HAWKE'S BAY
REGIONAL COUNCIL
TE KAUNIHERA Ā-ROHE O TE MATAU-A-MĀUI

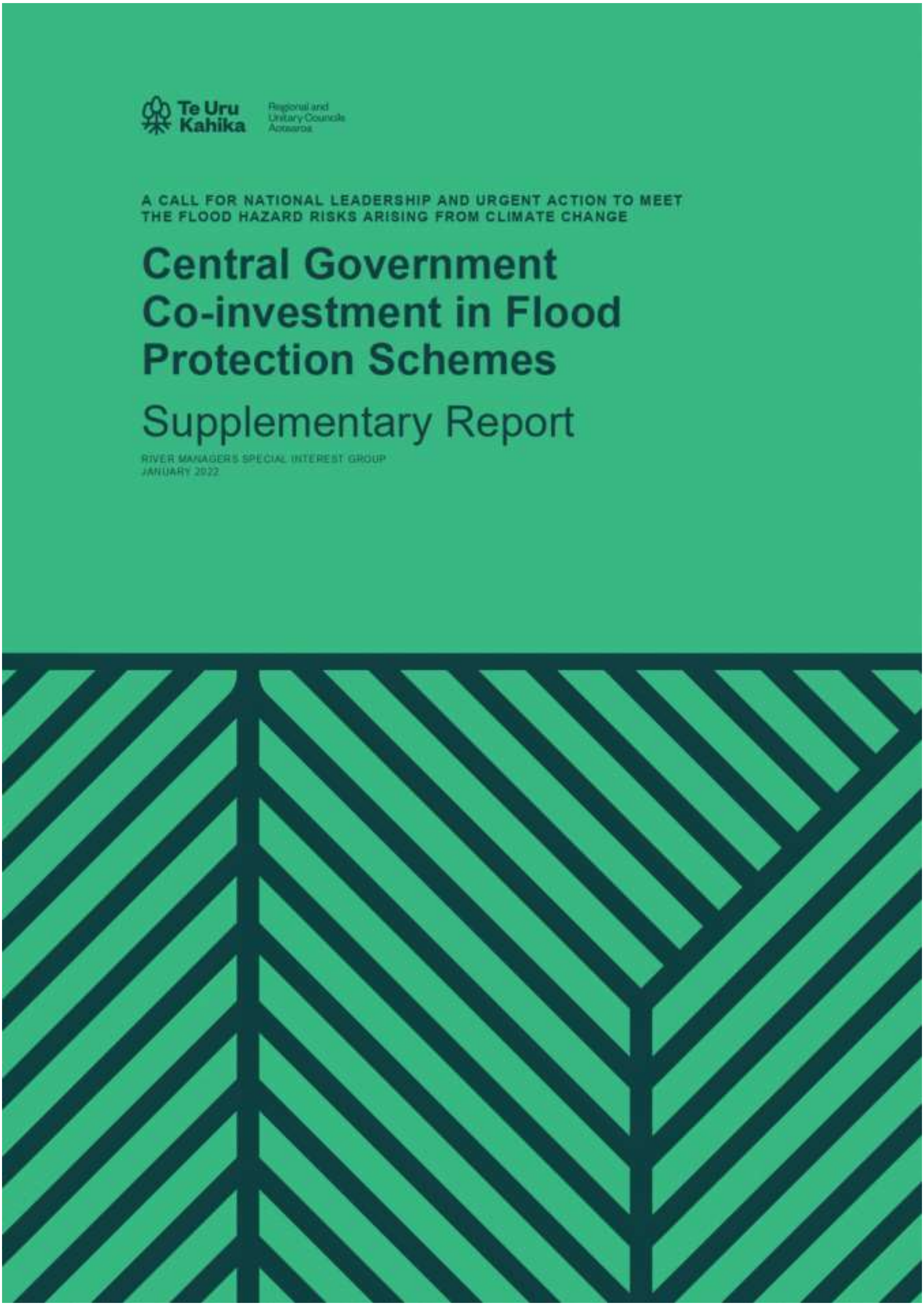
Meeting of the Environment and Integrated Catchments Committee

Date: 11 May 2022

Time: 9.00am

Venue: Council Chamber
Hawke's Bay Regional Council
159 Dalton Street
NAPIER

Attachments Excluded From Agenda



Te Uru Kahika
Regional and Unitary Councils Aotearoa

A CALL FOR NATIONAL LEADERSHIP AND URGENT ACTION TO MEET THE FLOOD HAZARD RISKS ARISING FROM CLIMATE CHANGE

Central Government Co-investment in Flood Protection Schemes

Supplementary Report

RIVER MANAGERS SPECIAL INTEREST GROUP
JANUARY 2022

Central Government Co-investment in Flood Protection Schemes
Supplementary Report

January 2022
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Preface

Purpose

The **purpose** of this report is to add weight to a 2019 regional council co-investment business case for central government co-investment in flood protection schemes. This is because the evidence continues to grow supporting the importance and urgency of government returning to the table to resource and help focus purposeful, timely and meaningful actions that result in practical flood protection scheme improvements.

Outcome

The outcome sought from these co-investment decisions would be New Zealanders having assurance that suitable 'fit-for-the-future', risk-aligned, climate change resilient and environmentally sensitive flood protection schemes are in place throughout New Zealand. This is the priority action to respond to the increased magnitude and frequency of climate-change-induced flood events. It sits alongside the need to apply a full suite of other actions e.g., spatial planning and integrated catchment management, to enhance community resilience against flood risks.

Vision

The vision underpinning this outcome is higher levels of safety, security and community resilience, enhanced protection of local and national assets and more sustainable regional economic activity. The **refocus** inherent is this vision is a necessary shift in central government attention from disaster relief and rehabilitation towards necessary 'top-of-the-cliff' mitigation of flood risks, with reduced all-up costs.

Audience for this report

The intended **audience** for this report is the Ministers for Local Government, Finance, Regional Development and Climate Change, alongside senior officials from MBIE (Kānoa) DIA, NEMA, MfE and Treasury, Environment Canterbury (who co-sponsored this report) and Regional Council CEOs and Chairs.

Requested action

The sought-after immediate action is central government urgently agreeing to co-invest in flood protection schemes. The subsequent and necessarily focused next step is to form a central government / region council group to define the quantum, timing, principles, framework, criteria, and priority projects for central government co-investment into flood protection schemes. We urge that central government commit to taking these steps.

Jenny Hughey

Chair, Environment Canterbury

Doug Leeder

Chair, Bay of Plenty Regional Council and
Chair, Regional Sector Group, LGNZ

JANUARY 2022

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Executive summary

Higher magnitude and more frequent floods are occurring

The 31 May – 2 June 2021 Ashburton / Canterbury flood event was extreme. Both branches of the Ashburton / Hakatere River burst their banks. The Defence Force was deployed to assist with potential evacuations. The State Highway One Bridge over the Ashburton / Hakatere River was closed because of concerns about its structural stability. Other Canterbury flood protection schemes were stretched to their maximum.

The Canterbury storm event and flooding caused extensive damage to farmland but little damage to residential properties. Thankfully, there was no loss of life. The town of Ashburton was largely saved from greater damage by a well-designed urban flood protection scheme. Further damage was averted by timely community leadership.

Similarly, the foresight of the Marlborough District Council was such that flood protection investments, made after the major 1983 flood, worked largely as expected. These protected Blenheim, and its extensive surrounding wine growing district, from the potentially much greater damage that could have occurred with the July 2021 flood.

Not so fortunate were other rural areas of the Marlborough District that were not protected by flood schemes. Roads and farms in the Rai Valley were extensively damaged. Five months later, transport disruptions caused by Marlborough-wide storm-induced slipping and related on-going recovery work, are still occurring six months after the event.

Westport was also not as fortunate. A relatively modest early investment ($10 - $20m) in flood protection works at Westport would have saved the area from the over $100m in direct flood damages to property it is currently enduring. It would also have avoided the substantial and on-going effects on the physical and mental wellbeing of the whole Westport community. The impacts of the July 2021 flood on Westport will take many years to recover from. The Government, insurers and the people of Westport will carry that cost.

The 2021 Canterbury, Westport and Marlborough floods are all examples of an increasing series of recent major flood events experienced throughout New Zealand. Other examples of extreme weather events have also occurred in 2021. The Kemeū area, west of Auckland, experienced its second wettest day on record on 31 August 2021. Up to sixty homes were evacuated. On 5 November 2021, Gisborne received three times the average rainfall normally received in the month of November. Widespread flooding, evacuations and 16 slips occurred but the CBD of Gisborne was largely protected.

Other major events have occurred in the last two years. The biggest of these were in Southland, Otago, West Coast, Northland, and the Bay of Plenty regions.

International precedents

New Zealand is not alone in facing the challenge of addressing the effect of extreme weather events and associated flood hazards. All countries are facing similar challenges. The United States and the United Kingdom have recently acted with urgency to significantly ramp-up their investment into flood protection schemes. The nature of New Zealand's landscape and our location in the 'roaring 40's' makes the challenge we face of even higher magnitude than in many other countries.

Flood protection schemes make a significant contribution to community resilience

The above New Zealand examples provide a stark reminder of the important role flood protection schemes play in defending 'at-risk' communities from the full impact of extreme weather events.

What is vital, is that the lessons learned from these latest disasters do not fade away. Putting in place substantive changes to improve the long-term resilience of communities, by – among other things, enhancing the role played by flood protection schemes, requires priority attention.

Flooding is the number one natural hazard in Aotearoa. New Zealand now faces, on average, one major flood event every eight months. Flood protection schemes are the first line of defence. They provide protection to around 1.5 million hectares of our most intensely populated and used land. They also provide safety, security and protection to the families, Marae, livelihoods, and communities living alongside our rivers in over 100 towns and cities. In total, these schemes currently provide an estimated annual benefit of over $11 billion each year. This is over five times the capital replacement value of the schemes.[1] The schemes have been some of the best value public investments ever made in New Zealand. Addressing contemporary challenges will require a step change in investment to occur like that made half a century ago. This investment will prove to be similarly valuable.

The challenge to be addressed

The challenge is this. Regional council[2] current annual maintenance and capital investments in flood protection schemes total close to $175m[3]. This is not a sufficient level of investment to provide for the level of security desired and now required by New Zealand communities. Regional councils intend to increase their investment by a further $25m in future years to total $200m. This will not be enough. They estimate the annual capital cost of building further resilience into flood protection schemes would be at least $150m beyond their current intentions.

Community tolerances about levels of acceptable risk are increasingly being tested. Regional councils now have improved knowledge about how schemes perform during severe floods and the flood levels they should be designed to withstand. These were not contemplated when the schemes were constructed decades ago. They are certainly not adequate to address climate change. The $200m of regional council increased investment is primarily to enhance[4] the ability of existing schemes to withstand the increased frequency and magnitude of climate-change-influenced future flood events. The need for $150m of additional central government funding must urgently be addressed.

There is no question that greater use of a 'multi-tool'[5] approach to building community resilience against the effects of flooding is required. More focus on the more effective use of improved planning tools to define where and how development occurs, will be particularly important. However, a focus on the use of planning tools cannot replace the fundamental importance of further investing in flood protection schemes. They will always remain the first line of defence against extreme flooding.

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[1] The total estimated capital replacement value of the 367 flood protection schemes throughout New Zealand is $2.3 billion.

[2] We use the term 'regional council' throughout this report to jointly encompass New Zealand's five unitary district / Auckland City Council and the eleven regional councils.

[3] Regional council Long Term Plans for the period 2021-31are currently being interrogated to provide a more precise figure of committed future investment. Work carried out as part of the previous flood protection report confirmed that planned investment was more than $175m per annum.

[4] In general terms, flood protection schemes should now be designed to withstand a flood with a return frequency of 200 years.

[5] We use the term 'multi-tool to encompass all of the approaches needed to manage floods. This may include district and regional plan requirements, building requirements, managed retreat alongside flood protection schemes and all other parts of a full suite of flood management approaches.

Equitable co-investment in flood protection is required

Present regional-council focused funding arrangements are neither equitable nor sufficiently sustainable to address present and emerging needs on their own. There is a strong case for central government to return, as a legitimate and justifiable co-investor, in improved flood protection schemes. For the past three decades, Crown-owned and related assets have received flood protection at a cost to regional and targeted local ratepayers, with little contribution from the Crown.[6]

These protected Crown assets include rail and road infrastructure, communication and electricity transmission infrastructure, some airports and education and health facilities etc. The Crown also has substantial contingent liabilities associated with public assets that it does not own, but significantly funds, such as local roads. Also protected by flood schemes is the capacity to sustain the efficient functioning of affected communities and their economies, in the face of significant flood events.

All up, Government has a broad and critical stewardship responsibility to protect and improve community resilience by reducing the risk of the failure of existing flood protection schemes. This responsibility extends far beyond their current focus on responding to flood events and assisting with recovery.

Previous regional council work to secure central government co-investment

A business case seeking a central government co-investment contribution of $150m per annum was presented to officials in 2019 by all New Zealand regional councils.[7] This business case has not yet achieved the task, nor central government attention, it was intended to achieve.

The business case was however valuable in helping to secure a one-off and very much welcomed central government commitment of $217m for expenditure on 55 'shovel ready'[8] / community climate resilience flood protection' projects throughout New Zealand[9]. Work to construct these scheme enhancements is now well underway. The progress being made confirms the capability and proven reliability of regional councils – in partnership with central government, to partner to deliver these projects, even with quite short notice and in despite the on-going challenges posed by Covid-19.

The earlier business case also had some influence on the content of a July 2020 Cabinet paper. This paper provided a welcomed indication of government willingness to develop a set of principles and a decision-making framework to guide further central government co-investment in flood protection schemes. But then in June 2021, the Minister of Local Government, the Hon Nanaia Mahuta, resolved to 'suspend' the contribution of central government resources toward progressing this work. Correspondence to LGNZ from Minister Mahuta suggested the was because budget 2021 constraints meant that resources were not available to '*continue a dedicated work stream on flood risk co-investment*.' Instead, the Minister advised the sector to focus their efforts on the National Adaptation Plan being led by MfE. The Minister also invited the regional sector to '*engage on the lessons learned and options for enabling greater resilience to flood events in the Buller region'*.

[6] In the past, (prior to the early 1990s), the capital cost of substantial river management and flood protection schemes was commonly supported at levels of 50% to 75% by central government. Maintenance and operating costs at rates of around 25% were also provided. A review of documents from the time suggests this national support typically amounted to over $114m per annum in today's dollars.
[7] Central Government Co-investment in River Management for Flood Protection: Critical Adaptation to Climate Change for a More Resilient New Zealand, July 2019
[8] The 'shovel ready' projects that received funding were not necessarily those projects sitting at the top of a list of national priorities. They were simply those projects that were 'ready to go'.
[9] Regional councils throughout New Zealand are now delivering these projects – within expected timeframes and budgets. When regional council funding contributions are added in, these projects have a value of $315m. 55 projects were initially agreed. More recently, some projects have been joined together and one project (the 'Muggeridge' pump project in Waikato) is now not being funded.

Regional council chairs and other community leaders have some sympathy for the workload currently being carried by central government officials but were nevertheless extremely disappointed by this decision. It ignores the reality that increased flood events and hazards are not 'on pause'.[10]

Community leaders are also conscious of the importance of all parties applying more attention to a multi-tool / broad fabric approach to the future protection of homes, buildings, and community assets from floods. Regional councils have worked with DIA and MfE over the last 12 months to contribute to the development of this broad fabric of initiatives. However, they are of the view that extending the toolbox of community protection cannot and should not be progressed without giving priority focus to flood protection schemes as the 'first line of defence.' This is the role played by flood protection schemes. Flood protection schemes remain the number one critical existing asset protection tool.

Without further investment in flood protection schemes, the risk of communities continuing to get flooded will be exacerbated. In addition, insurers will increase the premiums they charge for protecting flood prone areas. In some instances, they insurers withdraw coverage.[11]

Real events from 2021 demonstrate the need for urgent action

This report provides information drawn from 2021 case examples - with a focus on the 31 May 2021 Ashburton / Canterbury flooding but also drawing on information from the July 2021 Westport and Marlborough events.

The report describes these flood events and flood protection scheme locations and performance assessments, community responses, details about the on-going impacts of the flood events and scheme 'value propositions'. Most importantly, the report also provides event-specific details about the many millions of dollars of valuable crown assets protected from 2021 floods by flood protection schemes.[12] Protection of these assets is just one of the many reasons for significant government investment in flood protection schemes, as presented herein.

Re-purposed approach to flood protection

Regional councils know the flood protection schemes of the future, compared to those of the past, must satisfy a wider spectrum of community, environmental, cultural, climate change and economic objectives. The sector is aware of the role played by schemes in supporting integrated land uses, enhanced ecological outcomes and water quality improvements. They are also aware and are responding to the role played by schemes in potentially assisting to resolve 'drought-influenced' water resilience challenges[13] and contemporary iwi / Te Mana o te Wai objectives.

These objectives and challenges are real, substantial, and present right now. Regional councils have already demonstrated their ability to meet these needs. However, the high cost of meeting them, alongside the cost of increasing the 'climate change resilience' of existing flood protection schemes, adds to the burden for regional ratepayers to carry on their own.[14]

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[10] See correspondence from the Canterbury Mayoral Forum to the Minister for Local Government (appendix 1)

[11] Tower Insurance has already announced their intent to increase premiums in flood prone areas. Further details are provided in the body of this report. Enhanced investment in flood protection schemes, to keep this 'risk' to an acceptable level, is one of several critical actions required to keep insurers in the market.

[12] This information has been generated using valuation methods developed by economist Julian Williams.

[13] This may include by creating wetlands to enhance ground water recharge.

[14] Regional councils have already clearly displayed the need to extend their flood protection toolbox beyond simply constructing and maintaining flood protection schemes. They have applied the new principles to this area of their work. They have engaged with iwi / Māori – and will continue to actively participate in central government processes to develop a national planning framework – noting this will encompass the more extensive use of spatial planning and managed retreat tools (where appropriate).

Apportioning co-investment funding

As noted previously, central government annual funding of at least $150 million is required. This is proposed to sit alongside the $200m per annum to be committed by regional councils.

A long-term funding formula is proposed as a starter for a discussion about how central government funding should be apportioned. This recommends central government make:

- Co-investment of up to 75% assistance toward the cost of works to recognise the importance of adopting a **whole catchment climate change adaptation** approach, alongside achieving a wide range of other objectives.
- Co-investment of up to 50% toward the cost of the capital works required to **upgrade existing** river management and flood protection works.
- Co-investment of 33% of assistance toward the **maintenance** of existing scheme works.
- Co-investment of 75% of assistance towards the emergency repair of flood protection assets where substantial damage occurs from major storm events.

The above cost-share formula is offered as a start point for discussion. It is realistically and fairly determined and is focused on achieving the necessary step-up in protection, within a reasonable timeframe. The July 2020 community resilience / flood protection Cabinet paper offered a set of cost-share principles that should also be considered.

National leadership and urgent action required

The Government has an important and urgent role to play in leading and adequately resourcing the purposeful, timely and meaningful actions to help deliver practical scheme improvements. These improvements are fundamental to the task of greatly increasing community resilience against flooding and generally sustaining community well-being.

Details about the preferred design of a co-investment model should be prepared by a joint central and local government officials group, supported as needed by external advice. This group should be invited to provide recommendations to core Ministers and regional council chairs within three months of the receipt of this supplementary report. These recommendations should include decisions about the budget allocations required to meet immediate 2022 investment priorities[15] as well as the sums that should be included in budgets for each year extending from 2023 to 2033. The recently announced 'Climate Emergency Response Fund' is the likely and very appropriate source for these funds.[16]

For more than half a century, regional councils have demonstrated they have the capability and capacity to ensure flood protection schemes deliver flood protection to New Zealanders. Regional councils have further demonstrated their ability to deliver necessary improvements by their recent performance in rolling-out the fifty-five-flood-protection scheme improvement projects.[17] These selected projects were those that were 'shovel ready' at the time.[18]

Regional councils fully support government's December 2021 decision to establish a new Climate Emergency Response Fund (CERF). It is critically important for New Zealand to commit significant financial resources to respond to the climate change challenges that are with us now, noting these will

[15] The River-Link project in the Lower Hutt Valley and the proposed 'multi-tool' approach to flood protection at Westport are two current proposals lending themselves to immediate central government co-investment.
[16] The $1 Billion per year 'Climate Change Emergency Fund' was announced by the Minister of Finance on 15 December 2021. The purpose of the Fund is to assist to meet the cost of assisting communities to adapt to climate change and to build resilience against its effects.
[17] These were provided with the assistance of one-off funding through Kānoa as part of the Covid related Climate Resilience Programme.
[18] There are many more improvement projects requiring similar urgent action. Central government co-investment is essential if this is to occur.

increase in the future. Regional councils urge that central government give priority to expenditure of CERF-funding on necessary upgrades to flood protection schemes throughout New Zealand. Adaptation actions such as improvements to flood protection schemes are required immediately, regardless of the success or otherwise of international mitigation / decarbonisation measures.

The proposed 2022 National Adaptation Plan may be the instrument to guide expenditure of the CERF. Regional councils are participating in an MfE 'Local Government Adaptation Advisory Group.' One of the objectives of this participation is to ensure appropriate flood protection scheme investment provisions are considered by this Group and thereby included in the National Adaptation Plan. However, regional Councils fear the Local Government Adaptation Advisory Group deliberations will not be enough on their own to guide the necessary decisions. Councils therefore also urge central government support for the establishment of a working group with Treasury, DIA, MfE, NEMA and other officials (for example officials from MBIE's Kānoa Group) to develop the principals, priorities, and a project funding allocation framework to guide the necessary $150m per annum of additional central government co-investment expenditure decisions on flood protection schemes.

Back-work to achieve this objective needs to be underway now. Without necessary co-investment decisions being made immediately, then the flooding risk to our communities will continue to incrementally increase. The consequences of not acting do not bear thinking about.

National interest in flood protection – a summary of the case for co-investment

Flood protection schemes are nationally important. They underpin the integrity of public and private assets and lifelines and provide resilience and security to communities and their investments. Central government co-investment is vital because it:

- Is fiscally **responsible and fair** to make such investments.
- Reflects Treasury's **Living Standards Frameworks**.
- Is supportive of wellbeing and social inclusion and is likely to reflect **equity / ability to pay** considerations.[19]
- Is supportive of **job creation, protective of previous regional economic development investments** and contributes to the desire to lift the future productive potential of the regions.
- Contributes to the security of **access routes** (rail and road) and the communication infrastructure that is vital for commerce and community functionality.
- Directly protects significant **crown assets** such as hospitals, schools, infrastructure etc.
- Contributes to investment '**opportunity costs**.'
- Diminishes the risk of escalating **insurance** premiums, the reduction in the uptake of private insurance and the associated risk of insurance companies refusing to provide insurance cover in flood risk areas – leaving the Government as the 'bottom of the cliff ambulance'.
- Contributes to the **environmental** and water quality expectations of our communities and iwi / Māori partners.
- Provides for resilience and adaptation against the effects of **climate change-induced** 'above-design' storm events.

[19] Equity and ability to pay considerations are likely to be one of the many important elements considered in designing the detail of a central government co-investment programme.

The most important of the above reasons for central government co-investment in flood protection schemes is that it will contribute to the resilience and increased levels of safety and security sought by existing and future businesses, individuals, families, whanau, and communities. Central government has a duty to share in the cost of meeting this objective.

The fundamental foundations are already in place to 'crack on' with improvements to flood protection schemes. Regional council have proven they have the backbone and capability to lead this task.[20] What is missing is adequate and equitable funding. The long-term commitment of central government funding to help regional councils meet current and future climate change adaptation, and other flood protection scheme challenges, is urgently required.

[20], The 'back-bone' performance of regional councils has been clearly demonstrated by the roll-out of the Covid related Climate Resilience Programme through Kānoa.

JANUARY 2022

Central Government Co-investment in Flood Protection Schemes – Supplementary Business Case

Purpose

The purpose of this report is to provide further evidence to support the previously published[21] business case for future central government co-investment in flood protection schemes.

The paper is supported by case study examples. These display the scale of zero cost protection benefits provided to the Crown by regional council and local rate-payer investments. They also demonstrate that Government funding has been heavily concentrated 'at the bottom of the cliff', rather than being smart 'up-front' investment in risk mitigation and resilience.

Funding challenge

The essential challenge is this: the cost of upgrading, constructing, and maintaining flood protection schemes to meet future 'acceptable levels of risk' and other climate change / contemporary operational demands – including the protection provided to Crown assets, is beyond the reasonable capacity of regional ratepayers to meet on their own.

Funding solution

Central government co-investment of approximately $150m per annum is required. This investment should occur alongside an increased level of investment from regional councils and directly benefiting property owners.[22]

Frequency of flood events

As a group of small islands in the 'roaring forties', our weather patterns mean New Zealand regularly experiences high-intensity rainfall. On average, a major damage and productivity loss-causing flood event occurs every eight months.

Floods are New Zealand's most frequent and cumulatively - our most significant and most avoidable hazard.[23] They are the natural hazard most able to be mitigated through application of a well-proven package of flood protection schemes. They are also the natural hazard that has provided the best return on investment from measures contributing to active 'risk reduction'.[24]

Flood protection schemes are the first line of defence

Currently, flood damage is in most cases avoided because of the efficacy of existing flood protection schemes.

Regional council research indicates the current 367 flood protection scheme structures have generally been well maintained and managed in a prudent, professional, and efficient manner. They have also

[21] Central Government Co-investment in River Management for Flood Protection: Critical Adaptation to Climate Change for a More Resilient New Zealand', prepared by regional councils and completed in August 2019.
[22] The proposed increase in regional councils investment is from the previous $175m to $200m.
[23] Over the past 100 years, New Zealand has experienced over 1,000 serious floods. This is the most frequent natural hazard New Zealand faces (Ministry for the Environment, 2008).
[24] NZIER report to DIA, 'Investment in Natural Hazards Mitigation', August 2020.

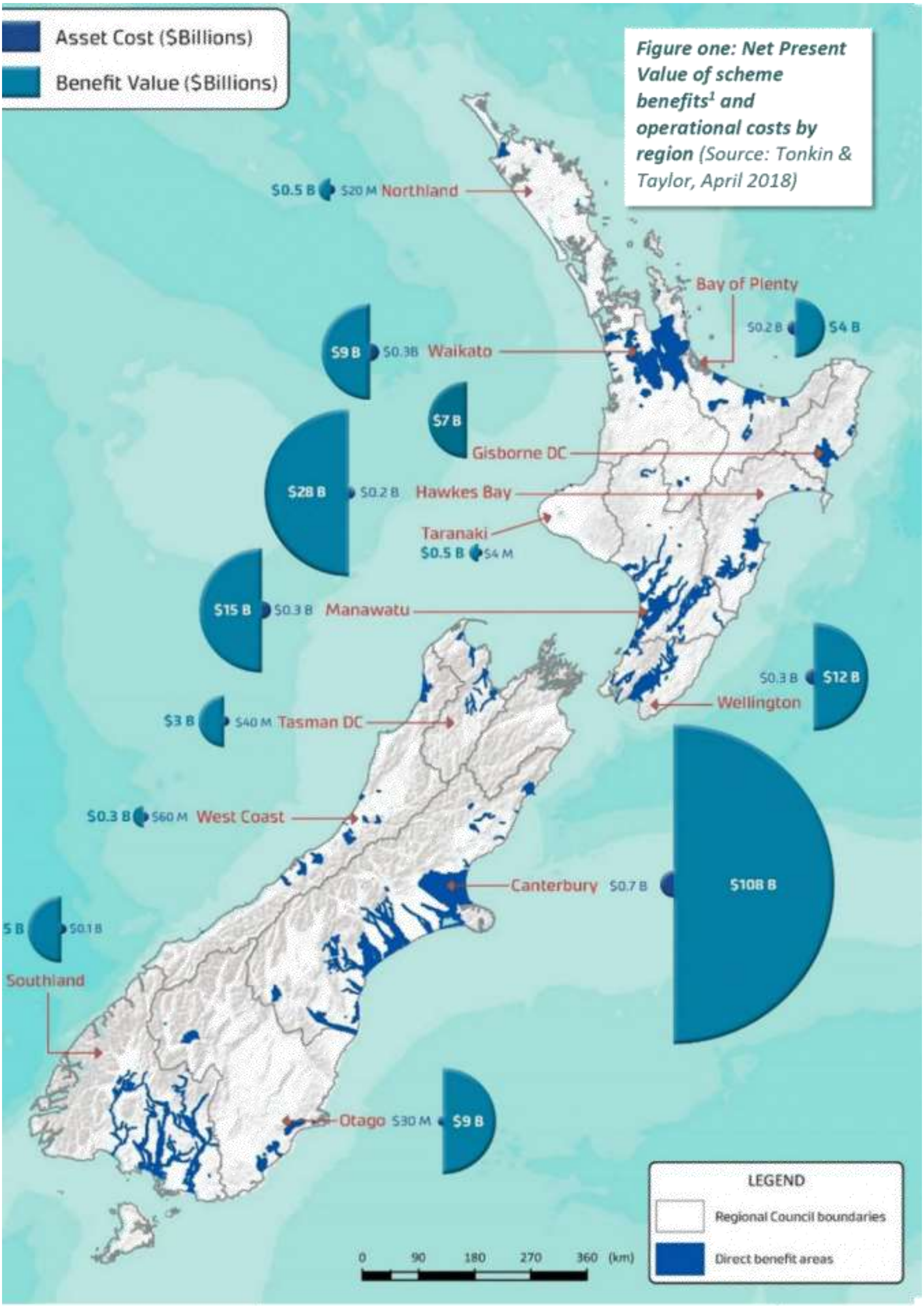

Figure one: Net Present Value of scheme benefits[1] and operational costs by region (Source: Tonkin & Taylor, April 2018) provided good value for money (Figure one)[27]. These schemes provide an estimated Net Present Benefit of over $11 billion each year. This benefit value has increased markedly since the schemes were constructed because of more intensive land uses and associated increased in property values. Unfortunately, climate change impacts are effectively reducing protection service levels at many locations.[28] More people are now being exposed to more risks to their safety than previously. Significant adjustments are now required in the scope and scale of these schemes to meet the challenges of the future.

Climate change

Changes to the intensity and frequency of climate change-induced flood events is the biggest natural hazard challenge New Zealanders face. Climate change will substantially increase the severity and frequency of the risk of flooding.[29] This will cause higher levels of damage and more frequent damage to the land and assets located behind existing flood protection structures and to adjacent communities. There will be associated increased in social and environmental costs. Recent events are a salient reminder of this.[30] Climate change will also shift the area of geographical risk of floods and make new areas, not presently affected by such events, more susceptible to floods.

The severity of the consequences of not securing and enhancing the integrity and service levels of existing scheme structures, and the community resilience role they play, increases every day.[31] The increased frequency and severity of flood occurrence is influenced by several climate change-induced 'additive influencers' because:

- More intense rainstorms generate higher river flows.
- Those flows cause more soil erosion.
- Higher sea levels and more significant storm surges increase flood heights for several kilometres up many river systems.[32]

In combination, the above additive factors lead to more deposition of rocks, stone, gravel, and silt with resultant significantly increased and compounded flood event effects on communities.

[27] Tonkin & Taylor, 'Hiding in Plain Sight' (March 2018) NB the use of the 'Hiding in Plain Sight' title is appropriate. The protection provided by engineered infrastructure located at the heart of river management and flood protection schemes, is not usually visually intrusive and is not often apparent. Such schemes 'do their job,' perhaps only once or less a year. Consequently, the protection provided by such schemes is often taken for granted by New Zealanders, despite the increasing risks currently faced.

[28] Schemes are facing a 'pincer' challenge, where simply maintaining current assets is seeing climate change erode service levels. Ideally service levels should be substantially increasing to protect the more valuable public and private assets located behind the protection infrastructure.

[29] In ideal circumstances, flood protection scheme designs should provide for climate change-induced storm events capable of managing storm events that may occur between now and 2100. Such schemes would provide for an increase in peak flood flows of approximately 20% more than those expected in the period to 2000. This is based on the latest NIWA report prepared for MfE (HIRDs V4). That report states for every degree of temperature increase there is a corresponding 10.1% increase in rainfall (this is called the augmentation factor). A 10% increase in rainfall will generally translate into a 10% increase in peak flood flows. These higher flows will also give rise to increased flood heights because of higher sea levels and greater sediment flows. NB COP26 (November 2021) is aiming to reduce climate change warming by 1.5 degrees by 2050.

[30] A Climate Change Research Institute paper ('Climate Change Attribution', Luke Harrington, co-author, 2021) found virtually all major rainfall events between 2007 and 2017 were at least partially attributable to climate change.

[31] Lawrence et al (2013) suggest that what is considered a 40-year return period event now, will be reduced to the equivalent of an 8-year return period event by 2090.

[32] This includes large areas of drained land on the Hauraki Plains of the Waikato region and land adjacent to Edgecumbe, which in some places is now below sea level.

Photo one: Canterbury late May 2021 flooding event (photo courtesy of David Williams – Newsroom)

Scope of this report

This report focuses on natural flood water flowing from catchments via rivers and streams to the sea. The paper does not include consideration of storm water systems and the network of water related infrastructure referred to within the 'Three Waters' reform programme.[33], [34]

Rivers generally flow in a natural pattern across our landscape, although sometimes their flows are boosted by drainage works and sometimes their flows are constrained and channelled via flood protection schemes (figure two). The report does not include consideration of the works required to mitigate against coastal erosion or the mitigation of the effect of land inundation from waves breaking over a foredune and flooding urban areas behind these sand-dunes.[35]

Figure two: Schematic of flood protection scheme and land drainage services (Source: Tonkin and Taylor, March 2018)

[33] The 'three waters' programme deals with drinking water / wastewater and storm-water treated and transported in reticulation systems such as sewers, pipes and street gutters.

[34] Nevertheless, the paper is entirely relevant to this reform programme. This is because of the need to manage flood water in such a way as to make it's 'interface' with stormwater systems as seamless and manageable as it can be.

[35] Addressing the effects on communities of climate change-induced sea level rise has strong parallel challenges to those addressed in this paper.

Assets protected by existing flood protection schemes

Over 100 towns and cities across New Zealand have families and communities living alongside rivers or on flood plains that are protected by flood protection schemes. In total, river and flood protection schemes protect around 1.5 million hectares of land or 5% of New Zealand's land area. This land is where a very high proportion of New Zealand's economic enterprise takes place and where community well-being is most frequently anchored. Marae are also often located in such areas.

Schemes are designed and constructed to achieve defined performance expectations. Higher levels of protection are generally provided to urban areas compared to rural areas. Where a flood event exceeds the design capacity of the flood protection scheme, there will be resultant flooding and damage.

The 2004 Manawatū floods provide an illustration of the extent of the types of costs incurred in rural areas because of this damage. Insured losses from that event were $112 million. However, the cost to the agricultural sector alone, in uninsured losses (lost production and uninsurable rehabilitation costs), were calculated at $185 million.[36]

A similar order of costs were incurred by rural communities because of the June 2021 Ashburton / Hakatere flood event. Futhermore, and as described further later in this report, recovery costs of over $100m now being faced by the small town of Westport could have been avoided by investing around 10% of that cost into a flood protection scheme.

By contrast, work undertaken by Horizons Regional Council (figure three) indicates that of the 28,730 properties in the greater Palmerston North urban area, 12,842 properties would be affected by a flood event if the existing flood protection scheme was not in place.[37]

Similar work – as undertaken by Greater Wellington Regional Council, indicates that over 6,500 commercial, residential, and industrial properties would have been inundated – including nine schools and many other Crown-owned properties if the existing scheme was NOT in place (figure four).[38]

All flood protection schemes throughout New Zealand operate in a living environment. They are subject to wear-and-tear. In addition, they must now endure increased loading because of the changing nature of climate-change-affected weather events,[39] the increasing value of the assets they protect, the larger numbers of people to whom they provide safety, and increased expectations about reducing their impact on the natural environment.

Budgeted expenditure on flood protection

The total replacement value of the 367 flood protection schemes throughout New Zealand is estimated to be $2.3 billion.[40]

Regional authority Long Term Plans for the period 2015 to 2025 show budgets for flood protection operating expenditure of at least $1 billion and capital expenditure of a similar amount. This excludes depreciation.

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[36] The cost of emergency services and infrastructure repairs during the 2004 Manawatū floods was put at a further $90 million. The flood was modelled as having a 150-year return period.
[37] This scheme protects these properties and communities from a flood sourced from the Manawatū and Mangaone Rivers with a magnitude greater than that occurring with a frequency of 1:100 years.
[38] This is the number of properties that would have been affected by the flooding that would have occurred in the area adjacent to the Lower Hutt River in 2015 if it were not for the presence of the Pharazyn and CBD stop-banks.
[39] This results in the 'design capacity' of these schemes being more frequently exceeded than in the past.
[40] Source: Tonkin & Taylor report '*Hiding in Plain Sight*' (April 2018).

These budgets are, to varying degrees, based on a continuance of the same design paradigms applied when the schemes were initially constructed. As such, they do not reflect the quantum of the changes now needed to recognise the impacts of climate change and other contemporary challenges.

> *Councils are aware that a 'step change' in flood scheme approaches and investment levels is required. Not only is climate change effectively reducing the service levels of current schemes, but existing service levels are in many cases in need of lifting, regardless of climate change effects. This is to better protect the greatly increased value of assets and the increased size and nature of the communities reliant on flood protection schemes.*
>
> *Regional councils also know they cannot and should not be obliged to meet the cost of meeting this demand solely from their own rate-payer-focused funding sources. They are saying 'central government should pay their legitimate share - as a direct and indirect beneficiary of these works, in partnership with regional councils'. They argue that, with central government help, the necessary 'step change' can be achieved.*

As part of their approach to the management of this challenge, Regional Council Chief Executives have formed the regional council 'River Managers' Special Interest Group' (SIG). This Group has developed a 'Five Year Sector Resilience, Sustainability and Improvement Plan' for flood protection. As part of this Plan, a work programme has been established to assist the sector to remain at the cutting edge of the challenges associated with their community resilience / flood protection task.

Regional councils[41] have the capacity to 'get the job done' provided co-investment funding is made available from central government to meet necessary agreed risk profile and prioritised flood protection enhancement programmes. This co-investment is now urgently required. Councils are also collectively investing in improving capacity and capability to meet the step change required to the nation's flood protection, across the full range of methodologies available for flood protection – not just schemes.

A reminder about the history of river management for flood protection

New Zealand previously led the world with its statutory recognition in 1941 that land and water management for flood protection needed to be catchment based. This need was reflected in the purpose of the Soil Conservation and Rivers Control Act 1941 ... '*to make provision for the conservation of soil resources and the prevention of damage by erosion, <u>and to make better provision with respect to the protection of property from damage by floods</u>*'.

The need to '*make better provision*' for protection against the effects of floods clearly needs to be put back on the table. The 1941 statute led to joint investment by central government, regional communities and the directly-benefiting property owners associated with or affected by river management, drainage, and flood protection schemes.

Central government, at that time, clearly recognised it was a property and Crown asset owner directly benefiting from these flood protection schemes. It also recognised it had wider national interest responsibilities. This understanding now appears to have been forgotten.

[41] We use the term regional councils throughout this report noting that it encompasses both regional councils and unitary district councils and noting these are often more formally jointly referred to as regional authorities.

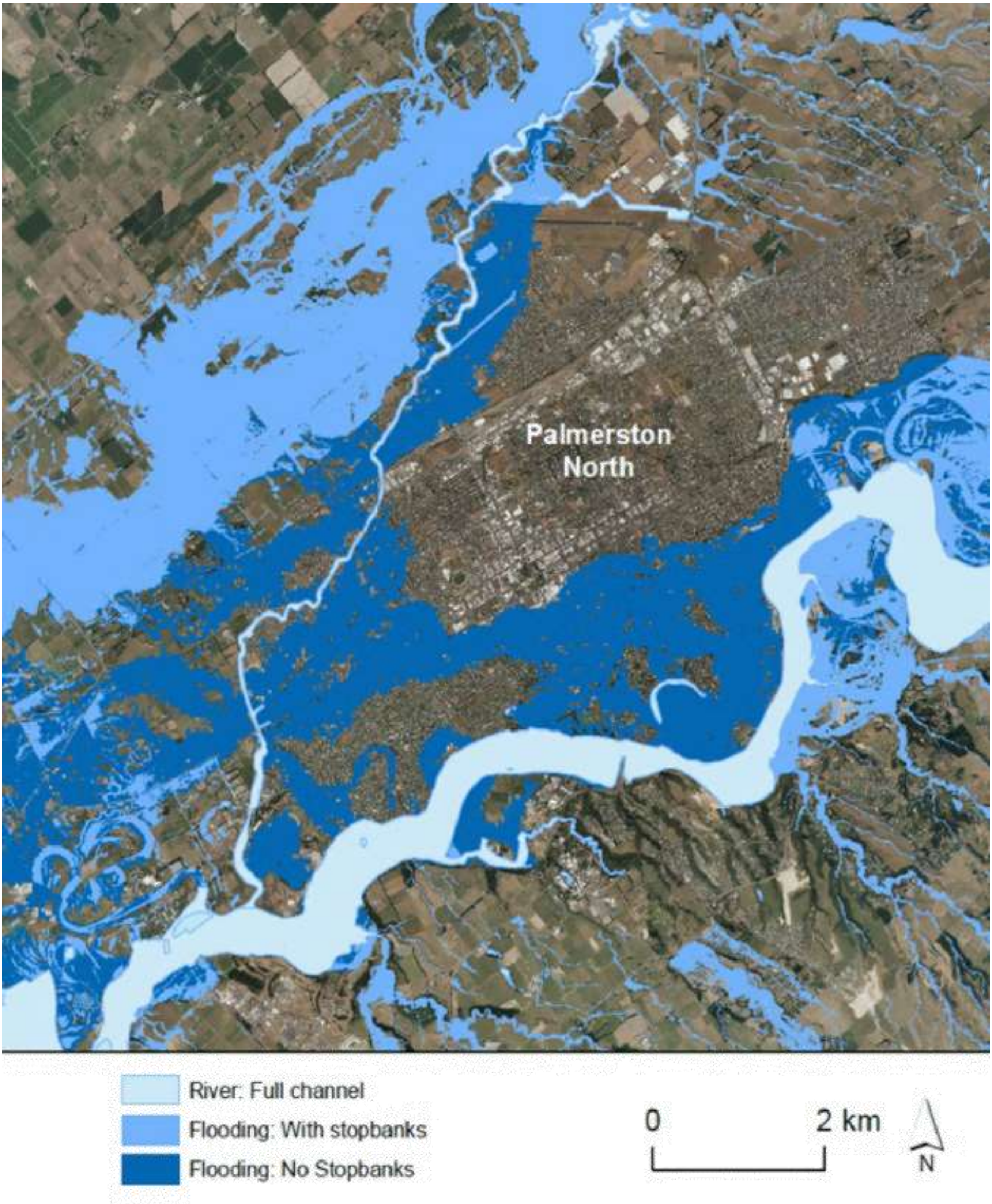

Figure three: Area of Palmerston North protected from flooding by Manawatū-Whanganui / Horizons Regional Council flood protection schemes.

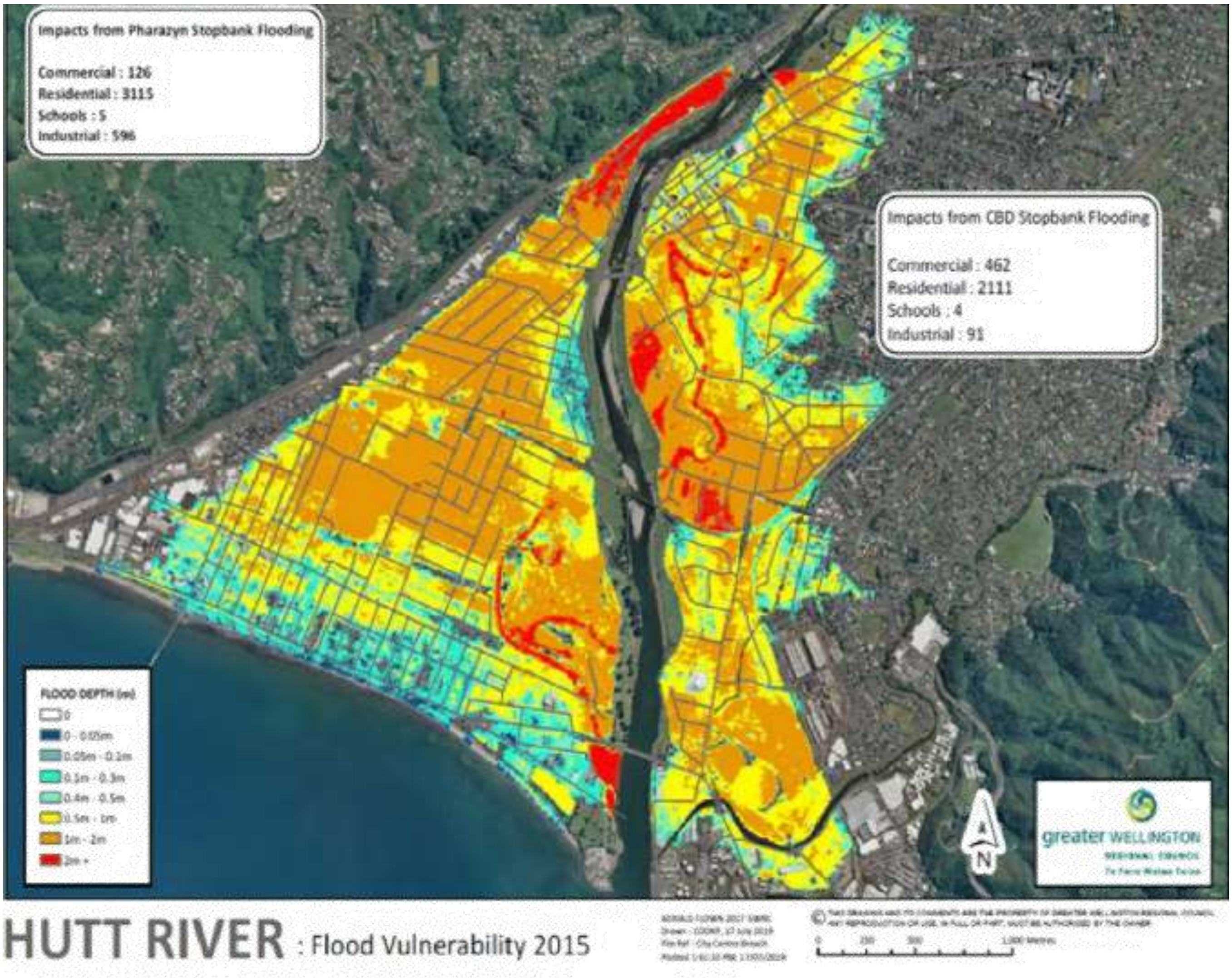

Figure four: Properties protected by Hutt Valley Flood Scheme

Refreshed perspective

A fresh perspective on the important role played by flood protection schemes is now required. Most river management, drainage and flood management schemes were constructed half a century ago. The value of the Crown, local authority and private assets protected by these schemes has incrementally increased. It is now very large. The type of land use activity carried out on this protected land is more intense than that envisaged at scheme design. In addition, the schemes are now required to operate in a more environmentally friendly manner.

Prior to the early-1990s, the capital cost of river management and flood protection schemes was commonly supported by central government at rates of 50 to 75%[42]. Maintenance, to ensure the integrity of the performance of these schemes, typically received 25% support from central government. Collectively, this level of support amounted to around $40m per annum from central government - equivalent to over $114m per annum in today's dollars.

[42] We would note for example that the Waihou Catchment control scheme – a very large whole catchment scheme (and the largest addressed in a holistic manner in the country), received an 87.5% government grant.

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Since the early to mid-1990s, river management and flood protection schemes' funding has relied almost entirely on regional rates and the contribution of directly-benefiting property owners, via targeted rates.

By comparison, internationally, including in Europe, Australia[43], and the UK[44], most developed countries currently have substantial levels of central government funding for flood protection activities. This recognises the national benefits they provide[45]. More multi-tiered international jurisdictions also have State as well as Federal co-funding with local authorities. It is now timely for New Zealand's government to draw from these models and reconsider the very valid reasons why it initially shared in the cost of flood protection.[46]

Current central government role in flood protection

Central government currently has just two roles with effect on the protection of communities from flooding. Firstly, it has an enabling role - to ensure regional councils have the legislative power to manage hazards, including flooding. This legislation includes the Local Government Act 2002, Resource Management Act 1991, Soil Conservation and Rivers Control Act 1941, Drainage Act 1908 and the Civil Defence and Emergency Management Act 2002.

Secondly, when an event occurs of a size beyond local government's ability to cope, central government assists with response measures. It also provides financial assistance to speed up recovery.[47] This assistance is as per the parameters described in the National Civil Defence Emergency Management Plan (2006). For example, if a major flood damages critical infrastructure, then central government will meet up to 60 percent of the asset's repair cost, once damages reach a certain threshold.[48] Event responses also require ramped up activities and support from MSD, MPI, EQC, NEMA and health agencies.

Central government's role for the last three decades has been focused on disaster response, relief, and rehabilitation rather than as a preventor of damage. Central government's current role may therefore be viewed as more of the 'ambulance at the bottom of the cliff' than as a funder, protector, and advisor at the 'top of the cliff'. Funding assistance to communities is generally applied after the event rather than before the event.[49]

Just as is the case with overseas jurisdictions, and consistent with the advice of the Productivity Commission,[50] central government must also now shift its focus toward partnering with regional councils to grow the 'first line of defence' role played by flood protection schemes.

[43] On top of existing 'state' contributions, the Australian Productivity Commission (2019) recommended the Australian government increase annual mitigation funding contributions to state and territory governments by $100 million in the first year, then to $150 million in the second year and $200 million in the third year

[44] In the United Kingdom the current Environment Agency programme, which runs from 2015-16 to 2020-21, includes 1,136 flood and coastal erosion projects at a projected total cost of just over £6bn.

[45] Central / provincial government responsibilities in Europe vary from those applied in New Zealand. The principle emphasised here is that European countries tend to give higher recognition to the national benefits of river management for flood protection than in New Zealand. New Zealand could learn from their approach.

[46] New Zealand is now well beyond the need to apply the funding principles applied during the period of 'Rogernomics.'

[47] Government may also provide aid to parties affected by flood events within the terms and conditions defined in the On-Farm Adverse Event Recovery Policy administered by the Ministry for Primary Industries.

[48] We understand this level of assistance is now under review.

[49] For example, research funded by central government through the science system provides some guidance to the flood protection role played by regional councils.

[50] Productivity Commission, Local Government Funding and Financing, 30 November 2019.

Potential changes to central government flood protection responsibilities

Central government have commenced developing a refocused approach toward natural hazard policy. One of the stimulants for this was a 2020 review of the Resource Management Act (RMA) carried out by a Panel chaired by Retired Court of Appeal Judge Tony Randerson QC. Based on the Panel's advice, Government now propose replacing the RMA with three new pieces of legislation.[51] These are the:

- Natural and Built Environments Act (NBA Act).
- Strategic Planning Act (SPA Act).
- Managed Retreat and Climate Change Adaptation Act (CCA Act).[52]

The new legislation is intended to overcome 'RMA problems' by, among other things, giving more prominence to the need to address natural hazard challenges. Solutions are proposed to be put in place by, among other things:

- Establishing a binding set of positive **national outcomes** and priorities for natural and built environments rather than using the 'effects management' regime entrenched within the current RMA.
- Recognising the concept of Te Mana o te Wai and the need for more active involvement of mana whenua in resource management decision-making (including that related to the protection of communities from the effects of flooding).
- Providing better national direction by preparing a robust **National Planning Framework** that will include content about the management of natural hazards and climate change.
- Giving more recognition to the need for Plans – including newly proposed regional spatial plans, to provide for adaptation to climate change, the avoidance of the risks arising from natural hazards, and better mitigating the emissions contributing to climate change.

The need for a comprehensive approach to flood risk management is clearly encompassed in the above advice (figure five[53]). In recognition of this, regional councils have embraced and are actively applying a more comprehensive approach (figure six) to flood protection than in the past. However, they argue that providing protection by building resilience into existing flood protection schemes must remain a clear, prioritised and strong tools in the toolbox for achieving these proposed legislative requirements.

One of the proposed 'National Outcomes' likely[54] to be included in the Natural and Built Environments Act will address natural hazards and climate change. The proposed new Act will likely require the National Planning Framework and by implication, all local authority resource management plans, to promote measures to ensure significant natural hazard risks are reduced and the resilience of the environment to natural hazards and the effects of climate change are improved. This is a necessary and supported change.

DIA have played an active role in the first ten months of 2021, alongside regional councils, to develop potential flood-related natural hazard content for inclusion in the proposed National Planning Framework.

[51] Cabinet Paper, December 2020.

[52] This Act will be developed in 2023. However, the Climate Change Response (Zero Carbon) Amendment Act 2019 requires MfE to lead the process of preparing a National Adaptation Plan. Details about what it may contain are currently uncertain. Regional councils are of the view that the Plan should record flood protection schemes as the critical tool for assisting communities to adapt to the effects of climate change.

[53] This diagram was prepared by DIA and was included in a presentation to MfE and regional council river managers (3 November 2021).

[54] An indication of what may be included in the Natural and Built Environments Act was revealed in an exposure draft released in August 2021.

In November 2021, responsibility for further developing the 'natural hazards' content of the proposed National Planning Framework was transferred to MfE. In making this transfer, DIA provided the following advice to MfE about how to best address flood protection schemes going forward:

- Take a 'systems approach' to flood risk management with greater integration of existing policy and practice on a range of fronts.[55]
- Use regional spatial planning strategies under the SPA to integrate flood risk management and climate change adaptation with strategic growth planning to enable future development to be risk-informed, climate resilient and sustainable.
- Set out where flood risk reduction will be prioritised over other outcomes.
- <u>Provide for the maintenance of flood protection schemes</u>[56] and adaptation for climate resilience.

Regional councils endorsed this advice.[57] What remains most salient in the above supported advice is DIA's clearly stated recognition of the importance of the foundation stone protection provided to communities by the existing 367 flood protection schemes. The recent passing of the Resource Management (Enabling Housing Supply and Other Matters) Amendment Act compounds this challenge.[58]

The challenge for both central and local government to now address is how to secure the funding to enable these foundation stones to be maintained and adapted to the changed operating environment. A solution to this challenge is critical if our communities are to withstand the increased frequency and magnitude of current and future 'climate change influenced' floods. In support of this point, DIA noted[59]:

- Local government should not be required to meet the costs of developing and maintaining flood protection works on their own.
- Repeat flood events are a challenge for central government to respond to.
- Insurers are moving to risk-based pricing and will withdraw and / or increase flood insurance in high flood risk areas.
- Co-investment will be needed by central government to support local government investment in flood protection infrastructure, adaptation for climate change and retreat, and for upgrading schemes to meet new environmental and cultural requirements set by the National Planning Framework.

Central government's application of this refreshed thinking to the funding models for flood protection was recorded in the July 2020 Cabinet paper 'Improving Resilience to Flood Risk and Supporting Covid-19 Recovery.' This Cabinet paper noted:

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[55] Investing in risk reduction through land use planning has been shown to be one of the most effective policy levers to reduce risk. Providing co-investment for flood protection helps with existing development but stronger national direction to limit new development in high-risk areas is agreed as being a necessary accompaniment to central government co-investment in flood protection.

[56] This <u>underlining</u> has been included by us to give this point necessary emphasis.

[57] This endorsement was provided by means of the active involvement of the River Managers SIG in DIA workshops and via submissions on draft documents.

[58] Government's Resource Management (Enabling Housing Supply and Other Matters) Amendment Act provides for significant intensification in Christchurch, Auckland, Wellington, Hamilton, Tauranga as of right. This will come into effect in August 2022. This will increase risk as it will allow for three dwellings on sites where there is currently one. There is some provision for exclusion of areas where there are natural hazard risks, but it is not clear how this will play out. Many of these cities have large areas of land that are prone to flooding from major rivers.

[59] This information was included in an A3 shared by DIA with river managers and MfE on 3 December 2021.

- Current funding arrangements for flood protection infrastructure were established over 30 years ago and they are no longer considered sustainable or consistent with delivering outcomes in line with (the) proposed framework and principles.
- Subject to further work, central government's funding approach to building resilience should consider the benefit principle, fairness, and intergenerational wellbeing.
- Officials will work with local government to develop a revised funding model for flood protection, based on the proposed framework and principles, which would be implemented over the longer term.

Regional councils welcomed the above commitments. They were therefore very disappointed to receive notice from DIA (June 2021) that further work on developing a co-investment framework for flood protection schemes had been suspended.

Notwithstanding, the proposed principles included in Appendix B of the July 2020 Cabinet paper remain valuable. The paper refers to an intention to use these principles to underpin the framework for central government's role in strengthening community resilience to flood risk by intervening where there is a national interest or national benefit. More explicitly, the appendix states an intention to:

- Target action where national assets and national interests warrant central government intervention and funding.
- Intervene in projects where there is a significant economy of scale or time constraints, distributional concerns, to protect health and safety, and to protect kaitiakitanga.

What is requested is the opportunity to urgently[60] work with central government to apply these principles, alongside the guidance offered in the previous regional council business case,[61] to develop a flood risk funding model that will provide co-investment support to regional councils and their communities to further enhance flood protection schemes.

Protection of Crown assets, values, national interest, and resilience – and the need to reduce Crown contingent liabilities

The cost of flood events may be counted not just in terms of the cost of replacing or restoring privately owned buildings and overcoming other property losses. There are also other tangible costs. These include the number of hours or days businesses cannot operate at full production and the cost of disruptions to the functionality of Crown assets.

In addition, flood costs have both an immediate and sometimes an on-going effect on people's lives. This includes the effect on the willingness of the residents affected by flooding to continue to live and invest in areas subject to flooding.

To avoid a worst-case flood disruption scenario, scaled-up central government and regional council investment in flood protection schemes is required. The priority reason for this co-investment is to create resilient communities and sustain economic enterprise.

[60] The 2021 Westport, Marlborough and Canterbury floods display the fact that the challenge is real and present.
[61] These are summarised in the executive summary and again toward the conclusion of this report.

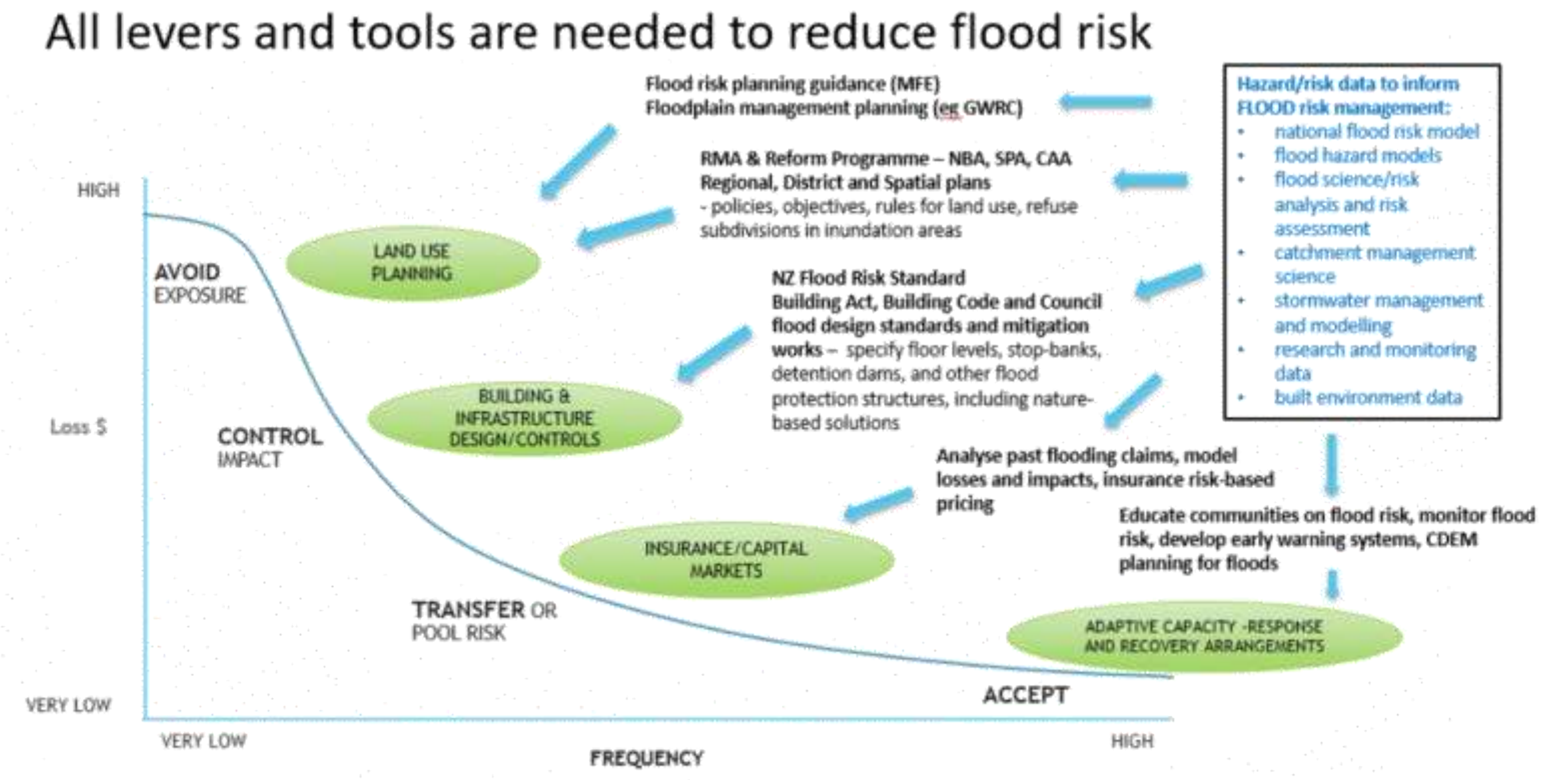

Figure five: Comprehensive approach needing to be applied to address flood protection challenges – as prepared by DIA (NB the blue circle has been highlighted by us to draw attention to the on-going critical importance of flood protection tools)

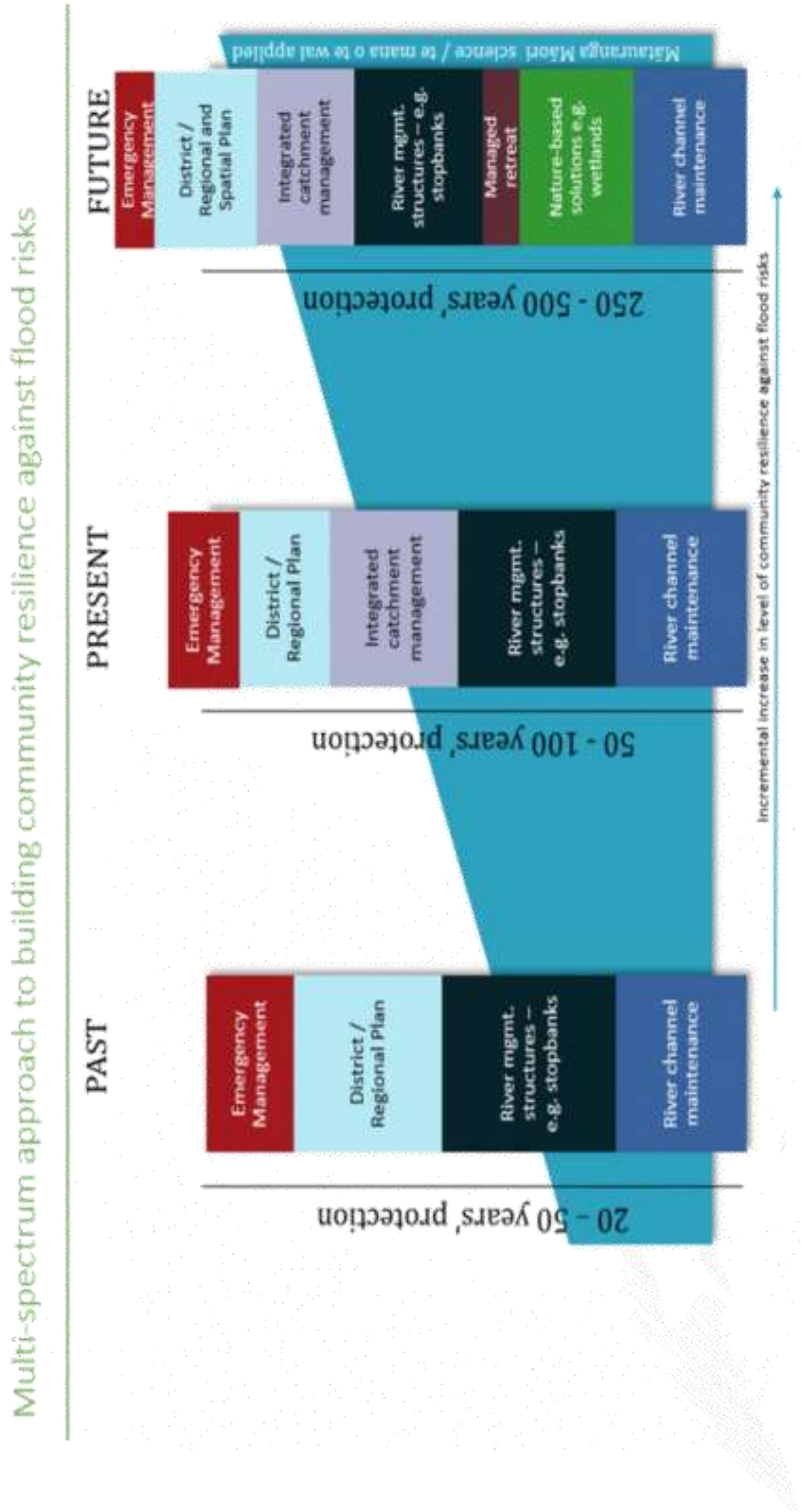

Figure six: Evolution of regional council approaches to flood protection

Companion objectives affecting the design of future flood protection schemes include the degree to which they may:

- Support well-functioning ecosystems.
- Improve water quality.
- Satisfy the expectations of our communities and Māori / iwi partners that our rivers will be managed as national treasures.
- Achieve integrated land use.
- Better reflect iwi / Māori / te Mana o te Wai and community aspirations about the management of natural systems.

