Princess Royal Harbour CHRMAP

Assessment of Risk Treatment Options

City of Albany

13 November 2023

Document Status

Version	Doc type	Reviewed by	Approved by	Date issued
V01	Draft	Astrid Stuer	Gildas Colleter	15/9/2023
V02	Draft	Astrid Stuer	Gildas Colleter	29/9/2023
V03	Final	Astrid Stuer	Astrid Stuer	13/11/2023

Project Details

Project Name	Assessment of Risk Treatment Options
Client	City of Albany
Client Project Manager	Adrian Nicoll
Water Technology Project Manager	Karl Ilich
Water Technology Project Director	Gildas Colleter
Authors	Karl Ilich
Document Number	22040008_PRH_CHRMAP_R05_V02

Ground Floor
430 Roberts Road
Subiaco WA 6904
Telephone (08) 6555 0105
ACN 093 377 283
ABN 60 093 377 283

ACKNOWLEDGEMENT OF COUNTRY

The Board and employees of Water Technology acknowledge and respect the Aboriginal and Torres Strait Islander Peoples as the Traditional Custodians of Country throughout Australia. We specifically acknowledge the Traditional Custodians of the land on which our offices reside and where we undertake our work.

We respect the knowledge, skills and lived experiences of Aboriginal and Torres Strait Islander Peoples, who we continue to learn from and collaborate with. We also extend our respect to all First Nations Peoples, their cultures and to their Elders, past and present. We respectfully acknowledge the past and present Traditional Custodians of this land on which the project focusses, the Menang People of Menang Noongar Country.

Figure 0-1 Shallow Waters of Princess Royal Harbour. Source: Google Maps.

EXECUTIVE SUMMARY

The Western Australian Government Western Australian Planning Commission's "State Planning Policy No. 2.6: State Coastal Planning Policy" (WAPC, 2013, herein referred to as "SPP2.6") addresses climate change, sea level rise, increased coastal inundation and coastal erosion. SPP2.6 recommends that management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) for land use or development vulnerable to coastal hazards. Specific CHRMAP Guidelines have been developed to assist this process (WAPC, 2019).

The Princess Royal Harbour region has been identified as potentially exposed to inundation hazard. Additionally, Little Grove (located within Princess Royal Harbour) is on the watchlist for coastal erosion (Seashore Engineering, 2019). This coastal hazard risk is a key trigger for the requirement of this CHRMAP. Therefore, the present study aims to investigate and plan for coastal hazards likely to affect Princess Royal Harbour. Figure 1-1 shows the study area. The study area is a semi-enclosed natural harbour in Albany on the south coast of Western Australia. The Harbour is approximately 4 km wide and 8 km long, with an approximate area of 28 km^2 within the City of Albany. The Harbour contains subtidal seagrass meadows and the working Port of Albany. The Port of Albany is a significant exporter for the state.

This CHRMAP increases knowledge and understanding of coastal hazard risks and identifies risk management and adaptation measures for implementation. The outcomes will be used to inform local 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 their objectives and SPP2.6. In addition, the project will identify the strategic direction for coastal adaptation scenarios from the present to 2122 (100-year management time frame) and determine 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 policymaking for the short-term (0-25 years), medium-term (25-50 years), and long-term (100 years).

This report presents Stage 6: Assessment of Risk Treatment Options by using Cost Benefit Analysis (CBA), which identifies preferred risk treatment pathways and options. The CBA analysis is contingent on NPV discount rates and unit cost rates assumptions. 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 the study area and should be the subject of further studies.

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.

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 projected 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 or permanent), 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 this process (WAPC, 2019).

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

The study area for this CHRMAP is the entire shoreline within Princess Royal Harbour, Albany, within the City of Albany local government area (refer Figure 1-1). It consists of various shoreline types and many coastal assets, involving multiple stakeholders:

- Port and breakwaters protected by physical controls
- Roads along the shoreline protected by physical controls
- Shallow sandy foreshore backed by vegetation
- River mouths and channels through the sandbars
- Sailing club, boat ramp and other coastal infrastructure
- Presence of rock features

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 their objectives and SPP2.6. In addition, the project will determine the strategic direction for coastal adaptation scenarios from the present-day to 2122 (100-year 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 policymaking for the short-term (0-25 years), medium-term (25-50 years), and long-term (50-100 years).

Delivery of this project will occur over 8 stages (as summarised in Figure 1-2), each representing a key hold point. The staged approach is developed according to the PRH's scope and is in line with the CHRMAP Guidelines (WAPC, 2019).

