DATA & INFORMATION GAP ANALYSIS
For Coastal Hazard & Risk Management

Gingin Dandaragan Coast
(Hill Primary Coastal Compartment)

September 2013

Coastal Focus

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This document was prepared for the Northern Agricultural Catchments Council, the Shires of Gingin and the Shire of Dandaragan by Coastal Focus.

This document is for coastal practitioners such as local and state government agency staff particularly town planners and coastal engineers, councillors, natural resource managers and consultants who are seeking guidance about coastal hazards. Written in plain English, this report is a source of information for the broader community who wish to build an understanding of how coastal processes shape the coast and how coastal hazards are likely to affect the Hill Primary Coastal Compartment in the foreseeable future. Coastal Focus.

Funding for this project was provided by the Shire of Dandaragan, the Shire of Gingin and the Northern Agricultural Catchments Council through the Australian Government's Caring for Our Country program.

ACKNOWLEDGEMENTS

Coastal Focus would like to thank Ashley Robb from NACC, Fangjun Li, Karl Illich, Steven James and Sharon Hu from the Department of Transport, Professor Lindsay Collins from Curtin University and the staff of the Shires of Dandaragan and Gingin for reviewing and editing. We would also like to thank Sira Tecchiato for the contribution to the report and Dr. Deborah Kennedy for editing assistance. We also acknowledge the contribution of Doug Vickery from the Cockburn Sound Coastal Alliance for his contribution.

Revisions History

Version	Author	Distribution			Review	
		Recipients	No. copies & Format	Date	Reviewer	Date
A	C. Danese	NACC	1 Docx	5/6/2013	Lindsay Collins, Li Fangjun, Karl Illich and Ashley Robb	5/8/2013
B	C. Danese	NACC	1 Docx	25/8/2013	Ashley Robb	2/9/2013

Approved for final release by:

Chiara Danese

Director of Coastal Focus

Coastal Focus

Disclaimer

Coastal Focus has prepared this report for the use of NACC and the Shires of Dandaragan and Gingin in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. The methodology adopted and sources of information used by Coastal Focus are outlined in this report.

Cover: Top image courtesy of Ashley Robb, smaller images courtesy of Paul Robb, from left Lancelin, Hill River, Seabird and Thirsty Point (Cervantes).

DOCUMENT STRUCTURE

Section I Introduction: aims and objectives of the report and methods used to undertake the data and information gap analysis.

Section II Coastal Hazards: a broad description of what coastal hazards are and the potential impacts on coastal assets.

Section III Coastal Processes: a summary of key coastal processes operating along the Hill Primary Compartment and existing data sets that describe these processes.

Section IV Knowledge Base for Hazard Mapping: data sets required for assessing and mapping coastal hazards.

Section V Recommendations for Future Studies: data gap analysis for each sediment cell and recommendations for future studies.

Key Tables:

Table 5 and 6 (page 28): Data requirements coastal erosion hazard mapping (second pass and third pass).

Table 7 (page 36): Available data sets and potential shortcomings in the existing information for the Hill Primary Compartment.

Table 8 (page 40): Recommended future data requirements for developing third pass coastal hazard risk assessment maps.

Table 9 (Appendix B): Summary Coastal Data sets for the Hill Coastal Compartment.

Table 10 (Appendix C): provides identifies common data and information gaps across sediment cells to help to create cost efficiencies in future data collection across sediment cells of interest, as opposed to collecting individually at different times.

EXTENDED SUMMARY

INTRODUCTION

Sections of the Hill Primary Compartment located across the Shires of Dandaragan and Gingin are particularly vulnerable to the impacts of coastal erosion and inundation due to the local topography, sensitivity to coastal processes and increasing development and recreational pressures on coastal ecosystems (Eliot et al. 2011). Coastal hazards are already causing temporary or permanent loss of natural and built assets, and the services that these assets provide. Change in coastal processes due to climate variability is likely to expose new areas to the impacts of erosion and/or inundation, and/or lead to more severe impacts, such as chronic erosion, in already vulnerable areas. In order to predict how private and public assets will be further impacted by coastal hazards it is necessary to understand how coastal processes operate at the sediment cell level. Understanding coastal processes requires reliable and accurate data sets that are not always available in regional areas.

PURPOSE

The purpose of this Data and Information Gap Analysis (Report) is to summarise existing coastal data sets for the Hill Primary Compartment and their usefulness for assessing and mapping coastal hazards at a scale that is useful for local planning and decision-making.

This Report, commissioned by the Shire of Dandaragan, the Shire of Gingin and the Northern Agricultural Catchments Council, represents the first step towards preparing and adapting to the impacts of coastal hazards in the Gingin Dandaragan region. The second step is to use the information gathered from this report to inform a **Project Partner Workshop** (to be held in July 2013) and prepare the **Workshop Summary Report** (September 2013).

SCOPE

This Report looks at existing data sets that describe the coastal processes operating between the Moore River and North Head (Figure 1). This stretch of coast was identified as the Hill Primary Compartment by Eliot et al. (2011) due to similar coastal landform features that occur along this stretch of coast. The Hill Primary Compartment is subdivided into four secondary compartments, 10 tertiary compartments and 28 primary sediment cells.

This Report identifies the best coastal data currently available to describe:

- meteorological drivers (winds, storms, rainfall and weather cycles)
- ocean drivers (water levels, tides, resonant phenomena)
- geological and geomorphic features
- sediment transport.

The objectives of this Report are to:

1. Provide a summary of the main physical coastal processes that are altering morphology (erosion and/or recession) or are causing coastal inundation within the Hill Primary Compartment.

2. Identify existing coastal data sets, their availability, location and characteristics.
3. Identify the data sets required for understanding coastal processes and for mapping coastal hazards.
4. Identify data gaps and shortcomings in the existing information that would limit its application in assessing and mapping coastal hazards.
5. Suggest appropriate monitoring mechanisms for the collection of new data sets for areas at greatest risk from coastal hazards including locations, frequency, responsible parties and indicative costs.
6. Identify research or investigatory work required to fill information gaps (e.g. analysis of data sets) in order of priority and over a five-year timeframe.

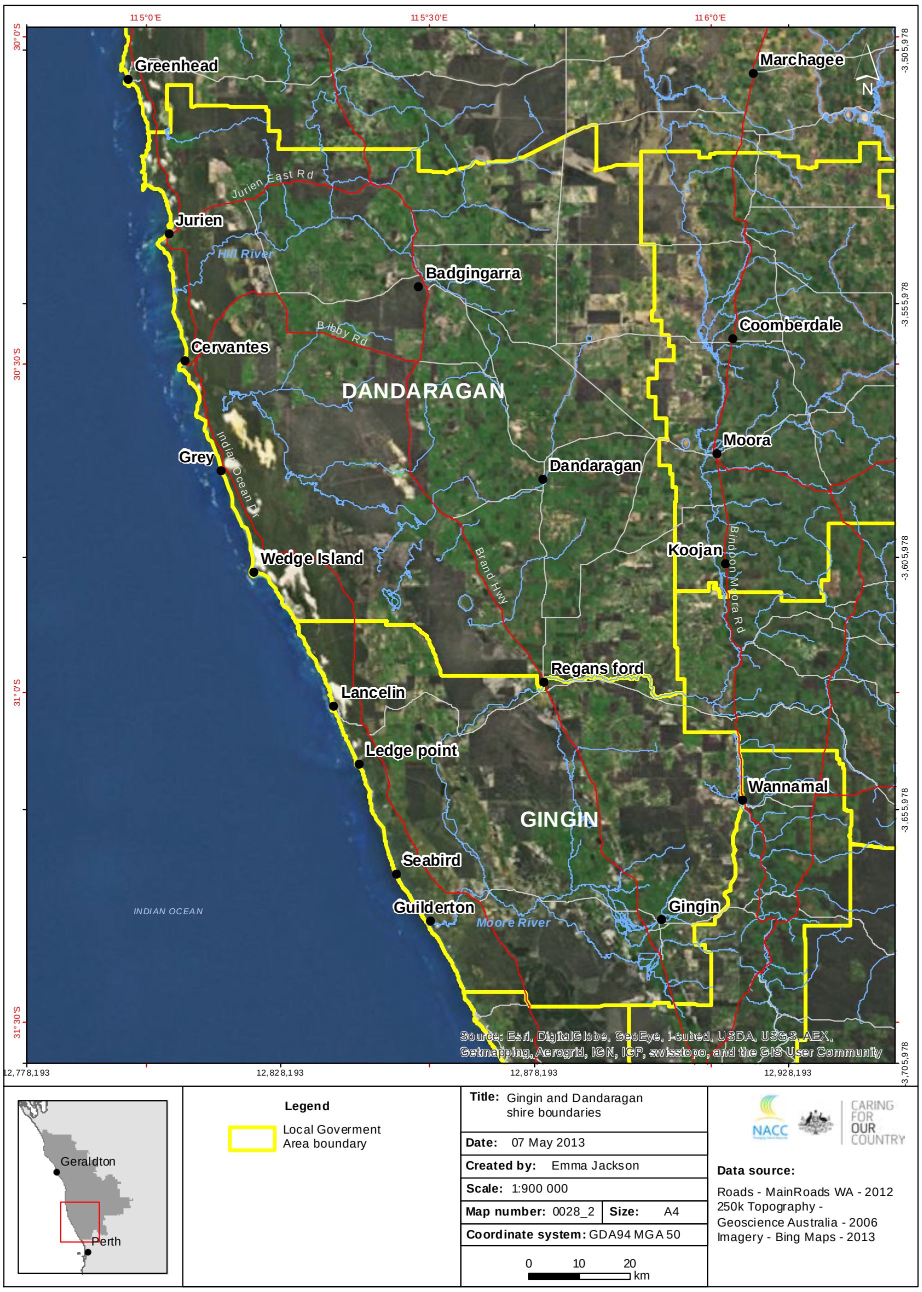

Figure 1 (Summary): Gingin Dandaragan coast, Study Area/

METHODS

Research for this report involved the following steps:

i. A desktop analysis of available coastal data sets, which included researching technical reports, scientific papers, studies undertaken for proposed coastal development and liaising with data custodians.
ii. A review of available data and information to assess data location, accuracy and relevance for coastal hazard assessment and mapping.

The majority of coastal data and information about the data (metadata) were provided by data custodians such as the Department of Planning, the Department of Transport and the Department of Water and publicly available. Some reports were not made available to the consultant due to confidentiality restrictions.

DATA REQUIREMENTS FOR COASTAL HAZARDS ASSESSMENT

Interactions in coastal processes are complex. Understanding how those interactions contribute to coastal change is difficult to predict with certainty. The time span for data records in regional areas can be too short to identify trends, or the quality of information is poor due to changes in instrumentation technology or location. These deficiencies can compromise the accuracy of numeric simulation models, projections and ultimately the quality of hazard assessment and mapping. Data collection programs can be put in place to remedy deficiencies in the spatial and temporal extent of data. Nevertheless, in the absence of high quality data, broad scale hazard assessments can provide a ‘first cut’ to planners and managers as to how the shoreline will change in the next 100 years and the location and extent of areas prone to coastal inundation. Broad scale assessments have limited value in areas where more robust information is needed about risks to private and public assets, such as areas experiencing significant development pressures.

Third pass assessments at the tertiary sediment cell level are likely to be required at locations where the uncertainty of future impacts on existing or future coastal assets needs to be reduced for planning and management purposes. Third pass assessments require site-specific, high quality data in order to provide sufficient detail for land-use planning mechanisms such as setback lines, coastal recession lines and zones subject to coastal inundation.

The key data requirements for finer scale assessments, such as second pass and third pass erosion and inundation hazard assessments, are listed in Table 1.

Good elevation and high resolution bathymetric data is required for more detailed inundation maps especially if complex modelling exercise is to be undertaken. Modelling is required to estimate shoreline changes (erosion, accretion) caused by long-term climatic processes (for the chosen climate change scenarios), storm surges, coastal inundation scenarios and sediment transport.

Table 1 (Summary): Key data requirements for second and third pass erosion and inundation hazard assessment and mapping.

DATA	SECOND PASS	THIRD PASS
EROSION HAZARD MAPPING		
Meteorological drivers (rainfall, winds, storms, weather patterns)	Long term records and analysis	Long term records and analysis
Topography	High resolution contours Topographic maps, LiDAR DTM & DEM Description of geomorphological, geological and geotechnical features at the regional scale.	At least 0.25m contours Topographic maps, LiDAR DTM & DEM Description of geomorphological, geological and geotechnical features at the tertiary scale.
Bathymetry	Bathymetric charts not more than 10 years old derived from singlebeam or multibeam hydrographic surveys or nautical charts. Older bathymetric charts can be validated with ground truth measurements (new bathymetries might not be required for certain sites).	Recent and high resolution bathymetric charts derived from bathymetric LiDAR or Multibeam hydrographic surveys
Geology, geomorphology and sediment transport	Description of geomorphological and geological features at the regional scale. Model for regional sediment transport.	Description of geomorphological and geological features at the tertiary scale. Determination of potential change of unstable landforms at the tertiary scale. Sediment/bedrock relationships and add geotechnical data. Mechanisms for beach/dune interactions. Analysis of current and future (long-term) sediment transport and sediment budget rates: i. Alongshore distribution of sediment ii. Cross shore distribution of sediment iii. Influence of in-situ rock and artificial coastal management

DATA	SECOND PASS	THIRD PASS
		structures Role of nearshore currents in sediment transport and budgets.
Shoreline movement plots and beach profiles	Shoreline change and future beach behaviour to sea level rise at the regional scale. Up to date shoreline movement plots	Shoreline change and future beach behaviour to sea level rise at the tertiary scale. On-going beach surveys at hot spots. Up to date shoreline movement plots
Storm surge and water level	Historic analysis of storm surge heights associated with extreme weather events (*) to determine Annual Recurrence Interval (ARI).	Historic analysis of storm surge heights associated with extreme weather events (*) to determine Annual Recurrence Interval (ARI).
Waves	Projected storm wave heights (wind related) - for specified ARI. Wave climate response to SLR. To be accurate wave data sets should cover a period longer than 40 years.	Projected storm wave heights (wind related) - for specified ARI. Wave climate response to SLR. To be accurate wave data sets should cover a period longer than 40 years.
SLR scenarios	Projected sea levels for the specified climate change scenarios.	Projected sea levels for the specified climate change scenarios.
Benthic habitats	Spatial distribution of sediments and seagrass communities to estimate sediment budgets and transport.	Spatial distribution of sediments and seagrass communities to estimate sediment budgets and transport.
INUNDATION HAZARD MAPPING		
Meteorological drivers (rainfall, winds, storms, weather patterns)	Long term records and analysis	Long term records and analysis
Topography	Existing topographic contours.	At least 0.25m contours, LiDAR DTM/DEM. Description of geomorphological, geological and geotechnical features at the tertiary scale. As the storm surge reaches shallow water and the complex nearshore environment, increasingly finer scale

DATA	SECOND PASS	THIRD PASS
		bathymetric and elevation data is required.
Bathymetry	Possibly not older than 10 years. Acceptable if derived from single-beam hydrographic surveys and/or nautical charts.	Recent and high-resolution bathymetric charts derived from bathymetric LiDAR or Multibeam hydrographic surveys. As the storm surge reaches shallow water and the complex nearshore environment, increasingly finer scale bathymetric and elevation data is required.
Storm surge and water level	Historic analysis of storm surge heights associated with extreme weather events (*) to determine Annual Recurrence Interval (ARI).	Historic analysis of storm surge heights associated with extreme weather events (*) to determine Annual Recurrence Interval (ARI).
Waves	Projected storm wave heights (wind related) - for specified ARI.	Projected storm wave heights (wind related) - for specified ARI
Hydrology	River flooding hazard maps if available (for estuarine areas).	River flooding hazard maps if available (for estuarine areas).
SLR scenarios	Projected sea levels for the specified climate change scenarios.	Projected sea levels for the specified climate change scenarios.

GAP ANALYSIS: KEY FINDINGS

Overall there is a lack of historical information and detailed analysis of metocean drivers and processes for the Hill Primary Compartment and future data collection will be required to fill the identified gaps.

Table 2 and Figure 2 describe the existing data sets (location and timeframe) and identify their key shortcomings for coastal hazard and risk assessment.

Table 2 (Summary): Existing data sets for the Hill Primary Compartment and relevant for coastal hazard and risk assessment.

PHYSICAL DATA	AVAILABILITY	DATA QUALITY & GAPS
Winds	40 years +	Interpretation of wind records need to take into consideration how winds are/have been affected by geography, topography and change in instrumentation as well as differences in records between observation stations.
Rainfall	40 years +	Good quality
Storm surge and water level	18 years of regional records, 40 + from Fremantle and Geraldton.	Geraldton and Fremantle records are reliable from 1965 (since establishment of AHD) while the Jurien Bay records are too short. The long-term historic sea level data records can provide information about possible change in storminess over the Hill Primary Compartment, extreme weather events and trends in sea level variations. Regional variability in oceanographic and meteorological phenomena such as astronomical tides, changes in atmospheric pressure, winds, river discharges, ocean circulation and changes in water density must be considered when analysing and applying long-term data sets from stations located outside the study area.
Waves	Sporadic in nature from 1971 to 1994. Records from Rottnest (from 1994 located at -48m) and Jurien Bay (from 1997 located at -	Longer and accurate records are required to provide a description of the wave climate for the Hill Compartment and better understanding of the impact of off-shore coastal structures on wave climate. Further investigation of coastal processes

PHYSICAL DATA	AVAILABILITY	DATA QUALITY & GAPS
	42m) provide the closest representation of the region's wave climate.	for the region will require a better understanding of variability, trends and extremes of both offshore and nearshore wave climate and improve the interaction between waves, local topography and geomorphology. This could be achieved by installing new wave buoys offshore and onshore at certain locations.
Currents	Studies on currents have been undertaken in Jurien Bay (2008) and surface current stations are installed at Seabird and Cervantes. AWAC installed temporarily in 1989, 2003, 2002 and 2006 at various sites provide information on nearshore and offshore currents.	More information is required on nearshore currents for the study area especially current behaviour in proximity of islands and reefs.
Bathymetry	40 years of nautical charts and hydrographic surveys at various location and timeframes.	Bathymetric data that is older than 10 years need to be repeated for better accuracy (Guilderton, Seabird, Ledge Point, Jurien Bay). Older bathymetric charts can be validated with ground truth measurements (new bathymetries might not be required for certain sites). Bathymetric LiDAR for the entire region or Multibeam hydrographic surveys to be collected at hot spots (erosion areas near developed areas or future development).
Beach levels & profiles	Beach levels have been undertaken for various years at various locations from 1970 to present day. Beach profile analyses were undertaken at Seabird (2002 and 2004), Thirsty Point and Jurien Bay.	Beach profiles should be collected for areas subject to erosion in proximity of coastal development and repeated every 5 years.
Shoreline Movement Plots	Exist for all coastal towns up to 2002.	Need to be up to date to 2013.
Topography	LiDAR was collected in 2013 by NACC and DoW	High Resolution data. To be repeated in 10 to 15 years.

PHYSICAL DATA	AVAILABILITY	DATA QUALITY & GAPS
Geology and Geomorphology	Geological maps available since the 1940s'. Various reports, studies also available for the study area.	An assessment of elevation and coverage of underlying rock (exposed and submerged) is required. A study of the perched beach system at the local scale is also recommended.
Sediment Transport & Budgets	To date not much information on local sediment transport regimes and budgets exist. The only information available comes from studies undertaken as part of site specific projects such as coastal protections, setbacks, dredging.	The sediment cell classification needs to be updated with more accurate topography and bathymetric data to identify tertiary sediment cell boundaries. Regional and local scale sediment budget analysis and sediment transport modelling is required for detailed coastal hazard risk assessments.
Sediment samples	Sediment analysis was undertaken at Seabird and Lancelin (2009).	Sediment thickness, availability and transport needs to be better understood.
Benthic habitat	Mainly around Jurien Bay.	Extend the mapping to priority areas as part of coastal hazard assessments.
Hydrology	Information on river discharge is available for the Hill River (1968 to present day) and the Moore River (1965 to present day). Hydrologic study was undertaken for the Moore River in 1991 and 2000.	Hydrological and flood studies should be conducted to improve the understanding of influence of rivers play on sediment transport and potential implications of riverine floods on coastal areas.
Groundwater	Regional study undertaken in 1994. Broader vulnerability assessment for Australia undertaken in 2012.	Improve understanding of local vulnerability of coastal aquifers.

