Coastal Adaptation

Adapting to coastal change and hazard risk in Aotearoa New Zealand

Special Publication 5, November 2022

Te Hunga Takutai o Aotearoa
NEW ZEALAND COASTAL SOCIETY

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The New Zealand Coastal Society was inaugurated in 1992 'to promote and advance sustainable management of the coastal environment'. The society provides a forum for those with a genuine interest in the coastal zone to communicate amongst themselves and with the public. The society currently has over 400 members based in New Zealand and overseas, including representatives from a wide range of coastal science, engineering and planning disciplines, employed in the consulting industry; local, regional and central government; research centres; and universities.

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Back cover: Waitarere Beach, Manawatu-Whanganui (Photo: T FitzGerald)

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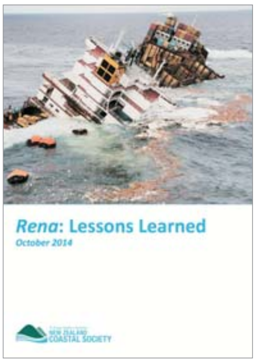
This publication is the fifth in the NZCS Special Publication series. The previous four titles are listed below and are available to download in pdf format from the NZCS website (www.coastalsociety.org.nz) or the University of Auckland's figshare site (https://auckland.figshare.com/coastalsociety).



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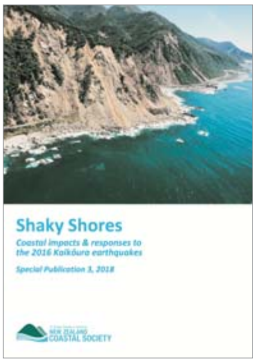

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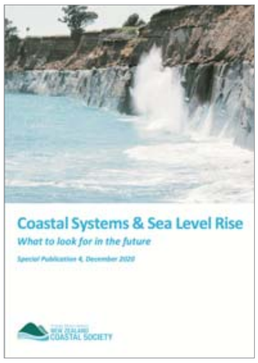

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Foreword

Amy Robinson and Mark Ivamy, NZCS Co-Chairs

The New Zealand Coastal Society – Te Hunga Takutai o Aotearoa (NZCS) takes a leading role in bringing people together to improve the sustainable management of our coastal environment. Our membership comprises planners, scientists and engineers who specialise in this mahi over the 18,000 km of Aotearoa coastline. The NZCS special publication series is an important initiative that brings together a collection of articles to improve our knowledge on nationally significant matters.

This is the fifth NZCS special publication and the focus is on adapting to coastal change and hazard risk. The NZCS is proud to share this special publication that tackles such a key issue critical to New Zealand's economic, social, cultural and environmental well-being. The publication covers policy framework and engagement recommendations, understanding of mātauranga and science, and the progress being made in the built environment to adapt to climate change near the coast. Each article is based on observations and experiences from both people working at the community level and by nationally recognised experts.

The publication offers insights on how communities can respond to coastal hazards and climate change risk, and will support the development of dynamic adaptive pathway planning to inform future community decision making. Many of the articles share leading edge work and are forging new ground for responding to coastal hazards and climate change risks. There are many practical learnings and honest observations offered by those working in this complex area.

On behalf of the New Zealand Coastal Society, we would like to sincerely thank all the contributors who have shared their work and crafted the content for this special publication. And thanks to the publication team for your passion and commitment to make this happen, in particular our fantastic lead editor Charles Hendtlass who has supported the NZCS over three decades.

We know this publication will be a valuable resource to build on the knowledge of coastal adaptation and we encourage you to share it widely.

Noho ora mai

Ocean Beach, Whangārei Heads, Te TaiTokerau (Photo: T FitzGerald)

1 Setting the scene

Coastal new build, Waihi Beach, April 2022 (Photo: Rob Bell)

The foundations of the sea-level rise challenge: Coasts are a special case for adaptation

By Judy Lawrence and Robert Bell

Introduction

Coasts pose a special case for adaptation due to the progressive and changing risks from sea-level rise (SLR). The IPCC Working Group II Sixth Assessment (IPCC 2022) concluded that sea-level rise poses a distinctive and severe adaptation challenge, as it implies dealing with both slow onset changes and increased frequency and magnitude of extreme sea level events, which will escalate in the coming decades. They will occur earlier where rates of relative SLR are locally higher (due to land subsidence) and to higher levels if low-likelihood, high-impact outcomes associated with collapsing ice sheets, occur.

There is already committed SLR stored in the oceans from past greenhouse gas emissions. Impacts are being observed now and near-term risks are projected to emerge well before 2050. The ability to adapt to current coastal impacts, to cope with ongoing and increasing coastal risks, and to curtail acceleration of sea-level rise beyond 2050, depends on near-term and ongoing mitigation and adaptation actions. But there are limits to adaptation in the face of progressive SLR that, over time, will be existential for many ecosystems and human systems. As protection becomes unaffordable and the limits to accommodation and advance adaptations become obvious, planned relocation/managed retreat becomes the only way to avoid inevitable flooding in low-lying coastal areas[1]. This makes SLR a particular challenge for adaptation. Figure 1 demonstrates this as an evolving and shrinking adaptation space as the sea rises.

By investing now in adaptations that have a limited life, lock-in of 'permanent' buildings and infrastructure, compounds the transition from the hazard and future risk, making it harder to change tack as the sea advances. Temporary adaptation options like seawalls, filling land, or raising buildings above flood levels may buy time, but they entrench development, making it harder to transition to managed retreat and increasing the adjustment costs for future generations.

To make matters worse, effective adaptation to SLR impacts has been delayed by the dominant decision-making paradigm that is driven by short-term thinking and vested interests, conventional static approaches, funding limitations, inadequate governance and institutional arrangements, financial policies, and blunt insurance levers. Compounding such influences are very strong incentives to house people, build infrastructure to service them like before, and a kiwi desire for living by the coast and the amenity it brings.

[1] Incremental types of adaptation include Protect, Advance and Accommodate, and will have limits that can be anticipated enabling parallel development of Avoid strategies to prepare for Planned Relocation/Managed Retreat. Protect includes hard structures like seawalls; Advance includes beach renourishment, dune, and estuarine planting; Accommodate includes land filling, raising floor levels, all of which are temporary. Planned Relocation and Managed Retreat are permanent transformational adaptations, including removal of housing, people and assets, and their relocation to another location in a staged and planned manner that removes the risk entirely.

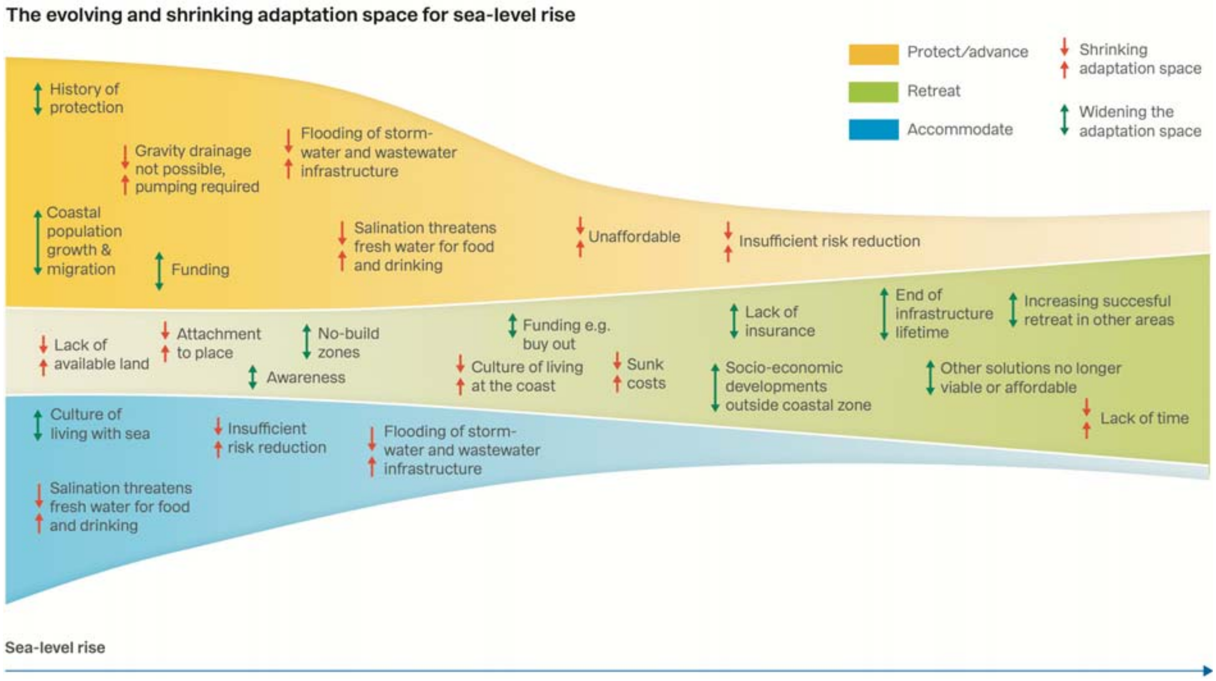

Figure 1: An illustrative example of adaptation options in an evolving and shrinking adaptation space. The coloured areas show the adaptation space to Protect/Advance/Accommodate, and Retreat changes as sea level rises. Different drivers and hard and soft limits shape this space. The figure highlights first, a general narrowing of the adaptation space as a whole and, second, a change in the ratio between the three adaptation strategies, with retreat becoming dominant. This will apply differently for different coastal archetypes due to local contexts (after Haasnoot et al., 2021).

Without considering both short- and long-term adaptation needs, including beyond 2100, communities are increasingly confronted with a shrinking adaptation space (Figure 1), and adverse consequences are disproportionately borne by those exposed, and socially vulnerable people and communities. Incremental short-term adaptation has limits and will not be enough to avert losses and damage from ongoing SLR.

Shifting planning, civil defence and engineering practice from reactive responses to extreme events, to addressing the risks through implementation of suites of adaptation options and pathways, can help anticipate the risks equitably and sustainably. This enables preparation for the inevitable transformational adaptation, in a timely manner. The IPCC recently concluded (IPCC 2022) that responses are more effective if combined and/or sequenced, planned well ahead, aligned with sociocultural values and development priorities, and underpinned by inclusive community engagement processes.

The extent to which governments at national and local scales embed enabling conditions into law and policy that address the planning and funding gaps, will determine when place-based adaptation pathways start to address the practice and implementation deficits and close the coastal adaptation gap. This gap will increase unless urgent action is taken to both mitigate greenhouse gas emissions and implement effective adaptation. Delay in both mitigation and adaptation is not an option anymore.

Key issues for coastal practitioners

SLR is happening now and is ongoing for centuries

SLR is already impacting ecosystems, humans and their infrastructure, cultural values, and livelihoods. The primary impact of rising sea levels may also be compounded by climate-related changes in waves, storm surge (albeit small), rising water tables, river flows, high-intensity rainfall, and alterations in sediment inputs to the coast. Erosion is thought not to be as sensitive to SLR in New Zealand (Lawrence et al., 2022) and in Australia (Short, 2022) as net sediment budgets may still provide a buffer. As sea levels rise, coastal flooding will become the dominant climate-related coastal hazard, while erosion will remain localised. The cumulative direct and residual effect from SLR and associated impacts are projected to continue for centuries, necessitating ongoing adaptive decision making. Ultimately, transformational adaptation will be needed (e.g., managed retreat) in many low-lying coastal areas (Lawrence et al., 2020a; Haasnoot et al., 2021).

Early impacts caused by exposure, coastal and tidal processes

Early impacts of accelerating SLR detected at sheltered or subsiding coasts include gradual chronic flooding at high tides, wetland salinisation and ecosystem transitions, increased erosion, and coastal flood damage (Oppenheimer et al., 2019; Cooley et al., 2022; Lawrence et al., 2022). The largest observed changes in coastal ecosystems are being caused by the concurrence of human activities (e.g., stopbanks, causeways, water allocation, catchment management), waves, sediment transfers, and extreme storm events. The exposure of many low-lying coastal populations and ecosystems to SLR is high and economic development is disproportionately concentrated at the coast. Risks from SLR are very likely to increase by one order of magnitude well before 2100 (Lawrence et al., 2022). In New Zealand, building and infrastructure exposure to SLR and extreme coastal flooding ramps up within the first 1 m rise, thereafter, gradually easing for rises of 2-3 m (Paulik et al., 2020). Further, the cumulative risk from more frequent nuisance and moderate coastal flooding will overtake the risk from an extreme flood event with a SLR of 0.3 m for half New Zealand's coastal urban centres, and for most centres when SLR reaches 1 m (Paulik et al., 2021). This provides the evidence base for urgent adaptation planning.

Committed SLR legacy

Greenhouse gas emissions in the recent past and in the near future commit the Earth system to a sea-level rise legacy, which will only fully unfold in the centuries to come; for example, committed global sea-level rise over the next 2000 years will be in the range 2–6 m with 2°C peak warming (Mengel et al., 2018; Fox-Kemper et al., 2021). This reflects the long lag in the response of the ocean-ice sheet system to warming and means that the effect of the substantial growth in global emissions over previous decades will increasingly be felt up to mid-century and beyond, when SLR projections start to diverge. It will not be until the latter half of this century that we will know whether our near-term global emissions reduction plans have been effective in slowing down SLR. It does mean though that we know what is coming, at least until about mid-century, including several decision thresholds. Beyond that, the possible futures diverge, so we need to plan adaptively, knowing SLR will be ongoing with deepening uncertainty about how quickly it will change, particularly if polar ice-sheet tipping points are exceeded.

Different approaches for existing and future development

Practitioners are confronted with progressive SLR affecting both existing developed areas and areas that are as yet undeveloped, but where development is likely in the near term and over time, including housing pressure. This suggests different approaches are needed for these two situations – one to stop further exposure in existing exposed developments, and one to avoid increasing the risk to greenfield sites in the foreseeable future. This is the approach that the national coastal hazards and climate change guidance (MfE, 2017) and the NZ Coastal Policy Statement 2010 take.

Assumption of protection

Prevailing decision-making practice assumes that coastlines can continue to be maintained and protected (Lawrence et al., 2019). This comes with entrenchment of both direct and residual risk that increases over time, reaching thresholds, without adequate preparation or incentives to relocate. Prevailing protection and accommodation practices (e.g., seawalls, land fill, raised houses) entrench the notion that the sea can be held back, since those 'protected' are lulled into a false sense of security leading to maintaining 'protection' in the face of ever worsening risk. Incremental adaptation has limits. The consequence is patchy with inadequate adaptation decision making transferring the risk to others today and into the future, for example, those least able to cope, governments, the banking and insurance sector, and future generations.

Shrinking adaptation space

Incremental adaptation may not keep up with SLR (see Figure 1 and Haasnoot et al., 2021). Because of the limits to protect/advance, accommodate adaptations, and to current static planning constraints in the face of ongoing SLR, practitioners need to have one eye on the future working towards managed retreat and avoiding lock-in of adaptation options along the way. For example, some councils are using 'planning constraints' as an adaptation option to avoid increasing the risk even further by excluding building intensification in existing areas increasingly exposed to SLR. However, these planning changes have definite limits and fixed planning horizons, whereas managed retreat is the only truly transformational adaptation option that can 'avoid' the increasing risk.

A paradigm shift from reactive to anticipatory adaptation

Table 1 sets out how coastal risk management and infrastructure projects are generally being undertaken now compared with what an anticipatory dynamic adaptive planning design approach could look like. The current resource management reforms offer an opportunity to align statutory processes. For example, spatial planning to better enable dynamic adaptive approaches, rather than having these operate largely as a non-statutory process and applied inconsistently across New Zealand. More agile governance and investment/funding systems could also embrace adaptive pathway implementation to move away from the prevailing single-investment perspective.

Monitoring fundamental for anticipatory adaptation

Three principles underpin a shift from reactive to anticipatory planning that are embodied in Dynamic Adaptive Pathways Planning (DAPP), an anticipatory assessment tool that also embodies vulnerability assessment:

1. Anticipate future conditions by stress testing potential adaptation options using a range of scenarios of the future (e.g., SLR and coastal hazards) to assure decision makers of the robustness of options under increasingly worsening and uncertain conditions.
2. Enable timely action by the monitoring of indicators that can give advanced warning and trigger actions before thresholds of risk are reached.
3. Create realistic lead time to implement the adaptive action.

   (See Figure 2 and Figure 3.)

Accordingly, the DAPP assessment process can embody risk elements into the way adaptation thresholds, triggers and signals are designed (Lawrence et al., 2020b). For example, the indicators of impending risk can be societal, economic, environmental, and cultural in character and be monitored as part of the ongoing decision process and part of existing monitoring and risk management regimes.

Adaptation is local, regional, national and global

The view that adaptation is local and therefore the impacts of climate change must be addressed locally, will not equip us to adapt effectively. The IPCC WGII (IPCC, 2022) and the New Zealand National Climate Change Risk Assessment (MfE 2020) highlighted observed and projected cascading and compounding risks as new types of risk that propagate across domains and space, inside and outside jurisdictional borders (Lawrence et al., 2020c). Such framing challenges the notion that only local actors should implement and be

Conventional approach	Dynamic adaptive planning/design
Single investment perspective: focuses on upfront one-off projects (system currently discourages planned follow-on investments).	**Several timely investment options:** mapped out in a pre-planned adaptive strategy with alternative pathways.
Nominal design life (or life cycle): usually 100 years in coastal environment (NZ Coastal Policy Statement (NZCPS)).	**For each stage or option, determine possible range of 'shelf life' from SLR/other scenarios** (before a switch to the next stage/option/policy in alternative pathways).
Predict-then-act: most-likely or worst-case scenario for SLR and hazards in managing risk chosen.	**Track-then-act:** scenario neutral, tracking the headway to a pre-agreed local adaptation threshold.
Uses quantitative predictive models & risk assessment: to optimise solution vs cost & benefits for design life.	**Applies multiple scenarios to stress-test options or select a robust decision:** using models, risk assessments & economic evaluation tools.
Potential lock-in or path dependency of selected options, subdivisions or planning decisions: at worst, could become stranded assets.	**Flexibility, in options/stages and when to invest or avoid:** responsive to changing risk preferences, modal shifts, de-carbonisation & technology changes.
Monitoring when required: mostly for consenting conditions, focusing on near-term effects of the project on the environment and social/cultural values – or effectiveness of policy.	**Monitoring change progressively:** tracking indicators of change relative to early signals & triggers (warnings & decision points) e.g., diminishing Level of Service, maintenance costs, frequency of outages/events, SLR impacts across social, economic, cultural, environmental domains, reduced insurability, and changed risk preferences.

Table 1: Change of paradigm from reactive to anticipatory adaptation to SLR.

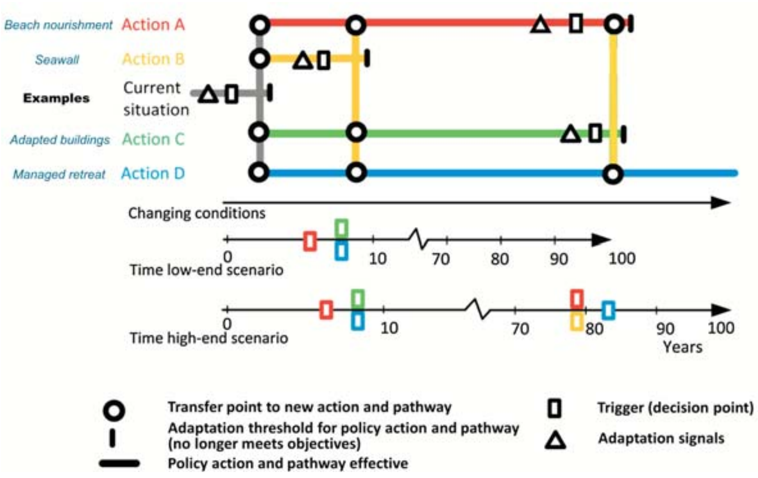

Figure 2: Conceptual metro-map of the dynamic adaptive pathways planning (DAPP) approach comprising four alternative actions or options (A–D) with examples to adapt to the current situation, which is almost at an Adaptation Threshold (AT) ('end of the line' represented by the vertical black bars). Triangles and rectangles symbolise the timing of an earlier signal followed by a trigger (decision point) to implement the next option in time to implement it before the AT is reached. For clarity, only two future scenarios are shown as timelines here. Note: The 2017 MfE Coastal Guidance recommends for coastal settings the use of four sea-level scenarios to stress-test pathways and assess the lifetime of options (after Haasnoot et al., 2013; Hermanns et al., 2017).

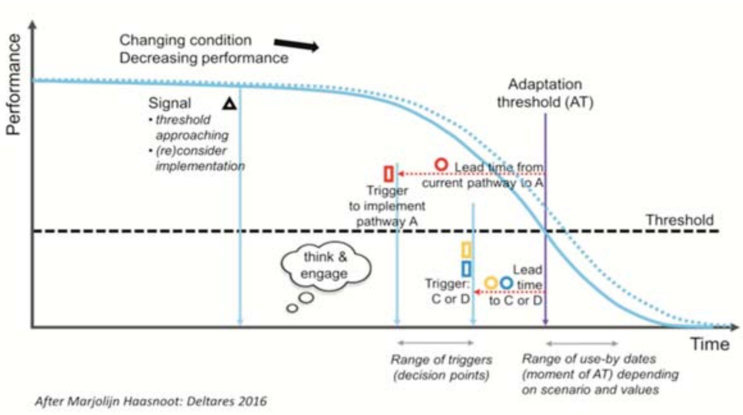

Figure 3: Concept of using monitored indicators, set up as defensible signals △ and triggers ▯ to awaken and prompt implementation of the next pathway option or action. In this example, option A requires a longer lead time than options C and D to implement. Note: Only two future scenarios are shown here for clarity, focusing the graphic on the bold blue line as an example. The 2017 MfE Coastal Guidance recommends using four sea-level scenarios to stress-test adaptation plans, including bracketing the time when the AT might occur.

responsible for adaptation (Nalau et al., 2015). Adaptation is local, regional, national and global linked to national, regional and local activities; for example, ports located at the coast and the trade flows to and from the hinterland and through cities intersect with the land and the sea as it rises, and the sediment flows that affect ship movements.

Conclusion

The predominantly reactive and short-term approach to adaptation that pervades our current mode of decision making does not serve us well for climate change adaptation. While our lifelines can prepare us for the extreme events that we have been used to from a relatively benign climate, the increasing extreme sea levels observed and projected, challenge our ability to be prepared and to respond effectively. Furthermore, the compounding nature of coastal climate change impacts, rising seas, and groundwater tables, require a proactive and planned approach to what we know is coming — they are foreseeable. Our planning system is simply not fit for purpose and requires creative design to make it fit in its current form. This has been mostly sub-optimal, locking in patterns of coastal development that are unsustainable. Even when there are opportunities to be proactive, they are not taken, due to inertia in the planning system, siloed professional practice, uncoordinated decision making, and unwillingness to act at a governance level due to political economy issues.

At the coast, the elephant in the room behind which inaction lies is who is responsible, who pays and when, across local, regional, and national governance levels. A fundamental part of answering these three questions is upskilling communities about the nature of the coastal adaptation challenge and enabling community involvement in the choices that will need to be made about the provision of services and potential managed retreat through sustained and transformational processes of adaptation. These will in most part be determined by national and local priorities, statutory requirements, enabling conditions that foster understanding and learning, funding models, and political will and leadership.

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Transformational adaptation in Aotearoa New Zealand: Towards a critical framing of coastal adaptation governance

By Bruce Glavovic

Introduction

Climate change is impacting many localities around Aotearoa New Zealand, especially along low-lying coasts. Coastal hazard risk is escalating. The need to reduce risk, adapt to change, and build community resilience is self-evident.

Coastal adaptation is underway. New adaptation legislation is being promulgated. However, notwithstanding these efforts, the pace and scale of coastal adaptation falls far short of what is necessary to ameliorate projected impacts.

The purpose of this article is to: (i) present a case for transformational coastal adaptation; (ii) describe governance challenges and enabling conditions to reduce coastal hazard risk; (iii) introduce a critical framing of coastal adaptation governance; (iv) spotlight key adaptation insights from the Coromandel Peninsula, Hawke's Bay, and Manawatū-Whanganui regions; and (v) identify priorities for enabling transformational coastal adaptation in Aotearoa.

The transformational coastal adaptation imperative

Coastal cities, settlements and communities are on the climate change frontline (Glavovic, 2013; IPCC, 2019; Glavovic et al., 2022). The IPCC Working Group II AR6 report (IPCC, 2022) shows that coasts are home to more than three billion people and associated infrastructure and economic activity. About a billion people are likely to be exposed to climate-compounded coastal hazard impacts around the middle of this century. Medium- to long-term prospects are bleak for people on low-lying coasts, including small islands, given accelerating and relentless sea-level rise (SLR). The transformational coastal adaptation imperative is therefore writ large.

Research for the Deep South National Science Challenge in Aotearoa indicates that an estimated 72,000 people and 50,000 buildings worth $12.5 billion were prone to extreme coastal flooding in 2019; and by 2100 a further 116,000 people will be exposed (https://deepsouthchallenge.co.nz/research-project/national-flood-risks-climate-change). Ten thousand properties may be uninsurable by 2050 (Storey et al., 2020) and the total replacement value of exposed infrastructure could be $5.1-7.8 billion for SLR of 1-1.5 m by 2100 (LGNZ, 2019). To compound matters, recent evidence of coastal subsidence means that SLR could occur much faster and reach higher than previously expected (https://www.searise.nz). A National Adaptation Plan (https://environment.govt.nz/news/national-adaptation-plan-released) has been released. Yet adaptation efforts are typically ad hoc, regionally variable, and wholly inadequate given the pace and scale of escalating coastal hazard risk. Transformational adaptation at the coast in Aotearoa is therefore urgent and compelling.

Transformational adaptation is distinct from incremental responses to climate change. It refers to systemic changes in unsustainable human-climate-environment interactions. It posits the reconfiguration of societal structures, processes and interactions to avert dangerous climate change and advances climate resilient development. It is especially compelling at the coast (Kuhl et al., 2021).

Translating this imperative into action is a governance challenge – one that involves and impacts all coastal actors, including governments, Indigenous Peoples, civil society, the private sector, science and the media, at all levels (Termeer et al., 2017). This inherently political process is complex and dynamic and fraught with uncertainty and contestation (Eriksen et al., 2015). Transformational adaptation challenges the status quo, including taken-for-granted assumptions about the political economy and power distributions that drive global warming and maladaptation. The pace and extent to which adaptation becomes transformative or languishes in incrementalism will drive medium- to long-term trajectories of coastal ecosystem health, livelihoods, and economic resilience, and vulnerability, equity, and justice in Aotearoa. Yet, calls for transformational adaptation are not being translated into real-world action. What key enabling governance conditions need to be institutionalised to reduce coastal hazard risk and adapt to climate change?

Governance challenges and enabling conditions to reduce coastal hazard risk

The IPCC identified five distinctive governance challenges and 10 critical enabling conditions for reducing coastal hazard risk in a changing climate (IPCC, 2019; Glavovic, et al., 2022).

First, the interconnected, dynamic and emergent character of coastal hazard risk gives rise to deep complexity. In response, enabling governance practices: (i) **leverage multiple knowledges** (including science, local knowledge and Indigenous Knowledges) to co-design enduring responses that are credible, salient and legitimate; and (ii) are founded on **robust institutional capabilities designed to tackle complex problems**.

Second, coastal adaptation governance has a **very long time-horizon**, but short-term decisions need to be made despite inevitable **uncertainty** about the distant future under relentless and irreversible SLR. The key is to: (i) take action now, but **maintain a long-term perspective and keep options open** to adjust responses as conditions change; and (ii) **prioritise anticipatory actions and avoid new development in exposed locations**.

Third, coastal hazard risk cuts across geographic, sectoral, temporal and jurisdictional boundaries giving rise to **major transboundary challenges**. Enabling governance responses are: (i) **coordinated** through networks and linkages built on trust to foster decision-making legitimacy; and (ii) geared towards building **shared understanding** through experimentation, innovation and social learning to craft locally-appropriate and widely-supported interventions.

Fourth, **inequity, injustice and social vulnerability are compounded by climate change** and hamper efforts to reduce coastal hazard risk. Enabling responses: (i) account for the *realpolitik* of adaptation and **prioritise vulnerability, justice and equity**; and (ii) build **community capabilities** to secure enduring resilience.

Fifth, **climate change compounds contestation at the coast**, increasing the prospect of destructive outcomes notwithstanding the potential for more productive outcomes through enabling coastal governance. Key is to: (i) i**nvolve stakeholders early and consistently** through tailor-made participatory processes that institutionalise negotiation best practice; and (ii) **create safe arenas for engagement** that foster inclusive, informed and authentic deliberation, reflexivity and collaboration.

Towards a critical framing of coastal adaptation governance

Traditional conceptualisations of adaptation governance – how societal or public choices are made and institutionalised in responding to climate change – have many strengths, notwithstanding vexing social dilemmas (Bisaro and Hinkel, 2016). Among other things, traditional adaptation governance scholarship accurately describes the physical perils of climate change and associated risks. It prescribes technically robust policy and management interventions rooted in rational-comprehensive planning. However, translating adaptation rhetoric into local reality remains elusive. The traditional emphasis on inputs (e.g., capacity) and outputs (e.g., assessments) is insufficient and more process-oriented approaches (e.g., centred on institutional change) are necessary to understand and enable effective adaptation governance (Patterson et al., 2019). Particular attention needs to be focused on the intersection of knowledge and power in shaping adaptation governance (Vink et al., 2013). Moreover, a critical framing of adaptation governance is key to institutionalising transformational adaptation governance at the coast.

A critical framing of adaptation governance centres on revealing and addressing the root causes and drivers of social vulnerability to climate change impacts and risk. Rather than advancing a linear, technocentric narrative of 'change-impact-response', a critical framing of adaptation governance recognises the social production and construction of climate change risk. It reveals how societal conditions structure and perpetuate climate risk through systemic inequities, injustices, and manifold forms of marginalisation and oppression. It engages directly with the politics of adaptation (Eriksen et al., 2015; Eakin et al., 2021). Revealing and addressing power imbalances, and giving voice to marginalised groups, is foundational to a critical framing that moves praxis from incremental to transformational adaptation. This critical framing recognises the irreducibility of the deep complexity, dynamism, uncertainty and contestation associated with climate change. Critical adaptation praxis embraces these conditions as inevitable and inherent in transformative endeavours instead of striving for simplicity, stability, certainty and consensus – as traditional adaptation governance does. Whereas traditional adaptation governance tends towards the techno-rational, a critical framing emphasises *relational interactions* between people and the world around them (Nightingale et al., 2021). Therefore, addressing the root causes and drivers of climate injustices and inequities, and underlying structural vulnerability manifest in 'politics as usual', is key to transformative and ultimately emancipatory adaptation governance. What insights can be gleaned from adaptation experience in Aotearoa to date, and what might this suggest for the future?

Adaptation in Aotearoa New Zealand: Insights from experience and a prognosis

Widely varying adaptation experiences in Aotearoa reflect divergent physical exposure and social vulnerability to climate risk. It manifests differential power, politics, civic leadership and institutional interactions and capabilities (i.e., within local government, e.g., district-regional council; between local authorities and iwi and hapū as well as community organisations and the private sector; and central-local government). Research in three regions underscores this heterogeneity and the imperative for countrywide transformative adaptation action.

Coromandel Peninsula

Fifteen years of ethnographic research reveals a nuanced and evolving Coromandel adaptation story. Attention here is focused on four key insights.

First, neighbouring Coromandel communities can be 'world's apart' (Schneider et al., 2017). For instance, Kennedy Bay is a predominantly Māori community for whom climate change appears to be of little concern. Addressing pressing day-to-day needs has been hampered by mistrust of the District Council and the shadow of colonisation. Strengthening rangitiritanga (Māori self-determination) and kaitiakitanga (Māori guardianship) are central to enabling community-based adaptation governance here. Nearby Whitianga/Mercury Bay is a rapidly developing resort town where shoreline property owners clamour for protective works. Short-term private interests appear to have been privileged and static responses prioritised over long-term public safety and environmental sustainability. Strengthening local democracy, civic leadership and the adaptive capacity of the Thames-Coromandel District Council are key to overcoming maladaptation and the perceived unfair exercise of power and influence.

Second, local leadership plays a crucial role in shaping the depth, extent and pace of adaptation. Over the last two decades, Thames-Coromandel Mayoral and District Council

Small islands off the Coromandel Peninsula (Photo: Alexander Klink, Wikimedia Commons under CC BY 3.0 licence, https://creativecommons.org/licenses/by/3.0/legalcode).

adaptation leadership have waxed and waned (Schneider and Glavovic, 2022). Recent Mayor Sandra Goudie (2016-2022) was a staunch climate change denialist and 'thumbed her nose' at efforts to prioritise climate action (https://www.stuff.co.nz/waikato-times/news/300517107/coastal-mayor-sandra-goudie-still-thumbing-her-nose-over-climate-change-signature). She continued previous inaction under Mayor Glenn Leach (2010-2015). In stark contrast, the 2004-2010 Mayor, Philippa Barriball, proactively championed community-based adaptation action. In more recent years, school children and community members have resorted to public protest, and even litigation, to challenge the Council's climate inaction.

Third, District Council adaptation planning efforts have been underway for about five years. Is this evidence of authentic adaptation action or is this merely a glossy veneer over 'business as usual'? The Coastal Management Strategy and Shoreline Management Plans are concrete steps to address coastal hazard risk. But some coastal specialists have expressed serious concern about these efforts, signalling they fail to engage mana whenua and community members in meaningful ways. Schneider and Glavovic (2022: 192) observe: 'Depending on who one might speak to "The Times They Are A-Changin" or "The Song Remains the Same".'

Fourth, extensive ethnographic research underscores the imperative to build trusting relationships between adaptation governance actors to enable transformational adaptation.

Hawke's Bay

The region's 100-year strategy to manage coastal hazard risk – the Clifton to Tangoio Coastal Hazard Strategy 2120 – is considered exemplary (Kench et al., 2018; Corbett and Bendall, 2019; Lawrence et al., 2019; Schneider et al., 2020; Ryan et al., 2022). Three insights are highlighted here.

First, the institutional architecture set up for the Strategy was far-sighted and robust. A Joint Committee was established and made up of elected representatives from the Hawke's Bay Regional Council (HBRC), the Napier City Council and the Hastings District Council and representatives of key parties involved in the Treaty of Waitangi settlement process, that is, He Toa Takitini, Mana Ahuriri Incorporated and the Maungaharuru-Tangitū Trust. A Technical Advisory Group (TAG), made up of senior staff from each council, and led by an independent Project Manager, guided the process. Working through a stepwise process, the Strategy was founded on a risk assessment; a decision-making process drawing on multi-criteria decision analysis, dynamic adaptive policy pathways, and real option analysis; and two community-based panel assessments. The panels' recommendations were adopted by the Joint Committee and devolved to each local authority for endorsement and implementation. In mid-2022, a proposal was put to the public for the HBRC to take the lead in finalising and implementing the Strategy. A decision will be made in the latter part of 2022 (https://www.consultations.nz/hbrc/the-future-of-our-coastline).

Māhia Peninsula, Hawke's Bay (Photo: Brucieb, Wikimedia Commons under CC BY-SA 3.0 licence, https://creativecommons.org/licenses/by-sa/3.0/legalcode).

Second, serendipitously, the National Science Challenge: Resilience to Nature's Challenges (NSC: RNC) was being established as the Strategy formulation process was getting underway. Researchers in the 'Living at the Edge' programme under the NSC: RNC began working with the Project Manager and the TAG to learn from the Strategy formulation experience, share research insights and recommend improvements to the process. The multi-disciplinary Edge team brought diverse expertise and extensive local and international applied adaptation research experience to the table. Edge team members worked as 'critical friends', providing independent and candid but constructively critical advice. This *pro bono* contribution was a significant boon to the Hawke's Bay. As one might expect, interactions that are constructively critical are not always easy to navigate. Ultimately the Edge team was a foundation stone in the robust institutional architecture established for addressing the region's coastal hazard risk.

Third, translating Strategy intentions into practical reality remains an ongoing challenge. A key 'sticking point' is uncertainty about the apportionment of costs arising from major interventions, such as protective works and/or managed retreat, and government's contribution in particular. Prevailing ad hoc cost sharing hampers action and can be inequitable.

Manawatū-Whanganui

This region is home to diverse communities, with many relatively small settlements exposed and vulnerable to climate change compounded riverine and/or coastal hazard risk. Horizons Regional Council (HRC) has prepared a Regional Climate Change Risk Assessment (Tonkin & Taylor, 2021) as well as a Regional Climate Action Strategy (Bowen, 2020), and a Regional Climate Action Plan (HRC, 2020) that outlines how the region's local authorities will work together to tackle climate change. Two key insights are highlighted here.

First, building on a 2019 Memorandum of Understanding and the above-mentioned Plan and Strategy, the HRC and Territorial Authorities have agreed to work together to address climate impacts and risks in the region. A Climate Action Joint Committee (CAJC) has also been established with representation by Mayors and Chief Executives from each of the region's Territorial Authorities and the Chair and Chief Executive of the HRC together with tangata whenua representatives. The CAJC informs strategic leadership on how the region can advance climate change mitigation and adaptation, drawing on mātauranga Māori and scientific evidence. Much remains to be done to fully operationalise these partnerships and provisions. But robust institutional architecture has been developed and bodes well for the future.

Second, a series of climate compounded extreme events in the region over the last two decades has stress-tested the

Kai Iwi Beach, Whanganui (Photo: Michal Klajban, Wikimedia Commons under CC BY-SA 4.0 licence, https://creativecommons.org/licenses/by-sa/4.0/legalcode).

Civil Defence Emergency Management (CDEM) legislative provisions set up, refined and implemented in the region since 2002. Among other things, these experiences have led to regional improvements in flood protection and early warning and evacuation provisions. However, these experiences have brought to the fore the imperative to prepare the most exposed and vulnerable communities for managed retreat. For example, a flood risk reduction and resilience building Strategy has been co-designed for Anzac Parade in Whanganui (https://www.horizons.govt.nz/anzac-parade; https://www.nzherald.co.nz/whanganui-chronicle/news/final-flood-risk-strategy-for-the-anzac-parade-area-in-whanganui-presented). The 'sticking point' is uncertainty about how to share the substantial costs of the recommended buy-out of about 50 homes. People living in Whangaehu Village on the Rangitikei River have been flooded four times since 2004 and moving to nearby higher ground was strongly supported by residents, valley stakeholders, tangata whenua and local authorities (https://www.nzherald.co.nz/business/future-new-zealand-on-the-frontline-in-the-anthropocene). The cost of relocating about a dozen homes and an engineering works was, however, beyond the means of residents and the Rangitikei District Council. In the absence of cost-sharing with government, the initiative ground to a halt and the recommendations sit on a shelf.

Experience in these three regions shows that it is not easy to reach agreement on adaptation pathways, let alone transformational adaptation governance. Contestation is inevitable. Agreement between those at risk, tangata whenua, key stakeholders and local government is necessary but not sufficient. Government plays a crucial role in enabling local communities and their governing authorities to institutionalise major adaptation measures. Continued uncertainty about the role of government in supporting and sharing the costs of adaptation remains a serious impediment to effective adaptation in Aotearoa.

Priorities for enabling transformational coastal adaptation in Aotearoa

Four priorities for enabling transformational adaptation governance are identified.

First, climate change is woven into every aspect of life in Aotearoa – from biodiversity conservation to food and water security, cultural identity, and the livelihoods and well-being of tangata whenua and current and future generations. Regional experiences underscore the imperative to establish robust but **fit-for-purpose local-regional institutional adaptation partnerships** that involve tangata whenua and local government together with local communities, the private sector, research community and media.

Second, the recently released National Adaptation Plan provides national leadership in support of regional and local adaptation planning. However, for many localities and regions, adaptation planning has been underway for a decade or more. Key enabling provisions at the national level are yet to be put in place. The promulgation of the **Climate Adaptation Act** is central to this endeavour. Government needs to provide a clear and consistent answer on **how adaptation costs will be shared between affected parties**, especially with respect to major interventions that could take decades to implement, for example, managed retreat. Further work is needed to identify practical ways for government to support local authorities in building **institutional capability** to deal with inevitable deep complexity, dynamism, uncertainty and contestation.

Third, much remains to be done to move beyond historic reliance on technocentric risk analysis towards vulnerability-centred adaptation planning and action. Key to this transition is institutionalising a **critical framing of climate change and disaster risk** so that the root causes and drivers of vulnerability, inequity and injustice are addressed. While traditional risk analysis has a role to play in tackling some risk problems, adapting to climate change necessitates a more critically reflexive response. Researchers can provide independent support through a 'critical friend' role. However, the challenge is more than technical. There is merit in establishing an **independent facilitation/mediation** service to assist local communities negotiate adaptation pathways in the face of inevitable contestation.

Finally, given the pervasive and pernicious impacts of climate change, an independent and cross-party **Public Inquiry on adaptation**, and managed retreat in particular, should be established, possibly through a Royal Commission to determine how best to translate these observations into action: How can enabling and transformational adaptation governance be institutionalised in Aotearoa? How should adaptation costs be apportioned in coming decades – especially for enabling managed retreat? How should impacts and responses be monitored and reflected on and disputes be resolved? How should institutional capability to deal with complexity, dynamism, uncertainty and contestation be developed by local communities, tangata whenua, the private sector and government?

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What does success look like? A flaxroots perspective of adaptation

By Janet Stephenson, Merata Kawharu, Sophie Bond and Gradon Diprose

Introduction

The rate and potential scale of climate change and its cascading environmental and societal consequences are unprecedented. The world is already in uncharted territory at 1.2°C above pre-industrial levels, and the sum total of all nations' policies will likely lead to a world hotter by 2.7°C and perhaps a catastrophic 3.6°C or more by 2100 and beyond[1]. Aotearoa has to be prepared for the worst-case scenario because we cannot trust that the highest carbon-emitting nations and powerful incumbent industries will take action in time. Even at a most optimistic rise of between 1.5°C and 2°C, every living thing will be affected. Local and global environmental and social systems will be destabilised.

At its most fundamental, success for Aotearoa means being prepared for this scale and rapidity of change.

We write this article from the perspective of socially engaged researchers, bringing together mātauranga (Māori knowledge), anthropology, human geography and sociology disciplines, including listening deeply to those who we work with. We see the climate crisis as a human and environmental predicament. The predominant social, cultural and economic systems that have spread around the globe through processes of colonisation and globalisation have evolved with an underlying assumption about the stability of global and local environmental systems. Climate change will increasingly destabilise these systems, unsettling what is 'normal' for whānau (extended families), kāinga (settlements), hapū (kin group collectives), iwi (larger collectives of kin groups), individuals, community and civic organisations, local and central government. In these uncharted waters, we draw from mātauranga and from the experiences and observations of those on the front line to propose seven principles to guide collective action.

Good process

'Success' might suggest that at some point in the future we will have adapted; that in all facets of society we will have achieved an effective response to climate change and can rest on our laurels. But the nature of the climate crisis means that the only certainty is ongoing change for decades and probably centuries. Changes to biophysical systems; changes to ecologies; changes to food systems; ongoing human displacement; impacts on health and wellbeing; increasing chances of geopolitical instability and global financial crises and more. In this new reality, success is not an end point. Success engages good processes, which in turn leads to improved outcomes for environments and for people.

By process we mean the ways in which people engage with each other and the problems we face. It includes how central and local government engage with each other and with communities, and how kāinga and wider communities take action in their own right. A focus on process encourages us all to think about who is involved in decision making, how those decisions are made, and what those decisions set out to achieve.

Good process needs to take into account not only direct impacts such as floods or storm events, but also longer-term shocks from cascading impacts, both locally and globally. As we are already seeing with a global pandemic and with energy becoming a weapon of war, global supply chains, food systems, energy prices and financial markets can easily be destabilised. Adaptation to climate change is just one aspect of the even more fundamental transition to a sustainable future for humanity. This includes the radical changes required over the next 30 years to decarbonise all aspects of production and consumption. These multiple challenges to business-as-usual require an integrated approach at every scale, but particularly at the local level.

Principles for adaptation

The authors of this article have worked with kāinga, hapū, iwi, wider communities and councils over many years as they start to grapple with the implications of climate change for both coastal and inland areas. We draw inspiration from their wisdom, stories, struggles and innovations to suggest principles to aid successful adaptation through the lens of those who will be most affected by climate change.

The principles presented here are applicable to all adaptation processes, regardless of who is involved. They guide us to think systemically and holistically about problems, to be concerned for health and wellbeing, to recognise and provide for the mana of communities as agents of change, and to ensure livelihoods are in balance with the life-giving attributes of ecosystems and environments. They remind us that responses to climate change will need to be locally relevant, and inclusive. They emphasise the importance of equity and fairness and the need to support kāinga and other communities that are already taking action because they can see the storm on the horizon.

The starting point is with mana whenua. The enduring commitment of mana whenua to place means that they have a critical role in developing locally-relevant responses to climate change. Partnerships based on Te Tiriti o Waitangi (the Treaty of Waitangi) are an essential part of effective adaptation, and are discussed elsewhere in this publication.

