Environmental Science and Policy 82 (2018) 100–107

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

National guidance for adapting to coastal hazards and sea-level rise: Anticipating change, when and how to change pathway

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ARTICLE INFO

Keywords:
Climate change adaptation
Sea-level rise
Decision-making
Uncertainty
Dynamic adaptive pathways planning
Coastal hazards
Engagement
National guidance

ABSTRACT

Sea-level rise challenges public policy-making because existing planning frameworks and methods are designed to promote certainty using static and time-bound planning and legal instruments. Sea-level rise is a dynamic and uncertain process, which is deeply uncertain towards the latter part of this century and beyond. Communities require decision making approaches that can enable adjustments to policies ahead of damage, without entrenching current exposure to hazards or incurring larger than necessary adjustment costs in the future. We first discuss the nature of the sea-level problem, the policy context that creates decision-making challenges and how they have been typically addressed through policy and practice. Secondly, we show how an assessment and planning approach, designed to address uncertainty and change (the Dynamic Adaptive Policy Pathways (DAPP) planning approach), has been integrated into national guidance for coastal hazard and climate change decision-making in New Zealand. The Guidance integrates hazard and sea-level rise assessments with uncertainty type and with the scale and scope of activity. It is underpinned with values-based community engagement, and uses signals and decision triggers for monitoring and adjusting pathways to meet objectives over time. The applicability of the approach in the Guidance for other policy problems involving uncertainty, is also discussed.

1. Introduction

Sea-level rise (SLR) poses a particularly challenging problem for public policy. It is a chronic ongoing change that will affect many communities in low-lying coastal situations. The rate and magnitude of SLR are deeply uncertain towards the latter part of this century and beyond, highlighting the need for adaptive management frameworks (Kopp et al., 2017). Sea-level rise compounds coastal hazard,[1] impacts through an increasing frequency of extreme inundation events, rising groundwater, and increased exposure of people and assets from the legacy of past decisions (Hinkel et al., 2014; Nicholls, 2011; Rouse et al., 2016). Many low-lying areas will become uninhabitable, necessitating eventual withdrawal in anticipation of the harm, or abandonment with all the associated social and economic disruption (Nicholls and Cazenave, 2010).

Governments at national and local levels have varying mandates to ‘do no harm’ and some have embedded consideration of climate change impacts into their regulatory frameworks and adaptation plans, for example, the United Kingdom, Netherlands, Canada and New Zealand. Nevertheless, sea-level rise challenges those frameworks and the public policy tools and implementation methods which are currently used, such as coastal hazard lines, fixed review timeframes, and cost benefit analysis. This is because they are primarily designed to create certainty for people and communities (Ruhl, 2012), by using spatially and temporarily static instruments within the statutory frameworks (Lawrence et al., 2013). While ‘plans’ are reviewed periodically (every 10 years or so), they fix current risk understanding in space and time for the duration. For example, land uses are either in or out of coastal hazard zones, and properties at the landward edge will only be affected toward the end of a planning period. Such zones also give no information about timing or frequency of impacts from sea-level rise (Lawrence and Saunders, 2017; Stephens et al., 2017). If review periods are at intervals of around 10 years, and long-term SLR is not considered, this can enable further development where it will be exposed to SLR, and thus increase

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[1] Hazard, risk and hazard risk to mean the physical characteristics of the stressor; the combination of the consequences of a hazard on people and assets and the likelihood of occurrence (where it can be calculated or where scenarios are used); and the combination of the two terms to describe the source of risk, respectively. Vulnerability is defined as the predisposition to be adversely affected encompassing both fragility of assets in an engineering sense and the ability of people and group’s to adapt.

https://doi.org/10.1016/j.envsci.2018.01.012
Received 12 June 2017; Received in revised form 27 December 2017; Accepted 21 January 2018
1462-9011/

the difficulty of changing course in the future; early decisions will be required for more frequent inundation even with modest SLR. Decision-making approaches therefore need to 'fit' (Young, 2002) the policy problem of increasing risk profiles into the future. Policy approaches must therefore, enable adaptation choices that can be adjusted at just the right time, ahead of damage occurring, without entrenching current exposure to hazards, nor incurring larger than necessary adjustment costs in the future.

The consequence of these challenges is two-fold. Any adaptation strategy must remove lock-in of people and assets and be cognisant of future levels of risk (some of which, like SLR, will go on for centuries), or transition communities away from areas at risk. This suggests that public policy tools need to be able to deal with widening uncertainty bounds to accommodate ongoing change, compounded by deep uncertainty in upper-range SLR if the polar ice sheets become unstable (Kopp et al., 2017; Slangen et al., 2017). Furthermore, considerable engagement will be required with communities and stakeholders that are imminently affected, to understand their needs and values (Tschakert et al., 2017), and with those that inevitably will pay for the adaptation actions – local ratepayers and national tax payers. Decision makers and communities world-wide are familiar with paying for the 'victims' of climatic disasters, and systems are largely in place to do that after the 'fact'. There is less familiarity with anticipatory planning that is dynamic in nature and which can operate and implement transformative change where deep uncertainty exists.

