A part of BMT in Energy and Environment

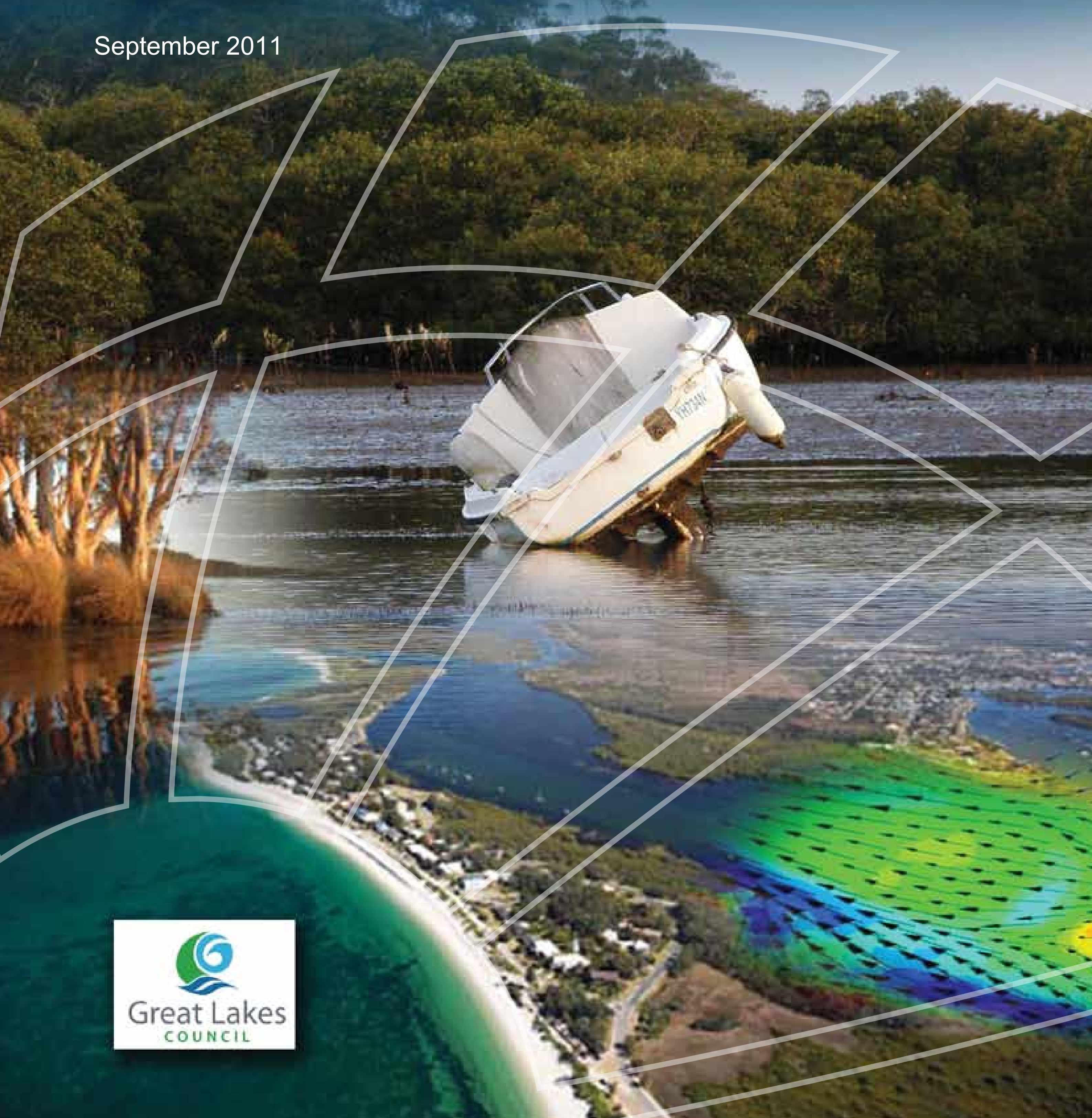
BMT WBM

"Where will our knowledge take you?"

Sediment and Hydrodynamic Assessment of the Lower Myall River Estuary and Preparation of Management Recommendations

Final Report

September 2011



Great Lakes COUNCIL

DOCUMENT CONTROL SHEET

BMT WBM Pty Ltd BMT WBM Pty Ltd 126 Belford Street BROADMEADOW NSW 2292 Australia PO Box 266 Broadmeadow NSW 2292 Tel: +61 2 4940 8882 Fax: +61 2 4940 8887 ABN 54 010 830 421 003 www.wbmpl.com.au	***Document :*** R.N1926.001.03.docx ***Project Manager :*** David Wainwright ***Client :*** Great Lakes Council ***Client Contact:*** Gerard Tuckerman ***Client Reference*** Contract No: 23/10 NS-SED-HYD-MYALLRIV

Title :	Sediment Hydrodynamic Assessment of the Lower Myall River Estuary and Preparation of Management Recommendations
Author :	David Wainwright, Dr Emma Gale, Dr Philip Haines, Luke Kidd
Synopsis :	A study report detailing an assessment of hydrodynamics and morphology of the Lower Myall River. The first part of the study identifies management issues through background data review, data analysis and community consultation. The study then involved development of hydrodynamic and morphodynamic numerical models of the Lower Myall River and entrance areas. Options for improving the condition of the river entrance were developed and were evaluated using the numerical models.

REVISION/CHECKING HISTORY

REVISION NUMBER	DATE OF ISSUE	CHECKED BY		ISSUED BY	
0- Draft (Data Review)	19/10/10	DJW		DJW	
2 – Second Draft	4/03/11	PEH		DJW	
3 - final	29/9/11	PEH		PEH	

DISTRIBUTION

DESTINATION	REVISION			
	0	2	3	4
Great Lakes Council	1-Electronic	1-Electronic	1-Electronic	
BMT WBM File	1-Electronic	1-Electronic	1-Electronic	
BMT WBM Library				

EXECUTIVE SUMMARY

The entrance of the Lower Myall River is highly dynamic. Ocean storms, swell waves, wind waves, tides and catchment runoff all contribute to regular changes in sand shoals and channels in and around the entrance area. Navigation through the entrance has been maintained by periodic and selective dredging of the Northern Channel, behind Corrie Island. The Eastern Channel, however, has not been dredged in recent years, and has progressively shoaled, particularly over the past 10 years or so.

This report investigates the shoaling of the Eastern Channel; its causes, its ramifications; and possible options for manipulation. A companion investigation, undertaken by DECCW in 2010, has explored the current ecological health and water quality of the Lower Myall River.

Recent shoaling of the Eastern Channel is linked to acute erosion of the Winda Woppa shoreline west of Barnes Rock, where a small wetland is now under threat. In this location, ocean waves have eroded the shoreline and are pushing sand westward toward the Eastern Channel (i.e. longshore drift). Analysis of beach data suggests that the **shoaling in the Eastern Channel is unlikely to be linked to erosion on Jimmy's Beach**, to the east of Barnes Rock.

Gauging and hydrodynamic modelling indicate that as the Eastern Channel has become constricted, more tidal flows are directed through the Northern (Back) Channel. Total tidal flows and levels upstream of the confluence of the two channels remains unchanged. What has changed, however, is the effectiveness of oceanic flushing within the lower reaches of the River. The Northern Channel is connected to Pindimar Bay some distance from the ocean, whereas the Eastern Channel is connected directly to the expansive Port Stephens flood tide delta. Therefore, water exchanged through the Eastern Channel is typically 'clean' seawater, whereas water exchanged through the Northern Channel is 'residual' Port Stephens water.

The DECCW (2010) study showed that Pindimar Bay and the Lower Myall River do not have poor water quality. Indeed the water quality is typical of estuarine environments, while the ecological health is considered very good, and comparable to other nearby estuarine locations in Port Stephens. **The recent constriction of the Eastern Channel therefore has not manifest in wider environmental impacts within the River to date.**

The shift in tidal flow preference from the Eastern Channel to the Northern Channel may, however, help to explain the perception of reduced water clarity and salinity within the River, which has been reported anecdotally over the past few years. Flushing analysis suggests that when the Eastern Channel dominates tidal exchange, environmental conditions in the lower Myall River would tend to be more oceanic/marine, whereas when the Northern Channel dominates, the conditions would tend to be more estuarine/brackish. Given the recent shoaling and associated shoreline erosion, it is conceivable that the Eastern Channel may eventually close completely. The timeframe for this to occur is unknown, and it may also require a catalyst, such as a large coastal storm. **If and when the channel does close, it is likely that the Lower Myall River will become more estuarine** (given 100% of tidal flows through the Northern Channel). Subject to further assessment, it is considered unlikely that complete closure of the Eastern Channel would have a detrimental impact on ecosystem health, although it may become less preferable for more marine-dependent species. There may also be a change to the aesthetics and amenity of the River, with a possible reduction in water clarity and effectiveness of seawater exchange.

Works within the Eastern Channel would be required to reduce the likelihood of complete closure, or to re-open the channel once closed. Depending on the scale of these works, seawater exchange could actually be increased within the river compared to existing conditions. But ultimately, such channel works would only primarily address aesthetics and amenity, through an increase in water clarity and seawater exchange. There is currently no over-arching environmental justification for undertaking channel works. But conditions should continue to be monitored closely in the future as the channel approaches closure. Any decision to undertake intervention works in the Eastern Channel would need to consider all benefits and costs, as well as the perspectives of all potential stakeholders, including the community.

Works in the Eastern Channel would essentially involve dredging. There is an opportunity for dredging of the Eastern Channel to be used as a source for future sand nourishment of Jimmy Beach. Recent nourishment works at Jimmys Beach have involved extraction of sand from the nearshore zone in an area near Yacaaba Headland. It is understood that the Yacaaba source may not be able to meet on-going nourishment demands in the future. The Eastern Channel therefore could be considered as an alternative or additional source for nourishment, subject to further investigations.

Any dredging program within the Eastern Channel would need to consider how quickly sand would re-fill the channel, and how often follow-up dredging may be required (if the channel is to remain open). Based on estimates of longshore drift, the channel would continue to infill at a rate of between 10,000 and 20,000m^3 per year. This rate could be reduced through the construction of a groyne at the western end of Winda Woppa Spit. A groyne would trap sand that continues to be eroded from the shoreline west of Barnes Rock and would help to maintain an open channel. The fillet of sand that builds in front of the groyne could also be used as a land-based source of sand for on-going nourishment.

If a groyne is not built, sand would need to be extracted subaqueously from the channel. This could be done using a mobile dredger as part of discrete dredging campaigns, or by using fixed-in-place infrastructure (such as a Sand Shifter device), where sand is fluidized, sucked into buried inlets and pumped ashore (this is currently done in the Noosa River and other locations for continuous nourishment of adjacent beaches).

Given that sand moving into the Eastern Channel is primarily the result of shoreline recession west of Barnes Rock, there may also be a need to return some sand to the eroded beach profile, particularly if access to the end of Winda Woppa Spit is to be maintained or the currently eroding wetland is to be protected. Excess sand removed from the channel by capital dredging could be stockpiled locally (e.g. at the end of Winda Woppa Spit) and used for nourishment as needed.

Initial capital dredging of the Eastern Channel would likely cost in the order of \$1.5 – 2.5 million, depending on the volume of sand removed (volumes of 55,000m^3 and 95,000m^3 have been investigated to date). The establishment of fixed-in-place infrastructure for permanent sand pumping from the channel would cost less than \$1 million, with on-going pumping costs of approximately \$150,000 per annum (delivering sand to Jimmys Beach at a rate of about 15,000m^3 per year).

By comparison, approximately \$1 million has been spent recently by Council and State Government nourishing Jimmy's Beach (total volume approximately 80,000m^3) as part of a 3 year nourishment trial (Jelliffe Consultants, 2003). Some 372,000m^3 of sand was previously (1984-1998) placed on Jimmy's Beach to mitigate erosion risks (Watson, 2000), giving an average beach nourishment of about 17,000m^3 per year over the past 25 years.

Background and History

The area of Port Stephens in the vicinity of the Eastern Channel (known locally as "Paddy Mars Bar") is ever-changing. The dynamism of the area is highlighted by the fact that Myall Point, a previous 2km long finger of sand extending south from the end of Winda Woppa, was completely destroyed during coastal storms in 1927 and 1929. Dredging of a navigable channel north of Corrie Island, dating back to the early 1900s, has also affected the pattern and distribution of tides and flood flows into and out of the Lower Myall River.

For the area west of Barnes Rock, coastal processes are continuing to push sand westward along Winda Woppa Spit. This sand has encroached into the Eastern Channel, which has responded by migrating westward and eroding the eastern shore of Corrie Island. Over the past 50 years, Corrie Island has receded by more than 100 metres. The rock wall in the Eastern Channel used to be the western (Corrie Island) edge of the channel - it now forms the eastern edge of the channel.

Consultation and Community Perspectives

Although the Eastern Channel has always been dynamic, it has become increasingly shoaled since about 2001. Local community members have raised concerns with all levels of Government regarding a perceived reduction in water clarity and water quality within the Lower Myall River.

As part of this project, a series of workshops were held with the Myall River Action Group (MRAG) to gather local perspectives. The first workshop involved clarification of the key community issues associated with Lower Myall River. At this workshop, the MRAG highlighted several areas of erosion and sedimentation as well as concern for reducing water clarity and water quality within the river, and in Pindimar Bay. As outlined above, the DECCW (2010) study showed that water quality and ecological health in the Lower Myall River and Pindimar Bay are typical of estuarine systems.

Areas of erosion and accretion raised by the MRAG included:

- Erosion of Corrie Island eastern shore;
- Erosion west of Barnes Rock into protected wetlands;
- Accretion along the edges of the Northern Channel;
- Accretion within the Lower Myall River main channel;
- Accretion in the vicinity of Singing Bridge.

The second workshop was carried out following background investigations and preliminary modelling of tides and oceanic flushing. The workshop put the previous MRAG issues into a scientific context, and helped explain why particular processes are occurring.

The third workshop was aimed at identifying a range of potential options that could address the initial issues of concern. The options were developed taking into consideration the science behind the issues, and practicalities of implementation and feasibility of outcomes. Although tabled initially, a number of grand-scale options like rebuilding Myall Point were rejected as impractical during the workshop.

It is envisaged that there may be a range of alternative community views on this topic, and wider community engagement is proposed through the public exhibition of this document.

Evaluation of Intervention Options

The ecological health of the Lower Myall River is currently not compromised by the shoaled condition of the Eastern Channel. Intervention options for the Eastern Channel were therefore evaluated on the basis of improvements to aesthetics and amenity of the river, which fundamentally were the concerns of the MRAG.

Options that were initially considered to have excessively high capital costs (e.g. a fully trained entrance or rebuilding Myall Point) or unacceptable environmental or social impacts (e.g. infilling of the Northern Channel) were excluded from detailed analysis. Remaining intervention options focused on dredging within the Eastern Channel, with and without a groyne at the end of Winda Woppa spit, which could potentially improve the longevity of a dredged channel.

As part of the evaluation process, consideration was given to the 'do nothing' option. For this option, it was assumed that the Eastern Channel was completely closed. In the absence of any intervention works, there is a reasonable likelihood that the channel would eventually close (although the timeframe for this to occur is unknown).

Computer modelling of the options confirmed that dredging within the Eastern Channel would increase tidal flows through the Eastern Channel, while reducing tidal flows through the Northern Channel. The ratio of flows between the Eastern and Northern Channels would return to about 3:1, which is comparable to the ratio measured in 1975 (this compared to the most recent flow gauging in 2009 when the ratio was approximately 1:1). Tidal flows upstream of the confluence would remain unchanged.

The increased flow through the Eastern Channel resulting from dredging would improve oceanic flushing in the lower reaches of the River. This is because tides in the River would exchange more with 'cleaner' seawater nearer the entrance to Port Stephens, and less with Pindimar Bay. There was no significant difference in flushing for the different dredging options modelled – all options gave a similar level of improvement.

Analysis of longshore drift along the shoreline west of Barnes Rock was used to determine the potential rates of infill for a dredged channel. A longshore drift rate of between 10,000 – 15,000m^3/yr has been calculated. For channel dredging of 55,000m^3, approximately 50% of the dredged material will return within about 3 years, while for dredging of 95,000m^3, 50% infill would take roughly 5 years. A groyne at the end of Winda Woppa spit would improve the longevity of dredging, but comes at a high capital cost given the length of the structure required. A groyne would also be a very prominent 'hard' feature of the landscape, and its wider environmental and social impacts would require careful consideration. Within such a dynamic environment, it would be difficult to ensure that the groyne remains functional in the future.

An alternative and possibly more pragmatic option may be a permanent sand pumping system, which can be modified and adjusted to suit specific requirements (including alternative disposal locations). This adaptable and flexible approach could also accommodate potential future variability associated with sea level rise and climate change impacts. It would require, however, an on-going financial commitment as part of a continuous maintenance program. This option would be particularly suited if sand pumped out of the channel could be directed onto Jimmys Beach as part of a permanent nourishment solution. Placement of sand onto Jimmy's Beach would need to be supported by an environmental assessment of the impacts of introducing 'new' sand to this part of the shoreline.

Benefit Cost Analysis

Undertaking intervention works in the Eastern Channel would likely improve the aesthetics and amenity of the River (through improved water clarity and oceanic flushing), but any wider benefits would be limited. When considering the possible dual function of supplying sand for on-going nourishment of Jimmys Beach, the benefit cost rate becomes more attractive. Indeed there may only be a marginal cost difference, if any, for extracting nourishment sand from the Eastern Channel compared to the current reserve adjacent to Yacaaba Headland, when considered over longer time periods (i.e. 20 years +). Again, this assumes that there would not be any detrimental impacts associated with using this sand on Jimmy's Beach.

Recommendation

A sand scoping study is being considered that will investigate long-term management and nourishment of Jimmys Beach (including sand sourcing, delivery and placement). It is important that the option of sourcing sand from the Eastern Channel, either via a permanent sand pumping system or discrete dredging campaigns, be included and evaluated in this context, as well as alternative sand sources such as the Yacaaba sand deposit that has been used for most recent nourishment works.

The ecological impacts of erosion on the eastern shore of Corrie Island as well as the small wetland to the west of Barnes Rock should also be assessed, and an alternative management strategy be developed if dredging of the Eastern Channel is not to be pursued in the near future.

If (and when) the Eastern Channel closes, the ecosystem health of the Lower Myall River should be re-assessed to examine any wider environmental impacts of the channel closure.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Study Area

The Port Stephens / Myall Lakes estuary is located approximately 50km north of Newcastle, NSW. The Lower Myall River enters Port Stephens from the north, while the other major tributaries to the estuary, the Karuah River and Tilligerry Creek, enter from the northwest and south, respectively (Figure 1-1).

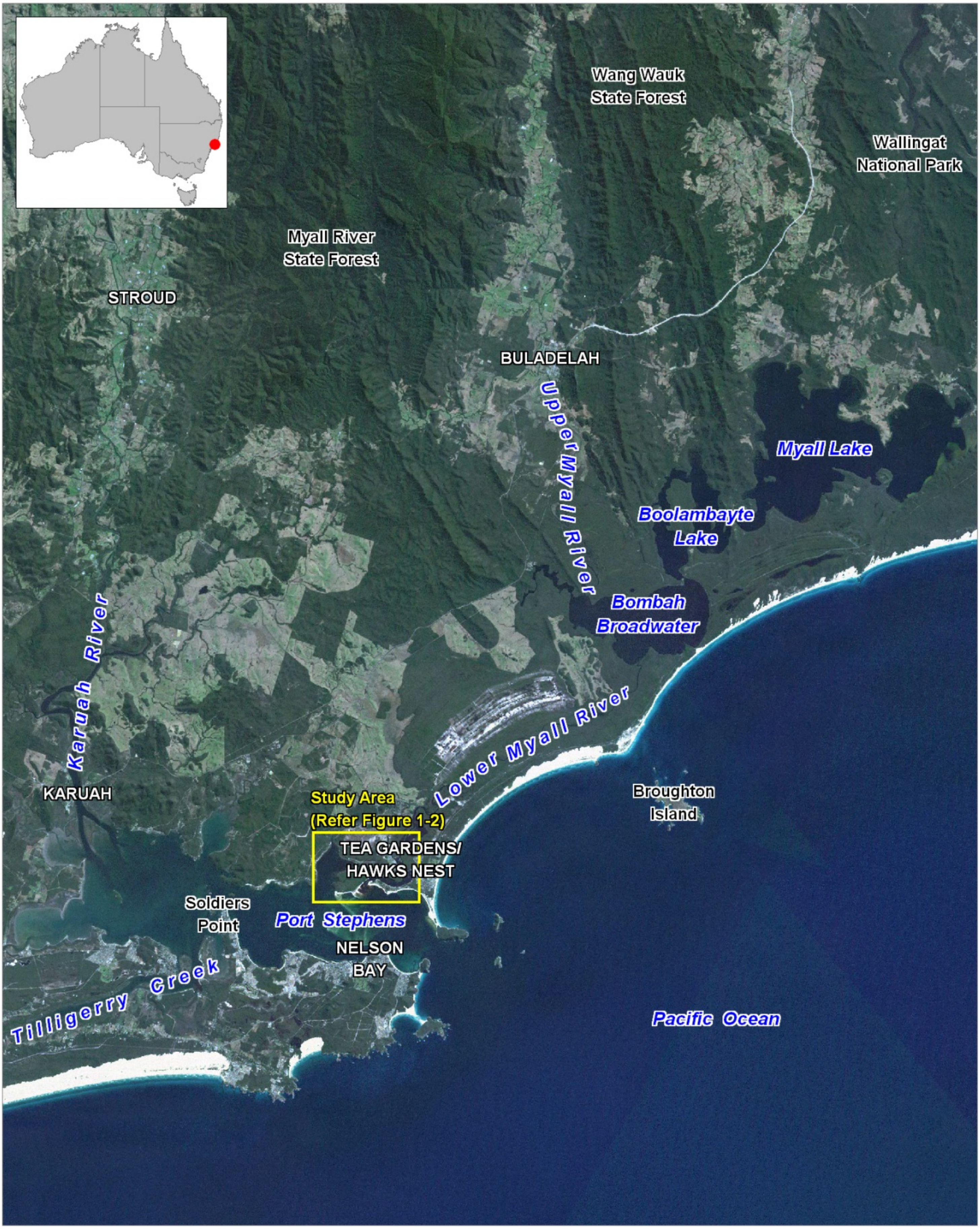
The Myall Lakes are located north of Port Stephens, connected via the Lower Myall River. The Lakes comprise a series of three interconnected lakes (Bombah Broadwater, Boolambayte Lake and Myall Lake). The Lower Myall River is around 30 km long extending from Bombah Broadwater to Port Stephens. The River enters Port Stephens through a channel between Corrie Island and Winda Woppa spit (the eastern or “Shortcut” Channel), and also through a channel to the immediate north of Corrie Island (the northern or “Back” Channel) into Pindimar Bay (Figure 1-2).

An extensive marine flood tide delta covering an area of some 22.5 km^2 extends across the entrance to Port Stephens and includes area adjacent to Winda Woppa and the Eastern Channel (Austin *et al*., 2009). This delta has been formed during the Holocene period by the complex interaction of tides, waves and minor flows from the Lower Myall River. The delta is shallow, typically less than 4 to 8 metres below mean sea level. A steep dropover at the distal edge of the delta into deeper water extends roughly north-south from Corlette Head to the western side of Corrie Island. West of the dropover, water depths increase to 20 metres (MHL, 1999).

Interactions between tidal currents, swell waves, wind waves and occasional fluvial flows from the Myall River continue to rework the sand shoals (e.g. Paddy Marrs Bar, Middle Ground), channels and islands (e.g. Corrie Island) of the flood-tide delta and adjacent shorelines. Episodic erosion of the eastern side of Corrie Island occurs during storms with large ocean waves. Tidal flows are also presently eroding the eastern side of Corrie Island.

An estuarine beach complex extends 4.2 km westwards from Yacaaba Headland to the Myall River mouth, including the Yacaaba barrier, Jimmys Beach and Winda Woppa spit. Detailed investigations are ongoing and aim to better understand morphologic changes of the flood-tide delta and these adjacent estuarine beaches. A recent report by Vila-Concejo *et al*. (2008) concluded:

- a sand wave at Yacaaba Barrier has undergone various cycles of accretion and erosion, with westerly migration of up to 70 metres per year between 1993 to 2003 followed by relative stability, with occasional storm events (e.g. June 2007) allowing for accretion of the sand wave;
- Ongoing recession of Jimmy’s Beach, to the east of Barnes Rock, threatens a number of residences along The Boulevard. Recession has occurred at an average rate of 1 metre per year between 1951 and 2006.
- The shoreline between the western end of the sand wave near Yacaaba headland to the recession area has been stable over the medium to long term; and



Title:

Locality Plan

Figure: 1-1

Rev: A

N

0 5 10km

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_001_100928 Locality Plan.WOR

Title:
Study Area

Figure: **1-2**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in 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.

N

0 0.75 1.5km
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_005_100929 Study Area.WOR

- Winda Woppa spit is subject to ongoing retreat and westward extension (approximately 800 metres since 1951).

Earlier work by Vila-Concejo *et al*. (2007) also notes that sediment transport patterns inside the Port Stephens estuary are not clear and that future investigation should be undertaken, using a morphodynamic model to represent the key processes. To improve management of the system, Vila-Concejo *et al*. (2007) highlight that sediment exchanges need to be quantified to better understand and protect public and private assets.

Historically, the main entrance to the Lower Myall River was the Eastern Channel between Corrie Island and Winda Woppa. Anecdotal evidence indicates that ships previously unloaded ballast rock within the channel prior to traversing the shallower depths to Tea Gardens (with the rock still evident today). The former Myall Point is claimed to have extended from the northern foreshore to within approximately 100 metres of the southern foreshore of the estuary (Umwelt, 2000), although historical mapping presented in Thom *et al*. (1992) suggests that this claim is unfounded, at least in contemporary times, with some 2.5km between the southern tip of Myall Point and the Port Stephens southern shoreline in 1920.

Myall Point was still nonetheless an historical sand feature extending southwards from Winda Woppa, parallel to Corrie Island extending the Lower Myall River well into the Port Stephens waterway. Myall Point was destroyed during severe storms in 1927 and 1929 (Umwelt, 2000). In addition, dredging to form the Northern Channel is believed to have commenced around the turn of the 20^{th} century to assist with navigation between Pindimar Bay and Tea Gardens. Both these events are reported to have initiated major changes to the entrance configuration of the Lower Myall River (MHL, 1999).

The changes to the Lower Myall River entrance include shoaling of the Eastern Channel, which has now become less tidally dominant compared to the Northern Channel. The Eastern Channel has become restricted to the point that access is only possible at high tide by experienced navigators. The Northern Channel has become the main navigable entrance to the Lower Myall River.

In the past, there has been pressure to dredge the Eastern Channel between Corrie Island and Winda Woppa spit, and subsequently use the dredged spoil to nourish Jimmys Beach. However, there is doubt that river flow would be able to naturally maintain such a channel, thus necessitating on-going dredging of the channel (MHL, 1999).

Shoaling of the Northern Channel has also been an ongoing issue, causing additional problems for navigation into the Lower Myall River. It has been necessary to dredge this channel to maintain navigation, particularly for the larger boats – dredging has most recently been carried out in late 2010.

The continued shoaling of both channels means that ongoing dredging has become a logistical and financial issue for Council and the State Government. Other issues associated with changes to entrance conditions include the cost of relocating navigational markers, risks to commercial and recreational vessels as they cross the shoals and potential loss of tourism into the Tea Gardens and Myall River due to difficulties with navigation (Umwelt, 2000).

1.2 Detailed Study Area

The present study focuses on the Lower Myall River downstream of the Singing Bridge (between Tea Gardens and Hawks Nest) and its entrance into Port Stephens (refer Figure 1-2). It includes the Northern (Back) Channel, the Eastern (Shortcut) Channel, Corrie Island, and Winda Woppa Spit to the west of Barnes Rock.

The issues of concern within the focus area are influenced by coastal and estuarine processes in adjacent areas, such as the Lower Myall River upstream of the Singing Bridge, Jimmy's Beach to the west of Barnes Rock and the broader flood tidal delta which occupies much of Port Stephens to the east and south of Corrie Island. In turn, processes and morphodynamic responses in those areas are influenced by hydrodynamics and wave processes in Port Stephens, the Myall Lakes and the ocean beyond Yacaaba and Tomaree Headlands.

While the issues of concern to this study apply to the detailed investigation area, the broader processes affecting those issues have been considered where appropriate.

1.3 Objectives

The objectives of this study are:

- To undertake a sediment and hydrodynamics assessment of the Lower Myall River estuary that provides specific recommendations for the long term management of navigation, shoaling and river health in the Lower Myall River;
- To incorporate inputs from stakeholders and community concerns particularly regarding the restriction to safe navigation caused by shoaling in the Eastern and Northern Channels and Lower Myall River, and erosion of the Winda Woppa Peninsula west of Barnes Rock;
- To address community concerns relating to hydrodynamic and sediment dynamic processes that influence waterway conditions within the study area noting that maintenance dredging has previously been identified within the Port Stephens and Myall Lakes Estuary Management Plan (2000) as a potential management option; and
- To present a better understanding of key coastal processes influencing waterway conditions (e.g. hydrodynamics, morphology, waves, climate change, and tidal interactions).

1.4 Methodology

A number of tasks have been undertaken to achieve the abovementioned objectives. These tasks have been undertaken broadly in three stages:

- Identifying the issues;
- Validating those issues; and
- Addressing the issues.

The project stages are shown schematically in Figure 1-3 and discussed further in the following sections.

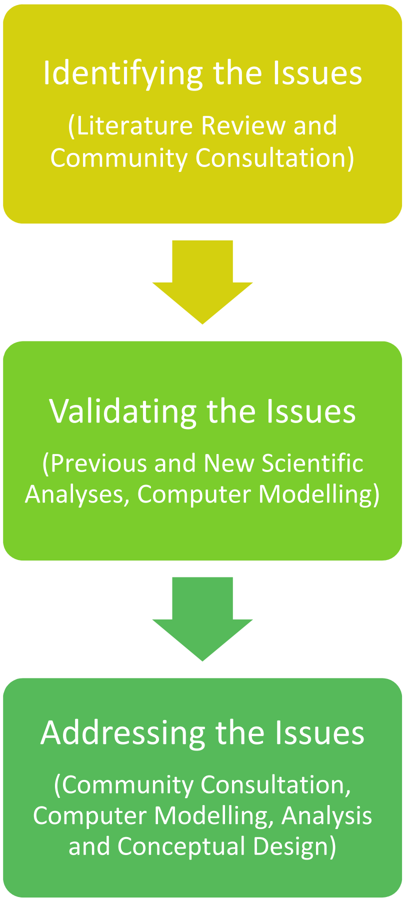


Figure 1-3 Project Stages

1.4.1 Identifying the Issues

Issue identification is described in Chapter 2. The first component of identifying the issues involved review of existing literature to extract those issues raised in the past. During this process, initial contact was also made with the community to highlight issues of present concern.

Following the literature review, local community representatives and other stakeholders were presented with the preliminary list of identified issues and asked to contribute further in refining that list.

1.4.2 Validating the Issues

The issue validation stage aimed to confirm and quantify the identified issues using both previous and new analyses of available data from the study area and surrounds. The background data and previous analyses are presented in Chapter 3, which also contains some further analyses undertaken as part of the present study (excluding numerical modelling, which is documented in Chapter 4).

Chapter 3 provides the building blocks necessary for the development of a computer model capable of simulating hydrodynamics, waves, sediment transport and geomorphology. The development and validation of the computer model to measured data is described in Chapter 4.

The computer model was subsequently used to replicate the processes underlying the identified issues. The computer model's predictive capability enables it to make quantitative assessments of future behaviour. This ability provides further validation of the importance of identified issues. The model can also predict the impact of future climate change (sea level rise, increased storminess). The validation stage has resulted in a refined list of issues that could be targeted by management strategies.

1.4.3 Addressing the Issues

This stage of the project focussed on the development and assessment of potential management options, assessment of those options and recommendation of a future management strategy. Possible options were identified through a process of community consultation, suggestions from the past and the experience of the study team, including insight gained from computer modelling during the validation stage of the project.

The options were shortlisted using a number of criteria including planning constraints, and a qualitative “triple bottom line” assessment of environmental, economic and social factors. The shortlisted options were subjected to further analysis, including computer modelling to determine their efficacy at addressing the identified issues.

The process of addressing the issues is presented in Chapter 5, and a preferred future management strategy and conclusion are presented in Chapter 6.

2 IDENTIFYING THE ISSUES

This chapter documents the identification of issues relevant to sediment and hydrodynamic processes in the Lower Myall River. The issues were identified through:

- Review of existing literature; and
- Community Consultation.

2.1 Existing Literature

A number of documents prepared in recent years describe coastal and estuarine processes in Port Stephens and the Lower Myall River. This section provides a summary of the relevant aspects of these documents, as they relate to understanding the hydrodynamics and sediment characteristics, within and around the study area.

2.1.1 Paleo Geomorphology

The period extending from around 2.6 million years to around 10,000 years before the present is known as the Pleistocene epoch. This epoch is characterised by glacial periods (lasting around 80,000 – 100,000 yrs. with a lowered sea level, typically around 120 m below present sea level) and interglacial periods (typically lasting around 20,000 years with higher sea level, typically at or near present sea level +/- 20 m). The period extending from around 10,000 years ago to the present is known as the Holocene epoch, and is characterised by an interglacial period with an approximate “still-stand” sea level for the past 6,000 years.

Processes acting during the late Pleistocene (from around 140,000 years ago) to the present have shaped many of the identifiable features of New South Wales present day coastline. During the last interglacial period (sea level peak at around 120,000 years ago) mean sea level was approximately 5 m above that of today. The dune system that formed under these times is now known as the Pleistocene inner sand barrier, and is located landward of the present coastline. Stabilisation of the present sea level, following subsequent glacial and interglacial times has formed a second or ‘outer’ Holocene barrier sand dune system along the present day coastline. The Lower Myall River presently drains the Myall Lakes system through the topographic depression between the inner and outer barriers.

In the area north of Port Stephens, the outer barrier presently comprises both stable and mobile sections with dunes up to 30 m in height (MHL 1993). The inner barrier is located further inland comprising dunes and beach ridges which are less pronounced and sometimes not readily discernible. The Port Stephens estuary sits primarily within in the inner barrier system which extends some 5 - 10kms inland, creating sandy lowland areas adjacent to the estuary foreshore for much of its perimeter (MHL 1999).

