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Capel to Leschenault CHRMAP

Chapter Report: Risk Treatment

Peron Naturaliste Partnership

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Client	Peron Naturaliste Partnership
Client Project Manager	Craig Perry
Water Technology Project Manager	Joanna Garcia-Webb / Julia Lima
Water Technology Project Director	Chris Beadle
Authors	Joanna Garcia-Webb, Karl Ilich
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Level 1
21 Adelaide Street
Fremantle WA 6160
Telephone (08) 6555 0105
ACN 093 377 283
ABN 60 093 377 283

CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

It is internationally recognised that the mean sea level has been rising globally since the nineteenth century and is predicted to rise at an increasing rate in the future (IPCC 2021). Rising sea levels and intensifying storm activity will increase the risk of coastal inundation (temporary coastal flooding), storm erosion and long-term shoreline recession. State governments across Australia have introduced obligations that require local governments to consider and plan for these hazards. In Western Australia (WA), the governing policy is the Western Australian Planning Commission's (WAPC) State Planning Policy No. 2.6: State Coastal Planning Policy (WAPC, 2013, herein referred to as "SPP2.6"). SPP2.6 recommends that management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) for land use or development potentially vulnerable to coastal hazards. Specific guidelines have been developed to assist in this process (WAPC, 2019).

SPP2.6 requires adequate risk management planning is undertaken where existing or proposed development is in an area at risk of being affected by coastal hazards over the 100-years planning timeframe. SPP2.6 and the CHRMAP Guidelines provide the risk assessment framework to be applied to identify risks that are intolerable to the community, and other stakeholders such as local governments, indigenous and cultural interests, and private enterprise. Risk management measures are then developed according to the adaptation hierarchy outlined in SPP2.6.

The Peron Naturaliste Partnership (PNP) comprises membership of nine local government authorities. The PNP's Coastal Adaptation Pathways Project identified the coastal areas of Capel, Leschenault and Greater Bunbury as being particularly exposed to coastal hazards and climate change, which triggered the need for this CHRMAP. Therefore, the present study aims to investigate the nature and severity of coastal hazards that are likely to affect these regions from Capel to Leschenault over future planning horizons. Refer Figure 1-2 for locality, study area extent and management units.

This CHRMAP project aims to increase knowledge and understanding of coastal hazard risks and identify risk management and adaptation measures for implementation. The outcomes will be used to inform local and state government policies, strategies and plans, including (but not limited to), planning strategies, community strategic plans, drainage strategies, asset management plans, emergency management plans, and foreshore management plans. The project will adhere to the WAPC (2019) guidelines with scope and deliverables to be consistent with the objectives identified by these guidelines and SPP2.6. In addition, the project will identify the strategic direction for coastal adaptation scenarios from the present-day to 2120 (100 yrs. management time frame) and identify an implementation plan to achieve this direction. Overall, this CHRMAP will develop a flexible adaptation pathway for the region and serve as a key reference for management, planning and policy-making for the short-term (0-15 years), medium-term (15-30 years), and long-term (100 years).

Delivery of this project will occur over 9 stages (as summarised Figure 1-1), each of which represents a key hold point. The staged approached is developed according to the PNP's scope and is in line with the CHRMAP Guidelines (WAPC, 2019).

This report presents the Stage G Risk Treatment Chapter Report, which assesses treatment options using Cost Benefit Analysis (CBA). The red bubble displayed in Figure 1-1 outlines Stage G in the context of the CHRMAP.

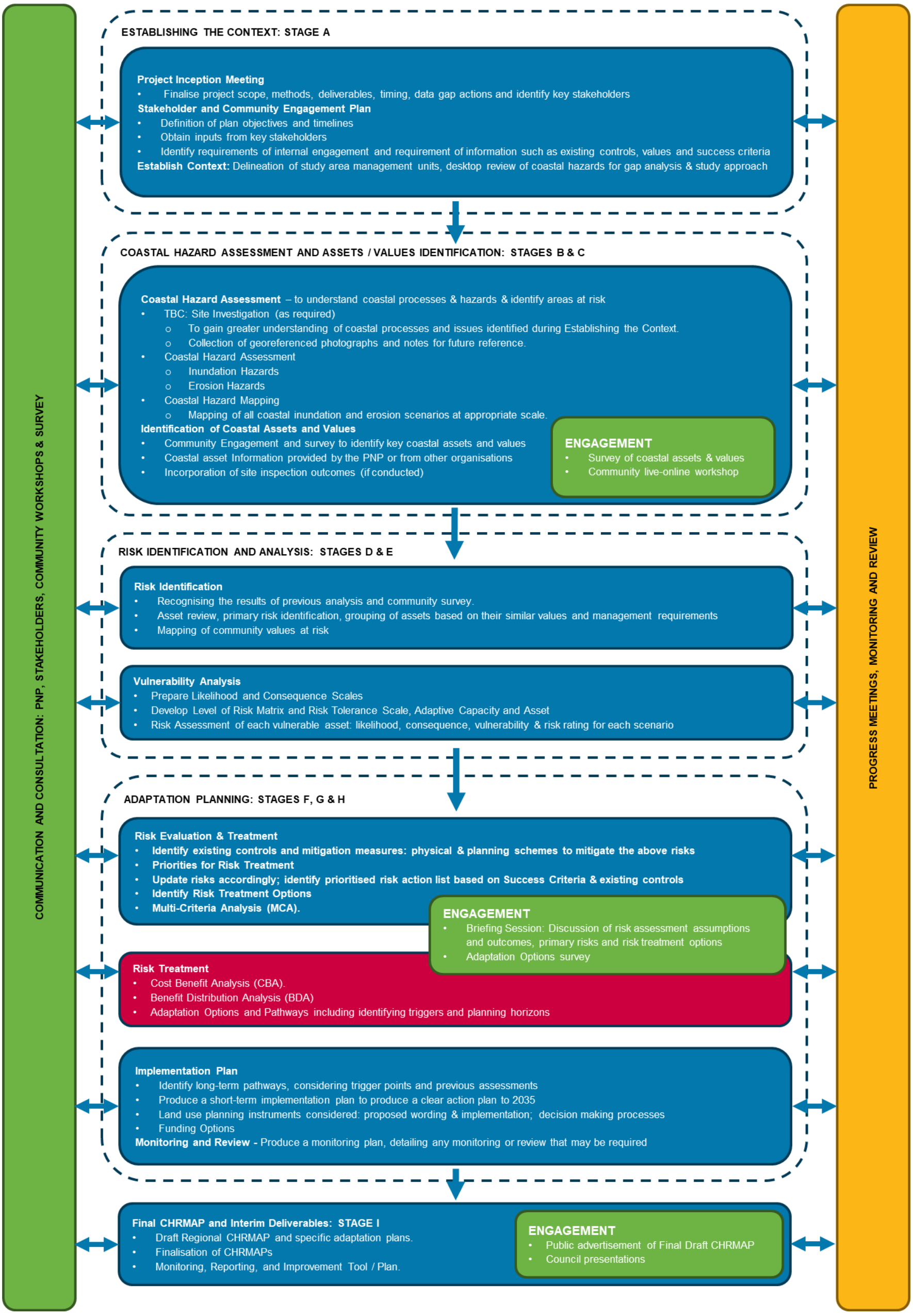

Figure 1-1 Methodology

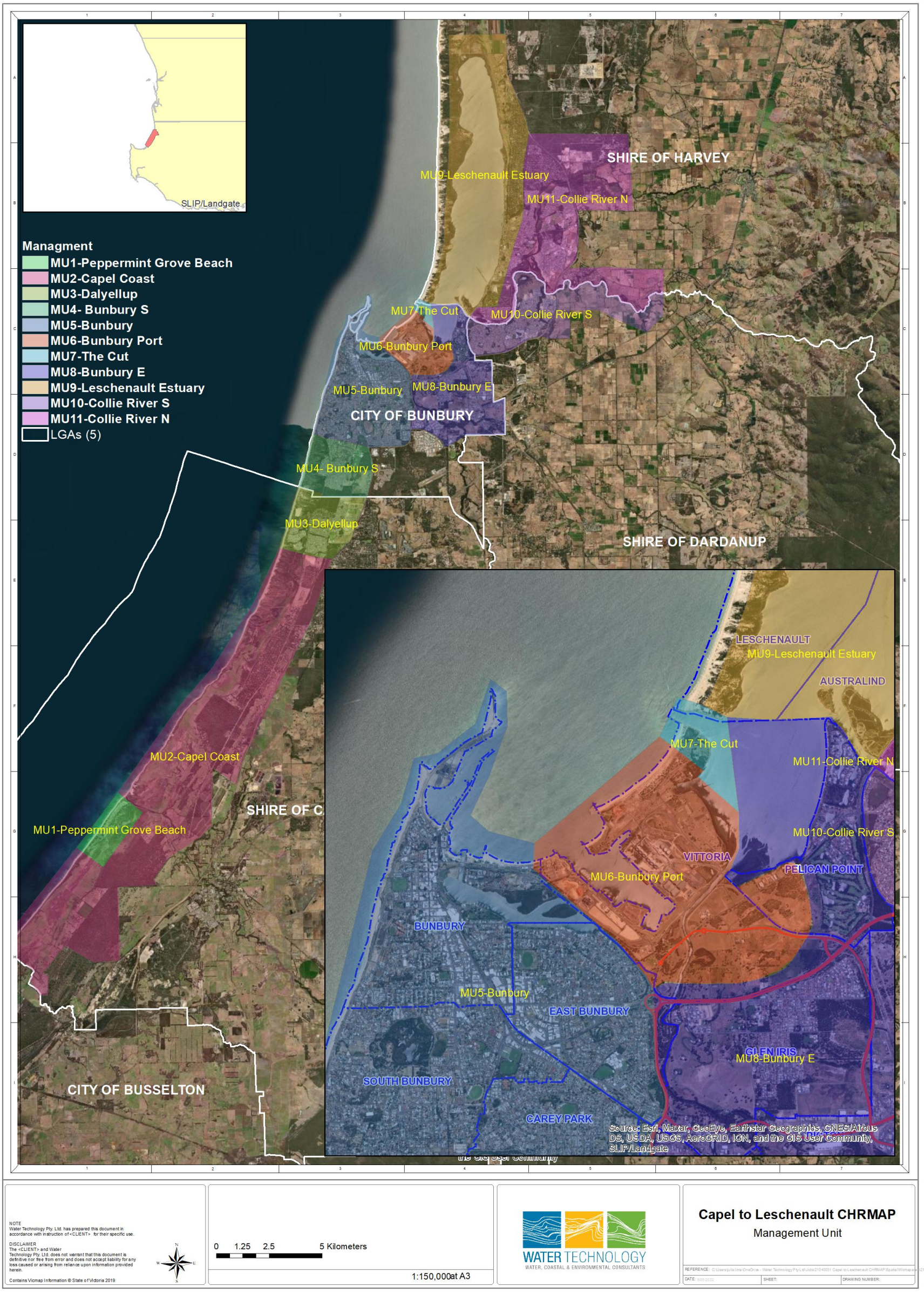

Figure 1-2 Study Area and Management Units (MU)

2 COST BENEFIT ANALYSIS

2.1 Approach

The Cost-Benefit Analysis (CBA) aims to examine the selection of coastal adaptation options through economic analysis. In the previous Chapter Report (Water Technology, 2022), potential coastal adaptation options were assessed against a range of criteria, including cost. This CBA includes coastal adaptation options requiring significant financial investment and scoring positively in the MCA. A rigorous assessment of costs and benefits for each coastal adaptation option will assist with preferential selection and potentially uncover any poor financial assumptions included in the MCA.