Higher levels of resilience against the risks of extreme floods will also contribute to a full suite of other Government objectives, including investment certainty and social cohesion. These benefits will be expressed in all regions, not just the 'richer' regions.

One of the effects of central government's current narrow 'response-focused' role is that, for three decades, Crown owners or Crown infrastructure agency owners, have been able to enjoy the benefits of the asset protection provided to them by flood protection schemes at the cost of regional and targeted local ratepayers. Using local authority property-based rates to fund the protection of Crown assets is plainly unfair.

These protected assets include rail and road infrastructure, lifeline infrastructure such as power lines, some airports,[62] communication services, schools, hospitals, universities, and public conservation land. The Crown also has substantial contingent liabilities in respect of non-Government owned assets such as local roads where it has funding responsibilities. In addition, if adequate protection is not provided to public and private assets, when major disasters occur, the Crown becomes the funder of last resort to restore community functionality.

Estimates[63] show that for floods in Nelson and New Plymouth in 1970 and 1971, losses associated with central government works and services (roading, railways, bulk power supply, flood control and drainage works) amounted to 49 per cent of the total value of all direct losses.

A further example is provided by the 2006 Dunedin flood. The Leith Flood Protection Scheme plays a large role in protecting the Dunedin CBD from flooding. This includes the protection of education facilities (University of Otago and Otago Polytech) and the protection of the new Dunedin hospital, public reserves, residential and commercial areas. The capital value of the Crown properties and non-relatable University land and assets in the area protected by the Scheme is 35 per cent of the total assets in the area.

Further examples of the direct benefits provided to central government may be drawn from Ashburton, Blenheim / Marlborough District and Westport. These three areas were all subjected to extreme flooding in 2021. Details about these case studies follow.

Live examples of the importance of the Crown being at the 'top of the cliff'

Ashburton flood event – June 2021

Across the Canterbury region, there are 110,000 houses located in flood hazard areas. These houses have an estimated replacement value of $34 billion. The region has 112 km2 of land at risk from

[62] Airports such as those at Christchurch are located on flood plains. Many New Zealand airports are 50% owned by the Crown.
[63] Ericksen (1986) cited by the NZIER (2004).

flooding. The region also has 3,900km of roading, 800km of national grid lines, 2,204 of drinking water supplies, and nearly 3000 km2 of dairy and pastoral land.[64]

Over the three days from 31 May to 2 June 2021, the Canterbury region experienced 551mm of rain, with the greatest intensity experienced in the Canterbury foothills. The event was characterized as a 1:200-year flood event in the foothills and a 1:50-year event towards the coast (see figure seven).

Met Service's 'Ensemble Forecast System' found that compared to a climate system unaffected by human activities, between 10 and 15 per cent more rain fell in this period than usual. Using a large collection of global climate model simulations, they also found that these events are at least 20 per cent more likely to occur today than in preindustrial times when the atmosphere was about one degree colder.[65]

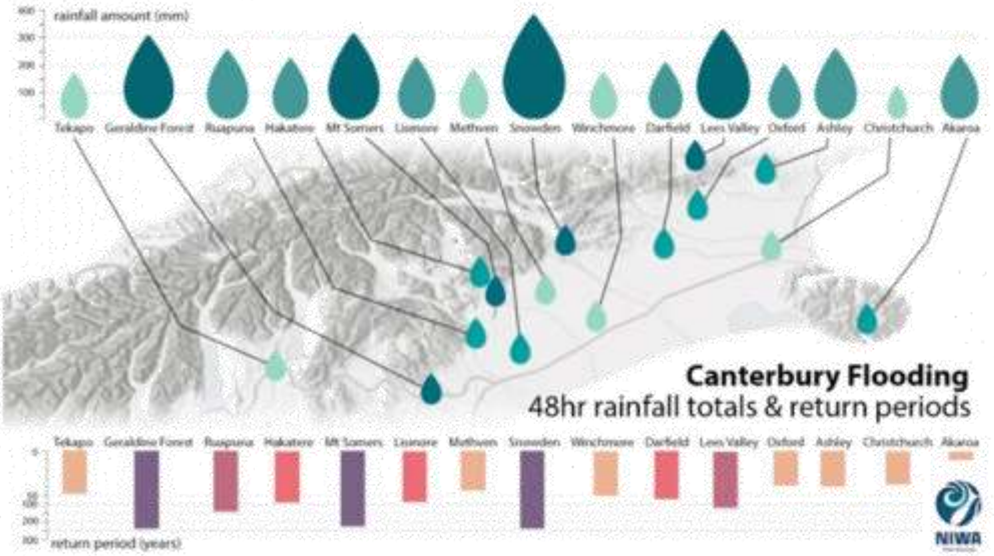

Figure seven: Canterbury rainfall event, 31 May to 2 June 2021, NIWA

River flow data showed a peak flow of 1,794m3/s in the Ashburton / Hakatere River at the State Highway One gauge. This is the highest flow recorded at that site since the gauge was installed. A total of 558 response 'needs assessments' were carried out by local authority and civil defence personnel and over 200 households / 300 persons were evacuated from five main locations around the district. All but 18 persons were able to return to their homes. A total of 32 houses were damaged by flood inundation. $5m of damage was done to local roads.

The town of Ashburton was saved from greater damage by a well-designed urban flood protection scheme. Further damage was averted by timely community leadership. The $2.5m spent a decade ago on upgrading the stop banks on either side of Ashburton town proved their value. There was little damage to residential properties in the town and no loss of life.

The focus of the flood event impacts was in rural areas, particularly in the Canterbury foothills around Mt Somers and on intensively farmed land between the two branches of the Ashburton / Hakatere

[64] The information provided in this case study was drawn from a report prepared by Pam Johnson from DIA.
[65] https://www.stuff.co.nz/environment/climate-news/127210511/climate-change-made-the-may-flooding-in-canterbury-more-severe--researchers

River. The two branches of the Ashburton / Hakatere River both suffered over-topping of stop-banks. This caused significant flooding because the event was "over design". This means there was more water than the flood protection scheme was ever designed to handle.

Farmland and rural infrastructure were damaged. This included damage to fences, bridges, irrigation equipment and stock feed etc. The safety of animals was placed at significant risk. Some evacuations were required in small rural communities including at Springfield in the Selwyn district. Other rural areas, such as Hinds, were also cut off.

State Highway One, the primary transport route for southbound travellers and freight, typically has around 24,000 vehicles per day going over it, including 2,000 trucks. Over 30,000 vehicles cross in weekends. The bridge was closed because of concerns about bridge damage and structural stability. Alternative routes south (including the rail line) were also closed by the flooding. This impacted supply chains to the whole of the lower South Island[66] with significant but difficult to accurately quantify impacts on the economy.

Nevertheless, the event gave rise to 3,800 insurance claims from the Ashburton district requesting $46.4m. The main claims may be broken down as follows:

	Number of claims	*Cost of claims $*
Domestic	2,446	$22,218,746
Commercial/material damage	889	$18,625,320
Business interruption / loss of profits	57	$1,050,779
Motor vehicle	302	$1,816,351
Other	82	$2,717,521
Total	**3,776**	**$46,428,717**

Crown-owned assets located in the Ashburton district total over one billion dollars in value. These may be categorised as follows[67]:

- Urban land and buildings $36m
- Rural land and buildings $10m
- Roads $685m
- Rail tracks $258m
- Transpower lines $28m
- **Total** **$1,100 million**

The total value of land and buildings on the floodplain in the Ashburton district is $4,867m.

The Ashburton / Hakatere river's control works consists of 76km of stop banks valued at $17.6m and other tree, rock, culvert, and flood gates valued at $62m.

[66] This was the second time that state highway one had closed due to flooding in recent times. In addition, the Rangitata bridge closed for three days in the December 2019 flood event.

[67] The dollar value of 'damage to assets avoided' has been calculated using 2020 dollars by applying level of service and scheme rating multipliers at a catchment level. This method of calculation was developed by economist Julian Williams using methods initially applied by Tonkin & Taylor - as included in their 2017 report "Hiding in Plain Sight". The method uses the capital value (rating data) of government owned property such as schools and hospitals and lineal distance in km times per km rate of national infrastructure networks (road, rail, and national power lines). For example, the current cost estimate to build 1 km of state highway is approximately $50 million.

These protection works generally provide benefits of protection to central government assets that vastly exceed their costs. The works are usually designed to provide a one in 50-year return frequency level of protection to rural areas inland from Ashburton and a one in 200-year return frequency level of protection around the township of Ashburton. As noted previously, the storm exceeded the design limit of the protection works located in rural areas but provided good protection to Ashburton town.

Other expenses will be incurred by both Environment Canterbury and NEMA[68] to restore flood protection scheme infrastructure and related vegetation (figure eight). The ratepayers of Canterbury will be required to meet unbudgeted flood recovery expenditure of around $12m.

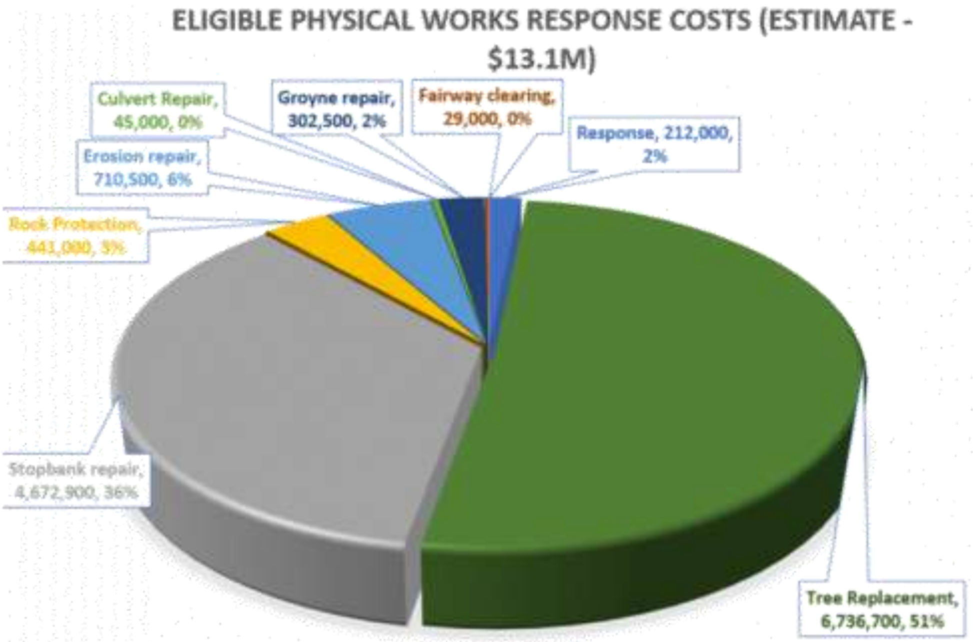

Figure eight: Environment Canterbury physical works 'response' cost estimates.

Similar, but not quite as intense flood impacts were felt in Selwyn, Waimakarere, Mackenzie, and Timaru districts.

The future state of affected Canterbury braided rivers may well be quite different to that existing prior to the June 2021 flood. This is not just because of the effects of the flood but also because of a need for Environment Canterbury and affected communities to consider the balance to be found in rural areas between:

- Providing for the tangible and intangible benefits of giving a stronger focus to river ecosystem and Te Mana o te Wai principles.
- Allowing the river more room to be a river.
- Affording the ratepayer cost of the capital works required for flood protection schemes capable of providing more than a 50-year level of protection.
- Meeting land use and ownership expectations, noting these include desires to have the opportunity for extending farming operations near river flood channels

[68] NEMA contributions are made at an average of 60% via their emergency response and recovery funding.

- Providing a fair and reasonable transition pathway, if it is agreed that intensive farming at these locations cannot continue.

Allowing the 'river to move' is a key challenge in some parts of the Ashburton catchment and elsewhere. The North Ashburton / Hakatere River narrows from around 300m between stop banks at Thompson's Track to 100m between stop banks at Shearers Road. Similarly, the Orari River narrows from around 650m between stop banks at Geraldine to around 250m near the coast.

These challenges are not matters upon which relief is sought with the assistance of central government co-investment. They are challenges, nevertheless, with farmer expectations about bedload gravel management being a salient sub-set of these issues. Regional councils are prepared to meet these challenges by encouraging managed retreat and other land use / spatial planning, where that is appropriate. In other instances, it may be the case that local landowners will increase their funding toward the achievement of a higher-level flood protection.

Rural parts of the Ashburton / Hakatere River, 31 May 2021. (Photo courtesy of Stuff).

Westport flood event – 20 July 2021

A West Coast Regional Council catchment weather station recorded 730mm of rain in the 48 hours extending through 19 / 20 July flood period. NIWA records show the last time the Buller River reached the heights experienced in the July 2021 flood was in 1926. The 7,640 cubic metres per second recorded on 20 July 2021 was the largest direct measurement of flow ever recorded in New Zealand.[69]

The cost of recovering from the effects of the Westport flood have been estimated at close to $100m. The flooding left 23 per cent of Westport's housing stock in need of repair. A total of 71 homes were severely damaged and deemed unsafe, while a further 388 homes will require significant repairs.[70] Over 1000 insurance claims were lodged.[71] A total of 2,000 Buller district flood damaged properties were assessed by the Council's Emergency Management team (figure nine).

[69] An article authored by scientists D. A Stone et al, as included in the journal 'Weather and Climate Extremes,' March 2022 (as quoted by Auckland Herald reporter Jamie Morton on 10 March 2022) found the planet's warming made the July 2021 West Coast weather event 10% more intense than would have occurred without climate warming.
[70] 'Development West Coast' Chair Renee Rooney described the flood as 'a devastating blow to Buller, damaging homes and farms, and causing much disruption to the region'.
[71] CEO Tim Grafton, Radio New Zealand, 20 July 2021.

Investment of between $10m and $20m in a flood protection scheme would likely have prevented this damage and avoided these recovery costs being incurred (figure ten).

Crown-owned assets in the Westport area, at risk of damage by flooding from the Buller River, may be categorised and valued ($2020) as follows:

- Urban land and buildings $15m
- Roads $730m
- Rail tracks $235m
- Transpower lines $13m
- **Total** **$1,000 million**

Figure nine: proposed flood protection structures for Westport. Source: West Coast Regional Council.

Additional protection to Westport communities may be provided by applying adaptation, 'working with nature' systems, relocation options, raised building floor level heights and other approaches. The relocation option involves shifting further development away from the potential flood zone to the area south-west of the current Westport township. This may be described as a multi-tool approach (figure eleven). Adaptation options include improving the efficiency of the Orowaiti River as an overflow channel (and potentially creating an ecologically rich wetland), reducing the flow-constraining effects posted by State Highway 67 and Kiwi Rail structures in some areas.

Considering the extensive damage that occurred to Westport in July 2021, what is now taking place is a multi-party process to reach agreement on a carefully phased and central government 'co-funded' approach to the rebuild of community resilience against flood risks at Westport. Flood protection structures must be at the centre of this process. Work undertaken by West Coast Regional Council recommends immediate expenditure of $10.2 million on these structures.

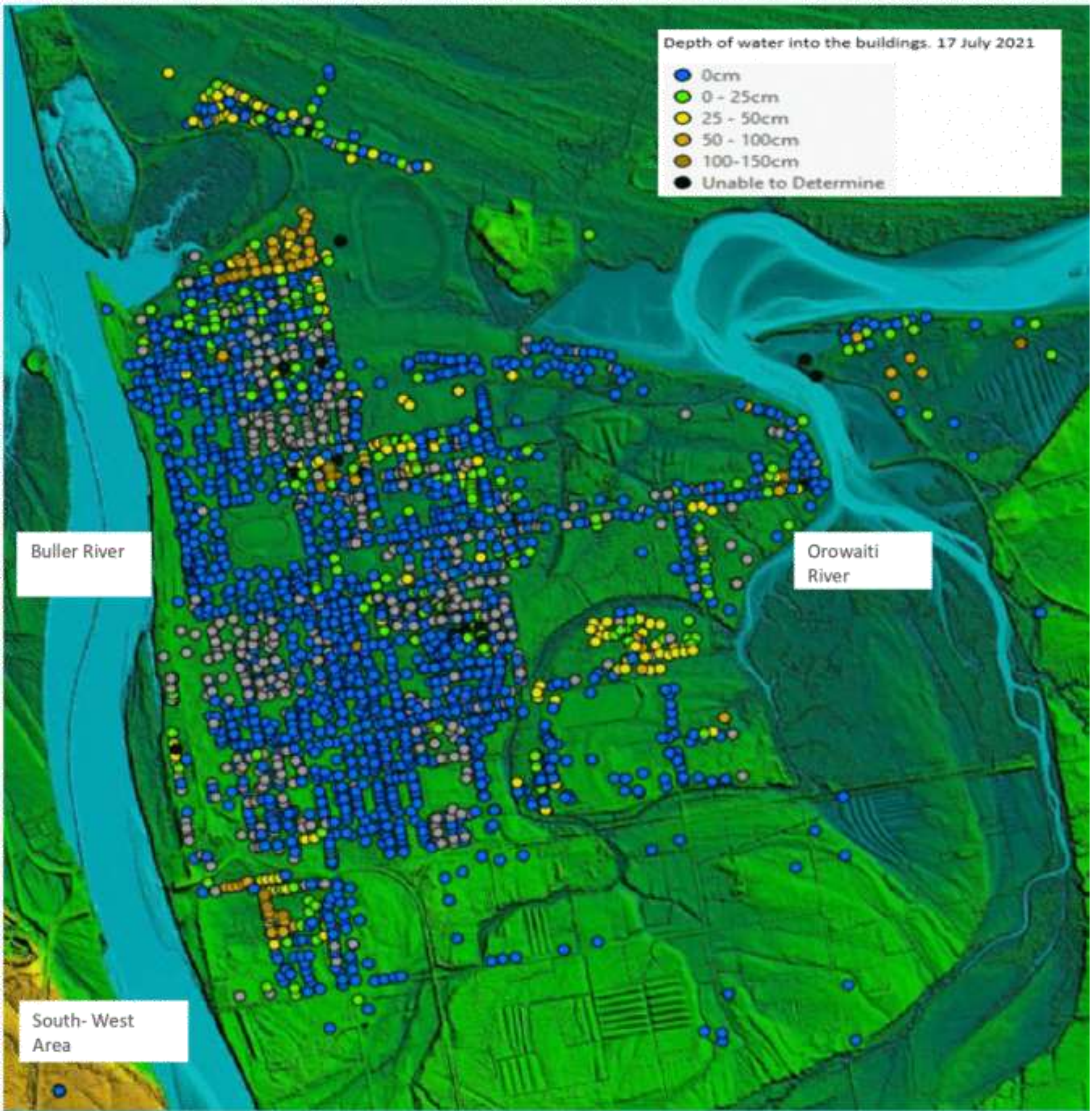

Figure ten: Inundation depth of buildings affected by Westport flood 17 July 2021: Source – West Coast Regional Council

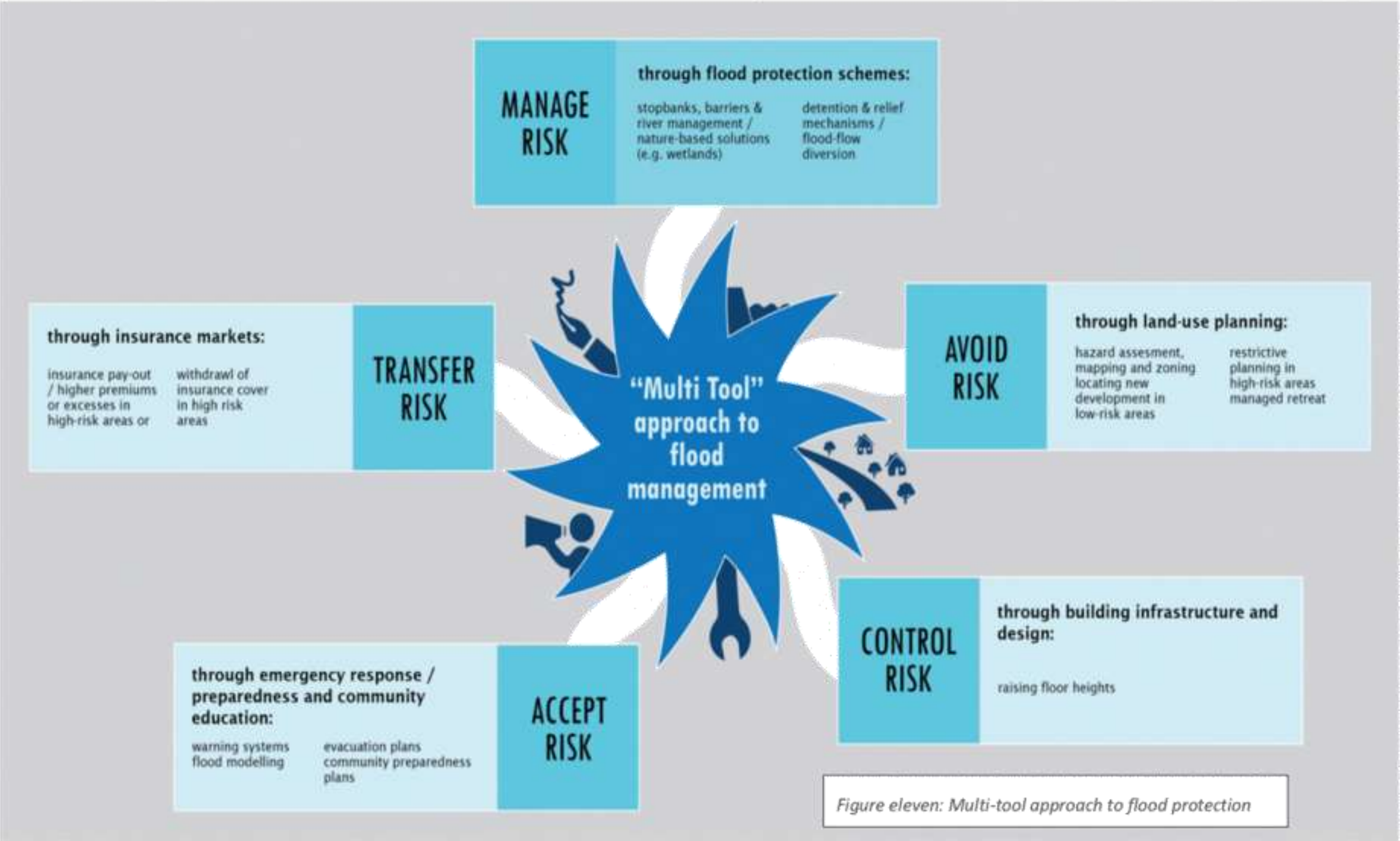

Figure eleven: Multi-tool approach to flood protection

Blenheim / Marlborough District

Almost 1000 people were evacuated from 500 properties and five people were rescued from parts of Marlborough town cut off by the worst flood ever recorded in the region. Evacuations at Spring Creek and Tuamarina were prompted by overtopping or breaching of stop banks on the Wairau River.

The effect of the flood event was exacerbated because of the flow constraining effect of the State Highway One bridge. Repairs amounting to $12m to scheme structures are now underway. Blenheim was largely protected because of flood protection scheme works constructed after the devastating 1983 flood event. This scheme was constructed with 75% funding from central government.[72] Hydrological analysis records the peak flow of the Wairau at Blenheim at 5200-5300 m3/sec, almost exactly a 1% Annual Exceedance Probability (AEP) event but slightly below the target scheme capacity of 5500m3/sec. (figure twelve).

The District's engineer recommends a new flood protection scheme peak flood capacity design is required for Marlborough's growing population, intensified land use patters - particularly viticulture, and to better manage the storm flow effects caused by climate change. The engineer suggests that such a step change will require a significant Crown involvement, both as a major infrastructure owner (including two key bridges) and as a funding partner. Excluding the cost of the replacement bridges (State Highway Six, State Highway One and the railway bridge), investment in the order of $50 - $100m may be required to make this step change.

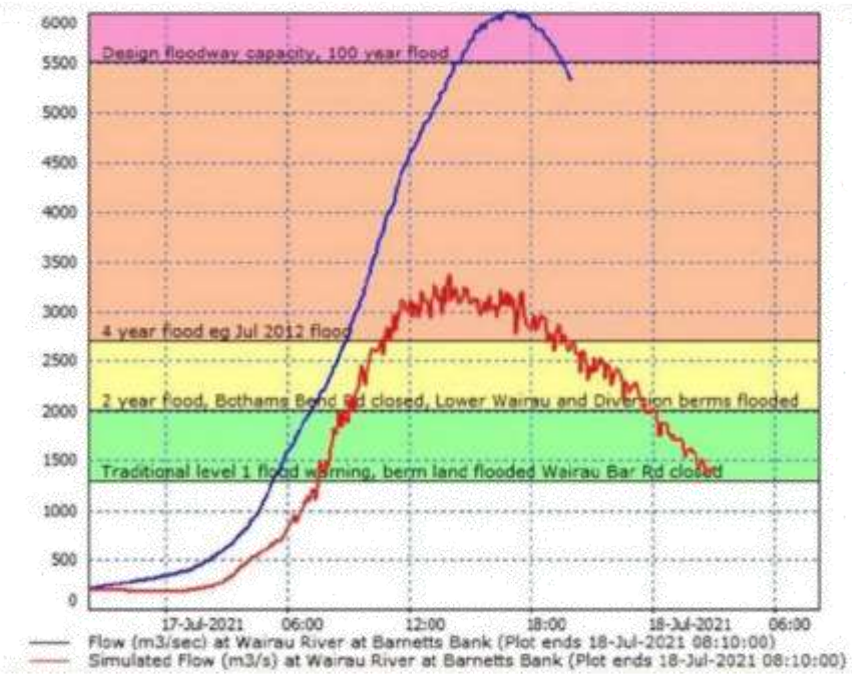

Figure twelve: Wairau River flow 17 / 18 July 2021 (Source – Marlborough District Council).

[72] This scheme is currently being enhanced with the assistance of a $3m 'shovel ready' central government grant.

Crown-owned assets in the Blenheim, at risk of damage by flooding from the Wairau River, may be categorised and valued ($2020) as follows:

- Urban land and buildings $68m
- Rural land and buildings $51m
- Roads $556m
- Rail tracks $121m
- Transpower lines $12m
- **Total** **$808 million**

Implications that may be drawn from recent flood events

The main insight from the above three cases is that the Crown is substantially exposed to flood risk damage. The Crown assets with the biggest vulnerabilities are the extensive network of road and rail assets present in these and all areas subject to flooding throughout New Zealand.

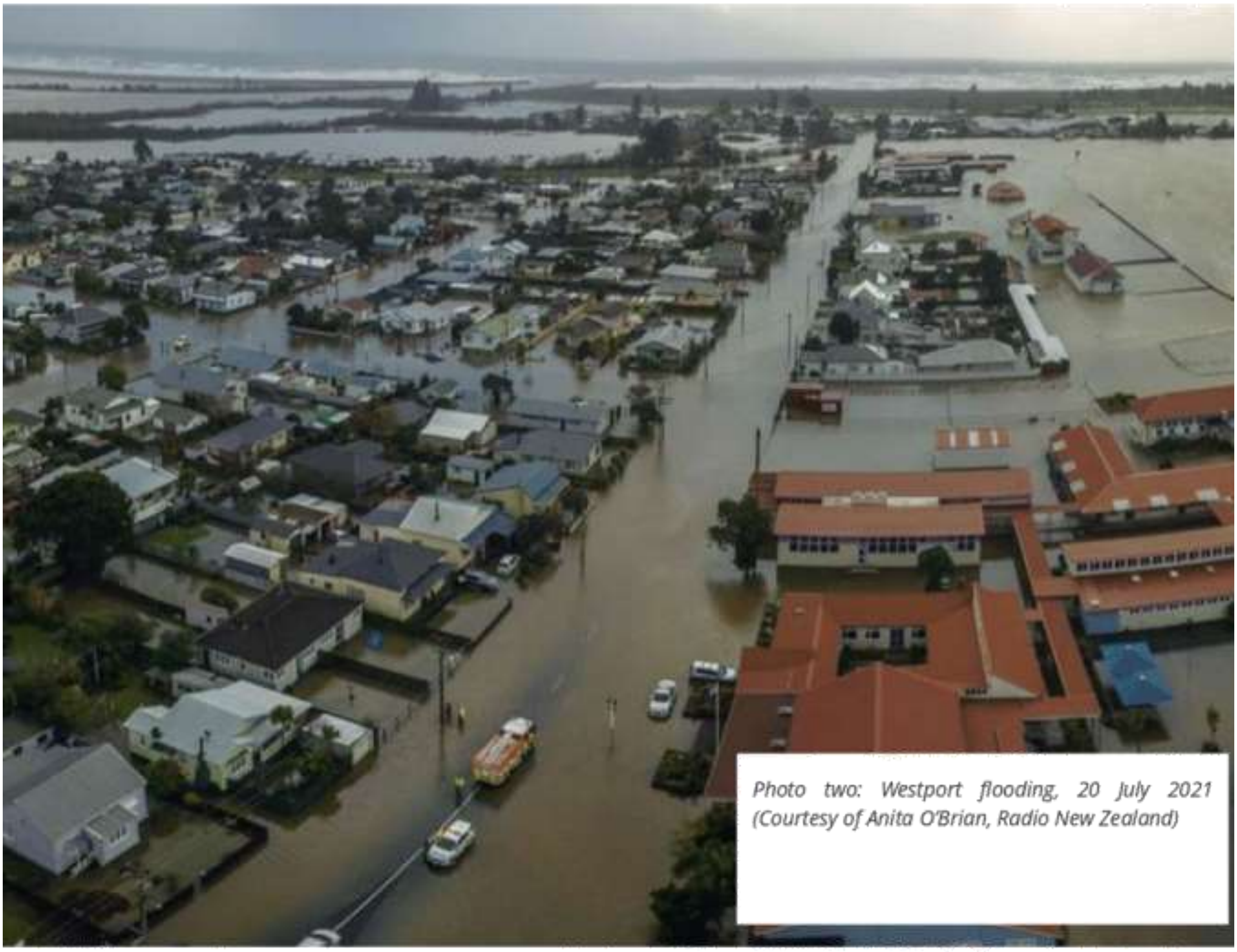

Photo two: Westport flooding, 20 July 2021 (Courtesy of Anita O'Brian, Radio New Zealand)

In addition, damage to Crown land and buildings such as schools may cause on-going disruptions (indirect costs) to community functionality. Other indirect Crown benefits arising from flood protection schemes include the following:

- Fiscal revenue (taxes and excise duties) is maintained.
- Regional economic activity is sustained because infrastructure networks (road, rail, power, and communications) keep operating.
- Expenditure by central government departments (e.g., MBIE, MPI), to rehabilitate industries, is avoided (refer Ashburton Flood Recovery Plan 2021).
- Expenditure by central government departments (e.g., MSD, MoH, FENZ, NZ Police) on community welfare and safety, is avoided (refer Ashburton Flood Recovery Plan 2021).
- Investments made by central government as part of the Provincial Growth Fund are protected.
- Resilience and increased levels of safety and security is provided to existing and future businesses, individuals, families, and communities.

The wine industry in Marlborough, the dairy industry in Ashburton and the fruit and vegetable processing industry in Marlborough are examples of the 'value-add' economic contributions, of national importance, from each of these regions.[73] Existing flood protection schemes in Marlborough and Ashburton enabled the national importance of these industries to be protected from the full effect of the July 2021 floods. Westport industries were not so fortunate. Seafood processing is one of Westport's main employers (120 employees in 2020). In addition, new initiatives, some of them established with the support of PGF-funded, were placed at risk. These included the high value tourism services provided by the Riverbank project and the Kawatiri Coast Trail. The PGF also supported the EPIC innovation hub and the development of a commercial fishing precinct.[74]

Photo three: Marlborough / Blenheim Flood 20 July 2021 (Photo courtesy of Stuff)

[73] In 2020, Marlborough district accounted for 72% of the total New Zealand land area planted in wine growing grapes. In 2020, Canterbury accounted for 20% of total NZ dairy cattle. Ashburton accounted for 7% of total NZ employment in dairy cattle farming. Of total employment in the fruit and vegetable processing, Marlborough accounts for 12% and Ashburton accounts for 11%. Marlborough accounts for 33% of total New Zealand employment in aquaculture.
[74] This precinct and the Westport Deepsea Fishing School are envisaged as providing further opportunity to take advantage of Westport's competitive position in the commercial fishing industry.

Other reasons for co-investment by central government

Withdrawal of the insurance sector from flood protection

The other main implication that may be drawn from recent events is that the increasing frequency of severe floods is not on the horizon – it is with us now.[75] The examples clearly demonstrate the scale of central government expenditure on responding and recovering from these events. The scale of this expenditure would be significantly reduced with investment in proactive risk mitigation and resilience improvement.

Some insurance companies have now provided notice of their intention to raise their cost of providing insurance cover over properties subject to flood risk. Tower Insurance was the first to act.[76] They have now given notice to their New Zealand home insurance customers[77] about increases to the flood risk portion of their premiums. Other companies such as AIG will more than likely follow suit. There is also the possibility that some insurers may decline cover for those properties subject to higher levels of risk.

Tower Insurance's proposed increases reflect a pricing model based on the individual risk faced by the property subject to damage by flooding[78]. Properties are to be allocated a risk rating of low, medium, or high. One in ten properties will be subjected to higher premiums of about $50 per year. Some property owners could see increases of several hundreds of dollars, upwards to $1000, depending on the risk level, size, and location of their property. Crown properties and assets will be placed in the same position as private property owners.

Tower have said they had made these policy changes because they wanted to make sure people were aware of the options, they, councils, and government had at their fingertips to reduce risk, including elevating / raising the floor levels of homes. They noted available options for reducing flood insurance premiums clearly included constructing flood protection scheme infrastructure.

Tower also said that flooding events in the last 18 months in Northland, Napier, central Otago and big storms in Canterbury, Westport, West Auckland and more recently in Gisborne and the East Coast had all influenced their decision to increase premiums (figure thirteen).[79]

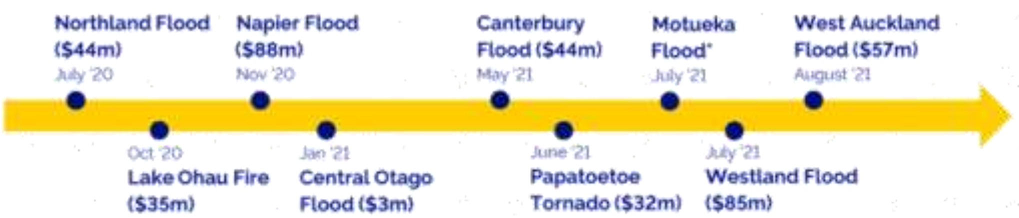

Figure thirteen: The cost incurred by Tower Insurance in assisting insured property owners to recover from recent flood events.

[75] Climate change deniers may argue that several swallows do not make a spring – in this case several flood events are not a cause for alarm because they do not have statistical validity. This could not be further from the truth – as indicated by the Tower Insurance data provided below.
[76] Tower hold 10% of the New Zealand house insurance market.
[77] November 2021
[78] Tower Insurance have used a New Zealand inland flooding model based on simulations and probabilities of difference scenarios using data obtained from NIWA, LINZ, regional councils, and the Insurance Council of New Zealand.
[79] Auckland Herald, 10 November 2021.

In addition, Tower referred to data gathered by the Insurance Council of New Zealand dating back to the 1960s to justify their decision to increase premiums (figures thirteen and fourteen). This shows an increasing trend-line in terms of natural disasters, with almost half based around floods.[80]

Of concern to Tower was not just the frequency of the floods but the severity of them. They noted, *'in the last 10 years the cost of flood damage was equivalent to the previous 45 years'*. They also noted that in the past 50 years, nearly half (45%) of all natural disasters – despite the effect of the Christchurch / Kaikoura earthquakes, were from floods.

The Insurance Council's CEO Tim Grafton telescoped the likely increase in insurance premiums in a radio interview immediately after the July 2021 Westport floods. He said, *'some flood-vulnerable communities would face difficulty getting insurance as risks of flooding increased'*. He advised *'the best path as being not just transferring risk to insurance but rather to control, adapt, avoid and be more aware (rather than be blindsided through lack of information) of the level of risk that was comfortable for each property owner to endure.'*[81]

Tower Insurance explicitly addressed this point in their recent announcements. They said that people who choose to raise the elevation of their house or be protected by flood schemes would be offered a reduced flood risk premium.

Despite awareness of the risks, some property owners will choose to not insure. The pressure and cost for local government to take preventative action will therefor increase. All 'response' actions will need to be considered by regional councils when considering their reactions to this pressure. This may include building relocation / managed retreat, requiring house floor levels to be lifted above minimum flood heights, and preventing further urban intensification in those areas subject to flooding.

The implications arising from Tower's decisions are large. Other insurance companies will inevitably follow their lead. The cost of property ownership will go up. This will remove discretionary income from other potentially more productive parts of the economy. Mitigation of flood risk by improving the integrity of existing flood protection schemes is a 'smart option' for central government and regional councils. This is better than passively accepting the obligation on the Crown and private property owners to pay insurance increases or in some cases to have to essentially act as default insurer.

In areas of existing concentrated urban development, the best option will, in almost all cases be enhancements to the level of protection provided by existing flood protection schemes. The integrity and the resilience provided by these schemes can be increased at modest cost when compared to the cumulative social, infrastructure, personal identity / security and crown-asset protection costs associated with managed retreat or raising the floor levels of potentially hundreds of buildings.

[80] Llyod's Global Underinsurance Report (2012) notes that New Zealand's local authorities operate in an environment that is highly vulnerable to natural hazard risks. New Zealand is rated as one of the most vulnerable economies in the world in terms of the impact of natural disasters, as a percentage of GDP.
[81] Radio New Zealand, 20 July 2021

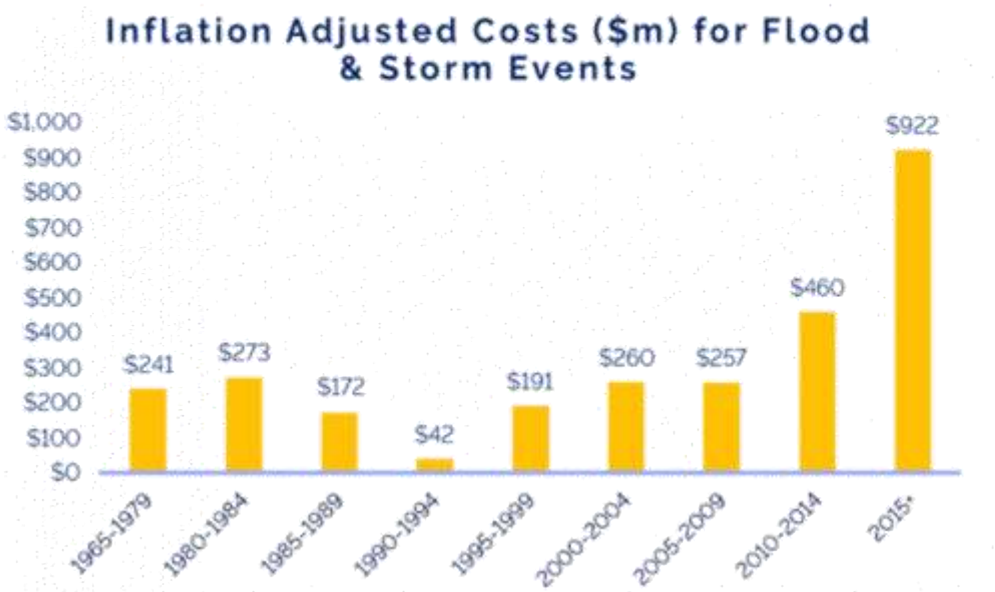

Figure fourteen: Data from Insurance Council of New Zealand about flood event costs incurred by the insurance sector

In this context, a NZIER (2020)[82] report notes that mitigation can remove hazards whereas insurance cannot. They state '*the case for mitigation depends on finding incremental reduction in exposure or vulnerability of human activities and infrastructure that avoids future hazard losses at low cost and with limited unintended effects. While insurance provides compensation for losses though risk transfer and is an important long-term element of risk management for New Zealand, it does not reduce the likelihood of such events or the risk of them happening again.* This NZIER report also noted that flooding hazards (when compared to other natural hazards) have the most scope for cost-beneficial mitigation.

Unfunded crown liability – responding after a flood event

The government's 'Thirty Year Infrastructure Plan'[83] records that the average annual costs of responding to flood events now exceeds $50 million. While necessary, this is sub-optimal expenditure compared to preventative investment. As such, it does not minimise future risk to the community or central government and Crown assets. This 'after event' focus also means government bears an excessive unfunded future liability in its fiscal accounts.

The severity of the consequences of not securing and enhancing the integrity and service levels of existing flood protection structures, and the community resilience role they play, increases every day. The fiscal consequences for government of not proactively investing at the top of the cliff are growing at a similar rate.

It is fortunate that the 2021 floods in Ashburton, Westport and Marlborough district did not result in a loss of life. It is only a matter of time before lives are lost. This is an even bigger liability and responsibility for the Crown to carry.

[82] NZIER, 2020. 'Investment in Natural Hazards Mitigation – forecasts and findings about mitigation investment', a report to DIA
[83] Treasury, Thirty Year Infrastructure Plan, 2015.

Treasury's Living Standards Framework

Treasury's Living Standards Framework has moved towards a 'four capitals' approach. These 'capitals' include:

- Natural capital, with reference to all parts of the environment needed to support life and human activity.
- Financial / physical capital, with a direct role in supporting incomes and material living conditions.
- Human capital, with reference to the things which enable people to participate fully in work, study, recreation, and society.
- Social capital, with reference to the norms and values that underpin society.

All elements of the new Living Standards Framework imply a need for more active investment by central government in the management of flood risks.

The Sendai Protocol

The Sendai Risk Management Protocols of the United Nations, to which New Zealand is a signatory, recognise the importance of investing in risk mitigation activities. The National Resilience Strategy developed by the Ministry of Civil Defence and Emergency Management aligns with the Sendai Protocols.

The Sendai Protocols reflect four priorities:

- Priority 1: Understanding disaster risk.
- Priority 2: Strengthening disaster risk governance to manage disaster risk.
- Priority 3: Investing in disaster risk reduction for resilience.
- Priority 4: Enhancing disaster preparedness for effective response and a commitment to "Build Back Better" as part of recovery, rehabilitation, and reconstruction.

As a signatory to the Sendai Protocol, these priorities clearly imply a need for central government to play a more active role in risk mitigation.

Productivity Commission – local government funding and financing

The Productivity Commission enquiry into local government funding and financing[84] selected flood protection schemes as an example of a function for a stepped-up co-investment-focused-arrangement between central and local government. The terms of reference for the enquiry, as issued by the Ministers of Finance and Local government, noted that:

- Local authority debt has grown steadily since 2006 to the point where some councils are now coming close to their covenanted debt limits.
- One of the major factors influencing local authority debt is the cost of adapting communities and infrastructure to mitigate risks and hazards associated with climate change.

The Commission favours the "benefit principle" as the primary basis for deciding who should pay for local government services. In this regard, the Commission noted '*some local assets and their associated services could benefit... national interests. In these cases, the benefit principle points to shared funding with a contribution from central government.*

[84] Productivity Commission, Local Government Funding and Financing, 30 November 2019.

In addition, the Commission identified four key areas where the existing funding model is insufficient to address cost pressures:

- Supplying enough infrastructure to support rapid urban growth.
- Adapting to climate change.
- Coping with the growth of tourism.
- The accumulation of responsibilities placed on local government by central government.

All four of these identified areas support the need for co-investment by central government in flood protection schemes. In addition, the Commission suggested the Government should extend the role of the New Zealand Transport Agency (NZTA) in co-funding local roads. This should be to assist councils facing significant threats to the viability of local roads and bridges from climate change and / or to overcome the exacerbation of flood risks because of the narrowing of river channels because of these structures.

International precedent

President Jo Biden has introduced a $1.76 trillion-dollar (NZ dollar equivalent) bipartisan infrastructure Bill to the US Senate calling for roads and power infrastructure to be made more resilient to storms.[85]

In the United Kingdom, more than 1,000 flood protection schemes will benefit from a record investment of more than $10 billion (NZ dollar equivalent) of investment over the next six years.[86]

The Australian Productivity Commission has called for the Australian government to increase annual flood mitigation funding contributions to state and territory governments by $100 million in the first year, then to $150 million in the second year and $200 million in the third year.[87]

These important precedents present a model for New Zealand to follow.

Summary – reasons for central government co-investment

In summary, the reasons for a return to active central government co-investment in flood protection schemes are that it:

1. Is more fiscally responsible than focussing on post-event response and recovery.
2. Reflects Treasury's new performance measurement and Living Standards Frameworks.
3. Is supportive of wellbeing and social inclusion.
4. Has the potential to better reflect equity / ability to pay considerations at the heart of this government's election promises.
5. Is supportive of job creation and the potential to lift the productive potential of the regions.
6. Contributes to the security of the vital access routes (rail and road) for commerce.
7. Directly protects Crown assets.
8. Contributes to investment 'opportunity costs.'
9. Works against escalating insurance premiums and the risk of insurance companies failing to provide insurance cover in flood risk areas – with the long-term consequence of Government

[85] CNN, 2 December 2021
[86] UK government press release, 2 December 2021.
[87] This recommended 'federal' commitment is on top of commitments already made at the state and local levels.

inevitably being required to step-up and stump-up to fill the gap occurring because of the absence of private insurance.

10. Contributes to the environmental and water quality expectations of our communities and iwi partners.
11. Provides for resilience and adaptation against the effects of climate change-induced 'above-design' storm events.
12. Above all else, provides resilience and increased levels of safety and security to existing and future individuals, communities, and businesses.

Moving forward

The options for the future funding of flood protection range from a 'business as usual' approach, to application of all the other options displayed in figures five and ten. These include better spatial planning to avoid flood hazards, managing the retreat of some communities from certain areas, to the construction of enhanced flood protection schemes, in association with whole-of-catchment solutions.

For all situations, options need consideration within the context of present-day reality and the circumstances applying at any one location. In most instances it is likely that the full range of risk reduction methods should be applied in tandem although as noted earlier, improving the integrity and capability of existing flood protection structures is in most instances, likely to be the most cost-beneficial and therefore priority intervention.

Do-nothing approach

Maintaining existing scheme service levels[88] is not tenable, nor practical, primarily because the influence of climate change is such that current levels of resilience will continue to be eroded. This, in turn, will result in:

- Increased risk to public and private local, regional, and national assets.
- Increased demands on emergency and recovery funding.
- Increased insurance premiums.
- Increased risks to public safety and a risk to life.
- Increased numbers of communities unable to get insurance and / or decreased insurance coverage.
- Increased community and personal hardship and distress.
- Increasingly negative impacts on local, regional, and national economies and the environment / ecological and iwi values.

[88] A 'Service Level' is calculated using one of three methods: a scope of physical works agreed with the affected community; or a scope of physical works with a target capacity e.g., a maximum channel flow and or a scope of physical works with a level of performance defined in terms of a target return period e.g., a one in one-hundred-year event.

Business as usual and do-nothing approaches are therefore not tenable. Regional councils know this. They have already committed to increase their level of future investment by $25m per annum. They are also grateful for the 'one-off' $217m investment made by central government into the 55 flood protection projects that were 'shovel ready' in 2020. However, there are many more scheme upgrade projects also requiring increased investment to meet future needs – with an estimated cost of $150m each year. Central government should co-invest this sum by making provision for a line-item in their annual budgets. Responding to location-specific requests on an ad-hoc basis is not an appropriate way to address this challenge.[89]

Community / managed retreat / planned withdrawal approaches

This option proposes to reduce risk by asking residents and businesses to withdraw from locations at risk of being flooded. As noted previously in this report, this relocation / managed retreat is extremely difficult - particularly when this involves established and well-developed urban communities. The sunk costs of existing investments are very large. Stranded assets will have zero value. The impact on landowners of moving, to allow rivers to flow more freely, will extend both upstream and downstream of the 'run free' location.

The social and political disruption and 'stranded asset' effects associated with this option are likely to make it unpalatable in most cases. Nevertheless, there will be some locations within catchment schemes where this solution may be considered an acceptable part of a more holistic approach.

Whole of catchment approaches

The desires of iwi / Māori, ecological considerations and the broader interests of regional and national communities are such that regional councils must apply their river management intentions in an environmentally benign / ecologically sensitive and whole catchment manner.

Integrated and sustainable land management or 'whole-of-catchment' approaches have always been a core part of regional council business. More substantial investment in whole-of-catchment solutions will be required in the future. Applying this option reduces the level of sedimentation, bed load deposition and erosion occurring within catchments. It also improves the water quality in rivers, estuaries and coastal waters and contributes to biodiversity values.

To successfully adopt and achieve a 'whole-of-catchment' approach requires extensive outreach work, including one-on-one collaboration with landowners. This is to help them become aware of how they may alter land use practices, adjust internal property infrastructure, and change the nature of the enterprises they apply to their land to achieve more holistic long-term water quality, soil, flood management and environmental outcomes.

Part of this work will involve planting trees. The one billion trees programme and carbon sequestration planting have played an important role in contributing to the outcomes sought from these 'whole-of-catchment' solutions. Other initiatives contributing to whole of catchment solutions include:

- Accelerating application of sustainable land use practices.
- Promoting the conversion of some areas from pastural uses into indigenous forest.
- Promoting and co-funding more extensive riparian planting.
- Accelerating careful consideration of the use of some areas for Mānuka planting and honey production.

[89] The preparation of a business case and the provision of central government funding for a multi-tool assistance package for Westport will provide a useful pilot to guide the development of a comprehensive national / central government approach to co-investment.

- Promoting expanded plantation forestry in suitable locations.

The net effect of the above initiatives is that they will help to forestall the risk of transferring this generation's flood management 'challenges' into compounded problems for the next generation. Whole catchment approaches are therefore an essential element in the 'multi tool' approach to be applied to enhanced flood protection.

The new spatial planning and national planning tools, proposed as part of the resource management legislative reform programme, are also essential. Regional councils look forward to being active leaders and participants in the development and application of these tools, but they will not be enough on their own.

Enhanced flood protection schemes, in association with whole-of-catchment and spatial planning approaches

Sustainable land use is an essential ingredient of flood risk management. Investment in sustainable land use needs to be increased. However, no matter how successful sustainable land use tools may be, they cannot and will not be enough on their own to manage the impact of significant flood events. This is because more sustainable land uses will have only a minor effect on the increasing amount of rainfall occurring from the inevitable and more intense, climate change-induced storms transported by our rivers and streams. Enhanced flood protection schemes must remain a central part of the solution.

Potential unintended consequences of Crown co-investment in flood protection schemes

The 'counterfactual' or unintended consequences of central government co-investment in flood protection schemes is a matter that has been considered by regional councils. Two primary risks have been identified, both of which are highly unlikely to be displayed:

1. <u>Regional councils place too much reliance on flood protection schemes and fail to sufficiently invest in other flood risk management tools:</u> Regional councils fully understand and are fully committed to the application of a multi-tool approach to flood risk management.[90]
2. <u>Regional councils invest less in flood protection schemes because rate payer sourced funding is substituted by tax-payer sourced funding</u>: Regional councils have committed to spend an extra $25m per year on flood protection schemes, over and above their current $175m per year commitment.

Request to central government

Regional councils seek central government commitment to co-invest in the improvement of the integrity and resilience of flood protection schemes. This should be alongside the regional council-focused wide-spread and comprehensive adoption of whole-of-catchment and planning / resource management solutions[91].

Collectively, such a joined-up approach will better achieve integrated land use, enhanced ecological values, improved water quantity and quality outcomes, decarbonisation benefits and, generally a better reflection of iwi and wider community aspirations about how natural systems should be managed.

[90] Regional council involvement in discussions about the flood risk management at Westport provide a case example of this commitment.
[91] The co-investment propositions outlined in this paper do not include provision for soil conservation planting and or steep land retirement. Budgets for these complimentary activities should be combined with flood protection scheme investments and the planning solutions outlined in this paper.

Regional communities and directly-benefiting private property owners cannot fund the necessary step-change needed to manage increased flood risks, in the more sophisticated manner set out above, on their own. Central government, regional councils and territorial local authorities must equitably share the task of addressing this challenge. This is not about failure or blame about the efficacy of current systems. Rather, it's about the overwhelming need to cement a new co-investment and funding partnership approach with central government.[92]

Regional council river engineers have engaged in an active 'foresight' process to estimate spending of $350m / year is required to ensure river management and flood protection schemes are 'fit for the future'. Regional council Long-Term Plans (2018-2028) currently indicate necessary operational and capital expenditure of approximately $200m / year. The shortfall required to make the necessary step-change in the level of protection provided by flood protection schemes is therefore estimated at $150m / year. Central government co-investment of $150m per annum is viewed as a pragmatic contribution to this necessary expenditure.

Source of revenue and possible funding formula

Regional councils have extended their congratulations to the government[93] on its decision to establish a new $1 Billion per annum 'Climate Emergency Response Fund' (CERF). The purpose of this fund is to mitigate the effects of climate change by applying adaptation interventions.

Investment in flood protection schemes should be a priority matter for attention in considering CERF expenditure options. Flood protection schemes are the intervention measure with likely greatest effect in helping communities to adapt to the effects of climate change. Adaptation actions are required immediately, regardless of the success or otherwise of international mitigation / decarbonisation measures.

The proposed 2022 National Adaptation Plan[94] may be the instrument to guide expenditure of the CERF. Regional councils are participating in an MfE 'Local Government Adaptation Advisory Group.' One of the objectives of this participation is to ensure appropriate flood protection scheme investment provisions are considered by this Group and thereby included in the National Adaptation Plan.

Regional Councils fear the Local Government Adaptation Advisory Group deliberations will not be enough on their own to guide the necessary decisions. Councils therefore also urge establishment of a working group with Treasury, DIA, and other officials (for example officials from MBIE's Kānoa Group). Their task would be to develop the principals, priorities, and a project funding allocation framework to guide central government co-investment expenditure decisions on flood protection schemes. This group should be requested to provide its recommendations to core ministers and regional council Chairs and Mayors within three months from initiation.

Back-work to achieve this objective needs to be underway now. Without necessary co-investment decisions being made in the very near future, then the flooding risk to our communities will continue to incrementally increase. The consequences of not acting do not bear thinking about.

The actual co-investment share of the CERF at any single location should reflect a range of considerations.[95] The principles outlined in the July 2020 Cabinet paper provide a starter for considering how apportionment of this increased investment may be guided. From a regional council

[92] Regional authorities acknowledge that, alongside a government decision to co-invest in river management and flood protection schemes, there is a need to establish related funding-accountability measures.
[93] Correspondence to Ministers 23 December 2021
[94] This Plan is currently being developed by MfE.
[95] Ae precedent for this is the financial assistance rate (FAR) applied to central / local co-investment in road transport solutions.

perspective, proposed central government co-investment starter thoughts were outlined earlier in this report. In essence, what is sought is:

- Co-investment of up to 75% toward the cost of **whole catchment climate change adaptation** approaches.
- Co-investment of up to 50% toward the cost of **upgrading existing** river management and flood protection works.
- Co-investment of 33% toward the **maintenance** of existing scheme works to recognise the role they play in protecting Crown assets / related infrastructure and their role in sustaining the operation of national and regional economies and communities.
- Co-investment of 75% for **emergency repair** works to schemes where substantial damage occurs from major storm events.

Although variable, indications are that for any year, approximately half of the total annual spend would comprise works in the maintenance category, with the balance being split approximately evenly between the first two categories of expenditure.

The above cost-share formula is believed to be realistically and fairly determined. It needs to be applied urgently. It clearly recognises the need for a step-change in investment to improve the 'design capacity' of existing flood protection schemes. It will result in much needed improvements to community resilience against the effects of climate change.

Conclusion - national leadership and urgent action required

The Government has an important and urgent role to play in leading, resourcing and focusing purposeful, timely and meaningful actions that result in practical improvements to flood protection schemes. These improvements are fundamental to the task of greatly increasing community resilience against flooding.

Regional councils have successfully delivered flood protection to New Zealanders for more than half a century. They cannot continue to be expected to do this on their own. There is a strong case for central government co-investing in flood protection schemes. The Crown owns flood-protected assets and shares in the benefits provided by these schemes. The Crown currently make close to zero funding contribution to their maintenance and improvement.

The central governments of the United States and the United Kingdom have both recently committed to substantial increased expenditure on flood protection schemes. They have seen the writing on the wall. The government of New Zealand should join them by taking similar action.

The essential request to New Zealand's central government is for it to 'return to the table' to share financially in the task of providing fit-for-purpose protection against New Zealand's primary natural hazard – 'flooding.' Flood protection schemes are the first line of defence.

Now is the time when schemes need to be re-purposed, modified, upgraded, or renewed to meet increased climate change-induced flood frequency and magnitude changes, alongside other contemporary challenges. These other challenges include meeting a wider spectrum of community, environmental, cultural, iwi / Māori and economic needs.

In some cases, planning solutions and raised building-floor heights will meet these needs. However, in most cases these initiatives will be expensive and will take a long time to be effective. Flood protection schemes need to be improved immediately to enable them to help New Zealanders to go about their businesses and carry out their lives without the fear and disruption caused by floods.

The central government co-investment of $150m per annum from the CERF – as proposed in this report, reflects the national interest in protecting public safety, providing community resilience, mitigating risks to the national economy, and protecting nationally-significant publicly-owned infrastructure.

Flood risks are real, they are trending upwards and the effects of flooding on the communities who live and work on flood plains are significant and growing. A committed central government / regional council response is required so that necessary changes can be implemented in an orderly, timely, community-focused, and adaptive manner.

To achieve this objective, regional councils urge central government to work with them to reach agreement about the location-specific, principled, prioritised, short, and long-term combined flood protection scheme investments that can be made to address increasing flood risks.

The sought-after urgent action is central government agreeing to co-invest in flood protection schemes. The subsequent next step is to form a central government / region council group to reach speedy agreement about the quantum, timing, principles, framework, criteria, and priority projects for central government co-investment into flood protection schemes.

Appendix one: Correspondence from Environment Canterbury to Hon Nanaia Mahuta

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

27 September 2021

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Dear Ministers,

Co-investment in river management and flood protection schemes

Flooding is New Zealand's most common natural hazard estimated to cost the country $160 million per year.The 31 May – 2 June Canterbury regionwide flood event (and the flooding that followed in Buller and Marlborough) highlights the bias of our current system toward recovery and response action, rather than coordinated investment in early risk reduction and preparedness.

A new case study based on recent flood events in the South Island is now being prepared for your review asan update to the 2018 business case *Central Government Co-investment in River Management for Flood Protection* to further support the recommendation for permanent central government investment. We expect this to be completed by November 2021.

The Canterbury flood event was extreme, with Ashburton particularly hard hit. Concerns about structural stability temporarily closed the Ashburton River bridge on State Highway One, cutting off lifeline services reminiscent of the Rangitata floods of December 2019. The limits of Canterbury's flood protection schemes were tested and flooding in rural areas left many landowners to deal with significant erosion and gravel deposition.

This event alone will take us at least two years to reinstate schemes to pre-flood levels of protection at anestimated cost of $15 to $20 million just for infrastructure replacement on a like-for-like basis.

Current funding inadequate for the challenges of climate change

Furthermore, the recent flooding is a stark reminder of our changing climate, placing flood resilience front and centre for a concerned public. The community experienced significant flow-on effects and many areas remain vulnerable to future rainfall events with landowners on high alert. We will be working alongside key stakeholders with affected communities whose lives and livelihoods have been significantly affected forsome time, even as we continue to manage the impacts of the 2019 Rangitata flood.

Together with other regional councils in the River Managers Special Interest Group, we acknowledge that meeting future flood resilience objectives is beyond the reasonable capacity of ratepayers alone, particularly when flood risks are magnified by climate change. Communities are struggling to pay for the maintenance of current infrastructure, let alone additional works required to meet the challenges of more frequent and higher magnitude weather events.

Ratepayers currently bear a disproportionate share of scheme costs when compared to who benefits. We have also noted considerable post-flood community concern regarding how current schemes are funded andhow works out of scheme are not.

Increasing complexity of river management

River management has evolved significantly in recent years. Multiple values prioritised at the national levelmust also now be supported as part of river management and flood resilience.

We work alongside iwi as tangata whenua and Treaty partners, acknowledging the special status of our relationship to ensure that Māori values and interests are protected and enhanced.

The emphasis by government, Māori, and the public on the importance of ecological, environmental, and whole of catchment considerations has resulted in an increasingly complex environment requiring community engagement, co-design of solutions with iwi, consideration of ecological and environmental issues and development of strategies for adaptive responses that must in turn be coordinated with otheragency partners.

Successful co-investment for future resilience

Crown co-investment with regional communities and directly benefiting property owners in rivermanagement and flood protection is required on an urgent basis.

We are confident that our $24.2 million climate resilience programme of flood protection projects, part- funded by the Ministry of Business Innovation and Employment's *Kānoa – Regional Economic Development& Investment Unit (REDIU),* will prove the case for ongoing central government co-investment. These ambitious projects are currently supporting transformative initiatives that improve the resilience of our communities and support multiple values.

To consider the details of crown co-investment in flood protection, we reference the recent Local Government New Zealand (LGNZ) Regional Sector meeting with Ministers Mahuta and Shaw on climate resilience. Council fully supports the LGNZ request to establish, as a priority, a joint working group of officerswho would report to Resilience Ministers in time for appropriate provisions to be included in the 2022 budget.

Investment at this critical time will pay dividends in the future to secure the intergenerational health and wellbeing of all New Zealanders and ensure that we have a resilient economic network ready to adapt to thechanges we know are coming. We look forward to your response.

Yours sincerely
Jenny Hughey
Council Chairperson

CENTRAL GOVERNMENT CO-INVESTMENT IN FLOOD PROTECTION SCHEMES – SUPPLEMENTARY REPORT

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REPORT

Tonkin+Taylor

Hiding in plain sight

An overview of current practices, national benefits and future challenges of our flood protection, river control and land drainage schemes

Prepared for

River Managers' Special Interest Group

Prepared by

Tonkin & Taylor Ltd

Date

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Executive summary

Water management has become a pressing concern for many New Zealanders from grassroots level through to our national political dialogue.

In recent years, conversations about water management have tended towards how our communities can be better provisioned by resilient 'three waters' services, and the limits of our regulatory approaches on maintaining an acceptable amount and quality of water within our lakes, streams and rivers.

Flooding is the most common natural hazard that New Zealanders face. The role that a low profile and separate layer of infrastructure – the vast network of critical flood protection, river control and land drainage schemes – plays within water management has generally been absent from these conversations.

Over 100 towns and cities across the country have been built alongside rivers or on flood plains. Between the 1930s and 1980s, billions of dollars were spent building stopbanks, pump stations and related assets to protect our citizens and lifeline infrastructure, and enable regional economic stability by preventing regular flooding of our communities and productive land.