Based on the dating of shell fragments from a remnant tidal delta in Bombah Broadwater, Thom *et al*. (1992) surmise that the Myall Lakes previously discharged directly to the ocean in the vicinity of Mungo Brush where the outer barrier is very narrow. It was estimated that approximately 2000 years ago, this entrance closed permanently, and all catchment inflows to the lakes were subsequently diverted southwards along the low lying inter-barrier depression, creating the Lower Myall River.

The Lower Myall River has become wider and deeper over the past 2000 years, and the net direction of marine-origin bed sediment transport is now upstream, towards Bombah Broadwater. This is evidenced by inspection of aerial photography showing the development of a flood tide delta where the Myall River enters the Bombah Broadwater, and the shape of bed forms in the Lower Myall River, which are typically oriented in an upstream direction.

2.1.2 Recent Geomorphology

Port Stephens can be split into two different geomorphologic sections, which are located to the east and west of Soldiers Point (a bedrock ridge). The deepest part of the Estuary (depths > 30 m) are located offshore of Soldiers Point. Port Stephens presently acts as a depositional environment for both marine and fluvial sediments (east and west of Soldiers Point), as discussed below.

The depositional areas of Port Stephens, as presented by Thom *et al.* (1992) are shown as Figure 2-1.

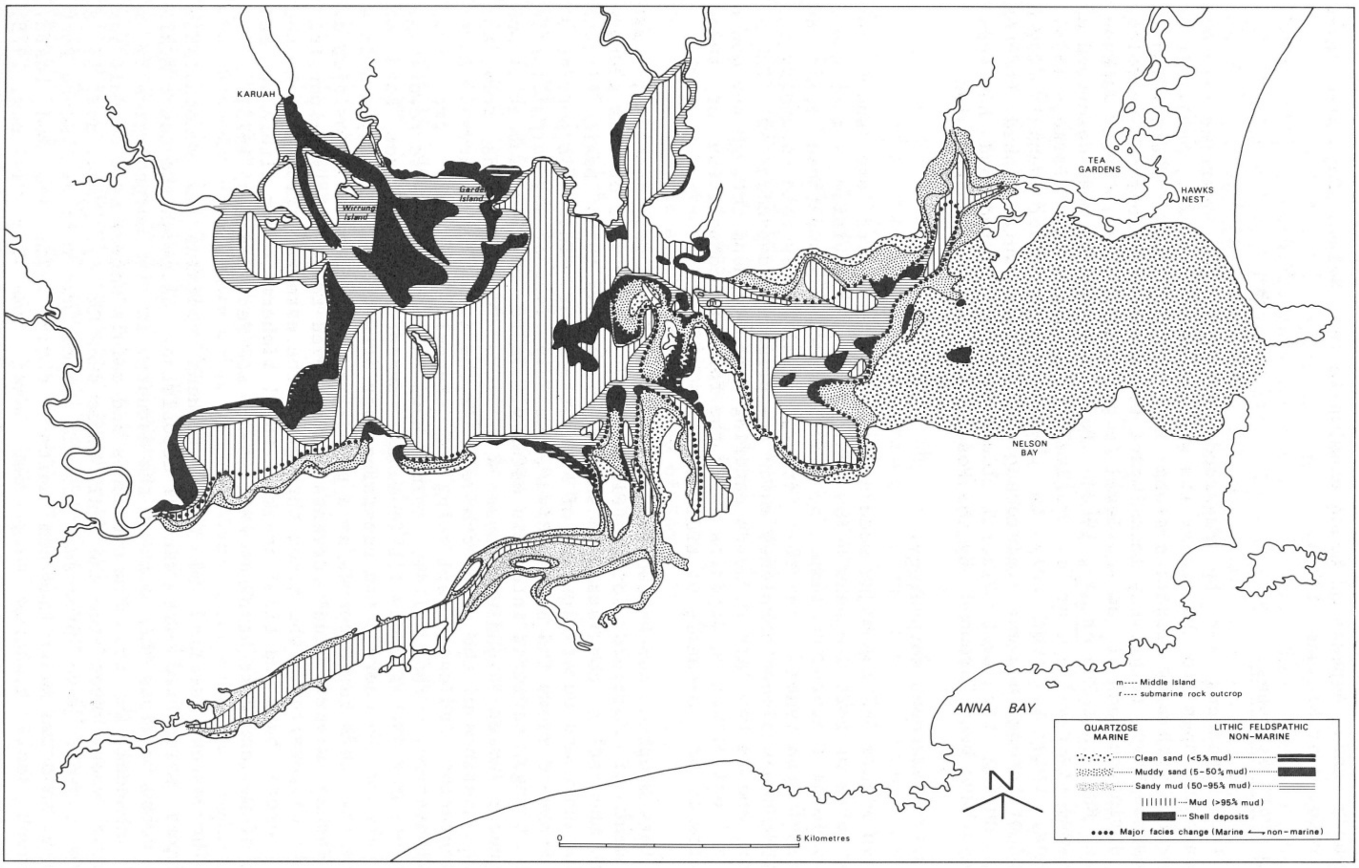


Figure 2-1 Depositional Areas Within Port Stephens (from Thom *et al.*, 1992)

To the east of Soldiers Point is an active marine flood tide delta, adjacent to the Lower Myall River entrance. The flood tide delta is very shallow, typically no more than 4-8 m below mean sea level (refer Figure 2-2), and waves break at low tide on sand shoals that extend most of the way across the mouth of the estuary (MHL 1999).

To the west of Soldiers Point is a shallow mud settling basin with water depths typically <10m (refer Figure 2-2). The Karuah River is the only significant supply of fluvial sediment to the whole estuarine system.

The Lower Myall River meanders through non cohesive (sandy) alluvium deposits, estuarine sand and mud (MHL 1993). It is understood that the vegetation in this area established before the meanders of the River, and that the vegetation now controls development of the River's plan form. The sandy bed of the River also contains some silt and organic material.

The bed of the present study area is located within the marine delta of Port Stephens, and the downstream reaches of the Lower Myall River, which comprise a mixture of marine sediments carried into the mouth by the combined action of waves and tides, and sands derived from the interbarrier depression. The area is constantly changing under the influence of complex interactions between tides, ocean swell, wind waves and flows from the Myall River.

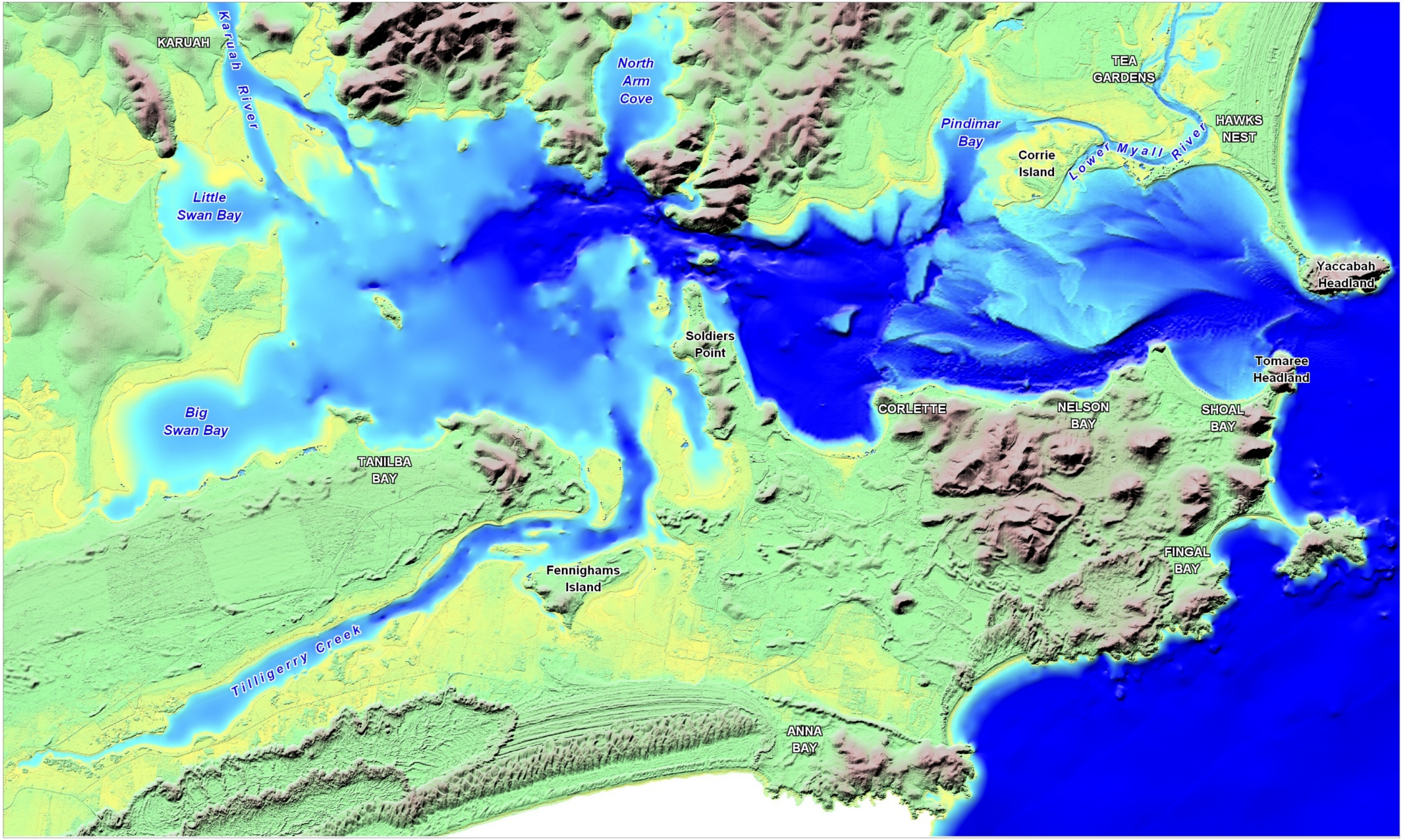
A steep dropover at the edge of the delta into deeper water extends roughly north-south from Corlette Head to the western side of Corrie Island. West of the drop over, water depths increase up to 20 metres (MHL, 1999) (refer Figure 2-2).

Changes in the immediate study area have been significant since European settlement of Australia. Thom *et al*. (1992) examined historical maps of Port Stephens from 1795 through to 1941, reducing the mapped features to a common scale and presenting them in a sequence of graphics, reproduced here as Figure 2-3. A more comprehensive set of adjusted charts is available from Watson (2008), although Figure 2-3 reproduces the key aspects.

The most notable feature is the variation to Myall Point over time. It appears likely that this feature provided protection from ocean swell, and enhanced the growth of Corrie Island. During a field inspection on 17th August, 2010, the exposure and active erosion of indurated sands known as "Coffee Rock" on the eastern edge of Corrie Island was noted. This indicates that Corrie Island at least partly comprises sediments laid down as part of the inner barrier during the Pleistocene epoch.

Myall Point was ultimately destroyed by a storm in 1927. As described in Thom *et al*. (1992):

> *"a spit was initiated from a sand shoal about 170 years ago, conforming in plan with the diffracted swell wave patterns which enters Port Stephens and crosses the shallow sand surface of the flood tide delta. The spit (Myall Point) reached its maximum length in about 1910. It was "trimmed" by erosion until 1927 when it was catastrophically removed in a storm. Since then, there has been considerable reworking of sand landwards to form a beach across a formerly sheltered mangrove island (itself initiated in the early 19th century) Lateral extension of both Corrie Island to the southwest and Winda Woppa to the west has occurred in recent years"*



LEGEND

Elevation (m AHD)

- -10
- -1
- 0
- 2
- 50

Title:

Present Day Bathymetry of Port Stephens and the Lower Myall River

Figure: 2-2

Rev: A

BMT WBM endeavours to ensure that the information provided in 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.

N

0 1.25 2.5km
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_006_100930 Bathymetry.WOR

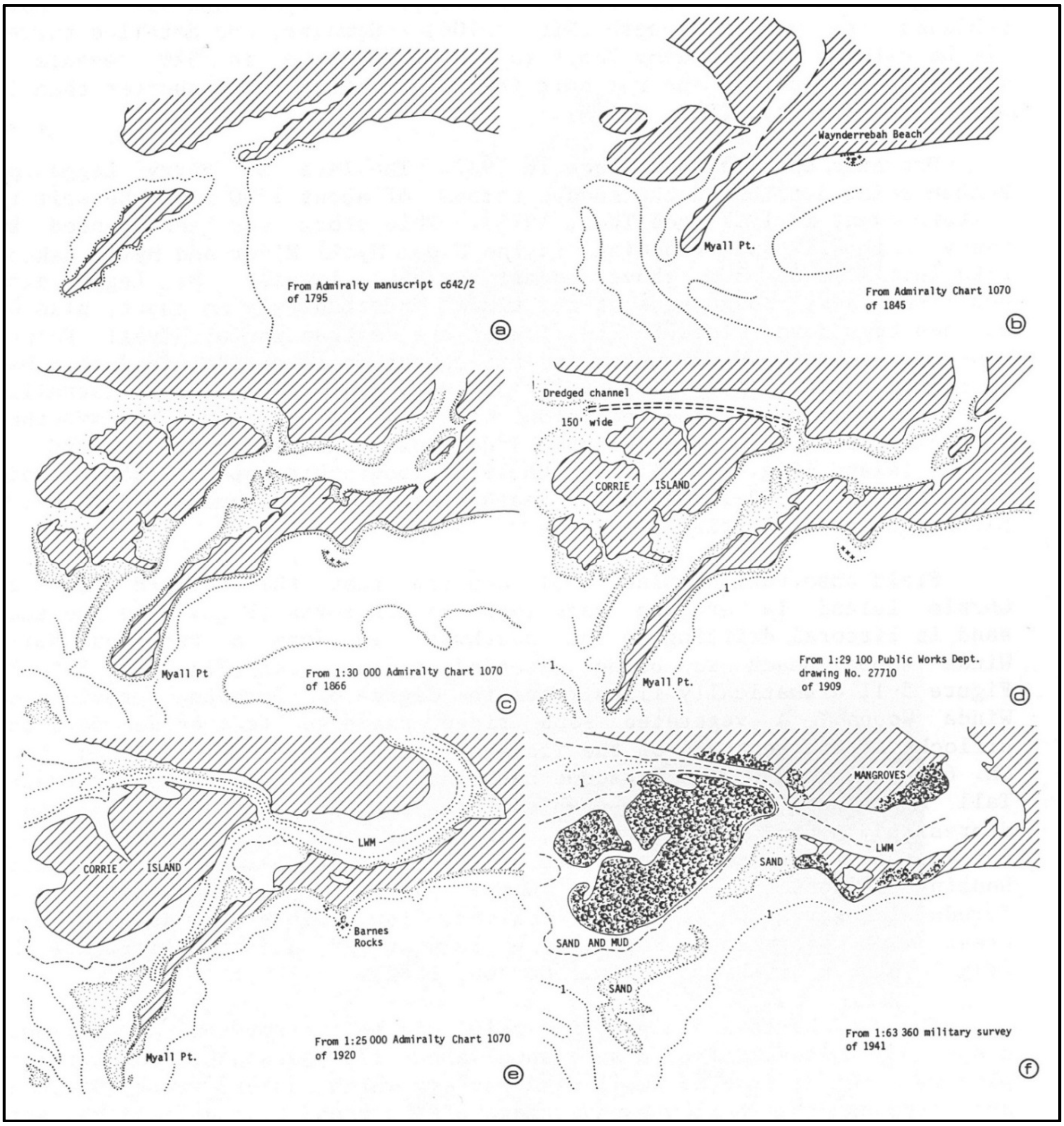


Figure 2-3 Historical Development of the Study Area (from Thom et al, 1992)

Whether or not the spit growth only initiated 170 years ago could be argued, due to the poor quality of underlying maps used to develop Figure 2-3. The presence of Coffee Rock along the actively eroding shoreline (Figure 2-4) indicates that Corrie Island has been present, at least partly, since Pleistocene times.

The beach of Winda Woppa, to the west of Barnes Rock, has been extending westwards as noted above for some time. The ongoing growth of Winda Woppa is causing a contraction of the tidal channel between Winda Woppa and Corrie Island, and this is contributing to the ongoing erosion of Corrie Island by pinching tidal flows hard against the edge of the Island.

Figure 2-4 Coffee Rock Eroding from Eastern Edge of Corrie Island (17/08/2010)
(courtesy Martin Fitzhenry, DECCW)

The beach at Winda Woppa is known to be receding (Thom *et al*., 1992). Evidence from field inspection indicates recent breakthrough of the low sand barrier forming the beach in this area. Vila Concejo et al (2007) link evolution of the beaches on the northern shoreline of eastern Port Stephens to flood-tide delta morphodynamics. They suggest a net westward directed sediment transport based on field measurements and observations. Earlier work by the Public Works Department of New South Wales, however, computed a net eastward direction for the sediment transport along Jimmy's beach (near threatened properties along The Boulevard), dominated by waves created by westerly winds. Vila-Concejo *et al*. conclude that that sediment transport patterns inside Port Stephens estuary are not clear and a morphodynamic model should be established to examine the processes driving these patterns.

Jimmys Beach is located to the east of Barnes Rock and is not part of the immediate study area. Sediment transport patterns around Barnes Rock, however, are of relevance to the present study and there is present conjecture in the literature relating to the processes acting at Jimmy's Beach (Watson *et al*., 2000; Vila-Concejo *et al*., 2007). Recession at Jimmy's Beach has been a notable management issue for at least the past 30 years, and has been managed primarily by on-going beach nourishment. Residential development behind Jimmy's Beach began in the 1960's (Watson, 2000), and has driven much of the concern for recession. The issues at Jimmy's Beach are discussed within this report, as necessary to inform understanding of the present study area.

Of significance is the present day Northern Channel ("Dredged Channel" noted on the 1909 survey). Comparison of tidal volumes between the Northern Channel and the Eastern Channel indicate that an increasing proportion of the tides is exchanging through the Northern Channel with time.

Vila-Concejo et al (2009) note that the shoreline within and adjacent to the study area contains alternating areas of erosion and accretion, terminating at the westward extending Winda Woppa spit. Using rectified aerial imagery, Vila-Concejo *et al*. (2008) estimated that Winda Woppa spit had undergone around 800 m of westward extension and between 50 – 100 m of recession since 1951.

2.1.3 Catchment Hydrology

The Port Stephens catchment contains steep areas that drain into two major river networks, the Karuah and Myall Rivers. These two rivers have a combined total catchment area of 2900km^2 (MHL 1999). The Myall Lakes have a total waterway area of approximately 100 to 150 km^2 (MHL 1999) and a catchment area of some 1660 km^2. The steep hills of the hinterland provide a source of groundwater that contributes inflow to the Lakes (MHL 1999).

Normally the mean water levels within Myall Lakes are higher than in the Ocean, due to the constrained nature of the Lower Myall River, which retards the flow of water from the Lakes to the ocean. During periods of high evaporation (summer) and low precipitation in the Myall Lakes catchment, the mean water level in the Lakes may fall below mean sea level (MHL, 1993). Lake water levels do not respond significantly to semi-diurnal ocean tides. The main tributary of the Myall Lakes is the Upper Myall River which flows into the Bombah Broadwater. Boolambayte Lake has a minor tributary (Boolambayte Creek) and Myall Lake has a small catchment receiving most of its inflow from Boolambayte Lake.

Water levels in the study area (i.e. Lower Myall River and Port Stephens) are overwhelmingly dominated by ocean tides. Flow from the Lakes into the study area may be significant following substantial rainfall, which elevates water levels in the Lakes. Sanderson (2008) shows that water levels in the Lakes rise quickly in response to rainfall, but fall slowly as water is released through the Lower Myall River. He concludes that the constricted connection between the Broadwater and ocean causes runoff events (primarily from Upper Myall River into Bombah Broadwater) to raise water levels throughout Myall Lakes, causing backflow from the Bombah Broadwater "up-lake" into Boolambayte and Myall Lakes. Flow between the lake basins occurs when there is an imbalance between water levels, which can occur due to differential catchment runoff, wind stress and ocean water levels variations of lower frequency than the tides.

Within the catchment south of Port Stephens, there is minimal runoff, with most excess rainfall on the flat terrain percolating through the sandy soils, eventually entering the unconfined aquifers of the Tomago and Stockton sand beds. The main tributary entering the southern side of the Port is Tilligerry Creek, although flow in this creek is predominantly tidal.

2.1.4 Hydrodynamics

2.1.4.1 Tides

The estuary is located along a micro-tidal, wave dominated coastline and contains a wide entrance to the ocean. Measurements of tidal velocities and circulation patterns across the Port Stephens tidal delta (Austin *et al*., 2009) demonstrate that flood tides dominate on the shallower wider regions of the flood tide delta, whereas ebb tides dominate in the narrow, deeper channels.

Tidal discharges through the Northern Channel (*Site 3, Corrie Channel)* and the Eastern Channel (*Site 4, Eastern Channel)* were measured using Acoustic Doppler Current Profiling (ADCP) on 24th September, 2009 (MHL, 2010).The total flood tide volumes measured were 2.8 x 10^6 m^3 in the Northern Channel and 2.51 x 10^6 m^3 in the Eastern Channel, while ebb tide volumes were 2.55 x 10^6 m^3 in the Northern Channel and 2.27 x 10^6 m^3 in the Eastern Channel. This monitoring indicates that tidal exchange is presently approximately evenly split between the two channels with a slight dominance towards discharge through the Northern Channel.

During a similar tidal gauging exercise in 1975, total flood tide volumes (0.96 x 10^6 m^3 in the Northern Channel, 4.60 x 10^6 m^3 in the Eastern Channel) and ebb tide volumes (1.65 x 10^6 m^3, 4.61 x 10^6 m^3 respectively) were measured. 35 years ago, discharge through the Northern Channel was notably less than in the Eastern Channel. The change in dominance of the Northern Channel is of some concern to the community, and potentially impacts on flushing and mixing in the Lower Myall River.

2.1.4.2 Salinity, Mixing and Flushing

Mixing within the Port Stephens estuary is driven by tidal, wind and fresh water runoff events. Mixing within smaller bays and tributaries of the Port are dependent on the exchange and mixing with the main waterbody of Port Stephens, and will typically have longer flushing times. Stratification can develop in the Lower Myall River following large rainfall events (PWD 1978), however, temperatures measured during a dry weather period on 17th December 1997 showed no vertical stratification in the water column, although there was significant variation along the river (MHL 1999).

The Lower Myall River constrains mixing between the Port Stephens estuary and Bombah Broadwater, evidenced by the large reduction in tidal range between the two locations (1.8m reducing to 0.1m: MHL, 1999). Flushing times vary significantly along the Lower Myall River, from approximately 1 day at the river mouth, to days to weeks within the lower reaches, and several months in the upper reaches, particularly during drier periods (MHL 1999). The Myall Lakes experience very little tidal flushing and the majority of saltwater entering the Lakes is trapped in the Broadwater, and then slowly dispersed through the rest of the lakes system (PWD 1978). Salt is flushed out of the system following catchment rain which elevates water levels in the Lakes (Sanderson, 2008). Using salinity data, MHL (1999) estimates the time to exchange the whole volume of Myall Lakes with water from Port Stephens as approximately 750 to 800 days.

The salinity in Port Stephens is similar to the ocean, at approximately 35 ppt. The salinity of the Lower Myall River is affected by floods and droughts with dramatic changes occurring after either a period of wet weather (promoting brackish/fresh waters) or drought periods (promoting saline waters) (PWD 1978). Further upstream, a flood entering the Broadwater from the Upper Myall River may produce an initial increase in salinity in Myall Lake, as water is pushed further upstream. Groundwater is also expected to provide a small but consistent baseflow of freshwater (<150mg/L of Total Dissolved Solids) to the Myall Lakes and Lower Myall River system.

2.1.4.3 Waves

Generally, ocean swell waves do not penetrate further than Soldiers Point or into the Myall River entrance and their effects are confined to the lower port (MHL 1999). Waves are important in driving sediment transport and morphology of the River mouth, which affect hydrodynamics in the Lower Myall River significantly.

2.1.5 Sediment Dynamics

The movement of sand in the study area is effected by waves, tides, wind and river discharges which can cause notable changes over relatively short periods, such as during a storm.

These processes mobilise sand from the bed and transport it from one area to another, resulting in areas of erosion and accretion.

At the entrance to the Lower Myall River, swell waves dominate the sediment transport process and drive a longshore transport from east to west along Winda Woppa Spit (Jiang et al 2009). This presently results in the erosion of sand from the shoreline west of Barnes Rock and deposition of that particular sand at the end of Winda Woppa spit and in the Eastern Channel. As presented in Section 3.7 and Appendix D, on-going erosion of Jimmy's Beach does not have a significant contribution to sediment accumulation within the Eastern Channel of the Lower Myall River.

The shape of the mouth of the Lower Myall River is also affected by the tides and their interaction with waves. River discharges and wind waves also affect sand movement in the study area, but their relative importance is small.

Further inside the Lower Myall River, the predominant wave energy is created by boats, and the banks of the River are very susceptible to erosion (MHL 1999). The transport of sediments, sourced from bank erosion, along the Myall River to the Lower Myall River entrance is expected to be small (MHL 1999).

Over longer periods, broad scale changes can affect the context within which waves and tides transport sand. For example, sea level rise since the end of the last glacial period is responsible for the ongoing movement of the flood tide delta into Port Stephens. Similarly, the sea level rise expected over the next century will also alter sand movement.

Sustained dredging or the construction of groynes or breakwaters will also alter the way that sand is transported within the study area, if adopted as a management strategy for the site.

Waves, tidal hydrodynamics and sediment transport are of primary significance to this study, and further technical information is provided in Section 3.

2.1.6 Estuarine Vegetation

The wetlands and vegetation surrounding the fringes of Port Stephens, Myall Lakes and the Lower Myall River comprise mangroves, open scrub, saltmarsh, rushland and swamp forest. The mangrove stands are the largest in NSW whilst the saltmarsh constitutes 18% of that remaining in the state (MHL 1999).

Groundwater flowing through the wetlands surrounding Myall Lakes can pick up tannins and humic acids, which result in tea brown coloured waters and an additional organic nutrient load to the estuary. The groundwater therefore influences water quality in the Lakes.

Figure 2-5 shows approximate extents of mangrove, saltmarsh and seagrass distribution as mapped by the Department of Primary Industries (2006). The locations of these vegetation features will change over the course of a few years, which is highlighted by the differences with the background aerial image in Figure 2-5, which dates from April, 2010.

Areas along the Lower Myall River form part of the Myall Lakes National Park. The National Parks and Wildlife Service also manage the Corrie Island Nature Reserve. A number of gazetted SEPP-14 wetlands are also located adjacent to the study area.

The Port Stephens – Great Lakes Marine Park includes a sanctuary zone offshore of the southern and western shorelines of Corrie Island. A smaller sanctuary zone is also located offshore and to the east of Barnes Rock. A habitat protection zone is located immediately north of the Singing Bridge.

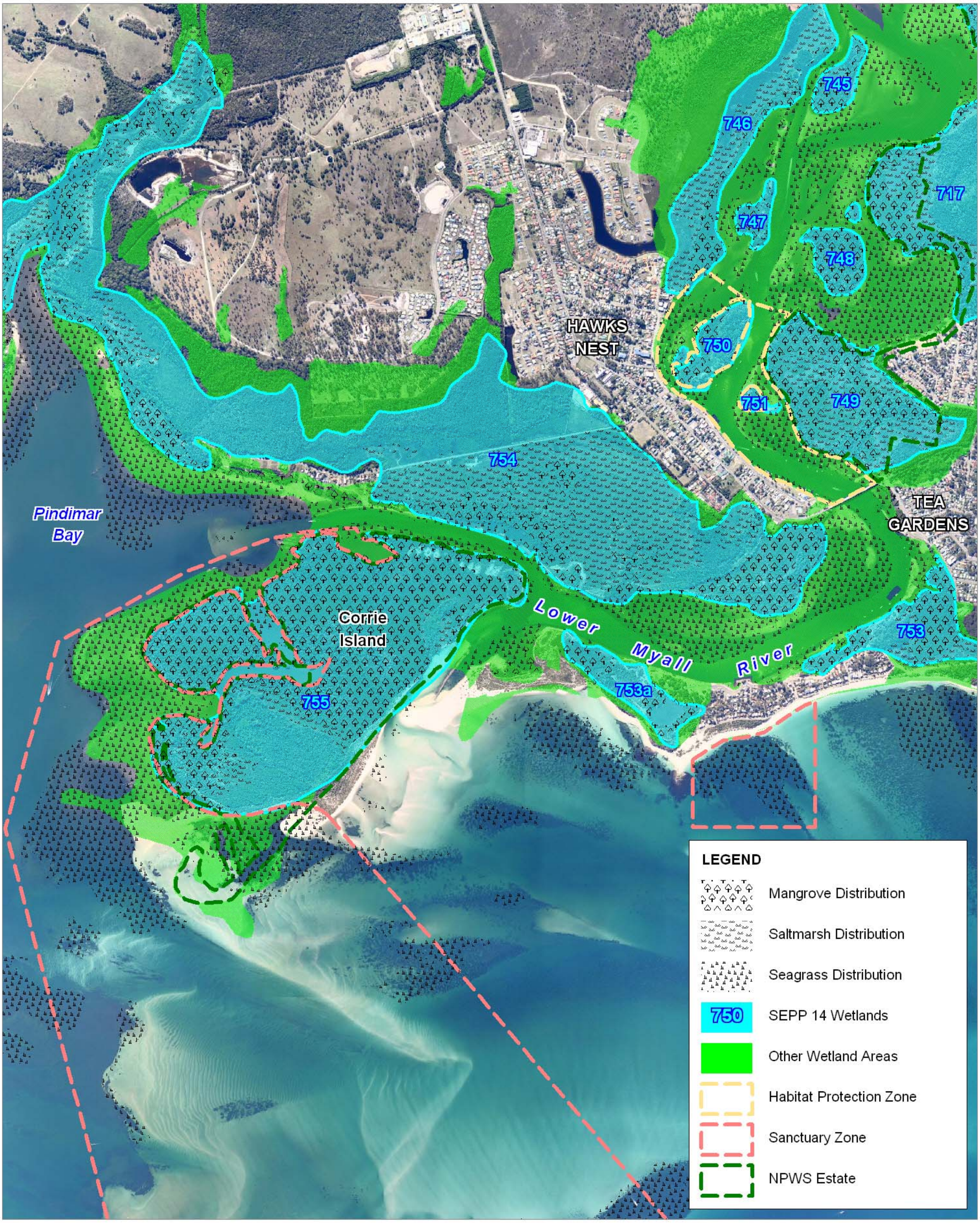
2.1.7 Assessment of Estuarine Health

Parallel to the present study, the New South Wales Department of Environment, Climate Change and Water (DECCW) has undertaken “Estuarine Health” study of the Lower Myall River. The draft study report (Scanes *et al*., 2010) focuses on actual ecological condition, with assessment based on field experiments of indicators ranging from low level measures such as habitat availability and water chemistry, up to high level measures such as fish ulcers and mangrove parasitism.

A similar set of field experiments were conducted at other sites in Port Stephens (Pindimar Bay, Salamander) and a comparable site in Wallis Lake. Overall, that study finds that *“the ecological health in the river is excellent and equivalent to other comparable estuarine locations that have not experienced changed entrance conditions”* and that *“there is no evidence that changes to the river mouth channels are negatively impacting on the estuarine ecology”.*

Scanes *et al*. (2010) note that the slow release of freshwater from the Myall Lakes system after rainfall has a significant impact on the Lower Myall River estuary, including salinity and tidal characteristics. However, tides still dominate the local currents up to and in the vicinity of Tea Gardens.

The report does note, that westward extension of the Winda Woppa shoal has constricted the channel and affected the tidal flow in the Eastern Channel over the last 4 years. This loss in tidal flow appears to have been offset by an increase in tidal exchange through the Northern Channel.



Title:

Estuarine Vegetation and Planning Boundaries

Figure: 2-5

Rev: A

N

0 0.5 1km
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_002_100928 Estuarine Veg.WOR

2.1.8 Existing Numerical Models

A number of numerical models have been developed to help describe and understand hydrodynamics and sediment transport in and around the study area. These models are noted below.

2.1.8.1 Myall Lakes and Lower Myall River Numerical Model (2008)

Sanderson (2008) reports on two dimensional numerical modelling of the Myall Lakes, linked to a one dimensional model of the Lower Myall River. The study focused on mixing in the Myall Lakes water bodies, while the Lower Myall River was only included to provide tidal input into the lakes system. As a consequence, this model provides limited value to the present study.

2.1.8.2 Lower Myall River Numerical Model (1980)

PWD (1980) undertook one dimensional, unsteady flow, numerical modelling of the Lower Myall River. The model allowed the input of upstream flows and downstream (tidal) water levels (MHL 1993). The bathymetry was derived from cross section data obtained during a hydrographic survey in 1977, covering the river channel and tidal flats. The cross sections were spaced at 500 m. Sediment transport modelling, using the Ackers and White formulae, was also undertaken based on the results of the 1D modelling.

This model is limited in its coverage of estuarine processes, such as the wave driven sediment transport process, and as such, is also limited in its value to the present study.

2.1.8.3 University of Sydney, School of Geosciences Model

The University of Sydney, School of Geosciences have established a numerical model covering the entrance of Port Stephens and Lower Myall River using the Mike-21 software (University of Sydney, 2010). Details of the model extent and capabilities were published in Jiang *et al* (2009) which indicates the model faithfully reproduces Port Stephens and the coastal zone. In place of the main tributaries (Lower Myall River and Lakes, Tilligerry Creek and Karuah River) rectangular areas of tidal storage were included. The model solves the Reynolds Averaged Navier Stokes equations on a flexible mesh and propagates waves into the system using a spectral wave model. The methods are similar to those implemented in the present study.

The model appears to be well validated to current measurements offshore of Jimmy's Beach. However, the detail present in the Lower Myall River does not meet the requirements for the present study.

2.1.8.4 Model Described in Watson (2000)

Watson (2000) describes the use of "computer based numerical modelling, wave refraction analyses, wind induced current studies, wind wave correlations, sand transport rates and shoreline recession analyses" indicating a net transport rate of 5,000 m^3/yr eastwards towards the Yacaaba Headland.

Although relatively recent, this model still does not include many of the advanced algorithms that characterise present day numerical models that have resulted from research efforts over the past decade. Therefore, this model is unlikely to be a suitable tool for application in the present study.

Despite the lack of suitability of the model, a series of surveys were undertaken by the New South Wales Government as described in Watson (2000). Some of the raw data from these surveys were provided for use by this study, although it appears that a full set of data covering all surveys from the 1990's is still not readily available.