While the CBA process assists in contrasting options available "*at the time of the analysis"* and "*for a set of specific assumptions",* it is not the Panacea for decision-making. For instance, changing scientific, environmental and macro-economic considerations can upset cost estimates in the future. Some of the CBA assumptions may not hold true for the long duration often considered in CBA analysis for major infrastructure (CoVID pandemic, technological advances, etc.).

The CBA analysis allows selection of coastal adaptation options which are economically defendable. The CBA has only addressed valuing the loss of assets, managed retreat and physical protection options. Indirect costs that another user might consider to be a loss are not considered in this CBA. For example, costs associated with Special Control Area (SCA) title notifications, emergency planning, and development restrictions were not included in our analysis. Also options selected have been designed to provide similar level of beach and foreshore amenities to the present-day situation. This may not be practical. Possibly, there may be further decisions about coastal amenities management (such as policies, planning decisions, legal proceedings, etc.), guided by community values, which may alter this assumption. In this CBA all coastal adaptation options are designed to provide beach and foreshore amenities into the future.

The cost-benefit of each coastal adaptation option is presented in net present value (NPV) terms. NPV is a standard economic analysis to compare options with time-variable costs and benefits. It allows for the adjustment of all future economic considerations to present-day dollars for a more direct comparison. This relates to the time-value of money, as planned expenses in the future are, in a sense, cheaper than equivalent costs today. This is because the money required for a future expense could be spent elsewhere today to provide value over time (i.e., it can be invested now to generate a return). An expense that occurred today could not be invested elsewhere. In this case, all our cashflows are costs, so options with a lower net present cost are considered better investments from a financial standpoint.

The real discount rate chosen for this project was 4% with sensitivity analyses at 7% and 2%. This decision was based on similar assessments (DPMC, 2016; Transport for NSW, 2022; Baird, 2020; APH, 2018; Abelson and Dalton, 2018), the very long timeframe of analysis, and concerns about valuing future spending so low, which is at odds with resilient coastal planning principles.

The discount rate converts all future costs back to today's dollar value for comparison (in the NPV). For example, a project that costs $10 million today would have an NPV of $10 million. However, a project costing $1 million per year for 10 years would discount to an NPV of roughly $7.5 million discounted at 7%. Similarly, a project with only a single outlay of $10 million in 10 years' time would have an NPV of roughly $5.4 million discounted at 7%. This example shows the importance of when a cost is realised.

The CBA has been performed over a 100-year period, to match the project planning timeframe and meet the requirements of the CHRMAP. It should be noted that the uncertainty around the CBA estimates and assumptions made grows with time. Cost estimates beyond 2040 should be viewed as indicative trends only. Long-term coastal adaptation pathways should be monitored and updated regularly.

2.2 Options Suitable for Cost-Benefit Analysis

The CBA has only addressed options, including practical and economic actions across the planning timeframe. The economic base case used for comparison is calculated by valuing the loss of assets and values in an assumed scenario of inaction rather than "Business As Usual" (BAU). Total inaction is unrealistic in practical terms as emergency management works and obligations of other legislation would require LGAs and State Departments to act when projected coastal erosion and inundation occur. The scenario of economic inaction is also therefore different to the "Do-Nothing" adaptation option which would assume that no actions or management are undertaken by anyone over the planning timeframe, and that hazards and resultant asset loss/damage occurs exactly as the hazard analysis suggests. The adaptation options considered suitable for CBA are summarised in Table 2-1 – managed retreat and physical protection options (e.g., nourishment, groynes, seawalls, artificial reefs, offshore breakwaters, levy/weir/storm-surge-barrier).

Table 2-1 Risk treatment options from WAPC (2019) suitable for CBA. Note PR4 is greyed out as it did not progress through MCA for any MUs.

Option Category	Option Name	Option Code
Planned / Managed Retreat	Voluntary acquisition	PMR4
Protect	Beach nourishment or replenishment	PR1
	Groyne	PR2
	Seawall	PR3
	Artificial reef	PR4
	Offshore breakwater	PR5
	Levy / Weir / Storm Surge Barrier	PR6

2.3 Other Options

The remaining adaptation options from WAPC (2019) are not considered suitable for CBA and have been costed using traditional budgeting techniques for MUs where they received a positive MCA score. Table 2-2 and Table 2-3 provide cost estimates and notes on any scoping details or assumptions.

Table 2-2 Budget cost summary for options not suitable for CBA analysis – MU1 to MU5.

Option	MU1	MU2	MU3	MU4	MU5
Locating assets in areas that will not be vulnerable to coastal hazards (AV)	▪ $100,000 ▪ Item cost for investigations and management plans	▪ $150,000 ▪ Item cost for investigations and management plans	▪ $150,000 ▪ Item cost for investigations and management plans	▪ $150,000 ▪ Item cost for investigations and management plans	▪ $150,000 ▪ Item cost for investigations and management plans
Leaving assets unprotected (PMR1)	▪ $415,000 ▪ To 2035 for low-value public assets ▪ Assumes a clean-up rate following damage/loss ▪ No private land acquisition included ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 3% annual maintenance of $12,450)	▪ $244,000 ▪ To 2035 for low-value public assets ▪ Assumes a clean-up rate following damage/loss ▪ No private land acquisition included ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 3% annual maintenance of $7,320)	▪ $501,000 ▪ To 2035 for low-value public assets ▪ Assumes a clean-up rate following damage/loss ▪ No private land acquisition included ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 3% annual maintenance of $15,030)	▪ $59,000 ▪ To 2035 for low-value public assets ▪ Assumes a clean-up rate following damage/loss ▪ No private land acquisition included ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 3% annual maintenance of $1,770)	▪ $2,011,000 ▪ To 2035 for low-value public assets ▪ Assumes a clean-up rate following damage/loss ▪ No private land acquisition included ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 3% annual maintenance of $60,330)
Demolition / removal / relocation of asset from inside hazard area (PMR2)	▪ $993,000 ▪ To 2035 for public built assets ▪ Allows for removal of building at Wave Walk ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 1% annual maintenance of $9,930)	▪ $537,000 ▪ To 2035 for public built assets ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 1% annual maintenance of $5,370)	▪ $1,102,000 ▪ To 2035 for public built assets ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 1% annual maintenance of $11,020)	▪ $129,000 ▪ To 2035 for public built assets ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 1% annual maintenance of $1,290)	▪ $4,506,000 ▪ To 2035 for public built assets ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 1% annual maintenance of $45,060)
Prevention of further development / prohibit expansion of existing use rights (PMR3)	▪ $100,000 ▪ Item cost for investigations and management plans ▪ (Plus 1% annual maintenance of $1,000)	▪ $100,000 ▪ Item cost for investigations and management plans ▪ (Plus 1% annual maintenance of $1,000)	▪ $100,000 ▪ Item cost for investigations and management plans ▪ (Plus 1% annual maintenance of $1,000)	▪ $50,000 ▪ Item cost for investigations and management plans ▪ (Plus 1% annual maintenance of $1,000)	▪ $100,000 ▪ Item cost for investigations and management plans ▪ (Plus 1% annual maintenance of $1,000)
Design assets to withstand impacts (AC1)	▪ $200,000 ▪ Item cost for investigations and management plans – primarily any case-by-case work needed for public assets ▪ (Plus 1% annual maintenance of $2,000)	▪ $200,000 ▪ Item cost for investigations and management plans – primarily any case-by-case work needed for public assets ▪ (Plus 1% annual maintenance of $2,000)	Not applicable	▪ $150,000 ▪ Item cost for investigations and management plans – primarily any case-by-case work needed for public assets ▪ (Plus 1% annual maintenance of $1,500)	▪ $500,000 ▪ Item cost for investigations and management plans – primarily any case-by-case work needed for public assets ▪ (Plus 1% annual maintenance of $5,000)
Monitoring (NR1)	▪ $20,000 ▪ Beach survey for storm behaviour and to track HSD and inundation levels ▪ (Plus 10% annual maintenance of $2,000)	▪ $20,000 ▪ Beach survey for storm behaviour and to track HSD and inundation levels ▪ (Plus 10% annual maintenance of $2,000)	▪ $20,000 ▪ Beach survey for storm behaviour and to track HSD and inundation levels ▪ (Plus 10% annual maintenance of $2,000)	▪ $20,000 ▪ Beach survey for storm behaviour and to track HSD and inundation levels ▪ (Plus 10% annual maintenance of $2,000)	▪ $30,000 ▪ Beach survey for storm behaviour and to track HSD and inundation levels ▪ (Plus 10% annual maintenance of $3,000)
Protection Structure Audit (NR2)	Not applicable	Not applicable	Not applicable	Not applicable	▪ $75,000 ▪ Item cost to inspect condition, influence on sediment transport and inundation and remaining design life on all coastal management structures ▪ (Plus 2% annual maintenance of $1,500)