Iwi, hapū and kāinga are genealogically embedded into lands and hold the knowledge of generations of people who have lived there. They continue to enact (as far as they are able despite the impacts of colonisation) the perpetual responsibilities of kaitiakitanga (guardianship/stewardship) in relation to those lands, irrespective of freehold title. Te Ao Māori (Māori worldview) offers values and ways of thinking that are of immense relevance to the process of adaptation.

Principle 1: Oranga

Oranga refers to health and wellbeing, and is the ultimate goal of adaptation. Oranga reminds us that human health and well-being are dependent on environmental health and

[1] https://climateactiontracker.org/publications/glasgows-2030-credibility-gap-net-zeros-lip-service-to-climate-action/

therefore will be affected by climate change. From more dramatic scenarios where homes are lost to flooding or encroaching seas, to more subtle situations where gardens wilt from a lack of water year after year, the effects on health and well-being are undeniable. We are also likely to see worsening mental health through the anxieties of dealing with issues such as insurance, local councils, banks and costs related to home alterations/repairs and the innumerable related health issues arising out of stress. There are multiple other contexts also where human health will be affected (Royal Society, 2017). Centring oranga means considering health and wellbeing holistically in all adaptation processes.

Principle 2: Ki Uta ki Tai

Ki uta ki tai refers to connectedness: between inland and coastal areas, between freshwater and sea water, between people and waterways, between an ancestral past and a descendant present and generations yet to come. This connectedness is also tied to the health of people. For example, if waterways are not healthy, then people can be at risk from already-degraded water being further degraded by increased flooding or droughts. These create further pressures to already vulnerable ecosystems. Ki uta ki tai is a fundamental planning principle that draws attention to environmental, cultural, ecological, and economic interconnections.

Principle 3: Mana

Mana, meaning here authority, power, stance, or positioning, can be broadly applied to communities as agents of change (Kawharu and Tapsell, 2019). As policies, plans and actions start taking shape to support communities to adapt to the challenges of climate change, it is important to recognise and provide for their mana throughout these processes. This means identifying the social (including cultural and political) source(s) of mana, considering capacity and representation issues or limitations, and designing engagement processes accordingly.

Principle 4: Kaitiakitanga

Kaitiakitanga, meaning custodianship, trusteeship, or guardianship, can guide all towards achieving resilience in the face of climate change challenges. It accentuates the importance of learning from (ancestral) past precedents of how to live well in balance with the life-giving attributes of ecosystems and environments. Applying kaitiakitanga also means seeking modern ideas and technologies in developing solutions to climate change problems. It reminds us that a reciprocal relationship with our environment is important to sustainable resource use. Our environments and all living things – the world around us – have their own mana or integrity and function within a system. Communities are caretakers of these systems for following generations.

Building resilience and safeguarding future generations will involve much more than just adapting – significant behavioural changes will be needed to address the cause of the climate crisis, which ultimately stems from a capitalist colonial system that has disrupted the natural systems of our world through commodification and the over-exploitation of resources, people, and wider environments. Kaitiakitanga is a foundational principle to guide this comprehensive transition whilst recognising the life-giving and healing attributes of environmental systems (Kawharu, 2020).

Principle 5: Tailored responses

The impacts of climate change will be very different depending on the locality. From a purely physical perspective it will depend on factors such as the coastal geomorphology, degree of sea-level rise, exposure to storm events, flooding from inland, or increasing marine heat waves. From a built perspective it will depend on the location of infrastructure, housing, commercial operations, and social facilities. From a human perspective, impacts will depend on kāinga and wider community engagement, who lives where and how people are affected. All of these factors mean that each place, and the people of the place, will be uniquely impacted and differently affected even within those places.

This means that responses must be tailored to place and people. At a national level, new laws, policies and institutional arrangements need to be robust and equitable. At a local level, adaptation responses must be locally responsive. Local authorities have a particular responsibility in this respect.

Principle 6: Long-term relationships

To help forge a path into an uncertain future, local authorities will need to develop long-term relationships with mana whenua (inclusive of marae to iwi) and other communities. For mana whenua, this is about providing for the expression of mana/rangatiratanga, that is, the right to self-determination as promised by Te Tiriti o Waitangi (Ihirangi, 2021). This may take many forms depending on people and place and is covered more fully in other articles in this publication.

More generally, the conventional approach used by councils to interact with the public has traditionally involved inviting formal public responses to pre-planned options, such as through submissions or public meetings. This approach is not appropriate for adaptive processes. It limits who attends and participates, and misses large sectors of communities who have important contributions to make and a right to be involved in decisions that affect them. Some people and groups are well accustomed to ensuring their voices and values are represented in local, regional and even national decision-making processes, and may use costly legal avenues to ensure their views and values are considered by decision makers. Those who miss out could be hampered by having other more immediate concerns (like accessing suitable food or housing), or due to systemic and unequal access to resources (including education, time, and having the 'right' kind of knowledge). If this imbalance is not corrected it increases the risk of maladaptive decisions that only benefit the wealthy or privileged who are able to work within the typical practices of local government. It increases the risk of inequitable and short-term solutions that will exacerbate existing inequalities.

Instead, local authorities need to reach beyond those who can easily come to the table, and put a special focus on those who struggle to engage, who find local authorities convoluted, frightening, confusing, or inaccessible. They need to build trusting relationships with the communities they are responsible to, and these relationships need to be sustained over time, so that when hard adaptation decisions are made, there is understanding on both sides that enable a collective path forward to be planned. This may require thinking beyond the technical or engineering questions generally considered in 'coastal adaptation', to wider concerns like how communities make their livelihoods, access critical services, grow and distribute food, care for one another, and meet other core human needs. In this sense, effective adaptation is effective community development, and may require new skills amongst council staff (Stephenson et al., 2020).

When a local authority has strong community relationships, they have an in-depth understanding of issues, concerns, values, and place attachments. They are culturally competent and responsive to kāinga, hapū and iwi needs and aspirations. The authority will know the most appropriate forms of engagement for different groups within that community, and will be able to work meaningfully with them to ensure there is a sense of self-determination including shared decision making that follows. They will be confident that the decisions are robust, fair, and inclusive.

Principle 7: Supporting self-determination

This final principle recognises the power of communities to drive their own transitions. This is an extension of the principle of mana discussed above. In our research with kāinga and wider communities we have seen many examples of how they are already taking action on their own initiative. Most are environmentally-focused; some are also social needs-focused (e.g., energy, housing). This includes developing their own climate change plans, developing community gardens, housing improvements, skill-sharing platforms, predator control, restoring wetlands and rivers, and coastal restoration. Some are already experiencing the early impacts of climate change and all are preparing for a challenging future. They are also reaching out to work with councils and other organisations, making submissions, and looking at how to collectivise and share their experiences. They see little distinction between mitigation and adaptation – it is about climate response, and more generally doing what they can to build resilience and sustainability at a local scale in ways that also have wider impacts.

These initiatives are not random and nor are they inconsequential. Kāinga and many place-based communities are not protected from the realities of climate change by wealth or the ability to relocate. They are at the frontline of impacts, so they observe changes, learn what they can, and kōrero (converse) amongst themselves about what they can do. Anyone working professionally in the adaptation space should be in awe of them, because this is what the future needs to look like.

Oromahoe Marae, April 2020. Rereata Makiha speaking on maramataka, mātauranga, climate change and seasonal environmental indicators. Photo: Merata Kawharu.

But people in kāinga and communities more widely are often not resourced to do this work and instead undertake actions because they are deeply worried for current and future generations and for the health and wellbeing of all living things. This is what kaitiakitanga means. For kāinga leaders, these duties are inbuilt and ancestrally-framed. To achieve the kinds of transformative changes needed to respond to climate challenges, these currently dispersed bottom-up initiatives must become widespread and normalised. This won't happen without support. Communities need to be adequately supported and resourced to develop and undertake their own resilience strategies. From this they can build a body of knowledge and experience that can be shared with others to amplify the benefits.

Conclusion

If we had a single measure of success, it would be that kāinga and communities face this uncertain future with confidence. Effective adaptation processes will require a multitude of changes to regulations, funding arrangements, policies, and infrastructure investments. But unless local decisions are strongly shaped by those who are directly affected, there will be resistance, contestation, maladaptation and delays.

Successful adaptation means developing equitable, fair and inclusive processes which give proper recognition to the mana/rangatiratanga of kāinga and engage meaningfully with affected communities. It means embedding ki uta ki tai, oranga, mana and kaitiakitanga into decision-making processes and actions at every level. Adaptation does not have a foreseeable end. The closest we can get to success is having communities that are prepared for, and empowered to respond to, an increasingly unpredictable future.

Acknowledgements

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2 Planning and policy frameworks

Awatarariki Debris Fan, May 2005
(Photo: Whakatāne District Council)

Our evolving coastal planning framework – relying on the best of the old while awaiting the new

By Sylvia Allan

New Zealand pioneered effects-based resource management and planning with the introduction of the Resource Management Act (RMA) in 1991. The intention was to recognise the whole environment, including all natural systems, people and communities, and the myriad interactions between different parts of the environment while enabling development, but ensuring that predetermined environmental bottom lines were not overstepped. Changes within the environment brought about by human intervention to meet social, economic and cultural needs were to be managed so that adverse effects were avoided, remedied or mitigated. Regional councils were responsible for managing a region's water resources, air quality, some elements of land use, biodiversity and, in conjunction with the Minister of Conservation, all aspects of the coastal marine area. Territorial authorities, including city and district councils, were responsible for land use and subdivision within their areas. The responsibility for ensuring the avoidance or mitigation of natural hazards was allocated to both levels of local government with the actual responsibilities to be set out and allocated in the primary planning document for each region – the regional policy statement.

With the passage of time, the RMA has been amended many times. It is now no longer considered adequate for purpose. Following a review in 2020, recommendations were included in 'New Directions for Resource Management in New Zealand' (widely referred to as the Randerson Report). The report's recommendations have been largely adopted by the current government and work is now proceeding on the development of three replacement statutes – a Natural and Built Environment Act, a Spatial Planning Act, and a Climate Adaptation Act. The first two are intended to come into law in 2023, and the third will follow.

In the meantime, the web of national policy statements, regional policy statements, and regional, coastal and district plans remain in place, underpinning all resource management decision making. The full transition period is expected to take several years.

Working quite well – national coastal policy and guidance

Considerable foresight was shown when the Resource Management Act included a requirement that there must at all times be a New Zealand Coastal Policy Statement (NZCPS) relating to the coastal environment (RMA s56, s57). Local authorities are required to give effect to the NZCPS and must amend their plans to achieve this national direction (RMA s55).

Equally important has been the statutory requirement of the NZCPS to *'state objectives and policies in order to achieve* *the purpose of this Act in relation to the coastal environment of New Zealand'*. Recognising that the coastal environment is a broad concept, not confined to a hard line between land and sea at mean high water springs, means that national policy can provide an appropriate framework for adaptive planning at the coast.

Matters of national importance that must be recognised and provided for in all RMA decision making (RMA s6) include the preservation of natural character of the coastal environment from inappropriate subdivision and development, protection of public access to and along the coastal marine area, and recognition of Māori relationships with ancestral land and water areas and other taonga. Together these concepts have provided for policy, including the NZCPS, plans and decisions, which have limited unbridled development in some parts of the coast, required careful investigation of impacts of new subdivision and development, and added conditions to consents including mitigation conditions. Only relatively recently (2017) was the management of significant risks from natural hazards added to RMA s6 as a matter of national importance. Its interpretation has been hampered by questions around what comprises a 'significant' risk, so elevating natural hazards as a matter of national importance has proved relatively ineffectual, including in the coastal environment. However, the approach to the management of natural hazards in the NZCPS transcends such details and has been widely supported – for example, through interpretive guidance issued by the Department of Conservation and the Ministry for the Environment.

The NZCPS contains provisions that set out in detail how managing natural hazards in the coastal environment should be approached and undertaken. There must be no increased risk of harm from coastal hazards – requiring limits on future development or intensification of existing land use in areas at risk.

These are fundamental precepts for adaptive planning in the coastal environment. The most relevant objective, Objective 5, is *'to ensure that coastal hazard risks taking account of climate change, are managed by:*

- *locating new development away from areas prone to such risks;*
- *considering responses, including managed retreat, for existing development in this situation; and*
- *protecting or restoring natural defences to coastal hazards.'*

This leads into a suite of policies, specifically Policies 24, 25 and 27, which together set out in detail how to identify areas at risk from coastal hazards, a hierarchy of actions to manage risk in coastal areas that may be exposed to coastal hazards over the next 100 years, and a range of strategies and principles to apply to decisions where there is already significant existing development in identified hazard areas. The overall management approach is shown in the Ministry for the Environment's 'Guidance for Local Government' publication (Ministry for the Environment, 2017), shown in Figure 1.

Within the NZCPS policy framework, the Guidance promotes an iterative, community-based, planning approach, focused on five key questions over time. This framework is shown in Figure 2, and each step is expanded in the Guidance.

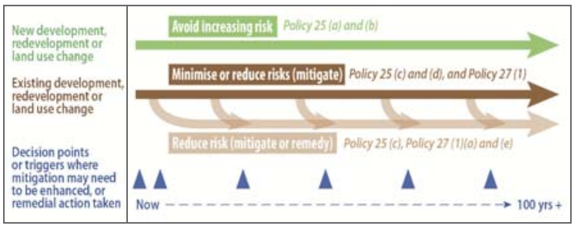

Figure 1: Broad planning decision context for coastal areas exposed to coastal hazards and climate change (New Zealand Coastal Policy Statement 2010) (MfE Guidance for Local Government).

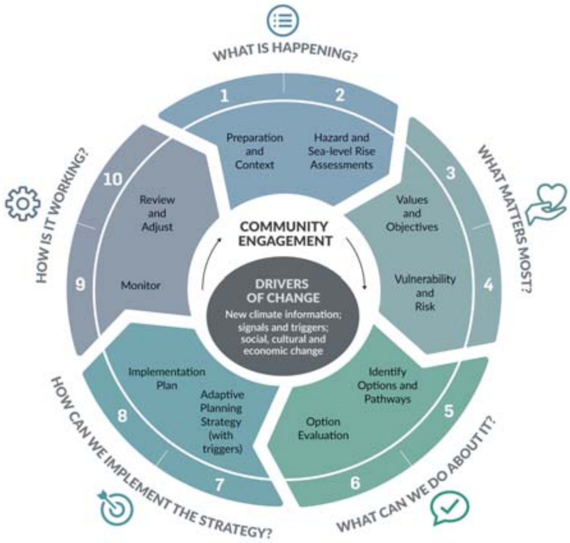

Figure 2: The 10-step decision cycle for planning in coastal areas (MfE Guidance for Local Government).

Adaptive management, where the nature of coastal change arising from a changing climate is generally understood but the timing and detail at local level is not, is at the heart of this approach. It is particularly useful for existing communities and developed areas.

Steps 5 to 8 of Figure 2 involve a process of detailed investigation of the potential impacts of sea-level rise and other climate change impacts at the local level, dynamic adaptive pathways planning (DAPP) to scope out and identify pathways to manage the practical implications of these changes, and suitable triggers for when a shift to a different pathway must be made. Monitoring is an essential part of the adaptive process, investigating community-agreed signals in the lead-up to the triggers of community response. The DAPP process is ideal for planning in a time of dynamic and uncertain coastal change, as it is not time bound. Rather it depends on pre-determined circumstances or triggers being reached, initiating a change to a different response pathway. Triggers can be expressed as physical measurements (such as when mean high water springs reaches an agreed marker) or functional circumstances (such as the number of days an access road is unusable per year). The method enables strategic planning at a regional level for future land uses and infrastructure, and existing communities can map out their future with a greater level of certainty in a changing world.

There are a large number of tools within the current planning and local government frameworks that enable the processes to take place and begin to be implemented through current plans. However, there are also impediments within the current planning system that limit the long-term effectiveness of such approaches.

Shortcomings for adaptive planning within existing frameworks

The NZCPS was prepared and adopted at a time when case law indicated a 'balanced approach' to planning. Wording containing strong imperatives (such as 'avoid increasing the risk' and 'avoid redevelopment, or change in land use, that would increase the risk') has only been accorded full weight since the King Salmon decision[1] in 2014. This, together with the lack of a specified timeframe to amend plans, means that some councils are still functioning with looser policy. Further issues limiting the successful uptake of adaptive planning are embedded in the current resource management and interrelated statutes.

Much coastal development relies on favourable rules in district plans and/or existing use rights. Existing development is thus usually able to re-establish as of right even after significant storm or erosion damage. While existing use rights can be cancelled by regional land use rules (RMA s10.4(a)), regional councils are reluctant to take on a land use planning role, so such rules are rare. Regional councils can not directly control subdivision, meaning that intensification in urban areas through subdivision, and lifestyle rural subdivision, can continue to occur. Legacy subdivisions and land use consents, often provided for on a staged basis, enable further development in some areas now considered risky. Where consents for further development are required, there is a strong tendency for decision makers to accept mitigation responses, where hazards are accommodated by, for example, requiring raised ground levels or minimum floor levels in buildings, rather than declining consent. Such examples are adding to the foreseeable risks, problems and issues that future generations will have to face. Specific provisions in sections 71 to 74 of the Building Act also facilitate consents in many such circumstances.

New rules introduced through notified plan changes or plan reviews do not have immediate effect and must proceed through the processes of submissions, decisions and appeals. There are some exceptions to this, for example, for rules that relate to water, historic heritage, or the protection of indigenous habitats, but not rules for managing the risk of natural hazards. Thus, development consents can be and are obtained under rules applying before hazard areas were included in plans. A council can obtain the agreement of the Environment Court to have specific rules made effective from notification, but this is rarely used. One example is Tasman District Council's successful application to the Court for new rules relating to natural hazards at Mapua.

With rising seas, there is a particular issue around the RMA's different regimes for the coastal marine area and the land side of the coastal environment. Regional coastal plans may have strict policy and rules for new structures seaward of mean high-water springs, thus ensuring careful consideration of proposals for hard protection, but district rules may enable the construction of retaining walls or fences as permitted activities immediately landward of mean high-water springs. Such structures can be built as coastal protection by owners, causing erosion at their ends over time. Even the combined plans of unitary authorities may incorporate such provisions, as was found in the Environment Court case of Auckland Council vs Auckland Council[2] where a proposed sea wall at Orewa was able to gain consent by being moved inland so that a coastal permit was no longer needed.

Finally, there are major problems in embedding the outcomes of DAPP processes into RMA statutory planning documents. DAPP takes a long view that transcends the 10-year life of all RMA plans. The process maps out pathways and specifies circumstances when there will be a change from one pathway to another, but the timing of the change cannot be known with precision. Although RMA plans can include techniques such as deferred zones for future development, or indicative alignments for new roads or other infrastructure, bringing these into effect usually involves a further cumbersome plan change. Monitoring of coastal change is also an essential underpinning of DAPP and few councils have prioritised this.

While some district and regional plans include provisions designed to facilitate adaptive planning in coastal areas, specifically placing limits on development in areas expected to be affected by rising sea levels over the next 100 years, these are rare and are often the result of extensive enquiry and lengthy litigation.

The Minister for the Environment has made it clear that current national direction, including the policy for the management of coastal hazards within the NZCPS, will be carried over into the future National Planning Framework. However, there is no indication as to how the many problems that currently beset detailed implementation of adaptive planning in vulnerable areas near the coast will be addressed. Future legislation will need to provide for, *inter alia*, integrated long-term techniques that span ownership of public and private property, control of buildings and infrastructure, public health and natural hazard risk management, and financing of processes and actions.

What should councils and communities be doing in the present state of legislative change?

With the current state of legislative reform, and the pressure many councils have recently come under to meet the more forceful targets of the National Policy Statement for Urban Development (see Box 1), planning for the impacts of climate change in coastal areas is often not being accorded high priority. A recent review (Lawrence et al., 2021) (the review) looked at what councils should be doing and identified examples of emerging good practice. Findings are briefly outlined here.

NZCPS Policy 24 requires the identification of areas at risk from coastal hazards and a hazard risk assessment. This responsibility has primarily been picked up by regional councils, with considerable development of techniques and processes, including iwi input and the use of advisory panels, with the expectation that it will be needed to support adaptive planning. Local government is being aided by national investigations such as those undertaken by Local

[1] New Zealand Supreme Court – Environmental Defence Society Inc v New Zealand King Salmon Company Ltd [2014] NZSC 38.

[2] Environment Court of New Zealand – Auckland Council v Auckland Council [2020] NZEnvC 70 (27 May 2020).

Box 1: A conflict of national direction – managing coastal hazards while planning for significant urban growth

The introduction in 2020 of the National Policy Statement for Urban Development (NPS-UD) with its highly directive language, followed by changes to the RMA in December 2021, mean some councils must now make provision to accommodate additional residential development in many parts of urban areas. While both seek to achieve ‘well-functioning urban environments’ their effect is to make more intensive residential development possible as a permitted activity, thus removing the scrutiny that would normally prevail through the planning system.

In making planning decisions affecting urban environments, the NPS-UD requires that particular regard must be had to ‘the likely current and future effects of climate change’. Under both instruments, required densities can be scaled back if a council can show a ‘qualifying matter’ applies. Qualifying matters include RMA s6 matters and provisions of national policy statements, including the NZCPS. This suggests that the development density otherwise permitted should be able to be significantly reduced in areas likely to be exposed to the effects of rising seas within at least 100 years (NZCPS Policy 25), that areas subject to significant risk of natural hazard should be excluded (RMA s 6(h)), and that inappropriate development should be excluded from areas of natural coastal character (RMA s 6(a)).

In practice, the ‘softer’ language of the NZCPS and even the complexities of interpreting RMA section 6 matters to be applied (including whether natural hazards would be ‘significant’ in any circumstance) mean that councils are struggling to exclude even apparently quite vulnerable areas from the intensification requirements. The short time frame available to document reasons for exclusion of areas on the basis of qualifying matters contributes to the practical difficulties for councils.

The first tranche of plan changes under these new requirements were open for public submissions in August 2022, to be followed by hearings and decisions. Risks from coastal natural hazards have not always been effectively portrayed as a reason to reduce densities that would otherwise be permitted, and new opportunities to intensify development in vulnerable coastal areas have been created. Coastal adaptation is likely to become more difficult if this continues through decision making.

New medium density residential development under construction on a brownfields site at Petone – close to the sea and close to the current level of mean high-water springs (Photos: Sylvia Allan).

Government NZ and the Parliamentary Commissioner for the Environment, outputs from national science programmes, and national information sources such as RiskScape. The Guidance has assisted councils to develop information based on a range of climate change scenarios, to which information on vertical land movement can now be added. The review cited above found many examples of councils sharing approaches and information within and between regions. The purpose of the information collection is to complete stages 1 to 4 of the 10-step decision cycle in Figure 2 and to ready communities for further adaptive planning steps. This will be needed for all coastal environments and should be a priority for regions and districts with hazard-prone coastlines.

A fundamental requirement, if it has not yet been done, is for regional and district councils to agree on responsibilities for natural hazards management at the coast and to embed those responsibilities in the regional policy statement. These responsibilities may include the circumstances in which regional rules may be used to manage land uses in some areas. Along with this is the need for all regional policy statements to contain policy for managing coastal hazards that reflects the NZCPS imperatives to avoid increasing the risk of harm from them, and the more nuanced requirements relating to areas of existing development, including the promotion of risk reduction techniques and the strong preference for natural defences over hard protection structures. It is also appropriate for regional policy statements and plans to set out methods to achieve policy, and methods such as DAPP are now mentioned in a handful of regional policy documents. While the review found that some regional policy statements had comprehensive policy that was well-aligned with the NZCPS, other regions lagged behind.

Councils should also be looking at working with the range of existing planning tools to make progress in line with NZCPS and stated regional policy. Once the priority areas for coastal hazard risk management have been identified, including through consultation and collaboration with affected communities, provisions to manage the risk can be included in regional and district plans. This is not necessarily straightforward, and some communities are resistant to such provisions. Nevertheless, a range of techniques such as restrictive zoning (including prohibited activities), hazard lines on planning maps with rules for development reflecting the anticipated degree of risk, density controls, and subdivision controls have been used. Asset management plans under the Local Government Act can also indicate areas where services will not be provided, where infrastructure items will need to be shifted or abandoned, where future levels of service may be reduced, and where relocated infrastructure should go. The review report sets out examples where various techniques have been applied. As with information, councils are learning from each other and sharing experiences.

Perhaps the most important goal at present is for councils to ensure that their areas are ready to face the challenges ahead by readying communities to undertake DAPP over the next decade. This means ensuring a sound information base, educating communities on the risks and implications of the inevitable changes ahead, identifying priority issues and action areas, and ensuring that the policy framework is in place to manage future change. It also means preventing new development, subdivision, and land use changes that will expose more people and investment to future foreseeable and unacceptable risk.

Consideration of the needs of future generations is embedded within the present RMA framework, and this is becoming a greater imperative under a changing climate with rising seas and growing risk exposure to coastal hazards.

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Calm before the storm: Can we avoid extreme house price swings from extreme weather events?

By Olga Filippova and Ilan Noy

About 450,000 homes – an estimated one quarter of all homes in Aotearoa, New Zealand – are within a kilometre of the coast. Tens of thousands of these are likely to experience the effects of climate change-induced sea-level rise, including coastal erosion and inundation, in the next few decades. The long coastline of Aotearoa supports a high concentration of the New Zealand population which, along with a high percentage of home ownership, makes the importance of the price of coastal homes beyond doubt.

For most households, their home, if they own it, is by far their biggest financial asset. The value of a house can even surpass the overall wealth of a homeowner, as is the case when the mortgage loan is larger than a homeowners other assets. As such, the market-determined price of a home is an incredibly important aspect of a household's long-term financial planning, and their financial wellbeing more broadly.

The housing market is an important determinant of economic and financial stability, and is affected by international monetary conditions and a wide range of other factors. Policymakers from local and central government, banks, and insurance companies are all important in shaping house prices, and are all affected by differing and often flawed risk perceptions. As such, house prices, like all other assets, are vulnerable to swings in value that originate from changes in these perceptions.

Insurance is a common tool that homeowners use to protect the value of their house. Almost all houses in Aotearoa New Zealand are insured by private insurers, and thus indirectly covered by the Earthquake Commission (EQC) for a wide range of natural hazards. Property insurance is also instrumental in accessing and maintaining residential mortgages. For now, insurance for climate change-induced losses from extreme weather events remains widely available, and is generally affordable. This is evidenced by the very high share of houses that are insured. However, at present insurance premiums do not fully reflect future risk of climate-change induced changes in extreme weather event patterns and sea-level rise (SLR). Notably, this discrepancy is likely set to increase to an unsustainable level unless there is some change in the current practice in insurance markets.

We wanted to assess if homeowners factor-in the warnings provided by scientists and the International Panel on Climate Change (IPCC) about the risk of sea-level rise when purchasing a home. We examined how changes in policy direction within a single coastal community affected the way people made decisions on purchasing a home, to see whether prices of coastal properties change as property-specific risks of future SLR become available.

In the Kāpiti Coast, the council produced detailed projected erosion risk maps (SLR-related) for the whole of the district's coastline and for several climate change scenarios. These projections were published in 2012. Their projected risk assessment was conducted for 50- and 100-year horizons and with managed and unmanaged coastal protection policies (Figure 1 illustrates the four coastal erosion lines with an example from the Kāpiti settlement of Waikanae). The council then sent letters to almost 1,700 affected households that were placed in zones deemed to be at risk of coastal erosion because of future SLR. This hazard risk information was also placed on the Land Information Memorandums (LIM) held by the council and available to any prospective buyer of a property.

Following the placement of this risk information on the LIMs, a backlash against the publication of this information developed among the current owners of these properties. Coastal Ratepayers United, a community group representing Kāpiti Coast ratepayers, was formed and fought to remove the hazard warnings from the LIMs. The group challenged, through the courts, the accuracy of the Local Council's analysis and the limited scope of public consultation. Reaching the High Court, the presiding judge ruled that while the Council was within its legal rights to assess and notify hazards on LIMs, the lines indicating modeled change to the shoreline had the 'potential to seriously affect the value and marketability of coastal properties in the district' putting 'millions of dollars at stake' and hence the process needed to be more 'clear, fair and balanced' (Weir v Kapiti Coast District Council 2013). Following this decision, and in spite of the judge's endorsement of their approach, the Council decided to remove the hazard lines from the LIMs and these maps were removed from online access as well.

Of the 1633 properties on whose LIMs these hazard warnings were placed, about a third were sold on between 2012 and 2017 (Cann, 2017). Given the known timing of the posting of this information (2012), and its subsequent removal

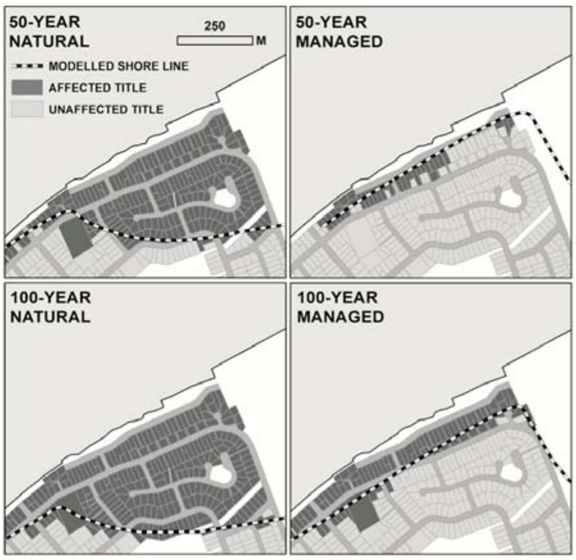

Figure 1: Example of coastal erosion scenarios in Waikanae, Kāpiti (Source: Authors' maps using data supplied by Roger Shand of Coastal Systems Ltd).

(2014), we estimated the impact of the public posting of this climate-change risk information on house prices to ascertain if public disclosure of climate change risk alters the marketability of coastal properties. These questions are still relevant for the residents of the Kāpiti Coast, as removal of warnings did not remove the risk itself; indeed, the council is now starting a new process for inserting similar warnings about SLR risk (Green, 2021).

Most New Zealanders worry about climate change – 80% according to a recent poll (Morton, 2019). In New Zealand, as is true in most other places, there is a generation gap in climate change perceptions, but all age cohorts are becoming increasingly concerned about the changing climate (Milfont et al., 2021). SLR caused by anthropogenic greenhouse gas emissions warming the atmosphere and subsequent transfer of this heat into the ocean, in particular, has drawn the attention of researchers, policymakers, and laypeople. In theory, in a market where homeowners are well-informed of the risks, fully insured properties should sell at a lower price, with the difference equal to the aggregate value of insurance premiums that will be paid to cover those risks during the lifetime of the building (Bin and Landry, 2013). Therefore, if homeowners and insurance companies previously underestimated the risks, or the risk had increased, these increasing insurance costs will lead to reductions in property value as risk perceptions are adjusted to reflect actual current and future climate risks.

Coastal hazards come together with the benefits of living close to the beach. Households are therefore faced with a trade-off between the risks of living in a coastal hazard area, and the benefits of doing so. Factors such as sea views can therefore mask any property value discounts associated with these SLR risks. Yet, in Aotearoa New Zealand's property markets, which have risen for most of the past few decades, expectations of future price increases can potentially desensitise prospective buyers to SLR risks. In spite of recent price decreases, the general expectation is that the long-term trend for house prices will continue to be positive.

Councils find themselves needing to navigate between two treacherous cliffs – a Scylla and a Charybdis. On the one hand, their efforts create controversies and often draw backlash and anxiety from affected households, as happened with Coastal Ratepayers United. On the other hand, councils are interested in raising awareness of coastal risks, and thus managing a gradual price adjustment. They would like to prevent abrupt downward price adjustments that can otherwise happen, once the risks become salient. To complicate matters, research from other countries suggests that these coastal risks are already priced into property markets leading to an observable price discount to at-risk properties (Bakkensen et al., 2021; Bernstein et al., 2019; and Votsis and Perrels, 2016). If this is also true in New Zealand, disclosure will make no difference anyway, and the Ratepayers United's battle against the council may have been for nought. In that case, the recent decision by the council to start this process anew, and re-draw these risk zones, but through a more deliberate and consultative mapping process, may also be irrelevant (see https://takutaikapiti.nz).

To assess the sensitivity of house prices to climate change disclosures in Aotearoa New Zealand we examined what actually happened in the Kāpiti property market around the time of the disclosure in 2012 and its removal in 2014. Inspection of the turnover of properties during the period in which the hazard maps appeared on LIMs does not seem out of the ordinary for the affected properties in terms of the number of sales (Figure 2). As for all other properties, there was a slowdown in sales that started in 2006 and hit a trough in 2008; this was the local manifestation of the Global Financial Crisis. The volume of residential sales did recover eventually, in 2011, but never reached the peaks of the previous property cycle. The volume of transactions of affected properties in the months following the removal of hazard lines from LIMs, in October 2014, is well within the normal range; any uptick merely correlates with a more general uptick in property sales across the district. In short, owners decisions to sell do not appear to be related to the placement of erosion risks on LIMs in September 2012 or to their removal in October 2014.

Once we examine prices, rather than the number of transactions, we find that public disclosure of the future

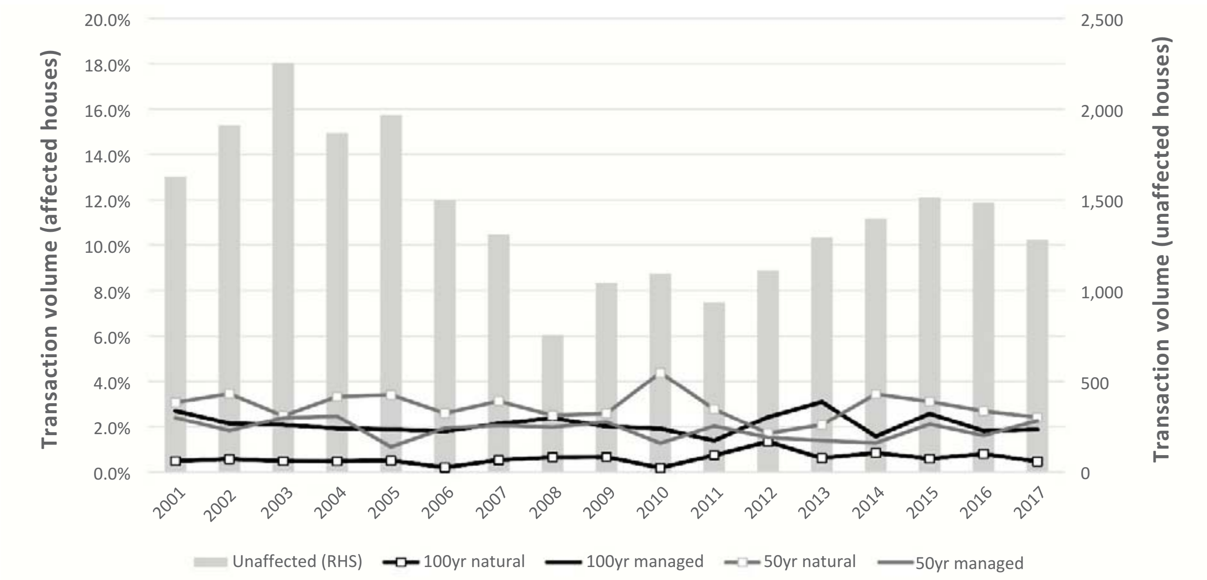

Figure 2: Property transactions on Kāpiti Coast. The y-axis (LHS) represents the transaction volume of affected houses as a percentage of total transactions (Filippova et al., 2020).

coastal erosion risk found on a property's LIM report had no statistically meaningful effect on house prices. This is contrary to the Ratepayers United expectations of a decline in prices because of (in their view) inaccurate disclosures of erosion risks. It appears that buyers of houses closer to the waterfront have become a bit more aware of the coastal hazard risks as a result of the disclosure, but the effect is small (about 5% of the house price for the highest risk properties) and difficult to identify precisely. In short, our evidence suggests that the erosion risk information being placed in the LIM reports seemed to have had only a minor effect on property pricing.

Evidence from elsewhere suggests that what we find in the Kāpiti Coast is not that unusual. People often consistently ignore low-probability risks, or ones that are further out into the future, until they became salient because of some external event. This kind of salient external event might be: (1) a high and damaging storm surge; (2) an insurance retreat; or (3) a shift in government policy. It can also be some combination of these scenarios, for example, an insurance retreat triggered by a storm surge event.

A destructive storm surge, maybe caused by an exceptionally strong extra-tropical cyclone, can potentially damage a large number of properties. There are several areas around the coast in which there are a significant number of exposed properties. Figure 3 presents analysis from NIWA that attempted to quantify how many houses, in each region, would be exposed for various levels of SLR (Paulik et al., 2020).

An alternative salient trigger for people's change in expectations about future events is a decision by private insurance companies to incorporate these risks more aggressively in their insurance premium pricing decisions; or, alternatively, to retreat altogether from some areas. Storey et al. (2020) analysed this retreat scenario in detail, to identify both the likely exposed properties, and the timing of partial or full retreats of private insurance from these coastal properties most exposed to SLR risks.

A third scenario might be an explicit commitment by government not to insure this erosion/storm-surge hazard. Some testimony and haphazard evidence suggests that some people, homeowners included, expect the government to always prioritise the protection of private homes, and to provide either indefinite physical protection with sea walls, or indefinite insurance cover (explicitly through the EQC, or implicitly with ad hoc assistance programmes). Indeed, recent discussions within the government about Climate Change Adaptation included floating the idea of an extension of the public insurance cover now available for earthquakes and landslides (through the EQC) to coastal erosion and flooding. Extension of cover will clearly further dampen the climate risk signal, and lead to a mispricing of properties located in hazardous areas. Equally, an announcement by government that this kind of extension is 'off the table' may generate the opposite, a strong price correction. This correction – reflecting actual risk – will be especially pronounced if there are now large constituencies that believe the government will proceed in the 'extend insurance to all weather risks' path.

While it is impossible to predict if any of this will happen, there seems to be a greater recognition by the government of the limits of physical structures in protecting coastlines against SLR. Indeed, managed retreat, a policy that was almost a political taboo until recently, is now gaining ground as a viable alternative, and the government is now considering it as part of its adaptation plan. This is notable given the very painful, expensive, and prolonged process that accompanied the very small managed retreat programme in Matatā.

These questions, and these alternative scenarios, are obviously relevant not just for the Kāpiti Coast, but for all other locations where the risk of SLR is real – this includes tens of thousands of properties all over the country's coasts, and especially in the densely populated urban areas, where property values are highest. As changes in the values of residential properties on the coast may also affect the value of nearby properties and entire neighbourhoods and towns, these questions have an indirect impact on the home value of almost all homeowners in New Zealand.

An extreme price correction that will wipe out the wealth of many families, and possibly lead to banking instability through mortgage defaults, is in no one's interest. If we are to continue along the current path, without appropriate disclosures of the risks and with little government action to nudge us in the right direction, an extreme price correction seems almost inevitable. Do we allow our coastal property markets to be thus disrupted, and just hope that it does not happen on our watch, or do we try and evince a controlled, gradual, and inevitable descent in prices, through a recognition of the risk the rising seas pose to us all?

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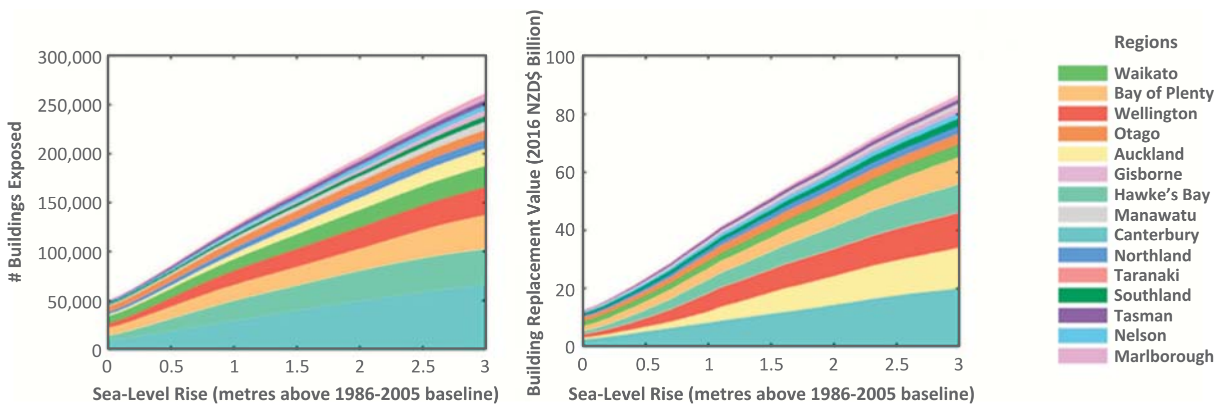

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Managed retreat at Matatā – a challenging solution

By Jeff Farrell

The natural hazard event

Between 17-19 May 2005, total rainfall of 367.5 mm was recorded at a rain gauge at Awakaponga, approximately 4 km from the coastal township of Matatā. The peak rainfall intensities of 94.5 mm (1 hour) and 307.5 mm (24 hour) were estimated as being between 200-500 year annual exceedance probability (AEP) based on extreme value statistics, however Blackwood (2005) regards them as ~20 percent greater than the 1% AEP estimated rainfall intensities. Morphological evidence at Matatā strongly indicates that rainfall intensities in the storm centre were somewhat higher again (ibid).

A period of very high intensity rainfall between 1600 and 1730 on 18 May 2005 was the triggering mechanism for landslides and debris avalanches into the headwaters of a number of streams (McSaveney et al., 2005). The landslides and debris avalanches evolved into five large debris flows simultaneously impacting the Matatā township and environs. Each debris flow transported boulders, large trees, and suspended silts at a velocity of 15-30 km/hr within the confines of the catchments, before depositing an estimated 700,000+ cubic metres of rock, wooden debris, silt and slurry onto debris fans.

The debris flows and associated debris floods damaged 87 properties and destroyed 27 homes. State Highway 2 was closed for 12 days and the Kawerau to Tauranga railway closed for more than 20 days. Total damages to the Matatā area exceeded $20 million. Miraculously there were no fatalities.

The most destructive debris flow in the 2005 event was from the 4.5 km^2 Awatarariki Stream catchment, the subject of this case study, which saw around 300,000 cubic metres of debris deposited throughout the fan. Boulders of up to 7 metres diameter were mobilised in this debris flow with a large percentage being in the 1.5 to 2.0 metres diameter range. In terms of peak discharge comparisons, the 100-year flood design flow for the Awatarariki catchment is 44 m^3/s whereas the estimated peak debris-flow discharge for the May 2005 event was 700 m^3/s (Tonkin and Taylor Ltd, 2015).

Initial assessment of options and community engagement

Immediately after the event, the Whakatāne District Council (WDC) engaged external experts to advise on options to manage the risk to the Matatā community from future debris flows. Immediate advice was that another event was possible at any time the rainfall pattern was repeated. This was followed by further advice that evidence existed of equally large and larger debris flows having occurred at Matatā many times over the last 7,000 years, with four smaller flows occurring since 1860 (McSaveney et al., 2005).

WDC acted on the expert advice and sought a Building Act determination from the Department of Building and Housing (DBH)[1] to prevent damaged debris fan properties from being reoccupied. DBH determined that WDC should allow residents to reoccupy their homes (Department of Building and Housing, 2006). The DBH decision was subsequently extended to those wishing to rebuild homes destroyed by the debris flow resulting in six replacement homes being built between 2006 and 2011.

[1] Incorporated into the Ministry of Business, Innovation and Employment in 2012.

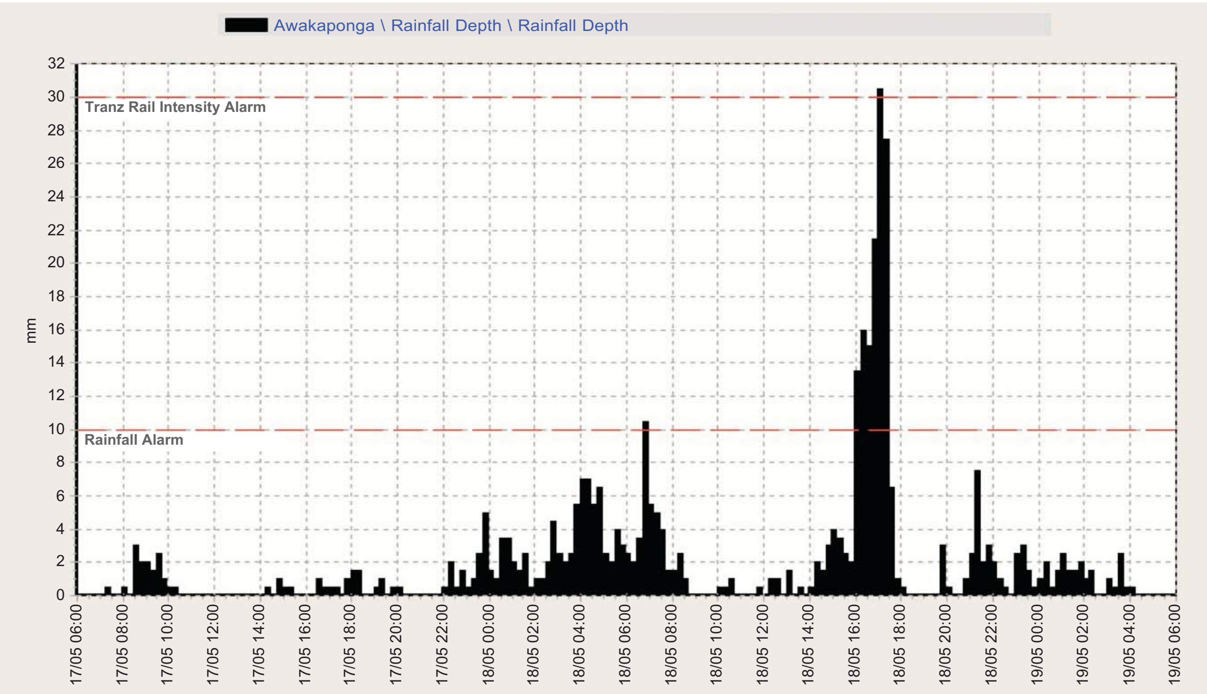

Figure 1: Awakaponga hytegraph illustrates extreme rainfall intensity for a period of 1.5 hours.