2.2 Community Perspectives

A community and stakeholder meeting was held at the Tea Gardens office of Great Lakes Council on 6th October 2010. Outlined below are the main issues that were identified by attendees of that meeting. Information presented in this section represents the views and opinions of the meeting attendees, and is not necessarily scientifically validated, nor is it necessarily the express views of the study team responsible for preparing the present study.

2.2.1 Perception of Existing Problems

A number of specific but inter-related problems were identified within the Lower Myall River region. The relevant issues are described below, and locations are shown on Figure 2-6.

2.2.1.1 Poor Water Quality in the Lower Myall River

Community members believe that water quality in the Lower Myall River is declining, possibly because the River now exchanges more readily with Pindimar Bay than through the eastern channel.. Since 2008 the community believe that salinity in Pindimar Bay has been less than 18ppt. This is considerably fresher than seawater (35ppt) and indicates a possible reduction in full tidal exchange with the ocean.

Tidal data indicates a time lag in tidal flows between the eastern and western side of Corrie Island (MHL 1993). As the flood tide is flowing into the Eastern Channel, the ebb tide is still flowing westward out of the Northern Channel, which results in "short circuiting" of the tidal flows. The community have also witnessed this process.

A tidal data collection campaign in September 2009 (DECCW 2010) found that tidal exchange between the estuary and the Lower Myall River is now evenly split between the Northern and Eastern Channels with a slight dominance towards discharge through the Northern Channel. This intimates that a greater flow from the Lower Myall River is discharging into Pindimar Bay, potentially making it fresher.

Higher levels of freshwater discharge from the Myall Lakes in recent years also delivers higher levels of tannins to the Lower Myall River, thus reducing water clarity. The community tend to directly relate water clarity to water quality. When combined with a possible reduction in flushing by 'clean' ocean water through the Eastern Channel, the higher levels of tannin staining in the water lead to perceptions of reduced water quality in the Lower Myall River.

Poor water quality in the Lower Myall River may result from factors including exchange of waters with the lesser flushed Pindimar Bay, blockage of the Eastern Channel and point sources of pollutants / nutrients entering the river.

2.2.1.2 Sand Nourishment at Jimmys Beach

Jimmys Beach has been nourished with sand a number of times over the past few decades. This is an ongoing and costly exercise. Some community members believe that this introduces large volumes of sand into the local coastal compartment, that then become redistributed across Winda Woppa, resulting in the progressive infilling of the Eastern Channel.

The community also consider that material used for on-going nourishment could be obtained by dredging the Lower Myall River and the Eastern Channel, rather than other locations.

2.2.1.3 Loss of the Myall Spit

The destruction of Myall Spit in the late 1920's, caused redistribution of a large volume of sand in the area to the east of Corrie Island and at the mouth of the Lower Myall. Loss of the Spit removed the barrier protecting Corrie Island from ocean swell waves.

Re-building Myall Spit would restore protection to the eastern shoreline of Corrie Island and by addressing the westward transport of sediment, reduce infilling of the Eastern Channel. As discussed above, the community has linked this infilling to reduced flushing and poor water quality in the Lower Myall River

2.2.1.4 Sand Accumulation along the River

Sand accumulation is occurring at a number of locations within the Lower Myall River, and around the southern edge of Corrie Island. As a consequence seagrass and oyster leases are now being smothered. Sand accumulation has also occurred at locations along the Lower Myall River (Figure 2-6) including:

- The waters where the Northern Channel enters Pindimar Bay;
- Mainland shoreline opposite the northern end of Corrie Island where spat collection sticks are now covered in sand;
- Northern shoreline prior to the splitting of the Lower Myall River around Corrie Island;
- Shoals opposite the town site of Winda Woppa; and
- Upstream and downstream of the Singing Bridge.

2.2.1.5 Connection of Corrie Island to the Mainland

Effort may be required to ensure Corrie Island remains separated from the mainland. Corrie Island is an internationally recognised Ramsar listed wetland (included in the Myall Lakes group of Ramsar wetlands, Ramsar site no.944) and is an important roosting and nesting ground for migratory birds, including the Little Tern.

The accumulation of sands in the Eastern Channel has produced a sand barrier that almost joins Corrie Island to the mainland, which may allow predators, including dingoes to access the Island. Community concern, over the connection of the Island to the mainland, has been documented in the media (Figure 2-7).

Title:

Community Identified Problems

Figure: 2-6

Rev: A

N

0 375 750m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_011_101018 Community Concerns.WOR

Jewel lies neglected

Island desperate for conservation

MATTHEW KELLY

CORRIE Island should be the jewel in the crown of the Myall River, a nesting sanctuary for endangered birdlife including the little tern and the mangrove kingfisher.

Instead, siltation of the river's eastern entrance has allowed predators such as dingoes to roam freely around the Ramsar-listed nature reserve.

Tea Gardens residents are calling on the state government to urgently increase protection for the island's sensitive ecology.

It follows recent installation of fencing to protect the nesting area of the endangered little tern from feral pests and human activity in Swansea Channel and Botany Bay.

To back their concerns, Tea Gardens residents have taken numerous photos of foxes and dingoes crossing onto Corrie Island via the silted waterway at low tide.

A long-running community campaign to have the eastern channel dredged has to date been unsuccessful.

Myall River Action Group spokesman Gordon Grainger said the National Parks and Wildlife Service had shown no interest in protecting the island.

"While we applaud their efforts in protecting the little tern in Sydney and Lake Macquarie, we wonder why there isn't similar concern for Corrie Island," he said.

National Parks and Wildlife Service spokesman Lawrence Orel said there had been no reports of little terns nesting on the island.

"The temporary fencing, along with advisory signs on about a quarter of Sand Island in the Swansea Channel, is designed to provide protection and help create awareness by users of active nesting attempts by the little terns for the first time since 1966," he said.

THREATENED: The little tern (above) is in danger on Corrie Island from predators such as marauding dingoes, left.

WARNING: Tourists are asked to stay clear at Marks Point, Swansea.

Figure 2-7 Newspaper Article on Corrie Island (Newcastle Herald, 25th September 2010)

2.2.2 Initial Community Suggestions for Potential Solutions

In addition to identifying the issues of concern, attendees at the 6th October, 2010 meeting also provided ideas regarding management of those issues. The suggestions are described in the following sections. Specific management actions are addressed in more detail in Section 5.

2.2.2.1 Poor Water Quality in the Lower Myall River

Investigations are required to confirm the presence of poor water quality within the Lower Myall River, and to identify the source of the problem, and the environmental processes contributing to the problem. The issue of poor water quality could be addressed by increasing tidal exchange between the Lower Myall River and the Ocean.

One strategy aimed at increasing tidal exchange is to restrict further sand accumulation in the Eastern Channel. Additionally an option to block the Northern Channel would further promote tidal exchange through the Eastern Channel, potentially making that channel more self-sustaining.

2.2.2.2 Sand Nourishment at Jimmys Beach

The direction of sand transport along Jimmys Beach requires clarification to manage sand nourishment works and ensure adequate beach widths are maintained. Management options that limit the introduction of additional volumes of sand to the system and promote stability of the beach should be investigated.

Once the dominant direction of longshore sand transport has been defined, additional options to stabilise the sands may be investigated and could include offshore structures to reduce the wave energy reaching Jimmys Beach, or groynes along the beach to restrict longshore sand transport.

Sand nourishment for Jimmys Beach was initially sourced from the Eastern Channel, beginning in 1984 (Watson 2000). That sand was quickly eroded by a series of storm events.

Community members believe sand should be sourced from within the immediate coastal compartment to reduce the addition of more sand into an already “sand flooded” environment. Potential sources include the Eastern Channel/Paddy Marrs Spit, sand spits at the southern end of Corrie Island locations for the sourcing of sand, aside from the Eastern Channel/Paddy Marrs Spit, may include sand spits at the southern end of Corrie Island, or shoals as identified in sand accumulation areas within the river.

2.2.2.3 Loss of the Myall Spit

Investigations are required to identify the positive and negative impacts of re-building the Myall Spit, with specific focus on the redistribution of wave energies, tidal flows and sediment transport. In addition, a variety of materials could be utilised for re-building including sand, rocks or concrete. If the spit were to be constructed from sand then revegetating the spit may provide further protection.

Training walls along either side of the Eastern Channel may also provide permanent separation of the island from the mainland although this option should be coupled with detailed investigations into the impacts of such structures. Another option may include closing the Northern Channel; which would ensure that all tidal exchange occurred through the Eastern Channel into the Lower Myall River.

2.2.2.4 Sand Accumulation along the River

Identification of sand sources and transport processes associated with the accumulation of sand at various locations within the Lower Myall River and shorelines is required.

Shoals in the Lower Myall River show little spatial movement, but erode and accrete periodically resulting in a redistribution of sediment. The recent development of new shoals and sand accumulation along shorelines may indicate an additional source of sediment and/or change to the hydrodynamics and sediment transport within the region.

2.2.2.5 Connection of Corrie Island to the Mainland

Management solutions are required to ensure that Corrie Island remains separated from the mainland.

A range of management solutions may include dredging the Eastern Channel, re-building Myall Spit to restrict sand transport into the Eastern Channel, and seawalls or training walls to provide barriers to sand transport. The impact of any such structures would need to be investigated.

2.3 Summary of Issues and Likely Causes

The perceived problems in the Lower Myall River have been linked by the community to the interrelationships of hydrodynamics and sediment transport. A change to hydrodynamics can affect sediment transport and vice versa (Figure 2-8).

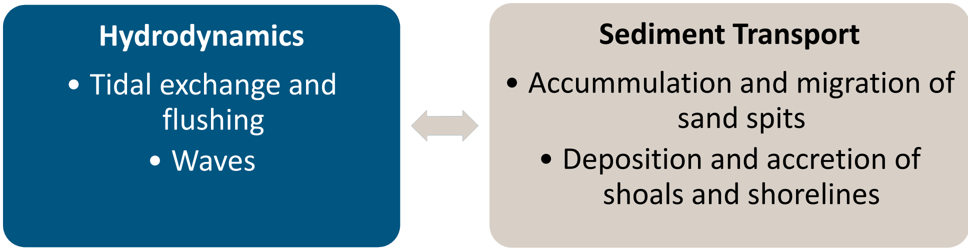


Figure 2-8 Interaction of Processes Leading to Perceived Problems

There are numerous examples of these interactions and the feedback they can cause:

- Dredging of the northern channel has altered the distribution of tides around Corrie Island;
- The redistribution of tides around Corrie Island has resulted in a reduced capacity for the eastern channel to 'self-scour' and remain open; and
- The reduced tendency for the eastern channel to remain open further encourages more tidal flow through the Northern Channel.
- Ongoing movement of the flood tide delta into Port Stephens results in the redistribution of wave energy along the foreshore;
- Variation in wave energy along the foreshore results in variation of longshore transport rates for exposed beaches (such as Winda Woppa);
- Longshore transport along Winda Woppa is causing extension of the Winda Woppa Spit, which has progressively filled the eastern channel over the past 10 years; and
- Filling of the eastern channel further increases the tendency of tidal flows towards the Northern Channel.

These interactions make predicting behaviour of the system a complex task. The required analyses are typically, which is typically addressed through the application of numerical (computer) models considering all of the required processes (Wind, Waves, Tides, Sand Movement, Erosion and Deposition).

The key concern to the community is one of reduced clarity and perceived poorer water quality in the Lower Myall River. The community believes that this is caused by less effective tidal flushing, as an increasing proportion of the tide is carried through the northern channel, which exchanges with Pindimar Bay, and not the Outer Basin of Port Stephens. Changes to the tides are also considered responsible to changing shoal dynamics within the Lower Myall River.

The less effective flushing relates to progressive closure of the Eastern Channel in recent years. That closure is related to sand movement along Winda Woppa spit and on the Port Stephens Marine tide delta, which is presently pushing against the eastern edge of Corrie Island.

These processes are examined further in Chapters 3 and 4, which validate the processes using existing data and computer modelling respectively.

3 AVAILABLE DATA AND ANALYSIS

A variety of available data provide insight into hydrodynamics and sediment transport processes within the Lower Myall River. These data sets and associated analyses are documented below.

3.1 Bathymetric Data

3.1.1 Existing Information

Numerous hydrographic surveys are available for regions within Port Stephens and the Myall River, dating back to 1866. The most recent hydrographic surveys for the study area are:

- **September 2009** - Myall River Entrance Hydrographic Survey, collected and supplied by DECCW, covers the Lower Myall River, Corrie Creek (Northern Channel) and Paddy Marrs inlet (Eastern Channel);
- **2007** - Port Stephens Hydrographic Survey (Draft) collected and supplied by DECCW covers the central and eastern basin regions of Port Stephens;
- **2006** - Australian Bathymetry and Topography Grid - 250 m Digital Elevation Model supplied by Geoscience Australia. The data set comprises relatively coarse regular grid data;
- **2001 / 2002** - Myall Lake & Myall River Hydrographic Survey collected and supplied by DECCW, covers the Myall Lakes, Myall River, and the north eastern section of Port Stephens;
- **2001** - Australian Hydrographic Service bathymetric chart AUS00209 of Port Stephens. The Chart covers the whole region of the Port Stephens estuary; and
- **1990** – Cross Sections of the Upper Myall River, extending from the Broadwater to Bulahdelah.

In addition to the above mentioned data sets, there are also a number of historical surveys (referring to those that have been superseded by data sets mentioned previously) that are also available for the study area, including the following:

- **1998** – Pre and Post Dredge Hydrographic Surveys of Jimmy's Beach at dredging Locations 1 and 2;
- **1994** – Hydrographic Survey of Shoal Bay, extending from Tomaree Head to Yacaaba and Nelson Heads;
- **1984 and 1986** – Cross section profiles from Jimmy's Beach to approximately 150m offshore. The 1984 data set includes 6 different dates for the hydrographic data and 4 different dates for the land based surveys, and the 1986 data set includes profiles for 1985 and 1986;
- **1983, 1982, 1981, 1980, 1978, 1976, 1974, 1969 and 1955** – Hydrographic survey of Jimmy's Beach, extending approximately 200m offshore;

- **1983** – Hydrographic survey of Barnes Rock, just offshore from Jimmy's Beach;
- **1982** – Beach profiles to the west of Barnes Rock;
- **1982** – Beach profiles across Yacaaba Spit, comparing data obtained from profiles measured in 1969, 1978 and 1982;
- **1978, 1977 and 1976** – Hydrographic survey of the Myall River entrance extending from the Northern Channel and around the southern edge of Corrie Island;
- **1977 and 1963** - Hydrographic survey along the Lower Myall River from Tea Gardens to the Broadwater; and
- **1969** - Hydrographic survey of Port Stephens and the nearby coastal ocean, extending from Cabbage Tree Island / Boondelbah Island in the east, and Fame Cove and Soldiers Point to the west;
- **1866** – Hydrographic survey of Port Stephens extending from Cabbage Tree Island and Boondelbah Island in the east, to the western edge of Corrie Island.

3.1.2 Historical Features and Trends

Historical hydrographic surveys (Appendix A) provide evidence of sediment transport patterns within the study region. Previous analysis of historical hydrographic surveys, by Watson (2008) and MHL (1993), can be summarised into the following features and trends.

The evolution of Corrie Island has involved the gradual deposition of sediments (sands) at a location downstream from the mouth of the Myall River, which has then slowly stabilised and become vegetated (Table 3-1). The shape of the island has experienced some changes, most likely from the waves and tidal flows. Photographic evidence of Coffee Rock along the edge of Corrie Island (Figure 2-4) collected by this study indicates that Corrie Island has existed in some form since well before European Settlement.

The evolution of the Myall Point / Spit (refer Table 3-2) has been described as a gradual accretion of sediments at the end of Winda Woppa, which has slowly become vegetated. The spit began to reduce in length from around 1910 onwards (Thom *et al*., 1992). The spit was then destroyed during the 1927 storms.

The depth of the channels surrounding Corrie Island have been subject to natural and artificial changes (Table 3-3), which have resulted in changes to tidal and current velocities, discharges and associated sediment transport.

Table 3-1 Evolution of Corrie Island

Year	Description
1792	Shallow shoals appear on charts. However, the presence of Coffee Rock along the presently eroding eastern foreshore of Corrie Island indicates that at least part of Corrie Island has been present since the Pleistocene.
1795	Shoals form a sand island
1828	The island becomes covered in mangroves and becomes known as 'Mud Island'
1845	The island becomes covered with low scrub and referred to as a 'Sand Island'
1969	Erosion on the eastern side of Corrie Island and the shoreline has retreated and rotated anti clockwise to a more north-south direction; Accretion has occurred at the south eastern end (progradation of 200 – 300m) as a result from littoral drift.

Table 3-2 Evolution of Myall Point / Spit

Year	Description
1826	Myall Point first appears on maps
1828	Shoal extends from the southern tip of the island, through the Middle Ground and join Jimmys Beach, completely blocking the south eastern inlet to the Lower Myall River
1845	Myall Point broadens and becomes vegetated
1866	Myall Point appears as a low sand point covered with small scrub
1909	Myall Point becomes elongated by 450m (most likely from littoral drift, as evident by the direction of growth northeast – southwest) and narrows, suggesting sand movement from the seaward face of the Point to the tip
1920	Narrowing of Myall Point continues, with a 350m erosion retreat of the tip above high water mark
1927	Myall Point destroyed by an extreme storm and flood event and reduced to shoal area known as 'Paddy Marrs Bar;
1972 / 1977	Myall Spit accumulating with sand

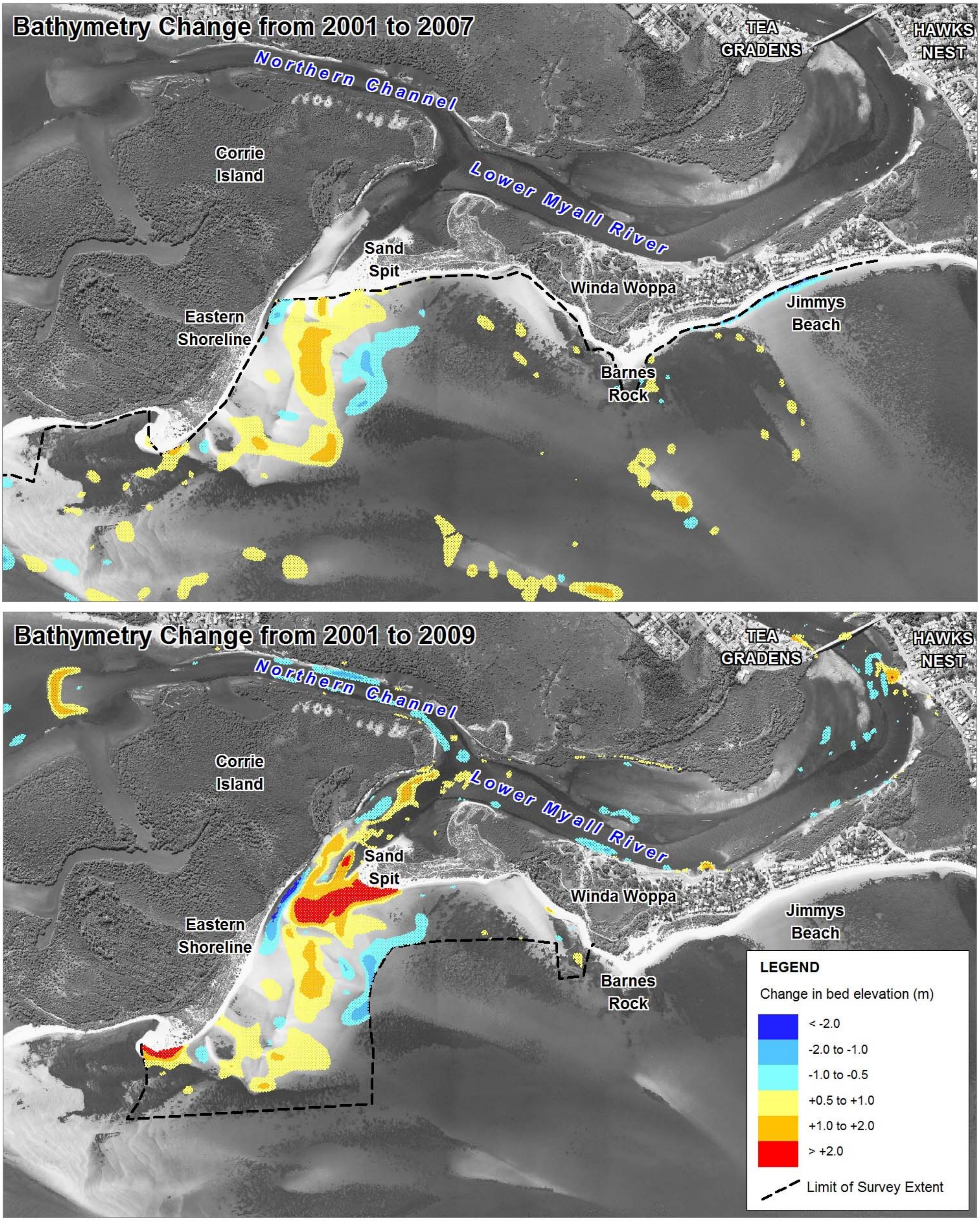
Table 3-3 Channel Dynamics surrounding Corrie Island

Year	Description
1792	The Lower Myall River entrance is shown as an unspecified inlet.
1795	A well-defined channel is now located to the north of the island.
1828	A huge shoal completely blocks the southern channel to the Lower Myall River.
1845	A well-defined southern channel is now present with a minimum depth of 2m and the northern channel is blocked.
1866	The southern channel, now known as Paddy Marrs Inlet appears as a well-defined channel with a depth generally greater than 1m and the north channel is blocked.
1909	A 50m wide navigation channel is dredged on the northern side of Corrie Island. This is accompanied by shoaling of the southern Channel.
1909-1920	The north channel deepens to 6m (likely from dredging), except between Myall Point and Middle Ground, where shoaling occurs (to less than 2m) and the river entrance channel shallows.
1920	Large sand bar forms in Paddy Marrs Inlet.
1963	The northern channel, also known as Corrie Creek, decreases in depth by about 0.5m.
1969	Sand bar still present in Paddy Marrs Inlet, with erosion and realignment of the north channel to a more east-west orientation.
1972-1977	Paddy Marrs Inlet is pushed in a south-west alignment by the rebuilding of Myall Spit.

3.1.3 Recent Features and Trends

Bed level changes surrounding Corrie Island and the Lower Myall River have been identified for the years 2001 to 2007, and 2001 to 2009 (Figure 3-1).

The most significant change has been the accretion of the sand spit from Winda Woppa and the accretion of the sand spit at the southern end of Corrie Island, with bed levels changes of >+2.0m. At the western end of the Northern Channel there is also an area of accretion where ebb tide velocities decrease upon entering Pindimar Bay.



Title:

Changes in the Study Region Bathymetry from 2001 to 2009

Figure: 3-1

Rev: A

N

0 0.5 1km

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_009_101011 Bathy Comparison.WOR

The most significant erosion has occurred along the eastern shoreline of Corrie Island, with bed level changes of >-2.0m. A similar region of erosion is located on the other side of the Winda Woppa sand spit, in both of the figures, and may contribute some sand to extension of the sand spit.

Smaller erosion areas are located in the Northern Channel and along the Lower Myall River and may be due to movement of shoals or artefacts of dredging. The data does not indicate widespread instability of the Lower Myall River Channel. The issues of sedimentation and erosion raised by the community therefore appear to be localised, but may be affected by changes to the depth and shape of the eastern channel.

Although the survey extent does not cover the entire area where sediment transport is likely to occur, there is a clear indication of greater accretion than erosion within this area of the estuary. This is likely to be related to sand arriving from areas that are not well represented by the survey. These are likely:

- Erosion from the foreshore of Winda Woppa; and
- Progressive migration of the flood tide delta from offshore towards the eastern edge of Corrie Island.

3.2 Tidal Data

A series of data collection campaigns have been undertaken within the Lower Myall River region, and these are summarised below.

3.2.1 Tidal Data Collection Campaigns

- Myall River Tidal Data Collection, 22nd October 1975 (PWD 1982)

Field data was collected from a number of transects in and around the confluence of the Myall River as it enters Port Stephens. Data collected included tidal water levels, tidal gradients, float tracking of currents, tidal velocities and tidal flows. The data record is incomplete due to inclement weather and equipment failure.

- Lower Myall River, Process Study Datum Establishment, September 1979 (PWD 1981)

Field data was collected on the 16th November 1977, with some additional sampling on surrounding dates. Data collected included: water levels (7 locations), water velocities (4 lines), salinity and temperature (infrequent measurements) and bed samples for suspended sediments at a number of locations.

- Port Stephens Tidal Data Collection, September 1993 (PWD 1998)

Two field data collection exercises were undertaken on the 29 and 30th September 1993, each over a full tidal cycle. Data collected included: water levels (7 sites), tidal discharge (6 sites), tidal velocities (12 sites), water quality (10 sites).

- Myall River Data Collection, September 2008 to September 2009 (DECCW & MHL 2010)

Two separate data collection exercises were undertaken between September 2008 and 2009. The first occurred during September 2008 - February 2009, when water levels and salinity were monitored at 3 sites within the estuary. Additional water quality profiles were measured during the high water slack on 5th September and the low water slack on 25th October 2008. Measurements included: density, conductivity, temperature, salinity, DO, pH, chlorophyll-a, photosynthetically active radiation (PAR), turbidity and water depth.

The second data collection period involved intensive field sampling from the 21st to 24th September 2009. The locations of various collection sites are shown on Figure 3-2, measuring tidal velocities, flow discharges and tidal prisms at 3 sites (Northern Channel, Eastern Channel and Monkey Jacket Creek) in the estuary over a full spring tide cycle. Hydrographic survey of the Lower Myall River was undertaken in conjunction with the tidal gauging. A temporary meteorological station was also established in the front yard of a house on, Winda Woppa, during the second data collection period. Salinity data was measured at Pindimar Bay (site 2), Corrie Island Confluence (site 5), Monkey Jacket Upstream (site 8), Brasswater (site 10) and Bombah Point (site 12).

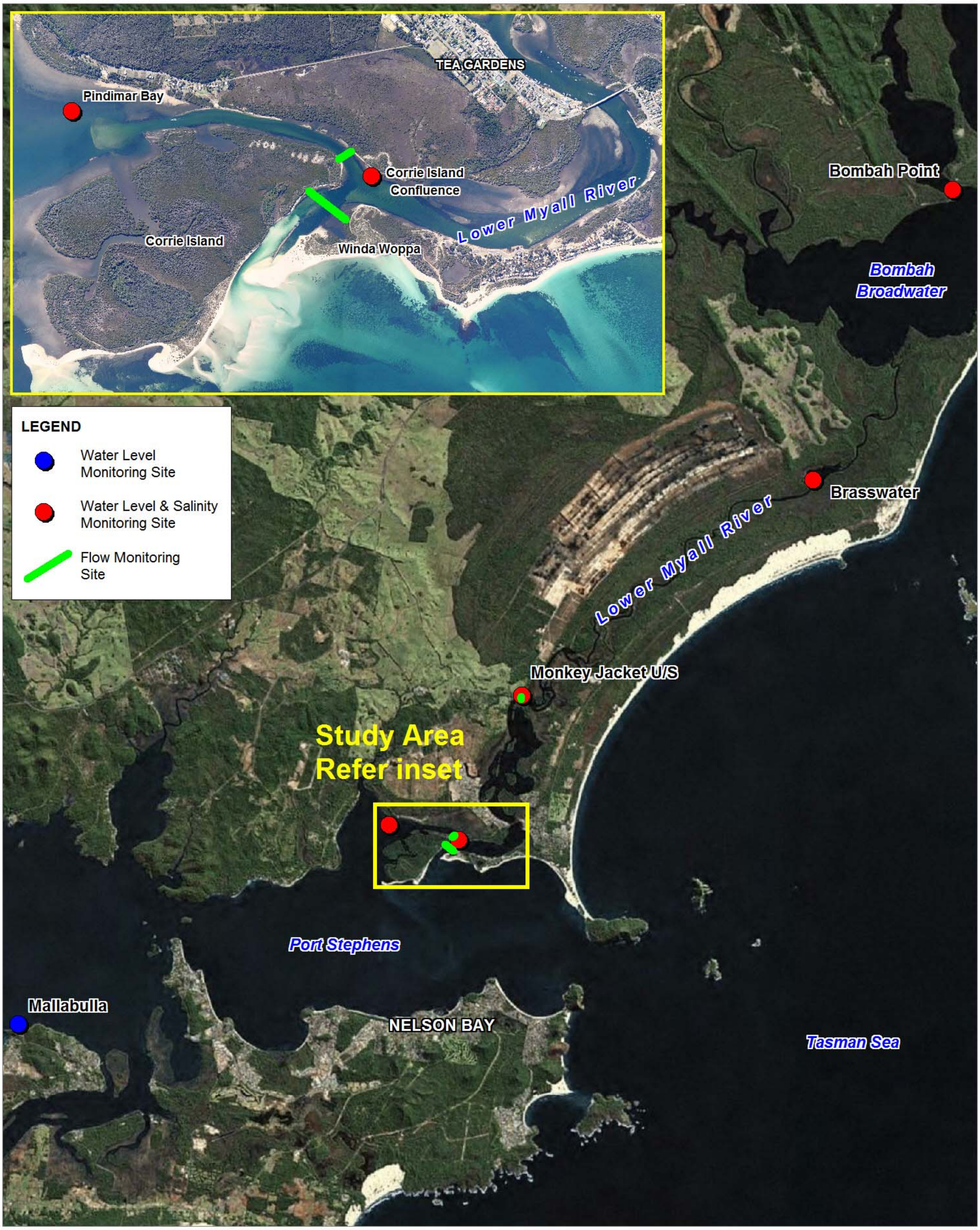
The September 2009 data represents the most complete and useful data set for validation of the numerical models established for this study.

3.2.2 Tidal Characteristics

Tides along the NSW Coast, including Port Stephens, are micro tidal (i.e. < 2 m in range) and semi-diurnal (i.e. ~ two tides occur every day). Specific tidal ranges and planes for Port Stephens are outlined in Table 3-4. The tidal range exhibits minimal attenuation across the Port Stephen's estuary flood tide delta, due to the estuary's wide entrance (1.24 km, Vila-Concejo *et al*., 2007). The tidal range within Port Stephens is amplified along the estuary, with field measurements collected on the 29th September 1993 demonstrating the flood ranges of 1.13 m recorded at Tomaree, 1.19 m at Soldiers Point 1.25 m at Tilligerry Creek 1.28 m at Mallabulla and 1.31 m at Karuah (PWD 1998). Water levels in the Upper Myall River are driven by water levels in the Lakes with negligible tidal range (MHL 1993).

Water levels for the model calibration period are shown in Figure 3-3 and demonstrate the amplitude in water levels from Tomaree (at the ocean entrance to the estuary) and Mallabulla (western basin of the estuary) as well as the large reduction in tidal influence within the Myall Lakes (Bombah Point).

Elevated water levels can promote greater tidal ranges for short periods of time, and occur along the coast in response to storms. The combined elevated water levels at Fort Denison in Sydney (reasonably consistent with the entrance to Port Stephens) for various ARIs are given in Table 3-5 (DECCW, 2009). The values do not include wave set-up, however, for most ocean conditions, water depths at the entrance to Port Stephens are such that wave breaking is not occurring and, therefore, wave set-up at the mouth of the Port is not a significant factor (MHL 1999).