New Zealand has come to rely on the protection provided by over 350 flood protection, river control and land drainage systems. The effectiveness of these systems combined with the low frequency, high impact nature of flooding keeps public awareness of flood risk to life, property, livelihoods and the economy low – until there's a failure – and flood risk is expected to increase as society anticipates more extreme weather events and sea level rise.

This has prompted New Zealand's river managers – the stewards of these critical assets – to stop and think about how well their current practices will serve future generations of New Zealanders.

Environmental engineers, Tonkin + Taylor, and resource economists, Covec, were commissioned to conduct this national assessment of current practices, quantify benefits at a national level and identify future challenges associated with the flood protection, river control and land drainage schemes managed by regional councils.

This national assessment is intended to raise the profile of this hidden infrastructure and its importance. It has not been possible to fully explore all of the issues and challenges identified in this report. It is expected that this report will serve as a starting point for more detailed assessments of these issues.

Takeaway messages

This national assessment has found that, regional councils appear to have, overall, adopted an appropriate level of asset management, renewal and upgrade processes. However, the methods used by councils to understand, interpret and approach both technical and non-technical river management issues are inconsistent, and this variability may unknowingly expose some New Zealand communities to a greater likelihood of asset failure and its consequences.

These infrastructure assets are vital in protecting and supporting New Zealand communities and economic development. These assets protect around 1.5 million hectares of land – including highly productive primary production land, and many urban areas. This report does not cover the effect that historic and current land use practices have had on our water ways, which undoubtedly have a place in water management conversations.

All of these assets have a combined capital and operational value of $3.6 billion, and in aggregate for every dollar of invested there is some $55 of avoided losses on average. These assets provide $13 billion in benefits to New Zealand every year.

Many technical and non-technical challenges face the sector tasked with managing our river management infrastructure. This river management sector is relatively small, with limited capacity and capability to address these challenges. Therefore the sector will need to work together across organisational boundaries, and in collaboration with external parties to adequately face these challenges and serve future generations of New Zealanders.

Key findings

Survey data. Data for this assessment was gathered from over 350 flood protection, river control and land drainage schemes managed by regional councils throughout New Zealand. These schemes directly protect some 1.5 million hectares of land which comprises about 5.5% of New Zealand's land mass, and includes highly productive primary production land, and both small and large urban areas.

Scheme funding. Funding is generally provided through targeted rates on rateable land that either directly or indirectly benefits from the schemes. The schemes also protect or provide a benefit to non-rateable land (Crown estate), regionally significant public utilities – such as three waters infrastructure – and nationally significant infrastructure such as roading and rail networks, and energy and telecommunication links. Current funding practices impact on how councils manage and deliver flood protection, river control and land drainage infrastructure and services.

Scheme management. Indicators of how well the schemes are being managed include infrastructure asset condition, criticality, and performance. Our assessment of asset condition scores for river management infrastructure indicates that, on the whole, regional councils appear to have adopted appropriate levels of asset management, renewal and upgrade processes for various asset types. However, documented asset management practices are variable between councils, and do not generally describe asset criticality and asset performance.

Asset value. The infrastructure assets comprising the schemes – stopbanks, dams, river structures, flood gates, drains, pump stations, and the like – have a collective replacement value of $2.3 billion. In comparison to other publically owned infrastructure, the national value of this infrastructure is small.

Cost benefits. The schemes included in our assessment provide an estimated Net Present Benefit of $198 billion ($NZD at 2016), over $11 billion each year. These benefits includes the wider social and economic benefits of the schemes. The Net Present Cost to operate, maintain and rebuild the schemes total an estimated $3.6 billion ($NZD at 2016).

Consistency. Variability in how councils understand, interpret and approach both technical and non-technical flood protection and land drainage issues was found throughout this assessment. Nationally consistent methodologies in how flood protection and land drainage infrastructure are managed and delivered would assist in ensuring an appropriate level of investment in this infrastructure and associated services to New Zealand communities. We would also expect this to deliver financial efficiencies for ratepayers.

Communication. Many councils describe large flood events to their stakeholders in terms of occurrence probabilities, which has limitations due to the uncertainties associated with estimating these probabilities. It would be useful for the river management sector to reframe these community discussions with a primary focus on event consequences with less emphasis on event probabilities. This is in line with the risk based approach now prescribed in the Resource Management Act. These discussions may be most effective when they include data and illustrative scenarios which convey the consequences and residual risks of events, and community and scheme vulnerabilities.

Technical and non-technical challenges. Many technical and non-technical challenges face the river management sector. These challenges include understanding the impact of more frequent extreme rainfall events, involving much wider stakeholder groups in decision making, scheme funding and affordability, and how environmental, social and cultural values are considered in river management activities. Many of the challenge themes are similar to those that councils face in the delivery of other infrastructure and services, but the specific challenges facing the river management sector and how it may respond to them are unique.

Given the relatively small and distributed nature of the asset base managed by the sector, a coordinated response from river managers and collaboration with external parties is required to address these challenges. For this to happen effectively, there needs to be further standardisation of whole-of-life asset management and resilience planning methodologies across councils, and development of an enabling environment which supports knowledge sharing and knowledge transfer. Inter-organisational transfers and collective staff training would help staff to work effectively across organisational boundaries. Consideration should be given to how these types of cross-organisational activities are collectively funded.

We've identified a number of areas for further work which will help the river management sector to better address issues and challenges that it faces. **Our recommendations** are to work across the following themes:

Working together across the sector

a Provide resources to river managers to enable and support a step change in professional collaboration and development across regional council river managers and with external organisations, so that the sector as a whole can proactively respond to the challenges identified in this national assessment.

Communication and enabling environment

b Communicate as 'one voice' the state of the river management sector and the outstanding value the schemes provide to New Zealand as identified in this assessment.

c Proactively engage as 'one voice' in discussions about potential changes to the regulatory environment (for example, managing natural hazards under the RMA, development of National Disaster Resilience Strategy, other RMA reforms, etc) so the views of the river management sector are understood by central government.

d Develop methodologies and programmes to enable river managers to effectively engage with stakeholders on the schemes, and their benefits, including how the schemes work and help manage flood risk.

Quality people

e Increase the capacity and capability of the sector to deliver future-focused, successful community outcomes, which may include formal graduate intake and professional development programmes.

f Partner with tangata whenua to bring new skills, networks, and views into the river management sector.

Practices, methodologies and standards

g Benchmark each regional council against key metrics including staffing levels, service levels, funding levels, and the like.

h Prepare nationally consistent asset management methodologies, metadata standards, targeted asset management maturity levels, funding and payment metrics, reporting frameworks (e.g. AMPs), and level of service standards.

i Assess on a scheme by scheme basis asset criticality and performance against asset condition, to better understand how well infrastructure assets are being managed including how river structures integrate with flood protection schemes, and identify where key vulnerabilities lie.

j Compile a technical body of knowledge to establish best practice, and identify knowledge gaps or uncertainties, and research needs (e.g. water quality, risk communication, climate change, river geomorphology).

k Carry out an assessment of cultural and environmental values of the schemes and take them into account when assessing the schemes' benefits and costs.

l Develop a river management resilience framework and supporting decision making tools to enable regional councils to better inform and position communities so they respond to shocks and stressors with minimum disruption, and to formally include environmental, social, cultural and economic values into projects.

m Understand the financial viability of the schemes and common funding issues (asset revaluation, depreciation and renewal expenditure, borrowing, etc) on a national scale and their implications on future affordability of the schemes, and what the impacts of removing protection or decreasing a level of protection may be.

n Investigate alternative funding rationales and strategies, for example, to avoid a higher proportion of scheme costs sitting with fewer ratepayers and to recognise the wider benefits of the schemes.

1 Introduction

In conjunction with Tonkin + Taylor and Covec, regional councils have combined forces to carry out a national assessment of river control, flood protection and land drainage schemes (collectively, 'the schemes', or 'river management activities') that are managed by regional councils. The River Managers' Special Interest Group, which reports to the Regional Council CEO Special Interest Group, has overseen this project. Specifically through this project we have sought to identify at a national level:

- The location and state of the schemes' infrastructure assets
- The benefit they provide in protecting and developing communities and economies
- The quality of asset management and ability to deliver community agreed service levels
- The present and future opportunities and challenges associated with river control, flood protection and land drainage

The outcomes from the project will enable the river management sector to:

- Understand the current state of the schemes in New Zealand
- Communicate the nation's reliance on and value of investment in river control, flood protection and drainage schemes
- Quantify the investment in the schemes' infrastructure by regional councils and their predecessors
- Quantify annual maintenance/renewal expenditure in maintaining agreed levels of service defined in asset management plans
- Quantify the benefits of these schemes to the community
- Understand the extent to which work or plans are in place to meet increasing expectations of communities which benefit from them, including the predicted implications of climate change on the schemes
- Identify strengths and weaknesses in current institutional performance of the river management sector

1.1 Background

Regional councils have been responsible for the construction, maintenance and improvement of river control, flood protection and land drainage scheme infrastructure since 1989. This is when the powers of catchment boards under the Soil Conservation and Rivers Control Act 1941 Act were vested in regional councils and unitary authorities. Prior to 1989 this infrastructure was developed and managed by catchment authorities — often working in partnership with central government who helped fund this infrastructure.

In the absence of seeing this infrastructure tested in significant rainfall or flood events, communities may well forget the purpose, and therefore the importance and value, of this infrastructure. By its very nature, over time this infrastructure simply becomes part of the landscape.

The lack of widespread awareness of the role, state and value of this infrastructure to New Zealand may have contributed to its general omission from the National Infrastructure Unit's *Thirty Year New Zealand Infrastructure Plan 2015*.

1.2 Methodology

Tonkin + Taylor conducted a review of spatial (GIS-based) information provided by regional councils of their river control, flood protection, and drainage schemes to identify the areas that benefit from the schemes' infrastructure assets.

With this spatial information we undertook a high level analysis of the economic benefit afforded by the schemes. The cost benefit analysis was carried out by our project partner Covec, a company specialising in natural resource economics. In carrying out this analysis, Covec undertook an international literature review of flood protection economic evaluation methods to inform their analysis.

We also received detailed responses from the river manager at each regional council in the form of a written questionnaire. Questions and responses covered factors that influence how river management services are delivered. Topics were categorised under the broad headings of People, Equipment, Environment, Processes, Organisation, and External (PEEPOE framework). The questionnaire is included in Appendix C.

The matters raised by river managers, and the outcomes of our analyses were discussed with the river managers' project steering group in three workshops held throughout the course of this project.

Our research covered the way councils manage delivery of other infrastructure assets in NZ, the difference between delivery of river management infrastructure to other infrastructure, and how the history of river management in NZ has influenced the sector we have today. Where appropriate, we've drawn on our knowledge and experience of working within the river management sector.

1.3 Limitations

This project has relied on information provided to us by river managers and regional councils. Most of this information was provided via Asset Management Plans, councils' GIS and ratings databases, and through responses by river managers to the PEEPOE questionnaire. Data was also gathered through follow up questions and workshops with the river managers' project steering group.

Information provided to us has been taken at face value, with data anomalies queried and checked with relevant river managers. A detailed review of all information provided is outside the scope of the project. Based on our experience and understanding, we consider that the results of our analysis represent a reasonable overview of NZ's state of management of river control, drainage and flood control schemes, and their value. Limitations include:

- Data was provided by all regional councils and unitary authorities with the exception of Nelson and Marlborough
- Data provided by Otago Regional Council had some gaps in asset value that could not be resolved within the constraints of this project
- Schemes managed by territorial local authorities — such as Christchurch City Council — are outside the scope of this project[1]
- The economic assessment and cost benefit analysis are based on 2016 costs
- The cost benefit analysis does not attempt to fully account for all environmental, social, and cultural benefits and costs of the schemes as discussed in Section 5.3 Exclusions on page 19.

[1] The scope of this survey included regional councils and the regional council functions of unitary authorities.

2 The nature of river management and land drainage activities

River control and flood protection activities exist to reduce the severity of impacts on communities from low frequency, large flooding events. Land drainage activities allow the use of low lying land predominantly for agricultural production or improve the productivity of agricultural land. These activities provide communities with greater security from substantially mitigated flooding risks and confidence from better knowledge of how frequently their land may be inundated. This has enabled economic growth through increased productivity of land.

Ironically, the success of these schemes, particularly in reducing the impacts of flooding, has resulted in a low awareness of these activities amongst the wider community. Failure of this infrastructure to provide a particular level of service – or even recognition that the infrastructure exists – is often not immediately apparent.

The relatively infrequent nature of these events stands in contrast to other infrastructure assets — for example, the wastewater, stormwater, or transport links that are utilised on a near daily basis. While many of those assets, such as underground pipes, are unseen and taken for granted by the general public, it quickly becomes apparent when a council doesn't deliver these services to the standard expected by the community. Feedback to councils and agencies responsible for managing these assets is often immediate and very clear. However, similar feedback is infrequently available for river management activities because a scheme's performance may only be tested once or twice within a generation.

A combination of event infrequency and subsequent lack of performance feedback presents many challenges to the river management sector. Not least, are communities' engagement and understanding of their infrastructure needs, and the ability of managers to secure and maintain funding for scheme assets. These challenges are discussed further in this report.

3 Brief history of river management and land drainage in New Zealand

The economic, social, and cultural development of New Zealand is intricately linked with human interventions to manage the direction of rivers to protect people and property from flooding, and to drain low-lying land for productive use.

Settlement in New Zealand has primarily occurred on and around the coastal alluvial flats near rivers and streams. In locating settlements on flat land adjacent to rivers and surrounding land, Maori and European settlers were able to use the rivers to their advantage. Fertile soils, drinking water, and transportation links were afforded by these waterways. Conversely, this also exposed them to the hazards of flooding, erosion and sedimentation, and water borne diseases.

Early activities and legislation (1850s-1900s)

By the mid-19th century, settlers had initiated various river management and land drainage works on an ad hoc basis in an attempt to guard against the hazards posed by the rivers. Although various pieces of legislation were enacted to formalise river management and land drainage activities (notably the River Boards and Land Drainage Acts of 1908), a fairly piecemeal and localised approach to these activities continued until the late 1930s. By this time soil erosion and its impact on waterways had become prevalent issues in catchments nationwide. These issues, and the Esk Valley floods of 1938, prompted a response from central government that resulted in the passing of the Soil Conservation and Rivers Control Act 1941.

Formation of the Soil Conservation and Rivers Control Council (1941)

The 1941 Act established the Soil Conservation and Rivers Control Council (SCRCC), which centralised soil conservation, river management and land drainage activities under the Ministry of Works and Development, and gave rise to a formal, interventionist approach to river management and land drainage activities. During this time central government subsidised capital river management works of between 30% and 87.5% of the capital cost of the works. Higher subsidies were provided for larger, nationally important schemes, and lower subsidies provided for smaller, locally important schemes. Although most of the works were subsidised in the order of 70% to 75%, the local funding contribution engendered a sense of ownership among communities that benefitted from the works.

The 1941 Act also established Catchment Boards (or Commissions) and made them responsible for river functions and objectives. These included controlling or regulating water flows into and out of watercourses, preventing or lessening the likelihood of overflow and associated damage from watercourses, preventing or lessening erosion, and promoting soil conservation.

To achieve these objectives Catchment Boards were given powers to compulsorily acquire land, make by-laws, control land use, undertake river management and land drainage activities, and recover their costs from communities. However instead of acting unilaterally with these powers, the Catchment Boards endeavoured to take a collaborative approach with communities, who in many instances were financially assisted to undertake works at the direction of Catchment Board staff.

It was under this regulatory regime, with some later amendments[2], that most of the country's now existing river control, flood protection, and land drainage infrastructure was planned, designed and constructed.

[2] Notably the Water Pollution Act 1953, the Water and Soil Conservation Act 1967 (which also created the National Water and Soil Conservation Authority), the Town and Country Planning Acts of 1953 and 1977, and the Local Government Act 1974.

The rise of environmental awareness and an understanding of the interconnection between land use and water quality in the 1960s and 1970s led to a raft of regulatory changes. Most notable was the Water and Soil Conservation Act 1967. This created the National Water and Soil Conservation Authority (NWASCA) and generally resulted in the morphing of catchment boards and commissions into regional water boards. Boards were charged with responsibility for regulating any significant uses of water through a water rights system.

Local government reforms (1980s-current)

The major state sector and local government reforms[3] of the 1980s essentially completed the transition of river management and associated soil conservation functions to regional authorities. These reforms included the dissolution of NWASCA and the allocation of its responsibilities and those of the Catchment Boards to regional councils. Central government retained a limited transfer policy and monitoring role through the Ministry for the Environment.

These reforms also eliminated central government funding of capital and maintenance works for river control, flood protection, and land drainage activities. Prior to NWASCA's abolition, central government's servicing department (the Ministry of Works and Development) typically applied a funding vote of more than $40 million per annum to support these functions. These are now largely paid for through rates levied by regional councils.

Transitioning from a position of very substantial Government funding support to total reliance on local and regional funding sources posed many political and technical challenges. In general, however, that transition has been successfully made, albeit with some community-negotiated changes to protection service levels, both upwards and downwards.

Regional councils are now the organisations primarily responsible for soil conservation, maintenance and enhancement of water quality, water quantity, aquatic ecosystems, and the avoidance or mitigation of natural hazards. But whereas the primary consideration of most river management infrastructure built during the mid-20th century was safety and economic growth – social, cultural, and environmental values of water resources are now prominent policy and activity drivers. This can be seen in the start of freshwater co-management with tangata whenua, more collaborative engagement on freshwater issues from statutory and industry organisations, and the National Policy Statement for Freshwater Management.

River management activities supporting safety and economic growth still remain vitally important to the communities and primary industry sector that directly benefit from them, as well as their supporting infrastructure, such as the nationally important transport and telecommunications links that underpin the functioning of modern society.

[3] Including the Local Government Act 1989 and the Resource Management Act 1991.

4 An overview of New Zealand schemes

So what do New Zealand flood protection and land drainage schemes look like? This section provides a snapshot of river control, flood protection, and land drainage schemes. It covers what's included and excluded from a scheme, the extent and quantity of the schemes nationally, and the state of the infrastructure assets within schemes.

Figure 4.1: Stopbanks protected Palmerston North from inundation during the 2004 Manawatu River flood event. Source: teara.govt.nz

4.1 Schemes – what's in and what's out?

The river management activities undertaken by regional councils generally deal with the management of rainfall runoff on a catchment scale, and are broadly classed into four scheme types based on the nature of their benefit as follows:

- Land drainage – getting water off the land into a stream or river
- Flood protection – keeping water in the river and off land
- River management – keeping the river where it is
- Tidal inundation – keeping sea water off land

Each regional council classifies schemes and their infrastructure assets into these four broad types. This publically available information has been used in this assessment.

What is not covered under these schemes and is excluded from this assessment is the management of stormwater runoff in urban or semi-urban settings by city and district councils. The management of some flood control and coastal protection schemes by city and district councils such and the Avon-Heathcote River in Christchurch or the Maitai River in Nelson is also excluded[4].

Additionally, regional councils undertake soil conservation activities to reduce soil erosion and in some instances these are key elements of flood protection schemes. Although these soil conservation activities are important to water quality and overall catchment health, assessing the state and value of them is beyond the scope of this assessment.

Figure 4.2: Surface flooding on productive land served by land drainage scheme, Waikato 2008. Source: Waikato Regional Council.

Figure 4.3: Schematic of flood protection, river control and land drainage services

4.2 Scheme extents

The geographic coverage of river control, flood protection and land drainage schemes can be described as follows:

- **Infrastructure assets** – physical structures which protect land from being inundated by water, for example, stopbanks, flood gates, pump stations, and river training works

Capital and operational expenditure associated with these assets are generally funded by rates from the following areas:

- **Direct benefit areas** – areas of land which are immediately protected from flooding by infrastructure assets and would otherwise be subject to flooding during storm events up to and including the size of a design event
- **Indirect benefit areas** – areas of land which sit outside the direct benefit area and receive a 'community good' from protection afforded by the infrastructure assets
- **Exacerbator areas** – upper areas of land in a catchment that contribute runoff to low-lying portions of a catchment and contribute to drainage or flooding issues experienced in these lower lying areas

The direct benefit areas for all scheme types across New Zealand is shown in Figure 4.4, below.

[4] The scope of this survey included regional councils and the regional council functions of unitary authorities.

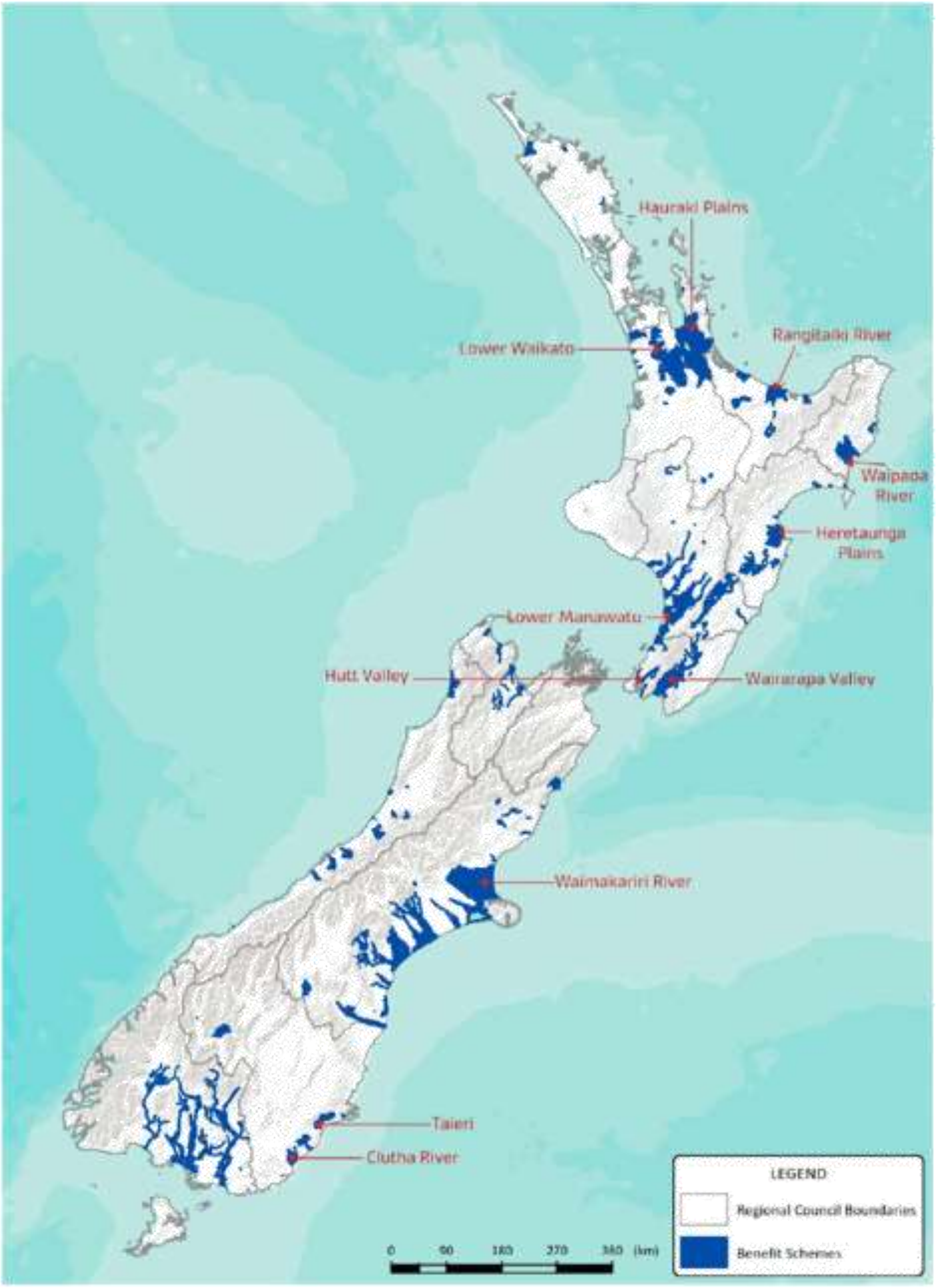

Figure 4.4: Extent of direct benefit areas

4.3 Number of schemes

There are around 364 river control, flood protection, and land drainage schemes administered by regional councils across New Zealand that have been included in this assessment.

A breakdown of the number of scheme types by region is given in Table 4.1 below. We found that how the nature of scheme benefit is described varies depending on the scheme. Specifically, some schemes provide a single benefit type only, while other schemes provide multiple benefits. For those schemes that provide multiple benefit types, the available data was insufficient to understand the proportion of benefit type.

For example, there are a large number of schemes in the Waikato that are identified as only providing drainage benefit. This is contrasted with the Kaituna scheme in the Bay of Plenty that provides flood protection for an event having a 1% Annual Exceedance Probability (AEP) and drainage protection for events up to 20% AEP.

Schemes with multiple benefit types were most common for regional councils in the Bay of Plenty, Hawkes Bay, Manawatu, and West Coast. Future data analysis would be made easier if the schemes or their constituent parts were able to be classed under a single benefit, though we recognise this may be difficult.

Table 4.1: Number of scheme types by region

Council	Benefit Type Flood	Drainage	River Management	Tidal	Mixed Benefit	Total Schemes
Northland	2	0	0	0	1	3
Auckland[1]	-	-	-	-	-	-
Waikato[2]	3	86	0	0	5	94
Bay of Plenty	0	1	0	0	4	5
Gisborne DC	2	17	0	0	0	19
Hawkes Bay	2	0	2	0	21	25
Taranaki	0	0	0	0	2	2
Manawatu	7	6	6	0	15	34
Wellington	51	15	0	0	0	66
Marlborough DC	-	-	-	-	-	-
Nelson CC	-	-	-	-	-	-
Tasman DC	0	0	16	0	6	22
West Coast	3	1	2	1	13	20
Canterbury	15	13	28	0	4	60
Otago	3	3	1	0	1	8
Southland	6	0	0	0	0	6
Grand Total	**94**	**142**	**55**	**1**	**72**	**364**

Notes:

1. Council reported it does not have any relevant schemes under management.
2. No data was provided for schemes protecting urban settlements in Taupo and Thames – Coromandel Districts.

4.4 What schemes protect

The 364 schemes for which data is available provide direct benefit to some 1.5 million hectares of land (about 5.6% of New Zealand's land area). As noted previously, schemes provide benefit beyond the areas of direct benefit. Regional councils recognise this through the identification of indirect benefit areas and exacerbator areas for the purposes of striking a rate to fund the schemes.

In addition to the rateable areas of benefit that schemes protect — or otherwise provide a 'community good' — schemes also protect non-rateable land and regionally and nationally significant infrastructure, including transportation, energy and telecommunication links. For example, State Highway 1, the North Island Main Trunk Line, and a trunk fibre optic cable are protected by the Lower Waikato scheme. Social and cultural infrastructure, for example, the Hutt Hospital and numerous schools, marae, libraries and churches, are protected by the Hutt Valley scheme.

The available scheme rating databases from each region were combined to prepare Figure 4.5, below. This figure shows the four benefit types relative to each other for rateable land area, rateable land value, and rateable capital improvements (capital value less land value).

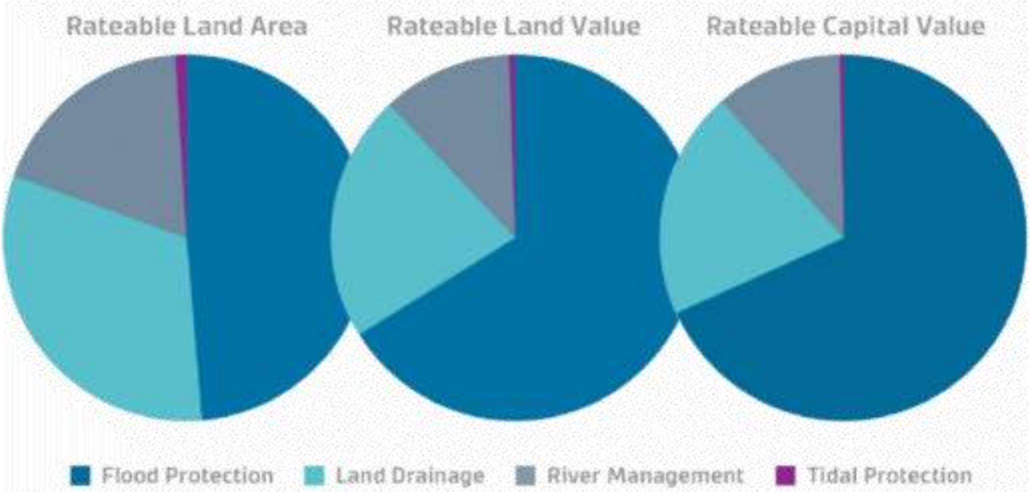

Figure 4.5: Comparison of benefit proportions for rateable area, land value, and improvements value by scheme type based on available data

4.4.1 Discussion

As illustrated in the pie charts, flood protection schemes protect an increasingly greater proportion of rateable land area, land value and capital value compared to other scheme types. This indicates that flood schemes may protect a greater portion of urban land — with capital improvements —than other scheme types.

Land drainage schemes comprise approximately half of the total number of schemes in this assessment. However, they protect a disproportionately small amount of rateable land area, and a diminishing proportion of rateable land value and capital improvements. This is indicative of the more rural nature (primary industry production) of land protected by these schemes.

The same diminishing proportion of rateable land area, value, and capital improvements are observed for tidal protection schemes. Again this is indicative of the rural nature (primary industry production) of land protected by these schemes. For example, the area protected from tidal inundation in lower Piako River is the largest area of tidal protection benefit, as this scheme covers an extended area of low-lying farmland near or below sea level.

A diminishing proportion of rateable land area, value, and capital improvements is also observed for river management structures. However, these structures are often integral to flood protection schemes. The data does not clearly illustrate a linkage between these structures and the type of land they benefit. Further work would be required to demonstrate this link at a national or regional level.

4.5 Infrastructure assets

4.5.1 Asset value

The total replacement value[5] of river control, flood protection and land drainage infrastructure assets is approximately $2.3 billion. This is about 4.5% of the estimated $45 billion replacement value of assets for three waters infrastructure (drinking water, waste water, and stormwater) as stated in Treasury's Thirty Year NZ Infrastructure Plan 2015-45.

The total replacement value of infrastructure assets (about $2.3 billion) is broken out by asset type in Figure 4.6, below.

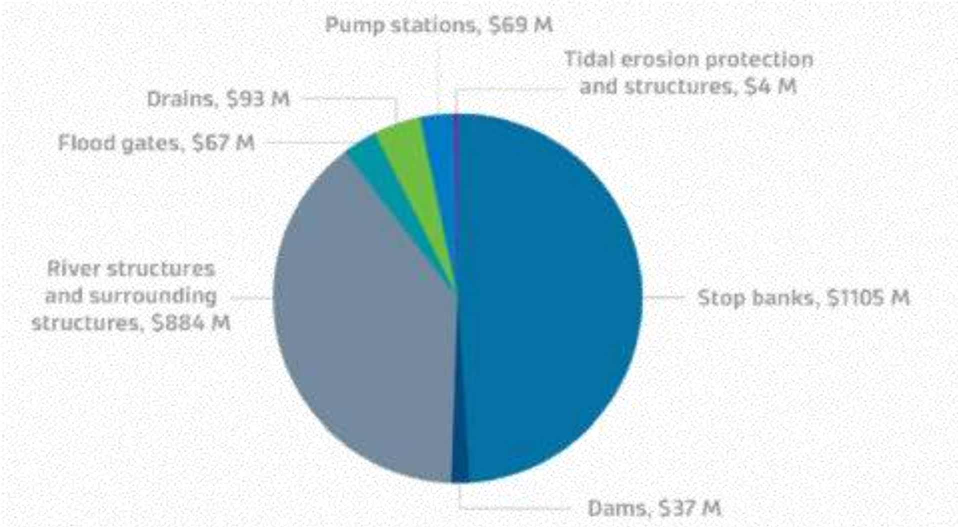

Figure 4.6: Summary of total replacement value by asset type for provided data

Flood protection is generally provided by stopbanks and dams. Across the assessed councils, these assets make up about half of the capital investment but provide almost three quarters of the capital value protected. In other words the capital value of land protected by stopbanks and dams is disproportionally higher than the asset value.

The same pattern can be seen for assets including pump stations, floodgates and drains which provide land drainage. These assets make up about a tenth of the total capital investment and from this provide benefit to around a fifth of the capital value protected.

River structures, such as groynes, rockwork and other armouring, training banks, weirs, and trees/vegetation, are associated with both flood protection and river management as noted above. However, based on the data provided it is difficult to apportion value of these assets to those benefit types. We note that river structures are often capital intensive and integral to flood protection schemes, and the river structures themselves may not directly relate to a large area of benefit.

Further work is needed to better understand how river structures integrate with flood protection schemes, and how the river structure capital and economic values could be apportioned to discrete benefit types.

[5] Total replacement value of the infrastructure assets is based on the valuations published in the asset management plans available for this assessment.

4.5.2 Asset condition

A fundamental aspect of asset management is the systematic inspection and recording of asset condition. The International Infrastructure Management Manual (IIMM) 2015[6] uses a five point scale for asset management scoring. For the purposes of this assessment we have used the IIMM qualitative descriptors (Excellent/Good/Average/Poor/Failed) instead of a one to five scale.

Based on the data available for this assessment, it appears all regional councils use the NAMS scale. However, there is little, if any, asset condition assessment standardisation across the councils or even within a council. In our experience, the way asset condition is assessed can vary depending on who undertakes the assessment and when the assessment is carried out. For example, staff who are very familiar with an asset can become complacent with its condition and overlook some shortcomings. Additionally, in absence of condition scoring guidance staff departures can result in new staff using a different reference point to score asset condition.

The sector has recognised that standardisation in asset condition scoring is important, and has recently developed a stopbank condition assessment framework that all councils should adopt. Development of further assessment frameworks for assets such as for pump stations, floodgates and the like, is beneficial and should be considered by river managers.

The overall condition of river control, flood protection and land drainage infrastructure assets is summarised in Table 4.2, below. Data is based on conditions published in the asset management plans made available for this assessment.

Table 4.2: Asset condition summary

Infrastructure asset type	Condition (qualitative descriptor)
Stopbanks	Average or better
Floodgates	Average or better
Drains	Good or better, some Average
Dams	Average or better
Pump stations	Average to Good, some Poor
River structures	Good, some Poor to Average

At an overview level, the asset condition scores suggest regional councils have adopted an appropriate level of asset management, renewal and upgrade according to asset type. Scores also reflect councils' general asset management approach of maintaining stopbanks in perpetuity while river and mechanical structures are worn and then replaced, hence the latter group having a wider range of condition. A summary of regional asset condition by type is included in Appendix A.

The condition of an infrastructure asset does not tell the whole story of how well that asset is being managed. Asset condition needs to be assessed in conjunction with asset criticality and performance to understand if and when maintenance or renewal work needs to be carried out. Asset criticality and performance are generally not well documented by regional councils, and an assessment of these criteria is beyond the scope of this report. Further work to assess these factors against asset condition would require a more in depth scheme by scheme review.

[6] The IIMM 2015 is identified by the New Zealand Asset Management Support Organisation as best practice in asset management.

4.6 Regional breakdown

A regional breakdown of the number of schemes by type is given in Figure 4.7, below. There is significant variation between councils in terms of the size and make up of schemes. Figure 4.7 is ordered by total value of each councils' scheme assets with two cohorts emerging. One is a cohort of councils — Canterbury, Manawatu, Waikato, Greater Wellington, Bay of Plenty and Hawkes Bay — covering a significant overall proportion of asset value. The other, a cohort of councils collectively making up a smaller proportion of the asset value.

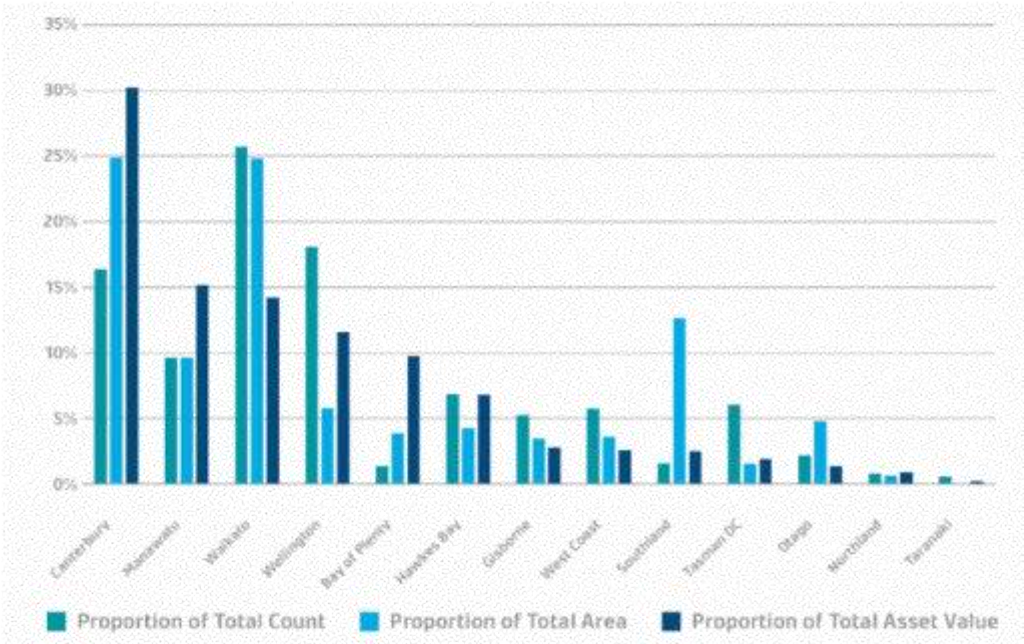

Figure 4.7: Scheme attributes as proportion of assessed total

5 Economic value of the schemes to New Zealand

A cost benefit analysis was undertaken by economic consultants, Covec, to help define the total economic value of the schemes included in this assessment. Covec's report is attached in Appendix E and its analysis is summarised in this section.

Covec estimates that the river control, flood protection, and land drainage schemes included in this assessment provide a Net Present Benefit of $198 billion ($NZD at 2016). Using the sum of the regional councils' published infrastructure asset replacement values and operational expenditure of $3.6 billion ($NZD at 2016), the average Benefit Cost Ratio (BCR) of these schemes to New Zealand is approximately 55:1. For comparison, large infrastructure projects in New Zealand, such as those for the NZ Transport Agency, are considered economically viable if the BCR is greater than 1:1[7]. As such, with an average BCR of 55:1, these schemes provide outstanding value for money to New Zealand.

5.1 Methodology

A cost benefit analysis (CBA) of the schemes was undertaken by adding all of the estimated benefits of the schemes and subtracting estimated operational and maintenance costs. To undertake CBA, two scenarios were assessed:

- The factual case – that is the overall benefit to the community with the schemes in place, and
- A counterfactual case – that is the overall benefit to the community where there are no schemes in place

Covec considered three different situations for the counterfactual case, and evaluated situations in terms of the assumptions needed to define them, the analytical problems arising from these approaches, and whether and to what degree any approach adopted is consistent with best practice for CBA.

The counterfactual approach that was used for this analysis assumes that to continue to receive the current scheme benefits, the community is willing to pay an amount equal to value of assets and land currently protected by the schemes. This assumption, which is further described in Covec's report attached in Appendix E, is made on the basis that the owner of the scheme could otherwise remove these assets.

The approach used to evaluate the benefits to the community was predominantly based on the value of damage to residential and other buildings, and the valuation of various land use types that are protected by the schemes. These are described in detail by Covec, and summarised in Table 5.1.

[7] Economic evaluation manual, New Zealand Transport Agency, January 2016.

Table 5.1: Valuation approach by land use and scheme type (Covec 2017)

Land use/ land type	Flood protection	Tidal protection	Drainage	River management
Built-up areas (residential and other buildings	NPV of avoided damage	Value of improvements plus difference in value of land uses	Value of improvements plus difference in value of land uses	Value of improvements plus difference in value of land uses
Other land uses	Greater of NPV of avoided damage or Difference in value of land uses possible with/ without flood protection	Difference in value of land uses possible with/without tidal protection	Difference in value of land uses possible with/ without drainage	Difference in value of land uses possible with/ without river management

For flood protection, the Net Present Value of avoided damage was estimated through the development of flood risk density curves, whereby the annual average damage for an area of land can be determined with and without a scheme in place, as shown in Figure 5.1 below. For the purposes of estimating annual average damages, data from the NZ Insurance Council for floods between 1976 and 2016 was used.

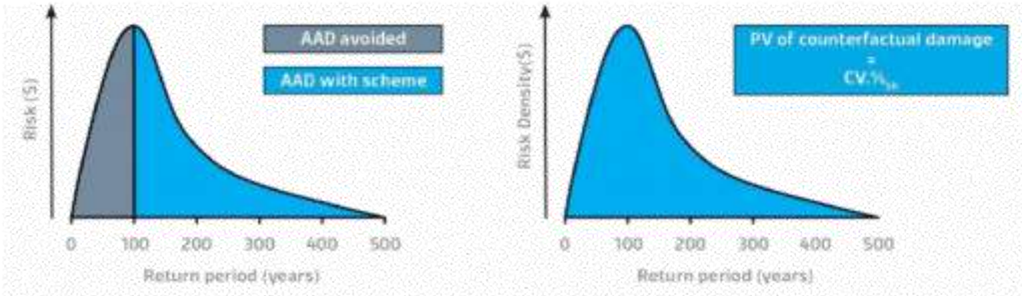

Figure 5.1: Annual Average Flood Damage (AAD), and Average Annual Damage avoided with a flood control scheme in place that has a 100 year return period level of service. The counterfactual is also shown.

Finally, the level of flood damage avoided was modified based on each scheme's benefit rating, as set out in their relevant asset management plans.

For differences in land use, Covec used the difference in value of land based on the current use, and counterfactual use assuming that no scheme was in place.

Covec reviewed potential non-market values such as insurance costs, emergency cost multipliers and health impacts on the community. Based on work carried out for the Greater Wellington Regional Council, Covec adopted a value of 100% of direct damage costs to take account of a range of non-market costs associated with flooding in urban areas. This cost was allocated on a pro rata basis for non-urban areas based on average population densities for rural areas in NZ.

The data used by Covec for this analysis is outlined in their report. It included:

- The flood level of service for the schemes used in this assessment
- The capital value of land within the scheme's benefit area
- The land value within the scheme's benefit area

- The level of benefit provided (low, medium, high)
- Land cover descriptions.

5.2 Results

The results are presented across all schemes assessed and separated into scheme types, and are summarised in Table 5.2 below.

Overall the benefits of the schemes are significant with a Net Present Benefit of approximately $198 billion ($NZD at 2016) at an average Benefit Cost Ratio (BCR) of 55:1. The highest benefits come from flood control, drainage, and mixed benefit schemes followed by tidal and river control schemes.

The annual benefit of over $11 billion provided by the schemes is nearly five times their published infrastructure replacement value. .

Due to the project steering group's concerns of the significantly large difference in benefit calculated for Canterbury region compared with other regions, we reviewed the input data for Canterbury and Wellington regions and performed a few sensitivity checks. In this review we found some differences in how these regions supplied their data and rate their schemes.

However, the differences between Canterbury and Wellington appear to be overshadowed by the relatively large areas of direct benefit, and population within these areas. Using the latest census meshblock information Canterbury has about 350,000 normally resident population in direct benefit areas compared to 75,000 for Wellington's Hutt Valley.

Table 5.2: Estimated benefit (2016 $ million) of flood control, drainage, river management, tidal and multiple schemes

Protection type	Land type	Estimated benefit (PV) ($m)	Annual benefit (at 6% Discount Rate) ($m)
Flood control	Built-up area	$134,601	$7,619
	Other land use type	$12,553	$711
	Total	$147,154	$8,329
Drainage	Built-up area	$12,796	$724
	Other land use type	$629	$36
	Total	$13,424	$760
River Management	Built-up area	$2,167	$123
	Other land use type	$83	$5
	Total	$2,250	$127
Multiple types	Built-up area	$34,631	$1,960
	Other land use type	$895	$51
	Total	$35,526	$2,011
Total		$198,354	$11,228

It should be evident that built-up areas that are protected by these schemes represent the greatest benefit, which together represent over $184 billion NPV or over $10 billion of annual benefit, compared with over $14 billion NPV or an annual benefit nearly $1 billion for other land use types protected by these schemes.

While not all councils are represented in this analysis we consider that the information is sufficient for an evaluation of the benefits of the schemes to be made at a national level. It is expected that inclusion of schemes not included in our analysis would return a similar, outstanding BCR.

Figure 5.2 depicts the cost and benefit of the schemes for each region in our assessment.

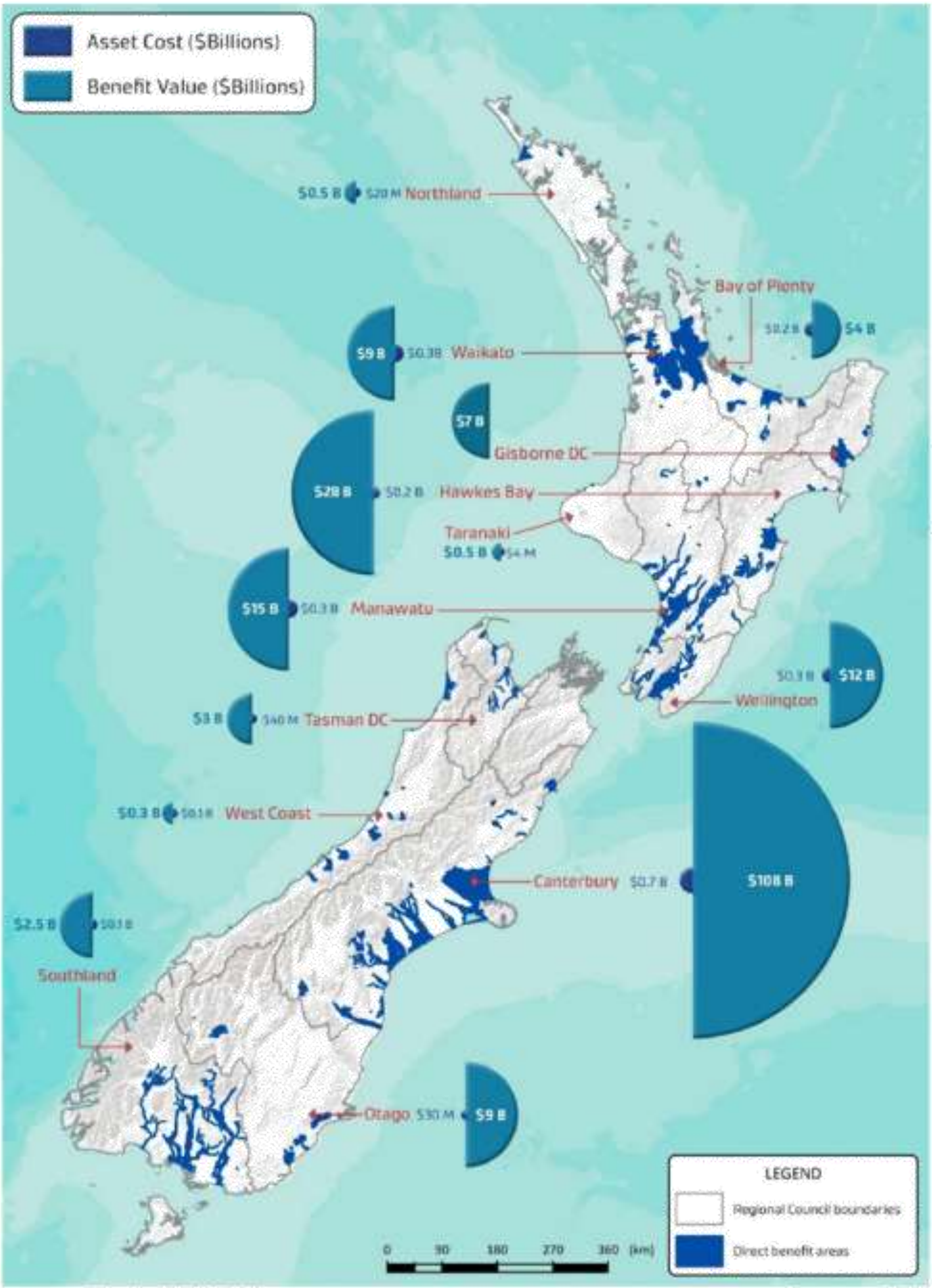

Figure 5.2: NPV of scheme benefits and capex + opex costs by region (values indicated where available, subject to rounding)

Figure 5.3 below shows the combined benefit and the benefit cost ratio for each region. This clearly shows the significant benefit derived from the protection provided in various locations throughout New Zealand, at various scales, and with different land use types being protected.

Figure 5.3 shows that the Canterbury region has a very high BCR. This is because virtually all of the Christchurch urban area receives flood protection benefit from the Waimakariri Flood Protection Scheme. We note that parts of Christchurch are protected by Christchurch City Council's flood protection schemes. The costs of these schemes have not been incorporated into our analysis and if incorporated would reduce the BCR for the Canterbury Region. However, given the small scale of the city's schemes relative to the direct benefit area for all of the Canterbury schemes, we would expect little change to our overall findings, i.e. flood protection schemes in Canterbury provide outstanding value for money.

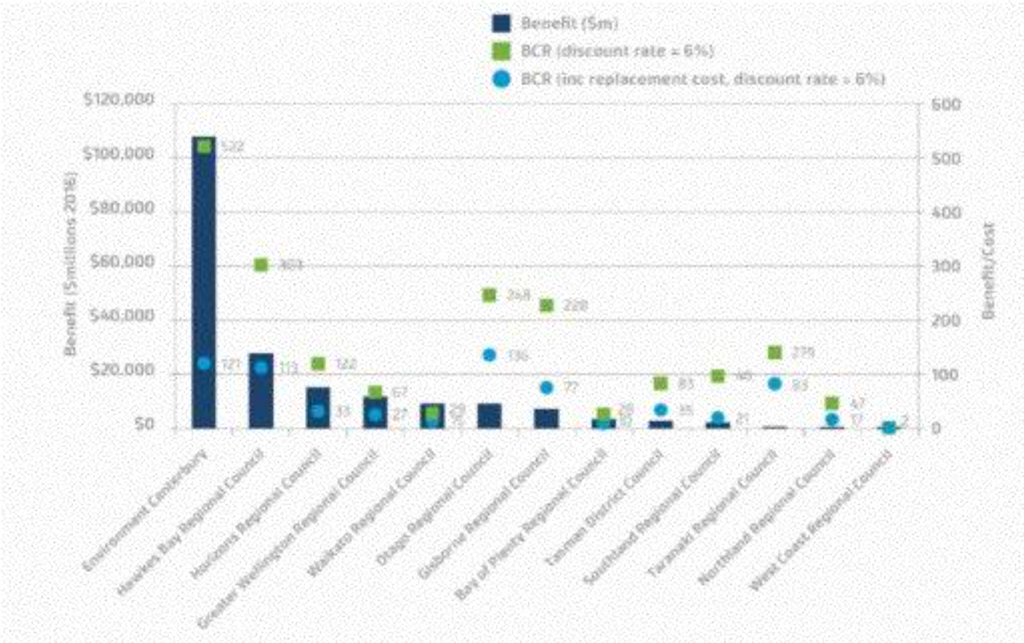

Figure 5.3: Benefit, costs and benefit cost ratios for schemes included in this assessment

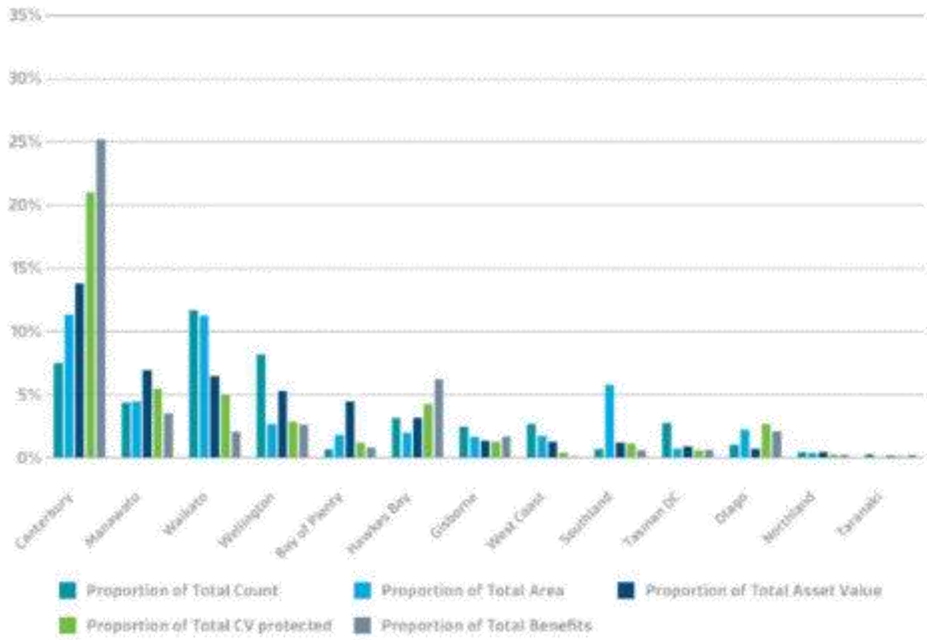

Figure 5.4: Scheme attributes as proportion of national total including economic information

5.3 Exclusions

The economic assessment included in this assessment represents a snapshot of economic benefits and costs as at 2016. A longitudinal study of how these benefits and costs have changed historically and might change in the future was excluded from the scope of this review. We would expect that given the increase in New Zealand GDP and land prices over the past two decades the benefit provided by the schemes is likely to have increased over this period as a result. However, we are less certain on how scheme costs and their cost benefit ratios may have changed over that period. Special care would need to be taken in selecting time periods for such a longitudinal assessment so the results are not overly influenced by selection bias.

The economic assessment included in this assessment is traditional in that a factor was applied to the economic analysis to account for wider social and economic benefits of the schemes. This analysis excluded a formal assessment of the cultural and environmental costs and benefits given its overview nature and the complexities associated with assessing these values on such a large scale. We would expect that the calculated BCR would change if these values were included in a cost benefit analysis. We would also expect that if these values were included, the schemes overall would still provide a net benefit to New Zealand given the large economic BCR calculated in this assessment. Further detailed analyses of individual schemes or portions of schemes may reveal that some are not economic.

Further work would be required to address these exclusions as well as understand infrastructure asset valuation practices and outcomes, and forecast how the benefits and costs of the schemes might change in the future.

6 Management of the schemes

6.1 Asset management maturity

Asset management plans (AMPs) are the central documents for describing the purpose and performance of a scheme and outlining how the scheme is managed.

Councils are required to prepare AMPs for flood protection assets under s101B of the Local Government Act 2002. AMPs are optional for assets that deliver benefits to other areas — for example, drainage, river management, and tidal protection.

We assessed the maturity of the asset management plans provided by regional councils using the Asset Management Maturity Methodology published by Treasury[8]. Assessment was based on an evaluation of a small selection of AMPs from each council. Treasury's framework and our asset management maturity assessment is included in Appendix B.

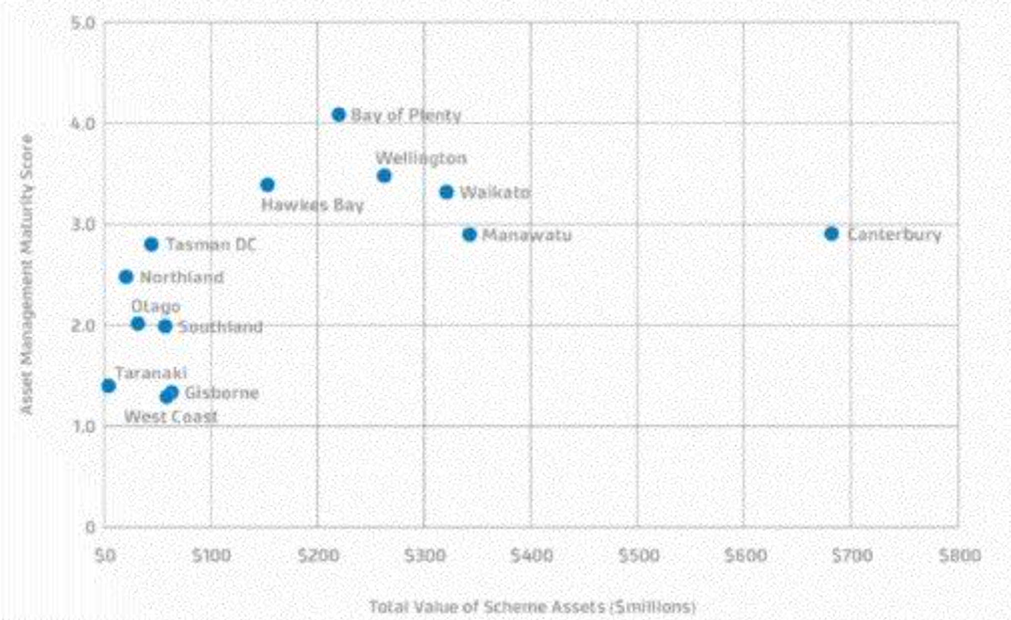

Figure 6.1: Asset management maturity by council

As seen in Figure 6.1 there is some variation in asset management maturity amongst the cohort of councils managing a larger asset base (greater than $150M replacement value). Although all were assessed as meeting or nearly meeting a 'core' level of overall asset management maturity (an asset management maturity score of three). Canterbury and Manawatu fell just short of reaching a 'core' level, indicating that some aspects of asset management weren't well described in the AMPs reviewed.

Amongst the cohort of councils managing smaller asset bases (less than $100M replacement value) asset management maturity scores varied more widely, with Tasman being the only council to nearly achieve a 'core' rating. We expect this is due to their broader asset management responsibilities for

[8] http://www.treasury.govt.nz/statesector/investmentmanagement/review/icr/information/assetmgmt, accessed 27 May 2017

areas such as three waters and transport, which has helped them develop a stronger internal capability to document their activities in AMPs.

It should be noted that AMPs may not reflect actual management practice. This is because some river managers reported that they carried out the necessary asset management activities but did not document it in their AMPs. This feedback predominantly came from managers of smaller schemes.

Asset management maturity at district councils

Although asset management maturity scores that district councils target vary depending on the asset class, a 'core' level of maturity is considered the minimum acceptable score.

Some asset classes — for example, roading — have higher minimum acceptable scores. NZ Transport Agency funding for roads drives better asset management practices in the transport sector and an 'intermediate' level of maturity is required.

It is our view that regional councils should agree on a nationally consistent minimum level of asset management maturity. We would expect that at a minimum, regional councils should target a score of 'core', though a higher level of maturity may be desired.

6.2 Providing a level of service

One of the fundamental metrics across all of the schemes is the level of service that the schemes deliver to their benefit areas. Using a broad sample of asset management plans provided, we reviewed the approach regional councils have taken and the levels of protection offered by schemes[9].

6.2.1 Ways of measuring the level of service

We found that councils generally adopted one of three methods for determining the level of service provided by a scheme:

- Agreeing on a scope of physical works with the community without reference to a target capacity or return period
- Providing physical works with a level of performance provided in terms of a target capacity — for example, stating a maximum channel flow
- Providing physical works with a level of performance in terms of a target return period — for example, referring to a 1 in 100 year event

The proportion of these three levels of service methods across the schemes in this assessment is shown in Figure 6.2.

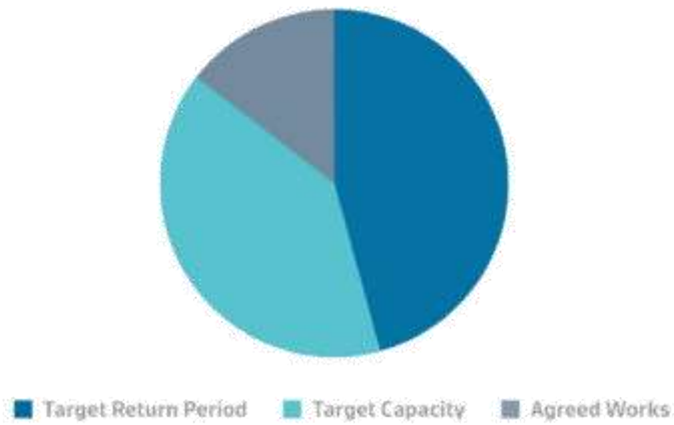

Figure 6.2: Proportions of level of service methods weighted by asset value

[9] The terms level of protection, level of service, and service level are used interchangeably in this document.

6.2.1.1 Agreed works

The level of service provided by 'agreed works' schemes is defined by their performance during past flood or rainfall events. For many of these schemes, both council staff and the community agree that the scheme size does not justify the cost of detailed analysis. However, there are some documented instances where council staff recommended technical analysis that did not proceed due to community resistance to cost. With the scheme performance undefined, councils are only able to track their service delivery through measures around maintenance works programmes or a general description of channel condition.

6.2.1.2 Target capacity

The level of service provided by 'target capacity' was most common in mid-sized schemes. An example of 'target capacity' flood scheme channel capacity with a flowrate of 900 m^3/s or a pumping rate in a drainage scheme of 7 mm/day. This type of service level provision focuses on managing the natural processes and asset lifecycle issues that reduce the capacity below the target, and the integrity of the scheme over time. Meaningful comparisons and conclusions between schemes and councils with 'target capacity' levels of service cannot be made as their service level is specific to each scheme.

Many of New Zealand's hydraulic and hydrologic record lengths are relatively short – in the vicinity of 40 to 60 years. As time passes and these record lengths increase, the frequency that a scheme's 'target capacity' occurs will change. This phenomenon, combined with climate change will likely cause the 'target capacity' of a scheme to be exceeded more frequently in the future. Climate change is widely acknowledged to likely lead to more frequent high intensity storms and may result in increased flood damages and poorer community outcomes if left unmanaged.

6.2.1.3 Target return period

The larger schemes have a level of service based on a 'target return period' or 'target AEP', for example protection from events up to a 50 year return period or 2% AEP. For flood schemes, rural return periods ranged from 5 years (20% AEP) to 100 years (1% AEP), with the return periods for urban schemes ranging from 100 years (1% AEP) to 500 years (0.2% AEP).

Under a 'target return period' level of service, the notional level of service – say 2% AEP – will stay the same over a given period until the agreed level of service is changed. However, the actual size of the design event, such as flow and water level, will vary as the length of hydrologic record grows. In addition, as environmental changes — ranging from land use change within the catchment, sea level rise, and increased frequency of high intensity rainfall events to river channel aggradation or degradation — take place, the frequency of a flood of a particular size will vary.

Given this, schemes that use a 'target return period' rather than a 'target capacity' to set the level of service for a scheme need regular and detailed technical analysis to quantify the size of the design event. Also, these schemes may require physical works to ensure the agreed level of service is maintained. Schemes using a 'target capacity' approach will also require periodic technical analysis, though on the face of it this should be more straightforward than that carried out for a 'target return period' approach.

6.2.1.4 Discussion

Each of the three methods for determining the level of service currently in use may be suitable for a given scheme, provided that information about event likelihood, scheme and property vulnerability, potential consequences, and residual risk to the community are well understood and communicated. Each of the three methods may also be suitable for a class of schemes. For example, the 'agreed works' method may be suitable for low risk schemes, the 'target capacity' method for medium risk schemes, and the 'target return period' method for high risk schemes.

In addition, a 'target return period' may be more effectively communicated in terms of cumulative probability rather than a return period or annual probability. For example, what is commonly known as a 100 year flood is technically an event having a 1% probability of exceedance annually. People regularly dismiss this risk believing there is a low probability of it occurring in their lifetime.

But statistically, a 1% AEP event has a 26% chance of occurring during the life of a 30 year mortgage, and a 39% chance of occurring during a 50 year design life of a standard building[10].

Providing this and other contextual information may assist in increasing the public's understanding of a 'target return period' level of protection.

This approach, however, does not consider the uncertainty associated with event likelihood given New Zealand's relatively short record periods. These short record periods mean that any estimate of rainfall or flood events larger than one having a 10 to 20 year average recurrence interval (or a 10% to 5% annual exceedance probability) is potentially unreliable. A summary of the length of historical record required to reliably estimate return period events is presented in Table 6.1.

Table 6.1: Length of historical record required to reliably estimate return period events

Average recurrence interval (ARI, years)	Annual exceedance probability (AEP which is the inverse of ARI, %)	Length of record required to reliably estimate return period events (years)	
		95% reliable estimate	80% reliable estimate
2.33	43%	40	25
10	10%	90	38
25	4%	105	75
50	2%	110	90
100	1%	115	100

Source: *Landslide risk assessment*, Lee E.M. and Jones, D.K.C., Thomas Telford, 2004.