The precautionary principle is one policy concept that anticipates uncertainty by alerting decision makers to situations where the consequences could be serious or irreversible (United Nations, 1992). This suggests cautious anticipation ahead of climate change impacts, and not using lack of certainty as a reason to postpone action where irreversibility is present. In the context of SLR, if the principle is embedded within statutory instruments and there is guidance as to its use as intended (United Nations, 1992), the precautionary principle can provide a framework within which adaptive planning and the tools that fit the type of problem being addressed, can be situated. Such an approach has been evolving in New Zealand through statutory and non-statutory instruments. This paper uses a New Zealand example of how national guidance has been crafted and is being embedded into practice, to inform how adaptive actions can be framed, socialised, designed, implemented and monitored in situations of different types of uncertainty and dynamic change, ahead of harm and damage.

2. Background

The illustrative setting for this paper is New Zealand, an island nation with a long coastline (18,200 km) (Rouse et al., 2003) and with many of its major cities and smaller communities located in low-lying coastal areas. Some areas have experienced periodic coastal erosion, or have been subjected to coastal storm flooding (Stephens, 2015) increasing on the back of the historic average rise in mean sea-level of 0.2 m since 1900 (Stephens et al., 2017). Risk exposure (replacement value of buildings only) around the New Zealand coast has been estimated at \$3 billion and \$19 billion (2011 NZ\$) for coastal land elevations within 0.5 and 1.5 m respectively of spring high tide mark – based on ~85% of developed areas (Bell et al., 2015).

However, these signals have been insufficient for policy settings to shift from a focus on disaster response, to an anticipatory focus that can address uncertainties and changing risk profiles as sea-levels continue to rise and accelerate (Kopp et al., 2017; Slangen et al., 2017). The responses to more widespread and frequent climate-related events around New Zealand, have begun to highlight the inadequacies of current policy settings for addressing the challenge of rising seas (Parliamentary Commissioner for the Environment, 2015), and the effects of climate change more generally (Gluckman, 2013; Royal Society of New Zealand, 2016). Within this context, and following the last Intergovernmental Panel on Climate Change (IPCC) review (Reisinger et al., 2014), the Ministry for the Environment decided to revise its 2008 coastal guidance for local government and for those providing services and infrastructure in coastal areas. Four aspects for particular attention were:

- changes to the roles and responsibilities of local government in managing coastal hazard risks, for example the revised New Zealand Coastal Policy Statement (Minister of Conservation, 2010);
- the growing understanding of SLR impacts, including coastal flooding (which will overtake coastal erosion in terms of hazard exposure) impacts further inland including salinization and rising ground water;
- new adaptive tools that can enable uncertainty to be addressed in policy development and decision making;
- new public engagement approaches for communities affected by SLR to develop adaptation transition pathways.

Such non-statutory guidance sits within a suite of available instruments from national to local. The hierarchy of instruments is set out in the Resource Management Act (RMA) 1991, the primary statute for integrated planning and resource management. The New Zealand Coastal Policy Statement (Minister of Conservation, 2010) (the NZCPS) is the only national *statutory directive* for decision makers and includes direction for climate change adaptation at the coast for SLR, storm surge and associated wave height, with a planning horizon of at least a 100 years. Associated non-statutory national guidance includes the coastal hazards and climate change guidance and implementation guidance for the NZCPS. Plans developed by regional and district councils must give effect to the NZCPS objectives and policies.

Implementation in plans is required through three main RMA components: a) consideration of climate change, including its cumulative and high-probability effects, and low-probability events with high potential effects; b) management of significant risks from natural hazards as a matter of national importance; c) a general requirement to avoid, remedy or mitigate natural hazards. The Guidance, along with statutory provisions, on the face of it, can enable SLR as a policy problem to be addressed. However, in practice, the institutional framework has been unable to motivate actions that address the uncertainty around the rate and magnitude of sea-level rise, especially for decisions that have long lifetimes, such as decisions on the subdivision of land, buildings, above and below ground infrastructure and existing uses. A number of factors are at play here – the contested nature of climate change as a policy problem, in part due to the perception that the issue is uncertain and distant (Weber, 2006), development pressures in coastal areas, short-term political cycles, inadequate use of statutory instruments, methods for public engagement and analytical tools for managing uncertainty over long timeframes, and un-coordinated governance across scale and domains of interest (Lawrence, 2015; McIntosh et al., 2013; Spence et al., 2012; Weber, 2010).

While institutional arrangements globally and in New Zealand are well embedded in policy and operational practice for preparedness, responding and recovering from natural disasters, avoiding and minimising disasters through anticipatory planning is less well developed (Basher, 2016). Shifting decision making from a post hoc response towards anticipating potential impacts and thus reducing risk and costs across generations, has been slow to evolve. The 2015 Sendai Framework (UNISDR, 2015) focuses on this shift.