Figure 2: Awatarariki debris fan, May 2005 (Whakatāne District Council).

Community engagement informed risk reduction option selections. For all of the five catchments, cost-benefit analyses ranked engineering solutions higher than managed retreat (Walton and Clough, 2005). Engineering solutions were completed for four of the five Matatā catchments, the exception being the Awatarariki Stream catchment.

Consistent with the preferences of residents of the other Matatā debris fans, the Awatarariki fan community wished to re-establish the residential environment through an engineering solution that reduced the risk from future debris flows to acceptable levels. Despite several potential upper catchment and debris fan engineering solutions being explored between 2005 and 2012, WDC's expert external engineering consultants eventually advised that no engineering option was viable.

In December 2012, WDC formally resolved to not proceed with an engineering solution and to investigate and develop a planning framework to manage the risk. This was a pivotal decision by WDC, not just for the affected landowners but also for WDC itself in its regulatory roles of building consent authority and resource consent authority. The WDC decision formally recognised that the properties known to be at risk from the debris-flow hazard from the Awatarariki Stream catchment would continue to be exposed to that risk into the future.

The evidence to support managed retreat

In 2013, WDC was undertaking a Quantitative Landslide Risk Assessment (QLRA) of the Whakatāne and Ohope escarpments following numerous landslides over the preceding decade, combined with a landslide fatality in 2011. Based on external expert advice, the QLRA used the Australian Geomechanics Society Guidelines for Landslide Risk Management (AGS, 2007), an internationally well-respected framework for calculating landslide risk to people and property. As landslides are a component of debris flows (Hungr, 2005), the QLRA programme was extended to include Matatā.

The QLRA of the Awatarariki debris fan generated an annualised loss-of-life risk distribution across the fan that ranged from 10^{-2} (1 in 100 annual probability of occurrence) to 10^{-6} (1 in 1,000,000 annual probability of occurrence) (Tonkin and Taylor, 2013). International comparisons indicated that an annual loss-of-life risk greater than 10^{-4} (1 in 10,000 annual probability of occurrence) for an existing environment was unacceptable for residential use. F-N diagrams provide a way of presenting information about societal risk, where F represents the predicted frequency

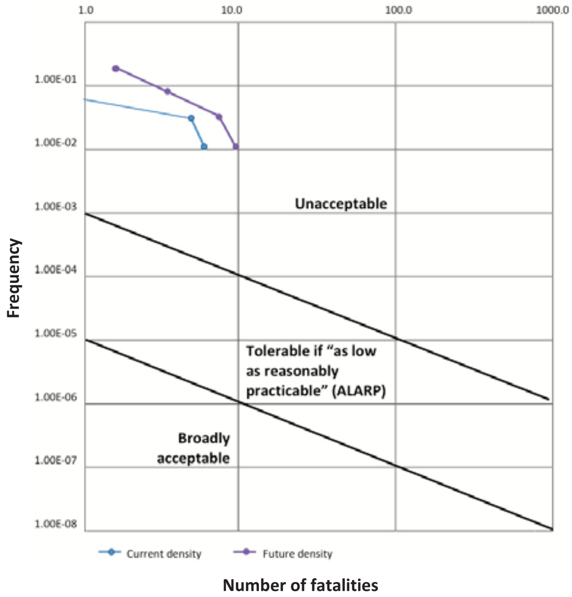

Figure 3: F-N Curve for the Awatarariki fan. Commonly adopted acceptance criteria (AGS, 2007) are indicated (Tonkin and Taylor Ltd, 2015).

of occurrence of an event and N the predicted number of fatalities. Societal risk for both, the existing (2013) development on the Awatarariki fan and, if all sections were developed, were plotted on a F-N chart presented in AGS (2007). In both scenarios, the level of life safety risk was unacceptable.

The criterion of 10^{-4} as a threshold of unacceptable annual loss-of-life risk was also adopted for rockfall risk assessments on the Christchurch Port Hills following the 2010-2011 earthquakes (Massey et al., 2014).

The risk assessments were provided to Awatarariki fan residents together with supporting information. WDC invited a representative group of residents to participate in a process to explore a way forward for both the residents and WDC. A Consensus Development Group was formed comprising property owners (resident and non-resident), an elected member and senior staff from WDC, and a senior manager from the Bay of Plenty Regional Council (BOPRC). The Group was supported by expert technical and planning advisors and independent facilitators. After four meetings over a two-month period, a wide range of potential solutions had been canvassed. There was general agreement that:

- A high level of risk existed
- Continuing with the status quo was not desirable
- WDC had statutory responsibilities to manage natural hazard risk to all members of society
- Engineering solutions were likely to be unaffordable.

However, there were also substantive differences within the Group on individual tolerances to risk with some residents wanting the decision on acceptance of risk to reside with individuals. A way forward was agreed and consisted of several workstreams that included:

- Additional peer reviews of the QLRA and efficacy of early warning systems
- An investigation into whether management of log jam dams in the catchment could effectively reduce risk

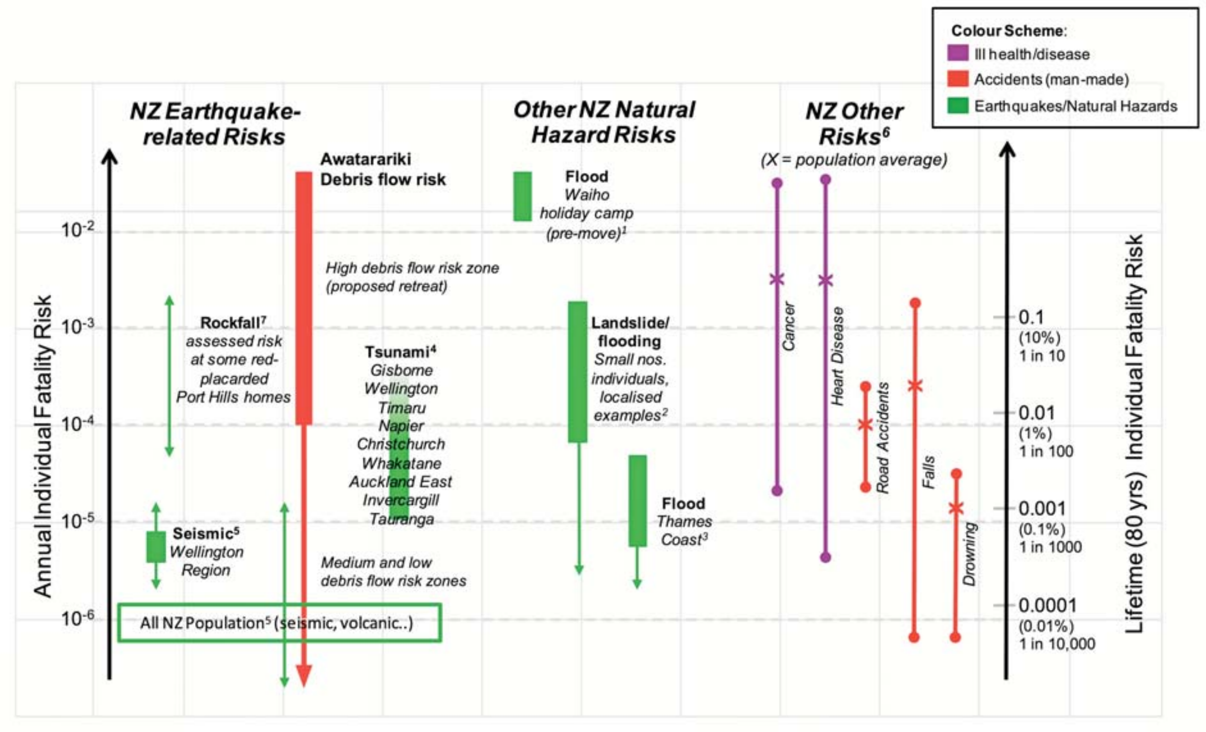

Figure 4: Comparison of Awatarariki debris flow risk against other risks in New Zealand (adapted from Taig, 2012). The thicker portion of the red Awatarariki line reflects 'unacceptable risk', that is, annual loss of life risk greater than 10^{-4}.

- Consideration of site-specific mitigation options, and development of a voluntary buy-out programme should site-specific mitigation of the risk prove to be not feasible.

The workstreams evolved into 13 workstreams, which made up the 'Awatarariki Debris Flow Risk Management Programme'.

A second peer review of the QLRA recognised limitations in the modelling and extended the area of 10^{-4} modelled risk out to the modelled 10^{-5} risk contour line (one order of magnitude) in order to ensure the risk was not underestimated and to better reflect the area of high risk. The reviewers concluded that the risk in the expanded area (the 'high risk area' hereafter) made residential use unsafe (McSaveney and Davies, 2015). This area included 34 private properties, of which 16 had dwellings and the balance vacant sections, with another 11 publicly-owned properties used for transport infrastructure and reserves.

A 2016 Building Act determination relating to building consent applications for two new dwellings within the high risk area, accepted the levels of risk in the risk assessment and peer review and supported WDC's building consent authority's refusal to grant the building consents. This meant that owners of vacant sites within the high risk area would be unable to build until the life safety risk was reduced.

Early warning systems were investigated by GNS Science (Litchfield, 2015; Massey, 2020). Due to a 3-6 minutes time interval between a debris flow initiating within the Awatarariki catchment and its arrival at the debris fan, an early warning system was not considered to provide an effective risk reduction mechanism in this instance.

Reducing risk through regular removal of log jam dams was discounted by Davies (2017) and Phillips (2018) on the basis that, although technically feasible, regular removal was not practicable, likely to be cost prohibitive, and would have no material impact on reducing the debris flow risk.

Elimination of engineering solutions, site mitigation works, early warning systems, and catchment management options defaulted WDC to the final risk reduction option identified by the Consensus Development Group, that of voluntary managed retreat.

Voluntary managed retreat

Moving to a managed retreat option presented complex and formidable challenges for WDC and Awatarariki fan owners. In 2015, New Zealand became one of 187 signatories to the Sendai Framework for Disaster Risk Reduction. This framework reflected a national (and international) policy shift away from disaster management to disaster risk management. Proactively identifying and managing risk was considered a more cost-effective investment than maintaining the status quo, that is, to respond to events when they occurred. However, although the new policy intent was clear, no consideration had been given to what policy implementation might look like.

The immaturity of natural hazard risk management policy development was problematic for WDC, which was facing a situation where an extremely damaging event had occurred, a high level of ongoing debris flow risk to 34 residential properties had been identified for which the only viable risk reduction option was managed retreat, but no precedent or national or regional guidance existed on what to do next. Although a programme of managed retreat had been delivered in Christchurch following the 2010-2011 Canterbury earthquake sequence, the government enacted special legislation to enable property acquisition. The small scale of the Awatarariki fan high risk area in comparison meant special legislation was not a viable proposition. As a consequence, in 2015 WDC was faced with developing a bespoke managed retreat framework to manage a natural hazard that had devastated a community once, and could do so again at any time.

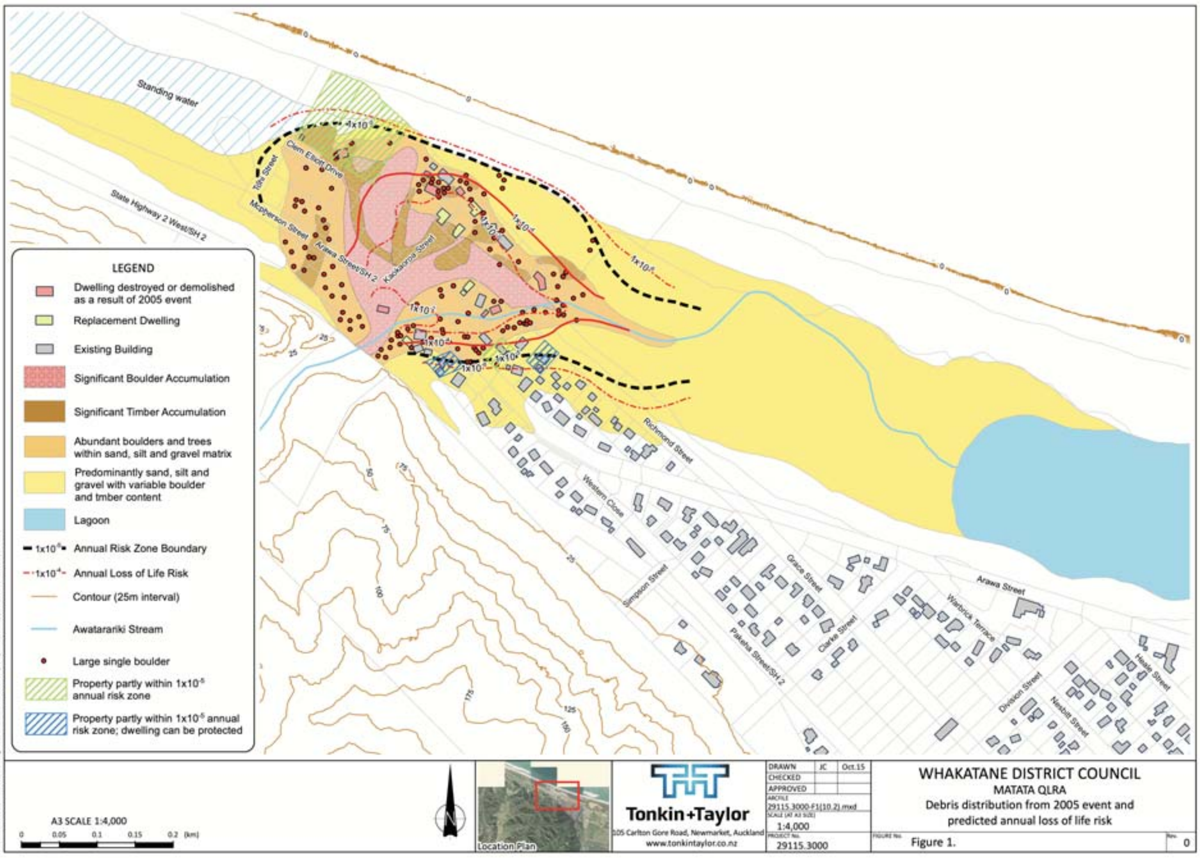

Figure 5: Loss of life risk profile, Awatarariki fan. The black hashed line is the modelled 10^{-5} annual loss-of-life risk contour line.

The funding challenge

The greatest implementation challenge was to find support funding for a managed retreat programme as acquisition of the 34 residential properties was beyond the financing capability of WDC, a provincial territorial authority serving a population of around 32,000 residents. Awatariki residents and WDC looked in the first instance to the government to support an outcome consistent with that provided to property owners in Canterbury. In order to be able to engage meaningfully with the government about funding, priority was given to preparing a business case using the NZ Treasury Better Business Case Methodology and to developing an Acquisition Strategy framework to guide property buy-outs.

The Awatarariki Acquisition Strategy (Sanders, 2016) incorporated the tried and tested principles that underpin the Public Works Act (PWA) acquisition process, namely:

- Equivalence – the landowner should be no better or worse off after the acquisition and pay-out
- Liberality – the benefit of doubt must run in favour of landowner
- Ultra Vires – the acquisition process must be in accordance with the law
- Natural Justice – full information and disclosure is required.

Although the core principles of the PWA were incorporated, the PWA was not available for the Awatarariki managed retreat programme because the land was not being compulsorily acquired for the purposes of a public work.

Experience of managed retreat in the United States indicated that unless residents were incentivised to relocate, take-up of a retreat package was highly likely to be low (Freudenberg et al., 2016). In response to evidence provided by property owners confirming that a significant proportion of those in the high risk area had nil to limited capacity to take on additional debt, the Acquisition Strategy excluded any financial contribution from property owners and included incentives to encourage owner participation. The Acquisition Strategy was finalised in 2016.

Two investment objectives were identified for the business case:

- To protect the life safety of residents in the high risk area
- To provide certainty to residents and the wider Matatā community and support community resilience.

In order to inform the financial parameters of the business case, WDC sought Awatarariki property owner support to have property valuations undertaken. Comprehensive valuation information was necessary to enable meaningful conversations with potential external funding agencies without whose support a managed retreat programme could not be delivered, and to prepare indicative acquisition offers that would be updated should funding be realised. Very few property owners declined to participate.

Valuations confirmed the property acquisition budget component of a managed retreat programme was in the order of $13 million if undertaken in 2016. The business case concluded there were compelling reasons to invest in a managed retreat programme for all of the 34 privately-owned properties (that is, 16 properties with dwellings and 18 vacant sections) over a three year period with funding shared between WDC, government and BOPRC (Stewart and Farrell, 2017).

The QLRA, business case and the Acquisition Strategy provided a solid foundation of evidence to support meaningful engagement with the government and BOPRC by WDC, on behalf of the Awatarariki fan community. However, and despite regularly socialising the compelling reasons for investment with government ministers and BOPRC elected representatives, external political traction and funding support proved elusive.

In 2017, national and regional policy settings moved more decisively to embrace risk management of natural hazards. Firstly, s6 of the Resource Management Act 1991 was amended by the Resource Legislation Amendment Act 2017 to include significant risks from natural hazards as a matter of national importance. Secondly, BOPRC adopted Plan Change 2 (Natural Hazards) to the Bay of Plenty Regional Policy Statement (RPS), which introduced a risk-based approach to the management of natural hazards, set descriptors for different levels of risk, and required high and medium risk to be reduced to as low as possible. WDC actively participated in the associated First Schedule process.

Both initiatives introduced much-needed policy direction to the conversations WDC had been having with government and BOPRC, but it took another two years of discussions and additional evidence building before a funding agreement was finally cemented.

Plan changes

In early 2017, WDC was advised that a prerequisite to government participation in funding an Awatarariki managed retreat programme was for WDC to utilise, as a legal backstop to the retreat programme, the formal statutory provisions relating to the extinguishing of existing use rights in the Resource Management Act 1991 as provided for by parliament, consistent with and utilising the recent changes to the RPS. WDC was reluctant to run with this as it meant that, if successful, property owners with established residential uses would lose their ability to occupy their land. Also, the process and potential outcome was highly likely to generate additional stress upon individuals who were already stressed due to the long period of uncertainty they had had to live with over the preceding 12 years since the event.

WDC was also cognisant that the extinguishing of existing use rights under the Resource Management Act 1991 had no legal precedent so, if WDC did as the government requested, it would be again faced with the challenge of pioneering a pathway on another matter of some complexity with high national interest.

After giving due consideration to the combination of the new policy settings, the 2016 Building Act determination, the conclusions from the business case, WDC's statutory responsibilities under the Local Government Act 2002 and Resource Management Act 1991, and taking legal advice, WDC decided to take up the baton and progress a change to the District Plan[2] that would give effect to the new Regional Policy Statement provisions around management of new risk. The District Plan change proposal was to rezone the land from residential to coastal protection, create debris flow risk policy areas, and make residential use in the high risk area a prohibited activity. In effect, the plan change recognised the 2016 Building Act determination and co-located it into a resource management legislative framework, thereby increasing the transparency around development constraints that applied to the fan area.

WDC also decided to request BOPRC to initiate a plan change to the Regional Natural Resources Plan to manage the existing risk, that is, those properties with dwellings. However, BOPRC declined WDC's request. After further legal advice, WDC made a private plan change request to the Regional Natural Resources Plan[3]. Rather than adopting the private plan change as requested, BOPRC accepted it, leaving WDC as the initiator of both plan changes. Both plan changes were publicly notified in June 2018.

As anticipated, commencing the plan change process further polarised the Awatarariki fan community between those owners that considered WDC was doing its best to deliver a positive outcome for them, and those that wanted to remain. The polarisation of the fan community extended to the wider Matatā and Whakatāne communities and became evident through Annual Plan submissions and submissions on the publicly notified plan changes. Mana whenua strongly supported both plan changes and the managed retreat programme.

Following receipt of submissions and further submissions on each plan change, a combined hearing to determine both plan change proposals was held in March 2020. The breadth and complexity of issues traversed was reflected in the number of witnesses (17) for WDC that crossed multiple disciplines:

- Public policy
- Planning
- Debris flow behaviour
- Natural hazard risk management
- Early warning systems
- Catchment management
- Property valuation
- Property acquisition
- Social impact
- Multi-criteria analysis
- Community engagement.

In stark contrast, no expert evidence was presented on behalf of submitters.

The imbalance of independent expert evidence was picked up on by submitters opposing the plan changes as reflective of both an uneven contest, and a wasteful use of resources by WDC. In contrast, WDC considered it essential that any decision to extinguish existing use rights be based on robust, comprehensive, and independently validated evidence. WDC considered further that the Environment Court's Code of Conduct requirements for experts involved in resource management hearings to impartially assist the hearing panel on relevant matters within the expert's area of expertise and to not advocate for the party that engages them, would

[2] Plan Change 1 (Awatarariki Fanhead, Matatā) to the Operative Whakatāne District Plan.

[3] Plan Change 17 (Natural Hazards) to the Bay of Plenty Regional Natural Resources Plan.

ensure that experts' evidence would be objective and accurate. Unfortunately, submitters opposing the plan changes did not perceive WDC's logic as having any legitimate merit.

The independent panel of hearing commissioners (engineer, barrister, planner, cultural expert) approved both plan changes on 26 March 2020. Their decisions were adopted by the two councils. An appeal by one submitter, representing some of the residents, was filed in the Environment Court. The appeal was settled through mediation with the Mediation Agreement ratified by the Environment Court in December 2020[4].

Property acquisition

On 4 July 2019, the Minister of Local Government formally advised that Cabinet had confirmed an out-of-budget allocation of $5.019 million, being a one-third share of an estimated $15.058 million total cost for the Awatarariki voluntary managed retreat programme. The funding was available for one year. BOPRC had previously confirmed its participation on the same proportionate funding basis, subject to the Crown confirming support. The Minister's formal confirmation of Crown funding was the trigger to commence the formal buy-out phase of the programme. The challenge for WDC was to deliver the programme efficiently and within budget.

WDC had continued to keep residents informed throughout the risk assessment and funding engagement phases. Consequently, once the buy-out phase became available, there was pressure on WDC to convert the 2016 indicative buy-out offers into formal acquisition offers reflecting current market values consistent with the Acquisition Strategy framework. Buy-outs progressed rapidly and, despite the arrival of the Covid-19 pandemic in March 2020, within 12 months two thirds of the 34 properties had been purchased.

Delays in acquisitions were generated through the valuation mediation and arbitration dispute processes that WDC had developed. Mediation was less formal than arbitration and involved the valuer acting for the landowner and the valuer acting for WDC meeting with a mediator to reconcile differences in valuation assumptions/interpretations. Arbitration was carried out by an appointee from the NZ Institute of Valuers who reviewed all of the documentation, made one or more site visits, and provided an independent assessment of market value.

In developing the dispute process, due to the compulsory acquisition option under the PWA not being available to WDC, and because WDC was trying to make the acquisitions property owner-centric, WDC elected to make the mediation and arbitration outcomes binding on WDC but not on the property owner. This was an error on WDC's part in that with no obligation to accept a mediated value, those property owners that sought mediation generally continued to contest the valuation figure through to arbitration. In every case, arbitration resulted in a valuation figure that sat mid-way between the valuation carried out for the property owner and the valuation carried out for WDC. This produced a perception that 'gaming the system' was worthwhile and generated additional pressure upon the project budget.

[4] Awatarariki Residents Incorporated v Bay of Plenty Regional Council and Whakatāne District Council [2020] NZEnvC 215.

Site clearances were another budget pressure. The budget estimate for removal of buildings and clearing the sites had been calculated following advice from Land Information New Zealand, which was based on experience with site acquisitions in Canterbury. In that context, site clearance was revenue neutral, that is, the costs of clearing the sites were balanced by the sale of the assets upon them. This did not prove to be the case at Matatā. Due primarily to the scale of the managed retreat and the size and architectural design of several of the buildings, budget estimates for site clearance were quickly exceeded.

With project budget caps in place for its funding partners, WDC was faced with financing all over-budget expenditure. An important funding lesson for future managed retreat programmes is that budget arrangements need to span more than one financial year to recognise the duration of retreat programmes, and contain provisions that enable original estimates to be revisited and supported where legitimate reasons exist.

Conclusion

Whereas current conversations around managed retreat in coastal settings typically focus on retreat over time due to incremental sea-level rise, the Awatarariki Voluntary Managed Retreat Programme at Matatā was a public policy response to an identified life-threatening risk from a natural hazard (debris flow) that was unable to be mitigated. Notwithstanding, the risk assessment methodology to identify the levels of risk that underpinned the need for managed retreat at Matatā are directly relevant to developments above coastal cliffs threatened by undercutting erosion of the cliffs by wave and wind action. The implementation challenges faced at Matatā do have a much wider application.

The Awatarariki Programme has provided an opportunity to identify and examine the multiple and complex challenges associated with delivering a programme of managed retreat applying a resource management framework. Without doubt, the programme has been successful in eliminating the high debris flow risk to 34 residential land parcels, however the journey has not been an easy one for some of the property owners and for the two councils.

A summary of the lessons that the programme has delivered include:

- Open and regular engagement with the affected community is important and processes and procedures need to be people-centric
- Adequate funding is essential and funding partnership arrangements need to provide for inflation and other contingencies
- A structured policy framework is required that is clear and directive
- The risk assessment methodology used must be credible
- Risk assessments need to be robust and defensible
- There is a need for common understanding of risk across agencies and legislative frameworks
- A shared community understanding of individual and collective risk is required
- Skilled people across a range of disciplines are required to work through the wide range of issues

- Quality assurance processes that reflect the magnitude of the potential outcome for people are essential
- Land valuation and acquisition processes need to be credible, fair, transparent, and include independent resolution of valuation disputes.

It is refreshing that the difficulties identified during the Awatarariki voluntary managed retreat programme have been recognised at a national level and have helped drive some of the pending legislative reforms associated with the RMA.

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Same, same but different; three approaches to setting and defining thresholds, signals and triggers using Dynamic Adaptive Pathways Planning

By Jamie Boyle, Nina Murphy, Gavin Ide and Amon Martin

The Hawke's Bay, Wharekawa coast and Coromandel Peninsula are three distinct coastal regions in the North Island currently going through the process of coastal adaptation planning using dynamic adaptive pathways planning (DAPP), as guided by the Ministry for the Environment (2017). The structure and processes followed by these projects using DAPP differs and contrasts significantly because of their unique geographical settings and distinct communities. All three projects are at the nitty gritty stage of understanding and setting risk adaptation thresholds, signals, and triggers.

This article outlines and discusses the distinct approaches employed by these projects to understand and define risk appetite for appropriation of flexible adaptation pathway options. We then reflect on broad questions around the applicability of practical guidance with the on-the-ground deliberative consultation process. What level of information is suitable for setting thresholds? Does one size fit all? How does scale affect the outcomes of community-defined thresholds? Why do sometimes signals and triggers get put in the too hard basket and left until last?

This article also provides a summary of the key challenges and lessons learnt from each project. These three projects have been underway for several years now and none would be described as plain sailing – so this is a chance to improve on adaptation planning moving forward.

Signals – an early warning that identifies when a trigger point or adaptation threshold may be approaching.

Triggers – the decision point(s), allowing sufficient time to take an action prior to an adaptation threshold being reached.

Indicators – individual or combined metrics or qualitative values that can pick up changes or trends and be used to monitor for both signals and triggers. Indicators should be salient, credible and legitimate for decision makers and the community (see Lawrence et al., 2020).

Adaptation Thresholds – the conditions to be avoided by taking a new action, that is, what people do not want to happen.

Adaptation Pathway – an approach designed to schedule adaptation decision making: it identifies the decisions that need to be taken now and those that may be taken in future. The approach supports strategic, flexible and structured decision making. It allows decision makers to plan for, prioritise, and stagger investment in adaptation responses.

Introduction

The Hawke's Bay Regional Council (HBRC)[1], Hauraki District Council (HDC)[2] and Thames-Coromandel District Council (TCDC)[3] have begun the journey towards adaptation planning to manage the impacts of climate change. All three councils have followed the Ministry for the Environment's (2017) guidance in similar yet different approaches and are attempting to implement dynamic adaptive pathways planning (DAPP). As a challenging task, all three councils are also initiating the tricky task of incorporating appropriate signals, triggers, and thresholds (STATs) that allow for an appropriate shift in adaptation option.

This article explores the unique approaches employed by each council, including what was required and what transpired leading up to the development of STATs. Firstly, we outline what information and knowledge was used, what engagement looked like, and the timing of the process. Secondly, we delve into risk tolerance – including the who, what, when and how and the challenges faced. Lastly, we compare the outcomes of the three approaches in the context of published guidance and postulate what a future adaption programme might consider for scale-specific success.

The resources available to each council and differences in project size and scale have necessitated the forging of unique paths in initiating DAPP. Table 1 outlines the key elements of each project and highlights the range of tools used to adapt to changing coastal risk. A central theme connecting the three projects was that each has been community-led, with coastal (community) panels set up and tasked with identifying preferred adaptation pathways. The coastal panels comprise members of the local community and are the engine room of the adaptation planning work, debating options and STATs, ultimately driving the decision-making process (see Table 1 for makeup). These have been supported by similar project governance structures.

Features common across each councils' project governance arrangements were:

- A joint oversight committee comprising elected members and representatives from relevant hapū collectives, Iwi or post-Treaty settlement governance entities.
- None of these three committees had an independent chair.
- A technical advisory group in support of the committee, with experienced staff from each of the participating councils and key involved stakeholders.

[1] Together with Hastings District Council, Napier City Council and three Treaty post-settlement governance entities.

[2] Together with Waikato Regional Council, Waikato District Council, Ngati Paoa and Ngati Whanaunga.

[3] Together with Pare Hauraki.

	TCDC Shoreline Management Plan Project (SMP)	HDC Wharekawa Coast 2120	HB Clifton to Tangoio Coastal Strategy
Geography			
Coastline type(s)	Range of coastal embayments, coastal plains, beach-barrier systems, harbours, and estuaries	North – steep pebble and cobble beaches Middle – shelly gravelly sands with low beach ridge South – wide beach and intertidal area, muddy sands that extend offshore from the beach	Gravel/sand beaches featuring Napier Port at mid-point; several estuarine areas, anchored by coastal cliffs at northern and southern ends
Length of coastline	~400 kms	~21 kms	~50 kms
Compartments	4 coastal panel areas (140 Policy Units); Kopu to Thames coast, Coromandel to Kennedy Bay, Whangapoua to Hot Water Beach,Tairua to Whangamata	5 compartments (each split into coastal and inland sub compartments)	2 'cells' split into 16 'units' (9 of which are 'priority' units)
Population	33,000	~800	~7,000
Settlements	28 communities, 7 towns	3 coastal settlements, plus rural area	6 coastal settlements, plus urban areas of Napier
Natural hazards			
Natural hazards in scope	Coastal erosion, inundation, and coastal land instability	Coastal erosion and inundation, tsunami, river flooding, instability	Coastal erosion, inundation, tsunami
Governance			
Governance structure	TCDC and The Pare Hauraki Collective	HDC, Waikato Regional Council (WRC), Waikato District Council (WDC), Ngāti Pāoa and Ngāti Whanaunga	HBRC, Hastings District Council, Napier City Council plus three Treaty entities (as below)
Entities actively involved in the project team	TCDC, WRC, Waka Kotahi	HDC, WRC, WDC, Waka Kotahi (involved mainly with coastal panel)	As above
Iwi represented	Pare Hauraki Collective – 11 iwi	Ngāti Whanaunga, Ngāti Pāoa	Maungaharuru-Tangitu Trust; Mana Ahuriri Trust Heretaunga Tamatea Settlement Trust
Project management			
Estimated project funding	$3.2M	$400,000	$2.4M
Project timeline	Commenced in 2019; 3 years to develop initial plan then implementation	Commenced in 2018; 4 years to develop initial plan, then implementation	Commenced in 2014; 8 years and counting...

Table 1: Adaptation project details (continued on next page).

	TCDC Shoreline Management Plan Project (SMP)	HDC Wharekawa Coast 2120	HB Clifton to Tangoio Coastal Strategy
Community engagement			
No. of coastal panel(s)	4	1	2
Membership of coastal panels	12-15 people; including members of local businesses, community board, public, community groups	12-15 people, including community members, civil defence emergency management, Rural Support Trust, Waka Kotahi	17-22 people, including members of local communities' businesses, infrastructure services, Department of Conservation, Port company and recreational interests, some observers also in attendance
Broad engagement processes	e-newsletter, dedicated website, letter box drops, Facebook, community workshops/drop-in/ meetings, online (teams) meetings	e-newsletter, dedicated website, letter box drops, Facebook, community workshops/drop-in/ meetings	e-newsletter, dedicated website, short online videos, letter box drops, community workshops and drop-in sessions, hui, online surveys
Adaptive planning			
Use MfE's Coastal Hazards Guidance	Yes	Yes	Yes
Current stage in MfE's 10-step decision cycle	Step 7	Step 7	Steps 6 & 7
Have developed adaptation pathways	Yes	Yes	Yes
Time horizon	100 years	100 years	100 years

Table 1: Adaptation project details (continued).

- Coastal panels with members from local businesses, community groups, key infrastructure providers, tangata whenua and residents.

The path to adaptation thresholds

The three projects all ended up working on adaptation thresholds (ATs) in 2021. For TCDC and HDC this work was done during the development of adaptive pathways for priority areas and compartments. For the Hawke's Bay project however, adaptation thresholds work started after

Clifton Seawall (top left, photo HBRC); Pauanui beach (above, photo TCDC); Coastal wetland (bottom left, photo HDC).

preferred adaptation pathways had already been identified for each of the nine priority units. The Hawke's Bay project had chosen to defer earlier work on thresholds, because:

- The Hawke's Bay project commenced in 2014 and was already well underway when the MfE guidance was being developed;
- It was determined that pathways could be readily defined without them;
- There was no guidance available at that time on how to develop them; and
- The collaborative coastal panels phase had already been very time and resource intensive without adding further tasks.

The coastal panels played a key role in developing the projects' respective thresholds, although the inputs and basis for how this worked in each location differs. The journey for all three projects getting to the thresholds work involved a significant amount of behind the scenes work to build an appropriate knowledge base of current and future hazards, and risk assessments. This work was necessary in bringing the coastal panels and public up to speed to enable meaningful discourse. The background work included:

- Creation and collation of coastal hazard data (new and existing).
- Completion of risk assessments to define high-risk communities and locations. The 'what matters most' section of the MfE guidance was undertaken alongside this work to incorporate the values and objectives for living at the coast.
- Community engagement alongside these, including several public open days, online surveys, and coastal panel meetings.
- Revision of coastal hazard data for better clarity and communication of risk (as required).
- Presentation of insurance information (including 'insurance retreat' discussion) and alternative approaches to managed retreat such as 'climate leases' (TCDC, HDC only).
- Reflection and comparison of recent and historically damaging events (TCDC, HDC only) with new hazard and risk information.

All of the projects had mixed success when incorporating a range of available and new data to inform the risk assessments and hazards analyses, and when working with communities through their engagement processes. For TCDC, the engagement process made it apparent that the information (particularly around the coastal inundation hazard) required better clarity. Community comments such as 'Need to understand the frequency of flooding, whether it is temporary or more permanent, incremental SLR would help with understanding this risk' and 'How do we accurately determine tolerability and adaptation thresholds, for example, a road going into Whangapoua without SLR increments' reflected this. Consequently, the project reworked hazard data and incorporated incremental sea level rise every 0.2 m as well as new frequency/return period data. This new information enabled a more refined risk assessment and greatly assisted public communication of risk. For the coastal panel in HDC, it was the vast amount of hazard and risk information presented to the panel to consider in determining their community risk threshold that led to difficulty in progressing the work. The coastal panel recommended that this information be broken down and compartmentalised so that it would relate much better to places they were locally familiar with, rather than a broad-scale approach. This change in approach aligned with the compartment approach employed from the outset by TCDC and HBRC.

Defining adaptation thresholds

For the most part, the approach to defining ATs by all three projects followed the recommended guidance by aligning the values and objectives for living at the coast with the assessment. Examples of thresholds discussed include:

- Insurance retreat
- Loss of public amenity
- Loss of public access (to and from the coast, residential areas, community services)
- Loss of private access
- Excessive maintenance costs
- Loss of coastal habitat
- Unsustainable levels of service (assets)
- Disruptions to residents and tourism sectors
- Civil defence emergency response capability impacted.

The coastal panel in HDC actively participated in how the adaptation thresholds were assessed (booklet)[4]. The booklets enabled impacts to be described for six compartments (five coastal, one inland) across six impact categories (homes, properties, and disruption to residents; rural land; roads and bridges (road access); services; recreation and tourism; overall impacts). This enabled a more meaningful approach where the panel felt the metrics used to assess risk tolerability were more reflective of their values and objectives. In contrast, the Hawke's Bay project's technical advisory group designed a 'template' for defining potential thresholds for each of the nine priority units. The formats of the two approaches are highlighted in Figure 1.

Hauraki

Using their booklet (Marsh, 2021), HDC undertook two risk threshold assessments, one assessed by staff from Hauraki District Council, Waikato Region Emergency Management Group, and Waka Kotahi. The thresholds assessment was undertaken at a workshop by council staff to document the tolerance of resources required for them to respond to natural hazard events. The other risk threshold assessment approach was community led.

While the coastal panel in HDC was initially going to do the thresholds assessment on their own, they felt that they could take a broader community-led approach and requested that the wider community had input. It was also discussed that this approach would be more suitable given the low levels of trust of the councils within the community. This resulted in 83 members of the wider community providing valuable feedback. This feedback was gained through the coastal panel members providing the booklets to people in

[4] https://wharekawacoast2120.hauraki-dc.govt.nz/wp-content/uploads/2021/07/community_risk_thresholds-1a.pdf

Mark your community risk thresholds here

ARP	200 yr	100 yr	75 yr	50 yr	20 yr	10 yr	5 yr	2 yr	1 yr	6 mth	2.4 mth
Major event											
Moderate event											

Coastal Hazard Consequence	Proposed Threshold	Threshold Evaluation and Selection			Relevant Unit									
		1. Coastal Hazards are the cause of the threshold being breached (Yes/No/ Indirect)	2. Data to assess threshold is available or can readily be collected and interpreted (Yes/No/TBD)	3. Selected as a threshold? (Yes/No/TBD)	ALL	Ahuriri	Pandora	Westshore	Bay View	Whirinaki	Clifton	Te Awanga	Haumoana	East Clive
Loss of Road Access (Community Scale)	Coastal inundation in {NAME} causing loss of road access for the majority of the community How long: At least 24 hours How often: More than once every 5 years	✓	✓	✓						✓	✓	✓	✓	✓
	Coastal erosion in {NAME} causing loss of road access affecting the majority of the community.	✓	✓	✓					✓	✓	✓	✓	✓	

Figure 1: Presenting examples of the threshold assessment templates used for HDC (top) and HBRC (bottom).

their community and going through it with them. This was a quantitative process of asking people to identify at what frequency the described impacts of coastal inundation and river flooding scenarios could no longer be tolerated. In addition, much qualitative information about how people experienced the impacts of natural hazards was received through the comments sections in the booklet. This was reflected by comments such as 'Waharau is a small treasure of a place, sheltered by the hills from the Auckland light pollution, the night skies are spectacular. Tikapa is the soul. We live here to be by the sea and the forest, the awa, moana, ngahere. We are here to live WITH the forces these elements bring. Including floods, it is a part of the connection to the place.' They also provided suggestions for mitigating and adapting to events, based on their local knowledge.

The results were collated by the technical advisory group (TAG) about the community assessment, and the median point identified. This gave community adaptation thresholds per compartment and for both scenarios of each impact category, resulting in an overall community adaptation threshold.

Hawke's Bay

HBRC included asset managers and planners from the three HB councils and the two coastal panels in a series of short workshops to populate threshold matrices (for a sample, see Figure 1).

The workshops helped identify potential qualitative thresholds, and several potential quantitative thresholds for the nine priority units. In many cases, the thresholds have proved applicable across all units (e.g., loss of road access) while several others remain unit specific. Thresholds were determined in the sense of it being 'too late' if this something happens or when intolerable 'frequency' is expressed as being one too many – not multiple events. Some panel members suggested wider community engagement on risk tolerability was needed.

Thames Coromandel

The focus was understanding adaptation thresholds for TCDC at a community level. The work focused on coastal inundation and followed much more of a qualitative exercise. Although no scoring or rating was done, the approach taken allowed the panels to voice their opinion on risk tolerability. Working through the most at-risk policy units (PUs) and alongside the results from the risk assessment work, conversation on risk tolerance was balanced on the potential impacts to known community values and objectives. Scenarios presented were commensurate on the risk to these PUs and allowed for better efficiency for threshold discussion. These included examples such as a king tide event combined with 0.5 m of SLR or impacts from a 5%AEP event. The insurance retreat event (5%AEP) provided a useful indicator as either a threshold or trigger and a realistic example of the type of impacts that might be felt by coastal hazards, noting 'at 0.8 m properties may be un-insurable, so is that (threshold) too late?'. As such, this metric could readily translate as a measure of risk tolerance.

For all projects, the community adaptation thresholds have been used to influence the adaptation options being considered for each compartment and will also be used to prioritise sub-compartments and impact categories where risk will need to be addressed sooner. In some cases, community engagement results indicate that the adaptation thresholds have already been reached or exceeded.

Reflections

A key theme of the thresholds setting work, and as communicated by HDC and HBRC, was that some panel members felt that wider engagement on risk tolerability was needed to improve the rigour of ATs being defined. The approach taken by the panel at HDC ties in nicely with the guidance and emphasises the importance that flexibility in applying DAPP can have in gaining meaningful results. It also highlights the high level of engagement and input achieved within a relatively small community area. For the most part, and because of the fixed scope of the project, TCDC have not had the luxury of employing this strategy. However, one panel member residing in Te Puru followed HDC's approach in door knocking and taking residents through the hazards, risks, and adaptation options. This allowed for a more refined community-wide understanding on what was tolerable and what was not, ultimately leading to a more comprehensive adaptation pathway in Te Puru.

Resulting from the identified need to further engage on ATs, and following the example of HDC's panel, both TCDC and HBRC have set out more consultation, including targeted online hui and targeted mail drops. This further consultation reflects the MfE guidance that places community engagement at the heart of DAPP. Both projects also recognise that more substantial community engagement is required and will need to happen when many moving parts of mahi come together in more cohesive proposed 'adaptation strategies' and where funding and implantation sequencing is required. They also recognise that the approach is a first cut of a flexible and iterative process that will allow for further alterations over time. The assessment of ATs undertaken with council asset and emergency managers at both HDC and HBRC was considered important in terms of timing for the provision and potential withdrawal of services. It was also identified that the levels of service in asset management plans could influence the community's ATs. Interestingly, in HDC, the results showed that council and asset managers had higher levels of tolerance (were more tolerant) to the potential impacts of coastal hazards than the community. There was no discernible difference between asset managers and the community identified in the Hawke's Bay. However, there were several specific asset management-related thresholds that coastal panels did not identify themselves.

To better communicate risk, TCDC internally presented a synopsis of the hazards and risks to relevant council staff. The approach has identified further work (on thresholds, signals, and triggers) as outside of the scope of the SMP process and has been deferred.

Signals and triggers, the too hard basket?

Both HDC and HBRC have deferred setting triggers and signals until after preferred pathways and thresholds have been defined. These projects recognise the importance of triggers and signals to the implementation of the pathways but consider these more technical in nature than setting ATs (e.g., events and physical characteristics that can be measured or seen). Accordingly, both these projects feel that those triggers and signals can be developed by council staff and experts in the first instance, rather than collaboratively by the community panels. This reflects several broader issues arising with the collaborative approach to the projects, such as the amount of time taken to develop the pathways, the resources involved, the large contribution that the panels are making to the project, and not wanting to overload them with yet more tasks.

