Royal HaskoningDHV
Enhancing Society Together

PAPER

Ruawai Adaptive Pathways

APPROACHES TO ADAPTATION

Client: Kaipara District Council

Reference: PA3219-RHD-RW-RP-C-0002
Status: Draft/01
Date: 4 September 2023

HASKONING AUSTRALIA PTY LTD.

Level 15
99 Mount Street
North Sydney NSW 2060
Australia
Water & Maritime

+61 2 8854 5000 **T**
project.admin.australia@rhdhv.com **E**
royalhaskoningdhv.com **W**

Document title:	Ruawai Adaptive Pathways
Subtitle:	Approaches to Adaptation
Reference:	PA3219-RHD-RW-RP-C-0002
Status:	01/Draft
Date:	4 September 2023
Project name:	Ruawai Adaptive Pathways Adaptation
Project number:	PA3219
Author(s):	Royal HaskoningDHV
Drafted by:	Royal HaskoningDHV
Checked by:	Kaipara District Council
Date / initials:	29/08/23 NL
Approved by:	Kaipara District Council
Date / initials:	04/09/23 KS

Classification
Public

Table of Contents

1 Introduction

The purpose of this paper is to introduce the various approaches to adaptation that are available to communities at risk from climate change related hazards; in support of the Ruawai Adaptive Pathways Project.

The approach being taken to the project is based on the national and international best practice and aligns with the requirements of the Department of Conservation's *New Zealand (NZ) Coastal Policy Statement (CPS) 2010* and the Ministry for the Environment's (MfE's) *Coastal Hazards and Climate Change Guidance for Local Government (2017).*

Drawing from this information, this paper provides a background to adaptation policies and strategic approaches, and provides examples of different adaptation and management options that align with these policies. It summarises approaches adopted elsewhere that are relevant to the study area based on a targeted review. It is accompanied by a draft 'adaptation options menu' (i.e., a long list of adaptation options) for the Ruawai-Raupo-Te Kowhai study area.

2 Defining adaptation

***Change in the way a feature, such as a habitat or community functions**.*

The MfE (2017) defines adaptation as a response strategy to anticipate and cope with impacts that cannot be (or are not) avoided under different scenarios of climate change.

Adaptation involves adapting to life in a changing climate to reduce the risks associated with its harmful effects (such as sea level rise (SLR), more intense extreme weather events, or food insecurity) and make the most of any beneficial opportunities (for example, longer growing seasons or increased yields in some regions).

Some types of change can be adapted to by making relatively small adjustments to the way we currently manage the environment using an incremental adaptation approach. Other types of change may require completely new ways of doing things and involve large societal adjustments that are transformational in character (see **Figure 2-1**). Different types of adaptation exist depending on the system and scale of adaptation required (IPCC, 2022: Annex II: Glossary).

Adaptation can be proactive or reactive, spontaneous or planned, private or public, and in some cases maladaptive (i.e., increase exposure and vulnerability in the longer term, including stopbanks for ongoing SLR and an increased frequency of storm and flood inundation; see 'residual risk', **Section 5**). It can take many forms and includes:

- **Being prepared** – through information provision.
- **Behavioural change** – for example, hazard avoidance and accommodation strategies (avoid and accommodate) based on good information.
- **Interventions that focus on the management of natural systems** – for example, wetland, foreshore or floodplain management.
- **Interventions that involve installing/improving physical infrastructure** – for example, sea walls and flood embankments (stop banks).
- **System change** (including new planning policy) – for example, controlling development on floodplains or partial relocation.
- A combination of these approaches.

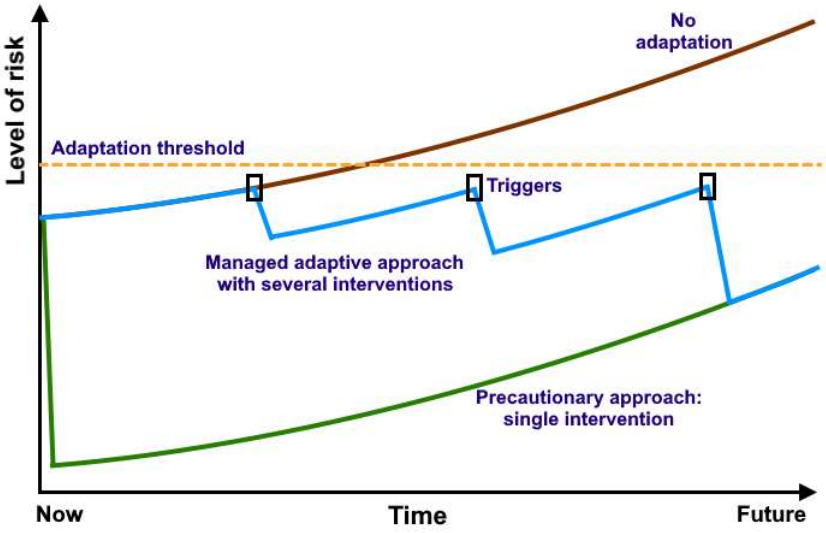


Figure 2-1: How incremental and precautionary (avoid) approaches to adaptation can affect the level of tolerable risk over time (adapted from MfE, 2017)

Adaptation options tend to be categorised based on their 'nature'. That is: whether they relate to preparation, avoidance, acceptance (accommodation), protection or retreat (see **Figure 2-2**). The categories proposed for use in Ruawai Adaptive Pathways project are summarised in **Section 6** and reflected in the draft Adaptation Options Menu.

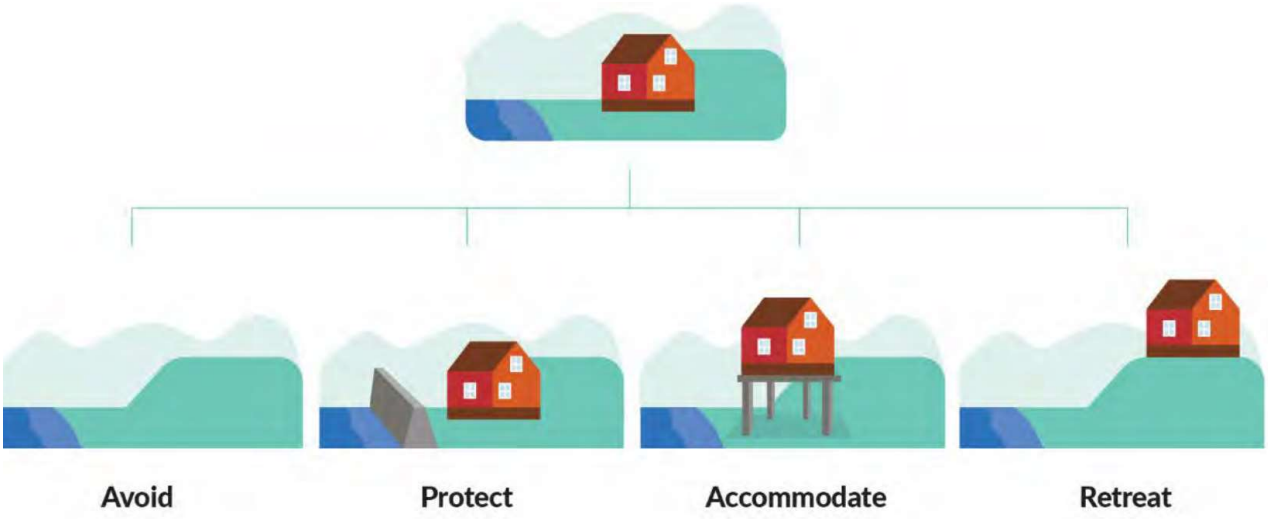


Figure 2-2: Avoid, protect, accommodate and retreat options (https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/adapting-to-climate-change/)

What is important to recognise in the selection of appropriate adaptation options for a location, is that what might "work" now (based on current circumstances), may not work in 10 or 20 years and, what might work in 10-20 years, is unlikely to work in 50-100 years (based on the rate of advance of climate change). Therefore, most communities will require an adaptation pathway (or strategy) to be developed that is reflective of possible changes in risk overtime, rather than the selection of a single adaptation option.