In the New Zealand context, development of regional rules has been limited as regional councils are naturally reluctant to start discussions with district/city councils on withdrawal from the coastal margins. Where they have done so, they have received opprobrium, but if they delay, the risk will escalate as further investment at the coast takes place. Consequently, the planning and emergency management activities are not well integrated. It is only recently that councils are starting to use processes that encompass anticipatory adaptive planning in coastal areas (e.g. Tasman District, Mapua and Ruby Bay Plan Change

22[2] Hawkes Bay Clifton to Tangoio Coastal Strategy 2120[3]).

If the planning system is unable to reduce ongoing exposure to SLR, coastal erosion and inundation, then the growing burden is shifted to the emergency management system to deal with increasing frequency of inundation events and other ongoing impacts of rising seas (e.g., rising groundwater and reduced drainage capacity). The burden also increases for the homeowners affected, for the State as an insurer of last resort through the EQC Fund[4] or as it continues to make ad hoc 'event' based payments for disaster relief, as private insurers withdraw or increase prices beyond the ability of people to pay, and for future generations. The national guidance on coastal hazards and climate change provides a process for making the shift from responding to climate events when they occur, to anticipatory planning and governance.

3. National guidance

National coastal guidance (Guidance) (Ministry for the Environment, 2017),[5] on coastal hazards including SLR provides nationally consistent processes and benchmarks to help local government manage uncertainty and changing risk profiles when exercising statutory functions. The following discussion sets out how the Guidance addresses uncertainty and change over long timeframes, how it was developed, how it can be applied in hazard and risk assessment, and provides some examples of its practical application.

3.1. Who is the guidance for?

The Guidance was developed to assist local government to assess, plan and manage the rising hazard risks facing coastal communities. It is targeted at multiple functions and services provided by local government for coastal and estuarine areas, which will be subject to increasing risk as seas rise or new hazards emerge in areas previously unaffected e.g., lowland rivers, rising groundwater. Consideration and application across all council functions, and their integration through policy and strategy decision-making (e.g., in planning, asset management, transport planning, civil defence, building control, and river/coastal engineering) will better ensure the development of a coherent and coordinated coastal adaptation strategy. Familiarity with the Guidance will also be essential for those providing support services to local government, communities, iwi and hapū[6]; as tangata whenua[7] of Aotearoa – New Zealand[8] including consultants, scientists, infrastructure providers, surveyors, lawyers, planners, and community-engagement facilitators. A summary document is designed for a wider audience, including coastal residents, iwi and hapū, property owners (present and purchasers), the general public, educators, insurers, executives, regional and district councillors and government officials.

3.2. How the guidance was developed

National guidance on coastal management has been in place since 2008 (Ministry for the Environment, 2008), based on risk management principles and is reviewed from time to time as circumstances change or as new information becomes available. The 2017 Guidance was developed by an expert group with backgrounds in hazard and risk assessment, SLR modelling, uncertainty and adaptive planning, statutory planning and engagement practice, alongside a user's group.

Several factors combined to catalyse a change in approach from providing specific SLR numbers for use in planning, to an adaptive approach that better reflects uncertainty and changing climate impacts and takes into account community values. Factors that influenced the Guidance revisions are set out in Lawrence and Haasnoot (2017) and include; *Context change* to statutes in 2004 and 2014 and NZCPS in 2010; IPCC Assessment Reports 2007 and 2014; science funding and reporting visibility; a national risk-exposure assessment – Preparing New Zealand for Rising Seas report (Parliamentary Commissioner for the Environment, 2015); extreme weather and earthquake events that raised visibility of natural hazards; media coverage of hazard events; *Interest created* by new risk framing in Kwadijk et al. (2010); the role of an independent change agent; *Increasing interest* created by the use of a New Zealand tailored simulation game based on the Netherlands Sustainable Delta Game[9]; *an experiment* applying the Dynamic Adaptive Policy Pathways (DAPP) planning approach (Haasnoot et al., 2013) in a real-life decision setting for a major flood risk management scheme in the Hutt valley, New Zealand; a survey of users and a series of workshops with practitioners in national and local government with consultants and academia. The workshops and the PCE report formed the basis of a review specification. During the Guidance preparation, drafts were provided to the users group, to key coastal community groups, and peer reviewed by legal, policy, uncertainty and coastal experts.

The framework of the Guidance is an iterative 10–step decision cycle (Fig. 1) for developing a robust coastal adaptation strategy based on; agreed objectives expressing the values of iwi and hapū, the community and other stakeholders; changes to how uncertainty is addressed in hazard and SLR assessments; use of an adaptive planning approach, and monitoring of changing risk.

The Guidance involves approaches that are often new for New Zealand decision makers and their advisors. It is expected to take time to fully mainstream the changes to hazard and risk assessment, the DAPP and engagement approaches. This transition will be supported by local government "champions", a pilot initiative in 2017 working alongside the Hawke's Bay Coastal Hazards Strategy 2120 where the DAPP and engagement processes were socialised (with council officials, elected members, consultants and public participants), and from post-release workshops on the new elements of the guidance.