6.3 Changing the level of service

Changes to a scheme's targeted levels of service typically do not happen very often. As noted above, schemes using the 'target return period' and 'target capacity' methods of providing a level of service will require periodic technical analysis to quantify the size of the design event, and possibly physical works upgrades to ensure a scheme continues to provide the target level of service. There is not the same need to review the underlying technical analysis of schemes where the 'agreed works' approach is adopted.

Even though most schemes would benefit from a level of service review, the scale of investment required to improve service levels and the longevity of the associated infrastructure assets mean there are long periods between planned reviews. By not having a regular programme of level of service reviews, there is a risk that a scheme may not actually deliver on the community's expectations of performance.

[10] Rather than using event AEP as a design basis, the New Zealand structural loadings code uses cumulative probability language such as "an event having a 10% chance of occurring over 50 years". This equates to a 475 year return period, and approximately a 0.2% AEP.

For example, the Heretaunga Plains Flood Control Scheme was 30 years old before undergoing its first level of service review. Events that exceed a targeted level of service, for example the Whanganui River floods of 2015, may also trigger a service review. However, these large scale events are infrequent and any review is therefore on an ad hoc basis.

Regional councils generally undertake incremental reviews of scheme performance on an ongoing or revolving basis. For example, the Waikato Regional Council has a programme of works to update each of their hydraulic models on a 10 year rolling basis. The way this works is that a proportion of their models are updated each year so that by the end of a 10 year period all models have been updated. These reviews may identify changes in actual performance, for example, a reduction in channel capacity. Or, they may identify changes in the understanding of actual performance, for example, from an improved scheme model. These incremental reviews may produce updated works programmes requiring consultation with the community.

Further work is required to standardise the timing and frequency of a level of service review across the sector. This could be undertaken as part of the package of work described above to provide a framework for determining the level of service by scheme class, and how risk is understood and communicated.

6.3.1 Adequacy of existing levels of service

A comparison of the large economic BCR of the schemes and the relatively low performance standards of schemes when compared with other hazards[11], suggests that, on the whole, the schemes may be under-designed for what they protect and enable. Further work would be required to understand if the existing levels of service are appropriate and sufficiently in line with best practice.

We would expect this conversation to be informed by a better understanding and communication of flood risk information. This includes data on probability and likelihoods, scheme vulnerability and that of protected properties, consequences, and residual risks, as well as the physical works and associated costs required to provide a higher level of service. In our experience, the magnitude of a 200 year flood event is not twice that of a 100 year flood event even though the former is statistically twice as rare as the latter. Further, we would expect the marginal cost of providing protection from a 200 year event to be less than the cost of providing protection from a 100 year event. Nonetheless, current pressures on scheme funding and affordability would need to be considered in opting for a higher level of service. These pressures are further discussed in Section 6.6 of this report.

6.4 Community consultation

The requirements, processes, and techniques for effective community consultation on river management activities can largely be classed into routine and non-routine matters.

6.4.1 Existing practices

Consultation on routine operational and maintenance matters including annual renewal programmes, annual plans and the like are reported by river managers to be generally relatively easy and straightforward to carry out. Consultation is reported by river managers to be effective for smaller schemes and where stakeholders are direct beneficiaries.

[11] The Reserve Bank of New Zealand's solvency standards require insurers to be solvent after a 0.1% AEP (1 in 1,000 year) earthquake, and after other events (e.g. storms and floods) with an AEP of 0.4% (1 in 250 year). The New Zealand structural loadings code is designed to provide buildings that do not endanger human life during a 0.2% AEP equivalent (1 in 475 year) earthquake, while many flood protection schemes are designed to protect from events up to 1% AEP (1 in 100 year).

A summary of consultation methods used by councils is given in Table 6.2, below. All councils report using liaison committees which are comprised of stakeholders, although on some very small schemes, the number of stakeholders is so small that the council deals directly with ratepayers.

Table 6.2: Consultation methods employed by councils

Council	Consultation methods				
	Long term plan	Liaison committee	Direct consultation (ie no committee)	Annual ratepayer meeting	Survey
Canterbury	✓	✓			
Manawatu	✓	✓	✓	✓	
Waikato	✓	✓			
Wellington	✓	✓			
Bay of Plenty	✓	✓			
Hawkes Bay	✓	✓	✓		✓
West Coast	✓	✓	✓		
Southland	✓	✓			
Tasman DC	✓	✓			✓
Otago	✓	✓	✓	✓	
Northland	✓	✓			
Taranaki	✓	✓			
Gisborne DC	✓	✓			

Consultation on non-routine matters is generally more difficult as these matters represent a significant change to scheme operation or level of service. For these issues, a unique consultation strategy is required for each change or issue. This typically requires educating various stakeholders about an issue, then gathering key stakeholders around a table to develop a consultation strategy before finally consulting more widely. This process is reported to generally provide a better chance of successful consultation on a major issue but doesn't guarantee its outcome.

6.4.2 Willingness to pay

River managers also reported that communities are generally more willing to pay for tangible measures of protection, such as stopbanks rather than soft responses – for example, land use controls or managed retreat. Also, that communities often opt for a larger capital outlay in the near term rather than an adaptive response carried out over many decades. These two incidences were reported by Greater Wellington as results of their public consultation regarding the recent Hutt Valley scheme upgrade for a future state of 2115.

6.4.3 Effective engagement

The ability to conduct effective stakeholder communications will be vital if communities are to understand the rationale for, and gain the potential benefits — such as cost savings and improved quality — from soft or adaptive approaches to flood hazard management. Especially as these approaches are often controversial. For example, managed retreat may be the best long term option for some communities. But this approach will require greater collaboration, and a willingness to consider alternative strategies that provide a similar outcome to physical works – such as providing safety and security from flooding.

Given the uncertain level of impact surrounding many of the sector challenges outlined in Section 7, river managers will need to be collaborative and engage early with stakeholders to deliver successful outcomes for the community. This early engagement process may challenge river managers who the community potentially perceives as having a vested interest in the ongoing maintenance of a particular intervention. It may also challenge asset managers to consider whether and how the community may respond to an event – such as flooding— and to then tailor their communication appropriately at an early stage.

6.4.4 Risk communication

The importance of how well risk information — probability or likelihood, vulnerability, consequences, and residual risk — is communicated to stakeholders cannot be emphasised enough[12]. Reframing by the river management sector of the risk discussion to one of consequences first and cumulative probability and uncertainty second may be a good first step towards better risk communication with stakeholders.

Understanding and building a national picture of flood risk vulnerability and consequences, underpinned by development of a nationally consistent methodology for understanding and documenting asset criticality, performance, and level of service, would be a useful foundation for communicating this risk to communities and stakeholders.

6.5 Council staffing

Recruiting, retaining, and developing great staff is fundamental to the success of any organisation. Current river management staffing levels are just sufficient to carry out day to day activities, and staff often have a narrow technical skill set or limited understanding of river management in a New Zealand context. Staffing issues that inhibit regional councils from producing successful river management activities and community outcomes include:

- A chronic shortage of versatile, multi-faceted engineers with an understanding of the broader non–engineering aspects of river management activities
- A lack of visibility of a professional river management career by university students
- No formal, sector-wide graduate engineer intake or development programme
- Lack of awareness of the regional council business by the wider public, and a lack of positive news stories about regional council activities in the mainstream media
- Unstructured in-house and sector professional development programmes that are geared towards future issues facing the sector

Case study – Development of River Management Asset Performance Assessment Code of Practice

New Zealand's river managers have already recognised the importance of greater consistency in assessing the condition and performance of river management infrastructure. Development of a guidance document for this purpose was recently developed by Greater Wellington RC, and endorsed by other river managers.

However, we understand that uptake of the Code of Practice has not been uniform across the regional councils. We would expect that implementation of the methodologies outlined in the document would require each river manager to affect change within their council. Achieving this in a timely manner across all regional councils may be difficult depending on the priorities of each council.

Additionally, development of this document by a single regional council in the current working environment raises some questions about how it may be revised and updated. We could see each council using the document as a starting point, with individual councils modifying it to suit their context in isolation from others.

Clearly this is not what was intended when the document was developed, though it appears a real possibility given the current working environment within NZ's river management sector.

[12] This approach is effected through a risk-based approach to natural h Management Act, see http://www.mfe.govt.nz/publications/rma/reso series, Fact Sheet 10, accessed 27 May 2017.

- A lack of sophisticated employee transfer arrangements between councils and with other organisations

Addressing these staffing challenges is critical, and the ability of river managers to resolve them individually is constrained by several factors, including the current level of funding at each council, and level of coordination amongst regional councils.

Partnership and collaboration is essential to addressing staff and resource challenges successfully. This could take the form of working with an existing organisation (e.g. IPENZ or LGNZ) or the formation of a new pan-sector partnership to promote the river engineering sector. Activities by this group of sector professionals could include:

- Guest lecturing at engineering schools in New Zealand universities
- Establishing a chair in river engineering and management at a New Zealand university
- Developing a formal graduate intake and development process
- Creating a river management continuing education framework and supporting coursework
- Facilitating movement of staff within and among regional councils, and with similar organisations overseas

6.6 Scheme funding

As noted in Section 2, schemes were heavily subsidised via central government between 1941 when the SCRCC was formed and 1987 when NWASCA was disbanded. The Local Government Act 2002 now provides councils with tools for fair and equitable allocation of rates according to benefit received.

6.6.1 Funding sources

All regional councils generally use targeted rates as the primary funding source for the schemes[13]. These rates are typically banded into benefit levels to reflect spatial variation in the benefit received from a scheme. For example, a property on the second terrace of a flood plain will not receive the same benefit from a flood control scheme as a property lower down and immediately adjacent to the river.

Some councils incorporate all relevant benefits into a single targeted rate, where others separate out different costs and benefits as separate rating bases. In one instance 11 different targeted rates overlapped. Obviously councils need to balance transparency, administrative practicality and efficiency, fairness and accuracy when funding these schemes.

Some councils also use either a targeted or uniform rate for indirect benefit to provide part funding of scheme costs by the wider community. This is restricted to schemes that are large enough to have a clear benefit for the wider (or entire) region – either as an individual scheme or the cumulative benefit from a number of schemes.

Overall, we found that each of the rating schemes was developed in its own context and provenance, so even among schemes with simple rating areas it is difficult to use the rating information as a basis for compiling and comparing scheme funding data. Future national data analysis would be enabled by a consistent rating methodology and regional councils should consider if this would be valuable and achievable.

[13] A notable exception to this is Greater Wellington's move towards funding schemes on the Kapiti Coast through a general rate on properties in that sub-region.

6.6.2 Funding issues

Funding affects many aspects of a regional council's river management business including:

- The future affordability of the schemes and their renewal programmes
- Whether a scheme's level of service can be maintained, upgraded or may need to be downgraded
- The ability of councils to employ, retain and develop, appropriately trained people to effectively deliver work programmes
- The ability of councils to share information and experiences with other river managers
- Their success in educating the community about the value of schemes, what they protect and the residual risks that the communities face

In our assessment we found a number of issues relating to funding and operational expenditure pressures on river management activities including:

- Desire of some communities to control rate increases at the expense of infrastructure asset investment or renewal
- The general expectation to do more for less
- Changing community expectations, the widening of stakeholder groups, and how environmental, social and cultural values manifest themselves in river management activities, including but not limited to:
  - National Policy Statement for Freshwater Management 2014
  - Health and Safety at Work Act 2015
  - Co-governance commitments through Treaty of Waitangi settlements
- A greater incidence of non-rateable properties (and corresponding decline in rating base) within areas of benefit from the schemes — for example through construction of new state highways
- How asset condition is measured (discussed in Section 4.5.2 above), and how this informs asset revaluation practices
- An increase in actual costs to renew or replace infrastructure above the planned expenditure and / or asset book value. This can result from a variety of factors including poor financial and asset management planning, a change in community expectations or legislative environment, and construction costs increasing faster than general inflation
- The way operational and maintenance activities are funded. For example, depreciating asset book value and renewal expenditure, borrowing, and the resulting balance of payments

These issues and downward pressures on funding levels for river management activities discourage best practice, and force staff to 'make do' by cutting expenditure elsewhere. This is particularly relevant for unplanned additional expenditures. For example, on a recent capital works project on the Lower Waikato scheme, the Waikato Regional Council decided to use more costly mechanical components to provide better environmental outcomes while still providing the same level of service, and had to trim budgets elsewhere to accommodate this unplanned expenditure.

Many of these issues are common across the regional councils, though how councils record, report and manage them varies considerably. Further work would be required, for example, to better understand the balance of operational payments on a national scale and its implications on future affordability of the schemes. Standardisation in operational expenditure reporting would make this assessment easier. As with other challenges, this appears to be one that would benefit from greater cross-council collaboration.

As previously discussed, property rates paid to regional councils are the backbone of funding river management activities. Ratepayers, however, are generally unable to offset a property rates increase through increased productivity (i.e. income generation) from their land, and cannot release their property's capital value until it is sold. This creates a challenging situation where communities may not be willing to pay for river management infrastructure upgrades and renewals despite professional advice from river management experts. It is our view that alternative funding strategies should be explored so that regional councils can deliver a better river management service to their communities.

Willingness to pay – a West Coast Regional Council case study

The West Coast Regional Council (WCRC) has low population growth and GDP per resident close to the national average. Many of the flood protection schemes WCRC is responsible for benefit, and are funded by, a small local community.

Council staff sought to better understand changes to the risk posed by the Matanui Creek through a flood study. When council staff approached the community to gauge support for this work, the community declined to spend the money, preferring to leave the current performance of the scheme unknown.

6.6.3 Environmental, social and cultural context of scheme funding

It is our view that to meet changing community expectations and make investment decisions transparently, developing a framework that formally accounts for environmental, social, cultural, and economic outcomes of council projects and schemes would be beneficial. We expect that this framework would be supplemented by a decision support tool, such as that recently developed for NZ Transport Agency[14]. This would enable councils to be more proactive in responding to or adapting to stressors or shocks on their infrastructure assets within a timeframe and to a cost that is acceptable to the community.

In April 2017, the International Public Sector Accounting Standards Board (IPSASB) published a consultation paper on Financial Reporting for Heritage in the Public Sector. In this context 'heritage' includes 'natural heritage', that is, the environment. NZ takes its accounting standards from the IPSASB and the inclusion of environmental outcomes into this formal financial framework represents a significant change in public sector accounting.

This may require regional councils to quantify in their financial reports the natural environment as assets, and costs associated with maintaining the environment as liabilities. Further professional advice would be required to understand how the consultation paper and subsequent standards may affect the river management sector.

6.7 Regulatory environment

The regulatory environment relevant to river management in New Zealand is in a state of flux with changes to the Resource Management Act (RMA), and the National Policy Statement for Freshwater Management, the development of a National Policy Statement for Natural Hazards, funding of emergency response / recovery under the Guide to the National CDEM Plan – Section 33 Government Financial Support, and development of a National Disaster Resilience Strategy.

In addition to the overarching national legislation and guidance, each river manager negotiates a different regional regulatory environment, which has been developed in response to their communities' needs and desires and their own physical settings.

The following subsections outlined details of legislation as relevant to river management activities.

[14] *Establishing the value of resilience*, New Zealand Transport Agency research report 614, Money C. et al, 2017.

6.7.1 Soil Conservation and Rivers Control Act 1941

The 1941 Soil Conservation and Rivers Control Act (SCRCA) was a key piece of legislation that enabled construction of many of the flood protection, river control, and land drainage schemes in New Zealand. Key elements of this Act that continue to enable river mangers to carry out their work include:

- Section 2 - The breadth of the definition of "defence against water"
- Section 10 - Objectives of the Act (c) the prevention of damage by floods and (d) the utilisation of lands in such a manner as will tend towards the attainment of the said objects
- Part 7 Powers and Duties of (Catchment) Boards
  - Section 126 (2) - General powers to construct, reconstruct, alter, repair and maintain works and do other acts to fulfil function to minimise and prevent damage. These powers are important to carry out river management activities. However, given their breadth and reasonably unfettered nature, we note they could be subject to challenge in a legislative review process
  - Section 131 - Public Works Act 1981 to apply to construction works. This power is also conferred to regional councils under the Local Government Act 2002
  - Section 132 - Powers to enter for assessment and investigation
  - Section 133 - Maintenance and improvement of watercourses and defences against water
  - Section 135 - Incidental powers, including the ability to acquire land under the Public Works Act, enter & use land to take materials, access and load/unload materials and establish work areas
  - Section 137 - Notice in respect of works on private land. This could be subject to challenge in a legislative review process
  - Section 138 - Apportioning costs of works with owners of land
  - Section 139 - Land can be purchased on system of time payment
  - Section 140 - Leasing powers
  - Section 143 - Supervision of drainage works and river works
  - Section 146 & 147 - Ability of Board to pay for private works and purchase land injuriously affected
  - Section 148 - Liability for damages arising from neglect

The objectives of the Act are indirectly encompassed in the purpose and principles of the RMA, with some powers under the Act included in the Local Government Act 2002. Should any repeal of the Act, or parts of it, be proposed river managers should carefully consider how these changes may affect the functions and powers they currently have to enable their river management activities.

To access and maintain their assets some councils rely on good relationships with private landowners and the provisions of the SCRCA. This, however, is variable as some councils own many of their assets, or at least maintain easements over private land.

The ability of regional councils to own the land beneath their assets, or at least maintain an easement across private land would remove some of the concerns river mangers have around getting to and protecting their scheme assets. It must be noted that requiring regional councils to buy land or negotiate easements would substantially increase their costs.

Many of the aspects of the Soil Conservation and Rivers Control Act (SCRCA), along with other pertinent legislation have been repealed. A broad based, blues skies review covering key pieces of legislation, including *inter alia* the Resource Management Act 1991 (RMA) and Local Government Act 2002, has been suggested by several organisations including Local Government New Zealand and the Productivity Commission. Should such a review occur, there is a potential threat to regional councils that the remaining residual provisions of the SCRCA, which enable river management activities and are described above, could be inadvertently repealed.

Repeal of these remaining provisions would affect the ability for regional councils to develop new schemes, manage and maintain existing schemes and, potentially, to upgrade schemes to respond to the effects of climate change. Should a blue skies legislative review occur, how these activities are enabled needs to be considered. Not only in the context of the way that these schemes have been historically developed, but in light of current and likely future environmental and societal expectations. This represents a significant challenge, not only to ensure that legislation allows regional councils to effectively fulfil their obligations, but also to understand how those obligations may change.

Additionally, there is a potential for significant additional cost on communities should these powers be inadvertently removed. Costs could arise from:

- Councils being unable to maintain schemes if access is denied by land owners
- Legal costs associated with maintaining access rights
- Costs of land or easement purchase.

6.7.2 Resource Management Act 1991

The RMA affects river management and land drainage activities, which means river managers can be both applicants and potentially affected parties under the Act. The way in which river managers undertake their works and activities, and the ease of doing so, largely comes down to how the effects of these activities are provided for through regional and other plans.

Provisions in Regional Plans are variable across the regional councils. Some plans have policies that explicitly recognise some scheme structures as natural and physical resources and have specific provisions that enable river managers to undertake a range of activities. For example in Hawkes Bay and Taranaki a range of river management tasks can be undertaken as permitted activities (subject to terms and conditions in the plan), or in some instances compliance with a Code of Practice or similar document. Other regional plans, such as Greater Wellington Regional Council's, are much more restrictive and require resource consents to be obtained for nearly all works and activities that river managers may need to undertake.

Some plans and council practices identify scheme asset managers as potentially affected parties, enabling them to be consulted on resource consent applications that may affect them – other plans and council practices don't. Those managers have reported they have little influence on decisions that may impact on their infrastructure or their ability to deliver services to their communities.

Some regional councils use river management staff as experts in the evaluation of consent applications — which raises potential conflict of interest issues — whereas others would tend to use people from other parts of the organisation or commission this advice from an independent expert.

How these elements play out in any regional council — along with the size or value of assets under management by a regional council — may affect the ability of councils to meet their obligations to the community effectively and efficiently. In some circumstances these elements may affect the councils' ability to retain river management staff.

The river management sector could benefit significantly from a nationally consistent approach to managing the effects of their schemes under the RMA. This approach would allow for more effective collaboration and sharing of resources across councils because staff wouldn't have to learn how to work in a new regulatory setting. This would likely have a wide ranging and significant impact, including providing further consistency in the delivery of services across the sector, normalising compliance costs, expediting processes, and standardising expected outcomes.

6.7.3 Local Government Act 2002

River managers report that the Local Government Act 2002 generally enables and supports their activities, and identified the following provisions as notably important to their activities:

- Ability to have targeted rates
- Use of the special consultative procedure
- Development of infrastructure management strategy
- Use of long term and annual planning processes to implement their infrastructure strategies.

6.7.4 Civil Defence and Emergency Management Act 2002

River managers also have a good connection to the Civil Defence and Emergency Management Act 2002 and see this as integral to their activities. Specifically in areas of emergency management planning, providing advice to emergency controllers, and managing residual risk to communities.

The Ministry of Civil Defence and Emergency Management is currently developing a new National Disaster Resilience Strategy that will replace the current National Civil Defence Emergency Management Strategy[15].

The Ministry has prioritised the following areas for improvement:

- Understanding disaster risk
- Strengthening disaster risk governance to manage disaster risk
- Investing in disaster risk reduction for resilience
- Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction.

6.7.5 Summary

The regulatory environment relevant to river management in New Zealand is complex and varies from region to region. Key powers given to river managers under legislation such as the SCRCA may inadvertently be removed under a 'blue skies' legislative review. As these potential issues affect the sector as a whole, the sector would benefit from better collaboration to create 'one voice' and assist in the development of policy and law on these issues.

[15] This is in response to international best practice that suggests a shift in focus from 'managing disasters' to 'managing risk' will improve the resilience of our communities. New Zealand is also signatory to the Sendai Framework which seeks: *a substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries.*

7 Resilience challenges for river management

Many of the challenges facing river management activities have been outlined in the preceding sections and in this section we describe the concept of resilience. Many organisations understand resilience in the context of natural hazards, however it also relates to other technical and non-technical challenges. Many challenges facing the river management sector fit within the resilience concept.

7.1 Resilience – in concept and practice

The concept of resilience is often simply thought of in terms of how a community responds to a large earthquake or other natural disaster – how quickly will the community return to normal? Resilience is much more than that.

Definitions and themes of resilience include understanding, communicating, and managing risk though lenses as diverse as governance and leadership; health, wellbeing, stability and security for individuals, families and communities; and the built and natural environment.

Central government and many of its agencies recognise the value that adopting a multi-faceted resilience framework brings to their ability to deliver successful outcomes to their communities. As noted above in Section 6.7, the Ministry of Civil Defence and Emergency Management is developing a new National Disaster Resilience Strategy in line with the Sendai Framework for Disaster Risk Reduction, of which New Zealand is a signatory. The NZ Transport Agency has a national resilience programme and recently proposed a definition[16] of resilience as: ***the ability of systems (including infrastructure, government, business and communities) to proactively resist, absorb, recover from, or adapt to, disruption within a timeframe which is tolerable from a social, economic, cultural and environmental perspective.***

In practical terms, if river management activities among regional councils were resilient one would see a sector that, among other things:

- Values business continuity, and performs effectively in a crisis
- Is resourced in terms of capability and capacity to respond to known and unknown changes relevant to the sector —including climate change or funding pressures
- Understands and effectively communicates risk information — event probability or likelihood, vulnerability, consequences and residual risk
- Proactively engages with diverse stakeholder groups, and has the ability to measure the environmental, social, cultural, and economic value of the services it provides
- Builds and maintains infrastructure assets that are robust and have spare capacity to accommodate disruption and uncertainty
- Can adopt alternative strategies to continue to provide an agreed outcome — including safety and security from flooding — to the community

Some regional councils are carrying out aspects of resilience without the benefit of working within a systematic framework. In this assessment we've found that some councils may be better than others at some aspects of resilience. These practices are not widely adopted, however, and are carried out on an *ad hoc* basis without a vision or strategy of making our communities more resilient. Cross-sector collaboration is needed to develop a river management resilience framework and associated decision making tools to enable all regional councils to respond to their common challenges with minimum disruption to their communities.

[16] Money C. et al, 2017.

7.2 Challenges as shocks and stressors

The challenges facing river management in New Zealand threaten the ability of regional councils to effectively deliver their agreed services to the communities they protect. Challenges can be classed as either shocks or stressors, depending on their nature. Shocks occur suddenly, often without warning, test an organisation's resilience, and can precipitate a crisis. Stressors are issues that persist over a long time or recur frequently, and inhibit the capacity and capability of an organisation to deliver its service or respond effectively during a crisis.

7.2.1 Potential shocks

The findings of this assessment indicate the main potential shocks facing the river management sector include:

- Large flooding events, including infrastructure asset failure during a design event and over design events
- Earthquakes, which can damage infrastructure assets and deplete council and/or insurance reserves
- Future changes to how central government financially supports local authorities during emergencies
- Changes to the regulatory framework that enables river management activities
- Implementation of new policies or standards that may make it difficult for river managers to meet their consent compliance obligations. Refer Appendix D for a discussion on national metadata standards.

Due to the complex systems and environments where river management is practiced in New Zealand, the occurrence of a potential shock can have an impact far beyond the immediate community that receives direct benefit from the scheme. Examples include:

- The March 2016 flooding of the Franz Josef township and closure of State Highway 6. This highlighted that the failure of flood protection in a small settlement on the West Coast can have a disproportionately large impact on national and economically important tourism opportunities and connectivity
- The September 2010 Darfield earthquake, which severely damaged infrastructure assets in Canterbury's Waimakariri scheme. Urgent and timely repairs were undertaken and completed just days before the December 2010 flood event in the Waimakariri River thereby protecting the surrounding community from flooding
- Insurance claims from Christchurch City and Waimakariri District Councils to cover infrastructure damage from the September 2010 and February 2011 Canterbury earthquake sequence. Claims exhausted the reserves of the Local Authority Protection Programme Disaster Fund, which placed other participating councils at risk of not having insurance coverage for their infrastructure assets.

Insuring for Maximum Probable Loss

Following insurance claims resulting from the 2010-11 Canterbury Earthquake Sequence, the reserves in the Local Authority Protection Programme Disaster Fund were depleted.

As a result of this, and other changes to disaster recovery funding for councils, many councils are considering alternative insurance mechanisms. As part of this, councils estimate their Maximum Probable Loss during a natural hazard event, then seek insurance for this amount.

There are a few consultancies operating in the New Zealand loss estimation marketplace, each with their own estimation methodology. Hawkes Bay RC and Greater Wellington RC are two regional councils known to have carried out this exercise, and each have used a different consultant / methodology.

Regional councils should consider carrying out this beneficial exercise for each of their portfolios. Before doing so it would be prudent to compare the usefulness of methodologies available, and consider whether a consistent methodology across the councils is preferred.

7.2.2 Potential stressors

The findings of this assessment indicate the main potential stressors and their implications facing the river management sector include:

- A lack of effective collaboration prevents regional councils from presenting themselves as 'one voice'
- Inconsistent data gathering and reporting prevents regional councils from easily identifying issues common to the sector
- Different regional regulatory environments which result in inconsistent outcomes across the regions and inhibits collaboration between councils

Figure 7.1: Example challenges facing river management sector as shocks and stressors

- A varied understanding of flood risk information —probability or likelihood, vulnerability, consequences, and residual risk — which inhibits effective communication with the community on these key concepts
- Staffing issues as discussed in Section 6.5 which inhibit regional councils from producing successful river management activities and community outcomes
- Funding and scheme affordability issues as discussed in Section 6.6 activities which discourage best practice river management practices, and force staff to 'make do' by cutting expenditure elsewhere
- The rate of change in current policies and procedures which are not keeping up with changing community expectations, the implications of wider stakeholder groups, and how environmental, social and cultural values manifest themselves in river management activities
- Land use change (increased urbanisation) may lead to increased consequences of infrastructure asset failure during an event or of larger-than-design events
- Climate change which may result in:
  - More frequent high intensity rainfall events
  - Higher peak river flows during large rainfall events
  - Increased erosion and sediment discharge into watercourses leading to changes in river geomorphology
  - Increased instances of flood flows transitioning to debris flow (as at Matata, Bay of Plenty, 2005)
  - Increased likelihood of existing infrastructure not meeting agreed levels of service
  - More frequent drought periods, and lower low flows in river channels leading to changes in river geomorphology as low flow channels are infilled by sediment

- Increased likelihood of existing infrastructure assets not meeting agreed levels of service if low flow channels infilled or river course changed
- Sea level rise, causing an increase in water levels during flood events in tidally affected areas; and an increased likelihood of existing infrastructure assets not meeting agreed levels of service

- Active river geomorphology may require an increased width of river management corridors that will likely encroach on what is currently private land, and a change in river management philosophy, including type and location of river controls
- Biosecurity incursions —for example, the willow sawfly in 1999 and giant willow aphid identified in 2013 resulted in destruction of some river management structures leading to in increased risk of river alignment changes during more routine flood events
- Peat settlement, which can cause existing infrastructure assets to become redundant when ground levels shrink, and a lowering of the level of service provided by the asset

7.3 Responding to challenges – mitigation or adaptation

Understanding the implications of each of the above shocks and stressors is a significant gap in the current New Zealand river management body of knowledge. Closing this gap and development of appropriate response strategies will be important for river managers and is a large piece of work in its own right.

Once implications of shocks and stressors are well understood a response strategy can be developed. Response strategies are either one of mitigation – finding ways to reduce the impact – or adaptation – the process of preparing for and adjusting to new conditions to minimise disruption and take advantage of opportunities that these new conditions provide.

In developing these strategies, regional councils would benefit from a coordinated approach that is flexible enough to accommodate the diverse scale, range, and criticality of river control, flood protection and land drainage schemes. These strategies can include controls from one of more of the types listed in Figure 7.2.

Figure 7.2: Control types to increase resilience of response strategies

Response strategy – adaptation to climate change

An example of an adaptation response to climate change is Greater Wellington Regional Council's policy decision to make allowances for sea level rise and an increased flow in its rivers over a 100 year planning horizon when infrastructure assets are designed or a design review is undertaken.

This response required leadership and governance by policy makers, and accounts for uncertainty through robust design assumption. This response is a good start to building resilient infrastructure, and could be further improved by creating design features to manage uncertainty, and improving the ability of a community to recover after a catastrophic flood event.

8 Delivery of infrastructure in New Zealand

In recent years a considerable amount of work has been done by central government agencies and some sector organisations to improve the delivery of infrastructure services in New Zealand. This has involved work by the Department of Internal Affairs, the National Infrastructure Unit (NIU) of Treasury, the Office of the Auditor General and Local Government NZ. This section presents a broad review of the work that these agencies have carried out.

8.1 Department of Internal Affairs

The Department of Internal Affairs (DIA) is responsible for implementation of the Better Local Government programme announced by Government in 2012. This broad improvement programme included improvement in infrastructure delivery and asset management practices in local government. Among other things, the local government improvement programme:

- Placed greater emphasis on quality asset management planning
- Instituted mandatory timeframes for a review on the cost effectiveness of infrastructure service delivery
- Directed the development of thirty-year infrastructure strategies
- Introduced an expectation that councils should actively seek to collaborate and cooperate to improve effectiveness and efficiency

8.2 National Infrastructure Unit of Treasury

Central to much of the work to improve delivery of infrastructure services is the development of the Thirty Year New Zealand Infrastructure Plan by the NIU, which comprised a critical assessment of New Zealand infrastructural needs, including the provision of water, wastewater, and stormwater services and infrastructure. Within this context the management of flooding is recognised fleetingly in the context of urban stormwater, and there is no comment on the provision of flood control and land drainage infrastructure or services in NZ.

Despite this, several themes have emerged from NIU that are common to the provision of river management infrastructure. These have been recognised in this assessment and the most notable among them include:

- Networks continue to operate without widespread service failures, but concerns about aging infrastructure and asset deterioration are increasing
- Larger authorities with capacity and capability generally better manage their infrastructure, while small provincial councils with static or declining populations and ratings bases face potentially significant servicing issues
- There is no national data framework, standards or benchmarks to understand how infrastructure is being managed nationally
- Councils have generally poor information regarding the condition of their infrastructure assets
- In general, three waters infrastructure is generally less well managed than other council assets (such as roads)

The NIU identified key challenges facing the infrastructure sector as:

- Aging infrastructure, and the corresponding need to invest in renewals and replacement
- Infrastructure affordability in the face of demographic changes

- The role of technology in the provision of infrastructure services
- Climate change, and how this may affect infrastructure assets

8.3 Office of the Auditor General

In response to the development of Long Term Plans by local authorities as required under the Local Government Act, the Office of the Auditor General (OAG) summarised the issues and matters arising from its review of councils' 2015-25 Long Term Plans.

The OAG found that although councils were planning to look after their major assets, there has been a recent shift towards meeting additional demand, renewals and replacement of assets at the expense of improving the level of service.

The OAG identified a close match between depreciation and renewal and replacement expenditure for road and footpath assets, and found that replacement and renewal expenditure of water, wastewater and stormwater assets is well below the level of depreciation. Depreciation on flood protection assets is significantly lower than other assets, which the OAG considers is a result of flood protection expenditure being on land that is not depreciating.

The OAG was unable to draw conclusions about whether the level of infrastructure funding will be sufficient, or that depreciation has been adequately addressed. The generally low level of planned expenditure across the three water assets could indicate a similarly low level of expenditure on flood control and drainage assets. The OAG also noted a decrease in spending to improve levels of service and a corresponding increase in spending on renewal and replacing existing assets.

The OAG noted that almost half of the local authorities identified the need to collect better information about their assets, and a smaller number were actually putting in place programmes to capture better data. While most councils had reasonable information regarding their aboveground assets, they understood less about the condition of underground assets. Additionally, there was little discussion on the risks and implications associated with a lack of reliable asset information.

Finally, the OAG reported that many councils did not adequately address financial sustainability and affordability of expenditure throughout the full life-cycle of infrastructure assets.

8.4 Response by Local Government New Zealand

In response to these concerns, Local Government New Zealand (LGNZ) has put in place a programme to improve New Zealand's water, wastewater and stormwater sector. LGNZ acknowledges the challenges associated with increased levels of infrastructure reliability, quality, and resilience while maintaining its affordability.

As part of this programme, LGNZ identified the priority outcomes for the three waters sector as:

- Performance transparency and performance improvement over time
- High quality asset information which improves asset management practices
- Resolving competing interests during decision making processes

Additionally, LGNZ recognised the characteristics of a strong sector performance as:

- Understanding customer needs and expectations
- Effectively managing and investing in physical assets
- Effectively recovering costs
- Promoting efficient use
- Continuing to learn and grow

To achieve these outcomes LGNZ considered three ways to effect change. These include minor modifications to existing practices, a strong, sector-led approach, and economic regulation. LGNZ identified the preferred way forward as a strong, sector-led approach.

8.5 Comparison with river management sector

Our assessment of New Zealand's flood protection, river control and land drainage activities managed by regional councils has identified many of the same issues raised by several government agencies in relation to infrastructure delivered by district councils, unitary authorities and utility providers. This should not be surprising given the overall regulatory context, demographic changes and their impact on infrastructure funding, and historic infrastructure investment patterns.

However, there is a real concern that given the relatively small size of the river management sector, the needs of river managers could be overlooked through any programme of reform. We believe there is a real need for the river management sector to speak as a united voice to communicate the challenges and opportunities, and ensure the sector is identified as a key stakeholder and recognised as an expert advisor in any reform process.

9 Conclusions and recommendations

This national assessment of river control, flood protection and land drainage schemes was carried out at a high level across the river management sector of New Zealand's regional councils. Overall we have found that NZ's flood protection, river control and land drainage schemes deliver significant benefits and effective, widespread communication of these benefits should be a priority. Our conclusions are outlined below, followed by recommendations for areas and actions that will address specific challenges and opportunities in the river management sector.

9.1 State of the schemes

Approximately 364 river control, flood protection, and land drainage schemes for which regional councils are responsible were included in this assessment. These 'schemes' directly protect some 1.5 million hectares of land (about 5.5% of New Zealand's land mass), including highly productive primary production land and both small and large urban centres. The 'schemes' also protect or otherwise provide a benefit to non-rateable land (Crown estate) and nationally significant infrastructure including roading and rail networks, and energy and telecommunication links. Funding for the schemes is generally provided through targeted rates on rateable land that either directly or indirectly benefits from the schemes.

9.2 Economic value of the schemes

The schemes included in this assessment provide an estimated Net Present Benefit of $198 billion ($NZD at 2016). This Net Present Benefit includes the wider social and economic benefits of the schemes by way of applying a factor to the calculated direct economic benefit. Costs for the schemes if they were constructed today are given by the sum of the regional councils' published infrastructure asset replacement values and capitalised annual operational expenditure, and provide an estimated Net Present Cost of $3.6 billion ($NZD at 2016). Thus the average Benefit Cost Ratio (BCR) of the schemes to New Zealand is approximately 55:1.

Costs and benefits will obviously vary from scheme to scheme and a more detailed analysis of individual schemes or their elements may find that some are uneconomic. Further work is required to include cultural and environmental capitals of the schemes into a broader cost benefit analysis. One of the most compelling findings of this assessment was the annual benefit of over $11 billion provided by the schemes is nearly five times their published infrastructure replacement value.

9.3 Management of the schemes

Scheme management is informed by the state of infrastructure asset condition, criticality, and performance. Our assessment of asset condition scores for river management infrastructure indicates that, on the whole, regional councils appear to have adopted an appropriate level of asset management, renewal and upgrade processes for various asset types. However, documented asset management practices are variable between councils, and do not generally describe asset criticality and asset performance.

9.4 Challenges facing the river management sector

Various challenges face those responsible for river management. Challenges facing the sector come from both external and internal sources and can be classed as natural or systemic stressors and shocks. Given the distributed nature of the asset base managed by a relatively small sector, a coordinated response from river managers and collaboration across regional councils and with external parties will be required to address these challenges efficiently and comprehensively in the future.

To deal with some of the internal challenges that the sector faces, an enabling environment will need to be created to support further standardisation across councils. A formal process or Memorandum of Understanding should be developed to support council staff working across organisational boundaries. This would also position the river management sector to effectively address external challenges. Consideration should be given to how these cross-organisational activities are collectively funded.

9.5 Recommendations

This assessment has identified a number of areas that need further work to better understand and address issues and challenges. We recommend the river management sector work on areas that encompass the following themes: cross sector collaboration, practices and standards, people, and environment.

Working together across the sector

a Provide resources to river managers to enable and support a step change in professional collaboration and development across regional council river managers and with external organisations, so that the sector as a whole can proactively respond to the challenges identified in this national assessment.

Communication and enabling environment

b Communicate as 'one voice' the state of the river management sector and the outstanding value the schemes provide to New Zealand as identified in this assessment.

c Proactively engage as 'one voice' in discussions about potential changes to the regulatory environment (for example, managing natural hazards under the RMA, development of National Disaster Resilience Strategy, other RMA reforms, etc) so the views of the river management sector are understood by central government.

d Develop methodologies and programmes to enable river managers to effectively engage with stakeholders on the schemes, and their benefits, including how the schemes work and help manage flood risk.

Quality people

e Increase the capacity and capability of the sector to deliver future-focused, successful community outcomes, which may include formal graduate intake and professional development programmes.

f Partner with tangata whenua to bring new skills, networks, and views into the river management sector.

Practices, methodologies and standards

g Benchmark each regional council against key metrics including staffing levels, service levels, funding levels, and the like.

h Prepare nationally consistent asset management methodologies, metadata standards, targeted asset management maturity levels, funding and payment metrics, reporting frameworks (e.g. AMPs), and level of service standards.

i Assess on a scheme by scheme basis asset criticality and performance against asset condition, to better understand how well infrastructure assets are being managed including how river structures integrate with flood protection schemes, and identify where key vulnerabilities lie.

j Compile a technical body of knowledge to establish best practice, and identify knowledge gaps or uncertainties, and research needs (e.g. water quality, risk communication, climate change, river geomorphology).

k Carry out an assessment of cultural and environmental values of the schemes and take them into account when assessing the schemes' benefits and costs.

l Develop a river management resilience framework and supporting decision making tools to enable regional councils to better inform and position communities so they respond to shocks and stressors with minimum disruption, and to formally include environmental, social, cultural and economic values into projects.

m Understand the financial viability of the schemes and common funding issues (asset revaluation, depreciation and renewal expenditure, borrowing, etc) on a national scale and their implications on future affordability of the schemes, and what the impacts of removing protection or decreasing a level of protection may be.

n Investigate alternative funding rationales and strategies, for example, to avoid a higher proportion of scheme costs sitting with fewer ratepayers and to recognise the wider benefits of the schemes.

10 Applicability

This report has been prepared for the exclusive use of our client River Managers' Special Interest Group, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
....	....
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Project Manager	Project Director

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Appendix A: Regional Scheme Information

- **Regional asset replacement costs by asset group**
- **Regional asset condition by asset group**
- **Regional total benefit areas by benefit type, and combined total area**
- **Regional total protected rateable capital value by benefit type, and combined total**
- **Regional opex budgets**

Appendix B: Asset Management Maturity Framework and Results

- IIMM2011 Asset Maturity Framework
- Assessment results by Council

Appendix C: River Manager Survey

- Survey Questionnaire
- Survey Results

Appendix D: Data Standards

- Discussion of national metadata standards

Data standards

Land Information New Zealand, in conjunction with the Ministry of Building Innovation and Employment and Treasury, are currently developing metadata standards (how data should be captured, described and stored) for the three waters sector. It is our view that development of similar standards would benefit the river management sector, and lead to improved asset management practices.

The National Environmental Monitoring Standards (NEMS) are a suite of non-regulatory technical documents prescribing technical standards, methods and other requirements associated with the continuous monitoring, recording and processing of environmental parameters (e.g. water level, rainfall, open channel flow, ratings, etc) that were first published in June 2013. Since then, a number of these documents have been reviewed and rereleased, and many others are planned or under development. Whilst they are entitled 'standards', they are considered best practice and not ascribed a formal status in this regard by Standards New Zealand or our legislative environment.

The NEMS documents set out a generic framework ascribing a level of data quality. This is developed based on a range of factors including but not limited to:

- Whether and how the data are processed
- If an empirical relationship is used to derive the data
- The equipment used for data collection, including processes around its selection, installation, verification and calibration

The generic NEMS quality framework is included here as Figure D.1.

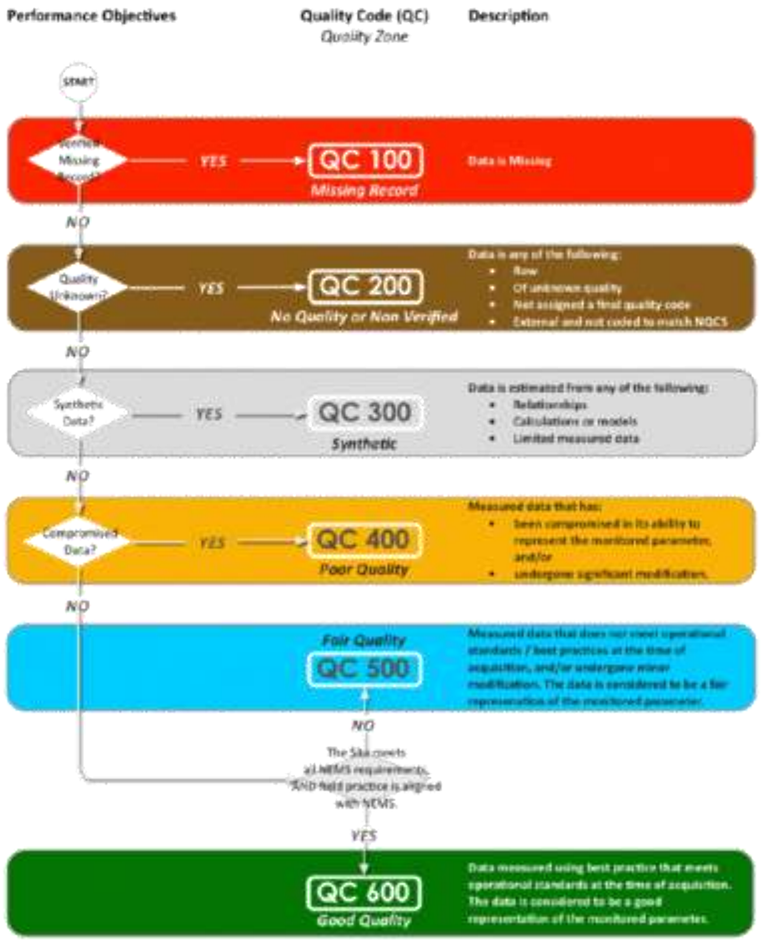

Figure D.1: NEMS generic quality flow chart

In our experience, data of 'fair' quality (QC 500) appears to be a reasonable balance between data accuracy and price tag – 'good' quality (QC 600) data is often associated with expensive installations which may be unaffordable if deployed *en masse*. We would expect that 'fair' quality (QC 500) data would provide enough confidence for regional councils to engage with the National Policy Statement on Freshwater Management and other regulatory processes.

A review of council data acquisition and management processes was outside the scope of this assessment. Further work is required to confirm to which NEMS quality code the river management sector should target, understand each regional council's current data quality codes and what, if any, changes to existing data acquisition and management processes are needed to meet the agreed target NEMS quality code.

Appendix E: Economic Analysis

- Full report on the analysis of economic benefits

Appendix F: Regional Benefit Tables

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Table: Replacement value of asset types by council

Council	Stop banks	Dams	River structures & surrounding	Flood gates	Drains	Pump stations	Tidal erosion protection and structures	TOTAL ASSET VALUE
Canterbury	$278,923,657		$371,248,236	$7,226,900	$26,071,755			$683,470,548
Manawatu	$113,042,895	$9,671,684	$185,942,357	$12,977,898	$11,809,258	$9,323,395		$342,767,486
Waikato	$205,908,535	$4,114,093	$37,358,139	$26,239,557		$47,061,214		$320,681,538
Wellington	$122,675,537	$3,182,601	$124,883,114	$10,330,872	$1,748,104			$262,820,228
Bay of Plenty	$194,726,033		$21,183,621	$4,217,467				$220,127,121
Hawkes Bay	$57,388,072	$4,064,781	$43,580,101	Included in river structures	$34,795,564	$13,006,775	Included with river groynes	$152,835,293
West Coast	$20,518,239		$33,047,105	$185,581	$1,545,378		$3,670,231	$58,966,534
Southland	$43,163,609	$9,621,882	$3,954,210					$56,739,701
Tasman DC	$10,217,014		$32,554,963	$1,057,418				$43,829,395
Otago	$15,312,000		$13,036,000		$2,490,000			$30,838,000
Northland	$9,874,598	$6,557,625	$428,947	$3,656,606				$20,517,776
Taranaki	$3,925,050			$19,000				$3,944,050
Gisborne	$29,766,984		$16,689,619	$1,421,867	$14,771,868			$62,650,337
Grand Total	**$1,105,442,223**	**$37,212,666**	**$883,906,413**	**$67,333,165**	**$93,231,927**	**$69,391,384**	**$3,670,231**	**$2,260,188,008**

Table: Asset condition ranges by asset group

Council	Condition Stopbanks	Condition Floodgates	Condition Drains	Condition Dam	Condition of Pump Station	Condition River Structures	Condition Coastal structures
Canterbury	Good	Good	Good	N/A	N/A	Good	N/A
Manawatu	Good but some don't meet Horizon's dimension specifications	Good	Good	Good	Good	Good with some average	N/A
Waikato	Good-fair	Good-fair with some excellent	N/A	Good-fair	Good-fair with some poor	Good-fair	N/A
Wellington	Good-average	Good-average	Good-average	Good-average	N/A	Good-poor	Good
Bay of Plenty	Excellent	Excellent	N/A	N/A	No information	Excellent	Excellent
Hawkes Bay	Good-average with some excellent	Good-average with some excellent	N/A	N/A	Good-average with some excellent	Good-average	Good-average
West Coast	Good-average	Good	Good	N/A	Good	Good	Good
Southland	Good	Good	N/A	Good	N/A	Good	Good
Tasman DC	N/A	N/A	N/A	N/A	No information	N/A	N/A
Otago	Good	Good	Good	N/A	Good	No information	No information
Northland	Good	Good-excellent	Good	Excellent	N/A	Excellent	N/A
Taranaki	Good	Good	N/A	N/A	Good	No information	No information
Gisborne	No information	No information	No information	No information	No information	No information	No information

Table: Area of rateable land receiving each type of benefit (multiple benefit not double counted in total)

Council	Flood Area (Ha)	Drainage Area	River Management Area	Tidal Area	Total Area (Ha)
Canterbury	252,772	59,372	48,965		333,738
Manawatu	58,522	56,792	47,112		128,822
Waikato	197,904	200,834	43,151	16,360	332,522
Wellington	76,659	6,914			77,571
Bay of Plenty	31,187	43,209			51,866
Hawkes Bay	57,056	32,790	29,989		57,318
West Coast	47,314	1907.933885	42,042		48,201
Southland	57,903	62,901	66,093		169,582
Tasman DC	4,922		20,614		20,614
Otago	33,688	28987.89724	20,331		64,635
Northland	8,909	5457.893029	1,104		8,909
Taranaki	156		156		156
Gisborne	7,952	45,963			46,549
Grand Total	**834,944**	**545,128**	**319,557**	**16,360**	**1,340,482**

Table: Capital value of rateable land receiving each type of benefit (multiple benefit not double counted in total)

Council	Flood CV	Drainage CV	River Management CV	Tidal CV	Total CV
Canterbury	$92,117,897,443	$4,872,626,678	$1,507,987,123		$94,900,694,209
Manawatu	$21,348,006,898	$2,827,208,051	$1,771,452,604		$24,247,119,010
Waikato	$10,947,337,410	$14,847,392,427	$2,148,707,206	$893,323,497	$22,288,051,017
Wellington	$12,859,154,551	$193,811,052			$12,894,929,020
Bay of Plenty	$4,194,110,972	$2,613,341,778			$5,136,727,022
Hawkes Bay	$18,950,570,109	$18,199,541,111	$18,227,580,628		$18,988,072,729
West Coast	$1,366,713,912	$41,646,617	$1,365,060,055		$1,367,695,612
Southland	$2,581,229,504	$1,678,071,118	$1,214,075,692		$4,853,170,098
Tasman DC	$1,430,733,661		$2,551,668,407		$2,551,668,407
Otago	$10,302,073,156	$1,562,577,629	$175,163,851		$11,560,204,481
Northland	$911,566,113	$185,178,412	$26,335,712		$911,566,113
Taranaki	$239,456,163		$239,456,163		$239,456,163
Gisborne	$785,513,485	$5,344,567,327			$5,394,058,373
Grand Total	**$178,034,363,379**	**$52,365,962,200**	**$29,227,487,439**	**$893,323,497**	**$205,333,412,253**

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Appendix XX: Asset management maturity scores using the IIMM maturity framework.

	Asset Management Category	Canterbury	Manawatu	Wellington	Bay of Plenty	Hawkes Bay	West Coast	Southland	Otago	Northland	Taranaki	Tasman DC	Waikato	Gisborne DC
1	AM Policy and Strategy	45	60	55	55	50	0	25	20	45	20	55	45	5
2	Levels of Service and Performance Management	80	95	90	90	90	45	25	60	80	40	45	80	45
3	Demand Forecasting	40	45	65	95	50	0	30	10	35	20	45	50	25
4	Asset Register Data	65	75	90	80	80	21	40	60	75	40	60	80	40
5	Asset Condition Assessment	60	60	85	100	60	40	45	40	55	40	40	65	25
6	Risk Management	60	45	45	100	95	10	20	25	60	40	65	85	10
7	Decision Making	60	55	60	40	60	35	40	35	45	25	60	60	25
8	Operational Planning and Reporting	45	80	50	95	65	35	40	45	40	35	60	80	40
9	Maintenance Planning	45	50	55	70	65	35	50	40	45	45	45	65	35
10	Capital Investment Strategies	45	30	75	80	75	25	25	40	40	20	65	50	25
11	Financial and Funding Strategies	80	70	50	80	65	25	50	40	40	25	60	70	25
12	Asset Management Teams	60	60	85	90	60	34	60	55	70	30	70	55	25
13	AM Plans	60	40	75	80	75	25	55	40	40	25	60	80	35
14	Information Systems	60	60	55	80	55	36	55	60	80	40	65	70	25
15	Service Delivery Models	40	40	40	80	40	31	52	25	40	25	65	45	15
16	Quality Management	65	55	75	55	50	25	40	35	35	25	70	40	25
17	Improvement Planning	50	35	75	60	70	19	25	55	20	0	60	75	25

Source for this data: T:\Hamilton\Projects\62067\62067.0010\WorkingMaterial\JYJC Graphs.xlsx

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					Maturity Levels				
Reference	Question				Aware	Minimum	Core	Intermediate	Advanced
		Section	Questions	Why	0-20	25-40	45-60	65-80	85-100
Understanding and Defining Requirements									
IIMM 2.1	1	**AM Policy and Strategy**	To what extent has your organisation's AM Policy and AM Strategy been articulated, approved, communicated and acted on? How consistent is this policy and strategy with current government policies?	The AM Policy supports an organisation's strategic objectives. It articulates the principles, requirements and responsibilities for asset management (AM). It articulates the objectives, practices and action plans for AM improvement, audit and review processes. The AM Policy and Strategy may be incorporated into the AM Plan.	The Organisation is aware of the need to develop an AM Policy, but hasn't yet completed this work.	Corporate expectations are expressed informally and simply, e.g. "all departments must update AMPs every three years".	There are defined policy statements for all significant business activities. There is a clear linkage to corporate goals. AM Policy is supported by high level action plans with defined responsibilities for delivery.	Expectations of each business activity are supported by detailed action plans, resources, responsibilities and timeframes. AM Policy and Strategy is reviewed and adopted by Executive Team each year.	AM Policy and Strategy is fully integrated into the organisation's business processes and subject to defined audit, review and updating procedures.
IIMM 2.2	2	**Levels of Service and Performance Management**	How does your organisation determine what is the appropriate level of service for its customers and then ensure that asset performance is appropriate to those service levels?	Levels of service are the cornerstone of asset management and provide the platform for all lifecycle decision making. Levels of service are the outputs a customer receives from the organisation, and are supported by performance measures. One of the first steps in developing asset management plans or processes is to find out what levels of service customers are prepared to pay for, then understand asset performance and capability to deliver those requirements.	The organisation recognises the benefits of defining levels of service but has yet to implement guidelines for development of these.	Basic levels of service have been defined and agreed, along with the contribution of asset performance to the organisation's objectives.	Customer Groups have been defined and requirements understood. Levels of service and performance measures are in place covering a range of service attributes. There is annual reporting against targets.	Customer Group needs have been analysed and costs of delivering alternate levels of service have been assessed. Customers are consulted on significant service levels and options.	There is formal consultation over levels of service. Customer levels of service and technical (ie asset performance) levels of service are an integral part of to decision making and business planning.
IIMM 2.3	3	**Demand Forecasting**	How robust is the approach your organisation uses to forecast demand for its services and the possible impact on its asset portfolios?	This AM activity involves estimating demand for the service over the life of the AM plan or the life of the asset. Demand is a measure of how much customers consume the services provided by the assets. The ability to predict demand enables an organisation to plan ahead and meet that demand, or manage risks of not meeting demand.	The organisation recognises the benefits of demand forecasting but has yet to implement processes to forecast demand.	Demand forecasts are derived by experienced staff (rather than data models), taking account of past demand trends and likely future growth patterns.	Demand Forecasts are based on robust projections of a single primary demand factor (e.g. population growth) and extrapolation of historic trends. Risk associated with changes in demand is broadly understood and documented.	Demand forecasts are based on mathematical analysis of past trends and primary demand factors. A range of demand scenarios is developed (e.g.: high/medium/ low).	As for intermediate, plus there is an assessment of risks associated with different demand scenarios, and mitigation actions are identified.
IIMM 2.4	4	**Asset Register Data**	What sort of asset-related information does the organisation collect, and how does it ensure the information has the requisite quality (accuracy, consistency, reliability)?	Asset data is the foundation for enabling most AM functions. Planning for asset renewal and maintenance activities cannot proceed until organisations know exactly what assets they own or operate and where they are located	The organisation recognises the benefits of capturing asset data but has yet to implement systems to capture the data.	Basic physical information recorded in a spread sheet or similar (e.g. location, size, type), but may be based on broad assumptions or not complete.	Sufficient information to complete asset valuation – as above plus replacement cost and asset age/ life. Asset hierarchy, asset identification and asset attribute systems documented.	A reliable register of physical and financial attributes recorded in an information system with data analysis and reporting functionality. Systematic and documented data collection process in place. High level of confidence in critical asset data.	Information on work history type and cost, condition, performance, etc. recorded at asset component level. Systematic and fully optimised data collection programme. Complete data-base for critical assets; minimal assumptions for noncritical assets.
IIMM 2.5	5	**Asset Condition Assessment**	How does the organisation measure and manage the condition of its assets?	Timely and complete condition information supports risk management, lifecycle decision-making and financial / performance reporting.	The organisation recognises the need for monitoring asset condition but has not developed a coherent approach. Measures are incomplete, predominantly reactive. There is no linkage to asset management objectives.	Condition assessment at asset group level ('top-down). Supports minimum requirements for managing critical assets and statutory requirements (e.g. safety).	Condition assessment programme in place for major asset types, prioritised based on asset risk. Data supports asset life assessment. Data management standards and processes documented. Programme for data improvement developed.	Condition assessment programme derived from benefit- cost analysis of options. A good range of condition data for all asset types (may be sampling- based). Data management processes fully integrated into business processes. Data validation process in place.	The quality and completeness of condition information supports risk management, lifecycle decision-making and financial / performance reporting. The organisation conducts periodic reviews of the suitability of its condition assessment programme.
IIMM 2.6	6	**Risk Management**	How does your organisation manage the interplay between business risks and asset-related risks?	Risk management helps identify higher risks, and identify actions to mitigate those risks. This process reduces the organisation's exposure to asset related risk, especially around critical assets, and drives renewal and rehabilitation programmes and decision making.	The organisation recognises the benefits of risk management but has yet to implement processes for development of these.	Critical assets understood by staff involved in maintenance / renewal decisions.	Risk framework developed. Critical assets and high risks identified. Documented risk management strategies for critical assets and high risks.	Systematic risk analysis to assist key decision-making. Risk register regularly monitored and reported. Risk managed consistently across the organisation.	A formal risk management policy in place. Risk is quantified and risk mitigation options evaluated. Risk is integrated into all aspects of decision making.

					Maturity Levels				
					Aware	Minimum	Core	Intermediate	Advanced
Reference	Question	Section	Questions	Why	0-20	25-40	45-60	65-80	85-100
Lifecycle Decision Making									
IIMM 3.1	7	**Decision Making**	How does your organisation go about making decisions on the replacement or refurbishment of existing assets or investment in new ones?	Decision techniques provide the best value for money form an organisation's expenditure programmes. These techniques reveal strategic choices, and balance the trade off between levels of service, cost and risk. ODM is a formal process to identify and prioritise all potential asset and non-asset solutions with consideration of financial viability, social and environmental responsibility and cultural outcomes.	The organisation recognises the benefits of optimised decision making but has yet to implement processes.	AM decisions are based largely on staff judgement and agreed corporate priorities.	Formal decision making techniques (eg using BCA) are applied to major projects and programmes.	Formal decision making and prioritisation techniques are applied to all operational and capital asset programmes within each main budget category/business unit. Formal decision making techniques (eg BCA) are applied to major projects and programmes. Critical assumptions and estimates are tested for sensitivity to results.	As for Intermediate, plus the decision making framework enables projects and programmes to be optimised across the whole business. Formal risk-based sensitivity analysis is carried out.
IIMM 3.2	8	**Operational Planning and Reporting**	How does your organisation manage the cost effective performance of its key business assets over time (e.g. in terms of utilisation, availability, fitness for purpose)?	Effective operational strategies can mitigate risk, defer the need for asset renewals and minimise service downtime following asset failures. Planning for business continuity and full utilisation of assets are key factors in good asset management processes.	The organisation recognises the benefits of operational planning and asset performance reporting but has yet to implement processes to implement these.	Operational responses are understood by key staff, but plans aren't well-documented, or are mainly reactive in nature. Asset performance is measured for some key assets but is not routinely analysed.	Emergency response plan is developed. Demand management is considered in major asset planning. Asset performance is measured for critical asset groups and is routinely analysed.	Emergency response plans and business continuity plans are routinely developed and tested. Demand management is a component of all operational decision making. Asset performance is measured and analysed for most asset groups.	Operational plans are routinely analysed, tested and improved. Formal debriefs occur after incidents. Asset performance is measured in real-time and cost-effectiveness is analysed across all asset groups. Operational programmes are optimised using benefit-cost and risk analysis.
IIMM 3.3	9	**Maintenance Planning**	How does the organisation plan and manage its maintenance activity?	Maintenance is "all actions necessary for retaining an asset as near as practicable to its original condition, but excluding rehabilitation or renewal". Maintenance slows deterioration: it is mechanism to ensure assets continue to deliver performance associated with the required level of service. A major challenge for the asset manager is striking the appropriate balance between planned maintenance (inspections and scheduled maintenance etc.) and unplanned maintenance (arising from unexpected failures)	The organisation recognises the benefits of maintenance planning but has yet to implement such processes.	Managers and operators understand how asset functions support organisational objectives. Processes comply with legislation and regulations. Maintenance records are maintained. Critical assets have been identified.	Asset criticality considered in response, fault tracking and closure processes. There is a strategy for prescriptive vs. performance-based maintenance. Key maintenance objectives have been established, measured and reported on.	Contingency plans exist for all maintenance activities. Asset failure modes are understood. Timing and frequency of major preventative maintenance is optimised using benefit-cost analysis. Maintenance management software is being applied appropriately.	Forensic root cause analysis is conducted for major faults. All reactive and planned programmes are optimised with respect to renewal planning. Different procurement models have been fully explored. Maintenance operations represent value for money.
IIMM 3.4	10	**Capital Investment Strategies**	What processes and practices does the organisation have in place to plan and prioritise capital expenditure?	Capital investment include the upgrade, creation or purchase of new assets, typically to address growth or changes in levels of service requirements, or for the periodic renewal of existing assets, to maintain service levels. Agencies need to plan for the long term asset requirements relative to future levels of service. The decision on whether to create a new asset is typically the time when there is the most opportunity to impact on the potential cost and level of service. Cabinet expects all capital-intensive agencies to disclose 10 year capital intentions and make appropriate use of the better business cases methodology for programmes and individual investment proposals.	The organisation recognises the benefits of capital planning, but has yet to implement such processes.	There is a schedule of proposed capital projects and associated costs, based on staff judgement of future requirements.	Projects have been collated from a wide range of sources such as business unit planning processes and corporate risk processes. Capital projects for the next three years are fully scoped and estimated.	As for core, plus formal options analysis has been completed for major projects that need to be bought into service within the next 5 years. Capital intentions reports identify all major capital projects for the next 10 or more years with broad estimates of the costs and benefits of those projects or programmes.	Long -term capital investment programmes are developed using advanced decision techniques, such as predictive renewal modelling. The organisation has a reliable and approved 10 year view of its future capital requirements and the strategic choices available to meet changing fiscal or level of service requirements.
IIMM 3.5	11	**Financial and Funding Strategies**	How does your organisation plan for the funding of its future capital expenditure and asset-related costs?	Poor financial management can lead to higher long run life cycle costs, inequitable fees and charges, and financial "shocks". Good collaboration between financial and asset managers is important, especially in relation to long term financial forecasts and asset revaluations. Asset valuation is required by International Accounting Standards, and can be used in lifecycle decision making. Robust financial budgets are a key output of any asset management planning process.	The organisation recognises the benefits of developing medium to long term financial and funding strategies, but does yet have any in place. The organisational focus is on the operating statement rather than the balance sheet.	Financial forecasts are based on extrapolation of past trends and broad assumptions about the future. Assets are re-valued in accordance with NZ International Accounting Standards (NZ IFRS).	Ten year+ financial forecasts based on current AMP outputs. The quality of forecasts meets NZ IFRS requirements. Significant assumptions are specific and well reasoned. Expenditure captured at a level useful for AM analysis.	Ten year+ financial forecasts are based on current and comprehensive AMP's with detailed supporting assumptions / reliability factors. Asset expenditure information is linked with asset performance information.	The organisation publishes reliable ten year+ financial forecasts based on comprehensive, advanced AMPs with detailed underlying assumptions and high confidence in accuracy. Advanced financial modelling provides sensitivity analysis, evidence-based whole of life costs and cost analysis for level of service options.