Option	MU1	MU2	MU3	MU4	MU5
Notification on title (NR3)	▪ $250,000 ▪ Item cost for investigations and implementation plans ▪ (Plus 1% annual maintenance of $2,500)	▪ $250,000 ▪ Item cost for investigations and implementation plans ▪ (Plus 1% annual maintenance of $2,500)	▪ $250,000 ▪ Item cost for investigations and implementation plans ▪ (Plus 1% annual maintenance of $2,500)	▪ $50,000 ▪ Item cost for investigations and implementation plans ▪ (Plus 1% annual maintenance of $500)	▪ $250,000 ▪ Item cost for investigations and implementation plans ▪ (Plus 1% annual maintenance of $2,500)
Emergency evacuation plans (NR4)	▪ $250,000 ▪ Item cost for investigations and evacuation plans ▪ (Plus 1% annual maintenance of $2,500)	▪ $250,000 ▪ Item cost for investigations and evacuation plans ▪ (Plus 1% annual maintenance of $2,500)	Not applicable	Not applicable	▪ $250,000 ▪ Item cost for investigations and evacuation plans ▪ (Plus 1% annual maintenance of $2,500)

Table 2-3 **Budget cost summary for options not suitable for CBA analysis – MU6 to MU11**

Option	MU6	MU7	MU8	MU9	MU10	MU11
Locating assets in areas that will not be vulnerable to coastal hazards (AV)	▪ $50,000 ▪ Item cost for investigations and management plans	▪ $50,000 ▪ Item cost for investigations and management plans	▪ $100,000 ▪ Item cost for investigations and management plans	▪ $150,000 ▪ Item cost for investigations and management plans	▪ $150,000 ▪ Item cost for investigations and management plans	▪ $150,000 ▪ Item cost for investigations and management plans
Leaving assets unprotected (PMR1)	▪ $360,000 ▪ To 2035 for low-value public assets ▪ Assumes a clean-up rate following damage/loss ▪ No private land acquisition included ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 3% annual maintenance of $10,800)	▪ $88,000 ▪ To 2035 for low-value public assets ▪ Assumes a clean-up rate following damage/loss ▪ No private land acquisition included ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 3% annual maintenance of $2,640)	▪ $111,000 ▪ To 2035 for low-value public assets ▪ Assumes a clean-up rate following damage/loss ▪ No private land acquisition included ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 3% annual maintenance of $3,330)	▪ $351,000 ▪ To 2035 for low-value public assets ▪ Assumes a clean-up rate following damage/loss ▪ No private land acquisition included ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 3% annual maintenance of $10,530)	▪ $44,000 ▪ To 2035 for low-value public assets ▪ Assumes a clean-up rate following damage/loss ▪ No private land acquisition included ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 3% annual maintenance of $1,320)	▪ $44,000 ▪ To 2035 for low-value public assets ▪ Assumes a clean-up rate following damage/loss ▪ No private land acquisition included ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 3% annual maintenance of $1,320)
Demolition / removal / relocation of asset from inside hazard area (PMR2)	▪ $791,000 ▪ To 2035 for public built assets ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 1% annual maintenance of $7,910)	▪ $194,000 ▪ To 2035 for public built assets ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 1% annual maintenance of $1,940)	▪ $244,000 ▪ To 2035 for public built assets ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 1% annual maintenance of $2,440)	▪ $853,000 ▪ To 2035 for public built assets ▪ Allows for removal of building – Leschenault Discovery Centre on Old Coast Road ▪ Maintenance assumes ongoing allowance for foreshore reserve ▪ (Plus 1% annual maintenance of $8,530)	▪ $97,000 ▪ To 2035 for public built assets ▪ Maintenance assumes ongoing allowance for reserve along riverbank ▪ (Plus 1% annual maintenance of $970)	▪ $97,000 ▪ To 2035 for public built assets ▪ Maintenance assumes ongoing allowance for reserve along riverbank ▪ (Plus 1% annual maintenance of $970)
Prevention of further development / prohibit expansion of existing use rights (PMR3)	▪ $30,000 ▪ Item cost for investigations and management plans ▪ (Plus 1% annual maintenance of $300)	Not applicable	▪ $100,000 ▪ Item cost for investigations and management plans ▪ (Plus 1% annual maintenance of $1,000)	▪ $150,000 ▪ Item cost for investigations and management plans ▪ (Plus 1% annual maintenance of $1,500)	▪ $250,000 ▪ Item cost for investigations and management plans ▪ (Plus 1% annual maintenance of $2,500)	▪ $100,000 ▪ Item cost for investigations and management plans ▪ (Plus 1% annual maintenance of $1,000)

Option	MU6	MU7	MU8	MU9	MU10	MU11
Design assets to withstand impacts (AC1)	▪ $100,000 ▪ Item cost for investigations and management plans – primarily any case-by-case work needed for public assets ▪ (Plus 1% annual maintenance of $1,000)	▪ $50,000 ▪ Item cost for investigations and management plans – primarily any case-by-case work needed for public assets ▪ (Plus 1% annual maintenance of $500)	▪ $500,000 ▪ Item cost for investigations and management plans – primarily any case-by-case work needed for public assets ▪ (Plus 1% annual maintenance of $5,000)	▪ $500,000 ▪ Item cost for investigations and management plans – primarily any case-by-case work needed for public assets ▪ (Plus 1% annual maintenance of $5,000)	▪ $150,000 ▪ Item cost for investigations and management plans – primarily any case-by-case work needed for public assets ▪ (Plus 1% annual maintenance of $1,500)	▪ $150,000 ▪ Item cost for investigations and management plans – primarily any case-by-case work needed for public assets ▪ (Plus 1% annual maintenance of $1,500)
Monitoring (NR1)	▪ $10,000 ▪ Beach survey for storm behaviour and to track HSD and inundation levels ▪ (Plus 10% annual maintenance of $1,000)	▪ $20,000 ▪ Beach survey for storm behaviour and to track HSD and inundation levels ▪ (Plus 10% annual maintenance of $2,000)	▪ $30,000 ▪ Beach survey for storm behaviour and to track HSD and inundation levels ▪ (Plus 10% annual maintenance of $3,000)	▪ $30,000 ▪ Beach survey for storm behaviour and to track HSD and inundation levels ▪ (Plus 10% annual maintenance of $3,000)	▪ $20,000 ▪ Riverbank survey for storm behaviour and to track HSD and inundation levels ▪ (Plus 10% annual maintenance of $2,000)	▪ $10,000 ▪ Riverbank survey for storm behaviour and to track HSD and inundation levels ▪ (Plus 10% annual maintenance of $1,000)
Protection Structure Audit (NR2)	▪ $50,000 ▪ Item cost to inspect condition, influence on sediment transport and inundation and remaining design life on all coastal management structures ▪ Includes Port breakwaters ▪ (Plus 2% annual maintenance of $1,000)	▪ $50,000 ▪ Item cost to inspect condition, influence on sediment transport and inundation and remaining design life on all coastal management structures ▪ Includes structures at The Cut ▪ (Plus 2% annual maintenance of $1,000)	▪ $50,000 ▪ Item cost to inspect condition, influence on sediment transport and inundation and remaining design life on all coastal management structures ▪ Includes walls along Collie River ▪ (Plus 2% annual maintenance of $1,000)	▪ $50,000 ▪ Item cost to inspect condition, influence on sediment transport and inundation and remaining design life on all coastal management structures ▪ (Plus 2% annual maintenance of $1,000)	Not applicable	Not applicable
Notification on title (NR3)	▪ $50,000 ▪ Item cost for investigations and implementation plans ▪ (Plus 1% annual maintenance of $500)	▪ $50,000 ▪ Item cost for investigations and implementation plans ▪ (Plus 1% annual maintenance of $500)	▪ $250,000 ▪ Item cost for investigations and implementation plans ▪ (Plus 1% annual maintenance of $2,500)	▪ $250,000 ▪ Item cost for investigations and implementation plans ▪ (Plus 1% annual maintenance of $2,500)	▪ $250,000 ▪ Item cost for investigations and implementation plans ▪ (Plus 1% annual maintenance of $2,500)	▪ $100,000 ▪ Item cost for investigations and implementation plans ▪ (Plus 1% annual maintenance of $1,000)
Emergency evacuation plans (NR4)	▪ $100,000 ▪ Item cost for investigations and evacuation plans ▪ (Plus 1% annual maintenance of $1,000)	Not applicable	▪ $250,000 ▪ Item cost for investigations and evacuation plans ▪ (Plus 1% annual maintenance of $2,500)	▪ $250,000 ▪ Item cost for investigations and evacuation plans ▪ (Plus 1% annual maintenance of $2,500)	▪ $250,000 ▪ Item cost for investigations and evacuation plans ▪ (Plus 1% annual maintenance of $2,500)	▪ $100,000 ▪ Item cost for investigations and evacuation plans ▪ (Plus 1% annual maintenance of $1,000)

2.4 Cost Benefit Analysis Methodology

The steps taken to complete the CBA are:

1. Re-analysis of GIS vulnerability datasets to extract asset category data by area. This was undertaken where previous counts of assets were not considered to provide enough detail for economic analysis
2. Finalise quantities of assets at risk for all nine categories for both erosion and inundation hazards for each Management Unit (MU) at each timeframe
3. Determine an appropriate unit value for each category for both loss to erosion or damage by inundation
4. Valuing the loss of existing assets and values – this assumes the scenario of complete inaction over the next 100 years
5. Scoping and designing the adaptation options
6. Pricing the adaptation options
7. Reducing all costs to NPV
8. Conducting sensitivity analysis on NPV discount rate used in analysis
9. Presenting summary of the inaction scenario and adaptation options in NPV for both erosion and inundation
10. Recommendation of options to proceed to for further consideration.

2.5 Valuing the Loss of Existing Assets and Values

The size and complexity of the study area has best suited the use of a rapid 'unit cost method' for estimating erosion and / or coastal inundation damage costs to properties and assets. This method primarily assumes a single cost for each land parcel in each category. Where parcel sizes and shapes vary too greatly, a value has been assigned per area or lineal length. The total damage costs for each category are estimated by using the count of each property or asset type, which might be expected to be affected for each hazard type at each timeframe.

This simplified method does not consider the proportion of a property or asset that is affected, the presence or location of buildings within a property, or the inundation depth at the building. However, given the large size of the study area, the accuracy of the erosion and inundation modelling, and the lack of suitable building data with surveyed floor levels, we consider the method suitable for estimating damage costs for the purposes of a cost benefit analysis.

2.5.1 Updated Assets and Values at Risk

Review of the asset category counts produced from GIS in the vulnerability analysis showed that three categories were not considered to provide enough detail for economic analysis, as follows:

- Roads
- Developed Foreshore
- Undeveloped Foreshore

These categories were re-analysed in GIS to extract quantities in spatial units for each category for each timeframe and hazard in each MU. The foreshore quantities were extracted as areas and given their nature, the roads were extracted as lengths, assuming a 15m width. The other six categories have used asset counts from the vulnerability analysis. Final quantities are presented in 4Appendix A.