3.3. The elements of the guidance that address uncertainty

Analysing, characterising and dealing with uncertainty is fundamental to decision making about climate change adaptation (Jones et al., 2014). Four elements of the new guidance support the development and implementation of strategies to deal with uncertainty over long time frames;

- different levels of uncertainty including statistical, scenario and deep uncertainty
- community engagement
- dynamic adaptive pathways planning (DAPP)
- a monitoring regime, with early signals and triggers (decision points)

The 10-step decision cycle is iterative, with steps re-visited in light of new climate-change information, social and economic change, changes in adaptation capacity of the community or service levels, or as a result of monitoring how the strategy is tracking. This decision cycle can also be applied to other policy problems that are characterised by

[2] http://www.tasman.govt.nz/policy/plans/tasman-resource-management-plan/plan-change-projects/operative-changes-and-variations/change-22-mapua-and-ruby-bay-development

[3] http://www.hbcoast.co.nz/strategy-development/

[4] Earthquake Commission (EQC) manages a fund under the Earthquake Commission Act 1993. The Fund provides insurance for residential property damage from natural disasters. It is funded through a levy on private property insurance for underwriting damages up to $100,000 per claim

[5] Available at http://www.mfe.govt.nz/publications/climate-change/coastal-hazards-and-climate-change-guidance-local-government

[6] Iwi and Hapū are the tribal and descent groups respectively

[7] Tangata whenua are the original inhabitants of Aotearoa New Zealand

[8] A partnership approach around decision-making is an obligation under the Treaty of Waitangi signed in 1860 and given effect in law in The Treaty of Waitangi Act in1975

[9] https://www.deltares.nl/en/software/sustainable-delta-game/

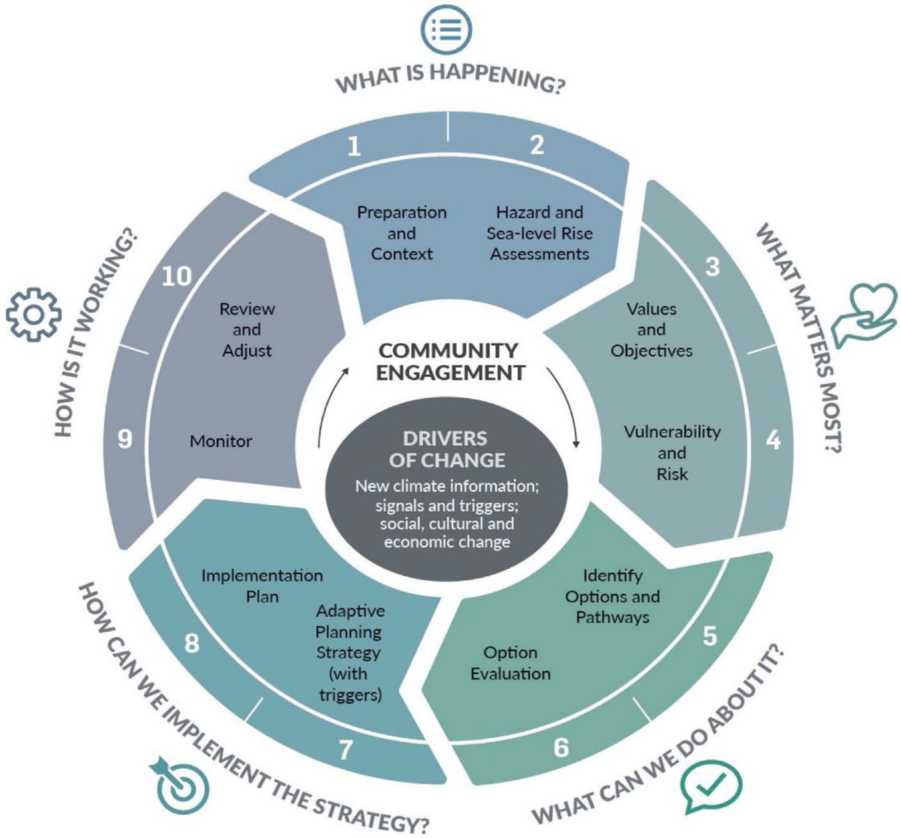

Fig. 1. The 10-step iterative decision cycle in the revised 2017 NZ coastal guidance, grouped around five questions that frame each stage in the process (Source: (Ministry for the Environment, 2017). Adapted by the Ministry for the Environment from (UN-Habitat, 2014).

changing and uncertain conditions.

