Lower Pindimar, Pindimar, Upper Pindimar and Bundabah Foreshore Erosion Study

Final Report

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December 2011
Lower Pindimar, Pindimar, Upper Pindimar and Bundabah Foreshore Erosion Study

Prepared For: Great Lakes Council
Prepared By: BMT WBM Pty Ltd (Member of the BMT group of companies)
**Title:** Lower Pindimar, Pindimar, Upper Pindimar and Bundabah Foreshore Erosion Study

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**Synopsis:** This report presents the findings of the Foreshore Erosion Study for Lower Pindimar, Pindimar, Upper Pindimar and Bundabah foreshores, on the northern shoreline of Port Stephens. Included in this document are the outcomes of the background data review, community consultation activities and outcomes, the methodology and outcomes for assessing foreshore erosion, and recommended actions to manage and treat foreshore erosion in this area.

### REVISION/CHECKING HISTORY

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### DISTRIBUTION

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EXECUTIVE SUMMARY

**Purpose**
Upper Pindimar, Pindimar, Lower Pindimar and Bundabah are located on the northern shoreline of Port Stephens Estuary within the Great Lakes Council Local Government Area.

This study investigated foreshore erosion issues along these shorelines, including:
- The extent of erosion in residential areas, including both private and public lands;
- The potential causes of any observed erosion (e.g. waves, tidal currents, boat wake, stormwater discharges, mangrove dieback); and
- Protection options to manage identified erosion.

The outcomes of the investigations are detailed in this report.

**Context and Background**
Over recent years, concerns have been raised over the occurrence of erosion at some sections of the Pindimar to Bundabah foreshores. Foreshores in these areas comprise both residential and rural landholdings.

One of the “priority actions to improve baseline information” recommended in the Port Stephens / Myall Lakes Estuary Management Plan (Umwelt, 2000) was to “investigate causes of shoreline erosion at Pindimar”. This study fulfils that action.

*Living on the Edge: A Foreshore Management Plan for Port Stephens* (Umwelt, 2009) recommended a suite of community education actions focusing on the value of foreshore vegetation such as mangroves in reducing erosion, soft engineering solutions including foreshore vegetation and, as a last resort, hard engineering and seawalls. The foreshore management plan presents methods to encourage modification of existing ad hoc seawalls and rehabilitation of public reserves and boat ramps in the study area. The present study investigated the causes of foreshore erosion to provide greater detail and guidance on these aspects.

**Study Area**
The study area comprises the areas of residential and rural zoned lands (including some parcels of Council owned or managed public reserves) within the Lower Pindimar, Pindimar, Upper Pindimar and Bundabah foreshores, particularly where there is existing development.

The study area is confined to the foreshore boundary, extending as far seawards and landwards as required to investigate the erosion hazard. The study area did not include undeveloped lands, nor the small area of National Park around Fame Cove. An illustration of the study area and localities is given in Figure 1-1.

**Shoreline Sections**
To investigate shoreline erosion and develop shoreline protection guidelines, the study foreshores were broken into sections or precincts, as shown in Figure 1. The division of the shoreline considered factors such as the presence or otherwise of structures and the orientation relative to processes such as wind, wind waves, ocean swell and tidal currents. The shoreline division was as follows:
- Lower Pindimar comprises shoreline sections 1 to 4, discussed in Chapter 5;
- Pindimar comprises shoreline sections 5 to 9, discussed in Chapter 6;
- Upper Pindimar comprises shoreline sections 10 to 14, discussed in Chapter 7; and
- Bundabah comprises shoreline sections 15 and 16, discussed in Chapter 8.

**Legislative Framework**
There are numerous legislation and policies pertaining to the foreshores in the study area. A summary of the legislation applicable to land holder and Council activities (of the scale expected in the study area at this time) is given in Table 2.1. Comprehensive detail of all potentially applicable legislation is given in Appendix B.
The large scale physical processes operating on the shoreline include tides, ocean waves (swell) and locally generated wind waves (seas). Swell and sea waves were modelled during this study (refer Section 4.10). Tidal currents and hydrodynamics were discussed based on existing data and observations. The geomorphology of the study area and consideration of historical change of the shoreline was investigated and outlined for each shoreline section. Information provided by the community, particularly historical photos and anecdotal accounts were also considered. Combined with wave model results and site observations, conclusions regarding likely causes of foreshore erosion were made.

It was found that historical recession of some shoreline sections had occurred, particularly in relation to removal of mangroves in the early 20th century. Recovery of foreshore mangroves in recent years has progressively slowed or ceased erosion at natural foreshore sections. At other locations, existing protection structures (typically ad hoc, vertical impermeable structures, at varying states of repair and of various materials, most of which would not meet current coastal engineering standards) were suggested to have exacerbated erosion.

Where extensive protection structures exist, broad scale removal would be both unworkable and unacceptable to the local community. Some modifications to existing structures may enhance both the erosion protection offered and environmental performance of the structures. For sections of mostly natural foreshores, preservation of existing mangroves or other vegetation is recommended, as these sections are already providing protection, with only minor “to-ing and fro-ing” of the shoreline, as is typical of natural systems.

A suite of strategies to enhance and improve foreshore protection and habitats in the study area is detailed in Table 1 below. Actions to implement these strategies have been provided, to aid implementation by Council (and others as required).

For each shoreline section, the proposed strategies have been mapped, as given in Figures 2 through 7.

To assist Council in implementing the strategies, various actions, responsibilities and indicative costs have been detailed in the strategy table.

Existing Structures Maintenance Guidelines and Natural Foreshore Protection Guidelines have been prepared for each of the relevant shorelines (Lower Pindimar, Pindimar, Upper Pindimar and Bundabah) to guide residents in the best methods for enhancing foreshore protection at their specific localities. The Natural Foreshore Protection Guideline advocates enhancing natural vegetation on foreshore land, which is already providing significant protection from erosion at existing natural foreshores. The Existing Structures Maintenance Guideline provides a conceptual design for modification of existing vertical structures to improve erosion protection and provide for enhanced foreshore habitat. The foreshore guidelines are provided as Appendix G.

A Community Education Strategy, to assist the local community in implementing the guidelines is presented in Section 9.4. The strategy includes Council “leading by example” by inviting the community to participate in field days involving repair of public reserve foreshores. The strategy aims to engage and involve the local community in best practice foreshore maintenance.

Conceptual designs for rehabilitation of the boat ramp in Lower Pindimar have been provided in Appendix H. The concept aims to halt recession of this shoreline with a mixture of rock protection, wave barrier fencing, mangrove planting, and sand replenishment, to provide for the ongoing use and enjoyment of the boat ramp and sandy beach sections for the local and visiting community.
**Community Consultation**

To engage the community and compile information regarding historical erosion, a variety of approaches were used, including:

- An information newsletter, made available through local shops, newspapers and mailed directly to foreshore residents;
- A questionnaire mailed to residents, requesting information and offering both continued contact and/or individual interviews; and
- Follow up Interviews, where residents had indicated interest on their returned questionnaire.

Information compiled from the community was used extensively through the study (refer Chapters 3, 5 - 8). The information included photographs, anecdotal and historical accounts and site inspection of various properties and issues during interviews. Public Exhibition and an on-site Community Meeting were conducted in January and February 2011. Comments from the meeting and formal submissions have been incorporated into this Final Report as appropriate. Overall, the community endorsed the study and supported the content and initiatives for foreshore restoration detailed in the study.

<table>
<thead>
<tr>
<th>Study Conclusions</th>
</tr>
</thead>
</table>

- The suite of tools provided for foreshore management, included protection strategies (Table 1), guidelines, conceptual designs, community education strategy and recommendations for the Estuary Foreshore DCP. These aim to assist in managing both community expectations regarding foreshore property ownership and the various erosion issues in the study area while preserving the good quality natural foreshores in the study area.

The *Existing Structures Maintenance Guidelines* aim to improve existing structures to be more environmentally friendly and more effective as erosion protection. This approach aims to provide a balance of environmental and foreshore protection that is palatable for the community. Council will need to liaise further with Marine Parks regarding the approach.

The approach encourages that foreshores currently in a natural state be retained and preserved. There are many natural foreshores performing well to both stabilise erosion as well as provide valuable habitat. Improving the perception of natural foreshores amongst the community is hoped to assist in retaining these areas in a natural state, and this is a key component of the Community Education Strategy and *Natural Foreshore Protection Guidelines*.

Work to implement the strategies, monitor their success and continue to educate the community will be required in the long term. It is hoped this will help prepare the community to adapt and cope with increasing impacts from coastal processes, resulting from climate change over the long term.

Due to present uncertainties regarding climate change, we have adopted a 20 year time frame as appropriate for the conceptual designs and guidelines outlined in this document. Wherever possible, the strategies have aimed for flexible approaches that may be modified without impeding the capability of the community to adapt in the future, particularly as scientific understanding improves and climate change predictions change over time.
EXECUTIVE SUMMARY

Figure 1

Title:
Shoreline Sections 1 to 16 in the Study Area

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Figure 1
EXECUTIVE SUMMARY

Map of Foreshore Protection Strategies
Lower Pindimar: Shoreline Sections 1 to 4

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Figure 2
Figure 3
Map of Foreshore Protection Strategies
Pindimar: Shoreline Sections 7 to 9

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Promote removal or remodelling of foreshore structures to more effective and environmental form and encourage enhancement of foreshore vegetation (e.g. mangroves)

11: Existing Modified

Use Council Reserve as example of rehabilitation with 'existing structure maintenance guideline'

Remediate erosion from pipe outlet off Warri St

Wooden 'seawall' structure to be removed

Encourage enhancement of foreshore vegetation (e.g. mangroves)

10: Natural Foreshore

Map of Foreshore Protection Strategies
Upper Pindimar Shoreline Sections 10 to 11

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EXECUTIVE SUMMARY

14: Existing Modified

Promote removal or remodelling of foreshore structures to more effective and environmental form and encourage enhancement of foreshore vegetation (e.g. mangroves).

13: Existing Modified

Encourage enhancement of foreshore vegetation (e.g. mangroves).

12: Natural Foreshore

Declare Council owned land as Public Reserve

Remediate erosion from Kiora Street Drain

Remediate erosion at Peel St Creek

Map of Foreshore Protection Strategies
Upper Pindimar: Shoreline Sections 12 to 14

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Figure: A

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Use Council Reserve as example of rehabilitation using 'Natural Foreshore Protection Guideline'

Repair sandstone wall to insert geotextile fabric and replace backfill as part of field day activities at Council’s Reserve

BUNDABAH

Promote removal of inappropriate materials (bricks, concrete) and replanting of vegetation on the foreshore

Figure 7

Title: Map of Foreshore Protection Strategies
Bundabah: Shoreline Sections 15 & 16