TCDC have taken a slightly different course, where basic signals and triggers work has been worked through with their four coastal panels during and following the 'identify options and pathways' phases (steps 5 and 6 of the guidance). The design of signals and triggers has aligned with the guidance (Stephens et al., 2018; Lawrence et al., 2020), set around the measurability (metrics, qualitative) of change. In saying that, most signals and triggers identified rely on physical measurements of sea levels and shoreline movements. On reflection, these metrics are like that proposed by HDC and HBRC. However, key points came up in TCDC panel meetings around the signals and triggers needing to reflect metrics like changes in levels of service (e.g., lawn mowing, use or viability of recreational areas, or beach access). In this case, it was apparent that a broader suite of indicators (not just technical or scientific) may be required to allow for more 'salient and credible' approaches and truly dynamic and adaptive planning (Stephens et al., 2018).

These reflections give rise to key questions for future work, for example, are these technical approaches suitable when considering that a range of other social, economic, cultural, or environmental indicators are required (Stephens et al., 2018; Lawrence et al., 2020) to address the uncertainty inherent in climate change risks, and will this enable appropriate outcomes when set by councils? Will the exclusion of broader socio-economic, cultural or other environmental indicators and reliance on physical-based triggers and signals lead to maladaptation?

While we are not sure the outcomes of these decisions or how adaptation will play out as a result, problems in applying DAPP in practice may be evident here. We have taken a complex process and reduced it to fit existing knowledge and structures and allow for a simpler mechanism for monitoring. It is clear that more work is required to incorporate a broader range of indicators and to avoid potential maladaptation. However, the time and resources required to further explore these has been deemed out of scope for all projects. This highlights the additional support that might be required for councils, and particularly small councils, to be able explore and adopt more site-specific indicators. There are many valuable lessons to be learned from our experiences.

Lessons learnt and key takeaways

All three projects have shown that in applying DAPP, coastal adaptation planning can be flexible enough to encompass the inherent differences across coastal communities in New Zealand. We have shown that the MfE guidance is clear enough for a range of councils to follow, with some similarities and differences apparent dependant on the scale, scope, priorities and resources within each project. The journey in preparing for the impacts of climate change for our councils is still underway, but several key lessons that should be considered for current and future adaptation planning are highlighted below:

- Engagement is difficult at a district-wide scale and the engagement method is crucial to engaging everyone (online vs in person) and dependent on community demographics (access to technology, presentations, face-to-face, etc.)
- Scale and scope are important considerations in the setup phase of DAPP
- Community-specific consultation is likely required for meaningful determination of risk tolerance
- Consultation burn-out is a very real thing
- Information provided to the general public is often technical, difficult, and time consuming to translate into plain language
- Good robust science is required to gain trust and get off on the right foot from the start
- Commencement of thresholds work largely follows guidance but is often constrained by area-specific context, such as size, community connections, trust, and engagement methods employed
- Monitoring for broader STATs may be very difficult; many councils may struggle with implementing a system to allow for this, particularly with limited staff resources and budget
- Contextualising modelling work equivalent storm events historically allowed for a clearer approach to setting

thresholds and makes the process more 'real' and not just an academic exercise

- Iteration of the DAPP process may be key to be able to follow the guidance completely and especially when considering large-scale projects, resources, time, and budget constraints; there are options of extending out a project (e.g., HBRC) to allow for this to be incorporated over time, yet this may risk further consultation burn-out or losing traction of what has begun.

Clearly, it is difficult to provide a complete package of planning work in 'one hit' when using the guidance. However, it is with hope that the iterative process of DAPP will allow for the complexities discussed to eventually make their way into comprehensive long-term coastal adaptation plans.

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3 Engagement, collaboration and partnership

Pukehina Beach community planting, 2019 (Photo: Paul Greenshields, Coast Care Bay of Plenty)

The role of coastal marae in natural hazard response and climate change adaptation

By Akuhata Bailey-Winiata, Shari Gallop, Daniel Hikuroa and Iain White

Significance of marae

Marae are the ancestral meeting grounds of Māori, the Indigenous peoples of Aotearoa New Zealand. Marae today generally consist of an ātea (courtyard) and a complex of buildings, including the wharenui (meeting house), wharekai (kitchen/dining quarters), wharepaku (bathrooms), and often also kōhanga reo (Māori pre-school), wharekarakia (place of prayer), and other facilities such as housing for kaumātua (elders) (see Figure 1).

But marae are much more than infrastructure, they are at the centre of Māori culture, identity, and spirituality (Tapsell, 2002). Marae connect Māori to our tipuna (ancestors), and to future generations. Marae are spiritual buildings and places, symbolising the connection between the primordial parents Papatūānuku (Earth Mother) and Ranginui (Sky Father). The foundations of wharenui are secured in Papatūānuku, and the roof ascends to Ranginui, providing a space in between where Māori can connect to our primordial parents and ancestors who now reside with the atua (see Figure 2) (Kawharu, 2010).

Marae have whakapapa (genealogy) to the environment, which includes tangata whenua (people of the land). Marae are tūrangawaewae (a place to stand), providing a sense of belonging through whakapapa, which is an integral concept to Māori identity. Marae are often adorned with carvings and other depictions or representations of significant ancestors to the associated hapū (sub-tribe) or iwi (tribe). These artworks often illustrate pūrakau (ancestral stories) that encode the history and philosophy of the people in traditional narratives (Hikuroa et al., 2018).

Marae are also community hubs, including as a place for celebrations such as birthdays and weddings, as well as mourning life during tangi (funeral), through to hui (meetings) and wānanga (places of learning). Marae provide shelter, food, and recently hosted highly effective COVID-19 community vaccination initiatives (for example, Penetito et al., 2021; Hossein et al., 2022). Beyond COVID-19, marae are a critical emergency response infrastructure for natural hazard responses, for example as Civil Defence sites for people to evacuate to during natural disasters (Hudson and Hughes, 2007). Central to this, is that many marae have the capability to accommodate large numbers of people with facilities such as large-scale kitchens, dining rooms and sleeping areas. At marae manaakitanga (generosity/kindness) is shown to all guests, which is common, such as during hui, wānanga, tangi and celebrations. The hau kāinga (home people) rally together to support the kaupapa (agenda) to manaaki (support) people seeking refuge, providing accommodation, food, medical support, and post-disaster support such as counselling (Kenney and Phibbs, 2015).

Marae at the water's edge

Marae are often located near waterbodies including rivers/streams, estuaries, and the ocean. In Te Ao Māori (Māori world), water has mauri (life force) and is the

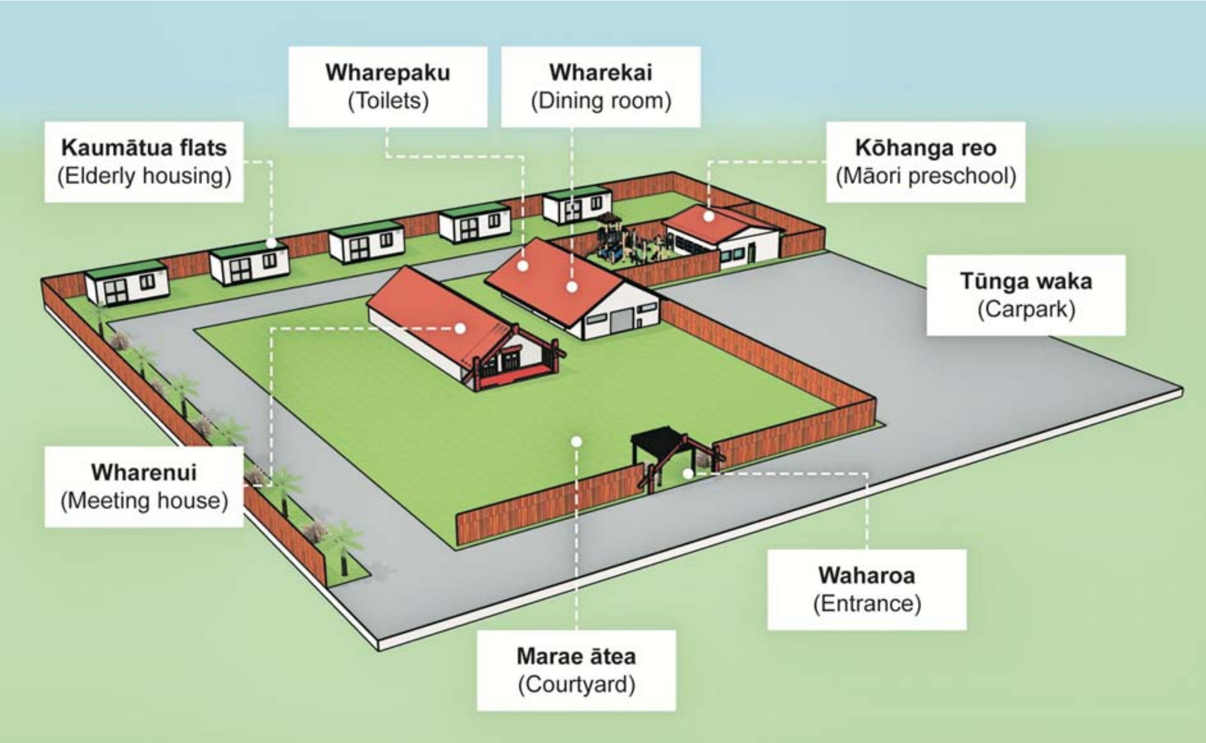

Figure 1: Generalised marae complex (graphic compiled by Gemma Conn, sourced from Bailey-Winiata, et al., in review).

originator of all things, and that it is akin to humans, giving rise to a well-known whakatauki , 'Ko wai ko au, ko au ko wai' – 'I am the water, and the water is me' (Stewart Harawira, 2020). As a resource, water sustains the most basic of human needs, and is used by Māori to irrigate māra (gardens), a source of kai awa (freshwater food) and kai moana (seafood). Water is also highly spiritual for Māori and is used in rituals and purification processes. Waterbodies, were also a dominant transport route of Māori, connecting whānau, hapū and iwi for trade and resolution of conflicts.

Marae are often positioned in places that are known to be safe based on mātauranga a whānau/hapū/iwi (often more generally referred to as mātauranga Māori – Māori knowledge). Marae were often positioned in locations that were safe from attack, such as on headlands, or close to resources, such as within estuaries. Positioning of some marae is reflected in pūrākau, which speak of caution. For example, in Matatā there is a taniwha in the form of a lizard where the flicking tail reflects the changing course of Waitepuru stream. The four marae are positioned well clear of the flicking tail and avoided the devasting debris flows of 2005 (Hikuroa, 2017).

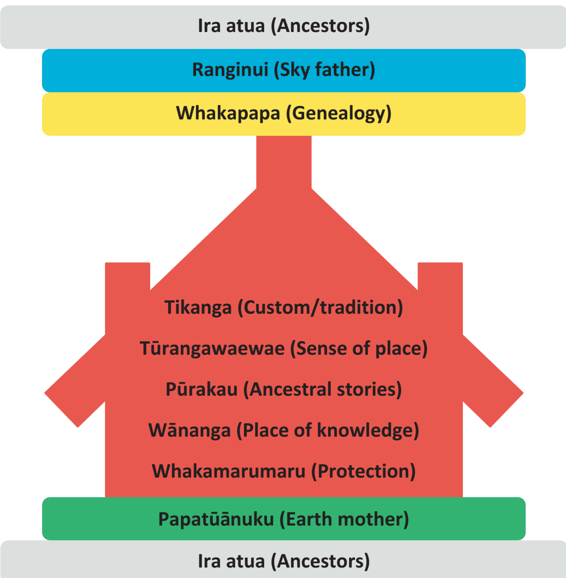

Figure 2: Schematic of marae showcasing key values contributing to their significance (adapted from Kawharu, 2000).

Although there are many advantages to living near to waterbodies, such features are prone to natural hazards such as flooding and erosion, meaning hapū/iwi have had to be adaptable and resilient in response to natural hazards (King et al., 2007). Hapū and iwi have in the past adapted to the impact of natural hazards, and continue to do so, and are now adapting to climate change through a carefully considered process informed by mātauranga Māori developed through generations of observations.

The impact of many natural hazards is being exacerbated by climate change, particularly at our coasts, including via coastal flooding and erosion due to increased storm frequency and magnitude in some places, intensified by sea-level rise (SLR). Focusing on coastal marae and climate change, King et al. (2012, 2013) found that the coastal Māori communities of Manaia, Waikato-Hauraki and Mitimiti (Hokianga, Northland) were particularly at risk to the impacts of climate change, ranging from Māori business and health to the physical impacts of damage to infrastructure and accessibility. Bailey-Winiata (2021) undertook a broad-scale national approach to understand marae exposure to SLR and found that 191 marae are within 1 km of the coastline (see Figure 3a), proximally adjacent to highly diverse coastal geomorphologies ranging from estuaries to open coast beaches. They also found that six marae are exposed to a 100-year extreme sea level event at current mean sea level, and 41 coastal marae are exposed to a 100-year extreme sea level event with 3 m SLR (see Figure 3b). These investigations highlight the extent to which coastal marae,

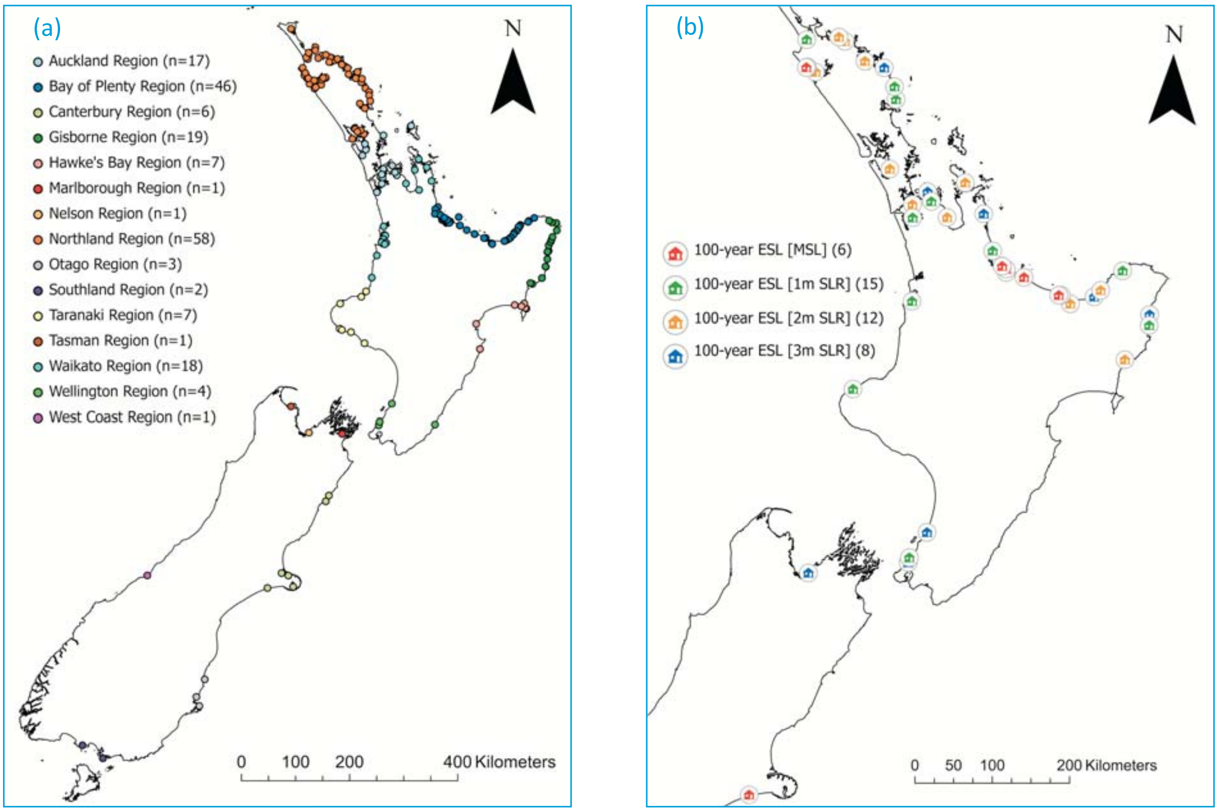

Figure 3: (a) National coastal marae categorised into Regional Government Boundaries; and (b) National coastal marae exposure to a 100-year extreme sea level event with +1 m increment of SLR (Source: Te Pōtiki National Trust, 2011 (maps) and Paulik et al., 2020 (dataset)).

and their associated wāhi tapu (sacred sites of significance, such as urupā – burial grounds, and mahinga kai – traditional food gathering sites) are at risk of coastal flooding due to SLR.

When establishing ancestral marae, careful consideration was given to the risks associated with natural hazards, based on careful and detailed observations through time. However, climate change has intensified environmental hazards and impacts, and hence many marae are now at risk. Coastal adaptation is topical around the world as coastal communities are having to adapt to the impact of sea-level rise.

To manage the risk as we head into the future with our changing climate, hapū and iwi can and are drawing on their mātauranga a hapū/iwi and are developing innovative solutions to adapt and mitigate the risk. Coastal adaptation is generally categorised into three broad types: (1) Protect, (2) Accommodate and (3) Retreat, with many coastal marae already adapting across all these responses. For example, Maketū marae in Kawhia has experienced erosion since the 1940s until the 1970s and in response the hapū, Ngāti Mahuta, constructed a seawall in 1971 and it was reinforced in 2004 (Tonkin+Taylor, 2007).

Accommodation options for sea-level rise and flooding are being considered by some marae, such as at Mirumiru marae, in the Waikato region. This marae is only accessible by boat and is situated on the Marokopa River. The hapū of Mirumiru marae, Ngāti Peehi, Te Kanawa and Kinohaku and the National Institute of Water and Atmospheric Research (NIWA) discussed potential options for adaptation in response to coastal flooding and erosion with SLR in Te Ao Maori News (Day, 2018).

Retreat is often the most controversial adaptation solution and aims to reduce risk by relocating and/or abandoning infrastructure, buildings and communities away from at risk areas (Hino et al., 2017). In the past, many marae have retreated or relocated in response to natural hazards. For instance, a landslide flowing down the Waimatai stream devastated inland Waihi village near Lake Taupō in 1846. This event killed 64 people, and another in 1910 lead to one fatality (Taig et al., 2012). These events lead to the relocation to its current position to the east of Waihi Bay, Lake Taupō.

At the coast, Waikari Marae in Tauranga Moana was relocated to higher ground by the hapū, Ngāti Tapu, in response to coastal flooding and erosion in the late 19th century (Tauranga Moana District Maori Council, 1989). In addition, Waipapa marae in Taranaki was relocated to higher ground in 1940 in response to river flooding, and again in 2009 (Waipapa Marae Trust, 2022). More recently, many other marae have begun the conversation of potentially relocating their marae. However, this is not always deemed a suitable option such as for Tangoio Marae on the East Coast of the North Island, which focused their attention on protection measures and sound evacuation procedures (Colliar and Blackett, 2018).

Heading into the future with climate change, marae are likely to play an increasingly important role for communities of Aotearoa New Zealand. They will continue to protect and shelter people from hazards and following disasters, and sites of community engagement about risk. Marae are also examples of mātauranga in action, such as where and how to position communities, infrastructure, and other marae to avoid hazards, if retreat is determined to be the right course of action.

Self-determination and coastal adaptation

In terms of Indigenous communities, retreat or relocation in many places around the world must be conducted carefully given the potential to perpetuate historic injustices that occurred through the process of colonisation – for example, confiscation of Indigenous land, forced removal of Indigenous peoples from traditional land, and forced assimilation into western society (Whyte, 2017). This disconnection from ancestral lands means that Indigenous peoples have sometimes been unable to fully adapt to the natural rhythms of the environment. Current issues surrounding land ownership and availability of land to relocate to, makes adaptation more difficult compared to adaptation pre-colonisation, and if relocation is deemed appropriate, for some, lack of land precludes this option entirely.

This argument emphasises that adaptation for marae needs to be cognisant of this history and ensure Māori self-determination, as outlined in both Te Tiriti o Waitangi and the United Nations Declaration on the Rights of Indigenous Peoples. Furthermore, in the context of Aotearoa New Zealand, any adaptation must uphold the principles of active protection, partnership, and participation of Māori consistent with the intent of Te Tiriti o Waitangi. This should involve Māori at every stage of the process, from knowledge collation and generation through to the selection of adaptation options. The latest Intergovernmental Panel on Climate Change Sixth Assessment report highlighted the need for Indigenous engagement and collaboration with Indigenous knowledge to the betterment of all peoples heading in to a climate changed future (IPCC, 2022). The challenge now is how to put those words into practice.

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Embedding Te Ao Māori within local government decision making: a Te Tai Tokerau approach

By Bernadette Aperahama, Puawai Kake, Ripeka Read and Shelley Wharton

Council decision making poses a significant risk for tangata whenua when adapting to and taking opportunities to reduce the impact and severity of climate change. Transformation in our current governance is required and is long overdue. That is the wero (challenge) laid down by tangata whenua in Te Tai Tokerau/Northland to council staff working on climate change adaptation. It is the challenge that a specialised project team has taken up in the co-development of a decision-making framework for local government based on te ao Māori worldviews (the framework).

Within the local government context, decisions are made regularly that impact the care, management and use of our environment. This is exercised through key pieces of legislation such as the Resource Management Act 1991, the Local Government Act 2002, and others. Participation of iwi and hapū in resource management and local government decision-making processes is a direct way for tangata whenua to uphold, practice and exercise their rangatiratanga and kaitiakitanga as guaranteed under Te Tiriti o Waitangi 1840. However, actual participation is unnecessarily limited and the achievement of outcomes is largely connected to the timing, resourcing and quality of that participation.

Councils have a key role under legislation to provide good environmental, social, cultural and economic outcomes for communities. However, it has been widely acknowledged that within this context, tangata whenua have been effectively, if not legislatively, excluded from participatory decision-making processes since colonisation. It is in this context that environmental degradation and breaches to Te Tiriti o Waitangi continue.

The development of this new approach to Council decision making within Te Tai Tokerau (the framework) is also occurring within a significant context of central government-led legislative reform that pervades multiple domains, including three waters infrastructure, planning and environment, conservation, local government, climate change, and whenua Māori. Many of these reforms are working to address previous inequities, but much detail, and the intricacies and machinery of implementation, remain unknown.

The framework will be used to:

- Help guide and inform the way in which tangata whenua are included in planning and policy responses to climate change.
- Recognise that adaptation is local and contextual.
- Provide tangata whenua, Council staff and decision makers with the tools to make the shift to a Te Tiriti based relationship.
- Improve decisions to address the climate crisis.
- Apply a te ao Māori lens across council functions – such as infrastructure, corporate planning and resource management.

Regional context and genesis of the project

Since 2019, the four Northland Councils have been working on developing a regionally consistent approach to climate change adaptation. In early 2020, staff hosted a series of co-design workshops to elicit risks to different domains (such as the natural environment, infrastructure, private property and tangata whenua) posed by natural hazards. At the workshops with tangata whenua, iwi and hapū raised concern about the risks to wāhi tapu from coastal erosion. Tangata whenua also noted that coastal inundation and flooding from storm events posed risks to access between marae and urupā. The risks in this instance were not only physical but spiritual and cultural and would disrupt the ability to practice tikanga and care appropriately for those deceased.

The nature of such physical risks is not new and is well understood in the literature. However new feedback emerged during the workshops that highlighted how the fundamental way local government goes about making decisions in fact poses the biggest threat to the ability of tangata whenua to achieve their own climate adaptation goals. Regionally relevant examples were cited such as:

- Major coastal developments by council-controlled organisations being promoted in opposition to outcomes seeking to preserve the coastal environment.
- High elevation whenua Māori (that might otherwise be able to offer a solution for managed retreat away from the coast) is being restricted in use by provisions stemming from broader regulations such as the proposed National Policy Statement on Indigenous Biodiversity.
- Councils planning for climate change adaptation while enabling intensification in areas subject to increasing risk of coastal inundation under climate change scenarios.
- Councils declaring a climate emergency while not prioritising rural tangata whenua at risk of natural hazards.

In light of these examples, Council staff and tangata whenua discussed the need for a fresh approach that turns to te ao Māori worldviews to guide climate adaptation planning processes more holistically. Funding was successfully sought from the Department of Internal Affairs Three Waters Stimulus Fund and a strong project team was formed of locally based, experienced and well connected wahine Māori practitioners.

In Te Tai Tokerau, He Whakaputanga o te Rangatiratanga o Nu Tireni 1835, the Declaration of Independence of the United Tribes of New Zealand (He Whakaputanga), acts as the founding document of this country to many whānau, haukāinga, hapū and iwi who reside and whakapapa back to the area. He Whakaputanga confirms the mana motuhake and rangatiratanga o ngā hapū and provided the basis for many Rangatira to sign Te Tiriti o Waitangi, and others the Treaty of Waitangi[1].

Connected to these foundational constitutional documents is the Waitangi Tribunal inquiry of Wai 1040, Te Paparahi o Te Raki (Northland) claim. Wai 1040 is an inquiry into around 420 claims brought by a number of claimant groups including Ngāpuhi, Ngāti Wai, Ngāti Hine, Patuharakeke, Ngāti Rehua, Ngāti Whātua and Ngāti Manuhiri. The Stage 1 report addressed the issues posed by the Waitangi Tribunal, which (uniquely in Tribunal inquiries) focused on Māori and Crown understandings of He Whakaputanga, Te Tiriti o Waitangi/the Treaty of Waitangi 1840, the nature of sovereignty, and whether the Māori signatories to the Treaty of Waitangi intended to transfer sovereignty. The Inquiry found that 'rangatira who signed Te Tiriti o Waitangi in February 1840 did not cede their sovereignty to Britain'. It is clear in this regard that both He Whakaputanga and Te Tiriti recognised the mana and tino rangatiratanga of hapū. This finding provides a significantly different view of the intended nature of the relationship between local government (as a crown agent) and Māori, than currently exists.

He Kōrero Rapunga: Te Ao Māori Research Methodology

To guide the development of the framework, the project team are using a kaupapa Māori research methodology: He Kōrero Rapunga. The five phases of He Kōrero Rapunga include: Te Rapunga (the search), Te Kitenga (the vision), Te Whāinga (the pursuit), Te Whiwhinga (the acquisition), and Te Rawenga (the celebration).

The project is currently (in late 2022) working through 'Te Whāinga: the Pursuit' stage to understand, through co-design hui and whakawhiti kōrero (sharing of dialogue), what a framework might look like for Councils in Te Tai Tokerau.

From the outset, the intent has been to co-design a framework of benefit to both tangata whenua and Councils within Te Tai Tokerau. Integral to this is a pathway for better partnerships between local government and tangata whenua to lead climate change adaptation in each respective haukāinga and rohe based on their own kōrero tuku iho and mātauranga Māori (knowledge systems, local observations and lived experiences). This provides local authorities with the opportunity to enable and support a mana motuhake and rangatiratanga approach to climate adaptation planning and implementation across Te Tai Tokerau. The framework may also assist in decolonisation strategies across local government and, in practice, prioritise Māori leadership in forging an adaptive path forward.

[1] In this context Te Tiriti o Waitangi is the Māori text and is the prominent document signed by many hapū Rangatira from Te Tai Tokerau. The English text is referred to here as the Treaty of Waitangi.

Engagement to date

From inception in 2021, the project team has been guided by kaumatua, kuia, tohunga, kaitiaki, iwi and hapū representatives from across the region. Collaboration has also occurred with hapū and iwi representative forums (some comprising tangata whenua and Council elected members) across Te Tai Tokerau, as well as Māori kaimahi and climate change specialists from the four Northland Councils. In addition to presenting to tangata whenua forums and Council-centric forums of elected members and tangata whenua, the project team have held two phases of engagement on the kaupapa, with a third phase planned.

To date, the engagement phases have included online and kanohi-ki-te-kanohi hui (face-to-face meetings) across Te Tai Tokerau. The Covid-19 pandemic impacted the ability to host additional kanohi-ki-te-kanohi hui and reach some in isolated or vulnerable communities. However, it did offer over-stretched kaitiaki and kaimahi (and those feeling uncertain or apprehensive) the opportunity to attend in a more time-efficient and health-conscious manner.

In the first phase of engagement the project team sought perspectives of tangata whenua on climate change, kaupapa Māori decision making, and also local government decision making. This included seeking to understand the pūrākau and kōrero tuku iho regarding te taiao (the environment) and climate change. In particular, it looked at how changes in the climate are understood and explained, how certain risks from environmental change can be known, and how appropriate adaptation and mitigation responses based on pūrākau and whakapapa can be applied.

Key themes from the first round of engagement with tangata whenua included:

- Te reo Māori and pūrākau are important to understand climate change from a te ao Māori perspective.

Phases of Research	Description
1. Te Rapunga	The Search: Informed by strategic drivers
2. Te Kitenga	The Vision: Te Ao Māori decision-making framework
3. Te Whāinga	The Pursuit: Engagement hui, analysis of kōrero & draft framework
4. Te Whiwhinga	The Acquisition: Sign off received, piloted, tested, implemented and adopted across TTT
5. Te Rawenga	The Celebration: Decision making framework delivering outcomes (monitoring)

He Kōrero Rapunga, a depiction of a Te Ao Māori research methodology the project is employing to develop the Te Ao Māori decision-making framework for local government.

- Pūrākau, kōrero tuku iho, mātauranga and tikanga Māori need to inform environmental management responses (including using rāhui) and climate change planning and responses.
- Climate change/Te Ao Hurihuri is understood in te ao Māori, as Māori have had to adapt to changes in the environment since the arrival of Kupe and other navigators to Aotearoa.
- Community/hapū must lead climate change planning as they know their areas best.
- Bespoke, localised climate change planning and adaptation responses are required.
- It is important that western science and mātauranga Māori are aligned and complimentary.
- Tohu (signs or cultural indicators) should be used to inform environmental monitoring and resource management in areas.
- Sufficient resourcing for iwi and hapū kaitiaki is vital to undertake environmental monitoring.
- More education and training is needed for future and current generations about the effects of climate change and adaptation planning.
- There are flow-on effects within ecosystems if a taonga species or an endangered species or its environment is impacted or depleted. For example, loss of taonga species within mahinga kai sites will create flow-on effects for tangata whenua and impact their ability to uphold their food sovereignty.
- Climate change (in particular coastal erosion and sea-level rise) is impacting traditional practices on where and how Māori live – including their papakāinga and other sites of significance such as mahinga kai sites, marae and urupā.
- Whānau have to continue to learn to pivot to a new environment and the changes occurring.
- Bottom lines for Māori differ from those of the council and developers.
- We need to uphold the tuakana and teina[2] relationship between people and the environment. Humans need to acknowledge our role as teina, the younger siblings, in our relationship to the environment.
- Increased commercialisation and consumerism of products leads to environmental effects and increased waste, for example ocean plastics.
- There is a need to support circular economies and local businesses in Northland to minimise carbon emissions and waste.

[2] Tuakana-teina is a concept from te ao Māori and refers to the relationship between an older (tuakana) person and a younger (teina) person. Within teaching and learning contexts, this can take a variety of forms such as peer to peer, younger to older, older to younger, or able/expert to less able/expert.

Building on kōrero in the first phase, Phase 2 engagement included a 'check-in' with tangata whenua to ensure that their kōrero was recorded as intended and to confirm their understanding and expectations on how their kōrero would be used or shared. A draft framework and examples of its application were also shared and tested. During this second phase of engagement the project team learned that while the project was supported and feedback was supportive and positive, it was clear that the framework needed to be reworked. Specifically, feedback was received on the need for stronger, more direct language and clearer responsibilities to better reflect the constitutional and legislative context described above. Greater clarity was also sought to understand 'who the framework was for' and how it would be implemented. It was emphasised at this time that the methodology for the framework must be led and developed by Māori for Māori.

Where to next?

The approach to decision making around climate change must be considered on a case-by-case basis for respective communities that are feeling the effects directly on the ground. It is important to acknowledge that western science has a part to play in climate change planning. But we must fundamentally acknowledge the role that tangata whenua have in decision making, embedded in He Whakaputanga and Te Tiriti and enabled through legislation.

Climate change planning is not new for many Māori communities here in Aotearoa, having lived within te taiao for generations and being descendants of tūpuna who regularly interpreted and adapted to changing environments.

Reducing the severity of climate change and adapting to the inevitable changes will require a departure from the singular dominant decision-making methods and current perspectives of local government. Despite all the challenges, climate change can be a catalyst for changing how Councils in Te Tai Tokerau make decisions, forging stronger, locally relevant relationships with tangata whenua.

As the reader will have noted and can no doubt imagine, the development of such a framework is not without challenges. Appropriately recognising context, taking the time to engage and reflect and finding commonality across iwi and hapū have posed challenges. Implementation of the framework will need to occur within governance and operational decision making. Training will be required to demonstrate how successful application can be achieved and this is likely to differ across the Northland councils and between and within different council departments and functions.

Despite those challenges, one overwhelming positive outcome that deserves repeating is that developing stronger relationships with tangata whenua and te taiao can only act to better serve our tamariki and mokopuna for many generations to come.

Elevating engagement with communities

By Gemma Greenshields and Tom Simons-Smith

Adaptation, sea-level rise, hazards and risk are terms that conjure up uncertainty and even fear, particularly for communities[1] that face these challenges to their homes and livelihoods. As practitioners in the adaptation space, we are responsible for daylighting risks and drawing communities in to think about what can be done to adapt. Adaptation plans are often considered the primary product and purpose of our work. However, increasingly the adaptation planning process is being recognised for its function as an educational opportunity for council, iwi and communities. Perhaps the process of adaptation planning could benefit from greater emphasis on inclusivity and education, both to increase the community's interest and understanding in the science, and to achieve the mandate that these processes are currently reaching for.

This article draws on the experiences from the St Clair-St Kilda Coastal Plan, reflecting on what went well and what did not. This adaptation planning process saw input from more than 2,300 people over two years. The resulting plan has been adopted unanimously by the Dunedin City Council (DCC). The work is now moving towards assessment and implementation and is benefiting from a strong platform of community input. This project has been recognised for its iterative and authentic engagement through the Australasian International Association for Public Participation awards, where it won the Planning Category and Australasian Project of the Year.

The first section of this article focuses on three simple but important principles of engagement. The second section dives into how these principles were applied through the St Clair-St Kilda Coastal Plan process. The final section reflects on what went well and what didn't.

Our engagement principles

Engaging with communities on climate adaptation is a big task. It's a complex topic with a lot of uncertainty. We want input from our communities. We don't want to consult just to tick a box; we want to genuinely engage and reflect the community's input in our work.

The St Clair-St Kilda Coastal Plan put the community at the heart of developing the coastal adaptation plan. For us, three principles stand out because they helped deliver a meaningful process of adaptation engagement. These are:

- Inclusivity
- Sequencing – taking the community on the journey
- Being iterative – continually engaging at each stage of developing the plan.

Our process was guided by the Ministry for the Environment's *Coastal hazards and climate change: Guidance for local government* (2017), which recommends planning for the impacts of climate change and coastal hazards and follows a 10-step decision cycle. While we adapted the process to meet the needs of the community, engagement remained at the heart of all adaptation planning activities. By taking a purposeful approach, guided by the agreed principles of engagement, we were able to engage broadly and deeply with a diverse community, build trust, elevate our engagement, and deliver an adaptation plan that reflected the community's aspirations.

Inclusivity – enabling communities to participate and engage

Inclusivity is the practice of providing equal access to opportunities and resources for people who might otherwise be excluded or marginalised, such as those with disabilities or other minority groups. Recognising that one method of engagement won't suit everyone is key!

Thinking about engaging with a broad audience requires a range of methods for the same topic. When thinking about methods, it's important to reflect on who the method is attracting and who it is excluding. We should consider the challenges/barriers that individuals/groups face in engagement and make sure that we offer alternatives. A workshop between 6pm and 8pm, for example, might exclude parents as they are with children in the evening. Conversely, having everything online might exclude elderly people or those that don't have access to the internet, while a hard copy form with freepost might allow them to engage. At times, more resources and time are required to support engagement with one group than another to achieve inclusivity.

Creative expressions and the arts can help inclusivity as they allow families to get involved and support people who struggle with words but thrive with visual and physical expression. They provide many opportunities for cultural expression as well. The ability to get whānau around a topic and create something together can break down barriers and engage people in a process that they otherwise wouldn't get involved in.

Including the youth voice in our engagement is similarly important because this group is the generation who will be addressing the consequences of a changing climate. Going to youth is a great way to hear from them, for example, by going to schools and universities. By engaging with youth, we get a greater balance of views and values (across generations). In doing so, we can better reflect the collective community voice in our work.

When it comes to inclusivity have a think about:

- Are locations for engagement activities accessible?
- Can you go to where the people are?
- When are you holding your events?
- Can community leaders/groups guide you on what would work best?
- Is your information easy for people to understand, are you using plain language?

[1] Please note, throughout we will refer to 'community' as stakeholders and the public collectively. This does not refer to mana whenua as they are partners to the process and as such have a unique relationship with the organisation outside of the engagement processes referred to within this article.

Sequencing – taking the community on the journey

As practitioners we need to be challenging ourselves: can we move beyond providing a consultation opportunity or two and towards a more authentic and pragmatic approach to engagement? It's not just about listening to people, it's about hearing people and valuing what you hear in ways that work for them. Understanding where people are at early allows us to tailor the adaptation process and provide the information needed to fill knowledge gaps, building capacity for the community to engage in subsequent conversations.

Authentically listening and valuing community input should be done from the outset, to allow them to have most influence and provide direction for future stages of work. It's important that we use the right technical information (i.e., local hazard and risk assessments), but equally we need to be cognisant that this information becomes a real focus and can place individuals on the back foot, making them defensive. It also makes it difficult for the community to think longer term and express their values and aspirations for the coast when all they are seeing is what they might lose to the hazards. Some smart sequencing can help to provide space for positive community expression before too much focus on the technical information.

The nature of climate adaptation planning means we work with incomplete and often uncertain information. On top of this, the adaptation legislation and practice is under development and will continue to evolve. We need to become more comfortable with starting conversations with information that we know will change, iterating and conveying the uncertainties in a robust and open way. Being transparent about what we know, what we are finding out, and what we may never know helps to build trust and greater understanding with the community.

We don't always need to start with all of the technical information right away – what if we got to understand the community's position, values and ambition first? Could we do a better job of delivering processes that worked for them? Could we better focus our technical work to address the community's knowledge gaps (and not just our own) – to help avoid drawn out conversations later?

When it comes to sequencing engagement have a think about:

- What do you want to know from your community?
- What does the community want to know from you?
- What parts of your process can the community influence?
- How individuals might react to technical information, and how it might best be communicated?

Iterating and improving engagement

Iterative engagement is about constantly reflecting on who you are hearing from and who you are not. What is working and what is not. This reflection should happen throughout the engagement so you can make changes to increase participation and inclusivity. It may be that part of the engagement requires more time for people to digest the information, and that phases of engagement should be extended to allow the space for important conversations. At each phase of engagement this reflection and iteration is important to meet both the needs of the project team AND the community. If you realise through engagement that you haven't heard from a group, then what can be done to provide opportunity to these groups/individuals? Perhaps new methods or time could be added?

When it comes to iterative engagement have a think about:

- Being self-critical and honest about your process – after your initial engagement what have you heard, what is concerning people, what engagement methods worked well, and what did not?
- How could the programme change to include some alternative methods?
- Are you getting what need is needed out of the process? And is the community?

Our engagement principles in practice – St Clair-St Kilda Coastal Plan

Throughout the St Clair-St Kilda Coastal Plan work, the three engagement principles discussed above helped to elevate our engagement.

The St Clair-St Kilda Coastal Plan is an adaptation planning process focused on the coastline of St Clair and St Kilda beaches, Dunedin. Figure 1 shows photographs of each section of the St Clair-St Kilda coastline. The current coastline is comprised of a combination of hard and soft defences, including a sea wall, geotextile (sand-filled) barrier, and a length of sand dune. Collectively this coast shelters the low-lying inland South Dunedin area, providing defence from coastal inundation and erosion. This section of coast is heavily used by the city with many people using the coast year-round for recreation activities such as walking, surfing and other sports. The community cares deeply about this coast.

In early 2018, the Dunedin City Council began its journey to develop an adaptation plan for the St Clair-St Kilda coast – the city's first plan dedicated to addressing the effects of coastal hazards and climate change. The progressive loss of beach amenity, public access and environmental values that had resulted from land-use, engineered intervention and beach erosion over the past decades played a significant role in initiating this work.

The following sections of this article focus on the three principles of engagement discussed above and provide a candid account of what went well and what did not, during the St Clair-St Kilda Coastal Plan's two year engagement process.

Inclusivity

Recognising that one method of engagement won't suit everyone is key! Through the St Clair-St Kilda Coastal Plan a wide variety of engagement methods were used to provide for an accessible process that went to the community. Over the engagement period methods included public meetings, workshops, drop-in sessions, beach intercept surveys, online

Figure 1: Photographs of beach sections, St Clair (top), Middle Beach (middle), and St Kilda (bottom).

surveys, interactive experiences, printmaking sessions, and presentations and workshops with primary, secondary and tertiary education providers (schools and the local university). Stakeholders were also provided opportunities for one-to-one meetings at various stages in the process. Figure 2 illustrates some of the engagement methods used.

DCC staff attended more than 100 different engagement events during the process of developing the adaptation plan. More than 10,000 people were reached and direct feedback was received from more than 2,300 people. The breadth of methods was key to reaching a diverse group and allowing a range of values and ideas to be drawn into the plan development process. The result is a vision and set of community-derived objectives that reflect input from the community and a diverse group of stakeholders. The work has established a direction of travel that is both informed and understood by many members of the community.

Sequencing – taking the community on the journey

The St Clair-St Kilda Coastal Plan process placed emphasis on community input from the outset and carefully considered the sequencing of conversation topics with the community. Pre-engagement involved reaching out to community groups to gauge interest and seek feedback on how different groups would like to be involved. This helped to shape the process of outreach (methods) and tailor the information presented. Engagement proper started with an assessment of community values and aspirations with the goal of

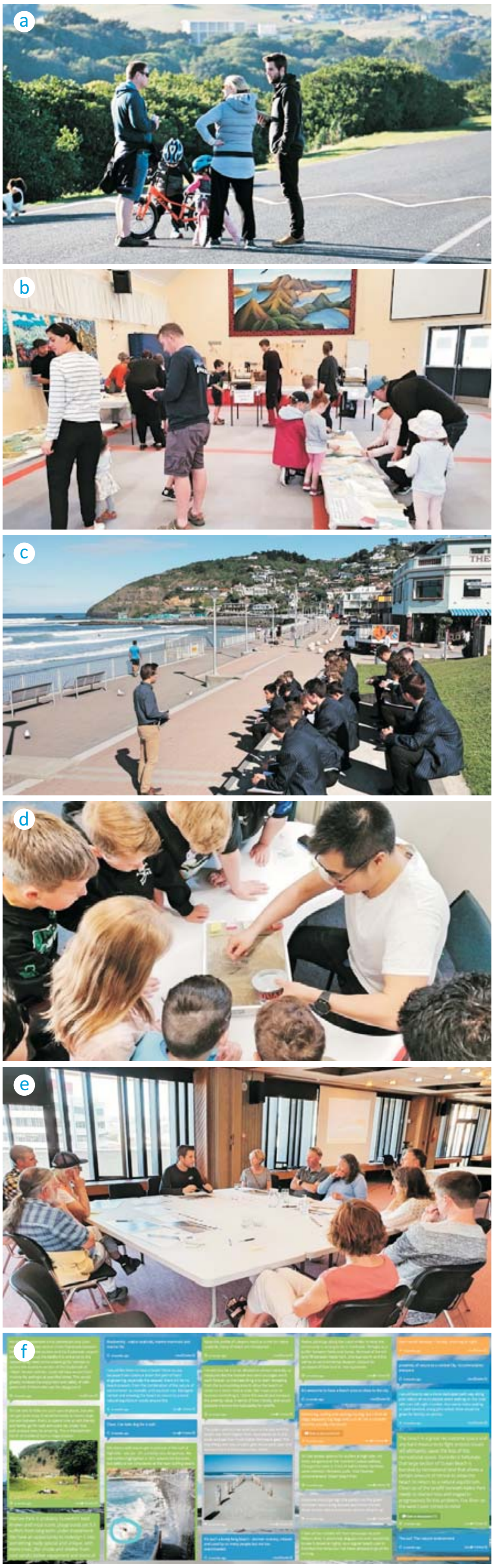


Figure 2: Photographs of some engagement methods used for the St Clair-St Kilda Coastal Plan: (a) beach intercept surveys; (b) printmaking sessions; (c) secondary school talks; (d) primary school education sessions; (e) public workshops; (f) online survey social Pinpoint.

understanding what the community loves about the coast. While we were talking to the community about what mattered most to them, we also started to educate them on what was happening at the coast. This two-way exchange of information started productive conversations about the history of the coast and allowed the concerns of the community to be heard. This informed the later development of management objectives and criteria used in the screening of management options.

Iteration

Good engagement is as much about ongoing reflection and being open to making changes as it is about upfront planning and preparation. The St Clair-St Kilda Coastal Plan engagement process used a two-tiered engagement approach involving the development of an engagement strategy, which identified the key values and principles of engagement and the desired outcomes. Beneath this, engagement plans informed the activity on the ground. Throughout engagement, the project team undertook analysis of feedback, identifying gaps and reflecting on the level of reach. As a result of this ongoing evaluation the team were able to re-allocate resources to fill gaps (in reach) and undertake supplementary technical assessments to inform upcoming conversations. More specifically, two public printmaking sessions were held in response to mid-engagement analysis that identified gaps in reach, namely that we needed to connect more with families. The second printmaking sessions saw more than 100 people involved in a morning full of creative expression. Each print, produced by a member of the public, was accompanied by a narrative (description and meaning behind the work) and collectively the artwork has been used to inform the vision and objectives of the plan and develop the design of the St Clair-St Kilda Coastal Plan document shown in Figure 3. Commitment to continual evaluation and subsequent iteration throughout the process added depth and demonstrated a willingness on the DCC's part to listen.