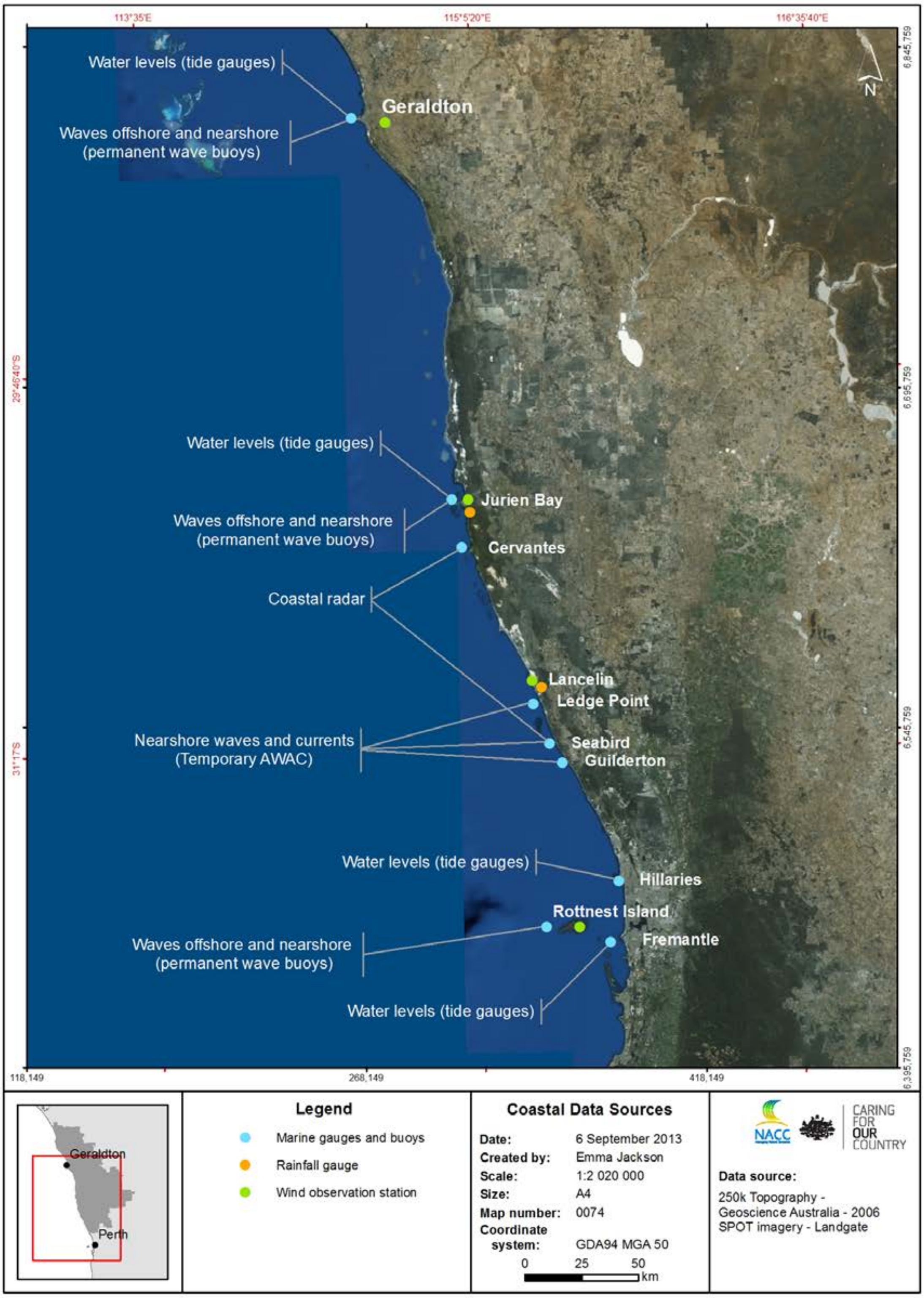

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Figure 2 (Summary): Coastal Data Sources for the Hill Primary Coastal Compartment. Map: Emma Jackson (NACC).

RECOMMENDATIONS

The following recommendations are drawn from the findings of the Gap Analysis and informed by research and lessons learned from coastal hazard risk assessments undertaken in other regions.

Recommendation 1: That existing data sets are improved in order to develop second pass erosion and inundation hazard maps for the Hill Primary Compartment. The maps will identify areas that are likely to be more vulnerable to coastal erosion and/or inundation at different timeframes and climate change scenarios. Second pass assessments are generally undertaken for the entire coastal compartment (or sub compartments) as a 'first cut' to provide planners and managers with a basic level of information regarding potential impacts of hazards on natural and built coastal assets. In many cases these 'first or second pass' assessments identifies areas that require additional investigations. It is important to note that alone, broad scale assessments have limited value in areas where more robust information is needed regarding future risks to private and public assets, such as areas experiencing significant development pressures. However, these broad scale assessments help to prioritise and frame finer scale assessments at the local level by identifying compartments and sediment cells that are likely to be more vulnerable to coastal change over time. For this purpose the following project tasks are recommended:

I. **Coastal Sediment Cells Study** to identify sections of the coast that exhibit similar processes and morphology as the framework for estimating sediment budgets and local scale assessment of hazard and risk. Improved bathymetric data is a key requirement.
II. **Bathymetry Mapping Program** to identify priority locations for new bathymetric surveys for improved data on nearshore structures, behaviour and responses, sediment transport and sediment distribution on the seafloor and sediment cell classification. A LiDAR bathymetric survey for the entire compartment would provide a wider context for available bathymetric information and facilitate a more complete assessment of natural resources, including sediment availability and distribution, although a costly option. A cheaper option would be to collect Multibeam Hydrographic Surveys at priority areas. Older bathymetric charts can be validated with ground truth measurements (new bathymetries might not be required for certain sites).
III. **Regional Sediment Transport Model** specific to the Hill Primary Compartment to estimate sediment sources, sinks and key transport pathways and determine rates of coastal change.
IV. **Analysis of Historic Water Levels and Storm Surges Data** associated with historic extreme weather events and determine ARI events for the Hill Primary Compartment.
V. **Shoreline Change and Movement Plots Analysis** to assess historical shoreline change for the Hill Primary Compartment and help predict future coastal change.
VI. **Coastal Assets and Values Study** to gather information on coastal assets, uses and values that are potentially at threat from future coastal hazards and to identify areas of high vulnerability and high value.

Recommendation 2: That existing data sets are improved in order to undertake a 'third pass' erosion and inundation hazard assessment and mapping at priority areas. The priority areas will be identified from the Coastal Sediment Cells Study (I) and the Coastal Assets and Values Study (IV) projects. Site specific hazard and risk assessment will require the following projects:

VII. **Bathymetry Mapping Program** to generate high-resolution bathymetric charts at the tertiary sediment cell level at identified priority areas. This will improve data on nearshore structures, behaviour and responses, sediment transport and sediment distribution on the seafloor and sediment cell classification at identified priority areas.

VIII. **Additional Wave Buoys** for areas that require installation of temporary wave buoys for improved site-specific wave and current data.

IX. **Sediment Transport and Budgets Analysis** to estimate sediment sources, sinks and key transport pathways to determine the rate of coastal change at the tertiary level (key priority areas) and assess potential migration or retreat of unstable landforms.

X. **Geotech Investigations** to assess the elevation and coverage of underlying rock at priority sites.

XI. **Shoreline Movement Plots and Beach Profiles** to be extended to the whole compartment or at key priority areas for assessment of shoreline change and sediment budget calculation.

Recommendation 3: That on-going data collection programs are continued. Specifically, the following programs be maintained:

XII. **Beach monitoring program** (profiles, historic photos and community photo-monitoring) for assessment of shoreline change and sediment budget calculation and potential impact of engineered structures at identified priority areas.

XIII. **Sediment Sampling Program** for improved understanding of sediment transport pathways, sinks and supplies.

Table 8 (page 56 of this report) lists the recommendations for future data requirements for undertaking a hazard risk assessment and mapping at a scale useful for planning and management decision making.

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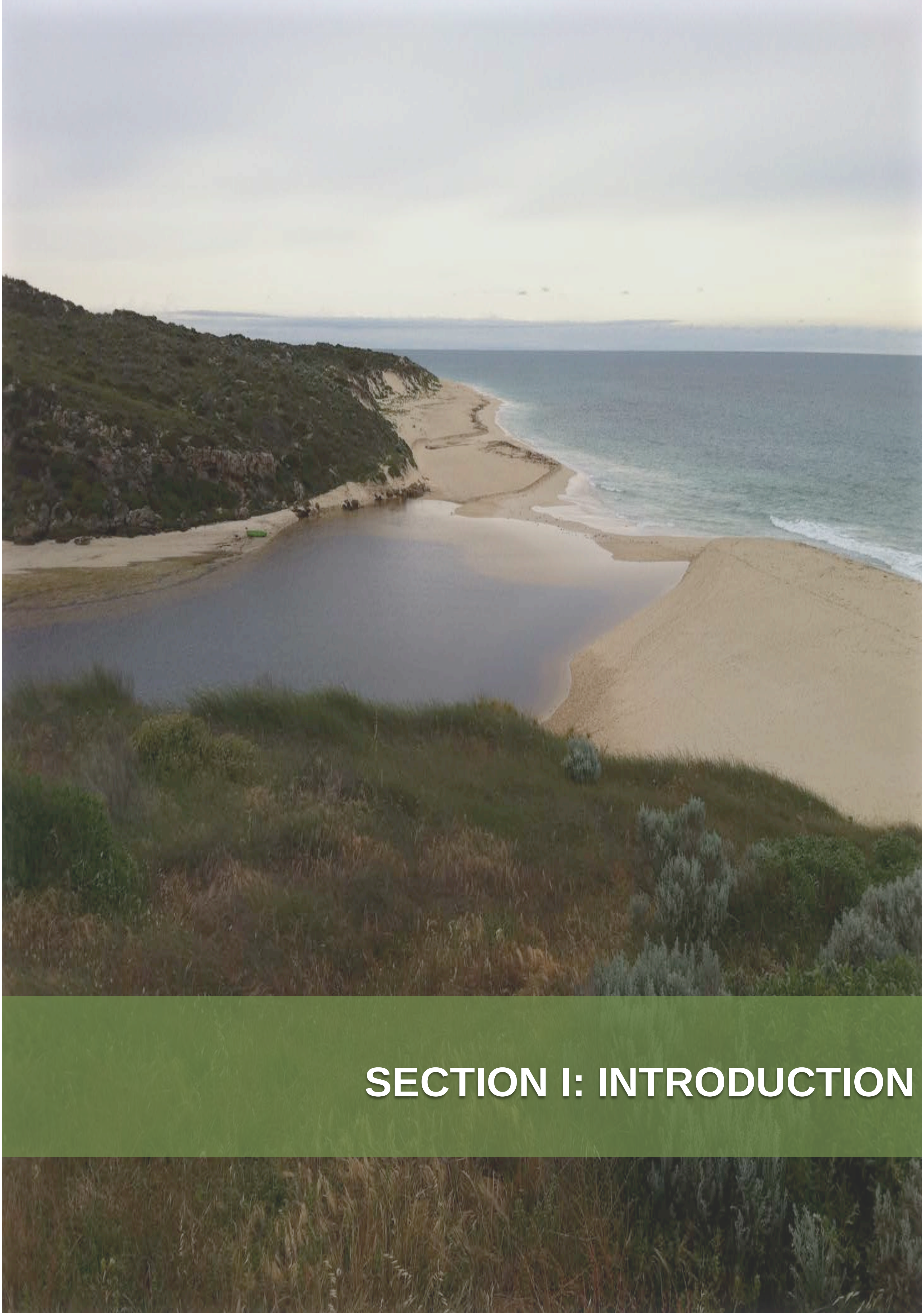


SECTION I: INTRODUCTION

1. INTRODUCTION

This section describes the aims and objectives of the Document and the methods used to undertake the data and information gap analysis.

1.1 BACKGROUND

The Gingin and Dandaragan coast, although relatively undeveloped, is experiencing increasing pressures from growing urban development and tourism. Development pressures, changing climatic conditions and localised effects of coastal processes make the coast a highly dynamic environment. The combination of these factors can pose risk to natural and built assets such as temporary damage to, or permanent loss of, public infrastructure, residential properties, natural habitats and cultural sites. For local governments to plan and manage their coast effectively it is crucial to understand how coastal processes operate at the local scale and how coastal assets may be impacted by 'coastal hazards' such as coastal erosion, inundation and salt-water.

In 2012 the Northern Agricultural Catchments Council (NACC), the Shire of Dandaragan and Shire of Gingin formed a partnership to take the first steps in helping communities along the Gingin Dandaragan coast to prepare and adapt to the impacts of coastal hazards. The first step was to commission the **Data & Information Gap Analysis** for the entire study area (this Dcoument). The second step is to use the information gathered from this Document to inform a **Project Partner Workshop** (to be held in July 2013) and prepare the **Workshop Summary Report** (September 2013) to help inform coastal hazard risk management processes within the study area. This Document aims to summarise what coastal data sets currently exist for the Gingin Dandaragan coast and how useful they are for assessing and mapping coastal hazards at a scale that is useful for local planning and decision-making.

This partnership demonstrates a response to a range of recent WA State Government initiatives, such as the revised State Planning Policy SPP 2.6 (gazetted in July 2013), the State Government's 2010 Sea Level Change in Western Australia - Application to Coastal Planning (2010)", and the WA Department of Transport's Coastal Adaptation and Protection Grants. These initiatives help ensure that risks that may result from changing coastal processes are identified and strategies for managing these risks developed in consultation with the community. Figure 3 shows the standardised approach recommended in *State Planning Policy No. 2.6 (State Coastal Planning Policy)* for dealing with risk in the coastal zone.

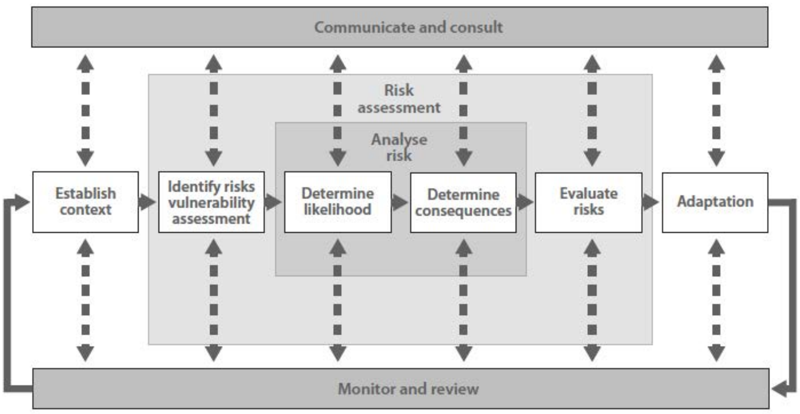


Figure 3: Coastal hazard risk management and adaptation planning process (State Planning Policy SPP 2.6).

1.2 OBJECTIVES

The objectives of the Gingin Dandaragan Data & Information Gap Analysis are to:

1. Provide a summary of physical coastal processes that are important in altering morphology (erosion and/or recession) or causing coastal inundation within the Hill Primary Compartment and the level of their understanding at present.
2. Identify existing coastal data sets, their availability, location and characteristics.
3. Identify data sets required for understanding coastal processes and mapping coastal hazards.
4. Identify data gaps and shortcomings in the existing information that would limit its application to assess and map coastal hazards.
5. Suggest appropriate monitoring mechanisms for the collection of new data sets for areas at greatest risk from coastal hazards including locations, frequency, responsible parties and indicative costs. Research or investigatory work required to fill information gaps (e.g. analysis of data sets) shall be identified in priority order and over a 5 year timeframe.

1.3 STUDY AREA

The study area extends from south of the Moore River (Guilderton) to North Head (Figure 4) comprising of two local government jurisdictions: the Shire of Dandaragan (North Head to Wedge Island) and the Shire of Gingin (Lancelin to Guilderton).

For coastal planning and management purposes, this coastal stretch has been identified as the **Hill Primary Compartment** by Eliot et al (Eliot et al 2011), due to similar coastal landform features that occur along this coast. From this point forward the Document will refer to the Gingin Dandaragan coastline as the ‘Hill Primary Compartment’ or the ‘Study Area’.

Eliot et al. (2011) identifies the alongshore boundaries of secondary and tertiary compartments and primary sediment cells within the study area (Figure 5 and Table 3). Primary sediment cells are areas that share similar physical features. Definition of sediment cells and criteria for mapping sediment cell boundaries is provided in *Coastal Sediment Cells Between Cape Naturaliste and the Moore River, Western Australia*, (Stul et al. 2012).

Seven areas of planning interest were also identified in this Report (Eliot et al. 2011 page 103) as areas where site-specific hazard risk assessments are mostly needed. These areas are Guilderton and South of Moore River, Seabird, Ledge Point, Lancelin, Cervantes, Jurien Bay and Ardross Estate, and North Head.

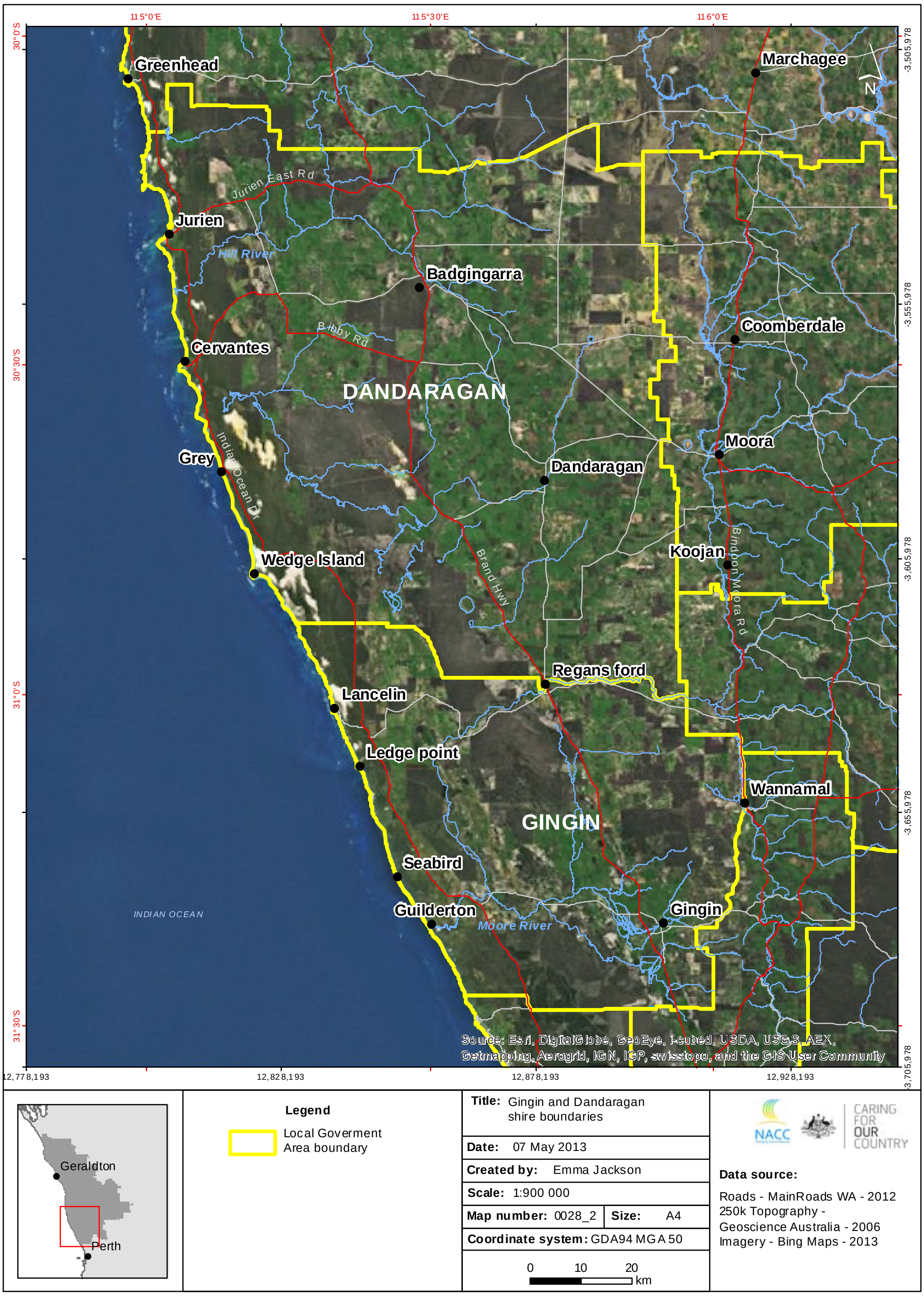


Figure 4: Map showing the Gingin Dandaragan coast and Shire boundaries (NACC).