This report presents Stage 6: Assessment of Risk Treatment Options by using Cost Benefit Analysis (CBA), which identifies preferred risk treatment pathways and options. The red bubble in Figure 1-2, indicates where this component sits in the CHRMAP methodology.

Figure 1-1 Princess Royal Harbour Study Area

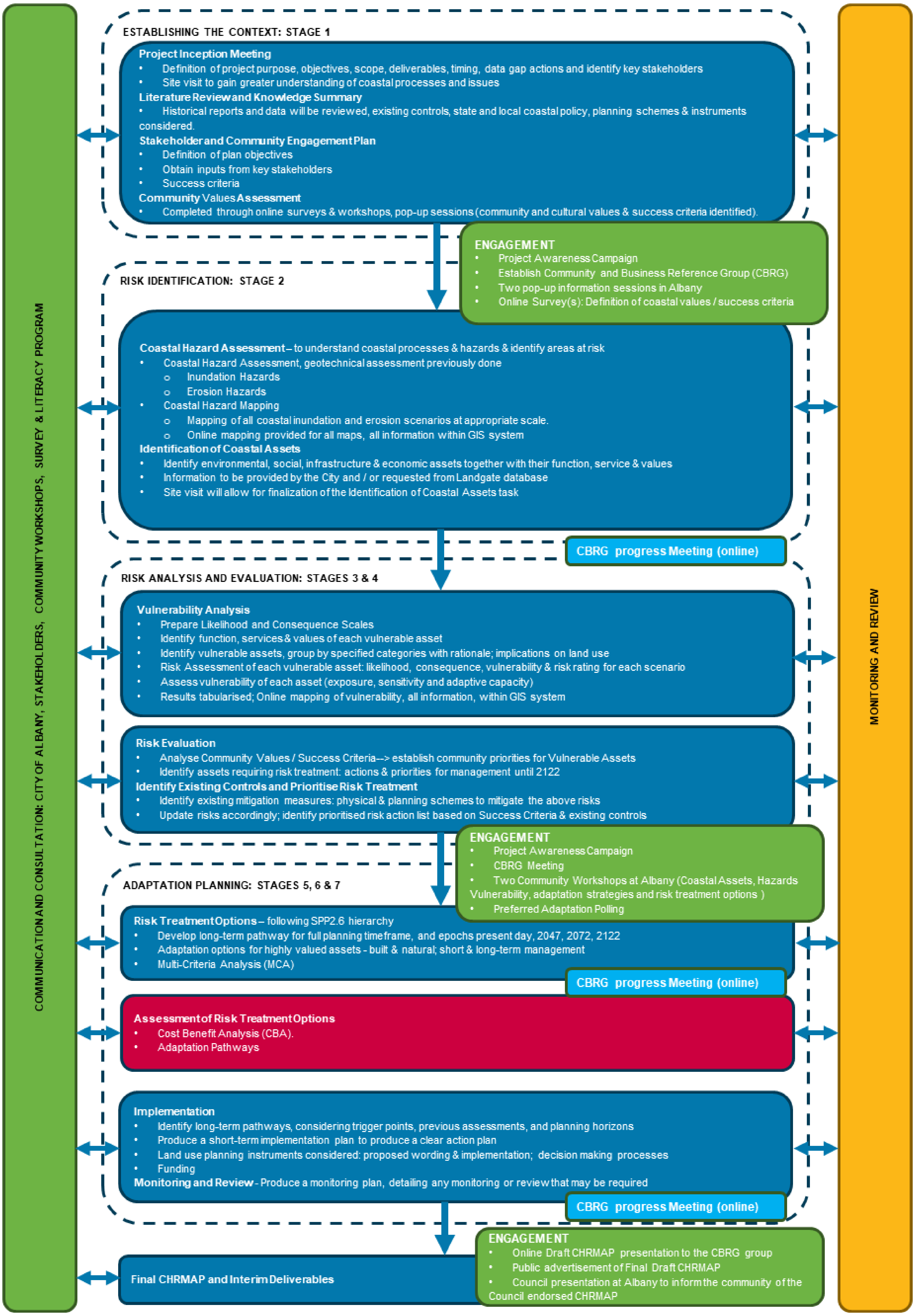

Figure 1-2 Methodology

2 COST BENEFIT ANALYSIS APPROACH

The purpose of the Cost Benefit Analysis (CBA) is to further examine the selection of adaptation options through economic analysis. In the previous project stage 5, potential adaptation options were assessed against a range of criteria, including cost. Options that may require significant financial investment and scored positively in the MCA have been included in this CBA. A rigorous assessment of costs and benefits for each option will assist with preferential selection and potentially uncover any poor financial assumptions included in the MCA. This analysis will also ensure that a selected adaptation option is economically defendable. The CBA has addressed valuing the loss of assets, managed retreat and physical protection options. Losses or costs are assessed at each project timeframe. Indirect costs that another user might consider to be a loss are not considered. For example, costs associated with Special Control Area (SCA) title notifications, emergency planning or development restrictions are not considered.