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<tr>
<th>Strategy</th>
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<th>Priority</th>
<th>Timeframe</th>
<th>Indicative Cost</th>
<th>Actions and Responsibilities</th>
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<tr>
<td>Provide a ‘Natural Foreshore Protection Guideline’ (Appendix G) to</td>
<td>SS1, SS2, SS3, SS7, SS8,</td>
<td>High</td>
<td>Immediate (1 - 2 yrs)</td>
<td>Council = staff time. Private owner = costs of maintenance works and revegetation (according to</td>
<td>• Council to mail out guidelines to all foreshore landholders and residents&lt;br&gt;• Private landholders and residents to undertake the activities specified by the guidelines (on as needs basis)</td>
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<td>landholders and residents along the foreshore.</td>
<td>SS9, SS10, SS12 and SS15 &amp;</td>
<td></td>
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<td>guidelines) as required&lt;br&gt;</td>
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<td>SS16 (Bundabah specific)</td>
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<td>Provide an ‘Existing Structures Maintenance Guideline’ (Appendix G) to</td>
<td>SS4, SS11, SS13, SS14</td>
<td>High</td>
<td>Immediate (1 - 2 yrs)</td>
<td>Council = staff time. Private owner = costs of maintenance works and revegetation (according to</td>
<td>• Council to mail out guidelines to all foreshore landholders and residents&lt;br&gt;• Private landholders and residents to undertake the works specified by the guidelines (on as needs basis), including development applications as required</td>
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<tr>
<td>landholders and residents along the foreshore.</td>
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<td></td>
<td></td>
<td>guidelines) as required&lt;br&gt;</td>
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<td>Strategy</td>
<td>Location (SS = shoreline section)</td>
<td>Priority</td>
<td>Timeframe</td>
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| Undertake community education for local landholders and residents to promote the ‘Natural Foreshore Protection Guideline’ and to demonstrate the ‘Existing Structures Maintenance Guideline’. | All sections, but especially SS4, S11, SS13, SS14, and Bundabah Specific for SS15 & SS16 | High      | Immediate (1 - 2 yrs) | Council = staff time, materials for rehabilitation works | • Council to liaise with PS-GLMPA, CLD, OEH & DPI Fisheries to ensure performing the activity is consistent with existing legislation and obtain any approvals required.  
• Council shall encourage the agencies, particularly PS-GLMPA to be involved in the activity, such as to promote the values of the marine park.  
• The Council Public Reserve at Lot 30 Section B DP 255453 shall be used as the example rehabilitation site in the Pindimar Region (the end of Wombo Street may also provide a suitable location, if required).  
• The field day should demonstrate ‘Natural Foreshores’ to local residents, for example at Orungall Point or Pindimar  
• The Council Public Reserve at Lot 10 Section 1 DP 10915 shall be used as the example rehabilitation site in Bundabah Region.  
• Rehabilitation at the Bundabah Public Reserve shall additionally include insertion of geotextile fabric and replacement of backfill at the boat ramp sandstone seawall, as well as guideline recommendations such as removal of bricks and concrete and replanting of foreshore vegetation.  
• Council to mail out invites for the field day to all foreshore residents  
• Council to run and manage field day, including making staff available, supplying materials to complete the works  
• Council to retain contact and follow up with local champions in each foreshore section  
• Local champions responsible for undertaking works on their property (including obtaining relevant approvals) and encouragement of other residents, on a volunteer basis |
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<th>Strategy</th>
<th>Location (SS = shoreline section)</th>
<th>Priority</th>
<th>Timeframe</th>
<th>Indicative Cost</th>
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<tr>
<td>Ensure Council officers who assess development applications are aware of the requirements in the ‘Natural Foreshore Protection Guideline’ and ‘Existing Structures Maintenance Guideline’ at the respective shoreline sections, and legislation applicable to activities on foreshore land.</td>
<td>Natural: SS1, SS2, SS3, SS7, SS8, SS9, SS10, SS12 Modified: SS4, SS11, SS13, SS14, SS15, SS16</td>
<td>High</td>
<td>Immediate (1 - 2 yrs)</td>
<td>Council = staff time.</td>
<td>• Council environmental officers to advise planning officers of guideline and legislation requirements, as relates to the different shoreline sections (i.e. ‘natural foreshore’ and ‘existing modified’).</td>
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<td>Include in the Estuary Foreshore Development Control Plan (DCP) the recommendations given in this study (Section 9.5) for foreshore management.</td>
<td>SS1, SS2, SS3, SS7, SS8, SS9, SS10, SS12</td>
<td>Medium</td>
<td>Short term (2 - 5 yrs)</td>
<td>Council = staff time.</td>
<td>• Council environmental officers and planning officers to work together to develop the DCP, ensuring recommendations from this study are included.</td>
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<td>Rezone SEPP 14 Wetlands 756, 757, 757a and 757b as Environmental Conservation (E2) lands.</td>
<td>SS1, SS7, SS9, SS10</td>
<td>High</td>
<td>Immediate (1 - 2 yrs)</td>
<td>Council = staff time</td>
<td>• Council to undertake changes to draft LEP to rezone the lands.</td>
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<td>The following council owned lots should be converted into public reserves and rezoned for environment protection (e.g. Environmental Conservation (E2)):</td>
<td>SS7, SS12, SS14</td>
<td>Medium</td>
<td>Short term (2 - 5 yrs)</td>
<td>Council = staff time</td>
<td>• Council to make changes to draft LEP to ensure land is zoned to an appropriate level of environmental protection (e.g. Environmental Conservation (E2)).</td>
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<td>• Lots 2 to 7 and 14 to 17 of Section 44 DP 10869 (shoreline 7)</td>
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<td>• Lots 12, 13, 48 and 49 Section C DP 13095 (shoreline 12)</td>
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<td>• Lots 28 to 29 Section D DP 8287, Lots 15 to 21 Section Y DP 8287 and Lots 1 to 10 Section Z DP 8287 (shoreline 14)</td>
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| Illegal rock ‘revetment’ type protection works within Pig Hill Station Creek channel and outlet (Lot 10 Section 85 DP 10869) should be removed, by order to the property owner. | SS1                               | High     | Immediate (1 - 2 yrs) | Council = staff time, Private owner = removal costs, replanting costs (low) | • Council to consult with CLD and the GL-PSMPA on correct approach to the order and required rehabilitation  
• Council / CLD to issue order to private property owner(s)  
• Private property owner(s) to remove structures and rehabilitate as required |
| Illegal vertical wooden seawalls on the foreshores of Lots 1 – 10 Section 85 DP 10869 should be removed, by order to the property owner(s). | SS2                               | High     | Immediate (1 - 2 yrs) | Council = staff time, Private owner = removal costs, replanting costs (low) | • Council to consult with CLD and the GL-PSMPA on correct approach to the order and required rehabilitation  
• Council / CLD to issue order to private property owner(s)  
• Private property owner(s) to remove structures and rehabilitate as required |
| Implement protection works to remediate erosion at the Norfolk Island Pine, boat ramp and adjacent foreshores, as per the conceptual diagram provided in Appendix H. | SS5, SS6                          | High     | Short term (2 - 5 yrs) | Council = staff time, materials for rehabilitation works | • Council to undertake detailed design of conceptual works  
• Council to consult with CLD and the GL-PSMPA on correct approach to the order and required rehabilitation  
• Council / CLD to issue order to private property owner(s)  
• Private property owner(s) to remove structures and rehabilitate as required |
| Promote growth and enhancement of native foreshore vegetation such as mangroves along shoreline section 5. | SS5                               | Medium   | Short term (2 - 5 yrs) | Council = staff time, materials for rehabilitation works | • Council to undertake detailed design of conceptual works  
• Council to consult with CLD and the GL-PSMPA on correct approach to the order and required rehabilitation  
• Council / CLD to issue order to private property owner(s)  
• Private property owner(s) to remove structures and rehabilitate as required |
| Reduce scour impacts on the shoreline at corner of Curlew and Cunningham Street. | SS5                               | Medium   | Short term (2 - 5 yrs) | Council = staff time, materials for rehabilitation works | • Council to investigate appropriate treatment of scour from discharge, ensuring environmental impacts such as to foreshore vegetation are minimised.  
• Council to undertake and maintain the revegetation, as part of works at SS6 |
| The dumped building wastes and ad hoc ‘structures’ on Lot 2, 4 and 5 of Section N DP 8287 (shoreline section 8) should be removed by order to the landholder(s). | SS8                               | High     | Immediate (1 - 2 yrs) | Council = staff time, Private owner = removal costs, replanting costs (low) | • Council to consult with CLD and the GL-PSMPA on correct approach to the order and required rehabilitation  
• Council / CLD to issue order to private property owner(s)  
• Private property owner(s) to remove structures and rehabilitate as required |
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| **The wooden vertical seawall-type structure on Lot 1 DP 177889 (Fish Depot) should be removed, by request / order to the landholder.** | SS10 | Medium | Immediate (1 - 2 yrs) | Council = staff time. Private owner = removal costs, replanting costs (low) | • Council to consult with CLD and the GL-PSMPA on correct approach to the request and required rehabilitation  
• Council / CLD to issue order / request to private property owner(s)  
• Private property owner(s) to remove structures and rehabilitate as required |
| **Remediate the erosion caused by the pipe outlets at the end of Warri Street and bordering property Lot 67 Section B DP 1084957, based on recommendations in Appendix I (from WBM, 2002).** | SS11 | Medium | Medium term (> 5yrs) | Council = staff time, materials for rehabilitation works | • Council to review the design recommendation from WBM (2002) study, and update as relevant to site.  
• Council to compile REF (or update original WBM (2002) REF), licence from CLD, notification to DPI Fisheries and consultation with PS-GL MPA and other agencies as required  
• Council to implement (build) the works  
• Council to maintain works over time |
| **Undertake remediation of erosion from creek outlet along the border between Lot 3 Section C DP 8287 and Council owned Lot 12 Section C DP 13095, based on recommendations in Appendix I (from WBM, 2002).** | SS12 | Medium | Medium term (> 5yrs) | Council = staff time, materials for rehabilitation works | • Council to compile REF (or update original WBM (2002) REF), licence from CLD, notification to DPI Fisheries and consultation with PS-GL MPA and other agencies as required  
• Council to implement (build) the works  
• Council to maintain works over time |
| **Implement protection works to stabilise the drain outlet at the end of Kiora Street and mitigate erosion at adjacent properties (Lot 35 Section C DP 8287 and Lot 1 Section D DP 8287), as per recommendations in Appendix I (from WBM, 2002).** | SS13 | High | Immediate (1 - 2 yrs) | Council = staff time, materials for rehabilitation works | • Council to compile REF (or update original WBM (2002) REF), licence from CLD, notification to DPI Fisheries and consultation with PS-GL MPA and other agencies as required  
• Council to implement (build) the works  
• Council to maintain works over time |
CONTENTS

Executive Summary i
Contents xvi
List of Figures xx
List of Tables xxii

1 INTRODUCTION 1
1.1 Study Area 1
1.2 Shoreline Sections 5
1.3 Structure of this Report 5

2 LEGISLATIVE FRAMEWORK FOR FORESHORE MANAGEMENT 8

3 COMMUNITY CONSULTATION 12
3.1 Strategy for Community Engagement 12
3.2 Information Newsletter 12
3.3 Questionnaire 12
  3.3.1 Questionnaire Results 12
  3.3.2 Site Interviews 16
3.4 Stakeholder Interviews 20
3.5 Public Exhibition 22
3.6 Conclusions 23

4 BACKGROUND TO PHYSICAL PROCESSES 24
4.1 Introduction 24
4.2 Summary of Background Data Review 24
  4.2.1 Aboriginal Heritage 24
4.3 Tides 25
  4.3.1 Elevated Water Level Anomalies 26
4.4 Offshore Wave Climate 26
  4.4.1 Significant Wave Height 26
  4.4.2 Wave Direction 27
  4.4.3 Wave Period 28
  4.4.4 Applicability to SWAN modelling 28
4.5 Wind Climate 28
CONTENTS

4.6 Hydrodynamics 29
4.7 Geomorphology 30
4.8 Photogrammetry Analysis 31
4.9 Site Inspection 31
4.10 Wave Modelling in SWAN 31
  4.10.1 The SWAN Model 32
  4.10.2 Bathymetric Grid 32
  4.10.3 Selection of Model Input Parameters 33
  4.10.4 Model Simulations 34
  4.10.5 Model Outputs and Discussion 34
    4.10.5.1 Swell Waves 34
    4.10.5.2 Wind Waves 34

5 LOWER PINDIMAR 39
  5.1 Area Description 39
    5.1.1 Geomorphology 39
  5.2 Photogrammetry 41
  5.3 Site Inspection 42
  5.4 Community Consultation 43
  5.5 Wave Modelling Results 44
    5.5.1 Swell Waves 44
    5.5.2 Wind Waves 45
  5.6 Tidal Hydrodynamics 46
  5.7 Conclusions 46
    5.7.1 Sea Level Rise 47
  5.8 Recommended Strategies for Foreshore Protection 47
    5.8.1 Decision Matrix 47
    5.8.2 Strategies for Foreshore Protection 47
      5.8.2.1 Shoreline Sections 1, 2 and 3 47
      5.8.2.2 Shoreline Section 4 49

6 PINDIMAR 53
  6.1 Area Description 53
    6.1.1 Geomorphology 53
  6.2 Photogrammetry 55
  6.3 Site Inspection 57
  6.4 Community Consultation 58
  6.5 Wave Modelling Results 58
## APPENDIX I: RECOMMENDED EROSION MANAGEMENT AT KIORA ST., WARRI ST., AND PEEL ST. OUTLETS