2.5.2 Unit costs

Different unit costs have been used for erosion, which would be assumed to result in a total loss of the asset, compared to inundation, which would be assumed to result in non-permanent or repairable damage. Unit cost values for different asset categories are listed in

Table 2-4 and Table 2-5. For the three private categories (Commercial, Residential, Farming / Agricultural / Rural) approximation of current market value has been used. Although the exact timeframe and speed at which this value would be lost is unclear, at the time of writing market value is applicable and at some point in the future, it would be reduced to zero under an economic scenario of complete inaction over the next 100 years. For public categories with built infrastructure, construction cost information from Cardno (2018) after Rawlinsons (2016) has been considered and factored. This is in line with current uncertainties in construction costs due to Covid19, and to ensure public infrastructure, situated on land which is frequently not subject to land acquisition costs is adequately valued.

Inundation estimates are generally adapted from the DECC (2007) residential flood damage curves, and DNRE (2000), applying work by CRES (1992) for commercial flood damage curves, road repair costs and rural flood damage costs. All costs have been factored to present-day using the relevant changes in CPI.

All public asset categories are not considered to appreciate in value in real terms. There is an argument that private asset categories, however, are a special case as these asset classes historically appreciate at a higher rate than inflation (RBA, 2015). For this analysis, we have assumed that residential real estate does not appreciate. In addition, construction costs and all other costs are assumed to increase at the expected inflation rate; therefore, no adjustment is required in the analysis.

The economic benefits of the beach (both use and non-use values) are not included as no meaningful inputs were available. This means the cost of the do-nothing base case may be a little higher than presented. However, this has been partially offset by using higher rates for the loss of foreshore areas.

2.5.3 Value of Existing Vulnerable Assets and Values

The base-case economic scenario of assuming complete inaction over the next 100-years was costed for each MU for each timeframe by multiplying the quantity of assets identified as vulnerable by the unit rate for that timeframe. The resultant amounts for each timeframe were then converted to one summary NPV.

Table 2-4 Erosion costs for each asset category

Asset Category	Erosion Cost ($AUD)	Notes
Commercial	$375,000 / each	A review of sales in the study area was undertaken (Real Commercial, 2022) to establish an estimate. Also equivalent to five times the inundation damage amount. This method represents a market value. For economic analysis this may be considered on overestimate because the zoning value of the land is typically not included in pure economic analysis.
Residential	$500,000 / each	Market value, based on review of median house prices in study area (On The House, 2022). For CBA this may be considered on overestimate because the zoning value of the land is typically not included in pure economic analysis.
Farming / Agricultural / Rural	$90,000 / each	Average size of parcels for this category, from GIS, is 7.5ha. A rate of $12,000/ha has been used to determine an average parcel rate (Rural Bank, 2021).
Roads	$3.0M / km	Assumes two lanes of 3.5m and 1.5m, shoulders with $300/m^2 rate from DIRDC (2018) and Cardno (2018).
Developed Foreshore Reserve	$3.125M / hectare	This category has been valued highly because of the method used for private residential property and to represent the non-use values of this space evident through previous community and stakeholder consultation. Allowed 125% of Undeveloped Foreshore category due to presence of built infrastructure.
Undeveloped Foreshore Reserve	$2.5M / hectare	As a qualitative category, but integral to the purpose of the CHRMAP, this has been valued cognisant of the more easily valued developed/quantitative categories to ensure it is adequately represented in the CBA. This category has been valued highly because of the method used for private residential property and to represent the non-use values of this space evident through previous engagement. Available information, based on studies considering people's Willingness to Pay for access and use of wetlands (Brander et al 2006) were interpolated for foreshore as direct data was not found to be available.
Public and Community Utilities	$375,000 / each	Allocated same rate as Commercial to ensure government infrastructure accounted for adequately.
Environmental	$250,000 / each	A qualitative category, that has frequently been identified by the community as one of the most important during previous CHRMAP stages, this has been valued cognisant of the more easily valued developed/quantitative categories to adequately represent it in the CBA. Many environmental assets cannot be practically relocated. Assumed 50% of Residential category.
Heritage	$2.0M / each	As a qualitative category, but integral to the community fabric of the study area, this has been valued cognisant of the more easily valued developed/quantitative categories to ensure it is adequately represented in the CBA. It may not be practical for many assets in this category to be relocated. Assumed 400% of Residential category.

Table 2-5 Inundation costs for each asset category

Asset Category	Inundation Cost ($AUD)	Notes
Commercial	$75,000 / each	DNRE, 2000 DECC, 2007 CRES, 1992
Residential	$100,000 / each	
Farming / Agricultural / Rural	$3,750 / each	
Roads	$50, 000 / linear km	
Developed Foreshore Reserve	$6,000 / hectare	Estimate of replacement cost of damaged infrastructure.
Undeveloped Foreshore Reserve	$2,000 / hectare	As a qualitative category, but integral to the purpose of the CHRMAP, this has been valued cognisant of the more easily valued developed/quantitative categories to ensure it is adequately represented in the CBA. Nominal value estimated at 33% of Develop Foreshore Reserve. Acknowledges likely impacts of increased saltwater intrusion – both the distance inland and the increased frequency of events and the subsequent increased expected cost to maintain vegetation.
Public and Community Utilities	$75,000 / each	Assumed equivalent to Commercial category.
Environmental	$25,000 / each	As a qualitative category, that has frequently been identified by the community as one of the most important categories during previous stages of the CHRMAP this has been valued cognisant of the more valuable developed/quantitative categories to ensure it is adequately represented in the CBA. Nominal value estimated at 25% of Residential; some environmental assets will likely have very little impact from coastal inundation while others could be completely destroyed.
Heritage	$400,000 / each	As a qualitative category, but integral to the community fabric of the study area this has been valued cognisant of the more valuable developed/quantitative categories to ensure it is adequately represented in the CBA. It may not be practical for many assets in this category to be relocated. Assumed 400% of Residential category.

2.6 Planned / Managed Retreat – Voluntary Acquisition

The costs for this option have been determined for each MU using the following steps:

1. Calculate the acquisition cost for the three private categories at market values for the timeframe they are considered vulnerable to erosion.

2. Calculate the infrastructure removal and subsequent land improvement cost to return land to undeveloped foreshore reserve for all six categories with built infrastructure (Table 2-6). A factor of 25% has been allowed for preliminaries, project management, design, mobilisation and demobilisation. A contingency of 30% has been included for uncertainties in budget estimating. An annual maintenance cost of 2% has been applied.
3. Include the value of losing the three categories itemised and described below. The three private categories have been priced to be acquired so are not counted again. Roads are not counted as they have been considered service assets – without the need to access other land uses, they are no longer needed, so they are not considered an economic loss. Both foreshore categories are not valued as a loss again because new usable foreshore is what is being created by this option:
    a. Public and Community – These facilities are considered lost to the study area as no cost to replace them elsewhere is included. Valuation is same as the base-case economic scenario.
    b. Environmental – It is assumed assets in this category cannot be practically relocated, and no cost is included to attempt to relocate such assets.
    c. Aboriginal Heritage – It is assumed not practical for many assets in this category to be relocated. And no cost is included to attempt to relocate such assets, which cannot be replaced.
4. The resultant amounts for each timeframe were then converted to one summary NPV.

It is important to note that the process of purchasing developed private property for the purposes of planned / managed retreat is not considered to result in an economic benefit – it is simply transferring the cost from one party to another. For the purposes of this CBA, the methodology is considered appropriate to budget all options and compare their financial implications over time for the coastal land managers (primarily LGA's).

Table 2-6 Valuation considerations for voluntary acquisition option

Category	Acquisition Cost	Infrastructure Removal and Land Improvement Cost
Commercial	Same as base case valuation	20% of 2020 base-case
Residential	Same as base case valuation	20% of 2020 base-case
Farming / Agricultural / Rural	Same as base case valuation	5% of 2020 base-case
Roads	Zero – government owned	20% of 2020 base-case
Developed Foreshore Reserve	Zero – government owned	5% of 2020 base-case
Public and Community Utilities	Zero – government owned	5% of 2020 base-case

2.7 Protection Options

2.7.1 Beach Nourishment – PR1

The costs for this option have been determined for each MU using the following steps:

1. Calculate a sand nourishment volume, based on the length of coast requiring protection and a height and width estimate. Example values used on the open coast are 2.0m high and 30m wide. A 10-year useful life has been assumed – after which the nourishment would be repeated.

2. Estimate a sand volume that could be delivered each day – considering location, access.
3. Estimate the number of mobile plant required to place the sand.
4. Calculate the initial nourishment cost.
5. A factor of 25% has been allowed for preliminaries, project management, design, mobilisation and demobilisation. A contingency of 30% has been included for uncertainties in budget estimating. An annual volume increase in cost of 1% has been applied.
6. The resultant amounts for each timeframe were then converted to one summary NPV.

This concept cost estimate requires the use of several assumptions, as follows:

- Assume there is a suitable sand source in the sub-region that can supply adequate quality, particle size and volume of sand over the project timeframe.
- Assume a cost of $\$27/m^3$ to supply and transport sand to work site.
- Assume an average day rate of $1,500 per piece of mobile plant

2.7.2 Rock Structure Options – PR2 to PR5

The costs for this option have been determined for each MU using the following steps:

1. Scope and design the structural option using information from the existing CHRMAP chapter reports and taking indicative design waves and water levels from the numerical model used to estimate the coastal hazards.
2. Estimate an appropriate crest level, toe depth, structure length, structure slope
3. Calculate quantity of materials required – rock, sand, geofabric
4. Use assumed costs to calculate initial costs of material purchase and installation.
5. A factor of 25% has been allowed for preliminaries, project management, design, mobilisation and demobilisation. A contingency of 30% has been included for uncertainties in budget estimating.
6. An annual maintenance cost of 2% has been applied.
7. The resultant amounts for each timeframe were then converted to one summary NPV.

This concept cost estimate requires the use of several assumptions, as follows:

- Assume required armour sizes are available in sub-region and quarry production rates are suitable to supply adequate volume of required sizes
- Assume initial costs of rock armour of $75/tonne and core of $55/tonne and Geofabric of $\$30/m^2$
- Complex features have been approximated by modifying characteristics of cross-sections
- Groynes are assumed to be two-sided revetments
- High level assumptions regarding the structure shape and construction style.