The cost-benefit of each 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, 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 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 that valuing future spending too low is at odds with resilient coastal planning principles.

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

The CBA has been performed over the original project timeframe – notionally 2022 to 2122, 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. Estimates beyond 2040 should be viewed as indicative trends only. Long-term adaptation pathways should always be monitored and updated over time.

2.1 Options Suitable for Cost Benefit Analysis

The CBA has only addressed options which include 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. This inaction is unrealistic in practical terms as severe erosion would require the City to implement public safety measures. The scenario is therefore different to the Do-Nothing adaptation option and assumes literally 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 recommended for further analysis from previous Multi-Criteria Analysis, and considered suitable for CBA, are summarised in Table 2-1 - managed retreat and physical protection options.

Table 2-1 Risk treatment options from WAPC (2019) to be considered for CBA

Option Category	Option Name	Option Code
Planned / Managed Retreat	Voluntary acquisition	PMR4
Protect	Beach nourishment	PR1
	Groyne(s)	PR2
	Seawall	PR3
	Levee	PR6

2.2 Other Options

The remaining adaptation options from WAPC (2019), presented in Water Technology (2023) are not considered suitable for CBA and have been costed using traditional budgeting techniques for MUs where they received a positive MCA score. Future reporting for this project, at the Stage 7 Implementation Report will provide cost estimates and notes on any scoping details or assumptions for implementation of these options.

3 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 information about the assets were not considered to provide enough detail for economic analysis.
2. Finalise quantities of assets at risk for all categories for erosion for each MU at each timeframe.
3. Determine an appropriate unit value for each category for loss to erosion and inundation.
4. Valuing the loss of existing assets and values – this assumes the scenario of complete inaction over the project timeframe.
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.
10. Recommendation of options to be considered for implementation.

3.1 Valuing the Loss of Existing Assets and Values

In order to adequately compare the cost of different adaptation pathways we first must estimate the total value of assets at risk if projected erosion and inundation were to occur. This will form the asset value component of the 'do nothing' strategy. The total damage costs for each category are estimated by using the area of each asset category, which might be expected to be affected for each hazard type at each timeframe. Note that these cost estimates are estimates only intended for general comparison.

The size of the study area has best suited the use of a detailed 'unit cost method' for estimating erosion loss and inundation damage costs to properties and assets. This method primarily assumes a locally determined cost for each unit area in each category. The total damage costs for each category are estimated by using the sum of areas of each category type which might be expected to be affected for each timeframe. Given the size of the study area, the accuracy of the erosion modelling used, we consider the method is suitable for estimating damage costs for the purposes of a cost benefit analysis.

3.1.1 Updated Assets and Values at Risk

Review of the asset information available resulted in a need to re-analyse the local planning scheme data in GIS as the existing information were not considered to provide enough detail for economic analysis. A summary of the input quantities for each category for each MU used are presented in Appendix A and land areas were quantified against the same categories:

- Roads
- Residential property
- Commercial property
- Developed Foreshore
- Public and Community
- Environmental
- Heritage

3.1.2 Unit costs

Reasonable economic assumptions have been used to determine unit costs for erosion loss and inundation damage. Unit cost values for erosion for different asset categories are listed in Table 3-1 and for inundation in Table 3-2. For the two private categories (Commercial, Residential), 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 project timeframe. For public categories with built infrastructure, construction cost information from Cardno (2018b), 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.

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 as it is uncertain how this trend will continue into the future. Construction costs, and all other costs, are assumed to increase at the expected inflation rate and therefore no adjustment is required in the analysis.