The 'nested pathways' approach to adaptation (Chhetri, *et al.*, 2019) refers to:

- **Coping responses** (accommodate) – which are often reactive and short-term.
- **Incremental responses** – which maintain the essence and integrity of a system but aim to improve resilience overtime (and can accrue to result in transformational adaptation).
- **Transformational responses** – whole system changes that alter the fundamental attributes of a social-ecological system (e.g., reconfigure or retreat).

The Rauora framework[1] provides a set of cultural values and principles from which to approach climate action and promotes transformative action (adaptation) as a means through which the resilience of communities can be strengthened (MfE, 2022). The principles of balance, interconnectedness, working together and inter-generational equity are outlined and complemented by a set of Māori values.

Regardless of the approach selected:

- Effective hazard forecast, warning and emergency response systems should be in place always.
- Management areas that are adjacent to each other must be considered collectively rather than in isolation.
- Inappropriate development should be discouraged in areas at risk from current and future hazards.
- Decisions on adaptation options should be based on robust scientific/technical information that is agreed by the community and other stakeholders.
- Only fit for purpose (technically, environmentally, and economically sound and sustainable) protection measures should be provided.
- The justification for public investment should be based on the consideration of all foreseeable impacts and benefits of an adaptation option, both quantifiable and unquantifiable. Experience has demonstrated, for example, that protection measures initially promoted in some instances have been subsequently found to be unacceptable or impossible to justify in the long term, either in terms of economics or from the perspective of what communities' value.
- It is important that the approach selected is realistic and takes account of relevant legislation and constraints. There is no value in long-term plans that include policies driven by reactionary politics or recommend works that prove to be detrimental when considered several decades into the future.
- A range of different futures could emerge, and management plans need to evolve to remain effective.

It is important that decisions made now enable feasible and affordable adjustments to be made over time (MfE, 2017).

As an overarching principle, all management actions should be designed to achieve the objectives of – in a Te Tai Tokerau context – the NZCPS 2010, the Resource Management Act (RMA, 1991), the Regional Policy Statement for Northland (2016) and the Operative Kaipara District Plan (2013).

[1] *Developed by Ihirangi, the operational arm of Te Pou Take Āhuarangi (the climate lead) for the National Iwi Chairs Forum.*

3 Lessons from other places

3.1 Background

A targeted review of approaches to adaptation adopted elsewhere, relevant to the study area, was undertaken and the results are summarised in this section.

3.1.1 United Kingdom

In the United Kingdom (UK), where shoreline management planning (arguably) began three decades ago, adaptation options were classified based on four broad policy categories (DEFRA, 2006) that reflected the extensive presence of flood defences in this location. That is (further details are provided in **Appendix 1**):

- **No active invention** (or do nothing) – where there is to be no investment in adaptation or intervention because this is not warranted (i.e., there is no need) or would not provide the best outcome (i.e., the ecosystem should be allowed to evolve naturally).
- **Hold the line** (protect) – by maintaining or improving the standard of protection (where this is warranted) currently provided by a natural system or structure (e.g., beach recharge, rebuilding the toe of a flood wall, building offshore breakwaters and so on).
- **Advance the line** (protect) – by building new structures on the "wet" side of the natural system of existing structures.
- **Managed retreat** (retreat) – by allowing the foreshore to move backwards and requiring the setback or relocation of buildings, services and/or infrastructure a suitable distance inland.

This classification is reflected in **Figure 3-1**, used by Thames Coromandel District Council to illustrate different adaptation strategies (or categories) but modified to exclude 'advance the line' and include 'limited intervention' (which could form part of an accommodate or protect strategy).

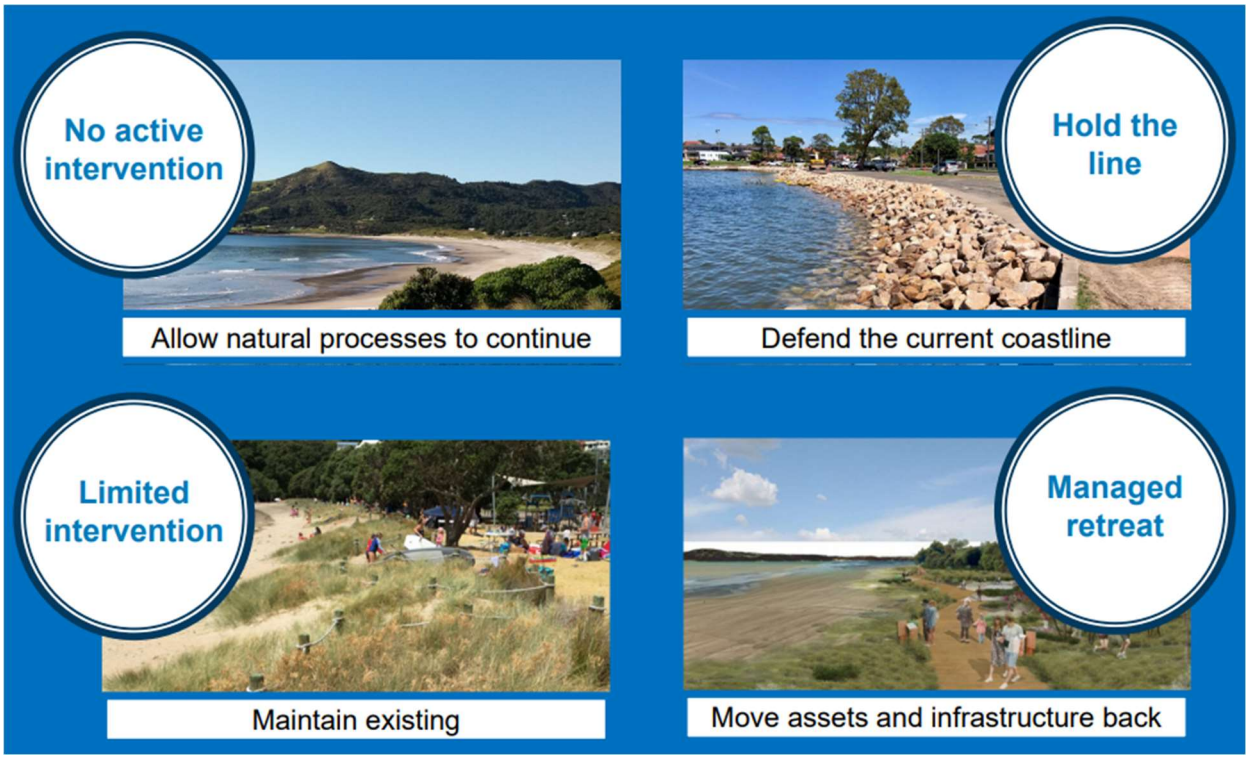


Figure 3-1: Adaptation strategies (sourced from Thames Coromandel District Council shoreline management planning consultation materials, see https://thames-coromandelcaps.ireport.royalhaskoningdhv.com/)

3.1.2 Australia

In New South Wales (NSW) Australia, where risk assessment identifies unacceptable risks within the coastal zone, the Coastal Management Manual (State of NSW and Office of Environment and Heritage, 2019) advocates that different management options (termed 'risk treatment measures') are considered. Five strategic approaches – relevant to different levels of and attitudes to risk – are defined (**Figure 3-2**):

- **Alert** – includes management actions that seek to 'watch and wait', such as monitoring change and setting adaptation thresholds, 'low regret' responses and research to improve knowledge.
- **Avoid** – includes recommending proactive land use planning practices and encouraging new development only in locations of low-risk, to avoid future risks.
- **Active intervention** – includes management actions that seek to protect assets or accommodate change, while maintaining current systems and values.
- **Planning for change** – includes management actions that seek to facilitate habitat migration and transformative changes to natural systems. For areas of existing development, this includes planning to relocate or redevelop assets in light of the dynamic nature of the natural environment. Actions may be timed to commence as opportunities arise or when thresholds of exposure, impact or risk are exceeded.
- **Emergency response** – includes coastal management actions to address residual risk in emergency situations.

