, and rainfall is removed via drains and pipes, it no longer replenishes water tables and groundwater. Streams and rivers may run more slowly or dry up entirely, with impacts on biodiversity and complex ecosystems.⁴³ Pollution, particularly caused by runoff from roads and from roofs, is also a major problem exacerbated by traditional stormwater management systems.⁴⁴

Cities in Aotearoa New Zealand are becoming less green

While the country's main cities are endowed with good green space overall, it is concerning that the amount of urban greenspace is declining, both in total area and in area per capita. Between 1980 and 2016, for example, green space per person fell thirty per cent in

Auckland, and at least twenty per cent in Hamilton.⁴⁵

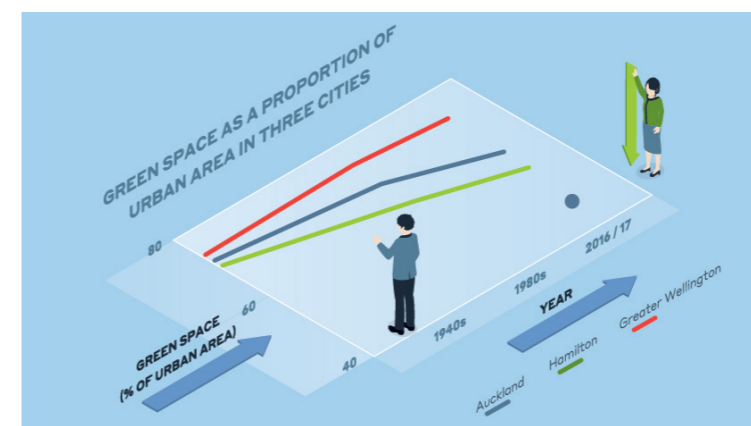
There is significant variation between cities. In 2021, 45 per cent of Hamilton's urban area was green (including private lawns). The equivalent figure in Wellington was 64 per cent. The imagery available for Auckland is older – in 2011, 55% of Auckland's urban area was green space, but that area has reduced since, under the pressure of intensification.⁴⁶

These pressures have led to an increase in the proportion of the total urban surface area that is feeding directly into stormwater networks, rather than being absorbed by the land onto which it falls.

Analysis by the Parliamentary Commissioner for the Environment, drawing on work by Cameron Moore found that decline in green spaces in major cities in Aotearoa New Zealand can be attributed mostly to changes on private land, and is driven by two trends.

First, as land values increase, there is a huge incentive to build houses in backyards and other undeveloped green space within cities ('infill development'). Second, where development trends used to favour small houses on big sections, new greenfield developments now favour much larger houses on smaller sections. As just one example, average new houses in Papatoetoe in the 1970s covered less than one quarter of the land they sat on. In 2016 in Flat Bush, the size of land parcels

Figure 2. Source: Martin et al⁶³, Parliamentary Commissioner for the Environment⁶⁴



had reduced by nearly half, and dwellings covered half of the much smaller space. Sealed driveways and paths now cover much of the remaining space (Figure 3).

On average, green space accounts

Figure 3. Adapted from Cameron Moore^{65,66}

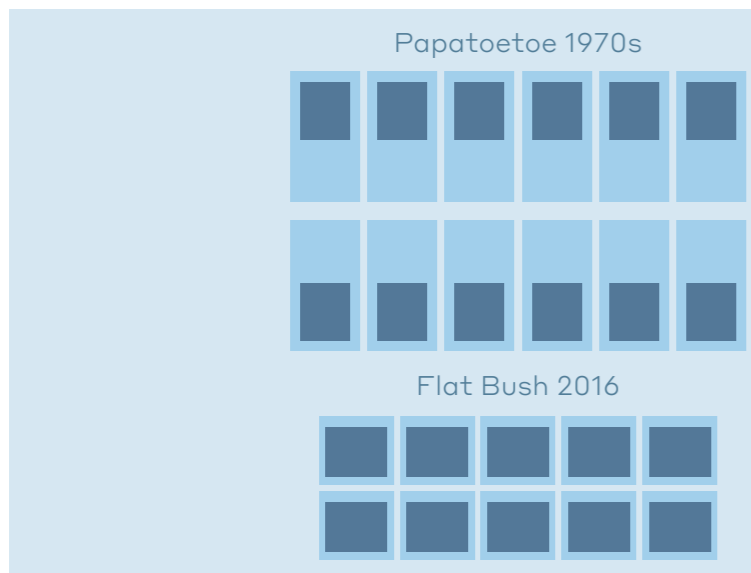


Figure 4. The picture on the left shows a suburb in Mt Roskill, built after World War II. The picture on the right is a suburb in Flat Bush, built in 2010.⁶⁷



for roughly fifty to sixty per cent of the existing area of private land in Auckland, Hamilton and Greater Wellington. This contrasts with the green space provided in the most recent developments - which on average amounts to only around twenty to thirty per cent of each section. Most councils do not appear to be trying to set aside larger areas of public green space to compensate for these losses in green spaces.⁴⁷

Cities are also losing trees

The type of green space in a city is also very relevant. Lawns create far more runoff than trees or shrubs, and can act very similarly to impervious surfaces when dry and compacted.⁴⁸

It is therefore concerning that cities in Aotearoa New Zealand are losing trees. Increasing development, combined with a permissive current legislative environment has led to a massive reduction in the number of urban trees over the past decade or more.⁴⁹ According to Global Forest Watch, Auckland has lost as much as nineteen per cent of its tree cover in the past twenty years, Dunedin a staggering 24 per cent, Greater Wellington around eleven per cent and Christchurch thirteen per cent.⁵⁰

The ecosystem services provided by trees are essential in cities. An international study of 10 'megacities' calculated that trees provide each city with more than \$500 million each year in services, including reducing

stormwater runoff, and make urban environments cleaner, more affordable and more pleasant places to live.⁵¹ The quantity of trees and other green spaces in cities has even been linked to how fast or slowly people age.⁵²

Trees also absorb carbon dioxide, helping to mitigate the impacts of climate change. They provide cooling shade in warming cities, and can remove pollutants and filter particulate matter from the air.⁵⁴ Existing Auckland woodlands have been estimated to remove 1,320 tonnes of particulate matter annually.⁵⁵

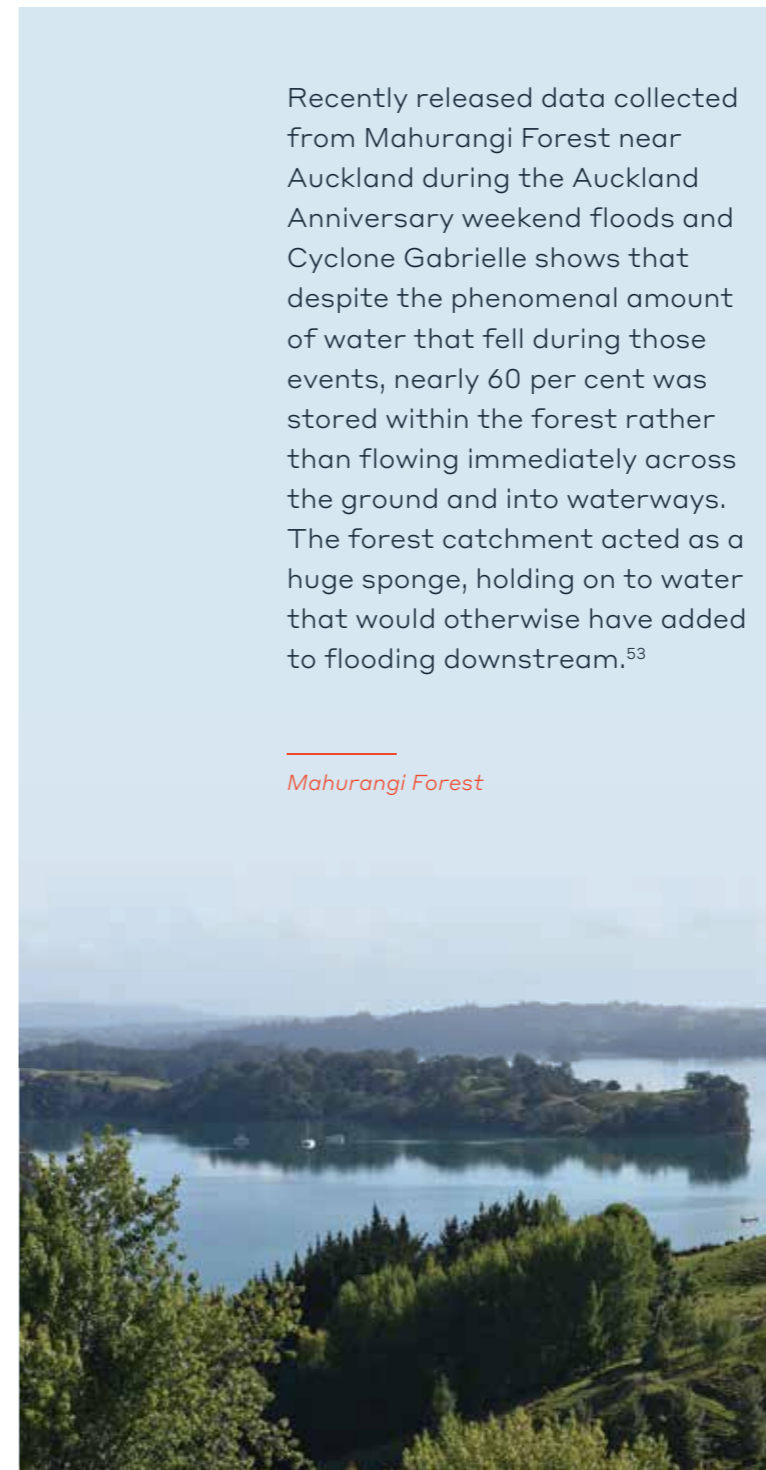
Aotearoa New Zealand cities need to house more people

Sitting behind these existing difficulties is the compounding challenge of the continuing growth of the population. The median projection from Statistics New Zealand is that the population will increase by about 1.5 million between 2022 and 2073 to 6.6 million people⁵⁶. Nearly three quarters of this growth is expected to be in cities. By 2048, it is projected that there will be almost one million more people living in cities in Aotearoa New Zealand than there were in 2018.⁵⁷

This there is a risk under current settings of covering more and more of remaining green spaces with built infrastructure. Aotearoa New Zealand needs a new approach, and urgently. Could sponge cities offer that solution?

Recently released data collected from Mahurangi Forest near Auckland during the Auckland Anniversary weekend floods and Cyclone Gabrielle shows that despite the phenomenal amount of water that fell during those events, nearly 60 per cent was stored within the forest rather than flowing immediately across the ground and into waterways. The forest catchment acted as a huge sponge, holding on to water that would otherwise have added to flooding downstream.⁵³

Mahurangi Forest



What are sponge cities?

THE TERM 'SPONGE CITY' WAS COINED BY A LANDSCAPE ARCHITECT, DR KONGJIAN YU IN 2003. HE HAD OBSERVED THAT FLOODING WAS BECOMING INCREASINGLY PREVALENT ACROSS CHINESE CITIES UNDER CLIMATE CHANGE, AND SET OUT TO DEVELOP NEW APPROACHES. YU WAS INSPIRED BY CHINESE FARMERS OF 2,000 YEARS AGO, WHO SET ASIDE TWENTY PER CENT OF THEIR CULTIVATED LAND FOR PONDS, TO REGULATE WATER THROUGH THE RAINY AND DRY SEASONS.^{68,69}

Yu observed that natural and constructed wetlands alongside rivers function like giant sponges, retaining water during flooding and recharging water tables during times of drought. His proposal therefore was to turn whole Chinese cities into giant, absorbent sponges using a network of 'blue' and 'green' nature-based infrastructure comprised of natural green areas, rivers, lakes, and wetlands.⁷⁰



China launched a massive-scale Sponge Cities Programme 10 years later, investing billions of dollars towards sixteen pilot projects.⁷¹ The programme has been described as a “fundamental, transformative change of China’s water management from the traditional sector based, engineering oriented paradigm to a nature-based, holistic approach.”⁷²

SPONGE CITIES INCLUDES A RANGE OF RESPONSES, TAILORED TO THE LOCATION

The sponge city approach promotes a range of green and blue measures, such as:

- creating or improving parks and greenspaces to make them more absorbent, improve water retaining capacity and biodiversity
- increasing wetland areas, daylighting streams, and dredging urban rivers and lakes
- protecting and restoring overland flow paths
- improving the connectivity of the urban water system and urban green spaces, to allow unimpeded water flows and create corridors for wildlife
- introducing green infrastructure such as rain gardens, green roofs and rainwater harvesting systems



- using porous materials to construct permeable roads, carparks, and pavements.⁷³

The sponge city approach is not only about cities becoming more absorbent, but also includes an acceptance that many cities and towns will be more 'watery' in the future. This may mean moving houses and businesses from harm's way, making space for water alongside rivers and flow paths, and no longer building on flood plains, for example.

The vision in China is that green and blue infrastructure should replace traditional grey infrastructure where possible. So for example, naturalised waterways would replace concrete dams and dikes, bioswales would replace stormwater pipes, and constructed wetlands would replace sewage treatment plants (these can be constructed to use natural and biological processes to provide the same kind of services). Separating stormwater and

sewage pipeline networks is a key feature of the approach.

In practice, it is unlikely that many cities would want to get rid of grey infrastructure entirely. This would involve huge cost, and is unlikely to be practical in most built-up urban areas. Instead grey systems would be upgraded to work seamlessly with the new nature-based infrastructure, and green infrastructure would be seen as a complement to existing stormwater networks.⁷⁴

The sponge city is conceived as both a large-scale intervention that happens at the city or catchment level – including urban river restoration and building of wetlands, for example. But it also relies on small-scale infrastructure such as bioretention devices, rain gardens and local tree planting that can be implemented in a small-scale way at the community level, and in private homes and gardens.⁷⁵

THE SPONGE CITY APPROACH BRINGS A RANGE OF BENEFITS



"We need a paradigm shift in planning and designing our cities to adapt to the changing climate. We need to rethink single-minded, industrial technology-based engineering solutions and turn to nature-based and symbiotic solutions. Ultimately, we need to rediscover the ancient art of survival that has been evolving for as long as humans have been on the earth." Dr Kongjian Yu, initiator of the sponge cities concept in China.⁶⁸

Sponge cities are intended not only to help with flood mitigation, but also to enhance cities and ecosystems in additional ways. That is a huge part of their value proposition.

Sponge cities help to restore and promote biodiversity by cleaning contaminated water and providing nourishing habitats.⁷⁶ If implemented well, they should be able to provide improvements to the integrity of, and mauri ('life force'), of the whole environment, with additional benefits for cultural well-being and connections to nature and whakapapa. Ecological connections are built and maintained using blue belts and green belts throughout the city.⁷⁷

Sponge cities are designed to be resilient to climate change and natural disaster. They aim not only to slow down rainwater runoff, but also to retain and reuse water, meaning they can mitigate the impacts of droughts as well as floods.⁷⁸

In addition, sponge cities approaches can help to mitigate the impacts of climate change. Whereas conventional approaches to urban development can be carbon-intensive and polluting, sponge city approaches rely on green infrastructure such as trees. The overall impact should be a net positive for the environment.⁷⁹

Finally, sponge city approaches make cities more pleasant places in which to live. They can reduce inner city temperatures and noise pollution, and create beautiful spaces that contribute to well-being, and improvements in physical and mental health.⁸⁰

THE TECHNIQUES THEMSELVES ARE NOT NEW

While the name 'sponge cities' is new and has caught the public imagination, a gradual evolution in thought in stormwater management has taken place in many countries, under different names. The 'new' part of sponge cities as a concept is really the comprehensive ambition of the projects that have begun in China, the planning and funding that has gone into getting those off the ground, and the sheer scale of the projects that have been undertaken there.

Other concepts that inform or are similar to sponge city approaches include:

- ◆ Indigenous approaches worldwide, including mātauranga Māori in Aotearoa New Zealand
- ◆ Water Sensitive (Urban) Design (WSUD) (Australia and Aotearoa New Zealand)
- ◆ Sustainable Urban Drainage Systems (SUDS) (United Kingdom)
- ◆ Blue Green Infrastructure (BGI) (UK, Europe and the United States)
- ◆ Low Impact Development (LID) (United States).
- ◆ Nature-Based Solutions (NBS) (international).^{81,82}

Benjakitti Forest Park, Bangkok



These approaches all aim to reduce runoff and improve water quality using low-impact technologies, and various types of blue and green infrastructure. Some approaches (WSUD and SUDS, for example) place a greater emphasis on the water cycle. Others place a greater emphasis on reducing runoff (GI and LID for example). They also differ in the specific approaches they use, their scalability, and the emphasis they put on the integration of other benefits, such as increasing biodiversity.⁸³

Indigenous approaches, along with nature-based solutions are worth highlighting as the most holistic of the approaches listed above. They are not just focused on water, but also provide a philosophical framework for the wellbeing of the environment as a whole. The mātauranga Māori approach

(discussed below) respects the life-force or 'mauri' of water, for example, and promotes the overall health of the natural world, of which humans are seen as just one part.

MĀTAURANGA MĀORI VALUES NATURE IN A HOLISTIC WAY

While the term 'sponge cities' is imported, an Aotearoa New Zealand-specific approach would draw on mātauranga Māori (knowledge and wisdom), which values nature as something to be respected and honoured. Māori have a long history of facing natural hazards using mātauranga Māori.⁸⁴

The health of the natural world, and the connections that exist between all living things are of critical importance to Māori, who see humans as part of the natural world, and in service to it, rather than dominant over it. For Māori, all aspects of nature are intertwined and connected through whakapapa - the Māori relationship to the land is one of kinship⁸⁵.