There has been considerable advance internationally in understanding barriers and enablers to implementing strategies or plans in the face of uncertainty around the future rate of SLR, and how communities can transition to a more sustainable future. In particular, more dynamic or agile forms of adaptive planning or policy approaches that specifically address various types or levels of uncertainty have come to the fore (Haasnoot et al., 2012; Kwakkel et al., 2016; Walker et al., 2003; Walker et al., 2013), including for undertaking hazard and risk assessments (Stephens et al., 2017). These dynamic adaptive planning approaches have been developed and applied in a variety of contexts e.g., Lakes Entrance – Gippsland Lakes (Barnett et al., 2014), Thames Estuary Flood Strategy 2100 for London (Ranger et al., 2013), Rhine-Meuse delta (Haasnoot et al., 2013) and for a flood risk management plan in Hutt City (Wellington, New Zealand) (Lawrence and Haasnoot, 2017). The Guidance has built on those developments and applications as being particularly germane to managing uncertainty in coastal situations.

3.3.1. Uncertainty and use of scenarios

When considering adaptation to the effects of climate change, treatment of uncertainty is unavoidable. For coastal areas, it is "*virtually certain*" (in the calibrated language of IPCC) that SLR will continue beyond 2100 for many centuries (Church et al., 2013) – but what is deeply uncertain is the rate and magnitude of rise in sea-level. We face a widening future window towards and beyond the end of this century when different adaptation options and different pathways will be needed (Kopp et al., 2017). There is more certainty in the near-term e.g., global SLR by 2040-60 is projected to be in a relatively narrow range of 0.2–0.4 m for a range of emission scenarios, compared to 2100 and beyond. Near-term decisions, however, still need to build in flexibility to enable changes to actions or pathways that can accommodate higher sea-levels over longer timeframes, and not lock in potential maladaptation or path dependency. This is critical for decisions with long lifetimes such as new subdivisions and infrastructure.

3.3.1.1. SLR scenarios versus single planning values. The range of plausible SLR projections widen around 2050–60 and increasingly out to and beyond 2100, across the four Representative Concentration Pathways (RCP) (as adopted by IPCC for the 5th Assessment Report). More recent SLR projections that include updated polar ice sheet responses (Kopp et al., 2017; Slangen et al., 2017), mean that it is difficult to pre-determine what coastal future might eventuate for any community, even over planning timeframes of the next 100 years. It is therefore more appropriate and inherently flexible to use a range of SLR scenarios to test the emergence of an adaptation threshold for the current situation and the performance of adaptive actions, than attempting to provide either a worst-case or "most-likely" estimate of SLR to devise a policy or plan.

The previous New Zealand coastal guidance (Ministry for the Environment, 2008) recommended that hazard and risk assessments consider a range of SLR values for the 2090 s planning timeframe, but provided two numeric SLR tie points (starting with a minimum 0.5 m, and to consider *at least 0.8* m by the 2090s). Beyond 2100, a 10 mm/year heuristic was recommended. In practice, users either simply adopted the minimum value or used the second value without running through hazard and risk assessments for a range of SLR values. The revised Guidance instead applies tools and a monitoring regime (e.g. approaching decision points) that can specifically address uncertainty.

The Guidance uses a suite of four scenarios for SLR projections to 2150, based on three of the four RCPs, including a median and upper range SLR trajectories for RCP8.5 to cover plausible polar ice-sheet responses.

These four scenarios primarily support: i) initial hazard and risk screening assessments over a range of plausible scenarios to determine potentially-affected areas and when risks first emerge (Stephens et al., 2017); and ii) stress testing various actions and adaptive pathways, to determine their robustness, their "shelf life" and flexibility for

Table 1
Levels of uncertainty
Adapted from (Walker et al., 2003; Walker et al., 2013).

Levels of uncertainty
1. A clear enough future (with sensitivity) (*little uncertainty*)
2. Alternate futures, with probabilities (*statistical uncertainty*), or alternate future scenarios with ranking (*ranked scenario uncertainty*)
3. A multiplicity of plausible future scenarios, which can't be ranked (*scenario uncertainty*)
4. Are unknown or disagreed upon by experts and/or stakeholders with no consensus on what the future might bring (*recognised ignorance*)

switching to alternate pathways. The SLR scenario approach for adaptation planning is used in the UK and USA – for example the recent suite of scenarios for the USA (Sweet et al., 2017).

To enable decision makers to transition to this new planning approach, various types of development or activity decisions have been linked to the different level(s) of uncertainty and therefore are better aligned with the extent and detail required for hazard, risk and vulnerability assessments (Stephens et al., 2017).

3.3.1.2. Matching uncertainty type to hazard and risk assessments, and decision type. When using hazard and risk assessments in decision making, there are different levels of uncertainty (Table 1) (Walker et al., 2003; Walker et al., 2013) to consider when deciding on the assessment approach or treatment of the coastal hazard components (including SLR) and scale of development, and thus the appropriate adaptation action (Fig. 2). (Stephens et al., 2017).

The approach in the Guidance is therefore designed to address the various levels of uncertainty (Walker et al., 2003; Walker et al., 2013) present in the coastal hazard and climate change policy problem. Accordingly, we have translated the different types of uncertainty into different decision types (accept, adapt, or avoid the hazard) and tools to use (values and scenarios) to simplify the consideration of uncertainty for decision makers.