Table 3-1 Erosion costs for each asset category

Asset Category	Erosion Cost ($AUD/m^2)	Notes
Residential property	1000	Based on review of median house prices in study area (On The House, 2023 and Real Estate, 2023). This method represents a market value. For pure economic analysis this may be considered on overestimate because the zoning value of the land is typically not included in pure economic analysis, but for CBA,financial and budgeting preparations for the City it is considered appropriate.
Commercial property	750	A review of sales in the study area was undertaken but there were too few results to be relied upon. Rawlinsons (2016) was reviewed for an average rate of applicable developments to establish an estimate.
Roads	300	$300/m^2 rate from DIRDC (2018) and Cardno (2018).
Developed Foreshore Reserve	312.5	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.
Public and Community	500	Allocated at 66% as Commercial to ensure government infrastructure accounted for adequately.
Environmental	250	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 25% of Residential category.
Heritage	1000	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 equal to Residential property category.

Inundation cost 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.

Table 3-2 Inundation costs for each asset category

Asset Category	Inundation Cost ($AUD/m^2)	Notes
Residential property	200	DNRE, 2000 DECC, 2007 CRES, 1992
Commercial property	150	
Roads	60	
Developed Foreshore Reserve	0.6	Estimate of replacement cost of damaged infrastructure.
Public and Community	100	Allocated at 66% as Commercial to ensure government infrastructure accounted for adequately.
Environmental	50	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 20% of Residential; some environmental assets will likely have very little impact from coastal inundation while others could be completely destroyed.
Heritage	200	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 equal to Residential property category.

3.1.3 Value of Existing Vulnerable Assets and Values

The base-case economic scenario of assuming complete inaction over the project timeframe 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.

3.2 Planned / Managed Retreat – Voluntary Acquisition (PMR4)

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

1. Calculate the acquisition cost for the two private categories at market values for the timeframe they are considered vulnerable to hazards.
2. Calculate the infrastructure removal and subsequent land improvement cost to return land to undeveloped foreshore reserve for all size categories with built infrastructure (Table 3-3). 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 $1/m^2 has been applied.

3. Include the value of losing the Public and Community category – 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. The two 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 not considered an economic loss; and the developed foreshore category is not valued as a loss again because new usable foreshore is what is being created by this option.
4. The resultant amounts for each timeframe were then converted to one summary NPV.

Table 3-3 Valuation considerations for voluntary acquisition option

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

3.3 Protection Options

3.3.1 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 are open coast are 1.0m high and 15m 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 in response to climate changes (e.g. sea level rise and changes to sediment transport).
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.

3.3.2 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 reports and design drawings of existing structures in the study area.
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 (40% for seawalls as they need to interface with any infrastructure crossing the shoreline).
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 $90/tonne and core of $75/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.
- Replacement cost for the structure at 50yrs, assumed to be 100% of capital cost.
- Beach and foreshore amenity is expected to be broadly similar to current levels, with the exception of PR2-Seawalls which will likely result in the loss of a usable sandy beach. Due to uncertainties in monetising this loss it has been decided to consider this impact qualitatively in the analysis.

3.3.3 Inundation Protection – Levee – PR6

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 levee 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.
   e. An increased cost to supply, deliver and place material.
3. The resultant amounts for each timeframe were then converted to one summary NPV.
4. Levees have been costed without consideration of land acquisition, or easement establishment costs, legislative fees, or costs to resolve internal drainage issues.

4 RESULTS

4.1 MU1

CBA results for erosion are presented in Table 4-1, no inundation options were analysed in the CBA due to the results of the previous Multi-Criteria Analysis, however the economic Do Nothing scenario is presented for reference in Table 4-2.

Table 4-1 MU1 CBA results for erosion adaptation

Net Present Value 2020	Do Nothing Economic Base-Case	PMR4: Voluntary Acquisition	PR1: Beach Nourishment	PR2: Groynes	PR3: Seawall
Option Notes	▪ Economic base case for comparison purposes.	▪ Acquisition assumed in same year as hazard line identifies land as vulnerable.	▪ Assumes treatment of 1000m of shoreline west of Albany Waterfront Marina. ▪ Assumes suitable sand source available (grain size, volume, cleanliness, proximity). ▪ 2072 implementation.	▪ Assumes 4 rock groynes, 100m long, approximately 250m apart to treat 1000m of shoreline west of Albany Waterfront Marina. ▪ 2072 Implementation. ▪ Ancillary foreshore costs are not included.	▪ Assumes seawall to treat 1000m of shoreline west of Albany Waterfront Marina. ▪ 2072 Implementation. ▪ Does not include sand nourishment - beachfront not maintained - not a monetised loss as currently no beach amenity. ▪ Ancillary foreshore costs are not included.
7% NPV	$427,546	$468,582	$89,015	$166,308	$146,113
4% NPV	$4,488,073	$4,866,755	$505,913	$771,056	$677,428
2% NPV	$30,233,385	$32,736,515	$1,821,570	$2,315,074	$2,033,958

Table 4-2 MU1 do nothing economic base case results for inundation

Net Present Value 2020	Do Nothing Economic Base-Case
Option Notes	▪ Economic base case.
7% NPV	$723,928
4% NPV	$978,559
2% NPV	$2,150,737

4.2 MU2

CBA results for erosion and inundation are presented in Table 4-3 and Table 4-4.