The Māori way of viewing nature is therefore more holistic than traditional western approaches, and includes both the physical and the metaphysical. It translates as finding a way to work with the environment, rather than needing to change the world to fit around people.

Wai is an integral part of Māori wellbeing and identity.⁸⁶ Legend

tells of water originating as the tears of grief of Ranginui and Papatūānuku when they were forcefully separated from one another, with their tears creating the waterways and oceans of te whai ao (the world as we know it today).⁸⁷

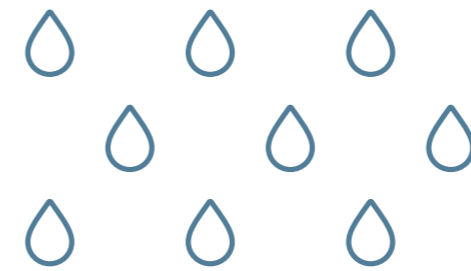
Central to the approach is the concept of 'mauri', the essence or life force that provides life to all living things and gives water and land the potential to support life. Mauri can also be translated as the "gift of life and wellness".⁸⁸ It is inherently related with other metaphysical characteristics, including tapu (sacredness), mana (authority), and wairua (spiritual existence or soul). All water bodies have their own mauri, which gives them distinct personality and mana. The Māori approach therefore is to respect water and its life energy as tapu - sacred, spiritual, and cleansing.⁸⁹

Wai can be described in many different states, including:

- ◆ waiora (water in its most 'pure' form)
- ◆ waimāori (water for consumption)
- ◆ waimate (water that has lost its mauri and is no longer able to sustain life)
- ◆ waikino (water that is dangerous, such as rapids)
- ◆ waitai (seawater, the surf or the tide).^{90,91}

Stormwater starts as rainfall (waiora) but is transformed into waikino once it flows over impervious surfaces, or makes contact with pesticides, fertilisers, and other pollutants. This contamination diminishes water's mauri. Discharging stormwater (waikino) into clear water (freshwater or seawater) is an example of unnatural mixing of mauri, and to be avoided.⁹²

Figure 5. Adapted from Water NZ, Ngā Momo Wai⁹⁵ - Types of water



Te Puhinui Stream, Auckland

Te Puhinui Stream Regeneration Project

Stormwater approaches that value mātauranga Māori look very similar to nature-based sponge city approaches. For example, cleansing polluted water by passing it through a planted 'soil' filter can help transform waikino back to waimāori before it enters a stream. Tikanga approaches also incorporate other values and benefits in terms of community and social development.⁹³

Te Whakaoranga o te Puhinui is a regeneration programme in south Auckland which is focused on the ancestral stream of Te Puhinui. The programme aims to regenerate Te Puhinui "in a way that is "inclusive, place-sourced, culturally led and community-fed so that Te Puhinui and its people can thrive once more".⁹⁴

The programme is a collaborative partnership between Te Waiohū iwi, the Auckland Council, crown agencies, community organisations, and members of the community, with Waiohū iwi taking a lead in delivery.

Over the next five years, thirty million dollars of investment is planned across the catchment, to pay for new wetlands, cycleways, stream restoration and significant native planting. The project also includes a range of initiatives such as education, food sovereignty, work development, and pollution prevention.

NATURE-BASED SOLUTIONS ADDRESS SOCIETAL CHALLENGES

Nature-based solutions are increasingly recognised as an approach internationally, and in Aotearoa New Zealand are often expressed as sitting within a mātauranga Māori framework. Nature-based solutions protect, sustainably manage, or restore natural ecosystems. They aim to address societal challenges such as climate change, threats to

human health and food and water security. They also aim to reduce disaster risk, simultaneously providing both human well-being and biodiversity benefits.⁹⁵

Indigenous approaches and nature-based solutions are much wider than stormwater management, but can inform the way sponge cities are framed. Approaches such as water sensitive urban design (WSUD), are tools or techniques that can be used as part of sponge city approaches (see Figure 6).

Figure 6. How sponge cities fit with existing design.



Reginald Proffit

HARNESSING MĀTAURANGA MĀORI

Integrating Mātauranga Māori (traditional Māori knowledge) with contemporary flood management strategies presents an opportunity to better prepare for climate-fuelled extreme weather events. WSP Director Pou Arataki Māori Reg Proffit explains.

Waipuke (floods) can be devastating natural disasters, inflicting significant damage on communities, infrastructure, and the environment. With the increasing frequency and intensity of wild weather events due to climate change, exploring innovative and complementary approaches to flood mitigation is crucial.

WORKING IN HARMONY WITH NATURE

Mātauranga Māori lets communities tap into Indigenous wisdom, observations, and sustainable practices developed and refined by Māori over centuries.

Central to Mātauranga Māori is an emphasis on working harmoniously with nature instead of trying to dominate or control it. Traditional practices, rooted in an understanding of natural landforms and waterways, can inform flood mitigation strategies.

Panoramic view of Waiaatarua Reserve wetland area, Remuera - Auckland





Māori knowledge recognises the natural flow patterns of rivers and respects ecosystems' ability to absorb water, giving valuable insights into sustainable approaches for managing floodwaters. Examples include re-establishing wetlands and protecting riparian vegetation, which enhance water retention and minimise the impacts of flooding.

There's plenty of examples of Mātauranga Māori in this context. A project is underway in Gisborne to enhance urban stream networks that drain into the Tūranganui estuary.⁹⁶ It's using Mātauranga Māori and modern science to help restore the health of the culturally significant estuary system. By the end of the project in June 2026, around 170,000 native plants will have been used in wetland and riparian planting.

The reimagining of Southland's Mataura River system combines modern catchment science with Mātauranga Māori to foster cultural, environmental, and economic resilience within the catchment.⁹⁷ And in rain-lashed Northland, Māori Councillors at Northland Regional Council are making sure Mātauranga Māori and te taiao (nature) are considered in decisions around flood relief efforts.⁹⁸



RESPECTING WHAKAPAPA

At the heart of Mātauranga Māori is the concept of whakapapa, which recognises the interconnectedness of all living beings and elements of the natural world. This perspective acknowledges the interrelationship between land, water, and people, enabling a comprehensive understanding of the complex systems at play in flood mitigation efforts.



COMMUNITY COLLABORATION AND DECISION-MAKING

Whanaungatanga, the principle of kinship and collective responsibility, is another crucial aspect of Mātauranga Māori. In the context of flood mitigation, this principle emphasises involving local communities and stakeholders in decision-making processes.

Inclusive participation is encouraged by Mātauranga Māori, ensuring diverse voices are heard, and traditional knowledge is integrated into flood management strategies.

In Northland, a major project focussed on restoring and protecting rare wetlands in the Wairua River system / Te awa o Wairua has brought together the people of the awa through hui wānanga (meetings) to discuss a new pathway of ecological



management based on Mātauranga Māori.⁹⁹

When developing community resilience programs, targeted engagement with Māori communities in high-risk flood areas becomes essential. Incorporating Māori perspectives, which prioritise long-term sustainability and the well-being of future generations, enables the achievement of more holistic and culturally appropriate solutions.

KNOWLEDGE SHARING, ADAPTATION, AND COLLABORATIVE SYNERGY

Mātauranga Māori isn't just a static body of knowledge; it's a living and evolving approach that adjusts to changing circumstances. As flood risks continue to rise, embracing this approach becomes a promising pathway towards effective and sustainable flood mitigation.

To advance the development and use of Mātauranga Māori, Massey University hosts the Te Toi Whakaruruhau o Aotearoa New Zealand research hub.¹⁰⁰ The hub aims to generate and apply Mātauranga Māori in shaping new knowledge for risk reduction. Through a Māori viewpoint, it highlights the interconnectedness of all aspects of natural hazard risks and catastrophic events.

By fostering collaboration between Māori knowledge holders and scientific experts, a powerful and constructive interaction emerges. This collaboration enables the integration of traditional wisdom with contemporary flood mitigation technologies and strategies. The combination of indigenous knowledge and scientific expertise paves the way for resilient and sustainable solutions that benefit both Māori communities and wider society.

This collaborative effort enhances our ability to mitigate and adapt to floods. It provides an opportunity to develop solutions that are resilient and culturally appropriate. By using Mātauranga Māori, we can create solutions that will benefit all Aotearoa New Zealand's present and future generations.



THERE IS GOOD EVIDENCE FOR THE USE OF SPONGE CITY APPROACHES

While large-scale sponge city approaches are relatively new to modern planning, they are already showing significant promise in flood mitigation and other benefits.¹⁰¹

Examples from China include:

- in Jinan, the number of city areas at high risk of flooding decreased by approximately 45 per cent for one-in-fifty-year rainfall events after undergoing a 'sponge cities' transformation¹⁰²
- in Wuhan, 389 sponge city projects across 38.5 square kilometres have reduced flooding, sequestered 725 tons of CO₂ a year, and reduced temperatures by more than 3°C in the city¹⁰³
- In Shaoxing, the city installed 45,000m² of permeable pavements, as well as sunken greenbelts, landscaped water bodies and rainwater reuse systems. After project completion, 87 per cent of rainfall across the city (by volume) was being captured, rather than directed to stormwater networks - nearly double what was captured previously using traditional methods (45 per cent).¹⁰⁴

Analysis by Fu et al.¹⁰⁵ found that sponge cities in China have been effective in reducing or mitigating

high probability floods but are less able to deal with very low-probability, high-damage events (such as one-in-100-year events). In short, they have been able to significantly reduce, rather than eliminate, risks from increasing flooding – at least in their current form.

In other parts of the world, the IPCC evaluated ecosystem-based adaptation approaches such as urban greening and restoration of wetlands and upstream forest ecosystems and found them to be effective in reducing flood risks and urban heat, with a high degree of confidence.¹⁰⁶ The IPCC also points to benefits in terms of carbon uptake, reduced energy use, and reduced risks from extreme events such as heatwaves and droughts, while generating co-benefits for health, well-being and livelihoods.

A literature review by Junqueira et al.¹⁰⁷ found that the use of green infrastructure can reduce total flood volumes on average by a huge 30–75 per cent. A study by design firm Arup found nature-based infrastructure to be fifty percent more affordable than human-made alternatives, and 28 percent more effective.¹⁰⁸



Green infrastructure provides 30 - 75% reduction in flood volumes.

SOME EXAMPLES OF SPONGE CITY APPROACHES

Naturalisation, rehabilitation, and daylighting of streams and rivers

Sponge city approaches, in common with mātauranga Māori and nature-based solutions, promote the rehabilitation and restoration of rivers and streams. This may include 'daylighting' streams that had been covered over, re-profiling channels, dredging sediment, changing the natural forms of rivers, and extending pluvial floodplains.¹⁰⁹ Sponge city approaches also entail the establishment and restoration of planted buffer zones alongside rivers, to decrease the speed of runoff into rivers and stop pollutants entering freshwater systems.¹¹⁰

Stream daylighting is the practice of uncovering streams that had previously been buried and concreted over, culverted, or diverted into pipes. Urbanisation and stream modification have had significant impacts on stream ecological health¹¹¹. In Wellington alone, estimates suggest there may be as many as 700km of culverted streams within city limits, compared to as little as 60km of open streams.¹¹²

Stream daylighting is intended to help with flood management by reducing flow velocities and increasing capacity, and it can also enhance local ecology.¹¹³ It can be comparable in cost, or less costly, than continuing to maintain and replace existing piped infrastructure. The practice can provide significant economic returns and social benefits¹¹⁴.



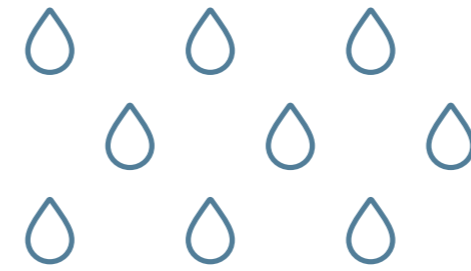
Travis Wetlands, Christchurch



Creation of wetlands and ponds

Wetlands and ponds provide some of the best absorptive capacity of any blue-green infrastructure solution. They also provide huge ecological benefits, including temperature regulation and biodiversity enhancements.¹¹⁵ Christchurch City Council's construction of wetlands and other green infrastructure in the southwest suburbs has not only helped mitigate flooding, but also has created places for walking, cycling, and other public recreation.¹¹⁶

Timaru Wetland



Hainan Island

Hainan Island was picked as one of the Chinese Sponge City project's leading demonstration sites because of its frequent flooding, pollution and habitat loss¹¹⁷. The project began in 2015 in the cities of Haikou (2.3 million population) and Sanya (640,000 population). Areas at risk of flooding were integrated with wetlands, ponds, rice paddies, parks and coastal habitats to form a 'holistic sponge system' to retain, clean and recycle water. Buildings were removed from the flood plain and concrete flood walls were replaced with embankments made from earth and vegetation.¹¹⁸



Figure 7. Meisha River corridor, Haikou City, 2016. Elevated pedestrian paths are integrated with the mangroves.¹⁴⁶



Figure 8. Meisha River Corridor, Haikou City, 2016. Terraced wetlands are densely covered with various plants that remove nutrients from primary treated wastewater.¹⁴⁷

Making space for water: flood plains and flow paths

Flood plains are areas of low-lying land next to rivers which are particularly susceptible to flooding. Unfortunately, in Aotearoa New Zealand cities housing is often built on them, using hard infrastructure such as flood banks and stormwater drainage to minimise, but not eliminate, the risks.

The sponge city approach is to restore natural flood plains to create extra storage for flood waters. This can mean not building on flood plains, or in some cases abandoning areas currently used for buildings. Corridors alongside rivers can function as environmental corridors, or 'blue belts'.¹¹⁹

Sponge cities also promote the restoration of overland flow paths within cities. A flow path describes the pathway water takes to get to the nearest stream when drainage systems are overloaded. When blocked – by fences, landscaping, or fallen trees for example, they can cause flooding.¹²⁰

Hamilton aerial view over Lake Rotorua.



Designing public spaces to flood

In extreme rainfall events, it will not always be possible to prevent flooding entirely. Therefore, it is preferable to design public spaces to store or absorb as much water as possible, rather than have water flowing into houses, businesses, and essential infrastructure.

In Aotearoa New Zealand, a playing field in Greenslade Reserve in Northcote was designed to flood and then quickly drain. During the Auckland Anniversary Weekend floods it handled an estimated twelve million litres of water within fifteen hours, slowing down water that would otherwise have rushed through the town centre and houses¹²¹.

Greenslade Reserve Northcote, Auckland



Enhancing the quantity and quality of public and private green spaces

A large component of the sponge city approach is to increase and enhance the green spaces in a city, on both public and private land. Green spaces act like giant sponges, slowing the flow of rainwater, trapping and filtering pollutants, and delivering the refreshed water slowly to underground water tables.



When rain falls on green spaces, up to one third is caught by vegetation and later evaporates.

Of the rainwater that hits the ground, some percolates into the soil and is taken up by plant roots, or stored in the earth. Some percolates deeper, recharging groundwater systems and replenishing streams and rivers.¹²²

In heavy rainfall, a densely planted green area may well have some runoff, but this will be significantly less than from an area covered in impervious

surfaces such as buildings and asphalt. The more impervious surfaces, the more runoff created, the faster it will flow, and the more chance the existing hard stormwater infrastructure will be overwhelmed in a heavy rainfall. The United States Environmental Protection Agency estimates a typical city block generates more than five times more runoff than a woodland area of the same size¹²³.

Green spaces also regulate temperatures and provide other services

Green spaces cool surrounding areas, mitigating one of the more dangerous effects of global warming by preventing the formation of so-called 'urban heat islands'.¹²⁴ Blue spaces such as ponds also have a cooling effect.¹²⁵

Other 'biophysical services' provided by parks and other green spaces include carbon sequestration, erosion control, food provision, air and water filtration and habitat for biodiversity.¹²⁶



All blue and green space is not equal

Analysis from the Parliamentary Commissioner demonstrates the differing benefits of different kinds of blue and green spaces (Figure 9). The most beneficial for stormwater control and water filtration are wetlands. Along with tree cover, wetlands also offer the best impacts for biodiversity. Lawns offer some benefit for cooling, stormwater control and water filtration - but only at a low level compared to other forms of green space.¹²⁷

Research examining the health and public health benefits of access to nature is extensive.¹²⁸ Lower exposure to green space has been associated with a number of lifestyle diseases such as obesity, Type II diabetes and stress-related illnesses such as depression, heart diseases and mental fatigue. Studies indicate that exposure to biodiverse environments can promote mental health and alleviate stress.¹²⁹

Figure 9: The relative benefits of four broad types of green space. Adapted from Parliamentary Commissioner for the Environment.¹⁴⁸



ASSOCIATED BENEFITS	TYPES OF URBAN GREEN SPACES			
	Lawn	Low shrubs	Wetlands	Trees
Air-filtering	Very little	Some	Some	A lot
Biodiversity	Very little	Some	A lot	A lot
Shading	Very little	Some	Some	A lot
Cooling	Some	Some	Some	A lot
Stormwater control	Some	Some	A lot	Some
Water filtering	Some	Some	A lot	Some

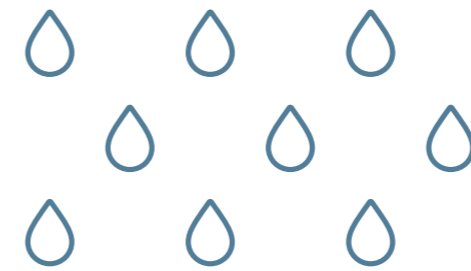


Figure 10. Singapore has maximised urban green space along the river banks to help soak up rain.



