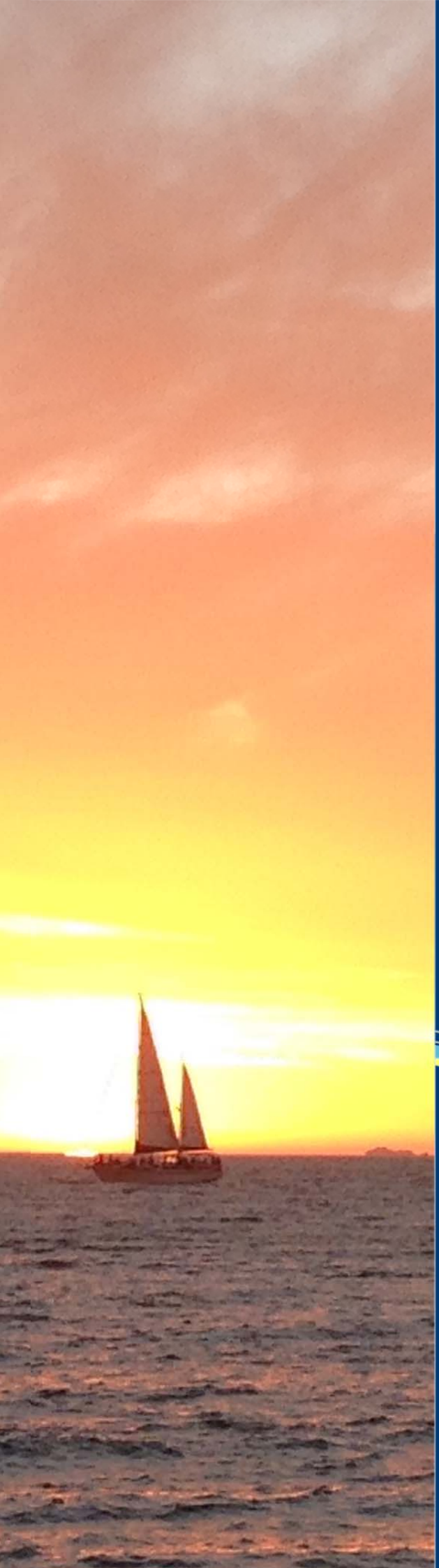


South Fremantle Coast

Coastal Adaptation Plan

June 2016

Prepared as part of the Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project

GHD

COCKBURN SOUND COASTAL ALLIANCE

City of Fremantle

Executive Summary

Sections of the Fremantle coast are exposed, and vulnerable to coastal processes, including erosion and inundation. Over time, the coast will become increasingly vulnerable to the impacts of sea level rise, storm surges and changes in sediment regimes.

The City of Fremantle, together with the Cities of Cockburn, Kwinana and Rockingham, forms part of the Cockburn Sound Coastal Alliance, which is delivering the Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project. The stages of the Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project are:

Stage 1 – Coastal Vulnerability Assessment (completed in February 2013):

Stage 2 – Values and Risk Assessment (Completed in November 2014)

Stage 3 – Coastal Adaptation Plan

Stage 4 – Implementation and Monitoring

Stage 3 of the project aims to ensure that coastal communities and local governments along the Owen Anchorage and Cockburn Sound coast are informed of the risks and are prepared to respond to the threats posed by current and future coastal hazards.

This plan has been prepared to adapt to the changing coast south of the Swan River, and provides recommended timeframes and trigger points for decision-making and planning for the Fremantle coast from South Mole to South Beach. The plan has been prepared as the first iteration of an evolving, long-term planning and decision-making process for the City of Fremantle, the community and key stakeholders to adapt our settlements and infrastructure to coastal processes – including risks of coastal erosion and inundation.

The adaptation plan includes an implementation stage that recommends specific coastal adaptation activities to be delivered in the immediate (15-year) planning horizon. Supporting this, the plan provides a road map for incorporation of adaptation planning into the City of Fremantle's strategic plans, land use planning framework, long-term financial plan, and decision-making processes. The plan also identifies key regional strategic planning activities recommended to be delivered by the state government to facilitate adaptation planning at the local scale.

Irrespective of the lead for preparing adaptation plans, there are a number of stakeholders and decision makers involved in adaptation planning. Successful adaptation planning over time requires cooperation from all levels of government, the community, together with asset owners and managers. Funding will be a key issue for the implementation of adaptation planning.

The adaptation plan has been prepared based on a number of principles that underpin the adaptation planning process.

- Principle 1 Adaptation planning in the current planning horizon does not impede the ability of future generations to respond to increasing risk beyond current planning horizons.
- Principle 2 Adaptation requires a decision-making framework that enables the right decision to be made at the right time, in line with the values and circumstances of the time.
- Principle 3 Adaptation planning reflects the public's interest in the social, environmental and economic value of the coast.
- Principle 4 Alternative adaptation measures should consider the full range of land uses and values.
- Principle 5 The full life-cycle benefits, costs and impacts of coastal protection works should be evaluated in considering adaptation options.

These principles are the basis of a flexible adaptation pathway for the City of Fremantle.

Flexible Adaptation: we prepare our governance and planning frameworks to maintain flexibility in available adaptation options, so that the right decisions can be made at the right time.

As risk to coastal assets increase from tolerable to intolerable over time, decisions will need to be made about how we adapt to that risk. These points in time, when decisions are required, are trigger points for adaptation planning.

Adaptation planning is cyclical. The flexible adaptation pathway combines decision-making on specific adaptation options (avoid, retreat, accommodate, interim protection) at the time of trigger points with an ongoing strategic planning process that plans for, and therefore maintains, the same range of adaptation options for future decisions in the longer term. In this way, by choosing to accommodate or protect in the short-term, we are not binding future communities to the long-term cost of that decision beyond the design life of the infrastructure or asset.

The adaptation plan includes two planning horizons for decision-making:

Immediate (15-year) planning horizon: test values and act on any immediate trigger points.

Long-term (100-year) planning horizon: monitor, set up planning and governance frameworks.

Coastal hazard mapping suggests that no significant triggers requiring major protection works or retreat are anticipated along the Fremantle coast south of the Swan River in the immediate planning horizon. The flexible adaptation pathway will enable the community and decision makers to be ready for these triggers when they occur in the long-term planning horizon and beyond.

The table below identifies the key focus areas for implementation to establish the flexible adaptation pathway for the long-term planning horizon, and specific adaptation measures to manage coastal risks in the immediate planning horizon within the City of Fremantle.

Focus for implementation	Responsible Agency
Prepare management plans for Bathers Beach, South Beach, and the Esplanade to provide an implementation framework for adaptation, and include immediate term adaptation measures such as: – Dune management and revegetation – Responsive beach nourishment	City of Fremantle
Fill information gaps that affect decision-making, including modelling of stormwater contributions to inundation in extreme events and rising groundwater levels in Fremantle's west end	City of Fremantle
Engage with the community on coastal risks, impacts, values and the adaptation plan.	City of Fremantle
Incorporate flexible adaptation pathway into strategic planning and governance frameworks	City of Fremantle
Review regional planning documents to facilitate decisions and implementation regarding long-term managed retreat.	Department of Planning and Western Australian Planning Commission
Commence dialogue with infrastructure and land owners and managers regarding the adaptation plan and coastal risk.	Department of Planning and City of Fremantle
Review local planning strategy and scheme, to include investigation of special control area and necessary development controls for the vulnerable coastal areas.	City of Fremantle
Monitor risk levels to land and infrastructure	City of Fremantle

The adaptation plan identifies focus areas/actions for implementation by state government, particularly in relation to policy, expansion of the foreshore reserve (where necessary in the longer term), and major infrastructure. This plan does not bind state government or other stakeholders to the actions. However it recognises that long-term adaptation requires the support of these key stakeholders. The City of Fremantle, alongside the Cockburn Sound Coastal Alliance, will work closely with the state government and other key stakeholders to deliver the actions necessary to achieve an adaptation pathway.

The adaptation plan should be reviewed regularly, alongside the ten-yearly reviews of the City of Fremantle Strategic Plan.

Review processes should include targeted community and industry consultation to update values and views about coastal development and assets that will be at risk both within a 15-year planning horizon and beyond. Revised values and new learnings should be used to test recommendations of this adaptation plan, and determine whether adaptation strategies for the 15-year planning horizon require modification as a result of changing values.

It will be necessary to update the hazard mapping from time to time to reflect actual sea level rise, updated projections of future sea level rise and the response of the coast to changing conditions. These updates should occur as new information becomes available.

Contents

1. Introduction

1.1 Project background

The City of Fremantle, along with the Cities of Cockburn, Kwinana and Rockingham, is part of the Cockburn Sound Coastal Alliance, which is delivering the Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project. The stages of the Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project are to:

Stage 1 – Coastal Vulnerability Assessment (completed in February 2013):

- Improve the understanding of the coastal features, processes and hazards of the study area (coastal landforms, geological features, sediment supplies, sediment distribution and meteo-ocean processes);
- Identify the degree of exposure and sensitivity of the various sections of coastline to the potential impacts of future weather events and sea level rise associated with both natural variability and climate change.
- Develop an understanding of the vulnerability of the coast within each coastal compartment based on an understanding of current and future physical changes (output from Stage 1);
- Identify significant vulnerability trigger points and respective timeframes for each sediment cell to mark the need for immediate or medium term adaptation action;

Stage 2 – Values and Risk Assessment (Completed in November 2014)

- Facilitate the understanding of climate science, coastal hazards and risk management amongst key stakeholders (including community);
- Identify what assets are situated along the coast and what services and functions those assets provide;
- Identify the 'value at risk' of coastal assets potentially affected by coastal processes and climate change under different timeframes and climate change scenarios
- Identify and evaluate potential adaptation options for vulnerable areas;
- Quantify the risks in terms of consequence and likelihood of those hazards identified.

Stage 3 – Coastal Adaptation Plan

- In consultation with the key stakeholder groups and community, verify the intrinsic current and anticipated economic, socio-economic and ecologic values of assets at risk;
- In consultation with the key stakeholder groups and community, assess and verify the most effective and feasible adaptation options which can include coastal protections, planning instruments and market interventions;
- Share best practices and lessons learnt; and
- Identify critical data gaps.

Stage 3 of the project aims to ensure that coastal communities and local governments in Cockburn Sound are informed of the risks and are prepared to respond to the threats posed by current and future coastal hazards.

1.2 Purpose of this plan

This coastal adaptation plan provides a decision-making framework and recommended adaptation actions to assist the City of Fremantle adapt to coastal risks in the immediate and long-term.

This coastal adaptation plan is the beginning of the conversation and journey with the community and stakeholders to understand and respond to our changing coast. The plan has a very long-term planning horizon – considering the decisions that will need to be made from now until 2110.

This plan has been prepared to adapt to the changing coast south of the Swan River, and provides recommended timeframes and trigger points for decision-making and planning for the Fremantle coast from South Mole to South Beach.

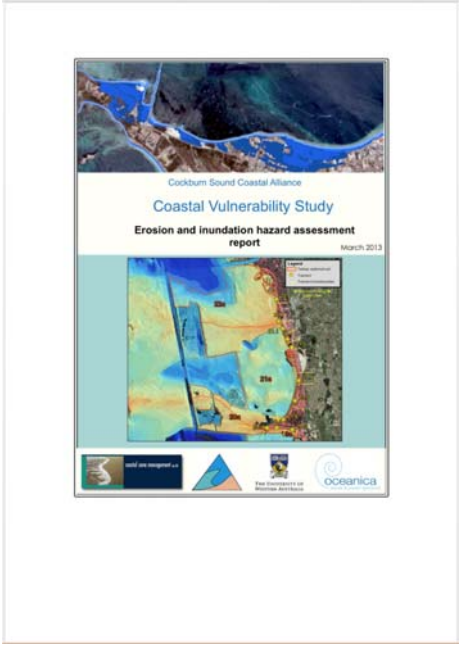
The plan has been prepared as the first iteration of an evolving, long-term planning and decision-making process for the City of Fremantle, the community, and key stakeholders to adapt our settlements and infrastructure to coastal processes – including risks of coastal erosion and inundation. As the City, stakeholders and the community learn more and understand more about how our coast will change in future, this plan and recommended adaptation responses will evolve to reflect and respond to the values, aspirations, and learnings of our community and stakeholders.

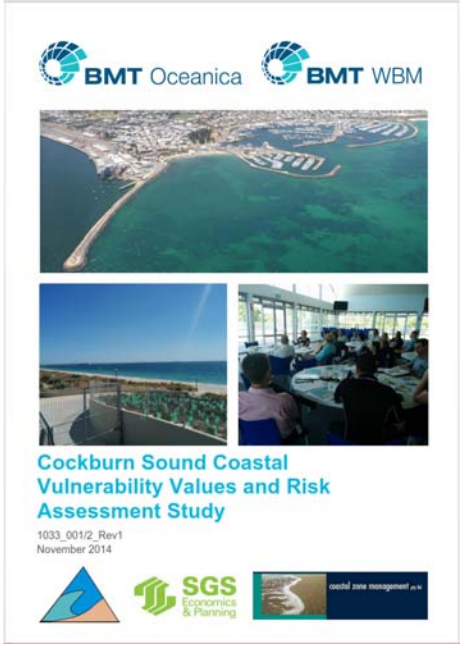
1.3 Previous reports

This plan is based on important work undertaken by the Cockburn Sound Coastal Alliance to understand the coastal vulnerability and the values and risks of assets in the coastal areas around Owen Anchorage and Cockburn Sound.

Stage 1 of the Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project delivered the *Cockburn Sound Coastal Alliance – Coastal Vulnerability Study – Erosion and inundation hazard assessment report*. The report provides a coastal vulnerability assessment for Cockburn Sound, Owen Anchorage and the east coast of Garden Island. The assessment focussed on potential impacts to the coast from coastal processes, influenced by climate change and associated sea level rise. The investigation identified inundation (flooding) and erosion hazards for the study area for present day, 2070 and 2110.

Stage 2 of the project delivered the *Cockburn Sound Vulnerability Values and Risk Assessment Study* to understand in more detail the potential impact of the coastal hazards on assets along the coast. The study used a risk-based approach to determine the likelihood of impacts to coastal assets, assessed the value of the assets at risk, and determined the potential consequence of the impacts to understand the cost of the risk. The study also undertook a first pass of potential adaptation options for the coast.





1.4 Strategic context

This plan provides a road map for incorporation of adaptation planning into the City of Fremantle's strategic plans, land use planning framework, long-term financial plan, and decision-making processes.

As indicated by Figure 1, this plan is not an individual action plan for delivery. It is a blueprint to assist future iterations of the City's and the state government's strategic plans integrate and deliver coastal adaptation, in consultation with the community. In this way, coastal adaptation planning will be delivered in the City of Fremantle through existing strategic and capital planning processes at the state and local level.

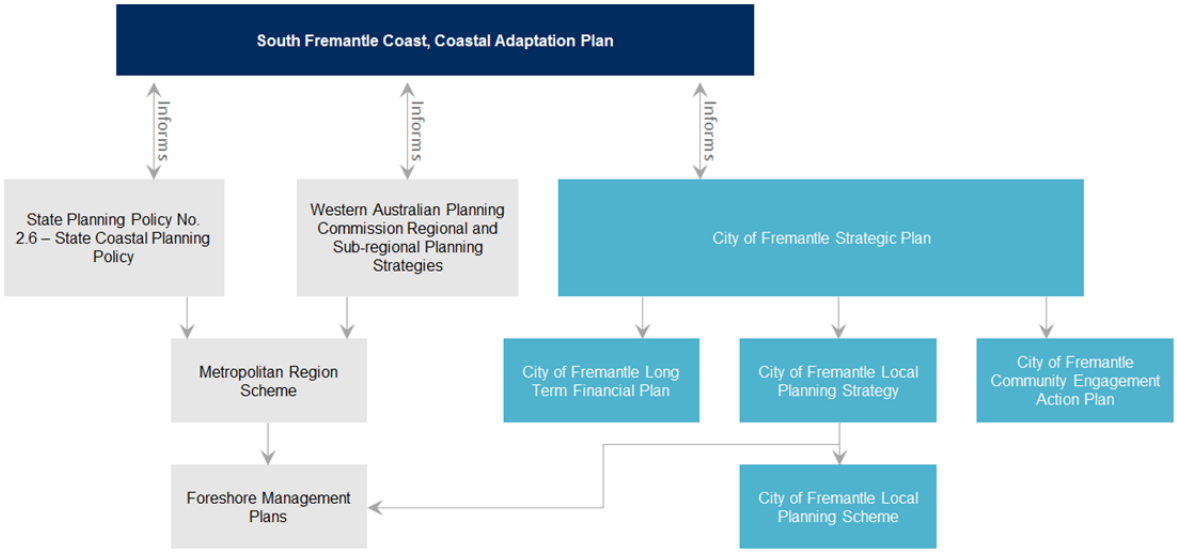


Figure 1 Strategic context – South Fremantle Coast, Coastal Adaptation Plan

2. The Fremantle coast

2.1 Coastal assets

Fremantle is home to the state's largest working port with a strong historical and cultural connection with the foreshore and the coast. The fishing port is home to a large commercial fishing fleet and was showcased to the world in the America's Cup Defence in 1987, forming part of Western Australia folklore. The historic West End of Fremantle is located in close proximity to the coast, which includes the Roundhouse - the oldest remaining intact building in Western Australia - and the University of Notre Dame Australia.