Guidance is provided on the range of hazard modelling scenarios to undertake (e.g., number, hazard probabilities and SLR scenarios or increments of SLR) and the associated modelling complexity and cost that match the level of uncertainty appropriate for that decision (Stephens et al., 2017). Similarly, guidance is provided on a tiered approach to vulnerability and risk assessment starting with hazard and risk screening assessments across a region or district, moving to more detailed assessments using the recommended SLR scenarios to support the development, option evaluation and implementation of dynamic adaptive pathways planning.

3.3.2. Community engagement

Engaging stakeholders early and throughout the decision process has efficiency, time and costs benefits, and helps develop shared understanding of social values and interests (Pahl-Wostl et al., 2007) to reach decisions that can be implemented (Voinov and Bousquet, 2010). An appropriate level of community and stakeholder engagement is central to acceptance of the need for the tough choices required about an uncertain future, and the development of a long-term coastal adaptation plan. Delivering on foreseeable needs and services for future generations, alongside an ongoing changing environment, is challenging for local government.

However, different impacts and coping capacities in each local situation, means that there will be different values and expectations, making consensus difficult. Transparent and well-designed community engagement processes are therefore essential. The focus of the Guidance is on establishing guiding principles and providing answers to common questions (e.g., who should participate? How should participation proceed at each stage of the decision cycle?). The Guidance adopts the International Association of Public Participation (IAP^2) spectrum starting from *inform*, through increasing levels of engagement – *consult*, *involve*, *collaborate* and *empower*. Guidance is provided on the level of engagement at various steps in the adaptation planning process.

A values-based approach is core to the Guidance, where community and stakeholder values are canvassed, as a basis for reflecting community objectives. The objectives can then fed into the development of adaptive pathways, and tested for their ability to meet those specific objectives into the future.

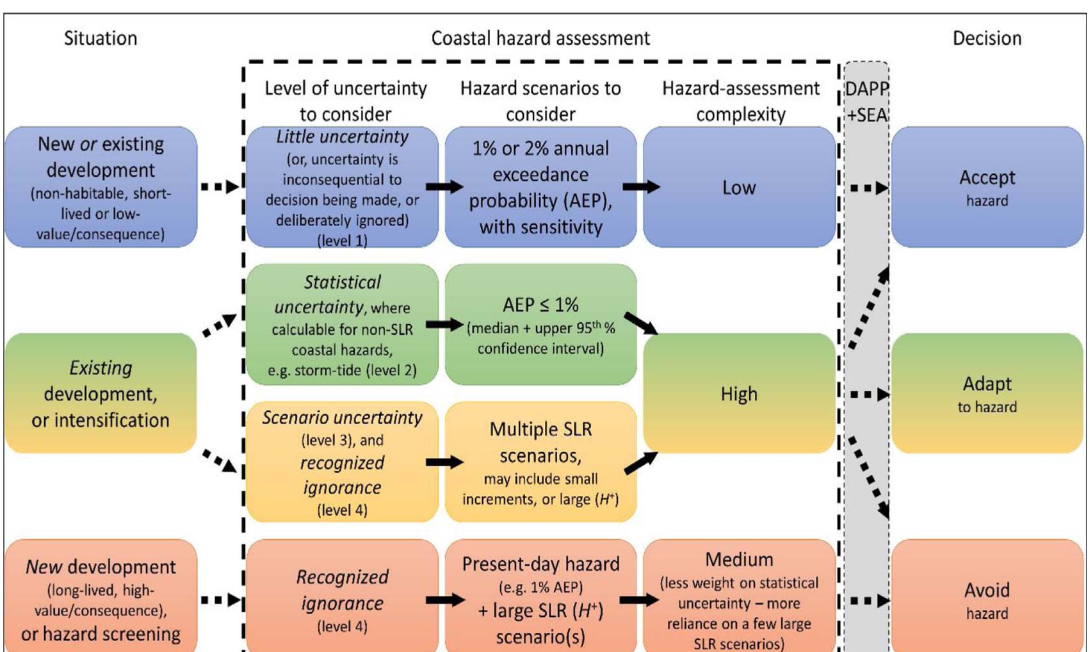

Fig. 2. Uncertainty framework for coastal hazard assessments to support the DAPP process, showing a logical flow from the situation, to the related level of uncertainty as determined by the situation, the hazard scenarios to model, the likely hazard modelling complexity, and the possible decision type. A distinction is drawn (represented by the dashed arrows and dashed box) between the situation, the coastal hazard assessment process, the DAPP process and socio-economic assessment (SEA), and ultimately the decision type. Adapted from Stephens et al. (2017).