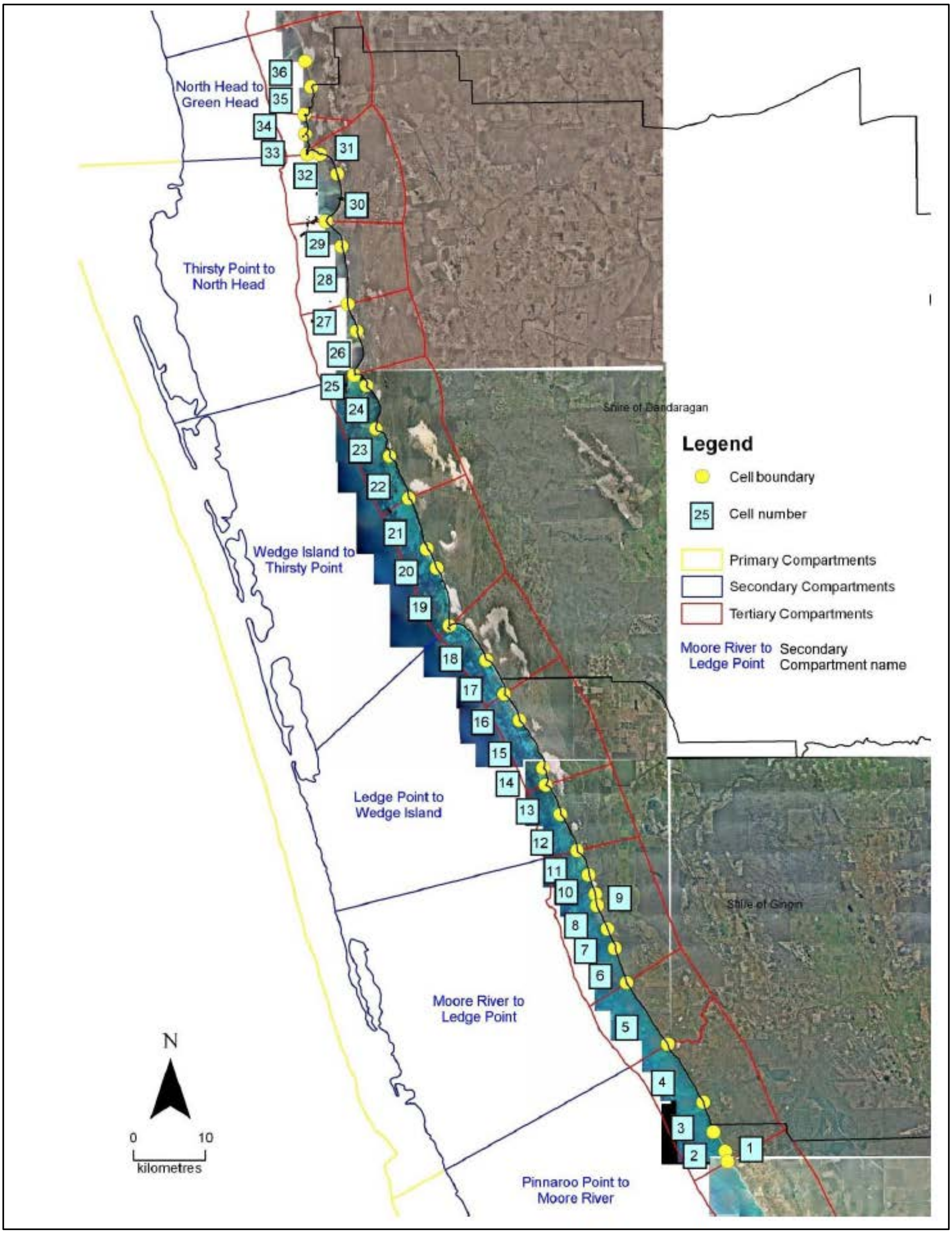


Figure 5: Hill Primary Compartment and (primary) Sediment Cells (Eliot et al. 2011).

Table 3: Coastal Compartments and (primary) Sediment Cells from Eliot et al. 2011.

Primary compartment	Secondary compartment	Tertiary compartment	Primary sediment cells
HILL PRIMARY COASTAL COMPARTMENT (Moore River to North Head)	Thirsty Point to North Head	**Island Point to North Head**	32. Pumpkin Hollow to North Head 31. Middle Head to Pumpkin Hollow 30. Island Point to Middle Head
		South Hill River to Island Point	*29. South Booka Valley to Island Point* *28. South Hill River to South Booka Valley*
		Thirsty Point to South Hill River	*27. Black Head (Black Peak) to South Hill River* *26. Thirsty Point to Black Head (Black Peak)*
	Wedge Island to Thirsty Point	**Grey to Thirsty Point**	*25. Hansen Head to Thirsty Point* *24. Kangaroo Point to Hansen Head* *23. Boggy Bay to Kangaroo Point* *22. Grey to Boggy Bay*
		Wedge Island to Grey	*21. South Grey to Grey* *20. North Wedge to South Grey* *19. Wedge Island to North Wedge*
	Ledge Point to Wedge Island	**Narrow Neck to Wedge Island**	*18. Magic Reef to Wedge Island* *17. Narrow Neck to Magic Reef*
		Edward Island to Narrow Neck	*16. Dide Point to Narrow Neck* *15. Lancelin Island to Dide Point* *14. Edward Island to Lancelin Island*
		Ledge Point to Edward Island	*13. South Pacific Reef to Edward Island* *12. Ledge Point to South Pacific Reef*
	Moore River to Ledge Point	**Seabird to Ledge Point**	*11. Green Reef to Ledge Point* *10. Manakoora Sand Patch to Green Reef* *9. South First Bluff to Manakoora Sand Patch* *8. Second Bluff to South First Bluff* *7. Eagles Nest Bluff to Second Blufff* *6. Seabird to Eagles Nest Bluff*
		Moore River to Seabird	5. Moore River to Seabird

1.4 METHODS

The preparation of this Document involved the following steps:

i. A desktop analysis of available coastal data sets, which included researching technical reports, scientific papers, studies undertaken for proposed coastal development and liaising with data custodians. Key documents include:
   a. The Coast of the Shire of Gingin and Dandaragan, Western Australia: Geology, Geomorphology & Vulnerability (Eliot et al. 2011).
   b. Coastal Compartments of Western Australia: A Physical Framework for Marine and Coastal Planning (Eliot et al. 2011).
   c. Defining Coastal Hazard Zones for Setback Lines - A Guide to Good Practice (Ramsay et al. 2012).

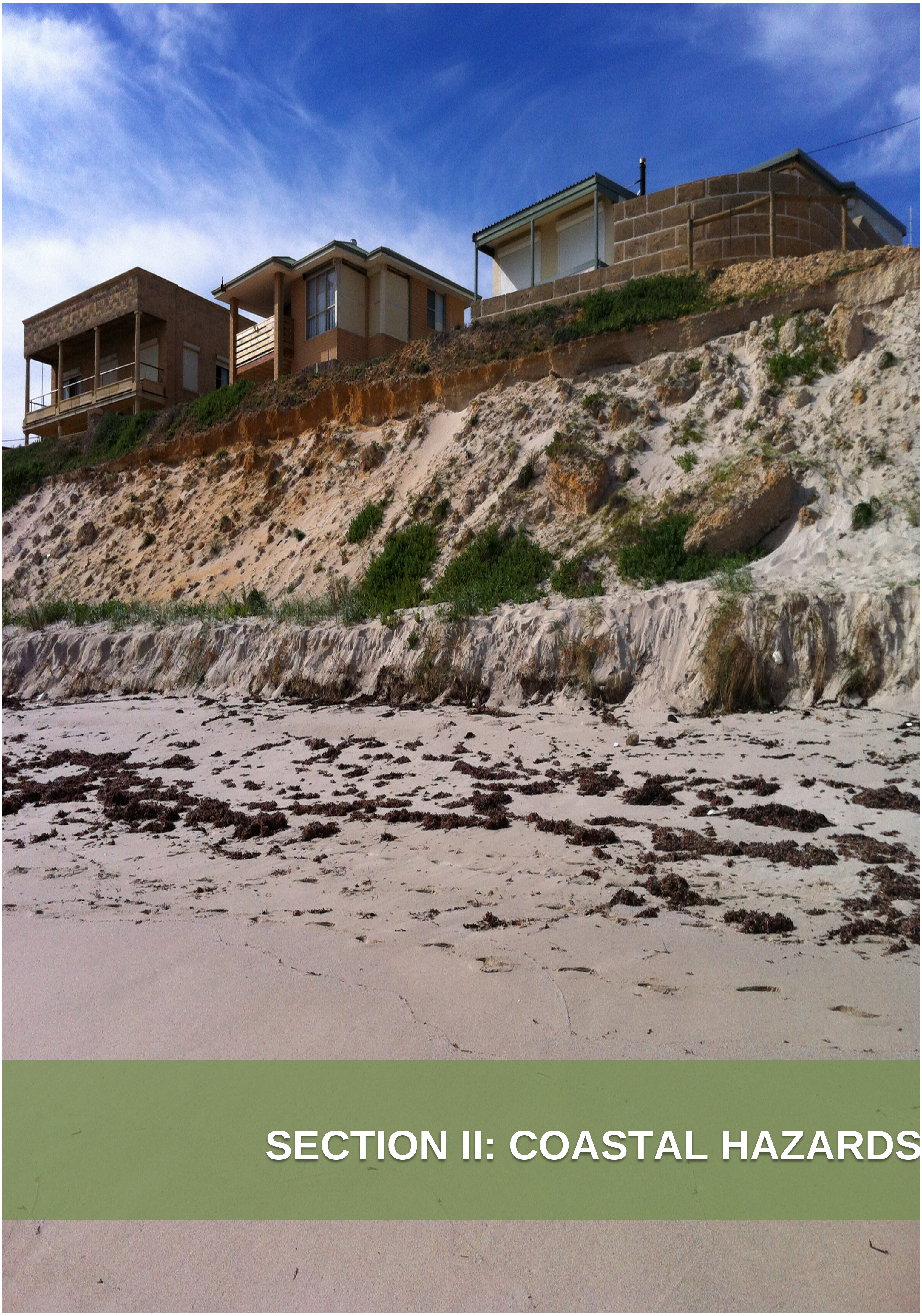
d. Coastal Hazard Mapping for Economic Analysis of Climate Change Adaptation in the Peron-Naturaliste Region (Damara WA 2012).
e. Coastal Hazards of the Northern Agricultural Region: Review of Information Sources and Gap Analysis (Oceanica Consultancy 2010).
f. Coastal Engineering Guidelines for Working with the Australian Coast in an Ecologically Sustainable Way (NCCOE 2012).

ii. A review of available data and information to assess data location, accuracy and relevance for coastal hazard assessment and mapping.

The majority of coastal data and information about the data (metadata) were provided by data custodians such as the Department of Planning, the Department of Transport and the Department of Water. Generally the data is publicly available however data and information held by consultants was not always accessible (Table 4).

Table 4: Stakeholder engagement log.

Contact	Date	Request	Comments
DoT – Karl Illich	15/4/2013	DoT coastal data sets	Provided
DoT – James Steven	15/4/2013	GIS databases	Provided
Curtin University – Sira Tecchiato	15/4/2013	Data Review	Provided
DoW – Peter Muirden	18/4/2013	LiDAR/DTM	Provided
DoT – Tony Lamberto (94357673)	15/4/2013	Metocean data sets	Provided
Geoscience – Martin Hazelwood and Brendan Brooke	21/5/2013	Databases	Provided
UWA – Renae Hovey	18/5/2013	Benthic habitat (seagrasses)	Provided
Laura Ashcroft	17/5/2013	Tourism WA – Lancelin coastal vulnerability study (setbacks)	Information about the Lancelin report provided. Report not available yet.
Worley Parsons – Samantha Free	7/5/2013	Lancelin study	Provided
Damara/GSWA – Eliot and Gozzard	12/5/2013	Sediment cell GIS files	Not provided
Ray Gordon – geotechnical and DoT	7/5/2013	Geotechnical assessment	Provided
Shire of Dandaragan (planner)	30/5/2013	North Head and Ardross development proposals/investigations	Provided
Shire of Gingin (planner)	30/5/2013	South Guilderton development proposals/investigations	Not Provided (confidential information)
City of Mandurah - Neil Carroll	2/6/2013	Cost for additional wave buoys	Provided
Geoscience Australia – Luke Wallace	20/5/2013	Groundwater Report	Provided



SECTION II: COASTAL HAZARDS

2. COASTAL HAZARDS

This section provides a broad description of what coastal hazards are and their potential impact on coastal assets.

Coastal hazard means the consequence of coastal processes that affect the environment and safety of people (WAPC 2012).

Coastal hazards that are **relevant** to the study area include:

- inundation of coastal land caused by storm surges and storm tides (astronomical tides with high sea levels)
- short-term or acute erosion of beaches and dunes caused by coastal processes and storm events
- long-term coastline recession due to sea level rise and storms
- salt water intrusion
- landslip on headlands (both in rock and unconsolidated sediments)
- storm water erosion.

2.1 COASTAL INUNDATION

Coastal inundation refers to the flow of water onto previously dry land. Coastal inundation may be a permanent occurrence (i.e. due to sea level rise) or a temporary occurrence during a temporary rise in sea levels due to a storm event (Figure 6 and 7). Coastal inundation is commonly associated with severe storm events and is often the result of a number of combining factors, including:

- strong onshore winds
- low barometric pressure
- high tides
- wave set-up
- wave run-up
- higher sea levels.

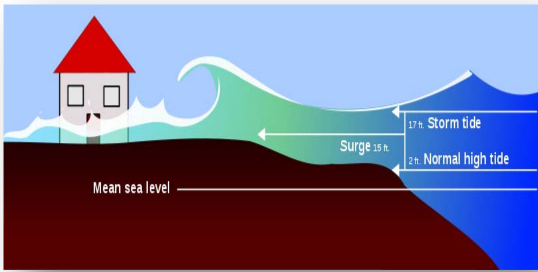


Figure 6: Storm tide causing coastal inundation (Source: Wikipedia).

Impacts of coastal inundation may include:

- damage to properties and infrastructure such as car parks and roads
- breaching of sand dunes
- damage to coastal protection infrastructure
- corrosion of electrical devices and other metal objects
- salinisation of flooded land
- secondary hazards such as land instability and possible fire.

Figure 7: Coastal Inundation affecting a beach access path in QLD. Image: Greg Stuart.

2.2 COASTAL EROSION & RECESSION

Coastal erosion occurs when waves and currents remove sand from the beach system. Coastal erosion can be **seasonal**, **chronic** (coastal recession) or **acute**.

While erosion and recession are natural processes that have formed the present coastline, they become a hazard when human life, property or aspects of the natural environment (coastal assets) are adversely affected. The impacts of coastal erosion can be on built assets such as roads, pipelines, recreational facilities, and buildings, on natural assets such as dunes and native habitat, or cultural heritage values such as important Indigenous sites.

Figure 8: Seasonal erosion at Geraldton. Image: Leanne and Steve Robb.

Seasonal erosion events are short-term responses that can occur as a result of storms or as a result of seasonal variations such as the winter–summer cycle of erosion and accretion (Figure 8). Typically, sandy shorelines recover from these short-term episodes. Seasonal erosion is most active during the winter months when higher energy waves impact the shoreline and transport sand offshore, depositing it into sand bars. Gentler waves that prevail during the summer season transport sand located offshore back onto the beach.

Figure 9: Coastal Recession at Thirsty Point, Cervantes (2012). Image: Paul Robb

If the coast is hit by an extreme event then the erosion can become **acute short-term erosion**. These are short duration events that can remove large volumes of sand and erode the shoreline within a few hours. This can cause:

- storm cut of beaches and dunes
- beach slope instability
- rock and cliff instability
- estuary entrance modification.

Chronic long-term coastal recession occurs when sand is lost in sediment ‘sinks’, resulting in longer-term ongoing recession of the shoreline. Coastal recession can be caused by sediment budget deficit (due to changes in wave climate, the erection of engineered coastal structures) and rising sea levels (Figure 9 & 10).

Coastal erosion is linked to the magnitude and frequency of storms that impact on the coast. For example, during a 1 in 100 year storm event (100 year ARI), waves may erode several metres into the foredune that sits well behind the normally active zone of accretion and erosion. Also, several lower-magnitude storms that occur in quick succession can produce a similar degree of erosion because the intervening periods are too short for waves to push a significant amount of sediment back to the shoreline.

Figure 10: Coastal Recession at Drummond Cove, Geraldton. Image: NACC.

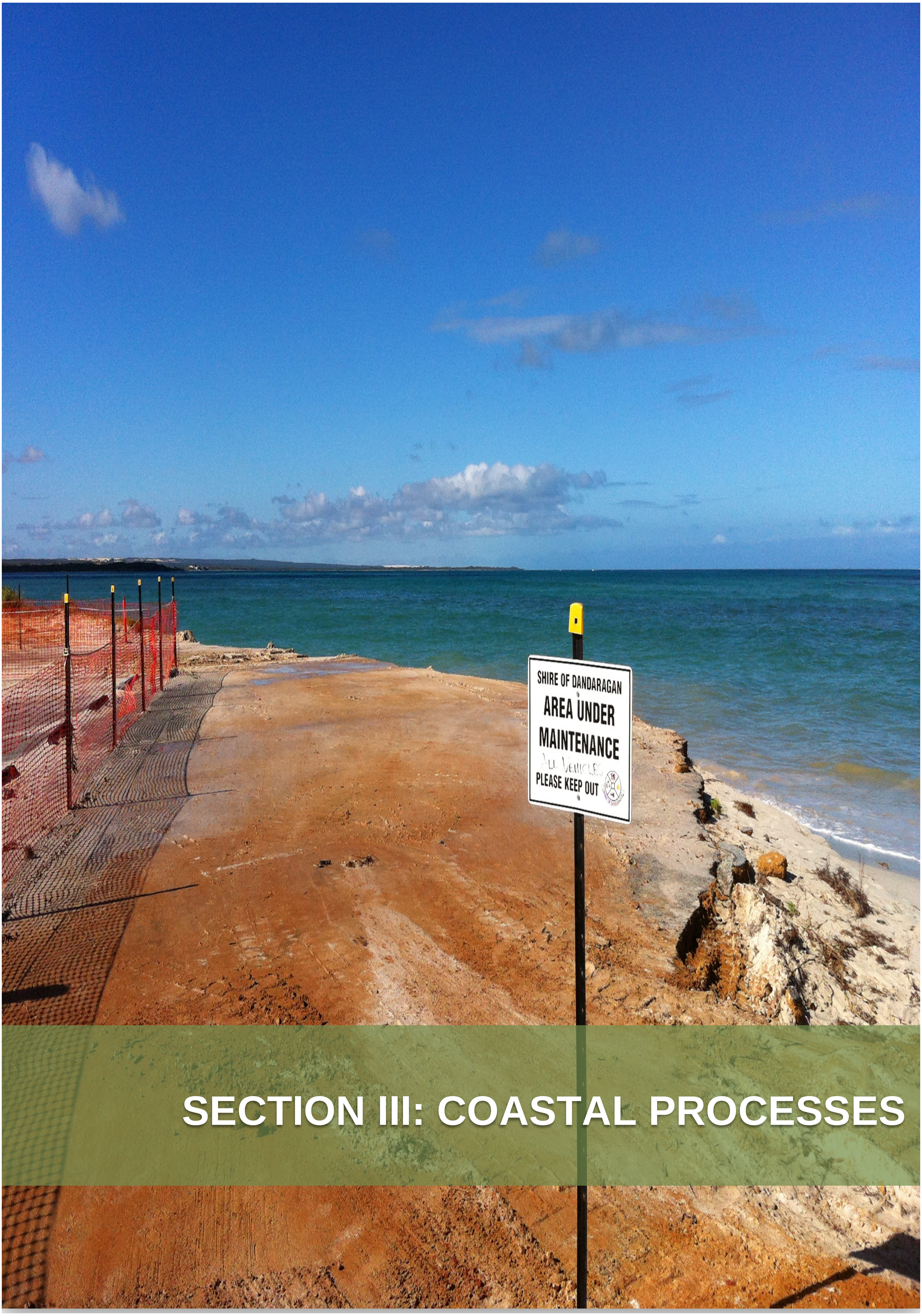
2.3 SALT WATER INTRUSION

Higher sea levels have the potential to raise the fresh water table and contaminate groundwater supplies due to landward and upward movement of seawater in coastal aquifers.

The intrusion of saltwater into groundwater systems may also impact coastal ecosystems such as wetlands, by changing the elevation of the freshwater-saltwater interface. Where freshwater tributaries exist, such as creeks, an increase in the water table elevation may also increase groundwater discharge and result in local changes in the underlying freshwater-saltwater interface.

In 2012 Geoscience Australia and the National Centre for Groundwater Research and Training undertook a national-scale assessment of the vulnerability of coastal aquifers to salt water intrusion (Ivkovic et al. 2012). According to the report, Western Australia had the greatest number of areas where the occurrence of salt water intrusion has been reported including the Northern Swan Coastal Plain (Jurien Bay, Dongara, Leeman), mostly driven by groundwater extractions coupled with below average rainfall recharge (associated with droughts).

An increase in the intensity of storms combined with a rise in sea level could result in much higher rates of coastal erosion which would in turn impact on the levels of saline intrusion. Understanding how changes in coastal processes and climatic conditions may impact the groundwater hydrology in shallow, unconfined coastal aquifers such as those occurring along the Hill Primary Compartment is important when assessing coastal hazards and associated risks. One mitigation option may be to reduce or prevent seawater from intruding by preventing the further loss of dune systems.



SECTION III: COASTAL PROCESSES

3. COASTAL PROCESSES

This section provides a summary of data sets that describe coastal processes operating along the Hill Primary Compartment.

Understanding how coastal processes interact and contribute to coastal change is complex and difficult to predict with certainty. Coastal processes can be defined as the natural forces and processes that affect the shoreline. Natural forces consist of meteorological drivers (winds, storms, rainfall, weather cycles) and ocean drivers (water levels, tides). These can also be referred to as 'metocean drivers'. Therefore, coastal processes relates to the complex interactions between the geology and the metocean drivers that affect the distribution of sediments along the coastline and subsequently, the formation and evolution of landforms.

A summary of regional coastal processes operating along the Hill Primary Compartment is provided in *The Coast of the Shires of Gingin and Dandaragan, Western Australia: Geology, Geomorphology & Vulnerability Report* (Eliot et al, 2011 page 47-69). This section provides a short summary of the key coastal processes affecting the Hill Primary Compartment focusing primarily on the availability and characteristics of data sets which describe these processes.

3.1 METOCEAN DRIVERS

WINDS & STORMS

Wind observation stations within the study area are located in Jurien Bay (1969 to present day) and Lancelin (1965 to present day). Outside the study area wind data is recorded in Geraldton (digitally from 1965) and Rottnest Island (1987 to present day). Wind records can be accessed from the Bureau of Meteorology (BoM) website. Analyses of long-term wind records provides information regarding dominant winds, patterns of change in wind direction and speed and winds associated with extreme storm events. Changes in instrumentation during the last 50 years need to be taken into consideration when interpreting available wind records.