The Fremantle coast has inherent community use and tourism value with the establishment of restaurants, cafes and bars located within the Fishing Boat Harbour. This part of the coastline has been popularised over recent years and provides a strong connection through the public open space of the Esplanade to Fremantle Town Centre. Additionally, the coast is home to Bathers Beach, a popular inner city beach, and South Beach in South Fremantle. The South Beach Recreation Reserve is a large public reserve stretching from the Fremantle Sailing Club in Success Harbour, to recent residential development overlooking South Beach.

A freight rail line runs parallel to the coast, alongside Marine Terrace, connecting commercial shipments from the port to greater Perth.

2.2 Coastal management units

To plan for Fremantle's changing coast, the coastal strip has been broken into a series of coastal management units. The coastal management units were defined in Stage 1 and Stage 2 of the Cockburn Sound Coastal Alliance Coastal Vulnerability & Flexible Adaptation Pathways Project.

The City of Fremantle includes two coastal management units:

- Management Unit 1 – Fishing Boat Harbour; and
- Management Unit 2 – South Beach.

Management Unit 1 – Fishing Boat Harbour

Management Unit 1 (Fishing Boat Harbour) extends from the South Mole to the northern boundary of South Beach, as shown in Figure 2. This unit's coastline is heavily modified and comprised of breakwaters and revetments for protection of the boat harbours with a small but highly valued public beach at Bathers Beach. This area has grown in popularity for aesthetic and recreational use over the last decade. This includes a change in the value of the place, in that past the community appreciated the area as a largely natural space, now with increased 'activation' of the space there is a greater expectation for a more manicured beach and parkland area.

The landside areas have high land values and are heavily urbanised containing a number of heritage, recreational, commercial and marine (including boating) assets.

Figure 2 Management Unit 1 – Fishing Boat Harbour

Management Unit 2 – South Beach

Management Unit 2 (South Beach) spans southward from the northern boundary of South Beach to the southern boundary of the City of Fremantle, at the southern edge of the carpark, as shown in Figure 3. This unit's coastline consists of two sandy stretches of beach evenly divided between three rock groynes to maintain sand levels. The unit has a coastal recreational reserve backed by an urban area.

South Beach is an area that has evolved considerably over time. In the last century it has changed from being a popular seaside playground, to an area taken over by industry, and has now returned to recreational use. As urban regeneration replaces industrial spaces, an increased number of local residents has increased demand for recreational use of coastal areas.

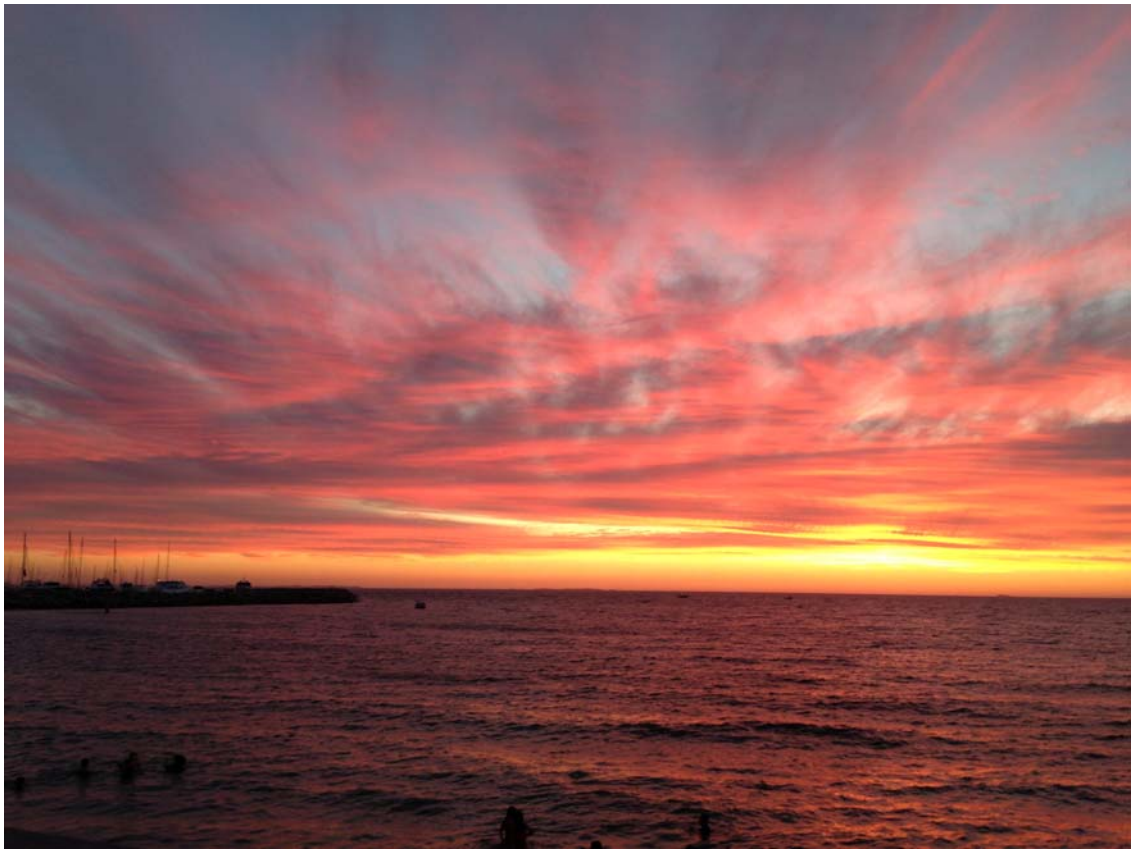
Figure 3 Management Unit 2 – South Beach

2.3 An evolving coastline

Sections of the Fremantle coast are exposed and vulnerable to coastal processes, including erosion and inundation. Over time, the coast will become increasingly vulnerable to the impacts of sea level rise, storm surges and changes in sediment regimes.

Over time, risks to coastal land and assets will increase from tolerable, to intolerable. This will require government and the community to make decisions about how they use the coast in the future.

The risk mapping undertaken in Stage 2 of the Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project for the Fremantle coast is provided in Appendix A.



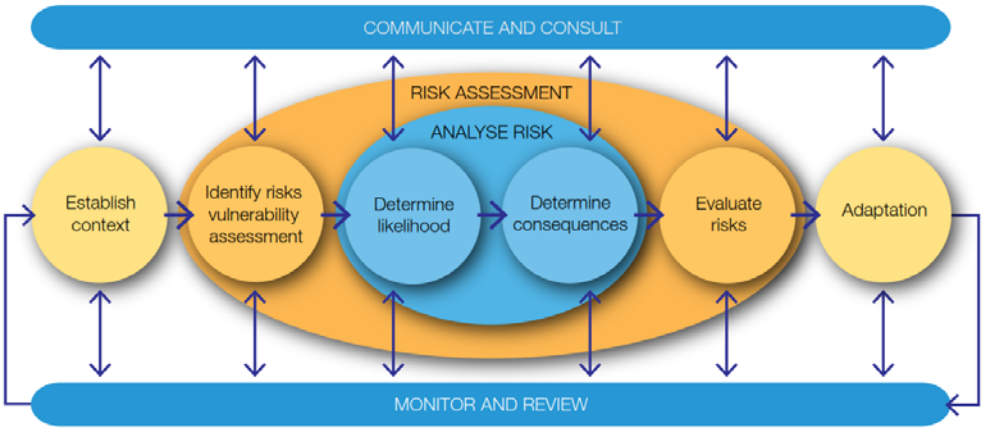
Ocean views from Bathers Beach, Fremantle

2.4 Adaptation planning

What is adaptation planning?

The coast has always been a dynamic, changing environment. As we have settled on the coast, continued changing of the coast line presents risk and impacts to our coastal assets – including social, environmental, and economic assets and values. Adaptation planning is about being ready to manage the risks and impacts of changes to our coast line, by planning for the most appropriate decisions and options to implement over time.

A risk management approach is being used increasingly, nationally and internationally, to deal with potential adverse impacts of coastal hazards. A risk management and adaptation planning approach is a systematic way to identify and understand coastal hazard risks, and implement controls and measures to manage those risks in consultation with the community and stakeholders.



Risk management and adaptation process from Coastal hazard risk management and adaptation guidelines (WAPC, 2014)

Who is responsible?

In July 2013, the amended State Coastal Planning Policy No 2.6 (SPP 2.6) was gazetted by the state government. The amended policy included a requirement for 'responsible management authorities' to prepare coastal hazard risk management and adaptation plans, where existing or proposed development is located in an area at risk of being affected by coastal hazards over a 100 year planning horizon. For many areas of the coast, local government is the land manager. Therefore, local government in Western Australia has been leading the development of coastal adaptation plans.

Irrespective of the lead for preparing adaptation plans, there are a number of stakeholders and decision makers involved in adaptation planning. Successful adaptation planning over time requires cooperation from all levels of government, the community, along with asset owners and managers. Key stakeholders and responsibilities for adaptation planning are shown in Table 1.

Table 1 Adaptation planning – roles and responsibilities

Role	Responsibility	Key Stakeholders
Planners and decision makers	*Strategic planning responsibilities:* Prepare adaptation plan for coastal land within their management. Inform coastal asset owners and users about risk and decision-making. *Decision-making responsibilities* Make adaptation decisions on land and assets within their management.	Western Australian Planning Commission Department of Planning Department of Transport City of Fremantle
Asset owners	Manage assets in the context of coastal risk. Undertake accommodation measures, where consistent with government decisions. Decommission and relocate assets where required by government decisions to retreat.	Private land owners Department of Transport (Facilities) Business owners and operators City of Fremantle Infrastructure agencies Public Transport Authority and Brookfield Rail
Other coastal users	Engage with decision makers regarding the values of the coast to inform decision-making.	Community

Funding will be a key issue for the implementation of adaptation planning. The responsibility for paying for coastal adaptation lies with the beneficiaries of those actions. This includes land and asset owners that benefit from protection strategies, and coastal users that benefit from coastal management approaches. Where public funds are used for coastal adaptation works, there should be a direct public benefit as a result of that investment. Ongoing cooperation between local and state government and key asset owners will be required to consider and address these funding issues and responsibilities.

Recreation space, South Beach, Fremantle

3. Adaptation principles and pathways

3.1 Adaptation principles

In developing a pathway to adapt to Fremantle's changing coastal processes, and to guide decisions that are appropriate for the community, the following principles underpin the adaptation planning process.

Principle 1 Adaptation planning in the current planning horizon does not impede the ability of future generations to respond to increasing risk beyond current planning horizons.

Preparation of erosion and inundation risk mapping that informs this plan considered possible scenarios for sea level rise to 2110. The projections for longer term sea level rise are dependent on the global action taken to mitigate climate change through greenhouse gas emission reductions, and are therefore uncertain. However all scenarios considered by the Intergovernmental Panel on Climate Change (IPCC) give rise to predictions that "sea level rise will continue for many centuries beyond 2100" (IPCC 2014). Accordingly the development of adaptation plans must take account of these predictions.

Existing erosion and inundation risk mapping identifies the zone likely to be affected to 2110, but inevitably beyond that timeframe the risk in this zone will steadily increase, and the zone itself will extend landwards beyond 2110. As no protection measures can be devised that remain effective for hundreds of years, any coastal protection works that are undertaken within the presently identified zone cannot be considered permanent. Ultimately, retreat may be the most cost effective option in the very long-term if appropriately planned for. As a result, combating long-term sea level requires different adaptation options alongside an underlying retreat approach that should be strategically identified in the initial stages. This does not necessarily mean that retreat will be the most appropriate option in the current planning horizon; however mechanisms should be in place to allow for this adaptation option to be implemented should future risk be heightened.

Principle 2 Adaptation requires a decision-making framework that enables the right decision to be made at the right time, in line with the values and circumstances of the time.

The dynamic nature of community needs and values requires a flexible approach when considering adaptation options. The effects of climate change on the coast have only recently been identified as a potential concern for some in the community. This was apparent in the minimal interest shown by the community during the consultation undertaken during the preparation of this adaptation plan. The interest and values of the community will change over time as more information becomes available, and impacts of climate change become more apparent. Our approach to coastal

adaptation will likely change with new technology and information, opening up new approaches to manage risk.

Making decisions based on community values that are likely to change can be considered short-sighted and potentially prevent the best possible outcome when considering short, medium and long-term measures to adapt to changing coastal processes. Adaptation planning should provide opportunity for future action to reflect new technologies and community values at the time of the decision.

Principle 3 Adaptation planning reflects the public's interest in the social, environmental, and economic value of the coast.

Western Australia is renowned for its flowing coastline and beaches. Social and recreation use of such spaces along the coastline form an integral part of Western Australian culture. Public access to the coast and beaches is an iconic part of Western Australia's lifestyle, contributing to the high quality public spaces enjoyed by the community. Our economy and quality of life is supported by coastally dependant infrastructure and industries located on the coast. In addition to existing infrastructure and industries, the coast might house future projects critical to the development of the Western Australian economy. The coast also provides important environmental values, with a unique ecology that includes marine, intertidal, and dune habitats.

Adaptation planning should respect the inherent value of the coast that is ingrained in the state's social, environmental and economic interests.

Principle 4 Alternative adaptation measures should consider the full range of land uses and values.

The objectives of State Planning Policy (SPP) 2.6 include the retention of coastal uses for a range of public and private uses including economic uses, coastal foreshore access and social and environmental uses and values, including:

- housing, tourism, recreation, ocean access, maritime industry, commercial and other activities;
- public coastal foreshore reserves and access to them on the coast; and
- landscape, biodiversity and ecosystem integrity, indigenous and cultural significance.

Principle 5 The full life-cycle benefits, costs and impacts of coastal protection works should be evaluated in considering adaptation options.

Coastal engineering works have the potential to provide protection to nearshore coastal assets over their design life, dependent on the rate of future sea level rise. There are two broad categories of protection that have potential for use on the Cockburn coast, and these are set out in the Adaptation Options Compendium (which is a companion to this document):

Engineering (hard) measures: seawalls, revetments, levees, groynes/breakwaters

Regenerative (soft) measures: beach nourishment and dune restoration

Seawalls and revetments, if implemented without ongoing beach nourishment, will eventually lead to a loss of beach and coastal habitat seaward of the structures, as sea levels rise. Beach nourishment measures require ongoing replenishment in response to storm-related erosion events and sea level rise. Coastal protection measures taken in a specific location may influence the adjacent coastal cells.

Interim protection measures also bring cost impacts. Engineering works can have a high capital cost, and require ongoing investment in maintenance. The cost impact of coastal engineering works should also consider decommissioning costs. Engineering options are designed to mitigate against a particular level of risk, and have a discrete design life. However, the presence of protection works can give a sense of expectation to asset owners, and can potentially limit future decision-making flexibility.

SPP 2.6 includes a presumption against coastal protection measures unless “all other options … have been fully explored”.

Adaptation principles recognise that the most appropriate adaptation decision may differ based on the values to be protected. For example, land protection measures (sea walls) can exacerbate erosion and severely affect beach amenity compared to retreat or natural recession.

3.2 Adaptation pathways

In line with adaptation principles, the most appropriate adaptation pathway is one that enables decision-making on adaptation measures to be made at the right time, in line with the values of that time.

So as to not pre-empt the values of the community in the future, the most appropriate adaptation pathway in Fremantle is:

Flexible adaptation: we prepare our governance and planning frameworks to maintain flexibility in available adaptation options, so that the right decisions can be made at the right time.

As risk to assets increases from tolerable to intolerable, decisions must be made. These points in time when decisions are required become trigger points for adaptation planning.

The Coastal Hazard Risk Management and Adaptation Planning Guidelines (WAPC, 2014) set out coastal adaptation options available when making decisions about managing coastal risk (Figure 4). The options shown in Figure 4 and Table 2 should be considered as a hierarchy – the further down the hierarchy, the less flexibility there is to consider alternative adaptation measures. Effectively, these options become decisions for government and the community to make when planning for the future of coastal assets and land.

The adaptation options set out in SPP 2.6 include:

Figure 4 Hierarchy of risk management and adaptation options (WAPC, 2014)

Table 2 Levels of risk mitigation

Planned or Managed Retreat:	In the face of intolerable risk;	Existing development
Accommodation:	Design and / or management measures that address the risk	
Protection:	Where there is a need to preserve the foreshore reserve, public access and public safety, property and infrastructure that is not expendable.	
Avoid	Avoiding development in areas at risk	New development

In the absence of coastal protection works (or other obstacles), as sea levels rise, the shore line, beaches and dune systems will gradually move landwards. Accordingly, the risk to nearshore coastal assets will increase, initially leading to loss of land through erosion (on sandy areas) and leading to occasional and then eventually permanent inundation.

As this sequence of events unfolds, the options available in any specific location depend on the likelihood and consequence of the risk at that time. The decision made will be informed by values of the coast, coastal assets and community. Values will change over time – as they have in Fremantle over the last 100 years – therefore it is important that decisions are made at the time of the trigger point.