Table 4-3 MU2 CBA results for erosion adaptation

Net Present Value 2020	Do Nothing Economic Base-Case	PMR4: Voluntary Acquisition	PR1: Beach Nourishment	PR3: Seawall
Option Notes	▪ Economic base case for comparison purposes.	▪ Acquisition assumed in same year as hazard line identifies land as vulnerable.	▪ Assumes 100% of shoreline treated (7000m). ▪ Assumes suitable sand source available (grain size, volume, cleanliness, proximity). ▪ 2022 implementation.	▪ Assumes 7000m seawall to cover 100% shoreline in MU. ▪ 2022 Implementation. ▪ Does not include sand nourishment - beachfront not maintained. ▪ Replacement cost in 2072 included. ▪ Ancillary foreshore costs are not included.
7% NPV	$16,319,495	$16,659,630	$14,221,023	$23,849,579
4% NPV	$39,764,243	$53,475,446	$21,941,894	$29,480,199
2% NPV	$119,931,599	$189,276,635	$38,029,716	$40,374,888

Table 4-4 MU2 CBA results for inundation adaptation

Net Present Value 2020	Do Nothing Economic Base-Case	PR6: Levee
Option Notes	▪ Economic base case.	▪ Assumes 3500m of levee required. ▪ High contingency (50%) to cover any treatment, revegetation challenges. ▪ Assumes 2022 implementation because various asset and values vulnerable. ▪ 2072 Replacement cost included.
7% NPV	$15,629,623	$14,949,800
4% NPV	$24,441,141	$18,848,379
2% NPV	$57,733,263	$26,326,607

4.3 MU3

CBA results for erosion and inundation are presented in Table 4-5 and Table 4-6.

Table 4-5 MU3 CBA results for erosion adaptation

Net Present Value 2020	Do Nothing Economic Base-Case	PMR4: Voluntary Acquisition	PR1: Beach Nourishment	PR3: Seawall
Option Notes	▪ Economic base case for comparison purposes.	▪ Acquisition assumed in same year as hazard line identifies land as vulnerable.	▪ Assumes 1400m shoreline treated to northwest of Princess Royal Sailing Club, with 2022 implementation. ▪ Assumes 3850m shoreline treated from Princess Royal Sailing Club to southeast, with 2047 implementation. ▪ Assumes suitable sand source available (grain size, volume, cleanliness, proximity).	▪ Assumes 1400m seawall northwest of Princess Royal Sailing Club with 2022 implementation. ▪ Assumes 3850m seawall from Princess Royal Sailing Club to southeast with 2047 implementation. ▪ Does not include sand nourishment - beachfront not maintained. ▪ Ancillary foreshore costs are not included.
7% NPV	$16,652,267	$18,397,671	$4,277,359	$7,221,680
4% NPV	$36,562,886	$45,869,218	$8,711,590	$11,992,686
2% NPV	$102,121,716	$145,912,911	$18,551,363	$21,197,867

Table 4-6 MU3 CBA results for inundation adaptation

Net Present Value 2020	Do Nothing Economic Base-Case	PR6: Levee
Option Notes	▪ Economic base case.	▪ Assumes 1700m of levee required split across four sections across MU. ▪ High contingency (50%) to cover any treatment, revegetation challenges. ▪ Assumes 2072 implementation.
7% NPV	$905,139	$242,870
4% NPV	$1,360,269	$1,147,800
2% NPV	$2,836,889	$3,512,760

4.4 MU4

CBA results for erosion and inundation are presented in Table 4-7 and Table 4-8.