What went well

The St Clair-St Kilda Coastal Plan helped to build stronger relationships and trust between the DCC, stakeholders and the community. This was enabled through a genuine communicative approach to engagement and keeping interested parties authentically engaged in the process. Getting involvement from community leaders and stakeholders at the engagement planning phase meant that delivering on the engagement approach itself built trust as we delivered on what we promised. More specifically, immediate issues relating to public access, safety and coastal hazard management were raised by the community and addressed quickly (mid-process). Examples of this include enhancements to public access, changes to DCC maintenance processes, and greater communication with stakeholders relating to storm response and monitoring. These kinds of practices generated trust, elevated community interest, and helped move the community beyond thinking about immediate needs for the coast and cast their vision further into the future.

The St Clair-St Kilda Coastal Plan identifies a range of 'shortlisted options/pathways'. In particular, the plan identifies a range of short-term activities, both physical works and investigations required to support ongoing management and further inform the assessment of options.

Figure 3: The Community Vision and Management Objectives of the St Clair-St Kilda Coastal Plan.

This transparent approach provides the community with an indicative roadmap and visibility of the next steps, motivating the DCC to get things started.

The engagement process extended over a period of more than two years, providing time for difficult conversations and for meaningful involvement on the community's part. The team are particularly proud of the level and depth of youth engagement that was achieved. Primary and secondary schools were provided with opportunities to learn about the coast and contribute their ideas and values to the development of the plan. We feel that this input has helped to provide a balanced community voice, as opposed to some previous processes where only 'the loudest' had been heard.

Media outlets play a role in sharing information (and misinformation) that can support or inhibit adaptation planning processes with communities. During the St Clair-St Kilda Coastal Plan engagement we worked hard to ensure consistent messaging and use of plain English. In particular, we held project-specific briefings with local media to ensure that messaging was clear and consistent.

What didn't go so well

Sequencing engagement in a way that allowed people to express their values and aspirations first was a useful way to draw out positive ideas around community ambition. This helped to separate these conversations from technical information (hazards and risks), which tends to create a different kind of conversation. To achieve a more robust outcome we could have integrated community input into a risk assessment to help work through what might be lost or gained through adaptation. Without this we were limited to more general conversations relating to the alignment between community values and technical options based on expert judgement.

The St Clair-St Kilda Coastal Plan represents a step-change in coastal adaptation planning for Dunedin. However, the resource required to deliver the process and its relative priority (within the district) might have been more appropriately determined through district-wide hazard and risk assessments in the first case. A range of coastal communities (and council assets) in the Dunedin District may be at greater risk than those that are liable to benefit from this adaptation planning process. The nature of local government is that resources and expertise can be scarce, but nevertheless a more systematic process of district-wide risk assessment and prioritisation of areas for adaptive planning may have served as a more sustainable and pragmatic approach. Additionally, a district-wide approach would provide the Council and community with a greater steer on the scale of risk, providing for the consideration of funding and resource priorities.

Final thoughts

Delivering a high standard of engagement demonstrates to the community that they have an active role in contributing to the adaptation planning process. By emphasising inclusivity and learning as we go, we position our engagement to have lasting benefits. Without good engagement we lack the mandate to progress adaptation planning and risk delivering processes that lack the teeth to affect meaningful change. As a group let’s elevate our engagement in adapting to our changing climate!

Establishing the Aotearoa Climate Adaptation Network

By Tom FitzGerald and the Aotearoa Climate Adaptation Network

Adapting to change at the coast is not just a phenomenon experienced in the natural world – change is now built into the way we respond to the challenges of climate change. Local governments are at the vanguard of this change and staff are being challenged to break new ground in the emergent profession of 'coastal adaptation'. As climate change is increasingly being felt (particularly on our coastal margins), and managing its impacts is becoming a priority focus of government attention internationally and nationally, more questions are being asked and more solutions sought. Where coastal management traditionally used to be the domain of scientists and engineers, coastal adaptation is requiring of a broader skillset – engagement professionals and facilitation expertise, environmental planning, legal analysis, economists and decision analysts, coastal modellers, climate scientists, building professionals and architects, social scientists, kaupapa Māori researchers, policy analysts, asset managers and emergency managers, to name a few.

The 2017 MfE coastal hazards and climate change guidance for local government (the Guidance) is the most recent in a series of guidance documents that have encouraged authorities to plan for the effects of climate change. Over time, the physical drivers of climate change at the coast have been increasingly well known. However, little attention has been devoted to identifying the changing demands on the coastal managers within local government. While discussion in the Guidance did emphasise that 'adaptive capacity' and 'coping capacity' of communities would be a critical or limiting factor in dealing with change, scant regard was had to the knowledge, skills, resources, governance and institutional capacity of those charged with leading these conversations and enabling the work[1]. It is these people who have the mandate to manage coasts and coastal communities right now. With the upsurge in councils undertaking coastal adaptation planning post-2017 a new home was required to accommodate the 'coastal adaptation professional'.

In 2021, the Aotearoa Climate Adaptation Network (the Network) was born to fill this gap. The Network provides a home where practitioners can connect with each other, support each other, feel comfortable sharing information, and collectively build on successes while moving away from approaches that aren't working so well. The Network is also a place where traditional silos and sectors can be broken down and bridged, and provides an opportunity for practitioners from across the country to make use of each others' skills and experience – essentially forming a nationwide 'coastal adaptation team'. This team ethic was a central goal in establishing the Network and means individuals in small and often poorly resourced councils can connect with colleagues in other places to start from a place of shared learning, reduce fragmentation, make more of a difference, and build professional, organisational and community resilience[2].

In July 2021, staff from around the motu were funded to attend an inaugural 'Coastal Adaptation Forum' at the Spruce Goose in Lyall Bay, Wellington. With a view toward the effervescent and dynamic southern coastal environment of Wellington, participants spent two days networking, sharing challenges and opportunities, commiserating, celebrating, and strategising with each other. A strong consensus was built around support for the Network, particularly its role in linking knowledge (science + mātauranga), policy and practice (see Figure 1), but also in its ability to influence and contribute to national discussions on new policy and legislation – especially the National Adaptation Plan and the forthcoming Climate Adaptation Act.

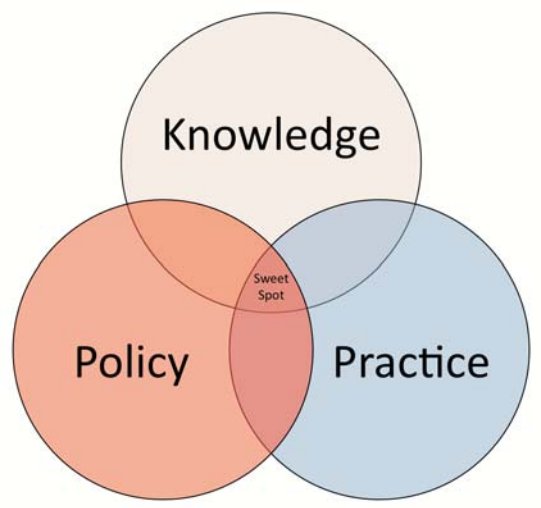


Figure 1: The inter-relationship and desired exchange between knowledge-policy-practice. The centre reflects a desired state where the best available knowledge informs and is informed by best practice and good policy – the sweet spot. The Aotearoa Climate Adaptation Network allows growth within the practitioners' sphere and in doing so strengthens the realms of policy and knowledge.

In early 2022, the Network expanded its remit from 'coastal' to all forms of adaptation, recognising that there is a long game to play and that many council staff are involved in broad 'climate change' related roles that traverse a range of natural hazards and natural resources and encompass a number of roles and responsibilities. This is reflected in the Network's Terms of Reference that was adopted in March 2022. The Terms of Reference state the core purpose of the Network is to facilitate:

- practitioner networking and collaboration
- support, guidance and resources for practitioners that build on successes while moving away from approaches that aren't working
- collaboration and advocacy with central government
- collaboration with the research community.

[1] Capacity building of practitioners within the adaptation profession has recently been recognised through the draft National Adaptation Plan as being a priority from 2025.

[2] See also American Society of Adaptation Professionals (ASAP) – https://adaptationprofessionals.org/about/

This purpose is supported by the following foundational values and beliefs:

- Climate change is a real and serious danger to all sectors and systems.
- Adaptation and resilience build stronger, more prepared regions, ecosystems, communities, neighbourhoods and households.
- Equity and environmental justice should be major considerations in all work done by adaptation professionals.
- The natural world renders countless essential services and intrinsic values, many of which are threatened by climate change.
- Creativity, innovation and transformative problem solving are essential tenets of work that aims to address new and changing climate conditions.
- Adaptation is, and will continue to be, a critical tool for ensuring that communities, infrastructure, the environment, cultural assets, or national security, and the economy continue to function and have the opportunity to thrive.
- Adaptive decision making is essential.
- Integrating consideration of future conditions and the full range of possible climate outcomes is essential for smart planning and in assessments of prospective risk and vulnerability.
- Adaptation research, policies, practices and actions are most effective when contextualised.
- Adaptation strategies should be evaluated as to their impacts (positive and negative) to other systems, scales and sectors.
- Climate adaptation strategies and processes should recognise the economic and social determinants that compound vulnerability to climate risks.
- A combination of science and mātauranga Māori is the basis of our knowledge of climate change and adaptation.
- Adaptation professionals are responsible to act on the basis of values as well as on what they know.

By joining the Network, new members sign up to 'live' these values and beliefs in the way they do their job.

Whilst currently focusing on, and limited to, participation by local government staff, the long-term aims of the Network are to promote recognition of adaptation as a transdisciplinary field in its own right and bring a broader range of practitioners, experts and other interested parties into the fold. Fundamentally, the Network seeks to build capacity and capability within the local government sector as the current government policy and legislative reform agenda highlights a critical role for local government to play in adapting to the locally specific, regionally significant, and nationally connected climate adaptation space.

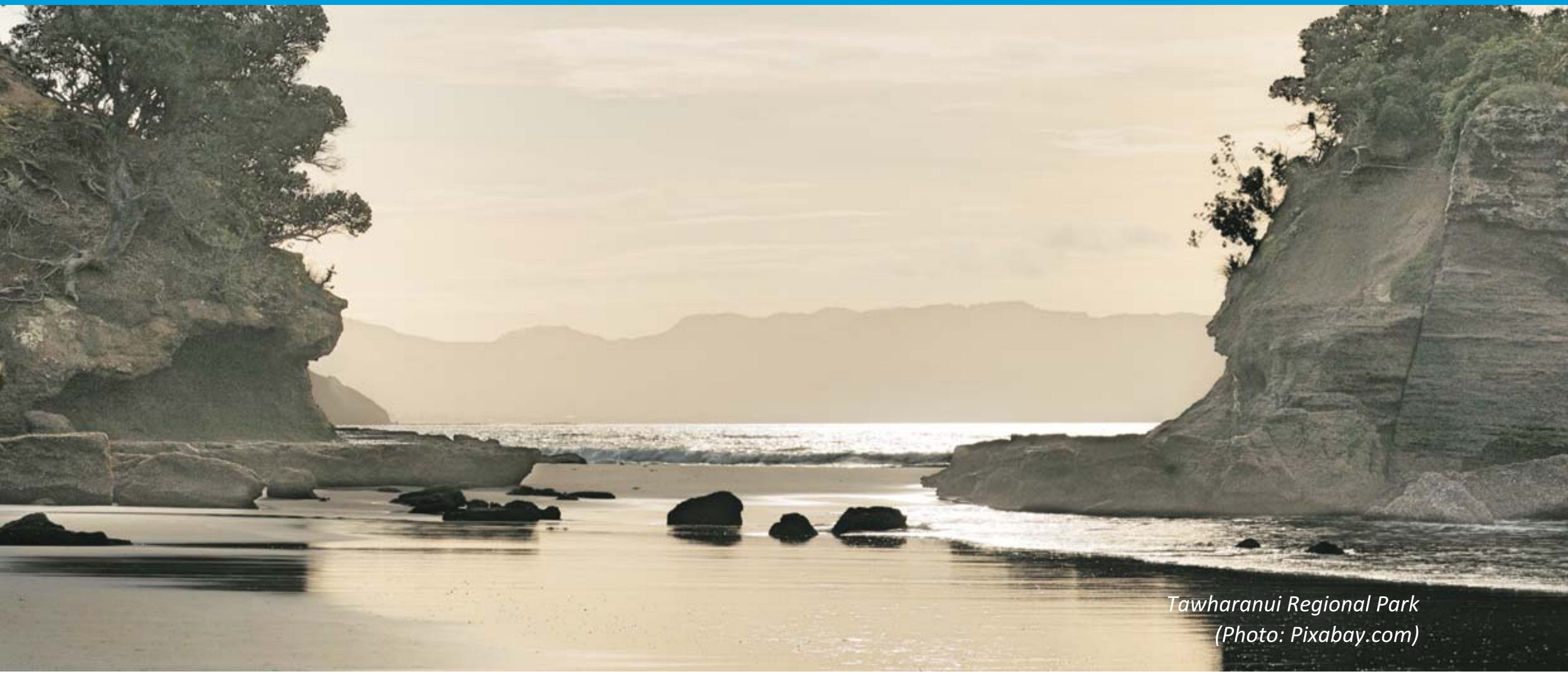
Looking ahead, it is hoped the Aotearoa Climate Adaptation Network will have an increasing role in bringing practitioners together and strengthening local government response to the climate crisis. Ongoing support for the Network will continue to be sought, with progress ultimately resting upon the unshakeable formation of an optimistic rōpū with arms linked, moving forward together.

Figure 2: Practitioners working together to ideate, solve problems, and build trust and understanding (Photo: B Wilson).

Figure 3: Participants at the Coastal Adaptation Forum ideated on the things they would like to see from the new Network (Photo: T FitzGerald).

Figure 4: Coastal Adaptation Forum participants gazing out to the unusually calm seas of the southern Wellington coast. The Forum provided the time and space for otherwise temporally and fiscally challenged council staff to think about how best they can support each other and create a strong foundation for coastal resilience in Aotearoa (Photo: T FitzGerald).

4 Advances in coastal science



Tawharanui Regional Park (Photo: Pixabay.com)

The use of historic and contemporary coastal-change data for adaptation decision making

By Mark Dickson, Murray Ford, Emma Ryan, Megan Tuck, Meghna Sengupta and Judy Lawrence

Introduction

Effective planning for coastal adaptation to sea-level rise (SLR) requires anticipating the future rate of SLR and the likely morphological response of the coast, both of which are uncertain. The science of coastal flooding under SLR is relatively advanced, but the effects of SLR on future coastal change (erosion and accretion) are less well understood. This is a significant gap in our knowledge that has relevance for decision making about the impacts of SLR on communities and the things they value. This article introduces how historic imagery from New Zealand's Crown Archive and recent satellite imagery are being used to consistently map plan-form coastal changes around Aotearoa over the past 80 years. This is the first national erosion stock take since the pioneering work of Gibb (1978) and is being conducted within the Coastal Programme of the Resilience to Nature's Challenges (RNC) National Science Challenge. The national coastal-change database will be publicly available by the end of 2024. Now in the middle stages of the project, we take the opportunity in this article to discuss the emerging dataset, its capacity to identify erosion hotspots and provide focus for monitoring, and the baseline it forms on which to ground future projections of coastal erosion for adaptation decision making.

Historical coastal-change analyses are a cornerstone of large-scale coastal erosion assessments, and national-scale mapping projects have been conducted in several countries (e.g., United States Geological Survey National Assessment of Shoreline Change Project, United Kingdom Shoreline Management Plans). New Zealand lacks an up-to-date national historic coastal change dataset. The last large-scale assessment was conducted by Gibb (1978), who deciphered historical coastal change using a range of data including cadastral plans, hydrographic charts, vertical aerial photographs, field measurements, and information supplied by people living near the coast. The momentous task of bringing these data together represents one of the most important milestones in coastal management in New Zealand. In total, erosion and accretion rates were reported for 471 locations around New Zealand. We have reproduced Gibb's (1978) Figure 6 (see Figure 1), which shows impressive national coverage and relatively few significant gaps. This mapping confirmed that historic erosion and accretion had generally occurred at rates between 0.5 and 4.0 m/y, with maximum erosion and accretion rates of ~-25 m/y and ~+70 m/y (North Head Kaipara and Farewell Spit), and maximum cliff erosion rates of 2.3 and 3.5 m/y, reported from Cape Turnagain and Ngapotiki.

Since Gibb's (1978) pioneering study, coastal change analyses within New Zealand have tended to focus on short-term (event-scale) aspects of beach erosion and recovery (see Bryan et al., 2008). Notable exceptions include multi-decadal case-study analyses of coastal change at Waihi Beach (Harry and Healy, 1978), the west coast of Auckland (Williams, 1977; Blue and Kench, 2016), Mokau spit, New Brighton

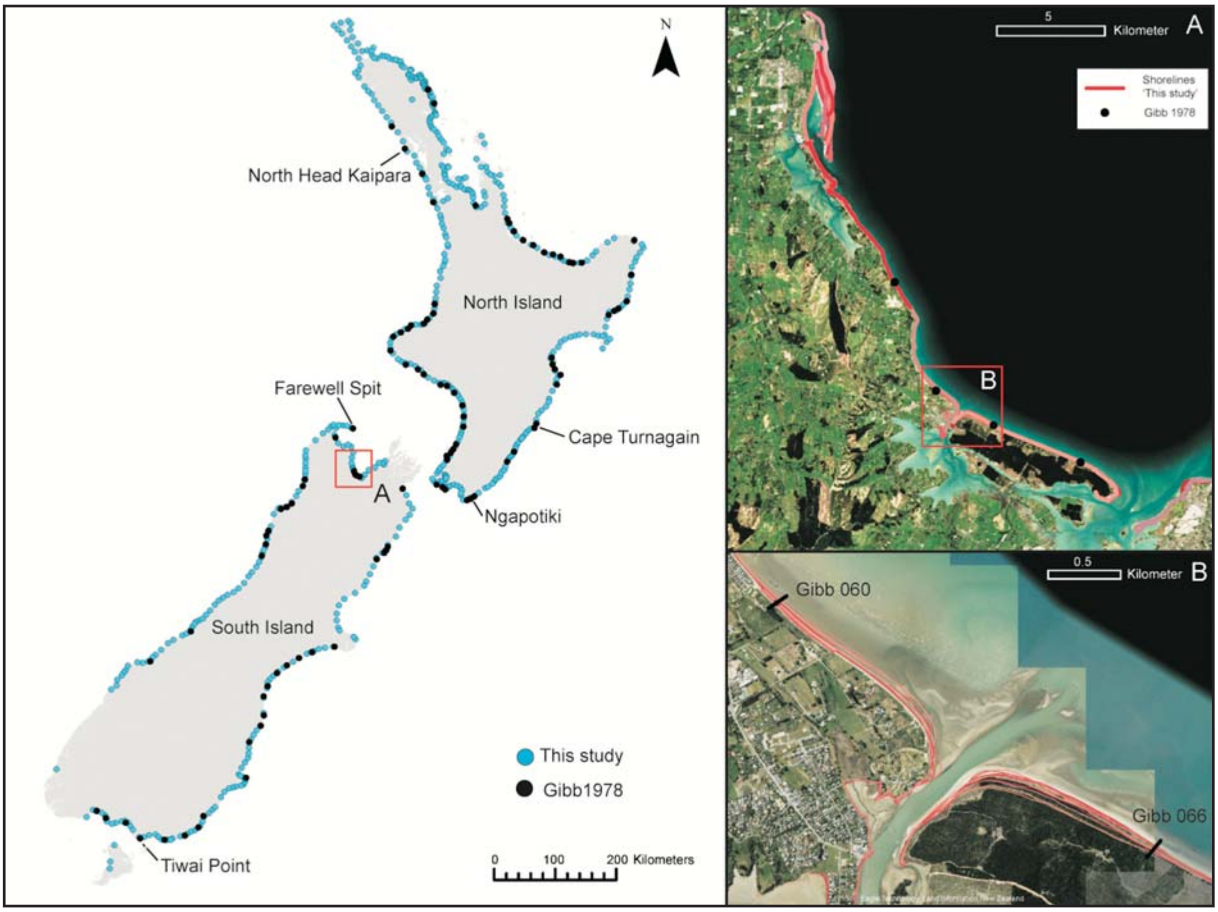


Figure 1: Location map showing every fifth transect mapped by Gibb (1978) and 'Area of Interest' centroids being mapped in the Resilience Challenge Coastal programme. Panels A and B draw attention to the continuous alongshore shoreline indicators mapped in the current study in contrast to Gibb's (1978) coastal-change rates collected at discrete point locations.

spit, and Ohiwa spit (Bryan et al., 2008). Many other local- to regional-scale coastal change studies have been conducted by multiple operators in response to the periodic requirement of councils to produce coastal hazard plans, and some of this material is available in technical reports. However, this fragmented and sporadic approach lacks a consistent methodology and reporting standards. Hence, it is impossible to comprehensively report on coastal erosion at national scale.

As part of the Coastal Programme within the RNC, we are developing a publicly available database that quantifies coastal-change patterns at national scale. We have begun releasing these data and, by the end of 2024, we will provide a national web-portal showing historic and contemporary coastal change data. This represents a significant step-change in data quality and availability for New Zealand. Now in the middle stage of the project we reflect here on how users can best utilise this dataset to improve coastal adaptation decision making. Below we briefly outline our approach, discuss issues associated with reliably and consistently identifying a 'shoreline' indicator, present a case-study illustrating the value of consistent, concomitant analyses of coastal-change data derived from both historical photographs and satellite images, and reflect on the relevance of the new dataset for science and for decision making.

Database compilation and 'shoreline' mapping

We divided New Zealand into Areas of Interest (AOIs) about 5 km in length. These areas comprise all open-coast beaches (inner harbour coasts are not mapped) and also soft cliffs where erosion rates are measurably high over the historical period (hard-rock cliffs are omitted). For each AOI we obtain all available historical photographs from New Zealand's Crown Archive from https://retrolens.co.nz and for selected AOIs we obtain satellite imagery from the past ~20 years from Maxar (https://www.maxar.com). Images are georeferenced by identifying temporally stable ground control points (GCPs), such as infrastructure, stable rocks, and fence lines. In areas where accurate GCPs are unavailable we use the autoregistration method (based on spectral similarity between ungeoreferenced images and overlapping georeferenced images), manually deleting inaccurate automated links. For beaches we select low elevation GCPs, whereas for cliffs we select GCPs near the cliff top as our aim is to map cliff-top erosion. For consistency, digitising is conducted by a single operator at a uniform scale (1:1000-1:2000) based on image resolution. The total uncertainty is then calculated based on errors associated with pixel resolution, rectification and digitising (Romine et al., 2009). The Digital Shoreline Analysis System (DSAS) (Thieler et al., 2009) is then used to analyse and report rates of coastal change.

Figure 1 illustrates that the national mapping coverage is considerably broader than was possible in Gibb's (1978) work, and it is now also possible to map a near-continuous shoreline indicator along-shore. A key decision point lies in choosing and mapping a meaningful coastal feature that is visible on images. There is no single 'correct' shoreline (Boak and Turner, 2005) and multiple indicators or proxies might be chosen for different types of coastal landforms. It is important that users of coastal-change data understand the different types of features that can be mapped, each with associated limitations. A lot of recent effort has been placed in automatically detecting the instantaneous water line (IWL) in satellite images using remote sensing algorithms that can detect the change between water and land. The technique is appealing because the IWL shoreline proxy can be rapidly automatically mapped at national to global scales (e.g., Luijendijk et al., 2018). However, this proxy is very sensitive to short-term environmental sensitivity, like fluctuations in wave runup that can be large on gently sloping beaches that are exposed to large waves. Hence, a large number of images are required to detect the average waterline position with confidence. The high-water line (HWL) is another shoreline proxy that can sometimes be mapped on historical images by a change in sand colour (e.g., Langfelder et al., 1970; Dolan et al., 1980), but often it is not visible or can be easily confused with other markers (Crowell et al., 1991). Like the IWL, this proxy is sensitive to short-term environmental variability such as anomalously high or low tides, or raised mean sea level during storms (Morton and Speed, 1998).

For the national coastal-change database we have chosen to map the 'edge of vegetation' (EOV) as our coastal change indicator on sand beaches. Gibb (1978) also used EOV to map historical coastal change around New Zealand. On sand coasts the EOV often comprises dune vegetation and coincides with the toe of the foredune or the top of an erosion scarp in a foredune. We chose this indicator because EOV change is less sensitive to short-term noise from variations in tidal and wave conditions (Morton and Speed, 1998), and more likely to reflect longer-term erosion and accretion patterns. However, the EOV indicator is sensitive to vegetation type and climatic differences between locations. We mitigate this effect by mapping within discrete AOIs such that the EOV indicator is internally consistent for that site. Other sources of interpretation error are possible, which we discuss further below. For rock coasts, it can be useful to map the cliff toe, but this is often obscured in images by the shadow of the cliff. The cliff top is generally more obvious, and we have chosen this coastal change indicator for sections of the coast we have mapped to date. As yet we have not mapped gravel coasts, but as with sand and cliff coasts, once an indicator is selected, the same indicator will be mapped within each AOI to ensure temporal consistency.

National coastal-change database: who might use this, and how might it be used?

When complete, users will be able to download shapefiles showing historical coastal-change data over several decades from most of the open-coast of New Zealand where rates of change are detectable. A broad range of stakeholders might utilise these data, including national to local government, insurers, various government authorities such as Waka Kotahi NZ Transport Agency, landowners, iwi, hapū and whānau.

National to local scale coastal erosion assessment

Benefits of the dataset will accrue from national to regional and local scales. A key feature of our approach concerns our method of upscaling from local to national. A lot of current scientific effort is afforded to large-scale (global and national) automated assessments (e.g., Luijendijk et al., 2018), but the resolution of these mapping efforts is typically too coarse to enable useful local analyses. We have mapped at local 'AOI-scale', meaning that we have quality data that matches the needs of local site assessments. This will help in minimising interpretation errors. For instance, the growth of vegetation on dunes leads to shoreward movement of the mapped EOV indicator, but this mode of accretion could represent contrasting drivers. In some cases, excess sediment supply to the coastal area might drive the development of vegetated embryonic foredunes, but in other situations dunes might be planted or naturally revegetated, and in these cases the apparent EOV accretion might be unrelated to the local sediment budget, rather reflecting vegetation dynamics. Hence, careful interpretation at the AOI scale will be required to avoid misrepresenting different modes of accretion.

Applying a consistent repeatable method at each AOI allows us to build a comprehensive and consistent nationwide coastal-change database that will then be analysed with other datasets (e.g., buildings and infrastructure, archaeological and cultural sites) to enable national coastal erosion risk assessment. Large-scale analyses may trigger detailed regional and local-scale analyses. For instance, the national coastal-change database will reveal coastal erosion hotspots that could then be prioritised based on environmental, cultural and social coastal vulnerability assessments, with subsequent application of Dynamic Adaptive Pathways Planning (DAPP) assessments and potentially more intensive monitoring (e.g., repeat LiDAR scan). One example is provided in Box 1, which shows the EOV coastal-change indicator from Tiwai Point, Southland. In this example, a concerning recent erosion trajectory between 2013-2020 is revealed from satellite imagery, but this stands in stark contrast to the longer-term coastal-change trend mapped from historical photographs. In Box 1 we ask whether the recent erosion trend may represent a decadal-scale phase that has occurred in the past, but been missed by infrequent sampling, or whether the current erosion trend might continue in the future?

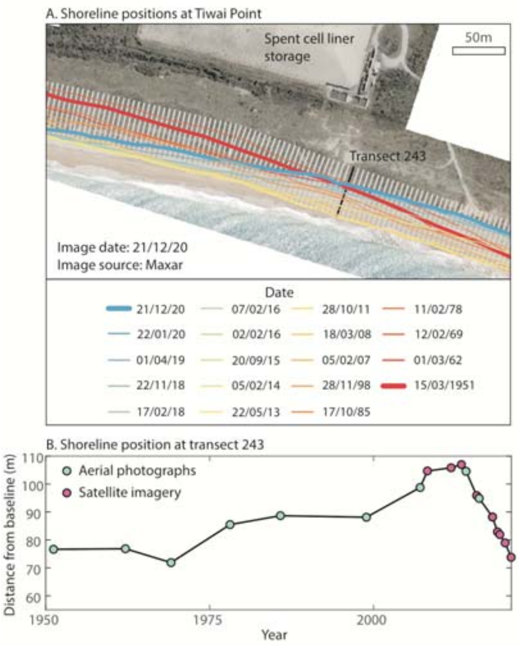
Understanding coastal change

Coastal systems are highly complex, involving multiple interactions. A key scientific aim of the RNC project is to use the national historical coastal-change database to better understand drivers of coastal change and how they might interact with SLR. Key analyses will involve considering national coastal-change change patterns alongside other national datasets, including sea-level change (https://searise.takiwa.co) and wave climate (https://coastalhub.science). It will be possible to identify sections of New Zealand's coast that have on-going systemic patterns of coastal change that are relatively predictable, in contrast to other sections that exhibit behaviour that is difficult to unravel.

The coastal-change database will provide a much-needed baseline against which to evaluate future change. Results from Northland show that a high proportion of east coast beaches have been remarkably stable over the past 80 years, despite historic SLR (Dickson et al., 2022). It is possible that there is inertia within the beach system that must be overcome before significant observable change manifests, or the effect of historic SLR may have been offset by sediment

Box 1: Coastal change at Tiwai Point

For much of New Zealand, the historic aerial photograph archive enables mapping of two to five 'Edge of Vegetation' (EOV) shoreline indicators between the late 1930s to 2010, with a further two to four lines from more recent photography. In the RNC project at selected sites we have improved the frequency of coastal-change mapping over the last 10 to 15 years using high-resolution optical satellite imagery. The number of satellites in orbit is ever-increasing and near-daily acquisition of 30 cm resolution imagery will be possible by late 2022. The usefulness of high-cadence imagery is evident at Tiwai Point where concern has been raised over the impact of erosion on toxic spent cell liner waste stored on the dunes near New Zealand's only aluminum smelter. Nine EOV shorelines were mapped from historic aerial photographs and ten were mapped from satellite imagery between 2008 and 2020. Interpretation of coastal change closest to the landfill using only aerial photographs indicates slight accretion between 1951 and 2016, but the addition of satellite data indicates (a) slight overall net erosion since 1951 and (b) rapid erosion between 2013 and 2020. Is the 2013-2020 erosion period a decadal-scale phase that has occurred in the past, but has been missed by infrequent sampling, or will the current erosion trend continue in the future? Given the potential environmental impacts of erosion at this site, the coastal-change dataset should be supplemented with more intensive monitoring at sub-annual timescales (e.g., regular high-resolution satellite images and potentially volumetric monitoring with repeat LiDAR).



supply to the coast. However, the rate of SLR is accelerating and thresholds will eventually be reached and historically stable coasts may begin eroding (Le Cozannet et al., 2015). The new database will provide a necessary baseline against which this change can be detected. Modelling of the potential drivers for such thresholds and the conditions that may signal change is coming would greatly help decision makers better understand the conditions to plan for. Modelling such coastal systems and using these to inform DAPP stress testing of decisions and adaptation actions would be a fruitful next step using the database.

At the scale of individual AOIs, scientists and engineers will be able to utilise the database to inform future erosion projections under SLR. It is important that such models are process-based and can incorporate a dynamic component to account for accelerating SLR (e.g. Walkden and Hall, 2005; Dickson et al., 2007), because the past is not necessarily going to be a good guide to the future due to the acceleration of SLR. In a New Zealand context, the coastal-change dataset will support the types of probabilistic projections for sand coasts that are already standard in the technical advice that various engineering consultants provide to councils around New Zealand (e.g., Shand et al., 2015). Ultimately these data can be used in the development of planning tools for managing coastal risk such as setback lines, rolling easements, the management of retreat from the coast where needed and other dynamic planning instruments based on DAPP and for a range of community adaptation planning processes (e.g., Ryan et al., 2022).

Conclusion

Historic photographs and satellite imagery are currently being used to consistently map coastal change around Aotearoa from the late 1930s to the present day. This work presents the first national coastal erosion assessment since Gibb's (1978) benchmark study. The national coastal-change database will be available by the end of 2024. Predominantly we have mapped the 'edge of vegetation', which is less sensitive to short-term fluctuations than the 'instantaneous water line' that can be automatically extracted from satellite imagery. A broad range of stakeholders can utilise the data being produced, which is suitable for local-, regional- and national-scale analyses. With accelerating rates of sea-level rise, the dataset provides an important new baseline on which to ground future projections of coastal erosion for adaptation decision making.

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How can coastal hazard models cope with the numerous scenarios required under adaptive planning for climate change?

By Rob Bell and Ceridwyn Roberts

A recent global survey (Hirschfeld et al., 2022) and presentations at the World Climate Research Programme Sea Level Conference in Singapore in July, 2022 (https://sealevelconference.org), highlight New Zealand as a high user of sea-level rise (SLR) projections in coastal planning. Access to sea-level rise data and advice provided through the national Coastal Hazard Guidance (Ministry for the Environment, 2017) has placed our coastal planners, engineers, and communities at the forefront of best practice. However, until now, our coastal practitioners have relied on a single set of SLR projections for the entire country and these projections do not include local estimates of uplift or subsidence (Ministry for the Environment, 2017).

Vertical land movement matters and can accelerate exposure to SLR in areas where land is sinking. New Zealand's coastline is highly dynamic due to its location at the boundary between the Australian and Pacific tectonic plates. Forces across this convergent margin cause land to slowly move up or down in between large seismic events (earthquakes) that occasionally drive large 'instantaneous' jumps in land elevation. The slow 'interseismic' movements can either accelerate SLR in regions that are sinking, or slow it down in areas that are rising. Land subsidence can also occur due to ground water extraction and sediment compaction in regions that have been drained or reclaimed. If the elevation of the coast is slowly changing, then relative sea level changes will be the combined effect of the rising height of the ocean due to global processes (ocean heat uptake, melting ice, etc.) and the local vertical movement of the land (Figure 1). When the ground subsides, the rising sea level can reach higher and further inland, particularly in low-lying areas. Subsidence can also accelerate the rate of rising groundwater levels where they may already be influenced by tides and can exacerbate coastal flooding, even if flooding due to waves and storm surge is not yet a common experience, but will be in the next few decades.

The NZ SeaRise Programme (Levy et al., 2020; Naish et al., in review) has used the same statistical modelling process as the IPCC Assessment Report 6 (Fox-Kemper et al., 2021; Garner et al., 2021) to generate SLR projections that include global and regional climatic processes and estimates of local vertical land movement (Hamling et al., 2022). These new projections of relative sea level change at 2 km spacing around New Zealand's coastline (Naish et al., in review) are now available for viewing and free download at https://www.searise.nz/maps-2. Users can download regional data by clicking on the 'for planners' tab, which takes them to the map hosted on the Takiwā data analytics platform. Users can click on individual points to see the local projection for that site to include IPCC emissions scenarios, both with and without vertical land movement. Users can also click the download button and either scroll to Download Regional Data or draw a polygon around an area on the map in which they are interested. Sea level projections data can be exported as Geodata and vertical land movement can be as exported as GeoJSON or CSV files.

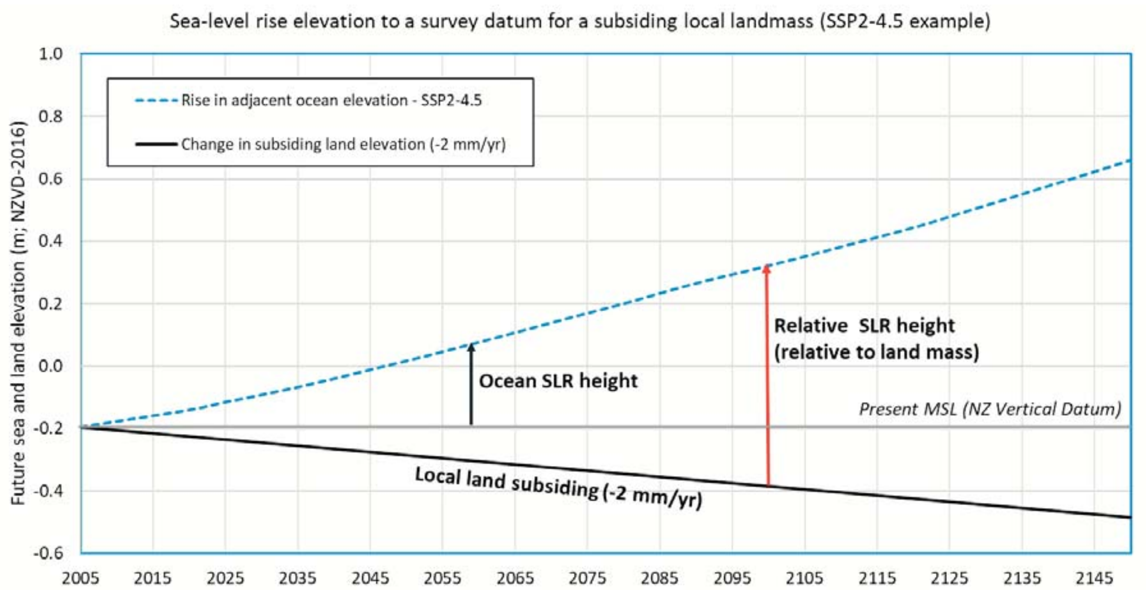

Figure 1: Schematic of relative sea-level rise (SLR) for a subsiding coastal area for one climate change scenario, which is a height relative to the sinking landmass (red arrow). To convert heights of relative sea-level rise projections (zeroed at 2005) to a survey elevation, add a mean sea level of the recent past in terms of a survey datum (e.g., NZ Vertical Datum -2016 in this example).

We know that at least 1 m of SLR (excluding vertical land movement) is already 'baked-in' (from 2095 onwards depending on how emissions pan out), so we must plan to adapt to unavoidable change at our coast, besides doubling down in our efforts to mitigate carbon emissions. However, uncertainty in global SLR projections widen over time and uncertainty in future rates of vertical land movement along our dynamic coastline adds further uncertainty. This means a 'predict-then-act' approach to adaptation planning, using 'worst case' or 'best case' scenarios, may miss the mark, with the potential for surprises either way (quicker or slower than anticipated). A dynamic adaptive approach[1] that avoids lock-in to particular options or path-dependency is best practice (Ministry for the Environment, 2017). This adaptive approach should be linked with ongoing monitoring of changes in sea level and vertical land movement to inform the appropriateness of a given adaptation option and when to switch to the next planned option in a pathway, allowing for sufficient lead time for implementation.

The new SLR projections are being incorporated into the next MfE guidance for local government practitioners on coastal hazards and climate change. An interim update guiding stakeholders on how to use the new sea-level projections within the context of the existing guidance is available from https://environment.govt.nz/publications/interim-guidance-on-the-use-of-new-sea-level-rise-projections.

[1] https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/topic-based-plans-strategies/environmental-plans-strategies/aucklands-climate-plan/preparing/Pages/DAPP.aspx

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Nature-based solutions for coastal hazards in Aotearoa New Zealand: results of a nation-wide expert survey on the current state of uptake, barriers, and opportunities

By Tommaso Alestra, Jacqui Bell, Mark Lewis, Sam Parsons, Rhys Girvan, Mapihi Martin-Paul, Frazer Baggaley, Tanya Blakely, Tom Moore, Derek Todd, Katie Thompson, Deirdre Hart and Mads Thomsen

As governments and communities worldwide scramble for solutions to address coastal hazards exacerbated by climate change, nature-based solutions are gaining traction within coastal science, engineering, and policy. Nature-based solutions are:

> *Actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits* (IUCN 2016).

Nature-based solutions for coastal hazards (hereafter NbS) are based on the protection, creation, enhancement, and restoration of natural coastal features including, but not limited to, beaches, dunes, saltmarshes, mangroves, seagrass meadows, seaweed forests, and shellfish reefs. These habitats can mitigate coastal hazards such as flooding, erosion, and wave impacts. Inland applications of NbS can also mitigate coastal hazards by attenuating flooding issues inland of the coast. Traditional engineered structures, such as seawalls, will continue to be widely used as part of coastal adaptation, but in many contexts NbS can offer more flexible and resilient approaches, while also providing a range of ecological, social, cultural, and financial benefits (Bridges et al., 2021; Morris et al., 2021).

In Aotearoa New Zealand, the importance of natural defences in reducing coastal hazards is recognised in the New Zealand Coastal Policy Statement 2010 (NZCPS), and their prioritisation is part of the National Adaptation Plan for climate resilience. Natural features such as beaches and coastal dunes have long been utilised to protect our shorelines. However, upcoming legislative changes and global trends toward ecosystem-based approaches for climate change adaptation provide greater potential for a wider uptake of NbS. In the absence of any synthesis of our national track record with NbS, we carried out a nationwide survey of professionals to better understand the practicality of a more systematic use of these methods in Aotearoa New Zealand, and to outline the challenges and opportunities that lie ahead.

Survey design and distribution

The survey targeted professionals with expertise and/or interest in coastal hazards and coastal adaptation. Specific expertise in, or previous involvement with, NbS was not required. The survey was set up in Survey Monkey and advertised across iwi organisations, councils, government departments, tertiary and research institutions, consultancies, professional societies, and non-governmental organisations (NGOs). Respondents were asked a range of questions about their background and their views on the current and future role of NbS for coastal hazards in Aotearoa New Zealand. The survey consisted of a mix of multi-choice and open-ended questions, with specific questions targeting respondents with previous involvement in NbS projects. To increase the accuracy of the results, respondents were allowed to skip questions and to specify when they did not know enough to provide an answer. Responses were anonymous[1].

The results presented here are based on 157 survey responses. For each question there were a number of respondents who did not answer, and we excluded those who declared to be unsure. Respondents represented mostly city, district and regional councils (45), consultancies (39), tertiary institutions (24), government departments (17), research institutes (14), and NGOs (9). Nine respondents represented iwi and other Māori organisations or had expertise in cultural hazard mitigation and mātauranga Māori (traditional knowledge). The most represented disciplinary backgrounds among the respondents included ecology and conservation (50), planning and environmental management (48), coastal processes and engineering (24), landscape architecture and design (11), and climate science (4). We used chi-square analyses to test whether respondents displayed significant preferences among multi-choice options.

Survey results and discussion

Views on our current track record with NbS are mixed

All respondents were asked to rate key components of the implementation of NbS based on their view of the current state of NbS in Aotearoa New Zealand (rather than focusing on individual case studies). Respondents with and without previous involvement in NbS projects were equally represented and provided similar responses. In general, there was an even split among positive, negative and neutral responses (Figure 1A), which indicates that views on NbS are mixed. These mixed feelings may result, at least in part, from gaps in communication and monitoring, as outlined below.

Information about NbS is not shared effectively

Sharing of information about NbS applications was the only item for which negative responses were significantly more numerous than neutral and positive views (Figure 1A). While there are notable exceptions[2], this suggests that not enough is done to raise wider awareness about NbS and inform future applications.