A successful adaptation pathway is achieved when decisions made now, in 20 years or in 50 years do not prevent other courses of action being chosen later, therefore retaining ongoing flexibility in decision-making in line with the hierarchy of options. For example, at the end of the life cycle of interim protection structures, the hierarchy of adaptation options should be reassessed and the adaptation most appropriate for the point in time progressed. There may be a point when the viability of less flexible measures (such as protection) is compromised due to social or economic costs. This requires ongoing strategic planning to retain the full flexibility of adaptation options for future decisions, even when other options are employed in the shorter term.

The recommended flexible adaptation pathway combines decision-making at trigger points on specific adaptation measures (avoid, retreat, accommodate, interim protection) with an ongoing strategic planning process that plans for, and therefore maintains, all adaptation options for subsequent trigger points over time. In this way, by choosing to accommodate or protect in early horizons, we are not binding future communities to the long-term cost of that decision beyond the

design life of the infrastructure or asset. The pathway and decision points are illustrated in Figure 5. More detailed description of the trigger points is provided later in this section.

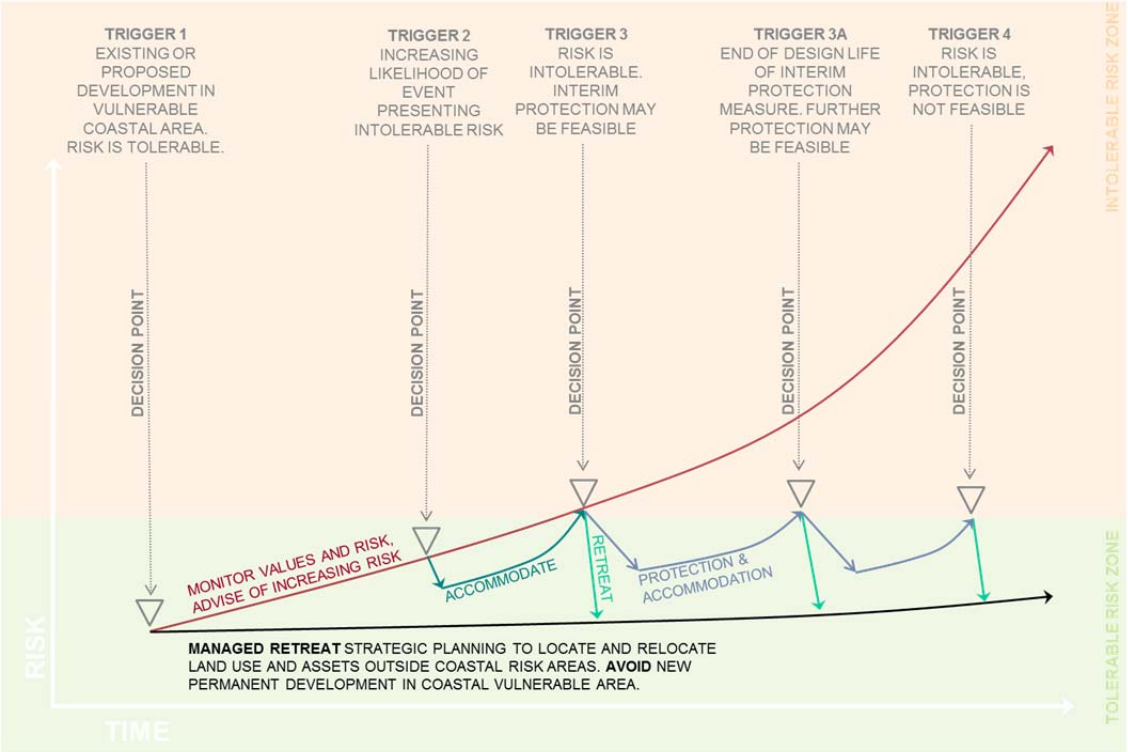


Figure 5 Flexible adaptation pathway

The flexible pathway provides a roadmap to enable retreat from the most vulnerable coastal land in the long-term. The pathway also facilitates responsible interim adaptation measures that continue land uses where those measures are justified on social, economic and environmental grounds.

For assets on vulnerable land, a decision to accommodate and/or protect or retreat is dependent on a wide range of factors, including:

- the consequences of taking no action,
- the feasibility and social/environmental/economic costs associated with accommodation/protection compared to the residual value and life of the asset;
- the disruption and costs involved with relocation.

There are parallel pathways for government and private asset owners. Whether government decides to facilitate interim protection measures on certain sections of coast, or allow the coast to

recede, private asset owners retain their ability to determine the pathway that reflects their own circumstances (where it is not incompatible with or less flexible than a government decision). In order for this approach to be workable and provide certainty to asset owners, it is recommended that the following principles apply to government decisions about coastal protection works:

- Decisions about the appropriateness of coastal protection works are made and implemented/facilitated by government alone, and occur on coastal reserves, notwithstanding whether or not private landowners contribute to costs;
- Any such measures are designed for a finite life, after which a new decision is required as to whether further, finite protection is justified or the coast be allowed to naturally recede; and
- Advice is provided to private asset owners about government decisions to protect or otherwise, and the likely residual risk associated with those decisions.

Accommodation measures need to be considered at all times for land identified as being within the vulnerable coastal area, (i.e. at all times after trigger 1 is reached). The nature and extent of accommodation measures will change over time as risks increase, but are still required even in circumstances where interim protection is put in place. All protection options are designed for a certain set of circumstances (e.g. 100 year ARI storm event), and there is a residual risk that either these circumstances will be exceeded or that the protection measure does not perform to expectations. Accordingly, accommodate options are also part of protect options, although the nature of the measures may differ.

Private assets within Fremantle Fishing Boat Harbour include a range of boating and tourism businesses

Planning horizons

The adaptation plan includes two planning horizons for decision-making:

Long-term (100-year) planning horizon: monitor, set up planning and governance frameworks.

Immediate (15-year) planning horizon: test values and act on any immediate trigger points.

For the long-term (100-year) planning horizon, strategic planning should focus on maintaining the ability of community and stakeholders to choose from the most appropriate adaptation measures at future decision points. This includes provision in planning tools for avoid and retreat measures, even if these measures are not put into action in the immediate term.

In the immediate (15-year) planning horizon, any decision points that will arise from increasing risk in that timeframe should be identified. Community values should be confirmed to understand the social, environmental, and economic influences on the decision. Using the values of the time, the decision on the most appropriate adaptation measure (avoid, retreat, accommodate, or interim protection) should be made and acted upon. This delivers a no-regrets adaptation decision, reserving the right to review investment and protection strategies over time. 15-years is sufficient to implement necessary planning controls in local planning schemes if retreat is required, and to commence budgeting for required adaptation measures.

This adaptation plan presents strategic planning measures to incorporate a flexible pathway into immediate (15-year) and long-term (100-year) planning horizons in the City of Fremantle. The plan recommends adaptation measures for the immediate (to 2030) planning horizon, and identifies possible measures for decision points that would occur beyond that. Provisional adaptation measures for planning horizons beyond 2030 should be subject to ongoing review and testing with the community, in line with the recommended long-term strategic planning approach.

Decision triggers

In order to make appropriate decisions it is important to identify the trigger points that separate the options available to decision makers. As noted above it is the decisions of government in relation to the interim protection or retreat of coastal units that are most important. It is recommended that the following trigger points become the basis of those decisions, using the combination of factors giving rise to inundation likelihood developed in the 2014 *Cockburn Sound Coastal Vulnerability Values and Risk Assessment Study* (Table 8.1, pp.).

The triggers occur when, within the immediate planning horizon (e.g. 15-years); the most seaward asset (i.e. parks, road / rail reserve or urban / industrial land) meets the criteria in Table 3. The proposed approach is shown graphically in Figure 6.

Table 3 Decision triggers and adaptation pathways

Trigger	Risk Level	Location of most seaward asset:	Government options	Landowner / asset manager options
Trigger 1	Tolerable	Landward of the 500 year ARI inundation event/acute erosion line*	Advise of increasing risk	Do nothing or Retreat
Trigger 2	Increasing likelihood of intolerable risk.	Landward of the 100 year ARI inundation event/acute erosion line* but seaward of 500 year ARI inundation line.	Accommodate	Accommodate or Retreat
Trigger 3	Intolerable. Interim protection may be viable.	Landward of the 50 year ARI inundation event/acute erosion line* but seaward of 100 year ARI inundation line.	Protect + accommodate or Retreat	Accommodate or Retreat
Trigger 4	Intolerable. Protection is not viable.	Seaward of the 50 year ARI inundation event/acute erosion line*	Retreat	Retreat

* reflects the S1 erosion allowance in SPP 2.6, which is the allowance of land required to absorb the current risk of storm erosion.

Figure 6 Decision triggers

4. Strategic planning framework

4.1 Development and planning control in the coastal zone

Developing a strategic planning framework that will adequately respond to coastal vulnerability over time needs to consider how planning and development decisions are made in relation to the coast, and who makes them. This depends on who owns the land that the development is on and the policies and strategies that govern land use and development, as shown in Figure 7.

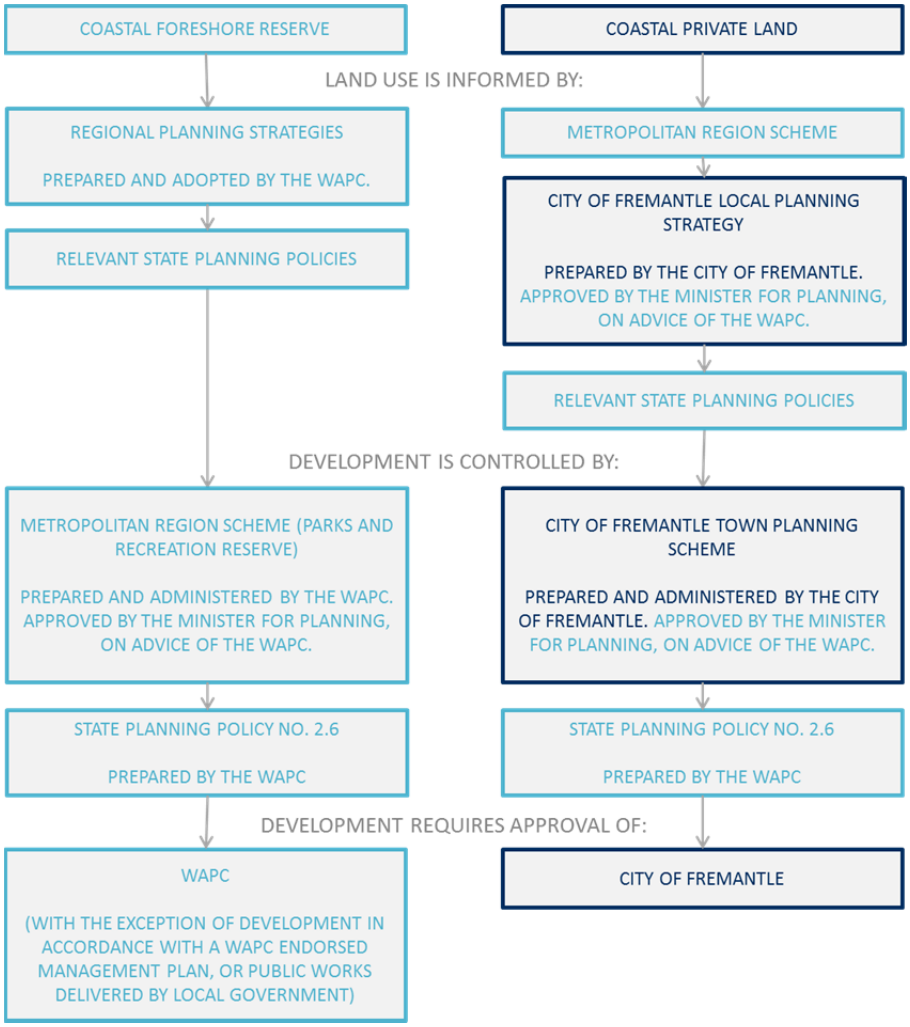


Figure 7 Overview of the statutory planning framework that applies to coastal development

As shown in Figure 7, much of the planning authority in Western Australia is centralised at the state government level. Whilst the City of Fremantle is responsible for preparing its local planning scheme and strategy, these documents must be consistent with higher level state planning documents, and must be approved by the state government. Therefore, strategic decisions regarding land use change and coastal reserves are ultimately confirmed by the state government, and not the City of Fremantle.

The Western Australian Planning Commission (WAPC) is responsible for much of the relevant planning and decision-making on coastal land. In addition to being responsible for the coastal foreshore reserve (which is classified as Parks and Recreation Reserve in the Metropolitan Region Scheme), the WAPC makes recommendations to the Minister for Planning on the acceptability of land use change proposed by the City of Fremantle outside that coastal reserve.

The City of Fremantle has responsibility for development on zoned land and therefore can use their planning system to influence development on private land near the coast. The City of Fremantle can also actively engage with the WAPC to encourage the state and regional planning framework to respond to long-term coastal vulnerability.

Several projects are necessary to develop the strategic planning framework for implementation of the measures set out in this document and to maintain flexibility in adaptation over time. Strategic planning projects are necessary to generate a policy framework that facilitates future, longer-term avoidance and retreat strategies beyond the design life of interim protection in the City of Fremantle.

Photograph – City of Fremantle

4.2 Regional planning strategies and Metropolitan Region Scheme

Recommended strategic adaptation measure

The WAPC should review the Metropolitan Region Scheme (MRS) and other regional planning documents including strategic landuse and infrastructure plans to provide the necessary land use framework to support the flexible adaptation pathway. This includes identifying:

- Necessary expansions to the Parks and Recreation Reserve (foreshore reserve); and
- New locations and reservations for infrastructure currently located in the vulnerable coastal area, to enable retreat as relevant triggers are reached.

The City of Fremantle, together with the Cockburn Sound Coastal Alliance, should request state government to review the MRS and regional planning documents.

Considerations in strategic adaptation measure

Regional plans and strategies – including the most recent Perth and Peel at 3.5 million – identify future urban and industrial development areas, strategic infill areas, and regional infrastructure locations. These plans form the strategic basis for the MRS, which zones and reserves land for development and public purposes. The MRS is the statutory planning scheme which applies the Parks and Recreation Reserve, which is the formal reserve applied to the foreshore reserve and the Esplanade in the City of Fremantle. Key infrastructure within the City of Fremantle planned for in regional planning documents includes:

- Fremantle Port and the freight rail reserve linking the inner harbour to the Kwinana Industrial Area (and potentially to the new outer harbour);
- Fremantle Fishing Boat Harbour; and
- Fremantle Foreshore Reserve.

Future iterations of regional plans and strategies should consider infrastructure, reservations and zoned land that that may be at risk within the immediate (15-year) planning horizon, or infrastructure in longer-term risk areas that is nearing the end of their its design life and requiring renewal. Where the interim protection of infrastructure or land is not supported by community values of the time, regional plans and strategies should include strategic planning projects to identify new locations and reservations for infrastructure outside areas of coastal risk, and plan for the appropriate expansion of the Parks and Recreation reserve.

The Metropolitan Region Scheme will require amendment to be consistent with future iterations of regional plans and strategies. This will include incorporating appropriate reservations for:

- Parks and recreation (coastal foreshore)
- Public purposes (as required by servicing agencies)
- Road and rail reservations (as required by transport agencies)

Amendments to the MRS should be progressed where land will be required or impacted within the immediate (15-year) planning horizon.

The freight rail line (and its rail reserve) that links the Fremantle Port to the Kwinana Industrial Area and beyond is a major piece of regional infrastructure. Any relocation in the long term, to facilitate retreat strategies, will require planning by the state government. Photograph – P Thompson.

4.3 Review of State Planning Policy No. 2.6 State Coastal Planning Policy

Recommended strategic adaptation measure

The WAPC should review SPP2.6 to provide greater policy guidance for coastal dependant development, in particular to manage the longer-term decommissioning or protection costs of such development as risk levels become intolerable.

The City of Fremantle, together with the Cockburn Sound Coastal Alliance, should request the state government to review SPP2.6.

Considerations in strategic adaptation measure

SPP2.6 lists a number of development types that are variations to the policy, and that might be considered appropriate within areas identified as being potentially impacted by physical coastal processes. These include:

- Public recreation facilities with finite lifespan;
- Coastally dependent and easily relocatable development;
- Department of Defence operational installations;
- Industrial and commercial development (including marinas);
- Coastal nodes; and
- Surf life saving clubs

Coastal nodes and commercial development – in particular marinas – provide important community access and enjoyment of the coast. However they also create community and landowner expectations of ongoing protection and retention of such facilities and land beyond the design life of these coastal assets. This presents potential for significant decommissioning or protection costs in the long-term to retain those facilities and protect any land sold in the area.

A review of the SPP to provide greater policy guidance for these types of development is necessary, where the policy supports their location in areas of risk. Additional policy measures to manage potential costs of protection or decommissioning following the design life or current long-term (100 year) planning horizon include:

- Consideration of impermanent land tenure (such as release of leasehold land) for coastal development to avoid future need for acquisition or compensation of private land;
- Incorporation of notifications on title to identify that the land is located in a vulnerable coastal area, and there is no long-term expectation of protection; and

– Consideration of the need for development contributions to support decommissioning or longer-term interim protection costs.