Winds are generated by the large-scale movement of air and are influenced by a wide range of factors, from large-scale atmospheric circulation patterns to the time of day and the nature of the surrounding terrain. Winds generate waves and currents that have an effect on long shore transport, local wind-wave climate (wind-waves, storm events, storm surges) and aeolian transport (which then modifies landform features such as dune ridges and parabolic dunes). A sea-breeze is a wind from the sea that forms by increasing temperature differences between the land and water; these create a pressure minimum over the land due to its relative warmth, and forces higher pressure, cooler air from the sea to move inland.

The study area is predominantly affected by NE winds in the morning and S to SSW winds (seabreeze) in the afternoon, with a considerable interannual variability (Eliot et al. 2011). The Hill Primary Compartment is partly sheltered from the dominant northwesterly frontal system and mostly affected by southwesterly swells and winds generated by S-SW sea breeze systems (Eliot et al. 2011).

Storminess in the region is influenced by both tropical and mid-latitude pressure systems with the latter being the most common source of extreme winds. Historically, tropical cyclones that bring extreme wind conditions are rare events in the study area (occurring approximately every 5 to 10 years) however this may change as ocean surface temperatures continue to warm. Extreme storm events were recorded in April 1978, June 1996, May 2003, August 2005 and March 2011.

Existing information: Forty years of wind data exists for the study area (BoM). Analyses of wind records and storm events can be found in reports and scientific papers written for the study area and listed in Appendix A, B and C. Future changes in wind speed and direction are expected as a result of a warming climate. Further investigation of coastal processes for the region will require a better understanding of the localised effect of climate variability on wind climate and wind driven wave climate; and how change in wind patters are likely to modify the direction of sediment transport and affect the stability of dynamic low-lying sandy areas (sandy cuspate forelands and tombolos) upon which coastal settlements are built on (e.g. Cervantes, Lancelin and Jurien Bay).

WATER LEVELS

Changes in sea levels are measured using devices called *tide gauges*. Tide gauges are used to measure tides, surges, quantify the size of tsunamis and derive mean sea level variations. Tide gauges closest to the Hill Compartment are located at Fremantle from 1897 to present day (The National Tidal Center holds records from 1897, DoT from 1977), Hillary's from 1991 to present day, Geraldton from 1966 to present day (the tide gauge shifted in 1977) and Jurien Bay from 1995 to present day. The tide gauges at Hillarys recorded a maximum level of 1.916m in May 2003 and the lowest level of -0.143m in February 1993. Changes in instrumentation need to be taken into consideration when interpreting tide records. The historical data is relatively continuous from 1995.

Tides are the periodic rise and fall of sea level caused by a combination of the gravitational pull of the Moon and Sun, and the rotation of the Earth. The diurnal tides in the study area are microtidal with a tidal range of 1.2-1.4m. High tides combined with large storms can result in acute erosional events. This combined with warmer ocean surface temperatures could explain the increased erosion processes along the study area over the past two to three years.

Tide gauges also measure **relative sea level**, which includes vertical movement of both the ocean surface and land mass. Fluctuations in sea levels are usually caused by low pressure and strong winds associated with severe weather events. Associated with storm surges are wind driven waves which can also contribute to elevated sea levels through wave setup. Variations in mean sea level also occur on seasonal and inter-annual time scales, the most significant contribution to inter-annual variations in sea levels around Australia are due to the El Nino Southern Oscillation. Falling atmospheric pressure contributes to elevated sea levels due to the inverse barometer effect, where sea levels increase by approximately 1 cm for every hPa fall in pressure relative to ambient pressure conditions. Satellite altimeters can also measure the height of the ocean surface using electro-magnetic pulses. Tide gauge data is used to examine, detect and study Tsunami events. The December 2004 Tsunami was first recorded at Jurien Bay (where the continental shelf offshore is the narrowest) at 0705 UTC with a travel time of six hours and three minutes.

The analysis of historical tide gauge records indicates that sea level has risen at a rate of approximately 1.4 mm/yr (Fremantle) and 0.5mm/yr (Geraldton) during the last 40 years (Eliot et al. 2011). This regional variability in relative sea levels can be a result of vertical land movements (anthropogenic or tectonic or/and groundwater extraction) and/or localised effects of metocean drivers (the Leeuwin Current) and weather cycles (La Niña and El Niño).

Storm Surges are a rise of water caused primarily by high winds (associated with a low pressure system) pushing on the ocean's surface. In the study area *atmospheric* surges are mainly caused by mid-latitude storms. The effect of storm surge is most severe when extreme meteorological events occur in conjunction with a high tide, often leading to acute beach erosion and coastal inundation. Recently in the USA, Hurricane Sandy caused a storm surge of 4.5m which had a devastating effect on the city of New York. *Extreme* surges along the Hill Primary Compartment are associated with major storm events such as extra tropical and tropical cyclones (Eliot et al. 2011). Storm surge heights recorded in Fremantle and Geraldton typically range from 0.5 to 0.9 m for a 1-in-100-year storm event (Eliot et al. 2011).

Existing information: The data available for Jurien Bay is too short for any detailed analysis. Analysis of tide gauge observations should be undertaken over a long time scale to establish the long-term pattern of sea level change. The most reliable data sets from Geraldton and Fremantle start from 1965 (when the AHD was established). Local studies should take into consideration the impact that the higher water levels may have on the waves-offshore reefs interface and on the development of resonant phenomena (such as seiches). Further investigation of coastal processes for the region will require an analysis of extreme weather events (including cyclone frequency change) and associated water levels. Analyses of water levels can be found in reports and scientific papers written for the study area and listed in Appendix A, B and C.

OFFSHORE AND NEARSHORE WAVE CLIMATE

Wave measurements are undertaken using devices called *waverider buoys.* The three (permanent) buoys most relevant to the study area are located at Rottnest Island (1994 to present day, updated to directional in 2004), Jurien Bay (1998 to present day, updated to directional in 2009), Geraldton (1999 to present day, updated directional in 2006). Rottnest (located at -48m) and Jurien Bay (located at -42m) provide the closest representation of the region's wave climate. DoT collects wave data and is the custodian of historic wave data records. Wave data provides information about distribution of wave heights, direction and trends. Satellite altimeter wave measurements may be used to determine seasonality and inter-annual variability of the offshore wave climate. Results from hind-cast wave models are a useful resource for identifying trends in offshore wave climate. Spatial variation of wave climate is provided by wave modelling.

Acoustic Wave and Current (AWAC) is a current profiler and wave directional system. It provides water speed, module and direction at different depths. In WA AWAC is used for short-term deployments to collect nearshore waves and currents data. AWAC data was collected in 2003, in 2004 at Seabird, in 2002 at Ledge Point and in 1989 in Guilderton.

For a description of the wave climate of the Hill Primary Compartment see Eliot et al. 2011.

Existing information: Analysis of wave data should be undertaken over a longer time scale to establish the long-term pattern of wave climate especially for trends and variability of wave climate associated with extreme storm events (parameter used in hazard assessments). The current wave record (less than 20 years) is quite short. The data sets listed above are useful for determining changes in offshore wave climate only. Although it could be expected that any major trends observed offshore will be propagated to the coast, bottom topography and coastal morphology complicate the process, causing regional and local variation in the response. Further investigation of coastal processes for the region will require an analysis of variability, trends and extremes of both offshore and nearshore wave climate and improve the understanding of the interaction between waves and local topography and geomorphology. Analyses of wave climate can be found in reports and scientific papers written for the study area and listed in Appendix A, B and C.

OFFSHORE & NEARSHORE CURRENTS

Regional offshore currents are being measured using satellite imagery, drifters and gliders. Limited information is available on nearshore currents for the study area. Information on sea surface currents (water velocity) is collected by UWA (ISMO) using a coastal radar installed at Cervantes and Seabird (Figure 10). The data collected by ISMO improves the understanding of the Leeuwin Current and its influence on the continental shelf environments, ecosystems and biodiversity.

Ocean currents are primarily generated by winds but can also be driven by differences in ocean temperatures, salinity, tides, waves and weather systems. Current patterns become complicated in shallow coastal waters because of sea bottom friction and the complex bathymetry of the coast (reefs and islands). In the surf and swash zones the effect of currents is influenced by currents that run parallel to the coastline (alongshore currents), which are caused primarily by waves approaching the coastline obliquely. Further investigation of coastal processes for the region will require a better understanding of how offshore and nearshore currents are affected by the bathymetry of the coast and coastal features

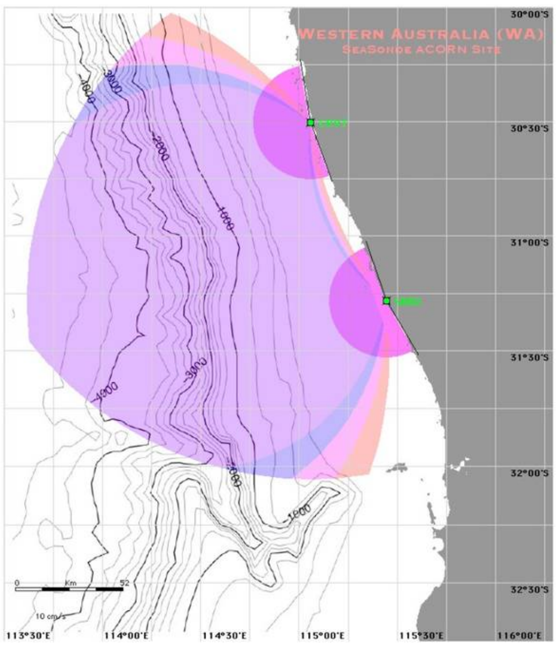


Figure 10: Coastal radar at Cervantes and Seabird (IMOS).

such as islands and reefs which consequently have an impact on sediment transport regimes.

Existing information: Limited information is available on nearshore currents for the study area. The majority of the information on currents comes from site-specific modelling work undertaken to understand the movement of water around lagoon and islands. Existing information on currents can be found in reports and scientific papers written for the study area and listed in Appendix A, B and C.

3.2 GEOLOGY, LANDFORMS, SEDIMENT SOURCES & TRANSPORT

GEOLOGY & GEOMORPHOLOGY

The coastal dunes and beaches of the study area are comprised of unconsolidated sediments with carbonate sands from the Holocene age, overlying older consolidated aeolian (wind borne) sediments such as the Tamala Limestone. The coast is also fragmented by a series of parabolic dunes and cuspate forelands. Offshore and inshore landforms (such as reefs, perched beaches, sand banks and cuspate forelands) cause inshore metocean processes (currents, waves, water levels) to interact differently with the shore, which alters water circulation, sand availability and sand transport patterns.

Existing information: The geological framework and major landform components within the Hill Primary Compartment are described in: *The Coast of the Shires of Gingin and Dandaragan, Western Australia: Geology, Geomorphology and Coastal Vulnerability Report* (Eliot et al. 2011), Smartline (Sharples et al. 20029) and the GSWA digital dataset. The Eliot et al. report provides a first pass assessment of the landforms and coastal features at the regional scale. However, for local scale coastal hazard risk assessments more information is needed on the geological features at the tertiary cell level. Identifying elevation and coverage of underlying rock is important in coastal hazard risk management because it identifies areas that are less likely to change due to projected changes in metocean conditions. Eliot et al. (2011) recommends specific assessment to be undertaken for highly dynamic landforms (Figure 11) such as cuspate forelands, shoreline salients and tombolos, especially if development on and adjacent to these areas is proposed or already existing. Appendix C summarises the geological reports and maps available for the study area.

SEDIMENT TRANSPORT & BUDGETS

The strength and direction of **sediment transport** depends on a number of interrelated factors, including wave height and direction, sediment size, local bathymetry, and coastal features such as islands and reefs. Cross shore transport is caused by high energy, steep waves that erode sand from the upper beach and move it to the deeper offshore area. The seaward extent of wave-driven offshore transport is a function of the wave height and period. Typically the limit of offshore transport is around -10 m to -20 m. Alongshore transport is the process whereby beach material is gradually shifted laterally as a result of waves meeting the shore at an oblique angle.

Sediment is brought into the coastal system at a particular location by a range of mechanisms, including:

- alongshore transport from another part of the coast
- shoreline erosion
- onshore transport from deeper water
- river and estuary supply
- biogenic production (breakdown of shells / seagrass banks)
- artificial nourishment

According to Eliot et al.:

> "Much of the unconsolidated sediment of the Gingin Dandaragan coast is calcareous sand with intrusions of quartzose sediment from the erosion of the underlying limestone beds. The source of sand is mainly from offshore communities such as reefs, seagrass meadows and algae with a small component discharging from the two rivers (Hill and Moore). Sand moves northwards, driven by strong seabreezes and southerly components of the metocean processes. The availability of sand (in terms of volumes and transport alongshore) is related to the underlying geological structure." (2011 pg. 37)

Sediment budgets help develop an understanding of the sediment sources, sinks, transport pathways and magnitudes for a selected region of coast and within a defined period of time (Figure 12). The sediment budget is a balance of volumes for sediments entering (source) and leaving (sink) a selected region of coast, and the resulting erosion or accretion in the coastal area under consideration. Sediment budgets are influenced by man-made structures (e.g. groynes, ports and marinas) and change in geomorphology (e.g. removal of dunes).

Future stability of the coast may depend upon a combination of a few factors: onshore sediment supply (beaches, dunes, rivers), influence of natural rocky features (e.g. offshore reefs and headlands), man made structures (engineered structures) and natural variability of metocean processes. Future assessments should consider the importance of conducting an analysis of sediment transport and sediment budget at the tertiary cell level.

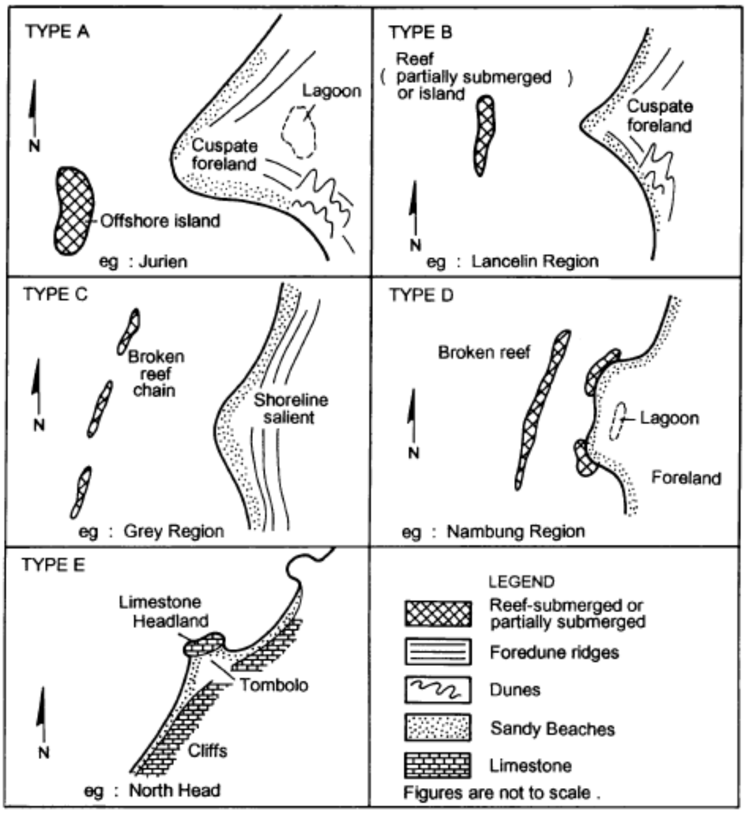


Figure 11: Cuspate foreland, shoreline salient and tombolo typical of the WA Central Coast. Source: Sanderson & Eliot (1996).

Existing information: further studies are required to understand sediment transport regimes and sources both at the regional and at the local cell level.

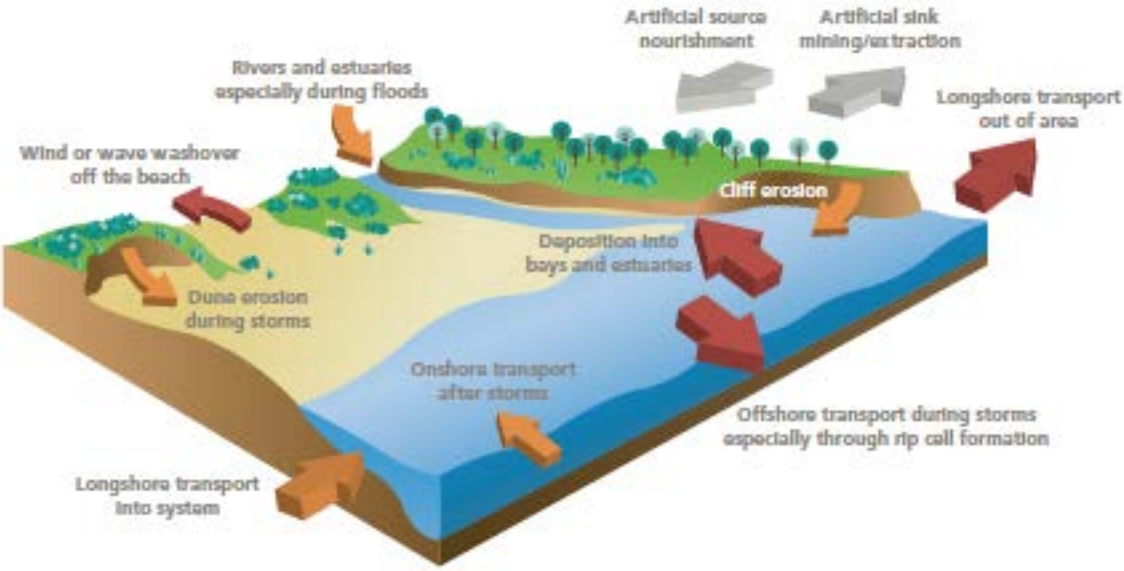


Figure 12: Component of a Coastal Sediment budget. Source: Victorian Coastal Hazard Guide.

GROUNDWATER

Coastal aquifer systems do not terminate at the coastline. The position of the freshwater–saltwater interface can shift in response to changes in hydrological conditions between the aquifer and the sea. This interface, called the 'transition zone', can range from a few metres to kilometres in width. The position and width of the transition zone is highly variable. The principal factors that control the position of the interface include groundwater extraction, recharge, sea-level rise, aquifer hydraulic properties and, to a lesser extent, tides. The time scales during which the position of the interface can change vary depending on the processes and the aquifer but, in the case of salt-water intrusion, may be difficult and expensive to reverse.

Existing information: Coastal aquifers and water resources for coastal settlements along the Hill Primary Compartment have been investigated and described in groundwater management plans and hydrogeological studies (Kern 1993; WRC 1997 and 1999). Coastal aquifers lie beneath a shallow layer of aeolian sand and limestone deposits that range in thickness from about 50 m (Cervantes) to a few metres only (Lancelin). Appendix A, B and C summarise the reports and maps available for the study area.

3.3 COASTAL DATA SETS (OTHER)

BATHYMETRY AND TOPOGRAPHY

Detailed coastal hazard assessments and mapping require high-resolution bathymetric, aerial imagery and topographic data. Digital elevation models (DEMs) are three-dimensional digital representations of the ground surface topography that show the elevation of the landscape. They represent a 'bare earth' model that excludes vegetation and buildings. DEMs integrate ocean bathymetry and land topography and they are derived using contour data, high points, hydrology features and boundaries. High resolution DEM has been captured by NACC using LiDAR (Light Detection and Ranging) technologies (NACC 2013) which provides 0.1m and 0.25m contours and accuracy better than 10cms. Digital topographic maps are also produced by Geoscience Australia.

Hydrographic soundings and levels gather images about ocean (seabed) topography. The results of these soundings are processed into bathymetry charts, beach volumes and beach (cross) profiles. The Department of Transport (DoT) has undertaken hydrographic (single beam) surveys and beach levels since 1980 for each coastal town in the study area at various time intervals and locations. Surveys extend to approximately -6 to -10 m offshore with a vertical accuracy of 0.05m. More recent surveys are associated with activities such as dredging, construction of coastal protection structures and ports.

Nautical charts are available for the entire study area (based on hydrographic surveys completed by DoT) from 1980 and updated via mariners. The main use of nautical charts is to show the prevailing hydrographic and navigational conditions. However, depending on the scale and detail, a nautical chart may show: depths of water and topography; natural features of the seabed; details of the coastline; navigational hazards; locations of aids to navigation; information on tides and currents; and man-made structures such as harbours, marinas and coastal defences.

The accuracy of bathymetries at some locations could be improved to inform site-specific coastal hazard mapping. For some areas where detailed hydrographic surveys are not available, nautical charts may be the best source of bathymetry information.

CROSS-SHORE BEACH PROFILES

Beach profiles are important for understanding shoreline changes and cross-shore sediment transport. Beach profiles in the region have been undertaken at various locations (Ledge Point, Cervantes, Seabird) to -10m water depth. An on-going beach survey program for the study area to monitor long-term changes in the coastal processes and shoreline position is strongly recommended.

SHORELINE MOVEMENT PLOTS

Shoreline movement plots are important for understanding long-term shoreline changes and alongshore sediment transport. DoT has created shoreline movement plots for the coastal towns within the study area for the period 1950-2000 at different time intervals. Shoreline movement plots map shoreline changes using aerial photos and topographic data. Shoreline plots can be used in the absence of hydrographic information to monitor shoreline change. The analysis of shoreline movements should be updated and undertaken every 5 years.