Figure 11. Singapore is known internationally for its integration of nature into the urban environment.

Singapore

With a tropical rainforest climate, Singapore has an average monthly rainfall of over 176mm¹³⁰ – significantly more than Auckland's 93mm monthly average.

After major floods in 2010 and 2011, Singapore refocused on urban flood resilience. Wetlands were reinvigorated. River channels that were previously concreted-over were naturalised, and in some cases deepened and widened, with native trees planted alongside to absorb and filter water. More and more green and blue spaces have been added over time, including on rooftops.¹³¹

Efforts in Singapore have seen flood-prone areas reduced from 3200 hectares in the 1970s to less than 30 hectares today. Flash floods are still common, especially during monsoons, but typically subside within an hour.¹³²

Smaller scale approaches that make cities more absorbent

Sponge city approaches include efforts at different scales. Green infrastructure devices on a smaller (neighbourhood, street or private property) scale, such as the ones outlined below, can be rolled out widely as finances in a city allow, and retrofitted into cities and towns.

Many of these devices have been used in Aotearoa New Zealand for at least fifteen years, although implementation of water-sensitive urban design and blue-green approaches is not yet mainstream in the country. Tools such as porous pavement, green roofs, and vertical green walls are not yet used widely. Bioretention devices such as rain gardens are used increasingly, but do not yet play a central role in spatial planning for urban stormwater management across the country.¹³³



Bioretention devices, including rain gardens and swales

Bioretention is the process by which contaminants and sedimentation are removed from stormwater runoff. Bioretention systems filter storm water through plants and soils. They either slow the water down, or completely stop it entering the stormwater system. This filtering and slowing of stormwater runoff helps reduce the polluting impacts of road runoff, protects waterways and reduces peak flows.¹³⁴

Bioretention devices include:

1. tree pits - runoff from carparks or roads filters through tree roots and the surrounding soil
2. swales – convey water away from a road or parking area using vegetated channels rather than pipes
3. bioretention basins or rain gardens – shallow basins or gardens used to slow and treat on-site stormwater runoff.¹³⁵

These are a relatively new technology for the country, but are now starting to be used widely. Bioretention devices generally look like normal gardens, but contain features directing water towards them (by being built below the pavement level, for example). They include a 'ponding area' where water can stand when needed (often gravel), and overflow systems in case they fill up with water.

Studies have shown reductions in peak flow from areas planted with bioretention devices ranging from 46–100 per cent and up to 56 per cent for infiltration trenches. The deeper the device, the more water it can store.¹³⁶

Green roofs and vertical green spaces

Rooftops can make up forty to fifty per cent of impermeable surfaces in urban areas. Thus, green roofs have the potential to play a major role in stormwater management.¹³⁷ They can help significantly reduce the runoff from a storm event, as well as lower city temperatures, support biodiversity, enhance air quality, and reduce pollution (such as heavy metals) that would normally flow from rooftops. They also provide insulation for buildings, reducing the need to heat and cool them.¹³⁸



A study modelling the effect of greening roofs in downtown Nanjing City concluded that overall surface runoff for the areas studied would be reduced by up to twenty per cent if green roofs were built on usable rooftops.¹³⁹

Plants can also be grown vertically up the sides of buildings and up fences, walls and trellises, allowing for high density and high diversity vegetation on existing structures. These vertical green spaces take up minimal space but bring many of the benefits of urban green spaces in terms of cooling, noise reduction, air purification, and biodiversity enhancement.

Figure 12. Milan's Bosco Verticale - a pair of residential towers that is home to over 21,000 trees, shrubs and perennial plants, and which converts an average of 44,000 pounds of carbon each year.



Permeable roads, pavements, car parks driveways and paths

Permeable pavement is a porous urban surface that can be composed of pavers, permeable concrete, or permeable asphalt, laid over an underlying porous medium that functions as a reservoir or filtration system. Rather than sending rainwater straight to drains as impervious surfaces do, permeable pavement catches the water in its 'pores', slowly allowing it to infiltrate into the soil below or discharge via a drain.¹⁴⁰

A literature review of more than 500 studies found positive results from its use across the board, though results varied widely. One study found it reduced total runoff volume by up to 97 per cent. It is more effective with shorter rainfall events than heavy storms.¹⁴¹

Because paved areas cover so much of a typical city's surface, replacing these surfaces with

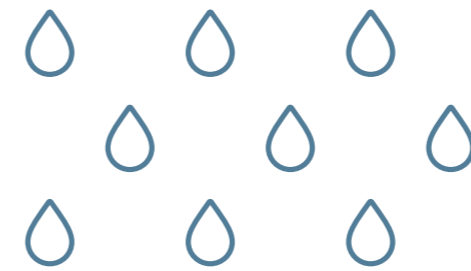
permeable pavement has great potential as a retrofit option for dense cities. Permeable pavements are more expensive than traditional hard surfaces, and are less durable. For this reason, permeable paving is only really suitable for low-traffic areas.

Green infrastructure vs grey - the distinction is often not so simple

While one of the advantages of green infrastructure over grey is that it uses less concrete, the distinction is often not clear cut. In practice, green infrastructure can be highly engineered, and infrastructure components may sit on a continuum of green, grey-green or grey solutions.¹⁴²

For example, chicanes (outcrops that slow traffic on suburban roads) often have a green component, but are made largely of concrete. While the ideal is to incorporate as little concrete as possible in the design, this will not always be possible when retrofitting densely built cities.

Green spaces in city

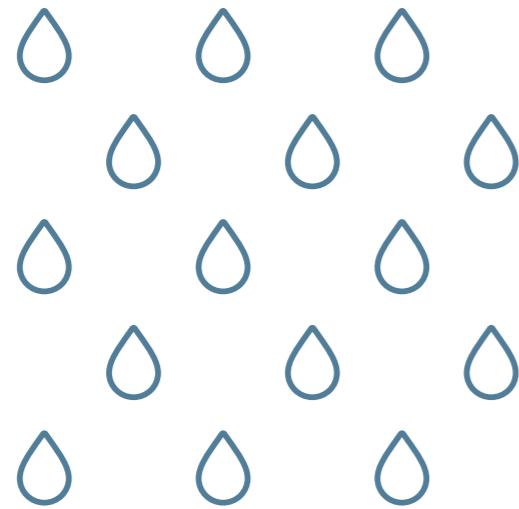


Mansfield, UK

Mansfield, UK

Mansfield (about the size of Dunedin) is the United Kingdom's first city-wide project to transform a whole town to make it more flood resilient and 'spongy'. The project is currently underway, and due to be finished in 2025. £76 million is due to be invested to pay for a range of nature-based solutions.

Around 20,000 Sustainable Drainage Systems devices will be built, including water basins, planters, swales, rain gardens and permeable paving. These are expected to reduce flood risks, cut pollution and bring more plant and animal biodiversity to the city.¹⁴³



CHAPTER 3.

Understanding the Aotearoa New Zealand context

THE REGULATORY FRAMEWORK FOR STORMWATER MANAGEMENT IS COMPLEX, AND CURRENTLY IN FLUX WITH CHANGES TAKING PLACE AT THE NATIONAL LEVEL. THIS PROVIDES BOTH A CHALLENGE AND AN OPPORTUNITY TO GET THINGS RIGHT FOR THE FUTURE.

THERE IS A CLEAR AGENDA FOR ADAPTATION ON THE INTERNATIONAL STAGE



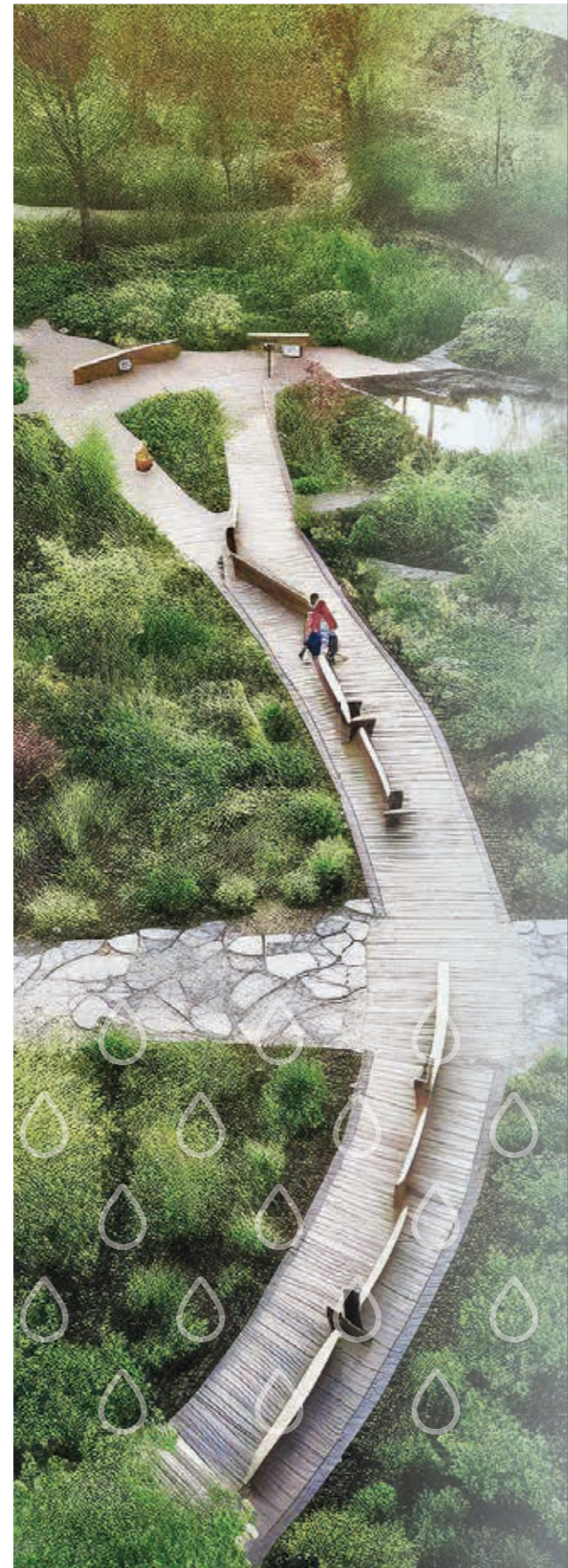
“Adaptation is not an alternative to a redoubled effort to stop climate change, but an essential complement to it. Failing to lead and act on adaptation will result in a huge economic and human toll, causing widespread increases in poverty and severely undermining long-term global economic prospects.” **Global Commission on Adaptation.**¹⁶⁹

In the face of increasing and more intense floods, droughts and other natural disasters worldwide, action to reduce risk has grown in importance on the international agenda. Climate adaptation is now seen as essential to safeguard sustainable development efforts and achieve the Sustainable Development Goals.¹⁴⁹

Some of the key international agreements that cover work in this space are:

- ◆ **the Sendai Framework for Disaster Risk Reduction**, which aims to reduce the impact of natural disasters. A key focus is 'building back better' after a disaster.
- ◆ **the New Urban Agenda**, which supports nature-based innovation in urban environments, and sustainable solutions to climate challenges.
- ◆ **the Sharm-El-Shiekh Adaptation Agenda**, which agrees outcomes in relation to extreme wet weather events, and promotes nature-based solutions.

The international community has recognised the need for all cities to take action to build resilience urgently, and green and nature-based solutions are increasingly an international focus.



AOTEAROA NEW ZEALAND IS MOVING TOWARDS AN ADAPTATION APPROACH

Central government is taking climate change-induced flood adaptation seriously at a national level, and there are signs it is beginning to turn to nature-based (spongy) approaches as a possible solution.

The National Adaptation Plan prioritises nature-based solutions in strategy and policy:



To address the climate and biodiversity crises together, the Government will prioritise nature-based solutions in planning and regulations, where possible, for both carbon removal and climate change adaptation ... By 2024, a framework will be developed, and prioritising of nature-based solutions in regulations and planning will be underway...¹⁷⁰

This initiative provides a basis for a nature-based sponge city approach to be developed in Aotearoa New Zealand. The Plan also encourages councils and communities to consider adaptation options for their area, and requires central government to identify options to increase the integration of nature-based solutions into urban form.¹⁵⁰

In Budget 2023, the Government dedicated an initial \$100 million for co-investment with local councils on projects to improve future flood resilience in areas impacted by the North Island weather events of early 2023. It also

dedicated \$22.9 million to increase Westport's flood resilience, and \$24.7 million to improve data on the impacts of climate change and on adaptation and mitigation responses taken.¹⁵¹

Similarly, the national strategy on biodiversity, Te Mana o te Taiao, references nature-based solutions, and cross agency working groups have been established to enable better integration of climate and biodiversity issues¹⁵².

Yet, despite these positive developments, specific and comprehensive responses to increasing flood risks — and the importance of nature-based solutions to strengthen this resilience — have not yet been woven systematically into Aotearoa New Zealand's policy frameworks.

WATER SENSITIVE URBAN DESIGN IS INCREASINGLY COMMON, BUT NOT MAINSTREAM

Water sensitive urban design (WSUD) is closely aligned with sponge city approaches, but tends to be implemented at the level of the individual development rather than at the city or catchment level. It prioritises minimising impervious areas to limit runoff, minimising earthworks to prevent soil compaction, protecting and enhancing vegetated areas and maintaining natural drainage systems where possible. In common with the sponge city approach, WSUD adopts green solutions such as wetlands, swales and rain gardens.¹⁵³

These approaches are not new in Aotearoa New Zealand, but nor are they yet mainstream,

Napier Gardens

or a first go-to for stormwater management. Central government has recently committed to working with local governments to encourage the use of WSUD.¹⁵⁴ The National Planning Standards define green infrastructure, but it is not a requirement for councils to follow a WSUD approach.

More councils are now adding green infrastructure such as rain gardens to built environments, restoring existing wetlands, and working with communities to daylight streams. However, Aotearoa New Zealand hasn't yet fully embraced the necessity of making space for water on flood plains and often continues to build on these. More than fifteen per cent of state houses have been built on flood-prone land, for example.¹⁵⁵

*Top: Christchurch Botanic Garden,
Bottom: Caroline Bay, Timaru*



It is also rare to find tall buildings sporting green roofs or green walls. Permeable paving hasn't caught on in a big way, and, unfortunately, Aotearoa New Zealand is going backwards in terms of the green spaces available in cities, both overall and per capita.

The way stormwater is managed varies significantly between local authorities, regions, and rural and urban areas. The technical and financial resources available to councils also varies widely, with the bigger cities having far more expertise to draw on¹⁵⁶.

In comparatively well-resourced Auckland, the Making Space for Water plan is expected to be released for public consultation in August 2023. It is an ambitious plan to sort out Auckland's flooding problems with an estimated price tag of \$1 billion. It includes a "substantial but achievable" acceleration of work to deliver new blue-green infrastructure. Whereas Healthy Waters has typically delivered a new blue-green network project just once every two years, 'Making Space for Water' proposes to deliver up to fifteen such projects within six years.¹⁵⁷

In addition to accelerating the provision of blue-green infrastructure, Auckland Council is adopting aspects of a sponge city approach by recognising the need to open up waterways, remove houses from flood prone areas to make space for flood water and develop new linear parks

alongside waterways.¹⁵⁸ Central government has agreed to work with local councils to make offers to buy up around 700 houses and properties in Auckland, Hawke's Bay, and Gisborne that can no longer be lived in since they were damaged or destroyed outright in the January floods or by Cyclone Gabrielle.¹⁵⁹

SADLY, CITIES IN AOTEAROA NEW ZEALAND ARE STILL LOSING GREEN SPACE

Analysis undertaken by the Parliamentary Commissioner for the Environment shows that private green space in Auckland currently covers around 30.6 per cent of the city's total urban area. This is predicted to fall to just 24.3 per cent coverage by 2043 on current settings. A similar analysis in Hamilton shows current private green space predicted to drop by 5.5 per cent by 2043, to cover just 18.9 per cent of the total urban area.¹⁶⁰

Our cities are losing these green spaces at the very time when these spaces are becoming more and more important for managing floods, protecting biodiversity, and sequestering carbon.





THE REGULATORY FRAMEWORK IS COMPLEX

Flood management in urban spaces is governed by a complex web of legislation, regulation, and policy statements, and suffers from a lack of coordination.

Currently, regional councils are responsible for managing rivers and catchments, mitigating soil erosion and flood control. They provide information on where flooding occurs and maintain flood defence systems. Territorial authorities (district and city councils) are responsible for the provision of stormwater infrastructure. They manage building consents, and controlling the effects of land use, such as natural hazards and Indigenous biodiversity.

At the local level, regional and district plans set out processes for managing stormwater and floods, as do hapū and iwi management plans and local treaty settlements.

The current statutory and regulatory framework governing and/or impacting stormwater management includes more than a dozen Acts of Parliament, including the Local Government Act 2002, the Climate Change Response Act 2002, and the Resource Management Act 1991.

Stormwater management is also addressed under a number of

national strategy documents and directions, including the National Adaptation Plan and the National Resilience Plan, which sets aside \$6 billion in initial funding to focus on 'building back better' from recent weather events.

One of the key documents worth noting is the strategic direction expressed by Te Mana o te Wai, which has been part of the National Policy Statement for Freshwater Management¹⁶¹ since 2014, and was strengthened in 2020. It is Aotearoa New Zealand's central concept for freshwater management. Te Mana o te Wai recognises the mana and the mauri of water and takes a mātauranga Māori approach to water management.