Such policy measures will help future communities – beyond the current long-term planning horizon – retain flexibility in the adaptation pathways available for coastal settlements, and do not bear unreasonable costs of protection, land acquisition or decommissioning.

Foreshore management plans (discussed later in this section) are a suitable tool to require public recreation facilities, relocatable development and surf lifesaving clubs to be planned and managed according to coastal risk.

Bathers Beach on a rainy day

4.4 City of Fremantle strategic plan

Recommended strategic adaptation measure

Future iterations of the City of Fremantle strategic plan should test values and act on any triggers that are predicted to occur in the immediate planning horizon of the plan.

Considerations in strategic adaptation measure

The current City of Fremantle strategic plan is coming to an end and a new five-year plan is being developed by council. Incorporation of coastal adaptation planning into the strategic plan will be necessary to provide a local governance framework for integrated decision-making in relation to strategic land use and infrastructure and capital works planning. In particular, the plan should reflect the adaptation pathway set out in section 3.2.

Five-yearly reviews of the strategic plan should operate as a trigger to undertake targeted community and industry consultation to test and update values and views about coastal development and assets that will be at risk both within a 15-year planning horizon and beyond. Revised values and any new information available (for example any reviews of risk and vulnerability mapping) should be used to determine whether adaptation strategies for the 15-year planning horizon require modification as a result of changing values.

Based on the strategic plan, the costs to the City of any interim protection works or associated measures required to be delivered within the 15-year planning horizon should be incorporated into the City of Fremantle long-term financial plan.

4.5 City of Fremantle local planning strategy and scheme

Recommended strategic adaptation measure

The City of Fremantle local planning strategy and scheme should be reviewed to incorporate a special control area for the vulnerable coastal area.

The local planning strategy and scheme should provide a policy framework to apply SPP 2.6 to infill development to manage location of increased densities. Future land use change should avoid intensifying density and development opportunity within the vulnerable coastal area.

Considerations in strategic adaptation measure

The City of Fremantle Local Planning Strategy was adopted in 2001. The City of Fremantle Town Planning Scheme No. 4 was gazetted in 2007. These planning documents are scheduled for review. The review of these documents should incorporate the requisite planning framework to adapt to coastal risks in the immediate (15-year) and longer (100-year) term.

The purpose of local planning strategies is to set out the local government's objectives for future planning and development and includes a broad framework by which to pursue those objectives. The strategy is therefore the appropriate document to clearly enunciate the longer-term nature of the challenges arising from sea level rise and its associated effects on the coastline, and the City of Fremantle's response to those challenges. Inclusion of planning measures in the strategy will be the precursor to the introduction over time of statutory measures in the local planning scheme, which provides the statutory framework for land use on private land adjacent to the coast.

The City of Fremantle local planning strategy and scheme is required to be consistent with regional plans, strategies, and the Metropolitan Region Scheme. For example, the City of Fremantle scheme will include the high level land uses and reserves determined by the state government in the Metropolitan Region Scheme and other regional plans.

Special control area for vulnerable coastal area

The local planning strategy review should incorporate a clear local coastal planning strategy in accordance with SPP 2.6. A key planning mechanism to deliver the local coastal planning strategy could be a special control area applied to the vulnerable coastal area, which provides additional planning controls for a specific area.

In developing a special control area for the vulnerable coastal area, the following elements should be considered in the local planning strategy review:

- Determination of an appropriate special control area that encompasses land that would be impacted by a) physical processes plus b) an appropriate foreshore reserve for a 100-year planning horizon:
    - Determination of the physical processes setback for a 100-year planning horizon in accordance with SPP 2.6 using best available information – this would include the coastal vulnerability mapping undertaken by the Cockburn Sound Coastal Alliance – Coastal Vulnerability Study. Erosion and Inundation Hazard Assessment Report (2013) supplemented by any further or more detailed investigations undertaken subsequent to the project;
    - Determination of the future foreshore reserve width for a 100-year planning horizon in accordance with Section 8 of the State Coastal Planning Policy Guidelines;
- A presumption that the special control area will expand landwards over time as sea levels rise;
- Investigation of necessary development controls for the special control area, and the timing or trigger points for inclusion of those controls in the scheme. This would include consideration of:
    - Notifications on title for properties within the special control area which are reviewed and updated over time;

- Policy provisions requiring coastal processes setback for all new development and redevelopment within the special control area, which would facilitate incremental relocation of private development to meet coastal setback requirements; and

- Rezoning of land to development zones that facilitate structure plans to be prepared that identify future foreshore reserve, and provide for the ceding of foreshore reserve with redevelopment of private land. Implementation of this strategy over time can be a challenging undertaking, particularly in areas of fragmented land ownership which can influence structure planning.

The local planning strategy should clearly identify at what point the scheme should incorporate controls on development or redevelopment in vulnerable areas.

The local planning scheme, informed by the strategy, should incorporate the special control area to advise land owners and planners that the area is in a vulnerable coastal area for the long-term (100 year) planning horizon. The extent of development controls included should reflect whether or not intolerable risk will be experienced in the immediate (15-year) planning horizon. If risks are tolerable in the immediate planning horizon, development controls may not be necessary. If risks are considered intolerable in the immediate planning horizon, then controls should be introduced.

The local planning strategy will be a key consultation and communication tool that will engage the community in decision-making, and communicate triggers and timeframes for additional controls of coastal land use to manage coastal risks.

Coastal settlement planning

Whilst SPP 2.6 requires that infill development consider the adaptation planning hierarchy, such infill development may not be subject to the same requirement for setbacks and ceding of foreshore reserves as new development and settlements, particularly where it is not contiguous with the current foreshore reserve. The local planning strategy review should consider the long-term implications of this, and investigate policy measures to provide a consistent approach to new and infill development.

In particular, the local planning strategy review should investigate:

- Policy measures that require infill development and proposals to increase density to be assessed against SPP2.6 as if it were new development;

- Density recommendations to locate increased densities outside the coastal vulnerable area;

- Infrastructure locations and strategies that avoid placing future infrastructure within the physical processes setback and adjacent long-term foreshore reserve, and avoid placing

linear servicing infrastructure (including roads) that run parallel to the coast, therefore potentially becoming a threatened asset in longer-term planning horizons.

The settlement recommendations identified in the local planning strategy review should be incorporated into the local planning scheme at the appropriate time.

4.6 Foreshore management plans

Recommended strategic adaptation measure

The City of Fremantle should prepare foreshore management plans for Bathers Beach, South Beach and the Esplanade reserve to provide an implementation framework for adaptation measures.

Considerations in strategic adaptation measure

Management plans are formal planning documents prepared for areas of Parks and Recreation Reserve under the MRS. These plans provide additional land use controls regarding appropriate development within the reserve, and also provide a tool to prioritise management activities.

Management plans should be prepared for South Beach, Bathers Beach, and the Esplanade reserve. Plans should be prepared by the City and adopted by the WAPC as management plans under the MRS. The plans will then form the statutory planning framework for all development within the foreshore reserve.

The foreshore management plans will be a key tool for communication and engagement with the community as they include detailed planning for community places and facilities. Therefore, they reflect a key opportunity to encourage awareness of the dynamic nature of the coast, the impermanent nature of coastal development, and how that will influence the future form of these areas.

Key elements to be considered in the foreshore management plans are:

- Identification, prioritisation, and funding of natural coastal and dune management techniques to enhance the ability of the natural system to buffer coastal processes;
- Consideration of sea level rise and coastal risk, defining any relevant trigger points for the reserve and whether there is a need for the relocation or decommissioning of existing assets as required;
- Identification of appropriate, impermanent community facilities to meet demand for coastal infrastructure in the immediate (15-year) planning horizon;
- Policy requirements for development, including:
  - Design life for assets to reflect risk timeframes;

  - Architectural and construction requirements for development to portray a temporary aesthetic – communicating to the community the impermanent nature of facilities;

  - Incorporation of community education, including interpretive signage – to educate the community about the dynamic nature of the coastal zone.

- Coastal interim protection works required in the immediate (15-year) planning horizon, including estimated costs, maintenance responsibility, and impacts on the reserve.

- Provisional coastal interim protection works that may be required in the long-term (up to 100 year) planning horizon, including costs and impacts on the reserve, to engage the community in future strategic planning cycles to test values and confirm adaptation options for these locations over time.

The level of information to be included in foreshore management plans – in particular related to detailed erosion and inundation modelling – will be dependent on the level of risk, and the timeframe to anticipated trigger points. Foreshore management plans should be reviewed on a five year cycle and updated to reflect changing values and adaptation options in line with future iterations of the City of Fremantle strategic plan.

Esplanade Reserve, Fremantle. This area – within CMU 1 Fishing Boat Harbour - is at risk of increasing storm related inundation in the future.

5. Adaptation measures

To recommend appropriate adaptation measures for the immediate and long-term planning horizons, this adaptation plan has developed, assessed, and prioritised appropriate adaptation options.

Consideration of adaptation options has resulted in recommended decisions on adaptation approaches and measures, for the trigger points anticipated to be experienced in the City of Fremantle. The following trigger points and decisions were analysed for the immediate and long-term planning horizons:

- Trigger 1 (risk tolerable): decision to avoid future development in vulnerable coastal area
- Trigger 2 (increasing likelihood of intolerable risk): decision to avoid and accommodate
- Trigger 3 (risk is intolerable, interim protection may be viable): decision required between interim protection and retreat

Trigger 4 (risk is intolerable, protection is not viable) is not anticipated in the current long-term planning horizon within the City of Fremantle. However, this should be confirmed in future planning horizons.

5.1 Developing adaptation measures

Avoid

Avoid measures involve avoiding the location of new development in an area of coastal vulnerability. This does not preclude the use and enjoyment of the coast; however it avoids locating future development in an area that would experience intolerable risk, at some stage during the life of that development. Strategies associated with avoid measures are set out in Section 4.

Managed retreat

Managed retreat means relocating assets outside the area of risk, to allow land at risk to naturally experience erosion and/or inundation. Retreat can be on a small scale, for example relocating a car park within a large foreshore reserve to an area outside immediate risk. In the long-term, retreat strategies can occur on a significant scale, for example the expansion and remediation of the foreshore reserve, which requires the relocation of infrastructure (such as road, rail, and sewer) and inclusion of private land within the expanding foreshore reserve. Large-scale strategic retreat will require coordination and partnership across state and local government. A potential model to deliver these outcomes is provided in Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project – Stage 3 Report Coastal Adaptation Plan (GHD, 2016).

Accommodation measures

Accommodation measures are asset specific activities that enable an asset to continue to operate whist being affected by coastal impacts. In the face of erosion, this includes measures to accommodate increased risk, such as dune revegetation to reduce the immediate impact of wave erosion. In relation to inundation, this includes measures to enable an asset to manage occasional flooding, such as flood gates on buildings and emergency management plans.

Key accommodation measures are presented in section 5.7.

Flood gates on heritage properties are a common inundation accommodation treatment in the United Kingdom

Interim protection measures

The role of coastal interim protection is to reduce the risks associated with the coastal hazards of erosion and inundation to land and assets. Engineering measures suitable to protect against these hazards can involve either soft or hard and passive or active engineering approaches. Descriptions and examples of these approaches are shown in Table 4.

Table 4 Interim protection measures

Approach	Description	Examples
Soft – Passive	Foreshore protection works that offer benefits to erosion and inundation but do not involve construction of structures and do not directly affect coastal processes.	Sand nourishment and dune stabilisation
Hard – Passive	Foreshore protection works that involve the construction of structures which alter the coastal processes that act on the land/beach with the intention to maintain or improve beach amenity through retention of sand.	Groynes and offshore breakwaters
Hard – Active	Works that involve the construction of structures which offer a source of protection to landside assets in proximity to the foreshore. The construction of hard active engineering measures can alter the way coastal processes act on the land/beach interface. These changes to the shape of the land (e.g. erosion of a beach in front of a seawall) can have implications on land use (e.g. loss of beach amenity).	Seawalls and Levees

* Refer to Cockburn Sound Coastal Adaptation Plan – Adaptation Options Compendium (GHD, 2016) for the definition of foreshore protection examples

Interim protection measures are only considered for implementation at the point where coastal assets are deemed to be reaching intolerable risk (i.e. at trigger point 3, refer section 3.2) during the near term planning horizon. This is based on the present land use, its consequence category and whether the relevant intolerable likelihood event crosses the land use area (i.e. beyond the beach / dune zone).

Offshore breakwaters and groynes are examples of hard passive interim protection measures. This groyne example (bottom picture) is made from geotextiles. Groynes can also be constructed from rocks to extend their design life. Offshore breakwaters can interrupt open views of the ocean, and groynes can create a barrier along the beach.

Sea walls are an example of hard active interim protection measures. Designed well, they can integrate well into the development of beach amenities, although they can exacerbate erosion (beach loss) in front of the wall over time if ongoing sand nourishment is not undertaken.

5.2 Assessing the available adaptation measures

A full description of the measure evaluation process is set out in Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project – Stage 3 Report Coastal Adaptation Plan (GHD, 2016) which accompanies this adaptation plan. The following sections provide a summary to inform the recommendations presented in this adaptation plan.

Triggers 1 and 2

Where triggers 1 or 2 are anticipated to occur in the immediate or long-term planning horizons, avoid and accommodation measures are considered appropriate for implementation.

Soft – passive protection measures, including reactive beach nourishment to major storm events, in the short-to-medium-term (subject to the availability of materials) is also considered as a management tool available to replenish beaches, and slow down the loss of land from erosion processes.

Trigger 3

The option analysis (including but not limited to financial costs) for trigger point 3 compared the following options:

- Retreat when risk becomes unacceptable; and
- Interim protection incorporating a range of options for short to long-term protection measures that delay retreat for the life of the structure (until the next trigger point is reached, be it another trigger point 3 or trigger point 4).

Accordingly, the purpose of the option evaluation process is to compare the costs and benefits of retreat to one or more interim protection measures for each coastal management unit.

The technique known as multi-criteria decision analysis (MCDA) was used to make these comparisons. The results of the MCDA, including the sensitivity analysis, are set out in Appendix B.

5.3 Decisions in the immediate planning horizon (to 2030)

Management Units 1 – Fishing Boat Harbour and 2 – South Beach

The vulnerability assessment and risk mapping (refer Appendix A), undertaken in the previous stages of this work identified areas in the City of Fremantle which are currently vulnerable to inundation and erosion. However an intolerable risk level (representing a trigger point 3 or 4) is not expected to be reached in the immediate planning horizon (15-years). Therefore no immediate decision between retreat and interim protection is required in the current planning horizon.

Adaptation in the immediate planning horizon relates to trigger points 1 and 2, and the following should be implemented:

Trigger point 1 (development in vulnerable coastal area; risk is tolerable)

- Monitor values and risk
- Advise land and asset owners of increasing risk over time
- Deliver the strategic planning framework discussed in Section 4

Trigger point 2 (increasing likelihood of event presenting intolerable risk)

- Responsive beach nourishment to erosion events at Bathers Beach and South Beach
- Dune management and revegetation
- Other accommodation measures listed in section 5.7.

Continued dune management and revegetation are an important short term adaptation measure for South Beach and Bathers Beach

5.4 Future decisions in the long-term planning horizon (post-2030)

Risk mapping suggests that trigger point 3 (risk is intolerable, interim protection may be viable), at which point a decision is required to either implement interim protection or retreat, will not occur until well into the future. Therefore, that decision should be made closer to the time of the trigger point, in line with the flexible, trigger-based adaptation approach. This will enable a decision based on the values at the time the trigger point is reached.

To gain a sense of what the future might look like at the time of trigger point 3, MCDA results provide a provisional recommendation of what decision might be made. This information should only be considered as provisional, and a future, actual decision will depend on:

- an ongoing risk assessment;
- the cost and technical feasibility of these and other measures that might be identified in future;
- future developments proposed in the area; and
- any changing attitudes to appropriate measures to address sea level rise in general and in these location specifically.

Coastal Management Unit 1 – Fishing Boat Harbour

Risk profile

The built nature of the coastline in Coastal Management Unit 1 – Fishing Boat Harbour (CMU 1) entails that erosion is unlikely to affect the majority of the shoreline except for the small sandy beach area of Bathers Beach. However, the coastal hazard assessment (Coastal Zone Management Pty Ltd et al, 2013) does not indicate Bathers Beach to be an area with a major erosion hazard. Although it can be expected that there will be beach loss as a result of sea level rise.

The coastal hazard assessment (Coastal Zone Management Pty Ltd et al, 2013) identifies CMU 1 – Fishing Boat Harbour as becoming increasingly vulnerable to inundation from coastal actions. The vulnerability mapping showed that the risk associated with inundation will likely become intolerable before 2070, refer Appendix A (BMT Oceanica Pty Ltd, 2014). This will likely require a decision between retreat and appropriate interim protection measures in the planning horizon leading up to 2070.