AERIAL PHOTOGRAPHS

Aerial photos are important for understanding changes to beaches and dunes, and can be used to create shoreline movement plots. Vertical aerial photographs are collected by Landgate on an annual basis for Guilderton (as part of the Metro mosaic) and every two years north of Guilderton. DoT has a collection of photos in hard and electronic copies of different years and scales going back to 1940 to the present day.

SEDIMENT SAMPLES

Sediment sampling is important for understating sediment transport pathways. However, not much sediment sampling has been undertaken across the study area. Lancelin has the most sediment data. A few sediment samples have been taken as part of site specific assessment often associated with dredging projects and construction of jetties or groynes.

FIELD PHOTOGRAPHS

Field photographs should be undertaken as an on-going exercise after winter, summer, and major storms. DoT collects field photos: however, the Department encourages each council to set up a beach-monitoring program. This is currently being undertaken by NACC in partnership with the Shires.

INVENTORY OF ENGINEERED STRUCTURES

A key feature of engineered coasts (Figure 13) is that the coastline may respond atypically to changing coastal processes because natural processes have been interrupted through infrastructure works of some type, such as rock groynes, marinas, boat ramps, seawalls, etc.

An inventory of existing engineered structures would provide up to date information regarding a structure's effectiveness, maintenance and schedule requirements. To date there is no official inventory of costal structures. As the onus of management responsibility lies with local governments they are best placed to keep such records.

Along the Hill Primary Compartment anthropogenic modifications are mainly associated with harbours, marinas and boating access facilities. Coastal hazard assessments for sediment cells that are characterised by the presence of engineered structures should include a detailed analysis of sediment budgets and alongshore sediment transport patterns.

Figure 13: Coastal protections in Italy. Image: Enzo Pranzini.

The existing engineered structures along the Hill Primary Compartment coast are:

- Groynes: two at Ledge Point, one at Guilderton
- Boat ramp: one in Seabird
- Jetties: one in Lancelin; two in Cervantes, one of which acts as a groyne as well.

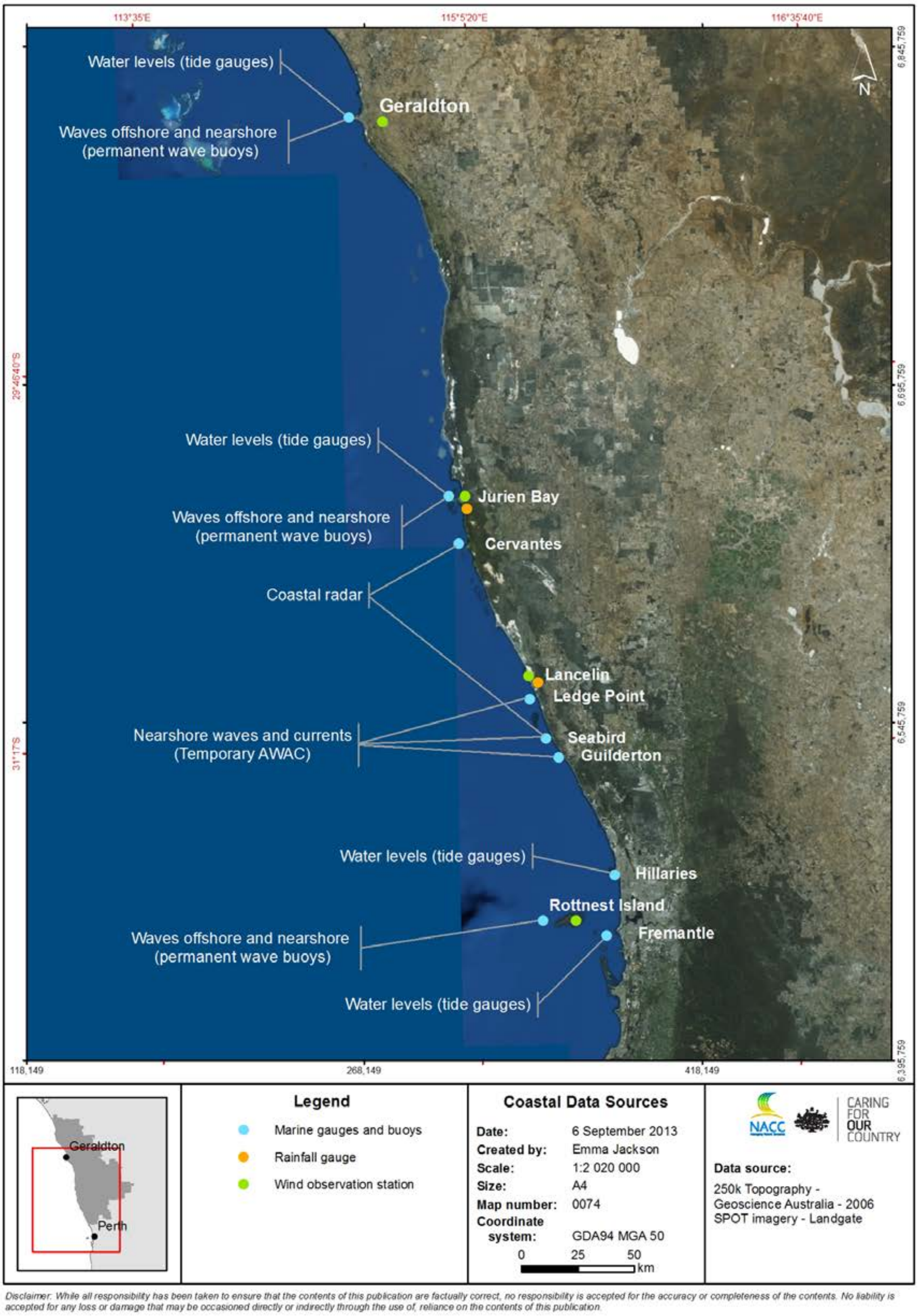


Figure 14: Coastal Data Sources for the Hill Primary Coastal Compartment. Map: Emma Jackson (NACC).

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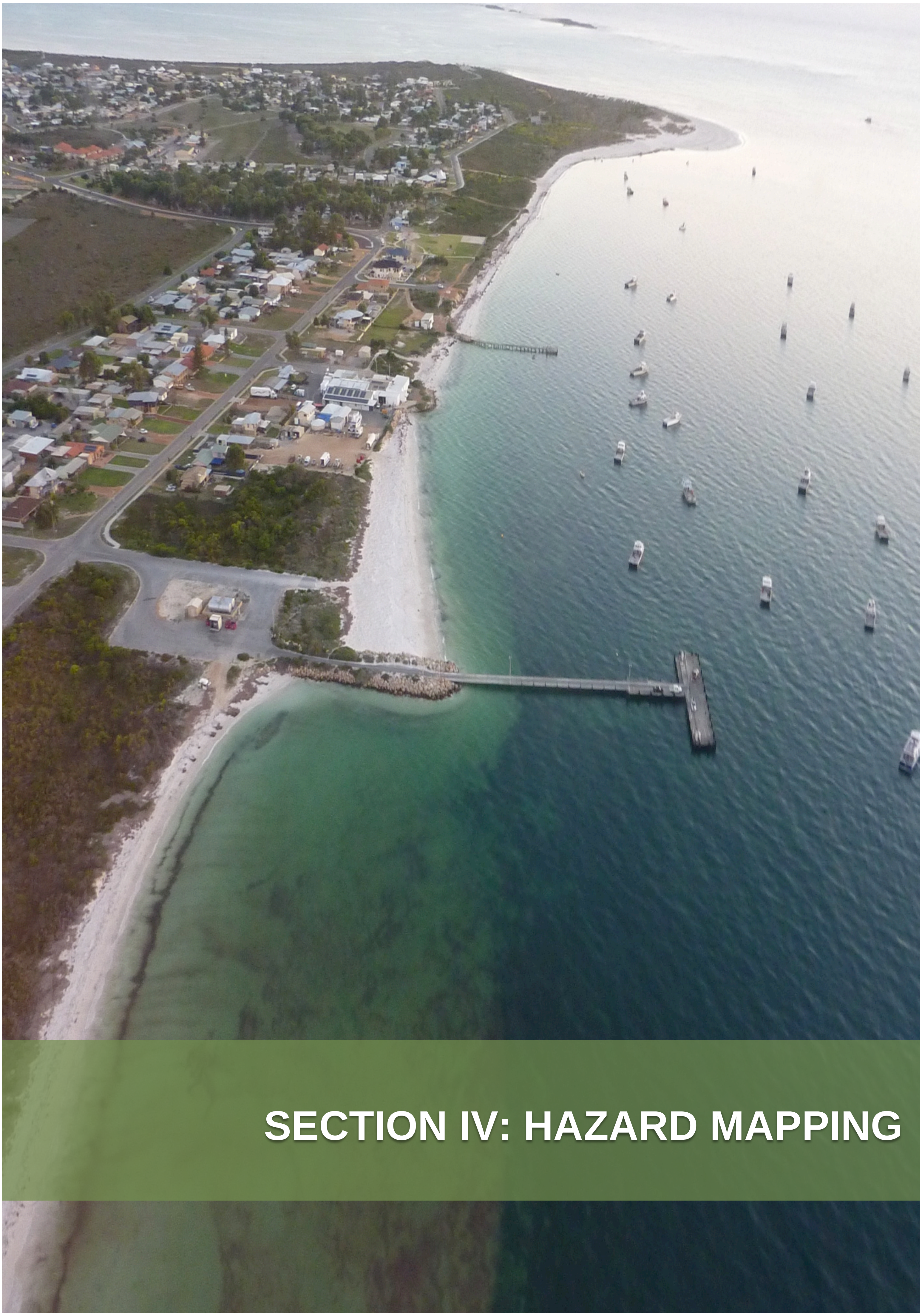


SECTION IV: HAZARD MAPPING

4. KNOWLEDGE BASE FOR COASTAL HAZARD MAPPING

This section identifies data sets required for understanding coastal processes and mapping coastal hazards, drawing upon lessons learnt from recent coastal hazard risk assessment projects undertaken in Western Australia (City of Cottesloe, Cockburn Sound Coastal Alliance, Peron Naturalist Partnership) and Tasmania (City of Clarence).

4.1 COASTAL HAZARD ASSESSMENTS & MAPPING

The process of understanding historic, current and future coastal change is a complex exercise that can be particularly resource intensive for those local government authorities who manage large stretches of coastline. Long term, detailed site-specific data sets help to reduce uncertainty and limitations when trying to quantify coastal hazards.

Coastal hazard assessment can be undertaken using a methodology (a combination of data, models, assumptions) developed for one area and then modified (or reinterpreted) to suit the new area. However, modifications can be costly and time consuming due to the diversity and complexity of the coastal environment, the limited data sets available for some regional areas, and constraints of numerical models (Damara WA 2012). Therefore, a 'one-size fits all' methodology for the analysis of inundation and erosion hazards is not likely to be applicable to all coastal regions. Subsequently, it is necessary to frame hazard assessments around the local or regional context, with consideration to site-specific knowledge of sediment cells and sediment transport. Project specific, short-term, data collection programs can be put in place to remedy deficiencies in the spatial and temporal extent of data. The judgment and experience of consultants is essential when undertaking coastal hazard assessments, due to the lack of detailed information and the limited understanding of existing processes and the likely changes that climate variability may cause. The key outputs of coastal hazard risk assessments are erosion and inundation hazard maps. These maps are becoming a popular tool used by planners and decision makers to identify areas that are potentially subject to coastal erosion and flooding.

Depending on data availability and quality, hazard and risk assessments can be undertaken at a broader scale (Primary and Secondary Cell Level) or at a local scale (Tertiary Sediment Cell Level):

Broad scale assessments (Primary and Secondary Cell Level or 'second pass) are generally undertaken for the entire coastal compartment (or sub compartments) as a 'first cut' to provide planners and managers with a basic level of information regarding potential impacts of hazards on natural and built coastal assets. In many cases these 'first or second pass' assessments will identify areas that require additional investigations. It is important to note that alone, broad scale assessments have limited value in areas where more robust information is needed regarding future risks to private and public assets, such as areas experiencing significant development pressures. However, these broad scale assessments help to prioritise and frame finer scale assessments at the local level by identifying compartments and sediment cells that are likely to be more vulnerable to coastal change over time.

Local scale assessments (Tertiary Sediment Cell Level or 'Third Pass') are likely to be required at locations where the uncertainty of future impacts on existing or future coastal assets needs to be reduced as much as possible for planning and management purposes. Often termed 'third pass assessments', these assessments require site-specific data in order to provide sufficient detail for informing land-use planning mechanisms such as setback lines, coastal recession lines, and zones subject to coastal inundation. The onus of undertaking these assessments does not necessarily lie solely with the local land manager and can be made a requirement of the development proposal process as stated in the State Planning Policy (SPP) 2.6, section 5.5 pg. 5:

> "Adequate coastal hazard risk management and adaptation planning should be undertaken by the responsible management authority and/or proponent where existing or proposed development or landholders are in an area at risk of being affected by coastal hazards over the planning timeframe. Coastal hazard risk management and adaptation planning should include as a minimum, a process that establishes the context, vulnerability assessment, risk identification, analysis, evaluation, adaptation, funding arrangements, maintenance, monitoring and review, and communicate and consult".

Based on a desktop review of recent coastal hazard risk assessments, the following common steps are:

1. Evaluate existing studies and data sets including an evaluation of data quality and relevance, and applicability of physical models.
2. Identify the scale of the assessment (broader (second pass) or site specific (third pass)) to meet specified needs.
3. Undertake further studies or collect more data if gaps are identified and new information is essential for meeting the specific needs of the assessment.
4. Re-interpret existing studies, data sets or models and incorporate any new information.
5. Undertake erosion/inundation hazard assessments.
6. Review and refine process (1-4) based on new information.

4.2 COASTAL EROSION HAZARD MAPS

Coastal erosion maps provide an overview of shoreline changes over a period of time. The level of accuracy and robustness of erosion maps depends on data availability and its applicability. Figure 16 shows a coastal erosion map developed for the City of Busselton.

Table 5 summarises the data requirements for regional scale erosion maps and local scale (sediment cell) erosion maps.

Table 5: Data requirements coastal erosion hazard mapping (second pass and third pass).

DATA	SECOND PASS	THIRD PASS
EROSION HAZARD MAPPING		
Meteorological drivers (rainfall, winds, storms, weather patterns)	Long term records and analysis	Long term records and analysis
Topography	High resolution contours Topographic maps, LiDAR DTM & DEM Description of geomorphological, geological and geotechnical features at the regional scale.	At least 0.25m contours Topographic maps, LiDAR DTM & DEM Description of geomorphological, geological and geotechnical features at the tertiary scale.
Bathymetry	Bathymetric charts not more than 10 years old derived from singlebeam or multibeam hydrographic surveys or nautical charts	Recent and high resolution bathymetric charts derived from bathymetric LiDAR or Multibeam hydrographic surveys
Geology, geomorphology and sediment transport	Description of geomorphological and geological features at the regional scale. Model for regional sediment transport.	Description of geomorphological and geological features at the tertiary scale. Determination of potential change of unstable landforms at the tertiary scale. Sediment/bedrock relationships and add geotechnical data. Mechanisms for beach/dune interactions. Analysis of current and future (long-term) sediment transport and sediment budget rates: i. Alongshore distribution of sediment ii. Cross shore distribution of sediment iii. Influence of in-situ rock and artificial coastal management structures Role of nearshore currents in sediment transport and budgets.
Shoreline movement plots and beach profiles	Shoreline change and future beach behaviour to sea level rise at the regional scale. Up to date shoreline movement plots	Shoreline change and future beach behaviour to sea level rise at the tertiary scale. On-going beach surveys at hot spots. Up to date shoreline movement plots

DATA	SECOND PASS	THIRD PASS
Storm surge and water level	Historic analysis of storm surge heights associated with extreme weather events (*) to determine Annual Recurrence Interval (ARI).	Historic analysis of storm surge heights associated with extreme weather events (*) to determine Annual Recurrence Interval (ARI).
Waves	Projected storm wave heights (wind related) - for specified ARI. Wave climate response to SLR. To be accurate wave data sets should cover a period longer than 40 years.	Projected storm wave heights (wind related) - for specified ARI. Wave climate response to SLR. To be accurate wave data sets should cover a period longer than 40 years.
SLR scenarios	Projected sea levels for the specified climate change scenarios.	Projected sea levels for the specified climate change scenarios.
Benthic habitats	Spatial distribution of sediments and seagrass communities to estimate sediment budgets and transport.	Spatial distribution of sediments and seagrass communities to estimate sediment budgets and transport.

*Particularly for active (exposed and less sheltered) coasts (e.g. north of Cervantes) wave run-up and setup need to be considered.

4.3 COASTAL INUNDATION HAZARD MAPS

Depending upon data availability and quality, coastal inundation zones can be identified using two methods:

- The 'bath tub' approach (which can be used in the absence of local data, see Figure 14 and 15 for examples), has potential application in broad scale strategic planning however has limited application for local level planning because it does not consider geomorphic change.
- More detailed, site-specific coastal inundation mapping that considers geology and geomorphology and is therefore viewed as more valuable for local level planning (Used by the Peron Naturaliste Partnership, Cockburn Sound Coastal Alliance and the Bunbury-Busselton inundation modeling by Geoscience Australia, Figure 16).

Good elevation and high resolution bathymetric data is required for more detailed inundation maps especially if complex modelling exercise is to be undertaken. Modelling is required to estimate shoreline changes (erosion, accretion) caused by long-term climatic processes (for the chosen climate change scenarios), storm surges, coastal inundation scenarios and sediment transport.

Table 6 outlines the key data sets required for both methods.

Table 6: Data Requirements for Coastal Inundation Hazard mapping (second pass and third pass).

DATA	SECOND PASS	THIRD PASS
INUNDATION HAZARD MAPPING		
Meteorological drivers (rainfall, winds, storms, weather patterns)	Long term records and analysis	Long term records and analysis
Topography	Existing topographic contours.	At least 0.25m contours, LiDAR DTM/DEM. Description of geomorphological, geological and geotechnical features at the tertiary scale. As the storm surge reaches shallow water and the complex nearshore environment, increasingly finer scale bathymetric and elevation data is required.
Bathymetry	Possibly not older than 10 years. Acceptable if derived from single-beam hydrographic surveys and/or nautical charts.	Recent and high-resolution bathymetric charts derived from bathymetric LiDAR or Multibeam hydrographic surveys. As the storm surge reaches shallow water and the complex nearshore environment, increasingly finer scale bathymetric and elevation data is required.
Storm surge and water level	Historic analysis of storm surge heights associated with extreme weather events (*) to determine Annual Recurrence Interval (ARI).	Historic analysis of storm surge heights associated with extreme weather events (*) to determine Annual Recurrence Interval (ARI).
Waves	Projected storm wave heights (wind related) - for specified ARI.	Projected storm wave heights (wind related) - for specified ARI
Hydrology	River flooding hazard maps if available (for estuarine areas).	River flooding hazard maps if available (for estuarine areas).
SLR scenarios	Projected sea levels for the specified climate change scenarios.	Projected sea levels for the specified climate change scenarios.

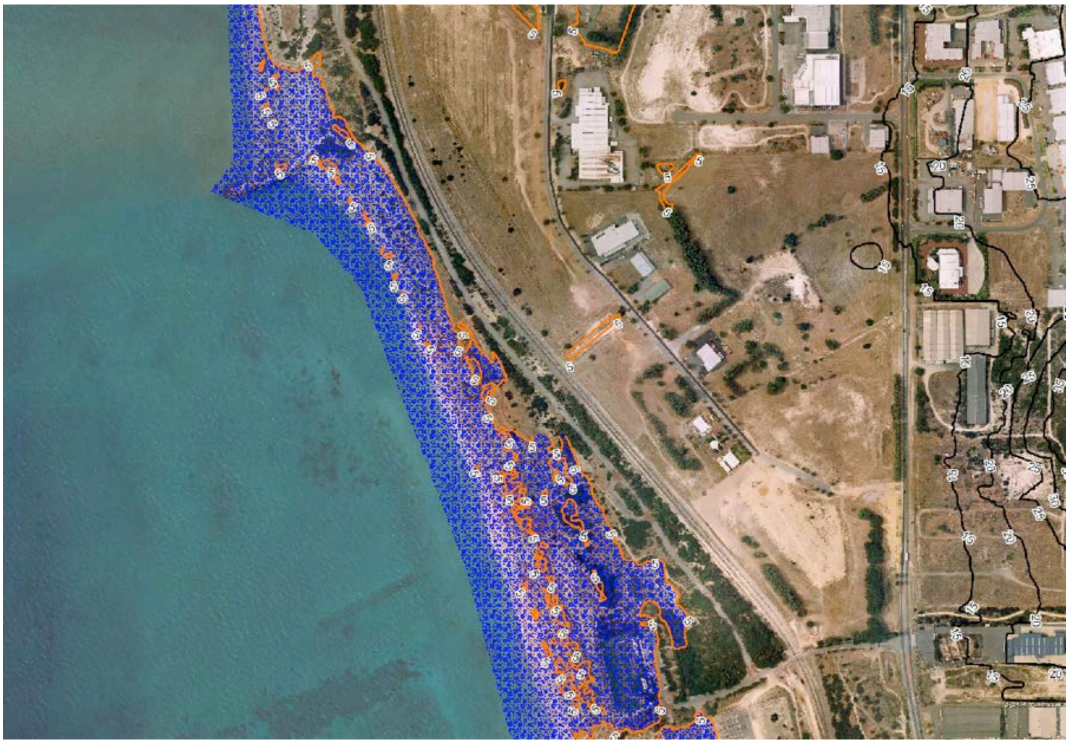


Figure 14: Coastal Inundation at Cockburn - bathtub approach using topographic contours (0.25m), undertaken by GIS officer at the City of Cockburn.