Figure 3-2: Strategic risk management approaches (State of NSW and Office of Environment and Heritage, 2019)

These strategic approaches can be adopted on their own for specific locations or issues; however, they are often combined, or the emphasis may change from one to another over time, as circumstances change. Within these strategic approaches, specific management actions (options) are considered for different areas. These are summarised in **Appendix 2** (for vulnerable coastal locations).

3.1.3 New Zealand

The MfE's (2017) guidance for local government describes (coastal) climate change adaptation options under the following headings:

- **Avoid** (hazard avoidance strategies) – stop putting people and assets in harm's way, primarily using land-use planning measures (e.g., restricting greenfield development in floodplains), spatial planning and adaptive management of assets and services.
- **Accommodate** – temporarily live with and work around the risk – adjust existing assets using measures that anticipate the risk, such as raising floor levels or roads, requiring minimum build levels, providing alternative inundation flow paths, or requiring relocatable houses.
- **Protect** – hold the line – attempt to manage the hazard by maintaining or enhancing natural buffers (like wetlands), soft engineering (geotextile sand tubes) or hard structures (like stop banks, tidal gates, pumps etc.).
- **Retreat** – permanently move existing people and assets away from the risk in a planned, staged and managed way over time or in response to erosion and inundation damage after climate-related events[2].

Significantly – in practice – a combination or sequence of these types of measures will be required as hazard zones are increasingly affected by climate change. That is, in a particular location a 'coping' response may be adequate in the short-term but in the medium- to long-term an 'incremental' response (to improve resilience) or 'transformational' response may be required. The ability to adapt relies on decisions that are flexible and can be adjusted, or switched to alternative pathways, based on the future that is experienced (MfE, 2017) (see **Section 4.4**).

A sequence of measures – an adaptive pathway – will be required and should be explored.

Auckland Council's Coastal Management Framework (CMF) (2017), which predated the 2017 MfE guidance, emphasises the importance of a long-term, holistic, regional-scale systems-approach to coastal assessment, planning, hazard management, decision-making and design. This means considering dynamic coastal processes, sediment systems and communities in their entirety. It comprises a hierarchy of decision-making shown in **Figure 3-3** (Auckland Council, 2017).

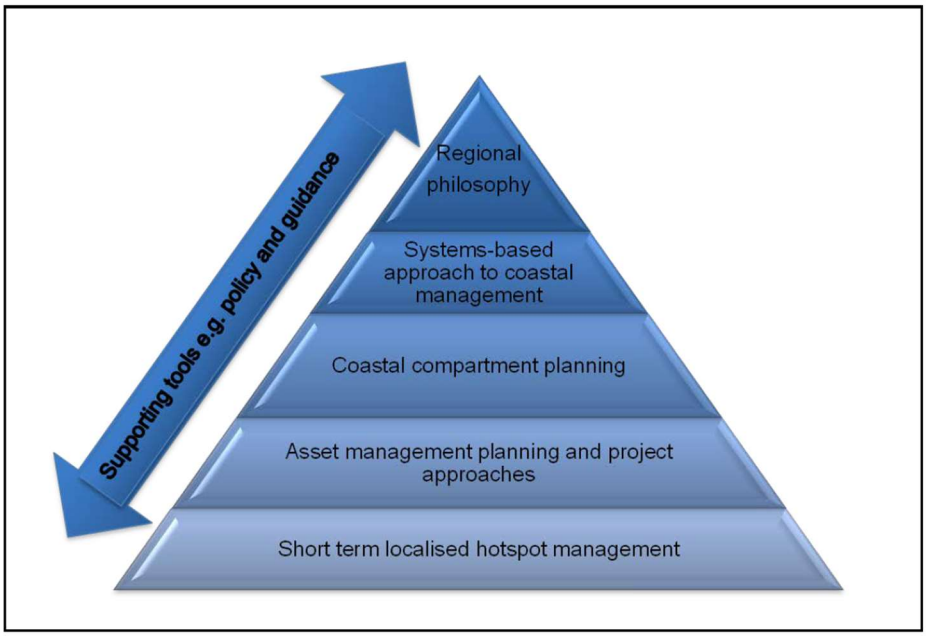


Figure 3-3: CMF hierarchy (Auckland Council, 2017)

[2] *Abandonment and gradual voluntary movement of people away from the coast by attrition constitutes unmanaged retreat.*

The CMF adopted four key policies for coastal management for four management epochs [epoch 1: 0 – 10 years], [epoch 2: 10 – 25 years], [epoch 3: 25 – 50 years] and [epoch 4: 50 – 100 years]:

- **Do nothing** – where no formal measures are to be put in place to control observed processes.
- **Protect** – where exposure to coastal hazards may be mitigated through a range of engineering solutions, including both 'hard' and 'soft' measures.
- **Adapt** – where it is recognised that management responses will need to be modified over time in response to climate change.
- **Managed retreat** – which involves the setback or relocation of buildings, services and/or infrastructure a suitable distance inland.

An important difference between the approach advocated by the MfE and the approach adopted in both the UK's shoreline management plans (SMPs) and by Auckland Council, is that the MfE guidance has moved away from defining management approaches based on timeframes (epochs) and towards defining approaches and pathways based on circumstances (i.e. defined physical changes; rising sea level; or a structure coming to the end of its design life) and thresholds/trigger points.

It is notable, that **adaptation strategies** ('adapt') can include doing nothing, protection, and retreat across different timeframes and based on the scale of change or the changing nature of the risk. This is reflected in the nested pathways approach which also incorporates a timescale element: coping responses; incremental responses; and transformational responses (see **Section 2**).

It is also the case that many adaptation options are not mutually exclusive. For example, no active intervention does not exclude ensuring that natural protection is not disrupted (or enhanced) and should be supported by the provision of information to affected stakeholders and hazard warning systems; it can also be facilitated by enhancing the resilience of critical infrastructure.

4 Categories of adaptation

4.1 Introduction

This section summarises categories of adaptation based on the lessons from elsewhere regarding best practice. This is framed around the 'nested pathways' approach developed in the USA, but first considers "doing nothing".

4.2 No active intervention or do nothing ≠ doing nothing

In support of the adoption of any adaptation option or pathway, including 'do nothing', certain low regret actions should be taken as a matter of course. In the health sector this is referred to as "watchful waiting". For example:

1. Hazard warning systems and preparedness for storm events (emergency response plans) → **always be prepared**.
2. Monitoring change, including long-term trends and responses to erosion, recession and inundation, and research to improve understanding.
3. Identifying potential future threats, vulnerabilities and risks resulting from changing processes.
4. Community awareness and education programmes about hazards and risks to public safety.
5. Monitoring community attitudes, objectives and values attached to risk, access and amenity.
6. Preparation and/or maintenance of an inventory of protection structures and other assets, that assesses their condition, effectiveness and influence.
7. Monitoring development pressure and population change.
8. Identifying opportunities and preparing and planning for change.