2.7.3 Inundation Protection – Levy/Barrier

The costs for this option have been determined for each applicable MU using the following steps:

1. Scope and design the structural option using information from the existing CHRMAP chapter reports and desktop review of proposed option location.
2. For levy options, a similar methodology as sand nourishment was used, with added conservative modifications:

a. Increased estimates for the number of pieces of mobile plant required
b. Decreased estimates on the volume of material able to be delivered and placed daily
c. A contingency of 50% has been included for increased uncertainties in budget estimating
d. An annual maintenance cost of 2.5% has been applied

3. For bespoke options such as construction of culvert with storm-flap one-way drains, similar principles as for other options were used:
   a. Estimate initial costs based on purchase and supply to site
   b. Estimate number of pieces of mobile plant required
   c. Estimate number of days' work
   d. Determine an initial cost estimate
   e. A factor of 25% has been allowed for preliminaries, project management, design, mobilisation and demobilisation
   f. Apply a contingency for uncertainties in budget estimating, typically between 30% and 50%
   g. Apply an annual maintenance cost
4. The resultant amounts for each timeframe were then converted to one summary NPV.

2.7.4 Inundation Protection – New Storm Surge Barrier at The Cut

An option identified in previous stages of the CHRMAP was a large-scale engineering option to construct a new storm surge barrier at The Cut to prevent coastal inundation to MUs 8, 9, 10 and 11, and the estuary-facing components of MU6 and MU7.

The economic base-case analysis of this option was undertaken using the following steps:

- Apply total do nothing NPV values for inundation for MUs 6,8,9,10,11. Note that inundation in MU7 is negligible on the estuary side and MU6 was factored down by 50% as an estimate for the estuary side
- Summed numbers to give a combined total do nothing inundation value for NPV discount rates
- Estimated cost of new storm surge barrier at The Cut (see below for assumptions and details)
- Estimated cost of additional levy works in the MUs which may be required
- Converted option construction and costs to NPV, assuming construction in 2035

A desktop review of existing storm surge barriers to mitigate coastal flooding risk was undertaken, with Table 2-7 summarising the information and references. Characteristics of these structures were compared, including:

- Location – country, coast, estuary, river
- Operational Span – the width of waterway that can be closed to water flow
- Operational Height – the vertical distance from the bottom of waterway channel to the design water surface level
- Construction cost
- Other features and notes

Due to different construction years, locations, jurisdictions and design features, the comparison of costs is difficult but Mooyaart et al (2014) analysed this in more detail and concluded there is an average indicative cost of 2.2M Euro per metre of operational span in 2014, with a standard deviation of 56%. Assuming average

inflation of 3% from 2014 to 2022 and converting to Australian dollars at an exchange rate of 1.48 AUD to 1.0 Euro at the time of writing produces cost estimates of approximately $4.1M/metre of operational span. The current depth of the channel at the Cut is less than 3m below low tide, so an operational height for concept design of a barrier is likely to be less than 10m, and therefore significantly cheaper than the initial estimated cost rate. A rate of $2.0M/metre of operational span has been used. Selection of an appropriate operational span would depend on further detailed analysis of freshwater and saltwater interactions at Leschenault Estuary as well as other factors such as maritime navigation and re-analysis of climate change projections. The current channel at The Cut varies between approximately 130m and 230m. An operational span of 80m has been assumed for a concept surge barrier. The following assumptions have been applied:

1. A factor of 25% has been allowed for preliminaries, project management, design, mobilisation and demobilisation
2. Contingency for uncertainties in budget estimating, typically between 30% and 50%
3. An annual maintenance cost
4. Resultant amounts for each timeframe were then converted to one summary NPV.

Table 2-7 Desktop comparison of large-scale storm surge barriers

Structure	Operational Span	Operational Height	Cost	Notes
Thames Barrier London, UK	520m	20m	Equivalent of ~1.6B UK Pounds in 2016	Completed 1984 (UK Environment Agency, 2022)
Hartel Barrier, Netherlands	150m	14m	98M Euro in 1997	Completed 1997 (Mooyaart et al 2014)
Maeslant Barrier, Netherlands	360m	20m	450M Euro in 1997	Completed 1997 (Mooyaart et al 2014)
Colne Barrier, Wivenhoe UK	130m	8m	15m UK Pounds in 1993	Completed 1993 30m span width for navigation (UK Environment Agency, 1993)

2.8 Cost Benefit Analysis Results

2.8.1 MU1

CBA results for erosion and inundation are presented in Table 2-8 and Table 2-9.

Table 2-8 MU1 CBA results for erosion adaptation options

Net Present Value 2020	Do Nothing	PMR4: Voluntary Acquisition	PR1: Beach Renourishment	PR2: Groynes
Option Notes	Economic base case	Acquisition assumed in same year as hazard line identifies parcels as vulnerable	▪ Assumes beach renourishment of 3,000m ocean coast ▪ Assumes suitable sand source available (grain size, volume, cleanliness. proximity) ▪ 2035 implementation	▪ Assumes 9 rock groynes 100m long, 400m apart ▪ 2035 implementation
7% NPV	$14,520,108	$9,177,898	$6,439,605	$10,448,300
4% NPV	$19,896,564	$13,064,903	$17,754,526	$18,465,578
2% NPV	$36,919,985	$32,808,196	$43,450,046	$30,244,997

Table 2-9 MU1 CBA results for inundation adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PR6: Levy / Barrier
Option Notes	Economic base case	▪ To address inundation of Stirling Wetland ▪ Assumes two levies either side of river, each 2km long ▪ 2035 implementation ▪ Less volume per day, as likely to be slower than beach nourishment ▪ Higher contingency (50%) to cover any treatment, revegetation, local drainage challenges
7% NPV	$3,301,716	$2,123,191
4% NPV	$3,392,130	$3,844,497
2% NPV	$3,789,201	$6,476,725

2.8.2 MU2

CBA results for erosion and inundation are presented in Table 2-10 and Table 2-11.

Table 2-10 MU2 CBA results for erosion adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PMR4: Voluntary Acquisition
Option Notes	Economic base case	Acquisition assumed in same year as hazard line identifies parcels as vulnerable
7% NPV	$49,128,122	$34,933,026
4% NPV	$57,439,172	$36,646,160
2% NPV	$76,834,706	$40,482,759

Table 2-11 MU2 CBA results for inundation adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PR6: Levy / Barrier
Option Notes	Economic base case	To address inundation of Stirling Wetland: ▪ Assumes new culverts with one-way valves installed at Higgins Cut with some associated earthworks ▪ Higher contingency than usual (50%) to cover any treatment, revegetation, local drainage challenges ▪ Assume 2035 installation" To address inundation at Yalgar River Mouth at Stirling Beach, north of Peppermint Grove beach, from flowing to connect with Stirling Wetlands: ▪ Assumes levy at 300m long ▪ Assume 2035 implementation ▪ Less volume per day as likely to be slower than beach nourishment ▪ Higher contingency than usual (50%) to cover any treatment, revegetation, local drainage challenges
7% NPV	$16,641,294	$412,843
4% NPV	$16,778,761	$747,541
2% NPV	$17,184,129	$1,259,363

2.8.3 MU1 and MU2 joint consideration of inundation

As coastal inundation from MU1 flows into MU2 as the major pathway it is important to consider the joint potential impacts and options cost for the inundation vulnerabilities at these MU's. Join CBA results for inundation are presented in Table 2-12.

Table 2-12 MU1 and MU2 CBA results for inundation adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PR6: Levy / Barrier
Option Notes	Economic base case	From MU1: ▪ To address the inundation of Stirling Wetland via the Capel River ▪ Assumes two levies either side of the Capel River, each 2km long ▪ 2035 implementation ▪ Less volume per day, as likely to be slower than beach nourishment Higher contingency (50%) to cover any treatment, revegetation, local drainage challenges From MU2: To address the inundation of Stirling Wetland: ▪ Assumes new culverts with one-way valves installed at Higgins Cut with some associated earthworks ▪ Higher contingency than usual (50%) to cover any treatment, revegetation, local drainage challenges ▪ Assume 2035 installation To address coastal inundation at Minninup Drain Outlet at Stirling Beach, north of Peppermint Grove beach, from flowing to connect with Stirling Wetlands: ▪ Assumes levy at 300m long ▪ Assume 2035 implementation ▪ Less volume per day as likely to be slower than beach nourishment ▪ Higher contingency than usual (50%) to cover any treatment, revegetation, and local drainage challenges
7% NPV	$19,943,010	$2,575,178
4% NPV	$20,170,891	$4,652,006
2% NPV	$20,973,330	$7,816,334

2.8.4 MU3

CBA results for erosion Table 2-13. Inundation is not a concern for MU3.

Table 2-13 MU3 CBA results for erosion adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PMR4: Voluntary Acquisition	PR1: Beach Renourishment	PR2: Groynes
Option Notes	Economic base case	Acquisition assumed in same year as hazard line identifies parcels as vulnerable	▪ Assumes beach nourishment of 2,800m of ocean coast ▪ Assumes suitable sand source available (grain size, volume, cleanliness. proximity) ▪ 2035 Implementation	▪ Assumes 6 rock groynes 100m long ▪ 2035 Implementation
7% NPV	$7,119,490	$7,275,455	$10,863,824	$11,136,564
4% NPV	$9,314,638	$10,607,575	$29,952,467	$19,681,967
2% NPV	$15,690,942	$21,222,330	$73,301,652	$32,237,336

2.8.5 MU4

There are no CBA options for MU4.

2.8.6 MU5

CBA results for erosion and inundation are presented in Table 2-14 and Table 2-15.

Table 2-14 MU5 CBA results for erosion adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PMR4: Voluntary Acquisition	PR1: Renourishment	PR2: Groynes	PR5: Offshore Breakwater
Option Notes	Economic base case	Acquisition assumed in same year as hazard line identifies parcels as vulnerable	▪ Assumes sand nourishment of 5km ocean frontage ▪ Assumes suitable sand source available (grain size, volume, cleanliness. proximity) ▪ 2020 Implementation	▪ Assumes 15 rock groynes 100m long, 400m apart ▪ 13 on ocean coast and 2 in Koombana Bay ▪ 2020 Implementation	▪ Assumes 15 offshore rock breakwaters 100m long, 300m apart ▪ 13 on ocean coast and 2 in Koombana Bay ▪ 2020 Implementation
7% NPV	$148,373,568	$50,155,220	$50,465,640	$72,027,835	$102,014,718
4% NPV	$163,438,159	$72,578,498	$93,273,566	$83,499,242	$123,950,438
2% NPV	$200,128,500	$135,047,435	$182,471,564	$104,337,185	$163,796,922

Table 2-15 MU5 CBA results for inundation adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PR6: Levy / Barrier
Option Notes	Economic base case	▪ Replacement of storm surge barrier at the Leschenault Inlet ▪ 2035 Implementation
7% NPV	$156,614,671	$10,765,544
4% NPV	$169,233,704	$17,917,396
2% NPV	$199,492,622	$27,183,146

2.8.7 MU6

CBA results for erosion and inundation are presented in Table 2-16 and Table 2-17.