[1] https://bit.ly/3vdndn8

[2] https://www.coastalrestorationtrust.org.nz

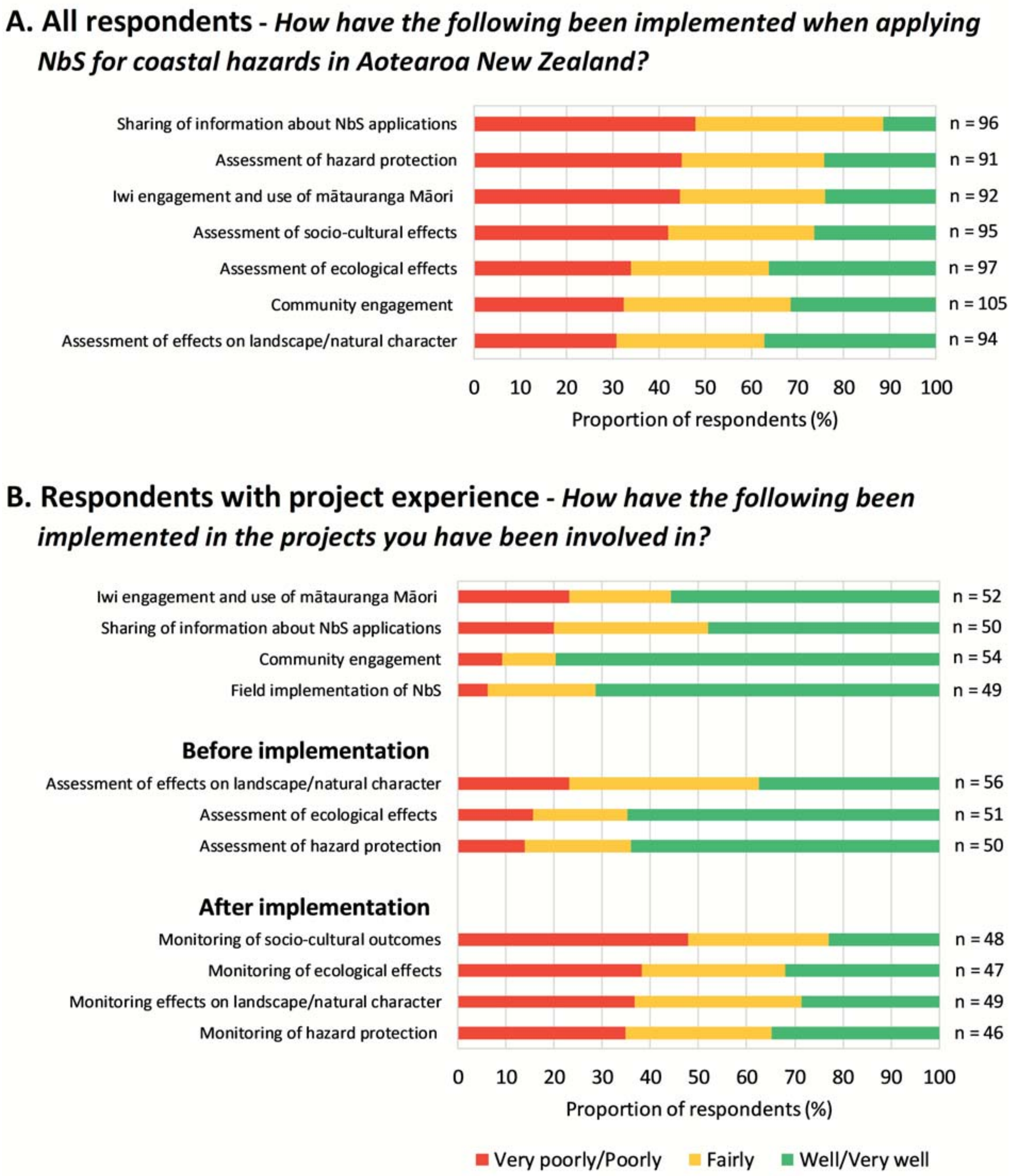

Figure 1: Respondents' views on key components of the implementation of NbS for coastal hazards in Aotearoa New Zealand (n = number of respondents).

Respondents with hands-on experience with NbS shared more positive views when asked to comment based on their own project experience (Figure 1B). Indeed, only 20% of these respondents considered the sharing of information about NbS as poor/very poor (Figure 1B). Respondents with direct project experience were also more positive about iwi and community engagement in relation to their projects than when considering NbS in general terms (Figure 1B). The more positive outlook of respondents commenting based on direct involvement with NbS may result in part from a more benevolent assessment of a respondents' own work, but it also reinforces the need for improving the sharing of information. There is probably a wealth of knowledge developed at the project scale, which is not easily accessible unless one is directly involved.

Better monitoring of the outcomes of NbS applications is needed, including a stronger focus on socio-cultural aspects

Responses based on project experience also show the need for better monitoring following the implementation of NbS. A significantly high proportion of respondents (over 60%) thought that assessment of hazard protection and ecological effects are generally well executed before NbS are implemented. However, only 30% of the respondents maintained the same positive view when commenting on the assessment of hazard protection and ecological effects after NbS are implemented (Figure 1B). This suggests that there is room for improving the assessment of the long-term outcomes associated with NbS.

Regular monitoring and evaluation are important to better understand the potential and limitations of NbS. Furthermore, monitoring ensures that NbS are managed adaptively (IUCN 2020) and can inform future implementations. Our results show that a stronger focus on socio-cultural aspects is particularly needed as part of post-implementation monitoring, as this was the element with the highest proportion of negative views (Figure 1B). This is an area where improvement is critical for Nbs to be associated with sustainable development and align with IUCN standards. A question about socio-cultural assessments pre-NbS implementation is missing in Figure 1B because of an oversight in the setup of the web interface. However, progress in this area is surely being made, and there are encouraging examples of coastal adaptation initiatives, which put social and cultural values at the forefront and incorporate NbS among the proposed strategies[3,4].

Beaches and dunes are dominant features of NbS, but the potential of other natural systems has also been explored

The information provided by respondents with project experience shows that, in line with global trends, beaches and dunes are the most common features of NbS projects, followed by saltmarsh vegetation and inland habitats (Figure 2A). Inland habitats include both habitats adjacent to the sea and further inland. Mangroves and shellfish are less utilised (Figure 2A), despite their ability to provide coastal protection being increasingly recognised worldwide (Bridges et al., 2021; Morris et al., 2021). Certain forms of aquatic vegetation such as seagrass and seaweed beds do not have a well-established track record as NbS internationally, but were mentioned by some of the respondents (Figure 2A). While our survey was not designed to collect information about individual case studies, it would be interesting to find out more about projects based on habitats other than beaches and dunes to better understand the practicality of making a more systematic use of a wider range of NbS in Aotearoa New Zealand.

NbS are often implemented at a small spatial scale, but examples across large areas are available

Responses based on project experience also indicate that, in most cases, NbS are implemented at small spatial scales, with many respondents having experience with work across areas of only a few hectares. A small proportion of the responses indicated that projects spanned across larger areas (Figure 2B). Further information about these large applications would be particularly insightful, as the feasibility of upscaling coastal NbS to large areas is still an area of ongoing debate (Bouma et al., 2014; Morris et al., 2021). In addition, as highlighted by some of the respondents and by recent research, large-scale applications are needed to unlock the full potential of NbS without limiting them simply to small-scale fixes.

Community support and funding availability are key for the implementation of NbS, but legislative provisions are often ignored

Insights from the respondents' project experience show that NbS projects are often driven by communities and by

[3] https://www.dunedin.govt.nz/__data/assets/pdf_file/0003/857505/stclair-stkilda-ctl-plan.pdf

[4] https://ccc.govt.nz/assets/Documents/Environment/Coast/CoastalAdaptationFramework0522.pdf

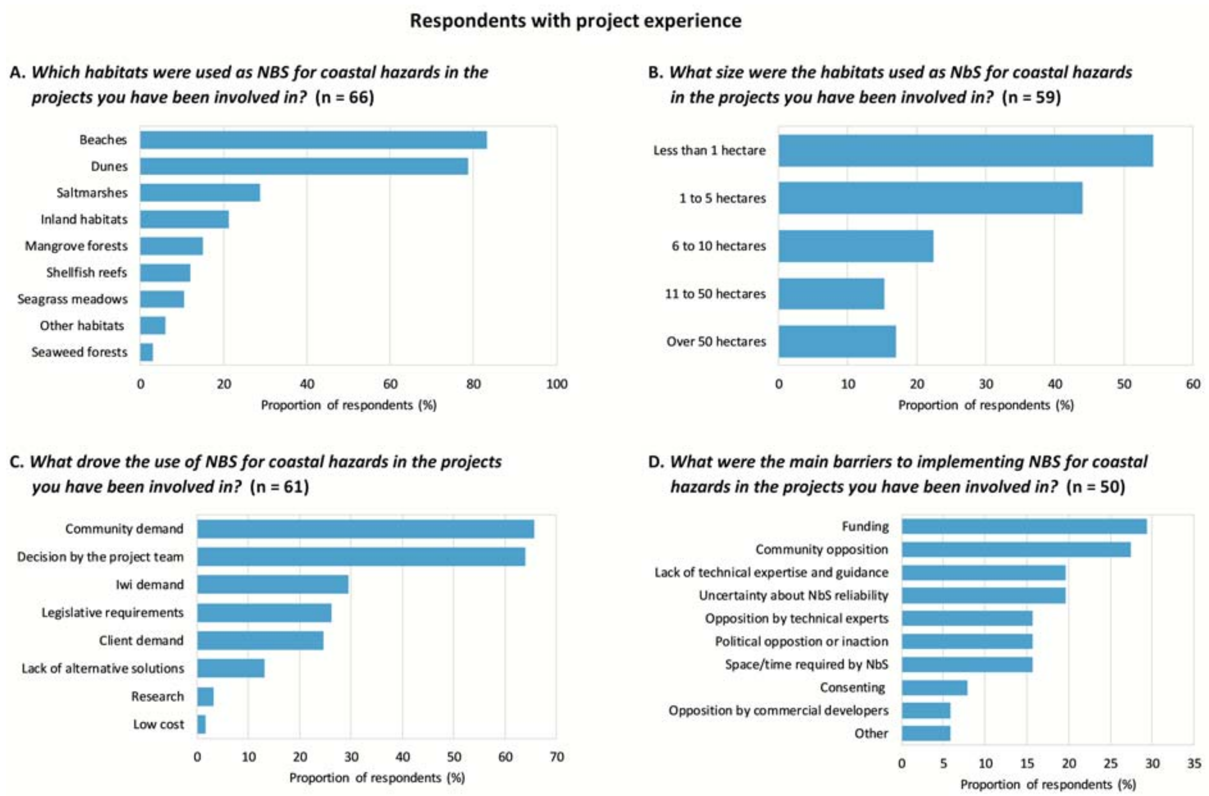

Figure 2: Information about the type and size of habitats used as NbS (A, B), and project drivers and barriers (C, D) provided by respondents with project experience (n = number of respondents).

the initiative of individual project teams, while legislative requirements were indicated as a primary driver in a limited number of responses (26%; Figure 2C). Respondents commented that the provisions of the NZCPS for the use of natural defences to coastal hazards are often ignored. This shows that the current legislative framework is not strong enough to enable a consistent uptake of NbS. The results in Figure 2C also show that very little research is done as part of NbS applications, and respondents lamented a general lack of funding and interest for research in this field.

Funding and opposition by communities were the most cited barriers to the implementation of NbS according to respondents' own project experience (Figure 2D). Many respondents said that there is a widespread lack of understanding of the requirements and potential of NbS, which extends from communities to technical experts and decision makers. The patterns seen here, with communities being both drivers and barriers for NbS outcomes, are not new for coastal adaptation initiatives (Schneider et al., 2020). NbS lend themselves to community-based approaches[5], which can contribute to promoting public awareness and support; however, not surprisingly, the experiences relayed by our respondents indicate that when private assets are on the line, there is strong demand for traditional engineering approaches.

Legislative changes provide opportunities to address challenges to NbS implementation

To look beyond individual project experience, we asked all respondents (with and without project experience) to rate 20 different challenges to the implementation of NbS in Aotearoa New Zealand (ranging from technical matters to aspects of our institutional and societal context) and to comment on the way forward. Funding availability topped the list again as the most significant challenge. Other challenges deemed as significant/very significant by a large proportion of the respondents (over 65%) included: lack of tools for assigning financial value to the co-benefits of NbS, uncertainty about the ability of NbS to adapt to sea-level rise, lack of community support, and poor integration of NbS in the legislative framework.

Many respondents indicated that better integration of NbS in the legislative framework may be key to addressing the main challenges identified here. The National Adaptation Plan and Emission Reduction Plan have prioritised the use of NbS across sectors in response to climate change. In addition, the Resource Management reform process has the potential to embed NbS into decision making and may represent a turning point for the future of NbS in Aotearoa New Zealand. The integration of NbS into well-defined adaptation pathways should open new funding avenues and ensure that NbS are provided with adequate time and space to establish and adapt to changing conditions. In particular, many respondents highlighted the importance of revised land use planning to prevent habitat squeeze as a result of sea-level rise in built-up areas. Another benefit that we see in the upcoming changes in legislation is that the formal inclusion of NbS within adaptation pathways would provide a framework for establishing when and where the use of NbS is appropriate. This should also promote large-scale applications and further research into NbS. Furthermore, the development of adaptation pathways sets the scene for public engagement and consultation, providing opportunities for promoting awareness and acceptance of NbS.

Leveraging on NbS case studies and co-benefits is key to tackling funding and community barriers

In addition to legislative changes, many respondents highlighted the importance of examples of previous NbS applications for building wider trust and understanding. Improving information sharing and long-term monitoring would help to create a visible national track record and to ensure that NbS are not perceived as untested and unconventional. The approach taken in Australia to illustrate precedents for NbS[6] could be replicated here to show communities and decision makers what has been achieved so far in Aotearoa New Zealand and inform a wider uptake of these methods.

Survey participants also suggested that an increasing awareness of the co-benefits of NbS is likely to improve political buy-in and public support. Considering how NbS are connected to the values of different stakeholders is an integral part of their implementation (IUCN 2020). This is an area with tremendous potential for a better consideration of Te Ao Māori and mātauranga Māori to develop a more in-depth appreciation of the potential of NbS and of their benefits within the context of Aotearoa New Zealand.

The uptake of NbS is likely to be assisted also by a clear indication of their benefits and trade-offs in decision-making frameworks. However, respondents pointed out that assigning financial value to the co-benefits of NbS is particularly complicated. This is an area of intensive research, and some examples and guidelines for ascribing non-financial values are starting to appear (Reddy et al., 2015; Morris et al., 2021). However, even when their market value cannot be established, it is critical to account for all services provided by NbS in cost-benefit analyses and other decision-support tools (Sutton-Grier et al., 2015).

Technical challenges are not insurmountable

While respondents saw the financial valuation of NbS co-benefits as a significant technical hurdle, the prevailing view was that, although not insignificant, technical challenges are secondary to institutional and societal barriers for the implementation of NbS. Despite the lack of detailed step-by-step design codes for NbS, which several respondents highlighted as beneficial for NbS to be seen as on par with traditional engineering approaches to coastal defence, respondents pointed out that there is a good amount of in-house knowledge and technical expertise, although this is mainly limited to dune and beach environments. Internationally, there is plenty of guidance on NbS approaches (e.g., Bridges et al., 2021; Morris et al., 2021), and the capacity to predict the hazard mitigation benefits provided by NbS through modelling scenarios is improving (Reddy et al., 2015; Silver et al., 2019).

Conclusions

Despite considerable challenges to a wider uptake of NbS, the prevailing view from the survey was that NbS should be seen as a fundamental part of coastal adaptation in Aotearoa New Zealand. The vast majority of respondents

[5] https://www.coastalrestorationtrust.org.nz/coast-care-groups

[6] https://livingshorelines.com.au

saw great potential in the use of NbS to address both coastal hazards and loss of biodiversity. However, respondents pointed out that the requirements and limitations of NbS needs to be well understood to ensure effective implementation and management. In addition, it is essential to move beyond pitching NbS against hard defences, so that synergies among different approaches can be better explored.

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Restoration of saltmarsh in the face of climate change: a regional council perspective

By Josie Crawshaw, Erin Fox, Mark Ivamy, Braden Rowson, Shay Dean, Heather MacKenzie, Jane Palmer, Nic Newman, Stacey Faire and Pim De Monchy

Introduction

Saltmarsh is an important component of an estuary, providing a natural margin between land and sea. Saltmarsh is a highly productive habitat that filters and deposits sediment and nutrients, acts as a buffer against introduced grasses and weeds, and provides an important habitat for a variety of fish and bird species. A range of ecosystem services are provided by saltmarsh, including flood and erosion control, water quality improvements, and these habitats are recognised as an important carbon sink (a form of blue carbon[1]).

Climate change impacts for the Bay of Plenty region include potential sea-level rise (SLR) of 0.7 m by 2070, and up to 1.6 m by 2130 (Pearce et al., 2019). The rate of sea-level rise in the Bay of Plenty is around 2.12 mm/year (calculated between 1961-2018 at Moturiki) (Bell and Hannah, 2019). As sea levels rise, saltmarsh will be pushed from its current elevation range. This may result in a landward migration to remain in the preferential tidal height; however, it is likely in many areas we may see a 'coastal squeeze', where seawalls, roads, land protection (stopbanks), and other human infrastructure will limit such movement (Swales et al., 2020). Saltmarshes have some resilience to the impacts of SLR due to their ability to trap and store sediments (Cahoon et al., 2021). However, if sea level rises too quickly, or the sediment supply or inundation through flooding is excessive, the saltmarsh may experience stress or deterioration (Mcleod et al., 2011). In the Bay of Plenty, there has been a 60% loss of saltmarsh to reclamation between the 1840s and the present day (Park, 2000).

There are several relevant international[2], national, and regional policy drivers that frame our response to managing saltmarsh restoration (Figure 1). Our response to international agreements is cascaded through in regulation and policy documents. Nationally, we have the Resource Management Act and four key policy statements[3] that direct the management, use, and protection of saltmarsh.

Regional planning documents include hapū/iwi management plans, which generally set out ancestral connection, aspirations to restore degraded areas, and direction to protect areas of culture significance. Department of Conservation's Conservation Management Strategies outline their priorities for regional biodiversity. Regional councils have the function of controlling the use of land for the purpose of maintaining and enhancing ecosystems in water bodies and coastal water (s30 Resource Management Act).

Figure 1: Policy drivers that link to restoration of saltmarsh habitats in New Zealand.

These functions are reflected in Regional Coastal Environment Plans, which local City and District Councils must be consistent with. The Regional Coastal Environment Plan includes both the coastal marine area and the adjacent land that interfaces with this environment. The objectives and policies aim to protect and/or enhance saltmarsh habitats, some of which are mapped as Indigenous Biological Diversity Areas[4]. These sites give effect to New Zealand Coastal Policy Statement Policy 11 by avoiding, remedying, or mitigating adverse effects of activities.

SLR has been identified as a stressor to existing and future saltmarsh habitat, and the Bay of Plenty Regional Council wants to consider how this may impact on planned and future saltmarsh restoration projects to support coastal adaptation. This work will support informed decision making on where to prioritise restoration and/or managed realignment[5] of saltmarsh habitats, where we expect higher potential impacts of SLR. Our method employs a simplistic spatial mapping approach using readily available data, that could be repeated by other agencies to investigate saltmarsh habitat restoration potential. Here we discuss some of the complexities of undertaking saltmarsh restoration projects using two case study sites.

Methods

The initial approach taken to investigate and model future saltmarsh in the Bay of Plenty Region is simple and readily repeatable using existing datasets, with a similar approach used in another New Zealand study (Stevens and Southwick, 2021). While there are several refinements that can be

[1] Carbon sequestration by marine ecosystems, such as algae, seagrass, mangroves and saltmarsh.

[2] Aotearoa is a signatory to the United Nations Convention on Biological Diversity and Convention on Wetlands of International Importance.

[3] New Zealand Coastal Policy Statement, National Policy Statement for Freshwater Management, the proposed National Policy Statement for Indigenous Biodiversity, and Te Mana o te Taiao – The Aotearoa New Zealand Biodiversity Strategy 2020.

[4] Living organisms or plants that occur naturally in New Zealand and their associated ecosystems.

[5] The creation of saltmarsh via removal of coastal protection, allowing flooding to an area previously protected from flooding.

undertaken before commencing any restoration works, the methodology has proved useful to support initial discussions and planning focusing on biodiversity goals and saltmarsh restoration. The spatial analysis made use of two key existing datasets: a region wide elevation model (LiDAR, 2011) and Manaaki Whenua's Land Cover Database (LCDB, version 5).

Field and aerial photography observations of existing saltmarsh were used to define the 'current elevation range' for saltmarsh habitats throughout the Bay of Plenty region. Using this methodology, the current lower and upper extent of saltmarsh was identified to fall between +0.6 and +1.2 Moturiki Reduced Level (RL). The region-wide elevation model was then utilised to identify all land within this potential current saltmarsh elevation range. Using elevation to map potential saltmarsh habitat enables us to identify regions where saltmarsh would be expected, however, due to hydrological barriers (e.g., stopbanks, bunds), saltmarsh is not currently present. Although not presented here, we were also able to distinguish between areas that were currently connected or disconnected from tidal connection, utilising the unpublished outputs of a regionwide Coastal Inundation Tool that uses a bathtub model to show static water levels, first developed in the Waikato region[6].

To model potential changes to saltmarsh elevation due to climate change, two absolute sea level rise scenarios were selected (+0.2 and +0.6 m) and corresponding 'future elevation ranges' for saltmarsh were determined as an initial test of this methodology. The impact of sea-level rise on saltmarsh was assessed by adding the estimated sea level rise value (e.g., +0.2 or +0.6 m) to the upper and lower current elevation ranges for saltmarsh. For example, an elevation range of +0.8 to +1.4 RL was selected under a +0.2 m scenario and +1.2 to +1.8 RL for +0.6 m scenario. After saltmarsh elevation ranges were identified, Manaaki Whenua's Land Cover Database (LCDB, version 5) was used to distinguish between land cover types within each selected elevation range. This dataset was used to distinguish suitability for restoration based on current land cover.

Two case studies are explored in this article to show two likely scenarios when planning for saltmarsh restoration with climate change (Figure 2). Study 1, Athenree Wildlife Refuge Reserve, shows an example of potential migration and expansion. Study 2, Wainui Repo Whenua, provides an example of coastal squeeze.

Athenree Wildlife Refuge Reserve and Steele Road Wetland

The Waiau Wetland complex once extended over an area of ~300 ha behind the now township of Waihi Beach and up the lower reaches of Waiau River (Figure 3). The wetland consisted of a mixture of palustrine and estuarine environments, providing significant habitat for native species and an important resource for tangata whenua. By the early 2000s, extensive drainage for agricultural production had reduced the wetland extent to ~30 ha, with areas of estuarine saltmarsh and mangrove shrubland remaining around the Waiau River mouth.

In 2006, the late Snow Brown bequeathed 26 ha of pasture to the Department of Conservation specifically for restoration and the Athenree Wildlife Refuge Reserve was gazetted in 2013. A collaborative restoration is being undertaken between BOPRC, Department of Conservation, Western Bay of Plenty District Council, Te Whānau o Tauwhao ki Ōtāwhiwhi, Ngāti te Wai, and Waka Kotahi. Significant

[6] https://www.waikatoregion.govt.nz/services/regional-hazards-and-emergency-management/coastal-inundation-tool

Figure 2: Tauranga Harbour (A) and the two case study sites: Athenree Wildlife Refuge Reserve (B); Wainui Repo Whenua (C).

Figure 3: Athenree Wildlife Refuge Reserve and Steele Road Wetland showing historical wetland coverage between 1942-1950, and the current extent in 2021; 2022 shows the upper wetland out towards the ocean.

restoration has been undertaken on the portions adjacent to the existing saltmarsh. Tidal inundation has been restored by removing flood protection structures, and brackish ponds for wading bird species have been created in areas of higher elevation. While considerable planting has been undertaken in the higher areas, tidal areas have reverted naturally to sea rush, oioi, saltmarsh ribbonwood, and a range of estuarine herbs.

The most recent project extends the restoration efforts to a 6 ha portion of the Athenree Reserve. The objective is to provide a diverse range of wetland habitat types, including inanga rearing habitat. The site contains a range of elevations with much of the site being at or above the natural saltmarsh range, so a series of ponds and channels have been created to maximise the area of potential saltmarsh restoration. Remaining higher ground areas are expected to transition to saltmarsh gradually under future sea level rise scenarios.

The current elevation range for saltmarsh aligns well with the existing wildlife reserve and coverage of saltmarsh and mangrove (Figure 4) and includes some areas of farmland that is protected from tidal influence. As sea level rises to +0.2 m, we see an increase in the potential elevation range available for saltmarsh into a region donated for restoration activities, whilst most of the existing saltmarsh remains in a suitable elevation range. As sea level increases to +0.6 m, there may be some significant losses of saltmarsh through the existing Athenree Reserve, however, there remains space inland for migration to occur. The reconnection of hydrology to the area has provided a protected migration pathway for saltmarsh to move into.

Wainui Repo Whenua

Wainui Repo Whenua is 20 ha of BOPRC owned land, which is undergoing restoration from marginal pasture back to saltmarsh habitat. The area was historically saltmarsh and mangrove habitat before ~1960, when it was converted for pastoral farming, then summer grazing (Figure 5). Several culverts have since been installed that restore hydraulic connectivity between the Tauranga Harbour margin and the upper Wainui River. The restoration plan aims to plant two broad estuarine saltmarsh community types, the 'rush community' (oioi and searush) and 'saltmarsh ribbonwood community' (ribbonwood).

While the majority of site is suited for saltmarsh restoration (based on its current elevation), future SLR scenarios predict that the site won't support saltmarsh (Figure 6) and indicate a squeeze will occur due to limited space for migration of saltmarsh. Although the saltmarsh elevation range is limited in future SLR scenarios, due to the water connection being restricted through two culverts, the hydrology at the site may provide some resilience to potential sea level rise changes or opportunities for tidal management.

This highlights that the utilisation of the future saltmarsh elevation range prior to restoration beginning may have dictated a modified approach at this site. This may have involved allowing a natural community to re-establish (i.e., an expansion of the mangrove habitat or conversion to mudflats), rather than attempting the long-term rehabilitation of saltmarsh habitat. The two future sea level rise scenarios highlight additional areas of land where saltmarsh may begin to migrate into as water rises, and these regions can be prioritised for restoration activities or early retirement of land to support a natural inland migration process.

Discussion

Current policy, including the Department of Conservation Biodiversity Strategy Implementation, provides a call to action on the desperate need to start protecting and enhancing biodiversity. As part of the implementation of these international, national, and regional drivers, the BOPRC is undertaking incentive-based restoration of marginal lowland habitats and is supporting landowners to achieve

Figure 4: (A) Athenree Wildlife Refuge Reserve and Steel Road Wetland (white dashed outline); (B) Current day potential saltmarsh elevation range (blue); (C) +0.2 m SLR elevation range (yellow); (D) +0.6 m SLR elevation range (red).

Figure 5: Historical saltmarsh habitat at Wainui Repo Whenua in 1963, reclaimed farmland on the historical saltmarsh site in 1974 and 2016, and the saltmarsh in 2021 following tidal reconnection.

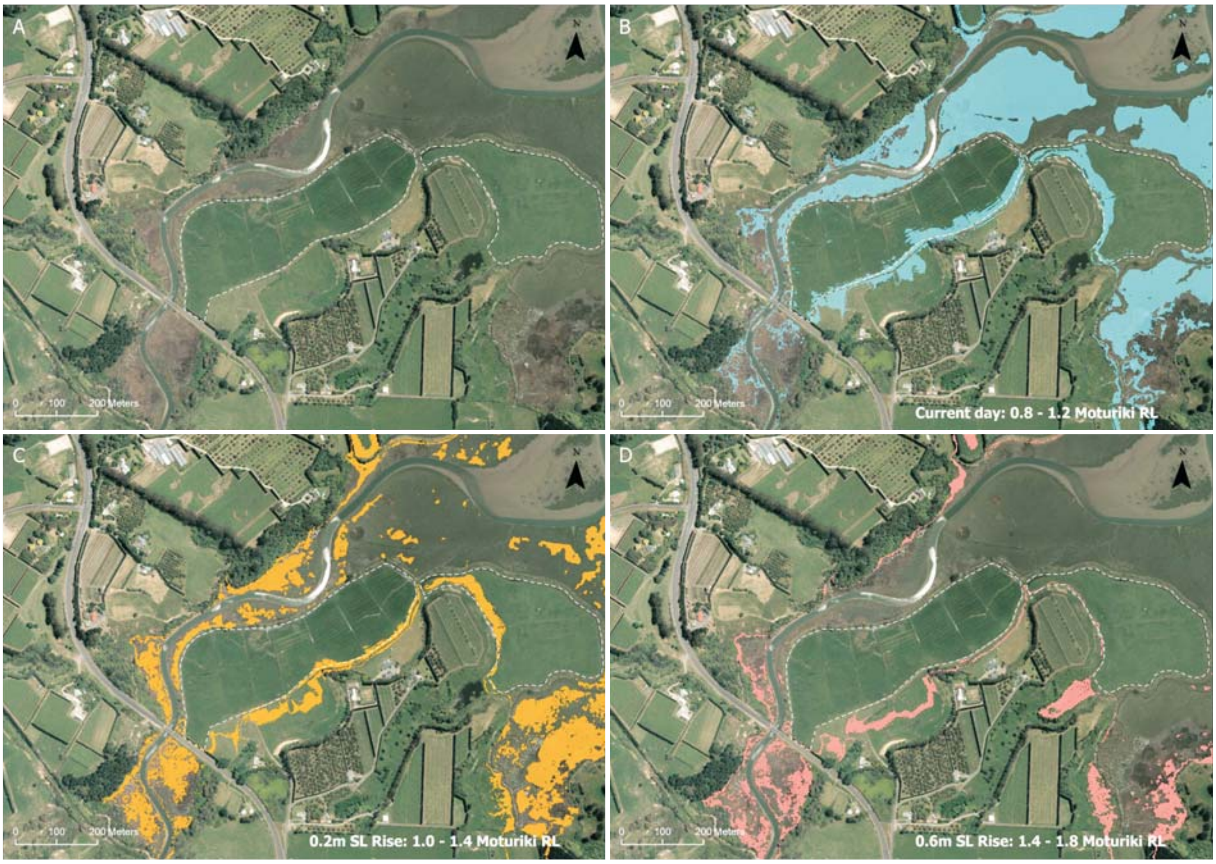

Figure 6: (A) Wainui Repo Whenua (white dashed outline); (B) Current day potential saltmarsh elevation range (blue); (C) +0.2 m sea level rise elevation range (yellow); (D) +0.6 m sea level rise elevation range (red).

biodiversity driven restoration projects. This work is funded by the Environmental Programme Grants Policy (BOPRC, 2021), which provides a mechanism to enact the statutory obligations under the RMA to protect and restore ecological integrity at biodiversity sites.

Spatial mapping provides a basis to assess current saltmarsh extent, model future scenarios for saltmarsh under sea level changes, and investigate how tidal connection could influence saltmarsh coverage. Mapping outputs have highlighted two divergent scenarios for saltmarsh under sea-level rise: increases through landward expansion or decreases in saltmarsh through coastal squeeze. The work has highlighted the importance of considering climate change adaptation, and more specifically managed realignment when undertaking saltmarsh restoration projects and has provided a means to do so. In a scenario, such as Athenree Wildlife Refuge Reserve, where there are opportunities for inland migration of salt marsh with increasing sea levels, identification of land areas and early planning can support this process. Strategic planning can support natural inland migration and ensure that the existing mechanisms for biodiversity protection can be amended to extend inland as migration occurs. In the case of Wainui Repo Whenua, where there is little opportunity for inland migration of saltmarsh, alternative considerations must be examined. The saltmarsh elevation mapping highlighted that saltmarsh at this location will become squeezed against the land topography with even small changes (+0.2 m) in sea level. Under this scenario, it may be important to manage stakeholder expectations of what restoration looks like. Site management may be different – that is, tidal restriction by culverts, and additional land will be required to ensure saltmarsh continuation in this region. In highly urbanised areas, retainment of saltmarsh habitat may not be feasible due to hard structures preventing landward migration, and future discussions with the community will need to find a middle ground between providing space for protecting natural resources and/or adaptation of the built environment and communities (Swales et al., 2020).

Public participation in environmental and habitat protection projects is often limited due to time and financial restraints; however, incentives can remove these barriers whilst fostering community goodwill and joint public good outcomes. Some of the financial support provided by an Environmental Grants Policy can include plant purchases, pest plant and animal control, ecological assessments, restoration of indigenous fish passages, and re-establishment of estuarine coastal wetlands. This involves funding support in Priority Biodiversity Sites, which are joint sites identified by Department of Conservation and BOPRC that meet several wetland biodiversity goals. Many of these projects include significant financial contributions into marginal estuarine habitats, such as saltmarsh, thus it is important to consider the potential longevity of restoration projects in the face of climate change and sea-level rise.

Estuarine wetland monitoring will help us determine whether Bay of Plenty saltmarsh wetlands can adapt to changing environmental conditions associated with climate change, or if mitigation is required. Surface Elevation Tables (RSET) are being installed at several sites to measure relative elevation change of wetland sediments resulting from sediment accretion, consolidation, and subsidence. RSETs provide highly accurate measurements of sediment elevation within wetlands over long periods of time. A comparison between measured accretion rates and relative SLR indicates whether a saltmarsh can adapt to rising waters. The monitoring of estuarine wetlands will further our understanding of the potential impacts of climate change and allow adaptive management.

Saltmarsh can play a significant role in storage of carbon and support future climate carbon reduction goals. Restored wetlands, in particular those being converted from pasture, will take time to reach their carbon storage potential (Burden et al., 2013). In New Zealand, the current knowledge of carbon stocks and potential value of blue carbon ecosystems including saltmarsh has been investigated (Weaver et al., 2022). They have identified 'blue carbon' credits that could be marketed at a local and national level for voluntary carbon off-setting. This could enable coastal blue carbon to function as a potential funding mechanism for coastal ecosystem conservation and restoration. Sea-level rise will also pose a significant risk to carbon storage and sequestration of saltmarsh habitats; thus, it will be critical to understand potential lifetimes of restoration projects if carbon storage goals are at the forefront.

Another assessment tool is the New Zealand Sea Level Rise project, which maps vertical land movement across New Zealand coastlines every 2 km using satellite imagery[7]. For the Bay of Plenty Region, it highlights that there is variation in vertical land movement; decreasing in some regions whilst in others it is increasing, providing resilience to SLR. This may also help with prioritisation of regions where impacts are likely to be the first to be evident due to subsidence via vertical land movement (e.g., from tectonic plate movements). These regions are also likely to be where we see the greatest risk from coastal hazards. Intertidal vegetation, including saltmarsh and mangroves, can help reduce wave run up at the coast through attenuation of short period wave energy. Thus, saltmarsh restoration projects may also provide additional benefits for protection of land and infrastructure in suitable regions.

Ultimately there are still many unknowns regarding the rate of climate change/SLR and what impacts it will have on saltmarsh habitats, however, there is a need for action now utilising the best available information. The case studies presented here are only two of the many saltmarsh restoration programmes occurring throughout the Bay of Plenty, and the saltmarsh elevation modelling will support our restoration activities to be climate change resilient.

[7] https://www.searise.nz/maps

Further work is required to prioritise our restoration efforts based on SLR risk, and further develop management and policy options to support a broad range of future climate scenarios. Our work continues to put biodiversity values at the forefront to support extensive restoration projects on marginal coastal land, where coastal adaptation is required to support the future of functioning coastal ecosystems.

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5 Adapting to coastal change in urban and built environments

New Brighton Pier, Christchurch (Photo: Public domain)

Adaptive tools for decisions on water infrastructure affected by compounding climate change impacts

By Andrew Allison, Scott Stephens, Judy Lawrence, Shailesh Singh, Paula Blackett, Yvonne Matthews and Jan Kwakkel

Introduction

Multiple interacting hazards at the coast pose a challenging problem for local government and decision makers with critical water infrastructure assets located in at-risk locations. Of particular importance is navigating the uncertainty around the timing, frequency, and magnitude of coastal hazards such as relative sea-level rise (RSLR), coastal inundation, erosion, rising groundwater and rainfall-runoff events, while providing an agreed level of service for three waters systems and constraining costs.

We outline ongoing research that seeks to address the impacts of compounding climate change and flood hazards on water infrastructure in Aotearoa New Zealand and support the navigation of uncertainties (Hughes et al., 2021). This is essential because traditional approaches have fallen short in identifying the most robust[1] suite of adaptation actions under deeply uncertain climate, hazard and socio-economic futures. Examples from overseas (e.g., Hummel et al., 2018) and in New Zealand (e.g., Kool et al., 2020) have shown that many existing wastewater treatment plants (WWTPs) are susceptible to flooding after 25-30 cm of RSLR. Failure of WWTPs to reach their operational objectives and expected Levels of Service can have widespread biological impacts (Jaskulak et al., 2022) and social and political ramifications. New approaches are required that can evaluate which suites and sequencing of adaptation actions would provide infrastructure operators with the most leeway for effective adaptive actions as conditions and performance approach inoperable thresholds (Kool et al., 2020). These actions need to be able to create ongoing flexibility to move between different options and pathways rather than producing stranded assets. The framework we outline is not restricted to use in Aotearoa New Zealand, or for water infrastructure, and can be adopted elsewhere.

We are applying Multi-Objective Robust Decision-Making (MORDM) within a Dynamic Adaptive Pathways Planning (DAPP) process to assist the adaptation of two wastewater treatment plants on low elevation coastal plains. Using a MORDM approach in conjunction with DAPP enables identification of adaptation thresholds (a state after which adaptation strategies no longer meet objectives) and facilitates timely decision making on adaptation actions with sufficient lead time for implementation. Subsequent discussion details the approaches used and how they were applied.

[1] Robust strategies are those that work well across a wide range of plausible scenarios, compared with optimal strategies that provide a best outcome within a single scenario and thus do not address deep uncertainty.

Deeply uncertain futures

Deep uncertainty is where the external context of the system, system function, and the outcomes driven by system function and their relative importance, are either unknown or can't be agreed on by experts (Marchau et al., 2019). For example, sea-level rise scenarios in national coastal guidance (MfE, 2017), derived from the AR5 IPCC projections, show near-term certainty of similar rises until 2050, but increasingly diverge thereafter (Figure 1). The severity of other hazard impacts, such as storm surge, erosion, coastal flooding, inundation[2] and associated rising groundwater are all influenced and exacerbated by RSLR; the more hazards that need to be considered when planning for infrastructure adaptation, the more complex and uncertain the future becomes.

Decision-Making under Deep Uncertainty (DMDU) is an approach for exploring the implications of decision making under the inherent uncertainty of a changing climate using a wide range of possible socio-economic futures. Indeed, one of the key ideas underpinning DMDU is the value in using models to explore uncertainty, rather than using models for predictive purposes (Kwakkel et al., 2016). Predictive modelling is limited by uncertainty, and aiming for optimal strategies can result in a plan that would work well in the one scenario used for prediction but is not robust across a suite of possible scenarios.

Dynamic Adaptive Pathways Planning

DAPP is a fit-for-purpose method for climate-change adaptation planning to address widening uncertainty and long planning timeframes. Applying a DAPP approach is useful for anticipating risk and where we need to make decisions today to avoid lock-in of actions that are maladaptive and limit the actions available for adaptation over time; risks change over time and increasing flexibility is needed to adopt different adaptation pathways and options (Figure 2).

A key component of DAPP is identifying signals and triggers that can be monitored using indicators of change (including hazard risks and Levels of Service) and approaching thresholds. These can be environmental, social, cultural or economic indicators. These enable timely adaptive actions to be taken, through an early warning signal of the emergence of the trigger – when a decision needs to be made – before the harmful or inoperable threshold is reached.

In Aotearoa New Zealand, DAPP forms a central component of the Ministry for the Environment (MfE) Coastal Hazards and Climate Change guidance for local government (MfE, 2017), marking (as far as the authors are aware) the first time in the world that DAPP has been embedded into national guidance. Methods for identifying the indicators that need to be monitored, and the signals and triggers which lead to a change in adaptive action, are developing beyond the traditional use of extreme hazard events to initiate adaptation after the event. DAPP and scenario modelling, on the other hand, are based on anticipatory planning to reduce and avoid the worst coastal risks. Day-to-day WWTP operations and the consenting process for water infrastructure upgrades, for example, rely upon assurances of adequate outflow quality to prevent negative impacts on mahinga kai[3], and to manage costs. DAPP can help assess a suite of adaptation options that are robust and able to operate across a range of uncertain conditions and thus assure a community of two-and-three waters Levels of Service (Kool et al., 2020).

Multi Objective Robust Decision Making

Once developed, a dynamic adaptive pathways plan offers a range of actions and potential pathways that may be

[2] We use the term 'coastal flooding' to describe periodic flooding during storm events, and 'inundation' to describe submergence of low-lying coastal land by RSLR.

[3] Mahinga kai is Te Reo Māori for the traditional value of food resources and their ecosystems, as well as the practices involved in producing, procuring, and protecting these resources.

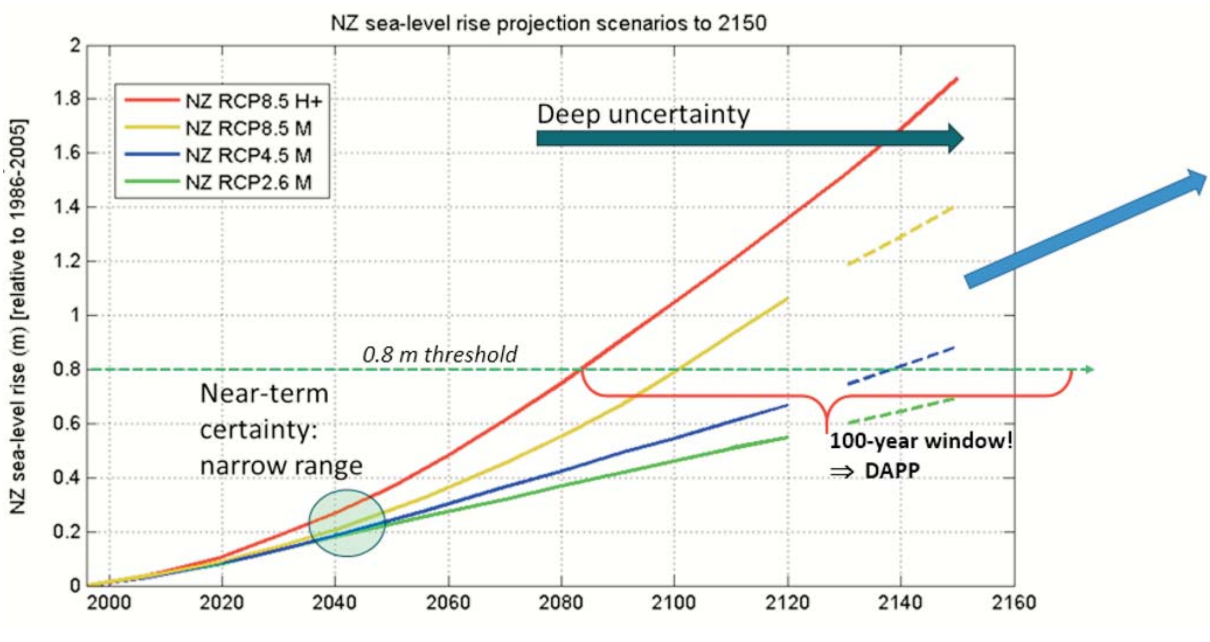

Figure 1: SLR scenarios for Aotearoa New Zealand, highlighting the diversion of possible sea-level rise trajectories from 2050 onward (R Bell, pers. comm., adapted from MfE, 2017: Figure 27).

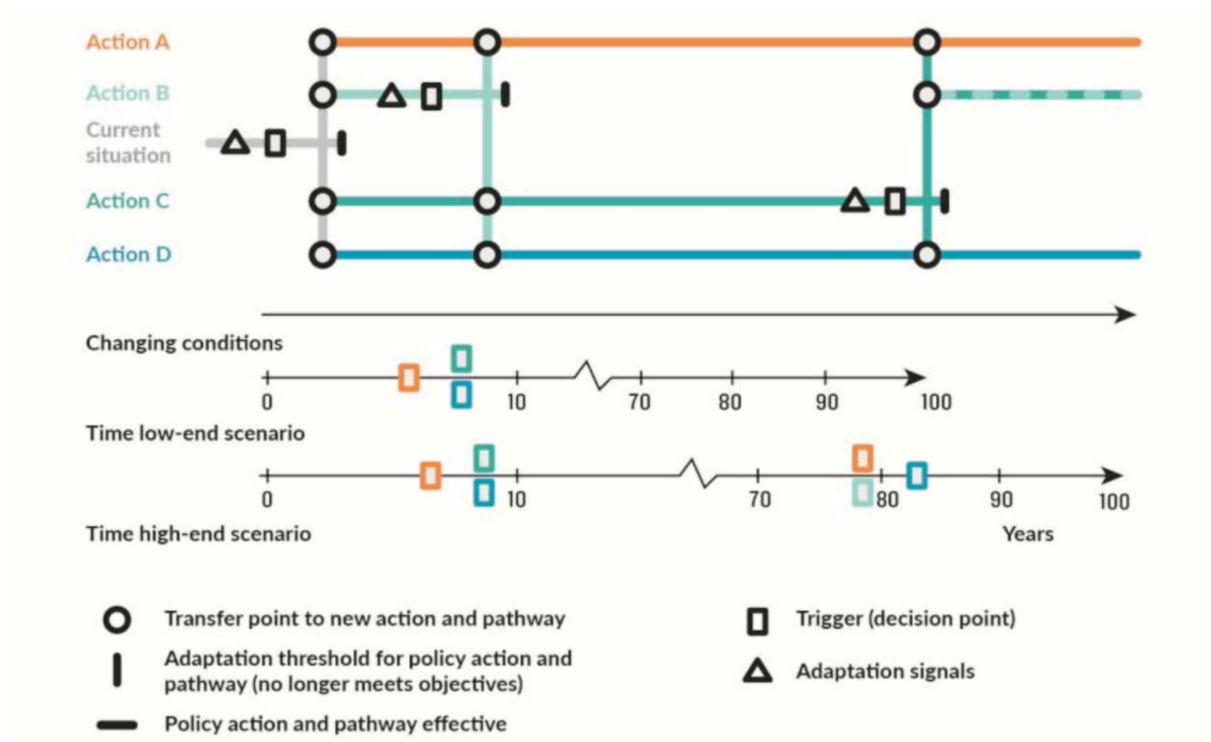

Figure 2: Example DAPP map showing four possible adaptive actions, transfer points to new actions and pathways, and lifespan of actions (from MfE, 2017: 200, Figure 66). A sequence of adaptive actions constitutes a pathway.

followed. However, it does not explicitly show which sequence of options should be followed to meet the objectives of hazard avoidance, cost management, and mitigation of social and regulatory pressures under an array of different possible futures. MORDM is an iterative process that can help determine the sequence of actions that best achieves a range of objectives (Lempert, 2019).