Title: **Water Level, Flow and Salinity Measurement Sites**

Figure: **3-2**

Rev: **A**

N

0 2.5 5km

Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure 3-2 Water Level, flow and salinity measurement sites.WOR

Table 3-4 Tidal Planes and Tidal Ranges for Port Stephens (source: MHL, 2009)

Tidal Planes	Water Level (m AHD)
HHWSS	0.979
MHWS	0.603
MHW	0.476
MHWN	0.349
MSL	-0.034
MLWN	-0.418
MLW	-0.544
MLWS	-0.671
ISLW	-0.939
Tidal Ranges	
Mean Neap Range (MHWN-MLWN)	0.766m
Mean Range (MHW-MLW)	1.020m
Mean Spring Range (MHWS-MLWS)	1.274m
Range (HHWSS-ISLW)	1.918m

**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).*

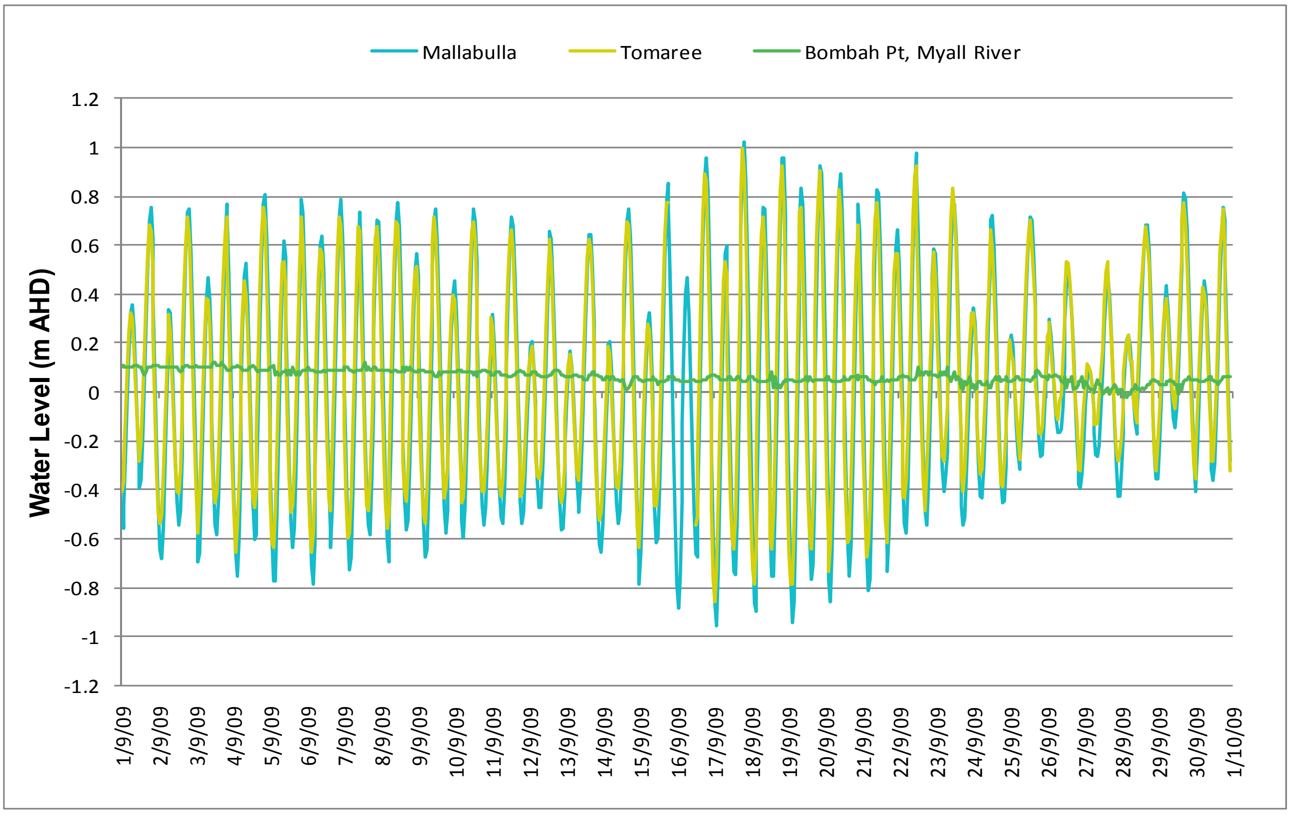


Figure 3-3 Water levels within Port Stephens and the Myall Lakes, September 2009 (MHL)

Table 3-5 Elevated Water Levels, Fort Denison, Sydney (WBM 2010)

Average Recurrence Interval (years)	Extreme Water Level (Storm Surge + HHWSS) Sydney (DECCW, 2009) (m AHD)
10	1.35
20	1.38
50	1.42
100	1.44

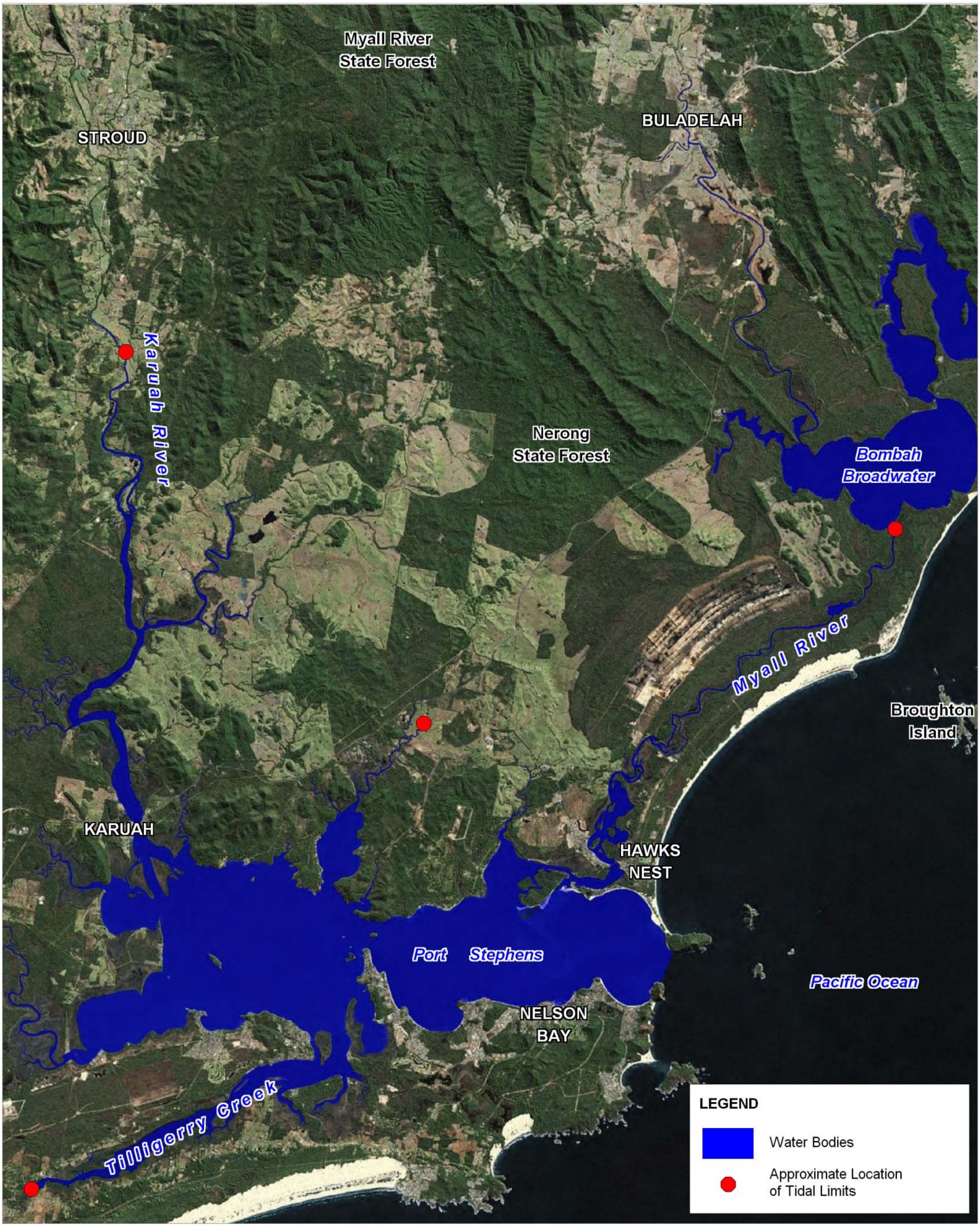
Tidal lags in peak water levels were evident at a number of locations within the Estuary. One significant time lag exists between the eastern and western side of Corrie Island (MHL 1993). During the flood tide, a change in direction of flow in the Northern Channel was observed 2hrs 30mins after that in the Eastern Channel. During the ebb tide the time lag was less, at 1hr 45mins. This resulted in an ebb tide in the Northern Channel that was much longer than the flood tide. (e.g. 7 hrs. 30 mins vs. 4 hrs. 45 mins). At the start of the flood tide, water from the Eastern Channel flowed directly into the Northern Channel instead of the Myall River (MHL 1993).

Tidal limits within the Port Stephens / Myall River are identified as follows (PWD 1988, DECCW & MHL 2010) and shown in Figure 3-4:

- 24 km upstream from Karuah, along the Karuah River (52 km from the ocean),
- in the Broadwater, 32 km along the Lower Myall River from Port Stephens (37 km from the ocean);
- 17 km from Port Stephens along Tilligerry Creek near Salt Ash, (33 km from ocean);
- 4 km upstream from Port Stephens in North Arm Cove; and
- 0.75 km upstream at a tidal barrage along the Crawford River, from the Myall River.

Maximum tidal velocities recorded by the NSW Public Works Department at the entrance to Port Stephens, exceeded 1m/s (PWD 1998). Austin *et al*. (2009) found the central channel entering Port Stephens was dominated by the flood tide (both for duration and velocities), while ebb-tide dominated channels existed adjacent to the north and south headlands at the estuary entrance.

Typical maximum tidal velocities surrounding Corrie Island were just over half that measured at the entrance and are shown in Table 3-6 (MHL 2010). The Northern Channel recorded greater tidal velocities and discharge than the Eastern Channel, and across all three sites the ebb tidal velocities were shown to be greater than the flood tide velocities, in this region of the estuary. These values, however, are for one particular tide and not necessarily representative of all tides that occur here.



Title:

Tidal Limits for Port Stephens

Figure: 3-4

Rev: A

N

0 5 10km

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_003_100929 Tidal Limits.WOR

Table 3-6 Typical Maximum Tidal Velocities

Location	Typical Maximum Flood Tide velocities	Typical Maximum Ebb Tide velocities
Northern Channel	0.66m/s	0.70m/s
Eastern Channel	0.40m/s	0.52m/s
u/s Lower Myall River	0.52m/s	0.56m/s

Tidal prism measurements by PWD (1998) over a spring tide indicated a significant reduction in the tidal prism between the estuary entrance and the western basin (from 168 x 10^6 m^3 and 165 x 10^6 m^3 for the ebb and flood tides respectively at the entrance to 5.5 x 10^6 m^3 and 4.9 x 10^6 m^3 for the ebb and flood tides respectively in the western basin).

Tidal prisms surrounding Corrie Island were measured in 2009, and are shown in Table 3-7 (MHL 2010). The largest discharge occurs through the Northern Channel. There is a significant reduction in discharge, with distance along the Lower Myall River. Fluctuations in the discharge were observed, when measurements were plotted (as seen in MHL 2010) and are thought to result from a coastal anomaly travelling north, up the NSW coast, independent of the tide (MHL 2010).

Table 3-7 Tidal Prisms (MHL, 2010)

Location	Flood Discharge (m^3 x 10^6)	Ebb Discharge (m^3 x 10^6)
Northern Channel	2.80	2.55
Eastern Channel	2.51	2.27
u/s Lower Myall River	0.67	0.57

3.3 Wave Data

Available data on waves within the Lower Myall River have been separated into three components: swell waves, wind waves and boat wake.

3.3.1 Swell Waves

Offshore wave data is collected in NSW using WaveRider buoys moored in approximately 85 m water depth, and approximately 10 km offshore. One WaveRider buoy located at Crowdy Head (140 km north of Port Stephens) does not measure wave direction; with the next closest being the Sydney buoy which is located approximately 200 km south of Port Stephens. MHL (1997) compared wave data from the Sydney buoy with measurements at Jimmys Beach in Port Stephens, and found the Sydney data to be sufficiently similar to represent the offshore wave climate at Port Stephens. As a consequence the information contained within this report has been obtained from the Sydney WaveRider buoy.

Significant wave height (H_s) is an average of the highest one-third of wave heights recorded during a set period of time. For Sydney, the average H_s is 1.63 m and maximum recorded H_s is 8.43 m (refer to Appendix B). 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 B. 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 3-8.

Table 3-8 Average Recurrence Interval Storm Wave Heights (derived from MHL, 2009)

Return Period (years)	1-hour H_s (m)	6-hour H_s (m)
1	5.8	5.3
20	8.2	7.4
50	8.9	8.1
100	9.4	8.6

The mid-NSW coast most commonly receives ocean waves from the south east and east directions, although north-east swells are also common in summer and spring. The larger swells occur most commonly from the south to south-east sector (MHL 1999).

The data provided in Appendix B 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 (WBM 2010). 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 in NSW (You and Lord, 2008), however, the waves that have produced the greatest damage and erosion around the Port Stephens estuary are typically H_s >6m (MHL 1999). 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 directions along the coast may be described by joint occurrence statistics (refer Table 3-9).

Wave period statistics for the dominant or peak, spectral wave period (T_p) at any given time is given in Table B-3 (Appendix B). 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.

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.

Wave data were obtained for September 2009 from Manly Hydraulics Laboratory, as recorded by the Crowdy Head and Sydney WaveRiders. The obtained data comprises time series' of significant wave heights (Hsig), peak spectral time periods (Tp) and wave directions (for the Sydney site only). There were some data gaps identified in the two data sets and these are shown by breaks in the lines within the figures

Table 3-9 Percentage Joint Occurrence of Wave Height and Direction, Sydney (March 1992 to December 2008, 16.84 years)

		Significant Wave Height (H_s, m)									
Dir'n	**(Deg, TN)**	**0 - 0.99**	**1 - 1.99**	**2 - 2.99**	**3 - 3.99**	**4 - 4.99**	**5 - 5.99**	**6 - 6.99**	**7 - 7.99**	**8 - 8.99**	**TOTAL (%)**
N	**348.75 - 11.24**	0	0	0	0	0	0	0	0	0	0
NNE	**11.25 - 33.74**	0.03	0.06	0	0	0	0	0	0	0	0.09
NE	**33.75 - 56.24**	0.45	2.3	0.31	0.01	0	0	0	0	0	3.07
ENE	**56.25 - 78.74**	1.26	6.53	1.02	0.11	0.02	0	0	0	0	8.95
E	**78.75 - 101.24**	1.74	7.54	1.37	0.26	0.06	0.01	0	0	0	10.99
ESE	**101.25 - 123.74**	1.89	6.3	1.49	0.28	0.06	0.01	0	0	0	10.04
SE	**123.75 - 146.24**	3.3	9.77	2.48	0.52	0.14	0.05	0.02	0	0	16.28
SSE	**146.25 - 168.74**	5.28	17.93	5.24	1.23	0.34	0.1	0.02	0.01	0	30.16

Dir'n	(Deg, TN)	Significant Wave Height (H_s, m)									
		0 - 0.99	1 - 1.99	2 - 2.99	3 - 3.99	4 - 4.99	5 - 5.99	6 - 6.99	7 - 7.99	8 - 8.99	TOTAL (%)
S	168.75 - 191.24	1.81	10.01	5.26	1.53	0.39	0.1	0.02	0	0	19.12
SSW	191.25 - 213.74	0.11	0.57	0.2	0.05	0.01	0	0	0	0	0.94
SW	213.75 - 236.24	0.03	0.04	0	0	0	0	0	0	0	0.07
WSW	236.25 - 258.74	0.01	0.03	0	0	0	0	0	0	0	0.04
W	*258.75 - 281.24*	*0.05*	*0.02*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0.08*
WNW	*281.25 - 303.74*	*0.05*	*0.03*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0.08*
NW	*303.75 - 326.24*	*0.05*	*0.01*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0.06*
NNW	*326.25 - 348.74*	*0.02*	*0.01*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0.03*
Total	%	16.08	61.16	17.39	4.00	1.03	0.28	0.06	0.01	0	100.00

Significant wave heights (Hsig) across the two sites were typically between 1-2 metres (Figure 3-5). Common peaks were observed around the 10-11th, 25th and the 30th September, and suggest large storms passing across the coastline. Uncommon peaks also occurred at the two locations, often with a time lag, and suggest smaller storms passing up or down the coast. Immediately prior to the field sampling time period (24th September) the offshore wave data contains significant wave heights building to 2.75m, peaking around the 25th Sept and again on the 30th September. The peaks correspond to two separate periods of strong southerly winds.

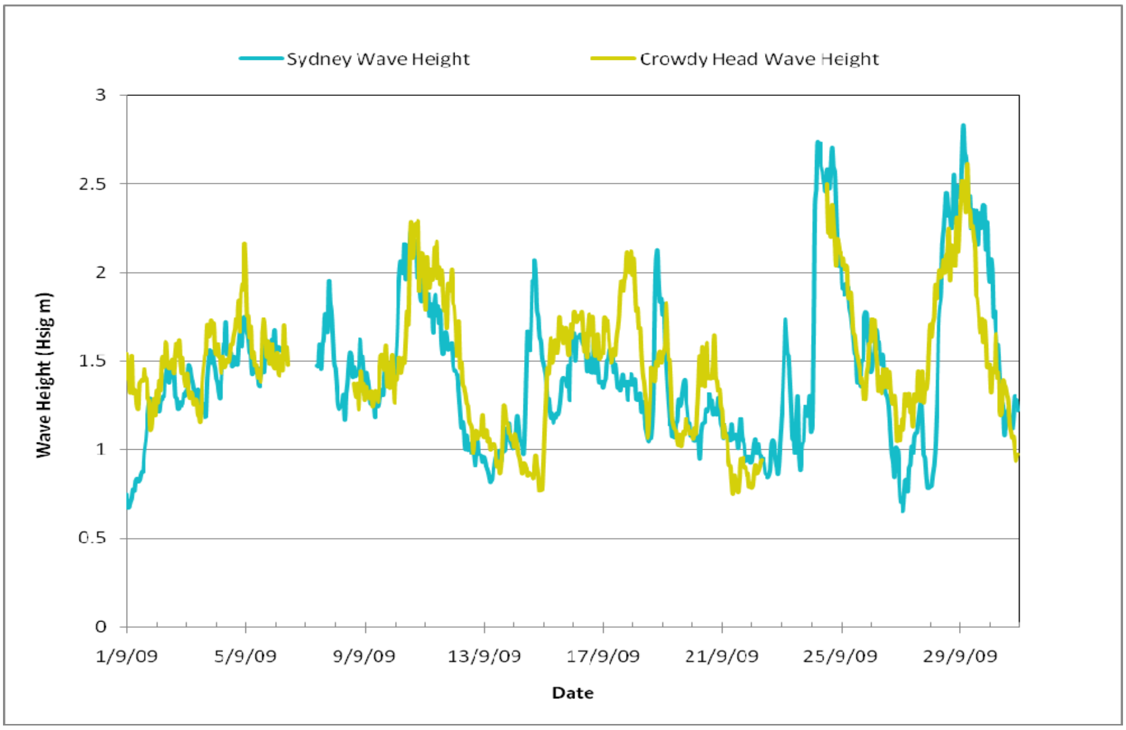


Figure 3-5 Wave heights for Sydney and Crowdy Head for September 2009

Wave directions offshore from Sydney showed large southerly waves (180 degrees direction) (Figure 3-6) which slowly decreased in magnitude and shifted in direction to easterly, then northerly and then back from the south again. This pattern appeared to be repeated on an approximate weekly basis. Five peaks in Hsig > 2m were also observed and corresponded with typically southerly waves, with one exception around the 19th September where the waves observed are from the north. On the 24th September (model calibration period) the waves originate from the south and slowly shift towards the south east.

Peak spectral periods for the majority of offshore waves were approximately 10 seconds (Figure 3-7). During the 24th September peak spectral wave periods decreased to approximately 4-6 seconds, indicating the addition of wind driven waves, but this only occurred for a short time period.

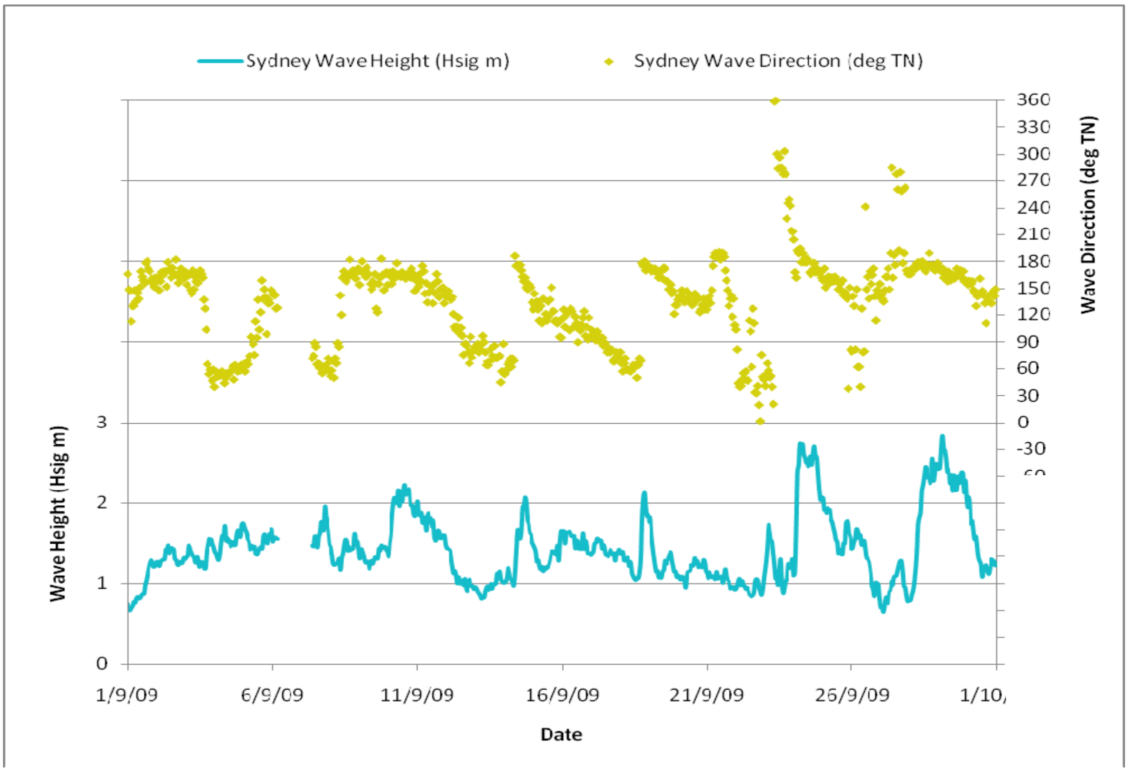


Figure 3-6 Offshore Wave Heights and Direction for Sydney, during September 2009

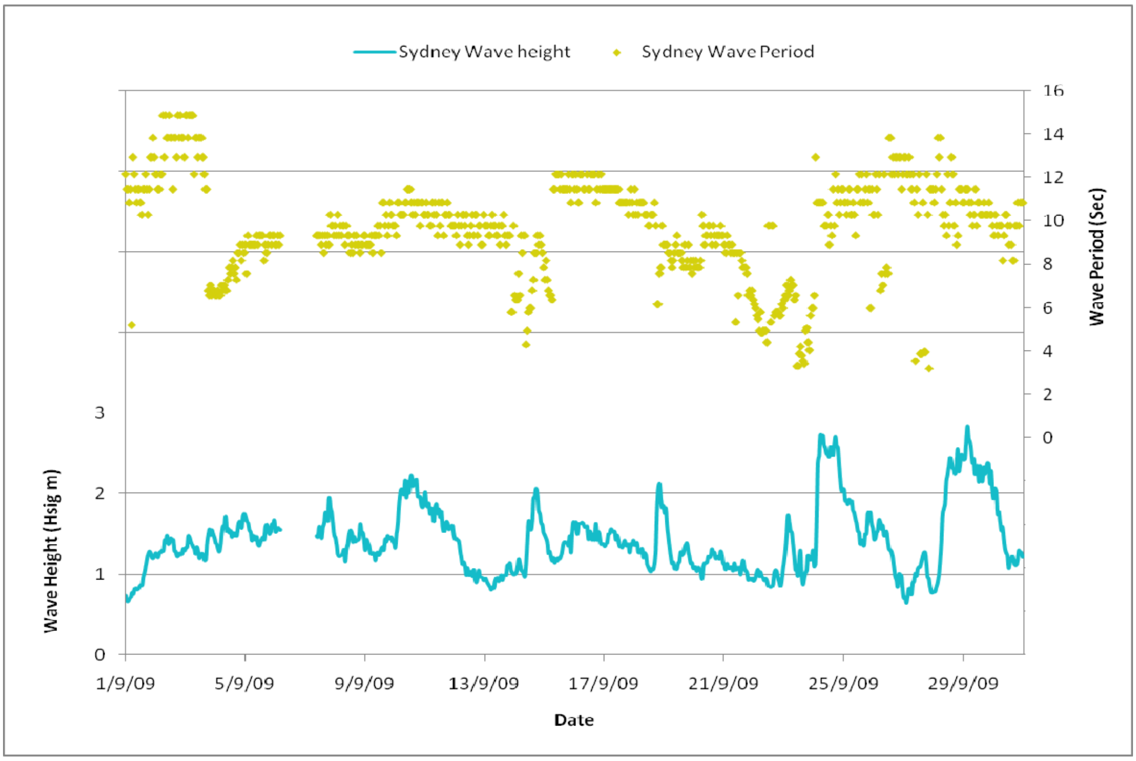


Figure 3-7 Wave Height and Wave Period for Sydney during September, 2009

3.3.2 Wind Waves

A 21 year long wind data record (1989 – 2009) from the Bureau of Meteorology's Williamtown weather station (approximately 30km south of Port Stephens) provides a good historical record for the site. Furthermore, MHL (1996) compared Jimmys Beach and Williamtown wind data, and found that Williamtown data is appropriate for use in Port Stephens.

The strongest winds occur from the north-west / west during winter (offshore directed wind), and east / south east directions over summer (onshore directed wind) (WBM 2010, MHL 1999), while the north-westerly direction has the most common occurrence of strong winds (above 12m/s or 25 knots) (MHL 1999).

WBM 2010 found the Generalised Extreme Value probability distribution provided a good fit to wind speed exceedance data across all of the wind directional sectors. The distribution was used to derive wind speeds for the 1, 5, 20, 25 and 50 year Average Recurrence Interval (ARI) events, as given in Table 3-10. For some wind directions, the data record was insufficient to define values for ARI's greater than 20 years (e.g., NE, SS directions).

Wind speed and direction data were obtained from the Bureau of Meteorology for September 2009, and are plotted as Figure 3-8 and Figure 3-9 respectively. This period covered the most recent and useful tidal data collection campaign between 21st and 24th September 2009. , Validation of the numerical model using this data is described in Chapter 4. During this time periodic changes in low wind speeds occurred from the 21st – 23rd September, followed by significant southerly winds, on the 24th September, exceeding 15m/s.

Table 3-10 ARI Wind Speeds at Each Wind Octant

Average Recurrence Interval (years)	Wind Speed (m/s)							
	N	NE	E	SE	S	SW	W	NW
1	7.84	9.99	10.88	12.21	13.59	12.41	15.76	15.80
5	9.84	11.60	12.69	14.43	15.32	14.73	17.88	18.46
10	10.44	12.20	13.42	15.55	15.87	15.43	18.55	19.23
20	10.92	12.78	14.11	16.78	16.34	15.99	19.09	19.81
25	11.06		14.32	17.20		16.15	19.25	19.98
50				18.60				20.40

3.3.3 Boat Wake

The dominant wave energy along the Myall River upstream of Winda Woppa is from boat wake (MHL 1999). Of particular relevance are the larger cruisers and commercial vessels which travel along the Myall River between Myall Lakes and Tea Gardens. No measurements have been taken at this location however investigations elsewhere indicate large cruisers travelling at low speeds may generate wave heights of 0.5m with short wave periods (2 to 3 seconds) (MHL 1999).

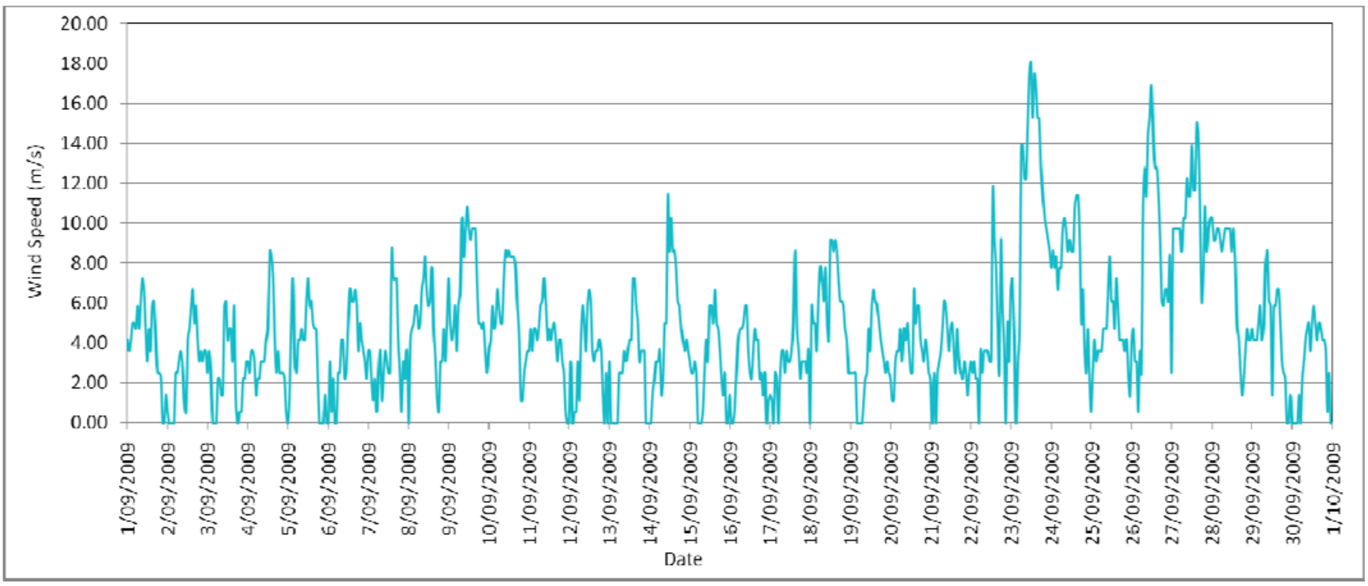


Figure 3-8 Wind Speed and Direction for September 2009

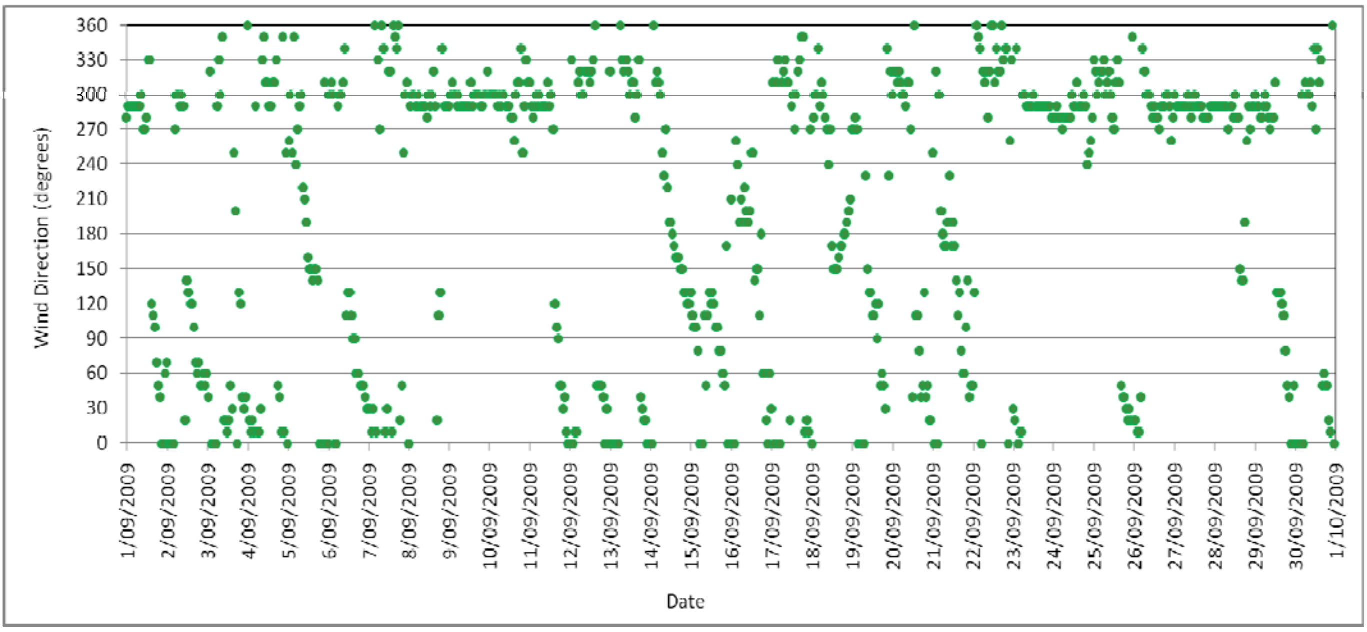


Figure 3-9 Wind Direction for September 2009

3.4 Aerial Photography

3.4.1 Existing information

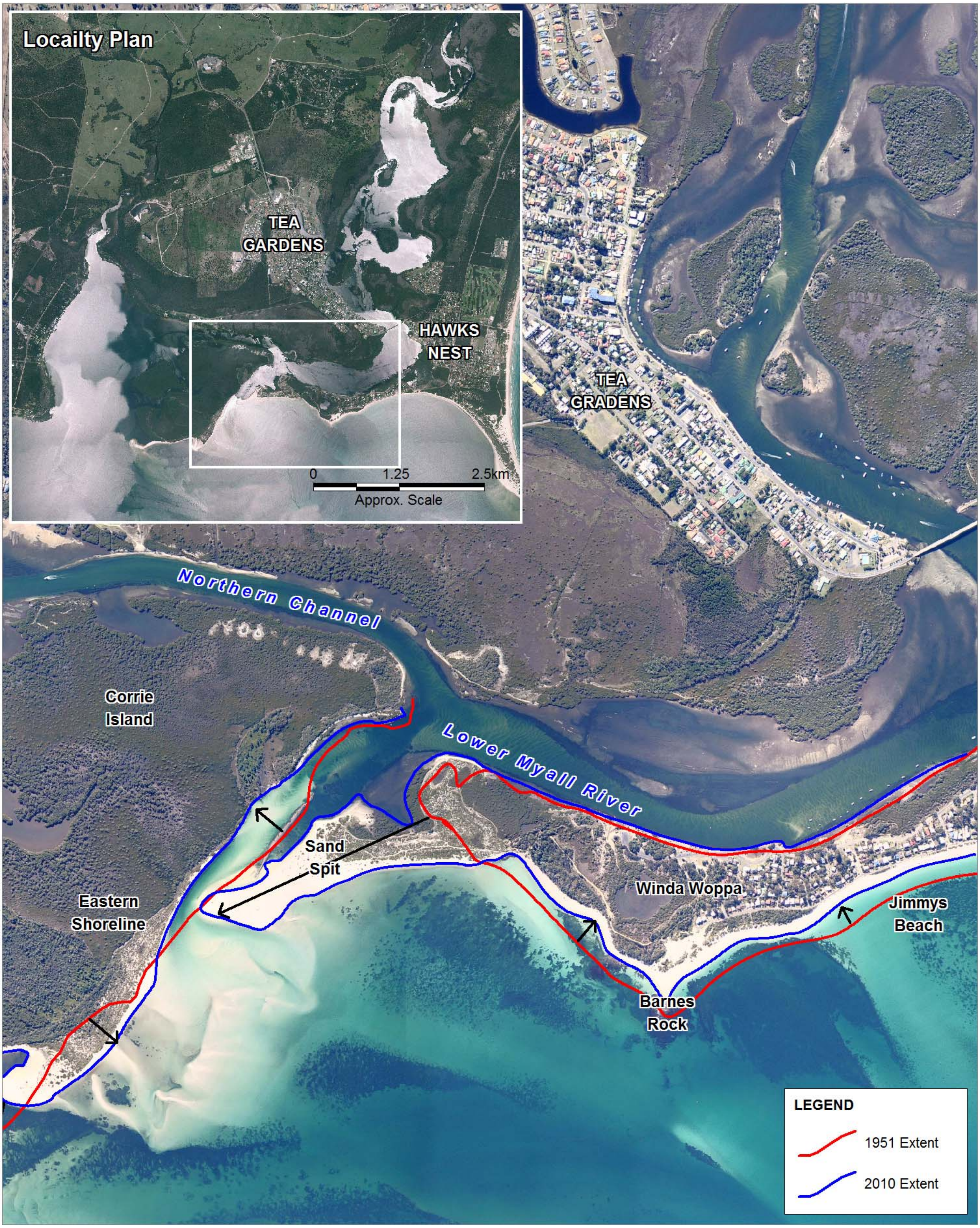
Aerial photographs of the Lower Myall River were obtained from DECCW, for a range of years spanning 1951 to 2008. An additional aerial photograph was obtained from Nearmap Pty Ltd (Nearmap 2010) for the year 2010. The images were geo-referenced to allow analysis in MapInfo, a GIS software package. The years include: 1951, 1963, 1966, 1977, 1979, 1980, 1986, 1991, 1993, 1994, 1996, 1999, 2001, 2006, 2008 and 2010.