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Reference	Question	Section	Questions	Why	Maturity Levels				
					Aware	Minimum	Core	Intermediate	Advanced
					0-20	25-40	45-60	65-80	85-100
Asset Management Enablers									
IIMM 4.1	12	**Asset Management Teams**	What is the level of organisational commitment to asset management? How is this reflected in existing organisation structure, responsibilities and resourcing of AM competencies?	Effective asset management requires a committed and co-ordinated effort across all sections of an organisation.	The organisation recognises the benefits of an asset management function within the organisation, but has yet to implement a structure to support it.	Asset Management functions are performed by a small number of people with AM experience.	An organisation-wide Steering Group or Committee coordinates all capital asset management activity. There is relevant training for key AM staff. The Executive Team have considered options for AM functions and structures.	All staff in the organisation understand their role in relation to AM, it is defined in their job descriptions, and they receive training aligned to their roles. A person on the Executive Team has responsibility for delivering the AM policy and strategy.	There is strong leadership of the AM functions across the organisation. There is a formal AM capability management programme. The cost effectiveness of the AM structure has been formally reviewed.
IIMM 4.2	13	**AM Plans**	How does your organisation develop, communicate, resource and action its asset management plans?	An asset management plan is a written representation of intended capital and operational programmes for it's new and existing infrastructure, based on the organisations understanding of demand, customer requirements and it's own network of assets.	The organisation recognises the benefits of asset management plan(s), but has not yet developed any.	The AM Plan contains basic information on assets, service levels, planned works and financial forecasts up to 5 years, and future AM improvement actions.	As for minimum plus a description of services and key / critical assets, future demand forecasts, description of supporting AM processes, 10 year financial forecasts, 3 year AM improvement plan.	As for core, plus analysis of asset condition and performance trends (past / future), effective customer engagement in setting LoS, ODM / risk techniques applied to major programmes.	As for intermediate plus evidence of programmes driven by comprehensive ODM techniques, risk management programmes and level of service / cost trade-off analysis. Improvement programmes are largely complete. There is a focus on maintaining appropriate practices.
IIMM 4.3	14	**Information Systems**	How does your organisation meet the information needs of those responsible for various aspects of asset management?	AM systems have become an essential tool for the management of assets in order to effectively deal with the extent of analysis required.	The organisation recognises the benefits of using an asset management system, but does not have one in place.	Asset register records core asset attributes - size, location, age, etc. Asset information reports can be manually generated for AMP input.	Asset register enables hierarchal reporting (from component level to whole-of-facility level). There are systems for tracking customer service requests and for planning maintenance activity. System enables manual reports to be generated for valuation, renewal forecasting.	More automated asset performance reporting on a wider range of information. Key operations, unplanned maintenance and condition information held.	Financial, asset and customer service systems are integrated and enable advanced AM functions. There is optimised forecasting of renewal expenditure.
IIMM 4.4	15	**Service Delivery Models**	How does your organisation procure asset-related services like maintenance and consumables for different classes of assets? How does the organisation exercise control over any outsourced asset management services?	The effectiveness of asset management planning is proven in the efficient and effective delivery of services at an operational level.	The organisation recognises the benefits of defining services delivery mechanisms and functions, but has yet to define these.	Service delivery roles are clear. Allocation of roles (internal and external) generally follows past procurement preferences.	Core functions defined. Contracts in place for external service providers. Tendering / contracting policy in place. Competitive tendering practices applied.	As for core, plus internal service level agreements in place with internal service providers. Contracting approaches have been reviewed to identify best value delivery mechanism.	All potential service delivery mechanisms have been reviewed and formal analysis carried out. Risks, benefits and costs of various outsourcing options have been considered and the best value arrangement has been or is being implemented.
IIMM 4.5	16	**Quality Management**	How does your organisation ensure that it's asset management processes and practices are appropriate and effective?	When AM processes are part of a Quality Management system the organisation is able to operate consistent and reliable processes,, provide evidence that what was planned was delivered, and ensure that knowledge is shared. In short, that processes are appropriate and consistently applied and understood.	The organisation recognises the benefits of quality assurance processes, but has yet to implement processes for these.	Simple process documentation in place for service-critical activities.	There is a clear quality policy and basic quality management system. All critical AM activity processes are documented.	Process documentation has been implemented in accordance with the Quality Management System plan. All processes documented to appropriate level detail.	Quality certification has been achieved. Surveillance audits demonstrate the quality management system is operating satisfactorily.
IIMM 4.6	17	**Improvement Planning**	How does your organisation ensure that it continues to develop its asset management capability towards an appropriate level of maturity?	Well performing agencies give careful consideration of the value that can be obtained from improving AM information, processes, systems and capability. The focus is on ensuring AM practices are "appropriate" to the business objectives and government requirements.	The organisation recognises the benefits of improving asset management processes and practises, but has yet to develop an improvement plan.	Improvement actions have been identified and allocated to appropriate staff.	Current and future AM performance has been assessed and improvement actions identified to close the gaps. Improvement plans identify objectives, timeframes, deliverables, resource requirements and responsibilities.	There is formal monitoring and reporting on the improvement programme to the Executive Team. Project briefs have been developed for all key improvement actions. Resources have been allocated to the improvement actions.	There is evidence that agreed improvement plans have delivered the expected business benefits.

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River managers questionnaire in PEEPOE framework

			Score				
Section			Absent	Minimum	Core	Intermediate	Advanced
		Questions	0	1	2	3	4
This questionnaire seeks to understand the factors that are helping or hindering your RC from delivering a high performing land drainage, river control, and flood protection service with the following objectives: - Water drains quickly - Farms stay productive - Design floods are prevented - Over-design is managed - Businesses stay open - Roads stay open - People stay safe.							
People	How well do your people enable delivery of a high performing flood protection, river control and land drainage service?	Rate your staffing levels in the following areas -Engineering -Planning -Operations -Management	Majority of our staff are graduates / inexperienced		Some of the staff have good experience however there are still some skill sets missing in the team.		We have specialised staff in these areas who have been doing this work for at least 10 years.
		How much do you rely on consultants to deliver your services? -Engineering -Planning -Operations -Management	Majority of our staff are consultants seconded for their services.		We rely on consultants for some of our core services.		We use consultants occasionally for specialised projects.
		How would you rate staff retention?	Most staff have been here less than four years		We have a mix of long serving and new staff		Majority of our staff have a 10 year celebration under their belt.
		Is it easy to find suitable candidates for your vacancies?	We struggle to find suitable applicants, positions may be open for more than 6 months.		We can usually find a suitable person in the first round of applicants		We have people coming in enquiring about vacant positions in the organisation.
		My staff know and understand our assets.	Staff have only a rudimentary understanding of the assets relating to their role.		Most of the team have a good understanding of assets but some are still learning.		Everyone has a good working knowledge of the scheme assets relevant to their role
		How much institutional knowledge does your staff retain?	When key staff leave, we have to rebuild their knowledge from scratch		More than one person are familiar with most of the our procedures or schedules for most of our responsbilities.		When someone leaves it is a smooth transition for the new person.
		How well does your council plan for succession of staff?	We'll cross that bridge when we get there		We have a template in place for staff to drive their own development.		We have procedures and team in place to look at staff development.
		Describe the level of training and development provided to staff.	Staff only have access to essential training (eg H&S)		Staff typically attend a conference or course each year for professional development.		We help staff prepare professional development plans and support them to achieve these.
		What needed skill sets does your council lack? (free form)					

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River managers questionnaire in PEEPOE framework

Section		Questions	Score: [illegible] 0	Minimum 1	Core 2	Intermediate 3	Advanced 4
Environment	Does the physical environment in which you work make it easy to deliver a high performing service?	The river and floodplain environment we work in makes it difficult to deliver: -Land drainage -River control -Flood protection Please explain the nature of your rivers and the reasons for your score - free text.	The rivers are unpredictable (big, braided, high energy). Extensive flood prone areas are adjacent.		Either rivers are predictable or surrounding lands allow natural protection for low lying towns.		Our rivers are quite consistent and predictable. Low lying towns are protected by surrounding hills.
		Our relationships with landowners make it difficult to deliver: -Land drainage -River control -Flood protection	We inform them of our work proposal in the mail. Relationship is poor when we try to dialogue.		We consult with the community and achieve reasonable engagement.		We have a strong working relationship with the community, working together on important decisions.
		We understand and document risks associated with our assets	Staff understand the risk associated with assets however there are no documentation in place yet.		We have risk descriptions for the assets we own.		We have a risk framework (quantify our risk) developed for our assets.
		We understand the residual risks associated with our schemes	We have not considered residual risks associated with our schemes.		We understand the residual risks however this has not been quantified.		We have quantified all major risks for our schemes.
		The residual risks of our schemes are appropriate for their context	We have not considered residual risks associated with our schemes.		We have identified inappropriate risks and have a plan to address them.		We have assessed our residual risks and any unacceptable risks have been addressed.
		We understand and document consequences of our assets failing	We have not considered the consequences of our assets failing		Partial documentation. Some people have good understanding of failure consequences for each scheme.		We have fully documented the consequences of asset failure at a level appropriate to each scheme.
		We clearly communicate risks and failure consequences to our community	We display flood risks on our website. Open to any interested users.		We send pamphlets to the community to inform them of risks and flood consequences.		The community understands the risks and what the plan is if there is a major asset failure.
		Urbanisation of areas protected by our assets is adequately managed	There is little management of development on the floodplain with respect to the scheme		Some planning or management is in place for growth, but issues are not full addressed		Coordinated planning in place for current growth with forecasts and budgets to address future growth.
		Free form to identify schemes where urbanisation is a problem					
		Free form to identify which schemes protect NZTA or other central government assets (e.g. schools)					
		Free form to identify schemes that protect other regional or national significant infrastructure					

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River managers questionnaire in PEEPOE framework

Section		Questions	Score: Absent 0	Minimum 1	Core 2	Intermediate 3	Advanced 4
Equipment	Do you have adequate equipment/tools to deliver a high performing service?	Our network of rain and river gauges enables us to -Monitor and manage flood events -update hydraulic models	We have engineers that go out in the field after the storm event to measure the flood levels.		We have flood models in place, and inspections after flood events to verify them.		We have systems in place that monitor flood levels during flood event.
		We have adequate tools to monitor flood events in real time	We rely on staff in the field for information		Sufficient gauges in place. If there are models, some key calibration points are available.		All critical scheme are monitored. Models can forecast levels on larger schemes based on gauge info.
		We have accurate models of our schemes -Land drainage -River control -Flood protection	We rely on historic events to estimate scheme performance		Most of our schemes have been modelled but some of these are getting a bit old.		Most schemes have mature models with improvement iterations and we have confidence in the results.
		We know what level of protection (e.g. 1% AEP flood) is actually provided for: -Land drainage -River control -Flood protection	We are satisfied if none of the protections have failed (i.e. LoS based on historic/initial).		Currently completing survey and modelling. Current LoS is still based on historic/initial.		Current level of protection determined and modelled from survey undertaken and reviewed x-yearly.
		We understand historic flood levels in the context of the level of protection currently provided	We describe the level of protection provided in terms of historic events		We have assessed the return period of historic events in terms of current ARI		We describe return period for historic events (current weather), and the current scheme LoS.
		We have appropriate knowledge of the following: -Functionality of M & E equipment -LiDAR coverage -Channel or river cross section surveys -flood hazard maps -field communications - telemetering -information management systems	We do not have this data, even though it is appropriate to deliver our services.		We mostly have this data, although some of it is out of date.		We have the data we need, it is up to date, and we have forward budget to keep it so.
		We have up to date hydraulic models and software to run them.	We don't have models in place.		We have models and software in place however have not been updated (i.e. not the latest version)		We have a team in place which collects, builds and collates information for these systems and updates them utilising latest cross section data.

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River managers questionnaire in PEEPOE framework

Section		Questions	Score: Absent 0	Score: Minimum 1	Score: Core 2	Score: Intermediate 3	Score: Advanced 4
Procedures	Do you have adequate procedures to enable delivery of a high performing service?	Do you have adequate procedures to enable delivery of a high performing service?	Our procurement processes are a significant handbrake or do not give good value.		We can achieve the outcomes we need but there is room for improvement in our procurement		Our procurement processes are streamlined and encourage best value.
		We have adopted Flood Protection Assets Performance Assessment Code of Practice, March 2015, in development of our procedures.	We have not adopted the Code of Practice.		We have adopted the Code of Practice for some schemes, and looking to do so for other schemes.		We have adopted the Code of Practice for all of our schemes.
		We have other written procedures on: - Asset condition monitoring - Flood warning - Data collection to enable better analyses - Demand forecasting - climate change - land use - other future planning	Staff understand how we do things but procedures generally aren't written down.		We mostly have written procedures in place but there is no review/update process.		We have a policy in place for these procedures and we review them in on a regular basis.
		Channel capacity monitoring or river cross section surveys - Updating river design flows and/or levels of protection - Sediment management - Stopbank condition and alignment	Generally, we do not monitor this on our schemes		We have this information for most of our schemes but it is mixed quality		We have a procedure in place for field surveys at appropriate frequencies.
		Our annual and long term planning rounds are effective in establishing a framework for our operations.	AM recognised in annual and long term planning but does not affect AM operations.		AM planning is crucial for decisions made in the long term planning.		AM planning is crucial for decisions made in both annual and long term planning.
		There are good linkages between asset management planning objectives and financial provisions included within LTPs and Annual Plans.	There is no realistic way that we can fund our planned objectives.		We can fund our planned objectives but often we sacrifice or delay some due to funding restrictions.		We are able to reliably fund and complete our planned objectives.
		We are proactive in programming and executing our annual maintenance programme.	Our annual maintenace spend is largely reactionary, and priorities change throughout a given year.		Most of our work carried out to a programme, but some gets deferred for emergency works.		All works delivered to a programme and emergency works doesn't affect our programme.
		We have procedures to update our knowledge of - changes in hydrology - changes in river shape/alignment - changes in design flows	We made assumptions which means there are no changes for the next 10 years.		We review and update information regularly.		We review and update information, including making future improvements and timing.
		We have procedures to assess and review the economic and community impact of our services	No procedures in place for assessment but we are aware of the impacts of our services.		We have written procedures in place, however there haven't been any updates/reviews recently.		We review and update procedures every x years.

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River managers questionnaire in PEEPOE framework

Section		Questions	Score				
			[illegible]	Minimum	Core	Intermediate	Advanced
			[illegible]	1	2	3	4
Organisation	Does your organisation make it easy to deliver a high performing service?	How enabling is your regional plan to your operations?	The regional plan creates inappropriate constraints on our schemes		The regional plan doesn't have much impact on the scheme.		The regional plan supports the operation and goals of the scheme
		How well is land use planning informed by department's knowledge of flood related hazards?	Land use planning largely happens in isolation of departmental knowledge		All planning staff understand and make some major decisions.		We work closely with the land use planners to incorporate our knowledge of flood hazards
		How well do your global consents enable your operations?	We generally don't have global consents		Our global consents generally work for us		Our global consents work really well
		How well do Codes of Practice enable your operations?	We don't have Codes of Practice for the operations we have.		We have Codes of Practice for all the operations and we implement some of them for the operations.		We have Codes of Practice for all the operations and we implement them for all the operations.
		How well does your organisation deliver - operational programme - capital improvement works -AMP improvement tasks	We are always behind, and core services remain undelivered.		We are consistently able to deliver our core services		We deliver all of our services and are able to tackle 'nice to have' items
		Our communities understand: -what we do -what level of protection they receive -Free form to list challenges and strengths in consulting with our communities	The community has a poor level of understanding		We have achieved good consultation in the past on key topics.		We have an ongoing programme to maintain awareness that acheives good results
		How well do the following groups know and understand your operations: -council staff not in your department - upper management in your department - managers outside your department - CE level	This group doesn't know or haven't heard of our operations.		This group understands the general gist of our major operations.		This group is part of the decision making for our operations.
		What regular reporting procedures do you undertake to your elected representatives?	We report through standard budget review processes.		We report against budgets and mandatory measures, and provide some narrative to current issues.		Dashboard system of mandatory measures and management priorities. Covers issues and risks.
		How well do the following groups support your operations: -council staff not in your department - upper management in your department - managers outside your department - CE level - elected councillors	This group doesn't have any connections to our operations.		This group provides support when we request it.		This group provides support on an ongoing basis.

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River managers questionnaire in PEEPOE framework

Section		Questions	Score: Absent 0	Score: Minimum 1	Score: Core 2	Score: Intermediate 3	Score: Advanced 4
		How well do the following groups enable retention of institutional knowledge - council staff in your department -council staff not in your department - upper management in your department - managers outside your department - CE level - elected councillors	Often difficult to find someone in the team who knows their stuff		It's usually not a problem to find someone who can give good advice on an issue		Solid understanding of the context and issues for relevant topics, backed up by supporting docs.
		How well does your organisation understand its maximum probable loss from natural hazards?	We only worry about likely damage, not the maximum probable loss.		We have considered maximum probable loss for some of our largest schemes.		We have a risk framework in place that considers this.
		How does your organisation determine asset valuation for insurance purposes?	Book value (depreciated)		Estimated replacement cost		Estimated replacement cost, plus allowance for cost of repairs following failure or partial failure.
		How does your organisation financially plan for disaster recovery (for your assets)?	We have some money set aside in our reserves		We have a formal self insurance and risk assessment programme		We use LAPP or other 3rd party insurance
		Our department is adequately funded for: -routine asset maintenance -asset renewal/replacement -river system changes -disaster response and recovery	We are always behind, and core services remain undelivered.		We are consistently able to deliver our core services		We deliver all of our services and are able to tackle 'nice to have' items

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River managers questionnaire in PEEPOE framework

Section		Questions	Score				
			[illegible]	Minimum	Core	Intermediate	Advanced
			[illegible]	1	2	3	4
External	Do external factors or organisations make it easy to deliver a high performing service?	Legal and regulatory factors make our job easy - Local Govt Act - RMA consenting - Recreational - Biodiversity - Cultural (eg co-management)	We struggle to work with this		We are generally OK but sometimes run into challenges		We find strong alignment between our responsibilities and these requirements
		We have strong relationships with special interest departments/groups - DoC - F+G	The relationship is non-existent / unhelpful.		We have a contact in the team who could help us.		Long standing relationship with them (directly contact them). We are comfortable working together.
		The communities of benefit we service are able to pay for these services.	Rely heavily on some form of subsidy. Affordable LoS are significantly lower than appropriate.		Financial constraints limit some aspects of the service we consider would be appropriate practice.		Financial constraints do not prevent us from providing appropriate services and protection
Other	Free form field to solicit feedback on any other significant issues that have the potential to impact adversely on scheme performance or maintenance.						

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	Questions		No Ans	1	2	3	4	5	Weighted average
1	Rate your staffing levels in the following areas:	Engineering				3	4	6	4.2
		Planning	1			4	4	4	4.0
		Operations				1	5	7	4.5
		Management					9	4	4.3
2	How much do you rely on consultants to deliver your services?	Engineering			1	8	3	1	3.3
		Planning				3	5	5	4.2
		Operations	1	1	1	1	3	6	4.0
		Management			2	1	1	9	4.3
3	How would you rate staff retention?					9	2	2	3.5
4	Is it easy to find suitable candidates for your vacancies?			6	4	3			1.8
5	My staff know and understand our assets.				1	5	4	3	3.7
6	How much institutional knowledge does your staff retain?				1	8	4		3.2
7	How well does your council plan for succession of staff?		1		5	4	1	2	3.0
8	Describe the level of training and development provided to staff.				1	3	6	3	3.8
9	What needed skill sets does your council lack?		- River engineering technicians and professionals hard to recruit/retain. Area engineers with combined technical/practical skillset very rare - Modelling - Consent Application Planning - Roles currently filled, but potential for lack of experience to arise in the near future with important staff leaving. - Professional engineering when I retire at the end of the year. - Hydraulic modelling. Surveying. - We generally have the skills We need						
10	The river and floodplain environment we work in makes it difficult to deliver:	Land drainage	3		3	3	3	1	3.2
		River control	2	5	1	4	1		2.1
		Flood control	2	3	2	3	3		2.5
10a	Please explain the nature of your rivers and the reasons for your score.		- Typically high energy gravel phase rivers with extensive floodplains - We have >200 rivers and streams, we have no major rivers in the region. Due to the high number of individual watersheds and high rainfall variability we have a 100year event every other year in one or more of the individual catchments. - A range of rivers are managed, and degree of predictability changes according to the reach of the river where our work occurs. We have both steep sloping high energy rivers, which reduce in energy as they reach the coast. - Southland plains are relatively flat and the river gradients reasonable. Major towns are Gore, Mataura and Invercargill City. - Only three large rivers in relatively stable channels many small rivers in stable channels - Other than the Riwaka delta quite rare for townships to be regularly affected by flooding. Ungauged waterways having short duration intense storms causing localised erosion and flooding are an issue. Land slippage and debris flows more damaging than flooding in general. - I am more talking about the technical information available to help make the decisions as we generally have to rely on staff and consultant experience rather than being able to use formulas or good models for River geomorphology						
11	Our relationships with landowners make it difficult to deliver.	Land drainage	2		1	5	3	2	3.5
		River control	2		1	4	3	3	3.7
		Flood control	2			3	6	2	3.9
12	We understand and document risks associated with our assets.		2		3	3	1	4	3.5
13	We understand the residual risks associated with our schemes.		2			5	3	3	3.8
14	The residual risks of our schemes are appropriate for their context.		2		2	6	2	1	3.2
15	We understand and document consequences of our assets failing.		2			6	3	2	3.6
16	We clearly communicate risks and failure consequences to our community.		2	1	5	2	2	1	2.7
17	Urbanisation of areas protected by our assets is adequately managed.		2		1	4	4	2	3.6
18	Identify schemes were urbanisation is a problem.		- Development on Ashburton & Kaiapoi River floodplains could be better managed - None - Te Ngarue Scheme - subdivision approved by TLA against HBRC advice. - Gore, Mataura and ICC where space is critical for upgrades - Lower Waitara River Flood control Scheme - Riwaka - historic not new urbanisation in scheme overflow paths. Tidal banking with limited outlets causing ponding. - Land use control is a significant issue as infill and new development continues to increase the value of assets protected by our flood protection work						

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	Questions		No Ans	1	2	3	4	5	Weighted average
19	Identify schemes that protect NZTA or other central government assets (e.g. schools).		- Kaikoura, Conway, Waiau Spotswood, Waiau Town, Waiau Rotherham, Hanmer West, Lower Pahau, Kowai, Sefton-Ashley, Ashley, Waimakariri-Eyre-Cust, Halswell, Wairewa/Little River, Te Waihora/ Lake Ellesmere, Selwyn, North Rakaia, Dry Creek, Ashburton Rivers, Ashburton-Hinds Drainage, Upper Hinds, Lower Hinds, Rangitata, Orari-Waihi-Temuka, Opihi, Washdyke, Taitarakihi, Saltwater Creek, Pareora, Otaio, Waihao-Wainono, Penticotico, Lower Waitaki, Omarama Stream, Twizel, Upper Waitaki. - Lower Taieri Flood Protection Scheme Lower Clutha Flood and Drainage Scheme Lower Waitaki River Control Scheme Leith Flood Protection Scheme - Waipaoa and Te Karaka schemes but minor works at various localities - Heretaunga Plains Flood Control and Drainage Scheme Upper Tukituki Scheme Plus a number of smaller Schemes including Kopuawhara, Paeroa, Wairoa, Esk, Whirinaki, Central and Southern Schemes - Schemes protect most utilities in the district. Phones, power, roads energy services - Lower Waitara River Flood control Scheme The Waitotara Scheme - Waimea and Lower Motueka flood control schemes. Balance of schemes being for erosion protection/river control only protect both local roads and state highways. - All of our schemes provide protection to road, rail, and other central government assets and the DOC estate as well as utility operator assets						
20	Identify schemes that protect other regional or national significant infrastructure.		- Seadown Drain, Lower Rakaia, Rakaia Double Hill - Lower Taieri Flood Protection Scheme Lower Clutha Flood and Drainage Scheme Lower Waitaki River Control Scheme Leith Flood Protection Scheme - The same as above as they are SH2 - Same as 19 - Lower Waitara River Flood control Scheme The Waitotara Scheme The lower Waiwhakaiho Scheme - As above. - We have very few assets listed as regionally significant infrastructure (Centreport) and our work does not protect this						
21	Our network of rain and river gauges enables us to:	Manage flood events	2	1		1	3	6	4.2
		Update hydraulic models	3	1	1	3	2	3	3.5
22	We have adequate tools to monitor flood events in real time.		2		1	2	4	4	4.0
23	We have accurate models of our schemes:	Land drainage	3	2	2	2	2	2	3.0
		River control	2	2	1	2	3	3	3.4
		Flood protection	2			2	5	4	4.2
24	We know what level of protection (e.g. 2% AEP flood) is actually provided for:	Land drainage	3	1	2	1	4	2	3.4
		River control	2	1		2	5	3	3.8
		Flood protection	2			2	3	6	4.4
25	We understand historic flood levels in the context of the level of protection currently provided.		2			2	3	6	4.4
26	We have appropriate knowledge of the following:	Functionality of M&E equipment	4			2	4	3	4.1
		LiDAR coverage	3		3	2	2	3	3.5
		Channel or river cross section surveys	2		1	3	4	3	3.8
		Flood hazard maps	2		2	3	5	1	3.5
		Field communications	2			2	5	4	4.2
		Telemetering	2		1		5	5	4.3
		Information management systems	3				6	4	4.4
27	We have up to date hydraulic models and software to run them.		2	1	1	1	4	4	3.8
28	Do you have adequate procedures to enable delivery of a high performing service?		3			1	7	2	4.1
29	We have adopted Flood Protection Assets Performance Assessment Code of Practice, March 3125, in development of our procedures.		2	1	5	5			2.4

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	Questions		No Ans	1	2	3	4	5	Weighted average
30	We have other written procedures on:	Asset condition monitoring	2		1	3	4	3	3.8
		Flood warning	2			4	3	4	4.0
		Data collection to enable better analyses	2		2	4	4	1	3.4
		Demand forecasting (climate change)	3		4	4		2	3.0
		Demand forecasting (land use)	3		4	3	1	2	3.1
		Demand forecasting (others)	3		5	2	1	2	3.0
31	Channel capacity monitoring or river cross section surveys:	Updating river design flows and/or levels of protection	3		1	2	2	5	4.1
		Sediment management	3	1	1	3	2	3	3.5
		Stopbank condition and alignment	3		1	3	2	4	3.9
32	Our annual and long term planning rounds are effective in establishing a framework for our operations.		2		1	4	1	5	3.9
33	There are good linkages between asset management planning objectives and financial provisions included within LTPs and Annual Plans.		2		2	1	4	4	3.9
34	We are proactive in programming and executing our annual maintenance programme.		2		1	2	6	2	3.8
35	We have procedures to update our knowledge of:	Changes in hydrology	2		2	5	2	2	3.4
		Changes in river shape/alignment	2		2	5	3	1	3.3
		Changes in design flows	2	2		5	3	1	3.1
36	We have procedures to assess and review the economic and community impact of our services		2	2	3	4	2		2.5
37	How enabling is your regional plan to your operations?		3	1	3	3		3	3.1
38	How well is land use planning informed by department's knowledge of flood related hazards?		3		1	3	2	4	3.9
39	How well do your global consents enable your operations?		3	2	1	4	1	2	3.0
40	How well do Codes of Practice enable your operations?		3	1	3	4	1	1	2.8
41	How well does your organisation deliver:	Operational programme	4			7	1	1	3.3
		Capital improvement works	4		1	5	2	1	3.3
		AMP improvement tasks	4		1	7		1	3.1
42	Our communities understand:	What we do	3	1		6	1	2	3.3
		What level of protection they receive	3		1	7		2	3.3

	Questions		No Ans	1	2	3	4	5	Weighted average
42a	List challenges and strengths in consulting with our communities.		- Challenges around maintaining interest for some Liaison Committees. Organisational priorities are focused on topics other than flood protection. - Limited consultation due to general apathy to regional council functions unless they are directly affected by them. When they are likely to be directly affected by works, there is generally good public interest. - Regular regional newsletter highlight important and significant activities Small communities wanting to be involved Interested liaison Committees - Lack of interest in general community. Special interest groups such as F&G / Freshwater Anglers Federation that vilify us. Many landowners have been here a long time so have a good understanding of flooding issues already - new landowners more of a challenge. - Maintaining current services if fine but when adaptation and change is required there is often a considerable amount of resistance						
43	How well do the following groups know and understand your operations:	Council staff not in your department	4		1	7	1		3.0
		Upper management in your department	4		1	1	4	3	4.0
		Managers outside your department	4		2	5	2		3.0
		CE level	5			4	3	1	3.6
		Elected councillors	4		1	2	5	1	3.7
44	What regular reporting procedures do you undertake to your elected representatives?		4		1		2	6	4.4
45	How well do the following groups support your operations:	Council staff not in your department	3		3	4	2	1	3.1
		Upper management in your department	3			5	1	4	3.9
		Managers outside your department	3		3	4	1	2	3.2
		CE level	3			5	1	4	3.9
		Elected councillors	3			3	5	2	3.9
46	How well do the following groups enable retention of institutional knowledge:	Council staff in your department	3			4	6		3.6
		Council staff not in your department	3		1	7	2		3.1
		Upper management in your department	3		1	5	2	2	3.5
		Managers outside your department	3		3	3	4		3.1
		CE level	3		1	4	4	1	3.5
		Elected councillors	3		3	5	2		2.9
47	How well does your organisation understand its maximum probable loss from natural hazards?		4	1	2	3	1	2	3.1
48	How does your organisation determine asset valuation for insurance purposes?		5			3	3	2	3.9
49	How does your organisation financially plan for disaster recovery (for your assets)?		3	1	1	1	2	5	3.9
50	Our department is adequately funded for:	Routine asset maintenance	3			7	2	1	3.4
		Asset renewal/replacement	3		1	7	1	1	3.2
		River system changes	3		2	6	1	1	3.1
		Disaster response and recovery	3		1	6	2	1	3.3

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	Questions		No Ans	1	2	3	4	5	Weighted average
51	The following legal and regulatory factors make our job easy:	Local Government Act	3		2	1	5	2	3.7
		RMA consenting	3	1	3	4	1	1	2.8
		Recreational	3		1	6	2	1	3.3
		Biodiversity	3			8	1	1	3.3
		Cultural	3			7	2	1	3.4
52	We have strong relationships with special interest departments/groups:	Department of Conservation	3		3		3	4	3.8
		Fish and Game	3		2	2	1	5	3.9
53	The communities of benefit we service are able to pay for these services.		3		2	4	3	1	3.3
54			- Unknown climate change effects including sea level rise - particularly associated with potential sea inundation. Aggradation of gravel affecting Scheme performance and cost effective approaches to address this. Co-management under Treaty of Waitangi settlements is a looming issue. Government have a focus on policy, but have no input, financial or otherwise, into implementation. This is a cost left to local authorities. Government only concern is that rates increase above the level of inflation. - Affordability is always questioned but in reality we feel we provide very good value for money considering the benefits we provide so feel there is a mismatch between telling the story of the value we provide and the cost of that service						

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Economic value of river control, flood protection and drainage (RCFPD) schemes in New Zealand

Tim Denne and Louis Wright

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1 Introduction

1.1 The Purpose of this Report

This report aims to define the total economic value of river control, flood protection and drainage (RCFPD) schemes in New Zealand. This is a forward-looking examination of value; it examines the benefits that will flow from the ongoing existence of the RCFPD schemes, net of any future costs. The study aims to demonstrate and communicate the value of these schemes to the communities that depend on them.

1.2 Approach to Analysis

The analysis aims to establish the total value of the RCFPD schemes. It evaluates the impacts on the total wellbeing of New Zealanders in aggregate. Wellbeing is not easily defined, but it represents the sum of the outcomes that people (as individuals or as groups) would regard as positive, less the sum of those they regard as negative. Overall changes in wellbeing (also referred to as welfare or utility) are measured using cost benefit analysis (CBA), rather than more narrowly-focussed economic valuations tools, such as economic impact analysis (EIA) which measures contributions to GDP. We explain the differences between these concepts below.

As with all valuation exercises, measuring the economic value of RCFPD schemes requires the comparison of two scenarios. In this case, the situation with RCFPD schemes in place (the factual) is compared with a scenario (the counterfactual) in which there are no RFCFPD schemes. We discuss the complexities of such an analysis below.

1.3 Valuation Concepts: CBA vs EIA

1.3.1 Cost Benefit Analysis

Cost benefit analysis (CBA) is an analytical approach that springs from welfare theory; it defines the best decision outcome in any circumstance as that which results in the maximum net gain in wellbeing for the community as a whole. Aggregate wellbeing gains to the community are estimated by adding all the estimated benefits (wellbeing gains) and subtracting all estimated costs (wellbeing reductions), taking account of their timing and adjusted by discounting.

Consistent with NZ Treasury CBA guidance,[1] we do not include distributional impacts. For example, we do not examine whether schemes have tended to provide greater benefits to people in particular income categories. Rather we assume that the benefits are widely distributed across the community.

CBA measures changes in wellbeing using monetary values. This is for convenience only. Money is already a currency for exchanging many kinds of goods, and it can be used, usefully, to measure relative wellbeing. This assumes that, in broad terms, patterns of monetary expenditure reflect relative preferences amongst consumption options. Monetary valuation is extended to things (or preferences) which are not normally measured in money terms so they can be compared on the basis of relative preferences.

1.3.2 Economic Impact Assessment

Economic Impact Assessment (EIA) typically measures impacts on Gross Domestic product (GDP) or regional equivalents, which is a measure of total economic activity in a country (or region). GDP is usually measured as total expenditure in a given year on final goods[2] or as total income. It measures

[1] The Treasury (2015) Guide to Social Cost Benefit Analysis.
[2] Final goods are those that are ultimately consumed rather than used in the production of other goods.

different things from a CBA. For example, it does not count the value of things that produce wellbeing but which are not bought and sold in a market, and it measures only the market price of a good and not any additional benefit (the consumer surplus, which is the difference between price paid and willingness to pay). Of relevance to this project, it would count the value of flood control protection of buildings but not the avoidance of indirect costs such as the stress of those experiencing a flood. GDP also tends to count expenditure as a benefit, eg GDP increases as a result of flood damage followed by rebuilding.

The Treasury notes that EIA can provide useful contextual information for decision-makers, but it is not suitable as a tool for measuring the balance of costs and benefits of a decision to society.[3] We agree. We use the CBA approach in this report as the basis for assessing the economic value of river control, flood protection and drainage schemes.

1.4 CBA Concepts

1.4.1 Defining Costs and Benefits

Costs are defined as opportunity costs. CBA assumes efficient markets which means that the prices of all goods and services are assumed to reflect their opportunity costs of supply. The opportunity cost of allocating a resource to any particular use is that the resource is not available for the next highest value use. This includes opportunity costs of capital (it could have been invested to create a return in some other venture), resources (they could have been used as inputs to some other industry) and labour (workers could be employed elsewhere). Effectively using an opportunity cost approach is the same as comparing the benefits of any given project with those of some other project or set of projects in which the inputs are all used productively.

Benefits are measured as the value that individuals place on the output. This includes any value paid in a market and any additional surplus that is based on what someone would be willing to pay, ie the value of any change in outcome is equal to what people would be willing to give up to obtain it. This is applied to effects or values that are not normally specified in a market, including the impacts on the environment. Such effects are measured using a mix of stated and revealed preference techniques.

1.4.2 CBA Outputs

The results of a CBA of an investment can be summarised in several ways.

- **Net present value (NPV)** – the sum of benefits minus the sum of costs over the lifetime of the investment, with all costs and benefits discounted to take account of their timing. A positive NPV means the investment will provide net wellbeing benefits.

- **Benefit cost ratio (BCR)** – the sum of discounted benefits divided by the sum of discounted costs. A BCR that is greater than 1 means that the investment is worthwhile and will produce net wellbeing benefits.

- **Internal rate of return (IRR)** – the discount rate which would produce an NPV of zero. IRRs can be used to rank investment options, with the project with the highest IRR being favoured. An IRR can also be used to compare with a hurdle (or targeted) rate of return.

The net present value (NPV) is usually the favoured indicator, and it is providing information that is closest to the interests of this project. It measures the sum of benefits minus the sum of costs over

[3] The Treasury (2015) Guide to Social Cost Benefit Analysis.

the lifetime of the project(s), with all costs and benefits discounted to take account of their timing. This can be used to estimate the total value of RCFPD schemes, rather than estimated returns on investment, which are largely historical. The benefit cost ratio (BCR) or internal rate of return (IRR) might be used to estimate returns on future costs, eg the value of maintaining (or expanding) existing infrastructure, but this is addressing a different question from the valuation question.

We use NPV analysis in this report. However, we also transform the values into annualised values (or equivalent annual value, EAV) to enable better comparison of projects which have different durations (see below). An EAV is an amount which, if spread equally over the lifetime of a project would result in the same NPV as the actual project costs and benefits. The formula for an EAV is:

$$EAV = \frac{r.PV}{1-(1+r)^{-n}}$$

Where: EAV = equivalent annual value
r = discount rate
PV = present value of project (or NPV)
n = project duration in years

It is estimated using the PMT function in excel.

1.4.3 Project Lifetime

Projects should be evaluated over the length of the project. This is until the end of the economic life of the capital invested, eg to a time when there is a need for a significant reinvestment. When comparing projects with different time frames, the NPV results should be converted into EAVs as discussed above.

1.4.4 Discounting

Discounting in the context of a CBA is a way to measure the time value of consumption. Two broad approaches are used: the social rate of time preference and the social opportunity cost of capital.

Social Rate of Time Preference

The social rate of time preference (SRTP) assumes that the primary interest of policy makers is in the timing of consumption and that public policy (or investment) decisions can affect that timing. The Ramsey equation is a standard formula for determining the SRTP. It includes two elements: [4]

- the time preference of people, ie the extent to which there is a preference for consumption earlier in time; and
- the relative value of consumption in different time periods because of changing income, ie an additional unit (eg dollar) of consumption is valued less when income is higher.

The SRTP is applied to wellbeing effects more generally by assuming that people would be willing to sacrifice present wellbeing in favour of greater future wellbeing at the same rate of time preference as evidenced in saving behaviour (saving forsakes current consumption in favour of greater future consumption).

[4] Ramsey FP (1928) A Mathematical Theory of Saving. *Economic Journal*, 38: 543–559.

The SRTP approach attempts to have wide applicability to the timing of all impacts on wellbeing, eg whether we would prefer to face the stress of a flood this year or next year.

Estimates of the SRTP for New Zealand include an estimate of 4.4% by the Ministry of Economic Development (now MBIE) in the context of the 2006 NZ Energy Strategy,[5] and a recommended rate of 4% by Auckland Council.[6]

Social Opportunity Cost of Capital

NZ Treasury emphasises the social opportunity cost of capital (SOC) concept, ie that government decisions are displacing private investments which would have yielded a rate of return. In its 2015 *Guide to Social Cost Benefit Analysis*, the Treasury states that "*the public policy objective must be to maximise the return that is obtained from the tax payer's dollar*" and that "*a useful way to think about the discount rate is as a hurdle rate of return.*"[7] Based on this argument, the guide recommends the rate of return in the share market is the next best, or most convenient, alternative investment, that could be used as an opportunity cost of capital-based discount rate.

Although the Treasury authors assume a wide view of possible effects (by 'return' they mean "*the net total of the social and economic impacts of a project, or the benefits net of the costs, all valued at their opportunity costs*"), they take a narrow assumption on initial costs (taxpayer funds). Their argument is that "*Assuming that all benefits have been valued correctly, we should be indifferent between one kind of benefit and another, if their value is the same.*"

Treasury's estimate of the opportunity cost of capital for public decisions is 7% in real terms.[8]

Recommended Discount Rate

Some approaches to discounting combine the two approaches, eg by isolating the investment items and using the SOC to estimate a shadow price of capital. All effects are then discounted using the SRTP.[9] In this study, we are not examining new investments but the value of existing investments which are sunk costs. The consumption effects are being valued.

For analysis in this study we use a discount rate of 6%, consistent with NZ Treasury, but with sensitivity analysis using 4%.

2 Avoided Flood Damage

2.1 Economic cost categories

A review of economic analyses of floods and other natural disasters suggests that costs (which are avoided as a result of RCFPD schemes) are often categorised as:[10]

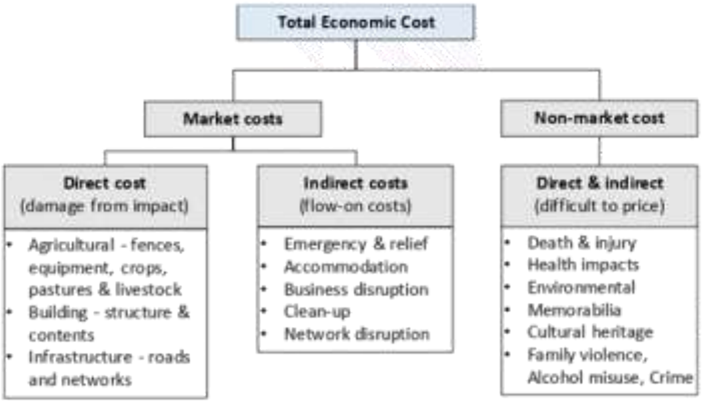
- tangible and intangible damages – those that are readily measurable in monetary terms and those that are not; and

[5] MED (2006) Choice of Discount Rate for the New Zealand Energy Strategy. POL/1/39/1/1
[6] Auckland Council (2013) Auckland Council Cost Benefit Analysis Primer.
[7] NZ Treasury (2015) Guide to Social Cost Benefit Analysis, p35
[8] http://www.treasury.govt.nz/publications/guidance/planning/costbenefitanalysis/currentdiscountrates
[9] Young L (2002) Determining the Discount Rate for Government Projects. New Zealand Treasury Working Paper 02/21
[10] Department of Infrastructure, Planning and Natural Resources (2005) Floodplain Development Manual the management of flood liable land. New South Wales Government. Appendix M Flood Damages

- direct and indirect damages – those that result from the direct contact with water and those that are secondary to this.

Figure 1 summarises cost categories building on a selection of Australian and New Zealand flood defence CBAs.[11] For clarity we use market and non-market values as categories rather than tangible/untangible; the market values category is split into direct and indirect reflecting whether the costs are directly attributable to the actions of water. Market costs (those for which there are market values) tend to be more tangible and their values somewhat more easily determined. Direct costs are generally damages caused by the flood, whereas indirect costs are inconveniences incurred as consequence of the event. Costs that fall under the 'non-market' category are generally less tangible and more difficult to value. Some indirect or 'flow-on' costs, such as network disruption, can also be classified as a non-market cost.

Figure 1 Summary of avoided costs in flood defence CBAs



Although the classification of avoided costs is based largely on flood defence projects, the set of categories is more widely applicable to river control and drainage schemes. The categories are developed to ensure that a comprehensive set of effects is taken into account, including those which are more or less easily estimated. The classification is similar to that used in defining Total Economic Value (TEV)[12] which is used to ensure that all values are incorporated in a CBA, particularly those relating to the environment.

In this study we have considerable data limitations. Nevertheless, we examine ways in which the widest set of values possible can be included in the analysis. Tonkin + Taylor (2014) reviewed the quality of the data that are available to describe flood damages and found it to be highly variable.[13] The best quality data are for tangible-direct damages and then, in order of decreasing quality, tangible-indirect, intangible-direct and intangible-indirect damages. The analysis in this study

[11] Bureau of Transport [BTE] (2001) Economic costs of natural disasters in Australia, report 103; Deloitte & Access Economics (2013) Building our nation's resilience to natural disasters. Australian Business Roundtable for Disaster Resilience and Safer Communities; Deloitte & Access Economics (2016) The economic cost of the social impact of natural disasters. Australian Business Roundtable for Disaster Resilience & Safer Communities; Wyatt S (2015) Flood, drainage and erosion protection benefits of Lower Wairarapa Valley Development Scheme. Report prepared for Greater Wellington Regional Council

[12] European Environment Agency (2010) Scaling up ecosystem benefits A contribution to The Economics of Ecosystems and Biodiversity (TEEB) study. EEA Report No 4/2010.

[13] Tonkin & Taylor (2014) Flood Damage Assessment methodology. Report Prepared for Auckland Council.

concentrates on the components of value that are most readily measured at an aggregate (national) level.

2.2 Treatment of Insurance

Insurance provides a means for households and businesses to pass on their risks to others. In a fully competitive insurance market with perfect information, the level of premium would reflect the risk and associated damage. In such a theoretical competitive world, if measures were taken to reduce the risk of flooding, this would be reflected in reduced insurance premiums and the total amount paid in premiums would reflect the total expected pay-out (damage times risk). In the short run, and at the margin, ie for the valuation of individual RCFPD schemes, premiums may not adjust efficiently with risk levels. This matters, because most insurance companies operating in New Zealand are foreign-owned. Risk reduction that was not met by reductions in premiums would largely result in benefits for insurance companies, and these benefits would be expatriated.

However, for this analysis, which assesses the effects of investments made over a significant period of time, spread widely across the country, we assume that the industry is relatively efficient and that premiums are reflective of risk. We thus ignore insurance payments (premiums and pay-outs) in estimating (avoided) damage costs.

2.3 International Experience

In this section, we briefly review international examples of CBAs used to evaluate flood defence schemes. Of particular interest to this study, the examples are used to examine how others have approached:

- the inclusion of the full range of effects; and
- the development of a counterfactual against which value is determined.

The findings below suggest that, over time, CBAs have taken account of an increasing number of effects, particularly as approaches to valuation have improved and monetary values have been published. Also, CBAs of flood defence have, in general, been used to analyse new schemes, rather than existing schemes. In that context, the counterfactual definition is generally "doing nothing in addition to what is there already", rather than "the removal of existing schemes".

2.3.1 USA

The 1936 Flood Control Act in the US is often cited as the first significant example of government-required use of CBA for decision making.[14] As a result, federal agencies adopted a damages-avoided method for flood control benefit assessment. This included the cost of replacing and repairing property that could be damaged and the foregone income from agricultural land (lost sales and/or increased production costs); the damages for each possible flood event were multiplied by the probability of each flood occurring and the impact was estimated as the difference between the with and without project scenarios.

Over time there was increasing criticism of the avoided damages approach because it tended towards a narrow focus on property damage.[15] Approaches shifted towards those that measured the willingness to pay (WTP) of beneficiaries for avoided flood damage. This would include assessment of the full range of effects.

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[14] Shabman L (1997) Making benefit estimation useful: lessons from flood control experience. Water Resources Update [Universities Council on Water Resources], 109: 19-24.
[15] Shabman (*op cit*)

Since 1983, direction has been provided to Federal agencies in the form of the Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies (PR&G). They provide advice when evaluating and selecting major water projects, including projects related to navigation, storm resilience, wetland restoration, and flood prevention.[16] The PR&G were finalised in 2014; they include a requirement for evaluation of the costs and benefits of alternatives, in addition to performance relative to a set of guiding principles[17] and formulation criteria.[18] The cost benefit analysis requirements include monetisation wherever possible, consistent with federal guidance;[19] impacts that cannot be monetised are to be described.

2.3.2 Australia

Over the early 2000s, the Australian government carried out a long-term research project to better understand the costs and benefits of flood mitigation expenditure. The first report by the Bureau of Transport Economics (BTE) analysed the past impacts of natural disasters in Australia to develop a model for costing future events.[20] Costing methods relied heavily on findings from past studies and insurance data to estimate total economic costs.

BTRE (2002)[21] used BTE methodologies to analyse five flood mitigation interventions (case studies) in Australia. The damage observed after a flood and with a specific intervention in place, was compared with the estimated damage without it (the counterfactual). Where feasible, damage avoided benefits were estimated as the reduced average annual damage (AAD) due to mitigation. The counterfactual was defined simply, eg flood damage observed in a nearby industrial zone was used to estimate the counterfactual damage to the Tamworth CBD, had its existing flood levee not been built. No detailed scenarios were developed of possible different types of development in the absence of flooding.

Cost estimation methods developed by BTE continue to provide methodologies and inputs for Australian flood protection analysis. However, recent research has recognised the lack of attention previously given to those less tangible, social costs of natural disasters. Impacts that are typically overlooked include damage to health and wellbeing of people and communities. These effects have been included in a recent study for the Australian Business Roundtable for Disaster Resilience & Safer Communities[22] (see below).

2.3.3 UK

In the UK, although chiefly for England, there are a number of documents that provide guidance on the evaluation of projects that would enhance current levels of flood protection or erosion risk. Consistent with a set of principles set out in a Defra policy statement on appraisal of flood and coastal erosion risk management (FCERM),[23] all publicly-funded FCERM strategies and projects developed by operating authorities must complete a FCERM appraisal. FCERM Appraisal Guidance (FCERM-AG) sets out methods to be used.[24] This includes guidance on:

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[16] Council on Environmental Quality: Updated Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies. Retrieved from https://obamawhitehouse.archives.gov/administration/eop/ceq/initiatives/PandG

[17] These principles are: (1) healthy & resilient ecosystems, (2) sustainable economic development, (3) floodplains (ie avoiding floodplain development), (4) public safety, (5) environmental justice, and (6) a watershed approach.

[18] The formulation criteria are completeness, effectiveness, efficiency and acceptability.

[19] Office of Management and Budget (OMB) Circulars A-94 and A-4

[20] Bureau of Transport Economics [BTE] (2001) Economic costs of natural disasters in Australia.

[21] Bureau of Transport and Regional Economics [BTRE] (2002) Benefits of Flood Mitigation in Australia.

[22] Deloitte Access Economics (2016) The economic cost of the social impact of natural disasters. Prepared for the Australian Business Roundtable for Disaster Resilience & Safer Communities

[23] Defra (2009) Appraisal of flood and coastal erosion risk management A Defra policy statement

[24] Environment Agency (2010) Flood and Coastal Erosion Risk Management appraisal guidance FCERM-AG

- setting a baseline for appraisal. This is defined as do-nothing, ie walk-away with no further intervention. This is forward looking and includes an assessment of how risks will change over time, eg as a result of climate change. The do-nothing baseline should set out a story on what is expected to happen in the future in terms of:
    - deterioration, failure/loss and time to failure of structures such as defences, coast protection works and pumping stations;
    - how the frequency of erosion and flooding events will change and whether or not there are existing structures or management activities; and
    - the impacts (positive and negative) that occur as a result.

- measuring costs and benefits. The main guidance is provided by the Green Book,[25] which is Treasury Guidance on cost benefit analysis. The FCERM-AG includes some guidance on the types of costs and benefits to be considered, with additional guidance provided in a separate handbook on environmental valuation.

The handbook on valuing environmental effects in the context of flood evaluation[26] includes default values for a number of impacts, while noting that these are "*best estimates of the likely levels of benefits*" but that new valuation studies should be used when the impacts are significant or likely to be contested. Table 1 shows some default values in £/ha/year for different ecosystem types; they are used to value habitat creation as a result of managed retreat.

Table 1 Range of indicative economic values ("default values") for different habitats (£/ha/yr, 2008 prices)

Habitat & ecosystem service provision	Indicative value	Range
Inland marsh: water quality improvement, recreation (non-consumptive), biodiversity, aesthetic amenity	~£1300	£200 - £4,300
Saltmarsh: water quality improvement, recreation (non- consumptive), biodiversity, aesthetic amenity	~£1400	£200 - £4,500
Intertidal mudflat: water quality improvement, recreation (non- consumptive), biodiversity, aesthetic amenity	~£1300	£200 - £4,300
Peat bog: water quality improvement, recreation (non- consumptive), biodiversity, aesthetic amenity	~£300	£0 - £1,000

Source: Eftec (2010) Flood and Coastal Erosion Risk Management: Economic Valuation of Environmental Effects HANDBOOK for the Environment Agency for England and Wales.

The values were derived from a number of studies, particularly that of Brander *et al*[27] which included techniques for scaling up data from individual studies to an aggregate national (or European) level, including taking account of:

- distance-decay functions in which the willingness to pay (WTP) for a particular improvement would decrease with distance from the valued ecosystem;
- taking account of substitutability, eg if benefit transfer is performed between landscapes that vary in level of ecosystem services (from poor to rich), WTP values are likely to be overestimated;[28]

[25] HM Treasury (2003) The Green Book. Appraisal and Evaluation in Central Government (minor updates in 2011)
[26] Eftec (2010) Flood and Coastal Erosion Risk Management: Economic Valuation of Environmental Effects HANDBOOK for the Environment Agency for England and Wales
[27] Brander LM, Ghermandi A, Kuik O, Markandya A, Nunes P, Schaafsma M and Wagtendonk A (2008) Scaling up ecosystem services values: methodology, applicability and a case study. Report to European Environment Agency.
[28] They note: "*For instance, respondents in an area with several lakes whose water quality is polluted will value cleaning up the first lake more than cleaning up the second lake, because (1) the first lake can be a substitute for the second lake, and (2) the respondent has a budget limitation which reduces the money available for cleaning up the second lake. Valuing goods separately and then adding up the values will overstate the true value, as every respondent will treat the ecosystem under study as if it were the first good.*" (Brander *et al* 2008, p7)

- differences in socio-economic factors (eg income and demographics) between the study site and the policy site; and
- differences in contextual factors that explain WTP, including (a) the spatial pattern of the social, demographic and psychological characteristics of the affected population and (b) the physical characteristics of the goods and services under valuation.

The handbook also included values relating to the value of recreation, but this is also translated into average values per hectare. The valuation approach focussed on developing an average annual damage (AAD), as discussed above. Additional guidance is provided on multi-criteria methodologies for effects that are difficult to measure in monetary terms.[29]

3 Evaluation of NZ Schemes

3.1 Defining the counterfactual

Any analysis of costs and benefits requires the comparison of two scenarios – with or without some action. In this case it is comparing a factual scenario (the current set of RCFPD schemes) with a counterfactual (no RCFPD schemes). This differs from most CBAs of flood defence schemes which have examined the costs and benefits of new investments or enhancements; typically, they have compared new investment and expenditure to a do-nothing counterfactual (no additional investment).[30] This cannot be used here because the interest is in valuing the existing stock.

There are different ways in which the counterfactual might be specified to answer the question that this study addresses. We outline three options below.

1. **New Zealand with no RCFPD schemes**
   This scenario would postulate a situation in which no RCFPD schemes had ever been put in place. It might be equivalent to imagining that no one in New Zealand had ever discovered or been aware of these techniques and technologies. This might lead to the need for a complex assessment of how New Zealand would have developed differently, including significant differences in land use activity and the location of economic activity, towns and cities. Such an analysis is both complex and highly speculative. For example, if a flood defence scheme protects an urban area from flooding, eg the Hutt Valley, it is likely that, in the absence of the schemes, the people and activities would have located elsewhere, away from the risk of flooding. Defining this counterfactual scenario might require an analysis of:
   - alternative locations for the residents, including whether this would be through expanding other urban areas at the same density, or through more intensive development; and
   - alternative economic activities and, potentially, a different economic structure, ie a different set of industries in New Zealand.

2. **No coordinated RCFPD schemes**
   Instead of assuming there are no RCFPD schemes, this scenario would assume there are no coordinated, community-developed schemes and that the schemes that exist are developed

[29] Environment Agency (2010) Flood and Coastal Erosion Risk Management appraisal guidance. Guidance on applying the scoring and weighting methodology.
[30] Middlesex University Flood Hazard Research Centre (2014) A common framework of flood risk management cost benefit analysis features; Deloitte Access Economics (2013) Building our nation's resilience to natural disasters. Australian Business Roundtable for Disaster Resilience and Safer Communities;

privately by individual landowners or small groups of them. This would require speculation on whether or not landowners would have coordinated their activities in a way which resulted in similar schemes to those that currently exist. The analysis would be of the value of coordination (or of public intervention) rather than of the schemes themselves.

3. **Removal**
   The third approach examines the value of what is currently protected by the existing RCFPD schemes, equivalent to asking the current community for its willingness to pay (WTP) for the continued provision of protection on the assumption that the (private) owner of the schemes could somehow remove them. Although this scenario is not realistic (the existing schemes would not be removed), it provides a basis for estimating the value of the existing schemes to the current communities protected by them.

The third option is the approach adopted in this study. It is consistent with the study's aim to identify the current value of existing schemes.

3.2 Analytical Approach

3.2.1 Counterfactual Application

Building on the discussion above, we have defined the analytical question as:

> *the estimated maximum willingness to pay by the relevant communities for the continued provision of protection and value by the river control, flood protection and drainage schemes, on the assumption that these schemes were removable such that their benefits were no longer available.*

The approach to valuation will differ with the land use or land type, and with the nature of the scheme. We set out the proposed approaches in Table 2. In all cases our interest is in estimating the present value of the change in scenario; this is the discounted sum of future costs. We discuss time frames for analysis below (Section 3.2.2).

Table 2 Valuation approach by land use and scheme type

Land use/ land type	Flood protection	Tidal protection	Drainage	River management
Built-up areas (residential and other buildings)	NPV of avoided damage	Value of improvements plus difference in value of land uses	Value of improvements plus difference in value of land uses	Value of improvements plus difference in value of land uses
Other land uses	Greater of: • NPV of avoided damage or • Difference in value of land uses possible with/without flood protection	Difference in value of land uses possible with/without tidal protection	Difference in value of land uses possible with/without drainage	Difference in value of land uses possible with/without river management

Built-up areas are characterised by the presence of buildings. These are capital assets for which there is a risk of:

- physical damage in the case of floods or tidal inundation; or
- land unsuitability, ie in the case of drainage or river management, the counterfactual would be that it would be too wet for the buildings.

The maximum WTP of communities protected by the existing schemes would be equal to the expected damage costs following removal of the existing schemes. For buildings, expected costs would be equal to:

- floods or coastal inundation: the change in risk level (risk of damage) times the cost of damage were it to occur, including market and non-market costs. Normally risks are expressed as annual risks so that the annual change in risks has to be converted to an NPV; or
- drainage or river management: the value of the buildings as these would be expected to be lost in the counterfactual scenario.

For land, including in built-up areas and **other land uses** elsewhere, the expected costs are the expected changes in land values, based on the change in the potential use of the land. Land values are equivalent to the present value of future benefits from the use of the land (or the value of the next best use where there is a competitive land supply market), so that they are already expressed in NPV terms.

We explore the approach to measuring expected costs below.

3.2.2 Expected Costs – Flood Damage to Built-up Areas

Approaches to flood risk analysis can vary according to differences in the counterfactual assumptions, the number of analysis sites (ie single-site or many sites) and availability of relevant data. However, all flood risk assessments require the following key factors to be considered:[31]

- flood hazard – the probability and magnitude of flooding;
- exposure – the economic value of assets vulnerable to flood hazard;
- vulnerability – the relationship between flood hazard and economic loss; and
- performance – the effectiveness of flood protection that modifies the above factors

The UK Flood Estimation Handbook (FEH) flood estimation methodology is internationally recognised as best practice. The FEH method uses flood frequency curves to define a relationship between the magnitude of a flood (peak flow) and the return period (expected frequency of occurrence). Box 1 defines probability terms often used in flood analysis.

Box 1 Definition of flood probability

> Flood probability is generally expressed as a return period (T) or an annual exceedance probability (AEP). A return period is the average interval of time between floods that equal or exceed a particular magnitude. The AEP is the probability of exceeding a specified flood level in any year (the inverse of the return period). For example, a flood return period of 50 years will have an AEP of 0.02 or 2%.

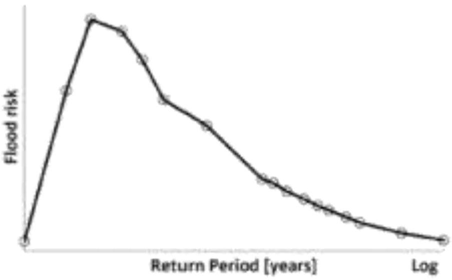
The FEH method requires historical data on the maximum flood each year for several consecutive years.[32] Flood data must be specific to the site, or to a site of similar characteristics. However, even if sufficient peak flow data are available, this method is infeasible given the large number and diversity of sites in our base data; we are trying to estimate an avoided cost of floods as an aggregate for New Zealand as a whole, without undertaking detailed analysis of each individual flood-prone site. Thus, we take an alternative approach and use historical insurance data and flood damage relationships observed in past studies to determine the association between flood return period and flood damage.

[31] National Research Council (2015) Tying flood insurance to flood risk for low-lying structures in the floodplain. Chapter: 3 methods for assessing flood risk. ISBN: 978-0-309-37166-7

[32] Environment Agency (2010) Fluvial Design Guide – Chapter 2.4.1 Probability and return period. Retrieved from http://evidence.environment-agency.gov.uk/FCERM/en/FluvialDesignGuide/Chapter2.aspx?pagenum=4

We adopt a flood risk estimation method demonstrated in Morita (2014)[33] and Olsen *et al* (2015),[34] in which the average annual damage (AAD) or expected annual damage (EAD) for a location is defined by the total area under its flood risk density curve (RDC). A flood RDC illustrates the risk (in dollar amounts) of a flood along a range of return periods. Using flood damage and return period data from Denmark, Figure 2 shows the RDC as a typical relationship between return period and annual flood risk. Although damage costs increase with return period, risk (or expected annual cost) approaches zero for larger events because of their low probability of occurrence.[35]

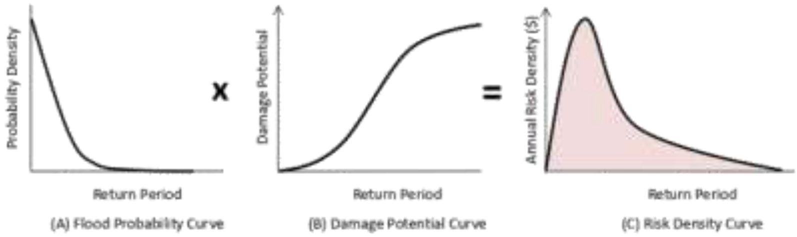
Figure 2 Flood Risk Density Curve



Source: Olsen *et al.* (2015)[36]

The RDC is the product of damage potential and event probability, as seen in Figure 3. Each point along the RDC represents the damage corresponding to a return period (Figure 3B), weighted by its exact annual occurrence probability (Figure 3A). The sum of these probability-weighted damages, ie the area under the RDC, equals the annual average damage (AAD) for a site.

Figure 3 Flood Probability, Damage and Risk Curves



Source: Modified from Morita (2014)[37]

Our approach assumes the entire area underneath the RDC is equivalent to a location's AAD without flood defence, ie the counterfactual AAD. We then assume AAD avoided, ie the flood benefit provided to a location, is determined by a scheme's level of service. For example, a scheme with a 100-year level of service will fully avoid damages up to a 100-year flood (Figure 4).

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[33] Morita M (2014) Flood Risk Impact Factor for Comparatively Evaluating the Main Causes that Contribute to Flood Risk in Urban Drainage Areas. Water 2014, 6 (2): 253-270; doi:10.3390/w6020253

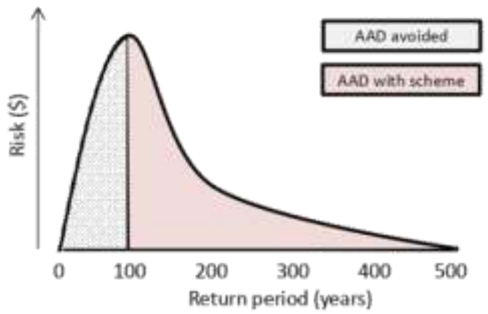
[34] Olsen AS, Zhou Q, Linde JJ & Arnbjerg-Nielsen K (2015) Comparing methods of calculating expected annual damage in urban pluvial flood risk assessments. Water, 7(1): 255-270.

[35] ibid

[36] ibid

[37] Morita M (2014) Flood Risk Impact Factor for Comparatively Evaluating the Main Causes that Contribute to Flood Risk in Urban Drainage Areas. *Water* 2014, 6, 253-270; doi:10.3390/w6020253

Figure 4 AAD with a 40-year flood protection level of service



Therefore, annual average damage (AAD) avoided because of flood mitigation can be denoted as:

$$AAD\ avoided = counterfactual\ AAD - AAD\ with\ scheme$$

We take the following steps to estimate the value of damage avoided for sites protected by flood defence:

1. Calculate the **flood probability curve** (see Figure 3A)
2. Calculate a **flood damage curve** (see Figure 3B)
3. Calculate a **risk density curve** (RDC) (see Figure 3C). The purpose of this step is to determine how flood damage changes with a scheme's level of service.
4. Estimate site specific **counterfactual flood damage.** This is done by combing counterfactual assumptions with base data information, eg site capital value and scheme rating.
5. Calculate site-specific **damage avoided** using level of service data.