The purpose of MORDM is to stress test candidate strategies over a large ensemble of scenarios; to identify what it is that strategies that don't meet your objectives have in common. Subsequent tweaking of the strategies ideally leads to identification of one or more strategies that perform well under the greatest number of scenarios within the ensemble. Once those have been identified, research can also look specifically at trade-offs, considering the objectives of a variety of stakeholders.

MORDM considers multiple different futures, seeks robust rather than optimal strategies, and employs adaptive strategies to increase robustness, simulating these via modelling. Rather than being about optimisation and finding the 'best' pathway, MORDM focuses on finding the most robust pathway under conditions of deep uncertainty. MORDM helps decision makers to find the adaptation pathways that are least likely to fail regardless of what happens, while ensuring that costs are minimised by avoiding premature or unnecessary adaptation. In this work, the MORDM analysis is being conducted using the Exploratory Modelling and Analysis (EMA) workbench, developed at TU Delft in The Netherlands (Jan Kwakkel, a project member).

There is a lot of international interest in information, tools, processes and practices that enable decisions makers to implement dynamic plans and make investment decisions under deep uncertainty. However, there are few examples of where DAPP and MORDM have been applied in real decision settings.

Case Studies

We are undertaking two case studies to test the use of DAPP-MORDM in tandem for WWTPs in Aotearoa New Zealand following the steps outlined in Figure 3. Both WWTPs are on low-lying coastal floodplains with elevations < 3 m above mean sea-level and each of the WWTPs represent significant long-term planning challenges. Each plant operator provides three-waters services for their respective communities, but faces uncertainty as to how they will continue to provide those services and adapt their WWTP ahead of the damage or the stranding of the assets. They service communities with increasing populations in areas vulnerable to coastal flooding hazards. WWTP 1 discharges into an adjacent river on the outgoing tide, ensuring dispersal of treated wastewater within a harbour.

Workshops were held with each of the plant operators to problem scope, and to identify critical points of interaction

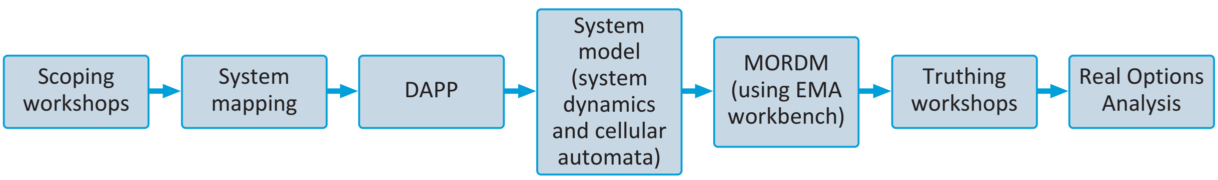

Figure 3: Sequence of methods used in this research.

between hazards and the infrastructure. Social and physical indicators of system stress and possible adaptation thresholds were identified. After the scoping workshops, we developed a systems diagram (a qualitative tool used to help understand and map a system, also known as a system map or a casual loop diagram) to ensure that the WWTP was considered within the broader human-environment system (Figure 4), and key adaptation thresholds for each plant were identified. Indicators were developed that would allow the plant operators to monitor hazards, and values were assigned to those indicators that would trigger a change in adaptive actions; the adaptation thresholds, signals, triggers and indicators were coupled with the adaptation options to produce a functional DAPP map.

Case 1: The operators of WWTP 1 independently developed a dynamic adaptive pathways plan for the WWTP with population growth rate the key variable (Figure 5). Through discussions with the provider, we adapted the DAPP so that inflow volume to the WWTP became the key variable, independent of population growth, time or RSLR. This allows us to investigate the lifespans of the adaptive actions in the DAPP under different scenarios. Some of the actions in the DAPP for WWTP 1 are incremental in nature, such as increasing processing capacity and reducing holding time, while others are transformational and requiring system change, such as relocating the plant or outfall pipelines while decommissioning the existing plant. Incremental actions involve alterations to the existing plant while allowing it to remain at the existing location, while transformational actions involve wholesale alterations to plant location, form, or function. Incremental and transformational options are not mutually exclusive – incremental adaptation can proceed before a switch to transformational adaptation.

We have developed two models for WWTP 1. Initially a system dynamics model (a computational version of the system diagram) was developed to simulate water mass balance through WWTP 1 from inflow to outfall; this identified thresholds (conditions) under which the WWTP will fail to achieve its operational objectives, but not where that failure would occur (e.g., tank/outfall pipeline/filtration unit). Plant operating information from the system dynamics model is being converted for use in a cellular automata model of the plant. Cellular automata models are spatially explicit, temporally dynamic, and can identify both when and where the WWTP is likely to fail in a range of different scenarios. Four submodules are being developed for each model: 1) WWTP; 2) external factors (hazards and inflow projections); 3) policy levers (adaptation options/DAPP); and 4) performance metrics (avoidance of adaptation thresholds).

Case 2: WWTP 2 is located on reclaimed coastal land subject to sea-level rise and land subsidence, which discharges into open ocean and has several emergency discharge points. This case study operator is in the process of commissioning a risk assessment and identifying a range of options to respond to the coastal hazards. The research team will workshop those findings with the plant operator to develop a dynamic adaptive pathways plan for WWTP 2 and associated assets (outfall pipeline and emergency discharges) using the same methodology as for Case 1.

Future steps

The research presented in this article is showing how the case studies are being approached. While workshopping, optioneering and model development are completed for WWTP 1, we recently began these processes for WWTP 2. Once completed, the MORDM analysis is the next step.

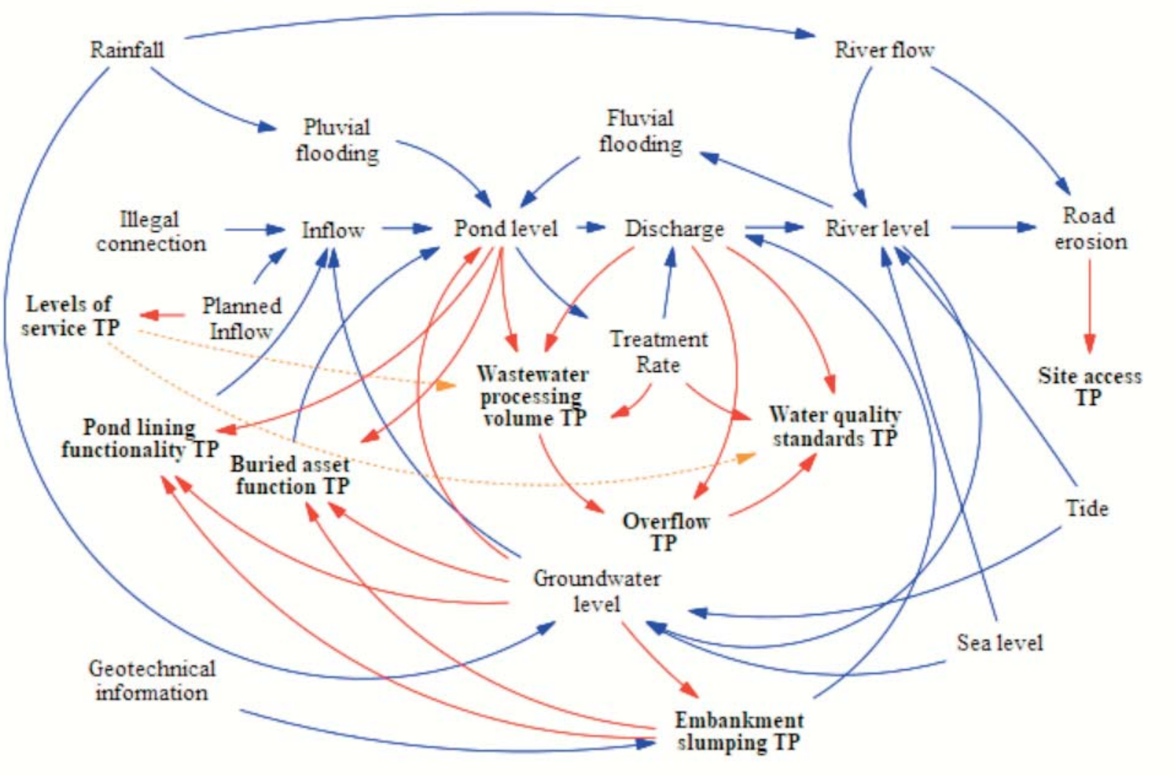

Figure 4: System diagram of WWTP 1 highlighting that the WWTP is part of a broader human-environment system. System components (plain text) and human and environmental drivers (bold text) are linked with blue arrows, with red and orange arrows pointing from stressors to potential adaptation thresholds (adapted from Stephens et al., 2021).

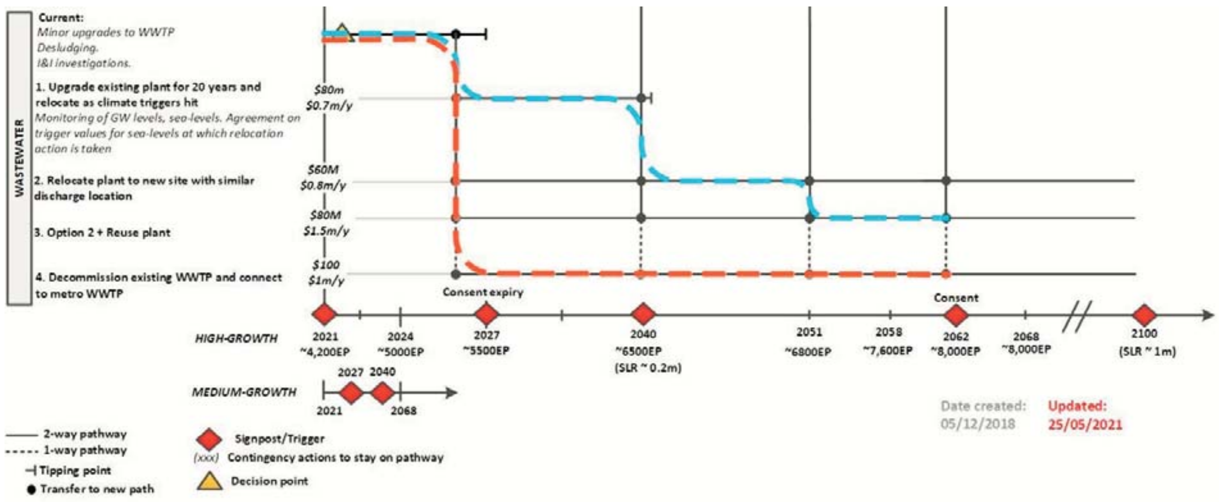

Figure 5: Dynamic adaptive pathways plan for WWTP 1. The blue-dashed line shows an incremental adaptation pathway and the red-dashed line shows a transformational pathway (from Stephens et al., 2021).

The sub-modules for each WWTP will be connected and a MORDM analysis undertaken. Unsuccessful combinations of adaptation actions will be ruled out iteratively until one or more strategies that meet the two main objectives of plant protection and regulatory objectives are identified. Trade-offs can then be analysed while considering the objectives of a variety of stakeholders such as social 'license to operate' and economic viability.

Following the MORDM process, a modified Real Options Analysis (ROA) will be undertaken on one plant to assess transfer costs (costs involved in changing from one adaptation action to another) at different times in the economic evaluation of pathways. In other analyses, ROA has shown that when economic transfer costs are included some actions are not as desirable as they may initially appear, and in cases may not be economically viable at all (Lawrence et al., 2019).

Once the research is complete, we will run workshops to upskill local government practitioners and decision makers in the adaptive tools we used – the grouping of MORDM, DAPP, EMA workbench and ROA. These workshops will be interactive and use qualitative exercises to demonstrate the combination of approaches and how they can improve decision making in the face of uncertainty compared to current approaches.

Preliminary findings

International application of the mixed-methods adaptive tools approach has indicated that they provide a sound platform for making robust adaptation decisions. To date, our work is demonstrating the value of the combined approaches in New Zealand's unique socio-economic and geophysical environments.

Preliminary findings include:

- The value of the scoping workshops to highlight the importance of understanding interactions between multiple hazards and developing robust sequences of adaptive actions to avoid the worst impacts, as also found by Kool et al. (2020). In particular, the process of discussing system form, function and possible future states introduced participants to the systems thinking technique that allows decision makers to grapple with deep uncertainty (Marchau et al., 2019).
- Difficulties exist for three-waters providers in engaging with deep uncertainty because different departments have different mandates generating different desired outcomes and objectives, and because current legislation takes a static approach and is geared to single numbers for decision making. However, they will need to act in unison and take a dynamic approach to address complex infrastructure adaptation issues.
- Interdependencies and co-ordination challenges will need considered exploration. Complex problems facing water infrastructure providers will require coordinated responses from multiple agencies and multiple departments within agencies. These responses need support from robust science and assessment methodologies such as DAPP-MORDM, to facilitate discussions around the viability of the case study WWTPs and associated assets. ROA will enable sensitivity analyses to compare the value of the different options.
- System dynamics modelling shows us the interconnections between different parts of the system. The DAPP-MORDM process enables us to test the conditions under which the WWTPs could become inoperable.

In summary, our on-going research is both demonstrating the value of mixed-methods adaptive tools approaches and providing illustrative examples of how to apply the tools. Over the next 18 months we will work to improve the uptake of DAPP, MORDM and ROA in New Zealand and to upskill Aotearoa New Zealand-based researchers, practitioners and decision makers in these methods via two workshops and published outputs.

Acknowledgements

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Adaptation of coastal protection infrastructure

By Holly Blakely, Peter Quilter, Seth Smith, Madeline Witney,
Tom Shand and Colin Whittaker

Introduction

New Zealand coastal infrastructure is currently at the onset of deteriorating performance associated with ageing of coastal protection infrastructure, ongoing sea-level rise, and potentially outdated design methodologies. The near-term decrease in performance can be attributed to two key components: an increase in structural damage, and an increase in wave overtopping frequencies (a precursor to more sustained coastal inundation).

This article provides an overview of a research project currently underway at the University of Auckland. This project aims to contribute to the understanding of the current state and required adaptation of New Zealand's coastal protection infrastructure with respect to structural damage and wave overtopping. From this it can be seen that this research is situated between the two Ministry for the Environment (MfE) adaptation stages – *What is happening now?* and *What can we do about it?* (Ministry for the Environment, 2017). We first consider existing approaches to monitor and measure overtopping, and the relevance of these measurements to tolerable limits, before discussing opportunities to manage overtopping through hybrid approaches. We then discuss some of the complexities encountered with existing coastal asset management practice, including current approaches used by asset managers, before discussing the effectiveness of different remediation options. Finally, we consider how changes in resource availability and environmental conditions will in turn affect future asset management decision making.

Wave overtopping of coastal protection infrastructure

Wave overtopping occurs during combinations of high waves and water levels that cause waves to pass over the coastal edge (or 'over the top' of a coastal structure, as shown in Figure 1), potentially resulting in a hazard to vehicles and pedestrians and flooding or damage to the built environment. Overtopping can affect critical transport links such as Tamaki Drive, as shown in Figure 2.

Van der Meer et al. (2016) defines **tolerable overtopping** discharge as 'the amount of water passing over a structure that is considered safe.' However, determining safe amounts based on existing laboratory and field datasets can be challenging.

Figure 1: Monitoring imagery of wave overtopping at Ohau Point, north of Kaikōura (Source: Shand et al., 2021).

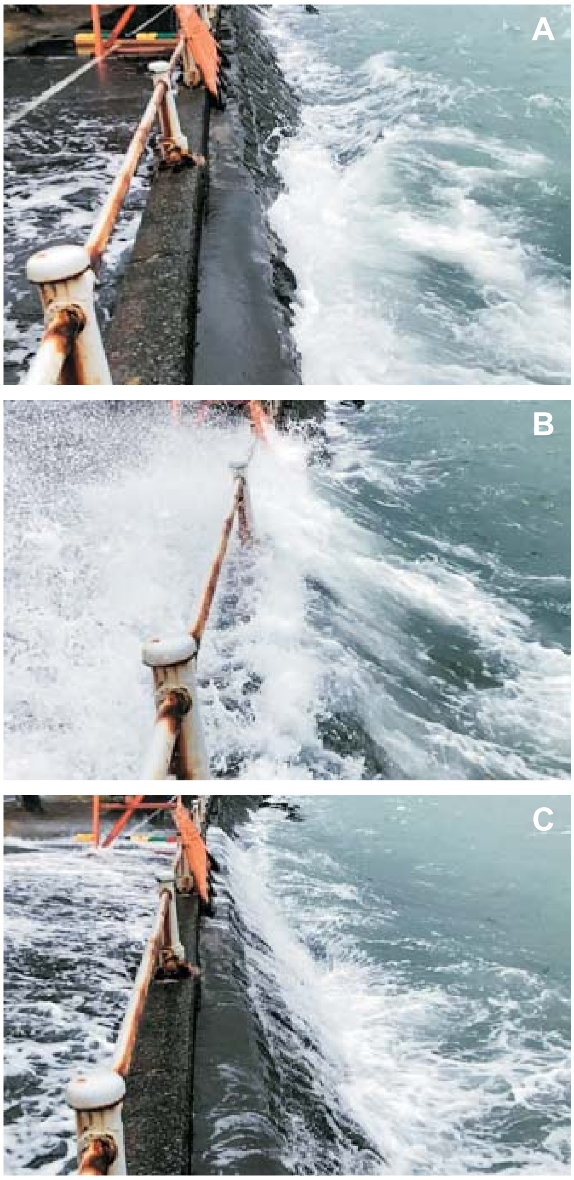


Figure 2: Wave overtopping along Tamaki Drive on March 20, 2022 showing (A) wave run-up, (B) sea spray and green water overtopping the seawall crest, and (C) resulting surface flooding/inundation of the coastal edge (Photos: Holly Blakely).

Existing studies on tolerable overtopping have been primarily developed in a laboratory setting, where conditions can be controlled and incrementally adjusted to understand the drivers of overtopping. This is typically quantified using volumetric quantities such as volume or discharge averaged over a number of waves. There are comparatively few studies that involve the field measurement of overtopping, because of the challenges in obtaining robust measurements in realistic wave overtopping conditions.

The differences between measurements from the field and from physical models that aim to emulate similar conditions can be significant (Silva et al., 2018; Shand et al., 2021). Despite physical modelling being widely considered to be a gold-standard approach for design (compared with simpler empirical or more advanced neural network approaches), there are a number of reasons (including scale effects) why this approach can still misrepresent realistic overtopping conditions.

While volumetric measurement has provided useful linkages between physical modelling and analytical tools, the physical act of measurement is far simpler within a scaled-down, controlled laboratory setting. Field monitoring studies appear to have been strongly influenced by these physical modelling approaches, scaling up the size of measurement apparatus (such as large collection tanks) despite the extensive work and cost involved (Victor and Troch, 2010). This equipment has typically not been easily transferable to other sites, naturally limiting opportunities for further field studies.

Volumetric quantities are useful to understand physical effects on a wide range of management issues, however, studies show that they provide limited insight into the risks overtopping poses for pedestrian safety (Altomare et al., 2020). This implies that our current measurement techniques *may not adequately capture information* about overtopping levels that may be 'tolerable' for different asset users and owners.

This research has included interviews with a number of local authorities in New Zealand, highlighting the following:

- Overtopping hazard is generally given less consideration than terrestrial flood hazard.
- When considering the effects of climate change, erosion hazard is typically prioritised over overtopping due to the apparent physical loss of land.
- Metrics regarding tolerable overtopping are not well understood, with warning systems based on 'rules of thumb' developed from past occurrences.
- Overtopping is not measured, with little indication of formalised record keeping even in those areas already subject to almost annual exposure.
- Mixed asset class owners (e.g., roads, built environment) and users (e.g., drivers, cyclists, pedestrians) perceive the effects of overtopping very differently.

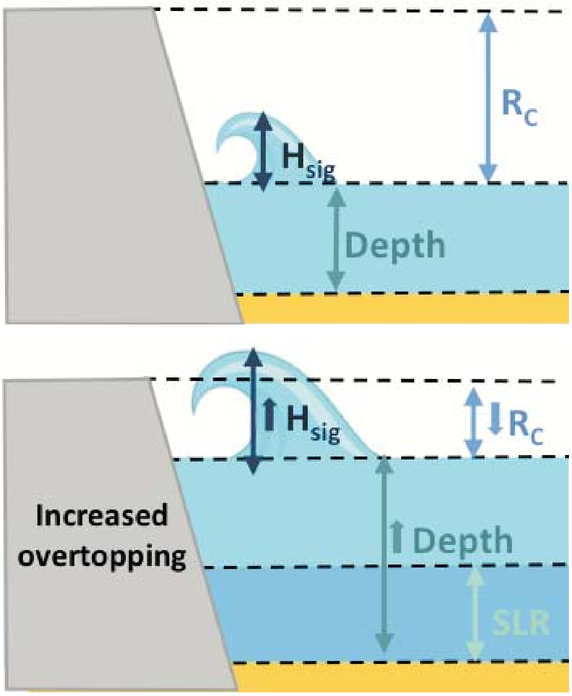
The above points raise the following questions, which have become central in the themes within this body of work:

- Are there other ways to measure overtopping in the field that are more cost-effective and less challenging so that different stakeholders can better understand what is happening now?
- Are there better metrics for tolerable overtopping and how might these feed into a more informed approach for forecasting that will be integral to future adaptive management of this hazard?

Answering these research questions will help to gather timely information on current levels of overtopping, and therefore current structure performance in limiting overtopping, while also informing our response to the future overtopping hazard.

Options for adaptation to mitigate overtopping

Sea-level rise has the potential to increase future water levels during storm events, resulting in increased overtopping, as shown in Figure 3.



Sea-level rise (SLR) increases mean sea level, resulting in:
1. A decrease in freeboard (R_C)
2. An increase in nearshore depth limited wave height (H_{sig})
Both increase wave overtopping

Figure 3: Sea-level rise and potential for increased overtopping.

The potential for increased overtopping in the future from sea-level rise highlights the need for improved wave overtopping monitoring alongside increased understanding of tolerable metrics. Refining these tolerable overtopping limits is fundamental to adaptation in response to wave overtopping. Tolerable limits can be used as adaptation thresholds within a Dynamic Adaptive Pathways Planning (DAPP) framework, marking a level in overtopping frequency or magnitude that is considered unsafe or unacceptable. Signals and triggers can be developed as warning signs for these thresholds. These signals and triggers form the initiating steps of adaptation, identifying when adaptation thresholds are approaching and allowing a variety of adaptation options to be considered in order to divert from these adaptation thresholds. However, for adaptation to wave overtopping to be successful, a foundation of knowledge on the available adaptation options and their associated performance is required.

Existing adaptation options specific to wave overtopping

Adaptation options that retrofit existing coastal protection structures to improve wave overtopping performance have been reviewed. Such retrofitting strategies may be attractive options due to the ageing of New Zealand's coastal protection structures alongside the difficulty and feasibility of constructing new protection structures. Traditionally, retrofitting adaptation options have consisted of 'hard engineered' structures such as crown or recurve walls. The performance of these strategies in reducing overtopping is widely understood with reduction factors quantifying their impact on overtopping discharges (van der Meer et al., 2016). Because these hard engineered structures have been extensively researched and readily used in design applications through standardised reduction factors, they are able to be reviewed as adaptation options within a DAPP framework.

Nature-based wave overtopping adaptation options

In a landscape where coastal engineering is transitioning to a 'softer' nature-based paradigm, there is an urgent need to understand the applicability of nature-based engineering solutions to wave overtopping adaptation. These nature-based options can provide an opportunity to reduce the embodied carbon of traditional adaptation techniques, where embodied carbon represents the carbon dioxide emissions associated with an adaptation option across its full lifecycle. Adaptation to wave overtopping has traditionally drawn from a knowledge base of 'hard engineered' protection. Quantifying the performance of nature-based adaptation options such as the one illustrated in Figure 4 will provide a far broader base of strategies to draw upon when planning for the adaptation of existing coastal structures. In addition to this, the environmental implications of strategies can be considered in design, with nature-based options likely to have lower or negative embodied carbon when compared to the 'hard engineered' options. However, until the performance of such nature-based approaches is quantified, uptake by coastal practitioners is likely to be limited.

Figure 4: Example of a hybrid coastal defence solution at Wattle Downs, Auckland (Photo: Tonkin+Taylor).

Hybrid wave overtopping adaptation

The use of nature-based strategies for adapting to wave overtopping has been reviewed in the context of 'hybrid' structures, where natural features are used to retrofit existing protection structures. Existing research has begun to explore the applicability of hybrid structures for use of erosion control as well as the promotion of biodiversity. These strategies have primarily concentrated on erosion control and biodiversity enhancement as opposed to wave overtopping performance. From this review numerous hybrid strategies were identified; these fit into three broad categories:

1. **Hybridisation by the incorporation of vegetation**. There are many ways this could be achieved. Examples include coastal protection structures fronted by submerged kelp beds, or the use of a floating breakwater containing plants to dissipate incoming wave energy.
2. **Hybridisation by the incorporation of habitat promoting elements**. Habitat promotion is achieved through textured elements or by incorporating biological elements (e.g., oysters) directly into the design of coastal protection structures.
3. **Hybridisation by mimicking dune-based systems**. Hybridising is achieved by creating dunes over hard engineered systems (Winters et al., 2020; Almarshed et al., 2020).

All options show potential for the reduction in overtopping and are candidates for additional research. Research currently underway will quantify the reduction in overtopping, with physical and numerical modelling aiming to identify the feasibility of the use of hybrid coastal strategies for wave overtopping adaptation. This will provide a starting point for the expansion of wave overtopping adaptation from a purely hard engineered domain to one that incorporates nature-based principles in design. This transition will allow for wave overtopping adaptation to occupy a space that considers both environmental effects and embodied carbon in design.

Assessing condition and performance of coastal protection infrastructure

General approaches to assessing condition and performance

A key function of coastal protection structures is to protect communities and their associated infrastructure from wave attack; however, wave impacts can cause the deterioration and failure of coastal protection structures themselves. A coastal protection structure is generally designed to maintain its form during the conditions anticipated over its design

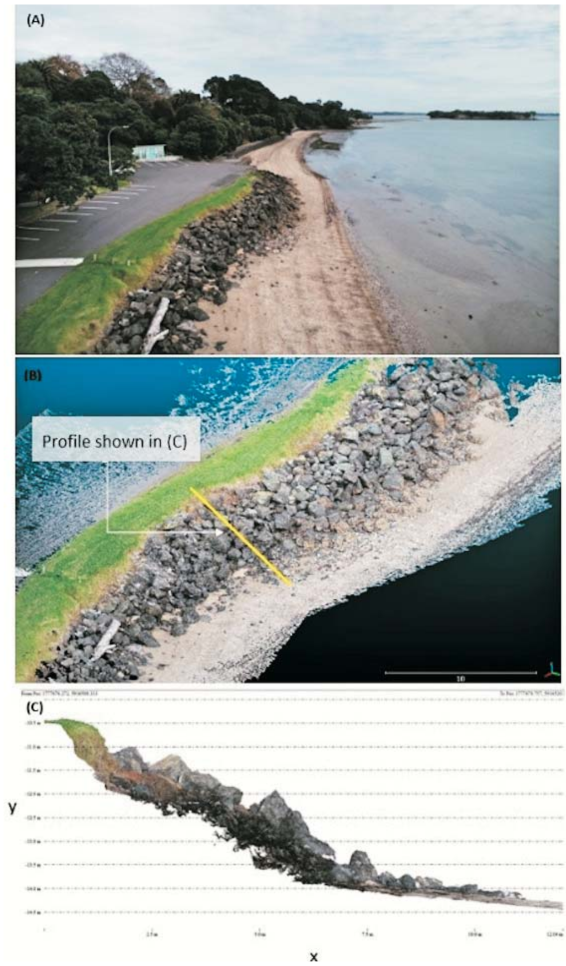


Figure 5: Example of a coastal revetment at Sunkist Bay, Auckland. (A) Aerial imagery collected by unmanned aerial vehicle (UAV) survey; (B) Point cloud generated from UAV survey; (C) Revetment profile generated from UAV survey.

life. Therefore, deterioration or damage is predominantly measured as a deviation from its design profile; a simple example is the dislodgement of rocks from a sloping revetment (Figure 5).

Periodic or post-storm event monitoring processes such as condition assessments are critical to ensure we maintain adequate protection of our communities and infrastructure. Condition profiles within asset management plans can help coastal asset owners make data-informed decisions, and in turn, prioritise resourcing and capital expenditure for structures that may be subject to higher risks of failure (Tarrant et al., 2018).

Condition assessment practices used internationally can be categorised into non-intrusive and intrusive methods. Each condition assessment practice provides an inspector with a different level of information; while some practices may identify a particular damage or failure, others may not. In other words, a condition assessment is not a 'one size fits all' procedure and must account for the structure type, the available funding and resources, and the desired level of accuracy. A summary of the various condition assessment practices and the respective failure mechanisms which the practice can identify is provided in Figure 6. Furthermore, an example of how a UAV survey can be used to identify damage to a revetment structure by means of rock displacement is provided in Figure 7.

Condition assessment methodologies used by New Zealand councils

Interviews have been conducted with participating local council employees to understand the current practices used to assess the condition of coastal protection structures. The interviews focused on the failure mechanisms of coastal assets, condition assessment methodologies and frequencies, and case study opportunities for future field and laboratory research. This section will discuss the condition assessment methodology findings.

The interviews indicated that councils generally use visual inspections as the primary method to assess the condition of coastal structures. The specific procedure of visual inspections varied between different organisations. Visual inspections depended on employee expertise and were often conducted by experienced employees who had a detailed knowledge of individual structures. The information collected by visual inspections is qualitative, and therefore a rating scale is often assigned to translate the findings into a quantitative form. This enables asset managers to monitor the condition over time by comparing multiple condition assessments.

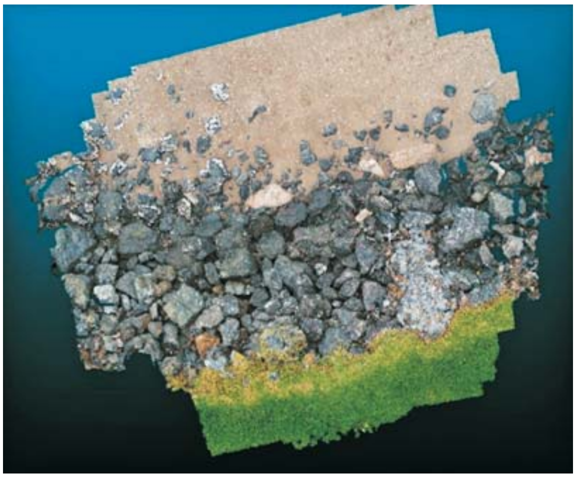
The quantitative data can also assist decision makers when determining if and when remediation is required. The interviews with council employees revealed that visual inspections are typically conducted in isolation, but can be followed up with further investigations such as a topographic or unmanned aerial vehicle (UAV) survey when required.

A review of the international literature has highlighted the risks of reliance on one type of condition assessment practice. Exclusive use of one technique could limit the accuracy of the assessment and lead to undetected damage, causing further deterioration or failure of the structure. Although visual inspections are a practical and low-cost option, they can also lead to subjective results and can limit the assessment to defects that are only observed at the surface (Long and Simm, 2006). Studies conducted in Australia (Rad and Scraggs, 2019; Garcia-Webb, 2019) suggest more than one approach should be used within condition assessments to improve accuracy.

It is important to consider the application of this in a New Zealand context. Much of the New Zealand coastline consists of small coastal townships with limited funding and resources. While current practices may take a high-level approach, implementation of multiple practices will need to balance funding, resources, and the assessment accuracy.

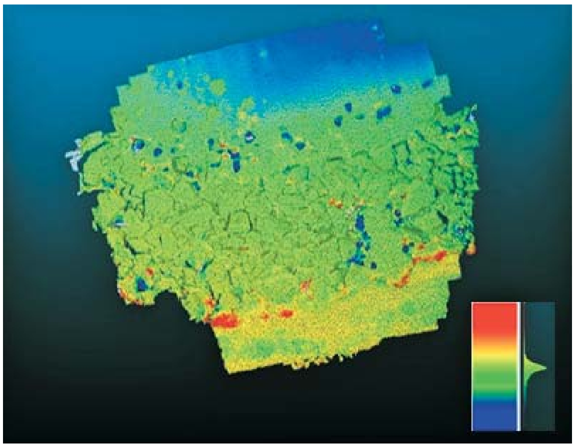
Condition Assessment		**Failure Mechanisms**									
Category	Technique	Crest damage	Damage to geotextile fabric	Loss of internal core	Toe Scour	Settlement/ consolidation	Overturning/ Sliding	Armour loss/ displacement	Armour abrasion	Structural failure	Outflanking
Visual	Visual (walkover) inspection	Green	Orange	Orange	Green	Orange	Orange	Green	Green	Green	Green
	Visual (dive) inspection	Green	Orange	Orange	Green	Orange	Orange	Green	Green	Green	Green
	Aerial Imagery (UAV, aircraft, satellite)	Green	Orange	Orange	Green	Orange	Orange	Green	Green	Green	Green
Topographic	Manual topographic survey	Green	Red	Red	Green	Green	Green	Green	Red	Green	Green
	Above water - Point Cloud (LiDAR, SfM)	Green	Red	Red	Green	Green	Green	Green	Red	Green	Green
	Bathymetric, Single or multi-beam survey	Orange	Red	Red	Orange	Orange	Orange	Green	Red	Orange	Orange
Subsurface	Ground penetrating radar	Orange	Red	Green	Red	Red	Red	Red	Red	Red	Red
Sensors	Sensors (tracking movement)	Red	Red	Red	Red	Green	Green	Orange	Red	Red	Red
Intrusive	Jet probing/ Air lancing	Red	Red	Red	Red	Red	Red	Orange	Red	Red	Red
	Test pitting or peeling back structure	Red	Green	Green	Red	Red	Red	Orange	Orange	Red	Red

Figure 6: Summary of condition assessment techniques that can be used to assess damage/failure mechanisms of coastal protection structures. Green = condition assessment is suitable to identify failure mechanism; orange = condition assessment may be suitable to identify failure mechanism; red = condition assessment is not suitable to identify failure mechanism.

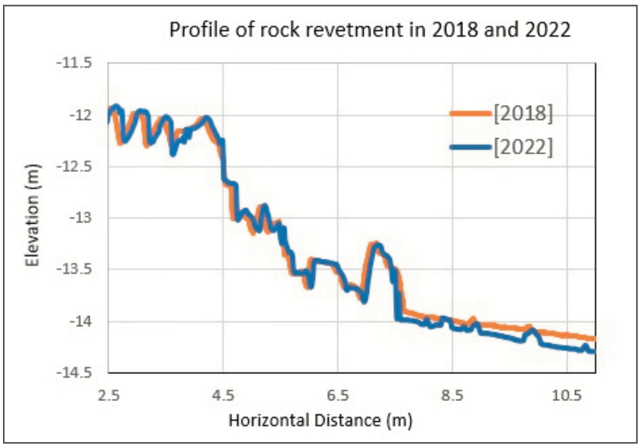


Point cloud generated from UAV survey conducted in 2018

Point cloud generated from UAV survey conducted in 2022



Computed distance betwen the 2018 and 2022 point cloud, representing rock displacement



Profile of rock revetment generated from 2018 and 2022 UAV surveys

Figure 7: Example of the difference between two UAV surveys conducted in 2018 and 2022 for a section of the Sunkist Bay rock revetment. On the difference plot, red represents a positive vertical elevation change and blue represents a negative vertical elevation change, compared to the first survey.

So, what level of uncertainty are we willing to accept? And what are the consequences of failure?

Future work on this topic will aim to improve the current methods for assessing the condition and performance of existing structures in New Zealand. A key area of research will focus on use of UAVs within condition assessments. In the last decade, UAVs have become a popular method to monitor coastline changes. Despite their low-cost and efficient data collection capabilities, there are few examples of their application in assessing the condition of coastal protection structures. A key focus will be determining the accuracy to which the data collected from UAVs can identify damage in a rock revetment structure. This is particularly important as rock revetments are commonly found along the New Zealand coastline.

Options for adaptation to mitigate damage

Damage overview

Sea-level rise will increase water levels near existing coastal structures. An increase in water depth will create larger waves in shallow water conditions, where wave heights are typically limited by the water depth. Excluding sheltered areas and deep-water breakwaters, many coastal protection structures lie within shallow water conditions, and sea-level rise may exacerbate damage (to rock revetment) via:

- Decreased stability of the rock armour units, and subsequent increase of damage progression rate of the entire revetment.
- An increase in overtopping rates and overtopping scour.
- An increase in sediment movement underneath rock armour units.

Sea-level rise will be an important factor in the future of coastal protection structures, but it is the past that often governs future performance. Many of New Zealand's breakwaters and ports were built in the late 19th and early 20th century, prior to current design practices, rock sizing formulae, and readily available wave data for design purposes. As such, current remediations often require the use of larger rocks to achieve satisfactory design levels (e.g., the Mooloolaba breakwater (Stem and Sorbello, 2020)).

Once a structure reaches a critical damage threshold, it needs to be repaired before a broader failure is imminent. The repair period is typically the best time to upgrade the structure to save on time and mobilisation costs. The primary aim is to produce a repair option cheaper than a complete redesign of a structure, or implementation of the next adaptation option (e.g., managed retreat) within a dynamic adaptive pathway.

Repair and upgrade options

This research has focused on adaptation options for rock revetment structures, as consultation with local councils confirmed that these are the most common coastal protection structures used in New Zealand. Furthermore, consultation indicated that typical damage to rock revetments arises from (hydrodynamic) displacement of armour units.

The stability of rock armour is predominantly assessed for standard design structures (i.e., double-layer rock revetments or homogeneous rock structures) using empirical formulations derived from laboratory testing, such as the van der Meer (1987) and Hudson (1961) formulae. These formulae appear in commonly used guidance documents (CIRIA, 2007; USACE, 2008); however, these formulae do not extend to repair methods, and designers must be wary when attempting to implement them outside the tested conditions. The Coastal Engineering Manual (CEM) (USACE, 2008) states that '*design guidance for armour layer repairs is sparse, ... discussion consists of common sense rules of thumb that can be applied along with consideration of the unique aspects of each particular repair*'.

When identifying possible remediation options for hydrodynamic instability, most engineers would consider the following four options (as illustrated in Figure 8):

1. Implementing an additional layer of rock (a,f,h,i) to increase structural stability from an increase in porosity, thus dissipating more wave energy.
2. Replacing amour layers with larger, more stable rocks (b,g), thereby effectively replacing the existing structure.
3. Implementing a high berm (c) to reduce wave forces on revetment rock armour units. The berm will reshape and provide an erosion buffer.
4. Implementing a submerged breakwater (d) or using nature-based aquatic vegetation seaward of the structure (e) to attenuate wave energy incident to coastal structure, thus reducing wave heights at the primary structure and increasing stability.

How can we assess the performance of these repair options?

A desktop study by Burcarth et al. (2014) assessed the use of a submerged breakwater, additional amour layer, crown wall, and high berm as upgrade options in response to sea-level rise and an increasing intensity wave climate; finding that an additional rock armour layer would be the cheapest and most effective option. Although useful for preliminary design, results were empirically derived using unsubstantiated assumptions. A number of questions remain unanswered: Would using differential armour unit sizes influence stability? Would a damaged profile and additional repair layer act similarly to the originally designed uniform slope?

There is a knowledge gap within the literature and these questions highlight a need for further research. Current guidance suggests that physical modelling is required to test each repair method, with the alternative being a 'general rule of thumb' and increased risk of damage. Currently it is more economical for councils to accept risk, rather than undertaking a detailed physical model for every site. This research aims to produce data from laboratory experiments

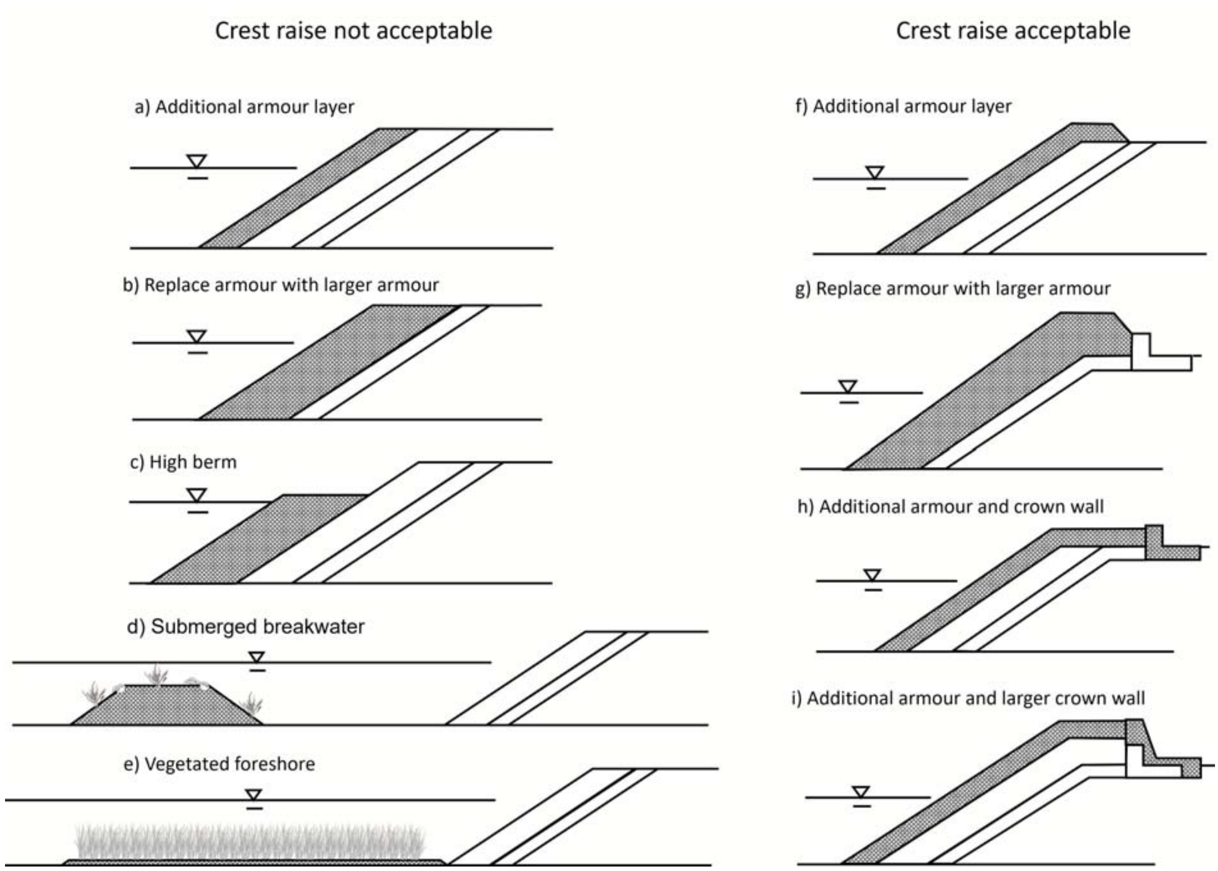


Figure 8: Concepts of upgrading a rock revetment in response to sea-level rise, if raising of the crest is not acceptable (left) or is acceptable (right). Upgrades are shaded, while the existing structure is not shaded. Adapted from Burcharth et al. (2014) with additional options.

that can be implemented more readily by practitioners; to reduce uncertainty without needing to conduct physical model studies of their own.

A berm is effective as an upgrade and repair option as it absorbs wave loading and subsequent damage, providing a buffer before instability of primary armour layers can occur. Guidance on design of berms is well covered in Chapter 5 of the Rock Manual (CIRIA, 2007) and by van der Meer and Sigurdarson (2016).

Constructing a submerged breakwater or vegetating the foreshore can be effective at attenuating wave energy, and has good coverage in existing literature. However, these upgrade options are generally unfavourable to implement by councils and designers for the following reasons:

- Submerged breakwaters are generally more expensive to construct.
- A repair of the damaged structure is still required.
- Works cover a much larger footprint (within the coastal management area, CMA) outside the existing structure footprint. This will likely require an entirely new resource consent and appropriate effects assessments to satisfy requirements set out within the Resource Management Act and the New Zealand Coastal Policy Statement (New Zealand Government, 2010).

Sourcing repair materials

Older damaged infrastructure generally requires larger armour units to improve stability, as design methods improve over the years. Sourcing larger rock is considered a significant challenge, as it is preferable to have a quarry close to the site location, yet most developed areas requiring coastal protection do not support active quarries and have limited site access and land use. Using Auckland as an example; many of its historical reclamations and defenses were made using readily available quarries located near/on volcanic cones and historical Māori Pā sites, for example, the Lunn Avenue quarry (now Stonefields development), Mount Roskill quarry, Mount Eden quarry, Puketutu island (now a WaterCare landfill). Currently, the largest quarries in the Auckland region are located at Drury and within the Hunua ranges. Transporting large armour rocks from either site to the central Auckland coastline will incur significant transportation costs and embodied carbon, and limit mode of transport.