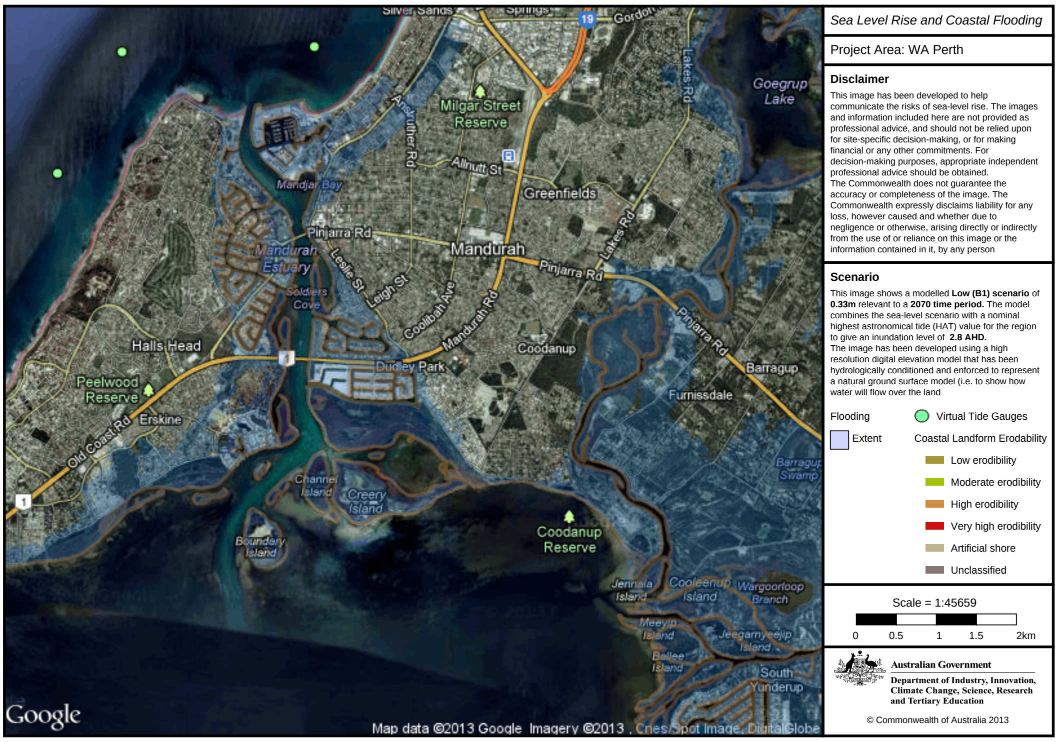


Figure 15: Coastal Inundation at Mandurah – bathtub approach by CSIRO.

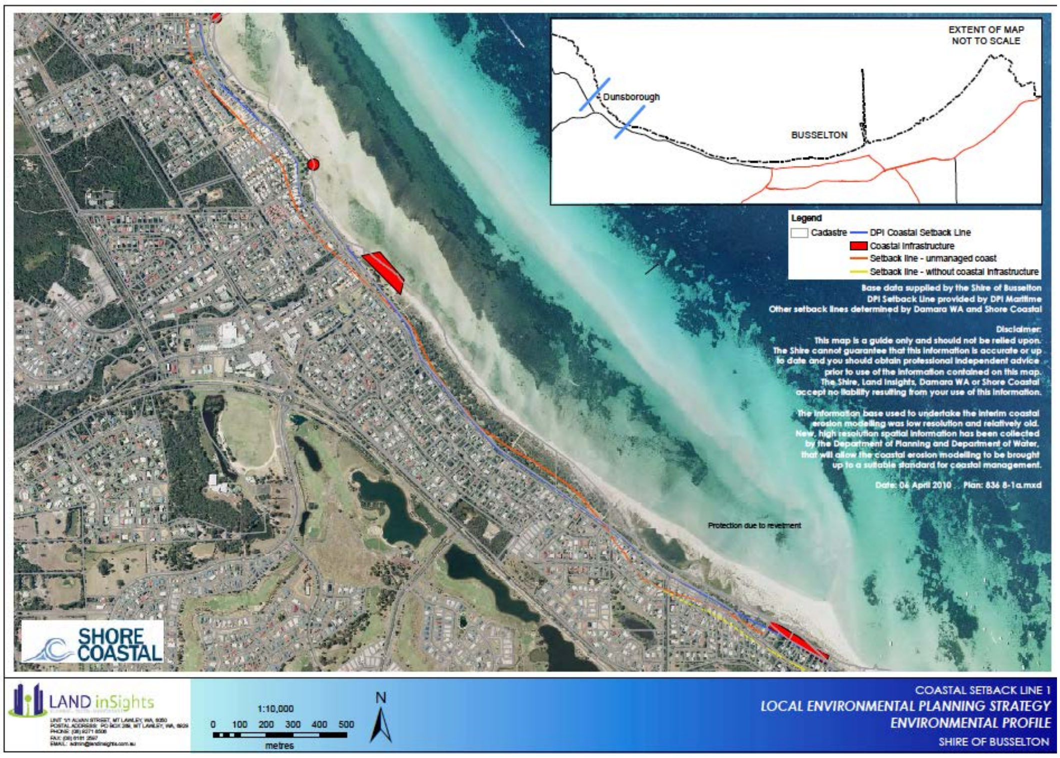


Figure 16: Coastal erosion lines Shire of Busselton.

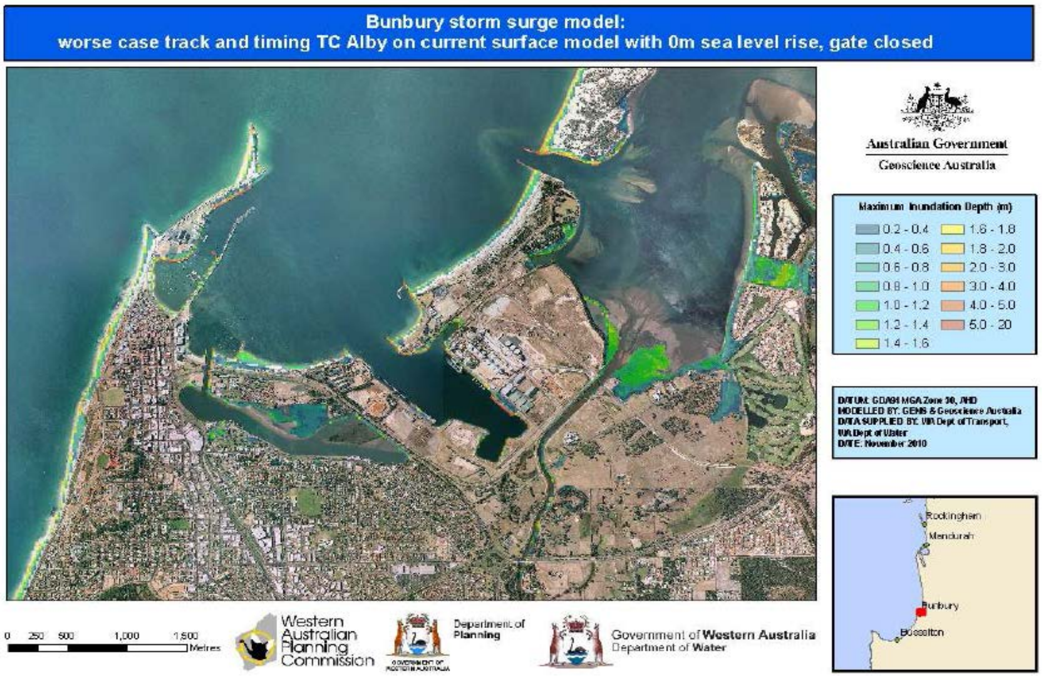
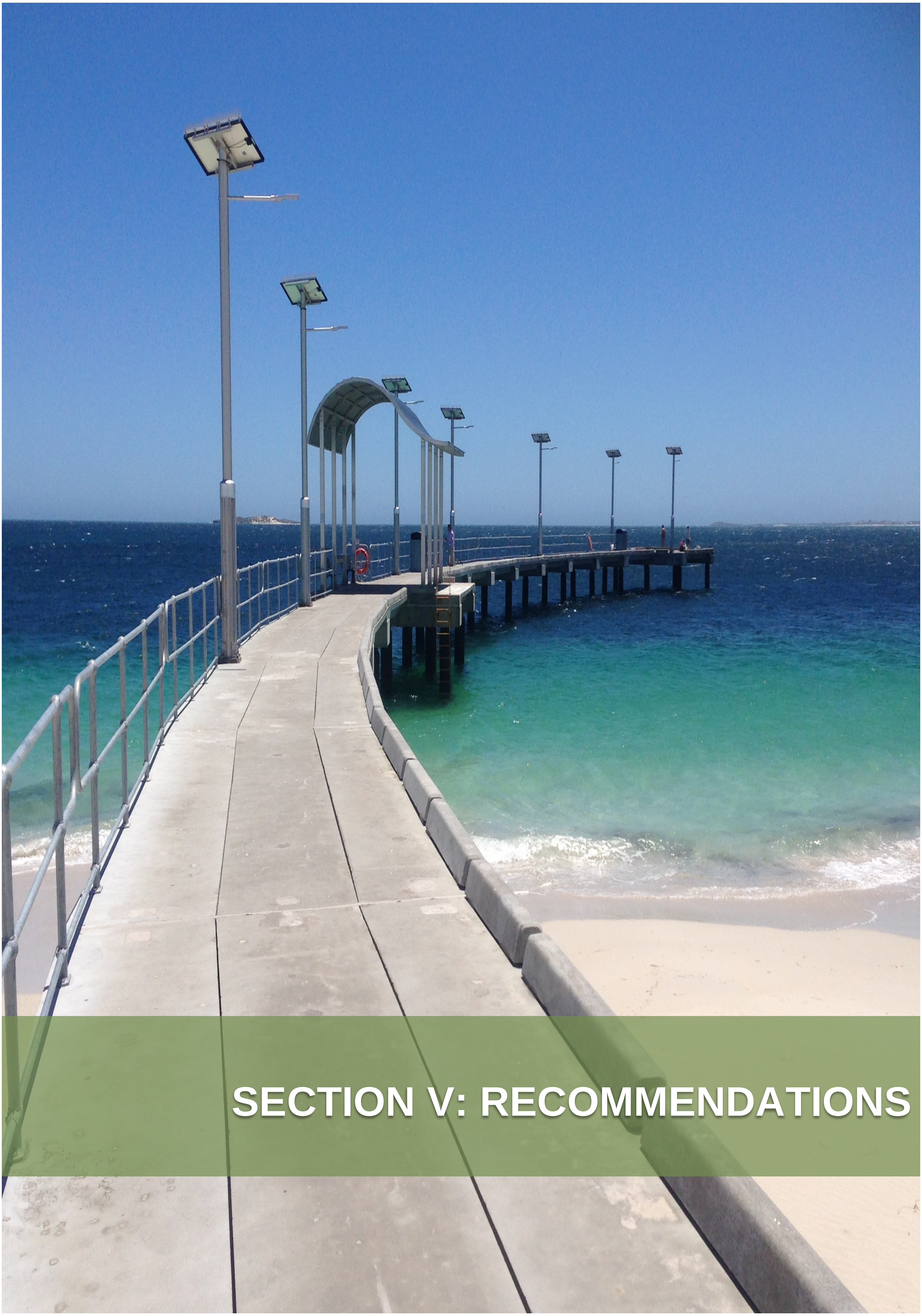


Figure 17: Inundation map for Bunbury developed by Geoscience Australia. Source: www.planning.wa.gov.au



SECTION V: RECOMMENDATIONS

5. CONCLUSIONS

This section identifies data gaps and shortcomings within the existing information that would limit its application to assess and map coastal hazards. Appropriate monitoring mechanisms for the collection of new data sets for areas at greatest risk from coastal hazards including locations, frequency, responsible parties and indicative costs are suggested. Recommendations are listed in priority order over a 5-year timeframe.

5.1 SUMMARY

Temporal relevance, spatial extent and quality of datasets are important factors that need to be assessed prior to undertaking Coastal Hazard Risk Assessments. Deficiencies in the spatial extent of data sets can compromise the accuracy of numeric simulation models and projections. Whilst, changes in instrumentation and/or observing practices may have an effect on the quality of long-term records. A lack of long-term data sets (e.g. wave data) can lead to errors in the identification of trends within these data sets (NCCOE 2012) which in turn can result in greater inaccuracies when modelling future coastal change.

In order to undertake meaningful coastal hazard risk assessments, limitations in the availability and consistency of data sets must be identified and where possible deficiencies addressed. Deficiencies in spatial extent of data sets can be overcome by commencing data collection programs for a specific site. Deficiencies in temporal extent can be overcome by taking particular care when extrapolating trends from short-term data sets.

Funding opportunities for hazard risk assessments and data collection programs are currently available through the Department of Transport's Coastal Adaptation and Protection (CAP) grant program. Natural Resource Management organisations such as NACC often provide financial support for community-based projects such as monitoring programs, on-ground works and engagement programs through small grant programs. Across Australia funding programs for costal adaptation have been favoring regional partnership models. Regional partnerships help stakeholders to pool resources for addressing gaps in data while enabling economies of scale which can help to attract universities and leading specialists. Partnerships can also help to avoid unnecessary duplication in contracting and grant writing. Examples of successful regional partnerships in WA include the Peron Naturaliste Partnership (PNP) and the Cockburn Sound Coastal Alliance.

Overall there is a lack of (long-term) historical information and detailed analysis of metocean drivers and processes for the Hill Primary Compartment. Therefore future data collection will be required to fulfill existing gaps prior to third pass coastal hazard risk assessments taking place in many areas within the Compartment. For example, in 2011 the Department of Transport and the Shire of Gingin explored the possibility of undertaking a Coastal Hazard Risk Assessment for the Lancelin Townsite however, the project did not progress due to the lack (or inconsistency of) data sets (the project was lead by Senior Coastal Engineer Charlie Bicknell.

Table 7 provides a summary of existing data sets that describe coastal processes operating in the Hill Primary Compartment. It also describes the potential shortcomings in the existing information for coastal hazard risk assessment and mapping. Table 10 in Appendix C provides identifies common data and information gaps across sediment cells to help to create cost efficiencies in future data collection across sediment cells of interest, as opposed to collecting individually at different times.

Table 7: Available data sets and potential shortcomings in the existing information for the Hill Primary Compartment.

PHYSICAL DATA	AVAILABILITY	DATA QUALITY & GAPS
Winds	40 years +	Interpretation of wind records need to take into consideration how winds are/have been affected by geography, topography and change in instrumentation as well as differences in records between observation stations.
Rainfall	40 years +	Good quality
Storm surge and water level	18 years of regional records, 40 + from Fremantle and Geraldton.	Geraldton and Fremantle records are reliable from 1965 (since establishment of AHD) while the Jurien Bay records are too short. The long-term historic sea level data records can provide information about possible change in storminess over the Hill Primary Compartment, extreme weather events and trends in sea level variations. Regional variability in oceanographic and meteorological phenomena such as astronomical tides, changes in atmospheric pressure, winds, river discharges, ocean circulation and changes in water density must be considered when analysing and applying long-term data sets from stations located outside the study area.
Waves	Sporadic in nature from 1971 to 1994. Records from Rottnest (from 1994 located at -48m) and Jurien Bay (from 1997 located at -42m) provide the closest representation of the region’s wave climate.	Longer and accurate records are required to provide a description of the wave climate for the Hill Compartment and better understanding of the impact of off-shore coastal structures on wave climate. Further investigation of coastal processes for the region will require a better understanding of variability, trends and extremes of both offshore and nearshore wave climate and improve the interaction between waves, local topography and geomorphology. This could be achieved by installing new wave buoys offshore and onshore at certain locations.
Currents	Studies on currents have been undertaken in Jurien Bay (2008) and surface current stations are	More information is required on nearshore currents for the study area especially current behaviour in proximity of islands and reefs.

PHYSICAL DATA	AVAILABILITY	DATA QUALITY & GAPS
	installed at Seabird and Cervantes. AWAC installed temporarily in 1989, 2003, 2002 and 2006 at various sites provide information on nearshore and offshore currents.	
Bathymetry	40 years of nautical charts and hydrographic surveys undertaken at different locations and at various timeframes.	Bathymetric data that is older than 10 years need to be repeated for better accuracy (Guilderton, Seabird, Ledge Point, Jurien Bay). Bathymetric LiDAR for the entire region or Multibeam hydrographic surveys to be collected at hot spots (erosion areas near developed areas or future development).
Beach levels & profiles	Beach levels have been undertaken for various years at various locations from 1970 to present day. Beach profile analyses were undertaken at Seabird (2002 and 2004), Thirsty Point and Jurien Bay.	Beach profiles should be collected for areas subject to erosion in proximity of coastal development and repeated every 5 years.
Shoreline Movement Plots	Exist for all coastal towns up to 2002.	Need to be up to date to 2013.
Topography	LiDAR was collected in 2013 by NACC and DoW	High Resolution data. To be repeated in 10 to 15 years.
Geology and Geomorphology	Geological maps available since the 1940s'. Various reports, studies also available for the study area.	An assessment of elevation and coverage of underlying rock (exposed and submerged) is required. A study of the perched beach system at the local scale is also recommended.
Sediment Transport & Budgets	To date not much information on local sediment transport regimes and budgets exist. The only information available comes from studies undertaken as part of site specific projects such as coastal protections, setbacks, dredging.	The sediment cell classification needs to be updated with more accurate topography and bathymetric data to identify tertiary sediment cell boundaries. Regional and local scale sediment budget analysis and sediment transport modelling is required for detailed coastal hazard risk assessments.
Sediment samples	Sediment analysis was undertaken at Seabird and Lancelin (2009).	Sediment thickness, availability and transport needs to be better understood.

PHYSICAL DATA	AVAILABILITY	DATA QUALITY & GAPS
Benthic habitat	Mainly around Jurien Bay.	Extend the mapping to priority areas as part of coastal hazard assessments.
Hydrology	Information on river discharge is available for the Hill River (1968 to present day) and the Moore River (1965 to present day). Hydrologic study was undertaken for the Moore River in 1991 and 2000.	Hydrological and flood studies should be conducted to improve the understanding of influence of rivers play on sediment transport and potential implications of riverine floods on coastal areas.
Groundwater	Regional study undertaken in 1994. Broader vulnerability assessment for Australia undertaken in 2012.	Improve understanding of local vulnerability of coastal aquifers.

5.2 RECOMMENDATIONS

The following recommendations are drawn from the findings of the Gap Analysis and informed by research and lessons learned from coastal hazard risk assessments undertaken in other regions.

Recommendation 1: That existing data sets are improved in order to develop second pass erosion and inundation hazard maps for the Hill Primary Compartment. The maps will identify areas that are likely to be more vulnerable to coastal erosion and/or inundation at different timeframes and climate change scenarios. Second pass assessments are generally undertaken for the entire coastal compartment (or sub compartments) as a 'first cut' to provide planners and managers with a basic level of information regarding potential impacts of hazards on natural and built coastal assets. In many cases these 'first or second pass' assessments identifies areas that require additional investigations. It is important to note that alone, broad scale assessments have limited value in areas where more robust information is needed regarding future risks to private and public assets, such as areas experiencing significant development pressures. However, these broad scale assessments help to prioritise and frame finer scale assessments at the local level by identifying compartments and sediment cells that are likely to be more vulnerable to coastal change over time. For this purpose the following project tasks are recommended:

I. **Coastal Sediment Cells Study** to identify sections of the coast that exhibit similar processes and morphology as the framework for estimating sediment budgets and local scale assessment of hazard and risk. Improved bathymetric data is a key requirement.
II. **Bathymetry Mapping Program** to identify priority locations for new bathymetric surveys for improved data on nearshore structures, behaviour and responses, sediment transport and sediment distribution on the seafloor and sediment cell classification. A LiDAR bathymetric survey for the entire compartment would provide a wider context for available bathymetric information and facilitate a more complete

assessment of natural resources, including sediment availability and distribution, although a costly option. A cheaper option would be to collect Multibeam Hydrographic Surveys at priority areas. Older bathymetric charts can be validated with ground truth measurements (new bathymetries might not be required for certain sites).

III. **Regional Sediment Transport Model** specific to the Hill Primary Compartment to estimate sediment sources, sinks and key transport pathways and determine rates of coastal change.
IV. **Analysis of Historic Water Levels and Storm Surges Data** associated with historic extreme weather events and determine ARI events for the Hill Primary Compartment.
V. **Shoreline Change and Movement Plots Analysis** to assess historical shoreline change for the Hill Primary Compartment and help predict future coastal change.
VI. **Coastal Assets and Values Study** to gather information on coastal assets, uses and values that are potentially at threat from future coastal hazards and to identify areas of high vulnerability and high value.