### APPENDIX J: SUMMARY OF SUBMISSIONS DURING PUBLIC EXHIBITION

### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>Study Area Locality Figure</td>
<td>2</td>
</tr>
<tr>
<td>1-2</td>
<td>Local Environment Plan Zoning of the Study Area</td>
<td>3</td>
</tr>
<tr>
<td>1-3</td>
<td>SEPP14 Wetlands and Estuarine Habitats in the Study Area</td>
<td>4</td>
</tr>
<tr>
<td>1-4</td>
<td>Shoreline Sections 1 to 16 in the Study Area</td>
<td>7</td>
</tr>
<tr>
<td>3-1</td>
<td>Shoreline at 28 Cambage St., Pindimar approx. 30 years ago (Photo: M. Dougett)</td>
<td>15</td>
</tr>
<tr>
<td>3-2</td>
<td>Shoreline at 28 Cambage St., Pindimar at present, with ‘X’ in foreground showing location of former swing (Photo: M. Dougett)</td>
<td>15</td>
</tr>
<tr>
<td>3-3</td>
<td>Pindimar shoreline (Morante St.) in 1950s (Photo: G. Fidden), showing jetty structures in the background that are still evident today, seaweed wrack and gentle slopes</td>
<td>17</td>
</tr>
<tr>
<td>3-4</td>
<td>Pindimar shoreline (Morante St.) in 1950s (Photo: G. Fidden), showing rail sleepers in the background that are still evident today, seaweed wrack and gentle slopes</td>
<td>17</td>
</tr>
<tr>
<td>3-5</td>
<td>Pindimar Shoreline at August 2009, showing sleepers emplaced ~ 1948 and remnant jetty structures in background</td>
<td>18</td>
</tr>
<tr>
<td>4-1</td>
<td>SWAN Model Grid Extents</td>
<td>35</td>
</tr>
<tr>
<td>5-1</td>
<td>Lower Pindimar Shoreline Sections 1 to 4</td>
<td>40</td>
</tr>
<tr>
<td>5-2</td>
<td>Recommended Foreshore Protection Strategies for Shoreline Sections 1 to 4</td>
<td>50</td>
</tr>
<tr>
<td>5-3</td>
<td>Shoreline Section 1 – Evident Erosion of Foreshore</td>
<td>51</td>
</tr>
<tr>
<td>5-4</td>
<td>Shoreline Section 2 – Illegal Seawalls on Piggies Beach</td>
<td>51</td>
</tr>
<tr>
<td>5-5</td>
<td>Shoreline Section 3 – Natural Shoreline without Erosion</td>
<td>52</td>
</tr>
<tr>
<td>5-6</td>
<td>Shoreline Section 4 – Illegal seawalls and groyne structures in background</td>
<td>52</td>
</tr>
<tr>
<td>6-1</td>
<td>Pindimar Shoreline Sections 5 to 9</td>
<td>54</td>
</tr>
<tr>
<td>6-2</td>
<td>Recommended Foreshore Protection Strategies on Shoreline Sections 5 and 6</td>
<td>65</td>
</tr>
<tr>
<td>6-3</td>
<td>Recommended Foreshore Protection Strategies on Shoreline Sections 7, 8 and 9</td>
<td>66</td>
</tr>
<tr>
<td>6-4</td>
<td>Shoreline Section 5 – Natural shoreline showing good condition</td>
<td>67</td>
</tr>
<tr>
<td>6-5</td>
<td>Shoreline Section 6 – Erosion at Base of Norfolk Is. Pine and Boat Ramp</td>
<td>67</td>
</tr>
<tr>
<td>6-6</td>
<td>Shoreline Section 7 – Natural Shoreline Section Showing Accretion</td>
<td>68</td>
</tr>
<tr>
<td>6-7</td>
<td>Shoreline Section 8 – Illegal foreshore works with dumping of building waste</td>
<td>68</td>
</tr>
<tr>
<td>7-1</td>
<td>Upper Pindimar Shoreline Sections 10 to 14</td>
<td>70</td>
</tr>
</tbody>
</table>
Figure 7-2  Recommended Foreshore Protection Strategies Shoreline Sections 10 and 11
Figure 7-3  Recommended Foreshore Protection Strategies for Shoreline Sections 12 to 14
Figure 7-4  Shoreline Section 10 – Ineffective Seawall with Erosion of Backfill and Edge
Figure 7-5  Shoreline Section 11 – Pipe Outlets Causing Erosion and Ad hoc Protection on Adjacent Private Property
Figure 7-6  Shoreline Section 11 – Adjacent Council Reserve (far left) with Inappropriate Vertical Wall Structure Requiring Rehabilitation
Figure 7-7  Shoreline Section 11 – Illustrating Ad hoc, Uncoordinated Structures
Figure 7-8  Shoreline Section 11 – Illegal Reclamation of Estuary (Crown) Land
Figure 7-9  Shoreline Section 12 – Natural shoreline with Exposure of Roots due to Erosion
Figure 7-10 Shoreline Section 13 – Stormwater Channel Causing Erosion of Adjacent Shores
Figure 7-11 Shoreline Section 14 – Sections With and without structures, Lack of Mangroves
Figure 8-1  Bundabah shoreline sections 15 and 16
Figure 8-2  Recommended Foreshore Protection Strategies for Shoreline Sections 15 & 16
Figure 8-3  Shoreline Section 15 – Minor “fretting” of shoreline
Figure 8-4  Shoreline Section 15 – Sandstone Wall with Erosion of Gravel Backfill Due to Lack of Geotextile Fabric Lining
Figure 8-5  Shoreline Section 15 – Inappropriate Use of Bricks and Other Materials for Protection
Figure 8-6  Shoreline Section 16 – Erosion of Casuarinas at Shoreline Edge
Figure 10-1  Photograph 5 by NSW Fisheries (2003), illustrating illegal cutting of mangrove trees at Pindimar
Figure 10-2  Photograph 4 by NSW Fisheries (2003), illustrating illegal poisoning of large mangrove trees at Pindimar
Figure 10-3  Piggy’s Beach and Fame Cove Marine Park Zoning
Figure 10-4  Permissible Uses in Marine Park Zones
Figure 10-5  Wave Height / Duration Curves for Sydney (MHL, 2009)
Figure 10-6  Modelled waves at Shoreline for input parameters: Hs 3.5 m ESE 0.98 m WL
Figure 10-7  Modelled waves at Shoreline for input parameters: Hs 6.5 m ESE 0.98 m WL
Figure 10-8  Modelled waves at Shoreline for input parameters: Hs 6.5 m ESE 1.38 m WL
Figure 10-9  Modelled waves at Shoreline for input parameters: Hs 3.5 m SE 0.98 m WL
Figure 10-10 Modelled waves at Shoreline for input parameters: Hs 6.5 m SE 0.98 m WL
Figure 10-11 Modelled waves at Shoreline for input parameters: Hs 6.5 m SE 1.38 m WL
Figure 10-12  Modelled waves at Shoreline for input parameters: Hs 8.9 m E 2.32 m WLE-17
Figure 10-13  Modelled waves at Shoreline for input parameters: Hs 8.9 m SSE 2.32 m WL E-17
Figure 10-14  Modelled waves at Shoreline for input parameters: Wind 1 yr ARI SE 0.98 m WL E-18
Figure 10-15  Modelled waves at Shoreline for input parameters: Wind 1 yr ARI SE 1.38 m WL E-18
Figure 10-16  Modelled waves at Shoreline for input parameters: Wind 25 yr ARI SE 1.38 m WL E-19
Figure 10-17  Modelled waves at Shoreline for input parameters: Wind 25 yr ARI SE 2.32 m WL E-19
Figure 10-18  Modelled waves at Shoreline for input parameters: Wind 1 yr ARI S 0.98 m WL E-20
Figure 10-19  Modelled waves at Shoreline for input parameters: Wind 1 yr ARI S 1.38 m WL E-20
Figure 10-20  Modelled waves at Shoreline for input parameters: Wind 20 yr ARI S 1.38 m WL E-21
Figure 10-21  Modelled waves at Shoreline for input parameters: Wind 20 yr ARI S 2.32 m WL E-21
Figure 10-22  Modelled waves at Shoreline for input parameters: Wind 1 yr ARI W 0.98 m WL E-22
Figure 10-23  Modelled waves at Shoreline for input parameters: Wind 1 yr ARI W 1.38 m WL E-22
Figure 10-24  Modelled waves at Shoreline for input parameters: Wind 25 yr ARI W 1.38 m WL E-23
Figure 10-25  Modelled waves at Shoreline for input parameters: Wind 25 yr ARI W 2.32 m WL E-23
Figure 10-26  Modelled waves at Shoreline for input parameters: Wind 1 yr ARI NW 0.98 m WL E-24
Figure 10-27  Modelled waves at Shoreline for input parameters: Wind 1 yr ARI NW 1.38 m WL E-24
Figure 10-28  Modelled waves at Shoreline for input parameters: Wind 25 yr ARI NW 1.38 m WL E-25
Figure 10-29  Modelled waves at Shoreline for input parameters: Wind 25 yr ARI W 2.32 m WL E-25

LIST OF TABLES

Table 2.1  Legislative Framework Checklist for the Pindimar and Bundabah Areas 9
Table 4.1  Tidal Planes and Tidal Ranges for Port Stephens (source: MHL, 2009) 25
Table 4.2  Elevated Water Levels, Fort Denison, Sydney 26
Table 4.3  Average Recurrence Interval Storm Wave Heights (derived from MHL, 2009) 27
Table 4.4  Percentage Joint Occurrence of Wave Height and Direction, Sydney (March 1992 to December 2008, 16.84 years) 28
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5</td>
<td>ARI Wind Speeds at Each Wind Octant</td>
<td>29</td>
</tr>
<tr>
<td>4.6</td>
<td>Wave, Wind and Water Level Inputs for SWAN Model</td>
<td>36</td>
</tr>
<tr>
<td>4.7</td>
<td>Summary of SWAN Simulations</td>
<td>38</td>
</tr>
<tr>
<td>8.1</td>
<td>Tidal velocities on 29 Sept. 1993, North Arm Cove (Source: MHL, 1998)</td>
<td>93</td>
</tr>
<tr>
<td>9.1</td>
<td>Recommended Strategies for Foreshore Protection</td>
<td>102</td>
</tr>
<tr>
<td>10.1</td>
<td>Design Inundation Levels for Pindimar Study Area, from MHL (1996) A-10</td>
<td></td>
</tr>
<tr>
<td>10.2</td>
<td>Maximum Wind Setup Increments (m) for the 100 year ARI – 1 hour duration,</td>
<td>A-12</td>
</tr>
<tr>
<td></td>
<td>with an initial water level of 0 m AHD, from MHL (1996)</td>
<td></td>
</tr>
<tr>
<td>10.3</td>
<td>Maximum Wind Setup Increments (m) for the 100 year ARI – 1 hour duration,</td>
<td>A-12</td>
</tr>
<tr>
<td></td>
<td>with an initial water level of 1.5 m AHD, from MHL (1996)</td>
<td></td>
</tr>
<tr>
<td>10.4</td>
<td>Maximum Wind Setup Increments (m) for the 100 year ARI – 2.5 hour duration,</td>
<td>A-12</td>
</tr>
<tr>
<td></td>
<td>with an initial water level of 1.5 m AHD, from MHL (1996)</td>
<td></td>
</tr>
<tr>
<td>10.5</td>
<td>Percentage Occurrence Wave Height, Sydney March 1992 to June 2009D-1</td>
<td></td>
</tr>
<tr>
<td>10.7</td>
<td>Percentage Occurrence Wave Period, Sydney March 1992 to June 2009D-3</td>
<td></td>
</tr>
<tr>
<td>10.8</td>
<td>Maximum Yearly Wind Speeds for Wind Direction Octants (Williamstown)D-3</td>
<td></td>
</tr>
<tr>
<td>10.9</td>
<td>Modelled Swell Wave Heights at Shoreline Sections in the Study Area, 0.98 m</td>
<td>E-2</td>
</tr>
<tr>
<td></td>
<td>WL</td>
<td></td>
</tr>
<tr>
<td>10.10</td>
<td>Modelled Swell Wave Heights at Shoreline Sections in the Study Area, 1.38 m</td>
<td>E-3</td>
</tr>
<tr>
<td></td>
<td>WL</td>
<td></td>
</tr>
<tr>
<td>10.11</td>
<td>Modelled Swell Wave Heights at Shoreline Sections in the Study Area, 1.42 m</td>
<td>E-5</td>
</tr>
<tr>
<td></td>
<td>WL</td>
<td></td>
</tr>
<tr>
<td>10.12</td>
<td>Modelled Swell Wave Heights at Shoreline Sections in the Study Area, 1.78 m</td>
<td>E-5</td>
</tr>
<tr>
<td></td>
<td>WL</td>
<td></td>
</tr>
<tr>
<td>10.13</td>
<td>Modelled Swell Wave Heights at Shoreline Sections in the Study Area, 2.32 m</td>
<td>E-7</td>
</tr>
<tr>
<td></td>
<td>WL</td>
<td></td>
</tr>
<tr>
<td>10.14</td>
<td>Modelled Wind Wave Heights at Shoreline Sections in the Study Area, 0.98 m</td>
<td>E-7</td>
</tr>
<tr>
<td></td>
<td>WL</td>
<td></td>
</tr>
<tr>
<td>10.15</td>
<td>Modelled Wind Wave Heights at Shoreline Sections in the Study Area, 1.38 m</td>
<td>E-8</td>
</tr>
<tr>
<td></td>
<td>WL</td>
<td></td>
</tr>
<tr>
<td>10.16</td>
<td>Modelled Wind Wave Heights at Shoreline Sections in the Study Area, 1.42 m</td>
<td>E-9</td>
</tr>
<tr>
<td></td>
<td>WL</td>
<td></td>
</tr>
<tr>
<td>10.17</td>
<td>Modelled Wind Wave Heights at Shoreline Sections in the Study Area, 1.78 m</td>
<td>E-11</td>
</tr>
<tr>
<td></td>
<td>WL</td>
<td></td>
</tr>
<tr>
<td>10.18</td>
<td>Modelled Wind Wave Heights at Shoreline Sections in the Study Area, 2.32 m</td>
<td>E-12</td>
</tr>
<tr>
<td></td>
<td>WL</td>
<td></td>
</tr>
<tr>
<td>10.19</td>
<td>Decision Matrix for Recommended Strategies</td>
<td>F-2</td>
</tr>
</tbody>
</table>
1 INTRODUCTION

Upper Pindimar, Pindimar, Lower Pindimar and Bundabah are located on the northern shoreline of Port Stephens Estuary within the Great Lakes Council Local Government Area. Over recent years, concerns have been raised over the occurrence of erosion at some sections of foreshore, on both public and private property. The shoreline in these areas comprises a small area of residential development and rural landholdings. Erosion along residential shorelines and public reserves is the focus of this study.