Concrete armour units could become a more prevalent repair option in the future as they introduce flexibility into transportation modes and construction methodology. However, the use of traditional cement binder within concrete has a high embodied carbon, making the use of concrete armour units during a climate crisis difficult to justify. Work has been undertaken to introduce new binders that reduce the embodied carbon of concrete and maintain suitability for use in coastal environments. Khan et al. (2016) introduced a geopolymer binder to fully replace the cement binder within concrete using a low calcium fly ash and ground granulated blast furnace slag (GGBFS) in combination with steel slag aggregate. Using these byproducts can reduce the embodied carbon of concrete by up to 60% (Shobeiri and Xie, 2021), and introduces some favourable properties, for example, reduced shrinkage, higher compressive strength, and higher density. Low carbon geopolymer concrete has been used to construct concrete armour units in some pilot projects within Australia, including the Port Kembla remedial works, where the higher density geopolymer concrete acts to improve stability for similar sized armour units (Mahmood et al., 2020).

Current practice in NZCS 3122: 2009 (Standards New Zealand, 2009) allows for a cement composition of up to 35% fly ash or up to 75% GGBFS as supplementary cementitious materials – these being byproducts of coal fired power stations and steel making industries, respectively. Fly ash is typically specified in coastal environments to improve corrosion protection of reinforced concrete. It should be noted that, in New Zealand, production of fly ash is limited to the Huntly coal power station and the one steel manufacturer in Glenbrook is not capable of producing suitable quality GGBFS from raw materials. Therefore, fly ash and GGBFS are typically imported from Australia, which then incurs higher embodied carbon from the transport of materials.

The use of concrete armour units with low embodied carbon is promising, and feasibility of use within a New Zealand context should be investigated further and compared to traditional rock sources.

Conclusions

This study has investigated the adaptation of coastal infrastructure, particularly considering overtopping and damage to coastal protection structures within New Zealand.

Our study highlights a general lack of practical tools currently available to monitor overtopping. Not being able to measure 'what is happening now' also makes forecasting and assessment of tolerable thresholds problematic. These ingredients appear to be missing when it comes to the consideration of overtopping hazard within a coherent adaptive management framework.

Noting the potential for increased future wave overtopping resulting from sea-level rise in the future, asset owners will need to consider the available adaptation options to manage this hazard. Conventional adaptation options primarily consist of hard engineered retrofitting techniques that have little consideration for environmental factors. The use of hybrid strategies for retrofitting existing protection structures is a potential method for expanding available adaptation options for wave overtopping. Further research is required to quantify the performance of these hybrid structures in order to assess their feasibility as adaptation techniques.

Current asset management practices for coastal protection structures in New Zealand were elicited through a series of interviews with local councils. The interviews highlighted that the primary, and often only, condition assessment practice was visual inspection; however, the exclusive use of one assessment practice may lead to an inaccurate assessment of the structure. Future research aims to improve the current condition assessment methodology, initially by investigating the capabilities of UAV surveying to assess rock revetment structures.

Acknowledging that hybrid adaptation options may not be feasible in all locations, this work also explores typical repair and upgrade options in the future for rock armoured revetments undergoing structural damage due to hydrodynamic instability. Rock displacement is generally attributed to inadequate design prior to current good practice methodologies, and remediation using an additional armour layer is generally considered a best first approach. The use of larger armour rocks and concrete armour units might be required to increase structure stability; however, sourcing of these materials will require a good understanding of their availability and embodied carbon.

Coastal protection structures remain important in protecting our coastal infrastructure assets from a number of coastal hazards, of which overtopping is often neglected. Additionally, these structures are also vulnerable to damage and may become more exposed as sea levels rise. Adapting these structures to mitigate overtopping and structural damage is vital.

Acknowledgements

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Shoreline Adaptation Plans for Tāmaki Makaurau: making space for coastal change

By Natasha Carpenter, Sage Vernall and Paul Klinac

Introduction

Auckland (also known as Tāmaki Makaurau) is a coastal city with the largest population density to coastline ratio in New Zealand. The region is characterised by over 3,200 km of diverse coast, from high energy, open west coast dune environments, through to extensive cliffed shores and urban beaches on the east coast looking out on to the many islands of the Hauraki Gulf. Sheltered environments include three major harbours (Kaipara, Manukau and Waitematā) and an extensive network of estuaries and inland waterways. Given abundant and easily accessible resources, Māori named the region Tāmaki Makaurau, which means Tāmaki desired by many or Tāmaki of a hundred lovers.

The magnitude and dynamic nature of Auckland's coast, combined with the proximity of urban development, supporting infrastructure and coastal assets, brings several management challenges. Coastal hazards including beach and cliff erosion, coastal inundation and rainfall flooding require innovative, proactive and reactive responses as well as longer term planning to manage risk and its exacerbation by climate change effects along our shorelines.

To ensure sustainable management of our coast and improved resilience of our local communities, Auckland Council is developing a series of Shoreline Adaptation Plans for its council-owned land and assets. The overall programme is a huge endeavour considering the scale of Auckland's coastline, our diverse population, and broad range of asset owners. The overall programme is expected to take some three to five years and is a collaborative, across-council effort. Once completed, the plans will provide site-specific adaptation strategies for all coastal areas, helping Auckland build a more resilient future.

Coastal framework

The amalgamation of Auckland into a Unitary Authority highlighted the need for a consistent and long-term approach for coastal management in Auckland. In 2017, Auckland Council published the Coastal Management Framework for the Auckland Region (Carpenter et al., 2017) to set out key coastal management principles and tools needed to support this process, while giving effect to the policy direction of the Resource Management Act and New Zealand Coastal Policy Statement.

The framework promoted the need for holistic, systems-based coastal management, reflecting international best practice approaches such as the United Kingdom's Shoreline Management Plans. Later in 2017, The Ministry for the Environment (MfE) also published the revised 'Coastal Hazards and Climate Change Guidance for Local Government'. This included promotion of the Dynamic Adaptive Pathways Planning (DAPP) approach, a concept to enable changing management strategies in response to pe-determined trigger points and account for future uncertainties in our changing climate.

Finally, in 2020, Te Tāruke-ā-Tāwhiri: Auckland's Climate Plan (Auckland Council, 2020) was published. The plan sees resilient coasts and communities as a key priority area as well as the need for long-term coastal management planning.

Through this series of documents and overarching legislation, Auckland's Shoreline Adaptation Plan work programme was developed. The plans have become a key tool in the implementation of Te Tāruke-ā-Tāwhiri and the methodology for their development provides both a practical and innovative approach for applying the MfE guidance to a highly complex social, economic and environmental setting.

What are Shoreline Adaptation Plans?

Shoreline Adaptation Plans are non-statutory, strategic documents that support long-term sustainable management of Auckland Council-owned coastal land and assets. This includes reserves, regional parks, coastal defence structures, coastal amenity structures (such as boat ramps, wharves and coastal accessways), and council-owned facilities. The plans focus on the potential impacts of coastal erosion, coastal inundation, rainfall flooding, and climate-change impacts (including sea-level rise) and aim to provide an adaptive planning approach focused on the needs and values of iwi and local communities. Acknowledging the environmental and landscape value of the shoreline, the plans also promote the preservation, enhancement, and ecological restoration of the coastal environment for future generations. As there are a high number of non-Auckland Council assets present in the shoreline areas, the plans also include input from stakeholder partners (Council controlled organisations such as Auckland Transport and Watercare).

To set long-term adaptation strategies for our coast, the plans adopt four high-level coastal management strategies and describe how these need to change over the short (0-20 years), medium (20-50 years) and long (50-100 years) term:

- No Active Intervention: Natural processes are allowed to continue. This includes no investment in coastal defences. Until guidance is available from central government on the management of private land, this strategy is automatically selected for areas of the coastline that are not owned by Auckland Council.
- Limited Intervention: Limited works are undertaken to extend the existing asset life or to ensure assets remain safe, including localised retreat of individual assets. This approach acknowledges that the coastline's position will not be fixed into the future and may include small-scale nature-based measures (e.g., dune planting) to support the coastline's resilience.
- Hold the Line: The coastal edge is fixed at a certain location, using nature-based options (e.g., beach nourishment) or hard structures (e.g., sea walls). Where possible, nature-based options are the preferred method.
- Managed Retreat: Assets and activities are moved away from hazard-prone areas in a controlled way over time. Managed retreat allows greater space for natural buffers and reduces asset exposure to natural hazards.

While the Shoreline Adaptation Plans are focused on council-owned land and assets, it is envisaged that the recommended long-term adaptation strategies will guide broader future decision making. This may include assessing the need for new infrastructure on land in the coastal hazards area, in alignment with national and regional policy direction.

Te Ao Māori

Mana whenua is a term used to describe Māori who have tribal links to Tāmaki Makaurau and are represented by 19 iwi (tribal groups). Shoreline Adaptation Plans include a te ao Māori (the Māori world) perspective by partnering with mana whenua to jointly develop the plans and identify places of importance to mana whenua. The management strategies subsequently reflect the best cultural outcomes for mana whenua. This engagement strategy gives effect to Te Ora ō Tāmaki Makaurau, the wellbeing framework developed by the Mana Whenua Kaitiaki Forum in response to Te Tāruke-ā-Tāwhiri: Auckland's Climate Plan. It is a regional innovation that is built on generations of knowledge and reflects the world view of the various mana whenua, iwi, rangatahi (youth), Māori and Māori communities of Tāmaki Makaurau.

In the spirit of partnership, the Mana Whenua Kaitiaki Forum developed the following guiding principles for all Shoreline Adaptation Plans. These principles align with the Te Ora ō Tāmaki Makaurau framework and help guide the Shoreline Adaptation Plans' work programme and their implementation:

- Responsive to iwi management plans
- Accept reversal of infrastructure to rectify hazard issues
- Naturalise, let nature take its course
- Look at emissions as well (if any)
- Whenua (land) concepts are written up and understood by all in plans
- Protect koiora (biodiversity) and traditional mahinga kai (food resources)
- Protect heritage where possible.

Whangaparāoa pilot

The first Shoreline Adaptation Plan was launched in 2021 with the Whangaparāoa Shoreline Adaptation Plan Pilot being the first of at least 20 individual Plans to be developed. To provide for the complexity and variety of Auckland's coasts, each Plan will provide site-specific adaptation strategies tailored to their own scale and unique character.

The Whangaparāoa peninsula is located on Auckland's north-eastern coast, approximately 25 km north of the city, and extends east some 11 km into the Hauraki Gulf. The area was selected because of its mix of sandy beaches, steep cliffs and modified coast, combined with strong, established communities and a range of council-owned coastal land and assets, including Shakespear Regional Park (Figures 1-3).

To ensure the Plan was developed based on a comprehensive knowledge base, several workstreams were undertaken including a technical assessment, mana whenua engagement, and community engagement, which are summarised below. These workstreams were recognised as fundamental to the success of the final plan.

Figure 1: Aerial image of Whangaparoa Peninsula 2021 (Photo: Auckland Council GEOMAPS).

Figure 2: Stanmore Bay Park, photographed facing east, November 2020 (Photo: M McNeil).

Figure 3: Te Haruhi Bay, photographed from clifftop facing east 2019 (Photo: J Farnworth).

Technical assessment

The technical workstream was based on a coastal hazard assessment and evaluated the exposure of council-owned land and assets over time to coastal hazards and climate change impacts. The assessment utilised Auckland Council's comprehensive and up-to-date coastal hazard datasets to indicate what elements of interest were located within hazard zones that may subsequently be adversely affected by hazard events. For Whangaparāoa, they included parks and reserve land, Auckland Council-owned infrastructure, ecological and environmental areas, and cultural heritage sites. They were defined through a combination of existing statutory layers (e.g., Auckland Unitary Plan overlays and controls), consultation with council experts, and feedback from community engagement. In combination with the coastal hazard assessment, their exposure was assessed using social, environmental, cultural, and economic indicators. To understand the varying impacts across Whangaparāoa, the peninsula was broken into a series of separate units.

The results indicated that the Whangaparāoa Peninsula will generally have low exposure to coastal hazards over the next 20 years. However, due to impacts of climate change, the hazard extents will grow over time, increasing exposure in the medium and long term. Hazard overlays and changes in the exposure profile were presented as maps to support community and mana whenua engagement and ultimately support the adaptation strategy decision-making process.

Community engagement

Local community insights and in-depth feedback were recognised as vital to developing appropriate adaptation strategies for the local coastline. Thus, community engagement for the Whangaparāoa pilot included a wide range of public outreach events alongside the establishment of a more focused Community Reference Group. Events included three public presentations to introduce the Shoreline Adaptation Plans and key coastal management concepts. These were supported by two workshops with the Community Reference Group and two public open days to bookend the community engagement period.

The Community Reference Group was established to enable detailed discussion of the Plan objectives, values, and proposed adaptation options for the peninsula. It included ten community members from a variety of backgrounds, supported by two members of the Hibiscus and Bays Local Board. Applications were sought across a range of community networks and a panel applied an agreed selection criteria to ensure a fair selection process. During these meetings, the reference group helped to:

- assess and confirm community values collected via the wider engagement;
- develop and state community objectives for coastal management; and
- provide insight into the importance of the three areas of interest (Stanmore Bay, Big Manly, and Shakespear Park) to the local community.

Parallel to the in-person engagement, innovative digital engagement was undertaken using Social Pinpoint, an online engagement platform that allows users to provide feedback via an interactive map (Figure 4). The information helped identify key community values across the peninsula and highlighted 'areas of interest'.

The extensive use of tailored public events and digital engagement resulted in the Whangaparāoa Shoreline Adaptation Plan receiving one of Auckland Council's highest rates of community feedback and has become a leading example of community engagement.

Mana Whenua engagement

Incorporating the historic and intrinsic value of the coast to local iwi is key to the development of each Shoreline Adaptation Plan. The Whangaparāoa Pilot was developed with two iwi groups that are closely connected to the area, Ngāti Manuhiri and Ngāi Tai ki Tāmaki, through a series of seven joint hui (meetings) with iwi representatives.

Below are the Mātauranga ā-iwi (knowledge from iwi) guiding values that Ngāti Manuhiri and Ngāi Tai ki Tāmaki have given to underpin coastal management on the Whangaparāoa Peninsula:

- Tino Rangatiratanga – Self-determination
- Rangatiratanga – Leadership
- Toitutanga – Sustainability
- Whakahautanga – Restoration
- Tiakitanga – Stewardship
- Manaakitanga – Support.

These values are categorised into three major themes that reflect the Kia Ora Te Tātai outcome:

- Value Whakapapa (Ancestry) by acknowledging and supporting the cultural and spiritual values of mana whenua and giving effect to the views of mana whenua regarding culturally significant sites or areas in any coastal management or engineering options.
- Value Taiao (Environment) by prioritising naturalisation of the shoreline and working to enhance and protect the natural environment. This includes restoration of the natural environment in areas where managed retreat has been recommended and considering nature-based options in areas of 'hold the line'.
- Value Tangata Hononga (Connecting People) by recognising and supporting the interdependence of people and their environment, providing mana whenua with kaitiaki (environmental guardians) opportunities, and working with the local community on volunteering opportunities.

For each theme, Ngāti Manuhiri and Ngāi Tai ki Tāmaki provided objectives on how the Shoreline Adaptation Plan will give effect to these values in Whangaparāoa. These objectives will be considered for all future shoreline projects on the Whangaparāoa Peninsula and provide an important foundation for future engagement.

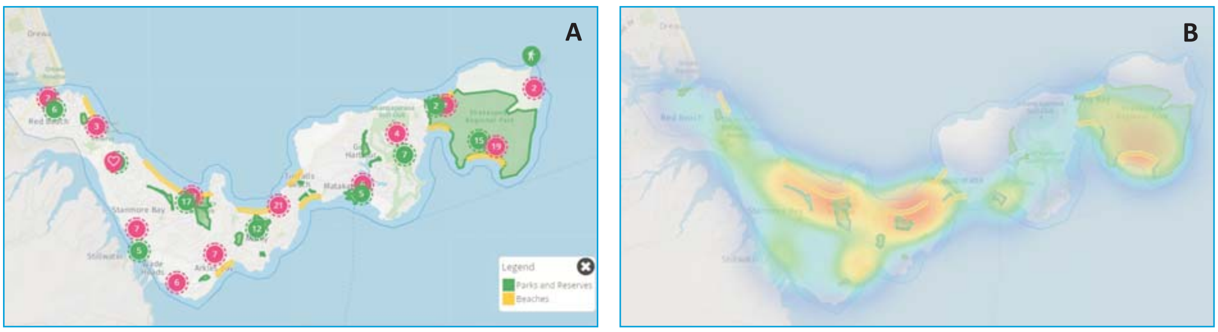

Figure 4: Excerpt from Social Pinpoint maps generated from the digital engagement. (Map A) Location of specific comments; a range of pins were used for people to highlight where they visit and what they value. (Map B) Heatmap highlighting the areas most commented on (red shading) during the engagement.

Results

For the pilot, the coastline was divided into 35 discrete 'coastal stretches', based on coastal geomorphology and processes, public land boundaries, and infrastructure considerations (Figure 5). Considering the exposure of the coast over time, the nature of the assets at risk, and alignment with mana whenua values, community and infrastructure provider objectives, it was found that most of Whangaparāoa's shoreline can be managed over the next 100 years with limited active intervention. However, for some of the low-lying shoreline areas, the escalating risk of coastal inundation and rainfall flooding will require managed retreat of assets in the medium or long term. As well, the need to set back assets out of areas susceptible to coastal erosion and instability has also been signalled.

Coastal stretches identified as 'hold the line' in the medium to long term have a strong link to critical infrastructure or amenity value. Areas of importance, either due to their landscape or heritage value, have also been considered, and a separate adaptation plan for managing cultural heritage sites is recommended.

A detailed example of the changing management strategies is provided for Red Beach at the northern boundary of the Whangaparāoa Shoreline Adaptation Plan extent. The area includes coastal stretches 1-4, which encompasses Amorino Park, Red Beach Surf Club, and 14 identified cultural heritage sites. Figure 5 provides an overview of the proposed changing coastal management strategies over time. In coastal areas not owned or managed by Auckland Council, a strategy of 'no active intervention' has been set as shown in Coastal Stretch 2 (Figure 6). The changing coastal management strategies are presented in the Plan with indicative timeframes considering changing hazard exposure, the ability to relocate assets beyond the hazards' extent, and to support Taiao through naturalisation of the coast where practicable. Refinement of the changing management strategies to link to specific triggers and signals as recommended through the Dynamic Adaptive Pathways Planning approach is being considered within the implementation of the Plan, as further discussed below.

The Whangaparāoa Shoreline Adaptation Plan has set the long-term strategic direction for management of the shoreline of the peninsula. It will ensure the preservation

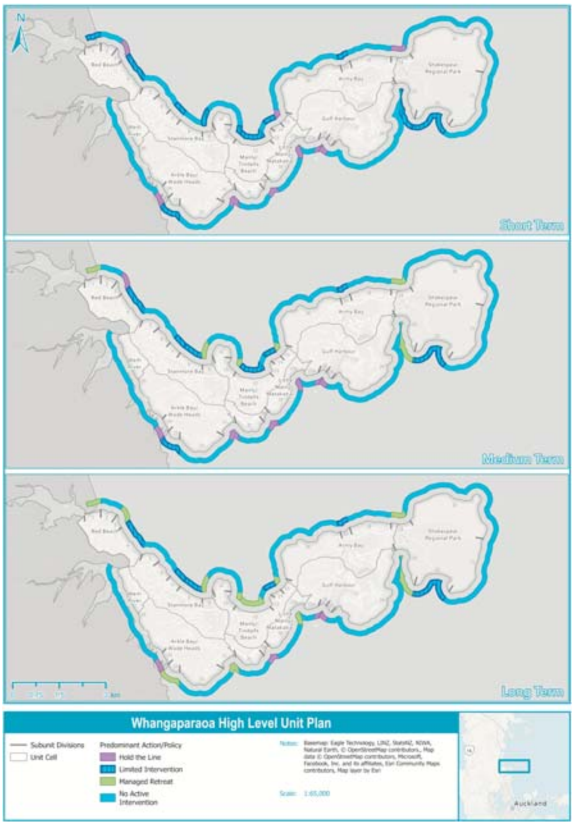

Figure 5: Adaptation strategies across all 35 coastal stretches over time.

of the shoreline for future generations, reflecting local iwi and community desires to protect the environment while maintaining access and amenity along this stretch of coast.

Implementation

Following completion of the Shoreline Adaptation Plans, their findings need to be incorporated into decision-making processes to ensure that the selected strategy is implemented. The results and recommendations of the Shoreline Adaptation Plans will be integrated into relevant Auckland Council documents and plans, including Reserve and Regional Park Management Plans and Local Board Management Plans.

As Shoreline Adaptation Plans are currently limited to land and assets owned by Auckland Council, a key tool for their

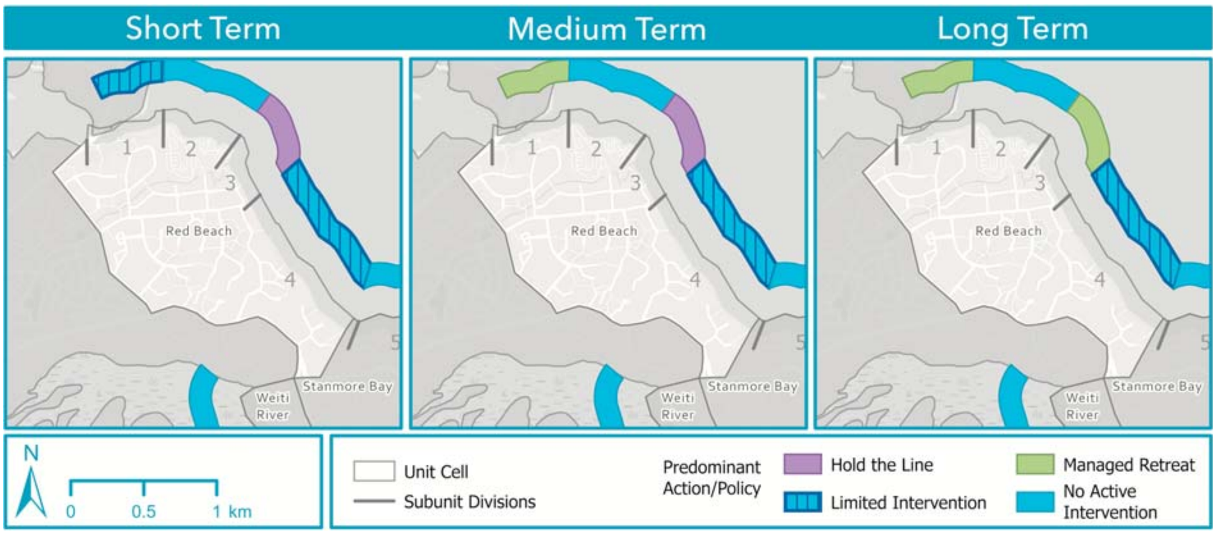

Figure 6: Adaptation strategies for coastal stretches within Red Beach unit area.

implementation is updating asset management plans to reflect the recommended strategies for each area. These plans outline how organisational objectives are to be implemented in relation to assets (ISO55000:2014). They define the funding requirements to achieve those objectives and enable sufficient funding to be made available in budgets to achieve acceptable outcomes.

Asset Management Plans also document the levels of service that will be delivered by each asset. For coastal protection structures, changing sea levels may alter future levels of service that are achievable. For example, a sea wall may no longer fully protect against flooding during a king tide, meaning that the frequency of flooding will increase above that it was originally designed for. In this case, a decision has to be made to either tolerate this change in levels of service or invest in mitigation or prevention measures.

To ensure that levels of service are set appropriately within the Asset Management Plans, they will be aligned to the community expectations that were identified through the consultation process. This will be balanced with legislative and budgetary realities through the political approval process.

While traditional Asset Management Plans assume that an asset will be renewed at the end of its useful life, the results of each Shoreline Adaptation Plan can be used to define alternative outcomes for each asset. This could range from enhanced maintenance to extend their useful life, to early decommissioning and replacement with naturalised alternatives. Expressing these options in the Asset Management Plan, and setting aside appropriate budgets to implement them, ensures that the strategies defined in the Shoreline Adaptation Plan are given effect to in key investment decisions.

Conclusions and next steps

The Whangaparāoa Shoreline Adaptation Plan Pilot is the first of at least 20 individual Shoreline Adaptation Plans to be developed across the Auckland region (Figure 7). It is a leading example of applying MfE's Dynamic Adaptive Policy Pathways philosophy and a critical project in delivering Auckland's Climate Plan. Completed as an initial pilot, it successfully trialled a best-practice process for development, including new and robust approaches for mana whenua and community engagement, coastal hazards assessment, and establishment of long-term adaptation strategies.

Lessons learnt will be continuously re-evaluated and refined as the programme progresses. To date, some of the key lessons learnt are:

1. The engagement process is critical to the success of each plan and needs to be supported by sufficient time allowances: The Shoreline Adaptation Programme is currently founded on an extensive four-month community engagement period, with end-to-end mana whenua and stakeholder engagement across the entire plan development cycle (approximately 10 months in total per plan).
2. Utilise a range of engagement methods, including in-person and digital engagement and supporting tools: In these changing times, this has become increasingly important to enable feedback from a broad range of Aucklanders. Experience to date has found in-person engagement is valuable to raise initial awareness of the project and encourage further engagement through other channels.
3. Coastal hazard risk assessment results supported by up-to-date coastal hazards information provide rigour to the decision-making process: Consideration of exposure alone provides limited detail on changing hazard impacts across the four wellbeings (social, environmental, cultural, and economic) over time. A full coastal hazard risk assessment is required to provide detail on the changing risk profile and inform the most appropriate adaptation strategies for each area. This must be supported by up-to-date, best available hazards information.
4. The development and adoption of coastal management strategies needs to be completed before individual Dynamic Adaptive Policy Pathways (DAPP) plans. This ensures greater community buy-in and acceptance with respect to implementation.

Following completion of the Whangaparāoa Pilot, a second pilot (Beachlands and East) is currently nearing completion for the coast between Pine Harbour, Beachlands, to the Auckland regional boundary at Matingarahi. Development of this plan as a second pilot has enabled lessons learnt from Whangaparāoa to be applied along with trialling an updated coastal hazard risk assessment methodology. As the Shoreline Adaptation Plan work programme gains momentum, the next two plans for Awhitu Peninsula and the Southern Manukau Harbour are now underway.

The Shoreline Adaptation Plan work programme is critical to providing a consistent, long-term approach to management of Auckland Council's land and assets in response to coastal hazards and climate change risk. The resultant high-level coastal strategies recommended for each area will be integrated across relevant asset management plans, including development of supporting dynamic adaptive pathways planning to inform future climate change responses and associated funding.

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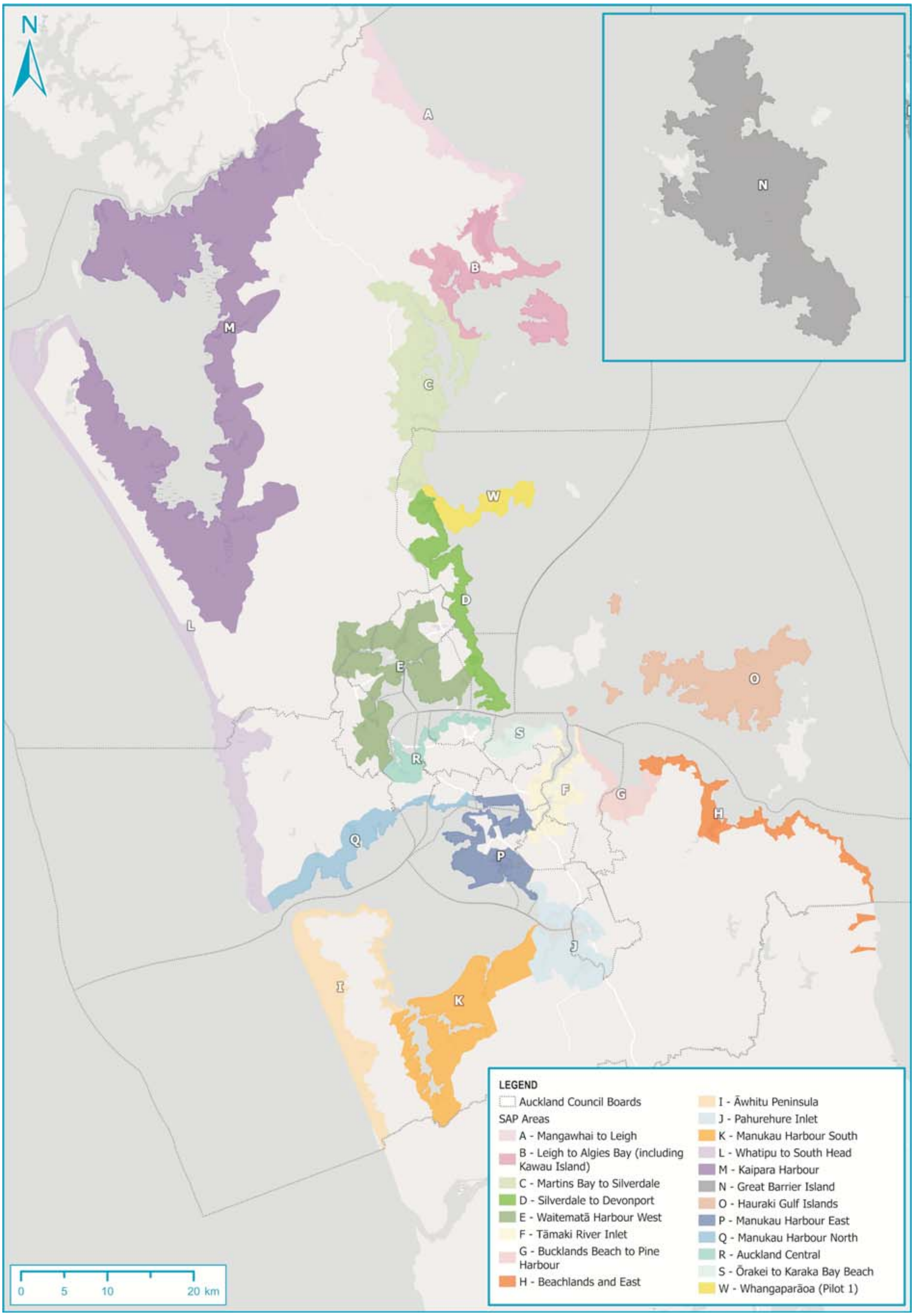
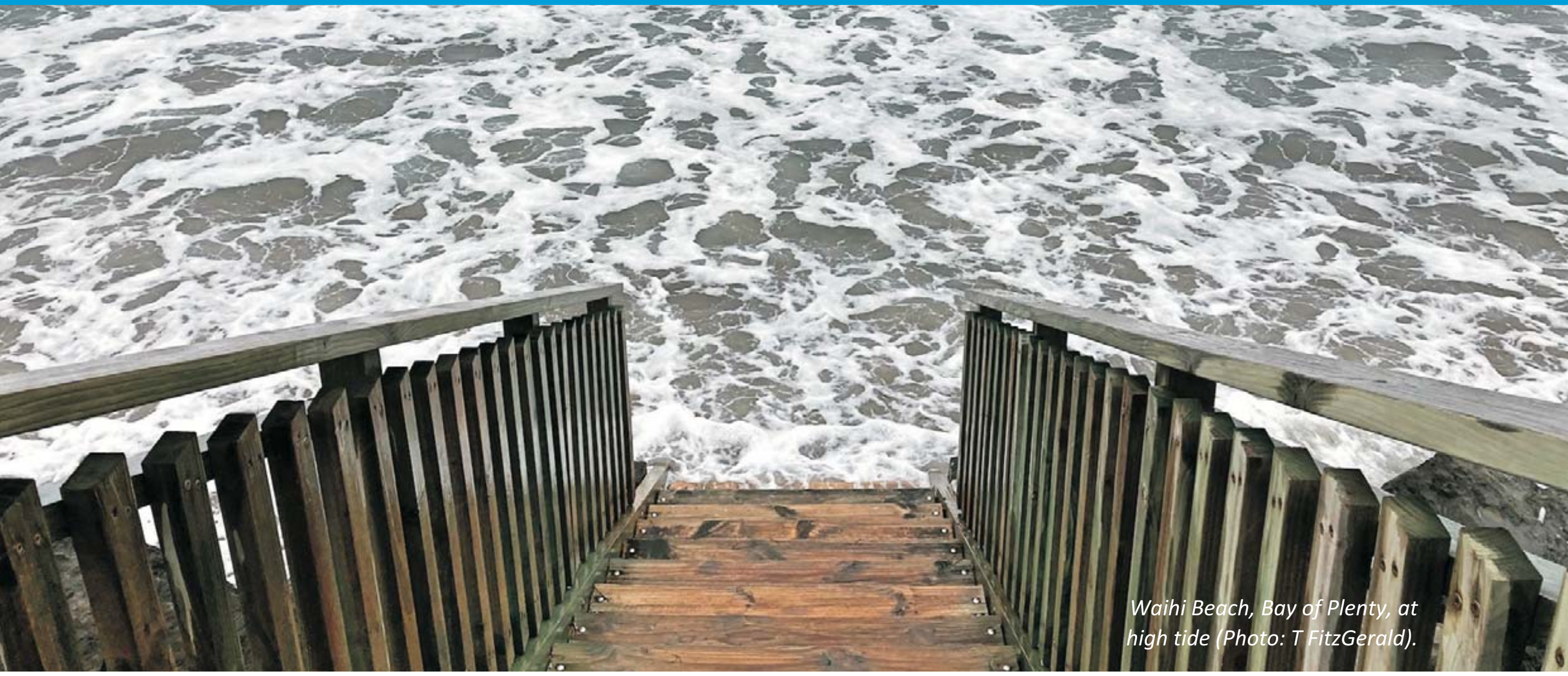


Figure 7: Current Shoreline Adaptation Plan boundaries to support the future work programme delivery.

Conclusions



Waihi Beach, Bay of Plenty, at high tide (Photo: T FitzGerald).

By Lucy Brake

Six years ago the NZCS launched one of its first Special Publications delving into how Aotearoa New Zealand was preparing for sea-level rise (SLR) and the associated effects of climate change. Now NZCS Special Publication #5 builds upon and advances this knowledge to focus on the complex challenge of moving Aotearoa New Zealand towards adaptation to coastal change and hazard risks. The five sections and 17 articles that make up this Special Publication include observations and thoughts from multiple perspectives of interdisciplinary experts and researchers who have drawn upon the rich and diverse knowledge and experiences in this field. This is all with one goal in mind – helping Aotearoa New Zealand progress toward an integrated approach to coastal hazard adaptation.

The overarching introductory section kicks off with the article *The foundations of the sea-level rise challenge: Coasts are a special case for adaptation*, which highlights that while our lifelines can prepare us for the extreme events we have been used to from a relatively benign climate, the increasing extreme sea levels observed and those projected challenge our ability to be prepared and to respond effectively. The authors discuss how Aotearoa New Zealand's current planning system is simply not fit for purpose and requires creative design to make it fit for the future. They conclude that "upskilling communities about the nature of the coastal adaptation challenge and enabling community involvement in the choices that will need to be made about the provision of services and potential managed retreat through sustained processes of adaptation" are a fundamental part of moving forward successfully.

By drawing on key findings of the IPCC's 6th Assessment cycle, the article *Transformational adaptation in Aotearoa New Zealand: Towards a critical framing of coastal adaptation governance* introduces a critical framing of coastal adaptation governance. The author highlights how transformational adaptation is distinct from incremental responses to climate change. He refers to "systemic changes in unsustainable human-climate-environment interactions" and "posits the reconfiguration of societal structures, processes and interactions to avert dangerous climate change and advance climate resilient development". He then offers a prognosis drawn from adaptation experience in three regions and distils priorities to enable transformational coastal adaptation in Aotearoa.

The final article in the introductory section, *What does success look like? A flaxroots perspective of adaptation*, looks at how coastal adaptation does not have a foreseeable end and that effective adaptation processes will require a multitude of changes to regulations, funding arrangements, policies, and infrastructure investments. The authors point out that "successful adaptation means developing equitable, fair and inclusive processes which give proper recognition to the mana/rangatiratanga of kāinga and engage meaningfully with affected communities". They conclude by observing that "the closest we can get to success is having communities that are prepared for, and empowered to respond to, an increasingly unpredictable future".

Understanding the policy and planning framework is key to progressing toward an integrated approach to coastal hazard management, which is covered in Section 2. By exploring the role of the existing planning framework through the article *Our evolving coastal planning framework – relying on the best of the old while awaiting the new* the author explains, in the context of current circumstances with rising seas and continuing pressure for coastal development, some of the most successful and most problematic aspects of the existing planning framework in terms of coastal adaptation. She also points out the work that councils and communities should be continuing with in the interim while the new legislation is developed and introduced. She observes that perhaps the most important goal at present is for councils to "ensure that their areas are ready to face the challenges ahead by readying communities to undertake DAPP (Dynamic Adaptive Policy Pathways) over the next decade", which means ensuring a "sound information base, educating communities on risks and implications of the inevitable changes ahead, identifying priority issues and action areas and ensuring that the policy framework is in place to manage future change".

In the article *Calm before the storm: Can we avoid extreme house price swings from extreme weather events?*, the authors investigate how there seems to be a greater recognition by the government of the limits of physical structures in protecting coastlines against SLR and how managed retreat, a policy that was almost political taboo until recently, is "now gaining ground as a viable alternative, and the government is now considering it as part of its adaptation plan". They point out that in all locations where the risk of SLR is real, the changes in values of residential properties on the coast may also affect the value of nearby properties as well as entire neighbourhoods and towns. In conclusion they posit the question of "do we allow our coastal property markets to be disrupted, and just hope that it does not happen on our watch, or do we try and evince a controlled and gradual descent in prices, through a recognition of the risk the rising seas pose to us all?", ultimately noting that these questions have an indirect impact on the home value of almost all homeowners in New Zealand. There are public policy response case studies around the country that provide insights into future management solutions.

In the article *Managed retreat at Matatā – a challenging solution* the author examines the Awatarariki voluntary managed retreat programme, which applies a resource management framework to high debris flow risk on residential properties. He identifies some lessons that the programme has delivered and considers it is "refreshing that the difficulties identified during the Awatarariki voluntary managed retreat programme have been recognised at a national level and have helped drive some of the pending legislative reforms associated with the RMA [Resource Management Act]".

Key takeaways for future decision making have been identified through the article *Same, same but different; three approaches to setting and defining thresholds, signals and triggers using Dynamic Adaptive Pathways Planning*. The authors recognised that "in application of DAPP, coastal adaptation planning can be flexible and adaptable enough to encompass the inherent differences across coastal communities in New Zealand". They illustrate locally different, contextual approaches to setting thresholds and key decision points that play a critical role in enacting a switch from one management response to another. They conclude that "it is with hope that the iterative process of DAPP will allow for the complexities discussed to eventually make their way into comprehensive long-term coastal adaptation plans".

Effective engagement with communities was a key focus of the Special Publication in 2016, and Section 3 places a contemporary lens on this by looking at the role of Te Ao Māori and coastal marae, how to elevate our engagement to make it more meaningful, and discusses the role of organisations.

In the article *The role of coastal marae in natural hazard response and climate change adaptation*, the authors delve into the increasingly important role that marae are going to play for community adaptation in Aotearoa New Zealand. Not only will they continue to protect and shelter people from hazards and following disasters, but they are also "examples of mātauranga in action, [and] where to position communities, infrastructure and other marae to avoid hazards, if retreat is determined to be the right course of action". They point out that adaptation for marae needs to be cognisant of the history of colonisation and Māori are involved at every stage of the adaptation process, "from knowledge collation and generation through to the selection of adaptation options".

In Te Tai Tokerau (Northland), a local government adaptation team has been developing and exploring the application of a Te Ao Māori decision-making framework for coastal adaptation, which they share in the article *Embedding Te Ao Māori within local government decision making: a Te Tai Tokerau approach*. They describe how the framework will be used to: help guide and inform the way in which tangata whenua are included in planning and policy responses to climate change; recognise that adaptation is local and contextual; provide tangata whenua, Council staff and decision makers with the tools to make the shift to a Te Tiriti based relationship; improve decisions to address the climate crisis; and apply a Te Ao Māori lens across council functions – such as infrastructure, corporate planning and resource management. To guide the development of the framework, the team makes use of a kaupapa Māori research methodology (He Kōrero Rapunga) and notes the challenges to integrating the framework into governance and decision making. "Despite those challenges, one overwhelming positive outcome that deserves repeating is that developing stronger relationships with tangata whenua and te taiao can only act to better serve our tamariki and mokopuna for many generations to come".

Engaging with communities on climate adaptation is a big task, as it is a complex topic and there is a lot of uncertainty, which is a concept considered through the article *Elevating engagement with communities*. The authors draw on experiences from the St Clair-St Kilda Coastal Plan in Dunedin, reflecting on what went well and what did not. They share their thoughts on establishing a common ground and platform from which to make decisions by "emphasising inclusivity, iterating and learning as we go and taking the community on the journey", ultimately positioning engagement to have lasting benefits.

Through the article *Establishing the Aotearoa Climate Adaptation Network* the author shares the journey taken in setting up a new model of collaboration in coastal adaptation. The author notes that coastal adaptation is challenging practitioners again to think outside traditional disciplines and reach across the divide to collaborate for better long-term decisions. He talks about the ongoing challenges and opportunities posed by this need and envisages the Network having an "increasing role in bringing practitioners together and strengthening local government response to the climate crisis".

Ultimately there are still many unknowns in science and the section on mātauranga and science presents an opinion into how to utilise the best available information in decision making. The authors of *The use of historic and contemporary coastal-change data for adaptation decision making* believe that there is a significant gap in our knowledge that has relevance for decision making about the impacts of SLR on communities. This has led to the first national coastal erosion stocktake (since the benchmark work in 1978 by Jeremy Gibb) being commenced, which will deliver new knowledge about erosion hotspots and identify opportunities for monitoring. They state that with accelerating rates of SLR, the dataset provides "an important new baseline on which to ground future projections of coastal erosion for adaptation decision making".

In the article *Nature-based solutions for coastal hazards in Aotearoa New Zealand: results of a nation-wide expert survey on the current state of uptake, barriers, and opportunities* a group of researchers carried out a nationwide survey of professionals to better understand the challenges and opportunities with using nature-based solutions (NbS) for coastal hazards. They found that "despite the considerable challenges to a wider uptake of NbS, the prevailing view from the survey was that NbS should be seen as a fundamental part of coastal adaptation". Moving beyond "pitching NbS against hard defences" was identified as critical in order to better explore synergies between different approaches.

The article *Restoration of saltmarsh in the face of climate change: a regional council perspective* presents new spatial mapping layers developed through saltmarsh elevation modelling which will support restoration activities to be resilient to climate change. The authors describe how their work continues to "put biodiversity values at the forefront to support extensive restoration projects on marginal coastal land, where coastal adaptation is required to support the future of functioning coastal ecosystems".

The final section considers the built environment and the importance of tools for adapting to coastal change and evolving hazard risks in Aotearoa New Zealand. Application of a mixed-methods adaptive tools approach is discussed in the article *Adaptive tools for decisions on water infrastructure affected by compounding climate change impacts*. The authors explain how the ongoing research is both "demonstrating the value of mixed-methods adaptive tools approaches and providing illustrative examples of how to apply the tools" as they work to improve their uptake in decision-making processes.

In the article *Adaptation of coastal protection infrastructure*, the authors draw attention to the need to consider overtopping and damage to coastal protection structures within New Zealand. They confirm that a "robust understanding of the current situation can inform our future options to mitigate the hazards and safeguard our coastal communities" and note that this is important even when coastal protection structures are "conceptualised as 'buying time' for communities to make challenging decisions about long-term adaptation or retreat".

Authors of the article *Shoreline Adaptation Plans for Tāmaki Makaurau: making space for coastal change* discuss their pioneering approach to applying an adaptive planning process and illustrate that Shoreline Adaptation Plans (SAPs) are a critical project in delivering Auckland's Climate Plan. They describe how the Whangaparāoa SAP was completed as an initial pilot which "successfully trialled a best-practice process for development, including new and robust approaches for mana whenua and community engagement, coastal hazards assessment and establishment of long-term adaptation strategies". This article outlines the key lessons learnt through this process which are now being applied in successive projects along with an updated coastal hazard risk assessment methodology.

It is clear that the future for our coastal environments is increasingly unpredictable and under growing and inevitable pressure from climate change. The policy framework and engagement recommendations, understanding of mātauranga and science, and the progress being made in planning for the built environment that are shared in this Special Publication form critical parts of the puzzle to providing a consistent, long-term approach to managing Aotearoa New Zealand' s valuable coastal environment. The insights offered provide an opportunity for us to proactively respond to coastal hazards and climate change risk and to support the development of dynamic adaptive pathways planning to inform future climate change responses and decision making.

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