Interim protection measures

Due to the modified nature of the shoreline in the Fremantle harbour areas, protection measures will typically require the addition of further hard-active engineering approaches applied along long stretches of existing infrastructure.

Three preliminary protection measures were considered for assessment and comparison to retreat in the MCDA process, which are listed below. These options are similar, but represent potential protection measures that will protect the coastline and particular assets in slightly different ways. Option 1 and 2 offer two longer-term methods of protecting assets on the ocean side of the railway. Option 2 will come at a lower cost but will not provide protection from intermittent flooding of the harbour areas during extreme events which may become more frequent in the future. In consideration of these options, feasibility and costs associated with relocation or alteration of services and the cost associated with any change to the rail track are not considered.

Option 1	Initial stage (2070) – Build flood levees along rail road route, including road – Raise revetments/breakwater along South Mole Fremantle – Install one way valves (flap or duck) on ocean stormwater outfall pipes Later stage (2110) – Install armoured flood levee at Bathers Beach – Upgrade breakwaters and harbour edge (Fishing Boat Harbour) – Land reclamation, upgrade wharf structures and increase levels
Option 2	Initial stage (2070) – Build flood levees along rail road route, including road – Raise revetments/breakwater along South Mole Fremantle – Install one way valves (flap or duck) on ocean stormwater outfall pipes Later stage (2110) – Install armoured flood levee at Bathers Beach
Option 3	Initial stage (2070) – Tidal barriers to Fishing Boat Harbour (x2) – Build flood levees along rail road route, including road – Install one way valves (flap or duck) on ocean stormwater outfall pipes Later stage (2110) – Upgrade breakwaters and harbour edge (Fishing Boat Harbour)

Cost of measures

The cost estimates for the protection options are summarised in Table 5. The basis for costing the protection options is described fully in Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project – Stage 3 Report Coastal Adaptation Plan (GHD, 2016).

Table 5 CMU1 – Fishing Boat Harbour Works Cost Estimates

	Option 1			Option 2			Option 3		
Timing	Capital ($k)	Annual ($k)	Decom ($k)	Capital ($k)	Annual ($k)	Decom ($k)	Capital ($k)	Annual ($k)	Decom ($k)
Present	-			-			-		
2070	18,746	94		18,746	94		39,065	781	
2110	240,420	677	66,223	2,808	29	14,645	31,200	156	82,133

Provisional adaptation recommendation

MCDA results suggest that interim protection – at the time of the trigger point – may be the appropriate decision over retreat within CMU 1 – Fishing Boat Harbour, based on assumed values (criteria weightings) for the current planning horizon. The MCDA should be repeated prior to the trigger point to confirm if this decision is viable at the time of the trigger.

Of the hard-active interim protection measures proposed, Option 2 was identified as the highest ranked option through the MCDA process.

In reviewing the sensitivity (and therefore reliability) of the outcome, Option 3 ranked second in the MCDA, and would become the preferred option if the weightings for criteria associated with protection costs and/or residual risk to property were varied slightly. Option 1 was only separated from Option 3 by cost. The decision between retreat and the protection options was not sensitive to weightings.

Based on MCDA results, it appears that the nature of the coastline and land in CMU 1 – Fishing Boat Harbour warrants the implementation of interim protection, the extent of which will be guided by the cost of works and the availability of funding.

A map of the preferred interim protection of Option 2 is included in Appendix C. The preferred option should be reviewed in more detail once risk levels rise closer to an intolerable level.

The preferred protection option entails the construction of a new flood levee, breakwater and outfall upgrades by 2070 with an additional armoured levee installed by 2110 as risk levels further

increase around Bathers Beach. The initial flood levee proposed would consist of artificially constructed fill structures constructed parallel to the shoreline along the railway to regulate water levels and to avoid inundation from storm tides to low lying land behind the levee. The levee would be constructed with a new roadway on top, which would assist to maintain accessibility. There was no cost allocation for the relocation of the railway included in this assessment.

Upgrades to the breakwaters and revetments would assist in reducing storm related inundation by offering a greater protection to assets by reducing overtopping during coastal events and restricting wave run-up and storm surge influencing inundation areas. Upgrades to the storm outfalls would also assist in removing water that could otherwise add to inundation issues.

The later stage, Bathers Beach levee, would consist of an armoured structure which will act as a seawall. This would protect land and assets behind, but may result in a loss of natural beach area.

The final nature of the interim protection works will therefore ultimately depend on the available funding and will need to be scoped accordingly. This should be considered by the City of Fremantle in partnership with the Department of Transport. Coastal protection works may require funding from state government budgets, as many of the assets in this area are state-owned and managed.

Future upgrades to breakwaters of Fishing Boat Harbour can assist in managing storm related coastal inundation.

Coastal Management Unit 2 – South Beach

Risk profile

The coastal hazard assessment (Coastal Zone Management Pty Ltd et al, 2013) indicates that Coastal Management Unit 2 – South Beach (CMU 2) is not an area which is currently or in the future expected to be significantly vulnerable to purely inundation events. However, CMU 2 – South Beach has been identified as becoming increasingly vulnerable to erosion and a loss of beach area from coastal actions and sea level rise. Vulnerability mapping shows that the risk associated with erosion and erosion-related inundation will likely become intolerable before 2070 (refer Appendix A).

This will require a decision between retreat and appropriate interim protection measures in planning horizon leading up to 2070, or as risk becomes intolerable.

Interim protection measures

Two protection options were initially considered for assessment and comparison to retreat in the MCDA process. The options listed below represent conceptual hard-passive and hard-active measures that would offer protection to the coastline and its assets.

Option 1	Initial stage (2070) Install a seawall between the boat harbour and the northern groyne Later stage (2110) Install a seawall between the northern groyne and the southern groyne
Option 2	Initial stage (2070) Upgrade, extend and build new groyne structures Undertake beach nourishment

Cost of options

The cost estimates for the protection options are summarised in Table 6. The basis for costing the protection options is described fully in Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project – Stage 3 Report Coastal Adaptation Plan (GHD, 2016).

Table 6 CMU2 – South Beach Works Cost Estimates

	Option 1			Option 2		
	Capital ($k)	Annual ($k)	Decom ($k)	Capital ($k)	Annual ($k)	Decom ($k)
Present	-			-		
2070	3,640	36		4,160	91	
2110	4,472	45	3,432	-	-	1,160

Provisional adaptation recommendation

MCDA results suggest that interim protection – at the time of the trigger point – may be an appropriate decision over retreat, based on assumed values (criteria weightings) for the current planning horizon. Option 2 was identified as the highest ranked option through the MCDA process ahead of Option 1, and lastly retreat. Preferring a hard-passive protection approach, as outline in Option 2, highlights the high value placed on the coastal assets in this area. A definitive preference indicated that the community is likely to be in favour of capital spending on interim protection measures that could help maintain the recreational beach and reserve areas, as long as viable, while offering some protection to urban assets.

CMU 2 – South Beach has existing coastal protection groynes, which have been built perpendicular to the shoreline and trap sand moving along the coast, causing sand build up on the up-drift side. As depicted in Appendix C, Option 2 proposes implementing improvements to the groynes which could assist in further defending the current shoreline position against erosion. In addition, to reduce the impact of beach inundation, an artificial beach and the back of the beach arrangement should be designed and constructed through beach nourishment to levels that reduce overtopping or flooding of the land area during storm conditions.

Although it was clear that current views and values warrant spending on a hard-passive protection approach, the implementation of this work should be reviewed during the long-term planning horizon prior to the trigger point being reached to confirm if this decision is viable at the time of the trigger.

5.5 Implementation of interim protection

Prior to the construction of coastal engineering protection structures, there are several steps that should be undertaken to develop the basis of design and confirm that the proposed interim protection methods are the most suitable approach from a performance and financial viability perspective. The following steps (as a minimum) are proposed:

1. Develop a data register and acquire long-term information on the Cockburn Sound and near shore site specific locations including: erosion and accretion patterns, wave climate, water levels, sediment processes, bathymetric data and shoreline area surface levels.
2. Review the data register to identify gaps in information required to inform design works.
3. Undertake the required investigations to fill any gaps in the data. This may require installation of data recording devices, survey work and modelling.
4. Develop a basis of design with available information.
5. Develop several concept designs based on the preferred approach to be optimised to confirm the most suitable design.
6. Obtain environmental approvals for the preferred design.
7. Once a final design option has been selected, detailed design and documentation can then be prepared.

The earlier that steps 1 to 3 can be undertaken in advance of any construction works the better informed the design work will be.

Existing interim protection measures, to the south of South Beach.

5.6 Outstanding issues to resolve prior to interim protection

Stormwater contributions to inundation

Future decisions to protect against inundation in CMU 1 should take into account other risks to land and heritage assets in this area from stormwater. The vulnerability assessment undertaken in the 2013 Cockburn Sound Coastal Alliance – Coastal Vulnerability Study Erosion and Inundation Hazard Assessment Report investigated inundation from coastal processes and excluded the effects of the management of land side stormwater, which is likely to add to the inundation risks during an extreme event. If decisions to protect Fremantle's West End are made, then the decision needs to consider how stormwater drainage can be effectively managed. Additional technical investigations are required to fully understand the likely impacts of stormwater in the area, and use this to inform future decision-making.

Groundwater levels and impact on heritage values

Future decisions to protect against inundation in CMU 1 should take into account other risks to land and heritage assets in this area from groundwater levels. It is expected that as sea level rises, there will be an increase in groundwater levels in coastal areas. There are already examples of increased groundwater levels impacting on the basements and foundations of heritage properties in Fremantle's West End. If decisions to protect Fremantle's West End are made on the basis of heritage values, then decisions need to consider how or whether those values can be maintained over time with groundwater impacts. Additional technical investigations are required to understand the likely impacts of groundwater in the area, and use this to inform future decision-making.

Materials availability and cost

The increase in construction and infrastructure development to support the expected population growth of Perth and Peel will increase the demand for basic raw materials including those commonly used in coastal works such as sand, limestone, and hard rock (EPA, 2015). This may limit the supply of suitable materials required for protection options.

Additionally, beach nourishment is proposed for a number of areas across the Owen Anchorage and Cockburn Sound in order to maintain public beach amenity. This will place a long-term demand on a limited supply. Sand may be sourced at localised accretion locations and from offshore dredging. However, the availability of suitable sources is likely to become increasingly limited in the future.

There are many variables to consider when predicting the potential future availability and cost of coastal protection materials that may be required for a long-term planning horizon. Developing a long-term material resource plan would require a detailed feasibility assessment for the entire Owen Anchorage and Cockburn Sound.

It is recommended that the City of Fremantle, together with the Cockburn Sound Coastal Alliance undertakes a study of the current and potential sources of materials suitable for coastal protection

works and any potential environmental impacts of their sourcing in order to adequately plan for the options identified over the long-term planning horizon. If it is determined that obtaining the required volumes of materials is unlikely, then alternative techniques or pathways may be required.

Environmental impact

The environmental impact of the proposed works on both the shoreline and benthic habitat would need to be established in further studies of the options. This should also include consideration of the impacts of adaptation decisions on neighbouring coastal management units. Potential issues to be resolved would include consultation with affected local government areas - especially if proposed measures were to accelerate a problem elsewhere, how impacts will be measured and monitored, and the reassessment of adaptation options under changed conditions.

5.7 Accommodation measures

Dune management

Proactive coastal management (including dune management and revegetation) will be important so that natural erosion processes are not accelerated by poor quality coastal environments. These management techniques are less of a response to the changing coast and more a management tool to delay the need for interim protection and planning responses.

Local planning policy – inundation mitigation

Local planning policy is an effective tool for the City of Fremantle to provide more detailed guidance for coastal development than is currently provided by state planning policy. If future iterations of the City of Fremantle strategic plan identify that the values of the community do not support interim protection to manage inundation within Fremantle's west end, local planning policy can be explored to determine opportunities to accommodate inundation risks through building design and retrofitting. Informed by greater detail of the likely extent of inundation, design guidelines implemented through local planning policy may enable the continued use and enjoyment of buildings where they are impacted by occasional inundation that is manageable through flood control measures and other building modifications. The policy needs to clearly articulate that inundation risks will increase over time.

Whether the responses of private owners should remain voluntary or be required by regulation (if possible) needs to be considered.

Policy development should include public education of risks associated with coastal living need so that they are better understood. This could be similar to areas of bushfire risk where there is an accepted level of risk and communications regarding preparedness for adverse events.

Building retrofitting

Private land and building owners, who wish to accommodate the risk of inundation rather than retreat, should consider the options available to retrofit their premises to better mitigate the risk of inundation during these extreme events. A number of flood proofing measures are outlined in the Building Code of Australia. When considering the potential accommodation measures available it is important to not only address the potential effects of flooding on the building fabric but also on services, particularly electrical equipment and their cables.

Public infrastructure

Increased risk of inundation also needs to be accommodated by infrastructure owners including roads (local government), electricity, gas, water, wastewater and drainage. It is recommended that government engage with infrastructure providers with assets in the coastal vulnerable zone (and/or proposed special control area) to develop plans for accommodation / protection and eventual removal of their assets over time.

Emergency planning

Emergency safety management plans and suitable forward planning should be maintained to address the risk of rare events and adequately plan for sea level rise, as risk increases over time.

Accommodation measures will be important to manage inundation within Fremantle's West End

5.8 Ocean and shoreline monitoring

As indicated in the 2014 Cockburn Sound Coastal Vulnerability Values and Risk Assessment Study, management of the coast would benefit from ongoing monitoring and interpretation. A list of monitoring and data acquisition/analysis that would be beneficial for coastal management in the City is below.

– The Department of Transport and other state agencies currently undertake monitoring and data collection within the Cockburn Sound. Long-term historic wave and water levels are publically available, as well as coastal surveys, vegetation line mapping, and ongoing scientific studies. Regular review of these data by the City is recommended to allow for trends d that may be affecting their coastline to be identified and to ensure that the information required for the design of coastal structures is readily available.

– Installation of nearshore hydrodynamic instrumentation to collect wave and water level conditions at locations where interim protection is expected to be implemented will enable better calibration and validation of any modelling required.

– Photo monitoring should be undertaken biannually (winter/summer) and during/post significant storm events, in accordance with the methodology recommended by Department of Transport (DaSilva 2012). Visual comparison of site photos provides context for interpretation of the measured profile, vegetation line and bathymetric changes.

– LIDAR survey and aerial photography of the coastline should be repeated on a regular basis (~5 to 10 years). When undertaken, it should be compared with previous datasets to identity coastal trends and interpret coastal management pressures.

– Local tidal stations should be established to record storm water level extremes and monthly mean sea level, to help interpret coastal management pressures, along with annual means (and exceedance levels). A local and global understanding of recorded sea level rise and future projections should also be maintained to inform future studies.

Working with and sharing relevant coastal data with the other members of the Cockburn Sound Coastal Alliance would allow for resources to be pooled and trends across LGA boundaries to be identified.

6. Implementation plan

Key adaptation measures recommended by this adaptation plan are summarised in Table 7, Figure 8 and Figure 9.

In line with the preferred adaptation responses, a range of specific implementation actions will be required over time alongside key strategic planning activities to deliver the trigger based, flexible adaptation approach. Table 8 provides a consolidated list of all recommendations and required actions from across this adaptation plan, for delivery by relevant stakeholders in the immediate planning horizon.

The adaptation plan identifies focus areas/actions for implementation by state government, particularly in relation to policy, expansion of the foreshore reserve (where necessary in the longer term), and major infrastructure. This plan does not bind state government or other stakeholders to the actions, however recognises that long term adaptation requires the support of these key stakeholders. The City of Fremantle, alongside the Cockburn Sound Coastal Alliance, will work closely with the state government and other key stakeholders to deliver the actions necessary to achieve adaptation principles.