Table 4-7 MU4 CBA results for erosion adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PMR4: Voluntary Acquisition
Option Notes	▪ Economic base case for comparison purposes.	▪ Acquisition assumed in same year as hazard line identifies land as vulnerable.
7% NPV	$17,066,014	$16,981,753

Net Present Value 2020	Do Nothing Economic Base-Case	PMR4: Voluntary Acquisition
4% NPV	$35,796,911	$38,427,479
2% NPV	$89,094,658	$106,229,837

Table 4-8 MU4 CBA results for inundation adaptation

Net Present Value 2020	Do Nothing Economic Base-Case	PR6: Levee
Option Notes	▪ Economic base case.	▪ Assumes 1250m of levee required along coast near Lake Vancouver. ▪ High contingency (50%) to cover any treatment, revegetation challenges. ▪ Assumes 2047 implementation.
7% NPV	$1,455,985	$1,000,327
4% NPV	$3,303,847	$2,531,909
2% NPV	$10,890,550	$5,531,901

4.5 MU5

CBA results for erosion and inundation are presented in Table 4-9 and Table 4-10.

Table 4-9 MU5 CBA results for erosion adaptation options

Net Present Value 2020	Do Nothing Economic Base-Case	PR1: Beach Nourishment
Option Notes	▪ Economic base case for comparison purposes.	▪ Assumes treatment of 750m beach and 150m of Camp Quaranup shoreline. ▪ Assumes suitable sand source available (grain size, volume, cleanliness, proximity). ▪ 2047 implementation.
7% NPV	$48,148,706	$670,004
4% NPV	$64,488,009	$2,021,499
2% NPV	$89,425,838	$5,118,310

Table 4-10 MU5 CBA results for inundation adaptation

Net Present Value 2020	Do Nothing Economic Base-Case	PR6: Levee
Option Notes	▪ Economic base case.	▪ Assumes 300m of levee required around Camp Quaranup and 50m for depression in Isthmus. ▪ High contingency (50%) to cover any treatment, revegetation challenges. ▪ Assumes 2072 implementation.
7% NPV	$1,721,028	$49,997
4% NPV	$1,931,140	$236,286
2% NPV	$2,539,008	$723,136

5 DISCUSSION

5.1 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 of the future spending of money is cheaper. Given the long planning timeframe it could be argued that the 2% in the sensitivity analysis should be used, or given more weight than the higher numbers, particularly if private property inflation continues into the future at historic rates.

5.2 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.

5.3 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 actual 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.
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 to a government body purchasing the property, 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.

5.4 Recommended Options for Each MU

The CBA has been used as an additional tool to assist decision making when assessing adaptation options with which to proceed. 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.

Review of the CBA results shows that the ranking of options for each MU by NPV 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.

From the WAPC hierarchy, "Avoid" is only practical for parts of MU4 and MU5. The "Accommodate" option principally applies to coastal inundation. The remaining results considered in the CBA process are essentially to consider the advantages and disadvantages of "Retreat" (PMR4) or "Protect Options" (PR1-5) for the erosion hazard.

Options recommended to proceed are presented in Table 5-1 for erosion and Table 5-2 for inundation. 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. There were no MU's where all options for all discount rates did not perform better than the economic base case.

For erosion, four out of the five MU's (not MU4) resulted in PR1 Beach Nourishment having a positive benefit/cost ratio, and/or outperforming the other analysed options. A key assumption for this option is that a suitable sand source is available (grain size, volume, cleanliness and proximity). For inundation, four out of the five MU's (not MU1 as no options were recommended for CBA for this MU) resulted in PR6 Levee having a positive benefit/cost ratio. Further investigations are required to confirm the assumptions used in the analysis to develop a more accurate scope for the recommended options. The Stage 7 Implementation Report will provide further detail for these investigations and implementation of options.

Table 5-1 Recommended CBA options for erosion for each MU

Management Unit	Recommended Option	Notes
MU1	PR1 Beach Nourishment	▪ PR1 is best value for all discount rates and has a positive benefit/cost ratio for all rates. ▪ PR3 Seawall is not recommended as it would mean the loss of the beach. Should the objectives of this MU change in the future PR3 Seawall may be suitable in the long-term. ▪ PR1 Beach nourishment could also later be transitioned to both PR2 Groynes or PR3 Seawall if required. ▪ PMR4 Retreat by voluntary acquisition is the worst value option for all discount rates.
MU2	PR1 Beach Nourishment	▪ PR1 is best value for all discount rates and has a positive benefit/cost ratio for all rates. ▪ PR3 Seawall is not recommended as it would mean the loss of the beach. Should the objectives of this MU change in the future PR3 Seawall may be suitable in the long-term. ▪ PMR4 Retreat by Voluntary Acquisition is the worst value option for all discount rates.