4.3 Coping responses

In the context of adaptation options, coping responses are often (but not always) reactive and short-term. They include **being prepared**, accepting or **accommodating** the hazard (e.g., through retrofitting infrastructure), and **protecting** by maintaining/enhancing natural systems or maintaining/improving (but not changing) existing protection.

4.3.1 Be prepared

1. Provide regular information through press releases, websites and open days to affected stakeholders and communities regarding predicted hazards and risks; and proposed management policies and actions (and their performance where applicable).
2. Implement hazard warning systems and prepare evacuation.

4.3.2 Accommodate

1. Retrofit buildings and infrastructure, including roads, drainage and sewer systems, to make them more resilient to climate change (e.g., raising floor levels of buildings and the level of roads to mitigate the effects of flooding). When buildings near the end of their design life and are to be renewed, there will be an opportunity to apply planning controls that require adaptation to suit known and predicted hazards.
2. Install innovative housing and/or infrastructure where applicable. For example, adjustable houses (screw piled), floating houses, and flexible, waterproof service connections, pressure sewer systems with elevated controls and/or overhead or off grid power supply.
3. Maintain ‘natural protection’ such as floodplains, beaches, sand dunes, foreshore vegetation, natural berms and other topographic features, saltmarsh and mudflats, mangroves and wetlands, through management (including restriction of access).

4.3.3 Protect

1. Enhance (reinstate and maintain) ‘natural protection’ such as beaches, flood plains, reserves and wetlands, for example, through planting, the creation of space and enhanced sediment supply. Grants can be provided to community groups to support such initiatives, potentially reducing public expenditure in the future if damage to public spaces is avoided or delayed.
2. Improve the resilience of existing coastal protection assets to climate change. For example, increasing the height/width of flood defences, seawalls and revetments, providing backstop walls or designing shorelines and floodplains that include a combination of green and built infrastructure.
3. Construct manual or automatic demountable (as required) flood barriers (from sandbagging to engineered flood gates). At the smaller scale, such action can be taken by individuals, potentially incentivised by Councils.

4.4 Incremental responses

4.4.1 Adopting new tools and techniques over time

In the context of adaptation options and pathways, incremental responses will often (but not always) improve resilience by adopting new tools and techniques (i.e., new to that location).

As for coping responses, incremental responses can include accommodating the hazard (e.g., through raising/retrofitting infrastructure) or maintaining/enhancing existing protection, but the focus will be on new approaches or a change in approach (short of transformation). Incremental responses or an evolving approach, aligns with the concept of adaptation pathways.

Management policies can change over time; but the requirements for the future need to influence management policies now.

4.4.2 Dynamic Adaptive Pathways Planning

Dynamic adaptive pathways planning (DAPP) is a risk-based approach to adaptation which avoids the need to have firm 'predictions' relating to the consequences or rate of climate change or to use only one scenario as a basis for decision making. That is, it accommodates uncertainty by advocating a series of actions or options (on a pathway) over time to achieve pre-set objectives under uncertain and changing conditions. This approach is built on the notion that decisions will be made over time as or if conditions change (and an agreed adaptation threshold is met) and cannot be predicted (MfE, 2017).

Figure 4-1 illustrates a DAPP approach and indicates how different adaptation options can be effective to a point as circumstances change (in this case as sea level rises), after which a shift to another option is needed, creating a pathway. The pathway illustrated suggests that (continued) protection will be viable for decades (more than likely) but that managed retreat will become an increasingly unavoidable adaptation response overtime in low-lying coastal and river floodplains, due to sea level rise and flooding from more intense rainfall (Lawrence, *et al*., 2020).

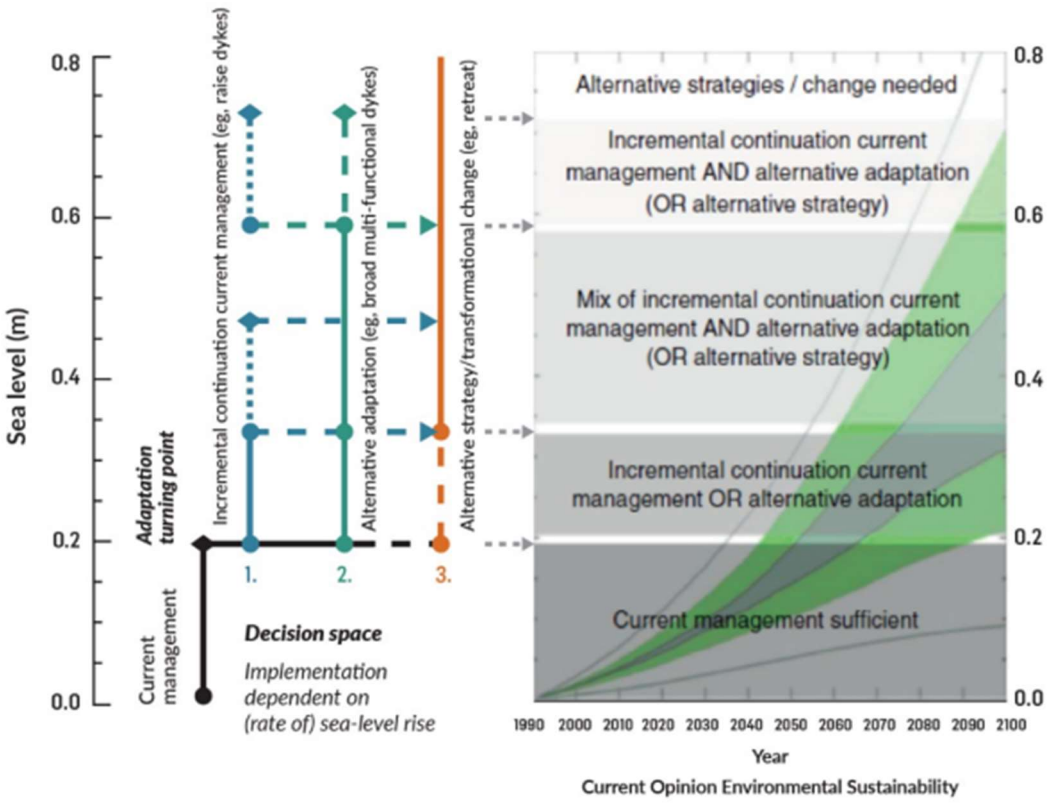


Figure 4-1: Adaptation route map illustrating how different adaptation options can be combined to form adaptation pathways: current management (black); adapt - stop banks (blue); active intervention - broaden banks (green); and retreat (red) (MfE, 2017)

By exploring different pathways and testing the consequences of different management or adaptation options under different scenarios, an adaptive strategy or plan can be designed that includes a mix of short- and long-term actions (MfE, 2017). Importantly, the plan should be monitored to identify adaptation triggers and/or thresholds that signal an approaching decision point regarding whether to implement the next step of a pathway (the next action) or reassess the options.

Figure 4-2 provides an illustration of a theoretical adaptive pathway that includes four viable actions (Actions A to D), that will each have different benefits and disbenefits, and the timeframe over which, or degree of change for which, they are likely to be applicable. For example, in circumstances where the hazard relates to flooding, Action A could be a large stop bank and Action D retreat. Whereas Action B and Action C could provide interim measures (e.g., wetland restoration and/or sediment recharge) that do not preclude protection or retreat in the future but avoid the need for transformational change in the short and, potentially, medium or even long term. That is, addressing more immediate issues while remaining cognisant of potential long term adaptation requirements. This approach does not preclude any viable (or constructable) options. A stop bank, for example, could be constructed in the short term even if it is not a viable long-term solution (e.g., due to height restrictions). In which case it could be designed to be taken down. However, once a wall is in place it is much less likely to be removed, particularly as the cost and environmental damage associated with it would have been incurred and a level of comfort provided.