We set out these steps in more detail below.

Step 1: Calculating the Flood Probability Curve

The flood probability curve used in the derivation of the RDC (Figure 3) is not the same as the annual exceedance probability (AEP). The AEP defines the probability of a flood exceeding a specific magnitude. Therefore it is the probability that a flood of a specific return period or greater occurs within a given year. In contrast, the flood probability curve uses the probability associated with each individual return period. This is referred to as the probability density of a return period (Figure 3A). Intuitively, a return period's probability density will always be lower than its AEP, except for return periods of 1, where the AEP and probability density is also equal to 1.

Flood probability density can be defined as a function of the return period. This equation is known as the flood probability density function (PDF). Mathematically, a PDF is equal to the derivative of the corresponding cumulative distribution function (CDF).[38] In flood analysis, the CDF is equal to 1–AEP, ie it is the annual probability that a flood of a given return period or less will occur:

$$CDF = P = 1 - \frac{1}{T}$$

Where: P = the cumulative probability
T = the return period in years

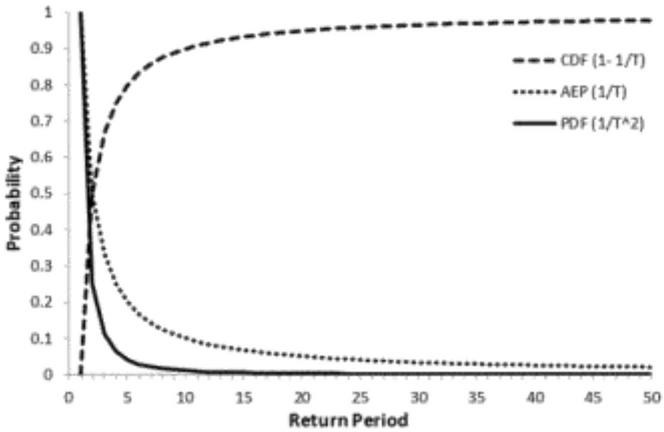
[38] Morita M (2014) Flood Risk Impact Factor for Comparatively Evaluating the Main Causes that Contribute to Flood Risk in Urban Drainage Areas. Water 2014, 6, 253-270; doi:10.3390/w6020253

Using calculus, we can calculate the derivative of the CDF to obtain the PDF, the probability for an exact return period (T):

$$PDF = \frac{dP}{dT} = \frac{1}{T^2}$$

Figure 5 illustrates these three key probability equations with respect to flood return period.

Figure 5 Different types of probability for flood return periods



Flood PDF is the probability curve (Figure 3A) used in our analysis. This same probability curve applies to all locations in the base data.

Step 2: Calculate the Damage Potential Curve

Damage potential curves define the expected damage for a range of return periods. We take two approaches to estimate damage potential:

A. Use historical insurance data to estimate the relationship between return period and flood damage.
B. Use numbers regarding the observed relationship between flood damage and return period in the UK.

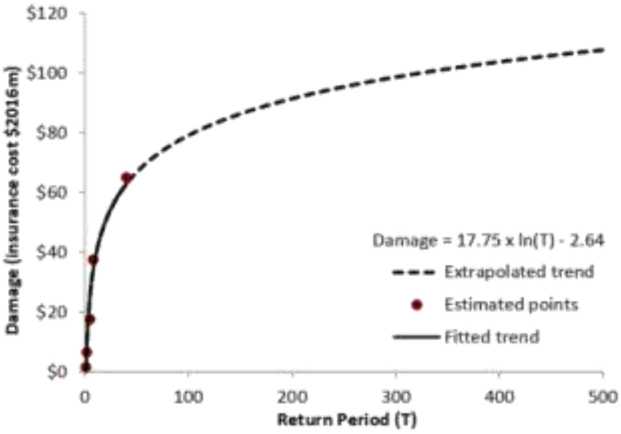
These methodologies are explained below.

A) Damage potential curve: NZ insurance data

The Insurance Council of New Zealand (ICNZ) has published a table of insurance costs which have occurred in New Zealand since 1968.[39] ICNZ data contain 77 flood events from 1976 to 2016. After adjusting insurance costs to 2016 prices, we count the number of floods within specified cost ranges: $0-2.9m, $3-9.9m, $10-$24.9m, $25-49.9m, $50-80m. To find the return period associated with each cost category, we divide the analysis period (40 years) by the number of flood events within a given cost category. For example, there were 8 floods within the $10-25m range, therefore we estimate a 5 year flood (40 years/ 8 floods) would cost $17.5m (median of $10-25m). We plot these data and fit a regression line to estimate the relationship between insurance cost and return period (Figure 6). The dotted line of Figure 6 is an extrapolation of this trend out to 500 years.

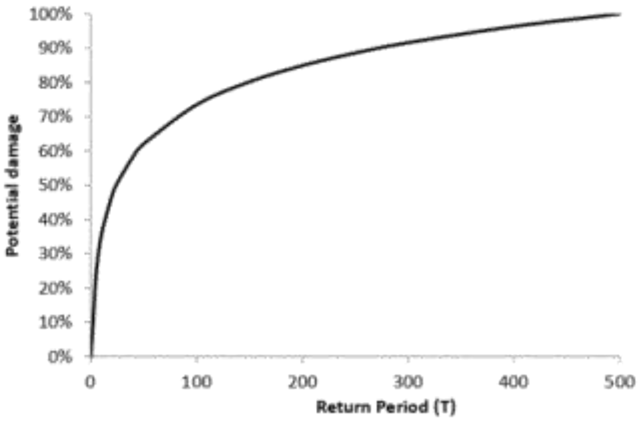
[39] http://www.icnz.org.nz/statistics-data/cost-of-disaster-events-in-new-zealand/

Figure 6 Insurance cost and return period



The insurance cost-return period relationship from Figure 6 serves as a proxy for the relationship between direct damage and return period. Under the assumption that a 500-year flood will incur the maximum flood damage, we can then calculate a damage potential curve, ie damage as percentage of that expected in a 500-year flood (Figure 7).

Figure 7 Potential Damage Curve: NZ data



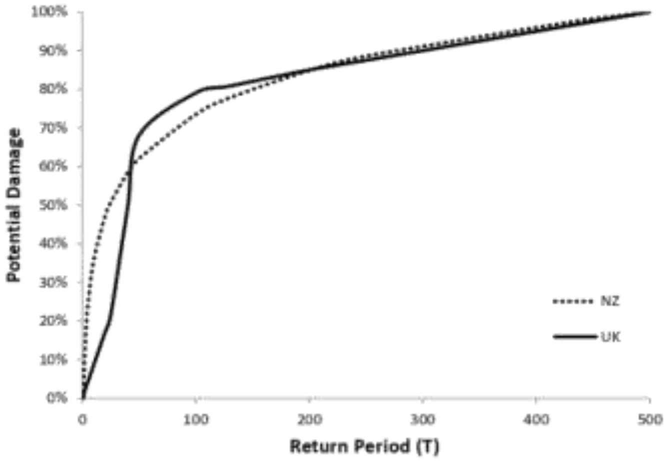
B) Damage potential curve: UK data

The Middlesex University Flood Hazard Centre (2014)[40] used UK data to estimate the percentage of properties affected (relative to a 200 year flood) by different floods. Using "percentage of properties affected" as a proxy for "damage potential" we can construct a second potential damage curve (Figure 8). To estimate UK damage potential as a percentage of a 500-year flood, we multiply these values by a factor of 0.85, which is equal to 200-year damage as a proportion of 500-year damage

[40] Middlesex University Flood Hazard Centre (2014) A common framework of flood risk management cost benefit analysis features. Version 3.

found in the NZ data (eg the average insurance costs of a 200-year and 500-year flood were estimated to be $91m and $107m, respectively).

Figure 8 Potential Damage Curve: UK vs NZ



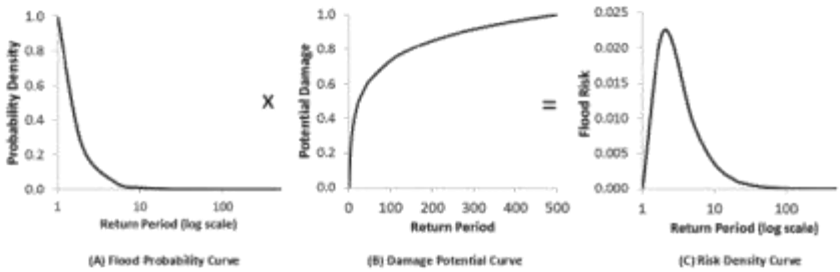
Source: Middlesex University Flood Hazard Centre (2014)

In comparison to the curve derived from NZ data, the UK-derived curve increases at a slower rate up to a return period of 20 years, and at a greater rate over return periods 20-50 years, after which the NZ and UK curves converge.

Step 3: Calculate the RDC

To calculate the RDC (flood risk), we apply the method shown in Figure 3 and combine the flood probability and potential damage curves (NZ or UK curve). Figure 9 illustrates this step using the damage curve estimated via NZ insurance data. Potential damages in the middle chart of Figure 9 are expressed as a proportion of the maximum damage (and not actual damage values as in Figure 3B); they are multiplied by the probability density to produce a flood risk density curve (RDC). To estimate damage in monetary terms they must be multiplied by the estimate of maximum flood damage (in monetary terms) for the specific area (Step 4).

Figure 9 Construction of the RDC



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Step 4: Estimate site-specific counterfactual AAD

The objective of this step is to multiply the previously estimated RDC (specified as a proportion of maximum damage - Figure 9C) by the maximum expected flood damage for a given site. The RDC is expressed as an annual flood risk so needs to be multiplied by the maximum annual damage. We make the standard assumption that a property's capital value (CV) is equal to the present value of the string of future annual returns (to infinity) from use of the land. Thus the maximum expected damage for a given year is estimated by calculating an annuity from the CV. When calculating a constant annuity to infinity, it is equal to the discount rate (r) multiplied by the capital value (CV). Therefore, a site's counterfactual AAD, ie with flood defence removed, is the total area under the RDC, and is equal to the capital value multiplied by the discount rate. The difference between the factual (with flood defence) and counterfactual (no flood defence) is estimated as some proportion of this area based on the Level of Service (LoS) of the flood defence scheme (see Step 5 below). However, flood defence schemes are also classified in terms of the level of benefit, as high, medium or low. We assume that this is a measure of the vulnerability of the area to flooding and we use this to adjust the counterfactual AAD. For example, a flood defence scheme defined as providing a low level of benefit, is assumed to provide protection of a small proportion of the total counterfactual AAD($CV.r$).

In the absence of data, we assume the counterfactual damage for schemes rated high, medium and low is 75%, 50% and 20% of the maximum counterfactual damage (Table 3).

Table 3 Assumptions for Scheme Rating Percentage

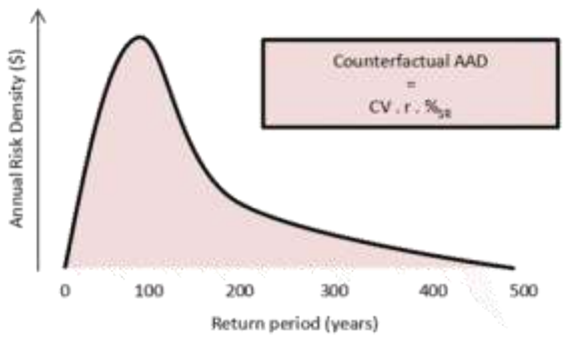
Council Scheme Benefit Rating	Scheme Rating Percentage ($\%_{SR}$)
High	75%
Medium	50%
Low	20%

Actual counterfactual AAD can then be expressed by the following equation and as the area under the RDC (Figure 10):

$$Counter\,factual\ AAD = CV\,.\,r\,.\ \%_{SR}$$

Where $\%_{SR}$ is the scheme rating percentage as shown in Table 3.

Figure 10 Site specific RDC (annual form)



By definition, AAD is an annualised value of flood damage. To find the present value (PV) of counterfactual flood damage, we divide the AAD by the discount rate (r). The PV of a site's

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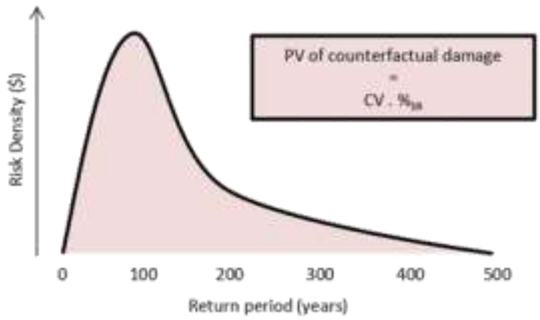
counterfactual damage can be simplified to its capital value multiplied by its scheme rating percentage:

$$PV\ of\ counterfactual\ AAD = \frac{counterfactual\ AAD}{r} = \frac{\%_{SR}\,.\,CV\,.\,r}{r} = \%_{SR}\,.\,CV$$

For example, with flood protection removed, a $500,000 site with a low scheme rating would incur $500,000 x 20% = $100,000 worth of damages. The annual RDC can be scaled to represent risk in PV form (Figure 11). The area under this curve represents the present value of counterfactual damage to a specific site.

Figure 11 Site specific RDC (PV form)

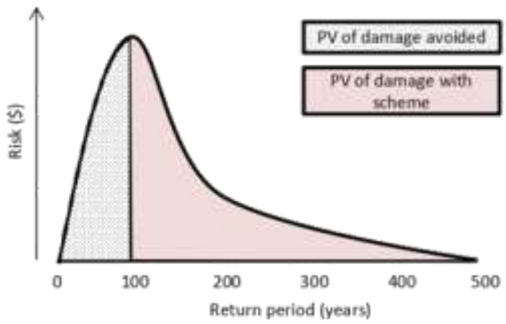


This methodology assumes landowners do not take account of the expected duration of the RCFPD schemes themselves. For example, if a high value land use is occurring that is only possible because of the RCFPD scheme, the landowners assume that the RCFPD scheme will always be in place. Under this assumption, the capital value = discounted annual benefits to infinity, rather than the value incorporating some risk that the scheme might depreciate (physically) over time and that, at some future date, the high value land use could not occur.

Step 5: Calculate damage avoided

A scheme's level of service is used in conjunction with the RDC to calculate the portion of the counterfactual flood damage that is now avoided. The key assumption here is that a scheme provides full protection from flood damage up to the level of service specified in the base data. Figure 12 gives illustrates the change in flood damage for a site protected by a scheme with a 100 year level of service.

Figure 12 Site specific avoided damages (PV form)



A specific level of service can be represented by a percentage ($\%_{LoS}$) that is equivalent to the left hand-side proportion of the total area under the RDC, ie damage avoided as a percentage of the counterfactual damage. To find the PV of damage avoided for a given site, this percentage is simply multiplied by a site's CV and scheme rating percentage:

$$PV\ of\ damage\ avoided = \%_{SR}\ .\ CV\ .\ \%_{LoS}$$

These classifications and assumptions are combined to produce the following assumptions regarding the benefit of a flood protection scheme (Table 4). The matrix of percentages represents the flood benefit as a proportion of a site's capital value, given the level of service and scheme rating.

Table 4 Flood damage avoided as a percentage of site capital value

Level of service	Counterfactual damage avoided[1] ($\%_{LoS}$)	Perceived flood benefit		
		High	Med	Low
		Counterfactual damage as % of maximum flood damage ($\%_{SR}$)		
		75%	*50%*	*20%*
10	**62%** (36%)	47%	31%	12%
50	**90%** (67%)	67%	45%	18%
100	**95%** (85%)	71%	48%	19%
200	**98%** (94%)	73%	49%	20%
500	**100%** (100%)	75%	50%	20%

Note: [1] UK expected damages as a percentage of a 500 year flood in brackets

3.2.3 Difference in land value

For differences in land use we examine the difference in value between current use and the alternative use under the assumption of no protection or no drainage. Table 5 sets out our counterfactual land use assumptions. It shows, for each land use, the assumption on the land use (or vegetation cover) that would exist if the protection was not there. For forestry and low value land uses, it is assumed that there is no change in land use. But for some, higher value land uses, alternatives are required.

The raw data distinguishes between 'high producing exotic grassland' and 'low producing grassland'. For some areas represented within the data, low producing grassland is more valuable (per hectare) than high producing grassland. This is unintuitive and becomes problematic when low producing grassland is used as the counterfactual land use for the high producing grassland. In other words, the data implies that high producing exotic grassland would be more valuable in absence of protection. To avoid this confusion, we have merged these two categories into a single land use (see Table 5).

Table 5 Counterfactual land use type by protection type and current land use

Simplified land use type	Counterfactual land use type
Depleted Grassland	Depleted Grassland
Exotic Forest	Exotic Forest
High or Low Producing Grassland	Non-productive land
Non-productive land	Non-productive land
Orchard, Vineyard or Other Perennial Crop	Non-productive land
Short-rotation Cropland	Non-productive land
Tall Tussock Grassland	Tall Tussock Grassland

3.2.4 Adjustments for Population and Economic Changes

It is common for flood defence CBAs to inflate future avoided costs to account for the increasing risk exposure of a growing economy and population.[41] Data on natural disaster costs from Australia support the application of this costing method.[42] However, in this analysis, we are using land prices as a proxy for the value of activity on the land. Land prices would be expected to incorporate future expected value of activities, discounted to the present day. Given this assumption, we do not adjust values further.

3.2.5 Inclusion of Wider Economic Benefits (Multiplier Effects)

Current communities that are protected by RCFPD schemes have economic connections beyond the geographical area in which they are based. This includes businesses and other organisations providing services to the community that would be affected by the flooding and which might suffer financially if the community did not exist.

However, to include these wider economic activities involves two questionable assumptions.

1. The counterfactual would need to be further refined to one in which, in the absence of flood protection, the people currently located in the flood prone area would move to somewhere completely different, such that they could no longer use those services. If they were simply located close by, they might continue to use the services.

2. The inclusion of wider benefits would assume that the out-of-area services are not being provided efficiently, ie that the prices paid by the community for goods and services from outside the flood-prone area do not reflect the costs of their provision.

To assume point 1 is to start to shift back towards a scenario in which we speculate on how New Zealand might develop differently in the absence of flood defence . This would raise the problems associated with counterfactual option 1 (see discussion in Section 3.1 above).

Point 2 refers to efficient provision of goods and services and pricing at opportunity costs of supply (costs to providers would fall in addition to revenues). This is the standard approach to CBA. To adopt an approach in which these wider benefits are taken into account is to shift towards EIA. This can be used to measure the value of wider economic activity *associated with* a region, but it cannot be used in this simple way to speculate on what the loss of economic activity would be as a result of change in current demand. The resources currently used to provide goods and services to the existing flood-protected community would be reallocated to different things. There may some overall reduction in economic activity (and economic value) but we do not know how large it would be. To count the full amount from using, eg regional multipliers, would be to grossly over-estimate the value.

3.3 Non-market Values

Section 2.1 above discussed the different cost categories and the need to include a wide set of costs of flooding, beyond simple estimates of damage to buildings and land uses. However, many of these damages are highly localised and the estimates of costs are site-specific. Rather than analyse each scheme in terms of local characteristics, in this section we explore the extent to which generalised ratios of market to non-market (tangible to intangible) costs can be identified from studies elsewhere and which might be used to estimate avoided damage costs in New Zealand.

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[41] Deloitte & Access Economics (2016) The economic cost of the social impact of natural disasters. Australian Business Roundtable for Disaster Resilience & Safer Communities.
[42] Risk Frontiers (2010) Bushfire Penetration into Urban Areas in Australia: A Spatial Analysis.

3.3.1 Non-market cost estimation

A review of "a small selection of existing literature" by Wyatt for an analysis of a lower Wairarapa Valley development scheme,[43] led her to adopt an assumption that human impacts (including risk to life, injury, disruption and worry) are equal to direct damage to property, but only in cases where the access to the dwelling is affected by flood." Wyatt noted that, following a review of other schemes in New Zealand and overseas, a report by Greater Wellington Regional Council assumed that intangibles would be equal to the direct damage to urban and rural buildings (structural and contents damage associated with floodwaters entering properties).[44]

These values might provide a useful basis for scaling up the initial assessment of damages avoided.

3.3.2 Insurance to economic costs

In Australia, Joy (1991)[45] used historical data to approximate 'insurance costs to total costs' multipliers for each disaster type. Floods were estimated to cost around 10 times the value of insured costs incurred. BTE notes that these estimates do not include intangible cost, and probably contain a large degree of error due to their simplicity.[46] Still, they have been used by a number of studies, including BTE, to roughly estimate the total tangible costs of natural disasters. Deloitte & Access Economics estimate the flood multiplier (total economic losses to insured losses) to be around 18 when intangible costs are included.[47]

3.3.3 Emergency costs multiplier

Middlesex University researchers observed that flood incidents in the UK in 2000 were accompanied by significant emergency costs.[48] These costs were quantified to be around 11% of property damages. Therefore, property damages could be multiplied by 1.1 to estimate this cost if better data are unavailable. Studies of flooding in the UK in 2007 showed proportionately lower emergency costs, around 5.6% of total property damage. These floods were more localised rather than geographically dispersed flooding.

In Australia, Deloitte Access Economics (2013) found that, on average, emergency costs are 4% of the insured natural disaster costs.[49]

3.3.4 Health impacts

Alderman *et al.*[50] assessed the effects of the 2011 Brisbane floods on residents' physical and mental health. Their results are presented in odds ratios (ORs), which represent the association between an exposure and an outcome. A statistically significant OR greater than 1 means exposure (ie being affected by a flood) is positively associated with a given outcome. The larger the OR, the greater the association between exposure and an outcome. Using regression analysis, and controlling for as

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[43] Wyatt S (2015) Flood, drainage and erosion protection benefits of Lower Wairarapa Valley Development Scheme. Report prepared for Greater Wellington Regional Council. Sapere Research Group.
[44] Greater Wellington Regional Council (2014) in Wyatt (*op cit*), p16
[45] Joy CS (1991) The cost of natural disasters in Australia. Climate Change Impacts and Adaptation Workshop, Climatic Impacts Centre, Macquarie University, New South Wales, Australia, 13–15 May.
[46] Bureau of Transport [BTE] (2001) Economic costs of natural disasters in Australia, report 103.
[47] Deloitte Access Economics (2016) The economic cost of the social impact of natural disasters. Australian Business Roundtable for Disaster Resilience & Safer Communities
[48] Middlesex University Flood Hazard Research Centre (2014) A Common framework of flood risk management cost benefit analysis features.
[49] Deloitte Access Economics (2013) Building our nation's resilience to natural disasters. Australian Business Roundtable for Disaster Resilience and Safer Communities
[50] Alderman, K., Turner, L. R., & Tong, S. (2013). Assessment of the health impacts of the 2011 summer floods in Brisbane. Disaster medicine and public health preparedness, 7(04), 380-386.

many factors as possible, they found residents whose households were directly affected by flooding were:

- 5.3 times more likely to report poorer health than those not affected by the floods;
- 2.3 times more likely to report respiratory issues;
- 1.9 times more likely to report psychological distress;
- 2.3 times more likely to report poor sleep quality; and
- 2.3 times more likely to have probable post-traumatic stress disorder (PTSD).

These probabilities could be matched with New Zealand statistics to estimate the number of additional health issues attributed to a given flood. We assume the magnitude of human health impacts from a flood is proportional to the population size of the affected area. As monetising different health impacts would be difficult and impractical, we take a simplified approach and include health impacts as part of the wider non-market/ intangible costs of flooding (see section 4.5.2).

4 Economic Analysis

4.1 Introduction

Table 6 lists the key components of the analysis used to derive scheme values. All involve the comparison of factual (with schemes) and counterfactual (no schemes) scenarios. The valuation of flood protection schemes in urban areas, where buildings are important, involves estimating the difference in expected flood damage with and without the flood protection schemes, using the analytical approaches discussed in section 3.2 above. This will vary with the level of service (return period protected against) and the scheme rating (high, medium or low levels of protection). In rural areas, the approach taken depends on whether buildings are significant; the values are estimated as the greater of the results using this same approach and a simpler method which compares current capital values of the areas protected with values under some counterfactual scenario of a different land use.

Table 6 Key elements used in scheme valuation

Scheme type	Flood	Flood	Other	Other
Land use type	Urban	Non-urban	Urban	Non-urban
Approach	Damages avoided	Greater of damages avoided or difference in land value	Improvement value	Difference in land value
Factual	Damages expected with flood protection	Land value with flood protection	Capital value with flood protection	Land value with flood protection
Counterfactual	Damages expected without flood protection	Land value without flood protection	Current land value	Land value without flood protection
Data required	• Capital value • Level of service • Council scheme rating	• Land value (LV) • Average LV/Ha by land use type	• Capital value • Land value	• Land value (LV) • Average LV/Ha by land use type

A simpler valuation method is used for river control, tidal protection and drainage schemes, because the analysis does not involve estimating factual and counterfactual damage levels. The analysis is examining the difference in land value between the factual and counterfactual scenarios. For urban areas, scheme value is estimated to equal a location's improvement value (i.e. the difference between land and capital value). For non-urban areas, protection value is estimated in the same way as for non-urban flood protection schemes: the difference in land values between current use and the expected use in the counterfactual (no scheme) scenario.

The analysis has been undertaken for each of the council areas listed in Box 2.

Box 2 Regions/ Council areas analysed

Bay of Plenty Regional Council	Otago Regional Council
Environment Canterbury	Southland Regional Council
Gisborne District Council	Taranaki Regional Council
Greater Wellington Regional Council	Tasman District Council
Horizons Regional Council	Waikato Regional Council
Northland Regional Council	West Coast Regional Council

4.2 Raw Data

The data given to us includes a list of land areas, the type of scheme, the level of benefit (including flood return period), land use, and land and capital values (Table 7).

Table 7 Raw data variables and definitions

Data variable	Definition
Identification number	Identification number for land area
Council	Region in which area is located
Scheme	Name of scheme
Flood Level of Service	The approximate return period for flood protection schemes (in years)
Flood Benefit	Level of flood benefit for a property (high, medium or low)
Drainage Benefit	Level of drainage benefit for a property (high, medium or low)
River Benefit	Level of river management benefit for a property (high, medium or low)
Tidal Benefit	Level of tidal benefit for a property (high, medium or low)
CV Prorated	Capital value of land area. Prorated as rows refer to only part of a property.
LV Prorated	Land value of area.
LCDB Name 2012	The detailed land cover descriptions
LCDB Simplified Class	Simplified land cover description
MB 2016	Census meshblock number
MB Percent	The percent of the meshblock for the row
UA 2016	Census Area Unit number
UA Name	Census Area Unit name
Hwy Number	State Highway number for any SH intersecting the area covered by this row
Hwy Length	The length (m) of SH intersecting this row
Area HA	Area in hectares
Area m2	Area in metres squared

4.3 Flood Protection Schemes

For flood protection, we have valued the benefit provided for each land area using one of two methods (see Table 2).

- For built-up areas (with residential and other buildings) – the NPV of avoided damages; and
- For other areas – the difference in land values possible with and without protection.

4.3.1 NPV of avoided damages

This method is used to value flood schemes in urban areas. It assumes that floods would damage the existing buildings and land uses. Calculation of avoided damages requires an estimate of damage without flood protection (counterfactual damage) and the proportion of this damage that would be avoided with flood defence.

According to the theory set out in Section 3.2.2, we estimate the counterfactual level of damage as a percentage of the capital value ($\%_{SR}$); this percentage is determined by the scheme rating as specified by councils (eg high, medium or low). We use the scheme's level of service to determine the proportion of this damage that is avoided ($\%_{level\ of\ service}$). These calculations can be summarised by the following equation:

$$PV\ of\ EAD = CV\ .\ \%_{SR}\ .\ \%_{LoS}$$

Where:

PV of EAD	=	Present value of expected annual damage
CV	=	Capital value
$\%_{SR}$	=	Scheme Rating Percentage (see Table 3)
$\%_{LoS}$	=	Percentage of the counterfactual damage avoided

The two percentage values used in the avoided damage calculation ($\%_{benefit}$ and $\%_{level\ of\ service}$) can be condensed into a single percentage value, the flood defence value percentage (FDVP), which is the product of $\%_{SR}$ and $\%_{LoS}$, as demonstrated in Section 3.2.2 such that:

$$PV\ of\ EAD = CV\ .FDVP$$

Table 4 contains FDVPs corresponding to each combination of scheme benefit and level of service. Each land area identified in the base data is assigned a FDVP based on the scheme benefit and the level of service specified. These FDVPs are then multiplied by the land area's capital value to calculate the value of flood defence. For example, an area with a capital value of $110,000, protected by a high benefit flood scheme with a 100-year level of service, will have a FDVP of 71% (Table 4) and a flood protection value of $78,100 (71% x $110,000). To find the total value of flood defence in urban areas, we sum all flood defence valuations and filter out all non-urban areas from this calculation.

4.3.2 Difference in land value, with and without protection

This method is used to value all schemes in non-urban areas, and for valuing drainage, tidal and river management schemes in urban areas. It is assumed that, in the absence of RCFPD schemes, all land uses would change from those used currently. The maximum WTP of existing landowners to avoid this is equal to the difference in value between the current land value and the average value of some assumed alternative land use. The alternative land use assumptions used are those shown in Table 5 on page 19.

To obtain the difference in land value, with and without protection, we subtract the counterfactual land value per hectare from the current land value per hectare and multiply the result by the corresponding area (in hectares).

A number of corrections have to be made:

- Some current land values are estimated as zero in the base data. We assign a land value to these areas, according to their respective regional average value per hectare and land use type, before the difference in land value calculation is applied.

- In some cases, the counterfactual land values are estimated to be higher than the current land values. As this is implausible, we assign a $0 difference in land values for such cases.

To obtain the total value of protection, we filter out all urban areas and sum the remaining values by protection type.

4.4 Other Schemes

Schemes other than flood protection schemes, ie river control, tidal protection and drainage schemes, do not have a level of service concept. The analysis assumes that the schemes have a binary effect so that their presence enables different land uses and thus an improvement in land value. The approach taken differs between rural and built-up areas.

- Built-up areas – the benefits are measured as the land and improvement value attributable to scheme; and

- Other areas – the difference in land values possible with and without protection.

4.4.1 Land and improvement value attributable to scheme

This method is used to value drainage, tidal and river management schemes in urban areas. The assumption is that, in the absence of drainage, tidal and river management, the current improvements (buildings) would not be present and that there would be different land uses. We calculate these effects separately.

An area's improvement value is its capital value less the land value. We assume that this total value is lost if the drainage, tidal or river management schemes are removed in urban areas. We calculate and sum the improvement values for every individual urban land area in the data set.

4.4.2 Difference in land value, with and without protection

This is the same approach as used for flood protection schemes and is discussed above.

4.5 Other Components

4.5.1 Avoiding Double Counting

Many of the individual areas within the raw data receive a benefit from more than one type of protection. To avoid double counting of scheme benefits, we only use the maximum relevant scheme value in such cases. For example, an urban area is protected by a flood protection and a river management scheme; we attribute the combined value of protection to be the greater of the NPV of damage avoided and the improvement value.

4.5.2 Accounting for non-market/ intangible costs

Section 3.3 sets out assumptions used in past studies to factor in damages that cannot be easily quantified. We follow the assumptions used by both Wyatt[51] and the Greater Wellington Regional Council[52] and assume that for urban areas, intangible loss is 100% of the direct damage estimate. As the magnitude of intangible loss is proportionate to the population affected by a flood, we use a

[51] Wyatt S (2015) Flood, drainage and erosion protection benefits of Lower Wairarapa Valley Development Scheme. Report prepared for Greater Wellington Regional Council. Sapere Research Group.
[52] Greater Wellington Regional Council (2014) in Wyatt (*op cit*), p16

smaller direct cost multiplier for non-urban areas. Statistics NZ[53] report the average population density of independent urban areas is 265.9 people per square kilometre. For rural areas, this value is 6.5 per square kilometre. Given this difference in population density, we scale up direct damage costs by 2.4% (6.5/265.9) to account for intangible loss in non-urban areas.

4.6 Summary of Results

The overall results are shown in Table 8. Flood protection schemes have the greatest total value, followed by areas with multiple schemes, drainage schemes, river management schemes and tidal management schemes. This is partly explained by the respective capital value protected by each scheme type: flood protection only ($143b), mixed protection ($35.1b), drainage only ($21.8), and river management only ($5.51). There are no areas subject to tidal protection only.

Table 8 Summary of Gross Benefits (2016$ millions)

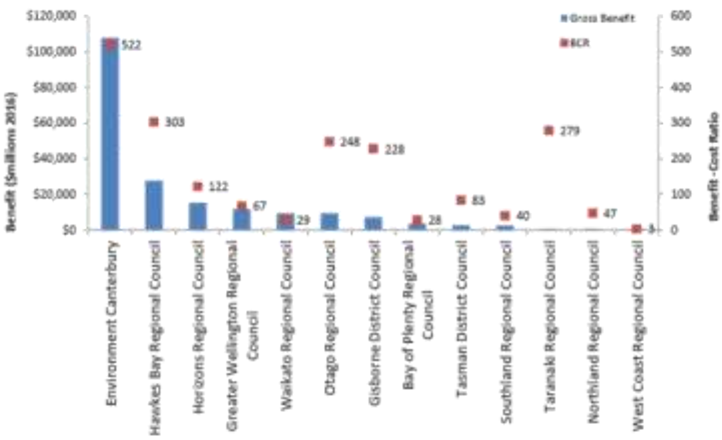
Protection type	Land type	Estimated benefit (PV)	Annual benefit	
			4% DR	*6% DR*
Flood only	Built-up area	$134,601	$5,177	$7,619
	Other land use type	$12,553	$483	$711
	Total	$147,154	$5,660	$8,329
Drainage only	Built-up area	$12,796	$492	$724
	Other land use type	$629	$24	$36
	Total	$13,424	$516	$760
River Management only	Built-up area	$2,167	$83	$123
	Other land use type	$83	$3	$5
	Total	$2,250	$87	$127
Multiple types	Built-up area	$34,631	$1,332	$1,960
	Other land use type	$895	$34	$51
	Total	$35,526	$1,366	$2,011
Total		$198,354	$7,629	$11,228

Note: DR = discount rate

Figure 13 shows a regional breakdown of total flood benefits and benefit-cost ratios (BCRs). Costs used in the BCRs are the present value of a council's stated annual operating expenditure on flood defence. The treasury's preferred discount rate of 6% is used for these calculations. Environment Canterbury has the greatest total flood benefit ($108b) and BCR (552). Values in other regions range significantly, for example, the West Coast region is estimated to benefit $0.27b and has BCR of 3, while the Hawkes Bay has a total benefit of $28b and a BCR of 303.

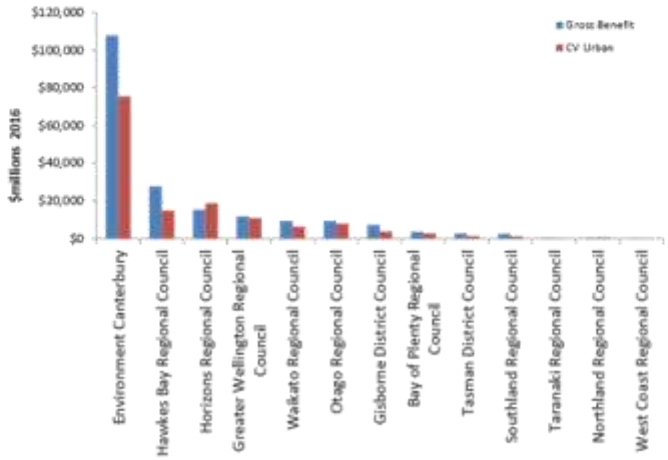
[53] Statistics NZ (2001) New Zealand: Urban/Rural Profile. Retrieved from http://www.stats.govt.nz/browse_for_stats/Maps_and_geography/Geographic-areas/urban-rural-profile/main-urban-areas/people.aspx

Figure 13 Flood benefit ($millions) and BCR by region



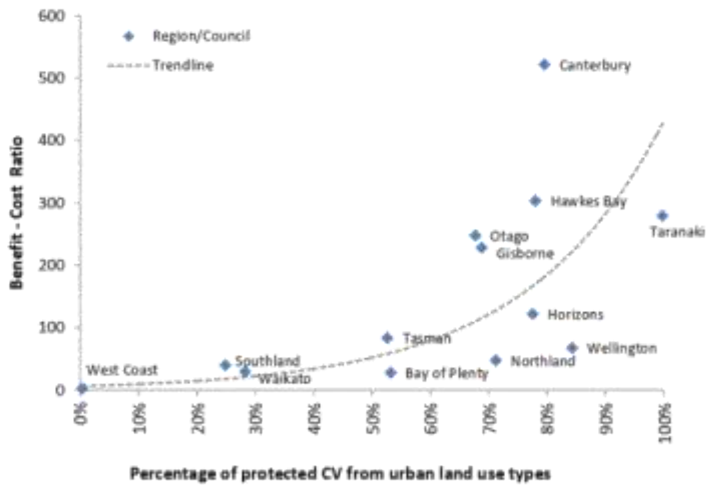
Regional variation of flood benefit values is largely explained by the differences in the amount of urban land protected, as illustrated in Figure 14. The significant non-market value associated with protecting urban land (such as the value of human life) means that regions with a large amount of urban land protected will yield greater benefits from flood defence.

Figure 14 Flood benefit ($millions) and CV of urban land by region



Similarly, differences in BCRs by council are largely attributable to the protected land's composition of urban and non-urban land use types. Figure 15 shows that regions which owe most of their protected land CV to urban land use types tend to have higher BCRs. Again, this is due to the high non-market inflation factor given to urban land use, as we would expect more damage to human life and health (the main components of non-market costs) in such areas in the event of a flood.

Figure 15 Relationship between BCR and non-urban land by region



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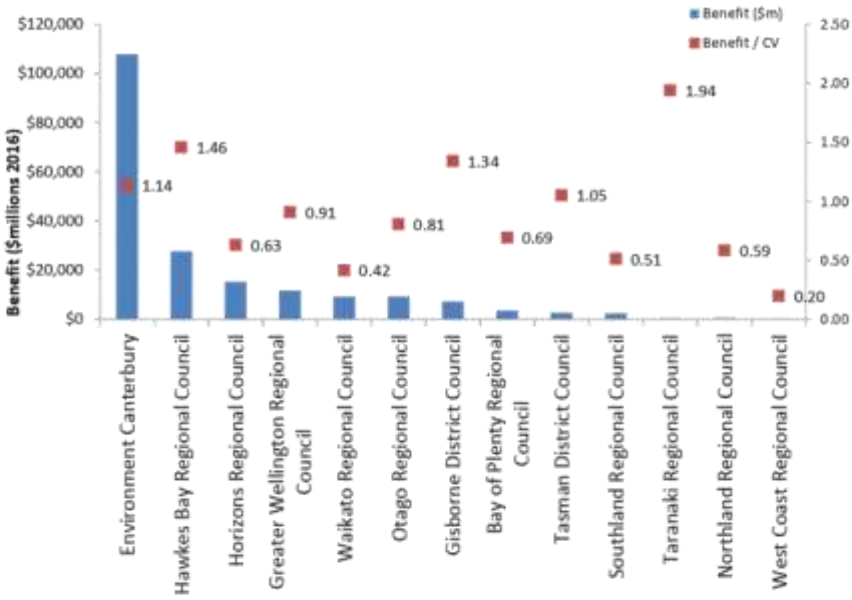
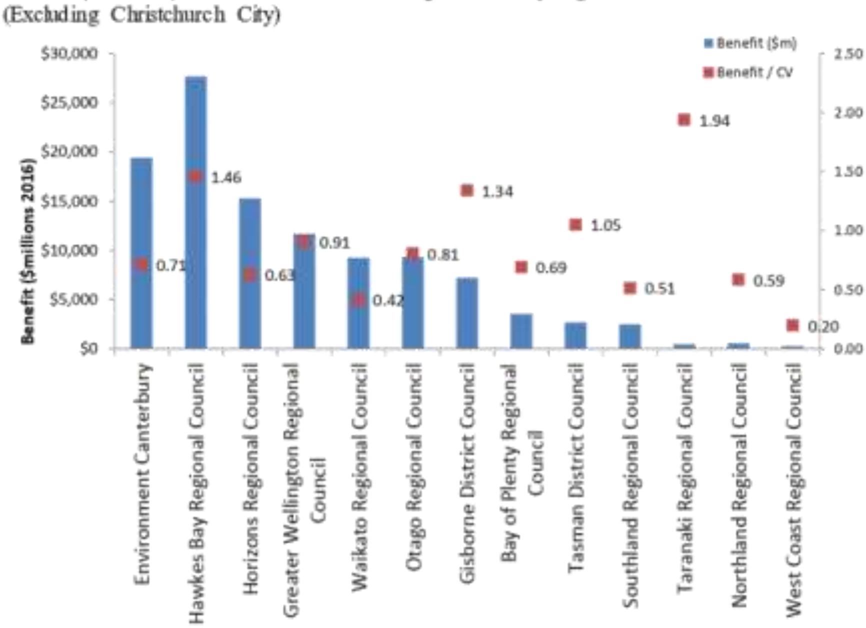
Benefit ($millions) and Benefit/CV of land protected by region



Benefit ($millions) and Benefit/CV of land protected by region
(Excluding Christchurch City)



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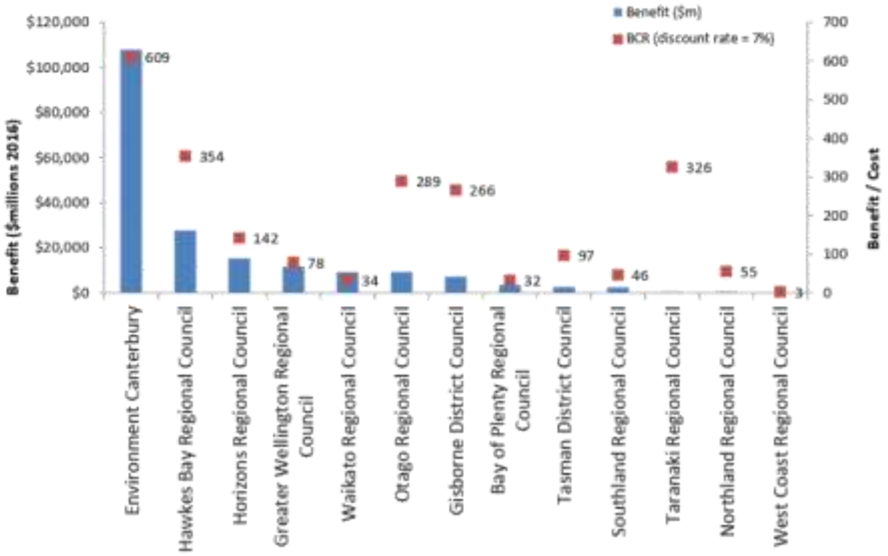
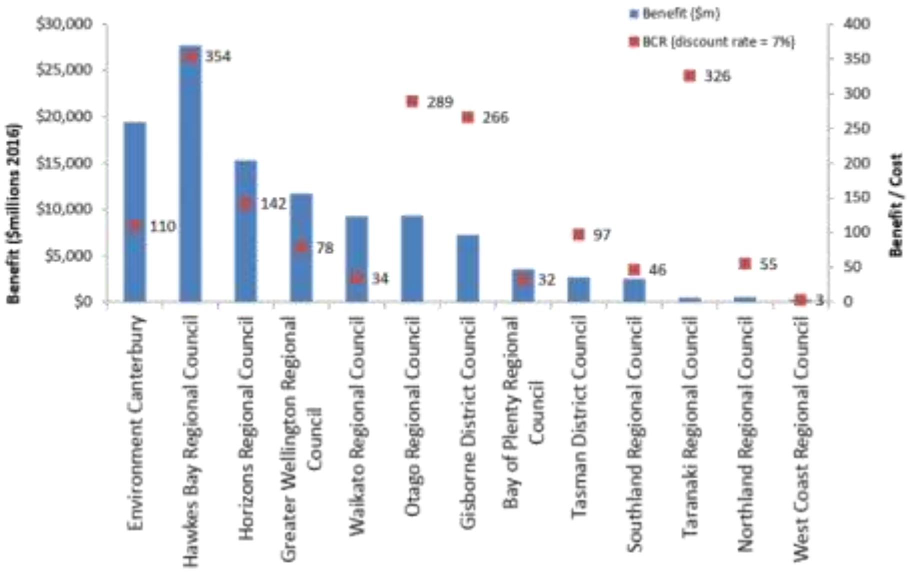
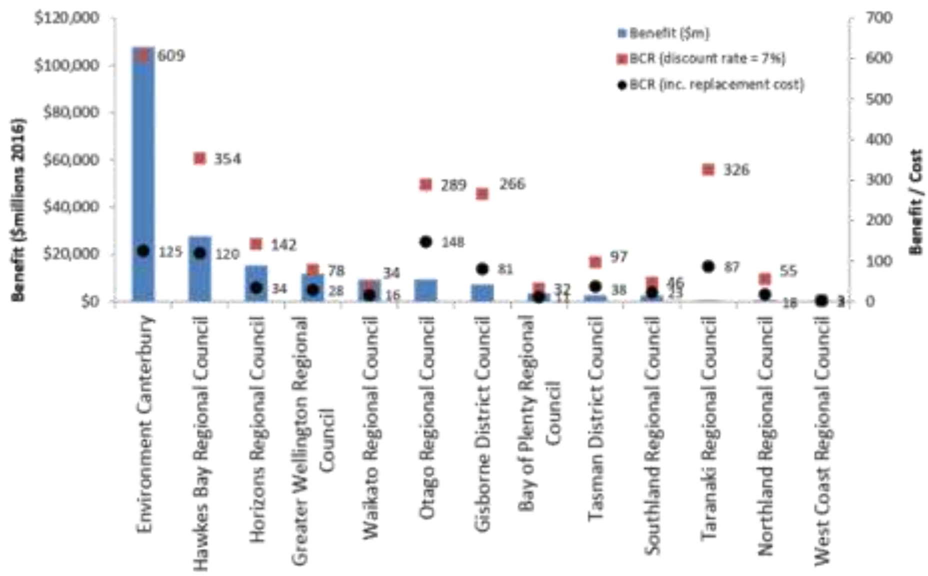
Benefit ($millions) and Benefit Cost Ratio by region
(Costs = present values of Opex using a discount rate of 7%)



Benefit ($millions) and Benefit Cost Ratio by region
(Costs = present values of Opex using a discount rate of 7%)
(Excluding Christchurch City)



Benefit ($millions) and Benefit Cost Ratio by region
(Additional markers for BCRs that include replacement cost)



Regional BCRs using different cost methods (Canterbury includes Christchurch city)

Region	Cost calculation			
	PV of Opex	PV of Opex + Replacement cost	PV of Opex	PV of Opex + Replacement cost
	Discount rate = 7%		*Discount rate = 4%*	
Environment Canterbury	609	125	348	109
Hawkes Bay Regional Council	354	120	202	96
Horizons Regional Council	142	34	81	29
Greater Wellington Regional Council	78	28	45	22
Waikato Regional Council	34	16	20	12
Otago Regional Council	289	148	165	107
Gisborne District Council	266	81	152	66
Bay of Plenty Regional Council	32	11	18	9
Tasman District Council	97	38	56	29
Southland Regional Council	46	23	27	17
Taranaki Regional Council	326	87	186	72
Northland Regional Council	55	18	32	14
West Coast Regional Council	3	2	2	1

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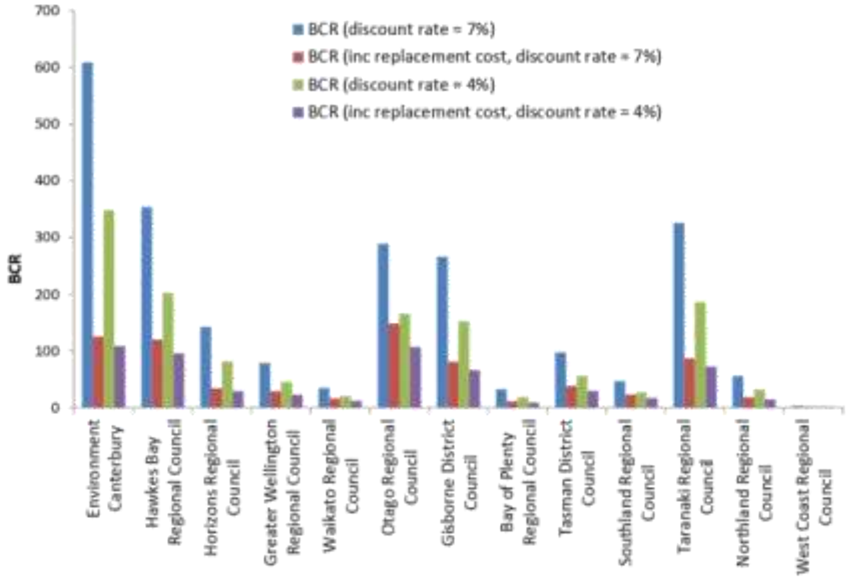
BCR sensitivity chart (including Christchurch city)



National summary table (including Christchurch city)

Protection type	Land type	Estimated benefit (PV) *(2016$ millions)*	Annual benefit *(2016$ millions)*	
			4% DR	*7% DR*
Flood only	Built-up area	$134,601	$5,177	$8,806
	Other land use type	$12,553	$483	$821
	Total	$147,154	$5,660	$9,627
Drainage only	Built-up area	$12,796	$492	$837
	Other land use type	$629	$24	$41
	Total	$13,424	$516	$878
River Management only	Built-up area	$2,167	$83	$142
	Other land use type	$83	$3	$5
	Total	$2,250	$87	$147
Tidal only	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area	$34,631	$1,332	$2,266
	Other land use type	$895	$34	$59
	Total	$35,526	$1,366	$2,324
Total		$198,354	$7,629	$12,976

Note: DR = discount rate

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Regional Benefit Tables

- *Estimated benefit = PV form*
- *4% and 7% = discount rate for annualised values*
- *All values are $millions*

Bay of Plenty Regional Council				
Protection type	**Land type**	**Estimated benefit**	**4%**	**7%**
Flood only	Built-up area	$2,177	$84	$142
	Other land use type	$176	$7	$11
	Total	$2,353	$90	$154
Drainage only	Built-up area	$301	$12	$20
	Other land use type	$49	$2	$3
	Total	$351	$13	$23
River Management only	Built-up area			
	Other land use type			
	Total			
Tidal	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area	$785	$30	$51
	Other land use type	$67	$3	$4
	Total	$852	$33	$56
Total		$3,556	$137	$233

Environment Canterbury including Christchurch City				
Protection type	**Land type**	**Estimated benefit**	**4%**	**7%**
Flood only	Built-up area	$96,989	$3,730	$6,345
	Other land use type	$7,716	$297	$505
	Total	$104,705	$4,027	$6,850
Drainage only	Built-up area	$198	$8	$13
	Other land use type	$11	$0	$1
	Total	$209	$8	$14
River Management only	Built-up area	$183	$7	$12
	Other land use type	$25	$1	$2
	Total	$208	$8	$14
Tidal	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area	$2,537	$98	$166
	Other land use type	$174	$7	$11
	Total	$2,712	$104	$177
Total		$107,834	$4,147	$7,055

(see end of document for EC excluding Christchurch city data)

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Gisborne District Council

Protection type	Land type	Estimated benefit	4%	7%
Flood only	Built-up area	$27	$1	$2
	Other land use type	$16	$1	$1
	Total	$42	$2	$3
Drainage only	Built-up area	$6,939	$267	$454
	Other land use type	$63	$2	$4
	Total	$7,002	$269	$458
River Management only	Built-up area			
	Other land use type			
	Total			
Tidal	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area	$166	$6	$11
	Other land use type	$26	$1	$2
	Total	$192	$7	$13
Total		$7,236	$278	$473

Greater Wellington Regional Council

Protection type	Land type	Estimated benefit	4%	7%
Flood only	Built-up area	$10,803	$416	$707
	Other land use type	$904	$35	$59
	Total	$11,708	$450	$766
Drainage only	Built-up area	$0.00	$0.00	$0.00
	Other land use type	$0.06	$0.00	$0.00
	Total	$0.06	$0.00	$0.00
River Management only	Built-up area			
	Other land use type			
	Total			
Tidal	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area			
	Other land use type	$0.27	$0.01	$0.02
	Total	$0.27	$0.01	$0.02
Total		$11,708	$450	$766

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Hawkes Bay Regional Council				
Protection type	**Land type**	**Estimated benefit**	**4%**	**7%**
Flood only	Built-up area	$169	$6	$11
	Other land use type	$280	$11	$18
	Total	$448	$17	$29
Drainage only	Built-up area			
	Other land use type			
	Total			
River Management only	Built-up area	$45	$2	$3
	Other land use type	$5	$0	$0
	Total	$50	$2	$3
Tidal	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area	$26,968	$1,037	$1,764
	Other land use type	$221	$9	$14
	Total	$27,190	$1,046	$1,779
Total		$27,688	$1,065	$1,811

Horizons Regional Council				
Protection type	**Land type**	**Estimated benefit**	**4%**	**7%**
Flood only	Built-up area	$13,532	$520	$885
	Other land use type	$576	$22	$38
	Total	$14,108	$543	$923
Drainage only	Built-up area	$78	$3	$5
	Other land use type	$38	$1	$2
	Total	$116	$4	$8
River Management only	Built-up area	$792	$30	$52
	Other land use type	$7	$0	$0
	Total	$799	$31	$52
Tidal	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area	$266	$10	$17
	Other land use type	$16	$1	$1
	Total	$282	$11	$18
Total		$15,305	$589	$1,001

Northland Regional Council				
Protection type	**Land type**	**Estimated benefit**	**4%**	**7%**
Flood only	Built-up area	$422	$16	$28
	Other land use type	$31	$1	$2
	Total	$453	$17	$30
Drainage only	Built-up area			
	Other land use type			
	Total			
River Management only	Built-up area			
	Other land use type			
	Total			
Tidal	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area	$72	$3	$5
	Other land use type	$9	$0	$1
	Total	$81	$3	$5
Total		$534	$21	$35

Otago Regional Council				
Protection type	**Land type**	**Estimated benefit**	**4%**	**7%**
Flood only	Built-up area	$6,926	$266	$453
	Other land use type	$1,292	$50	$84
	Total	$8,218	$316	$538
Drainage only	Built-up area	$1,066	$41	$70
	Other land use type	$8	$0	$1
	Total	$1,074	$41	$70
River Management only	Built-up area	$10	$0	$1
	Other land use type	$0	$0	$0
	Total	$10	$0	$1
Tidal	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area	$19	$1	$1
	Other land use type	$2	$0	$0
	Total	$21	$1	$1
Total		$9,322	$359	$610

Southland Regional Council				
Protection type	**Land type**	**Estimated benefit**	**4%**	**7%**
Flood only	Built-up area	$1,346	$52	$88
	Other land use type	$592	$23	$39
	Total	$1,938	$75	$127
Drainage only	Built-up area	$44	$2	$3
	Other land use type	$14	$1	$1
	Total	$58	$2	$4
River Management only	Built-up area	$239	$9	$16
	Other land use type	$11	$0	$1
	Total	$250	$10	$16
Tidal	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area	$240	$9	$16
	Other land use type	$9	$0	$1
	Total	$249	$10	$16
Total		$2,495	$96	$163

Taranaki Regional Council				
Protection type	**Land type**	**Estimated benefit**	**4%**	**7%**
Flood only	Built-up area			
	Other land use type			
	Total			
Drainage only	Built-up area			
	Other land use type			
	Total			
River Management only	Built-up area			
	Other land use type			
	Total			
Tidal	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area	$465	$18	$30
	Other land use type	$0	$0	$0
	Total	$465	$18	$30
Total		$465	$18	$30

Tasman District Council				
Protection type	**Land type**	**Estimated benefit**	**4%**	**7%**
Flood only	Built-up area			
	Other land use type			
	Total			
Drainage only	Built-up area			
	Other land use type			
	Total			
River Management only	Built-up area	$842	$32	$55
	Other land use type	$35	$1	$2
	Total	$877	$34	$57
Tidal	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area	$1,770	$68	$116
	Other land use type	$35	$1	$2
	Total	$1,804	$69	$118
Total		$2,681	$103	$175

Waikato Regional Council				
Protection type	**Land type**	**Estimated benefit**	**4%**	**7%**
Flood only	Built-up area	$2,210	$85	$145
	Other land use type	$972	$37	$64
	Total	$3,182	$122	$208
Drainage only	Built-up area	$4,170	$160	$273
	Other land use type	$445	$17	$29
	Total	$4,615	$178	$302
River Management only	Built-up area	$55	$2	$4
	Other land use type	$1	$0	$0
	Total	$55	$2	$4
Tidal	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area	$1,337	$51	$87
	Other land use type	$70	$3	$5
	Total	$1,407	$54	$92
Total		$9,259	$356	$606

West Coast Regional Council				
Protection type	**Land type**	**Estimated benefit**	**4%**	**7%**
Flood only	Built-up area			
	Other land use type			
	Total			
Drainage only	Built-up area			
	Other land use type			
	Total			
River Management only	Built-up area			
	Other land use type			
	Total			
Tidal	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area	$6	$0	$0
	Other land use type	$265	$10	$17
	Total	$271	$10	$18
Total		$271	$10	$18

Environment Canterbury Excluding Christchurch City				
Protection type	**Land type**	**Estimated benefit**	**4%**	**7%**
Flood only	Built-up area	$11,043	$425	$722
	Other land use type	$5,551	$213	$363
	Total	$16,594	$638	$1,086
Drainage only	Built-up area	$198	$8	$13
	Other land use type	$11	$0	$1
	Total	$209	$8	$14
River Management only	Built-up area	$183	$7	$12
	Other land use type	$25	$1	$2
	Total	$208	$8	$14
Tidal	Built-up area			
	Other land use type			
	Total			
Multiple types	Built-up area	$2,247	$86	$147
	Other land use type	$162	$6	$11
	Total	$2,408	$93	$158
Total		$19,419	$747	$1,270

Air Quality Management in Hawke's Bay

2021 update

March 2021

Hawkes Bay Regional Council Publication No. 5553

HAWKES BAY
REGIONAL COUNCIL
TE KAUNIHERA Ā-ROHE O TE MATAU-A-MĀUI

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Environmental Science

Air Quality Management in Hawke's Bay

2021 update

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Air Quality Management in - Hawke's Bay – 2021 update

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EXECUTIVE SUMMARY

The main air quality concern for urban towns in the Hawke's Bay Region is particles in the air less than 10 microns and less than 2.5 microns in diameter (PM_{10} and $PM_{2.5}$). The National Environmental Standard (NES) for particulate is based on PM_{10} (24-hour average of 50 µg/m^3 with one allowable exceedance per year). However, in 2020 the Ministry for the Environment (MfE) proposed the addition of a daily and annual $PM_{2.5}$ standard (of 25 µg/m^3 and 10 µg/m^3 respectively).

Napier and Hastings have both recorded breaches of the NES for PM_{10}. Air quality management introduced via the Resource Regional Management Plan Change 2 – Air Quality Plan (operative 1 January 2012) has resulted in significant improvements in PM_{10} concentrations in both Napier and Hastings.

As a result, Napier has been compliant with the NES for PM_{10} since 2014 with only one exceedance of 50 µg/m^3 in each of 2014 and 2018. An evaluation of trends in PM_{10} emissions and concentrations in Napier is consistent with both monitored concentrations and emissions evaluations showing similar results. Data indicates that sufficient reductions in daily winter PM_{10} have likely been achieved, no increases in emissions are anticipated and no additional regulatory measures are likely to be required. The safety margin for ongoing compliance is relatively small and there is the possibility that meteorological conditions worse than experienced over the 2006 to 2020 period may occur, however.

In Hastings PM_{10} concentrations exceeded the NES every year prior to 2015 with a maximum of 27 exceedences being recorded in 2008 and the highest measured PM_{10} concentration of 112 µg/m^3 being measured in 2006. Since 2015, three calendar years have recorded only one exceedance of 50 µg/m^3 (2015, 2017, 2020). An evaluation of the likelihood of Hastings being compliant with the NES for PM_{10} suggests that further reductions are required but that these may occur in the absence of additional regulation and potentially by 2025. However, there is some disparity between emissions and concentration reductions particularly for the years 2018 to 2020 with concentrations being on the high side relative to the estimated reduction in emissions. Additional measures may therefore be required for Hastings to achieve compliance with the NES for PM_{10}.

Monitoring of $PM_{2.5}$ has been carried out in Napier since 2019 and in Hastings since 2017. Annual average $PM_{2.5}$ concentrations in both areas are below the proposed NES of 10 µg/m^3. Annual $PM_{2.5}$ concentrations are not predicted to increase.

Daily $PM_{2.5}$ concentrations in both areas exceed the proposed NES for $PM_{2.5}$. In Napier, a reduction of around 20% is estimated to be required based on two years of monitoring. Daily $PM_{2.5}$ concentrations are not predicted to reduce by this magnitude by 2030 and additional management measures may be required. In Hastings $PM_{2.5}$ reductions in daily winter $PM_{2.5}$ concentrations of around 33% are required to meet the proposed NES and additional regulatory intervention is also implicated. Measures required could include introduction of an ultra-low emission burner (ULEB) criteria for new burner installations. However, clarification of the final NES $PM_{2.5}$ details would be of value before further measures are considered.

The Hawke's Bay towns of Wairoa, Waipawa and Waipukurau have also been identified as potentially having air quality issues with respect to compliance with the proposed daily $PM_{2.5}$ NES. An emission inventory for each town was conducted as a first step towards the scientific evaluation and a projection in daily winter $PM_{2.5}$ was implemented. Monitoring for compliance with the proposed NES is yet to occur.

The inventory found domestic heating was the main contributor to daily winter particulate (PM_{10} and $PM_{2.5}$) in each town although industrial discharges were also a significant source of particulate in Wairoa. Over half of the daily winter PM_{10} emissions from domestic heating were from burners installed prior to 2006 and therefore unlikely to be complying with the NES design criteria for burners. An evaluation of trends in emissions from 2020 to 2030 for each town predicts a reduction in PM_{10} and $PM_{2.5}$ because of the natural attrition replacement of these burners. If the proposed daily NES for $PM_{2.5}$ is adopted, monitoring using a NES compliant method would be of value to establish existing concentrations and whether the projected reductions will be sufficient to achieve compliance with the NES.

1 INTRODUCTION

Air quality management in urban towns of the Hawke's Bay has focused on compliance with the National Environmental Standard (NES) for particulate in the air less than ten microns in diameter (PM_{10}). The NES for PM_{10} is set at 50 µg/m^3 (24-hour average) with one allowable exceedance per year. Compliance with this standard was required by September 2016 in Napier and September 2020 in Hastings. The NES also includes a design criteria for new installations of wood burners which specifies an emission limit of 1.5 grams of particulate per kilogram of fuel burnt (g/kg) and an efficiency of 65% for new wood burner installations on properties less than two hectares.

In 2020, the Ministry for the Environment proposed amendments to the particulate NES which include both daily and annual standards for $PM_{2.5}$ (particles in the air less than 2.5 microns in diameter). The proposed daily limit is 25 µg/m^3 and the proposed annual limit is 10 µg/m^3.

Air quality monitoring for PM_{10} has been carried in Napier and Hastings since 2006 at the Marewa and St Johns monitoring sites. Monitoring for $PM_{2.5}$ has been carried out in Hastings since 2016 and in Napier since 2019. The main source of PM_{10} and $PM_{2.5}$ in these towns is solid fuel burning for domestic home heating (Wilton, 2020)

The Hawke's Bay Regional Air Plan sets air quality objectives for the region's four gazetted airsheds (Napier, Hastings, Awatoto and Whirinaki) and the remainder of the region. It defines three areas for the management of air quality in the region. These are:

- Air Zone 1: the main urban areas of Napier, Hastings and Havelock North.
- Air Zone 2: Areas surrounding the main urban areas of Napier, Hastings and Havelock North.
- The rest of the Region.

Management measures targeting domestic home heating were introduced via the Resource Regional Management Plan Change 2 – Air Quality Plan (operative 1 January 2012). Measures adopted in the Airzone 1 areas include phasing out wood burners and multi fuel burners not meeting the emission and efficiency limits specified in the NES design criteria for wood burners and open fires in Napier and Hastings. Outdoor burning was also prohibited in the airzone 1 areas.