Management Unit	Recommended Option	Notes
MU3	PR1 Beach Nourishment	▪ PR1 is best value for all discount rates and has a positive benefit/cost ratio for all rates. ▪ PR3 Seawall is not recommended as it would mean the loss of the beach. Should the objectives of this MU change in the future PR3 Seawall may be suitable in the long-term. ▪ PMR4 Retreat by Voluntary Acquisition is the worst value option for all discount rates.
MU4	PMR4 Retreat by Voluntary Acquisition	▪ PMR4 Retreat by Voluntary Acquisition is the best value option for one discount rate (7%) and has a positive benefit/cost ratio for this rate. ▪ PMR4 Retreat by Voluntary Acquisition does not have a positive benefit-cost ratio for the other two rates (4% and 2%) but no other options were deemed appropriate for CBA. ▪ Other non-CBA options will form part of the management approach and will be presented at the Stage 7 Implementation Report.
MU5	PR1 Beach Nourishment	▪ PR1 Beach Nourishment has a positive benefit-cost ratio for all rates.

Table 5-2 Recommended CBA options for inundation for each MU

Management Unit	Recommended Option (s)	Notes
MU1	N/A	▪ No options were considered appropriate for CBA. ▪ Other non-CBA options will form part of the management approach and will be presented at the Stage 7 Implementation Report.
MU2	PR6 Levee	▪ PR6 Levee has a positive benefit/cost ratio for all rates.
MU3	PR6 Levee	▪ PR6 Levee has a positive benefit/cost ratio for two discount rates (7% and 4%).
MU4	PR6 Levee	▪ PR6 Levee has a positive benefit/cost ratio for all rates.
MU5	PR6 Levee	▪ PR6 Levee has a positive benefit/cost ratio for all rates.

6 SUMMARY

The CBA analysis is contingent on NPV discount rates and unit cost rates assumptions. 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 out further design and procurement studies. In particular, the procurement of sand suitable for nourishment works may be questionable in the study area 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. Other non-CBA options will form part of the final recommended management approach and will be presented in the Stage 7 Implementation Report.

7 REFERENCES

Abelson, P. and Dalton, T., (2018), "Choosing the Social Discount Rate for Australia", The Australian Economic Review, Vol.51, No.1, pp.52-67

APH, (2018), [Discount-rates – Parliament of Australia (aph.gov.au)]

Baird, (2020). *Gingin Coastal Inundation Study – Lancelin, Ledge Point, Seabird and Guilderton*, Report 13288.101.R1.Rev1, prepared for Shire of Gingin

Cardno, (2018), "Shire of Dandaragan Coastal Hazard Risk Management and Adaptation Plan"

Cardno, (2018b), "City of Rockingham Coastal Hazard Risk Management and Adaptation Plan"

CRES, (1992), "ANUFLOOD: A Field Guide" Centre for Resources and Environment, Australian National University, Smith, D.I. and Greenway, M.A.

DECC, (2007), "Residential Flood Damages – Floodplain Risk Management Guideline", NSW Department of Environment and Climate Change

DIRDC, (2018), "Road Construction Cost and Infrastructure Procurement Benchmarking: 2017 update" Research Report 148, Department of Infrastructure, Regional Development and Cities, Australian Government

DNRE, (2000), "Rapid Appraisal Method (RAM) for Floodplain Management" Department of Natural Resources and Environment, Victoria, prepared by Read Sturgess and Associates

DPMC, (2016), "Cost-Benefit Analysis Guidance Note", Department of the Prime Minster and Cabinet Office of Best Practice Regulation

IPCC, (2021). Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

On The House, (2023), "Suburb Research – On the House", https://www.onthehouse.com.au/, [Accessed August 2023]

Rawlinsons (2016), "Construction Cost Guide"

RBA, (2015), [Long-run Trends in Housing Price Growth (rba.gov.au)]

Real Estate, (2023), "Sold Residential Property" https://www.realestate.com.au [Accessed August 2023]

Seashore Engineering, (2019), "Assessment of Coastal Erosion Hotspots in Western Australia" for the DoT

Transport for NSW, (2022), "Cost-Benefit Analysis Guide", https://www.transport.nsw.gov.au/projects/project-delivery-requirements/evaluation-and-assurance/transport-for-nsw-cost-benefit [Accessed September 2022]

Water Technology, (2023), "Princess Royal Harbour CHRMAP – Risk Evaluation and Treatment"

Western Australian Planning Commission (WAPC, 2013). State Planning Policy No. 2.6 – State Coastal Planning Policy, prepared under the Planning and Development Act 2005.