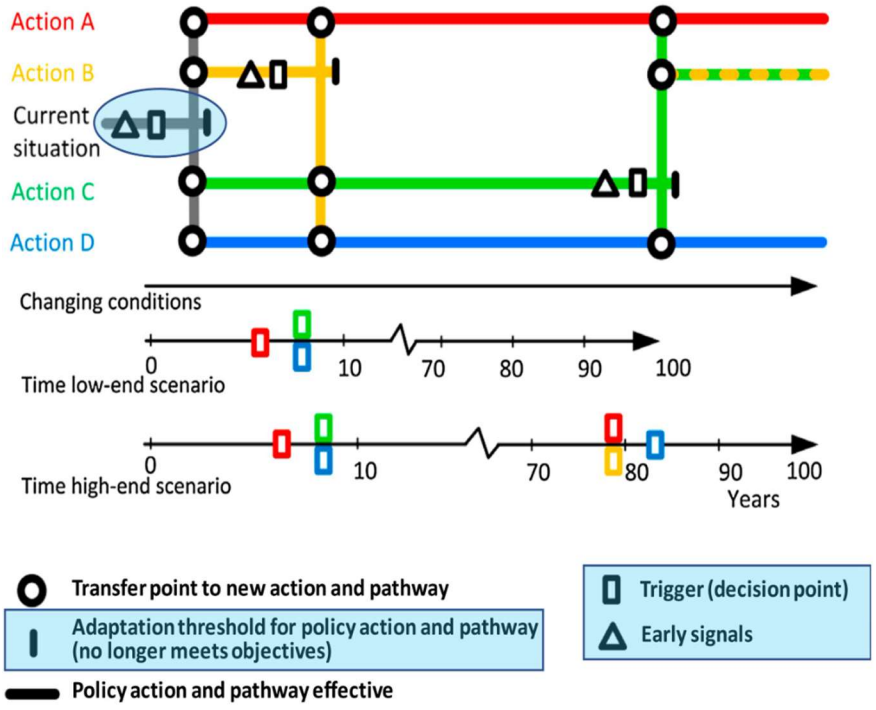


Figure 4-2: Adaptive pathways showing signals, triggers, transfer points and adaptation thresholds (Lawrence, et al., 2021)

Fundamental to this approach is that adaptive pathways need to be flexible (i.e., dynamic) – so they can be modified, if required, over time if 'triggers for action' (based on the outputs from monitoring) are reached or if community values change. **Figure 4-2** also illustrates the role of adaptation thresholds, transfer points and adaptation triggers and signals on an adaptive pathway. Adaptation thresholds, triggers and signals are detailed on the x-axis of the of an adaptation pathway (where adaptation actions are detailed on the y-axis) and vary based on the nature of the hazards and the risks posed by them.

4.5 Transformational responses

4.5.1 Introduction

Transformational responses refer to whole system changes but, again, can include coping responses (e.g., floating homes) and incremental responses (e.g., the introduction of protection measures). Transformational responses include **avoidance** policies (through changing planning practices), the **reconfiguration** or transformation of communities (e.g., see the long-term proposals for Copacabana Beach, Brazil below) and/or **managed retreat**. Like incremental responses, transformational responses can form part of adaptation pathways.

Adaptation in Copacabana, Brazil

Copacabana is the most densely populated coastal area in Brazil.

To protect the coastline from coastal inundation and beach erosion, Avenida Atlantica (seaside avenue) was doubled in size in 1970 and the beach nourished (Hoogendoorn, 2021) (see **Figure 4-3**). However, with extreme weather events predicted to increase in frequency and the sea level expected to continue to rise, it was recognised that a bolder adaptation strategy was required for the future. To create a more sustainable, resilient, and equitable landscape for future generations, a strategy has been developed that includes:

1. Elevation of infrastructure to increase climate resilience (avoid).
2. The use of streets as ecological corridors (accommodate) (**Figure 4-4**).
3. Retrofitting the plazas to accommodate and store water (accommodate).
4. Nourishing the beach to protect the coast (accommodate and protect).
5. The reduction of urban densities on the coastal plain to create more room for people and nature (retreat).

Watch more here.

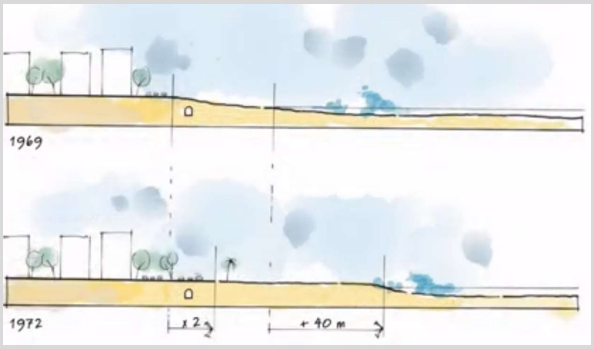


Figure 4-3: Doubling of Avenida Atlantica

Figure 4-4: Use of streets as ecological corridors

4.5.2 Avoidance through changing planning practices

1. To discourage the protection and rebuilding of existing or damaged private assets located in hazard zones. In this regard, Councils can put in place disincentives through planning policy that reduces risk.
2. To designate areas where redevelopment or infill development is not acceptable due to the risks or where only certain development types are appropriate (e.g., temporary, time-limited or removeable / relocatable structures).
3. To promote tenure arrangements that do not put prohibitive restrictions on land use in the short to medium-term (e.g., easements, voluntary purchase and leaseback).
4. To promote and incentivise transformation, i.e., spatial planning.

4.5.3 Managed retreat

Lawrence, *et al.* (2020) suggest that managed retreat will be inevitable where other adaptation options, such as protection structures or building controls, provide only temporary respite or are otherwise uneconomic, technically impractical or both.

'Managed' retreat needs to be pre-emptive (which Lawrence, *et al.* (2020) acknowledge is the limiting step), robustly planned and the thresholds and triggers for changing an adaptation response from accommodation (possibly through protect) to retreat should be established. Funding mechanisms and the criteria for compensation (if any) also need to be clearly established. The Government has more work to do in this context.

5 Residual risk

Even with the employment of interventions to reduce the harmful effects of climate change, risk cannot be eliminated (except where it is avoided). The purpose of adaptation, including intervention, is to reduce risk to an acceptable (or tolerable) level. The risk remaining after intervention has occurred is the **residual risk**.

Examples of residual risks related to flooding include:

- Failure of flood management infrastructure.
- Blockage of a surface water drainage system.
- Overtopping of an upstream storage area.
- Failure of a pumped drainage system.
- Failure of a reservoir.
- A severe flood event that exceeds the flood management design standard, such as a flood that overtops a flood defence.
- An intense rainfall event which overwhelms the drainage system (Burnham, 2015).

In general, residual risks have a relatively low probability of occurrence. However, the consequences arising from a failure of a protection structure or an event that exceeds the design standard or overwhelms the system can be extremely significant.