3.3.3. Dynamic adaptive pathways planning (DAPP)

The Guidance adopts an adaptive planning approach to address the uncertainty about the future rate and magnitude of SLR, to avoid locking in path dependency, which may occur if a "best-estimate" scenario is assumed. The particular adaptive approach used is dynamic adaptive pathways planning (DAPP) (Haasnoot et al., 2013; Lawrence and Haasnoot, 2017), because of its particular attention to uncertainty and its robustness in a range of decision settings globally and in New Zealand. The approach identifies alternative ways forward (*pathways*) that could, singly or in combination, meet agreed objectives despite uncertainty, while remaining responsive to changes when this might be needed (*dynamic*).

Following the hazard and SLR assessments, the DAPP involves engaging with communities and stakeholders to develop a range of adaptation actions or policies, which are then tested against several possible future scenarios (e.g., the four SLR and other coastal hazard scenarios). Inter-connecting alternative or staged pathways can then be mapped ahead of time and evaluated for their ability to manage, reduce or avoid increasing coastal hazard risk. A plan is then developed, with short-term actions and long-term options with pre-defined *triggers* (decision points) where the decision to switch pathways can be revisited (Fig. 3).

This flexibility allows the pre-agreed course of action to be changed, if appropriate, as a result of new or improved climate, emissions or social and economic information. Early warnings (*signals*) should be determined for ongoing monitoring, which provide sufficient lead time to the trigger to cover community engagement, policy development and implementation, well before the threshold of damage is reached. Triggers for a locality can be couched in terms of societal pressures such as occurrence of a certain number of coastal inundation events, a coastal erosion set-back distance to houses, or a decrease below a level of service, where assessments show risk or performance starts to become intolerable for sections of the community or a council service. Such triggers will need to be designed to avoid catastrophic events, after which it is too late to be anticipatory, resulting in a reactive response. Commitment to regular monitoring (e.g., progress towards signals and triggers, that can gauge how the current pathway is working, by documenting damaging or nuisance events and social tolerability) giving the ability to re-visit or adjust the plan in the light of new information (Steps 9–10, Fig. 1) is a key component of the DAPP within the decision cycle.

By accommodating a range of future coastal changes at the outset, which could be surprises either way (e.g., from polar ice sheet instabilities or achievement of severe curbs on global carbon emissions), this adaptive approach helps avoid locking in path dependency, including investments that could make future adjustments difficult and costly. Some options for a particular location (e.g., a seawall) may only have a short "shelf-life" if SLR accelerates more than anticipated or repeat storm damage becomes a maintenance burden. The adaptive approach enables councils and communities to "map out" future options, commencing with an agreed initial pathway, rather than waiting until uncertainties are reduced before making decisions. Thus, long-term sustainability, the needs of future generations, and community resilience can be addressed.

3.3.4. Linking present statutory framework to coastal adaptation

The statutory framework operating in the coastal environment in New Zealand currently provides for assessments of the actual and potential effects of climate change (s7 (i), RMA), controlling the use of land for the purpose of avoidance or mitigation of natural hazard risks (s30, 31 RMA) and a relatively prescriptive set of objectives and policies in the NZCPS that must be given effect to. For example, development of an adaptation strategy for significant existing development that could include retreat, with transition mechanisms (NZCPS Policy 27). Adaptation projects (including funding contributions) can also be integrated into council strategic, asset and financial planning. These methods enable a range of measures to be considered, along with other non-statutory or physical adaptation options, within in the DAPP process. Some councils have been able to implement restrictive land-use plan changes to cap any further development in low-lying coastal areas (Tasman District case study; p 43 the Guidance), where an RMA plan change included closed residential zones near the coast, but provided for development on higher ground nearby.

However, the short to medium term windows for most council planning processes is challenging, when matched with long-term coastal adaptation to ongoing SLR, and ensuring the shorter-term planning decisions do not lock in eventual maladaptation and incur significant additional future costs. While the NZCPS requires