Table 2-16 MU6 CBA results for erosion adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PMR4: Voluntary Acquisition	PR1: Renourishment	PR2: Groynes	PR3: Seawall
Option Notes	Economic base case	Acquisition assumed in same year as hazard line identifies parcels as vulnerable	▪ Assumes sand nourishment of 100m on west side of port and 1,200m on east side of port and 800m of estuary shoreline along Estuary Drive ▪ Assumes suitable sand source available (grain size, volume, cleanliness. proximity) ▪ 2035 implementation	▪ Assumes 5 rock groynes 75m long, 300m apart along ocean coast ▪ 2035 Implementation	▪ Assumes 1,300m seawall on ocean coast ▪ Assumes 800m seawall on estuary coast ▪ 2035 implementation ▪ No sand nourishment included - beach not maintained
7% NPV	$38,008,632	$23,958,369	$2,426,164	$5,006,448	$6,158,522
4% NPV	$40,598,186	$26,987,841	$6,689,136	$8,848,038	$10,884,132
2% NPV	$44,967,160	$32,900,566	$16,370,096	$14,492,310	$17,827,254

Table 2-17 MU6 CBA results for inundation adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PR6: Levy / Barrier
Option Notes	Economic base case	▪ Assumes 700m levy to cover ocean frontage (400m east of port and 300m on west). ▪ Does not address inundation risk from estuary frontage - this is assumed to be addressed separately with consideration of a new storm surge barrier at The Cut. ▪ Assume 2020 implementation ▪ Less volume per day as likely to be slower than beach nourishment ▪ Higher contingency (50%) to cover any treatment, revegetation, local drainage challenges
7% NPV	$26,312,888	$1,025,689

Net Present Value 2020	Do Nothing Economic Base-Case	PR6: Levy / Barrier
4% NPV	$26,621,894	$1,219,144
2% NPV	$27,256,539	$1,570,559

2.8.8 MU7

CBA results for erosion are presented in Table 2-18. There are no CBA options for inundation for MU7.

Table 2-18 MU7 CBA results for erosion adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PR1: Renourishment	PR2: Groynes	PR3: Seawall
Option Notes	Economic base case	▪ Assumes nourishment of 400m of ocean coast and 320m of estuary shoreline ▪ Assumes suitable sand source available (grain size, volume, cleanliness. proximity) ▪ 2050 Implementation	▪ Assumes 2 rock groynes 75m long on ocean-side beach ▪ 2050 Implementation	▪ Assumes 400m seawall on ocean foreshore ▪ Assumes 320m seawall on estuary foreshore ▪ 2050 Implementation
7% NPV	$20,628,835	$367,453	$741,882	$712,214
4% NPV	$25,970,239	$1,491,432	$1,991,796	$1,912,142
2% NPV	$32,947,529	$4,519,318	$4,251,845	$4,081,810

2.8.9 MU8

CBA results for erosion are presented in Table 2-19. The only CBA option for inundation in MU8 is addressed separately with consideration of a new storm surge barrier at The Cut in Section 2.8.13.

Table 2-19 MU8 CBA results for erosion adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PMR4: Voluntary Acquisition	PR1: Renourishment	PR2: Groynes	PR3: Seawall
Option Notes	Economic base case	Acquisition assumed in same year as hazard line identifies parcels as vulnerable	▪ Assumes 2600m shoreline treated along estuary and river shoreline around Pelican Point ▪ Assumes suitable sand source available (grain size, volume, cleanliness. proximity) ▪ 2035 Implementation	▪ Assumes 8 rock groynes, 30m long, 100m apart to cover estuary coast from Venezia Blvd north ▪ Assumes 6 groynes to cover section of river foreshore ▪ 2035 Implementation	▪ Assumes 2,600m seawall to cover shoreline in MU along estuary and river shoreline around Pelican Point ▪ No sand nourishment included; beachfront not maintained ▪ 2035 Implementation
7% NPV	$51,714,280	$39,762,016	$1,147,614	$1,154,403	$2,548,161
4% NPV	$56,866,153	$46,080,688	$3,164,068	$2,040,209	$4,503,438
2% NPV	$69,768,889	$64,537,160	$7,743,315	$3,341,683	$7,376,237

2.8.10 MU9

CBA results for erosion are presented in Table 2-20. The only CBA option for inundation in MU9 is addressed separately with consideration of a new storm surge barrier at The Cut in Section 2.8.13.

Table 2-20 MU9 CBA results for erosion adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PMR4: Voluntary Acquisition	PR1: Renourishment	PR2: Groynes	PR3: Seawall	PR5: Offshore Breakwater
Option Notes	Economic base case	Acquisition assumed in same year as hazard line identifies parcels as vulnerable	▪ Assumes only 25% of shoreline treated (6,250m) ▪ Assumes suitable sand source available (grain size, volume, cleanliness. proximity) ▪ 2020 implementation	▪ Assumes 63 rock groynes, 30m long, approximately 100m apart or as required to treat 25% of shoreline in MU ▪ Locations to be determined ▪ 2020 Implementation	▪ Assumes 6,250m seawall to cover 25% shoreline in MU ▪ 2020 Implementation ▪ Does not include sand nourishment - beachfront not maintained	▪ Assumes 63 offshore rock breakwaters 30m long, approximately 100m apart or as required to treat 25% of shoreline in MU ▪ Locations to be determined ▪ 2020 Implementation
7% NPV	$508,634,906	$77,785,411	$7,964,048	$13,373,146	$16,906,669	$16,571,412
4% NPV	$536,210,058	$87,030,699	$14,719,622	$15,503,000	$19,599,285	$20,134,680
2% NPV	$595,430,739	$111,541,986	$28,796,073	$19,371,905	$24,490,452	$26,607,398

2.8.11 MU10

CBA results for erosion are presented in Table 2-21. The only CBA option for inundation in MU10 is addressed separately with consideration of a new storm surge barrier at The Cut in Section 2.8.13.

Table 2-21 MU10 CBA results for erosion adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PMR4: Voluntary Acquisition	PR1: Renourishment
Option Notes	Economic base case	Acquisition assumed in same year as hazard line identifies parcels as vulnerable	▪ Nourishment along bank of river for 2,400m ▪ Assumes suitable sand source available (grain size, volume, cleanliness. proximity) ▪ 2035 implementation
7% NPV	$17,992,994	$18,834,065	$353,013
4% NPV	$19,370,105	$21,430,658	$973,287
2% NPV	$21,828,524	$26,534,391	$2,381,892

2.8.12 MU11

CBA results for erosion are presented in Table 2-22.The only CBA option for inundation in MU11 is addressed separately with consideration of a new storm surge barrier at The Cut in Section 2.8.13.

Table 2-22 MU11 CBA results for erosion adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PMR4: Voluntary Acquisition	PR1: Renourishment
Option Notes	Economic base case	Acquisition assumed in same year as hazard line identifies parcels as vulnerable	▪ Nourishment along bank of river for 2,400m ▪ Assumes suitable sand source available (grain size, volume, cleanliness. proximity) ▪ 2035 Implementation
7% NPV	$16,048,763	$17,997,344	$353,013
4% NPV	$17,950,371	$23,502,931	$973,287
2% NPV	$22,412,647	$36,366,576	$2,381,892

2.8.13 New Storm Surge Barrier at The Cut

The joint CBA option for inundation in MU8,9,10,11 and part of MU6 is addressed separately with consideration of a new storm surge barrier at The Cut, with results presented in Table 2-23 and Table 2-24

Table 2-23 New storm surge barrier at The Cut – Do Nothing Economic Base-Case results

Net Present Value 2020	MU6 (50% of total to represent estuary frontage inundation only)	MU8	MU9	MU10	MU11	Total
7% NPV	$13,156,444	$61,399,907	$30,580,105	$10,017,388	$6,341,631	$121,495,475
4% NPV	$13,310,947	$62,041,758	$31,510,116	$10,027,676	$6,368,017	$123,258,514
2% NPV	$13,628,269	$64,416,455	$33,535,323	$10,087,732	$6,535,317	$128,203,095

Table 2-24 New storm surge barrier at The Cut - CBA results

Net Present Value 2020	Do Nothing Economic Base-Case	PR6: Levy / Barrier
Option Notes	Economic base case	▪ New storm surge barrier at The Cut ▪ Provide protection from coastal inundation via estuary in MU's 8,9,10,11 and some of 6 ▪ Also assumes levy at 1,000m long to complement new storm surge barrier at The Cut ▪ Higher contingency (50%) to cover any treatment, revegetation, local drainage challenges ▪ 2035 Implementation
7% NPV	$121,495,475	$124,748,614
4% NPV	$123,258,514	$207,700,310
2% NPV	$128,203,095	$315,270,865

It is important to note for this MU's 8, 9, 10 and 11 that the effectiveness of erosion options may also depend on measures to manage inundation as the low-lying foreshore means options to manage erosion could be submerged. Compared to other MU's, the interrelationships of options to manage erosion and inundation should be considered in more detail.

2.9 Cost Benefit Analysis Discussion

2.9.1 Sensitivity Analysis of NPV Discount Rate

As the nature of CHRMAP principles requires robust and early planning for coastal hazards, the selection of a discount rate(s) to be used for NPV analysis is particularly important. The planning timeframe is very long compared to many CBA applications. The competing principles of early coastal planning making for more-resilient communities may not align well with the CBA principle that future spending of money is cheaper. Given the long planning timeframe it could be argued that the 2% sensitivity analysis rate should be used, or given more weight than the higher numbers, particularly if private property inflation continues into the future at historic rates.

2.9.2 Planning Timeframe

It is important to note that this is a concept-level CBA, that has used high-level cost estimates, coupled with the timeframe of projected hazards, and the very long timeframe for such economic analyses, the results should be used cautiously.