The document imposes a hierarchy of obligations beginning with protecting the health and well-being of water, then of people, and finally of other interests. This approach is new in the country's regulatory framework, and could be transformative. In practice, the strategy would mean that preserving or rebuilding the mauri of water in urban environments is placed before economic, financial, or other imperatives.

One new and potentially very impactful requirement is that each council will now need to go through a consent process to release storm water into a freshwater source. Te Mana o te Wai must be incorporated into regional council plans by October 2024. The strategy may help promote more widespread

implementation of sponge city approaches and nature-based solutions.

THE MANAGEMENT OF STORMWATER AND NATURE-BASED SOLUTIONS IS IN FLUX

The regulatory context for stormwater management and nature-based solutions is currently in flux, making it difficult to be clear about who is required to do what, and by when. However, this moving space provides significant opportunity for change.¹⁶²

Two pieces of legislation that are scheduled to replace the Resource Management Act later in 2023 – the Natural and Built Environment Bill and the Spatial Planning Bill – could have a significant impact on how the impacts of climate change are planned for, how stormwater is managed, and the extent to which sponge city approaches and nature-based solutions become mainstreamed.

While neither bill specifically provides for a framework that would support sponge city approaches, under the Spatial Planning Bill each region will be required to set out a long term high-level strategic direction, including consideration of which areas are vulnerable to the effects of climate change, and plans for stormwater management and major new infrastructure.

The proposed legislative changes provide an opportunity to ensure

that essential flood adaptation approaches are given priority, such as making space for water, preserving green spaces, protecting trees, and using approaches such as nature-based solutions and water sensitive urban design. A lot appears to rest on the National Planning Framework, which will sit under the Natural and Built Environment Bill when passed.

The third piece of proposed legislation as part of the Resource Management Act reforms, the Climate Adaptation Bill, is yet to be tabled but will also impact this space. It will cover the rules around relocating settlements away from vulnerable areas, and adaptation approaches such as installing seawalls, or putting houses on stilts.¹⁶³

Recent public statements from the main opposition party¹⁶⁴ imply that a change of government would see such new legislation overturned or at least significantly amended. This adds further uncertainty to the regulatory space.



THE 'AFFORDABLE WATER REFORMS' PROGRAMME

A significant change in the stormwater management regulatory space currently is the 'Affordable Water Reforms' programme, previously known as 'Three Waters'. Under the proposed reform, stormwater management will move from councils to 10 new water service entities (WSEs) by 2026.

Under new legislation, stormwater assets will be transferred from councils to the new WSEs. Where infrastructure is grey, such as a pipe, that process would be relatively straightforward. However, blue-green infrastructure that serves multiple purposes (such as parks) would require thought and cooperation between councils and WSEs.

Green stormwater infrastructure located on public land are referred to as 'mixed-use assets' – they have both a stormwater and another function, such as recreation. The operation of mixed-use assets will transfer to a WSE where the use of that asset is predominantly for stormwater purposes. However, in the case of a football field that is designed to flood during significant weather events, for example, that asset will remain the responsibility of the local council.¹⁶⁵

In either case, the council and the relevant WSE will be required to reach an agreement about how mixed-use assets will be co-managed between their

stormwater function and their alternative use.^{166,167}

The potential advantages of the reforms in terms of moving councils towards sponge city approaches are many. The new model should enable standardisation of approaches, and more consistent use of best practice by allowing specialisation in stormwater management to become more evenly spread across the country (some councils currently make do with very limited stormwater management expertise on staff). The new structure intends to ensure more consistent investment, even in places with low rates bases, as money will be gathered for a specific purpose and must be used for that purpose, rather than being subject to competing priorities.

The reforms could present an opportunity to introduce nature-based sponge city approaches as the standard approach, and to make sure that these are funded and implemented at a whole-catchment level.

However, the new system may also struggle with the additional layers of administrative complexity that



will result from responsibility being split between WSEs and councils. This will particularly be the case for blue green infrastructure which will have significant cross over with the responsibility of councils. The extent to which councils and new water services entities are able to work together on things like whether berms should be planted with natives, or roofs should be 'greened' will have to be agreed between them and this will require excellent relationship management.

Concerningly, the new entities will, it appears, have no basis to recover the costs of providing public benefits such as recreation and improving public health. This risks their decision making around stormwater focusing on options that are cheaper in the short-term such as piped, hard infrastructure, rather than solutions which promote cultural, social, and environmental wellbeing.¹⁶⁸

To ensure the new model helps, rather than hinders, the roll out of sponge city approaches, national direction promoting this approach should be embedded in all the various planning frameworks currently under development. Thought should be put into how the new entities can share those costs which provide benefits such as increased amenity, but do not relate strictly to stormwater management. Finally, there will need to be sound mechanisms for integrated planning and investment across the regional entities and councils.



CHAPTER 4.

Do sponge cities offer Aotearoa New Zealand a viable solution?

SPONGIER URBAN AREAS ARE JUST ONE PART OF THE SOLUTION

Sponge cities as a concept properly entered the public consciousness in Aotearoa New Zealand after the two major flood events that took place at the beginning of 2023 – the Auckland Anniversary Weekend floods and Cyclone Gabrielle. Whether or not the damage caused by those events would have been limited by ‘spongier’ cities has become an important topic for debate.

A crucial point is that the sponge city approach is designed for urban areas. It will not be a solution for rural, or agricultural, areas – though some of the approaches, such as remediating wetlands, may well be helpful in those places too, alongside whole catchment water management in general. Sponge cities cannot fix problems such as land erosion and slash from forestry, which increased the intensity of flood damage in areas such as Hawkes Bay and the East Coast during the cyclone.

The townships that bore the brunt of the flooding from the cyclone as rivers overflowed their banks

and stop banks were breached, likely wouldn't have been able to withstand the sheer quantity of water that flowed towards them, regardless of how absorbent they were.

A review of the literature and anecdotal feedback from experts shows mixed views on the extent to which sponge city approaches might have mitigated damage in Auckland and other northern towns after the January flooding. The January rainfall event was huge in scale – a 1-in-200-year event according to NIWA,¹⁷¹ and the biggest rainfall event in Auckland's modern history. Many parts of Auckland received more than 400 mm of rainfall during the five-day flood period. The Hunua East monitoring station recorded the most, with a phenomenal 639.6 mm.¹⁷²

While using green and blue infrastructure to manage flood waters would not be expected to present a full solution for that kind of extreme event¹⁷³, areas in Auckland that have incorporated sponge city concepts do appear to have done better than other areas in the January flooding.

In the Hobsonville Point housing development, for example, wetlands were preserved and various sponge city concepts were built in, including rain tanks, underground detention tanks, bioswales and rain basins placed over stormwater drains to slow flow. The area experienced very little flooding in January compared to neighbouring areas.¹⁷⁴

Similarly, in Northcote, which has historically suffered from flooding during storms, new stormwater provision prevented most private houses in the area from being flooded in January.¹⁷⁵ Two significant projects were completed there in 2022 - the daylighting of the Awataha Stream and the transformation of Greenslade Reserve into a stormwater detention park. Greenslade Reserve now incorporates a planted urban wetland and detention basin. The sports field was designed to hold twelve million litres of water, which limited damage to nearby houses in the January floods.

Te Ara Awataha Greenway, Northcote



OTHER APPROACHES WILL ALSO BE NEEDED TO OFFSET RISK, INCLUDING MANAGED RETREAT

The sponge city model likely to be most successful is one that acknowledges that a range of solutions will be required as flood risks increase over time. These solutions may require a combination of blue, green, and grey approaches alongside other mitigation strategies.

A successful sponge city approach will make space for water, recognising that from time to time, flood waters will need to take up significant space. Finding a way to let that happen with the least possible damage to life, property, and infrastructure, is key.

That will mean moving houses and businesses that have previously been built on particularly vulnerable flood plains, or in the way of overland flow paths, and ensuring that those areas cannot be built on again (an approach known as 'managed retreat'). IAG, the country's biggest insurer, estimates that this may affect 20,000 homes.¹⁷⁶ Over time, that number is likely to grow.

Dealing with increasing flood hazards in urban areas is likely to necessitate a combination of the following approaches, which could take place alongside a sponge city approach:¹⁷⁷

- ◆ Design bigger and better grey infrastructure in certain locations (pipes and drains).

That would be expensive but may be the only solution for flood prone areas that must be protected at all costs.

- ◆ Increase flood protections such as stop banks. Stop banks come with some risks – they may encourage growth in areas that are not suitable to be habited in the long term, for example.
- ◆ Raise houses, or design houses with living spaces on higher floors.
- ◆ Minimise damage by using wet proofing techniques on buildings, using materials for floors and cupboards that are less susceptible to flood damage, or siting electrics higher up.

- ◆ Develop better data – including data that updates in real time – to help communities mitigate risks in advance, and to help respond to floods as they happen.

Adapting to increasing flood risk brought about by climate change will pose unprecedented challenges, and it will not be possible to eliminate risk entirely. New Zealanders need to be having conversations both as a country, and locally, about what level of risk is acceptable in cities, and what level of cost can be tolerated to achieve higher levels of resilience.





EARLY ADAPTATION WILL COST, BUT SAVE MONEY LATER

China has invested significant sums into its Sponge Cities Programme. A total investment of around NZ \$20 billion was budgeted for the first three years of implementation, split between the sixteen pilot cities. Central government underwrote cities by up to twenty per cent of the full cost.¹⁸⁹

While this may seem a lot, across Aotearoa New Zealand, the estimated cost of renewing the 'three waters' network (wastewater, potable water and stormwater assets) is in the order of \$30 billion to \$50 billion over the next 15 years.¹⁷⁸ Any investment decisions must be seen in this context – and must also be compared with the cost of doing nothing.

Research by the Global Commission on Adaptation found that early adaptation is in countries' strong economic self-interest, with an overall rate of return on investment in improved resilience showing cost-benefit ratios of as much as 10:1 within ten years for some interventions.¹⁷⁹

Evidence for the cost-benefit value of sponge city approaches, both at the city-wide and development scale, include the following:

WUHAN'S TRANSFORMATION INTO A SPONGE CITY SAVED

≤ US\$600M

COMPARED WITH THE COSTS OF EQUIVALENT GREY INFRASTRUCTURE

180

NATURE-BASED SOLUTIONS ARE

181

50% MORE ECONOMICAL

AND ARE

181

28% MORE EFFECTIVE

A LITERATURE REVIEW FOUND WSUD ON AVERAGE SAVES

182

14 - 35%

ON SITE PREPARATION AND EARTHWORKS COMPARED TO CONVENTIONAL FORMS OF DEVELOPMENT

WSUD SAVED AN AVERAGE OF

183

22%

AT THE KIRIMOKO PARK DEVELOPMENT IN WANAKA

IN NZ, A CASE STUDY OF THREE DEVELOPMENTS FOUND WSUD DELIVERED A GREATER

184

RANGE AND LEVEL OF BENEFITS FOR LOWER COST

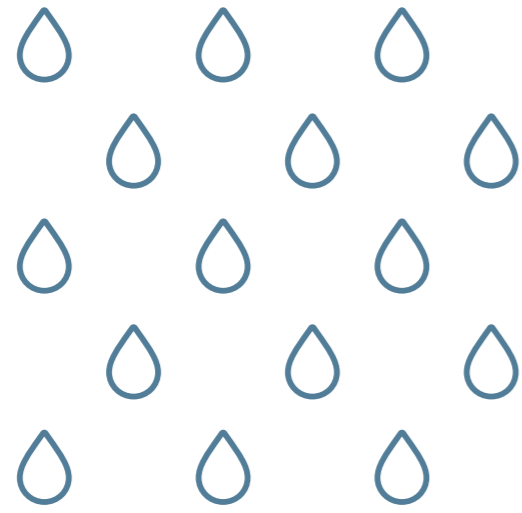


Investing in adaptation means making the most of a so-called 'triple dividend'. This holds that benefits should not be measured only in terms of avoided losses, but also in positive economic impacts (such as increased productivity and innovation), as well as in social and environmental benefits.¹⁹⁰

Sponge city approaches also have other benefits, such as supporting biodiversity, or improving public health, and these benefits are not usually calculated in cost-benefit analyses as they are difficult to monetise. Other cost-benefit challenges are that the best solutions for a given location are dependent on the characteristics of the soil and climate, the nature of the existing infrastructure, and whether the land in question is privately or publicly owned.¹⁸⁵ The costs of retrofitting compared with building in green infrastructure will also affect the cost-benefit of a proposed solution.¹⁸⁶

A key impediment to implementation of sponge city-type approaches in Aotearoa New Zealand has been the perception that these cost more to implement – often the short-term cost will be the most important decision-making criteria, rather than the full life cycle cost, and other wider benefits it may bring.¹⁸⁷

There are now tools available to help decision-makers calculate these extra benefits – the 'More than Water' assessment tool is one good example.¹⁸⁸



CHAPTER 5.

An Aotearoa New Zealand model for sponge cities

THIS REPORT PROPOSES AN AOTEAROA NEW ZEALAND MODEL FOR SPONGE CITIES THAT PRIORITISES RESILIENCE, NATURAL ABUNDANCE (RAUORA) AND HOLISTIC APPROACHES THAT CAN FULFIL MULTIPLE FUNCTIONS, AND WORKS TO VALUE AND RESPECT WATER FOLLOWING THE PRINCIPLES OF MĀTAURANGA MĀORI AND NATURE-BASED SOLUTIONS.

An approach for Aotearoa New Zealand will be most successful, and affordable, if it requires and incentivises sponge city approaches at the whole-city level as well as for new developments, and within private residences. Approaches should be tailored to location based on city size, geography and budget.

PRIORITISE RESILIENCE AND RAUORA (NATURAL ABUNDANCE)



RECOMMENDATIONS:

► **Have high aspirations.**

Aim to revive the mauri (life force) of water by improving its quality, achieve rauora (natural abundance) in the environment, and make beautiful spaces in which to live - rather than simply 'managing stormwater'.

'Climate resilience' is about being able to anticipate, prepare for and respond to the impacts of a changing climate¹⁹¹. A town or city's level of resilience is reflected in its ability to survive, adapt and (ideally) thrive in the face of climate-related pressures.¹⁹²

A key point in both international and local narratives, is that flood mitigation and climate resilience can be reframed by decision-makers as a net positive. Rather than being seen as a threat, it can be an opportunity, and an 'enabler for urban transformation'. Water management can be used to grow economic activity, reduce emissions, improve public health and contribute to thriving ecosystems.¹⁹³

The Māori concept of rauora sets out what it means to be

resilient. The Rauora Indigenous Worldview Framework, developed for the National Climate Change Adaptation Plan describes the need to work within a mindset of rauora and have high aspirations, using Indigenous knowledge to guide us in climate adaptation. The framework centres the principles of balance, interconnectedness, collectivity and inter-generational equity, complemented by Māori values. Rather than assessing outcomes against minimum requirements, they are assessed against a measure of natural abundance, vibrancy, regeneration and optimal health.¹⁹⁴

Under the Rauora Framework, a sponge city model should be considered not just for its ability to mitigate flood risks, but also for how well it is able to accelerate ecological restoration – not to a minimum baseline, but to flourishing levels. It should also provide beautiful spaces to live, work and play.

The Indigenous worldview also encourages society to look at the driving forces behind the current situation more holistically. Flood resilience is thereby not just a discrete issue of stormwater management, but part of bigger picture issues such as colonialism, and the western economic model that have contributed to environmental degradation and created the drivers for climate change.

BE GUIDED BY MĀTAURANGA MĀORI



RECOMMENDATIONS:

- **Be guided by mātauranga Māori and tikanga** in setting policy and community decision-making around flood adaptation.
- **Partner with tangata whenua in decision-making around sponge city approaches** at the national, local and community levels.
- **Increase Māori workforce in stormwater management-related professions**, to help mainstream tikanga and mātauranga approaches.

Māori knowledge and leadership is an important positive enabler towards implementing nature-based sponge city approaches model for Aotearoa New Zealand. Tikanga is closely aligned with sponge city approaches such as water conservation, restoring buffers of native vegetation alongside waters, and avoiding mixing water from different sources.

Mātauranga Māori knowledge and wisdom provides a supportive framework for addressing climate issues and biodiversity loss together, with a strong focus on innovation, cultural connections

to species and place. Sector professionals interviewed as part of qualitative research by Abbie Reynolds noted that Māori governance promotes integrated decision-making around climate issues, that balances economic considerations with the well-being of people and the environment.¹⁹⁵

The National Adaptation Plan recognises the importance of elevating te ao Māori and mātauranga Māori in the adaptation process, and of empowering Māori in adaptation planning. Actions under the plan include partnering with Māori to support Māori-led approaches to adaptation planning (Action 7.3), and producing guidance on integrating mātauranga Māori into planning together with mana whenua (Action 3.7.6).

Strengthening Māori workforce in stormwater related professions would help mainstream tikanga and mātauranga approaches within the sector.¹⁹⁶ Bringing more Māori into the workforce will take coordinated efforts from a range of stakeholders, including professional bodies, educational institutions, councils and central government.

SET A CLEAR VISION FOR SPONGE CITIES AND NATURE-BASED SOLUTIONS



RECOMMENDATIONS:

- ▶ **Act urgently and decisively, and plan strategically** for the long-term at the national, regional, and local levels. Name and prioritise nature-based sponge city approaches as a key climate adaptation approach for Aotearoa New Zealand. This strategic vision may sit in documents including: the proposed National Planning Framework, the next National Adaptation Plan, NEMA's National resilience strategy, the Climate Adaptation Bill, and future regional spatial strategies.
- ▶ **Build political consensus across the spectrum** for the importance of nature-based sponge city approaches.