Recommendation 2: That existing data sets are improved in order to undertake a 'third pass' erosion and inundation hazard assessment and mapping at priority areas. The priority areas will be identified from the Coastal Sediment Cells Study (I) and the Coastal Assets and Values Study (IV) projects. Site specific hazard and risk assessment will require the following projects:

VII. **Bathymetry Mapping Program** to generate high-resolution bathymetric charts at the tertiary sediment cell level at identified priority areas. This will improve data on nearshore structures, behaviour and responses, sediment transport and sediment distribution on the seafloor and sediment cell classification at identified priority areas.
VIII. **Additional Wave Buoys** for areas that require installation of temporary wave buoys for improved site-specific wave and current data.
IX. **Sediment Transport and Budgets Analysis** to estimate sediment sources, sinks and key transport pathways to determine the rate of coastal change at the tertiary level (key priority areas) and assess potential migration or retreat of unstable landforms.
X. **Geotech Investigations** to assess the elevation and coverage of underlying rock at priority sites.
XI. **Shoreline Movement Plots and Beach Profiles** to be extended to the whole compartment or at key priority areas for assessment of shoreline change and sediment budget calculation.

Recommendation 3: That on-going data collection programs are continued. Specifically, the following programs be maintained:

XII. **Beach monitoring program** (profiles, historic photos and community photo-monitoring) for assessment of shoreline change and sediment budget calculation and potential impact of engineered structures at identified priority areas.
XIII. **Sediment Sampling Program** for improved understanding of sediment transport pathways, sinks and supplies.

Table 8 (page 40 of this report) lists the recommendations for future data requirements for undertaking a hazard risk assessment and mapping at a scale useful for planning and management decision making.

Table 8: Recommended future data requirements for developing third pass coastal hazard risk assessment maps.

	PROJECT	SCALE	SCOPE	ORGANISATION	NOTES	COST ESTIMATE & FUNDING	TIMEFRAME
1	**Coastal sediment cells classification**	For the entire coastal compartment	To identify sections of the coast that exhibit similar processes and morphology (tertiary sediment cells) as the framework for developing sediment budgets and local scale assessment of hazard and risk	DoT, DoP	Identified as a priority by DoT and DoP.	DoT and DoP internal budget.	1 year
2	**Bathymetry collection program:** **Option 1: LiDAR / LADS survey for the entire compartment** **Option 2: Multi beam surveys at priority areas**	Hill Primary Compartment (Bathymetric LiDAR) or Sediment Cell (priority areas) (Multibeam Hydrographic Surveys)	High-resolution (multi beam) shallow water (0-20m) bathymetric surveys and marine habitat and seabed classification. To assist with: - near shore terrace structure, behaviour and response - sediment transport and sediment distribution on the seafloor (used in modelling) - sediment cell classification - identification of sediment transport tipping points.	DoT, Shires, developers, NRM	Marine LiDAR for the Hill Primary Compartment would provide a wider context for available bathymetric information and facilitate a more complete assessment of natural resources, including sediment availability and distribution (recommended in Eliot et al. 2011). Older bathymetric charts can be validated with ground truth measurements (new bathymetries might not be required for certain sites). Alternatively, hydrographic surveys with multi beam sonar to be undertaken in areas where bathymetries are more than 10 years old or for new	Cost of marine LiDAR survey: for the Hill compartment approximately $900,000. Cost of multi beam bathymetric surveys: $2.500 per square km ($5,000 per day). Costs increase for shallow areas. DoT CAP funding.	1 to 3 years

	PROJECT	SCALE	SCOPE	ORGANISATION	NOTES	COST ESTIMATE & FUNDING	TIMEFRAME
					developments. Hydrographic (single beam) surveys have been conducted by DoT and consultants through dredging programs between 1972 and 2011. The most recent surveys (2007 and 2011) were conducted for the Jurien Bay Boat Harbor pre and post dredging operations. Surveys extend to approximately 10m water depth offshore. Accuracy: horizontal 1m, vertical 0.1m. Distance offshore approx. 1-3 km.		
3	**Regional Coastal Assets & Values Study**	For the entire coastal compartment	To gather information on coastal assets, uses and values that may be at threat from future coastal hazards. This project will: ▪ identify natural and built coastal assets and associated values including services and functions provided by natural ecosystems ▪ identify priority areas for site specific hazard assessments ▪ identify potential	DoP, NRM, Shires	The key outputs will be: ▪ an inventory of coastal assets (natural and built) and services that these assets provide ▪ an inventory of community values and community views on the coastal impacts of climate change, and attitude towards current/future coastal development ▪ priority areas for future site-specific vulnerability studies. ▪ Baseline for future calculation of value at	$80,000 Coastwest grants	1 to 2 years

	PROJECT	SCALE	SCOPE	ORGANISATION	NOTES	COST ESTIMATE & FUNDING	TIMEFRAME
			social and economic factors at risk from future coastal changes ▪ Identify community perception of risk and attitude towards adaptation options ▪ Identify the 'value at risk' once the hazard assessment is completed.		risk.		
4	**Beach Monitoring Program:** **a) a compilation of historic beach photographs** **b) an on-going Community Beach Monitoring program** **c) Beach Profile Monitoring Program (historic and present shoreface and beach profiles)**	Priority areas	To assist with the analysis of shoreline movements, beach changes, impact of storms on beaches and impact of engineered structures. The profile data sets would be used to detect shorter-term trends and fluctuations. Profiles should be undertaken every five years, extend from the rear of the primary dune on shore and past the closure depth offshore (closure depth is generally the seaward limit of sediment transport). This information will be used to identify geomorphological tipping	Shires, NACC, DoT	All the data and information collated through existing and future monitoring methods (NACC Beach Monitoring Program, DoT field photographs) should be combined into one beach-monitoring database to improve the overall picture of the changes that are taking place along the Hill Primary Compartment. Project b) is currently being coordinated by NACC. Project a) could be incorporated into project b). Project c) will require preparing a Survey Brief as the basis for developing the Beach Profiles Monitoring Program. The brief should outline:	Project c) Indicative cost for the study brief: $25,000. Indicative cost for 20 profiles $20,000 plus analysis and reporting $20,000. CAP/NRM/Coastwest funding.	1 to 2 years to set up

	PROJECT	SCALE	SCOPE	ORGANISATION	NOTES	COST ESTIMATE & FUNDING	TIMEFRAME
			points (see glossary).		- analysis of existing coastal surveys and data sets; - location of appropriate survey points; - frequency of surveys.		
6	**Sediment Transport & Landform Stability**	For the entire coastal compartment and tertiary cell	The project will: - Estimate sediment sources, sinks and key transport pathways to determine the rate of coastal change; - Develop an alongshore sediment transport model that can be used for the hazard assessment at the regional scale or at the tertiary scale; - Assess potential migration or retreat of unstable landforms; - Identify	Shires with DoT assistance, developers	Build upon work undertaken by Curtin University (Stevens and Collins 2008, 2011) and utilize 2013 LiDAR DTM and hyperspectral data.	$150,000 DoT CAP grants	2 to 5 years

	PROJECT	SCALE	SCOPE	ORGANISATION	NOTES	COST ESTIMATE & FUNDING	TIMEFRAME
			geomorphological 'tipping points[1]' (see explanatory note).				
7	**Investigation of additional wave buoys**	Priority areas	This data is essential for understanding shoreline movements, currents and to calibrate numerical models.	DoT	Consideration should be given to installing new wave buoys offshore and onshore. Based on Project 1 and 2: hot spots and beach profile sites.	One directional wave buoy @ $95,000). AWAC buoy @ $45,000. (Prices do not include deployment ($30,000 and annual maintenance $10,000). These prices do not take into account any of the hardware and software used to collect, transmit and analyse the data collected,	1 to 3 years.

[1] Eliot et al. (2011) describe geomorphological tipping points as the points at which structural changes in geomorphological features take place and that can 'indicate' dramatic change to coastal behaviour (transition from net erosion to net accretion). For some features (transgressive barriers, lower and unvegetated dune systems), overwash and breaching processes caused by raising levels and/or storm surge can facilitate drastic local erosion.

	PROJECT	SCALE	SCOPE	ORGANISATION	NOTES	COST ESTIMATE & FUNDING	TIMEFRAME
						usually undertaken by DoT. DoT CAP grants.	
8	**Historic water levels and storm surge records**	For the entire coastal compartment	A baseline study to determine: ▪ historic analysis of water levels and storm surges associated with extreme weather events from tide gauge records. ▪ determine ARI for future assessment of the potential impacts of extreme metocean events on landforms.	Shires with DoT assistance, developers	The project will require an analysis of historical records.	$20,000 DoT CAP grants.	2 years
9	**Shoreline movement plots analysis.**	Hill compartment/Priority areas (town sites)	Currently available for the period 1950-2000. Useful for coastal hazards assessment (recession line and inundation mapping).	DoT, developers	Useful to compare with terrestrial LiDAR data (NACC 2013) and GIS data sets (Stevens and Collins 2008, 2011).	CAP funding or DoT internal funding.	On going, five year intervals
10	**Geology**	Priority areas	Assessment of elevation and coverage of underlying rock is important for more accurately determining potential hazard areas.	Shires with assistance of DoT, developers	For sites supporting urban-rural development and infrastructure that may be located on unconsolidated sediments overlying bedrock surfaces. The locations of geotechnical	$20,000/linear Km DoT CAP grants.	3 to 5 years

	PROJECT	SCALE	SCOPE	ORGANISATION	NOTES	COST ESTIMATE & FUNDING	TIMEFRAME
					surveys will need to be assessed case by case, based on existing geological information provided by the GWSA database (Gozzard 2011).		
11	**Sediment sampling program**	Priority areas	Collection of sediment samples improves understanding of sediment transport pathways, sinks and supplies.	Shires with DoT assistance, developers	Samples should be collected in summer and winter where possible. Best if done in combination with bathymetric surveys and beach profiles.	Costs vary depending on the type of survey. Seven samples can be collected by boat per day. . On land per day 30 samples. Approximate daily costs: $3,000 per day per boat and $1,000 per operator per day (minimum 4 operators per boat). DoT CAP grants.	3 to 5 years
12	**Infrastructure condition assessment**	Where coastal protection or marine infrastructure is present.	Useful for coastal hazards assessment and long term management of the coast.	Shires with assistance DoT	An inventory of coastal structures to examine the effectiveness, maintenance and schedule requirements of each structure. Also recommended in Eliot et al. (2011), “Identification of costs and allocation of responsibility for management of coastal protection and stabilisation works, such as engineered structures and sediment	$40,000 DoT CAP grants.	3 years

PROJECT	SCALE	SCOPE	ORGANISATION	NOTES	COST ESTIMATE & FUNDING	TIMEFRAME
				bypassing, for the adjacent coast, as well as for ongoing coastal monitoring, maintenance and management of the site".		

6. REFERENCES

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7. ACRONYMS

AHD: Australian Height Datum

ACDP: Acoustic Doppler Current Profiler

ARI: Average Recurrence Interval

AWAC: Acoustic Wave and Current

BoM: Bureau of Meteorology

CAP: Coastal Adaptation Protection Grants (DoT)

DER: Department of Environment and Regulation

DEM: Digital Elevation Model

DoW: Department of Water

DTM: Digital Terrain Model

GSWA: Geological Survey of WA

HAT: Highest Astronomic Tide

DoP: Department of Planning

DoT: Department of Transport

DoW: Department of Water

LADS: Laser Airborne Depth Sounder (LADS)

LiDAR: Light Detection and Ranging

NACC: Northern Agricultural Catchments Council

SLR: Sea Level Rise

SLR: Sea Level Rise

SWI: Salt Water Intrusion

8. GLOSSARY

Accretion: shoreline movement where the shoreline shifts seaward, increasing the width of a coastal foreshore reserve.

Adaptation: an adjustment in natural or human systems in response to actual or expected stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptation is the primary means for maximising the gains and minimising the losses associated with climate variability.

Aeolian transport: process of wind erosion, sediment deposition, and how sediment is transported.

Average recurrence interval (ARI) is the average time interval between occurrences of an event of a particular magnitude. Events of a given recurrence interval may, and often do, occur in far more rapid succession over a shorter interval (e.g. a 1 in 100 year storm event may in fact happen every 20 years).

Australian Height Datum: the current official standard Australian height reference (ICSM, 2006). AHD is an approximation of mean sea level only.

High Astronomic Tide: the elevation of the highest predicted astronomical tide expected to occur at a specific tide station over the National Tidal Datum.

Aquifer:a geological unit that holds, transmits and yields water at useful rates and quantities. The water in an aquifer is contained within its porosity. An unconfined aquifer has a water table as its upper boundary. A confined aquifer is bounded between two low permeability units.

Bathymetry: the vertical level of the sea floor in the ocean, seas and lakes; by common convention it is described as water depths below a nominated vertical datum, which typically corresponds to lowest astronomic tide.

Bath tub approach: the representation of inundation model results using a single vertical level. This method typically obscures spatial variation in elevation associated with a flood event.

Coastal compartment: length of shoreline bounded by broad scale changes in geology, geomorphic structures/landforms or changes in the aspect of the shore.

Coastal Hazard: the consequence of coastal processes that affect the environment and safety of people. Potential coastal hazards include erosion, accretion and inundation.

Coastal Processes:any action of natural force that impacts the coastal environment such as winds, tides, currents, swell, etc.

Coastal protection works: any permanent or periodic work undertaken primarily to alter physical coastal processes and/or manage the effects of coastal hazards. The influence of coastal protection works should be evaluated at the sediment cell level.

Coastal ocean surface radar: a land-based technique which uses scattering from the rough sea surface to obtain echoes which are Doppler shifted by the dynamics of the sea. This interaction gives two strong first-order lines in the echo spectrum; one from the resonant gravity wave moving radially away from the station, and one from the resonant gravity wave moving towards the station. It measures sea surface currents.

Cuspate foreland: a triangular-shaped accretion of sand extending seawards in the lee of an offshore reef.

Digital Elevation Model (DEM): a derived bare earth map of the Earth's surface with the heights of anthropogenic and natural features such as vegetation and buildings removed from the elevation data..

Digital Terrain Model: same as DEM**.**

Geomorphology: the scientific study of landforms and the processes that shape them.

Geomorphological Tipping Points: structural changes in geomorphological features caused by coastal processes that if reached can lead to dramatic change to coastal behaviour and potentially cause transition from net erosion to net accretion (e.g. changes to sediment availability due to removal of sand dunes).

Groundwater: Water below the earth's surface.

Erosion: shoreline movement where the shoreline shifts landward, reducing the width of a coastal foreshore reserve.

Inundation: flow of water onto previously dry land. It may be either permanent (for example, due to sea level rise) or a temporary occurrence during a storm event.

LiDAR (LADS): Laser bathymetric survey tool that has applicability in clear coastal waters down to approximately 70m depth in very low turbidity levels (realistically LiDAR is useful to up to 20 m in depth).

Meteocean:an abbreviation of meteorological and oceanographic (processes).

Nearshore: the region of land extending from the seaward edge of the foreshore to the beginning of the offshore zone.

Recession: long-term erosion of the shoreline due to metocean processes with permanent loss of sand from the beach-dune system.

Risk: specified in terms of an event and the consequence that may flow from it. Risk is measured in terms of a combination of the likelihood of an event occurring and the consequence of that event occurring.

Risk assessment: the overall process or method for evaluating risks associated with a specific coastal hazard and includes risk identification, risk analysis and risk evaluation.

Salient: part of sandy coast protruding seaward of the shoreline trend.

Sediment cell: a length of shoreline in which interruptions to the movement of sediment along the beaches or near shore sea bed do not significantly affect adjacent beaches. The sediments sources, transport pathways and sinks should be clearly definable within a sediment cell.

Seiches: A wave that oscillates in an enclosed water body such as lakes, bays, or gulfs from a few minutes to a few hours as a result of seismic or atmospheric disturbances.

Storm surge: the increase in water level at the shoreline due to the forcing of winds and atmospheric pressure.

Tombolo: a deposition landform in which an island is attached to the mainland by a narrow piece of land.

Transition zone: separates the fresh water and the saltwater zones in a coastal aquifer.

Vulnerability: the degree to which a system is susceptible to, or unable to cope with, adverse effects of changing coastal processes. Areas that are highly exposed (high energy coasts), sensitive (e.g. low-sandy coastlines) and less able to adapt (e.g. low vegetation cover) are most vulnerable.

Unconsolidated sediments: loose sediment particles such as gravel, sand, silt and clay that have not been lithified or consolidated into rock.

Wave run-up: the maximum vertical extent of wave uprush on a beach or structure above the still water level.

Wave setup: the rise in the Mean Water Level (MWL) due to a wave generated onshore transport of water mass. The calculation of a wave set up is necessary to know whether a low lying coastal area would be flooded or not in stormy waves.

APPENDICES

APPENDIX A: UPDATED BIBLIOGRAPHY

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APPENDIX B: SUMMARY COASTAL DATA SETS

Table 9: Summary Coastal Data sets for the Hill Coastal Compartment.

TITLE	DATE	SOURCE
Winds (local and regional)	Wind observation stations: Rottnest Island (1987-present day) Lancelin (1965-present day) Jurien Bay (1969-present day) Geraldton (1907-present day, digital from 1965)	Main source: BOM's website Broader studies: Bosserelle et. al. (2011); Steedman & Associates (1982); Panizza (1983); Nicholls et al. (2000); Nicholls (1992); Pattiaratchi et al. (1997). Site specific studies: Chua (2002); Worley Parsons (2008), Robinson (2011); MPRA (1996, 2006).
Rainfall	Jurien Bay (1968-present day). Lancelin (1969-present day).	BOM's website Report: Indian Ocean Climate Initiative (2002); JDA (2000). River discharges and rainfall stations near rivers DoW
Water levels (tide gauges)	Geraldton (1986-present day). Reliable since 1965. Fremantle (1977-present day; The National Tidal Center holds records from 1897, DoT from 1977). Reliable since 1965. Jurien Bay (1995-present day) Hillaries (1987-present day)	DoT, BoM websites, Department of Defence Australia National Tide Tables. Studies: National Tidal Facility (2000); Feng et al. (2004); Pattiaratchi & Eliot (2008); Eliot et al. (2010); Eliot et al. (2011).
Waves offshore and nearshore (permanent wave buoys)	Geraldton (digital since 1985 and a few stations removed initially installed in 1977) Jurien Bay (1982 analogue, digital from 1997, directional from 2009); Rottnest Island (from 1994 upgraded to directional in 2004 to present day)	DoT website Studies: Lemm (1996) and (1999) Wave modelling for the period 1997 to 2004 in Richardson et al. (2005)
Nearshore waves and currents (temporary AWAC)	Guilderton (1989) Seabird (2003) Ledge Point (2003-2004) at 2 locations with 2 instruments and several gaps Coastal radar: Cervantes and Seabird. Jurien Bay deployment of a ADCP in 2002 and 2006 in the Essex Lagoon (sea temperatures, currents, sea levels, wind speed and direction)	Coastal radar data and interactive maps: WAIMOS Portal (online) Studies: Worley Parsons (2004); Damara WA (2005) and Damara WA (2010); Cresswell et al. (1989); Pearce & Pattiaratchi (1997); Zaker et al. (2007); Damara WA (2005); Peirson et al. (2011), Presentation; Feng et al. (2010); Robinson (2011);
Bathymetries	Updates via mariners are available for the following areas: Guilderton 2003 Seabird 2004 Ledge Point 2006 Lancelin 2006 (refined in 2008 by Worley Parsons, WP 2008) Wedge Island 1996 Cervantes 1989 Jurien Bay 2006 North Head 1992	Nautical charts are based on hydrographic surveys completed by DoT over the last 40 years. DoT is the custodian of the data.