2.9.3 Assumptions

This concept-level CBA has necessarily used several high-level assumptions and estimates. As no design information is available until later phases of implementation it is necessary to undertake option scoping and concept design on limited information. Assumptions about price, extent of forecast vulnerabilities and the very long timeframe mean the results are suitable for the relative comparison of options, but preliminary and detailed design phases require further consideration of costs. A summary of key assumptions is provided below:

1. Hazards occur as projected and trigger losses, or decision points on option implementation in accordance with the same projected timeframes,
2. NPV discount rates of 7%, 4% and 2% are suitable for the timeframe and level of detail of cost estimates.
3. Unit costs are representative of the study area.
4. The economic benefits provided by the beach (both use and non-use values) are not included as no meaningful inputs were available to use. This means the cost of the do-nothing base case may be a little higher than presented, but this has been offset by using higher rates for the loss of foreshore areas.
5. It is important to note that the process of purchasing developed private property for the purposes of planned / managed retreat (PMR4 – Voluntary Acquisition) is not considered to result in an economic benefit – it is simply transferring the cost from one party to another. For the purposes of this CBA, the methodology is considered appropriate to budget all options and compare their financial implications over time for the coastal land managers (primarily LGA's).
6. The PMR4 Option – Voluntary Acquisition assumes purchase of private property at a standard market rate. It is unclear how the real estate market will react to erosion from sea level rise as coastal erosion following storm events have a more immediate and significant impact. It is, however, expected that market values may reduce in areas that are actively eroding. This was considered beyond the scope of this project to attempt to model. However, if there is a significant reduction in the purchase price for this option it may represent a significant cost saving that could make this option more competitive in more locations.
7. Options provide similar levels of beach and foreshore amenity as the present-day. Underlying this assumption includes several others around rehabilitation of rezoned land being practical and effective; resources required for coastal engineering will continue to be available as needed (construction rock and nourishment sand for example).
8. Coastal management technologies will not substantially change in the future.
9. Assumed base costs for works (informed by historical information) are representative of future markets, particularly as at the time of writing Covid19 is still having an effect and inflation rates are high, particularly in WA.

2.9.4 Recommended option(s) for further consideration for each MU

The "non-CBA" options will generally form a part of one or more overarching options selected from the CBA list.

The CBA has been used as an additional tool to assist decision-making when assessing adaptation options with which to proceed. However, the reality that only some of the WAPC adaptation options are suitable for CBA, and the uncertainty in effectiveness of those that are not suitable, means that the CBA results need to be used cautiously whilst considering the rest of the information identified during the CHRMAP project.

Several assessed options have negative benefit/cost ratios – they did not perform better than the economic do-nothing base case, for all discount rates. They should not be proceeded unless more detailed investigation can be undertaken to determine the scope and extent of such works. MU3 is the only MU where all options for all discount rates did not perform better than the economic base case.

Review of the CBA results shows that the ranking of options for each MU by current NPV price depends on which discount rate is used. If options stayed in the same ranking for all three discount rates there would be a much stronger argument for selection of a single option with which to proceed.

Options recommended to proceed are presented in Table 2-25 for erosion and Table 2-26 for inundation.

Table 2-25 Recommended CBA options for erosion for each MU

Management Unit	Recommended Option	Secondary Option (s)	Notes
MU1	PMR4	PR2	▪ PMR4 is best value for one discount rate (4%) and second best for the other two. ▪ PR2 is second best value for one discount rate (2%). Although this option has the worst value for the other two rates it has still been recommended over PR1 given concerns on sand source feasibility.
MU2	PMR4	Not applicable	▪ PMR4 is better value than the base case for all discount rates and no other options were recommended for CBA.
MU3	PMR4	PR2	▪ No options performed better than the base case for any discount rate. ▪ PMR4 performed best out of the options. ▪ PR2 performed second best
MU4	Not applicable	Not applicable	▪ There are no CBA options for MU4.
MU5	PR2	PMR4	▪ PR2 is best value for one discount rate (2%). ▪ PMR4 was best value for the other two discount rates (7% and 4%) but not by a significant amount. ▪ PMR4 has a lot more uncertainty around its implementation, given the large size of this MU and the large number of values and built assets that are vulnerable including the Transforming Bunbury Waterfront project. Further investigation could consider more detailed analysis on subsections of this MU. ▪ PR1 may be suitable as an interim option in parts of this MU.
MU6	PR2	PR1	▪ PR2 is best value for one of the discount rates (2%). ▪ PR1 was best value for the other two discount rates (7% and 4 %) and its risks around implementation and longevity are less of a concern within this more-sheltered MU. It may be suitable as an interim option.

Management Unit	Recommended Option	Secondary Option (s)	Notes
MU7	PR1	PR3	▪ PR1 is best value for two discount rates (7$ and 4%). ▪ PR3 is not recommended as it would mean the loss of the beach. Should the objectives of this MU change in the future PR3 may be suitable long-term. ▪ PR1 could later be transitioned to PR3 if required.
MU8	PR2	PR1	▪ PR2 is best value for two discount rates (4% and 2%) and almost equal best for the 7% rate.
MU9	PR2	PR1	▪ PR2 is best value for the 2% discount rate (2%), and very close to PR1 for the 4% discount rate. ▪ Uncertainties around PR1 could pose some risk. ▪ PR5 is a more-expensive option but could be designed with amenity as a focus in this sheltered environment. Could be a tertiary option to consider following further consultation
MU10	PR1	Not applicable	▪ PR1 is best value for all discount rates by a significant amount.
MU11	PR1	Not applicable	▪ PR1 is best value for all discount rates by a significant amount.

Table 2-26 Recommended CBA options for inundation for each MU

Management Unit	Recommended Option (s)	Notes
MU1	PR6	▪ PR6 is better value than the base case for only one discount rate (7%) and no other options were recommended for CBA. ▪ Due to the pathway of the inundation hazard this MU should be considered jointly with MU2.
MU2	PR6	▪ PR6 is better value than the base case for all discount rates and no other options were recommended for CBA. ▪ Due to the pathway of the inundation hazard this MU should be considered jointly with MU2.
MU1 & MU2	PR6	▪ Due to the pathway of the inundation hazard these MU's are considered together. ▪ PR6 is better value than the base case for all discount rates and no other options were recommended for CBA.
MU3	Not applicable	▪ Inundation is not a concern for MU3.
MU4	Not applicable	▪ There are no CBA options for MU4.
MU5	PR6	▪ PR6 is better value than the base case for all discount rates and no other options were recommended for CBA.
MU6 – ocean frontage	PR6	▪ PR6 is better value than the base case for all discount rates and no other options were recommended for CBA.

Management Unit	Recommended Option (s)	Notes
MU6 – estuary frontage	Not applicable	▪ Further investigation is required as the broader PR6 option comprising a new storm surge barrier at The Cut did not perform better than the base case for any discount rate.
MU7	Not applicable	▪ There are no CBA options for MU4.
MU8, 9, 10, 11	Not applicable	▪ Further investigation is required as the broader PR6 option comprising a new storm surge barrier at The Cut did not perform better than the base case for any discount rate. A feasibility analysis is recommended to assess its effectiveness with consideration of freshwater flooding events and further civil and maritime design considerations as to what scale of facility would be required.

2.9.5 Selection of Options for Benefit Distribution Analysis

After completing the CBA and reviewing the results, Water Technology discussed possible coastal adaptation options to proceed to Benefit Distribution Analysis (BDA). The contractual documentation for the CHRMAP project determined that three sites shall be considered in BDA. Following several discussions, considering projected vulnerable assets, nature of hazards, tenure of land projected to be vulnerable, the following three options were selected:

- MU 1 and 2 - PR6 - Levies along the banks of the Capel River to minimise inundation. This option shall also consider inundation protection at Higgins Cut and the mouth of the Yalgar River at Stirling Beach.
- MU 3 - PR2 - Groynes to protect Dalyellup, the old landfill site and wastewater treatment plant to the north from erosion. Although this option has not scored positively in the CBA, its analysis in the BDA will still be valuable and provide further information about the selection of adaptation options.
- MU 5 - PR2 - Groynes to protect Bunbury Back Beach from erosion.

3 SUMMARY & NEXT STEPS

The CBA analysis is contingent on NPV discount rates and unit cost rates assumption. Notwithstanding these assumptions, the process provides a tool to assist decision-makers in drawing comparisons between several coastal adaptation options. The large study area allows the consistent application of the CBA across a large section of the coast.

Sensitivity analyses on the NPV discount rate demonstrate the variability inherent in the methodology at some locations. A review of the CBA results shows that ranking options by NPV depend on which discount rate is used. If options stayed in the same ranking for all three discount rates, there would be a much stronger argument for selecting a single option with which to proceed. The unit cost assumptions would also need to be confirmed by carrying on further design and procurement studies. In particular, the procurement of sand suitable for nourishment works may be questionable in some of the MU and should be the subject of further studies.

One or more options have been recommended to proceed for further investigation and/or implementation for each MU for both erosion and inundation. The recommendations have considered the CBA results holistically as well as being cognisant of the findings of previous stages of the CHRMAP.

Options for BDA have been recommended. The next stage for the project is to complete the detailed BDA investigations for the three locations selected and provide implementation recommendations for each MU.