3.4.2 Analysis

Key depositional features have been identified in each of the aerial photographs and changes over time discussed. The absence or presence of depositional or erosional changes provides an indication of "morphological" activity (erosion and/or deposition of sediments).

Three notably active sediment transport areas within the study region were identified from the aerial photographs. These key areas were the sand spit extending from Winda Woppa, the eastern shoreline of Corrie Island and the recurved spit extending from the southern end of Corrie Island Figure 3-10, Figure 3-11 and Figure 3-12.

The sand spit at Winda Woppa has grown considerably over the years from 1951 to 2010 (Figure 3-10) and now extends approximately 720m further to the south west, with half of the extension covered in dune vegetation. The greatest changes are evident between 1963 and 1977, and between 1991 and 2006/2010 (Figure 3-11). Spits typically grow in the direction of predominant littoral drift and can only exist through the continued longshore supply of sediment, analysis of available survey data indicates that most of this sand comes from erosion of Winda Woppa to the west of Barnes Rock (refer Section 3.7 and Appendix D).



Title:

Historical Sediment Transport Trends

Figure: **3-10**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in 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.

N

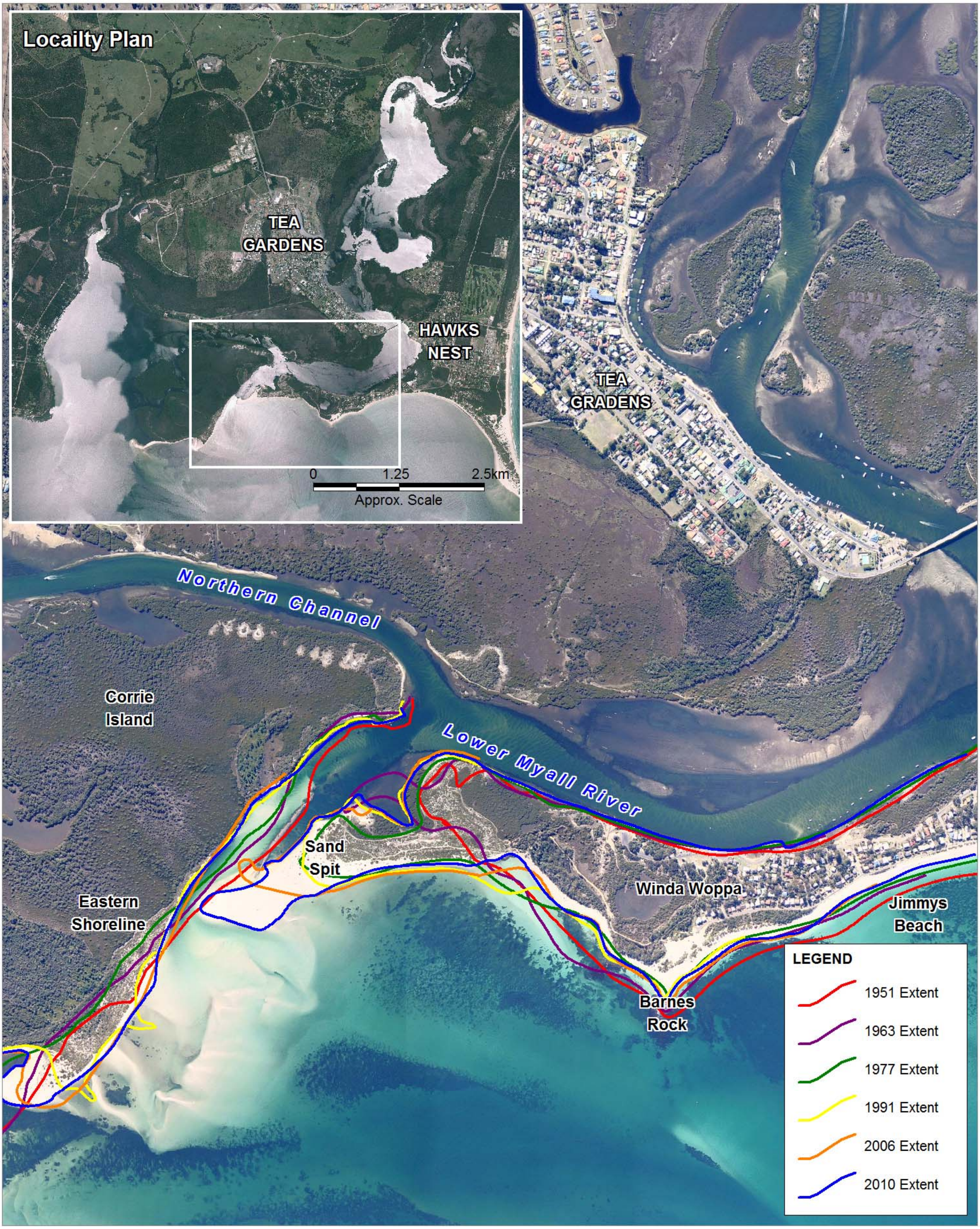
0 375 750m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_007_101007 Sediment Transport.WOR



Title:

Decadal Trends Around the Sand Spit

Figure: **3-11**

Rev: **A**

N

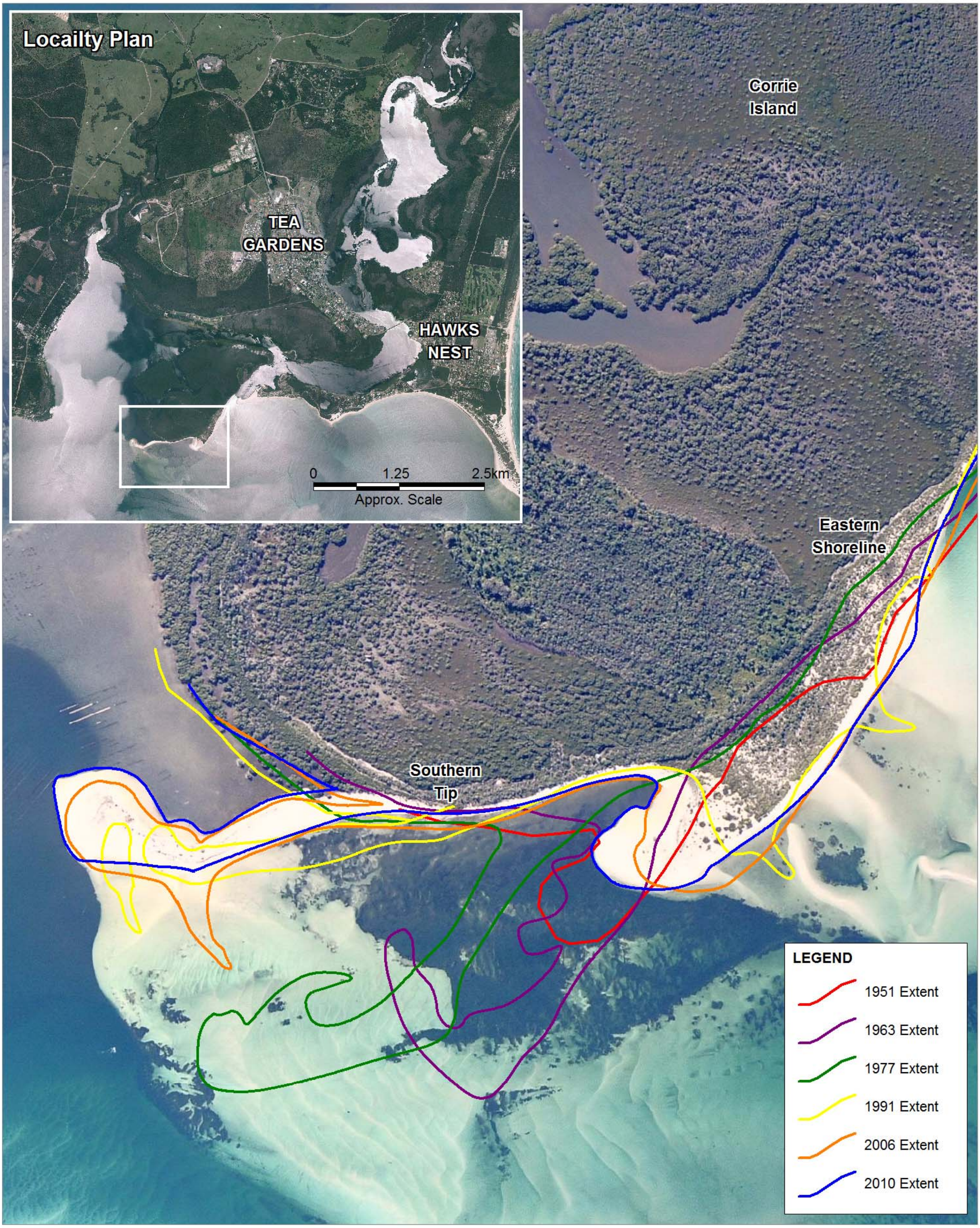
0 375 750m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_004_100929 Sand Spit.WOR



Title:

Decadal Trends Around the Tip of Corrie Island

Figure: **3-12**

Rev: **A**

N

0 200 400m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_008_101007 Corrie Island.WOR

The eastern shoreline of Corrie Island has undergone an anti-clockwise rotation towards a more north – south alignment, from 1951 to 2010 (Figure 3-11). The aerial photographs suggest erosion and accretion of approximately 130m, at the north and south ends respectively. The rotation is a likely consequence of increased erosion where the extension of Winda Woppa is pinching flows against Corrie Island, and deposition of some of this sediment towards the south along Corrie Island. The local wave climate may also be playing a role in the transport and affecting some of the change. Undulations can be seen on the eastern shoreline of Corrie Island in 1991 (Figure 3-11).

The recurved spit at the southern end of Corrie Island (Figure 3-12) has grown towards the southwest and west, between 1951 and 2010. In more recent years (1991 to present) another sand spit has begun to grow from the island, suggesting a significant ongoing longshore supply of sand.

Larger scale features in the estuary include the Sand Barrier known as the *Yacaaba Barrier* located between Yacaaba Head and Hawks Nest (Figure 1-2). This feature was present in all aerial photographs examined (1951 to 2010) with dune vegetation increasing over the barrier with time, suggesting increasing stabilisation.

Inside the estuary, the Flood Tide Delta (Figure 1-2) is the main depositional feature present in all of the photographs ranging from 1951 to 2010, with the western extent of the delta varying little over time.

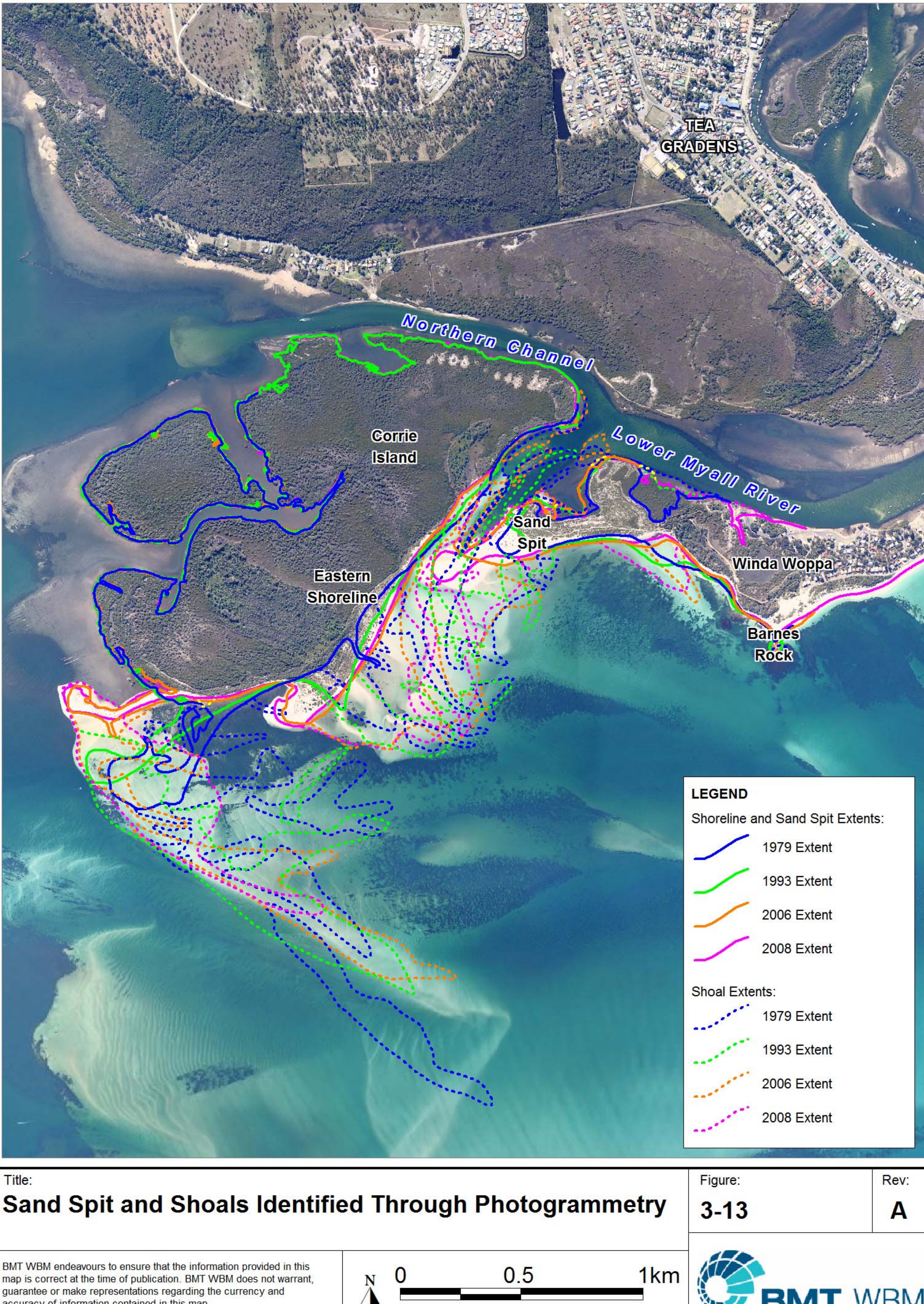
3.5 Photogrammetry

Photogrammetric analysis was undertaken by DECCW (2009) and involved the identification of sand spits and shoals in the study area (Figure 3-13). Submerged and emergent shoals, sand spits and shorelines were identified and mapped through stereographic analysis of aerial photographs from 1979, 1993, 2006 and 2008. There was consideration of water levels, and the extent of many features was limited to the extent of visibility on the aerial photographs. The numerous shoal outlines within the region to the south east of Corrie Island demonstrate the dynamic nature of this location. The southernmost submerged shoals indicate relocation to the north east from 1979 to 2008, and are likely to be providing a source of sand for growth of the sand spit at the southern end of Corrie Island. Evidence can also be seen of the migration of the remnant sands from Myall Spit. These processes have been documented previously (Section 3.4.2) in greater detail.

3.6 Sediments

Sediment types can be classified by their sand fraction and the four main sediment types relevant to the Lower Myall River entrance study area include the following (MHL 1993):

- *River Sand* – derived by terrestrial erosion and is relatively rich in lithic grains reflecting the rock types in the catchment.
- *Reworked Coastal Sand* – predominantly quartzose with very little lithic material. The sands are light grey to light brown, often with brown humic coatings. Grains are sub angular to well-rounded and moderately well sorted. Shells are generally absent and so it iron staining.
- *Beach and Near shore Marine Sand* – quartzose and fawn in colour due to iron staining. Shelly fragments are common, and the sand is rounded to well-rounded.



Title:

Sand Spit and Shoals Identified Through Photogrammetry

Figure: 3-13

Rev: A

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_010_1010 Shoals Pgram.WOR

- *Offshore Sand* – ranges from quartz to lithic of similar composition to river sand. It is fine grained, moderately sorted with angular to sub rounded grains and fine shell fragments.

The distribution of sediment types in the Lower Myall River are shown in Figure 3-14. Locations for a set of sediment samples are shown on Figure 3-15 (MHL 1993). Data on the particle sizes at these locations can be found in Table 3-11.

The data shows the sand in the vicinity of the Eastern Channel and Winda Woppa spit to be typically coarse and moderately well sorted with D_{50} grain size of around 0.50 mm.

Table 3-11 Sediment particle sizes for the Lower Myall River entrance (MHL 1993)

Sample Site	Particle Size (mm)		Remarks
	Mean	D50%ile	
1	0.55	0.41	Coarse sand, moderately well sorted
2	0.50	0.41	Coarse sand, moderately well sorted
3	0.43	0.36	Coarse sand, moderately well sorted
4	0.55	0.47	Coarse sand, moderately well sorted
5	0.50	0.42	Coarse sand, moderately well sorted
6	0.53	0.43	Coarse sand, moderately well sorted
7	0.45	0.37	Medium sand, moderately well sorted
8	0.37	0.34	Medium sand, well sorted
9	0.55	0.47	Coarse sand, moderately well sorted
10	0.44	0.29	Medium sand, moderately well sorted
11	0.75	0.59	Coarse sand, moderately well sorted
12	0.54	0.36	Coarse sand, moderately well sorted
13	0.35	0.24	Medium sand, moderately well sorted

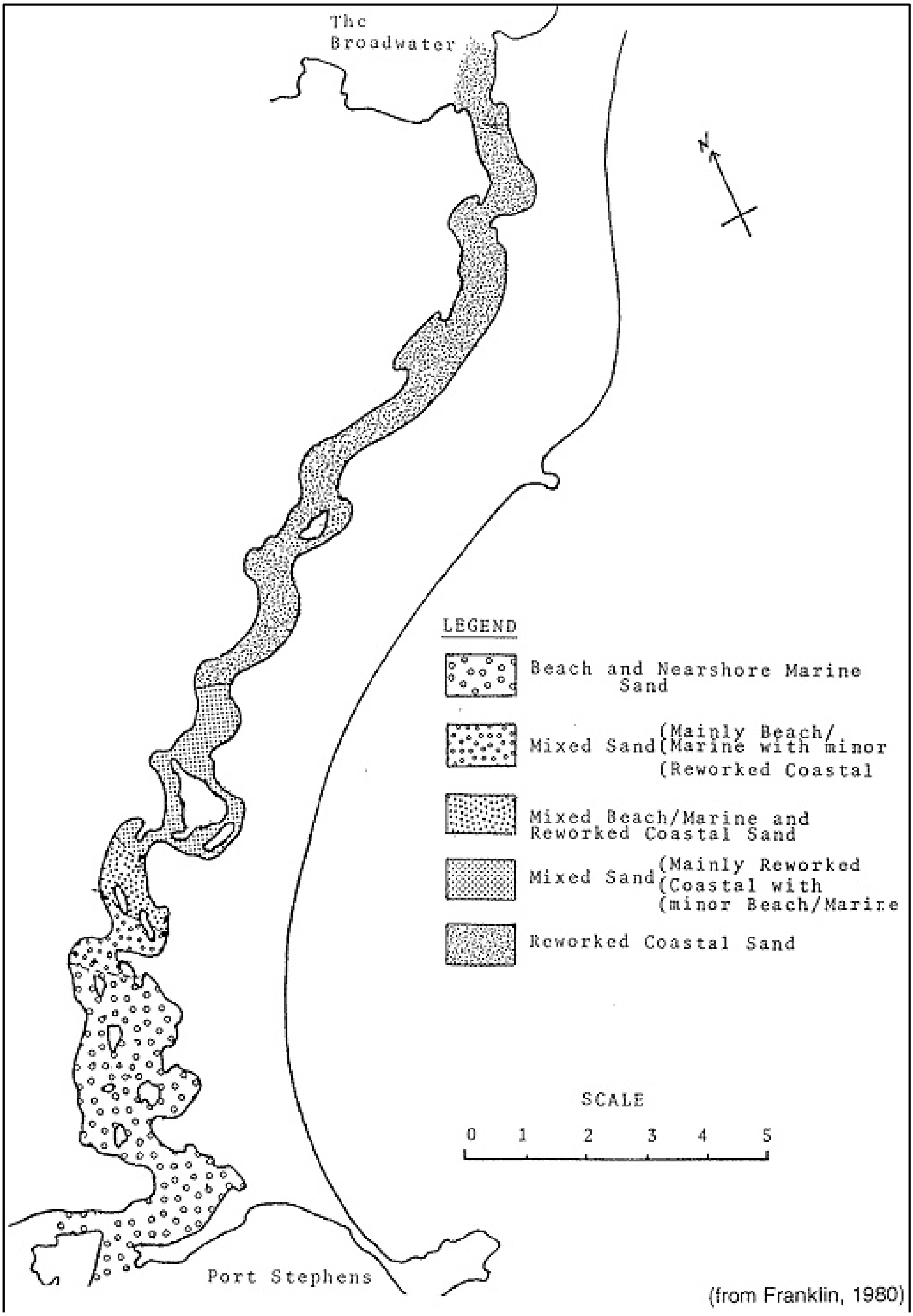


Figure 3-14 Sediment Distributions in the Lower Myall River (MHL 1993)

Figure 3-15 Sediment Sampling Sites for 1975 Study (MHL 1993)

3.7 Source of Sand Accumulation in the Eastern Channel

Appendix D provides a detailed assessment of Longshore Sediment Transport along the Winda Woppa peninsula. Volumetric analysis is also used and presented in Appendix D to compare the quantity of sediment accumulation within the Eastern Channel (and the new recurved spit) with the observed erosion occurring to the west of Barnes Rock. The results of this assessment suggest that the area west of Barnes Rock is a mostly-confined sediment cell. This means that the progradation of the spit and accumulation within the Eastern Channel has primarily been sourced from erosion of the foreshore of Winda Woppa Spit west of Barnes Rock. There is little net transport of sediment from Jimmy's Beach into the Eastern Channel of the Lower Myall River.

Detailed processes associated with the erosion of Jimmy's Beach have not been examined as part of this study. It is suggested that more research is required to gain a better understanding of the sediment transport processes of Jimmy's Beach, including the fate of introduced sand for nourishment purposes. Notwithstanding, based on the assessments carried out to date, it is reasonable to conclude that the sediment transport processes of Jimmy's Beach are not having a significant influence on the Lower Myall River.

3.8 Summary

The evidence from our review of background data supports many of the observations raised by the community. The bathymetric data illustrates the historical context of Winda Woppa spit extending westwards. The Eastern Channel is closing and a significant storm event could provide the catalyst that complete closes this channel.

The evidence suggests that erosion of the shoreline to the west of Barnes Rock is the primary source of sand that is currently extending the sand recurved spit and infilling the Eastern Channel. The dominant swell direction on the New South Wales coast enables waves to penetrate the entrance to Port Stephens and impact the shoreline. These swell waves are the most likely driver for erosion of the foreshore west of Barnes Rock, and for the longshore transportation of the eroded sand westward onto the new recurved spit across the Eastern Channel.

Tidal data shows that, over the past 30 years, the proportion of tides carried by the Northern Channel has doubled. In 2009, a tidal gauging indicated that approximately half of the tide is now carried by the Northern Channel. In the late 1970's it carried only 25% of the tides.

Aerial photographs and photogrammetry support the assertion that the area between Barnes Rock and the southern tip of Corrie Island is very dynamic. This dynamism introduces significant uncertainty when predicting the changes that may occur from intervention using some of the options suggested by the community (structures, dredging etc.). Numerical modelling is a useful tool to assist in reducing this uncertainty. The development and validation of numerical models is described in Section 4 and their use to assess different management options in Section 5.

4 COMPUTER MODEL DEVELOPMENT

4.1 Scope and Objectives

This section of the report details the establishment, calibration and validation of a coastal hydrodynamic and morphodynamic numerical model capable of simulating tidal hydrodynamics, waves, sediment transport and geomorphology for the Port Stephens / Myall Lakes estuary.

The primary application model prepared for this study was to investigate and assess existing environmental conditions to provide further understanding of estuarine processes (e.g. sedimentary, flushing, tidal and freshwater flow processes). The numerical model has also been used to validate key issues and concerns for the Lower Myall River and quantify changes that may result from implementation of potential management options.

4.2 Model Establishment

Development of the coastal hydrodynamic model requires a considerable amount of data to adequately represent hydrodynamic, advection / dispersion, waves and sediment transport processes occurring within the study area. The numerical model therefore requires the following datasets to simulate and / or calibrate hydrodynamics:

- **Bathymetric survey data** – used to describe the topography of the bed and coastline over the domain of a numerical model incorporating the full tidal extents of the estuary;
- **Wave, Water level and flow data** – used to calibrate and / or validate model predictions. Wave, Water level and flow data are most commonly used to ensure the model adequately represents the tidal prism of a waterway; and

For the present study, the two-dimensional hydrodynamic model (TUFLOW-FV), coastal wave model (SWAN) and sediment morphology model (TUFLOW-MORPH) were selected to satisfy the modelling scope and objectives (Figure 4-1). More detail on the selected models is provided in Appendix E.

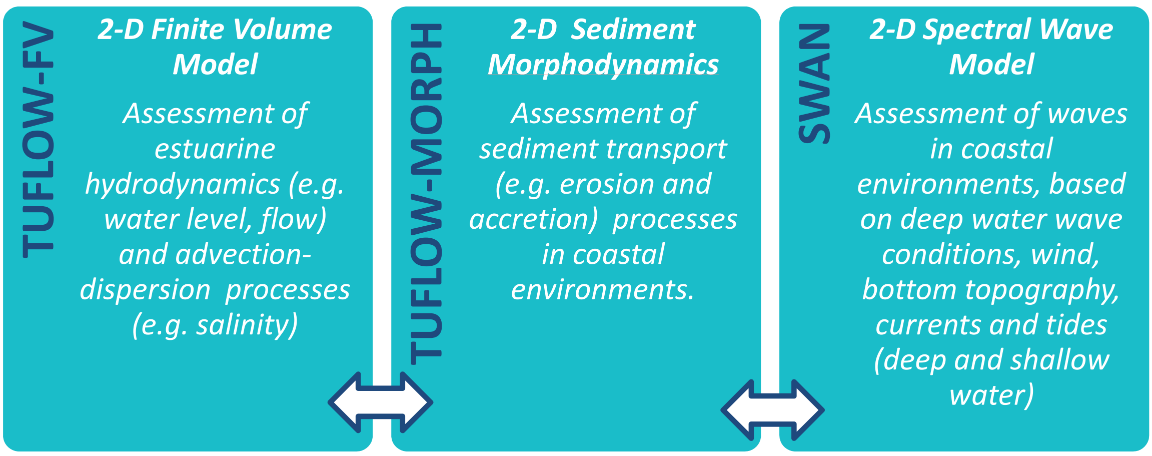


Figure 4-1 Numerical Models Adopted for the Investigations

For numerical modelling investigations, tidal flows occurring within the study area are predicted by the hydrodynamic model (TUFLOW-FV) with the effect of waves introduced from the wave model (SWAN). Sediment supply to the entrance may result from the combined effects of waves and tidal flows. As waves approach the coast, they refract, diffract, shoal (rear up) and break. These processes generate forces which act to:

- Drive longshore currents; and
- Set up the water level at the shoreline.

In order to properly model coastal sediment transport processes, it is important to provide the resulting wave forces (also known as wave radiation stresses) to the hydrodynamic model. The waves also have a direct effect in stirring sediment from the bed and thus making it more available for transport by the currents. For this reason the spatial wave field needs to be supplied to the sand transport model (TUFLOW-MORPH) as well.

Using the numerical models outlined above, the overall morphological modelling process, including the effects that waves and tidal flows have on sediment transport, follow the structure outlined in Figure 4-2. In all cases, the TUFLOW-FV hydrodynamic model is linked with the SWAN wave model, allowing the passage of wave stresses and the wave field to the hydrodynamic and sediment transport model, and bed elevations / current fields back to the wave model. This approach incorporates the important coastal processes occurring within the Estuary that influence its environmental condition and introduce changes to bathymetry over time.

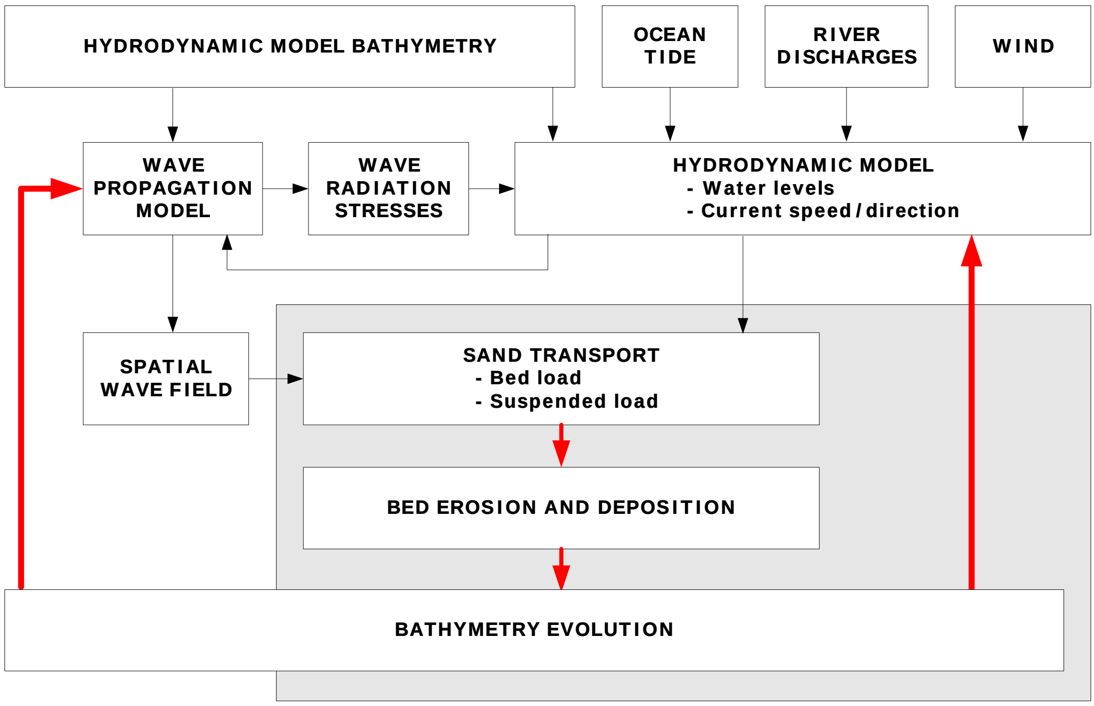
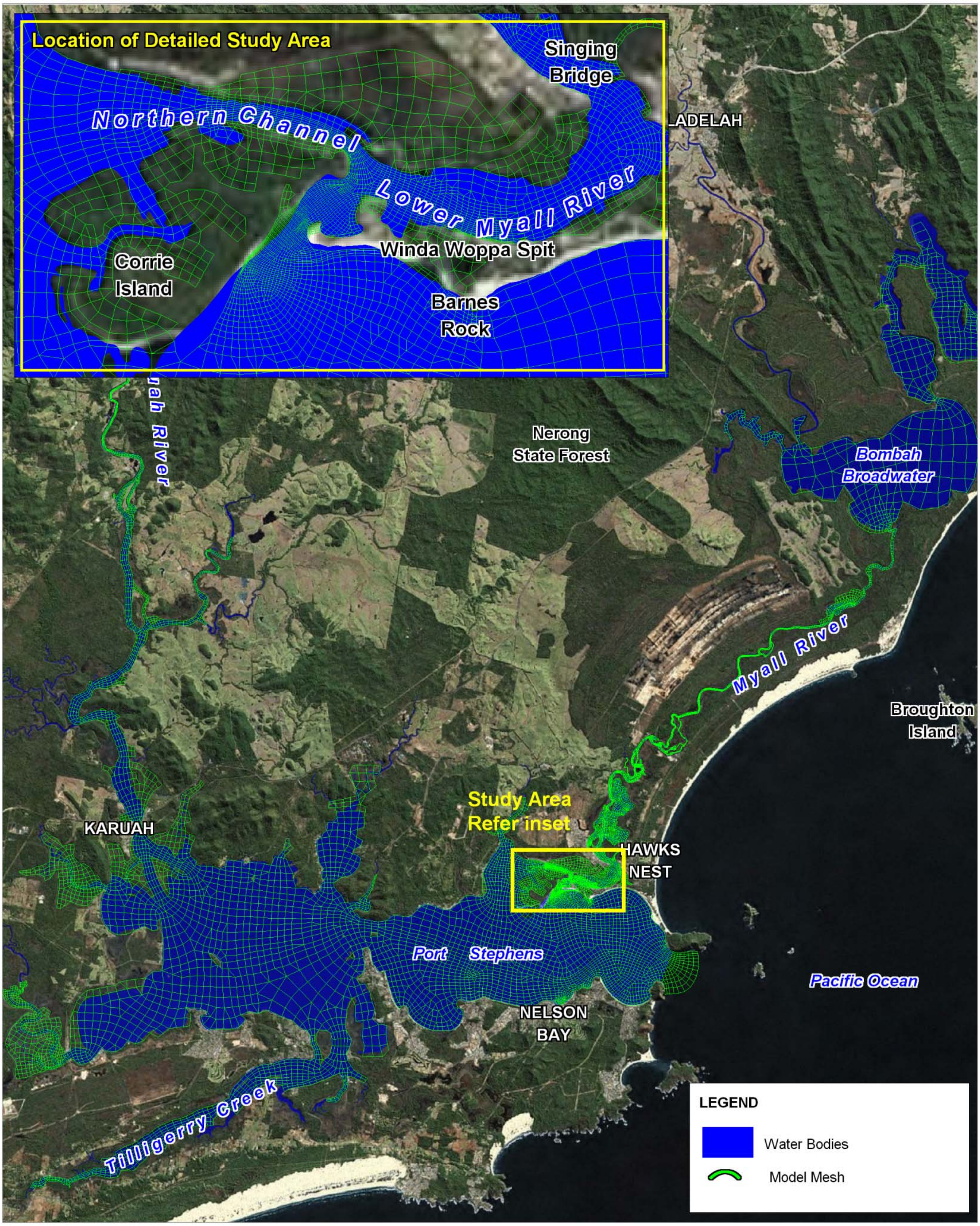


Figure 4-2 Combined Hydrodynamic, Wave and Morphological Modelling

The TUFLOW-FV mesh, which indicates the hydrodynamic and morphological model extents and resolution, is shown on Figure 4-3. The extents of the SWAN wave model, including a 'regional' model to bring in waves from deep water and a smaller 'nested' model providing more detail within Port Stephens, is shown on Figure 4-4. More details are provided in Appendix E.