Table 7 Summary of coastal vulnerability and preferred adaptation responses

Coastal Management Unit	Coastal Vulnerabilities	Immediate Planning Horizon (to 2030)	Long-term Planning Horizon (to 2110)
CMU 1 – Fishing Boat Harbour	Inundation, with intolerable risk presented to assets leading up to 2070.	Avoid Accommodate	Interim protection (using hard-active engineering measures such as flood levees) may be feasible
CMU 2 – South Beach	Erosion, with intolerable risk presented to assets and a loss of beach area leading up to 2070.	Avoid Accommodate	Interim protection (using hard-passive engineering measures such as groynes or offshore breakwaters) may be feasible

Figure 8 Recommended adaptation measures - Fishing Boat Harbour

Figure 9 Recommended adaptation measures - South Beach

Table 8 Immediate planning horizon – implementation plan

Action	Responsible Agency	Supporting Stakeholders
Strategic Planning Actions		
Determine funding responsibilities and identify opportunities for implementation of coastal adaptation across Western Australian.	Department of Planning	Department of Transport Infrastructure agencies Local government
Review State Planning Policy 2.6 to incorporate additional policy measures to manage development that is a variation to the policy.	Western Australian Planning Commission	Department of Planning City of Fremantle Department of Transport (Facilities Management)
Develop and deliver a community awareness campaign regarding coastal risks and impacts, and the adaptation plan.	City of Fremantle	Department of Planning Department of Transport
Review strategic plan, including significant community awareness and engagement regarding coastal adaptation and values.	City of Fremantle	Fremantle community.
Review local planning strategy, to include investigation of special control area and necessary development controls for the coastal vulnerable areas.	City of Fremantle	Department of Planning Western Australian Planning Commission Land owners and managers
Review local planning scheme to incorporate special control area and development controls as recommended by the local planning strategy review.	City of Fremantle	Department of Planning Western Australian Planning Commission Land owners and managers

Action	Responsible Agency	Supporting Stakeholders
Prepare foreshore management plan for South Beach	City of Fremantle	Department of Planning Western Australian Planning Commission
Prepare foreshore management plan for Bathers Beach	City of Fremantle	Department of Planning Western Australian Planning Commission
Prepare management plan for Esplanade Reserve	City of Fremantle	Department of Planning Western Australian Planning Commission
Prepare local planning policy for inundation mitigation.	City of Fremantle	
Commence dialogue (through advisory groups) with infrastructure owners and managers regarding adaptation plan and coastal risk.	Department of Planning	City of Fremantle
Prepare emergency safety management plan for extreme events.	City of Fremantle	

Action	Responsible Agency	Supporting Stakeholders
Specific adaptation actions – coastal management units		
Monitor risk levels to land and infrastructure within Fishing Boat Harbour	Department of Transport	
Monitor risk levels to land and infrastructure	City of Fremantle	
Provide information to lessees and users within the Fishing Boat Harbour regarding coastal risk and adaptation requirements	Department of Transport	
Provide information to land owners in vulnerable areas regarding increasing coastal risk	City of Fremantle	
Undertake responsive beach nourishment at Bathers Beach and South Beach	City of Fremantle	
Undertake a regular program of dune management and revegetation for South Beach coastal reserve	City of Fremantle	

Action	Responsible Agency	Supporting Stakeholders
Additional investigations		
Undertake modelling of stormwater contributions to inundation in extreme events.	City of Fremantle	Water Corporation Department of Water
Investigate groundwater levels, impacts on heritage values, and possible structural and building mitigation opportunities.	City of Fremantle	Heritage Council of Western Australia Department of Water
Investigate materials availability and cost for all potential long-term coastal protection options across Owen Anchorage and Cockburn Sound.	Cockburn Sound Coastal Alliance	Department of Planning Department of Transport
Undertake strategic environmental impact assessment of cumulative impact of all potential long-term coastal protection options across Owen Anchorage and Cockburn Sound.	Cockburn Sound Coastal Alliance	Department of Planning Department of Transport Department of Parks and Wildllife Environmental Protection Authority
Develop and implement coordinated coastal risk monitoring program.	Cockburn Sound Coastal Alliance	Department of Planning Department of Transport

7. Review framework

7.1 Adaptation plan review

This adaptation plan should be reviewed regularly, alongside the ten-yearly review of the City of Fremantle Strategic Plan. Ongoing liaison with the Cockburn Sound Coastal Alliance should occur to consider opportunities for coordinated review of adaptation plans, particularly if major state planning or infrastructure initiatives are undertaken that would influence decisions beyond local government boundaries (e.g. relocation of the freight rail line over time alters the economic value of the coast in that location, and may result in a different decision).

Review processes should include targeted community and industry consultation to update values and views about coastal development and assets that will be at risk both within a 15-year planning horizon and beyond. Revised values and new learnings should be used to test recommendations of this adaptation plan, and determine whether adaptation strategies for the 15-year planning horizon require modification as a result of changing values.

The regular testing of values and adaptation measures will involve the following actions incorporated into the review of future strategic plans, for land and assets identified as being at risk within 15-years of the strategic plan review:

- Identification of any new or alternative adaptation options based on greater information and new technology;
- Review of criteria used in the multi-criteria assessment;
- Community, stakeholder and industry consultation on the weighting of criteria;
- Review of the weighted scoring of adaptation options;
- Confirmation of adaptation options for a 15-year planning horizon.

7.2 Future hazard assessment

It will be necessary to update the hazard mapping from time to time to reflect actual sea level rise, updated projections of future sea level rise and the response of the coast to changing conditions. These updates should occur as new information becomes available.

It is recommended that the erosion and inundation hazard assessment is updated following the release of the next Intergovernmental Panel for Climate Change (IPCC) assessment report which is expected in 2020/21.

8. References

BMT Oceanica Pty Ltd in conjunction with BMT WBM Pty Ltd, Coastal Zone Management Pty Ltd, SGS Economics and Planning Pty Ltd and Damara WA Pty Ltd (2014) Cockburn Sound Coastal Vulnerability Values and Risk Assessment Study.

Coastal Zone Management Pty Ltd, the UWA School of Environmental Systems Engineering, Damara WA Pty Ltd and Oceanica Consulting Pty Ltd (2013) Cockburn Sound Coastal Alliance – Coastal Vulnerability Study. Erosion and Inundation Hazard Assessment Report.

DaSilva C (2012), How to photo monitor beaches, Coastal Infrastructure, Department of Transport, Fremantle, Australia.

GHD (2016) Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project – Stage 3 Report Coastal Adaptation Plan

GHD (2016) Cockburn Sound Coastal Adaptation Plan – Adaptation Options Compendium

Western Australian Planning Commission and Department of Planning (2010) Local Planning Manual. Western Australian Planning Commission, Perth Australia.

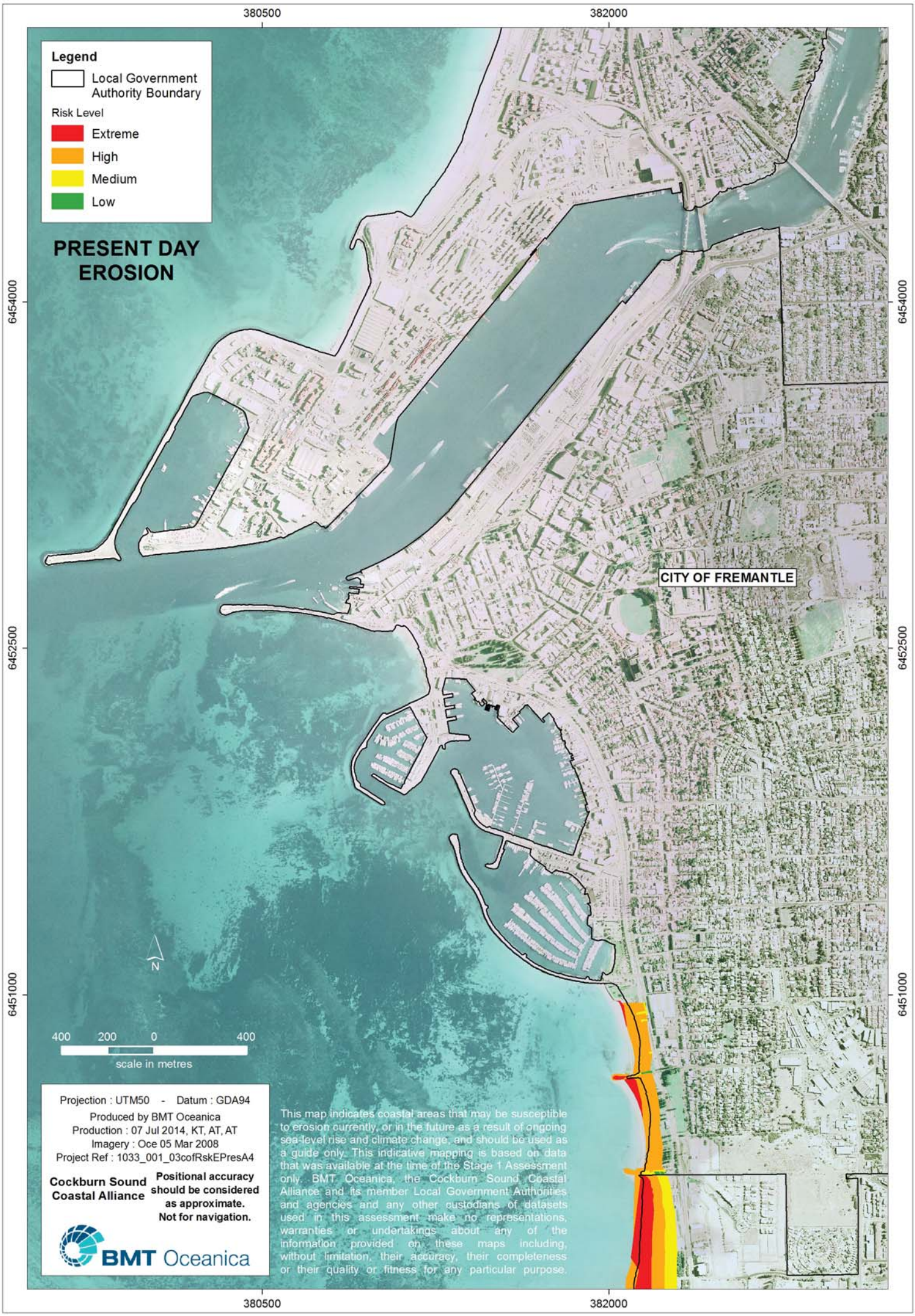
Western Australian Planning Commission (2013) State Planning Policy No. 2.6 State Coastal Planning Policy.

Western Australian Planning Commission and Department of Planning (2014) Coastal hazard risk management and adaptation planning guidelines, Perth Australia.