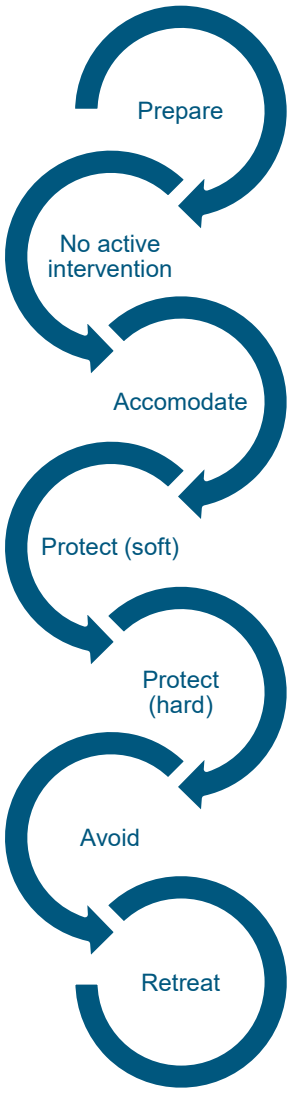
Councils need to approach the design, construction, operation and maintenance of protection measures with particular care, and an awareness of the potential liabilities. Decisions should consider their feasibility, practicality, cost effectiveness, acceptability to the community, consistency with industry guidance and government direction, policy and guidance and the timeframe in which they can be implemented (State of NSW Department of Planning and Environment, 2022).

With ongoing climate change, accommodate, protect and advance adaptations will become temporary measures, due to physical, economic, social and cultural limits to their performance. They can also create a false sense of security to those 'protected' and generate increased exposure (or residual risk) when their effectiveness ends. This, in turn, can prove to be an obstacle to planning a switch to another type of adaptation option as conditions worsen (resulting in high adjustment costs or reactive retreat in the future).

Emergency responses are required to address residual risks. Effective emergency responses will prioritise actions that support the continued functionality of essential infrastructure during and immediately after an emergency. They will also help to improve the resilience of communities and reduce their future reliance on emergency responses.

6 Adaptation approaches for Ruawai

Drawing on national and international best practice, and acknowledging that an **'incremental' DAPP approach** to adaptation is being applied, it is proposed that the adaptation options under consideration are classified based on the following categories:



References

Auckland Council (2017). *Coastal Management Framework for the Auckland Region.* Available at: https://infocouncil.aucklandcouncil.govt.nz/Open/2017/08/ENV_20170808_AGN_6831 AT_files/ ENV_20170808_AGN_6831_AT_Attachment_53367_1.PDF

Burnham, R. (2015). *Residual Risk.* Available at: https://www.floodtoolkit.com/glossary/residual/

Chhetri, N., Stuhlmacher, M. and Ishtiaque, A. (2019). *Nested pathways to adaptation.* Available at: https://iopscience.iop.org/article/10.1088/2515-7620/aaf9f9/pdf

DEFRA (2006). *Shoreline Management Plan Guidance Volume 1: Aims and requirements*. March 2006. Department of Environment, Food and Rural Affairs, London.

DOC (2010). *New Zealand Coastal Policy Statement.* New Zealand Government, Department of Conservation, Wellington NZ: December 2010.

Hoogendoorn, H. (2021). *A beach vulnerability study at Copacabana beach, Rio de Janeiro,* Delft: TU Delft and Boskalis.

IPCC (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability.* Annex II (Working Group II contribution) to the IPCC Sixth Assessment Report.

Lawrence, J., Boston, J., Bell, R., Olufson, S., Kool, R., Hardcastle, M. and Stroombergen, A. (2020). Implementing Pre-Emptive Managed Retreat: Constraints and Novel Insights. *Current Climate Change Reports 6,* 66–80(2020). https://doi.org/10.1007/s40641-020-00161-z

Lawrence, J., Stephens, S., Blackett, P., Bell, R.G. and Priestley, R. (2021). *Climate Services Transformed: Decision-Making Practice for the Coast in a Changing Climate.* doi: 10.3389/ fmars.2021.703902

MfE (2017). *Coastal Hazards and Climate Change: Guidance for Local Government.* Ministry for the Environment, ME1341, Wellington NZ: December 2017.

MfE (2022). *Exploring An Indigenous Worldview Framework for the National Climate Change Adaptation Plan.* Ministry for the Environment, Wellington NZ.

State of New South Wales (NSW) (2019). *Our Future on the Coast. NSW Coastal Management Manual Part B: Stage 3 – Identify and evaluate options*. Office of Environment and Heritage, NSW Government.

State of NSW Department of Planning and Environment (2022). *Flood Risk Management Manual.* Available at: https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Water/ Floodplains/flood-risk-management-manual-220060.pdf

Appendix 1 – UK policy approaches

Background

'Shoreline management planning' began in the UK in 1993 and, by 1999, 22 SMPs had been completed for the English and Welsh coastlines. In 2006, updated guidance was produced and a second round of shoreline management planning progressed. The approach adopted has continuously evolved and, between 2019 and 2021, an SMP Refresh was undertaken. Discussion with established Coastal Groups identified that, while the SMPs were widely used (providing a framework for coastal flood and erosion risk management), there had been changes in national policy, further understanding of the risks associated with sea level rise was available and, in some areas, further monitoring of coastal behaviour. The Refresh was seen as a way to ensure that SMPs were up to date, continued to underpin coastal management, and to support a shift from reliance on "an SMP" document to 'shoreline management' as an on-going process.

The UK approach proposes that for each management area[3] appropriate management policies are defined for distinct stretches of the coast (referred to as policy units). Once the policy has been agreed, different management approaches – or adaptation options – can be considered to achieve this.

No Active Intervention (NAI)

The policy of NAI developed from two distinct sets of circumstances. In the first, either no driver for intervention exists (i.e., there is no or limited risk[4]) or the need for the coast to be allowed to develop naturally has been identified. For example, erosion of a frontage is providing sediment to other sections of the coast and, therefore, it may be important that the coast can continue to erode; or the frontage provides valuable environmental or amenity value.

The second situation where a NAI policy may arise is where it is unlikely that the operating authorities would provide funding for protection. The benefit/cost ratio may not be beneficial or there may not be priority funding. In these circumstances privately funded works may still be permissible. However, there may be conditions associated with this specifying that private works cannot result in negative impacts elsewhere.

Hold the Line (HTL)

A HTL policy intends that coastal protection and beach management activities are maintained or improved to provide protection to important assets or features at the coast from coastal flooding and erosion. These assets might include centres of development and redevelopment, industry and commerce, agriculture, infrastructure etc. HTL is typically adopted where existing coastal protection structures are present. Maintaining or improving the line of defence may include local adjustments to the alignment of structures, replacing existing structures or constructing new structures, depending on local conditions and requirements.

A policy of HTL fundamentally relates to the coastal protection structure and use of the coast, not specifically any standard of protection. This can lead to situations where the line of defence is held but the level of protection is not increased, such that there is an increasing risk, which could lead to a requirement to change the management approach in the future. In other areas, the need to maintain the position of existing structures may be considered important even though the risk may still increase.

---

[3] Management areas are used to subdivide (in this case) the coast into manageable units for adaptation planning. Within a single 'management area', the intent of and objectives for adaptation and management should be consistent. However, because management areas can be quite large and different adaptation strategies may be relevant for different lengths of the coast within an area (i.e., developed and undeveloped), 'policy units' can be defined within them. They are individual units where coastal adaptation policy will be assessed over time.

[4] Acceptable risk.

HTL does not necessary mean that public funding will be available. Privately funded works may be permissible, although (as above) there may be conditions associated with this such that private works do not result in negative impacts elsewhere.