Western Australian Planning Commission (WAPC, 2019). Coastal Hazard Risk Management and Adaptation Planning Guidelines

APPENDIX A
UPDATED ASSETS AND VALUES AT RISK

Table A-1 Vulnerable area (m^2) of asset categories to erosion in MU1 for each project timeframe.

Category	2022	2047	2072	2122
Roads	0	0	0	131835
Residential property	0	0	0	51842
Commercial property	0	0	0	1739
Public and Community	353	0	0	153394
Developed Foreshore	0	0	0	43518
Environmental	0	0	0	42352
Heritage	0	0	0	24169

Table A-2 Vulnerable area (m^2) of asset categories to inundation in MU1 for each project timeframe.

Category	2022	2047	2072	2122
Roads	1505	664	1085	51025
Residential property	0	0	0	0
Commercial property	7	26	73	752
Public and Community	3480	1657	2515	24506
Developed Foreshore	354	381	903	16962
Environmental	2481	469	664	34059
Heritage	438	164	243	6244

Table A-3 Vulnerable area (m²) of asset categories to erosion in MU2 for each project timeframe.

Category	2022	2047	2072	2122
Roads	12484	25694	25192	74195
Residential property	0	2071	11344	117380
Commercial property	138	3266	76667	332474
Public and Community	1393	5778	14855	62662
Developed Foreshore	0	0	0	0
Environmental	9891	44293	47726	73688
Heritage	681	207	5	4

Table A-4 Vulnerable area (m²) of asset categories to inundation in MU2 for each project timeframe.

Category	2022	2047	2072	2122
Roads	11097	8397	38882	67435
Residential property	18727	37081	27281	670085
Commercial property	29335	27737	75971	255425
Public and Community	3069	2086	4389	357220
Developed Foreshore	0	0	0	0
Environmental	60455	26031	23623	34123
Heritage	136	90	181	543

Table A-5 Vulnerable area (m^2) of asset categories to erosion in MU3 for each project timeframe.

Category	2022	2047	2072	2122
Roads	3794	12232	17219	48655
Residential property	2042	6740	23368	148270
Commercial property	0	207	21954	173671
Public and Community	0	0	0	385
Developed Foreshore	2469	18078	21954	99158
Environmental	10657	44912	46841	64403
Heritage	1629	3239	5347	18720

Table A-6 Vulnerable area (m^2) of asset categories to inundation in MU3 for each project timeframe.

Category	2022	2047	2072	2122
Roads	2368	1819	3416	28097
Residential property	551	409	583	6021
Commercial property	0	10	2421	18148
Public and Community	0	0	0	0
Developed Foreshore	8488	6075	5014	9918
Environmental	8380	9686	16831	44188
Heritage	169	163	349	631

Table A-7 Vulnerable area (m^2) of asset categories to erosion in MU4 for each project timeframe.

Category	2022	2047	2072	2122
Roads	690	12908	20837	15575
Residential property	0	16	15168	112270
Commercial property	0	0	0	0
Public and Community	0	138	1270	3625
Developed Foreshore	0	0	0	1800
Environmental	23305	102254	118033	373309
Heritage	1571	8571	11863	38800

Table A-8 Vulnerable area (m^2) of asset categories to inundation in MU4 for each project timeframe.

Category	2022	2047	2072	2122
Roads	0	767	7060	26605
Residential property	0	0	0	15627
Commercial property	0	0	0	0
Public and Community	0	0	0	10915
Developed Foreshore	223	85	254	1648
Environmental	11887	8133	134700	538124
Heritage	2038	1582	2078	75677

Table A-9 Vulnerable area (m^2) of asset categories to erosion in MU5 for each project timeframe.

Category	2022	2047	2072	2122
Roads	0	0	0	0
Residential property	0	0	0	0
Commercial property	0	0	0	0
Public and Community	0	0	0	0
Developed Foreshore	0	0	0	5284
Environmental	28182	49341	33114	694
Heritage	28323	49354	33114	5982

Table A-10 Vulnerable area (m^2) of asset categories to inundation in MU5 for each project timeframe.

Category	2022	2047	2072	2122
Roads	0	0	0	0
Residential property	0	0	0	0
Commercial property	0	0	0	0
Public and Community	0	0	0	0
Developed Foreshore	498	375	1377	4895
Environmental	4723	1201	1879	7394
Heritage	6915	1662	3351	12485

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

Ground Floor, 430 Roberts Road
Subiaco WA 6008
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