Appendix A

Coastal hazard mapping

Prepared by BMT Oceanica for the Cockburn Sound Vulnerability Values and Risk Assessment Study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Local Government Authority Boundary
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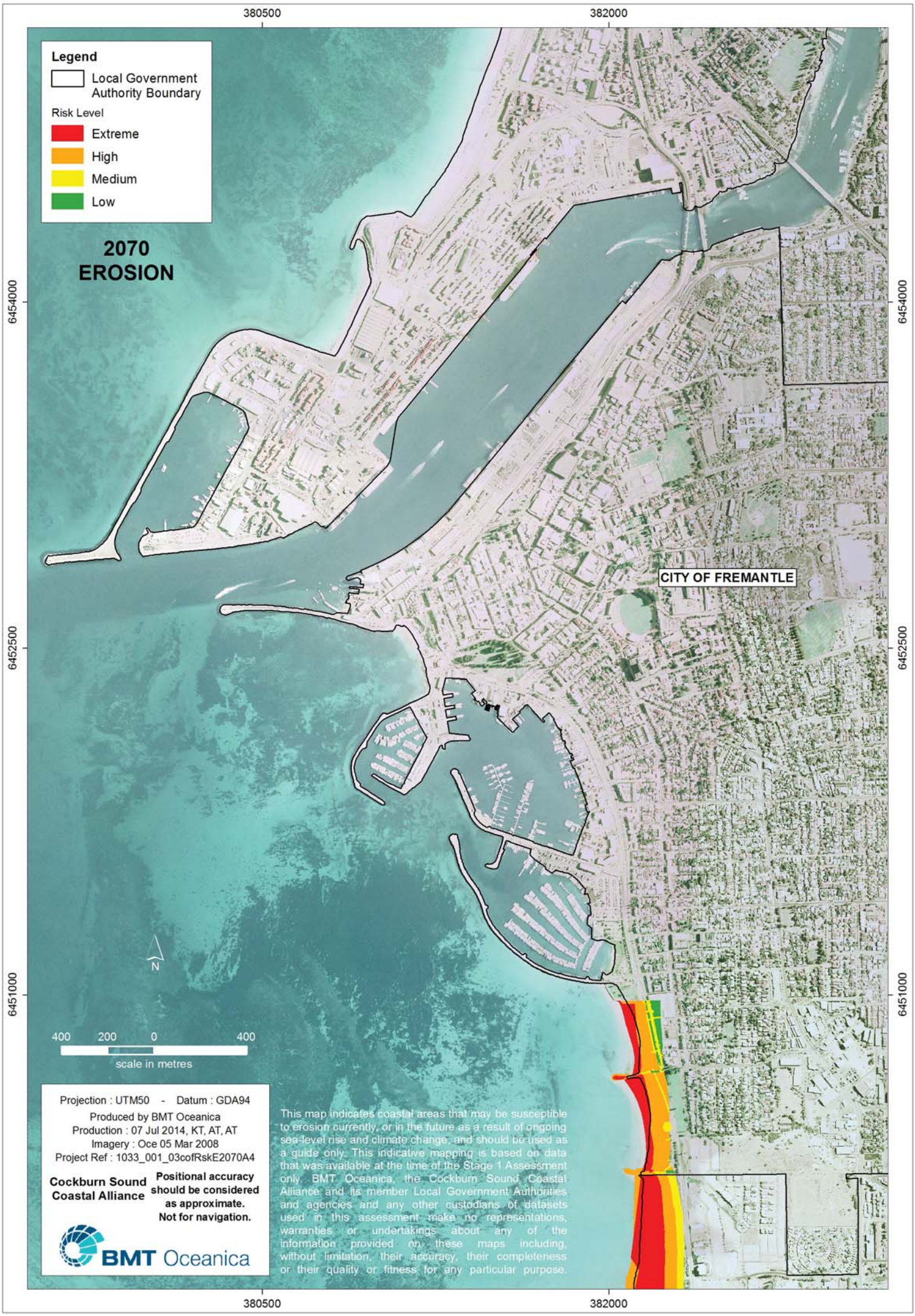
Produced by BMT Oceanica
Production : 07 Jul 2014, KT, AT, AT
Imagery : Oce 05 Mar 2008
Project Ref : 1033_001_03cofRskEPresA4
Cockburn Sound Coastal Alliance
Positional accuracy should be considered as approximate. Not for navigation.
BMT Oceanica
This map indicates coastal areas that may be susceptible to erosion currently, or in the future as a result of ongoing sea-level rise and climate change, and should be used as a guide only. This indicative mapping is based on data that was available at the time of the Stage 1 Assessment only. BMT Oceanica, the Cockburn Sound Coastal Alliance and its member Local Government Authorities and agencies and any other custodians of datasets used in this assessment make no representations, warranties or undertakings about any of the information provided on these maps including, without limitation, their accuracy, their completeness or their quality or fitness for any particular purpose.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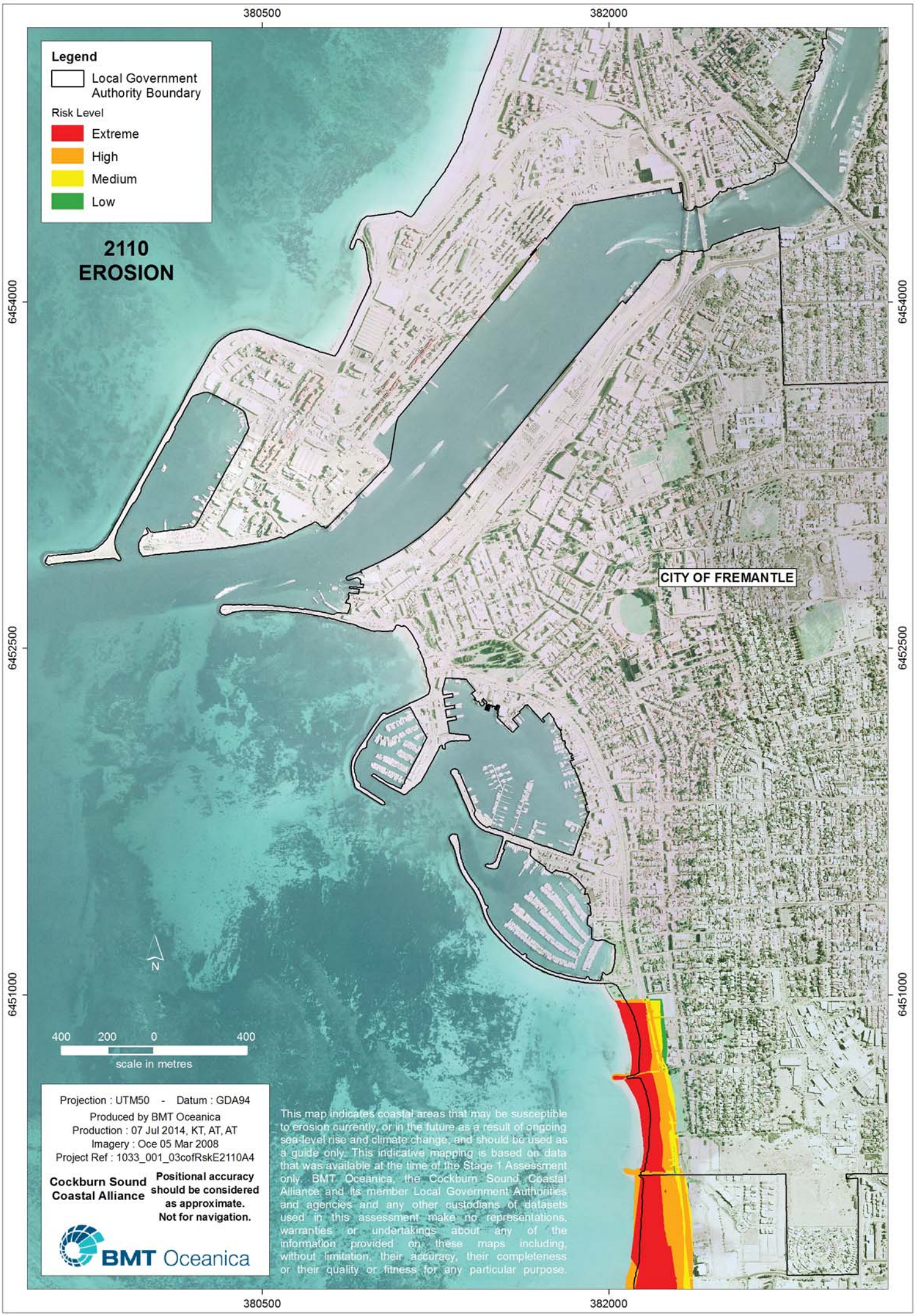
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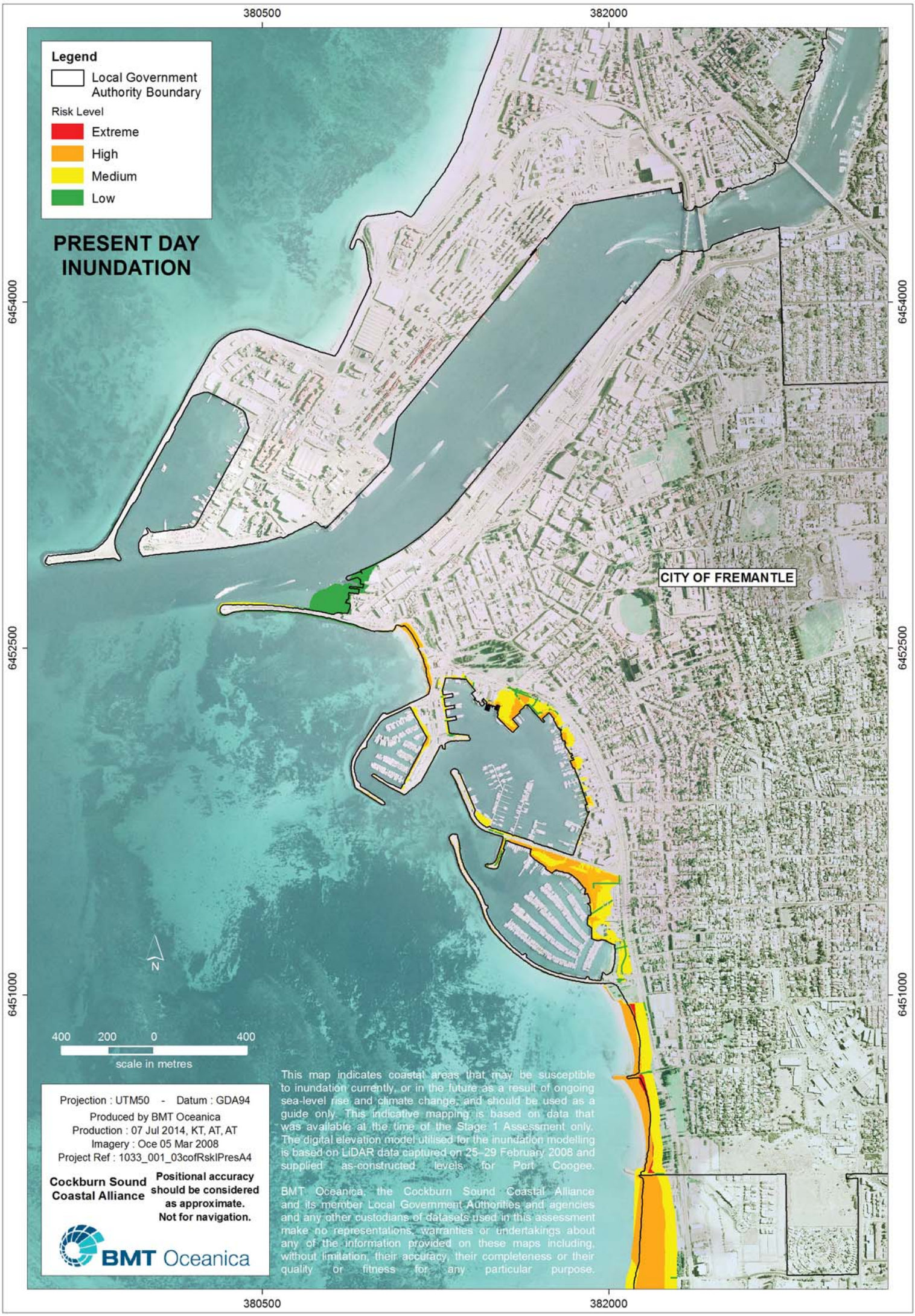
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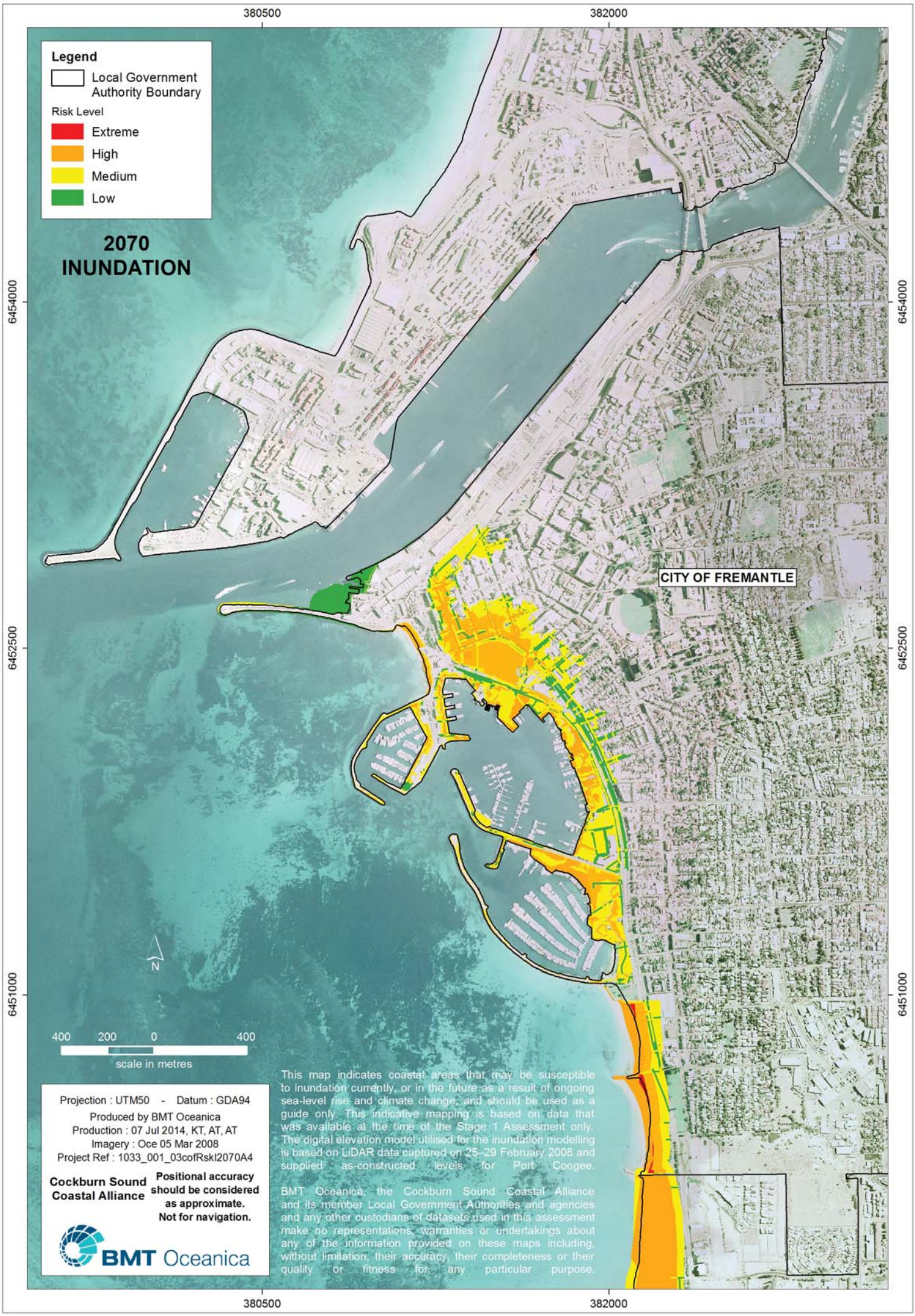
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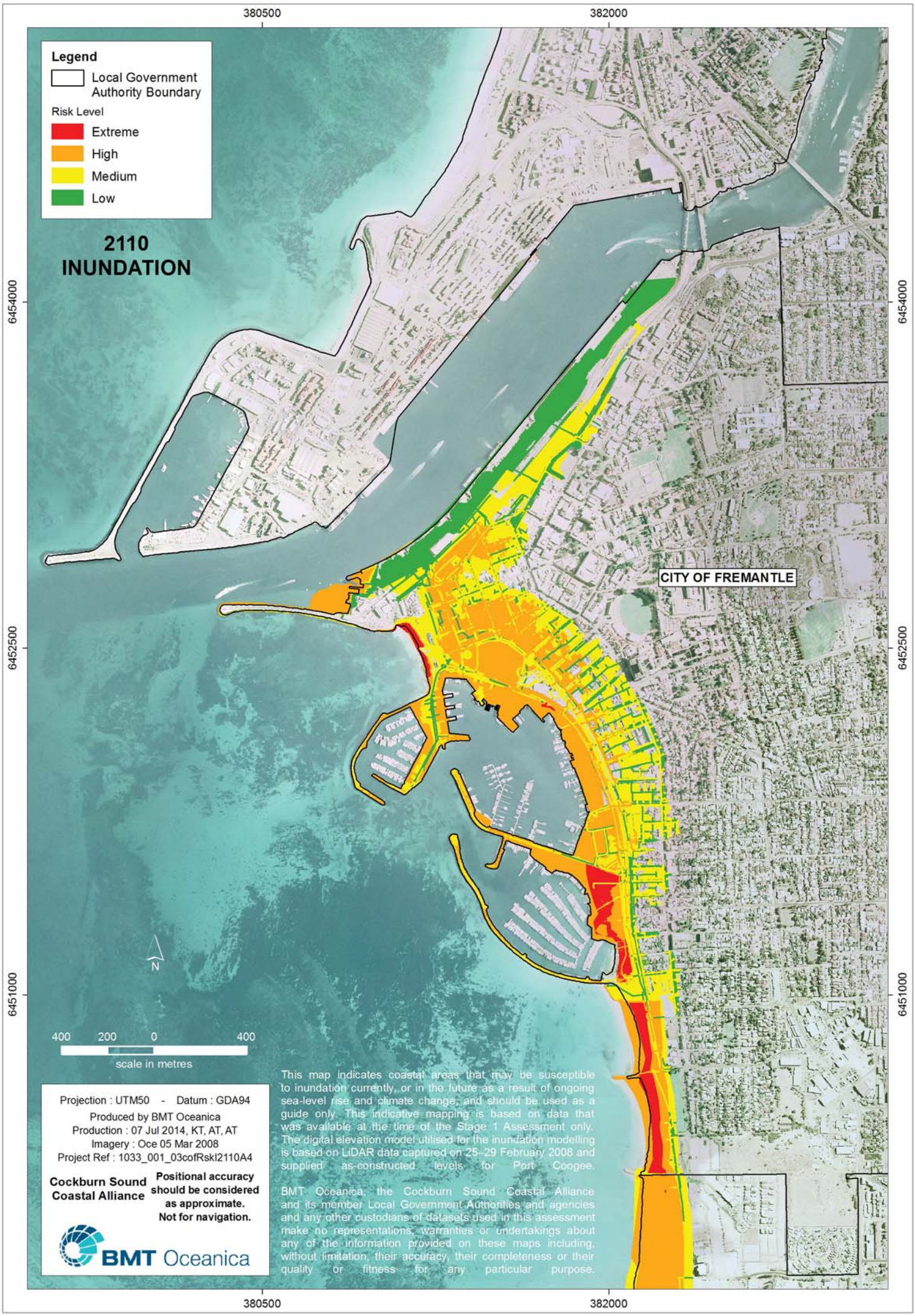
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Appendix B

MCDA results and sensitivity analysis

MCA results and sensitivity analysis

The results of the MCDA and associated sensitivity analysis plots are set out below.

The tables indicate the unweighted and weighted scores for each option.

The sensitivity analysis was carried out using HiView's inbuilt analysis plots.

Sensitivity down plots

The sensitivity down window calculates which criteria weights are sensitive. The criteria are listed down the middle of the screen. Where a change to the cumulative weight of a criterion can result in a new most preferred option, a bar is drawn on the graph. The bars are colour coded. A red bar is very sensitive, a yellow bar is less sensitive and a green bar would require a large weight change to change the most preferred option. The thresholds for colour coding are as follows:

Red - cumulative weight would have to change by 5 points or less in order to change the most preferred option.

Yellow - cumulative weight would have to change by between > 5 to 15 points in order to change the most preferred option.

Green - cumulative weight would have to change by more than 15 points in order to change the most preferred option.

The bars drawn to the left of the criteria list represent a decrease in cumulative weight, whilst the bars drawn to the right represent an increase. For each instance of a bar being drawn, the new most preferred option is displayed at the end of the bar. Where there is no bar, no amount of weight change will change the most preferred option. The sensitivity down window is used to direct further analysis of the model. Where criteria have a red bar, further analysis is a high priority.

Sensitivity up plots

The sensitivity up graph displays the sensitivity of the selected tree item with regard to the most preferred option at the top of the tree.

This graph demonstrates how the most preferred option at the top of the tree varies with the cumulative weight on node selected. The x-axis represents the cumulative weight on the criterion. The y-axis shows the total weighted values, at the root node, of each of the options. The vertical red line shows the current cumulative weight of the selected node. Reading the y-values for each option, these are the same as the total weighted scores in the node data window for the root node. The line for each option shows how this total weighted score will change as the cumulative weight on the criterion changes. The most preferred option at any cumulative weight has the highest y-value. At the vertical red line, whichever line has the highest y-value is currently the most preferred option.

Coastal Management Unit 1

Northern boundary:	South Mole
Southern boundary	North boundary of South Beach
Key assets	Boat Harbours and Heritage Areas

Interim protection options

Option 1: Initial stage (2070)

- Build flood levee along rail road and protect
- Raise revetments/breakwater along South Mole Fremantle
- Install one way valves (Flap or Duck) on ocean storm water outfall pipes

Later stage (2110)

- Armoured flood Levee at Bathers Beach
- Upgrade Breakwaters and Harbour Edge (Fishing Boat Harbours)
- Reclaim Land, upgrade wharf structures and increase levels

Option 2 Initial stage (2070)

- Build flood levee along rail road and protect
- Raise revetments/breakwater along South Mole Fremantle
- Install one way valves (Flap or Duck) on ocean storm water outfall pipes

Later stage (2110)

- Armoured flood Levee at Bathers Beach

Option 3 Initial stage (2070)

- Tidal Barriers to Fishing Boat Marina (x 2)
- Flood Levees along Rail Road route including roads
- Install one way valves (Flap or Duck) on ocean storm water outfall pipes

Later stage (2110)

- Upgrade Breakwaters and Harbour Edge (Fishing Boat Harbours)

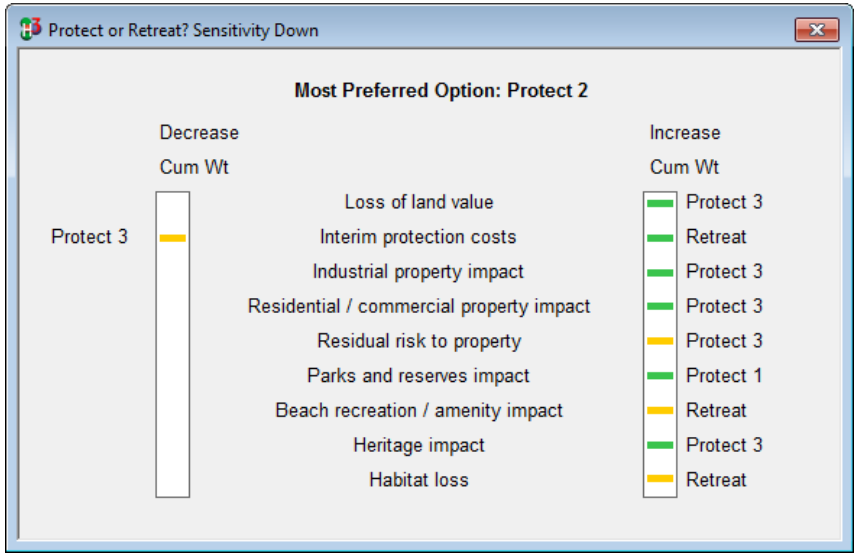
		Raw data						Normalised score				Weight	
		Retreat	Protect 1	Protect 2	Protect 3			Retreat	Protect 1	Protect 2	Protect 3	Nominal	Adjusted
Loss of land value	Discounted cost ($m)	291	70	70	70	177%	R/A	0	100	100	100	0.11	0.05
Interim protection costs	Discounted cost ($m)	0	147	26	100	215%	R/A	100	0	82	32	0.11	0.20
Industrial property impact	No. potential lots affected	0				0%	Ttl lots	0	100	100	100	0.19	0.15
Residential & commercial property impact	No. potential lots affected	682				26%	Ttl lots	0	100	100	100	0.11	0.15
Residual risk to property	Scale of 1-5	1	3	5	3			100	50	0	50	0.07	0.10
Parks and reserves impact	Area (ha)	17				4%	Ttl area	0	100	100	100	0.11	0.00
Beach recreation / amenity impact	m of beach	280				1%	Ttl beach	100	0	0	0	0.15	0.15
Heritage impact	No. of heritage properties affected	22				45%	Ttl props	0	100	100	100	0.04	0.15
Habitat loss	Area (ha)	1.5				1%	Ttl area	100	0	0	0	0.11	0.05
								400	550	582	582	1.00	1.00
					Weighted score			50	55	66	61		
					Rank			4	3	1	2		