This study aims to investigate the foreshore erosion issue, including:

- The extent of erosion on the study area shorelines, that is, in residential areas and including both private land and public reserves;
- The potential causes of any observed erosion (e.g. waves, tidal currents, boat wake, stormwater discharges, mangrove dieback); and
- Recommended protection options to manage identified erosion, as suitable to the causes of the erosion which may vary throughout the study area.

The outcomes of the investigations are detailed in this report.

1.1 Study Area

The study area is confined to the foreshore boundary, extending as far seawards and landwards as required to define and address the erosion hazard. An illustration of the study area and localities is given in Figure 1-1.

The majority of the land area within and behind Pindimar and Bundabah is zoned as rural land (1a), with the villages zoned as residential (2a) land. Land zoning is illustrated in Figure 1-2. There is a small area of National Park around Fame Cove, which is not part of this study. The cadastral survey indicates that the residential and rural landholdings typically extend to mean high water mark. That is, the property boundaries extend to the mean high water mark along the foreshores, which may exclude public foreshore access. However, as discussed in Section 2, there is an array of legislation which precludes the types of activity permitted upon foreshore lands, irrespective of this land being in private or public ownership. A key component of this study will be to ensure that private landholders are aware of the restrictions imposed by such legislation, and that foreshore protection methods are in keeping with such legislation.

The Port Stephens estuary is a state significant waterway (MHL, 1999). It is said to contain the largest area of mangroves in NSW and approximately 18% of NSW’s saltmarsh, as well as extensive seagrass beds. Areas of environmental significance in and around the study area, including wetlands, mangroves, seagrass and saltmarsh, are illustrated in Figure 1-3.
Figure 1-1  Study Area Locality Figure

Title:
Study Area: Upper Pindimar, Pindimar, Lower Pindimar and Bundabah Foreshores

BMT WBM endeavours to ensure that the information produced on this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

Filopath:
Figure 1-2  Local Environment Plan Zoning of the Study Area
INTRODUCTION

Figure 1-3  SEPP14 Wetlands and Estuarine Habitats in the Study Area
Within the study area there are four designated State Environment Planning Policy No. 14 (SEPP14) Coastal Wetlands, some of which are located within private landholdings. Tracts of coastal saltmarsh are also located within the study area. These are Endangered Ecological Communities under the Threatened Species Conservation Act 1995 (TSC Act). Immediately offshore of the study area are large tracts of seagrasses, while along the shorelines there are varying extents of mangroves. Both are protected under the Fisheries Management Act 1994 (the FM Act). SEPP14, the TSC Act and the FM Act and their application within the study area is discussed further in Chapter 2. The legislation governing these areas of environmental significance applies to all foreshore activities on both private and public lands. Prescribed foreshore protection methods given within this study will show consideration for the requirements to protect such areas of environmental significance.

1.2 Shoreline Sections

For the purpose of investigating shoreline erosion, its causes, and developing shoreline protection guidelines, the study area shoreline was broken into different sections or precincts, as shown in Figure 1-4. The division of the shoreline considered factors such as if the shoreline was natural or contained structures, and its orientation relative to wind, wind waves, ocean swell and tidal currents.

The outcomes of investigations have been discussed for each shoreline section. The site inspection for each section is discussed and representative points from the sections have been used in the analysis of physical processes, such as wave modelling results.

The shoreline sections are as follows.

- Lower Pindimar is separated into shoreline sections 1 to 4, discussed in Chapter 5;
- Pindimar is separated into shoreline sections 5 to 9, discussed in Chapter 6;
- Upper Pindimar is separated into shoreline sections 10 to 14, discussed in Chapter 7; and
- Bundabah is separated into shoreline sections 15 and 16, discussed in Chapter 8.

1.3 Structure of this Report

It is intended that this document provide a detailed review of physical processes and determine the nature and extent of foreshore erosion in the study area. Detailed investigations were undertaken and have been presented for each of the shoreline sections. Management strategies applicable to the issues at each shoreline section were also developed. To assist Council with the implementation of the strategies, the final chapter of this report provides a summary of all strategies in all locations in the form of an implementation table. This report is set out as follows.

- Chapter 2 provides a summary of relevant legislation and how this applies to foreshore protection in the study area.
- Chapter 3 details the approaches used and outcomes from the community and stakeholder consultation.
- Chapter 4 outlines the broadscale physical processes occurring in the study area and details the parameters used in the wave modelling.
- Chapters 5 to 8 outlines on a location basis the physical processes, consultation findings, wave modelling outputs and findings from site inspection and other data sources, for Lower Pindimar,
Pindimar, Upper Pindimar and Bundabah respectively. These chapters also outline strategies for foreshore management at each shoreline section in the study area.

- Chapter 9 provides a synthesis of all recommended strategies within a single implementation table. The chapter also provides details for a community education strategy, recommendations for an Estuary Foreshore DCP, community Foreshore Protection Guidelines, and conceptual design for large scale erosion management works. It is intended that this chapter be a quick reference for Council when implementing the strategies, with the prior chapters providing the detail and basis for the strategies as required.
Figure 1-4  Shoreline Sections 1 to 16 in the Study Area
2 LEGISLATIVE FRAMEWORK FOR FORESHORE MANAGEMENT

There is an array of legislation, environmental planning instruments and policies which apply to foreshore land. Some of these apply where such items as threatened species or Aboriginal heritage items are discovered. At the present time, no such records are known. Other parts may apply to large scale development proposal. There are no such proposals known in the study area at the present time. This section provides a shortened summary of the legislation applicable to land holder and Council activities of the scale expected in the study area at this time. The summary is presented in Table 2.1. Comprehensive detail of all legislation that may apply to foreshore land is given in Appendix B.
## Table 2.1 Legislative Framework Checklist for the Pindimar and Bundabah Areas

<table>
<thead>
<tr>
<th>Legislation</th>
<th>Details</th>
<th>Government Agency</th>
<th>Area</th>
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<tbody>
<tr>
<td><strong>Environmental Planning and Assessment Act 1979</strong> (the EPA Act)</td>
<td>A development application (DA) under Part 4 of the EPA Act is required for structures on foreshore land. The DA will also require concurrent approval from other agencies as described below.</td>
<td>Council, other state departments as required</td>
<td>All foreshore and other land</td>
</tr>
<tr>
<td>For certain works in the foreshore zone, Council may be required to</td>
<td>complete a Review of Environmental Factors (REF) under Part 5 of the EPA Act (refer SEPP Infrastructure below).</td>
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| **State Environmental Planning Policy (Infrastructure) 2007** (SEPP Infrastructure) | Council may undertake waterway or foreshore management activities (section 129), stormwater management activities (section 111) or environmental management works associated with upgrading a boating facility (section 68(2)) under this SEPP without consent. However, if the impact to the environment is likely to be greater than minimal, an REF is required. Regardless, Council will need to consult with / obtain concurrence from the following agencies regarding their respective Acts and functions:  
  - Department of Primary Industries Crown Lands Division (CLD) (land below mean high water is Crown Land)  
  - Port Stephens – Great Lakes Marine Park Authority (regarding the Port Stephens - Great Lakes Marine Park)  
  - Department of Primary Industries (Fisheries) (DPI Fisheries) (regarding marine vegetation)  
  - Department of Premier and Cabinet Office of Environment and Heritage (OEH) (regarding the Coastal Protection Act 1979, Threatened Species Conservation Act 1995 for foreshore vegetation)  
  - Department of Planning and Infrastructure (P&I) (regarding SEPP 71) | Council, other state departments as required                                                                                       | All Council owned foreshore land                                       |
| **Great Lakes Council Local Environment Plan 1996 (LEP)**                    | Permissible uses and development of land is dependent upon land zonings in the study area, which are either Rural (1a) or Residential (Low Density) (2a), under Council’s existing LEP. The number of housing entitlements is limited for rural lands, such that there may be only one housing entitlement for a group of lots along the foreshore. A low density housing entitlement is permitted per lot under the residential zoning. The LEP is currently under review and in draft (as per the Standard Instrument (Local Environmental Plans) Order 2006), however, it is likely that the existing zonings will remain. | Council                                                                                                                             | All foreshore and other land. LEP Zoning in the Study Area is illustrated in Figure 1-2. |
### Legislative Framework for Foreshore Management

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<thead>
<tr>
<th>Legislation</th>
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<tbody>
<tr>
<td><strong>Crown Lands Act 1989 (the CL Act)</strong></td>
<td>A license is required for foreshore protection works on land below the mean high water mark, as this is Crown Land. It is an offence under the CL Act (Section 155) to erect a structure on public land (i.e., below the mean high water mark) and penalties apply. The Minister for Lands may also order the removal of unauthorised structures (Section 158), with the costs of such removal to be borne by the person who erected the structure.</td>
<td>CLD, Minister for Lands</td>
<td>All foreshore land below the mean high water mark</td>
</tr>
<tr>
<td><strong>The Marine Parks Act 1997 (the MP Act)</strong></td>
<td>Port Stephens – Great Lakes Marine Park (the marine park) was declared under the MP Act. Landholders planning to undertake foreshore protection works (above mean high water) must complete a DA, the Port Stephens – Great Lakes Marine Parks Authority must be consulted, and their comments as well as the objects of the MP Act and the marine park zoning plan must be taken into consideration by Council when assessing the DA. If the proposed works will occur within the marine park (i.e., below mean high water), then concurrent approval is required from the Ministers for this Act.</td>
<td>Port Stephens – Great Lakes Marine Parks Authority (PS-GL MPA), Minister for Primary Industries and the Minister for the Environment</td>
<td>All foreshore lands</td>
</tr>
<tr>
<td><strong>The Water Management Act 2000 (the WM Act)</strong></td>
<td>A ‘controlled activity approval’ (Section 91 (2)) is required from the Minister for Water for all foreshore protection activities within 40 m landward of the mean high water mark. Council, as a public authority, is exempt from the requirement to obtain such a licence, in performing such activities on foreshore land.</td>
<td>Department of Primary Industries Office of Water</td>
<td>All foreshore land within 40 m of the mean high water mark</td>
</tr>
<tr>
<td><strong>State Environmental Planning Policy No. 14 – Coastal Wetlands (SEPP14)</strong></td>
<td>Hard structural foreshore protection activities within SEPP14 Wetlands are classed as ‘designated development’ and require concurrence from the Director for Planning, the Director of National Parks and Wildlife and an environmental impact statement to be prepared. For restoration works within SEPP14 Wetland boundaries (i.e. works to restore or enhance the wetlands to rectify a breach of the policy), a Restoration Plan must be submitted to Council and concurrence obtained from the Director for Planning.</td>
<td>P&amp;I, Council, OEH</td>
<td>All SEPP14 Wetlands Refer to Figure 1-3 for the location of SEPP 14 Wetlands in Bundabah – Pindimar.</td>
</tr>
<tr>
<td><strong>Threatened Species Conservation Act 1995</strong></td>
<td>The Endangered Ecological Community Coastal Saltmarsh occurs on foreshore lands. There may be other as yet unknown species or communities listed in the TSC Act in the study area. It is an offence under this act to harm, damage or remove plants, animals, communities or habitats listed in the TSC Act, unless a licence has been obtained from the Director-General for the Environment.</td>
<td>OEH</td>
<td>All areas of Coastal Saltmarsh, and locations of other threatened species, habitats and endangered ecological communities. See Figure 1-3 for coastal saltmarsh in the region.</td>
</tr>
<tr>
<td>Legislation</td>
<td>Details</td>
<td>Government Agency</td>
<td>Area</td>
</tr>
<tr>
<td>---------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------</td>
<td>------------------------------------------------</td>
</tr>
<tr>
<td>Fisheries Management Act 1994 (the FM Act)</td>
<td>It is an offence to damage, destroy or remove mangroves, seagrass or any other marine vegetation under the FM Act (section 205). A permit is required from the Minister for Fisheries to damage marine vegetation, otherwise fines of up to $220,000 apply. Likewise, foreshore reclamation or dredging is an offence under the Act (section 201), unless a permit has been obtained from the Minister.</td>
<td>DPI Fisheries</td>
<td>All marine vegetation, including mangroves, seagrass and saltmarsh (below mean high water), refer to Figure 1-3.</td>
</tr>
<tr>
<td>The Coastal Protection Act 1979 (the CP Act)</td>
<td>Foreshore land lies within the coastal zone as defined within the CP Act. Development, including foreshore protection works or the removal/propagation of marine vegetation, cannot be approved by Council without concurrence of the Minister for the Environment, unless the development is consistent with the principles of ecologically sustainable development and will not adversely affect the foreshore, bed or banks of the estuary, or the behaviour of the estuary.</td>
<td>Council, consultation / concurrence with OEH as required.</td>
<td>All foreshore land</td>
</tr>
<tr>
<td>State Environmental Planning Policy No 71 – Coastal Protection (SEPP 71)</td>
<td>Foreshore land in the estuary is classed as a ‘sensitive coastal location’ under this Policy. Therefore, the aims of this Policy must be taken into account by Council when determining DAs, and the DA should be referred to the Director-General of Planning for further comment. A key aim of the policy is to protect and improve public access to the foreshores to the extent that is suitable to the foreshore environment, even where the foreshore is privately owned, as well as protect and preserve native coastal vegetation and the marine environment. Council may refuse a development application (such as a foreshore structure) where it impedes or diminishes the public’s right of access to the foreshore.</td>
<td>Council, P&amp;I</td>
<td>All foreshore land</td>
</tr>
<tr>
<td>NSW Sea Level Rise Policy Statement 2009</td>
<td>The Statement indicates sea level rise planning benchmarks of 0.4 m by 2050 and 0.9 m by 2100 should be used in all assessments for development in the coastal zone. These benchmarks need to be considered when designing foreshore structural works, depending upon the planned life of the works.</td>
<td>Council</td>
<td>All foreshore land</td>
</tr>
<tr>
<td>Port Stephens Foreshore (Floodplain) Management Plan (WMA, 2002)</td>
<td>In lieu of specific studies, a zone extending 50 m inshore from the mean high water mark shall be applied as the indicative flood zone of the Pindimar study area.</td>
<td>Council</td>
<td>All land within 50 m landward of the mean high water mark.</td>
</tr>
</tbody>
</table>
3 COMMUNITY CONSULTATION

3.1 Strategy for Community Engagement

A strategy of community engagement was employed during this study to:

- Engage and involve the local community and facilitate ownership of the project outcomes;
- Gather information about the possible causes of foreshore erosion;
- Gather suggestions for potential foreshore protection and management actions; and
- Involve the local community in the development of foreshore management guidelines, to ensure the guidelines are implemented successfully.