"By reviving the knowledge of the old techniques and connecting them with contemporary sciences and arts, we are able to build nature-based green infrastructures replacing the conventional grey infrastructures... Living with nature is inexpensive and easy, comfortable and beautiful, and an art of survival". Dr Kongjian Yu²⁵⁰

The International Union for Conservation of Nature defines nature-based solutions as approaches that protect, sustainably manage, and restore natural and modified ecosystems. They aim to address societal challenges effectively and adaptively, simultaneously benefitting people and nature. Nature-based solutions target major challenges like climate change, disaster risk reduction, food and water security, biodiversity loss, and human health.¹⁹⁷

With many competing and increasing pressures on limited public funds, any proposed climate adaptation solutions must be efficient, evidence-based, and effective at reducing flood risks. The best way to get value for money is to choose approaches that are not just focused on one solution – in this case, flood mitigation – but that deliver multi-functional solutions that provide benefits across a range of indicators.

A sponge city model for Aotearoa New Zealand that incorporates the holistic principles of nature-based solutions, working together with mātauranga Māori, can produce those multiple benefits. An ideal model would ensure this holistic view is factored in as part of the cost-benefit analysis for any city-wide sponge city plan or smaller stormwater project.

Aotearoa New Zealand's first national adaptation plan, published in 2022, emphasises the value of working with nature in this way, rather than against it, pointing out that the climate and biodiversity crises are inextricably linked, and noting the importance of working with nature to restore and protect Indigenous ecosystems.¹⁹⁸

Building political consensus about the importance of nature-based sponge city approaches as a climate adaptation will be essential to keep momentum. Interviewees in a qualitative study led by Reynolds noted that changing government priorities make it harder to implement long-term nature-based projects at the local level. Building political consensus will help minimise this – though it is often easy to achieve.¹⁹⁹



APPROACHES AT THE CITY AND CATCHMENT LEVEL



RECOMMENDATIONS:

- ▶ **Require councils to set out nature-based sponge city approaches in their long-term plans.** This requirement may be set out under regulations for the new Spatial Planning Bill, for example. Solutions may include:
 - » making space for water – where necessary removing homes and other buildings from flood plains and major overland flow paths
 - » naturalisation, rehabilitation, and daylighting of streams, rivers and lakes
 - » restoration of flood plains
 - » protecting and restoring major overland flow paths
 - » creation of wetlands and ponds
 - » improving the connectivity of the urban water system and urban green spaces, to allow unimpeded water flows and create blue-green corridors for wildlife
 - » designing public spaces to flood – transport

networks such as roads and railways, and other public spaces, can be made to serve as “sacrificial storage areas” when it rains heavily²⁰⁰

- » increasing the quantity of public green and blue spaces – where limited space is available, ‘pocket parks’ and ‘tiny forests’ are an option
- » upgrading existing parkland to be more absorbent – by replacing lawns with native trees and shrubs, for example, or building wetland areas.

- ▶ **Value green spaces as essential infrastructure.**

Require councils to plan for and provide public green spaces as they do with other infrastructure. Plans should set out the multiple benefits each green space will be expected to fulfil, including stormwater management, amenity, and enhancing biodiversity.

- » National policy should set out minimum requirements for the quantity of public green spaces in urban areas, whether calculated by area, or by population.

- » Remove the limit on development contributions a council may charge for the development of new green spaces under the Local Government Act 2002 (LGA), to bring this into line with how other infrastructure is treated.

All towns and cities in Aotearoa New Zealand need long-term plans that assess flood risk for different areas, down to the neighbourhood level, and ideally in even more detail. The Spatial Planning Bill will require long-term spatial plans to be produced regionally, and to take into account matters relating to the effects of climate change. The challenge will be to ensure these plans take a catchment-wide approach to flood mitigation, and use sponge city approaches in preference to hard infrastructure. This report recommends such a requirement be developed, whether in legislation or within the National Planning Framework.

The quantity and quality of green spaces at the city level also need attention. Aotearoa New Zealand’s cities have increasingly less public green space as a percentage of the total area, and offer less public space per resident. Most councils spend only a fraction of capital expenditure budgets on parks and reserves.²⁰¹

Since the 1960s, there has been

no statutory requirement in place for councils to plan for, or to provide public green and blue space. This compares to other forms of infrastructure (such as stormwater infrastructure), for which they do have to plan and provide.²⁰² While most councils publish service statements for public spaces, targets often amount to just one-two per cent of areas used for new developments – far less than was historically provided.²⁰³

Public green and blue spaces should be considered essential infrastructure in their own right, rather than simply a nice-to-have amenity, and be planned for accordingly. Setting national minimum requirements would help to achieve this.

Under the LGA (s203(1)(a)), councils are empowered to require contributions from property developers to create new public green space. They may ask for contributions totalling up to 7.5 per cent of the value of additional allotments created by a subdivision. While the LGA caps development contributions for parks and reserves, there is no cap for development contributions for infrastructure. In fact, many councils are currently asking nowhere near the maximum they are entitled to.²⁰⁴

Amending the LGA to remove the contribution cap for green spaces would help support councils to provide essential green space – but they would need to use the powers they have to charge accordingly.

It is not always easy to find space in densely built urban areas suitable to convert to large new parks. Fortunately, evidence suggests that inserting smaller parks in residual spaces within neighbourhoods can also be very useful for flood mitigation if placed in the right areas. ‘Pocket parks’ can also help regulate the microclimate, allow for biodiversity, and improve air quality.²⁰⁵

Urban Creek Catchment Vision for Christchurch City Council.



In a similar way, urban forests, also known as tiny forests, can help with flood mitigation, both by absorbing water and by breaking up the soil for water to drain through more slowly. A tiny forest may be as small as a tennis court, yet support dozens of different species of trees and plants.²⁰⁶

Finally, making space for an increasing quantity of water in urban areas will necessitate moving some houses and businesses that have previously been built on vulnerable flood plains or in the way of major overland flow paths. Current estimates are that there are as many as 20,000 such homes in Aotearoa New Zealand.²⁰⁷ Removing at-risk buildings will involve difficult decisions, but is essential to minimise cost and heartbreak in the future. The upcoming Climate Adaptation Bill is due to set out the rules governing managed retreat.

APPROACHES AT THE NEIGHBOURHOOD AND DEVELOPMENT LEVEL

At the neighbourhood and development level, options include retrofitting existing areas, and working to ensure that new residential developments are designed to be more absorbent. To prevent further erosion of public green space caused by ‘infill’ development, policies should focus on ‘upwards’ development, alongside provision of adequate private and public green space.

Utilise large sections of land in urban areas, whether privately or publicly held



RECOMMENDATIONS:

- ▶ **Direct that all land owned by government agencies be considered for its potential to mitigate current and future flood hazards by incorporating sponge city approaches.**

- » Landowners such as the Ministry of Education and Ministry of Health should identify land, including sports fields for example, that may be retrofitted

to slow or retain flood water while retaining their original purpose, and develop plans to do so in areas facing flood hazards.

- » Types of land use that promote absorbability should be favoured on public land where possible, both at the design stage and as a retrofit (trees rather than concrete, for example).

- ▶ **Incentivise private owners of large sections to make these more absorbent.**

- » Incentivise large private landowners to replace concrete surfaces with permeable paving, plant trees in areas that are not being used, build rain gardens, or retrofit their property with underground bioretention tanks.
- » Options include providing rates rebates or tax breaks, or providing green certification for businesses that reach a specific ‘spongy standard’.
- » Councils (or WSEs) could also pay for green infrastructure to be built on private land in key areas, where landowners are amenable.



While it is administratively easier to focus on sponge city solutions for public land, private land – such as underused industrial sites – also provide opportunities to keep stormwater out of grey networks. Areas of industrial land that are underused could be fitted with green infrastructure, or car parking could be converted to permeable paving, for example.

Research by Muangsri et al.²⁰⁸ modelled the potential for a number of industrial properties in Christ church to be enhanced with green infrastructure for flood mitigation under different climate change scenarios. They found that adding in-ground stormwater storage into selected industrial properties could offset climate change-induced runoff impacts to a manageable level in those catchments. These findings held true even when a major climate change scenario was modelled.

While the research focused on industrial areas, the findings could equally well be applied to other types of large property, including land owned by councils, central government, or private trusts for example. Schools, universities, hospitals, and public housing all sit on large areas of land that may in many cases be put to better use.

Deal with densification by encouraging ‘upwards’ development rather than ‘infill’



RECOMMENDATIONS:

- ▶ **Focus national housing policies to encourage ‘upwards’ development** in preference to ‘inwards’ or ‘outwards’ development.
- ▶ **Ensure the new National Planning Framework gives clear guidance** on how to address any conflict between housing needs, and sponge city approaches.

Aotearoa New Zealand’s national housing strategy, set out in the Urban Growth Agenda²⁰⁹ is to encourage housing both on the urban fringe and as ‘infill’ and ‘upwards’ development. The country is currently experiencing a significant housing shortage. The recently introduced Medium Density Residential Standards (MDRS) aim to address that by requiring councils in our fourteen biggest cities to allow medium-density housing in residential areas, and multi-storey apartment buildings in city centre zones. Under the MDRS, three homes of up to three storeys can be built on most sites without the need for resource consent from local councils.²¹⁰

Councils were required to incorporate the MDRS into their regional plans by 2022, though some have sought extensions. The new standards should boost much-needed housing supply, but are also likely to place increasing strain on stormwater infrastructure as existing gardens in residential areas are covered over with impervious new buildings, driveways and patios.

Unfortunately, there is no straightforward solution. Housing is urgently needed in much of Aotearoa New Zealand and land is expensive, making subdivisions financially attractive. Building new houses at the urban fringe is also undesirable in most cities as it encourages sprawl, locks in higher emissions through increased transport needs, and creates competition between land for development and land dedicated to supporting biodiversity, or for food production.²¹¹

Building upwards uses urban land more efficiently than infill development, or medium density housing such as terraced houses. Buildings with more floors take up less space per resident, and, if planned well, can be designed to include a large amount of green space, and incorporate sponge city approaches as part of the development.

A recent analysis of cities around the world concluded that while there are tensions between density and urban green spaces, urban areas can be made to be both green and dense by taking advantage of green infrastructure.²¹² By prioritising upwards growth, ensuring development rules are fit for purpose, and utilising the sponge city approaches outlined here, Aotearoa New Zealand can grow denser while also future-proofing for floods.

Aotearoa New Zealand needs a clear vision on how it will balance the need for housing with the need to make cities more absorbent. Both are important, so clear direction will be important for decision-makers. This could sit within the National Planning Framework, for example.



Retrofit towns and cities with green infrastructure



RECOMMENDATIONS:

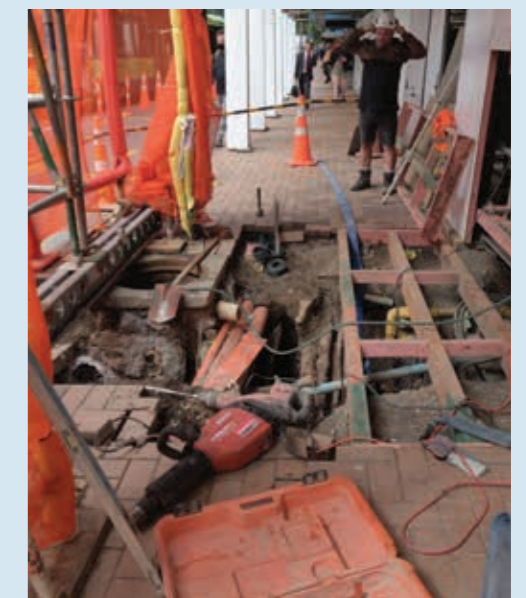
- ▶ **Use urban and suburban road corridors and other public places** to provide space for green infrastructure such as rain gardens, swales, tree pits and vertical walls. Replace grass with other plants where possible.
- ▶ **Require new buildings in the inner city to include green roofs or other equivalent infrastructure** to minimise runoff. Incentivise existing buildings to retrofit green solutions.
- ▶ **Where appropriate, unseal hard surfaces such as pavements and carparks**, and replace with permeable paving or plants. This may happen as part of scheduled upgrades.

Streets and roads represent a large proportion (fifteen to twenty per cent) of the surface areas of cities in Aotearoa New Zealand, and can therefore help connect green spaces into ecological and water management networks in a way that isolated parks cannot.²¹³ Retrofitting streets is highlighted in the literature as having good potential to take the pressure off

urban stormwater networks.²¹⁴

Although much of the existing road networks in Aotearoa New Zealand are already 'green', councils' willingness to plant on street berms varies widely, reflecting the impact on car parking, the extra maintenance costs created for councils, and the difficulties caused by plant and tree roots sharing underground space with utilities buried beneath the street.²¹⁵ Raised beds can sometimes provide a solution, though access to utilities for maintenance still must be provided.

Figure 13. Inner city footpaths in Wellington are narrow and contain more than 100 years-worth of old pipes and cables, making it hard to find a spot for plants.



Trees are the most valuable for water absorption, as well as for their knock-on benefits on air quality, biodiversity, and city cooling. However, trees can also interfere with power lines above and pipes below. Solutions include underground cages to keep roots contained, increasing the size of the road corridor, or locating infrastructure trenches under the road rather than the footpath. Combining infrastructure such as pipes and cables in single continuous conduits can also provide more room alongside for plants.²¹⁶

To deal with increased maintenance costs, councils might charge targeted rates, or require developers of new housing to continue paying for maintenance for green street infrastructure

in the mid-term. As extreme rainfall events become more common, the country will need to develop a change in mindset to regard nature in cities as critical infrastructure that must be worked around even where that is difficult and costly.

Other retrofitting ideas for inner cities include incentivising or requiring green roofs, tanks or other retention devices on rooftops of buildings. Finally, unsealing hard surfaces in public areas such as carparks, urban squares, and pavements, and replacing those surfaces with permeable paving and/or natural surfaces, such as plants, could significantly minimise runoff in cities.²¹⁷

Make new residential developments more absorbent, or compensate with new parks



RECOMMENDATIONS:

- ▶ **Raise the national minimum standard for new developments** for percentage of the development area that must be left unsealed. This should apply to both greenfield development and 'infill' development within existing residential areas.
- ▶ **Incentivise developers financially to do even better than the national minimum** (by charging lower development fees, for example)
- ▶ **Councils should invest more in compliance** to ensure current rules are followed.
- ▶ **Set a national minimum standard for percentage of parkland to be zoned as part of new greenfield developments** to avoid cities becoming less green overall. Ensure this space is designed to provide amenity as well as stormwater function.

- ▶ **Where it is not possible to leave sufficient space unsealed, provide additional new public green spaces,** funded by development fees.

As houses in new greenfield residential developments have become bigger, the parcels of land they sit on have become smaller. Meanwhile, it has become fashionable to surface over increasing amounts of the space not covered by houses for off-street parking, driveways and patios. A second major trend is for more and more back gardens and other available space within existing residential areas to be filled with new developments as housing pressures bite. This means green spaces held in private residential areas – one of the country's biggest contributors to green spaces – have been shrinking.²¹⁸

Until recently, the amount of land kept as green space in private developments has been left to councils. Most councils in the bigger cities allowed a total built area on new dwelling sites of 35–40 per cent.²¹⁹ New national rules under the MDRS provide that where new homes are built under those standards, buildings may cover up to half of the total site area, and only twenty per cent of the site must be landscaped with grass or plants. This policy will further erode green spaces in residential areas.²²⁰

To keep and improve the sponginess of cities in Aotearoa New Zealand the trend of losing green spaces on private land will either need to be reversed, or green spaces will have to be provided elsewhere – whether within new developments or nearby.

The Parliamentary Commissioner for the Environment proposes several options for doing that.²²¹ First, new developments could be required to leave a greater proportion of available land space within each section unbuilt and unsurfaced than is currently provided for in the MDRS.

Anecdotally, an additional issue here is that rules set by councils concerning areas to be left unsurfaced are not always complied with by developers, or are further eroded by landowners over time.²²² Dedicating more resourcing within councils to compliance would be a worthwhile investment to reduce costs later on.



Second, councils could zone more parkland within development areas, or require developers themselves to set aside more public green space than they currently do. This may be done as part of the consent process, and by applying covenants to the land.²²³ Councils can and should fund new parks and green spaces by raising levies against developers under the Resource Management Act or the Local Government Act.

A drawback of charging developers more is that the extra costs will be passed to new owners. That is particularly unpalatable during housing shortages. However, new housing that is designed poorly puts additional stress on the stormwater networks that are already buckling under the strain. An alternative is that the costs are passed on to the general public via increased rates, which would also not be welcomed.

To make up for some of the additional costs that may need to be paid by new owners to cover better and more public green spaces, councils could offer rate rebates or stormwater discounts to 'spongier' housing developments, meaning that homeowners could recoup some of the costs over time.

Change the way new housing sites are developed



RECOMMENDATIONS:

► **Require new developments to follow the principles of sponge city approaches / WSUD,** to retain natural drainage features and minimise soil disturbances across sites. Options include:

- » requiring natural drainage features such as wetlands, streams, and overland flow paths to be left intact as part of new developments²²⁴
- » requiring or incentivising developers to retain existing trees
- » clustering buildings to leave more green space with topsoil intact²²⁵
- » building houses on the areas within development sites that are the least valuable for drainage (on clay, for example), leaving the most absorbent areas undisturbed²²⁶
- » using different building techniques, such as building houses on stilts or pads, to minimise soil disturbances.²²⁷

» increasing the depth of topsoil that must be replaced after developments are complete to a level that can support full-grown trees rather than just lawns.²²⁸

► **Set standards around allowable runoff quantity, or require full 'hydraulic neutrality' from new developments.** New developments could be required to deal with more (or all) of rainwater in situ, for example by:

- » adding retention and infiltration systems such as ponds and tanks
- » reducing the quantity of impermeable outdoor areas in site designs
- » requiring footpaths, driveways and paved surfaces to reach a minimum permeability standard and detention storage volume²²⁹
- » installing rain gardens, swales and filter strips.