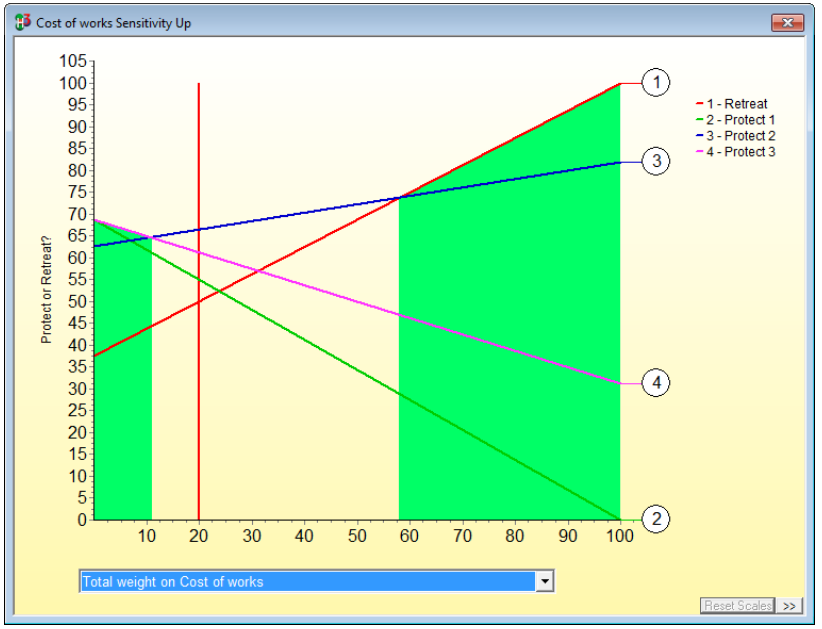
Notes:

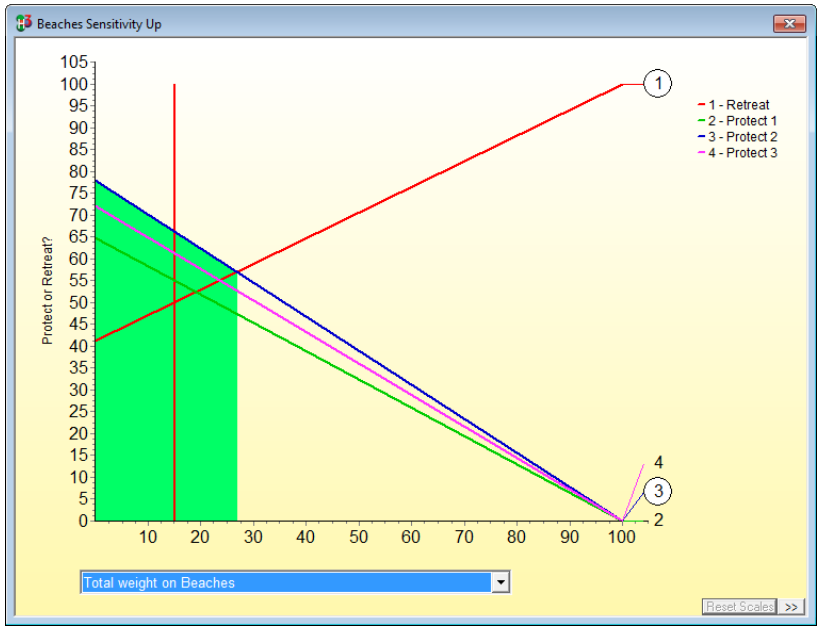
1. Industrial property impact derived from the rail reserve rather than the number of industrial lots

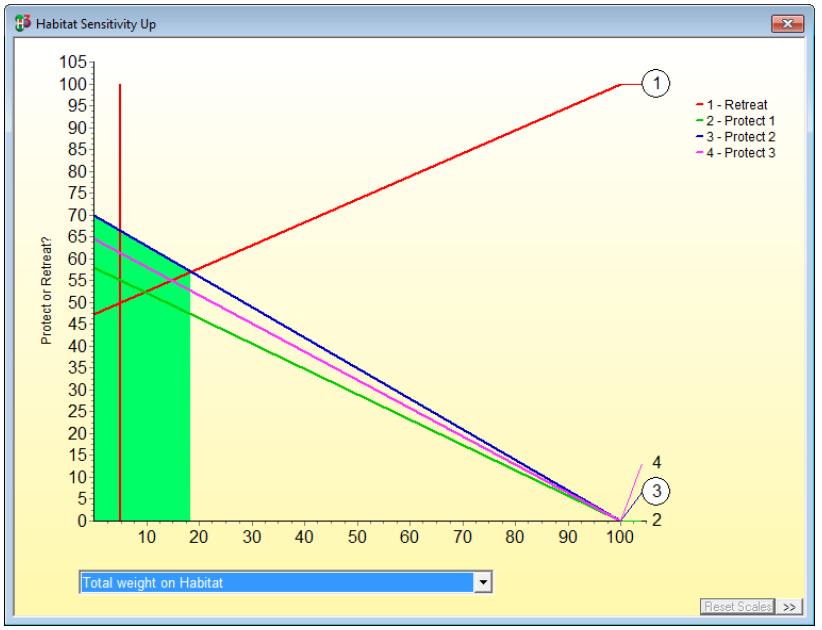
2. Weighting of zero for Parks and reserves assumes that the equivalent area can be retained in the Retreat option.

Sensitivity Analysis









Coastal Management Unit 2

Northern boundary:	North boundary of South Beach
Southern boundary	North boundary Pickled Fig Café
Key assets	South Beach and Heritage Areas

Interim protection options

Option 1: Initial stage (2070)

- Build seawall along the shore

Later stage (2110)

- Extend the seawall

Option 2 Initial stage (2070)

- Upgrade, extend and build new groyne structures
- Place sand and build beach

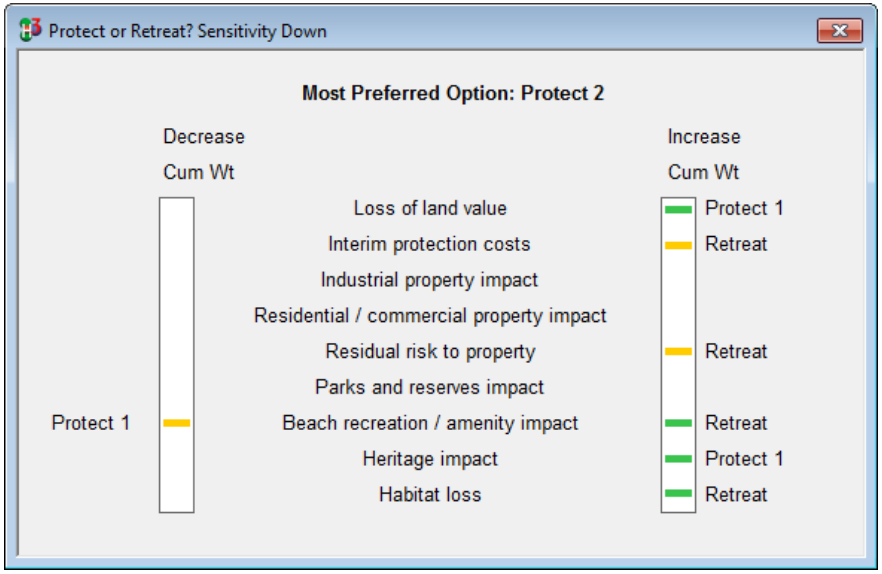
		Raw data						Normalised score				Weight	
		Retreat	Protect 1	Protect 2	Protect 3			Retreat	Protect 1	Protect 2	Protect 3	Nominal	Adjusted
Loss of land value	Discounted cost ($m)	70	17	38		128%	R/A	0	100	61		0.11	0.15
Interim protection costs	Discounted cost ($m)	0	8	7		157%	R/A	100	0	9		0.11	0.15
Industrial property impact	No. potential lots affected	0				0%	Ttl lots	0	100	100		0.19	0.15
Residential & commercial property impact	No. potential lots affected	80				3%	Ttl lots	0	100	100		0.11	0.15
Residual risk to property	Scale of 1-5	1	3	4				100	33	0		0.07	0.10
Parks and reserves impact	Area (ha)	7				2%	Ttl area	0	100	100		0.11	0.00
Beach recreation / amenity impact	m of beach	740				3%	Ttl beach	100	0	100		0.15	0.20
Heritage impact	No. of heritage properties affected	2				4%	Ttl props	0	100	100		0.04	0.05
Habitat loss	Area (ha)	4.8				2%	Ttl area	100	0	50		0.11	0.05
								400	533	620		1.00	1.00
					Weighted score			50	53	68			
					Rank			3	2	1			

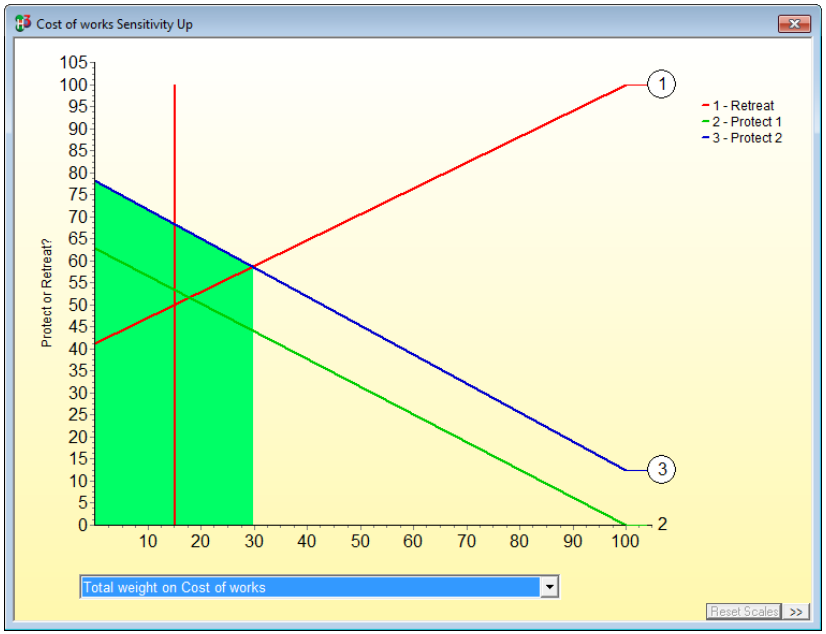
Notes:

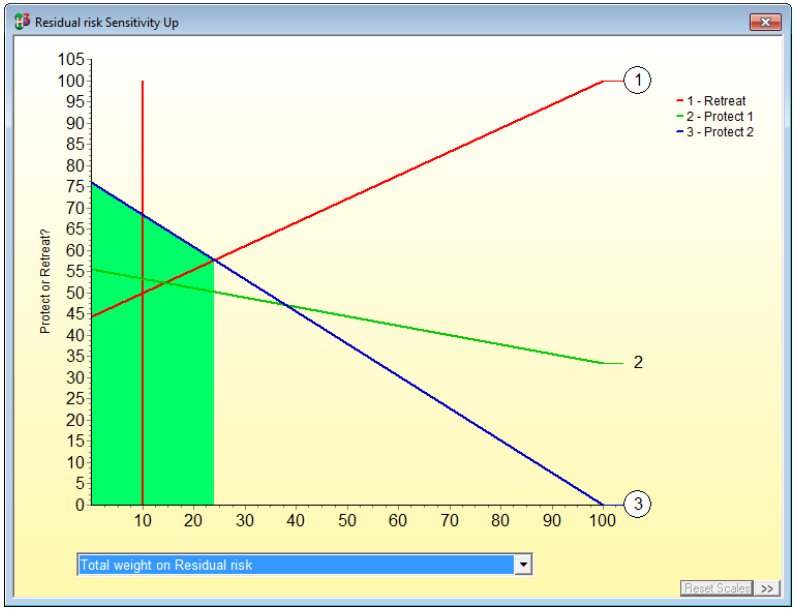
1. Industrial property impact derived from the rail reserve rather than the number of industrial lots

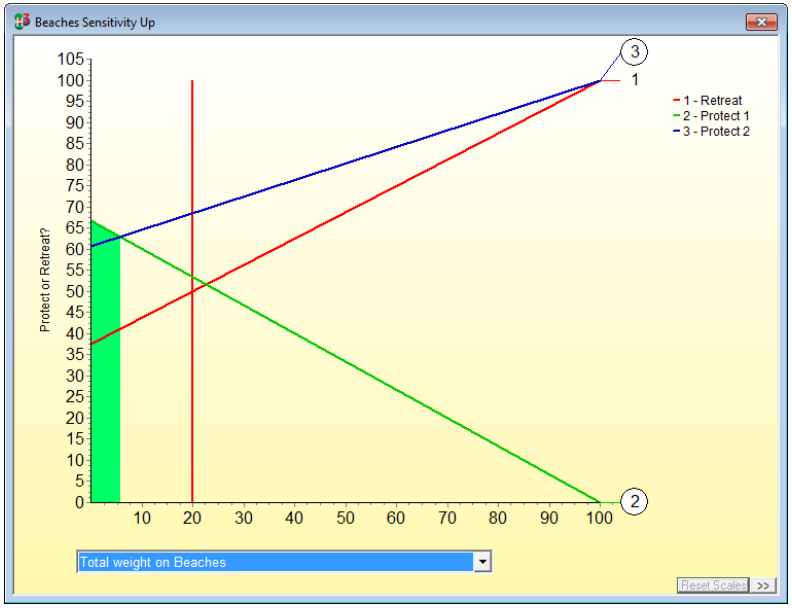
2. Weighting of zero for Parks and reserves assumes that the equivalent area can be retained in the Retreat option.

Sensitivity Analysis









Appendix C

Provisional adaptation measure maps

LEGEND

- Indicative Management Unit Boundary

Protection Works

- Dune Stabilisation
- Breakwater or Groyne (5m high)
- Offshore Breakwater
- Revetment or Seawall (6m High)
- 1.5m Levee - 15m Wide with Road on Top
- Investigate Groyne Modifications
- Beach Nourishment
- Dune Stabilisation
- Raise Ground Levels, Reclaim Land and Upgrade Wharf Structures
- Local Government Area Boundary
- Retreat

Breakwater or Groyne (5m high)
Offshore Breakwater
Revetment or Seawall (6m High)
1.5m Levee - 15m Wide with Road on Top

Cross Section

Paper Size A3

0 50 100 200 300 400 500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

Cockburn Sound Coastal Alliance
Cockburn Sound Coastal Adaptation Plan

Job Number 61-32106
Revision 1
Date 05 Feb 2016

Management Unit 1

Provisional Adaptation Measures

Figure 1

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Data source: Landgate: Imagery (Metro Central Feb 2015); GHD: Indicative Management Unit Boundaries - 20160204, Protection Works - 20151027; ABS: Local government area boundary - 20150416. Created by: mczekaj

LEGEND

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Cross Section

Paper Size A3

0 20 40 80 120 160 200
Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

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Cockburn Sound Coastal Alliance
Cockburn Sound Coastal Adaptation Plan

Job Number 61-32106
Revision 1
Date 05 Feb 2016

Management Unit 2

Provisional Adaptation Measures

Figure 1

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– Bicknell C 2010, Sea Level Change in Western Australia: Application to Coastal Planning, prepared by the Department of Transport,

– WAPC 2013, State Coastal Planning Policy Guideline, prepared by the Western Australian Planning Commission, Perth, WA.

These standards, codes and guidelines take into account potential sea level rise impacts only to the extent indicated by these policies and guidelines.

GHD

999 Hay Street, Perth WA 6000
P.O. Box 3106, Perth WA 6832
T: 61 8 6222 8222 F: 61 8 6222 8555 E: permail@ghd.com.au

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	Colleen Thompson Bill Grace Luke McKenzie Gemma Bertrand Rachel Marie	David Horn		David Horn		24.06.2016

City of Fremantle

Produced by Tangelo Creative (tel: 08 9430 4166) on behalf of economic development and marketing, City of Fremantle. tangelo/COF4174 08/12

Town Hall Centre, 8 William Street
Fremantle WA 6160

PO Box 807, Fremantle WA 6959

T 08 9432 9999 F 08 9430 4634
TTY 08 9432 9777
E info@fremantle.wa.gov.au

www.fremantle.wa.gov.au

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