The activities involved in community consultation included an information newsletter and a questionnaire, which were mailed to foreshore property owners. Follow up interviews were conducted with foreshore residents, where requested in the questionnaire replies. A series of interviews with representatives from the stakeholder agencies were also conducted. Last, the report was placed on Public Exhibition during January and February 2011, and this period included an informal Community Meeting at Pindimar, to invite both informal and formal submissions upon the report. Details and outcomes from these activities are given below.

3.2 Information Newsletter

An information newsletter was compiled, providing details of the project including findings from the background data review. The information newsletter requested readers to contact the study team, should they have any information regarding foreshore erosion causes or management in Pindimar. The newsletter was made available in local shops, post offices and Councils offices. The information newsletter is attached in Appendix C.

3.3 Questionnaire

The questionnaire sought specific information regarding erosion extents, weather conditions during erosion events and community feedback on erosion mechanisms. A request for photographs of foreshore erosion was also made in the survey. The questionnaire was mailed to foreshore residents. Foreshore residents were also invited to be interviewed by the study team, if they wished to have an on-site discussion with the Study Team. The questionnaire is attached in Appendix C.

Results from the questionnaire are discussed with respect to each of the foreshore sections, in following chapters.

3.3.1 Questionnaire Results

A total of 49 questionnaires were returned to the Study Team.

In general, residents who responded have owned their property or lived in the area for some time. Newer residents (< 10 years) comprised 25% of the respondents, 30% for between 10 and 20 years, and the remainder (45%) more than 20 years. Five percent of respondents have lived in the area for
45 years. Long term residents are important in gauging long term recession compared with localised or more recent erosion events.

Around half of the residents commented that they had experienced erosion on their own properties, however nearly three-quarters of respondents felt that erosion was occurring somewhere within the region. Locations which respondents noted as having erosion issues included (in order from most to least common response):

- The boat ramp and adjacent public reserve along Curlew Avenue in Lower Pindimar;
- Lower Pindimar foreshore west of Piggies Beach and the western end of Cambage Street;
- Erosion at the stormwater drain outlet at the end of Kiora Street
- Bundabah public reserve, road and boat ramp
- Various areas along Upper Pindimar foreshores, such as the informal boat ramp at the end of Wombo Street.

For example, at the western end of Piggies Beach, one resident reported a loss of ~ 10 m (30 ft) of foreshore compared with original 1920s and 1930s subdivision maps. It is unclear what may have caused this erosion.

Other additional comments regarding the location of erosion issues noted that regions of natural shoreline have not shown any evidence of long term erosion, that is, the erosion appeared to be cyclic, with both erosion and accretion phases. Further, some respondents reported that erosion issues had arisen only after seawalls had been built.

As indicators or markers of erosion, respondents have noted the location of the shoreline relative to older foreshore trees, or seawalls in some cases. Respondents were prompted to describe likely weather processes that may cause erosion, such as strong winds, big tides, waves caused by the wind and ocean waves. The majority of respondents noted strong winds (and wind waves) combined with big tides during storms resulted in foreshore erosion. Further, the majority of respondents noted events from the south to south-east as the most damaging, particularly when combined with high tides. In some locations, westerly winds were also noted as important.

A number of respondents, particularly those who had lived in the area for a number of years, noted there was a natural cycle of erosion and accretion on the foreshore, such that over the long term there was no ongoing foreshore recession pattern. Storm event based erosion of the shoreline occurred (in some cases, many metres of foreshore loss) then recovered over a period of months during calmer weather. Those respondents who did report the occurrence of erosion stated it was occurring slowly, but had been ongoing for a number of years.

Causes of erosion not related to weather conditions noted by the respondents were:

- Many respondents reported the construction of seawalls on natural shorelines had resulted in erosion of the beach in front the wall, and erosion at the edges of the wall. Vertical, solid walls in particular were viewed as forcing erosion and obstruction of natural shoreline movement. In contrast, a small number of respondents asked for additional walls to be constructed.
- Erosion at stormwater outlets has not been controlled was also highlighted. This is particularly evident at the end of Kiora Street.
Areas which did not have foreshore vegetation or where vegetation had been removed (particularly mangroves) were subsequently exposed to wind, waves and currents, resulting in erosion. Where vegetation removal was combined with the construction of seawalls, residents noted the occurrence of erosion on previously stable shorelines. Areas with natural vegetation were also noted to withstand storm events better and recover quicker.

A few respondents felt that the erosion of a former spit extending from Corrie Island a number of years previously has exposed the Upper Pindimar foreshores to greater ocean wave and current action, resulting in erosion.

The removal of oyster leases or oyster “rocks” was said to have caused erosion, as nearby shorelines become more exposed. A number of residents felt that the [former] oyster leases buffered the shoreline from wind and waves. Respondents also noted that the old oyster leases provided important and productive fish habitat, and raised concerns over their removal.

Land reclamation was observed in combination with the construction of seawalls by a number of residents. This was viewed by some as highly inappropriate and often resulted in greater erosion of the beach in front and adjacent to the reclaimed land. This is possible where the reclaimed land and seawalls are out of alignment with the natural shoreline and sediment transport processes.

In Lower Pindimar (Section 2 Cambage St) concerns were raised over the (natural) meandering of Pig Hill Station Creek across one owner’s property, which was said to have occurred over a number of years, resulting in flooding of the property. The owner believed this creek to be part of a Council drain, requesting that it be formalised. The creek is in fact a SEPP 14 Wetland (757a), and it is apparent that the owner is unaware of the status and required management of the creek. A former landholder in this location admitted to having emplaced rock protection along the banks of the creek outlet. The former landholder had sold the property when the SEPP14 boundaries were declared as they were unclear as to their rights on the property under SEPP 14.

Interestingly, respondents were divided about the response required to the issue of foreshore erosion in the Pindimar study area. A number of respondents were in favour of seawall or other structural protection works. In contrast, quite a number of residents highlighted that where natural foreshores remained or natural vegetation, particularly mangroves, were used instead of hard structures, the foreshores had been retained and in some cases even accreted over the years. Evidence of foreshore change was provided in sketches and photographs by many respondents. An example of foreshore stability of a natural shoreline provided by a respondent is given in Figure 3-1 and Figure 3-2 below.
Figure 3-1  Shoreline at 28 Cambage St., Pindimar approx. 30 years ago (Photo: M. Dougett)

Figure 3-2  Shoreline at 28 Cambage St., Pindimar at present, with ‘X’ in foreground showing location of former swing (Photo: M. Dougett)
3.3.2 Site Interviews

A total of 18 one-on-one discussions were held with foreshore residents, as per their request in the questionnaire survey. The site interviews enabled the study team a valuable opportunity to discuss and inspect site specific erosion issues with residents at their properties. Not surprisingly, many of the issues noted from the questionnaires were discussed during the site interviews. However, key issues of concern were similar to the outcomes from the background data review. Opinions varied regarding the use of ‘soft’ verses ‘hard’ engineering options for treatment. Key concerns and issues raised during the interviews are discussed below.

Recession, Erosion and Storms

A number of interviewees, particularly longer term residents, did not believe there was an ongoing or long term erosion problem. They noted cyclic “coming and going” of the shoreline only, typically in relation to storm events. Photographs of the shoreline from the 1950s were provided as evidence for the stability of the shoreline along Pindimar to Upper Pindimar, such as in Figure 3-3 and Figure 3-4 (provided by G. Fidden, Morante St., Pindimar). Further, log sleepers placed along the shoreline in 1948 were cited as evidence of the stability of the shoreline, as there has been little movement of the shoreline relative to the logs, as shown in Figure 3-5.

Changes in channels, shoals and currents around Corrie Island and erosion along the southern end of the island itself were thought to have changed currents and allowed greater exposure of the Pindimar to Upper Pindimar foreshore, causing erosion.

Large storm events reported included the “Sygna” storm of 1974, as well as smaller damaging storms in 1972, 1997, 1998 and 1999. Big tides and wave overtopping during storms is reported to reach some metres landward.

Boat wake was not reported to be an issue by the majority of residents.

Existing Foreshore Treatments

The Study Team was shown examples of privately constructed seawalls and other structures, which sometimes included the reclamation of foreshore land. It was apparent that many of the structures were inadequate for their purpose, displaying undermining, warping or potential collapse, and adjacent erosion or “edge effects”, as well as being constructed of inappropriate or ineffective materials. Interviewees often described considerable efforts they had undertaken to maintain the failing structures, particularly ongoing backfilling where wave overtopping continued to erode backfill from behind and beneath the structure, re-stabilisation of vertical walls where wave overtopping has caused slumping, warping and collapse, and treatment of erosion at the edge of structures.

At other properties, the study team was shown examples of natural shorelines or natural vegetation protections that experienced only cyclic erosion and required little to no maintenance effort from the owners.
Figure 3-3  Pindimar shoreline (Morante St.) in 1950s (Photo: G. Fidden), showing jetty structures in the background that are still evident today, seaweed wrack and gentle slopes.

Figure 3-4  Pindimar shoreline (Morante St.) in 1950s (Photo: G. Fidden), showing rail sleepers in the background that are still evident today, seaweed wrack and gentle slopes.
The use of disused building material, such as bricks, concrete, wood and other rubble, were noted by some residents and observed by the Study Team to have been used in the stabilisation of some sections of shoreline. The use of building materials was unsightly and not in keeping with either the surrounding natural or artificial shorelines, and may pose a danger to the public accessing the foreshore.

The deposition of seaweed wrack upon the shoreline is a natural process. Some interviewees noted that the wrack deposition, particularly when combined with dune vegetation such as “pig face”, assisted to capture sediment within the dune region of the foreshore zone, and provide protection and sediment supply during storms.

**Mangroves and other Shoreline Vegetation**

Large sections of the Pindimar study area comprised shorelines that are presently devoid of mangrove growth where regeneration has not occurred. The removal of mangroves along these sections was reported by residents to have occurred during the 1920s to 1940s when the land was farmed with cattle. Cattle ate the mangrove trees, and any subsequent seedlings. After this, the area was used for oyster leases, which would have prevented mangrove regeneration. A majority of oyster leases have since been removed. Mangrove seedlings are observed to sprout during spring each year, but appear to die off by the end of summer. Suggestions for the cause of mangrove seedling die-off provided by interviewees included freshwater runoff during rain storms, smothering by runoff of gravel and sediment and smothering by algae growth. Some interviewees admitted to removing
mangrove seedlings, as they considered the plants unsightly. However, it is most probable that seedlings damaged and destroyed because they are unprotected from incoming wave and tide action.

Some residents have observed accretion of the foreshores behind areas that are protected by mangroves.

The northern most end of the study area at Upper Pindimar is adjacent to the SEPP14 Wetland Kore Kore Creek (No. 754). Recent owners of the land adjacent to the wetlands have left their land untouched, resulting in a proliferation of saltmarsh and mangroves that provides support to the habitat of the adjacent important wetland.

**Oyster Racks**

A number of interviewees felt the removal of disused oyster racks has exposed sections of the Pindimar shoreline to greater wave energy (wind and swell), causing erosion. Interviewees further noted the oyster leases provided habitat and food for fish and other aquatic species and birds. A number of interviewees indicated they would prefer the old leases to remain, rather than be removed.

**Uncontrolled Stormwater Outlet**

There exists a Council ‘drain’ between properties at 1 and 2 Kiora Street. The drain is presently uncontrolled, consisting of an open trench between the properties. Residents have photographic evidence of the shoreline prior to construction of the drain, including a wider foreshore of white sandy beach. The drain was thought to have been constructed around 1983, as an outlet for water from behind the road, which acted to ‘bund’ the swamp behind the road. Residents also have photographic evidence illustrating the progressive state of the shoreline since the drain was constructed (‘dug out’). Considerable erosion has occurred at the drain outlet, including erosion and undermining of the rock and concrete walls either side of the drain. Based on the photographs, approximately 10 – 30 m of foreshore has eroded in the vicinity of the drain.