The way sites are prepared to make way for new housing developments reduces the ability of soils to absorb and retain water. This is because areas set aside for new residential developments in Aotearoa New Zealand are usually stripped of existing trees,

vegetation and topsoil and then compacted to provide a hard surface in preparation for building. Natural drainage features such as gullies, wetlands or streams may be smoothed over, diverted, covered up or filled in.

A thin layer of topsoil is then added back once the development is complete. Often this layer of topsoil is too thin to allow trees and shrubs to survive or grow to maturity. New development practices are needed, both to conserve soils for maximum drainage, and to preserve and enhance natural ecology and biodiversity in areas to be developed.²³⁰

As one example, clustering houses, rather than designing them to sprawl across a whole site as is typical in Aotearoa New Zealand developments, can significantly reduce the amount of impervious



area and volume of earthworks needed.²³¹ Water sensitive urban design techniques also include adopting measures that conserve natural areas, retain soils that are particularly valuable for infiltration, and work around flow paths.

The Government of the United Kingdom recently announced that it will be mandating sustainable drainage systems (SUDS) in all new housing developments.²³² SUDS use ponds, planters, green roofs, tanks, soakaways, tree pits, permeable paving and other green infrastructure to manage surface water sustainably.²³³ In Aotearoa New Zealand, the equivalent would be to require mandatory use of WSUD in new developments.

Some councils in Aotearoa New Zealand now require new sites to attain 'hydraulic neutrality', meaning no additional stormwater is to be discharged into the public stormwater system, either piped or by street drainage, as a result of the new development. Dealing with stormwater in situ eases the strain on public systems. Hydraulic neutrality is required for all new residential projects on the Kāpiti Coast, for example.²³⁴

AT THE LOCAL LEVEL, MAKE PRIVATE RESIDENCES MORE ABSORBENT



RECOMMENDATIONS:

- ▶ **Educate and incentivise homeowners to make their properties more absorbent, and not to block overland flow paths.** Approaches include minimising the use of sealed surfaces, replacing lawns with plants, and recycling rainwater. Incentives may include free advice (home audits), rates rebates or discounts on materials.
- ▶ **Ensure the new National Planning Framework provides sufficient protection for urban trees,** and provide local incentives (such as 'treebates') for homeowners to plant new ones.
- ▶ **Develop tools to monitor the quantity and quality of private green space in cities, and set goals (at central or regional level) to maintain minimum levels.** This is currently technically challenging to do accurately, though good estimates can be made.

- ▶ **As monitoring tools are developed,** consider charging homeowners stormwater rates based on quantity of impermeable surfaces on private properties.

Residential yards and gardens account for slightly more than half of available green space in the country's biggest cities. Meanwhile some cities, such as Auckland and Hamilton, are becoming less green due to changes on private land. This points to the potential for encouraging private landowners to make the most of existing spaces for flood mitigation.²³⁵

Homeowners can contribute to sponge city approaches in several ways. One of the most important is to observe where water congregates, and ensure existing overland flow paths are not blocked by garages, buildings, or fences.

All green space is not equal. Trees, shrubs and wetlands can absorb far more water than dry, hard lawns. Options for residential properties to absorb more stormwater include replacing lawns with trees and native plants, fitting rain tanks, and building small ponds or mini wetlands. Directing rainwater from the roof into the garden or a grass swale will not only reduce runoff, but will reduce the pollution caused by roofing materials.

As touched on earlier, Aotearoa New Zealand has been losing trees in private yards since changes to the Resource Management Act in 2009 and 2013 removed blanket tree protections - a phenomenon that has been referred to as 'death by a thousand cuts'.²³⁶ Cities have lost a staggering number of trees as a result.²³⁷

The Natural and Built Environments Bill, if passed, should improve the situation by requiring the National Planning Framework (NPF) to provide direction on urban trees (cl 58(f)). The key will be to ensure the NPF provides sufficient protection to halt the losses, while still enabling homeowners to remove trees where a case can be made that it is necessary.



Other options include financial disincentives to cut down native trees, combined with incentives to plant them. In Portland, Oregon, for example, ratepayers are offered a 'treebate' - a credit on their stormwater bill when they purchase and plant a tree in their private residential garden. Larger trees receive bigger credits.²³⁸

Paved spaces take up a large percentage of private yards. Homeowners could be incentivised to retrofit permeable surfaces with subsidised materials. Alternatively, they could be offered reduced rates if they undertake a certain number of interventions, or reach a certain standard in terms of runoff quantity.

Houses obviously take up the greatest portion of residential land. Options to reduce runoff from houses include green roofs and private rainwater tanks. Using water from roof areas for potable and non-potable purposes can significantly reduce the volume of water discharged to downstream receiving environments.²³⁹

ONE SIZE DOES NOT FIT ALL



RECOMMENDATION:

► Tailor approaches to suit different locations and budgets.

A key takeaway from the literature is that a 'sponge city' won't look the same as a 'sponge regional town'. In fact, every place is likely to benefit from a different combination of approaches, tailored to local geography and geology, climatic conditions, population density, and urban form.²⁴⁰

For example, Wellington is rich with trees and green spaces because of its topology, and a focus for the city is preventing landslips. Auckland is facing increasing densification and reduced tree cover, and suburban flooding is a major issue. Major water features in a city, such as the Waikato River in Hamilton, or the estuary in Porirua, also make different approaches necessary.

Large, built-up cities tend to have more impervious surfaces and are therefore often (but not always) more vulnerable to flash floods than smaller places. At the same time, land is also more expensive, making it harder and more expensive to retrofit sponge city approaches.

In big cities, lots of smaller initiatives may therefore be more appropriate, such as rain gardens, pocket parks, and green roofs, for example. Permeable paving can also be a cost-effective solution in built up areas.²⁴¹ Alongside these sponge city approaches, some grey infrastructure is likely to remain essential in larger cities due to their dense populations and the limited space available for green solutions.

Small towns by contrast generally have less money due to a lower rates base, and may have less technical expertise to draw on. However, they are also less built up, and so they may be able to choose between a greater range of different approaches to match their budget. In smaller towns, it may be easier to increase the number of parks, and create new green belts, for example.

It is important to reiterate that sponge city approaches will not work everywhere, or may only partially reduce flooding in some places. As one example, the water table in South Dunedin sits just below ground level, and the land is sinking slowly. When it rains, the rainwater has nowhere to go.²⁴² Building green infrastructure cannot fix that problem. At best it may help to reduce the worst impacts of climate change for a time. Areas that are built on wetlands, such as some parts of Christchurch, face similar problems.

Similarly, areas with peat, clay or silty soils will not be able to absorb large quantities of water, so in those cases, a combination of green and grey infrastructure may be more appropriate – such as on-site storage in holding tanks for example.²⁴³

Flooding south of Dunedin.



DON'T GET STUCK ON 'ALL OR NOTHING'



RECOMMENDATIONS:

- ▶ **Embrace incremental approaches as part of a long-term vision.** Where comprehensive sponge city approaches are not financially possible, towns and cities should consider a range of green infrastructure as part of a staged process.

Investing funds upfront to convert towns and cities in Aotearoa into sponge cities will be the most financially efficient approach over time. However, as towns and cities simultaneously prepare to deal with increasing flood hazards, a staged approach may be more realistic for some.



Even small, incremental steps to make urban areas spongier can have a swift impact.

Recent modelling of a large city and a small regional town in Aotearoa found that where 10 per cent of a given area incorporated green infrastructure, peak rate and total runoff volume in that sub-catchment could be reduced by 50–75 per cent.²⁴⁴

This research compared varying rainfall intensities and different types of green infrastructure. Even when only a very small area

of the whole catchment was converted (less than 1 per cent), modelling showed a reduction in the potential impacts of extreme precipitation events. This suggests the strategic implementation of targeted green infrastructure areas can be hugely effective.

Of particular interest in the results was the efficiency of relatively cheap alternatives such as permeable paving and bioretention technology. The authors concluded that many small projects – and a combination of different types of solutions – could potentially be even better than incorporating just a few big ones. These are particularly useful findings for towns considering how best to retrofit their existing built areas.

However, incremental approaches should be incorporated as part of a long-term strategic vision rather than in a piecemeal way. This ensures the investment is targeted to locations with the greatest capacity to reduce flood risks.



The alternative... is that we continue with our 'Groundhog Day' approach to flood policy, but with the unpleasant twist that with each repeated failure to understand the consequence of our actions, things get worse.²⁴⁵



Heather Wilkins

PUTTING DOWN ROOTS: THE IMPORTANCE OF NATIVES

By WSP principal landscape architect **Heather Wilkins**

The putaputāwētā (marble leaf) tree is a beautiful member of Aotearoa New Zealand's native flora. Thriving in wet conditions, the species is named after wētā that live in holes in its trunk. Come autumn, its masses of white flowers and small chewy berries attract flocks of insects and birds.

Since Aotearoa New Zealand separated from the ancient supercontinent of Gondwana, the native plant species found here have had millions of years to adapt to local rainfall patterns, humidity, temperature, and soil type – along with developing a symbiotic relationship to our unique fauna. As a result, we boast a dazzling array of indigenous plants from towering trees to small shrubs, climbers, and grasses.

Native plants such as putaputāwētā play an important role in flood mitigation and stormwater management. As water soaks into the ground, some is taken up by the plants and some evaporates out of the soil. At the same time, leaves emit some of the water they've picked up.

The putaputāwētā (marble leaf) tree.



This process is performed by all plants, but due to their superior adaptation to local conditions, native plants are generally more effective at using water. In places with thick canopies and lush undergrowth, they're also better at deflecting water - slowing it down before it hits the ground.

A study from Scion reveals the incredible sponginess of Aotearoa New Zealand's native forests. Data from Mahurangi Forest over Auckland Anniversary weekend and during Cyclone Gabrielle shows 60 percent of that intense rainfall was held within the forest, preventing excess runoff.²⁴⁶ Elsewhere, native planting along streams and rivers in Marlborough has been effective at mitigating flooding in catchment areas.²⁴⁷



INSPIRING URBAN TRANSFORMATION WITH NATIVE PLANTING

While we can't turn towns and cities into native forests, we can incorporate more natural systems and processes into our urban areas. Integrating well-designed (and properly cared for) native planting is an effective and cost-efficient way of bridging the gap between our built and natural environments.

Reducing impervious surfaces and increasing permeable areas of planting is a simple first step. This approach is often overlooked as a tool in the climate fight, due to competing space demands from other infrastructure. It also has significant benefits for biodiversity and potential for 'cultural harvest,' and can reduce urban heat islands.²⁴⁸

Over the past few decades, attitudes towards native planting have changed for the better. There's now greater recognition of its cultural and social values, and biodiversity benefits. In contemporary Aotearoa New Zealand, decorative exotic planting has lost much of its significance - especially in public spaces. In fact, most local authorities now prioritise the use of native species in public projects.

Take a stroll along Wellington's waterfront and see the beauty of such nature-based approaches. Developed in 2006, Waitangi Park uses water-loving natives to help manage the flow of stormwater. The entire area used to be a wetland fed by the Waitangi Stream before urbanisation. It's wonderful to see this part restored to a truer version of its former self.

Further south in Christchurch is the Dudley Creek waterway. An award-winning flood remediation project run by WSP, Beca and Eos saw flooding in the creek reduced to pre-earthquake levels. Along with waterway widening and infrastructure improvements, riparian and native tree planting was a strong feature of the project, helping inhibit flood capacity at times of peak flow - also providing an inviting and accessible corridor for locals and visitors. Collaboration between technical specialists, council organisations and community was a big part of the project's success.

Dudley Creek, Christchurch



To address these challenges, it's important that urban planners and landscape architects continue to work closely with the nursery industry to keep genetic plant material diverse, and with the science community to identify and use resilient local varieties that are better able to take the knocks.

CAREFUL PLANNING NEEDED

Landscape architects are fond of saying 'right plant, right place'. Much of that is about understanding the regional significance of a plant species, its relationship to other species, and what it needs to succeed.

Walk down a major throughfare and it's likely you'll see the consequences of poor spatial planning, where the built environment and infrastructure has been prioritised over natural systems and processes. All too often, natives in urban public areas are confined to narrow strips along the perimeters of new developments – usually as an afterthought to meet minimum requirements.

It's far better to take a cue from what natives are already thriving in an area and how they function in the water cycle. These days, landscape architects are also benefitting from scientific research into naturally occurring ecosystems and what would once have been the dominant land cover.

Using more native plants in urban areas is a powerful way to create a greener and more sustainable future. So, let's prioritise the right plant for the right place and embrace the beauty and benefits of naturally occurring ecosystems, while also making things a little easier when the heavens open!



BUT IT'S NOT ALL PLAIN SAILING

There's an inherent risk in propagating any plants – let alone natives. After all, they're living organisms that survive or die. For this reason, it's important to prepare plant supply contracts well in advance – especially if 'eco-sourcing' plants, where seed is gathered from local, naturally occurring populations. This too can be tricky when you consider some projects require tens of thousands of natives and have complex construction contract arrangements.

Thanks to climate change, plants of all varieties are at risk of being exposed to more pathogens.²⁴⁹ We're already seeing this, with myrtle rust and Kauri dieback diseases running rampant. Warm, moist environments are part and parcel of climate change, and we need to prepare ourselves for the arrival of more such diseases.

Making it happen

IDENTIFY AREAS AT THE GREATEST RISK AND PRIORITISE SUPPORT



RECOMMENDATIONS:

- ▶ **Continue to fund work on the flood hazard and risk assessment database** in the long-term, and improve this over time.
- ▶ **Supplement the information provided by identifying the locations that will need the most support** in the short and long term.
- ▶ **Develop a national risk assessment and planning strategy prioritising the localised support needed** to mitigate flooding risks in urban areas. The strategy will need to be a living document that can change as climate change science improves and develops.

Risk assessment and adaptation planning for increased flooding need to take place both at national and local level.

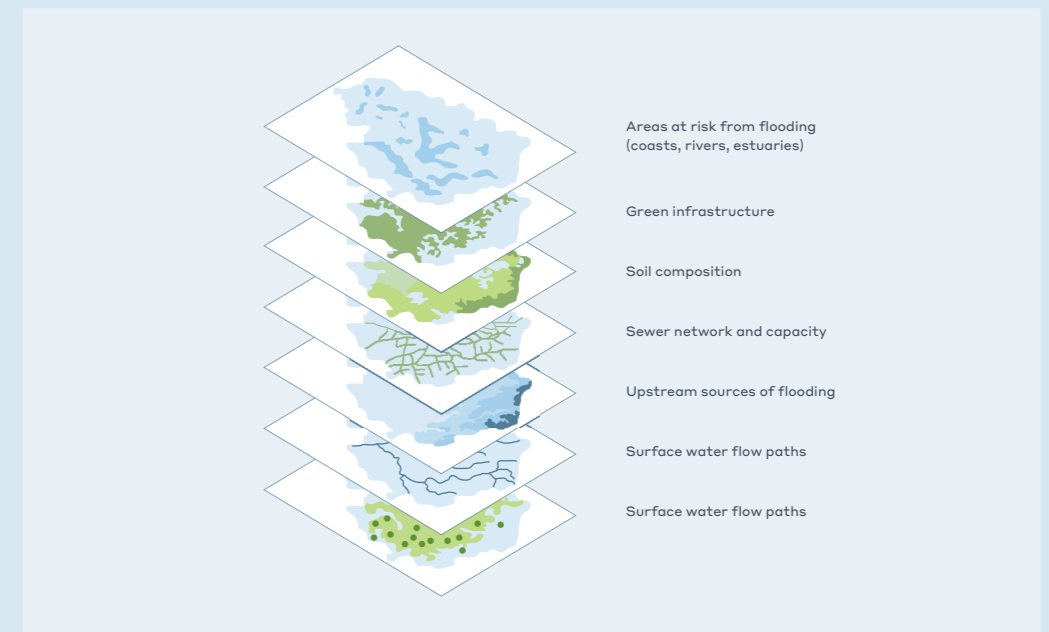
As discussed earlier in this report,

Aotearoa New Zealand does not yet have a national database that can show the relative risks of flooding in different urban areas. It is not easy to compare the risks in Dunedin with the risks in Napier, for example, nor to predict how this will change over time with climate change.

An MBIE Endeavour project currently underway is expected to provide information on flood risks now and under different climate change scenarios. The project will produce an updateable nationally consistent flood hazard and risk assessment database.²⁵¹ When completed it will provide an extremely valuable tool to help prioritise which urban areas may need more investment sooner, or other support from the national level.

However, once complete, the information provided will need to be supplemented by information from local areas about their local infrastructure, and their capacity to plan for and respond to hazards. This is not straightforward. White points to seven 'layers' of information needed to make good decisions about absorbent cities (Figure 14).

Figure 14. Different layers of knowledge needed in urban areas to become an absorbent city. Adapted from 'The Absorbent City' by Iain White.³⁹



At present, some cities may have developed many of these, whereas smaller places may have just one, or none.

Bringing this various information together, at both the national and local level, will enable comprehensive and long-term plans to be developed about which areas in Aotearoa New Zealand are particularly vulnerable, and which need additional support. This analysis will take time and require ongoing investment.