The final phase out dates for appliances were 1 January 2018 for airzone 1 in the Hastings Airshed and 1 January 2020 for airzone 1 in the Napier Airshed. The plan includes a few exceptions such as registered historical places.

A new category of wood burners has emerged because of the development of a real-life testing regime by Environment Canterbury. The burners are referred to as ultra-low emission burners (ULEB) and are required to meet an emission limit of 0.5 g/kg when tested under a regime that more closely simulates real life operation, including start up emissions for example. An extensive range of ULEB have now been authorised and are available throughout New Zealand.

The uptake of ULEB in Napier and Hastings was unclear from the 2020 inventory. Whilst the proportion of current burners that might be ULEB is likely to be low, increased uptake is likely given the range of appliances available and changes in affordability. The 2020 air emission inventory does suggest some open fires and pre 2006 burners are still in use following the final phase out dates. Whilst some may be authorised via the historical places exemption, the numbers indicated are higher than the levels likely to be legitimate.

This report updates previous assessments of the effectiveness of management measures contained in the Resource Regional Management Plan Change 2 – Air Quality Plan on daily winter PM_{10} concentrations in Napier and Hastings. It evaluates existing $PM_{2.5}$ concentrations relative to the proposed daily and annual NES for $PM_{2.5}$ and likely changes in these with time. Further management measures that may be required to meet $PM_{2.5}$ and PM_{10} targets are evaluated.

In addition, the report estimates emissions and likely trends in particulate in the towns of Wairoa, Waipawa and Waipukurau. This includes an air emissions assessment and an evaluation of likely changes with time and as a result of management interventions such as the introduction of ULEB.

2 AIR QUALITY IN NAPIER

2.1 Background

Assessments of the reductions required in PM_{10} concentrations and the impact of regulatory measures in Napier were made throughout the plan change process and adapted as scientific understanding and proposed rules changed. The original reductions in PM_{10} concentrations estimated for Napier were based on a Golder (2009) report detailing modelling of 2006 emissions and meteorological conditions. The reduction required for Napier was estimated at 47% of 2006 emissions (based on a modelled concentration of 95 µg/m^3).

An update of the airshed modelling in 2012 (Gimson, 2012) incorporated updated modelling methods, 2010 emissions and meteorological data from 2005 to 2010. This assessment found a reduction of 44% (relative to 2010 data) was required in Napier[1]. The relative contributions of different sources to the peak PM_{10} concentrations found domestic heating contributed 94% of the PM_{10} in Napier with natural sources contributing just over 4% and other sources around 2% (Gimson, 2012).

2.2 Air quality monitoring – PM_{10} and $PM_{2.5}$

Monitoring of PM_{10} has been carried out at the Marewa air quality monitoring site in Napier since 2006. The incidence of daily PM_{10} concentrations by year is shown in Figure 2.1 along with the maximum measured concentration each year. The graphs indicate that concentrations in the range of 5 -25 µg/m^3 are most common and that concentrations exceeding 50 µg/m^3 occur most frequently in 2007 and 2013. All years prior to 2012 experience breaches of the NES with more than one concentration each year in excess of 50 µg/m^3. Figure 2.1 also shows that the Napier airshed has been compliant with the NES for PM_{10} since 2014 with only one exceedance of 50 µg/m^3 in each of 2014 and 2018.

[1] Whilst the reduction required may appear lower it relates to a point in time when some reductions had already been achieved.

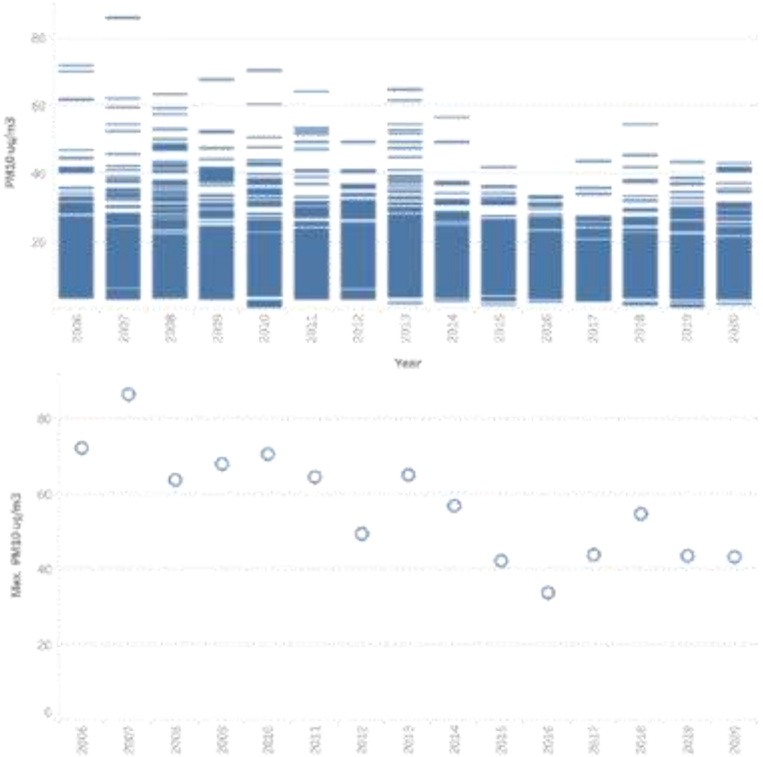

Figure 2.1: Distribution in Napier daily PM_{10} concentrations by year (top) and annual maximum PM_{10} concentration.

The annual average PM_{10} concentration in Napier from 2006 to 2020 ranges from a high of 16.3 μg/m³ in 2008 to a low of 12.8 μg/m³ in 2017. This compares with a proposed NES for annual PM_{10} of 20 μg/m³ (Ministry for the Environment, 2020).

The proposed NES also includes daily and annual indicators for $PM_{2.5}$ of 25 μg/m³ and 10 μg/m³ respectively. Concentrations of $PM_{2.5}$ have been measured at the Napier air quality monitoring site since 2019. Table 2.1 shows the annual average $PM_{2.5}$ and the daily average $PM_{2.5}$ concentrations relative to the proposed NES. Figure 2.2 shows the seasonal distribution in $PM_{2.5}$ concentrations and the relationship between $PM_{2.5}$ and PM_{10} concentrations is illustrated in Figure 2.3. The latter indicates the coarse component (PM_{10}-$PM_{2.5}$) comprises the majority of the PM_{10} (and around 10 μg/m³) during the summer months. The coarse component decreases slightly during the winter months (averaging around 6 μg/m³) and the $PM_{2.5}$ fraction increases. Higher winter $PM_{2.5}$ concentrations occur because of the seasonal nature of domestic heating emissions which are predominantly in the $PM_{2.5}$ size fraction and because meteorological conditions during these months are conducive to elevated concentrations from this source and other low level combustion sources (Wilton, 2020). Slightly lower absolute concentrations during the winter months may be a result of lower wind speeds as coarse particulate from dusts and marine aerosol can increase with higher wind speeds.

Table 2.1: Summary of $PM_{2.5}$ concentrations measured in Napier

	2019	2020
Annual average (µg/m³)	6	5
No. of exceedances of 25 µg/m³	5	11
No. of breaches of proposed NES (allows 3 exceedances per year)	2	8
4th highest concentration (µg/m³)	27	32
Maximum 24-hour average $PM_{2.5}$ (µg/m³)	35	40
Reduction required to meet proposed NES	7%	20%

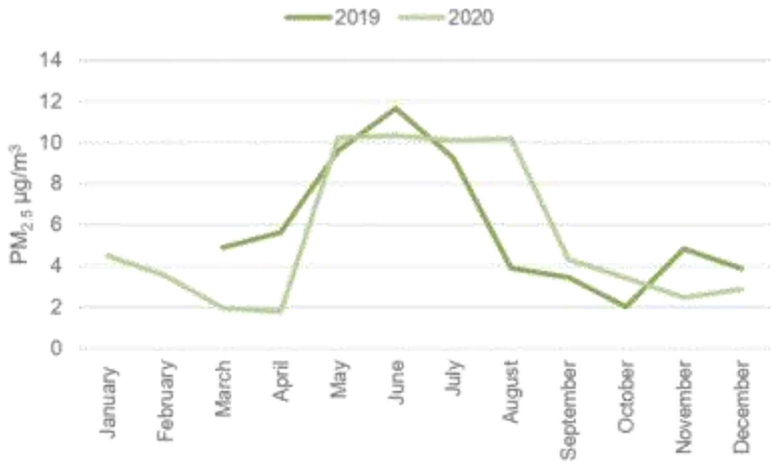

Figure 2.2: Monthly average $PM_{2.5}$ (2019 – 2020) in Napier.

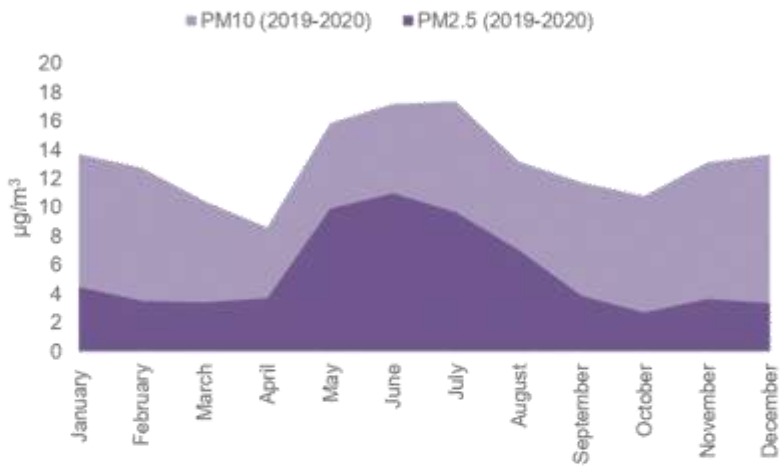

Figure 2.3: Monthly average $PM_{2.5}$ and PM_{10} concentrations (2019 – 2020) in Napier.

2.3 Air quality management for PM_{10}

2.3.1 Daily winter PM_{10}

The air quality target for daily winter PM_{10} for Napier is based on achievement of compliance with the NES for PM_{10} of 50 µg/m³ (24-hour average) and one allowable exceedance per year. Napier was required to be compliant with the NES for PM_{10} by September 2016. No breaches of the NES have been measured since 2014. However, worst case meteorological conditions may not have occurred over this period and scientific evaluation is required to check whether results are likely indicative of achievement of Air Plan reductions targets.

Figure 2.4 shows changes in emissions and second highest PM_{10} concentrations from 2005 to 2020 relative to the air quality targets set as a part of Plan Change 2. This is based on using average contributions of sources from the air emission inventory (winter) and source apportionment for the contribution from natural sources. A modelled worst case 24-hour average PM_{10} concentration of 95 µg/m³ was the basis for the target and implicated a 47% reduction in daily winter PM_{10} to achieve the 50 µg/m³ NES (Gimson, 2006). The consequent daily winter PM_{10} emission target was also 47% of 2005 emissions based on a linear relationship between emissions and concentrations.

In Figure 2.4 the concentration values are typically much lower than the projection line because the latter is based on worst case meteorological conditions which do not typically occur. It is noted that in 2013 and 2018 the concentration value is higher than for other years relative to the projection line. This indicates worst case meteorological conditions for the second highest PM_{10} concentrations during these years and suggests the original setting of worst-case concentrations at 95 µg/m³ may have been reasonably accurate for the meteorological conditions experienced during the period 2005 to 2020.

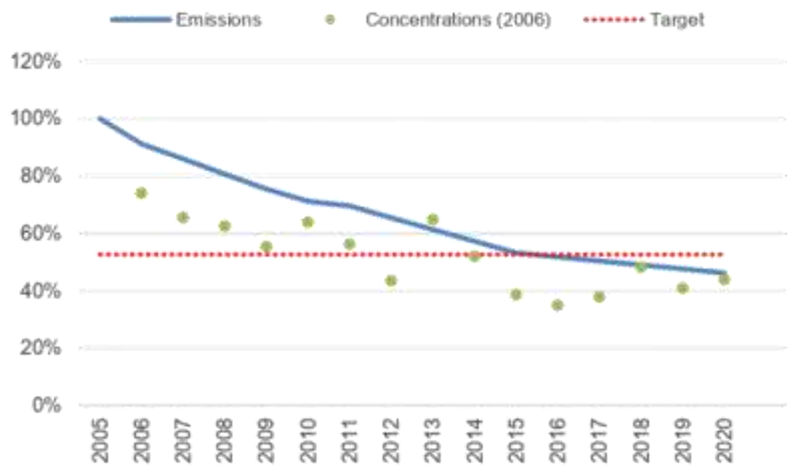

Figure 2.4: Daily winter PM_{10} emissions in Napier and second highest daily measured PM_{10} concentration – inventory contribution approach

The approach illustrated above was modified in 2012 (Wilton, 2012) as a result of updated modelling (Gimson, 2012) which used 2010 emission values and identified a worst-case concentration of 83 µg/m³ based on 2010 emissions (as opposed to 95 µg/m³ for the higher 2005 emissions). A key difference to the methodology, however, is that the modelling indicated only a 2.2% contribution of other sources to peak concentrations and a 4.8% contribution of natural sources. Figure 2.5 shows the emissions and PM_{10} concentrations from 2010 to 2020 based on the modelled source contributions and a maximum concentration of 83 µg/m³ (daily winter PM_{10}). Under the modelled contributions approach the domestic heating sector contributes a greater proportion of the daily winter PM_{10} (94%) and therefore the effectiveness of the regulatory measures targeting that source are greater. Consequently, the projection line presents below the air quality target, suggesting ongoing compliance with the NES for PM_{10} provided meteorological conditions worse than anticipated are not experienced.

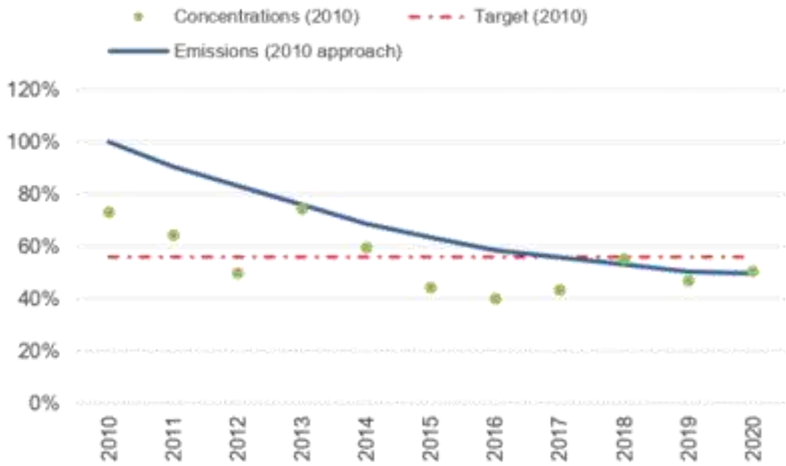

Figure 2.5: Daily winter PM_{10} emissions in Napier and second highest daily measured PM_{10} concentration – modelled contribution approach

Both approaches suggest that Napier is compliant with the NES for PM_{10} and that additional regulatory measures are unlikely to be required. It is possible, however, that meteorological conditions worse than those experienced during the period 2005 to 2020 could occur. The potential for meteorological conditions worse than estimated to result in a breach of the NES for PM_{10} will reduce if PM_{10} emissions continue to decrease beyond 2020.

To examine likely trends from 2020 a projections analysis was undertaken using 2020 emission inventory data as the base year and extrapolating to 2030 based on predicted changes in heating methods. The assumptions underpinning this analysis are detailed in Section 2.4.3. Figures 2.6 and 2.7 show the estimated emissions for Napier projected from 2020 to 2030 in the absence of additional regulation for both the inventory-based approach and model based approach respectively.

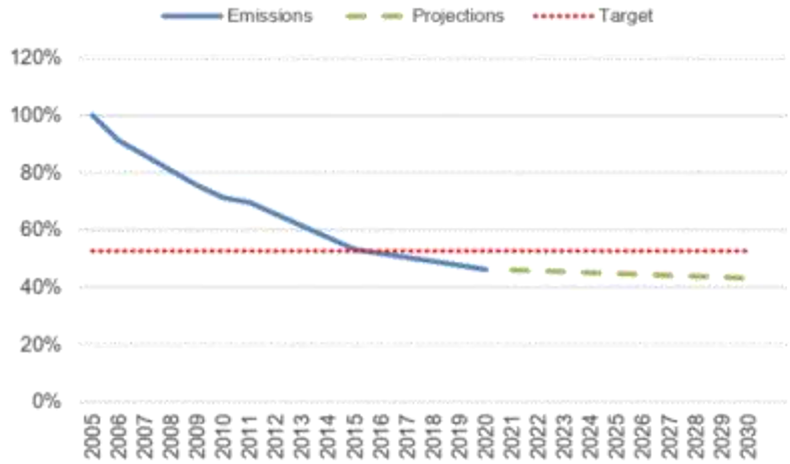

Figure 2.6: Estimated daily winter PM_{10} emissions in Napier from 2005 to 2020 with 2030 projections – inventory based approach.

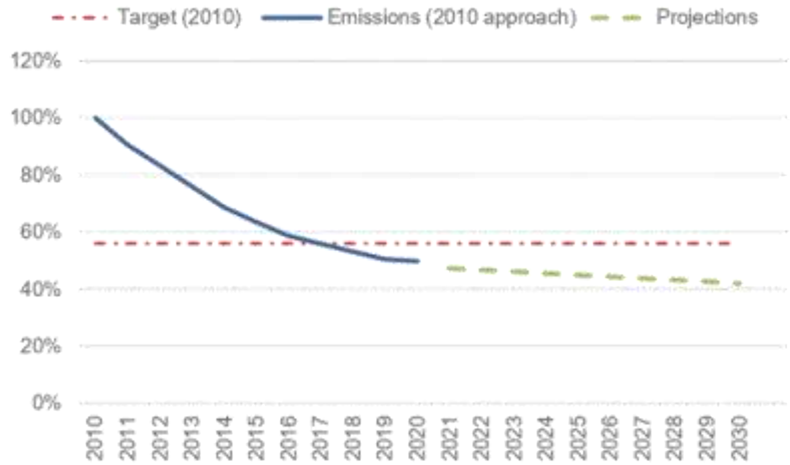

Figure 2.7: Estimated daily winter PM_{10} emissions in Napier from 2005 to 2020 with 2030 projections - model based approach.

Data for both approaches suggest that ongoing reductions in PM_{10} are likely to occur in Napier at a gradual rate with the model based approach suggesting greater certainty of ongoing compliance with the NES than the inventory based approach.

2.3.2 Annual average PM_{10}

Annual average PM_{10} concentrations in Napier do not exceed the current ambient air quality guideline of 10 μg/m³. Figures 2.6 and 2.7 suggest PM_{10} emissions are unlikely to increase. Ongoing compliance is therefore likely.

2.4 Air quality management for $PM_{2.5}$

2.4.1 Daily winter $PM_{2.5}$

The proposed NES for $PM_{2.5}$ (daily) is 25 µg/m³ with three allowable exceedences per year. Reductions required for compliance are therefore based on the fourth highest concentration rather than the second (as for PM_{10}). No modelling of worst case $PM_{2.5}$ has been carried out and with monitoring limited to a two-year period (2019 and 2020) it is unlikely that worst case meteorological conditions will have been captured. The impact on relative contributions of sources (compared with the inventory-based approach) will be minimal for $PM_{2.5}$ as the natural source contribution (which is a key difference between the modelled and inventory based approach) is nominal for $PM_{2.5}$ as the majority of the natural source contribution is in the coarse (PM_{10}-$PM_{2.5}$) mode.

It is our view that the proposed daily $PM_{2.5}$ standard is too low, as it is disparate in risk relative to the annual $PM_{2.5}$ standard, which is the exposure period of greater concern for health impacts. It remains disparate when the annual standard is reduced to a more protective 8 µg/m³ which is maximum level we would consider appropriate for an annual $PM_{2.5}$ standard. Monitoring data indicates that if the daily standard of 25 µg/m³ is adopted some reduction in daily winter $PM_{2.5}$ in Napier will be required. Monitoring data for 2019 and 2020 indicates a reduction in the order of 20% but this is likely to be an underestimate as worst-case meteorological conditions may occur.

Figure 2.8 shows projections in daily winter $PM_{2.5}$ relative to an estimated reduction of 20%. This suggests a slight reduction in $PM_{2.5}$ (daily winter) by 2030 but that compliance with the proposed NES for $PM_{2.5}$ is unlikely within this timeframe in the absence of additional regulation. Figure 2.8 also show that compliance may occur if the installation of new or replacement burners is limited to those meeting ULEB criteria.

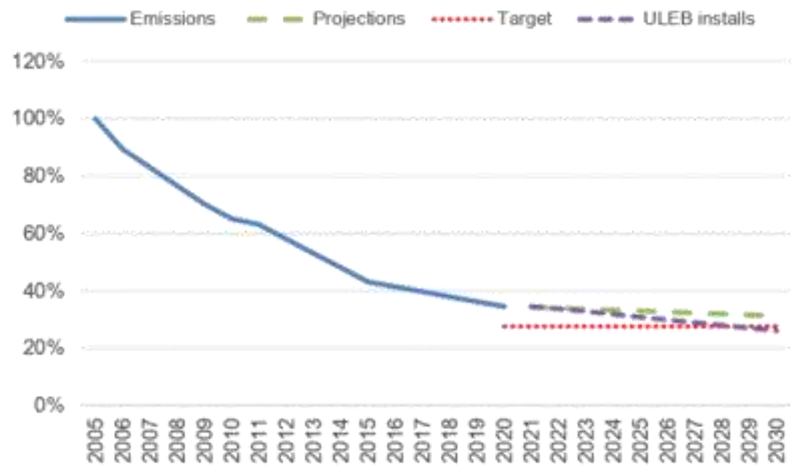

Figure 2.8: Estimated daily winter $PM_{2.5}$ emissions in Napier from 2005 to 2020 with 2030 projections - inventory based approach.

2.4.2 Annual average $PM_{2.5}$

Air quality data indicate annual average $PM_{2.5}$ concentrations in Napier around 6 µg/m³. These are below the proposed NES for $PM_{2.5}$ (annual average) of 10 µg/m³ as well as more protective standards (e.g., Canada at 8 µg/m³). Figure 2.9 shows the estimated annual average $PM_{2.5}$ concentrations in the absence of additional regulatory measures.

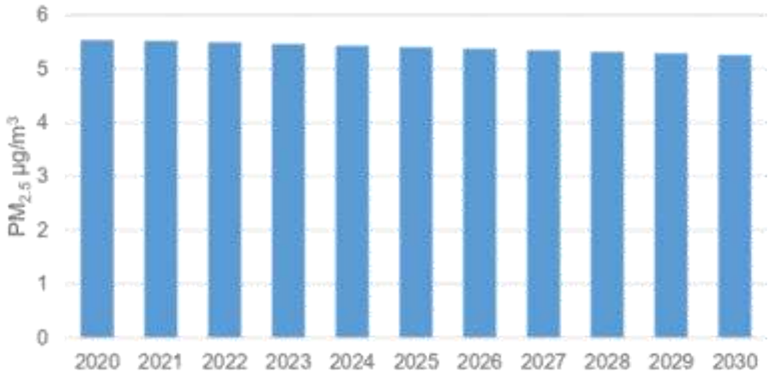

Figure 2.9: Estimated impact of existing air plan measures on annual average $PM_{2.5}$ in Napier.

2.4.3 Assumptions

- Inventory estimates for emissions for all sources (inventory-based approach) except for natural sources. Natural source contribution as per the Napier source apportionment (Wilton et al., 2010) added to daily winter 2008 PM_{10} emissions (assuming a linear relationship between emissions and concentrations).
- Daily winter fuel use by appliance type as per the 2020 air emission inventory.
- Population projections of 0.4% per year based on medium projections from 2018 to 2028 of 4% (Statistics NZ, 2018).
- No changes in households using open fires (note that open fires use is prohibited under Plan Change 2 in Airzones 1 unless the property is over two hectares or exempt), pellet burners or wood fired cookers from 2020 to 2030.
- Replacement of all pre 2006 wood burners and multi fuel burners by 2031 (note these are non-compliant unless exempt). A 25-year maximum life span was assumed for these appliances that have not been replaced.
- Uptake of ultra -low emission burners at 10% of new burner installations from 2020. New burner installations are estimated based on a natural attrition rate for post 2006 burners of 20 years in addition to replacements of other burners as detailed. The resulting proportion of solid fuel burners that are ULEB by 2030 is around 6% for Napier based on this assumption.
- No change in emissions from industry or outdoor burning from 2020 to 2030.
- Inventory based approach only - a reduction in motor vehicle emissions of around 6% from 2020 to 2030. This is based on a 15% increase in VKT and an 18% reduction in motor vehicle emissions. The latter is based on VFEM version 6.0 with a setting of 2030. This estimate has a high degree of uncertainty, including uncertainty around the uptake of electric vehicles but minimal impact on the projection as the base motor vehicle contribution is low at around 5% of the daily winter 2020 PM_{10} emissions.
- For $PM_{2.5}$ evaluations the contribution of natural sources to daily winter $PM_{2.5}$ was 6% of the 2008 emissions (Wilton et al., 2010).

- Annual average $PM_{2.5}$ impacts are estimated using seasonal variability in emissions from the 2020 air emission inventory and monthly average concentrations. The average of 2019 and 2020 $PM_{2.5}$ concentrations are used as the start point for the annual $PM_{2.5}$ projections.

2.5 Conclusions and recommendations

Concentrations of PM_{10} and $PM_{2.5}$ in Napier appear to be compliant with existing or proposed standards for daily PM_{10}, annual PM_{10} and annual $PM_{2.5}$. The latter is the most significant in terms of health impacts and compliance with this target is the most important in terms of health of the Napier community.

Concentrations of daily $PM_{2.5}$ are not compliant with the proposed NES for $PM_{2.5}$. A reduction of around 20% is indicated as required by monitoring carried out during 2019 and 2020. Projected emissions indicate a reduction of this magnitude is unlikely by 2030 in the absence of additional regulation. However, there is a high degree of uncertainty around compliance. Key variables include uptake of ULEB and representativeness of 2019 and 2020 $PM_{2.5}$ monitoring with respect to worst case (4th highest) daily winter $PM_{2.5}$.

2.5.1 Recommendations

- Maintenance of the status quo for the management of ambient PM_{10} and $PM_{2.5}$ concentrations.
- Review of position on release of NES for particulate.
- Ongoing review of $PM_{2.5}$ monitoring in Napier for compliance.

3 AIR QUALITY IN HASTINGS

3.1 Background

As with Napier, assessments of the reductions required in PM_{10} concentrations and the impact of regulatory measures in Hastings were made throughout the plan change process and adapted as scientific understanding and proposed rules changed. The original reductions in PM_{10} concentrations estimated for Hastings were based on a Golder (2009) report detailing modelling of 2006 emissions and meteorological conditions. The reduction required was estimated at 71% (based on a modelled value of 170 µg/m^3) of 2006 emissions. In addition to the regulatory measures proposed, around 40% of households replacing phased out burners needed to select non-solid fuel heating options to achieve the required reductions.

An update of the airshed modelling in 2012 (Gimson, 2012) incorporated updated modelling methods, 2010 emissions and meteorological data from 2005 to 2010. This assessment found a reduction of 48% (relative to 2010 data) was required in Hastings[2]. The relative contributions of different sources to the peak PM_{10} concentrations found domestic heating contributed 96% of the peak PM_{10} in Hastings with natural sources contributing 2% and other sources contributing 2% (Gimson, 2012). These contributions differ to the inventory (whole airshed average) based contributions and relate to a specific location and set of meteorological conditions likely to give rise to peak concentrations.

3.2 Air quality monitoring – PM_{10} and $PM_{2.5}$

The St Johns air quality monitoring site in Hastings has been monitoring PM_{10} concentrations since 2006. Figure 3.1 shows the incidence of daily PM_{10} concentrations and the maximum concentration by year. The maximum measured PM_{10} concentrations was 112 µg/m^3 (2006). Concentrations in the range of 5 - 40 µg/m^3 are most common and concentrations in excess of 50 µg/m^3 occur most frequently in 2006 (18 exceedances), 2008 (27 exceedances), and 2013 (16 exceedances).

[2] Whilst the reduction required may appear lower it relates to a point in time when some reductions have already been achieved.

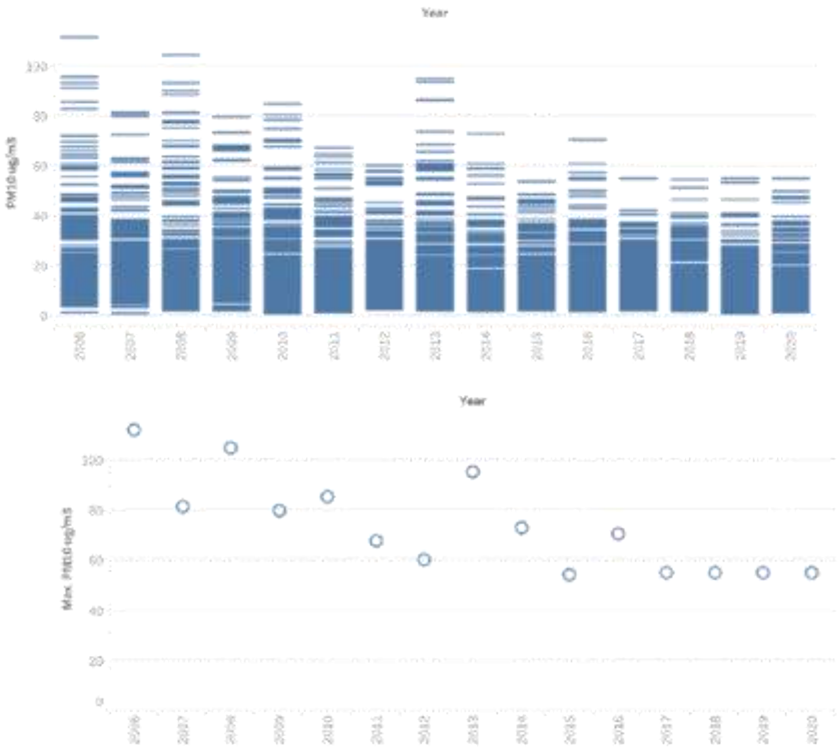

Figure 3.1: Distribution in Hastings daily PM_{10} concentrations by year (top) and annual maximum PM_{10} concentration.

The annual average PM_{10} concentration in Hastings from 2006 to 2020 ranges from a high of 19.2 µg/m^3 in 2008 to a low of 12.0 µg/m^3 in 2020. Concentrations are within the proposed NES for annual PM_{10} of 20 µg/m^3 (Ministry for the Environment, 2020).

The proposed NES also includes daily and annual levels for $PM_{2.5}$ of 25 µg/m^3 and 10 µg/m^3 respectively. Concentrations of $PM_{2.5}$ have been measured at the Hastings air quality monitoring site since 2017. Table 3.1 shows the annual average $PM_{2.5}$ and the daily average $PM_{2.5}$ concentrations relative to the proposed NES. Figure 3.2 shows the seasonal distribution in $PM_{2.5}$ concentrations and the relationship between $PM_{2.5}$ and PM_{10} is illustrated in Figure 3.3. The latter indicates the coarse component (PM_{10}-$PM_{2.5}$) comprises around half of the PM_{10} (and around 5 µg/m^3) during the summer months but only 10-15% of the PM_{10} during the winter months (and around 4 µg/m^3). Higher winter $PM_{2.5}$ concentrations occur because of domestic heating emissions which are predominantly in the $PM_{2.5}$ size fraction (Wilton 2020). Slightly lower absolute concentrations during the winter months may be a result of lower wind speeds as sources of coarse particulate such as dusts and marine aerosol are influenced by increased wind.

Table 3.1: Summary of $PM_{2.5}$ concentrations measured in Hastings from 2017 to 2020

	2017	2018	2019	2020
Annual average ($\mu g/m^3$)	8.9	8.2	7.7	7.7
No. of exceedances of 25 $\mu g/m^3$	31	15	10	11*
No. of breaches of proposed NES (allows 3 exceedances per year)	28	12	7	8*
4th highest concentration ($\mu g/m^3$)	37	37	34	36
Maximum 24-hour average $PM_{2.5}$ ($\mu g/m^3$)	54	43	43	49
Reduction required to meet proposed NES	32%	33%	26%	30%

* likely an underestimate as no data were available from 6 April to 17 June 2020.

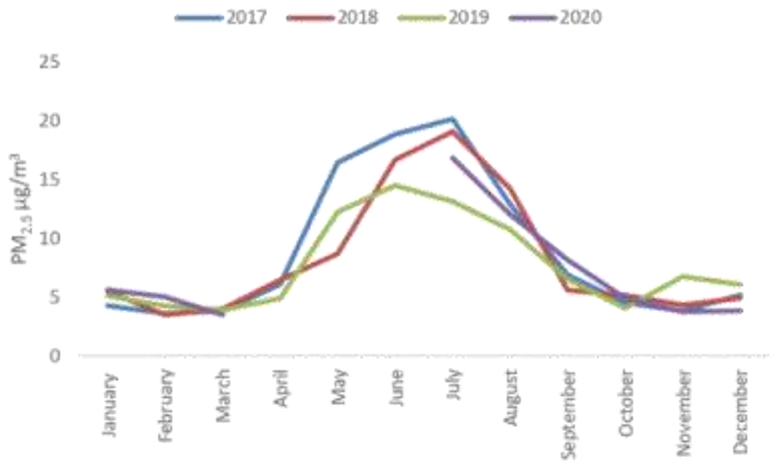

Figure 3.2: Monthly average $PM_{2.5}$ concentrations by year in Hastings.

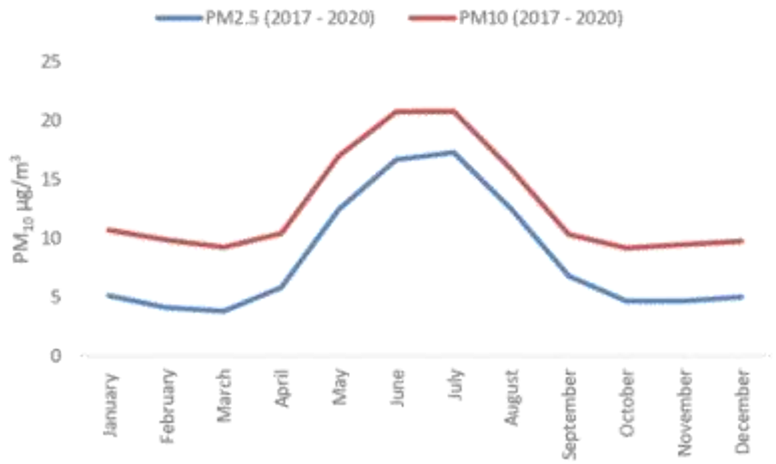

Figure 3.3: Monthly average $PM_{2.5}$ and PM_{10} concentrations (2017 – 2020) in Hastings.

3.3 Air quality management for PM_{10}

The air quality target for Hastings for daily winter PM_{10} is based on compliance with the NES for PM_{10} of 50 µg/m^3 (24-hour average) and one allowable exceedance per year. Hastings was required to be compliant with the NES for PM_{10} by September 2020. Data are indicative of progression towards achieving no breaches of the NES post 2020 with 2015, 2017 and 2020 all just having one exceedance each year of 50 µg/m^3.

Figure 3.4 shows changes in emissions and second highest PM_{10} concentrations from 2005 to 2020 relative to the air quality targets set as a part of Plan Change 2. This is based on using average contributions of sources from the air emission inventory (winter) and source apportionment for the contribution from natural sources. A modelled worst case 24-hour average PM_{10} concentration of 145 µg/m^3 was the basis for the target and implicated a 66% reduction in daily winter PM_{10} to achieve the 50 µg/m^3 NES (Gimson, 2006). The consequent daily winter PM_{10} emission target was also 66% of 2005 emissions based on a linear relationship between emissions and concentrations.

In Figure 3.4 the concentration values are typically much lower than the projection line because the latter is based on worst case meteorological conditions which do not typically occur. It is noted that in 2013 the concentration value is higher than the projection line signalling that meteorological conditions during this year may have resulted in concentrations greater than 145 µg/m^3 if emissions had been at 2005 levels. Alternatively, emissions in 2013 may have been underestimated, i.e., the reduction from 2010 to 2015 may have occurred more heavily in the 2014-2015 period rather than the more linear approach assumed in Figure 3.4.

Overall, the results suggest that PM_{10} concentrations have not reduced by enough to ensure compliance with the NES and that additional reductions are required.

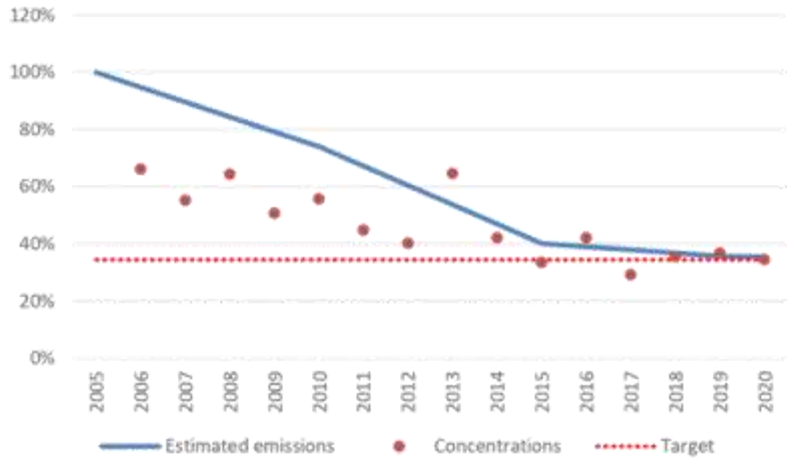

Figure 3.4: Daily winter PM_{10} emissions in Hastings and second highest daily measured PM_{10} concentration – inventory-based approach.

As with the Napier assessment, the approach illustrated above was modified in 2012 (Wilton, 2012) as a result of updated modelling (Golders, 2012) which used 2010 emission values and identified a worst-case concentration of 96 µg/m³ based on 2010 emissions (as opposed to 145 µg/m³ for the higher 2005 emissions). A key difference to the methodology, however, is that the modelling indicated only a 2% contribution of other sources and a 2% contribution of natural sources. Figure 3.5 shows the emissions and PM_{10} concentrations from 2010 to 2020 based on the modelled source contributions and a maximum concentration of 96 µg/m³ (daily winter PM_{10}). Under the modelled contributions approach the domestic heating sector contributes a greater proportion of the daily winter PM_{10} (96%) and therefore the effectiveness of the regulatory measures targeting that source are greater. Consequently, the projection line presents below the air quality target, suggesting ongoing compliance with the NES for PM_{10} provided worst case meteorological conditions are not experienced.

However, monitoring data for Hastings are not indicative of compliance with the NES with multiple exceedances occurring during 2016, 2018 and 2019 when the projections in Figure 3.5 suggest one or none. The inventory-based approach (Figure 3.4) appears to give the better representation of changes relative to monitored PM_{10} concentrations.

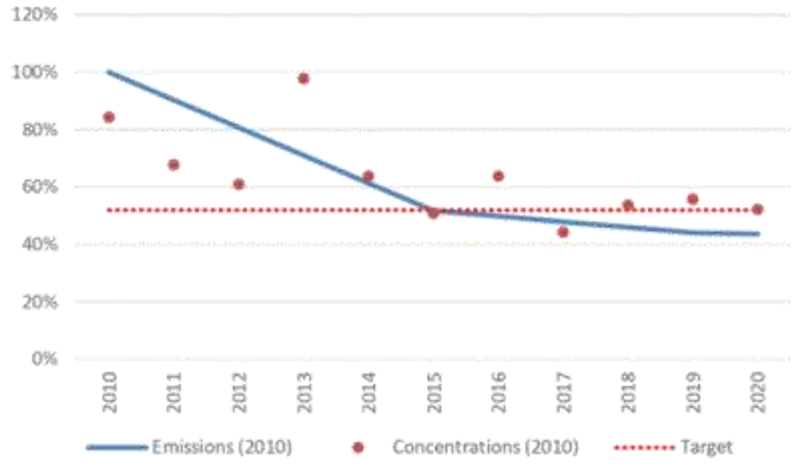

Figure 3.5: Daily winter PM_{10} emissions in Hastings and second highest daily measured PM_{10} concentration – modelled contribution approach.

To examine the potential for changes in emissions from 2020 a projections analysis was undertaken using 2020 emission inventory data as the base year and extrapolating to 2030 based on predicted changes in heating methods. The assumptions underpinning this analysis include the gradual replacement of burners that are non-compliant under the air plan that appear to still be operating. Figure 3.6 shows the estimated emissions for Hastings projected from 2020 to 2030 in the absence of additional regulation.

Figure 3.6: Estimated daily winter PM_{10} emissions in Hastings from 2005 to 2020 with 2030 projections – inventory based approach.

Figure 3.6 suggests compliance with the NES for PM_{10} is likely to occur by around 2025. However, the relativity between the projections line and the concentrations during the years 2018 to 2020 is of concern. The relationship between the target and the projections line is for the worst-case meteorological conditions so when the projection line reaches the target, concentrations should be below the projections line except for worst case meteorological conditions. For the years 2018 to 2020 the concentrations are all around the projections line suggesting that either all three years experienced worst case meteorological conditions or there may be an overestimate in the reductions in emissions. It would seem unlikely that worst case meteorological conditions occurred on all three years and in our view a slight overestimate of the reductions in emissions is likely.

Additional measures are likely to be needed to ensure compliance with the NES for PM_{10} in Hastings. There is potential for further reduction in daily winter PM_{10} emissions through targeting compliance with rules in the Air Plan, in particular the use of open fires and multi fuel burners. Figure 3.7 shows the impact of full compliance with air plan rules by 2023 and the impact of only allowing new ULEB installations from 2024. This suggests that the measures adopted in the air plan would have been successful in achieving the NES for PM_{10} had compliance been achieved.

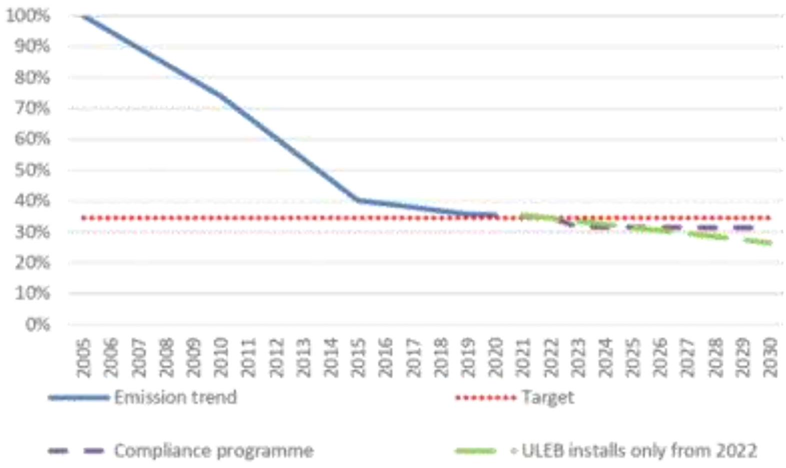

Figure 3.7: Estimated daily winter PM_{10} emissions in Hastings from 2005 to 2020 with 2030 projections for full compliance with air plan rules by 2023 and with limiting new installations of burners to ULEB.

3.3.1 Annual average PM_{10}

Annual average PM_{10} concentrations in Hastings do not exceed the current ambient air quality guideline of 20 µg/m³. Figure 3.6 suggests that PM_{10} emissions are unlikely to increase. Ongoing compliance is therefore likely.

3.4 Air quality management for $PM_{2.5}$

3.4.1 Daily winter $PM_{2.5}$

The proposed NES for $PM_{2.5}$ (daily) is 25 µg/m³ with three allowable exceedences per year. Reductions required for compliance are therefore based on the fourth highest concentration rather than the second (as for PM_{10}). No modelling of worst case $PM_{2.5}$ has been carried out for the fourth highest $PM_{2.5}$ concentrations for Hastings. Air quality monitoring for $PM_{2.5}$ has been carried out since 2016. However, it is still unlikely that worst case meteorological conditions will have been captured. As with Napier, the impact on relative contributions of sources (compared with the inventory-based approach) will be minimal for $PM_{2.5}$ as the natural source contribution (the main difference between the modelled and inventory-based approach) is minimal for $PM_{2.5}$ as the majority of the natural source contribution is in the coarse (PM_{10}-$PM_{2.5}$ mode).

Monitoring data indicates that if the proposed NES for daily $PM_{2.5}$ is adopted a reduction in daily winter $PM_{2.5}$ in Hastings of at least 33% will be required. This may be an underestimate as worst-case meteorological conditions may occur. It is also worth noting that there are significant discrepancies in the health risk for daily winter $PM_{2.5}$ relative to the proposed annual $PM_{2.5}$ and that revisions to the proposed NES could occur.

Figure 3.8 shows projections in daily winter $PM_{2.5}$ emissions relative to an estimated reduction of 33%. This suggests a slight reduction in $PM_{2.5}$ (daily winter) by 2030 but that compliance with the proposed NES for $PM_{2.5}$ is unlikely. The impact of restricting the installation of burners to ULEB is also unlikely to be effective in reducing $PM_{2.5}$ concentrations to meet the proposed NES by 2030 alone but may be effective in conjunction with a behaviour change campaign effective in reducing emissions by 10%.

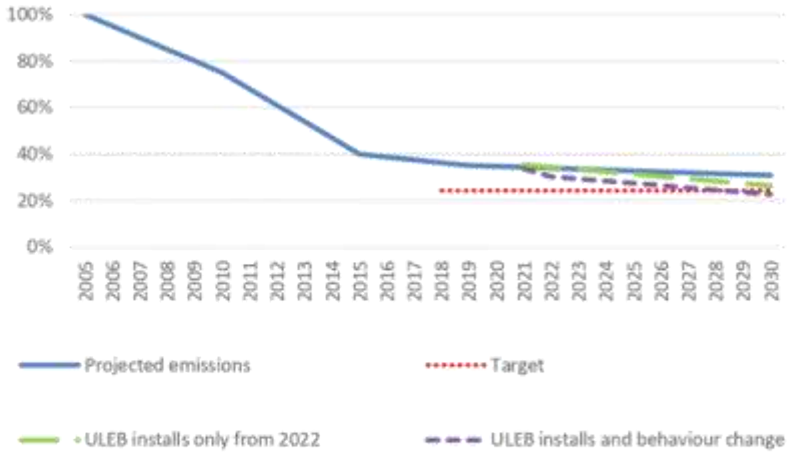

Figure 3.8: Estimated daily winter $PM_{2.5}$ emissions in Hastings from 2005 to 2020 with 2030 projections and management options evaluation-inventory based approach.

3.4.2 Annual average $PM_{2.5}$

Air quality data indicate annual average $PM_{2.5}$ concentrations in Hastings around 7-9 μg/m³. These are below the proposed NES for $PM_{2.5}$ (annual average) of 10 μg/m³ but the 2017 and 2018 concentrations are higher than the more stringent standards (e.g., Canada at 8 μg/m³). Figure 3.9 shows the estimated impact of trends in daily winter $PM_{2.5}$ on annual average concentrations.

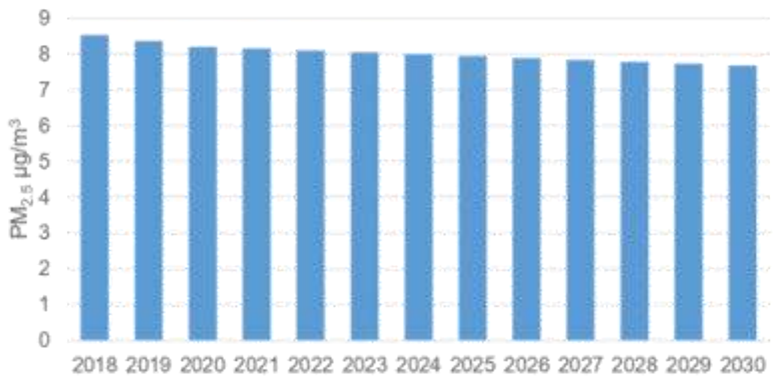

Figure 3.9: Estimated impact of existing air plan measures on annual average $PM_{2.5}$ in Hastings.

3.4.3 Assumptions

As per the assessment for Napier with the following specifics:

- Hastings population projections of 0.4% per year based on a 4% increase in population from 2018 to 2028 (Statistics NZ, 2018).
- Inventory estimates for emissions for all sources (inventory-based approach) with the exception of natural sources. Natural source contribution as per the Hastings source apportionment (Wilton et al., 2007) added to daily winter 2008 PM_{10} emissions (assuming linear relationship between emissions and concentrations).
- For $PM_{2.5}$ evaluations the contribution of natural sources to daily winter $PM_{2.5}$ was 6% of the 2006 emissions (as per Wilton et al., 2007).
- Annual average $PM_{2.5}$ impacts are estimated using seasonal variability in emissions from the 2020 air emission inventory and monthly average concentrations. The average of 2017 and 2018 $PM_{2.5}$ concentrations are used as the start point for the annual $PM_{2.5}$ projections.

3.5 Conclusions and recommendations

Hastings appears like it may be compliant with the NES for PM_{10} (24-hour average) but further monitoring and ongoing assessment is required. Annual PM_{10} concentrations are well within existing guidelines.

Concentrations of daily $PM_{2.5}$ are not compliant with the proposed NES for $PM_{2.5}$. A reduction of around 33% is indicated by monitoring carried out from 2016 to 2020. Projected emissions indicate a reduction of this magnitude is unlikely by 2030 in the absence of additional regulation. Additional measures such as the requirement that new burners installed meet the ULEB criteria and a behaviour change programme targeting burner operation may assist with achievement of this target.

Hastings appears compliant with the proposed annual average $PM_{2.5}$ NES of 10 μg/m^3.

3.5.1 Recommendations

1. Ongoing review of PM_{10} monitoring in Hastings for compliance with the daily NES.
2. Review of position on release of NES for particulate and in particular the levels set for $PM_{2.5}$.
3. Depending on outcomes of points 1 and 2 above, consider implementation of management measures such as limiting the installation of new wood burners to ULEB and behaviour change programmes targeting burner emissions.

4 AIR EMISSIONS ASSESSMENT WAIROA, WAIPAWA AND WAIPUKUARU

4.1 Introduction

An air emissions assessment was carried out for Wairoa, Waipawa and Waipukurau for a base year of 2018. Contaminants included in the assessment were PM_{10}, $PM_{2.5}$, CO, NOx, SOx, VOC and CO_2. Daily and annual estimates of contaminants from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning were included in the assessment. The purpose of the study was to identify the main contributors to daily and annual PM_{10} and $PM_{2.5}$ emissions and to collect data from which trends and the effectiveness of management measures could be estimated.

4.2 Methodology

4.2.1 Domestic heating

A combination of data from the 2018 census and databases of wood burner installations from territorial local authorities was used to estimate the number of households using wood. Table 4.1 shows the number of households based on 2018 census data for occupied private dwellings (Statistics NZ, 2019).

Table 4.1: 2018 Census dwellings data

	Dwellings (2018 census)	Area (ha)	Electricity	Gas	Wood	Coal
Wairoa	1554	756	738	282	903	6
Waipawa	843	691	501	111	582	6
Waipukurau	1758	804	1131	249	1131	6

Home heating methods were classified as; electricity, open fires, wood burners, pellet fires, multi fuel burners, gas burners. No households reported using oil in the 2018 census in these areas. In addition to the fuel type classifications, the 2018 census includes information on the type of appliance the fuels are burnt in. Table 4.2 includes the appliance types for each area. It is noted that the wood burner and pellet fire numbers equal the total wood used by households and the coal burner numbers equate to the coal households. This suggests that open fires are either not used in any of these areas or are classified as wood burners under the census. Similarly, coal is either not used on open fires or it is assumed if a household burns coal that it must be on a coal burner.

Table 4.2: 2018 Census heating method data

	Wood burner	Pellet fire	Coal burner
Wairoa	888	15	6
Waipawa	579	3	6
Waipukurau	1116	15	6

To estimate the proportion of dwellings burning wood (classified as wood burners in the Census) that use it on an open fire, data was used from a 2014 survey of urban north island towns (Ministry for the Environment, 2014). This indicated around 4.4% of total households used open fires at that time.

The wood burner ages were split into pre 2006 and post 2006 using data on burner installations collected by local authorities.

Emission factors were applied to the estimate of households using each appliance type and fuel to provide an estimate of emissions for each study area. The emission factors used to estimate emissions from domestic heating are shown in Table 4.3. The basis for these is detailed in Appendix B.

Table 4.3: Emission factors for domestic heating methods.

	PM_{10} g/kg	$PM_{2.5}$ g/kg	CO g/kg	NOx g/kg	SO_2 g/kg	CO_2 g/kg
Open fire - wood	7.5	7.5	55	1.2	0.2	1600
Open fire - coal	21	18	70	4	8	2600
Pre 2006 burners	10	10	140	0.5	0.2	1600
Post 2006 burners	4.5	4.5	45	0.5	0.2	1600
Pellet burners	2	2	20	0.5	0.2	1600
Multi-fuel[1] - wood	10	10	140	0.5	0.2	1600
Multi-fuel[1] – coal	19	17	110	1.6	8	2600
Oil	0.3	0.22	0.6	2.2	3.8	3200
Gas	0.03	0.03	0.18	1.3	7.56E-09	2500

[1] - includes potbelly, incinerator, coal range and any enclosed burner that is used to burn coal

Data from the 2020 air emission inventory for Napier was used to estimate the average daily fuel use for each fuel and appliance type.

4.2.2 Motor vehicles

The methodology for estimating emissions to air from motor vehicles involves collecting data on vehicle kilometres travelled (VKT) and the application of emission factors to these data.

Emission factors for motor vehicles are determined using the Vehicle Emission Prediction Model (VEPM 6.0). Emission factors for PM_{10}, $PM_{2.5}$, CO, NOx, and CO_2 for this study have been based on VEPM 6.0. The emission factors used for this assessment are based on the evaluation for Napier (2020) and are shown in Table 4.4.

The number of vehicle kilometres travelled (VKT) for the airshed was estimated using the New Zealand Transport Authority VKT data for 2013 which was available at census area unit level and extrapolated to 2020 based on the increase in VKTs across the district over the same period (Table 4.5).

Table 4.4: Emission factors based on the Napier 2020 vehicle fleet.

CO	CO_2	VOC	NOx	PM_{10}	$PM_{2.5}$	PM brake & tyre	$PM_{2.5}$ brake & tyre
g/VKT	g/VKT	g/VKT	g/VKT	g/VKT	g/VKT	g/VKT	g/VKT
2.09	223	0.18	0.58	0.019	0.019	0.021	0.011

Table 4.5: VKT estimates for 2020.

	VKT 2020
Wairoa	42939
Waipawa	53557
Waipukurau	44778

Emissions were calculated by multiplying the appropriate average emission factor by the VKT:

Emissions (g) = Emission Rate (g/VKT) * VKT

4.2.3 Industry

Information on consented activities discharging to air in Wairoa, Waipawa and Waipukurau was provided by the Hawke's Bay Regional Council. The selection of industries for inclusion in this inventory was based on potential for PM_{10} and $PM_{2.5}$ emissions. Most resource consents in the areas were for discharges of odour or landfill gases and were not included in the inventory.

The number of industrial activities in these towns is small with only two activities identified in each of Wairoa and Waipukurau and none in Waipawa.

Emissions were estimated based on equation 4.1 or equation 4.2 depending on the availability of site-specific emissions data. Activity data from industry includes information such as the quantities of fuel used, or in the case of non-combustion activities, materials used or produced.

Equation 4.1 Emissions (kg/day) = Emission rate (kg/hr) x hrs per day (hrs)

Equation 4.2 Emissions (kg) = Emission factor (kg/tonne) x Fuel use (tonnes)

The emission factors used to estimate the quantity of emissions discharged are shown in Table 4.6. Fugitive dust emissions from industrial and commercial activities were not included in the inventory assessment because of difficulties in quantifying the emissions.

Table 4.6: Emission factors for industrial discharges.

	PM_{10} g/kg	CO g/kg	NOx g/kg	SOx g/kg	VOC g/kg	CO_2 g/kg	$PM_{2.5}$ g/kg
Wood boiler	1.6	6.8	0.8	0.04	0.1	1069	1.4
Coal boiler - underfeed	2	6	5	19	0	2400	1
Diesel boiler	0.3	0.67	3.2	0.02	0.2	3194	0.2

4.2.4 Outdoor burning

Outdoor burning emissions were estimated based on data collected for other similar areas. No Hawke's Bay towns were able to be used because of in the areas where inventories have been carried out there are restrictions on outdoor burning. Towns in rural urban Waikato were examined and a value of 20% of households undertaking outdoor burning and an average burn size of around one cubic metre were used. Emissions were calculated based on the assumption of an average weight of material per burn of 159 kilograms per cubic metre of material[3] and using the emission factors in Table 4.7).

Table 4.7: Outdoor burning emission factors (AP42).

	PM_{10} g/kg	$PM_{2.5}$ g/kg	CO g/kg	NOx g/kg	SOx g/kg	CO_2 g/kg
Outdoor burning	8	8	42	2	0.5	1470

4.3 Wairoa emissions

4.3.1 Domestic heating emissions

Table 4.8 shows the distribution of heating methods and fuels in Wairoa. Around 820 households use wood burners and just under half of these were installed prior to September 2005.

Table 4.8: Home heating methods and fuels.

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	47%	738		
Total Gas	13%	202	0.2	1%
Flued gas	3%	42		
Unflued gas	15%	240		
Oil	0%		0.0	0%
Open fire	4%	68		
Open fire - wood	4%	68	2	10%
Open fire - coal	0%		0.0	0%
Total Wood burner	53%	820	15	88%
Pre 2006 wood burner	22%	338	6	36%
2006-2014 wood burner	19%	300	5	32%
Post-2014 wood burner	12%	182	3	20%
Multi-fuel burners	0.4%	6		
Multi-fuel burners-wood	0.0%		0.0	0%
Multi-fuel burners-coal	0.4%	6	0.1	0%
Pellet burners	1%	15	0.1	0%
Total wood	58%	903	16	99%
Total coal	0%	6	0.1	0.4%
Total		1,554	17	100%

In 2020 around 113 kilograms of PM_{10} was estimated to be discharged on a typical winter's day from domestic home heating in Wairoa. The annual $PM_{2.5}$ emission was estimated at 14 tonnes per year.

[3] Based on the average of low and medium densities for garden vegetation from (Victorian EPA, 2016)

Figure 4.1 shows that around 53% of the daily winter PM_{10} emissions are from pre-2006 wood burners. The NES design criteria for wood burners was mandatory for new installations on properties less than 2 hectares from September 2005. Wood burners installed during the years 2006 to 2020 contribute to 34% of domestic heating PM_{10} emissions. Open fires and multi fuel burners are estimated to contribute around 13% of daily winter PM_{10} emissions in Wairoa.

Tables 4.9 and 4.10 show the estimates of emissions for different heating methods under average and worst-case scenarios respectively. Days when households may not be using specific home heating methods are accounted for in the daily winter average emissions[4]. Under the worst-case scenario that all households are using a burner on any given night around 138 kilograms of PM_{10} is likely to be emitted.

The seasonal variation in contaminant emissions is shown in Table 4.11.

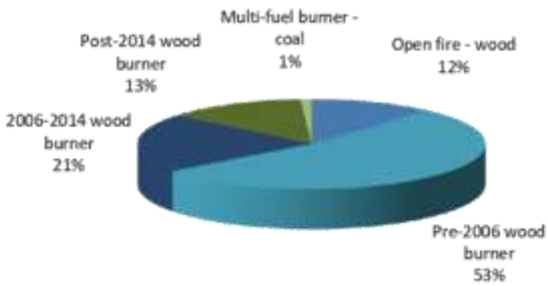

Figure 4.1: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating in Wairoa.

[4] Total fuel use per day is adjusted by the average number of days per week wood burners are used (e.g.,6/7) and the proportion of wood burners that are used during July (e.g.,95%).

Table 4.9: Wairoa winter daily domestic heating emissions by appliance type (winter average).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%
Open fire																							
Open fire - wood	1.7	10%	13	17	11%	94	124	7%	2	3	21%	0	0	9%	51	68	12%	3	4	10%	13	17	11%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner	14.6																						
Pre 2006 wood burner	6.0	36%	60	80	53%	842	1113	63%	3	4	31%	1	2	32%	198	262	47%	10	13	36%	60	80	53%
2006-2014 wood burner	5.3	32%	24	32	21%	240	318	18%	3	4	27%	1	1	28%	107	141	25%	9	11	32%	24	32	21%
Post 2014 wood burner	3.2	20%	15	19	13%	146	193	11%	2	2	17%	1	1	17%	65	86	15%	5	7	19%	15	19	13%
Pellet Burner	0.1	0%	0.1	0	0%	1	1	0%	0	0	0%	0	0	0%	1	1	0%	0	0	0%	0	0	0%
Multi fuel burner																							
Multi fuel– wood	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Multi fuel – coal	0.1	0%	1	2	1%	7	9	1%	0	0	1%	0	1	13%	1	1	0%	0	0	1%	1	1	1%
Gas	0.2	1%	0.01	0	0%	0	0	0%	0	0	2%	0	0	0%	0	0	0%	0	1	2%	0	0	0%
Oil	0.0	0%	0.00	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Wood	16.4	99%	111.67	148	99%	1323	1750	99%	9	12	97%	3	4	87%	422	559	100%	26	35	98%	112	148	99%
Total Coal	0.1	0%	1.17	2	1%	7	9	1%	0	0	1%	0	1	13%	1	1	0%	0	0	1%	1	1	1%
Total	17		113	149		1330	1759		10	13		4	5		423	560		27	35		113	149	

Table 4.10: Wairoa winter daily domestic heating emissions by appliance type (worst case).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%
Open fire																							
Open fire - wood	1.9	9%	14	19	10%	105	139	6%	2	3	20%	0	1	8%	57	76	11%	3	4	9%	14	19	10%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner	18.0																						
Pre 2006 wood burner	7.4	37%	74	98	54%	1036	1370	64%	4	5	32%	1	2	30%	244	323	47%	12	16	36%	74	98	54%
2006-2014 wood burner	6.6	32%	30	39	21%	296	391	18%	3	4	28%	1	2	27%	131	174	25%	11	14	32%	30	39	21%
Post 2014 wood burner	4.0	20%	18	24	13%	179	237	11%	2	3	17%	1	1	16%	80	105	15%	6	8	20%	18	24	13%
Pellet Burner	0.1	0%	0	0	0%	2	2	0%	0	0	0%	0	0	0%	2	2	0%	0	0	0%	0	0	0%
Multi fuel burner																							
Multi fuel– wood	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Multi fuel – coal	0.1	1%	2	3	1%	12	16	1%	0	0	1%	1	1	18%	2	2	0%	0	0	1%	2	2	1%
Gas	0.2	1%	0	0	0%	0	0	0%	0	0	2%	0	0	0%	0	0	0%	0	1	1%	0	0	0%
Oil	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Wood	20	99%	136	180	99%	1618	2140	99%	11	15	96%	4	5	82%	515	681	100%	32	42	98%	136	180	99%
Total Coal	0	1%	2	3	1%	12	16	1%	0	0	1%	1	1	18%	2	2	0%	0	0	1%	2	2	1%
Total	20		138	183		1630	2156		12	16		5	6		516	683		33	43		138	182	

Table 4.11: Monthly variations in contaminant emissions from domestic heating in Wairoa.

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	VOC kg/day	CO_2 t/day	$PM_{2.5}$ kg/day
January	0	1	0	0	0	0	0
February	0	0	0	0	0	0	0
March	2	23	0	0	7	0	2
April	14	129	2	0	54	4	14
May	73	855	7	2	276	18	73
June	109	1283	9	3	409	25	109
July	113	1330	10	4	423	27	113
August	99	1177	8	3	371	24	99
September	33	368	3	1	126	8	33
October	16	155	2	0	61	4	16
November	2	27	0	0	8	1	2
December	0	1	0	0	0	0	0
Total (kg/year)	14129	164016	1269	453	53237	3357	14116

4.3.2 Motor vehicles

Table 4.12 shows that around two kilograms of PM_{10} and one kilogram of $PM_{2.5}$ are emitted per day in Wairoa as a result of motor vehicles. Around 43% is from brake and tyre wear and 38% is from tailpipe emissions.