Managed Retreat (MR)

The intention of MR is to provide the conditions for the coast to realign and/or retreat (i.e., to provide space for natural fluctuations and response to sea level rise of necessary). For example, this policy may be considered for issues relating to flood storage capacity, sediment transport, economic viability (i.e., where a setback requires a shorter structure) or to meet the legal obligation to maintain habitat for coastal wildlife due to sea level rise (e.g., intertidal habitat creation to offset 'coastal squeeze'). Further, it simply may not be sustainable (operationally or economically) to maintain the current line of the coast or existing structures at the current protection line. In these circumstances, even with backstop protection, MR may negatively affect, or result in the loss of property, land, habitat, heritage or other assets.

Examples of managed retreat may be setting back coast protection to a more sustainable location or fixing, or even drawing forward, one section of the coast so that adjacent areas may be managed more naturally without loss of value. There may be no sensible fixed line to realign to but still an intent to allow the coast to retreat in a controlled manner. Managed retreat may also require compensatory sites or habitats to be created. Therefore, existing structures may need to be maintained until this has been achieved elsewhere.

Advance the Line (ATL)

An ATL policy may be adopted where advancement of the shoreline would assist in creating a more robust defensive position and provide additional opportunity for increased intertidal width and/or land reclamation. It is typically undertaken to 'create' new land because advancing the line will invariably cause the loss of the beach (by moving the high tide line forward). It may be undertaken to provide an additional buffer of protection but (again) at the cost of the beach and natural habitats.

This policy does not really form part of adaptive management, rather it represents defence from the sea.

Policy change over time

SMPs are intended to set out a process for adaptation, providing guidance on how issues could be addressed in the future. This will influence how management of the coast is approached in the present. In the UK this approach focuses on (but is not constrained to) three 'epochs' – 0-20 years (from present or the start of the plan), 20-50 years and 50-100 years. However, the need for policy change over time will be very dependent on the rate of coastal change, sea level rise or other climatic changes.

Where a management policy is proposed to change over time, it is important to consider the long-term intent of the plan. Where specific policies change from HTL to MR, NAI or even ATL, this must be a continuous process, not one of step changes. Then, if extreme storm and/or other events occur or present issues are resolved early, such that there is a need or opportunity to adapt earlier, the policy adopted for a certain period should not be seen as a constraint to changing the approach to management.

Where there are changes in policy over time, particularly from HTL to a more adaptive approach, this change also needs to be managed to ensure the safe use of the coast. Therefore, there may be a requirement to carry out works to maintain safety even though the policy is for NAI. Equally, where change is proposed because of the impact existing protection may have on the way in which we use the coast, or the way in which the protection influences other features of the coast, there may well be a need to remove existing structures.

More than one viable management option can be proposed for the future, where the decision to adopt an option will be based on the circumstances that arise on the ground (at a specific decision point or threshold).

Appendix 2 – NSW policy approaches for vulnerable coastal areas

Alert

Low regret responses

Low regret responses that are cost-effective, represent good practice and yield multiple benefits should be part of any risk management strategy and routine, best practice environmental management. These actions often increase community awareness and involvement or achieve environmental improvement outcomes (enhancing resilience), as well as reducing risks. However, low regret actions alone are seldom sufficient to manage medium to high risks, but they do allow time for resilience to be strengthened and management capacity to be built.

Examples of low regret actions in vulnerable coastal areas include:

- enhancing 'natural protection' such as sand dunes, foreshore vegetation and wetlands (see below);
- community awareness and education programmes about coastal processes, hazards and risks to public safety;
- early warning systems and preparedness for storm events;
- monitoring changes in the coastal environment, including long-term trends and responses to erosion, accretion, recession and inundation, and research to improve coastal hazard understanding;
- monitoring community attitudes to risk, changing values, safety and satisfaction with access and amenity; and development pressure and population change;
- identifying potential future threats, vulnerabilities and risks resulting from changing coastal processes and climate change;
- identifying opportunities and preparing and planning for change; and
- developing plans and strategies to improve the resilience of coastal assets to the impacts of climate change and extreme events (e.g. SMPs).

Natural protection

Natural protection actions include:

- dune management;
- reshaping the beach (re-profiling and beach scraping/push-ups);
- relocating nuisance wind-blown sand back onto a beach;
- relocating sand within a sediment compartment (sand back passing) or adding sand or more resistant material to the beach (beach nourishment);
- maintaining and enhancing foreshore vegetation and wetlands; and
- managing human and stock access to the foreshore.

Avoid

The land use planning framework can be used to avoid risk arising from the dynamic and ambulatory nature of shorelines and foreshores of the open coast (including sandy beaches and coastal cliffs and bluffs), estuaries and lagoons. Such approaches should be implemented early so they can provide long-term benefits.

An 'avoid' risk approach is particularly relevant for 'greenfield' sites where planning controls can be used to site new development and associated infrastructure in low-risk areas or outside a vulnerable coastal area for a relevant planning timeframe.

Recommendations to manage risk and provide opportunities for strategic controls on land use can take two different forms:

1. strategic planning and investigation to identify areas suitable for future development; and
2. recommendations for changes to land use planning and development controls, such as permitted and prohibited uses for land use zones and required design standards.

Examples of land use planning recommendations to avoid future risk include:

- The location of new or replacement essential infrastructure in low-risk areas or outside vulnerable coastal areas. This will result in significant savings/benefits for councils, public authorities and the community.
- The location of new critical infrastructure landward of a coastal hazard (i.e. a particular probability storm event) and outside the area rarely impacted by coastal hazards.
- Identifying land suitable for future settlement in regional and local strategies. Future development could be outside coastal areas vulnerable to hazard impacts from storms and flooding. The NSW CMM recommends at least equivalent to a coastal inundation or erosion event with a 1% probability of occurrence in any year (often termed a 1 in 100-year event) for a 100-year planning horizon, but such a prescriptive approach ought to be risk based.
- Identifying areas where redevelopment or infill development is not acceptable due to the risks.
- Identifying development types, design standards and controls to allow appropriate development to occur in areas where coastal risks are anticipated to change over time. The risk, level of uncertainty, desire not to unnecessarily sterilise coastal land and the importance of avoiding future legacy problems should be considered.
- Identifying and recommending alternative development sites to accommodate existing development that is expected to be displaced by shoreline recession or inundation in the future.

Recommendations for changes to land use planning and development controls, based on siting and allowing certain development and infrastructure in areas of specific and differing levels of coastal hazard, could include:

- time-limited and removable structures (such as lifeguard towers or picnic shelters) or mobile development;
- relocatable dwellings (with appropriate consent conditions) between the 50-year 50% and the 50-year 10% exceedance line; and,
- traditional housing on pile foundations.

Note: The NSW CMM presents suggested acceptable siting criteria for a range of development and infrastructure options, within different hazard probabilities areas. However, these are examples only and are not intended to be prescriptive.

Land use zones in coastal areas may also be used to encourage appropriate new development and create opportunities for coastal communities to be sustainable and resilient. Zoning is a mechanism to relocate settlement away from areas affected by hazards while maintaining community cohesion, resilience and socioeconomic viability. Examples of zoning changes that could be considered include:

- Zoning land likely to be subject to extreme events as open space, to provide access and recreation space (noting that compensation may need to be considered if the land is in private ownership).
- Zoning land as open space to facilitate the natural migration of coastal ecological communities, such as saltmarsh, mangroves and wetlands (noting that compensation may need to be considered if the land is in private ownership).
- Zoning areas as working waterways to encourage coast-dependent development, such as marinas and fishery infrastructure or tourism-related activities.
- Identifying opportunities for improved coastal access and public use on public land (or land acquired for this purpose).

- Encouraging new residential development to occur on land outside vulnerable coastal areas, where appropriate.