Title:

Model Mesh for Port Stephens and the Lower Myall River

Figure: 4-3

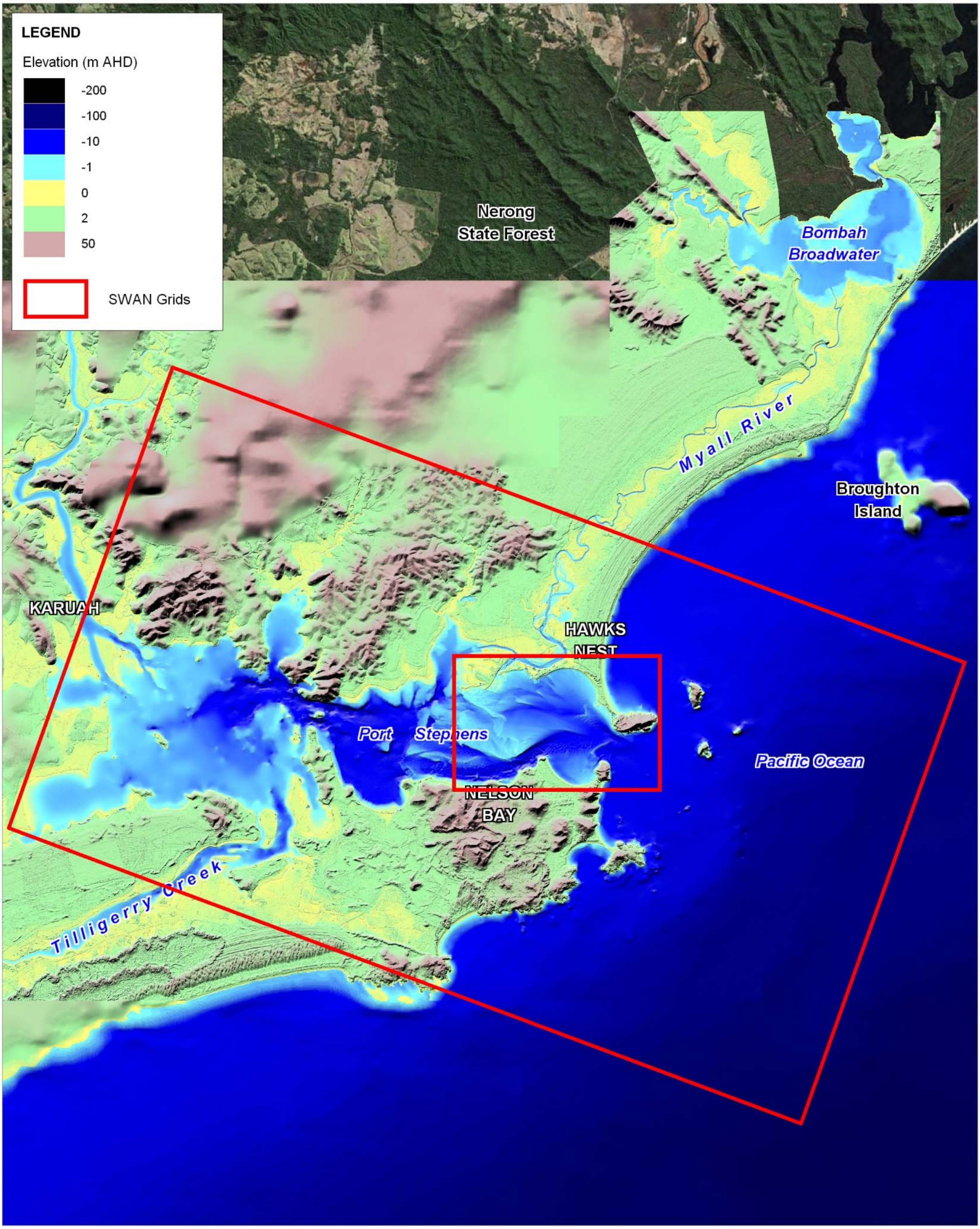
Rev: A

BMT WBM endeavours to ensure that the information provided in 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.

N 0 5 10km Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_012_110202 Model Extents.WOR



Title:

SWAN Model Grid extents

Figure: **4-4**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in 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.

N

0 5 10km

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure 4-6 SWAN Model Grid extents.WOR

4.3 Calibrating and Evaluating the Model

4.3.1 Availability of data

A number of tidal data collection campaigns have been undertaken by various government agencies for the Lower Myall region over the past 30 years or so. Our review of data collection during the late 1970's, revealed incomplete or missing datasets. These were subsequently not used. The tidal data collection undertaken by the DECCW and MHL in September 2009 represents the most up-to-date and relevant dataset for the study area.

4.3.2 Gauging locations

The data collection exercise is discussed in Section 3.2.1. The data collection locations for ADCP water levels and salinities are shown in Figure 3-2.

4.3.3 Approach to model calibration

The approach to model validation included preparing the model geometry to fit the hydrosurvey undertaken in 2009, definition of boundary conditions and adjustment of model parameters to represent the measured estuarine hydrodynamics (i.e. tidal range, current velocity / flow, water level) from 21st to 24th September, 2009.

The wave model was executed using the significant wave height, wave period and wave direction measured at Sydney over the calibration period. The outputs from the regional wave model were then fed into the nested wave model to acquire output wave forces, heights, directions and periods within the study area.

The nested wave model was run interactively with the hydrodynamic model, with the wave outputs passed through the hydrodynamic model as the simulation progressed.

The coupled hydrodynamic and wave model was run for the period 1 August to 30 September so that the model was 'warmed up' prior to the period of detailed measurement from 21st to 24th September. This means that processes such as the establishment of water level gradients through tidal pumping were appropriately represented over the model period.

4.3.4 Results of Hydrodynamic Calibration

Results including water levels and flows were extracted from the numerical model and compared to data collected during the tidal gauging. Water levels measured by MHL from permanent recorders at Mallabula and Bombah Point were obtained for September 2009 and used as an additional data source for informing calibration of model hydrodynamics.

During calibration, model parameters (i.e. bed roughness or Manning's *n* values were adjusted to match the propagation of tides, observed tidal gradients and flood / ebb flow discharges at measured locations.

The Manning's 'n' roughness values which were used in the final calibration are presented inTable 4-1.

Table 4-1 Bed Roughness Parameters Adopted

Bathymetric Feature	Manning's n Roughness
Embayment of Port Stephens	0.02
Elevated wetlands / mangroves areas	0.05
Mud flats / intertidal areas	0.03

4.3.4.1 Flow

The calibrated hydrodynamic model represents tidal conditions during the gauging period accurately with peak flood and ebb tide flow matching measured data closely at the three gauging sites. The phasing of the flow discharge curve (i.e. the rate of incline and recession between high and low water slack) is also simulated by the hydrodynamic model well as shown by Figure 4-5, Figure 4-6 and Figure 4-7.

The model results show that the relative distribution of flow into the Lower Myall River via the Northern Channel and Eastern Channel are close to those measured.

The quality of the model predictions provides a solid foundation for processes that are driven by the hydrodynamics such as mixing and morphology which are discussed further in Section 4.3.5 and Section 4.3.6.

When comparing the modelled results against the measured data there are some factors about measurement of the data that need to be considered. One factor is the transect location of the measured ADCP data, as seen in Figure 4-8, where the peak ebb and peak flood discharge plots for the eastern (i.e. 'shortcut') channel do not cover the same channel extents (i.e. different bed depths and shape). This will impact upon the measured flow volumes through these cross sections, and some discrepancy between modelled and measured values must be expected.

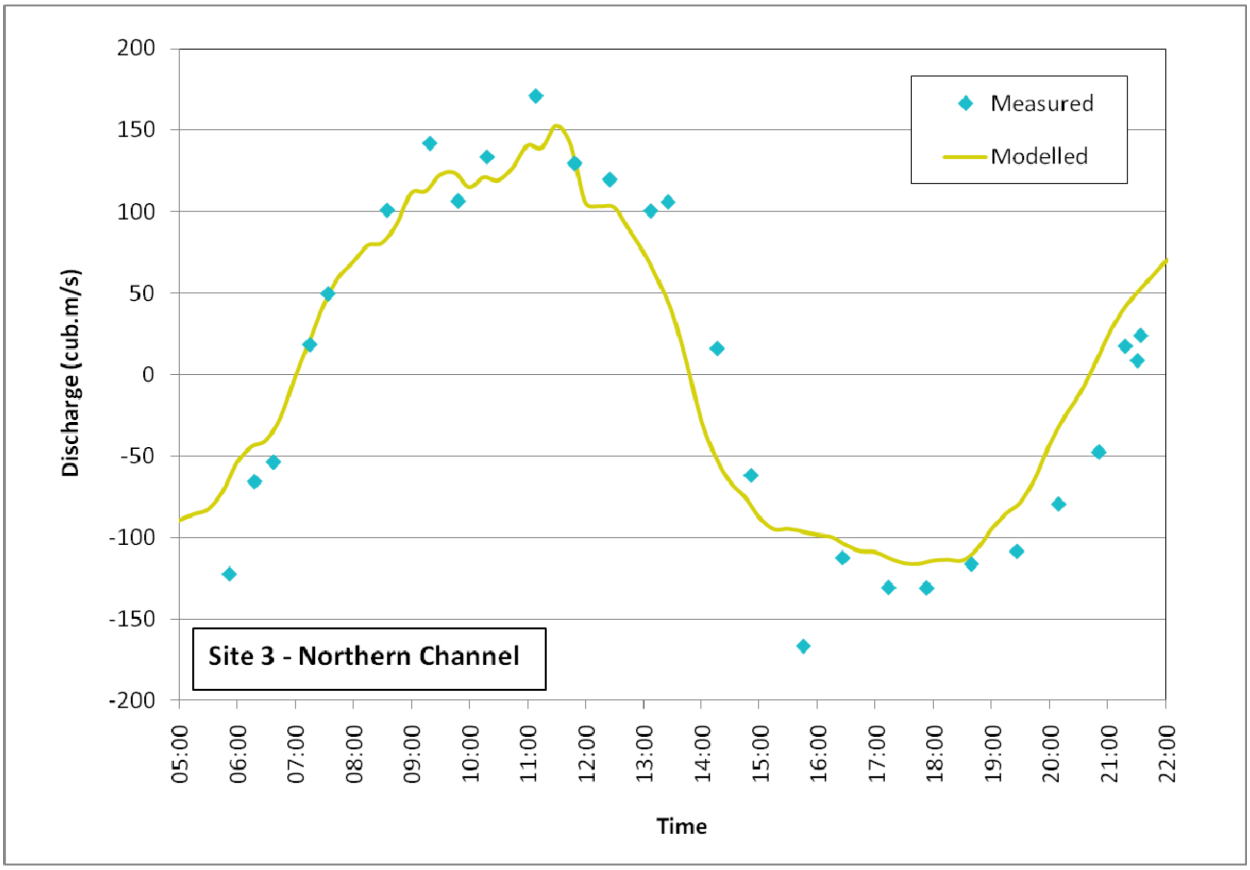


Figure 4-5 Flow Results for Northern Channel

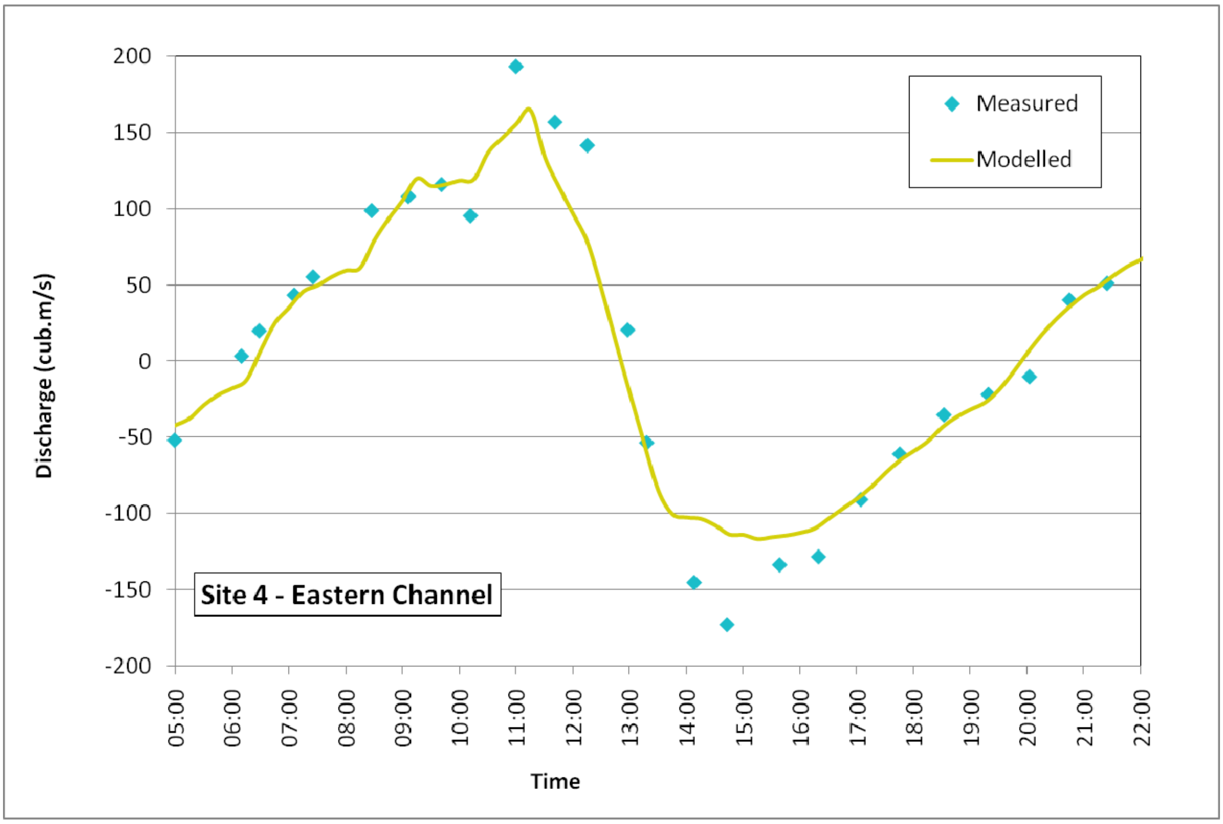


Figure 4-6 Flow Results for the Eastern Channel

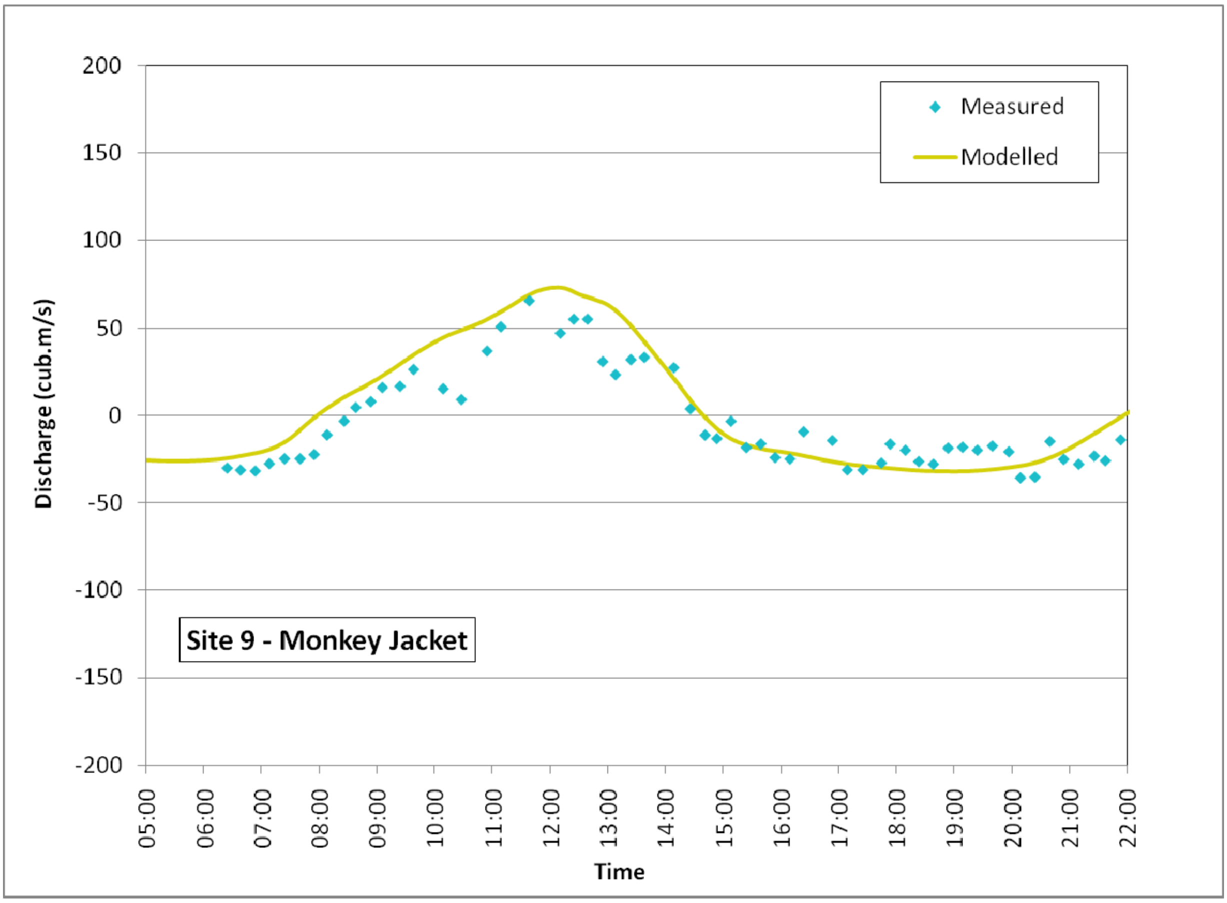


Figure 4-7 Flow Results for Monkey Jacket

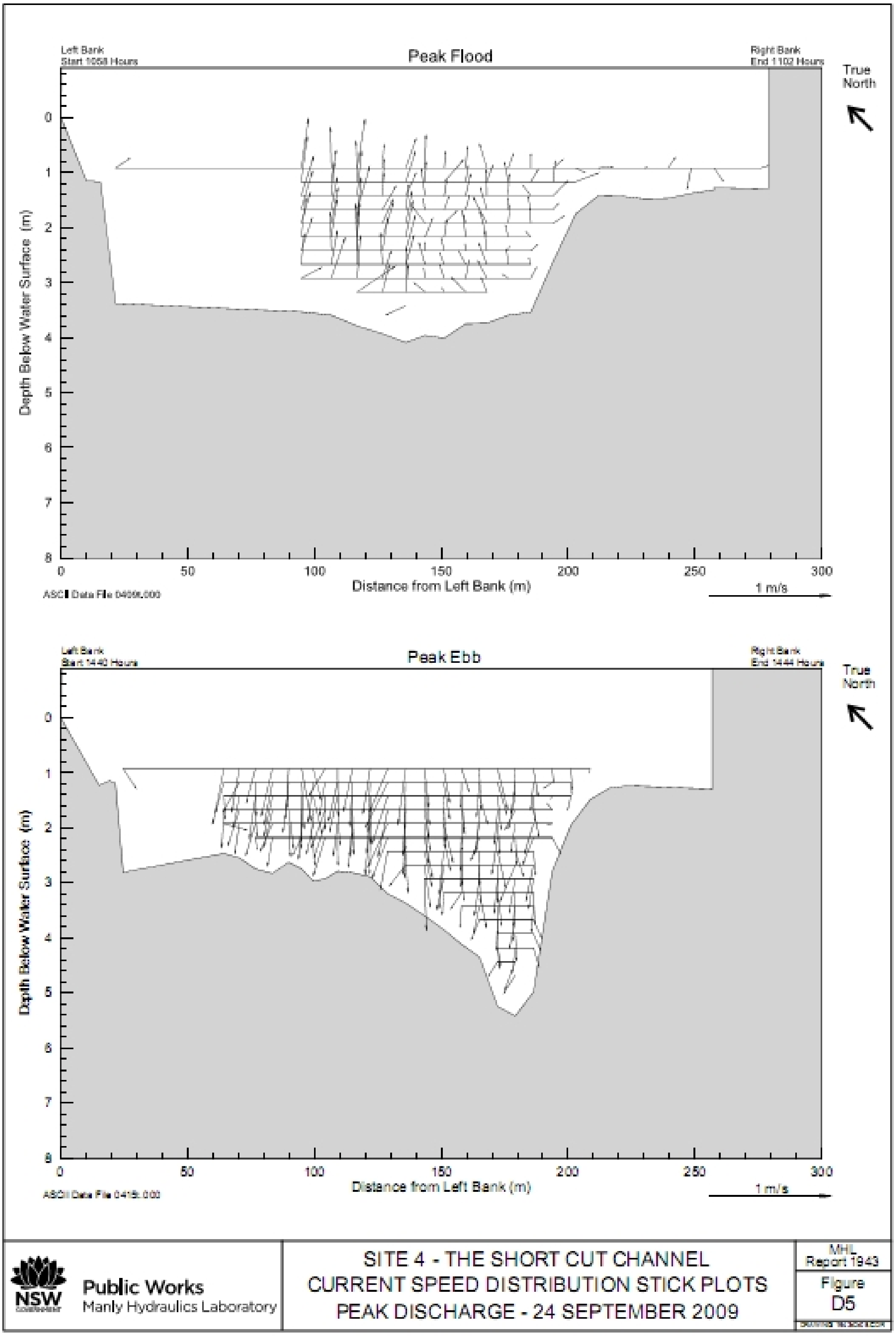


Figure 4-8 Eastern Channel Flow Vectors (MHL 2009)

4.3.4.2 Water level

Results of the water level calibration within the immediate vicinity of the study area and at other locations within the estuary are presented in Figure 4-9 to Figure 4-14. Modelled water levels compare well with observed water level data collected during the calibration period particularly around the study area (i.e. Site 3 and Site 4). The results show a good match with respect to the timing and magnitude of peak water levels during the flood and ebb tides at all gauging locations.

In the Myall Lakes at Bombah Point the model does not predict the decline in water levels as seen by the measured data (Figure 4-14). Reasons may be rainfall and evaporation or groundwater dynamics. However, as the site is well removed from the main area of interest, and the modelled results downstream are excellent, these discrepancies are acceptable.

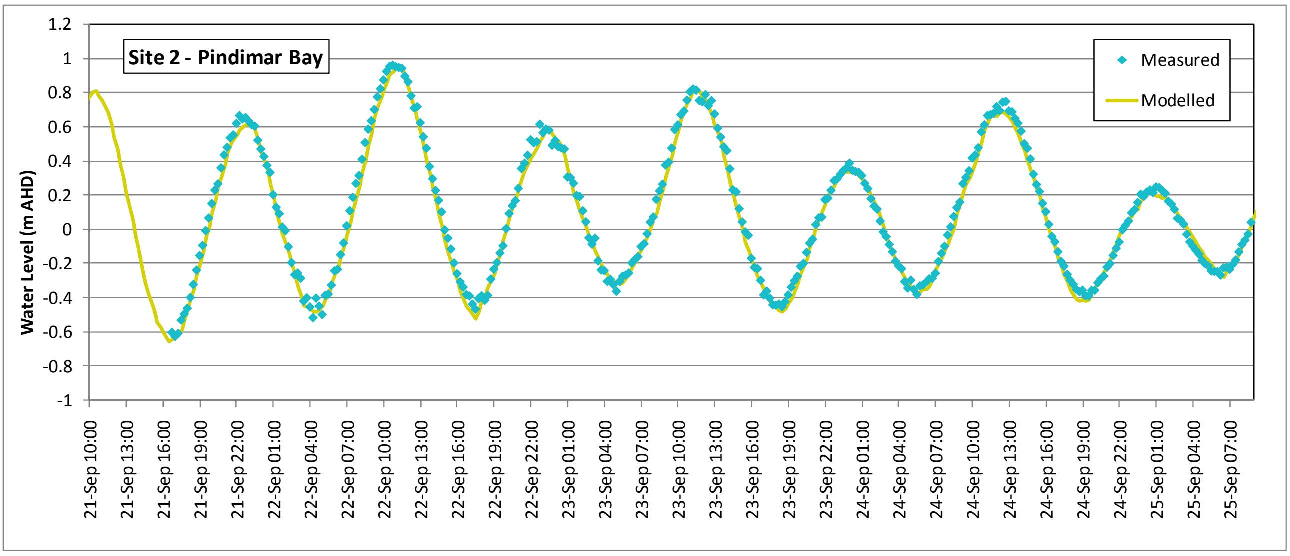


Figure 4-9 Water Level Results at Pindimar Bay

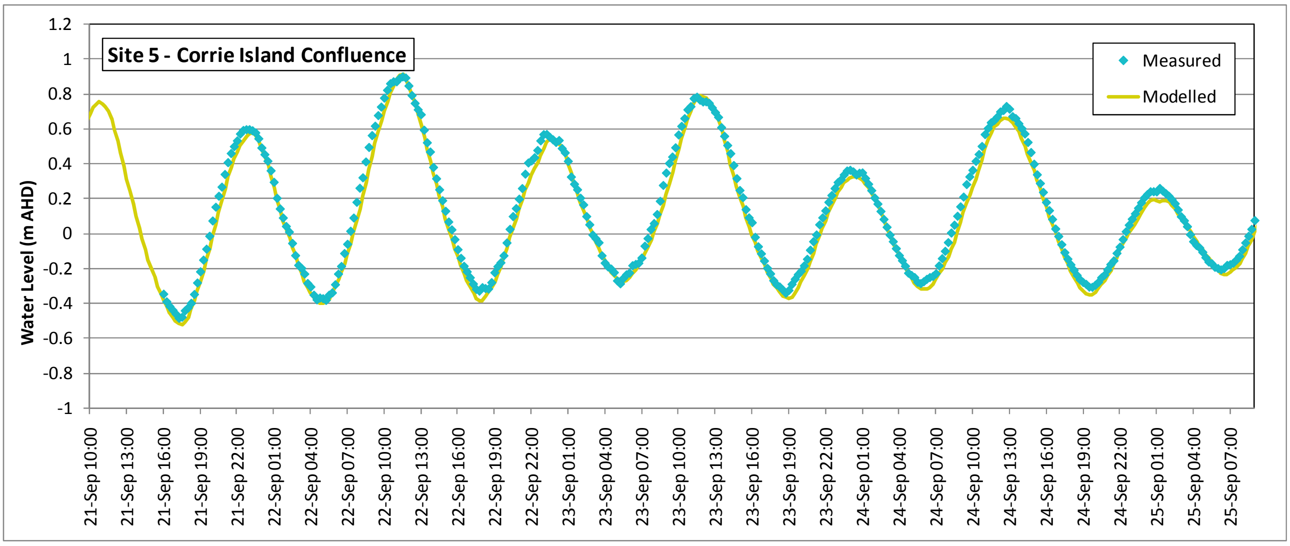


Figure 4-10 Water Level Results at the Confluence to Corrie Island

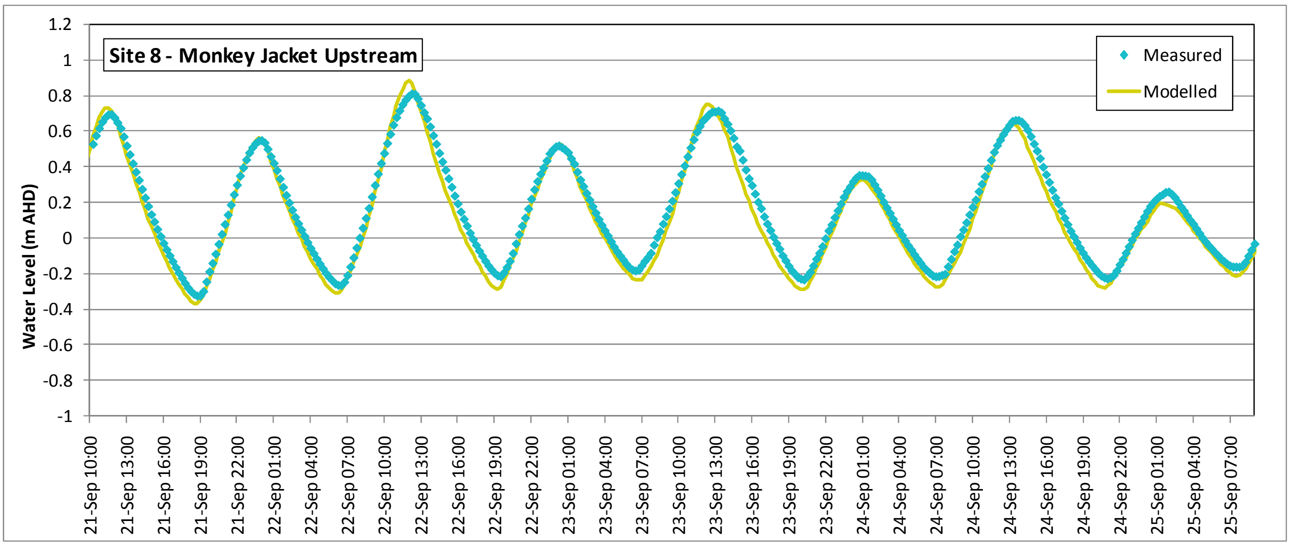


Figure 4-11 Water Level Results Upstream of Monkey Jacket

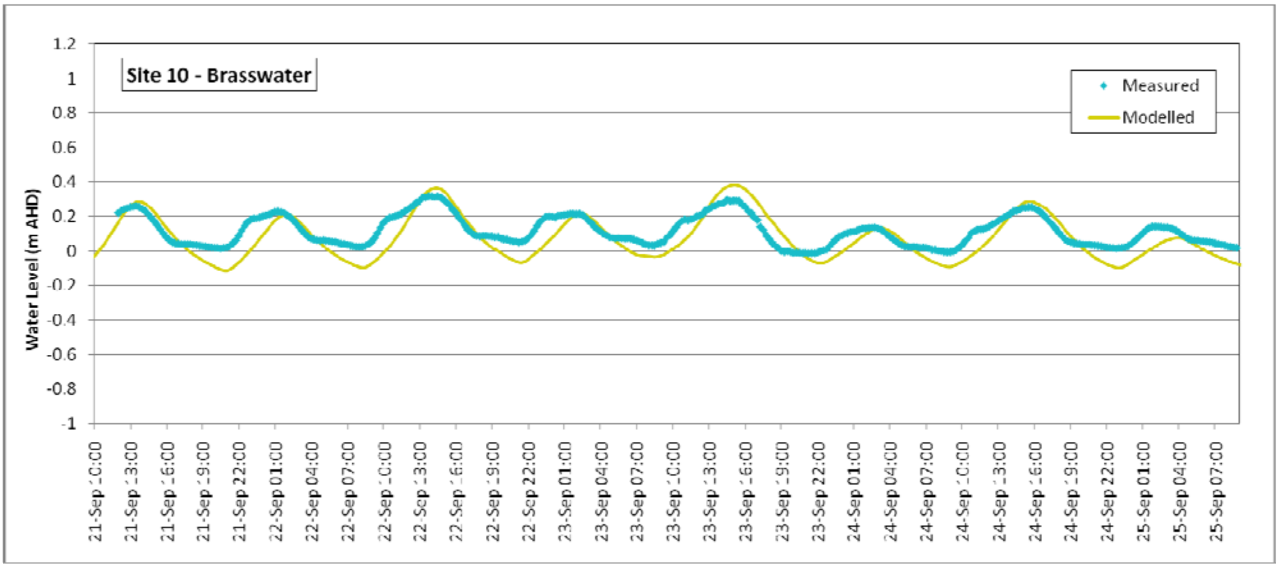


Figure 4-12 Water level Results at Brasswater

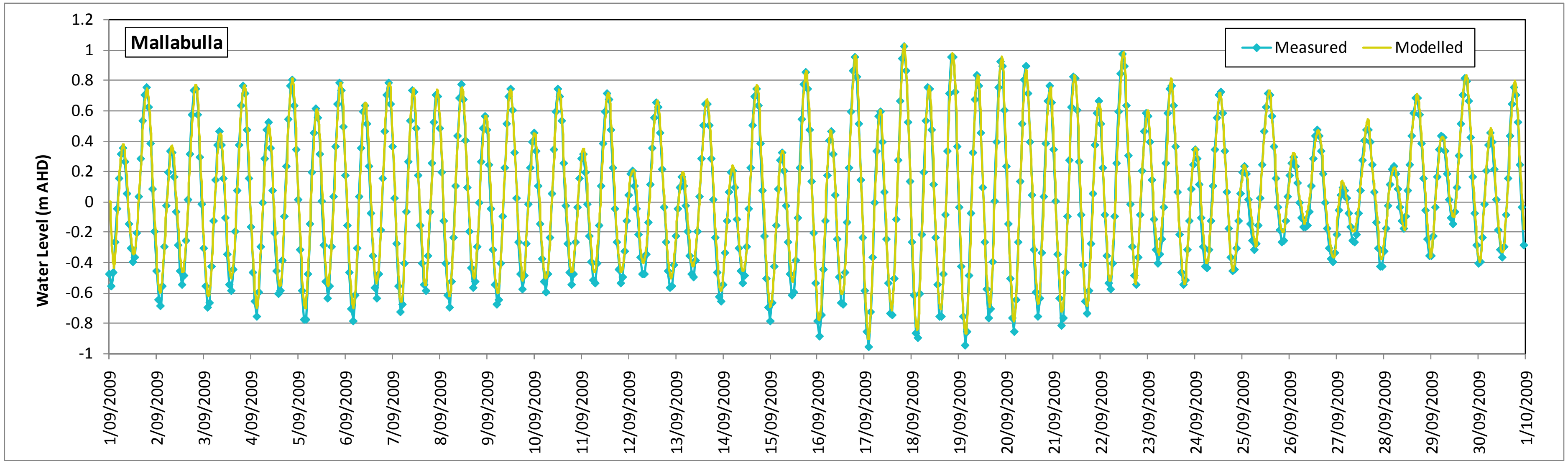


Figure 4-13 Water Level Results at Mallabulla, Port Stephens

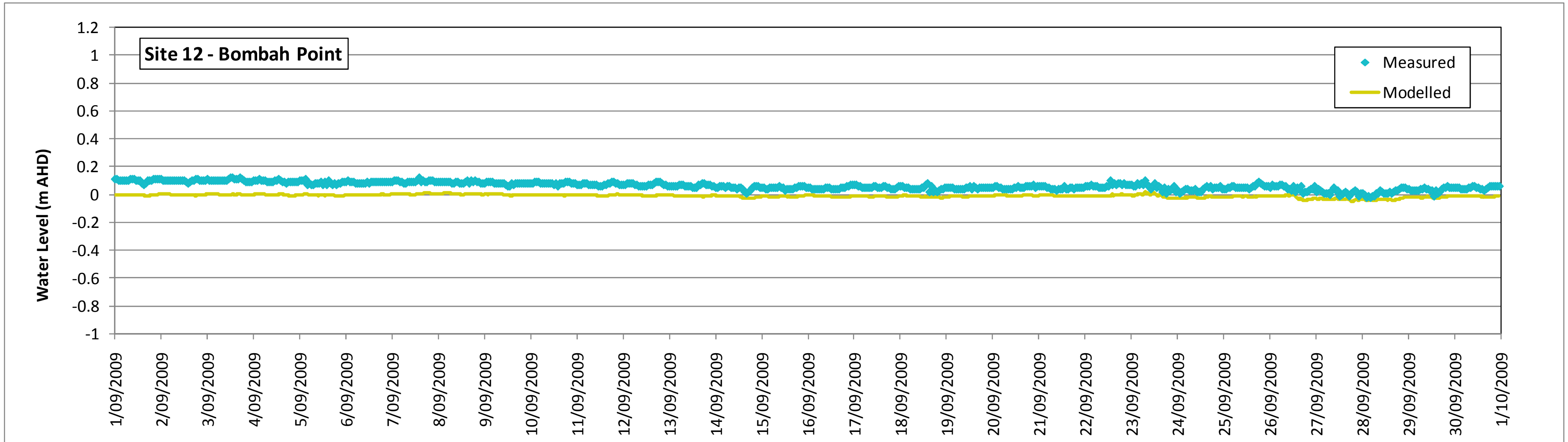


Figure 4-14 Water Level Results at Bombah Point, Myall Lakes

4.3.5 Results of Mixing and Transport (Salinity) Calibration

The primary objective of the salinity calibration was to match modelled salinity data to measured salinity data at specific locations around the study site. The field sites can be seen in Figure 3-2.