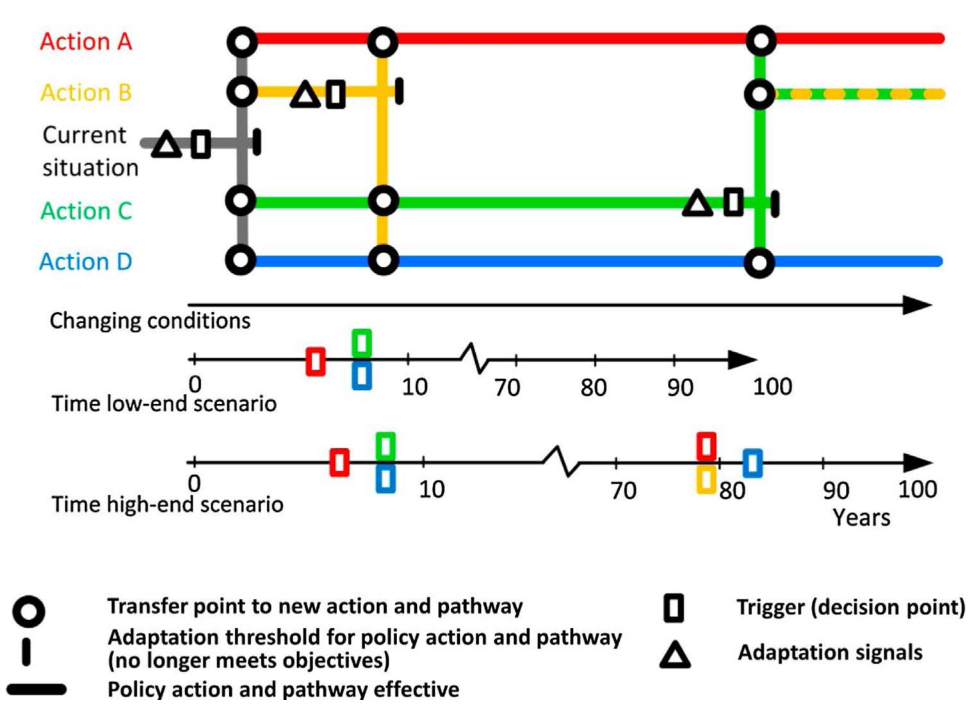

Fig. 3. An example of an adaptation pathways map using the DAPP approach. After Haasnoot et al. (2013), Hermans et al. (2017).

consideration of managed retreat for existing development when planning adaptation, there are practical issues as yet unresolved for implementing pathways planning for this outcome. These include property-owner acceptance of the need to eventually transition inland; equity for some groups in society including who pays and when; and how and to where communities might retreat. A Coastal Hazards Strategy 2120 underway on the Hawkes Bay coast from Clifton-Tangoio is a good example where these issues are currently being addressed by the councils, using a similar process to that set out in the Guidance, including involvement of the immediate and wider communities which are affected by decisions taken to reduce or avoid risk. Further research is underway on the elements necessary for implementing anticipatory managed retreat in the New Zealand coastal and statutory context. Under the rubric of two National Science Challenges (Deep South and Resilience to Nature's Challenges) research is underway on the signals and triggers for monitoring dynamic adaptive pathways, funding models (Boston and Lawrence, 2017), the relationship between funding and insurance (Storey et al., 2017) and the engagement, planning and legal aspects of managed retreat. This research will inform future revisions to the Guidance.

4. Relevance to other public policy problems

Most public policy problems are beset with different types of uncertainty. This means that the uncertainties germane to the particular problem will need to be transparent to decision makers, and addressed as to their criticality for the particular decision. The approaches used in the Guidance therefore has relevance for any such decision.

Furthermore, the DAPP approach has particular relevance in any jurisdiction to coastal hazard risk management for addressing climate changes over time as uncertainty bands increase. The approaches facilitate decision-making in the present time while maintaining flexibility to adjust as signals and triggers emerge. The approach also enables the navigation of uncertainty with communities whose values and preferences play an important role by either locking in, or unlocking path dependencies that make the climate change a challenging policy problem. In practice, it is social, cultural, economic and political dimensions that determine the effectiveness of policy outcomes. The Guidance provides for both the technical aspects of uncertainty (Steps 1 & 2 in Fig. 1), contested values and preferences and political dimensions (Steps 3 & 4 in Fig. 1).

5. Conclusions

The New Zealand Coastal Hazards and Climate Change Guidance addresses uncertainty in the decision-making process by applying four critical elements; treatment of uncertainty and changing risk profile; different types and levels of community engagement; dynamic adaptive pathways planning; and a monitoring regime, that enables flexibility while reducing path dependency. However, this leaves the enablers for implementation under-developed, and the role governance can play in supporting monitoring, reviews and policy commitment over long timeframes, largely unexplored.

Sea-level rise raises issues which current policy frameworks and practice largely ignore or struggle to address. Current decision makers rarely bear the 'cost' of their decisions, but with SLR, current and future generations will. The temptation to delay consideration of uncertainty and changing risk profiles, if taken, will increase the exposure to risk and transfer it to others and to future generations. SLR forces us to address uncertainty, and to discontinue hiding behind the 'safety' barrier that the static tools of trade encourage. The Guidance requires decision makers to think beyond the electoral cycle when making investment and planning decisions. By changing the mode of governance and undertaking constructive dialogue with communities and stakeholders, enables trust to be built through engagement and formalised commitments.

Our paper sets out an adaptive framework with processes and tools that can catalyse a change in our decision-making from traditions that largely assume a static system for a dynamic problem. This enables decision making that can anticipate the change in a way that gives decision makers confidence and the legitimacy for decisions that can be effective over the short- and long-term at a societal level.

Acknowledgments

All authors were funded by the Ministry for the Environment, New Zealand, to revise the Coastal Hazard Guidance, based on their respective expertise. NIWA authors were funded by the Sea-level Change project (CAVA1804) in the NIWA Strategic Science Investment Fund for preparation of this paper. The lead author and NIWA authors also received funding from the Deep South National Science Challenge for the Supporting Decision Making in a Changing Climate:Tools and Measures Project.

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