Given what is coming in terms of increasing hazards, it is essential

this risk assessment takes place and is accompanied by long-term planning as urgently as possible. As the Global Commission on Adaptation points out, making risk visible is the best way to ensure climate impacts are integrated into all planning decisions.²⁵²

Aotearoa New Zealand's first national climate change risk assessment, published in 2020, did not break down flood risks by area.²⁵³ Future risks assessments could do this as more information becomes available, and it would make sense to do so.

FUND SPONGE CITIES UPFRONT TO SAVE MONEY LATER



RECOMMENDATIONS:

- ▶ **Aim for a coordinated, comprehensive, large-scale approach** - at least in the most at-risk cities and towns. This may require co-investment between local and central government.
- ▶ **Develop and agree a national funding approach** to ensure those urban areas with the least resources are still able to prepare themselves for climate change.
- ▶ **Spread costs across stakeholders in the public and private sector** by requiring and/or incentivising practices that will reduce stormwater runoff.

Early adaptation clearly makes the most sense, financially. As mentioned in the previous chapter, the Global Commission on Adaptation concluded that early adaptation is in countries' strong economic self-interest, with an overall rate of return on investments in improved resilience showing cost-benefit ratios as high as 10:1, or higher.

Nevertheless, the costs involved are likely to be considerable. In China, billions of dollars were set aside for just a few cities.

Central government has put some thought into this already. The National Adaptation Plan includes several actions on investing in adaptation, including an action to integrate adaptation into Treasury recommendations on infrastructure (Action 4.6), and into decision-making for Waka Kotahi (Action 4.7).

Aotearoa New Zealand is rather smaller than many other places that have begun sponge city implementation. Our cities tend to be more sprawling and less densely populated. That means that the cost per capita of installing sponge city solutions could be much higher. Advantages for Aotearoa New Zealand include a better ratio of green spaces in urban areas than in many other places, thanks in large part to gardens in private residences. Maintaining and improving on these, while also addressing housing shortages, will help keep costs down.

To avoid the biggest losses in the future, Aotearoa New Zealand will need a coordinated, large-scale approach rather than a piecemeal one. This means finding ways to fund a potentially very large investment, quite soon.

Setting aside the overall total cost, preparing cities for climate adaptation is complex. That will be especially true if Aotearoa New Zealand adopts a holistic approach that aims to improve other indicators such as biodiversity and human wellbeing – essential, but not straightforward. Some of the issues to be addressed in the funding space include:

- ◆ Water catchment areas don't always align with political boundaries and associated budgets.
- ◆ A small town that may have flood risks equalling a larger one, but will have a far smaller rate base to work with
- ◆ Agencies or departments responsible for a sponge city solution may not be the agency that reaps the benefits. For example, a school may pay for a sports field designed to flood when it rains heavily, but the benefits will be felt by surrounding neighbourhoods, or a transport agency may pay for a street garden, and the local council benefits in reduced stormwater treatment costs. This makes it hard to identify who should be responsible, and makes it easier to go for cheaper but less effective options when funding decisions must be made.

- ◆ Some of the benefits of sponge city approaches not being easy to calculate – such as increased quality of life, better mental health outcomes, or a long-term contribution to biodiversity. This makes it harder to make good investment decisions.

The proposed changes under the Affordable Water Reforms programme could address some of these issues, for example by making it easier to spread costs across a bigger base of people within a region. They may however also add other layers of complexity, as the new water service entities juggle questions of jurisdiction with local councils.

What is clear from the research is that there is no silver bullet to solve the potentially very large funding gap facing councils and network operators in Aotearoa New Zealand as they prepare for climate change. In likelihood, a toolbox approach to funding will be needed, whereby costs are shared between national and local governments, the new water service entities, and the private sector (including developers, and business and house owners).²⁵⁴

The first approach at the local level should be to incentivise (or require) practices that will reduce the quantity of stormwater entering existing grey

infrastructure.²⁵⁵ This approach can help spread the costs across several stakeholders and thus reduce the costs shouldered by ratepayers.

A number of options for this were discussed in the previous chapter, and include:

- ◆ Finding incentives for private residential property owners to install swales or green roofs, or replace lawns with trees.
- ◆ Changing development practices around topsoil removal and requiring developers to leave a greater area of new developments unsealed, or to pay more towards the development of new public green spaces.
- ◆ Incentivising private investment in green infrastructure through use of tax incentives, for example, incentives (such as green branding certification) for local businesses who install bioretention devices on unused spaces of land.

Using a runoff-based stormwater fee for businesses and residential property is also a common means of funding stormwater services in the United States, Canada, United Kingdom, and Europe.²⁵⁶ Aotearoa New Zealand could consider something similar.

Other solutions proposed in the literature include:

- ◆ 'Green-score' accreditation schemes to encourage better green space outcomes on private land.²⁵⁷
- ◆ Land value capture - green infrastructure can increase the value of land nearby quite significantly.²⁵⁸
- ◆ Betterment charges or hypothecated rates paid by ratepayers in areas with new green infrastructure.²⁵⁹

Settling on the right options for Aotearoa New Zealand will require careful deliberation - the key point is that there are plenty of international examples to draw upon for inspiration and ideas.

Although there is potential to spread some costs in these ways, it is clear significant investment will also need to be found at both local and national government level to pay for sponge city solutions.

Although stormwater management is traditionally a local matter, the impacts of climate change are potentially so huge, and so unevenly distributed, that central government will have to play a role. Failure to do so will likely incur even greater costs down the line in compensation payments for uninsurable or destroyed homes,

or in foregone tax revenue if the social and economic impacts of climate change are as serious as anticipated. Investing in adaptation now will give Aotearoa New Zealand the best hope of a resilient future.

As one example of a way forward, regional and unitary councils recently submitted a proposal to central government suggesting a system of co-investment between local and national government to deal with risks posed by sea level rise and increasing pluvial flooding.²⁶⁰ The current government acknowledged the need for a national funding model for flood protection in a 2020 Cabinet paper. Though this has not yet been developed into policy, government has put some substantial sums towards this already.²⁶¹

One example of the Government investing in local flood mitigation efforts is the Kānoa Climate Resilience Flood Protection Programme initiative. This programme aims to develop and upgrade crucial river management and flood protection schemes via a co-investment partnership approach with central government. Through this initiative, \$312 million worth of flood resilience projects are being delivered around the country.²⁶²

The yet to be released Climate Adaptation Bill is expected to set out how funding should be split between government and local governments to recover managed relocation costs for people and businesses forced relocate due to climate change. Similar decisions will need to be made about how other types of adaptation should be funded - whether in the Bill or elsewhere.



“Climate change is expected to lead to more frequent and intense floods, and adapting to these increasing risks in the face of climate change comes with costs that can no longer be shouldered at a regional level alone”. Te Uru Kahika ²⁸⁰

While there is no silver bullet for funding sponge cities, there are a number of alternatives to consider. It's clear that relying solely on local councils to fund essential infrastructure is not going to be sufficient in many places. The new regional Water Service Entities may be better funded, but in all likelihood central government will still need to play a significant role.

RISE ABOVE SILOS AND OTHER STRUCTURAL BARRIERS



RECOMMENDATIONS:

- ▶ **Ensure clear national leadership on nature-based sponge city implementation, supported by a cross-agency work programme.**
- ▶ **Establish a sponge city or nature-based solutions stormwater expert advisory group** at national level, to identify research and funding needs, and advise on best practice and policy approaches.
- ▶ **Establish catchment scale working groups within councils and WSEs to implement sponge city approaches,** and fund these appropriately.

While the benefits of taking a holistic, nature-based approach to flood mitigation seem unarguable given the multiple challenges our urban areas face, the real difficulty lies with putting the approach into practice.

A qualitative study in Aotearoa New Zealand, in which 46 sector professionals were interviewed, identified a number

of barriers to joint action on climate change (including uptake of nature-based solutions).²⁶³

Some of the key barriers were political and institutional in nature – issues such as institutional fragmentation (silos), inconsistency in policies, lack of governance frameworks for implementation, and lack of political will.

The way our governance is structured means functions are often siloed, both at national and local levels. One agency, or one department within a council, will be responsible for biodiversity, another for flood mitigation, another for transport, and a fourth for parks and recreation. Decisions take longer to reach where many departments must work together to achieve goals. There can be uncertainty about roles and leadership.²⁶⁴

At the same time, the practicality of flood mitigation happens at several different spatial scales, from the whole catchment (such as river dredging), down to the level of individual properties (such as requiring homeowners to install rain tanks). This again makes it harder to coordinate, as plans, policies and agencies may be focused on work within specific spatial scales.²⁶⁵

These factors make it harder to support an integrated approach

that delivers a wide variety of benefits.²⁶⁶ At the national level, this can mean best practice is incorporated in some strategies, and not others – or worse: policies conflict. At the local level, decisions can be made for the easy, cheap, or 'known' option – often grey infrastructure – rather than the one that will give the best outcomes over the longer term and across a wider range of indicators.

One solution at the local level, already implemented in at least one council, is to set up a cross-departmental network that brings together staff from all relevant departments to develop a collective understanding of the implications of climate change, and agree on strategy.²⁶⁷

At the national level, clear strategy and a shared vision across departments is essential, including across environment, transport, housing, and internal affairs. Reynold's research highlighted the potential deep benefits to be gained by creating a coalition of people working on nature-based solutions who could share learning and insights, identify high priority actions to speed transition to adaptation, and identify good examples of the linkages between climate mitigation, climate adaptation and biodiversity loss.



ENCOURAGE COMMUNITY INVOLVEMENT TO ACHIEVE MORE EQUITABLE OUTCOMES



RECOMMENDATION:

- ▶ **Encourage community involvement** in nature-based solutions and climate resilience initiatives. Ensure voices that are typically under-represented are heard.

The impacts of increased flooding on individuals within urban areas, and their ability to adapt to or cope with those changes will be uneven, and will likely reflect existing inequalities. Some people will be disproportionately affected by financial impacts, or lack the resources to adapt – such as low-income and beneficiary households. Others will have specific adaptation needs – such as older people and disabled people.²⁶⁸

Involving communities in decision making around sponge city approaches to climate adaptation will be a long-term process, rather than a one-off.²⁶⁹ Councils and the new water service entities will need to be confident that when they engage they are hearing from

communities that are most at-risk, and that the community has sufficient trust, confidence and capacity to respond.



“At all levels disaster prevention measures are regularly designed without engaging the insights, wisdom and capacities of local and diverse communities. As a result, we all suffer from a less informed, less inclusive and ultimately less effective approach to reducing disaster risk.” IFRC Under Secretary General Xavier Castellanos.²⁸¹

IMPROVE ACCESS TO GOOD INFORMATION



RECOMMENDATIONS:

- ▶ **Create a nature-based sponge city information portal** – a one-stop shop for decision-makers who want to understand the science, identify their risks, and learn what to do about it.
- ▶ **Invest in public and professional education** on the need to adapt and the potential of nature-based solutions.

Reynolds identifies a clear need in Aotearoa New Zealand for better tools (for example to compare options), clearer science (for example on the value of biodiversity), and consolidation of current evidence and knowledge about why to favour nature-based solutions, and how to do it.²⁷⁰

A lack of quality information on nature-based solutions, including their suitability and application in different contexts, can hamper innovation and risk taking from decision-makers, including planners, engineers, private land-owners, councils, and political decision-makers.²⁷¹ Because the evidence base for blue-green

infrastructure, while compelling, is still being developed, there is still a widespread lack of knowledge, awareness and recognition of its potential.²⁷²

An example of good practice in this area is Naturvation, funded by the European Commission.²⁷³ Naturvation is an online toolbox that promotes the use of nature-based solutions in urban environments as an alternative to grey infrastructure and technology-driven solutions. The tool sets out information for local authorities in Europe, including how to finance projects, promote innovation, learn from international research and engage with communities.

A similar toolbox for Aotearoa New Zealand could help decision-makers be less wary of trying something new. Ideally, a database with information about flood risks across the country would also provide information on best practice solutions, as part of a one-stop shop. This could potentially sit alongside the information portal for climate adaptation proposed under the national adaptation plan.²⁷⁴

Alongside better information, there is a need for education and professional development on nature-based solutions across a range of sectors to help mainstream the approach.²⁷⁵

The general public will also need to be educated on the need for these approaches, to develop buy-in over the long term, to make it politically palatable to spend what needs to be spent and to ensure communities are able to consult on issues from a degree of knowledge.

Pittsburg, Pennsylvania USA



INVEST IN RESEARCH AND DEVELOPMENT



RECOMMENDATIONS:

- ▶ **Invest in research and development** to help prepare for climate change, and help choose the most appropriate sponge city solutions for each location.
- ▶ **Invest in further development and standardisation of tools** that can assess whole of life costs and incorporate non-monetary benefits.

Moore et al. highlight a number of gaps in Aotearoa New Zealand research that, if filled, could help prompt better uptake of sponge city approaches.²⁷⁶ Future areas of research could include the best ways for councils to incentivise the uptake of green infrastructure, the role of green solutions in climate change adaptation and/or mitigation, tools that can help select and prioritise the best approach for a specific location, and the potential for public health economics to contribute to a more comprehensive assessment of the benefits of WSUD.

Investing in research and development could also help Aotearoa New Zealand make

better and more effective decisions about flood-related climate adaptation. Better technologies and tools could help us assess the performance of different sponge city solutions across multiple potential climate scenarios, for example, or help measure and evaluate the cost-benefit (including the non-financial benefits) of those solutions.

As one high-tech example, creating 'digital twins' of cities shows good promise as a technology to help us map risks and choose the best solutions in different scenarios.²⁷⁷ A digital twin is a dynamic digital representation of the built and natural environment that can be used to plan, visualise, report on and control assets and operations.²⁷⁸ Creating a digital twin of a city can help us to understand what is happening in terms of stormwater management, what is likely to happen in different future scenarios and then model potential solutions in terms of effectiveness. A digital twin has already been developed for Wellington, though it doesn't yet cover weather-related information.



Conclusion

AOTEAROA NEW ZEALAND, ALONG WITH MANY OTHER COUNTRIES, IS FACING CLIMATE AND BIODIVERSITY CRISES. THIS REPORT HAS EXAMINED JUST ONE ASPECT OF THE IMPACTS THESE CRISES WILL CAUSE - RAINFALL, AND THE CERTAINTY THAT THIS WILL INCREASE IN BOTH FREQUENCY AND INTENSITY OVER TIME. WHILE SOME TOWNS WILL BECOME WETTER, AND OTHERS DRIER, ALL ARE LIKELY TO EXPERIENCE MORE EXTREME PRECIPITATION EVENTS, AND ALL NEED TO BE MAKING PLANS NOW ON HOW THEY INTEND TO MANAGE THIS.

It is the clear recommendation of this report that Aotearoa New Zealand cities need to become sponge cities. Nature-based sponge city approaches provide a promising way to help conceptualise and coordinate the work that urgently needs to be done to prepare for the impacts of climate change. While sponge cities are a relatively new concept, the ideas behind them are not, and there is good evidence to support the approaches they propose. They are also compelling from a cost-benefit point of view.

Adopting this approach will not be straightforward, and nor will it be cheap. However, in many places there will be no real alternative as the cost of enhancing the capacity of our pipes to deal with increasing water load becomes ever more prohibitive. The evidence strongly suggests that failing to prepare will be considerably more expensive. Perhaps, even more importantly, failing to act now will lead to multiple heartbreaks as people needlessly lose their homes and businesses.

The vulnerability of cities to intense and increasing rainfall – and the potential of sponge city approaches to reduce risk and improve resilience – are both high in the public consciousness following major rain events during 2023. This awareness, combined with multiple regulatory reform processes currently underway, presents an important opportunity to kickstart sponge city approaches in Aotearoa New Zealand.

Synergism of Pervious Pavement on Stormwater Management and Urban Heat Island Mitigation: A Review of Its Benefits, Key Parameters, and Co-Benefits Approach". In Water Research 221, (2022). <https://doi.org/10.1016/j.watres.2022.118755>.

142 Ksenia I. Aleksandrova, Wendy J McWilliam, and Andreas Wesener. "Status and Future Directions for Residential Street Infrastructure Retrofit Research". In Urban Science (2019). <https://researcharchive.lincoln.ac.nz/bitstream/handle/10182/10675/urbansci-03-00049.pdf?sequence=1&isAllowed=y>.

143 Severn Trent Water. "Doing Right by Our Water: Reducing Flood Risk in Mansfield". Accessed 30 June 2023. <https://www.stwater.co.uk/wonderful-on-tap/green-recovery/mansfield-sustainable-flood-resilience/>.

144 Yu, "The Sponge City: Planning, Design and Political Design", (2021).

145 Kia Kaha Te Reo Māori and Water NZ. "Ngā Momo Wai", 2018. https://www.waternz.org.nz/achment?Action=Download&Attachment_id=3346.

146 Yu, "The Sponge City: Planning, Design and Political Design", (2021).

147 "

148 Parliamentary Commissioner for the Environment, Are We Building Harder, Hotter Cities? 2023.

149 International Institute for Sustainable Development, Summary Report, 2023.

150 Ministry for the Environment, Aotearoa New Zealand's First National Adaptation Plan, 2022, Action 5.16.

151 New Zealand Government. "Wellbeing Budget 2023. Support for Today. Building for Tomorrow.". New Zealand Government 18 May 2023. <https://budget.govt.nz/budget/pdfs/wellbeing-budget/b23-wellbeing-budget.pdf>.

152 Abbie Reynolds. Twin Crises, Many Solutions. The Barriers to Addressing Climate Change and Biodiversity Loss Together. Next Foundation, 2023.