It is evident that properly engineered protection and control of the stormwater outlet is required, to treat and stop the progressive erosion of both public and private property.

**Bundabah**

Processes in Bundabah are somewhat different to those occurring along the Lower to Upper Pindimar foreshore. Ebb (i.e. outflowing) tidal currents from North Arm Cove have been described by interviewees as a key process causing erosion in this location. The ebbing tide is said to ‘jet’ out from North Arm Cove directly toward the exposed bedrock and overlying unconsolidated sediments at Bundabah. Wind wave action is considered less of an issue at Bundabah, although some wave action is noted to occur during westerly storms or wind conditions. Some observers noted the effects of boat wake to be occurring on the foreshores in this region.

Typically, the erosion is observed as ‘fretting’ of the foreshore, that is, minor cutting of foreshore edges, where unconsolidated sediments overly bedrock. However, the erosion is perceived as a problem by local residents.
Vertical structures along this shoreline have experienced erosion of backfill. Property owners have been placing rocks (and other material) along their foreshores to provide protection from ongoing erosion. The outcome is an ad-hoc assortment of materials, which are unlikely to effectively protect the shoreline.

A Council seawall exists adjacent to the boat ramp at the end of Bundabah road. The construction is of large (> 1 m) sandstone blocks in a vertical arrangement. Geotextile fabric behind the structure appears to have degraded, and the gravel backfill appears to be washing out through the sandstone blocks. Overall the rock structure is solid and appears to be in good condition. However local residents have raised concerns as to the inundation of this site at high tide, which is said also to form a helicopter landing pad for use as emergency access. The initial settling and slow loss of backfill through the rock structure is likely to have lowered the ground level at the pad.

The community has also expressed concern that the public reserve lands in Bundabah, which extend south west along the foreshore from the boat ramp and another small reserve and ramp at the end of Pleasant View Parade / Cove Avenue, are experiencing erosion and are in a poor state of repair. In some places along the public reserve, rocks and ad-hoc building materials such as bricks have been used to form a low (< 20 cm) structure.

Similar issues regarding the die off of mangrove seedlings (thought to be due to gravel in run off) and general lack of mangroves and minor erosion along the private foreshore lands north of the helipad / boat ramp were raised by residents at Bundabah.

The desire to retain the oyster leases to ensure passing boats must travel at lower speeds (as well as for fish habitat), and as a form of shoreline protection were also raised for Bundabah. Within North Arm Cove, the leases are believed by residents to ‘slow down’ or impede tidal flows, as well as control boat speeds.

3.4 Stakeholder Interviews

Interviews with the various stakeholder agencies were conducted. The agencies contacted to discuss this project and outcomes of the discussions are as follows.

**DECCW (Now OEH)**
- Noted investigations into erosion had begun in 2002-3, prior to the involvement of the current DECCW representative.

**Department of Lands (Now CLD)**
- Two requests (emails, phone calls) have been made regarding potential old reports upon the area
- No response was received.

**DII (Fisheries) (Now DPI Fisheries)**
- The erosion issue was noted to likely relate to property ownership to the foreshore edge, rather than an issue caused by physical processes, and due to the interference with the foreshore edge by property owners.
Reported the existence of a long southward extending spit off Corrie Island (which is evident in the current cadastral survey held by Council) and a longer middle shoal within the estuaries tidal delta, upon which waves would break, protecting shorelines such as Pindimar in lee of the shoals and spit. The spit and shoals have since eroded (due to natural processes), causing exposure of the Pindimar shoreline to greater wave energy.

At Upper Pindimar, ongoing maintenance of the back channel for the Myall River behind Corrie Island is thought to be causing an outflow during ebb tides and floods in particular which jets directly onto the upper Pindimar shoreline, potentially causing erosion.

Suggested the small amount of sea level rise of the prior 50 to 100 years is also likely to have had some effect on shorelines in the estuary, such as Pindimar.

**NSW Maritime**

- Suggested that wave action was likely to be the key driver of erosion
- Indicated little boat wash impact in the study area
- Suggested foreshore management by property owners in the study area is likely to have impacted upon the extents of erosion observed, with illegal dumping of rock (including quarry rock) at certain locations along the Lower Pindimar foreshore, at Piggies Beach
- Indicated that a public boat ramp exists at the end of Wood Street, which is currently disused because it is overgrown, and therefore not known to visiting boat users. The end of Wombo Street is used as an informal boat ramp instead
- Noted a sand bar has formed in Pindimar Bay at the entrance to the back channel to the Myall River, caused by flow out from the river.

**Port Stephens Marine Park Authority**

- Numerous calls and emails to the MPA have been made, however unfortunately contact with the representative could not be made.

**Hunter Central Rivers Catchment Management Authority (HCRCMA)**

- Discussed preferred foreshore protection mechanisms, stating the HCRCMA would support natural resource outcomes, particularly revegetation, and discourages outcomes that are focussed upon individual property owners interests
- If ‘hard’ engineering options are unavoidable in some locations, the HCRCMA encourages environmental rehabilitation to be a component of the design.
- Riparian officers of the HCRCMA are moving away from detailed structures, as costs and upkeep are prohibitive, and moving towards revegetation and simple re-fencing options
- In the case where “unapproved” foreshore protection works have been undertaken and currently exist, it is suggested that rehabilitation, modification or removal of such structures could be linked with new (or future) development approvals requested by land owners
- Indicated that mangrove seedlings observed sprouting along the study area foreshores are likely to have been ‘dying off’ due to wave energy particularly during storms, as the seedlings are unprotected
- Stated that the HCRCMA has successfully used rock fillet type designs, which encourage the growth of (natural and/or planted) mangrove seedlings by providing protection to the seedlings from wave energy at the Manning River (Harrington), the Macleay and Hastings Rivers.

- Noted that, where Councils in the past have spent considerable resources upon foreshore protection (or rehabilitation) upon private lands, they have had limited success as they can’t ‘police’ the works. Councils have had very good success on undeveloped and public lands.

- In response to the concerns regarding the removal of disused oyster leases, the HCRCMA noted that DPI Fisheries is attempting to remove as many as possible, as there are likely to be issues relating to contamination of the leases (from tarring), the habitat provided by the leases tends to favour introduced rather than native species, the leases are illegal structures according to the Crown Lands Act, and the leases are of particular concern within sanctuary zones of the Marine Park. The habitat provided by the leases is difficult to assess as very low tide conditions are needed, due to issues of visibility.

Port Stephens Council

- Provided reference to existing reports for the estuary, which have been reviewed as part of this study (refer Appendix A).

### 3.5 Public Exhibition

The public exhibition period was conducted in January and February 2011, and involved provision of the report to community electronically (via Council’s website) and from Council as required. The Public Exhibition period also involved and on-site Community Meeting, held at the public boat ramp on Curlew Avenue Pindimar, to enable informal discussion and submission of comments from community. The outcomes of the meeting and formal submissions are detailed below.

Formal submissions from the Public Exhibition period are provided in table format in Appendix J. A summary of overall comments from both the formal submission and informal feedback from the Community Meeting is provided below. In general, the community’s comments demonstrated:

- In principal support for the depth and breadth of the study;
- Support for the scientific integrity of the study;
- Support for the layout of the document;
- Endorsement of the educational strategy and restorative activities in plan;
- Endorsement for the removal of illegal inadequately built structures;
- Support for the improvement of existing structures in the "modified" sections as proposed in the Foreshore Protection Guidelines;
- Support for the intention to maintain natural foreshores and deter further hard engineering structures;
- Support for the re-establishment of SEPP 14 Wetlands that have structures interfering with their natural function;
- Support for the planting of mangroves where they have been illegally removed;
- Support for the development of an Estuary Foreshore DCP;
- Support for the remediation of erosion around the boat ramp and Norfolk Island pine tree, with the exception that the area originally drafted for mangrove regeneration be maintained in its existing form as a sandy beach due to the high usage of this section for swimming and similar recreation activities; and
- Support for the implementation of Council’s existing drainage and stormwater strategy and improvements (such as detailed in WBM, 2002).

### 3.6 Conclusions

Key conclusions from the community consultation activities are as follows.

There is a history of illegal and unauthorised foreshore management activity, including the emplacement of ad hoc, poorly designed, unsightly and ineffective seawalls, groynes and other protection type works. The construction of such works has often been combined with illegal land reclamation. Mangrove damage has also been reported in the past.

Many in the community are not aware of the legislation governing foreshore habitats (particularly mangroves, as well as seagrass, saltmarsh and SEPP 14 Wetlands), land reclamation and the construction of foreshore structures.

It is likely that planning and other legislation has changed over time and many residents are unaware of their rights and responsibilities when owning land to the mean high water mark. Education in this regard is required.

Erosion issues are likely caused by ineffective attempts to stabilise the foreshore, and reclaim land to the mean high water mark. Education as to appropriate and more effective ‘soft’ engineering solutions such as revegetation is required.

Changes in mangrove density resulting in the denudation of some sections of shoreline largely occurred more than 50 years ago, with more recent damage in some localised areas. Mangrove seedlings propagate along the shoreline frequently, however protection is required to enable the seedlings to properly establish.
4 BACKGROUND TO PHYSICAL PROCESSES

4.1 Introduction

This chapter discusses the large scale physical processes operating on this shoreline, including tides, ocean waves (swell) and locally generated wind waves (seas). A summary of the background data review is given, followed by explanation of the broad scale physical processes operating within Port Stephens. The chapter also discusses the wave modelling conducted as part of this study.

4.2 Summary of Background Data Review

A review of existing reports and data was conducted. Details from each of the relevant reports are given in Appendix A.

The reports agreed upon the likely causes and future actions to be taken to protect the Pindimar and Bundabah foreshores. The following conclusions were found in the documents:

- There does not appear to be a signature of long term erosion at natural shorelines in the study area;
- Foreshore erosion is apparent where foreshore protection works have been constructed and / or where there is an obvious absence of mangroves in the nearshore zone;
- There is a prevalence of foreshore protection works in the study area, particularly seawalls and groynes, however the majority of these structures are unauthorised, ad hoc, poorly designed and poorly constructed (i.e. do not meet coastal engineering standards). The structures are typically not performing as intended;
- The log and rock groynes in the study area are not performing to collect sediment, and are instead a danger to the public who may access these foreshores;
- The majority of seawalls are vertical, which will act to reflect wave energy and exacerbate erosion;
- The majority of seawalls have been constructed without consideration of potential edge effects, which can cause erosion of adjacent unprotected shorelines, eventually undermining and causing the seawall structure to collapse;
- The majority of seawalls do not adequately allow for drainage of water from wave overtopping. This can result in backfill materials washing through the wall and subsequent collapse of the seawall;
- Illegal mangrove removal has occurred in the past, and the denuded shorelines have subsequently been exposed to erosion processes; and
- Education campaigns to illustrate alternative foreshore protection methods are required.

4.2.1 Aboriginal Heritage

The Port Stephens estuary is likely to have sites of Aboriginal habitation relating to use of the estuary for food and resources, particularly prior to European settlement. A search of the Aboriginal Heritage Information Management System (AHIMS) database held by OEH has identified 7 sites in or near the...
study area which contain Aboriginal artefacts. The exact locations of such sites are not permitted to be made public knowledge. Further, OEH advises that while the artefacts have been geo-referenced, confirmation by re-location on the ground is recommended.

OEH also advises that large areas of NSW have not been subject to detailed or systematic study, with many of the sites listed provided by the Local Aboriginal Land Council or other representatives of the local Aboriginal people. In this case, there may be additional items of Aboriginal Heritage significance within the area that are not recorded on the AHIMS database.

Artefacts and sites found in or near the study area include middens and axe grooves. Middens are typically located along foreshores of estuaries and beaches. Then installation of foreshore protection works may uncover and disturb these or additional heritage sites. Under the National Parks and Wildlife Act 1974, it is an offence to destroy, damage or deface Aboriginal places or objects, unless approval is given by the Director-General of OEH.

### 4.3 Tides

Tides along the NSW Coast including Port Stephens are micro tidal (i.e. < 2m in range) and semi-diurnal (i.e., ~ two tides occur every day). Tidal Planes for the Port Stephens Tomaree ocean tidal gauge are provided by MHL, with the data funded by OEH. Tidal planes and tidal ranges are given in Table 4.1. The mean spring tidal range at Port Stephens is 1.3 m, consistent with other locations along the NSW Coast.

The occurrence of the Highest High Water Solstice Spring (HHWSS) tide at 0.979 m above AHD in combination with a storm event is likely to produce the greatest still water levels, enabling greater potential for wave erosion at shorelines in the study area.