A good correlation between the modelled and measured data ensures that adequate representation of processes such as advection; dispersion and mixing within the model domain are attained.

Influences on salinity within and along the Lower Myall River and Port Stephens are driven by a number of sources and sinks including river inflows, catchment runoff, groundwater, tidal flows, rainfall and evaporation. The model developed for this project includes tidal flows, direct rainfall and evaporation (i.e. rainfall and evaporation that exchanges directly at the water surface), but does not include river inflows, groundwater or catchment runoff.

There is not enough information presently available to account for groundwater inflows. Over the calibration period, it has been assumed that catchment runoff to the Lakes was not significant enough to drive significant flow from the Myall Lakes through the Lower Myall River.

The immediate study area is dominated by tidal flows and therefore, the exclusion of both groundwater and catchment inflows during the calibration period was not considered necessary.

4.3.5.1 Approach to validation

The model results were compared to measured salinity. The measurements are from September 2009 (MHL 2009).

The main boundary condition impacting upon salinity within Port Stephens is the ocean boundary. The ocean salinity was referenced from ARGO data (http://www.argo.ucsd.edu/index.html). These data are obtained from a dispersed array of thousands of floats that traverse the ocean measuring salinity and temperature. The data indicate that salinities offshore from Port Stephens during September 2009 ranged from 34.5 – 35.5 ppt, varying with depth. As a result the depth averaged salinity, assigned to the model domain ocean boundary was set to a salinity of 35 ppt.

Salinity was calibrated to measured values from 21st to 25th of September. The hydrodynamics at the start of this period were obtained from a restart or 'hot-start' from the hydrodynamic calibration. The initial salinity values were obtained by utilising a Geographic Information System to interpolate salinities across the model domain from those discrete locations where measurements were available from the 21st September. The sparse nature of available measurements means that the model simulation can be sensitive to the way values are interpolated between sites.

4.3.5.2 Results

At all sites the modelled salinities were typically within 1-2 ppt of the measured salinities and the trend of increasing salinity upstream along the Myall River was well correlated.

At Pindimar Bay the modelled salinities were found to correlate well with measured data (Figure 4-15), although the modelled data did begin to slightly overestimate (<1ppt) salinity towards the end of the field data record.

At the Corrie Island confluence modelled results underestimated salinity by approximately 1-1.5 ppt, with measured salinities increasing from ~34 ppt to 35.5 ppt and modelled salinities increasing from ~33 – 34 ppt (Figure 4-16). A closer examination of modelled salinities at this site identified that, at this locations, two streams of flow from the eastern and northern channels converge. Therefore, the degree of mixing of the two streams will strongly affect the overall salinity at this location. Furthermore, the absolute salinity here is strongly influenced by the salinity applied at the ocean boundary and the relatively sparse nature of the ARGO data means that errors may be introduced at that boundary.

Overall, the trends at the confluence are good, and the calibration further upstream is not unduly affected.

At Monkey Jacket the model initially overestimated salinity by approximately 1 ppt, however the diurnal fluctuations correlated quite well (Figure 4-17). Towards the end of the field data period, modelled and measured data correlate well with differences of <1 ppt.

At Brasswater (18km upstream from the study region), the observed trend of increasing salinity correlates well to the modelled data, especially given the large increase of ~15 ppt over a short period of time (3 days). The model does not, however fully replicate the scale of diurnal fluctuations in salinity (Figure 4-18).

At Bombah Point (Myall Lakes) the modelled data overestimates salinity by 1-2 ppt for the majority of the model run (Figure 4-19). This may be due to the lack of freshwater inflows or groundwater in the model. This site is a long way from the study site and not of primary concern. However, the processes discussed above should be examined further if the model were required to provide reliable salinity predictions in Myall Lakes..

The salinity calibration is very good. On the basis of these results, we can assume that the advection and dispersion processes that mix different water quality constituents through the system are well represented. This means the model is suitable for undertaking assessments such as flushing time calculations, which are described later.

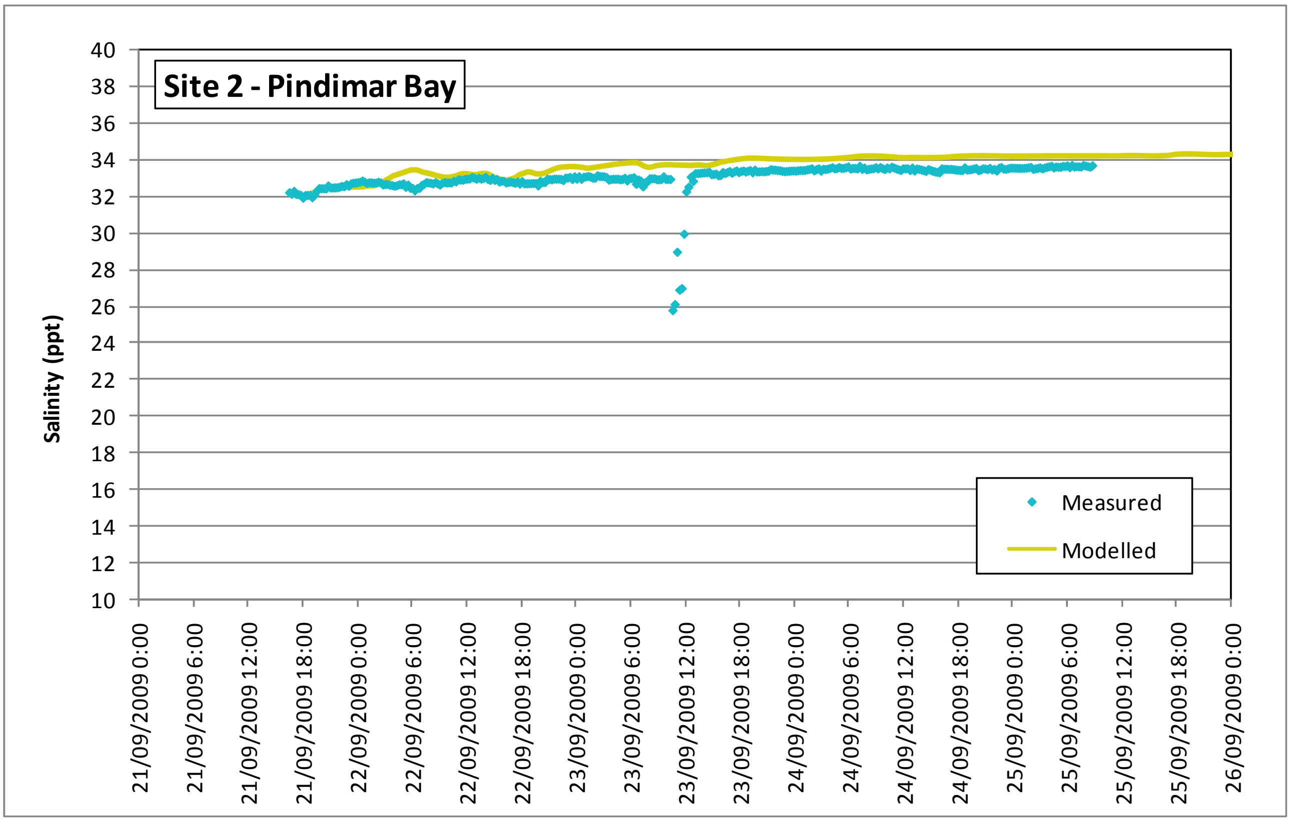


Figure 4-15 Salinity Results for Pindimar Bay

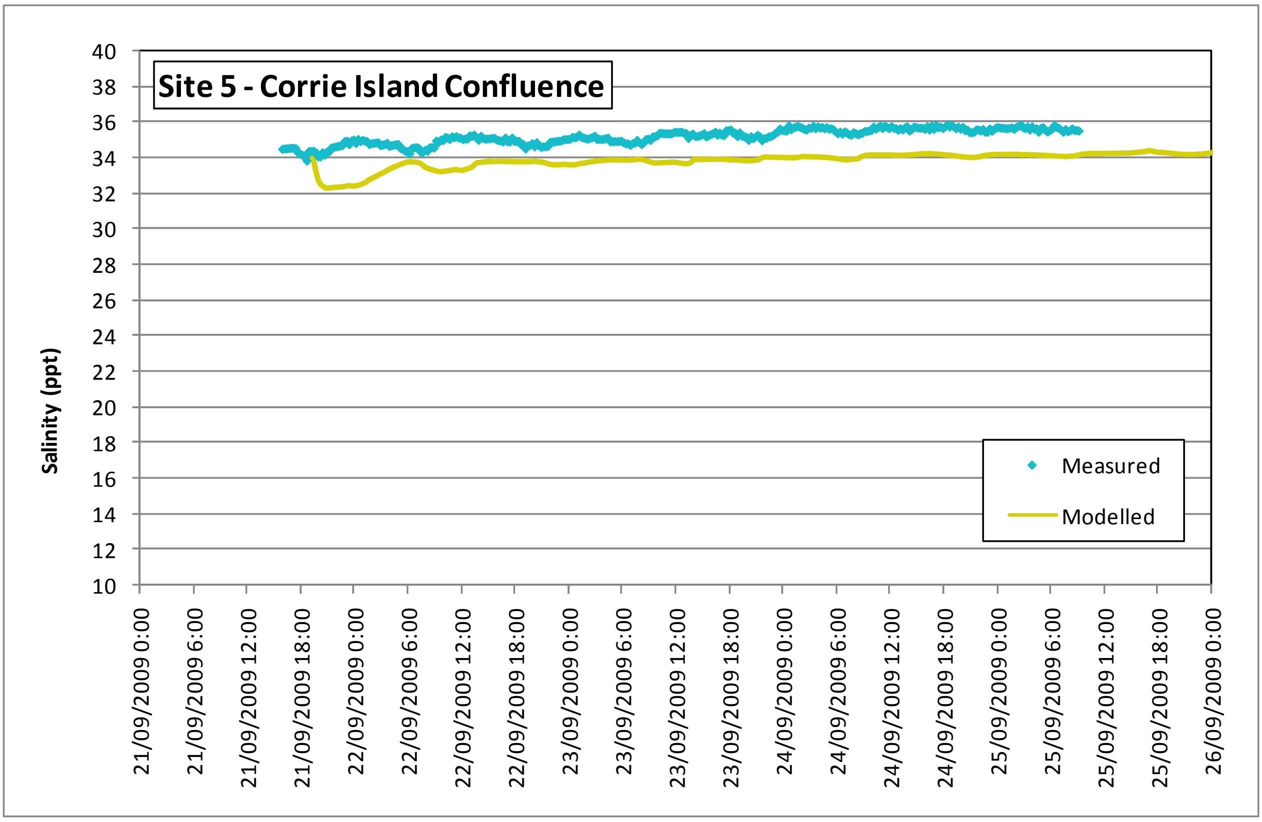


Figure 4-16 Salinity Results for Corrie Island Confluence

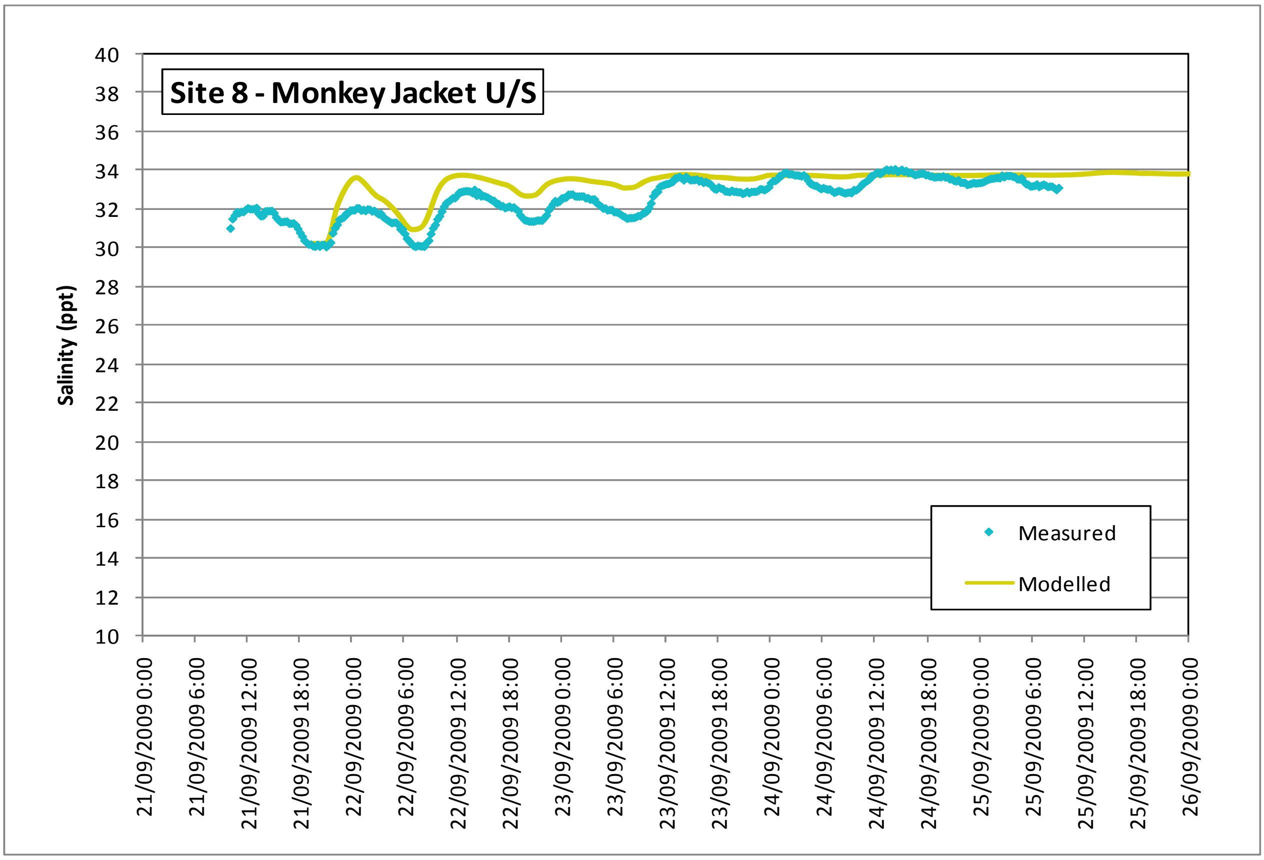


Figure 4-17 Salinity Results from Monkey Jacket

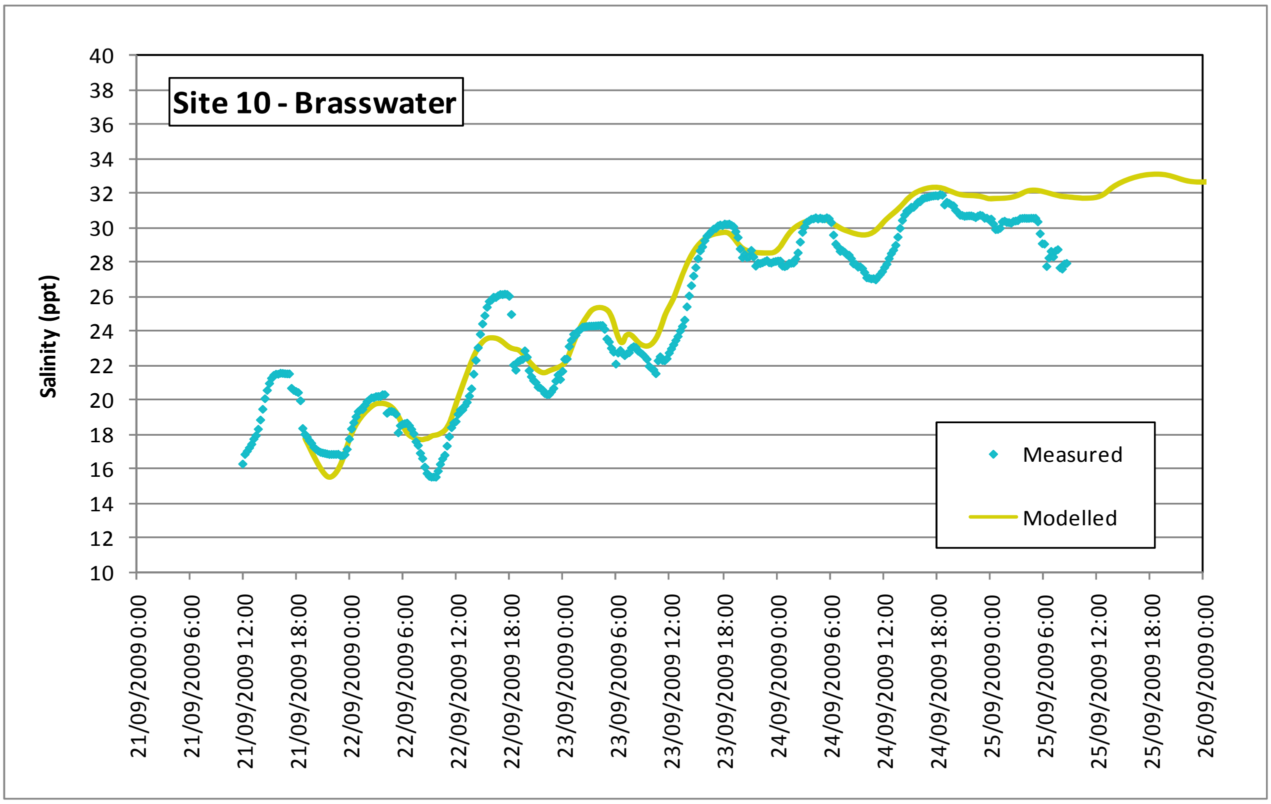


Figure 4-18 Salinity Results from Brasswater

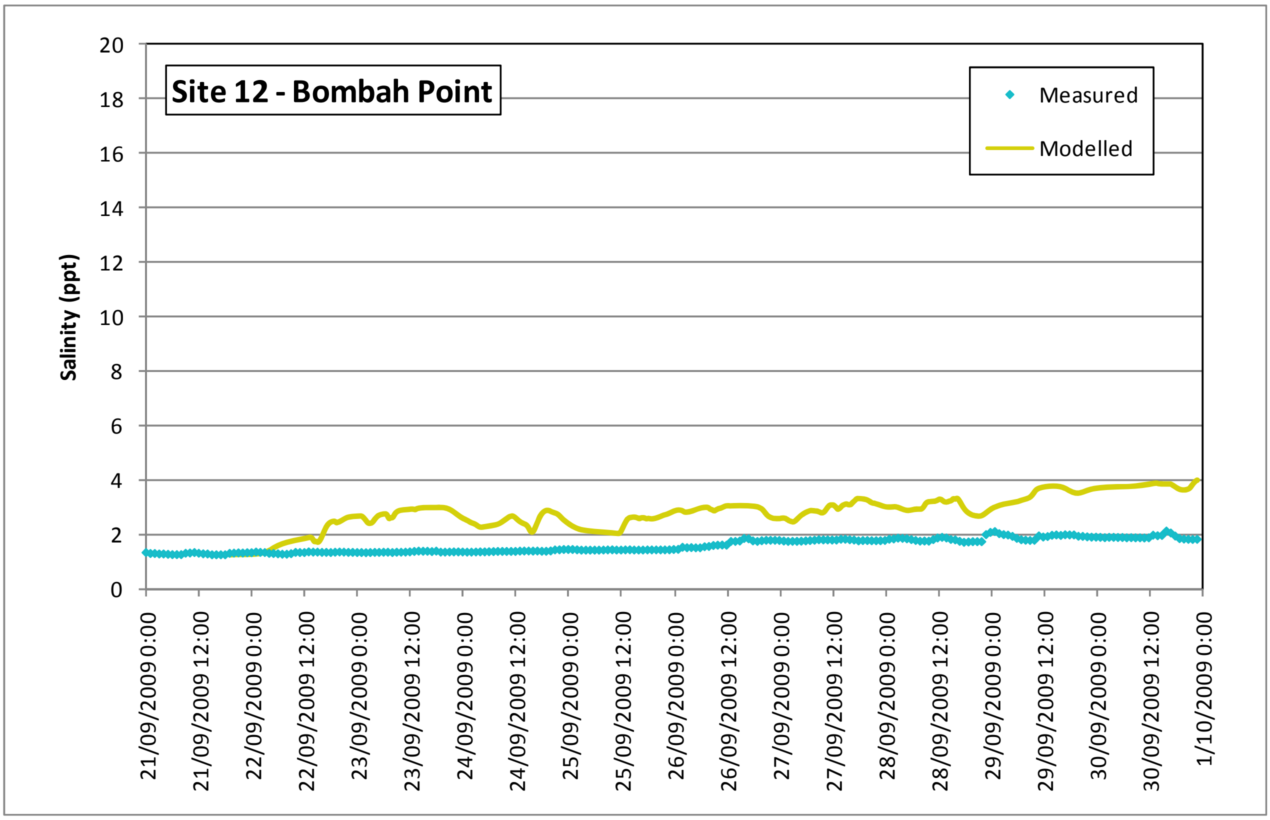


Figure 4-19 Salinity Results for Bombah Point

4.3.6 Performance of the Morphodynamic Model

4.3.6.1 Approach to Assessment

There is no quantitative morphological data available that would be suitable for calibration of the morphodynamic model.

Results from morphological models need to be approached with caution. The issue arises from a general inability of any available sediment transport algorithm to predict transport rates accurately within all possible transport conditions. It is generally considered reasonable if an algorithm predicts rates within 50 – 200% of values measured in the laboratory and field (van Rijn, (1993), Soulsby (1997)). Furthermore, the adjustment of bed elevations, and feedback of that process into the hydrodynamics of the model means that any diversion from the actual transport that is occurring can be amplified over time.

One other aspect of the morphological calculations that requires consideration is the morphological model does not predict swash zone sediment dynamics well. There presently exist no reliable methods for modelling swash related sediment transport that are also tractable for use in a numerical hydrodynamic model. Recent work by Jiang *et al* (2010) concludes that swash related transport at Jimmy's Beach is a significant component of the overall longshore transport. It is likely that this is also the case at the western end of the Winda Woppa Spit, where sand is washed by swash action across into the Eastern Channel.

To assess performance of the model, we have run a month long simulation and examined the bed changes afterwards to see if the general morphological patterns are feasible.

The following characteristics were adjusted within the model to achieve qualitative general trends in morphology:

- Resolution of the bathymetric mesh was refined in areas which demonstrated active sediment transport e.g. Eastern Channel, steep banks of the Lower Myall River and Corrie Island;
- Model parameters, including the dry slumping angle, were adjusted to accommodate for the local geology and soils e.g. coffee rock on the eastern edge of Corrie Island is unlikely to actively erode even though the bed angle is quite steep.

4.3.6.2 Results

The short term patterns and processes in key morphological features, as identified at the end of the 30 day model simulation, include the following:

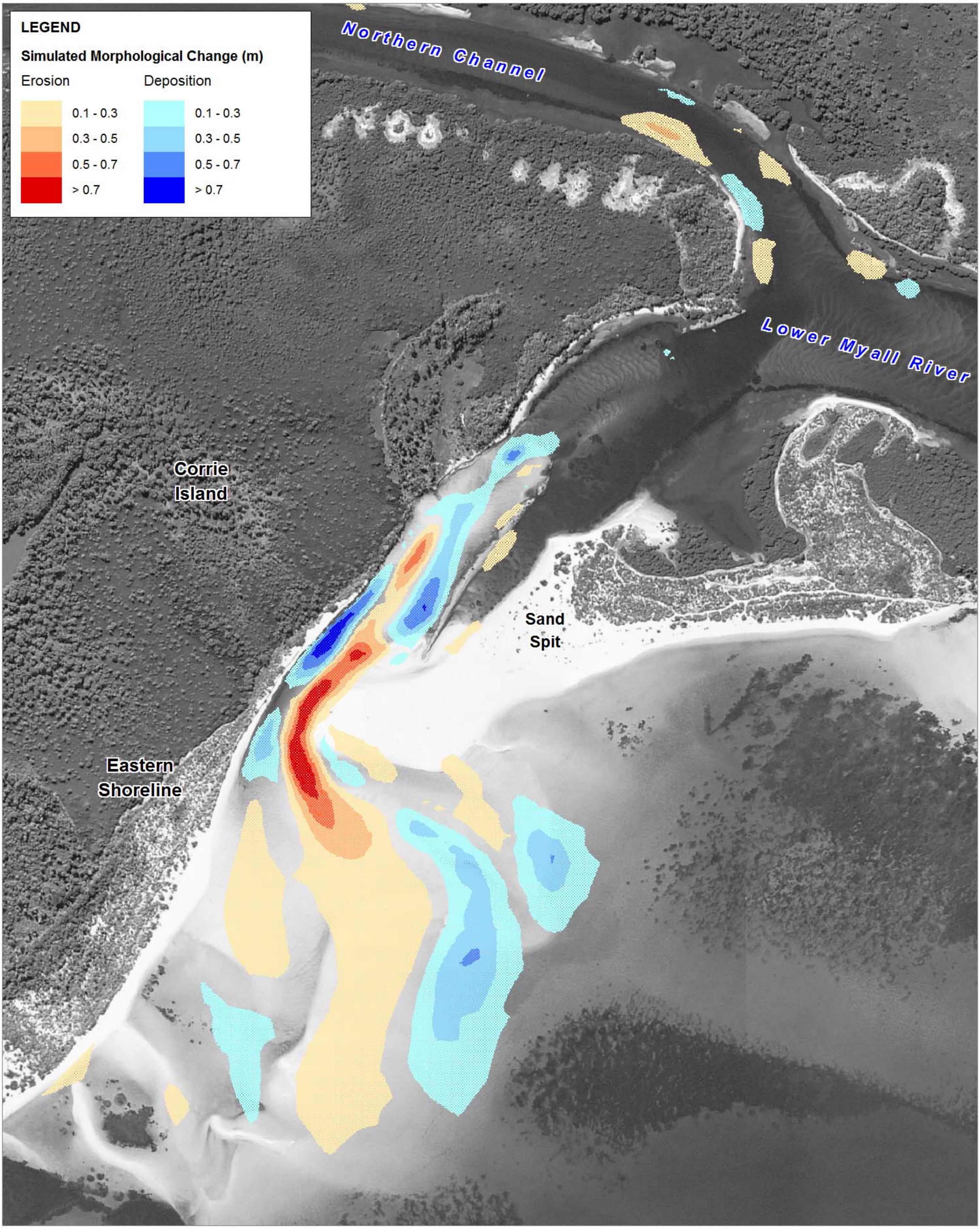
- The Eastern Channel experienced active sediment transport (Figure 4-20) especially around the ocean end of the channel. Erosion typically occurred in the higher velocity central areas of the channel (red areas) whilst corresponding deposition occurred at the channel fringes in the deeper and lower velocity areas (blue). The resulting patterns show some indication of the extension of the spit, to the south west, as seen in historical trends (Section 3.4). However, due to the limited representation of swash zone transport by the model, this is likely underestimated;
- The front edge of the flood tide delta and the dropover region within Port Stephens both exhibited active erosion and deposition within the model (not shown). These regions have been identified previously as active sediment transport areas, especially the flood tide delta which has shallow depths often experiencing breaking waves (refer section 2.1.2);
- The edges of the Lower Myall River experienced some minor sediment transport, typically on bends, which are characteristic patterns for riverine environments; and
- Minimal erosion and deposition occurred throughout the rest of the model domain.

Overall, the modelled patterns demonstrate some narrowing and deepening of the main Eastern Channel, with a slight tendency of migration towards the West. This is felt only slightly on Winda Woppa Spit, which is likely related to the previous point made regarding an inability to accurately represent swash zone dynamics. In reality, the degree to which infilling occurs at the tip of Winda Woppa would probably be more pronounced. The effects of wave action pushing the front edge of the marine delta against the edge of Corrie Island (i.e. to the south of Winda Woppa) are being represented, although the interaction of tides with wave action at this location make it difficult to separate this effect out from the transport caused by the tides.

The dynamics of the hard coffee rock edge at Corrie Island are also not perfectly represented. Firstly, the full extent of the coffee rock is not known. Secondly, the model presently considers this whole edge to be sandy, and the steep bathymetry results in slopes that the model considers unstable.

Modelled slumping in this area causes a simulated deposit of sand and the degree to which the channel would have otherwise migrated westwards is likely underestimated.

Aside from these limitations, the general trends in morphological patterns and processes within the model results are reasonable and form a useful basis for careful consideration of different management options.



Title: **Simulated Morphological Changes After One Month**

Figure: **4-20**

Rev: **A**

N 0 125 250m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure 4-23 Morph Model Results.WOR

5 ANALYSIS OF OPTIONS AND ALTERNATIVES

5.1 Processes / Issues to be Addressed

The DECCW (2010) study showed that environmental conditions within the Lower Myall River are typical of estuarine systems, with no significant difference from this location to other locations within the wider Port Stephens area. Therefore, the constriction of the Eastern Channel is not currently impacting on the ecosystem health or ecological condition of the River. As such, there is no overriding ecosystem health justification for removing the restriction in the Eastern Channel.

Irrespective of the DECCW (2010) scientific study, members of the community still perceive that the condition of the estuary has deteriorated over the past decade. Analyses presented in Chapter 3 highlight that the past 10 years or so has been characterised by a progressive infill of the Eastern Channel, and that this has impacted on the efficiency of oceanic flushing of the River. It is possible that this has manifest as a reduction in water clarity and/or a greater influence from freshwater flows, thus leading to the community's perception of deteriorating river conditions.

Furthermore, the infill of the Eastern Channel has forced the main flows in the channel to be redirected to the western side of the relic ballast rock pile, which has placed additional pressure on the Corrie Island foreshore, leading to bank erosion and toe scour of the foreshore embankment (exposing Coffee Rock in some locations).

Commensurate with this progradation has been the erosion of the shoreline west of Barnes Rock, where local wetland values are now being compromised. Simple volume estimates (refer Appendix D) suggest that the progradation of the new spit into the Eastern Channel can be approximately accounted for by the recession and loss of material along this part of the foreshore. This implies that infilling of the Eastern Channel is not significantly influenced by erosion of Jimmy's Beach.

5.2 Do Nothing

The 'Do Nothing' condition is a realistic scenario for the Lower Myall River. There are no significant environmental gains to the waterway condition and aquatic ecosystem if something is done, and commensurately, there is no significant environmental loss to the waterway if nothing is done. At risk from the do nothing option, however, would be further loss of dune vegetation and wetland habitats associated with on-going shoreline recession on Corrie Island and west of Barnes Rock, as well as further loss of access to the end of Winda Woppa Spit.

Also, it is difficult to predict how the Lower Myall River will behave in the future given current trends in hydrodynamic and sediment transport processes. Based on an appreciation of these processes and observations of changes that have occurred over the past few years, it is reasonable to assume that the Eastern Channel will continue to infill with sediment transported along the shoreline from the west of Barnes Rock. This on-going infill will continue to reduce tidal flows through the Eastern Channel, whilst the Northern Channel will continue to increase its relative share of tidal conveyance.

It is also reasonable to assume that there is a fair likelihood that that the Eastern Channel will eventually close, although the timeframe for such circumstances is unknown. A catalyst such as a large coastal storm may be required to initiate the final and sudden closure of the channel. Other factors and events, including flood events, may accelerate or retard the progressive closure process. Based on the analyses discussed in Section 5.5.5.2, complete closure of the Eastern Channel would more than double e-folding (flushing) times in the River at Tea Gardens. This may lead to further reduction in water clarity and salinity within the lower reaches of the Lower Myall River.

5.3 Development of Options

A number of potential options for addressing the issues associated with the Lower Myall River entrance were generated by the Study Team, in close consultation with the MRAG (representing the concerns of the community) and Council representatives.

The desire of the MRAG was stated as "*to return the Lower Myall River to its former healthy and well-flushed condition, and thus improve water quality and clarity, and reduce incidents of marine disease and sand build-up within the river*".

The scientific study (DECCW, 2010) demonstrated that water quality and ecosystem health of the Lower Myall River is not currently in a poor condition.

The key issues for the MRAG are therefore aesthetics and amenity, with water clarity possibly affected by the reduced efficiency of oceanic flushing caused by progressive infill of the Eastern Channel.

A range of options were developed that aim to reverse the changes in hydrodynamics and sediment transport processes that have occurred over the past decade or so. Central to the options was the restoration (i.e. dredging) of the Eastern Channel to a size and capacity that would dominate tidal flows into and out of the Lower Myall River.