Table 4.12: Summary of daily motor vehicle emissions in Wairoa

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Tailpipe	0.8	1	90	119	25	33	0	0
Brake and tyre	0.9	1						
Road dust	0.4	1						
Total	2.1	3	90	119	25	33	0	0
	VOC		CO_2		$PM_{2.5}$			
	kg	g/ha	t	kg/ha	kg	g/ha		
Tailpipe	8	10	10	13	0	1		
Brake and tyre					0	0		
Road dust					0	0		
Total	8	10	0	0	1	1		

4.3.3 Industry

A small number of activities hold resource consents for air discharges that include particulate emissions in Wairoa. Table 4.13 shows the daily winter emissions from these activities and indicates that around 37 kilograms of PM_{10} and 29 kilograms of $PM_{2.5}$ are emitted per day in Wairoa.

Table 4.13: Summary of emissions from industrial and commercial activities (daily winter) in Wairoa.

		PM_{10}		CO		NOx		SOx	
	Hectares	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Wairoa	756	37	49	383	506	99	131	234	310
		VOC		CO_2		$PM_{2.5}$			
	Hectares	kg	g/ha	t	kg/ha	kg	g/ha		
Wairoa	756	8	10.8	84	111	28.8	38.1		

4.3.4 Outdoor burning

Around 15 kilograms of PM_{10} from outdoor burning could be expected per day during the winter months on average in Wairoa (Table 4.14). It should be noted, that there are a number of uncertainties relating to the calculations. In particular, frequency of burning is based on outdoor burning rates in other similarly sized north island towns, rather than specific data for Wairoa. Additionally, it is assumed that burning is carried out evenly throughout the winter, whereas in reality it is highly probable that a disproportionate amount of burning is carried out on days more suitable for burning. Thus, on some days no PM_{10} from outdoor burning may occur and on other days it might be many times the amount estimated in this assessment. In addition, the emission factors vary by a factor of three for different materials being burnt. Outdoor burning emissions include a higher degree of uncertainty relative to domestic heating, motor vehicles and industry owing to uncertainties in the distribution of burning and potential variabilities in material type and density.

Table 4.14: Outdoor burning emission estimates for Wairoa.

	PM_{10}	CO	NOx	SOx	VOC	CO2	$PM_{2.5}$
	kg/ day	kg/ day	kg/ day	kg/ day	kg/ day	t/ day	kg/day
Summer (Dec-Feb)	13	66	5	1	6	2	13
Autumn (Mar-May)	17	89	6	1	9	3	17
Winter (June-Aug)	15	80	6	1	8	3	15
Spring (Sept-Nov)	14	75	5	1	7	3	14

4.3.5 Total emissions

Domestic heating is the main source of daily winter PM_{10} and $PM_{2.5}$ in Wairoa contributing 68% and 72% respectively (Figure 4.2). Industry and domestic heating are the main contributors to annual PM_{10} and $PM_{2.5}$ emissions. Outdoor burning also contributes 15-17% of the annual PM_{10} and $PM_{2.5}$ emissions. The relative contributions of sources to other contaminant emissions is shown in Figure 4.3. Seasonal variations in PM_{10} emissions by source is shown in Table 4.15 and daily and annual contaminant emissions by source in Tables 4.16 and 4.17.

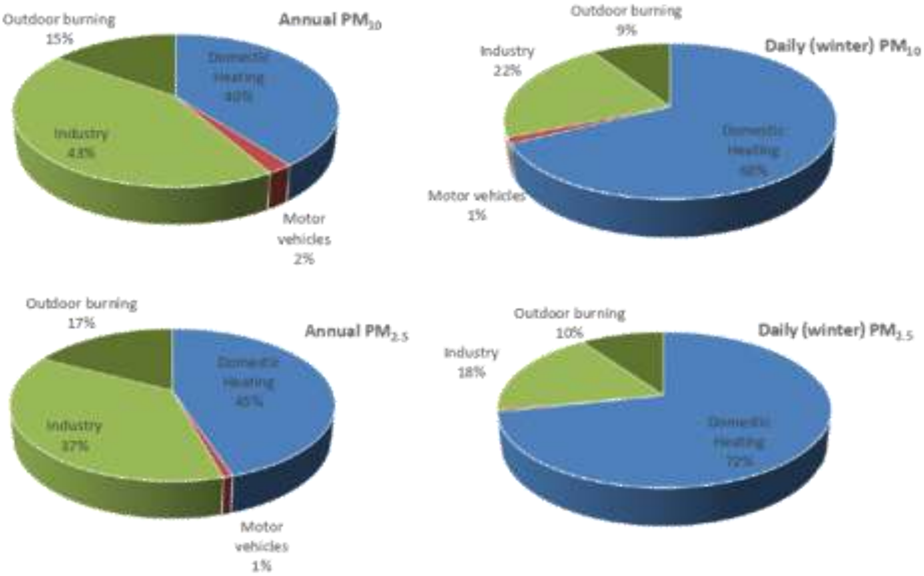

Figure 4.2: Relative contribution of sources to daily and annual PM_{10} and $PM_{2.5}$ in Wairoa.

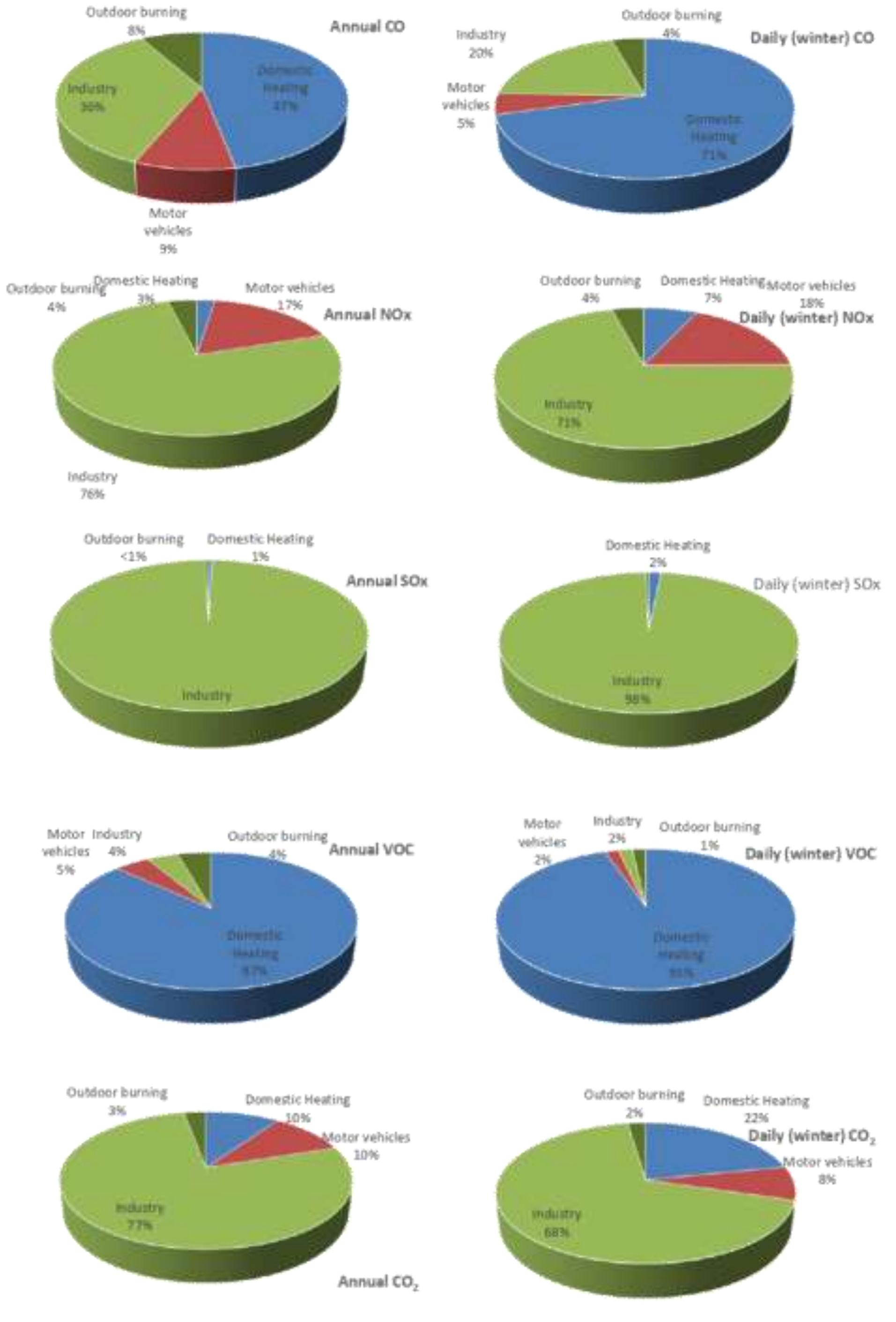

Figure 4.3: Relative contribution of sources to contaminant emissions in Wairoa.

Table 4.15: Monthly variations in daily PM_{10} emissions in Wairoa.

	Domestic heating		Outdoor burning		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day	%	kg/day
January	0	0%	13	19%	52	78%	2	3%	66
February	0	0%	13	18%	56	79%	2	3%	71
March	2	3%	17	25%	48	70%	2	3%	69
April	14	17%	17	21%	49	60%	2	3%	82
May	73	52%	17	12%	48	34%	2	1%	140
June	109	66%	15	9%	38	23%	2	1%	164
July	113	68%	15	9%	37	22%	2	1%	167
August	99	65%	15	10%	37	24%	2	1%	153
September	33	41%	14	18%	30	38%	2	3%	79
October	16	26%	14	23%	30	48%	2	3%	62
November	2	4%	14	29%	30	62%	2	4%	49
December	0	0%	13	19%	52	78%	2	3%	66
Total kg/year	14129	40%	5410	15%	15353	43%	763	2%	35655

Table 4.16: Daily contaminant emissions from all sources in Wairoa (winter average).

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	113	149	1330	1759	10	13	4	5
Transport	2	3	90	119	25	33	0	0
Industry	37	49	383	506	99	131	234	310
Outdoor burning	15	20	80	106	6	8	1	1
Total	167	221	1883	2490	140	185	239	316
	VOC		CO_2		$PM_{2.5}$			
	kg	g/ha	tonnes	kg/ha	kg	g/ha		
Domestic home heating	423	560	27	35	113			
Transport	8	10	10	13	1			
Industry	8	11	84	111	29			
Outdoor burning	8	10	3	4	15			
Total	447	591	123	163	158			

Table 4.17: Annual contaminant emissions from all sources in Wairoa.

	PM_{10} t/year	CO t/year	NOx t/year	SOx t/year	VOC t/year	CO_2 t/year	$PM_{2.5}$ t/year
Domestic Heating	14	164	1	0	53	3357	14
Motor vehicles	1	33	9	0	3	3491	0
Industry	15	124	40	109	3	26608	12
Outdoor burning	5	28	2	0	3	994	5
Total	36	349	53	109	61	34451	31

4.4 Waipawa emissions

Table 4.18 shows the distribution of heating methods and fuels in Waipawa. Around 542 households use wood burners and just over half of these were installed prior to 2006.

Table 4.18: Home heating methods and fuels in Waipawa.

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	59%	501		
Total Gas	13%	111	0.1	1%
Flued gas	4%	33		
Unflued gas	9%	78		
Oil	0%		0.0	0%
Open fire	4%	37		
Open fire - wood	4%	37	1	9%
Open fire - coal	0%		0.0	0%
Total Wood burner	64%	542	10	90%
Pre 2006 wood burner	34%	285	5	47%
2006-2013 wood burner	17%	141	3	23%
Post-2013 wood burner	14%	116	2	19%
Multi-fuel burners	0.7%	6		
Multi-fuel burners-wood	0.0%		0.0	0%
Multi-fuel burners-coal	0.7%	6	0.1	1%
Pellet burners	0%	3	0.0	0%
Total wood	0%		11	98%
Total coal	0%		0.1	0.6%
Total		843	11	100%

Around 79 kilograms of PM_{10} was estimated to be discharged on a typical winter's day from domestic home heating in Waipawa. The annual $PM_{2.5}$ emission was estimated at 10 tonnes per year.

Figure 4.4 shows that the largest portion (64%) of the PM_{10} emissions are from pre 2006 wood burners. The NES design criteria for wood burners was mandatory for new installations on properties less than 2 hectares from September 2005. Wood burners installed after 2006 contribute to 26% of domestic heating PM_{10} emissions.

Tables 4.19 and 4.20 show the estimates of emissions for different heating methods under average and worst-case scenarios respectively. Days when households may not be using specific home heating methods are accounted for in the daily winter average emissions[5]. Under the worst-case scenario that all households are using a burner on any given night around 98 kilograms of PM_{10} is likely to be emitted. Seasonal variability and annual emissions are shown in Table 4.21.

[5] Total fuel use per day is adjusted by the average number of days per week wood burners are used (e.g.,6/7) and the proportion of wood burners that are used during July (e.g.,95%).

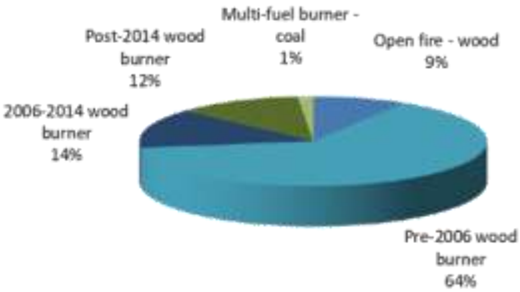

Figure 4.4: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating in Waipawa.

Table 4.19: Waipawa winter daily domestic heating emissions by appliance type (winter average).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%
Open fire																							
Open fire - wood	0.9	9%	7	10	9%	51	74	5%	1	2	18%	0	0	7%	28	40	10%	1	2	9%	7	10	9%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner	9.7																						
Pre 2006 wood burner	5.1	47%	51	73	64%	710	1028	73%	3	4	41%	1	1	39%	167	242	58%	8	12	47%	51	73	64%
2006-2014 wood burner	2.5	23%	11	16	14%	113	164	12%	1	2	20%	1	1	19%	50	73	17%	4	6	23%	11	16	14%
Post 2014 wood burner	2.1	19%	9	13	12%	93	135	10%	1	1	17%	0	1	16%	41	60	14%	3	5	19%	9	13	12%
Pellet Burner	0.0	0%	0.0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Multi fuel burner																							
Multi fuel– wood	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Multi fuel – coal	0.1	1%	1	2	1%	7	10	1%	0	0	2%	0	1	19%	1	1	0%	0	0	1%	1	1	1%
Gas	0.1	1%	0.00	0	0%	0	0	0%	0	0	2%	0	0	0%	0	0	0%	0	0	1%	0	0	0%
Oil	0.0	0%	0.00	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Wood	10.6	98%	78	113	99%	967	1400	99%	6	9	96%	2	3	81%	287	415	100%	17	25	98%	78	113	99%
Total Coal	0.1	1%	1	2	1%	7	10	1%	0	0	2%	0	1	19%	1	1	0%	0	0	1%	1	1	1%
Total	11		79	115		974	1410		6	9		3	4		288	417		17	25		79	115	

Table 4.20: Waipawa winter daily domestic heating emissions by appliance type (worst case).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%
Open fire																							
Open fire - wood	0.4	2%	3	4	3%	20	27	2%	0	1	4%	0	0	2%	11	15	3%	1	1	2%	3	4	3%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner	18.2																						
Pre 2006 wood burner	2.4	12%	24	33	24%	330	461	31%	1	2	11%	0	1	12%	78	109	19%	4	5	12%	24	33	24%
2006-2014 wood burner	8.3	43%	37	52	38%	372	519	35%	4	6	40%	2	2	44%	165	231	40%	13	18	42%	37	52	38%
Post 2014 wood burner	7.6	39%	34	47	35%	340	475	32%	4	5	36%	2	2	40%	151	211	37%	12	17	38%	34	47	35%
Pellet Burner	0.2	1%	0	1	0%	4	6	0%	0	0	1%	0	0	1%	4	6	1%	0	0	1%	0	1	0%
Multi fuel burner																							
Multi fuel– wood	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Multi fuel – coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Gas	0.6	3%	0	0	0%	0	0	0%	1	1	7%	0	0	0%	0	0	0%	1	2	4%	0	0	0%
Oil	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	1%	0	0	0%	0	0	0%	0	0	0%
Total Wood	19	97%	98	137	100%	1065	1488	100%	10	13	93%	4	5	99%	409	571	100%	30	42	95%	98	137	100%
Total Coal	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total	19		98	137		1065	1488		10	14		4	5		409	571		31	44		98	137	

Table 4.21: Monthly variations in contaminant emissions from domestic heating in Waipawa.

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	VOC kg/day	CO_2 t/day	$PM_{2.5}$ kg/day
January	0	1	0	0	0	0	0
February	0	0	0	0	0	0	0
March	1	17	0	0	5	0	1
April	8	84	1	0	32	2	8
May	51	623	4	2	187	11	51
June	76	939	6	2	278	16	76
July	79	974	6	3	288	17	79
August	70	865	5	2	254	15	70
September	22	262	2	1	83	5	22
October	10	103	1	0	38	2	10
November	2	20	0	0	6	0	2
December	0	1	0	0	0	0	0
Total (kg/year)	9843	119273	796	307	35881	2159	9831

4.4.1 Motor vehicles

Table 4.22 shows that less than three kilograms of PM_{10} and around one kilogram of $PM_{2.5}$ are emitted per day in Waipawa as a result of motor vehicles. Around 43% is from brake and tyre wear and 38% is from tailpipe emissions.

Table 4.22: Summary of daily motor vehicle emissions in Waipawa

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Tailpipe	1.0	1	112	162	31	45	0	0
Brake and tyre	1.1	2						
Road dust	0.5	1						
Total	2.6	4	112	162	31	45	0	0
	VOC		CO_2		$PM_{2.5}$			
	kg	g/ha	t	kg/ha	kg	g/ha		
Tailpipe	10	14	12	17	1	0.6	10	14
Brake and tyre					0	0.0		
Road dust					0	0.3		
Total	10	14	0	0	1	0.9	10	14

4.4.2 Industry

No activities with resource consents for discharges to air with particulate emissions were found for Waipawa. Whilst some small scale activities not requiring consent may exist, industrial and commercial activities are not a major emissions source in this area.

4.4.3 Outdoor burning

Around eight kilograms of PM_{10} from outdoor burning could be expected per day during the winter months on average in Waipawa (Table 4.23). As noted for Wairoa there are a number of uncertainties relating to the calculations and there is reliance on outdoor burning rates in other similarly sized north island towns and assumptions around the distribution of burning throughout the winter and potential variability in emission factors. Outdoor burning emission estimates include a higher degree of uncertainty relative to domestic heating, motor vehicles and industry.

Table 4.23: Outdoor burning emission estimates for Waipawa.

	PM_{10}	CO	NOx	SOx	VOC	CO2	$PM_{2.5}$
	kg/ day	kg/ day	kg/ day	kg/ day	kg/ day	t/ day	kg/day
Summer (Dec-Feb)	7	36	3	0	3	1	7
Autumn (Mar-May)	9	48	3	1	5	2	9
Winter (June-Aug)	8	44	3	1	4	2	8
Spring (Sept-Nov)	8	41	3	0	4	1	8

4.4.4 Total emissions

Domestic heating is the main source of daily and annual PM_{10} and $PM_{2.5}$ in Waipawa (Figure 4.5). Outdoor burning also has the potential to be a significant contributor particularly to annual PM_{10} and $PM_{2.5}$ emissions. The relative contribution of sources to other contaminant emissions is shown in Figure 4.6. Seasonal variations in PM_{10} emissions by source are shown in Table 4.24 and daily and annual contaminant emissions by source in Tables 4.25 and 4.26 respectively.

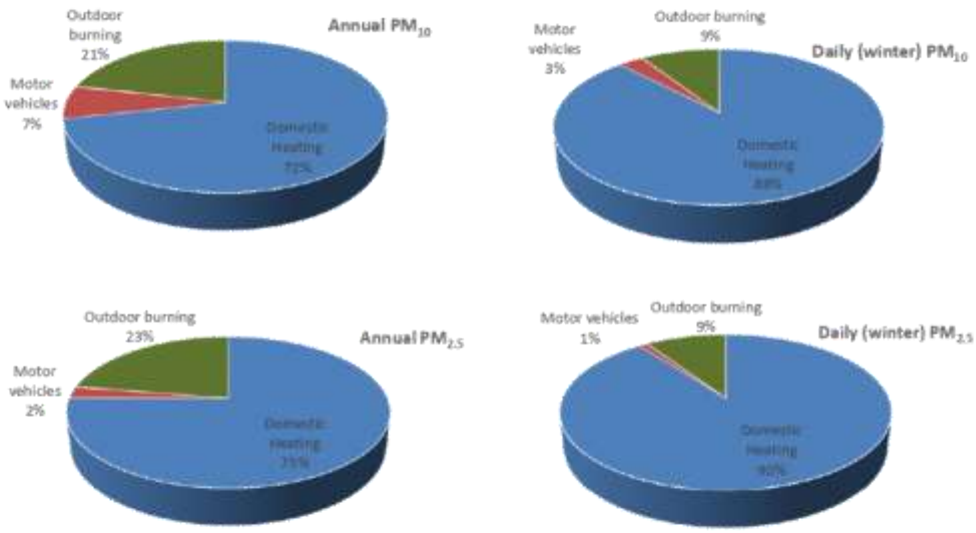

Figure 4.5: Relative contribution of sources to daily and annual PM_{10} and $PM_{2.5}$ in Waipawa.

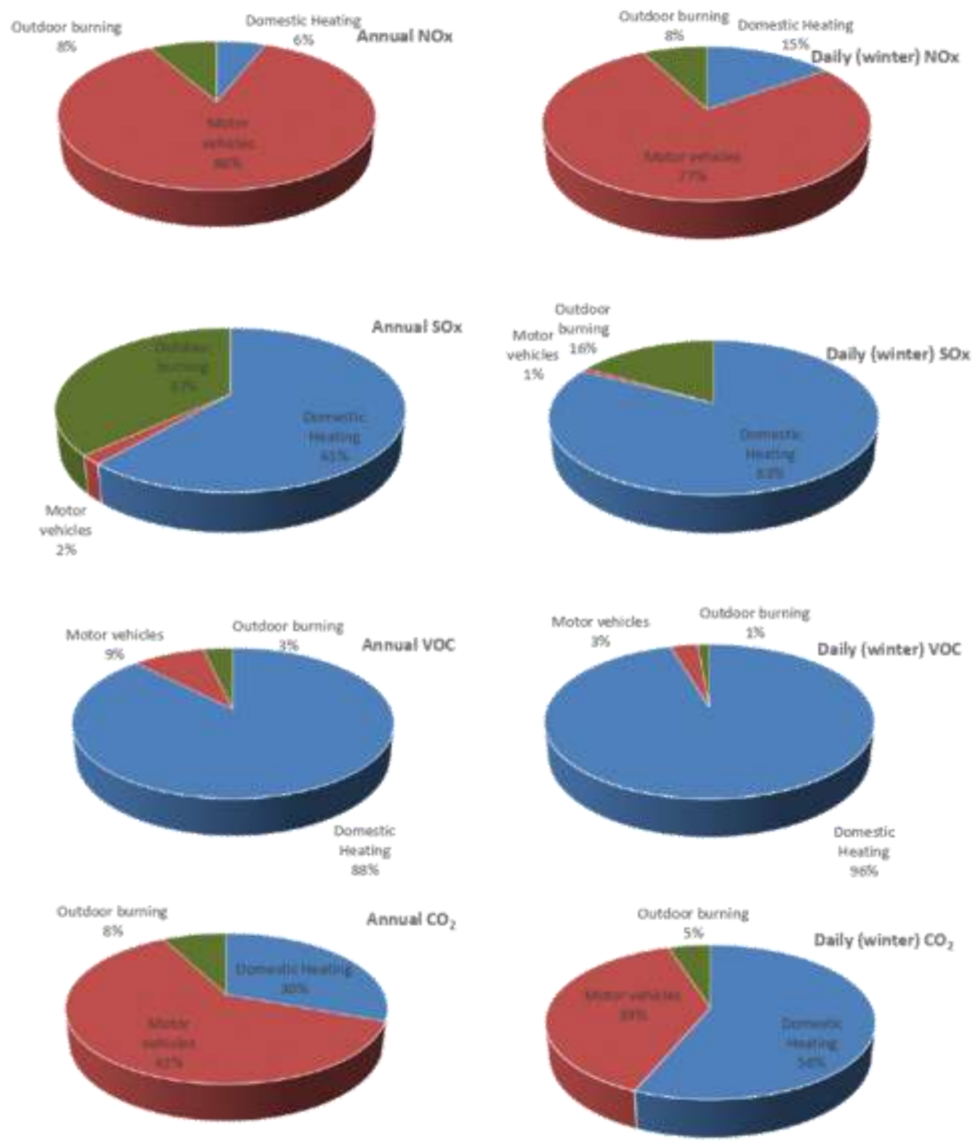

Figure 4.6: Relative contribution of sources to contaminant emissions in Waipawa.

Table 4.24: Monthly variations in daily PM_{10} emissions in Waipawa.

	Domestic heating		Outdoor burning		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day	%	kg/day
January	0	1%	7	72%	0	0%	3	27%	10
February	0	0%	7	72%	0	0%	3	28%	9
March	1	10%	9	70%	0	0%	3	20%	13
April	8	42%	9	45%	0	0%	3	13%	20
May	51	81%	9	15%	0	0%	3	4%	63
June	76	88%	8	10%	0	0%	3	3%	87
July	79	88%	8	9%	0	0%	3	3%	90
August	70	87%	8	10%	0	0%	3	3%	81
September	22	68%	8	24%	0	0%	3	8%	33
October	10	49%	8	38%	0	0%	3	13%	20
November	2	13%	8	65%	0	0%	3	22%	12
December	0	1%	7	72%	0	0%	3	27%	10
Total kg/year	9843	72%	2935	21%	0	0%	951	7%	13729

Table 4.25: Daily contaminant emissions from all sources in Waipawa (winter average).

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	79	115	974	1410	6	9	3	4
Transport	3	4	112	162	31	45	0	0
Industry	0	0	0	0	0	0	0.0	0.0
Outdoor burning	8	12	44	63	3	5	1	1
Total	90	131	1130	1635	41	59	3	5
	VOC		CO_2		$PM_{2.5}$			
	kg	g/ha	tonnes	kg/ha	kg	g/ha		
Domestic home heating	288	417	17	25	79	115		
Transport	10	14	12	17	1	1		
Industry	0	0	0	0	0	0		
Outdoor burning	4	6	2	2	8	12		
Total	302	437	31	45	89	128		

Table 4.26: Annual contaminant emissions from all sources in Waipawa.

	PM_{10} t/year	CO t/year	NOx t/year	SOx t/year	VOC t/year	CO_2 t/year	$PM_{2.5}$ t/year
Domestic Heating	10	119	1	0	36	2159	10
Motor vehicles	1	41	11	0	4	4355	0
Industry	0	0	0	0	0	0	0
Outdoor burning	3	15	1	0	1	539	3
Total	14	176	13	0	41	7053	13

4.5 Waipukurau air emissions

4.5.1 Domestic heating

Table 4.27 shows the distribution of heating methods and fuels in Waipukurau. Around 1039 households use wood burners over half of these were installed prior to 2006.

Table 4.27: Home heating methods and fuels in Waipukurau.

	Heating methods		Fuel Use	
	%	HH	t/day	%
Electricity	64%	1,131		
Total Gas	14%	249	0.2	1%
Flued gas	5%	87		
Unflued gas	9%	159		
Oil	0%	0	0.0	0%
Open fire	4%	77		
Open fire - wood	4%	77	2	9%
Open fire - coal	0%		0.0	0%
Total Wood burner	59%	1,039	18	89%
Pre 2006 wood burner	33%	589	10	50%
2006-2013 wood burner	15%	261	5	22%
Post-2013 wood burner	11%	189	3	16%
Multi-fuel burners	0.3%	6		
Multi-fuel burners-wood	0.0%		0.0	0%
Multi-fuel burners-coal	0.3%	6	0.1	0%
Pellet burners	1%	15	0.1	0%
Total wood	64%	1,131	20	99%
Total coal	0%	6	0.1	0.3%
Total		1,758	21	100%

In 2020 around 157 kilograms of PM_{10} was estimated to be discharged on a typical winter's day from domestic home heating in Waipukurau. The annual $PM_{2.5}$ emission was estimated at 19 tonnes per year.

Figure 4.7 shows that the largest portion (67%) of the PM_{10} emissions are from pre 2006 wood burners. The NES design criteria for wood burners was mandatory for new installations on properties less than 2 hectares from September 2005. Wood burners installed after 2006 contribute to 23% of domestic heating PM_{10} emissions.

Tables 4.28 and 4.29 show the estimates of emissions for different heating methods under average and worst-case scenarios respectively. Days when households may not be using specific home heating methods are accounted for in the daily winter average emissions[6]. Under the worst-case scenario that all households are using a burner on any given night around 584 kilograms of PM_{10} is likely to be emitted. Seasonal variability in contaminant emissions is shown in Table 4.30.

[6] Total fuel use per day is adjusted by the average number of days per week wood burners are used (e.g.,6/7) and the proportion of wood burners that are used during July (e.g.,95%).

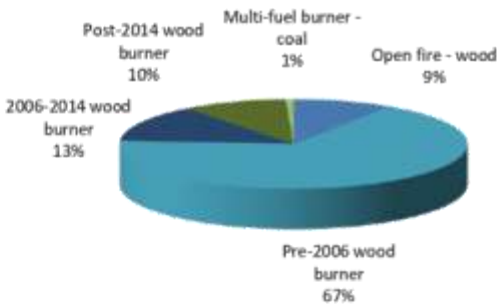

Figure 4.7: Relative contribution of different heating methods to average daily PM_{10} (winter average) from domestic heating in Waipukurau.

Table 4.28: Waipukurau winter daily domestic heating emissions by appliance type (winter average).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%
Open fire																							
Open fire - wood	1.9	9%	15	18	9%	106	132	5%	2	3	19%	0	0	8%	58	72	10%	3	4	9%	15	18	9%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner	18.5																						
Pre 2006 wood burner	10.5	50%	105	130	67%	1468	1825	76%	5	7	44%	2	3	46%	346	430	61%	17	21	50%	105	130	67%
2006-2014 wood burner	4.6	22%	21	26	13%	209	260	11%	2	3	19%	1	1	20%	93	116	16%	7	9	22%	21	26	13%
Post 2014 wood burner	3.4	16%	15	19	10%	151	188	8%	2	2	14%	1	1	15%	67	84	12%	5	7	16%	15	19	10%
Pellet Burner	0.1	0%	0.1	0	0%	1	1	0%	0	0	0%	0	0	0%	1	1	0%	0	0	0%	0	0	0%
Multi fuel burner																							
Multi fuel– wood	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Multi fuel – coal	0.1	0%	1	1	1%	7	8	0%	0	0	1%	0	1	11%	1	1	0%	0	0	0%	1	1	1%
Gas	0.2	1%	0.01	0	0%	0	0	0%	0	0	2%	0	0	0%	0	0	0%	1	1	2%	0	0	0%
Oil	0.0	0%	0.00	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Wood	20.5	99%	155.49	193	99%	1936	2407	100%	12	14	97%	4	5	89%	565	703	100%	33	41	98%	155	193	99%
Total Coal	0.1	0%	1.17	1	1%	7	8	0%	0	0	1%	0	1	11%	1	1	0%	0	0	0%	1	1	1%
Total	21		157	195		1942	2416		12	15		5	6		566	704		34	42		157	195	

Table 4.29: Waipukurau winter daily domestic heating emissions by appliance type (worst case).

	Fuel Use		PM_{10}			CO			NO_x			SO_x			VOC			CO_2			$PM_{2.5}$		
	t/day	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	kg	g/ha	%	T	kg/ha	%	kg	g/ha	%
Open fire																							
Open fire - wood	2.2	9%	16	20	8%	119	148	5%	3	3	18%	0	1	7%	65	81	9%	3	4	8%	16	20	8%
Open fire - coal	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wood burner	22.8																						
Pre 2006 wood burner	12.9	51%	129	160	67%	1805	2246	76%	6	8	44%	3	3	44%	426	529	62%	21	26	50%	129	160	67%
2006-2014 wood burner	5.7	23%	26	32	13%	257	320	11%	3	4	20%	1	1	19%	114	142	17%	9	11	22%	26	32	13%
Post 2014 wood burner	4.1	16%	19	23	10%	186	232	8%	2	3	14%	1	1	14%	83	103	12%	7	8	16%	19	23	10%
Pellet Burner	0.1	0%	0	0	0%	2	2	0%	0	0	0%	0	0	0%	2	2	0%	0	0	0%	0	0	0%
Multi fuel burner																							
Multi fuel– wood	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Multi fuel – coal	0.1	0%	2	3	1%	12	15	0%	0	0	1%	1	1	15%	2	2	0%	0	0	1%	2	2	1%
Gas	0.2	1%	0	0	0%	0	0	0%	0	0	2%	0	0	0%	0	0	0%	1	1	1%	0	0	0%
Oil	0.0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Wood	25	99%	190	236	99%	2370	2948	99%	14	17	97%	5	6	85%	690	858	100%	40	50	98%	190	236	99%
Total Coal	0	0%	2	3	1%	12	15	0%	0	0	1%	1	1	15%	2	2	0%	0	0	1%	2	2	1%
Total	25		192	239		2382	2963		14	18		6	7		691	860		41	51		192	238	

Table 4.30: Monthly variations in contaminant emissions from domestic heating in Waipukurau.

	PM_{10} kg/day	CO kg/day	NOx kg/day	SOx kg/day	VOC kg/day	CO_2 t/day	$PM_{2.5}$ kg/day
January	0	2	0	0	1	0	0
February	0	0	0	0	0	0	0
March	3	34	0	0	9	1	3
April	17	171	2	0	66	4	17
May	101	1243	8	3	368	22	101
June	151	1874	11	4	547	32	151
July	157	1942	12	5	566	34	157
August	138	1725	10	4	498	30	138
September	45	526	4	1	164	10	45
October	20	209	2	1	76	4	20
November	3	40	0	0	11	1	3
December	0	2	0	0	1	0	0
Total (kg/year)	19475	238209	1557	554	70723	4184	19462

4.5.2 Motor vehicles

Table 4.31 shows that around two kilograms of PM_{10} and one kilogram of $PM_{2.5}$ are emitted per day in Waipukurau as a result of motor vehicles. Around 43% is from brake and tyre wear and 38% is from tailpipe emissions.

Table 4.31: Summary of daily motor vehicle emissions in Waipukurau

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Tailpipe	0.8	1	90	119	25	33	0	0
Brake and tyre	0.9	1						
Road dust	0.4	1						
Total	2.1	3	90	119	25	33	0	0
	VOC		CO_2		$PM_{2.5}$			
	kg	g/ha	t	kg/ha	kg	g/ha		
Tailpipe	8	10	10	13	0	1		
Brake and tyre					0	0		
Road dust					0	0		
Total	8	10	0	0	1	1		

4.5.3 Industry

There are a small number of industrial and commercial activities discharging particulate to air in Waipukurau. Table 4.32 suggests that emissions from these activities are minimal with less than one kilogram per day of PM_{10} during the winter months.

Table 4.32: Summary of emissions from industrial and commercial activities (daily winter) in Waipukurau.

		PM_{10}		CO		NOx		SOx	
	Hectares	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Waipukurau		0.1	0.1	0.1	0.2	0.2	0.3	0.7	1.0
		VOC		CO_2		$PM_{2.5}$			
	Hectares	kg	g/ha	t	kg/ha	kg	g/ha		
Waipukurau		0	0	0.09	.13	0.1	0.1		

4.5.4 Outdoor burning

Around 17 kilograms of PM_{10} from outdoor burning could be expected per day during the winter months on average in Waipukurau (Table 4.33). As noted for the other areas, there are a number of uncertainties relating to the calculations and there is reliance on outdoor burning rates in other similarly sized north island towns and assumptions around the distribution of burning throughout the winter and potential variability in emission factors. Outdoor burning emission estimates include a higher degree of uncertainty relative to domestic heating, motor vehicles and industry.

Table 4.33: Outdoor burning emission estimates for Waipukurau.

	PM_{10}	CO	NOx	SOx	VOC	CO2	$PM_{2.5}$
	kg/ day	kg/ day	kg/ day	kg/ day	kg/ day	t/ day	kg/day
Summer (Dec-Feb)	14	75	5	1	7	3	14
Autumn (Mar-May)	19	101	7	1	10	4	19
Winter (June-Aug)	17	91	6	1	9	3	17
Spring (Sept-Nov)	16	85	6	1	8	3	16

4.5.5 Total emissions

Figure 4.8 shows indicates the main source of daily and annual PM_{10} and $PM_{2.5}$ in Waipukurau is domestic home heating. The relative contribution of sources to other contaminant emissions is shown in Figure 4.9. Seasonal variability in PM_{10} emissions is shown in Table 4.34 and daily and annual contaminant emissions in Tables 4.35 and 4.36 respectively.

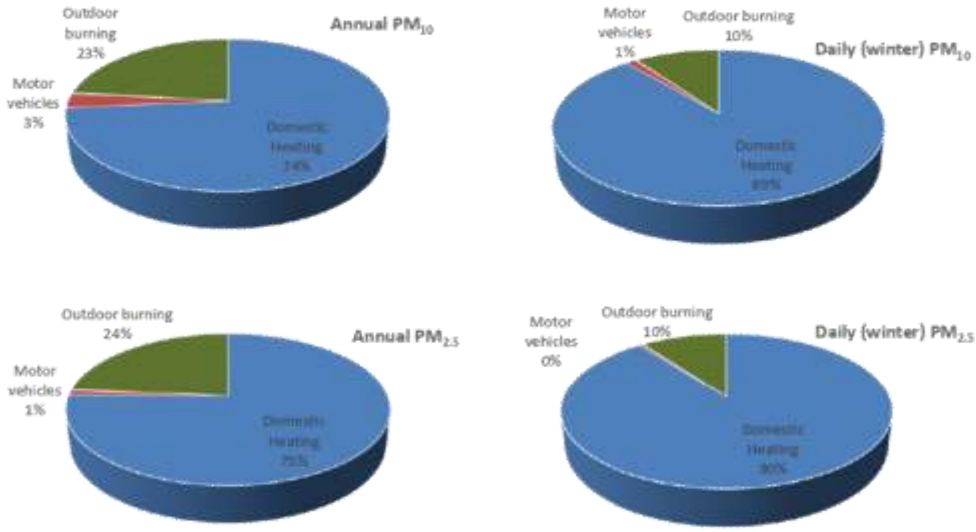

Figure 4.8: Relative contribution of sources to daily and annual PM_{10} and $PM_{2.5}$ in Waipukurau.

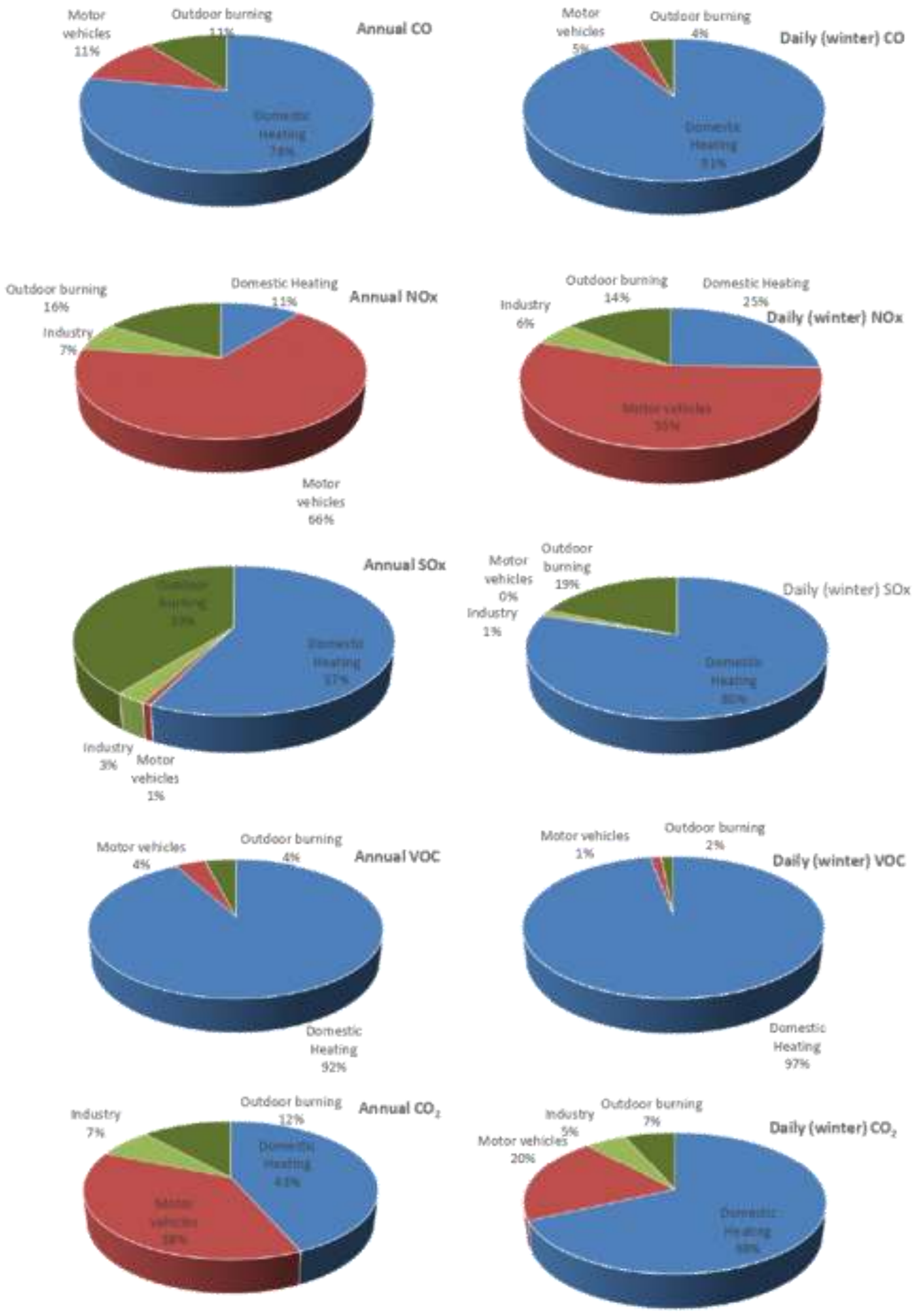

Figure 4.9: Relative contribution of sources to contaminant emissions in Waipukurau.

Table 4.34: Monthly variations in daily PM_{10} emissions in Waipukurau.

	Domestic heating		Outdoor burning		Industry		Motor vehicles		Total
	kg/day	%	kg/day	%	kg/day	%	kg/day	%	kg/day
January	0	1%	14	85%	0.2	1%	2	13%	17
February	0	0%	14	85%	0.3	2%	2	13%	17
March	3	11%	19	79%	0.2	1%	2	9%	24
April	17	44%	19	49%	0.2	1%	2	6%	39
May	101	82%	19	16%	0.2	0%	2	2%	123
June	151	88%	17	10%	0.2	0%	2	1%	171
July	157	89%	17	10%	0.2	0%	2	1%	176
August	138	87%	17	11%	0.2	0%	2	1%	158
September	45	71%	16	26%	0.2	0%	2	3%	63
October	20	52%	16	42%	0.2	1%	2	6%	39
November	3	14%	16	74%	0.2	1%	2	10%	22
December	0	1%	14	85%	0.2	1%	2	13%	17
Total kg/year	19475	74%	6120	23%	86.8	0%	795	3%	26477

Table 4.35: Daily contaminant emissions from all sources in Waipukurau (winter average).

	PM_{10}		CO		NOx		SOx	
	kg	g/ha	kg	g/ha	kg	g/ha	kg	g/ha
Domestic home heating	157	195	1942	2416	12	15	5	6
Transport	2	3	94	116	26	33	0	0
Industry	0.2	0	1	1	3	3	0.1	0.1
Outdoor burning	17	22	91	113	6	8	1	1
Total	176	219	2128	2646	47	59	6	7
	VOC		CO_2		$PM_{2.5}$			
	kg	g/ha	tonnes	kg/ha	kg	g/ha		
Domestic home heating	566	704	34	42	157	195		
Transport	8	10	10	12	1	1		
Industry	0.2	0.2	2.6	3.2	0.2	0.2		
Outdoor burning	9	11	3	4	17	22		
Total	583	725	49	61	175	217		

Table 4.36: Annual contaminant emissions from all sources in Waipukurau.

	PM_{10} t/year	CO t/year	NOx t/year	SOx t/year	VOC t/year	CO_2 t/year	$PM_{2.5}$ t/year
Domestic Heating	19	238	2	1	71	4184	19
Motor vehicles	1	34	10	0	3	3641	0.3
Industry	0.1	0.2	1.0	0.0	0.0	686	0.1
Outdoor burning	6	32	2	0	3	1125	6
Total	26	305	14	1	77	9635	26

5 WAIROA, WAIPAWA AND WAIPUKURAU PROJECTED PM_{10} AND $PM_{2.5}$

Air quality monitoring in Wairoa, Waipawa and Waipukurau has been limited to monitoring using screening or investigative methodologies. These data can not be used to assess NES compliance or quantify the magnitude of reduction required but do suggest that daily $PM_{2.5}$ concentrations may be in excess of the proposed NES and that some reductions may be required in all three towns. This evaluation assesses the potential reductions in PM_{10} and $PM_{2.5}$ emissions in these towns.

5.1 Methodology

Trends in emissions of PM_{10} and $PM_{2.5}$ in Wairoa, Waipawa and Waipukurau were assessed by combining the emission inventory results for 2020 (Section 4) with a natural sources contribution and estimating changes in emissions sources over time. The latter focuses on the domestic heating sector with changes in emissions occurring as older burners are replaced with NES compliant burners or ULEB as a result of natural attrition.

5.1.1 Assumptions

- A 9% contribution of natural sources to daily winter PM_{10} and a 6% contribution to daily winter $PM_{2.5}$ based on source apportionment data for Hastings.
- A 10% uptake of ULEB for new burner installations from 2021.
- A 25-year natural attrition replacement rate for older wood burners and multifuel burners.
- No changes in open fire or pellet burner usage.
- No change in industrial emissions from 2020 to 2030.
- A population increase of 17% from 2019 – 2031 for Waipukurau and 8% for Waipawa based on Central Hawke's Bay District Council's medium population projections (Central Hawke's Bay District Council, 2020) and a 3% increase in occupied dwellings for Wairoa from 2018 to 2028 (Wairoa District Council, 2017).
- 10% of new dwellings install wood burners[7].
- A 6% decrease in motor vehicle emissions by 2030. This is based on a 15% increase in VKT and an 18% reduction in motor vehicle emissions. The latter is based on VFEM version 6.0 with a setting of 2030. This estimate has a high degree of uncertainty, including uncertainty around the uptake of electric vehicles but minimal impact on the projection as the base motor vehicle contribution is low at less than 5% of the daily winter 2020 PM_{10} emissions.

5.2 Wairoa

Figure 5.1 shows the projected daily winter PM_{10} emissions for Wairoa in the absence of additional regulation and with the addition of a requirement that new burner installations meet the ULEB criteria. A reduction of around 20% in Wairoa PM_{10} is estimated by 2030 in the absence of regulatory measures and a 25% reduction

[7] The proportion of new dwellings installing wood burners was not obtainable from the district council records provided. The analysis is not sensitive to the assumption that 10% of new dwellings install burners because of the low number of new dwellings each year.

could occur by 2030 as a result of the ULEB requirement if implemented in 2025. No direct comparison to air quality targets is possible as representative concentrations for PM_{10} and $PM_{2.5}$ using NES compliant methods are not yet available for Wairoa.

The projected daily winter $PM_{2.5}$ emissions are shown in Figure 5.2 for the no regulatory intervention option and for the introduction of an emission criteria for new burner installations.

It is unclear whether management measures will be required in Wairoa to meet the NES for PM_{10} or proposed NES for $PM_{2.5}$.

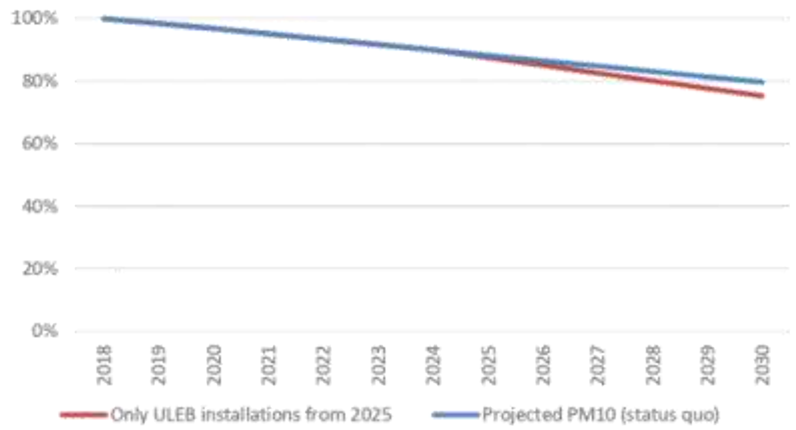

Figure 5.1: Projected daily winter PM_{10} emissions in Wairoa – no regulatory measures and the introduction of ULEB criteria for new burner installations from 2025.

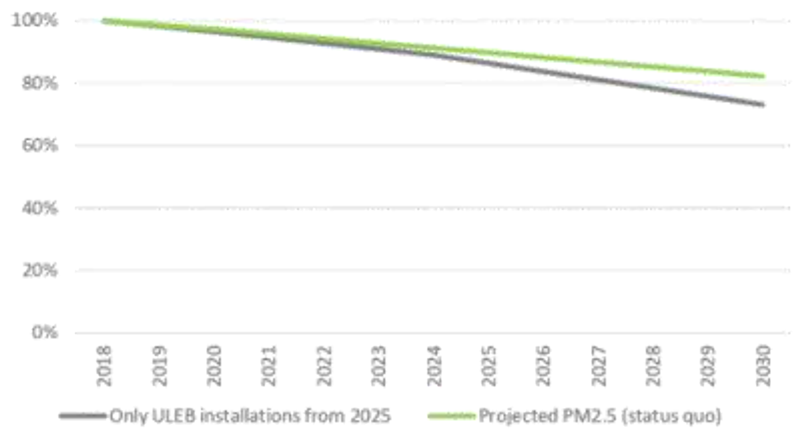

Figure 5.2: Projected daily winter $PM_{2.5}$ emissions in Wairoa – no regulatory measures and the introduction of ULEB criteria for new burner installations from 2025.

5.3 Waipawa

Figure 5.3 shows the projected daily winter PM_{10} emissions for Waipawa in the absence of additional regulation and with the addition of a requirement that new burner installations meet the ULEB criteria. A reduction of around 30% in PM_{10} is estimated by 2030 in the absence of regulatory measures and a 40% reduction could occur by 2030 as a result of the ULEB requirement if implemented in 2025. No comparison to air quality targets is possible as representative concentrations for PM_{10} and $PM_{2.5}$ are not yet available for Waipawa.

The projected daily winter $PM_{2.5}$ emissions are shown in Figure 5.4 for the no regulatory intervention option and for the introduction of an emission criteria for new burner installations.

It is unclear whether management measures will be required in Waipawa to meet the NES for PM_{10} or proposed NES for $PM_{2.5}$.

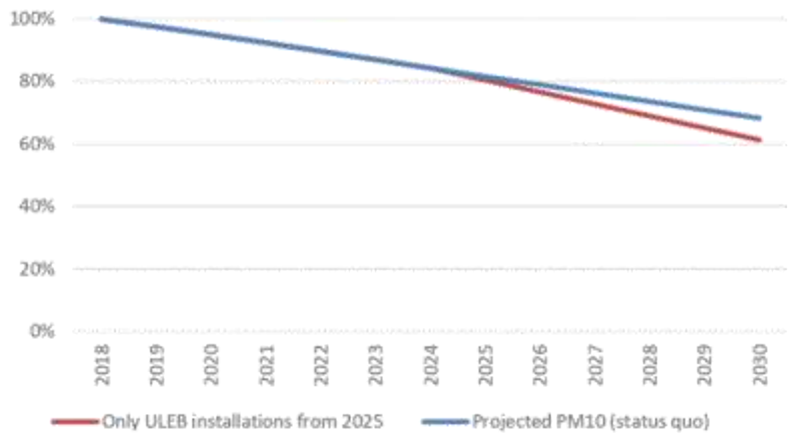

Figure 5.3: Projected daily winter PM_{10} emissions in Waipawa – no regulatory measures and the introduction of ULEB criteria for new burner installations from 2025.

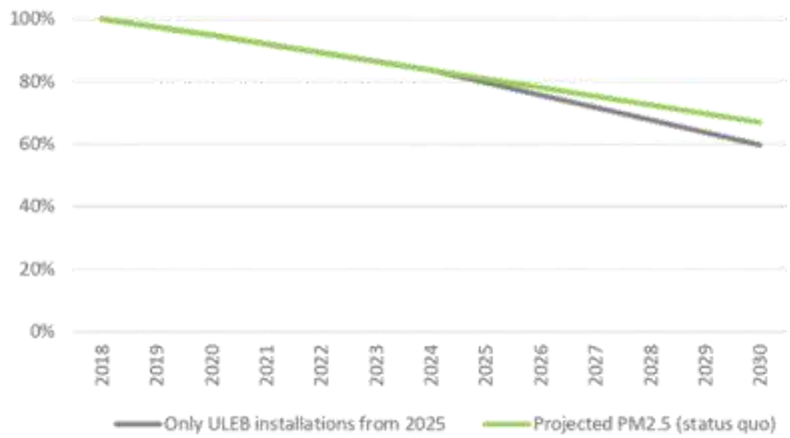

Figure 5.4: Projected daily winter $PM_{2.5}$ emissions in Waipawa – no regulatory measures and the introduction of ULEB criteria for new burner installations from 2025.

5.4 Waipukurau

Figure 5.5 shows the projected daily winter PM_{10} emissions for Waipukurau in the absence of additional regulation and with the addition of a requirement that new burner installations meet the ULEB criteria. A reduction of around 30% in PM_{10} is estimated by 2030 in the absence of regulatory measures and a 40% reduction could occur by 2030 as a result of the ULEB requirement if implemented in 2025. No comparison to air quality targets is possible as representative concentrations for PM_{10} and $PM_{2.5}$ are not yet available for Waipukurau.

The projected daily winter $PM_{2.5}$ emissions are shown in Figure 5.6 for the no regulatory intervention option and for the introduction of an emission criteria for new burner installations.

It is unclear whether management measures will be required in Waipukurau to meet the NES for PM_{10} or proposed NES for $PM_{2.5}$.

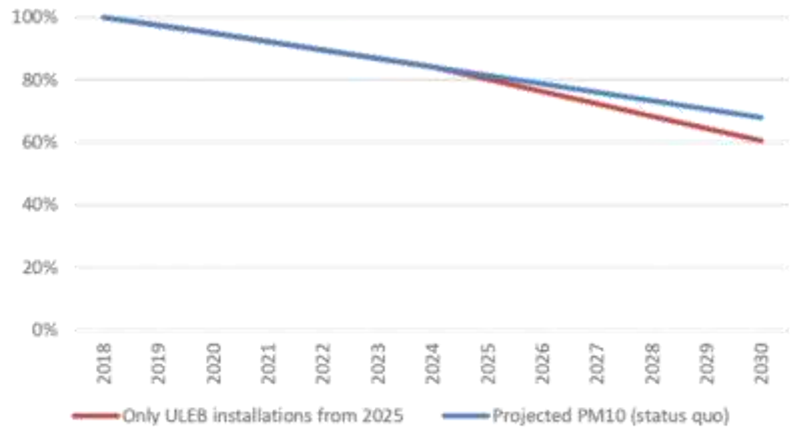

Figure 5.5: Projected daily winter PM_{10} emissions in Waipukurau – no regulatory measures and the introduction of ULEB criteria for new burner installations from 2025.

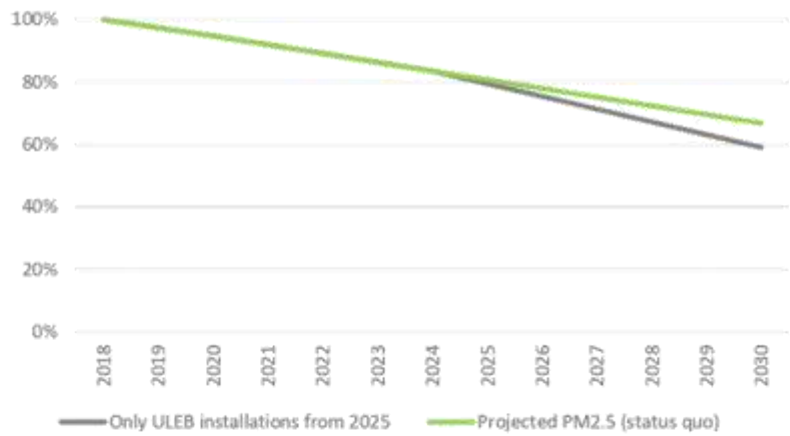

Figure 5.6: Projected daily winter $PM_{2.5}$ emissions in Waipukurau – no regulatory measures and the introduction of ULEB criteria for new burner installations from 2025.

6 CONCLUSIONS

Air quality management introduced via the Resource Regional Management Plan Change 2 – Air Quality Plan (operative 1 January 2012) has resulted in significant improvements in PM_{10} concentrations in both Napier and Hastings.

Napier has been compliant with the NES for PM_{10} since 2014 with only one exceedance of 50 µg/m^3 in each of 2014 and 2018. In Hastings three calendar years since 2015 have recorded only one exceedance of 50 µg/m^3 (2015, 2017, 2020) and the highest number of exceedences over this period is seven (2016). This compares with every year exceedences prior to 2015 with a maximum of 27 being recorded in 2008.

Data for Napier indicates that sufficient reductions in daily winter PM_{10} have likely been achieved, no increases in emissions are anticipated and no additional regulatory measures are likely to be required to meet the NES for PM_{10}. The safety margin for ongoing compliance is relatively small, however, and there is the possibility that meteorological conditions worse than experienced over the 2006 to 2020 period may occur.

In Hastings further reductions are required for compliance with the NES for PM_{10} but these may occur in the absence of additional regulation. The timeframe for compliance could be around five years (i.e., by 2025). However, there is some disparity between emissions and concentrations from around 2018 which brings uncertainty to the evaluation. Additional measures may be required for Hastings to achieve compliance with the NES for PM_{10}.

Monitoring of $PM_{2.5}$ has been carried out in Napier since 2019 and in Hastings since 2017. Annual average $PM_{2.5}$ concentrations in both areas are below the proposed NES of 10 µg/m^3. Annual $PM_{2.5}$ concentrations are not predicted to increase.

In Napier and Hastings, the daily $PM_{2.5}$ concentrations exceed the proposed NES of 25 µg/m^3. The reductions in daily $PM_{2.5}$ concentrations required to be compliant with the proposed NES could be around 20% and 33% in Napier and Hastings respectively. Napier estimates are based on only two years of monitoring data, however.

In Napier, daily $PM_{2.5}$ concentrations are not predicted to reduce by 20% by 2030 and additional management measures may be required. In Hastings, additional regulatory intervention is also likely to be required to meet the proposed daily NES for $PM_{2.5}$. Measures required could include introduction of an ultra-low emission burner criteria for new burner installations.

An emission inventory for each of Wairoa, Waipawa and Waipukurau identified domestic home heating as the main source of daily winter PM_{10} and $PM_{2.5}$ emissions and annual emissions in Waipawa and Waipukurau. In Wairoa industry is a significant contributor to PM_{10} and $PM_{2.5}$ emissions and contributes 43% of the annual PM_{10} and 37% of the annual $PM_{2.5}$ emissions. Monitoring for compliance with the proposed NES using reference or equivalent methods is yet to occur in these towns. An evaluation of trends in emissions from 2020 to 2030 for each town predicts a reduction in PM_{10} and $PM_{2.5}$ because of the natural attrition replacement of older burners not meeting the NES design criteria emission limit. Monitoring of $PM_{2.5}$ is required to establish existing concentrations and whether the projected reductions will be sufficient to achieve compliance with the NES.

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APPENDIX B: EMISSION FACTORS FOR DOMESTIC HEATING.

Emission factors were based on the review of New Zealand emission rates carried out by Wilton et al., (2015) for the Ministry for the Environments air quality indicators programme. This review evaluated emission factors used by different agencies in New Zealand and where relevant compared these to overseas emission factors and information. Preference was given to New Zealand based data where available including real life testing of pre 1994 and NES compliant wood burners (Wilton & Smith, 2006; Smith, et. al., 2008) and burners meeting the NES design criteria for wood burners (Bluett et al., 2009; Smith et al., 2009).

The PM_{10} open fire emission factor was reduced in the review relative to previous factors. Some very limited New Zealand testing was done on open fires during the late 1990s. Two tests gave emissions of around 7.2 and 7.6 g/kg, which at the time was a lot lower than the proposed AP42 emission factors (http://www.rumford.com/ap42firepl.pdf) for open fires and the factors used in New Zealand at the time (15 g/kg). An evaluation of emission factors for the 1999 Christchurch emission inventory revised the open fire emission factor down from 15 g/kg to 10 g/kg based on the testing of Stern et al., (1992) in conjunction with the results observed for New Zealand (as reported in Wilton, 2014). The proposed AP42 emission factors (11.1 g/kg dry) now suggest that the open fire emission factor may be lower still and closer to the result of the limited testing carried out in New Zealand. Consequently a factor of 7.5 g/kg for PM_{10} (wet weight) is proposed to be used for open fires in New Zealand based on the likelihood of the Stern et al., (1992) data being dry weight (indicating a lower emission factor), the data supporting a proposed revised AP 42 factor and the results of the New Zealand testing being around this value. It is proposed that other contaminant emissions for open fires be based on the proposed AP42 emission factors adjusted for wet weight.

The emission factor for wood use on a multi fuel burner was also reduced from 13 g/kg down to the same value as the pre 2004 wood burner emission factor (10 g/kg). The basis for this was that there was no evidence to suggest that multi fuel burners burning wood will produce more emissions than an older wood burner burning wood.

Emission factors for coal use on a multi fuel burner are based on limited data, mostly local testing. Smithson, (2011) combines these data with some further local testing to give a lower emission factor for coal use on multi fuel burners. While these additional data have not been viewed, and it is uncertain whether bituminous and subbituminous coals are considered, the value used by Smithson has been selected. The Smithson, (2011) values for coal burning on a multi fuel burner have also been used for PM_{10}, CO and NOx as it is our view that many of the more polluting older coal burners (such as the Juno) will have been replaced over time with more modern coal burners.

No revision to the coal open fire particulate emission factor was proposed, as two evaluations (Smithson, (2011) and Wilton 2002) resulted in the same emission factor using different studies. Emissions of sulphur oxides will vary depending on the sulphur content of the fuel, which will vary by location. A value of 8 g/kg is proposed for SOx based on an assumed average sulphur content of 0.5 g/kg and relationships described in AP42 for handfed coal fired boilers (15.5 x sulphur content).

Emission factors for $PM_{2.5}$ are based on 100% of the particulate from wood burning being in the $PM_{2.5}$ size fraction and 88% of the PM_{10} from domestic coal burning. The $PM_{2.5}$ component of PM_{10} is typically expressed as a proportion. The AP42 wood stove and open fire proportion is based on 1998 data and given as 93% of the PM_{10} being $PM_{2.5}$ (http://www.epa.gov/ttnchie1/efdocs/rwc_pm25.pdf). Smithson, (2011) uses a proportion of 97% which is more consistent with current scientific understanding that virtually all the particulate from wood burning in New Zealand is less than 2.5 microns in diameter (Perry Davy, pers comm, 2014). Literature review of the proportion of PM_{10} that was $PM_{2.5}$ returns minimal information for domestic scale wood use. The technical advisory group to the Ministry for the Environment (2014) air quality indicators project on emissions advised their preference for a value of 100% and we have opted for this value for subsequent work because information is indicative of a value nearing 100%. Further investigations into this may be warranted in the future given the focus towards $PM_{2.5}$. A value of 88% from Ehrlich & Kalkoff, (2007) was used for the proportion of PM_{10} in the $PM_{2.5}$ size fraction for small scale coal burning.

An emission factor of 0.5 g/kg was proposed for NOx from wood burners based on the AP42 data because the non-catalytic burner measurements were below the detection limit but the catalytic converter estimates (and conventional burner estimates) weren't. This value is half of the catalytic burner NOx estimate.

A ratio of 14 x PM_{10} values was used for CO emission estimates as per the AP42 emissions table for wood stoves. This is selected without reference to any New Zealand data owing to the latter not being in any publicly available form.

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