Hydrodynamics as driven by the ocean tide as it moves into Port Stephens Estuary are discussed in Section 4.6

<table>
<thead>
<tr>
<th>Tidal Planes</th>
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<tbody>
<tr>
<td>HHWSS</td>
<td>0.979</td>
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<tr>
<th>Tidal Ranges</th>
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<tr>
<td>Mean Spring Range (MHWS-MLWS)</td>
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<tr>
<td>Range (HHWSS-ISLW)</td>
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</tbody>
</table>

*Where: Highest High Water Solstice Spring (HHWSS); Mean High Water Spring (MHWS); Mean High Water (MHW); Mean High Water Neap (MHWN); Mean Sea Level (MSL); Mean Low Water Neap (MLWN); Mean Low Water (MLW); Mean Low Water Spring (MLWS); and Indian Spring Low Water (ISLW).*
4.3.1 Elevated Water Level Anomalies

Elevated water levels occur along the coast in response to storms and typically comprise: barometric pressure set up due to the storm itself; wind set up, where wind “piles” water onto the shoreline; astronomical tide; and wave set-up, which is the super-elevation of the water surface due to the energy released by breaking waves (and so is only relevant on shorelines where wave breaking occurs).

MHL is presently re-analysing elevated ocean water level anomalies along the NSW Coast. Completed analysis is currently only available for Fort Denison in Sydney. The combined elevated water levels at Fort Denison for various ARIs are given in Table 4.2 (DECCW, 2009). The values do not include wave set-up, which occurs in response to breaking waves along the shoreline. This is appropriate for the purposes of determining input water level parameters for use in wave modelling.

<table>
<thead>
<tr>
<th>Average Recurrence Interval (years)</th>
<th>Extreme Water Level (Storm Surge + HHWSS) Sydney (DECCW, 2009) (m AHD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.35</td>
</tr>
<tr>
<td>20</td>
<td>1.38</td>
</tr>
<tr>
<td>50</td>
<td>1.42</td>
</tr>
<tr>
<td>100</td>
<td>1.44</td>
</tr>
</tbody>
</table>

4.4 Offshore Wave Climate

Wave data statistics for Sydney were provided by the Department of Commerce’s Manly Hydraulics Laboratory (MHL). The wave data collection was funded by OEH. Wave data is collected by wave rider buoys moored in around 85 m water depth, approximately 10 km offshore. Sydney’s buoy is located approximately 200 km south of Port Stephens. Another wave rider buoy at Crowdy Head (140 km north of Port Stephens) does not measure wave direction, therefore Sydney’s record is the most useful. MHL (1997) compared wave data from the Sydney buoy with measurements at Jimmys Beach, and found the Sydney data to be sufficiently similar to represent the offshore wave climate at Port Stephens.

4.4.1 Significant Wave Height

Significant wave height ($H_s$) is an average of the highest one-third of wave heights recorded during a set period of time, providing a reliable indication of the swell wave height. Statistics for percentage occurrence of $H_s$ are provided in Appendix D, spanning March 1992 to June 2009. For Sydney, the average $H_s$ is 1.63 m and maximum recorded $H_s$ is 8.43 m. Average and maximum wave heights are greater during the autumn to early winter months (March to July). During this period three of the wave generation sources for the NSW coastline overlap in their seasonal occurrence, namely mid-latitude
cyclones, east coast low cyclones and tropical cyclones. Average and maximum wave heights are typically lowest during the spring to early summer months.

Storm wave height and duration curves for Sydney are given in Appendix D, Figure 10-5. From these curves, values describing the 1-hour and 6-hour duration storm wave heights for the 1, 20, 50 and 100 year average recurrence interval (ARI) storms have been derived. These are presented in Table 4.3.

<table>
<thead>
<tr>
<th>Return Period (years)</th>
<th>1-hour $H_s$ (m)</th>
<th>6-hour $H_s$ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.8</td>
<td>5.3</td>
</tr>
<tr>
<td>20</td>
<td>8.2</td>
<td>7.4</td>
</tr>
<tr>
<td>50</td>
<td>8.9</td>
<td>8.1</td>
</tr>
<tr>
<td>100</td>
<td>9.4</td>
<td>8.6</td>
</tr>
</tbody>
</table>

### 4.4.2 Wave Direction

The NSW Coast typically experiences waves arriving from the south east sector, with some seasonal variation. The data provided in Table 4.4 illustrates that, at Sydney, 65% of all waves arrive from the south east, south-south-east (SSE) and south (S) sectors combined, with 30% of all waves from the SSE alone. Mid-latitude cyclones generate this predominant south east swell, and these storms may occur throughout the year. Typically, mid-latitude cyclones occur closer to the southern Australian continent during winter and further south during summer, thus wave heights from these systems are typically greater during winter.

South easterly waves dominate the wave record during all months. However there is a noticeable shift in wave direction towards the north (with waves becoming more easterly in direction) during the summer months, as illustrated in Table 10.6, Appendix D. This is due in part to the tropical cyclone wave generation mechanism that occurs over the summer to autumn months, generating north-easterly waves on the NSW coast. In addition, north easterly sea breezes are also dominant during the summer (warmer) months, in response to the land heating faster than the ocean. This can generate smaller north to easterly wind waves along the coast in summer.

For coastal assessments, a storm is typically defined as $H_s > 3$ m (You and Lord, 2008). The highest waves in the NSW record occurred during east coast low cyclones, which generate south-easterly to north-easterly waves, depending on the location of the storm relative to the coast (Short, 2007). The highest waves on record arrived from the SSE direction. East coast low cyclones may occur any time of the year, but are more common from May to July. Other storm waves may occur infrequently from the north-east (NE) and south-west (SW) sectors.

The height and direction typical for storm waves along the coast may be described by joint occurrence statistics for wave height and direction (refer Table 4.4).
Table 4.4 Percentage Joint Occurrence of Wave Height and Direction, Sydney (March 1992 to December 2008, 16.84 years)

<table>
<thead>
<tr>
<th>Dir’n</th>
<th>(Deg, TN)</th>
<th>0 - 0.99</th>
<th>1 - 1.99</th>
<th>2 - 2.99</th>
<th>3 - 3.99</th>
<th>4 - 4.99</th>
<th>5 - 5.99</th>
<th>6 - 6.99</th>
<th>7 - 7.99</th>
<th>8 - 8.99</th>
<th>TOTAL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>348.75 - 11.24</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NNE</td>
<td>11.25 - 33.74</td>
<td>0.03</td>
<td>0.06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.09</td>
</tr>
<tr>
<td>NE</td>
<td>33.75 - 56.24</td>
<td>0.45</td>
<td>2.3</td>
<td>0.31</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.07</td>
</tr>
<tr>
<td>ENE</td>
<td>56.25 - 78.74</td>
<td>1.26</td>
<td>6.53</td>
<td>1.02</td>
<td>0.11</td>
<td>0.02</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8.95</td>
</tr>
<tr>
<td>E</td>
<td>78.75 - 101.24</td>
<td>1.74</td>
<td>7.54</td>
<td>1.37</td>
<td>0.26</td>
<td>0.06</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10.99</td>
</tr>
<tr>
<td>ESE</td>
<td>101.25 - 123.74</td>
<td>1.89</td>
<td>6.3</td>
<td>1.49</td>
<td>0.28</td>
<td>0.06</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10.04</td>
</tr>
<tr>
<td>SE</td>
<td>123.75 - 146.24</td>
<td>3.3</td>
<td>9.77</td>
<td>2.48</td>
<td>0.52</td>
<td>0.14</td>
<td>0.05</td>
<td>0.02</td>
<td>0</td>
<td>0</td>
<td>16.28</td>
</tr>
<tr>
<td>SSE</td>
<td>146.25 - 168.74</td>
<td>5.28</td>
<td>17.93</td>
<td>5.24</td>
<td>1.23</td>
<td>0.34</td>
<td>0.1</td>
<td>0.02</td>
<td>0.01</td>
<td>0</td>
<td>30.16</td>
</tr>
<tr>
<td>S</td>
<td>168.75 - 191.24</td>
<td>1.81</td>
<td>10.01</td>
<td>5.26</td>
<td>1.53</td>
<td>0.39</td>
<td>0.1</td>
<td>0.02</td>
<td>0</td>
<td>0</td>
<td>19.12</td>
</tr>
<tr>
<td>SSW</td>
<td>191.25 - 213.74</td>
<td>0.11</td>
<td>0.57</td>
<td>0.2</td>
<td>0.05</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.94</td>
</tr>
<tr>
<td>SW</td>
<td>213.75 - 236.24</td>
<td>0.03</td>
<td>0.04</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.07</td>
</tr>
<tr>
<td>WSW</td>
<td>236.25 - 258.74</td>
<td>0.01</td>
<td>0.03</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.04</td>
</tr>
<tr>
<td>W</td>
<td>258.75 - 281.24</td>
<td>0.05</td>
<td>0.02</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.08</td>
</tr>
<tr>
<td>WNW</td>
<td>281.25 - 303.74</td>
<td>0.05</td>
<td>0.03</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.08</td>
</tr>
<tr>
<td>NW</td>
<td>303.75 - 326.24</td>
<td>0.05</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.06</td>
</tr>
<tr>
<td>NNW</td>
<td>326.25 - 348.74</td>
<td>0.02</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.03</td>
</tr>
<tr>
<td>Total Percentage</td>
<td>16.08</td>
<td>61.16</td>
<td>17.39</td>
<td>4.00</td>
<td>1.03</td>
<td>0.28</td>
<td>0.06</td>
<td>0.01</td>
<td>0</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

4.4.3 Wave Period

Statistics for the dominant, or peak, spectral wave period (T_p) at any given time are given in Table 10.7, Appendix D. Swell waves typically have periods ranging from 8 to 12 seconds, and wind waves (seas) typically have periods between 2 to 5 seconds. The average and maximum T_p values in the record are 9.8 s and 20 s respectively (Table 10.7).

Wave period seasonality is also evident and consistent with the observations for wave height and wave direction. The spring and summer months are characterised by shorter wave periods, and this is consistent with the prevalence of wind waves generated by afternoon sea breezes during summer. Wave period is typically longer over the late autumn to winter months (March to August), and this is consistent with the occurrence of larger, storm waves.

4.4.4 Applicability to SWAN modelling

Wave parameters selected for use in the SWAN modelling program to represent the various storm wave heights, direction and periods that may occur at Port Stephens are described in Section 4.10.3.

4.5 Wind Climate

Wind data from the Bureau of Meteorology’s Williamtown weather station (~35 km southwest of Pindimar) were analysed for this study. The wind data record spans 21 years from 1989 to 2009 inclusive. MHL (1996) compared Jimmys Beach and Williamtown wind data, finding that Williamtown...
data is appropriate for use in Port Stephens. A summary of recorded maximum yearly wind speeds for each directional octant is given in Table 10.8, Appendix D.

Our analysis of the Williamtown data indicated the strongest winds occurred from the north west, west and south east directions. This correlates well with the analyses of MHL (1996). For combined ocean swell and wind events, winds from the east, south east and south are of relevance, as these directions combine with the most frequent storm wave directions at Port Stephens. Again, this analysis is consistent with the findings of MHL (1996).

The maximum yearly wind speeds from each wind direction were analysed for best fit to a range (65) of probability distribution functions. The Generalised Extreme Value probability distribution function was found to provide the best fit across all of the wind directional sectors. That distribution function was used to derive wind speeds for the 1, 5, 20, 25 and 50 year Average Recurrence Interval (ARI) events, as given in Table 4.5. For some wind directions, the data record was insufficient to define values for ARI's greater than 20 years (e.g., NE, SS directions).

<table>
<thead>
<tr>
<th>Average Recurrence Interval (years)</th>
<th>Wind Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NN</td>
<td>NE</td>
</tr>
<tr>
<td>1</td>
<td>7.84</td>
</tr>
<tr>
<td>5</td>
<td>9.84</td>
</tr>
<tr>
<td>10</td>
<td>10.44</td>
</tr>
<tr>
<td>50</td>
<td>18.60</td>
</tr>
</tbody>
</table>

4.6 Hydrodynamics

Port Stephens is a drowned river valley estuary (Roy et al. 2001). As tides dominate the overall estuarine hydrodynamics, it is classed as tide-dominated (Vila-Concejo et al., 2007). However, the estuary is located along a micro-tidal, wave dominated coastline with a wide entrance. As such, ocean waves restrict the deposition of an ebb-tidal delta and propagate into the estuary to affect the morphology of the flood-tide delta and adjacent estuarine beaches. Locally generated wind waves also affect sediment transport and morphology of the flood-tide delta and estuarine beaches (Vila-Concejo et al., 2007). Wave-induced currents at the sandy shorelines are said to be moderated by the tidal water level (Vila-Concejo et al., 2009).

There is minimal attenuation of the tide across the Port Stephens Estuary’s flood tide delta due to the estuary’s wide entrance (1.24 km, Vila-Concejo et al., 2007). The tidal range is amplified towards the western end of the estuary, with the measured tidal range greater at Karuah River than at the ocean entrance (MHL, 1998). The tidal range at North Arm Cove was also found to be amplified, by up to 0.1 m compared with the tidal range at Tomaree. In general, peak of the tide occurred ~ 1½ hours after the peak at Tomaree at North Arm Cove. Measurements by PWD (1998) over a spring tide indicated a significant reduction in the tidal prism between the estuary entrance and North Arm Cove (from $168 \times 10^6$ m$^3$ for the ebb and $165 \times 10^6$ m$^3$ for the flood tide to $5.5 \times 10^6$ m$^3$ for the ebb and $4.9 \times 10^6$ m$^3$ for the flood tide).
Tidal asymmetry refers to the dominance of either flood (i.e. incoming) tide or ebb (i.e. outgoing) tidal flow velocities during a tidal cycle. The dominant phase is said to be that with faster velocities, and so is typically of shorter duration (Austin et al., 2009).