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APPENDIX A
UPDATED ASSETS AND VALUES AT RISK

Table A-1 Total vulnerable area/count of asset categories to erosion in MU1 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	0	0.1	0.1	2
Residential (parcels)	2	3	3	154
Commercial (parcels)	0	0	0	0
Public and Community (parcels)		1	1	2
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	1.3	4.5	7.6	19.2
Environmental (item)	28	30	32	39
Agricultural / Rural (parcels)	0	0	0	0
Aboriginal Heritage (item)	0	0	0	0

Table A-2 Total vulnerable area/count of asset categories to inundation in MU1 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	1.6	1.8	1.8	2.6
Residential (parcels)	6	6	6	33
Commercial (parcels)	1	1	1	1
Public and Community (parcels)	3	3	4	5
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	2.7	2.9	2.9	3.7
Environmental (item)	87	90	91	99
Agricultural / Rural (parcels)	25	25	25	25
Aboriginal Heritage (item)	0	0	0	0

Table A-3 Total vulnerable area/count of asset categories to erosion in MU2 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	0	0	0	0.6
Residential (parcels)	0	0	0	0
Commercial (parcels)	0	0	0	0
Public and Community (parcels)	0	1	3	4
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	3.5	9.7	15.8	50.7
Environmental (item)	71	79	82	116
Agricultural / Rural (parcels)	20	21	21	55
Aboriginal Heritage (item)	6	6	6	6

Table A-4 Total vulnerable area/count of asset categories to inundation in MU2 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	23	24.1	25.4	36.6
Residential (parcels)	0	0	0	0
Commercial (parcels)	1	1	1	1
Public and Community (parcels)	5	5	5	8
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	3.3	3.4	3.7	5
Environmental (item)	450	452	465	529
Agricultural / Rural (parcels)	237	239	241	252
Aboriginal Heritage (item)	7	7	7	7

Table A-5 Total vulnerable area/count of asset categories to erosion in MU3 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	0	0	0	0
Residential (parcels)	0	4	4	64
Commercial (parcels)	0	1	1	1
Public and Community (parcels)	0	3	3	3
Foreshore - Developed (ha)	0	0	0.1	0.6
Foreshore - Undeveloped (ha)	0.2	0.8	1.3	3
Environmental (item)	17	20	21	42
Agricultural / Rural (parcels)	0	0	0	0
Aboriginal Heritage (item)	0	0	0	0

Table A-6 Total vulnerable area/count of asset categories to inundation in MU3 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	0	0	0	0
Residential (parcels)	0	0	0	0
Commercial (parcels)	0	0	0	0
Public and Community (parcels)	0	0	0	0
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	0	0	0	0
Environmental (item)	5	5	5	5
Agricultural / Rural (parcels)	0	0	0	0
Aboriginal Heritage (item)	0	0	0	0

Table A-7 Total vulnerable area/count of asset categories to erosion in MU4 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	0	0	0	0
Residential (parcels)	0	0	0	0
Commercial (parcels)	0	0	0	0
Public and Community (parcels)	0	0	0	2
Foreshore - Developed (ha)	17	21.5	25	43.2
Foreshore - Undeveloped (ha)	13	13	13	13
Environmental (item)	8	9	9	12
Agricultural / Rural (parcels)	0	0	0	0
Aboriginal Heritage (item)	0	0	0	0

Table A-8 Total vulnerable area/count of asset categories to inundation in MU4 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	0	0	0	0
Residential (parcels)	0	0	0	0
Commercial (parcels)	0	0	0	0
Public and Community (parcels)	0	0	0	0
Foreshore - Developed (ha)	11.3	11.3	11.3	11.4
Foreshore - Undeveloped (ha)	13	13	13	13
Environmental (item)	0	0	0	0
Agricultural / Rural (parcels)	0	0	0	0
Aboriginal Heritage (item)	0	0	0	0

Table A-9 Total vulnerable area/count of asset categories to erosion in MU5 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	9.7	13.4	16.9	27.4
Residential (parcels)	0	4	33	267
Commercial (parcels)	3	3	4	8
Public and Community (parcels)	5	5	14	50
Foreshore - Developed (ha)	20	22.7	24.6	26.2
Foreshore - Undeveloped (ha)	9.8	10.5	10.9	13.4
Environmental (item)	60	68	74	141
Agricultural / Rural (parcels)	0	0	0	0
Aboriginal Heritage (item)	0	0	0	1

Table A-10 Total vulnerable area/count of asset categories to inundation in MU5 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	31.2	34.5	38.7	90.9
Residential (parcels)	1180	1319	1614	2521
Commercial (parcels)	121	124	142	896
Public and Community (parcels)	163	166	187	236
Foreshore - Developed (ha)	25.3	28.3	29.4	33.8
Foreshore - Undeveloped (ha)	16.7	16.9	17.1	18.3
Environmental (item)	69	301	303	410
Agricultural / Rural (parcels)	0	0	0	0
Aboriginal Heritage (item)	5	5	5	5

Table A-11 Total vulnerable area/count of asset categories to erosion in MU6 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	0.2	0.2	0.2	0.3
Residential (parcels)	0	0	0	0
Commercial (parcels)	9	13	13	18
Public and Community (parcels)	2	2	2	2
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	7	9	10.6	12.5
Environmental (item)	49	56	56	90
Agricultural / Rural (parcels)	0	0	0	2
Aboriginal Heritage (item)	0	0	0	0

Table A-12 Total vulnerable area/count of asset categories to inundation in MU6 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	6.8	6.9	6.9	8.6
Residential (parcels)	0	0	0	0
Commercial (parcels)	297	297	317	337
Public and Community (parcels)	6	6	6	6
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	9.8	10.4	10.9	12.6
Environmental (item)	120	120	120	147
Agricultural / Rural (parcels)	7	7	7	7
Aboriginal Heritage (item)	0	0	0	0

Table A-13 Total vulnerable area/count of asset categories to erosion in MU7 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	0	0	0	0
Residential (parcels)	0	0	0	0
Commercial (parcels)	0	0	0	0
Public and Community (parcels)	0	0	0	0
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	1.8	2.6	3.3	8.8
Environmental (item)	28	118	118	129
Agricultural / Rural (parcels)	0	0	0	0
Aboriginal Heritage (item)	0	0	0	0

Table A-14 Total vulnerable area/count of asset categories to inundation in MU7 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	0	0	0	0
Residential (parcels)	0	0	0	0
Commercial (parcels)	0	0	0	0
Public and Community (parcels)	0	0	0	0
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	4.7	4.8	5	6.3
Environmental (item)	126	126	126	127
Agricultural / Rural (parcels)	0	0	0	0
Aboriginal Heritage (item)	0	0	0	0

Table A-15 Total vulnerable area/count of asset categories to erosion in MU8 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	0.2	0.2	0.3	1.7
Residential (parcels)	3	3	11	92
Commercial (parcels)	0	2	2	2
Public and Community (parcels)	16	17	17	22
Foreshore - Developed (ha)	2.5	3.9	5.4	10.7
Foreshore - Undeveloped (ha)	2.4	3.2	3.6	4.1
Environmental (item)	76	80	82	104
Agricultural / Rural (parcels)	0	0	0	0
Aboriginal Heritage (item)	3	3	4	4

Table A-16 Total vulnerable area/count of asset categories to inundation in MU8 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	13.5	13.7	13.9	20.7
Residential (parcels)	433	439	451	598
Commercial (parcels)	16	16	16	21
Public and Community (parcels)	66	66	66	73
Foreshore - Developed (ha)	19.8	19.8	20	20.7
Foreshore - Undeveloped (ha)	4	4	4	4
Environmental (item)	220	220	220	231
Agricultural / Rural (parcels)	13	13	13	13
Aboriginal Heritage (item)	13	13	13	14

Table A-17 Total vulnerable area/count of asset categories to erosion in MU9 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	0.7	1.5	2.5	9.3
Residential (parcels)	0	1	15	86
Commercial (parcels)	0	0	0	5
Public and Community (parcels)	0	0	6	27
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	162.5	182.6	201.7	279.6
Environmental (item)	266	285	296	359
Agricultural / Rural (parcels)	1	4	8	33
Aboriginal Heritage (item)	2	2	2	2

Table A-18 Total vulnerable area/count of asset categories to inundation in MU9 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	18	18.8	19.3	22.3
Residential (parcels)	142	154	174	245
Commercial (parcels)	5	5	5	9
Public and Community (parcels)	27	31	32	41
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	254.3	258.5	261.2	322.7
Environmental (item)	422	434	439	488
Agricultural / Rural (parcels)	66	66	66	72
Aboriginal Heritage (item)	2	2	2	2

Table A-19 Total vulnerable area/count of asset categories to erosion in MU10 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	0	0	0.1	0.9
Residential (parcels)	0	0	6	14
Commercial (parcels)	0	0	0	0
Public and Community (parcels)	6	7	7	8
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	0	0	0	0
Environmental (item)	57	66	69	75
Agricultural / Rural (parcels)	0	0	0	0
Aboriginal Heritage (item)	0	0	0	0

Table A-20 Total vulnerable area/count of asset categories to inundation in MU10 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	0.3	0.4	0.4	0.4
Residential (parcels)	53	53	53	56
Commercial (parcels)	3	3	3	3
Public and Community (parcels)	19	19	19	21
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	0	0	0	0
Environmental (item)	90	90	90	92
Agricultural / Rural (parcels)	0	0	0	0
Aboriginal Heritage (item)	2	2	2	2

Table A-21 Total vulnerable area/count of asset categories to erosion in MU11 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	0.3	0.4	0.4	0.9
Residential (parcels)	1	1	17	49
Commercial (parcels)	0	0	0	0
Public and Community (parcels)	3	3	3	6
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	0	0	0	0
Environmental (item)	49	50	50	57
Agricultural / Rural (parcels)	0	0	0	0
Aboriginal Heritage (item)	0	0	0	0

Table A-22 Total vulnerable area/count of asset categories to inundation in MU11 for each project timeframe

Category	2020 Quantity	2035 Quantity	2050 Quantity	2120 Quantity
Roads (km)	2.8	2.8	2.8	3.1
Residential (parcels)	38	38	38	52
Commercial (parcels)	0	0	0	0
Public and Community (parcels)	8	8	8	8
Foreshore - Developed (ha)	0	0	0	0
Foreshore - Undeveloped (ha)	0	0	0	0
Environmental (item)	72	72	72	72
Agricultural / Rural (parcels)	0	0	0	0
Aboriginal Heritage (item)	0	0	0	0

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Melbourne

15 Business Park Drive
Notting Hill VIC 3168
Telephone (03) 8526 0800

Sydney

Suite 3, Level 1, 20 Wentworth Street
Parramatta NSW 2150
Telephone (02) 9354 0300

Brisbane

Level 5, 43 Peel Street
South Brisbane QLD 4101
Telephone (07) 3105 1460

Adelaide

1/198 Greenhill Road
Eastwood SA 5063
Telephone (08) 8378 8000

Perth

Level 1, 21 Adelaide Street
Fremantle WA 6160
Telephone (08) 6555 0105

New Zealand

7/3 Empire Street
Cambridge New Zealand 3434
Telephone +64 27 777 0989

Wangaratta

First Floor, 40 Rowan Street
Wangaratta VIC 3677
Telephone (03) 5721 2650

Geelong

51 Little Fyans Street
Geelong VIC 3220
Telephone (03) 8526 0800

Wimmera

597 Joel South Road
Stawell VIC 3380
Telephone 0438 510 240

Gold Coast

Suite 37, Level 4, 194 Varsity Parade
Varsity Lakes QLD 4227
Telephone (07) 5676 7602

watertech.com.au