Active intervention

Active intervention may be advocated over both short or longer-term timeframes, as risk, management costs and community values and objectives change. Intervention aims to mitigate current and future risks from coastal hazards, taking account of the effects of climate change and the dynamic nature of the shoreline.

Accommodate

'Accommodate' measures are designed to reduce the immediate to medium-term consequences of risks in areas exposed to coastal hazards. This approach may extend the time a development can remain in place or a use can continue. This can be achieved by modifying the current land use to be more resilient or changing to a less vulnerable land use or development.

Accommodation strategies tend to work where hazards that do not lead to complete or permanent loss of built assets or where the built assets to be lost are of low value. 'Avoid' risk management responses can be used in conjunction with 'alert' and 'accommodate' risk responses in some cases.

Accommodate coastal management actions may include:

- Retrofitting buildings and infrastructure, including roads and sewer systems, by raising them up or anchoring them more securely, moving electrical wiring and valuables to above the expected flood line, etc.
- Enhanced or redesigned drainage systems to incorporate pumps and/or larger gradients/pipes.
- Changes to design requirements for infill and redevelopment of existing development areas.
- Strategic planning to reduce risk by relocating, or increasing the elevation of, infrastructure assets during maintenance or at the end of the asset life, without changing the general function and use of the land.
- Responses encouraging:
  - raised floor levels;
  - movement of assets and infrastructure; and/or
  - reinstating and maintaining natural protection, such as dune management, beach reprofiling or beach nourishment.
- Providing additional and regular information to affected landowners about coastal hazards and risks, and the performance of management actions.
- Improving the resilience of coastal assets to climate change.
- Potential tenure arrangements that do not sterilise land use in the short to medium-term. These may include easements, voluntary purchase and leaseback.

Protection

Protection options are generally proposed when a vulnerable coastal area includes high value uses or assets. A range of options are available where it has been determined that the protection of significant public and/or private infrastructure or other community assets is desirable. Choice will be influenced by the local context and acceptability to the community. The recommended approach should be restoring or enhancing natural protection (such as coastal dunes or wetlands) and maintaining the ability for natural processes and functioning to occur. However, it is important not to overestimate the resilience of natural protection to long-term coastal change or their capacity to protect assets on eroding coastlines.

Structural works are an option when natural protection is not sufficient to reduce risks from coastal hazards to an acceptable level. They include:

- seawalls and revetments (‘riprap’);
- entrance breakwaters;
- groynes;
- artificial reefs;
- stop banks and drains; and,
- cliff stabilisation works.

Each structural protection option has its pros and cons, and careful evaluation is necessary before any coastal protection is included in an adaptation plan. Coastal protection measures may also be designed to modify and diversify habitats or to improve public access and amenity.

When proposing coastal protection structures such as seawalls and revetments, it is important that the design criteria are clearly stated and that minimum design criteria for stability and safety are met. The engineering ‘design event’ is determined from the accepted probability of exceedance over the design life of the structure. Seawalls should be designed to be consistent with the design life of the development or assets they protect (typically for residential or commercial development it will be 50 or more years). Consideration also needs to be given to the maximum consenting life of a coastal protection structure which, in Thames-Coromandel District, this is limited to 35 years. Increasing risk to adjoining public and private land are also important considerations.

All planning for proposed coastal protection structures needs to acknowledge the residual risk associated with events larger than the design event. Potential impacts include overtopping, out-flanking (end effects) or failure of protective structures. Emergency action plans should be developed to address residual risks.

Planning for change

The need to plan for a long-term change to the location or extent of residential development and infrastructure is inevitable in locations when the risk to life and property from coastal hazards is high. Managed retreat is generally a last resort to be considered when mitigation measures are no longer technical feasible, financially viable or acceptable to the broader community. This situation may arise where coastal recession or permanent inundation is occurring and existing coastal assets, infrastructure, public safety, liveability and environmental values are being progressively lost or degraded, or lives are at risk.

If planning for long-term change is being considered, it is most appropriate to adopt a staged, adaptive approach that moves from accommodation and protection to long-term relocation or retreat over time, and once a predetermined and critical threshold has been reached. This approach allows development in vulnerable coastal areas to remain in place until the risks to life and property become unacceptable/intolerable. The planning for change approach also improves the resilience of coastal development, assets/infrastructure and communities by improving their adaptive capacity and reducing reliance on emergency responses. The capacity of communities to adapt (i.e. their adaptive capacity) will be enhanced through improved awareness and understanding, and staged action.

Where temporary or time-limited development is proposed, it is important to have a clear plan for the implementation of change that is developed with and understood by the community. Clearly defined steps, thresholds and stages in the removal or relocation of temporary development will assist community acceptance of the approach/change and help to reduce the impacts from coastal hazards. Recommending coastal management actions that lead to the relocation of assets may have a distinctive distribution of costs and benefits between public and private stakeholders.

Relocating private development and associated public infrastructure may be an option to consider when:

- the risks to existing residential development are unacceptable/intolerable;
- the public benefits associated with protection structures and mitigation measures are low;
- the benefits to the environment and the broader community are high;

- it is no longer feasible to mitigate the impacts of protection works on coastal processes, environmental values, beach amenity or public access;
- there are significant costs associated with maintaining coastal protection;
- there is a high degree of uncertainty about the adverse impacts of coastal protection works; and/or
- there are significant opportunities that would benefit environmental, cultural and social values, including maintaining public access to a beach.

Thresholds and triggers for change may be linked to a specific magnitude or frequency of an event or damage, the condition of environmental or built assets, or the effectiveness of other mitigation or emergency response measures. In determining thresholds and triggers, the interdependencies between service-related infrastructure and development that is reliant on it (e.g., roads, water supply and sewerage systems), should be a consideration.

Adaptation Options Menu – Long List (draft)

Policy / No.	Option
Be Prepared	
1.	Provide regular information to affected stakeholders on hazards, risks and risk reduction / management measures.
2.	Implement hazard warning systems and prepare / socialise emergency response plans.
No Active Intervention	
3.	No action necessary or advocated.
Accommodate	
4.	Maintain natural protection through good management, e.g., maintenance of foreshore vegetation / wetlands; planting; bank stabilisation; and management of access.
5.	Retrofit (including raising) critical lifeline infrastructure (e.g., SH12, power substations etc.) to improve resilience.
6.	Retrofit (including raising) buildings and other supporting infrastructure to improve resilience.
7.	Install innovative infrastructure (e.g., floating buildings, temporary flood barriers and/or pumps).
8.	Deepen / widen channels and drains to increase capacity.
9.	Reinstate floodplains and natural water courses (natural water retention measures); set back stop banks and drains.
10	Improve existing flood retention areas and basins.
11.	Create new flood retention areas or basins, set asides.
12.	Change land use, plant water resilient crops.
13.	Transition to off-grid living (e.g., water tanks)
Protect: Soft	
14.	Enhance natural protection through drain and foreshore management (e.g., vegetation buffers or introducing / introducing wetlands) or adding material to the foreshore (e.g., nourishment).
15.	Reprofiling waterways/riverbanks to increase capacity.
16.	Soft engineering, e.g., use of natural materials or geotextile matrices/tubes/bags, rock bags, buried backstop walls, etc.

Policy / No.	Option
Protect: Hard	
17.	Improve the resilience (height, width, capacity) of existing flood protection assets (including revetments, stop banks, drains and pumps).
18.	Construct new flood protection assets (including revetments, stop banks, drains and pumps).
19.	Construct manual or automatic flood barriers.
Avoid	
20.	Changing planning policy and practices to avoid development (including infill development) in hazard prone areas.
Managed Retreat	
21.	Relocate assets, including infrastructure and property.
22.	Provide accommodation space (e.g., space for water, space for habitats).