Deeper channels in estuaries tend to be ebb-tide dominated, while shallower areas are flood-tide dominated. In the study by Austin et al. (2009), ‘double’ dominance (i.e., both velocities and duration were greater) was found in parts of the estuary. The flood tide delta was found to be flood tide dominant (both for duration and velocities), while ebb-tide dominant channels existed adjacent to the north and south headlands at the estuary entrance.

For the Pindimar shoreline, we may assume that deeper channels suggest ebb-tide dominated areas, while shallower areas suggest flood tide dominated areas. The majority of the nearshore surrounding Upper Pindimar is flat, shallow and exposed during low tide. The southern shoreline of Bundabah (Section 16) appears to be fairly deep, while the northern shoreline section (15) has shallow sections. It is likely that there are both ebb and flood-tide dominant sections in North Arm Cove, the locations of which would need to be identified through more detailed flow gauging and modelling.

4.7 Geomorphology

Port Stephens is divided into two basins: an eastern basin extending ~ 10 km from the harbour entrance to the ~ 800 m wide channel confined by bedrock at Soldiers Point; and a western basin extending from Soldiers Point to the entrance of the Karuah River (MHL 1999, Austin et al., 2009).

The study area lies within the eastern basin, and is affected by the full tidal range and associated tidal currents as well as wind, wind waves and swell that may penetrate the Port Stephens entrance, particularly during large southerly swells.

The ocean entrance spans approximately 1.2 km between volcanic outcropping headlands (Tomaree, Yacaaba) and faces the south east, towards the dominant ocean swell directions. The basin has a maximum width of 5 km (Austin et al., 2009).

At the estuary mouth lies the large flood tide delta, which extends from the entrance westward over an area of 22.5 km² (Austin et al., 2009). Complex interactions between tidal currents, waves, wind and occasional fluvial flows from the Myall River have formed and continue to rework the sand shoals, channels and islands (e.g. Corrie Island) of the flood-tide delta and adjacent shorelines (e.g. Winda Woppa, Jimmys Beach, Shoal Bay). The Myall River is said to contribute minimal fluvial sediment input to the eastern basin (MHL, 1999).

Wave breaking across the marine tidal delta at the estuary entrance and across sand shoals within the estuary westward to approximately Corlette has been observed during large ocean swells. This illustrates the exposure of most of the eastern basin to oceanic swell.

The shoals act to dissipate wave energy before it reaches the shoreline. Natural changes to shoal depth and shape can change wave breaking patterns and wave focussing patterns. This may result in the increased exposure or protection of foreshores in lee of the shoals. Changes to the length of spits extending from Corrie Island have been suggested by stakeholders and the community as one possible cause of erosion at Pindimar. Shortening of that spit would increase exposure of the foreshores in the lee of Corrie Island. Results from wave modelling (Section 4.10) provide a better understanding of the exposure of Lower Pindimar and Pindimar shorelines to swell and wind waves.
The movement of sand and shoals and subsequent wave breaking is a natural and dynamic process and will variously result in erosion and accretion of shorelines. Such erosion and accretion cycles are an irregular and ever changing process that is typical for natural shorelines. However, such natural variations in shoreline behaviour can become a hazard where development is inappropriately sited, or inappropriate treatment measures (such as unauthorised seawalls) act to exacerbate the erosion impacts.

4.8 Photogrammetry Analysis

OEH provided photogrammetry of the Pindimar Study area, which involved digitisation of the shoreline and other features of interest (mangroves, sandflats, oyster leases, boat ramps, structures etc) from historical aerial photography in 1951, 1968, 1986 and 2001. Reference points such as houses and roads that have been present across the photographic dates show good agreement, suggesting the differences observed in shoreline position or mangroves etc are not an artefact of the photogrammetry itself, and instead are indicative of changes at the shoreline over time.

The photogrammetry from 1951, 1968, 1986 and 2001 has been compared and changes described for each of the shoreline sections in the following chapters.

4.9 Site Inspection

A detailed site inspection over two days was conducted of the Lower Pindimar, Pindimar, Upper Pindimar and Bundabah shorelines. Over the course of the inspection, a total of 139 GPS reference points with accompanying photographs and notes were recorded detailing:

- the extent of any erosion scarps or accretion events, and relative timing (e.g. recent, or slumped from age)
- foreshore protection structures, their general design and construction materials
- vegetation extents and general condition, particularly mangroves in intertidal areas
- other pertinent features which may provide evidence of physical processes (e.g. sediment build up at groyne structures, if present)

The outcomes of the site inspection for each the shoreline sections are discussed in the subsequent chapters.

4.10 Wave Modelling in SWAN

Wave modelling was conducted in order to investigate the potential wave heights at the study area shorelines, as generated by incoming swell waves or wind generated waves under various water level conditions. The Simulating WAves Nearshore (SWAN) wave modelling software was used to propagate swell waves from 100 m water depth offshore into the Port Stephens estuary and the study area shoreline. The SWAN software was also used to apply wind stresses to generate and propagate wind waves within Port Stephens. The wave parameter outputs (height, period and direction) along the shoreline were then assessed to determine which conditions (wind, swell, water level) generate waves that may result in erosion of the study area shorelines.
4.10.1 The SWAN Model

The Simulating WAves Nearshore (SWAN) model is a wave refraction model which may be used to simulate the formation and propagation of waves in deep, intermediate and finite depths.

The SWAN model is able to simulate the following physical phenomena of interest to this study (Delft, 2010):

- Wave generation by wind
- Wave propagation in time and space
- Wave shoaling and refraction, due to depth, bottom friction and bathymetric features
- Wave frequency shifting due to non-stationary depth.
- Nonlinear wave-to-wave interactions (quadruplets and triads).
- Depth-induced breaking and
- Wave-induced set up

While SWAN does not explicitly model diffraction, diffraction effects are simulated by applying directional spreading of the waves, typically taken to be 2 – 5 ° for swell waves, and 10 – 30 ° for wind waves.

4.10.2 Bathymetric Grid

Bathymetric data for the study area was derived from the following sources:

- Port Stephens Hydrographic Survey 2007 (Draft) collected and supplied by OEH (formerly Department of Environment, Climate Change and Water)
- Myall Lake & Myall River Hydrographic Survey July 2001 – July 2002 collected and supplied by OEH, used for regions in Pindimar Bay, the lower Myall River back channel and Corrie Island not covered by the 2007 Hydrosurvey
- The Australian Hydrographic Service bathymetric chart AUS00209 of Port Stephens. The Chart was used for regions of the Port Stephens estuary not covered by 2001 or 2007 Hydrosurvey (most notably west of Fame Cove, including Bundabah) and from the estuary entrance to approximately 6.5 km offshore
- The Australian Bathymetry and Topography Grid - 250 m Digital Elevation Model supplied by Geoscience Australia in 2006. This coarse bathymetric grid was used for oceanic regions beyond 6.5 km from the estuary mouth.
- Aerial Laser Survey data supplied by Great Lakes Council, to define land and intertidal areas of the Pindimar study area.

These data were combined (as described above) to produce DEMs: a coarse (50 m) DEM for offshore bathymetry; and a fine (10m) DEM for the Port Stephens estuary including the Pindimar study area.

Two SWAN model grids were then created from the DEMs. A coarse grid with points spaced at 150 m intervals, covering an area of 25.5 km² and extending from the Port Stephens entrance to ~
100 m water depth, using data from both DEMs as appropriate. A smaller grid with points spaced at 50 m intervals was created of the Port Stephens estuary extending from the entrance to the Karuah River (~ 30 km) using data from the fine grid DEM. The extent of the coarse and fine grid models and both DEMs are illustrated in Figure 4-1.

4.10.3 Selection of Model Input Parameters

The purpose of the wave modelling is to investigate the swell wave, wind wave and water level conditions that may result in erosion upon the study area shorelines. Thus, the parameters to be investigated with the modelling process were selected through consideration of the background data review, site inspection and site interviews.

The background data review and site interviews indicated that erosion was typically observed during storms, as opposed to average or seasonal conditions. The storms reported variously involved wind, high tide (high water levels) and waves (from wind or swell). Thus, the wave and wind parameters were selected to represent typical storm conditions that may be observed with particular emphasis on those events occurring over time scales within living memory (~ 50 years) and also, time scales relevant to engineering design (10 – 30 years).

Processes in Bundabah vary somewhat from Lower Pindimar to Upper Pindimar because of the location of Bundabah within North Arm Cove. Bundabah is protected from swell waves, and will be affected by wind waves driven by a different wind direction (and speed) than at Pindimar. Further, Bundabah is more strongly influenced by tidal currents, which flow through North Arm Cove. Tidal hydrodynamics were discussed in Section 4.6, and the potential interaction of waves with tidal currents is discussed, where relevant, in the remainder of this report.

To ensure the outcomes of the wave modelling were suitable for the development of foreshore erosion protection conceptual designs as part of this study, typical ARI wind and wave heights used for design purposes in coastal engineering were also selected.

The following parameters were selected for modelling with SWAN:

- storm wave heights (defined as Hs > 3m for more than 1 hour) from the various swell wave directions (based upon their probability of occurrence as given in Table 4.4);
- average seasonal wave heights, for comparison with storm conditions;
- for design purposes, a 1 in 20 yr ARI and 1 in 50 yr ARI wave height from SSE (the most probable large storm wave direction given by the wave record, Table 4.4) and E direction (to represent a potential storm from the summer wave climate which has a more direct line of approach into Port Stephens);
- winds of 1, 5 and 10 year ARI from the various wind sectors, which represent a range of additional conditions likely to have been observed within typical living memory;
- for design purposes, the 1 in 20 yr ARI or 1 in 25 yr ARI (where available) wind from all relevant wind sectors, and the 1 in 50 yr wind from the SE and NW directions (refer Table 4.5);
- to represent potential water levels during storms, the HHWSS tide, 1 in 20 year and 1 in 50 year ARI water levels; and
• predicted sea level rise for 2050 and 2100 (as stipulated by the NSW Government, 2009), applied to the above water levels.

The model parameters and their combinations are listed in Table 4.6. The combination of a 1 in 20 year ARI water level and swell wave height is considered highly conservative because the joint probability of the two occurring simultaneously is greater than 1 in 20 years. However, it was investigated to further inform the selection of relevant foreshore design conditions.

4.10.4 Model Simulations

The following table summarises the model simulations conducted in SWAN. In short, model runs were conducted on the coarse model grid to simulate the propagation of swell wave parameters from offshore into nearshore. Output from the coarse model grid calculations was then used to simulate swell wave parameters on a finer scale within the Port Stephens estuary using the fine model grid.

At the finer scale, simulations were also conducted to simulate the generation of wind waves within the estuary. The results from these simulations are used for comparison of wave heights from the various generation mechanisms.

4.10.5 Model Outputs and Discussion

4.10.5.1 Swell Waves

Significant wave heights ($H_s$) derived from modelling of ocean storm waves have been output at points along the shoreline sections (refer Figure 1-4) for all water level conditions modelled, as presented in Table 10.9 to Table 10.13, Appendix E. Spatial wave model output for various storm wave heights, direction and water level scenarios are illustrated in Figure 10-6 to Figure 10-13.

The wave modelling was extensive, considering greater scenarios and for various potential water levels including sea level rise to 2100. We have considered the results at each shoreline section in our analysis of potential erosion mechanisms and foreshore protection strategies. The results are discussed for each of the shoreline sections in the following chapters.

4.10.5.2 Wind Waves

Wind waves typically have shorter wave periods, as they are generated across shorter fetch lengths. It is typically accepted that waves of shorter period (for a given wave height) are more likely to be erosive, as the wave is steeper, and less affected by bottom friction as the wave approaches the shoreline due to its shorter wave period.

Significant wave heights at each of the shoreline sections (refer Figure 1-4) generated by wind the various water level conditions modelled are presented in Table 10.14 to Table 10.18 in Appendix E.

Model outputs indicated waves generated locally by wind within the estuary tend to be of greater height than from swell waves entering the estuary entrance. Modelled wave heights at the study area shorelines are discussed for each of the shoreline sections in the following chapters. Spatial wave model output for various wind speed and direction and water level scenarios are illustrated in Figure 10-14 to Figure 10-29.
Figure 4-1 SWAN Model Grid Extents
Table 4.6  Wave, Wind and Water Level Inputs for SWAN Model

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<th>Waves</th>
<th>Dir’n</th>
<th>$H_s$ (m)</th>
<th>$T_p$ (s)</th>
<th>HHWSS</th>
<th>1 in 20 yr ARI</th>
<th>1 in 50 yr ARI</th>
<th>1 in 20 yr ARI + 2050 SLR</th>
<th>1 in 50 yr ARI + 2100 SLR</th>
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Table 4.7  Summary of SWAN Simulations

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<td>Coarse</td>
<td>1 in 20 yr ARI</td>
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<td>Coarse</td>
<td>1 in 50 yr ARI</td>
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<td>Coarse</td>
<td>1 in 20 yr ARI + 2050 SLR</td>
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<td>within estuary)</td>
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