153 Ira and Simcock, Understanding Costs and Maintenance of WSUD in New Zealand, 2019.

154 Cabinet Economic Development Committee. Minute of Decision. Improving Resilience to Flood Risk and Supporting the Covid-19 Recovery. Wellington: New Zealand Government, 1 July 2020.

155 Gibbens, "More Than 400,000 Residential Buildings in Flood Prone Areas."

156 Stormwater Technical Working Group. Proposed Approach to the Transfer of Stormwater Functions and Delivery to New Water Service Entities 2021, [https://www.dia.govt.nz/diawebsite.nsf/Files/Three-waters-reform-programme/\\$file/stormwater-technical-working-group-transition-plan-report-25-august-2021.pdf](https://www.dia.govt.nz/diawebsite.nsf/Files/Three-waters-reform-programme/$file/stormwater-technical-working-group-transition-plan-report-25-august-2021.pdf).

157 Tim Murphy. "Auckland's Anti-Flooding Plan Now 'on Steroids'" 24 May 2023. https://www.newsroom.co.nz/aucklands-anti-flooding-plan-now-on-steroids?utm_source=Newsroom&utm_campaign=ab288d9235-Daily_Briefing+24.05.2023&utm_medium=email&utm_term=0_71de5c4b35-ab288d9235-97981517.

158 Auckland Council. "Mayor Supports 'Making Space for Water'", 17 May 2023. <https://ourauckland.aucklandcouncil.govt.nz/news/2023/05/mayor-supports-making-space-for-water/>.

159 Rob Stock. "Government's Buyout Plan 'Hope-Inducing,' Owners of Flooded Homes Say." Stuff NZ. 01 June 2023. <https://www.stuff.co.nz/business/132208092/governments-buyout-plan-hopeinducing-owners-of-flooded-homes-say>.

160 Parliamentary Commissioner for the Environment, Are We Building Harder, Hotter Cities? 2023.

161 Ministry for the Environment, National Policy Statement for Freshwater Management 2020.

162 Reynolds, Twin Crises, Many Solutions, 2023.

163 Giles Dexter. "Climate Change Minister's Legislative Balancing Act after Gabrielle." RNZ. 20 February 2023. <https://www.rnz.co.nz/news/national/484507/climate-change-minister-s-legislative-balancing-act-after-gabrielle>.

164 National Party. "National Will Repeal RMA 2.0 Bills". 27 June 2023. https://www.national.org.nz/national_will_repeal_rma_2_0_bills.

165 Water Services Reform Programme. "Stormwater". Accessed 30 July 2023. <https://www.waterservicesreform.govt.nz/the-case-for-change/stormwater/>.

166 "

167 Stormwater Technical Working Group, Proposed Approach to the Transfer of Stormwater Functions and Delivery to New Water Service Entities 2021.

168 Finance and Expenditure Committee, Water Services Legislation Bill: Select Committee Report, June 2023. (Differing view from the Green Party).

169 Global Commission on Adaptation. Adapt Now: A Global Call for Leadership on Climate Resilience. 2019.

170 Ministry for the Environment, Aotearoa New Zealand's First National Adaptation Plan, 2022, Action 5.9.

171 NIWA, "Auckland Suffers Wettest Month in History".

172 Julia Gabel and Chris Knox. "Auckland Floods - Interactive Map: How Hard Was Your Suburb Hit? ." NZ Herald. 5 February 2023. <https://www.nzherald.co.nz/nz/auckland-floods-interactive-map-how-hard-was-your-suburb-hit/OZZ3SVMVFUENBES7C2X2ANQFME/>.

173 Fu et al., "Are Sponge Cities the Solution to China's Growing Urban Flooding Problems?", (2023).

174 WaterSmart. "How One Suburb Made It through Severe Flooding, When Those around Were Hit Hard (Press Release)". 12 February 2023. <https://www.scoop.co.nz/stories/BU2302/S00138/how-one-suburb-made-it-through-severe-flooding-when-those-around-were-hit-hard.htm>.

175 Auckland Council. "Rain Drain: Northcote's New Stormwater Infrastructure Networks Tested to the Max". Auckland Council 7 February 2023. <https://ourauckland.aucklandcouncil.govt.nz/news/2023/02/rain-drain-northcote-s-new-stormwater-infrastructure-tested-to-the-max/>.

176 Connor Whitten. "Are Flood Protections Putting New Zealanders at Greater Risk?" 1 News. 5 March 2023. <https://www.1news.co.nz/2023/03/06/are-flood-protections-putting-new-zealanders-at-greater-risk/>.

177 Iain White, "The Absorbent City", (2008).

178 Moores et al., WSUD Can Be Cost-Effective and Low-Maintenance, 2019.

179 Global Commission on Adaptation, Adapt Now: A Global Call for Leadership on Climate Resilience, 2019.

180 Oates et al., "Building Climate Resilience and Water Security in Cities", (2020).

181 Kim Harrisberg. "Are 'Sponge Cities' Enough to Curb Climate-Fueled Floods?" Thomson Reuters. 19 April 2023. <https://www.reuters.com/article/safrica-climate-change-floods/feature-are-sponge-cities-enough-to-curb-climate-fueled-floods-idINL8N34V6IO>.

182 Moores et al., WSUD Can Be Cost-Effective and Low-Maintenance, 2019.

183 Ara Associates. "Kirimoko Park (Wanaka)". Accessed 30 June 2023. <https://www.arassociates.co.nz/kirimoko-park>.

184 Moores et al., WSUD Can Be Cost-Effective and Low-Maintenance, 2019.

185 Ira and Simcock, Understanding Costs and Maintenance of WSUD in New Zealand, 2019.

186 Junqueira, Serrao-Neumann, and White, "Managing Urban Climate Change Risks."

187 Ira and Simcock, Understanding Costs and Maintenance of WSUD in New Zealand, 2019.

188 Moores et al., WSUD Can Be Cost-Effective and Low-Maintenance, 2019.

189 James Griffiths, et al. "Interpretation and Application of Sponge City Guidelines in China". In Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 378, no. 2168, (2020). <https://doi.org/doi:10.1098/rsta.2019.0222>.

190 Global Commission on Adaptation, Adapt Now: A Global Call for Leadership on Climate Resilience, 2019.

191 Ministry for the Environment, Aotearoa New Zealand's First National Adaptation Plan, 2022.

192 Resilient Cities Network. "Climate Resilient Cities". Accessed 15 July 2023. <https://resilientcitiesnetwork.org/climate-resilient-cities/>.

193 "

194 Ihirangi. Insight to the Rauora Indigenous Worldview Framework for the National Climate Change Adaptation Plan. Wellington: Ministry for the Environment, 2 March 2021, <https://environment.govt.nz/assets/publications/Exploring-an-indigenous-worldview-framework-for-the-national-climate-change-adaptation-plan.pdf>.

195 Reynolds, Twin Crises, Many Solutions, 2023.

196 Phibbs and Kenney, "Indigenous Responses to Environmental Hazard Events." IUCN, "Nature-Based Solutions".

197 Ministry for the Environment, Aotearoa New Zealand's First National Adaptation Plan, 2022, Objective NE3.

198 Reynolds, Twin Crises, Many Solutions, 2023.

199 Iain White, "The Absorbent City", (2008).

200 Parliamentary Commissioner for the Environment, Are We Building Harder, Hotter Cities? 2023, 109.

201 "

202 "

203 "

204 "

205 Federica Rosso, et al. "Pocket Parks Towards More Sustainable Cities. Architectural, Environmental, Managerial and Legal Considerations Towards an Integrated Framework: A Case Study in the Mediterranean Region". In Environmental Challenges 7, no. 100402, (2022). <https://doi.org/10.1016/j.envc.2021.100402>.

206 Ben Webster. "Tiny Forests Help Towns to Tackle Climate Change." Y, 2020.

207 Whitten, "Are Flood Protections Putting New Zealanders at Greater Risk?."

208 Suphicha Muangsri, et al. "Effectiveness of Strategically Located Green Stormwater Infrastructure Networks for Adaptive Flood Mitigation in a Context of Climate Change". In Land 11, (2022). <https://doi.org/10.3390/land1112078>.

209 Ministry of Housing and Urban Development. "Urban Growth Agenda". Accessed 30 July 2023. <https://www.hud.govt.nz/our-work/urban-growth-agenda/>.

210 Ministry for the Environment. Medium Density Residential Standards: A Guide for Territorial Authorities. Wellington: Ministry for the Environment, July 2022.

211 Reynolds, Twin Crises, Many Solutions, 2023.

212 Robert I. McDonald, et al. "Denser and Greener Cities: Green Interventions to Achieve Both Urban Density and Nature". In People and Nature 5, no. 1, (2023). 84, <https://doi.org/https://doi.org/10.1002/pan3.10423>, <https://besjournals.onlinelibrary.wiley.com/doi/abs/10.1002/pan3.10423>.

213 Parliamentary Commissioner for the Environment, Are We Building Harder, Hotter Cities? 2023, 101.

214 Aleksandrova, McWilliam, and Wesener, "Status and Future Directions for Residential Street Infrastructure Retrofit Research", (2019).

215 Parliamentary Commissioner for the Environment, Are We Building Harder, Hotter Cities? 2023.

216 "

217 Wang et al., "Performance Synergism of Pervious Pavement on Stormwater Management and Urban Heat Island Mitigation", (2022).

218 Parliamentary Commissioner for the Environment, Are We Building Harder, Hotter Cities? 2023.

219 "

220 Ministry for the Environment, Medium Density Residential Standards: A Guide for Territorial Authorities, July 2022.

221 Parliamentary Commissioner for the Environment, Are We Building Harder, Hotter Cities? 2023.

222 "

223 "

224 Protection of wetlands is already required by the National Policy Statement for Freshwater Management, though exceptions can currently be made for some types of urban development. Ministry for the Environment, National Policy Statement for Freshwater Management 2020, 26.

225 Ira and Simcock, Understanding Costs and Maintenance of WSUD in New Zealand, 2019.

226 United States Environmental Protection Agency, "Protecting Water Quality from Urban Runoff".

227 Auckland Regional Council. Hydrological Effect of Compaction Associated with Earthworks. May 2009.

228 Parliamentary Commissioner for the Environment, Are We Building Harder, Hotter Cities? 2023.

229 Auckland Regional Council, Hydrological Effect of Compaction Associated with Earthworks.

230 Bradbury, Water City : Practical Strategies for Climate Change.

231 Ira and Simcock, Understanding Costs and Maintenance of WSUD in New Zealand, 2019.

232 Department for Environment Food and Rural Affairs. The Review for Implementation of Schedule 3 to the Flood and Water Management Act 2010. United Kingdom 2023.

233 E. C. O'Donnell, J. E. Lamond, and C. R. Thorne. "Recognising Barriers to Implementation of Blue-Green Infrastructure: A Newcastle Case Study". In Urban Water Journal, 14, no. 9, (2017). <https://doi.org/10.1080/1573062X.2017.1279190>.

234 Alide Elkink. "Hydraulic Neutrality". In Build 171, (2019). <https://www.buildmagazine.org.nz/assets/PDF/Build-171-36-Design-Right-Hydraulic-Neutrality.pdf?#:~:text=Move%20to%20hydraulic%20neutrality&text=With%20this%20approach%2C%20any%20rainfall,piped%20or%20by%20street%20drainage>.

235 Parliamentary Commissioner for the Environment, Are We Building Harder, Hotter Cities? 2023.

236 Margaret Stanley. "Where Have All the Trees Gone?" RNZ. 29 October 2018. <https://www.rnz.co.nz/national/programmes/afternoons/audio/2018668806/where-have-all-the-trees-gone>.

237 Global Forest Watch, "Interactive Charts".

238 City of Portland Oregon. "Treebate: Get a Credit on Your Utility Bill When You Purchase and Plant a Tree". Accessed 25 July 2023. <https://www.portland.gov/bes/grants-incentives/about-treebate>.

239 Ira and Simcock, Understanding Costs and Maintenance of WSUD in New Zealand, 2019.

240 Iain White, "The Absorbent City", (2008).

241 Juliana Reu Junqueira, Silvia Serrao-Neumann, and Iain White. "Developing and Testing a Cost-Effectiveness Analysis to Prioritize Green Infrastructure Alternatives for Climate Change Adaptation". In Water and Environment Journal (2022). <https://doi.org/https://doi.org/10.1111/wej.12832>.

242 James Renwick. "The Coast Is under Threat." Newsroom. June 12, 2023. https://www.newsroom.co.nz/the-coast-is-doomed?utm_source=Newsroom&utm_campaign=f950ee463c-Daily_Briefing+12.06.2023&utm_medium=email&utm_term=0_71de5c4b35-f950ee463c-98007622.

243 Junqueira, Serrao-Neumann, and White, "Developing and Testing a Cost-Effectiveness Analysis", (2022).

244 Junqueira, Serrao-Neumann, and White, "Using Green Infrastructure as a Social Equity Approach", (2022).

245 Graham Houghton and Iain White. "Groundhog Day: The Great Floods of 2015". In Geography 104, no. 2, (2019). <https://doi.org/10.1080/00167487.2019.12094070>.

246 Scion, "Forest Sponges: New Research Reveals How Forests Absorb Water in Extreme Weather (Press Release)".

247 Jennifer Eder. "Young Native Plantings Prove Hardy against Flood Damage in Te Taihū." Stuff. 18 September 2022. <https://www.stuff.co.nz/environment/129885050/young-native-plantings-prove-hardy-against-flood-damage-in-te-taihu>.

248 F Aram et al., "Urban Green Space Cooling Effect in Cities", (2019).

249 Brajesh K. Singh, et al. "Climate Change Impacts on Plant Pathogens, Food Security and Paths Forward". In Nature Reviews Microbiology 2023/05/02 (2023). <https://doi.org/10.1038/s41579-023-00900-7>.

250 Yu Kongjian. "A Green Sponge in the City – Nature-Based Solutions Benefiting Urban Planning". In Climate Diplomacy, (2020). <https://climate-diplomacy.org/magazine/environment/green-sponge-city-nature-based-solutions-benefiting-urban-planning>.

251 Lane, "Project Overview - Increasing Flood Resilience across Aotearoa. Power Point Presentation".

252 Global Commission on Adaptation, Adapt Now: A Global Call for Leadership on Climate Resilience, 2019.

253 Ministry for the Environment, National Climate Change Risk Assessment for Aotearoa New Zealand: Main Report, 2020.

254 Moores et al., WSUD Can Be Cost-Effective and Low-Maintenance, 2019.

255 Stormwater Technical Working Group, Proposed Approach to the Transfer of Stormwater Functions and Delivery to New Water Service Entities 2021.

256 Moores et al., WSUD Can Be Cost-Effective and Low-Maintenance, 2019.

257 Parliamentary Commissioner for the Environment, Are We Building Harder, Hotter Cities? 2023.

258 Moores et al., WSUD Can Be Cost-Effective and Low-Maintenance, 2019.

259 Oates et al., "Building Climate Resilience and Water Security in Cities", (2020).

260 Te Uru Kahika/Regional and Unitary Councils Aotearoa, Before the Deluge, 2022.

261 Cabinet Economic Development Committee, Minute of Decision. Improving Resilience to Flood Risk and Supporting the Covid-19 Recovery, 1 July 2020.

262 Te Uru Kahika/Regional and Unitary Councils Aotearoa, Before the Deluge, 2022.

263 Reynolds, Twin Crises, Many Solutions, 2023.

264 Janet Stephenson, et al. "Engaging with Communities for Climate Change Adaptation. Introducing Community Development for Adaptation". In Policy Quarterly 16, no. 2, (2020). <https://resiliencechallenge.nz/outputs/engaging-with-communities-for-climatechange-adaptation-introducing-communitydevelopment-for-adaptation/>.

265 "

266 Junqueira, Serrao-Neumann, and White, "Managing Urban Climate Change Risks."

267 Stephenson et al., "Engaging with Communities for Climate Change Adaptation", (2020).

268 Ministry for the Environment, Aotearoa New Zealand's First National Adaptation Plan, 2022.

269 Stephenson et al., "Engaging with Communities for Climate Change Adaptation", (2020).

270 Reynolds, Twin Crises, Many Solutions, 2023.

271 "

272 O'Donnell, Lamond, and Thorne, "Recognising Barriers to Implementation of Blue-Green Infrastructure: A Newcastle Case Study", (2017).

273 The Naturvation Project. "Naturvation: Cities, Nature, Innovation". Accessed 12 July 2023. <https://naturvation.eu/>.

274 Ministry for the Environment, Aotearoa New Zealand's First National Adaptation Plan, 2022, Action 3.2.

275 Reynolds, Twin Crises, Many Solutions, 2023.

276 Moores et al., WSUD Can Be Cost-Effective and Low-Maintenance, 2019.

277 Te Waihangā New Zealand Infrastructure Commission. Rautaki Hanganga O Aotearoa. New Zealand Infrastructure Strategy 2022 - 2052 Wellington: New Zealand Infrastructure Commission, Te Waihangā, 2022.

278 WSP Australia. "WSP Tool Demystifies Digital Twins". 10 November 2022. <https://www.wsp.com/en-au/news/2022/wsp-tool-demystifies-digital-twins>.

279 Iain White, "The Absorbent City", (2008).

280 Te Uru Kahika/Regional and Unitary Councils Aotearoa, Before the Deluge, 2022.

281 United Nations Office for Disaster Risk Reduction (UNDRR). "Inclusive Disaster Risk Reduction Means Resilience for Everyone". 2023. <https://sendaiframework-mtr.undrr.org/news/inclusive-disaster-risk-reduction-means-resilience-everyone>.