TITLE	DATE	SOURCE
	Hydrographic Surveys (soundings and beach levels) Guilderton 1975, 1983, 1995, 1996, 2000 Seabird 2002, 2003, 2004, 2005, 2006, 2007, 2008 Lancelin 1990, 1997-2005, 2007 1998 and 2007 Wedge Island 1982 and 1986 Cervantes 1972, 1984, 1986, 1990 – 1993, 1995, 1996, 1998, 200-2002 Jurien bay 1980-1982, 1985, 1988, 1989, 1991, 1992, 1995, 1998, 1999, 2000-2006. More recent surveys for the boat harbor in 2008 and 2011	
Topography	Landgate metadata accessible through SLIP (Shared Land Information Platform) NACC 2013 LiDAR Department of Water 2013 LiDAR	NACC, Landgate, Geoscience Australia, DoW
Geology & Landforms	Various years and extents.	Dongara-Hill River 1:250,000 (1973) Ledge Point 1:100 000 (1976) Geology of Wedge Island. Department of Minerals and Energy. 1:100 000 (1995) Geology of Hill River - Green Head. Department of Minerals and Energy. 1:100 000 (1994) WA Coast Lancelin to Kalbarri (Gozzard, JR 2011) and Perth to Lancelin (Gozzard, JR 2011). Maps: 1:100 000 (geological regions Hill River and Wedge Island) Hill River SH5009 (1937), Wedge Island SH5009 (1936). Smartline (Sharples et al. 2009). The geology, mineral resources and land-use capability of coastal lands Green Head to Guilderton (Gozzard, JR 1985) GSWA geological maps (Langford 2001) Geology and Landforms of the Perth Region (Gozzard JR. 2007) WA Coast Cape Naturalist to Lancelin (Gozzard JR. 2011) GSWA digital dataset. WA Lancelin to Kalbarri (Gozzard JR. 2011) GSWA digital dataset. The Coast of the Shires of Gingin and Dandaragan, Western Australia: Geology, Geomorphology & Vulnerability (Eliot et al. 2011) Coastal Geographic Information

TITLE	DATE	SOURCE
		System for the Northern Agricultural Region Coast, Western Australia (Stevens and Collins 2008). Smartline (Sharples et al. 2009). Geotech assessment: Seabird Geological Assessment (Gordon 2002); Wallis Drilling Pty Ltd 2001 (in MPRA 2006)
Groundwater	Regional studies: 1993-1997 Broader: 2012.	Regional groundwater behaviour is summarised in the Central Coast Regional Profile (DPUD 1994). Other references: Kern 1993, 1997; Moncrieff 1989; Ivkovic et al. 2012; JDA 2000; Stelfox 2001; Rutherford et al. 2005.
Sediment cells/Compartments	Recent data.	WA Coast Gozzard (2011) digital data sets The Coast of the Shires of Gingin and Dandaragan, Western Australia: Geology, Geomorphology & Vulnerability (Eliot et al. 2011) Coastal Sediment Cells between Cape Naturaliste and the Moore River, Western Australia, Stul T, Gozzard JR, Eliot IG and Eliot MJ (2012).
Aerial Photography	From 1940 to present day. Available from Landgate annually for Guilderton and every two years for the coast north of Guilderton.	Also available through DoT (hard and electronic copies of Landgate aerials). Vertical and oblique photos are available from 1940 to present day.
Beach profiles (analysis)	Seabird: Analysis of Survey Profiles February and July 2002 and Analysis of Survey Profiles & Rock Revels February 2002 and August 2002. Beach profiles undertaken by Worley Parsons as part of the Seabird Foreshore Investigation (Worley 2002 and 2004) Ledge Point: for the construction of the two groynes (1978-1986). Lancelin: in Lancelin Coastal Setback Study (Worley Parsons 2008). Cervantes (Thirsty Point): Thirsty Point Preliminary Shoreline Movement Investigation (MP Rogers 2009) Jurien Bay and Ardross Estate: 1996 (MRA 1996) North Head: 2006 (MRA 2006)	DoT and Shires.
Sediment sampling	Seabird: One known sediment sample form beach near town (DoT) Lancelin: A significant amount of samples (Nicholson 2009)	DoT and Shires.
Shoreline Movement Plots	Guilderton 1952-1998 Seabird 1941-2002 Ledge Point 1952-1993 Lancelin 1954-1990 (DoT) and in	DoT

TITLE	DATE	SOURCE
	Worley Parsons (2008) Cervantes 1943-1988 Jurien Bay 1942 – 1996 (MRA) book 566 North Head 1960-2006 (MRA)	
Engineered Structures	Groynes: two at Ledge Point, one at Guilderton Boat ramp: one in Seabird Jetties: one in Lancelin; two in Cervantes, one of which acts as a groyne as well; Two jetties, two groynes and the boat harbor breakwaters in Jurien Bay.	DoT and Shires
Hydrology	River discharge available for the Hill River and Moore River. Hydrologic study on flood levels was undertaken for the Moore River in 1991 and 2000. None for the Hill River. Floodplain map: Jurien Bay (JDA 2000)	DoW and Shires
Sediment budgets	Lancelin (Nicholson 2009 and Sanderson and Eliot 1999)	DoT and Shires

APPENDIX C: DATA INVENTORY (PER SEDIMENT CELL)

Table 10: Gap analysis for each sediment cell identified in Eliot et al. 2011.

LOCATION & CELL	DATASET	AVAILABILITY	GAPS
SHIRE OF GINGIN			
Guilderton (5)	Bathymetries	Hydrographic surveys undertaken by DoT in 1975, 1983, 1995, 1996 with the last soundings undertaken in March 2000. Surveys extent and location varies during the period of collection. Resolution: low Nautical chart latest update for Guilderton 2003 (1:25000). Database provided as a separate document.	High-resolution and recent bathymetries.
	Cross-shore beach profiles	Beach levels have been undertaken for various years between 1995-2000. Surveys extent and location varies during the period of collection). Database provided as a separate document.	Beach profiles.
	Shoreline movement plots	DoT analysis of vegetation lines: 1952-1998	Up to date shoreline movement plots using 2013 LiDAR data.
	Wave offshore and nearshore (wave buoy data) Nearshore and currents (AWAC)	Jurien Bay digital wave buoy records (1997 to present day) and Rottnest (2004 to present day) AWAC data - 9 months between 1988-1989 (McCance 1991) Current: from NOAA Wave Watch III	Nearshore data might be required for site-specific hazard assessment.
	Water levels	Available from Jurien Bay tide gauge records (1995 to present day) and Fremantle (1897 to present day)	Historic analysis of water levels associated with extreme weather events.
	Vertical and oblique aerial photographs	Hard copies: 1941, 1952, 1971, 1992 Electronic copies: from 1991 to present day Dongara to Guilderton: scale 1:20000 (1990) Guilderton to Perth (1973, 1976, 1977, 1981, 1985, 1987, 1988, 1991, 1992, 1994) Vertical aerial photographs are collected annually by Landgate (latest taken in 2012)	Good coverage.
	Field photographs	DoT collection available for the period 2008-2011 and from WA Coast Database (Gozzard, J.R 2011)	Field photos – on going collection
	Sediment sampling		Not essential for hazard mapping. Useful for sediment transport modelling. Sediment sampling can be undertaken at the time of new hydrographic surveys

LOCATION & CELL	DATASET	AVAILABILITY	GAPS
	Structure condition assessment	Not available, DoT holds the information at the moment.	LGs should be in charge of undertaking and updating structure condition assessments.
	Geotechnical survey		Rock location
	Sediment budgets (detailed studies or information useful for future assessment)	WA Coast GIS dataset (Gozzard, J.R 2011); Smartline (Sharples et al. 2009); Coastal Vulnerability Report (Eliot et al. 2011) Coastal Compartments of WA (Eliot et al. 2011) Possible from development assessment for south Moore River.	More information on sediment budgets, alongshore and cross-shore transport
	Wind & storm data	Lancelin 1965 to present day and in: Bosserelle et al. 2011 and (Pattiaratchi et al. 1997)	
Seabird (5, 6)	Bathymetries	Hydrographic surveys undertaken by DoT from 2002 to 2008 at different locations Nautical chart last edition January 2004 1:25000 Database provided as a separate document.	High-resolution and recent bathymetries.
	Beach Levels & Cross-shore beach profiles	Analysis of Survey Profiles February and July 2002 and Analysis of Survey Profiles & Rock Revels February 2002 and August 2002. Beach profiles undertaken by Worley Parsons as part of the Seabird Foreshore Investigation (Worley Parsons 2002 and 2004)	Recent beach profiles.
	Shoreline movement plots	DoT analysis of vegetation lines: 1941-2002	Up to date shoreline movement plots using 2013 LiDAR data.
	Wave offshore and nearshore (wave buoy data) Nearshore and currents (AWAC)	Available from Jurien Bay digital wave buoy records (1997 to present day) AWAC short-term investigation 0-15m deep (Damara WA 2005) Current: from NOAA Wave Watch III	Recent nearshore wave data
	Water levels	Available from Jurien Bay tide gauge records (1995 to present day) and Fremantle (1897 to present day)	Historic analysis of water levels associated with extreme weather events
	Vertical and oblique aerial photographs	1941-1943, 1970, 1972, 1975, 1978, 1981, 1998, 2000, 2004, 2007 Vertical aerial photographs are collected every two years by Landgate	
	Field photographs	DoT collection (2007-2012) and from WA Coast Database (Gozzard, J.R 2011)	Regular photo monitoring.
	Sediment sampling	One known sediment sample form beach near town (DoT)	Not essential for hazard mapping. Useful for sediment transport modeling. Sediment sampling can be undertaken at

LOCATION & CELL	DATASET	AVAILABILITY	GAPS
			the time of new hydrographic surveys.
	Structure condition assessment	DoT holds the information at the moment.	Up to date information about existing coastal structures. LGs should be in charge of undertaking and updating structure condition assessments.
	Geotechnical survey	Gordon Geological Consultants (GGC 2002)	
	Sediment budgets (detailed studies or information useful for future assessment)	WA Coast GIS dataset (Gozzard, J.R 2011); Smartline (Sharples et al. 2009); Coastal Vulnerability Report (Eliot et al. 2011); Coastal Compartments of WA (Eliot et al. 2011) Site specific: Seabird Foreshore Investigation Report (Worley Parsons 2002 and 2004)	More information on sediment budgets, alongshore and cross-shore transport is required for site-specific hazard assessment.
	Wind & storm data	Lancelin 1965-2012 and in Bosserelle et. al 2011; (Pattiaratchi et al. 1997)	
Ledge Point (11, 12)	Bathymetries	Hydrographic surveys undertaken by DoT in 1987, 1993, 1994, 1995, 1996, 1997, 1997, 1997, 1999, 1999 2000, 2000, 2001 at various locations and extent. Nautical charts last updated in May 1988. Database provided as a separate document.	Recent bathymetries
	Beach Levels & Cross-shore beach profiles	Beach levels have been undertaken for various years between 1990-2007. Surveys extent and location varies during the period of collection). Beach profiles were undertaken for the construction of the two groynes (1978-1986).	Up to date beach profiles.
	Shoreline movement plots	DoT analysis of vegetation lines: 1952-1993	Up to date shoreline movement plots using 2013 LiDAR data.
	Wave offshore and nearshore (wave buoy data) Nearshore and currents ()	Jurien Bay tide wave buoy records (1997 to present day) Current: from NOAA Wave Watch III AWAC 2003-2004 and Ledge Point Coastal Climate Analysis (Damara WA 2005) and Cyclone *Surges - Western Australian Tide Gauge Observations, Draft Report* (Damara WA 2010)	
	Water levels	Fremantle (1897 to present day) Jurien Bay (1995 to present day) Ledge Point Vehicle Access Management (Damara 2010)	
	Vertical and oblique aerial photographs	Oblique photos (DoT) from 1965 to 2009. Vertical aerial photographs are collected every two years by Landgate	

LOCATION & CELL	DATASET	AVAILABILITY	GAPS
	Field photographs	DoT collection (2007 to present day); From WA Coast Database (Gozzard, J.R 2011)	Ongoing photo monitoring
	Sediment sampling		Not essential for hazard mapping. Useful for sediment transport modeling. Sediment sampling can be undertaken at the time of new hydrographic surveys
	Structure condition assessment	Groynes were constructed in 1978 and 1986. DoT holds the information at the moment.	Up to date information about existing coastal structures. LGs should be in charge of undertaking and updating structure condition assessments.
	Geotechnical survey		Location of rock
	Sediment budgets (detailed studies or information useful for future assessment)	WA Coast GIS dataset (Gozzard, J.R 2011); Smartline (Sharples et al. 2009); Coastal Vulnerability Report (Eliot et al. 2011); Coastal Compartments of WA (Eliot et al. 2011) Two transects were surveyed to gain a profile of the transport pathways of the dune and beach south of the access ramp (Damara WA 2010)	More information on sediment budgets, alongshore and cross-shore transport is required for site-specific hazard assessment
	Wind & storm data	Ledge Point Vehicle Access Management (Damara 2010) Lancelin 1965-2012 and in Bosserelle et al. 2011 and Pattiaratchi et al. 1997	
Lancelin (13, 14, 15)	Bathymetries	Hydrographic surveys available for the periods 1990, 1997-2005, 2007 1998 and 2007 Last edition of nautical chart January 2004 for Lancelin, Wedge Island update in 1996. Database provided as a separate document.	Repeat bathymetry in the next 1 to 5 years
	Beach Levels & Cross-shore beach profiles	Beach levels have been undertaken for various years from 1998-2007. Surveys extent and location varies during on the period of collection).	Recent beach profiles
	Shoreline movement plots	DoT analysis of vegetation lines: 1954-1998	Up to date shoreline movement plots using 2013 LiDAR data
	Wave offshore and nearshore (wave buoy data)	Jurien Bay wave buoy records (1997 to present day) Current: from NOAA Wave Watch III Wave model in the Lancelin Coastal Vulnerability Report (Robinson 2011).	
	Water levels	Available from Jurien Bay tide gauge records (1991 to present	

LOCATION & CELL	DATASET	AVAILABILITY	GAPS
		day) and Fremantle (1897 to present day)	
	Vertical and oblique aerial photographs	Hard copies (DoT records) from 1943-2000; electronic format 2000, 2004 and 2006 Vertical aerial photographs are collected every two years by Landgate	
	Field photographs	From WA Coast Database (Gozzard, J.R 2011)	Regular photo monitoring.
	Sediment sampling	A significant amount of samples (Nicholson 2009)	Not essential for hazard mapping. Useful for sediment transport modeling. Sediment sampling can be undertaken at the time of new hydrographic surveys.
	Structure condition assessment	DoT holds the information at the moment.	Up to date information about existing coastal structures. LGs should be in charge of undertaking and updating structure condition assessments.
	Geotechnical survey		Identify location of rock
	Sediment budgets (detailed studies or information useful for future assessment)	WA Coast GIS dataset (Gozzard, J.R 2011); Smartline (Sharples et al. 2009); Coastal Vulnerability Report (Eliot et al. 2011); Coastal Compartments of WA (Eliot et al. 2011). Sanderson 1992, Sanderson & Eliot 1996, Sanderson & Eliot 1999. Nicholson 2009, Characterisation of Alongshore and Nearshore Sediment Characteristics and Provenance at Lancelin Bay between Lancelin Island and Edwards Island, Western Australia.	More information on sediment budgets, alongshore and cross-shore transport is required for site-specific hazard assessment. Detailed studies of coastal sediment budget in proximity of accretionary landforms such as barriers and cuspate forelands are highly recommended.
	Wind & storm data	Lancelin 1965-2012 and in Bosserelle et al. 2011 and Pattiaratchi et al. 1997	Historic analysis of water levels associated with extreme weather events.
SHIRE OF DANDARAGAN			
Cervantes (25, 26)	Bathymetries	Hydrographic surveys available for the period 1972, 1984, 1986, 1990 – 1993, 1995, 1996, 1998, 200-2002 at various locations and extent Last edition nautical chart December 1989 Database provided as a separate document.	Repeat bathymetry in the next 1 to 5 years
	Beach Levels & Cross-shore beach profiles	Beach levels have been undertaken for various years from 1990-2002. Surveys extent and location varies during the period of collection). For Thirsty Point: Thirsty Point Preliminary Shoreline Movement Investigation (MP Rogers 2009)	Extend beach profile analysis to all town area and south to Thirsty Point

LOCATION & CELL	DATASET	AVAILABILITY	GAPS
	Shoreline movement plots	DoT analysis of vegetation lines: 1943-1988 For Thirsty Point: Thirsty Point Preliminary Shoreline Movement Investigation (MP Rogers 2009)	Up to date shoreline plots utilising MRA (2009) and 2013 LiDAR
	Wave offshore and nearshore (wave buoy data)	Buoy data available from Jurien Bay from 1997 to present day Current: from NOAA Wave Watch III	Collection of nearshore data
	Water levels	Available from Jurien Bay tide gauge records (1995 to present day) and Fremantle (1897 to present day)	
	Vertical and oblique aerial photographs	DoT electronic format (2000, 2006, 2009); DoT Hard Copies: Cervantes (Thirsty Point) 5:000 (1999), 5:000 (1984, 1986, 1994), at various scales (2004) and oblique (1989, 1970) Vertical aerial photographs are collected every two years by Landgate	
	Field photographs	2008-2010 (DoT)	On-going photo monitoring program
	Sediment sampling		Not essential for hazard mapping. Useful for sediment transport modeling. Sediment sampling can be undertaken at the time of new hydrographic surveys
	Structure condition assessment	DoT holds the information at the moment.	Up to date information about existing coastal structures. LGs should be in charge of undertaking and updating structure condition assessments.
	Geotechnical survey		Identify location of rock
	Sediment budgets (detailed studies or information useful for future assessment)	For Thirsty Point: Thirsty Point Preliminary Shoreline Movement Investigation (MP Rogers 2009) Sanderson 1992, Sanderson & Eliot 1996, Sanderson & Eliot 1999; Ward 1983	Detailed understanding of the coastal sediment budget in proximity of accretionary landforms such as barriers and cuspate forelands
	Wind & storm data	Lancelin 1965 to present day; Jurien Bay 1969 to present day and in Bosserelle et al. 2011 and Pattiaratchi et al. 1997	Historic analysis of water levels associated with extreme weather events
Ardross Estate & Jurien Bay (28, 29)	Bathymetries	Undertaken in 1980-1982, 1985, 1988, 1989, 1991, 1992, 1995, 1998, 1999, 2000-2006. More recent surveys for the boat harbor in 2008 and 2011 Last edition nautical chart June 2006 Database provided as a separate document.	Recent high-resolution bathymetry for the whole town area
	Beach Levels & Cross-shore	Beach levels from 1998 to 2002. Setbacks for development,	Beach profiles

LOCATION & CELL	DATASET	AVAILABILITY	GAPS
	beach profiles	extreme storm event, wave climate (MRA 1996)	
	Shoreline movement plots	Plan book 566 has plot for this section of coast. Shoreline movement plots undertaken for Ardross development by MP Rogers & Associates MRA (1996) Shoreline movement plots 1942-1980 (Engineering Division Public Works Department of Western Australia 1984)	Up to date shoreline plots utilising MRA (2009) and 2013 LiDAR
	Wave offshore and nearshore (wave buoy data)	Wave buoy: 1982 analogue, digital from 1997. Setbacks for development, extreme storm event, wave climate (MRA 1996)	Collection of nearshore data
	Water levels	Jurien Bay: 1991- 2012 and in MRA Report (MRA 2006) Deployment of a ADCP in 2002 and 2006 in the Essex Lagoon (sea temperatures, currents, sea levels, wind speed and direction)	
	Vertical and oblique aerial photographs	Jurien Bay to Hill River scale 1: 40000 (1970), 1:4000 (1977), 1:3000 (1981), (1987) at 1:8000, (1988) at 1:4000, (1990) at 1:000 Electronic format: 1998, 2000, 2002, 2004, 2006, 2007, 2009, 2012 Hard copies (DoT): Jurien Bay: 1996, 1980, 1986 scale 15000, 2000; vertical 5000 or 8000 (1998), offshore island 50000 (1982). Jurien boat harbor 5000 (1986), 8000 (1981); Jurien Bay townsite 16000 (1978) Vertical aerial photographs are collected every two years by Landgate	
	Field photographs	DoT collection (2007-2012)	
	Sediment sampling	Information on seasonality of currents, current velocity and direction in Characterizing the Hydrodynamics of Jurien Bay, Western Australia (Halloway 2006)	Not essential for hazard mapping. Useful for sediment transport modeling. Sediment sampling can be undertaken at the time of new hydrographic surveys.
	Structure condition assessment	DoT holds the information at the moment.	Up to date information about existing coastal structures. LGs should be in charge of undertaking and updating structure condition assessments.
	Geotechnical survey		Identify location of rock
	Sediment budgets (detailed studies or information useful for future assessment)	Sanderson 1992, Sanderson & Eliot 1996, Sanderson & Eliot 1999; Ward 1983. Setbacks for development, extreme storm event, wave climate (MRA 1996 and 2006)	Detailed understanding of the coastal sediment budget in proximity of accretionary landforms such as barriers

LOCATION & CELL	DATASET	AVAILABILITY	GAPS
			and cuspate forelands
	Wind & storm data	Jurien Bay 1969 to present day Worth looking at: DoMH (1985, 1990); Ecologica (1997); EPA (1987); DoMH (1989); Chua (2002); Sanderson (1992), Sanderson & Eliot (1996), Sanderson & Eliot (1999) Setbacks for development, extreme storm event, wave climate (MRA 1996 and 2006) Bosserelle et. al 2011; (Pattiaratchi et al. 1997) Historic analysis of water levels associated with extreme weather events (MRA 2006)	Detailed understanding of the coastal sediment budget in proximity of accretionary landforms such as barriers and cuspate forelands.
	Hydrology	Hill River Floodplain Mapping (JDA Consultants 2000)	
North Head (30)	Bathymetries	Nautical chart update in 1992.	Recent bathymetries
	Beach Levels & Cross-shore beach profiles	MRA 2006	
	Shoreline movement plots	1960 – 2006 (MRA 2006)	Up to date shoreline movement plots which include recent LiDAR data
	Wave offshore and nearshore (wave buoy data)	Jurien Bay 1982 analogue, digital from 1997	
	Water levels	Jurien Bay tide gauge 1991- 2012	
	Vertical and oblique aerial photographs	1960-2000 Vertical aerial photographs are collected every two years by Landgate	
	Field photographs	MRA 2006	
	Sediment sampling	MRA 2006	Not essential for hazard mapping. Useful for sediment transport modeling. Sediment sampling can be undertaken at the time of new hydrographic surveys
	Currents	Halloway (2006) for Jurien Bay	
	Structure condition assessment		Up to date information about existing coastal structures. LGs should be in charge of undertaking and updating structure condition assessments.
	Geotechnical survey	Wallis Drilling Pty Ltd (2001)	Information available.
	Sediment budgets (detailed studies or information useful for	Setbacks: MPRA (2006)	If review of setback is required.

LOCATION & CELL	DATASET	AVAILABILITY	GAPS
	future assessment)		
	Wind & storms	Jurien Bay 1969 to present day and in MPRA (2006) and Bosserelle et. al (2011) and Pattiaratchi et al. (1997)	Historic analysis of water levels associated with extreme weather events