5.3.1 Dredging of the Eastern Channel and Winda Woppa Spit

In about 2001, the Eastern Channel contained a deeper section east of the relic ballast rock pile. This section conveyed the majority of tidal flows through the Eastern channel. Since then, Winda Woppa spit has grown, encroaching into this part of the channel and rendering it ineffective. The Spit now extends past the rock pile.

This option involves physical removal of the sand that has recently encroached into the Eastern Channel from Winda Woppa (refer Figure 5-2). Up to 100,000 cubic metres of sand would need to be removed, potentially through land-based and water-based equipment.

The aim of the dredging would be to re-establish a channel on the eastern side of the ballast rock pile comparable to the channel in width and depth that was present prior to 2001.

Whilst there are other shallow sections of the Eastern Channel to the west of the ballast rock pile, it is not intended to dredge these areas because 1) having too large a channel will simply reduce tidal velocities and promote sedimentation (possibly in undesirable locations), and 2) dredging close to Corrie Island may further compromise the stability of its foreshores. Indeed, realignment of the main channel away from Corrie Island will likely promote sedimentation in the nearshore area adjacent to the foreshore, which would help to stabilise foreshores, or at least stop or slow the current rate of shoreline recession.

The dredging may result in improved navigation through the channel, however, the intention of the works is not to provide safe navigable passage for vessels, but rather, to enhance and promote tidal exchange within the Lower Myall River. Navigability is intended to be maintained through the Northern Channel, which is less prone to sedimentation (with the possible exception of the drop-over edge, which was subject to dredging in late 2010).

5.3.2 Disposal of Dredged Sediments

As outlined previously, dredging of the Eastern Channel is not expected to have significant benefits for the water quality and aquatic ecosystem health of the Lower Myall River. However, dredging in the Eastern Channel may be beneficial in terms of supplying sand for on-going nourishment needs.

For the last three years, sand has been dredged from a nearshore sand sheet adjacent to Yacaaba Headland and placed on Jimmy's Beach as part of a specific 3 year nourishment trial. The volume nourished over the past three years has been approximately 70,000 – 80,000 cubic metres, although a proportion of this volume is likely to have already been lost through beach adjustment and natural reprofiling. Prior to this latest multi-year campaign, Jimmy's Beach was nourished using land-based material taken from large sand dunes behind Hawks Nest Beach, as well as some sand from the Lower Myall River. Approximately 372,000m^3 of sand was placed on Jimmys Beach up to 1998 (Watson, 2000). It is possible that the Eastern Channel can be dredged for the purposes of providing an on-going source of nourishment sand for Jimmys Beach.

Dredging typically requires considerable effort and cost with respect to deployment and set-up of equipment. Therefore, it is not feasible to take small quantities of sand on a regular basis. Alternatively, larger quantities of sand dredged from the Eastern Channel can be stockpiled locally at the end of Winda Woppa Spit, and used for nourishment of Jimmy's Beach on a smaller but more regular basis. A ready supply of locally stockpiled sand could reduce costs and time delays associated with on-going dredging of the Yacaaba sand sheet. It is possible that capital dredging of the Eastern Channel could provide enough sand for up to 10 years+ of nourishment at Jimmys Beach.

Another option for disposal is to place the material back onto the shoreline that is actively receding to the west of Barnes Rock. This is essentially the origin of the sand in the Eastern Channel, and at present, on-going erosion of the foreshore is compromising the values of a small estuarine wetland. If the erosion continues, the risk of a break-through of the Winda Woppa Spit will increase. Already, the pre-existing road access to the end of the spit has been severed by erosion. Nourishment of this shoreline could be expected to promote, and possibly accelerate, on-going longshore transport rates, given the relative unconsolidated nature of the placed material and lack of dune/beach vegetation. Thus, infill back into the Eastern Channel may become part of a looping cycle.

5.3.3 Permanent Sand Pumping System

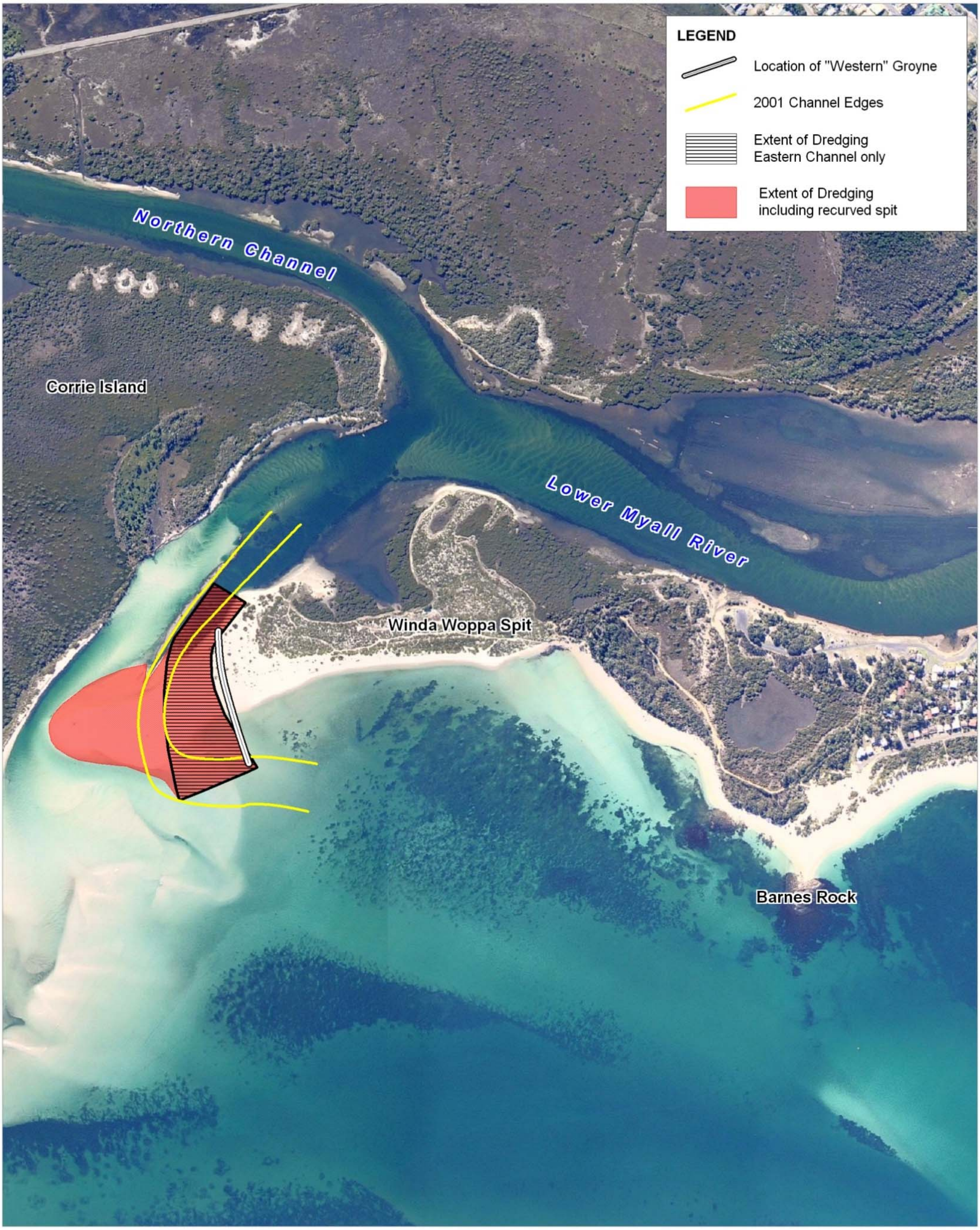
Given the dynamic nature of the entrance, sand will need to be removed from the Eastern Channel on a regular basis if the channel is to remain open. The mobilisation and establishment of dredging equipment at such frequent timeframes would mean that a disproportionate amount of costs are attributed to non-dredging activities. An alternative is to install a permanent sand pumping system within the dredged Eastern Channel. For this option, sand is extracted from the channel via a fixed induction and sand transportation system.

An example of this type of system would be the “Sand Shifter” Unit from Slurry Systems Marine (www.ssm.com.au) (refer Figure 5-1). This system involves an inductor unit buried within the area where sand accumulates. The inductor unit uses a water jet to fluidise the sand and mobilise the material into a vacuum line (the same as a suction dredger). The sand would be subsequently discharged to a nearby location (or locations). For this option, the sand could be disposed directly onto the foreshore either on Jimmys Beach, or west of Barnes Rock, or both. The Sand Shifter unit is self-burying and does not require a supporting pier or in-channel frame. The buried units are protected from storms and do not obstruct navigation, public access or interrupt the channel flows.

The Sand Shifter technology is used at Noosa, whereby sand is pumped from the Noosa River estuary onto Noosa Beach for sand nourishment. The sand equipment has also been used at the Port of Portland, Lakes Entrance, Patterson Lakes and on Adelaide Beaches. Although on a much larger scale, the permanent sand bypassing systems of Tweed River and The Broadwater, also use similar technologies and methods.

One of the major advantages of this system is its flexibility, adaptability and reversibility. Adaptive management is considered to be essential in highly dynamic environments such as the Lower Myall River entrance. Experience of the past has shown that fixed solutions to one problem in such areas often result in new problems elsewhere. Having an adaptive approach to management will enable these flow-on effects to be mitigated in the future as (and if) they become evident. A disadvantage, however, would be its need for active management and control. Past experience at Jimmy’s Beach shows that active management and control is preferable, with reactive works often very limited in effectiveness.

Figure 5-1 Sand shifter Permanent Sand Pumping System (source: Slurry Systems Marine)



Title:

Preliminary Options:
Dredging and Construction of Western Groyne

Figure: **5-2**

Rev: **A**

N

0 200 400m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure5_PreliminaryOptionsA.WOR

5.3.4 Western Groyne to Capture On-going Longshore Sediment Supply

Another option to reduce the on-going encroachment of sand into the Eastern Channel, once dredged, is to construct a groyne at the western end of Winda Woppa spit (refer Figure 5-2). The shore-normal groyne would capture sand transported alongshore west of Barnes Rock, primarily as a result of shoreline recession in this area. This option therefore would only be suitable in combination with the dredging of the Eastern Channel, as outlined above, and would only be effective until sand bypasses the groyne and resumes infill of the channel.

In order to minimise bypassing of sand around the groyne, either:

- the groyne would need to realign the local shoreline planform profile sufficiently to stop or significantly reduce the potential for longshore sediment transport around the structure, or
- sand accumulated on the updrift side of the groyne would need to be removed periodically (this would be an easier and cheaper process than periodic channel dredging, as it could be done in the dry using land-based equipment). The longer the groyne, the greater potential storage of sand, leading to less frequent sand removal (but greater construction cost).

The groyne would need to be designed to engineering standards and to withstand coastal storm conditions, and as such, would be a significant coastal structure.

5.3.5 Flow Constriction in Northern Channel

Part of the reason that the Eastern Channel has been subject to on-going sedimentation is that tidal flows can, alternatively, be conveyed through the Northern Channel. Prior to about 1900, the Northern Channel was very shallow (possibly inter-tidal). Dredging carried out circa 1910, to enable navigable access from Tea Gardens to Pindimar Bay, subsequently created a substantial tidal channel.

An option is to reduce the flow conveyance in the Northern Channel thus forcing tides to preferentially flow through the Eastern Channel (refer Figure 5-3). This increased flow through the Eastern Channel may be sufficient to reduced or prevent further sedimentation. If combined with the dredging option described above, the increased flows may be able to establish a self-scouring channel profile that would limit the potential for on-going sand infill from Winda Woppa Spit.

The conveyance of the Northern Channel could be reduced by constructing a constriction within the channel. At present the channel is about 80 metres wide. The constriction would need to be substantial in order to restrict tidal flows, with a width of less than 20 metres say, over a channel length of several hundred metres. The down-side with this option is that safe navigation through the Northern Channel would likely be compromised, whilst navigation through the Eastern Channel could not be assured.

There a number of unknowns associated with this option that would need to be clarified if the option was to be pursued further. For example, the optimum constriction profile would need to be established (width, depth, length) to meet the needs of redirecting tidal flows through the Eastern Channel. Ideally, the Northern Channel would be infilled completely, however, it is appreciated that some degree of navigation, albeit limited, would still be necessary.

Title:
Preliminary Options: Constrain Northen Channel

Figure: 5-3

Rev: A

N

0 200 400m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure5_PreliminaryOptions_NorthernChannel.WOR

5.3.6 Tombolo to Re-establish Myall Point

An option raised through the community was to re-establish Myall Point (refer Figure 5-4). An elongated finger of sand, or tombolo, extending southward from Winda Woppa spit would stabilise the shoals and channel behind. There would still likely be some sedimentation and flow constriction issues at the outlet of the channel behind the spit. The finger of sand would require an anchor at the southern end in order to maintain shoreline alignment and stability.

This option may be appealing as historical maps indicate a wide channel located behind the former natural Myall Point sand barrier. However, it must also be recognised that the Northern Channel was much smaller at that time, with the bulk of tidal flows to the Myall River conveyed through the Eastern Channel.

As the Eastern Channel is currently heavily shoaled, this option would still require dredging to re-establish a suitable channel profile that would attract a greater proportion of tidal flows and thus enhance tidal flushing and exchange in the river. Indeed, dredging would be required along the full length of the proposed new channel to construct a suitable and unconstricted flow path.

This option would involve construction of a substantial engineering structure. The tombolo would need to be approximately 800 metres long and minimum 80 metres wide (volume > 200,000m^3), with the end anchor structure comparable to a coastal breakwater/groyne. The sand could be sourced from dredging the channel behind.

It needs to be recognised that Myall Point was previously destroyed by a large coastal storm in the last 1920s, and that a new similar structure may suffer a similar fate given similar extreme ocean conditions.

5.3.7 New Alternative River Entrance

One of the main reasons for sedimentation issues in the Eastern Channel is that the entrance coincides with an area of high sediment dynamics, on the distal edge of the Port Stephens marine flood tide delta. Thus, no matter what works are carried out at this location, there will always be instability and ongoing adjustments due to the dynamism of waves and tides.

A more drastic option is to relocate the entrance of the Lower Myall River to an area that is less prone to bed sediment dynamics. Ignoring initially the scale of such an option, a new Eastern Channel that is not subject to sedimentation would potentially improve oceanic flushing within the Lower Myall River. One possible location would be to the west of Barnes Rock, in the area that is currently exhibiting rapid shoreline recession (refer Figure 5-5). The new channel would need to be stabilised, possibly with training walls that extend beyond the shoreline alignment.

With a new river entrance, the current Eastern Channel would infill rapidly, given the tendency for sedimentation and the significant reduction in tidal flows through the channel area. This would likely relieve existing erosional pressures of the eastern shoreline of Corrie Island.

Title:

Preliminary Options: Reconstruct Myall Point

Figure: 5-4

Rev: A

BMT WBM endeavours to ensure that the information provided in 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.

N

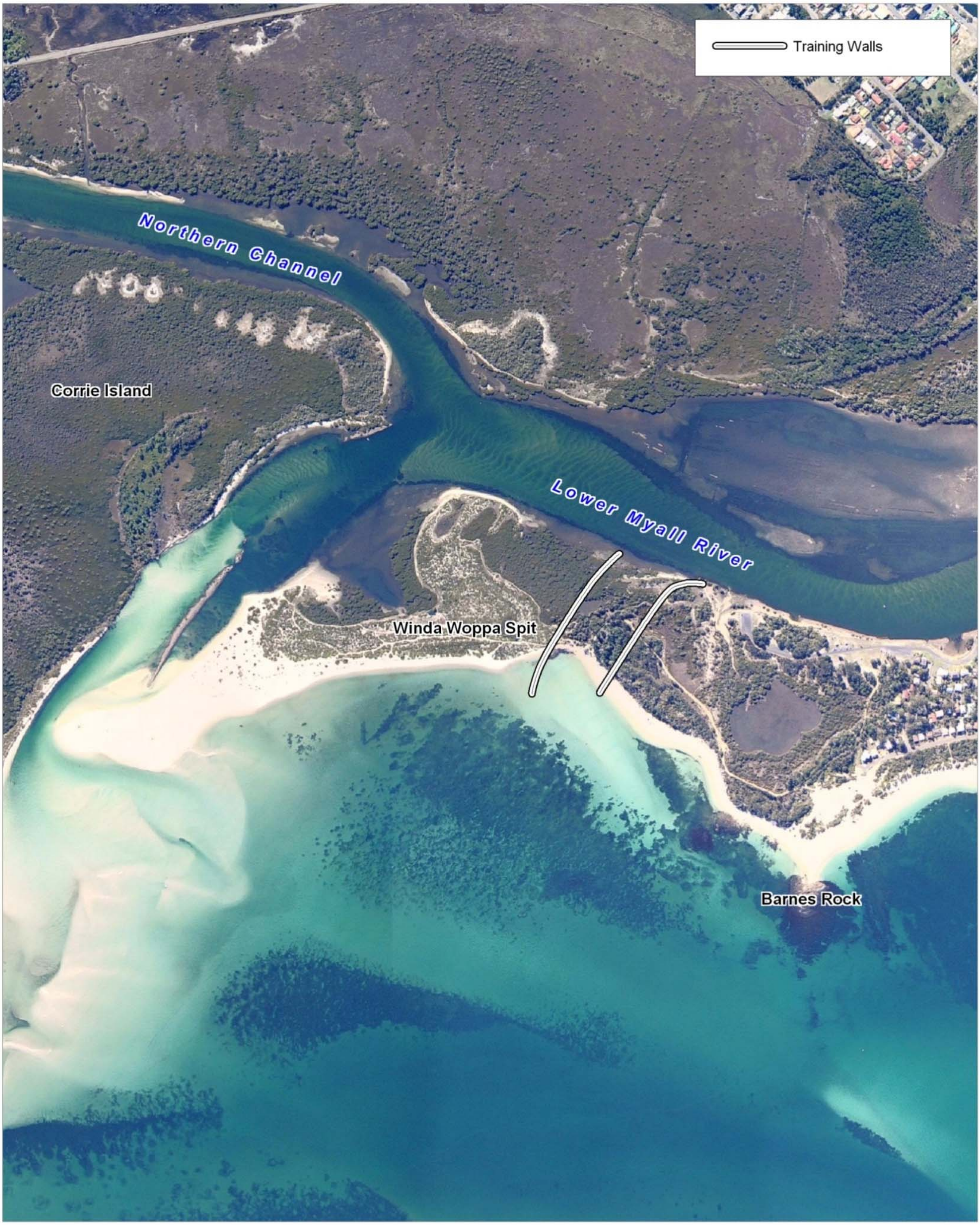
0 200 400m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure5_PreliminaryOptions_MyallPoint.WOR



Title:
Preliminary Options:
Alternative River Entrance

Figure: 5-5

Rev: A

BMT WBM endeavours to ensure that the information provided in 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.

N

0 200 400m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure5_PreliminaryOptions_MyallPoint .WOR

If this option were to be considered further, significant investigations would be required to optimise the location and dimensions of a new entrance. Careful assessment of localised sediment processes would be required to ascertain the likely infill rate, any need for on-going channel maintenance, and whether the channel should actually be navigable or not. Careful assessment of other environmental impacts elsewhere along the Lower Myall River would also be required, including the impact on flooding, and sea level rise vulnerability of Tea Gardens.

5.4 Initial Assessment and Short-listing of Options

A first pass qualitative multi-criteria assessment (considering environmental, social, economic, adaptability factors) was carried out to provide a relative analysis of the different options developed (refer Table 5-1). These were also compared to the 'do nothing' scenario, which involves future closure of the Eastern Channel.

From a purely economic perspective, all options will have a significant financial demand, which will require sourcing of special funding, as they are independent of any existing funding programs. There is, however, the opportunity to offset costs against future financial demands associated with the on-going nourishment of Jimmys Beach, if such a program of works was to be pursued by Council and the NSW Government. As stated previously, approximately $1m has been spent over the past 3 years nourishing Jimmy's Beach as part of a nourishment trial. Dredging of the Eastern Channel may represent a future source of material for on-going nourishment campaigns, with win-win benefits for both the channel and the beach.

Based on the first-pass qualitative multi-criteria assessment, the various options were given traffic-light ratings as either "has merit", "marginal" or "not suited". Only options considered to 'have merit' or 'marginal' have been assessed in further detail using the advanced hydrodynamic, sediment transport and salinity models that have been established, as outlined in Section 4. These short-listed options include:

- Dredging and nourishment onto Jimmy's Beach;
- Dredging and nourishment west of Barnes Rocks;
- Dredging and installation of a permanent sand pumping system (with nourishment of Jimmys Beach, and optionally the shoreline west of Barnes Rock as needed); and
- Dredging and construction of a groyne at the end of Winda Woppa spit.

Table 5-1 First Pass Qualitative Multi-Criteria Assessment of Options

Options	Environmental	Social	Economic	Adaptability
Do nothing ↔ STATUS QUO	Eastern Channel will eventually close, and oceanic flushing in River will be reduced. Change to ecosystem health unknown (likely to be small if any). Continued shoreline recession west of Barnes Rock, while Corrie Island will likely continue to erode until the channel closes. *Neutral / -ve result*	Loss of navigation through Eastern Channel; reduction in aesthetics (water clarity) and amenity of River due to reduced oceanic flushing *-ve result*	Possible reduction in tourism; No capital funding required. *Neutral / -ve result*	No infrastructure or construction works that would inhibit the ability to undertake actions in the future, although dredging of a fully closed channel may be more difficult. *+ve result*
Dredging with Jimmy's Beach nourishment ✓ HAS MERIT	No change to ecosystem health of River. Eastern Channel maintained open, with potentially improved oceanic flushing in River. Continued shoreline recession west of Barnes Rock, while erosional pressure on Corrie Island would be reduced *Neutral result*	Amenity of River would be maintained or slightly improved; navigation through Eastern Channel may be improved (but still not assured) *Neutral / +ve result*	High capital dredging costs (c. $2m) but may be offset by other finances dedicated to nourishment of Jimmy's Beach. On-going dredging may also be offset by on-going need for further beach nourishment. *Neutral/-ve result*	No major construction works, so option can be stopped, reversed or modified, as required, depending on the need *+ve result*
Dredging with shoreline nourishment west of Barnes Rock ✓ HAS MERIT	No change to ecosystem health of River. Eastern Channel maintained open, with potentially improved oceanic flushing in River. Shoreline recession west of Barnes Rock would be abated, while erosional pressure on Corrie Island would be reduced *Neutral result*	Amenity of River would be maintained or slightly improved; navigation through Eastern Channel may be improved (but still not assured) *Neutral / +ve result*	Significant capital dredging costs (c. $2m), with frequent on-going dredging required . *-ve result*	No major construction works, so option can be stopped, reversed or modified, as required, depending on the need *+ve result*

Options	Environmental	Social	Economic	Adaptability
Dredging with sand pumping system ✓ HAS MERIT	No change to ecosystem health of River. Eastern Channel maintained open, with potentially improved oceanic flushing in River. Abatement of shoreline recession west of Barnes Rock if sand placement incorporated, while erosional pressure on Corrie Island would be reduced *Neutral result*	Amenity of River would be maintained or slightly improved; navigation through Eastern Channel may be improved (but still not assured) *Neutral / +ve result*	High capital dredging costs (c. $2m) but may be offset by other finances dedicated to nourishment of Jimmy's Beach. Costs for permanent sand pumping system could also be offset by on-going need for further beach nourishment. *Neutral/-ve result*	Installation of sand pumping system is completely removable, and would only operate on an as-needs basis. *+ve result*
Dredging with groyne at end of spit ? MARGINAL	No change to ecosystem health of River. Eastern Channel maintained open, and on-going dredging limited. Possible improved oceanic flushing in River. Likely mitigation of shoreline recession west of Barnes Rock due to new sand accumulation. while erosional pressure on Corrie Island would be reduced. *Neutral result*	Amenity of River would be maintained or slightly improved; navigation through Eastern Channel may be improved (but still not assured) *Neutral / +ve result*	Significant capital works for groyne (c. $3m) in addition to channel dredging (c. $2m), but substantially reduced on-going cost for maintenance. Accumulated sand may be used for nourishing Jimmy's Beach or west of Barnes Rock. *-ve result*	Major construction works. The design could allow for some degree of adaptability, viz: the groyne could be lengthened, shortened or raised as required depending on changing needs *Neutral / -ve result*
Dredging with Northern Channel restriction ✖ NOT SUITED	No change to ecosystem health of River. Eastern Channel maintained open, but frequency of on-going dredging need is unknown. Possible improved oceanic flushing in River. Continued shoreline recession west of Barnes Rock. Sedimentation expected in Northern Channel. *Neutral result*	Uncertain impacts on amenity of River, as improvements to water clarity etc. would be offset by difficulties with navigation through the Northern Channel (whilst navigation through the Eastern Channel is still not assured). *-ve result*	Significant capital works for Northern Channel structure (c. $2-3m) in addition to channel dredging (c. $2m), and may still require on-going maintenance dredging; Expected economic loss due to reduced tourism if navigability is reduced/lost *-ve result*	Major construction works in Northern Channel, which would be difficult to remove or alter once in place. *-ve result*

Options	Environmental	Social	Economic	Adaptability
Dredging with Myall Point Tombolo ✖ NOT SUITED	No change to ecosystem health of River. Eastern Channel maintained open, and on-going dredging limited. Possible improved oceanic flushing in River. Mitigation of shoreline recession west of Barnes Rock and on Corrie Island due to new shoreline alignment. *Neutral result*	Amenity of River maintained or slightly improved with improved water clarity; navigation through Eastern Channel improved (but still not assured); new area of land possibly suitable for recreation *Neutral / +ve result*	Significant capital works required involving marine construction and dredging (c. $10m). On-going maintenance would be limited. *-ve result*	Major construction works, which would be difficult to remove or alter once in place. SLR would potentially cause landward migration of the tombolo compromising benefits *-ve result*
New River entrance ✖ NOT SUITED	No change to ecosystem health of River. New Eastern Channel that would remain open and possibly improve oceanic flushing in River. May cause other detrimental impacts elsewhere, including Northern Channel, and would involve loss of land and habitat. *Neutral / -ve result*	Amenity of River maintained or slightly improved (with improved water clarity); navigation through new Eastern Channel may be feasible (but not assured); loss of access to the end of Winda Woppa spit *Neutral result*	Significant capital works program required involving marine construction and dredging (c. $15m). On-going maintenance would be limited. *-ve result*	Major construction works, which would be difficult to remove or alter once in place. New Eastern Channel may increase exposure of Tea Gardens and River to ocean storms and storm surge. *-ve result*

5.5 Detailed Assessment of Short-listed Options

A semi-quantitative assessment of short-listed options has been carried out to further consider the potential benefits and costs of these options. This includes consideration of broader environmental benefits and costs (if any), as well as capital and on-going expenditure needs.

5.5.1 Comparison Options

In order to evaluate short-listed options, baseline conditions were included in the assessment for comparative purposes. For this assessment, two comparison options have been considered:

1. Existing conditions; and

2. 'Do nothing' conditions.

The existing conditions represent the current morphology of the Lower Myall River entrance (as defined by the most recent (2009) bathymetric survey).

As outlined in Section 5.2, the 'Do Nothing' conditions represent a hypothetical, but feasible future outcome if there is no intervention of hydrodynamic and sediment transport processes, that is, the 'Do Nothing' conditions assume that the Eastern Channel is completely blocked. It is emphasised that the timeframe for such conditions to develop is unknown. As sediment transport can be dominated by episodic events, there is a chance that the channel may close very quickly if a large coastal storm were to occur, and such a storm could potentially occur at any time. There is also a chance that the channel may continue to function near its current condition for many more years in the absence of major events or storms.

5.5.2 Dredging Options

Optimisation of a dredging profile would be the subject of detailed design, which would determine the most effective width and depth of the channel to be dredged, incorporating an agreed allowance for sedimentation over a specified timeframe (i.e. "insurance dredging").

Two approaches to dredging the Eastern Channel have been considered:

1. Dredge a channel cutting through the existing sand spit, with existing elevations retained except within the direct channel footprint; or

2. Dredge the whole spit, with a deeper dredge profile through the proposed channel section.

The first option would require removal of a smaller quantity of sediment, and thus would be cheaper, however, the second option may result in a more stable morphology (particularly under storm conditions), with less infilling of the channel profile in the future.

A third option was also included within the assessment process, which is the same as Dredge Option B, but with the inclusion of a groyne at the end of Winda Woppa Spit.

A summary of the dredging options considered is as follows:

1. Existing Conditions (base case) – this model simulation represents a baseline for comparison with short listed options adopting contemporary (September 2009) bathymetric conditions to represent a partially closed Eastern Channel;

2. 'Do nothing' Option – this model simulation represents possible future conditions in the vicinity of the Eastern Channel should there be no intervention of current morphological processes. The 'do nothing' option assumes that Winda Woppa Spit will continue to grow in a westerly direction resulting in complete closure of the Eastern Channel;

3. Dredge Option A – this model simulation represents dredging of a channel through the sand spit to re-establish connection between the Lower Myall River and Port Stephens via the Eastern Channel;

4. Dredge Option B – similar to Dredge Option A with additional sand removed from the western side of the proposed dredge channel to a level of -1.0 m AHD. Dredge Option B may be advantageous if there is an opportunity to maximise the extent and volume of material to be dredged from the Eastern Channel or should the extensive build-up of sand on the western fringe of the sand spit lead to premature infilling within the Eastern Channel;

5. Dredge Option C - same as Dredge Option B, but with the construction of a coastal groyne east of the dredged channel to increase the longevity of dredging activities by trapping westerly longshore sediment transport; and

6. Dredge Option D – same as Dredge Option A, but with the addition of a Sand shifter permanent sand pumping system for on-going channel maintenance.

Conceptual designs for dredging works adopted in the quantitative assessment have adopted a channel that transitions from the southern side of the spit (approximately -1 m AHD) to the northern side of the spit (where existing bed elevations within the Eastern Channel are about -4 m AHD). The proposed channel would be approximately 400 metres long, with the width varying between 60 metres (northern end) and 160 metres (southern end). Dredge extents would cover an area of approximately 4 ha and include removal of some 55,000m^3 for Dredge Options A & D (i.e. channel cut only), and an area of 8 ha and removal volume of 95,000m^3 of material for Dredge Options B & C (channel cut and removal of sand spit). For Options B & C, the whole spit on the western side of the dredge channel would be lowered to an elevation of approximately -1m AHD.

In Option C the configuration of the western rock groyne (refer Section 5.3.4) would likely adopt a crest width of 4 - 6 metres (depending on proposed functionality of the structure for future works), crest elevation of about 3 m AHD (to minimise overtopping and associated structural damage) and batter slopes of 1V:2H. The groyne would extend approximately 130 metres into Port Stephens along a generally southerly alignment from the current shoreline.

5.5.3 Disposal Options

Disposal options considered as part of this detailed assessment include placing of dredged spoil onto Jimmy's Beach, and placing dredged spoil onto the foreshore west of Barnes Rock. In reality, there are probably many other options available for the temporary or permanent placement of spoil, either as an alternative, or in combination with the two placement options noted above.

For both of these disposal options, numerical modelling analysis was limited, as for the most part, the disposal of sediment represents a removal of material from the immediate hydrodynamic and sediment environment.

5.5.4 Modelling Simulations

In assessing the impacts of the dredging options on hydrodynamics and morphology, two different time periods were utilised:

- On a monthly timescale the impacts of the potential dredge scenarios on flows, water levels and flushing were assessed. The model simulation and associated boundary conditions covered the period 21st September 2009 to 31st December 2009. Part of this data set was utilised for the calibration / validation period and represents typical spring – summer conditions.

- On a daily/weekly timescale the immediate impacts upon sediment transport were assessed. The shorter timescale was considered reasonable under the assumption that any changes to the morphology were likely to occur shortly after dredging, as the channel attempts to reach a steady state under the applied tidal flows and wave conditions. A review of ocean swell wave climate using historical wave data measured at Sydney revealed large SE swell wave events occurred between March-April 2005 (refer Appendix C).

A brief outline of the dredge scenarios modelled is provided in Table 5-2.

5.5.5 Evaluation of Environmental Impacts

5.5.5.1 Impacts on Flow Distribution

Potential changes to tidal flows are shown on Figure 5-6 as a comparison of the relative flow contribution between the Northern Channel and Eastern Channel. The modelling results show that dredging causes the Eastern Channel to become more dominant, and would contribute more tidal flow than the Northern channel. Under existing conditions, tidal flows through the Northern and Eastern Channels are approximately equal. For the ‘do nothing’ scenario, 100% of the flow would be through the Northern Channel, while for the dredge options (A, B, C & D), the Eastern Channel would take approximately 75% of the total tidal flow, and is similar to the flow distribution that was recorded by gaugings in 1975 (refer Section 3.2.2). There was a marginal increase in flows through the Eastern Channel for Dredge Option B (and C) compared Dredge Option A (and D), given the larger scale of channel dredging.

Table 5-2 Summary of Model Scenarios

Management Scenario		Bathymetry* Changes *The base bathymetry for all scenarios is the 2009 Hydrosurvey	Boundary Conditions	Simulation Period	Impact Assessment
1a	Existing conditions (base case)	Base bathymetry	Tides	21st Sept – 31st Dec 2009	Hydrodynamics
1b			Wind, tides, waves	17th Mar – 17th Apr 2005	Morphology
2	'Do nothing' option	Closure of the Eastern Channel	Tides	21st Sept – 31st Dec 2009	Hydrodynamics
-			Wind, tides, waves	Morphology not assessed, as eastern channel is assumed to be completed shoaled.	
3a	Dredge Option A	Dredge channel through the Myall Spit	Tides	21st Sept – 31st Dec 2009	Hydrodynamics
3b			Wind, tides, waves	17th Mar – 17th Apr 2005	Morphology
4a	Dredge Option B	Dredge channel through Sand Spit **AND** dredging of recurved spit to a depth of -1mAHD	Tides	21st Sept – 31st Dec 2009	Hydrodynamics
4b			Wind, tides, waves	17th Mar – 17th Apr 2005	Morphology
5a	Dredge Option C	Dredge channel through Sand Spit **AND** dredging of recurved spit to a depth of -1mAHD **AND** a Groyne	Tides	21st Sept – 31st Dec 2009	Hydrodynamics
5b			Wind, tides, waves	17th Mar – 17th Apr 2005	Morphology
-	Dredge Option D	Dredge channel through Sand Spit **AND** dredging of recurved spit to a depth of -1mAHD **AND** installation of a permanent sand pumping system	Tides	Same as Dredge Option A (run 3a)	
-			Wind, tides, waves	Same as Dredge Option A (run 3b)	

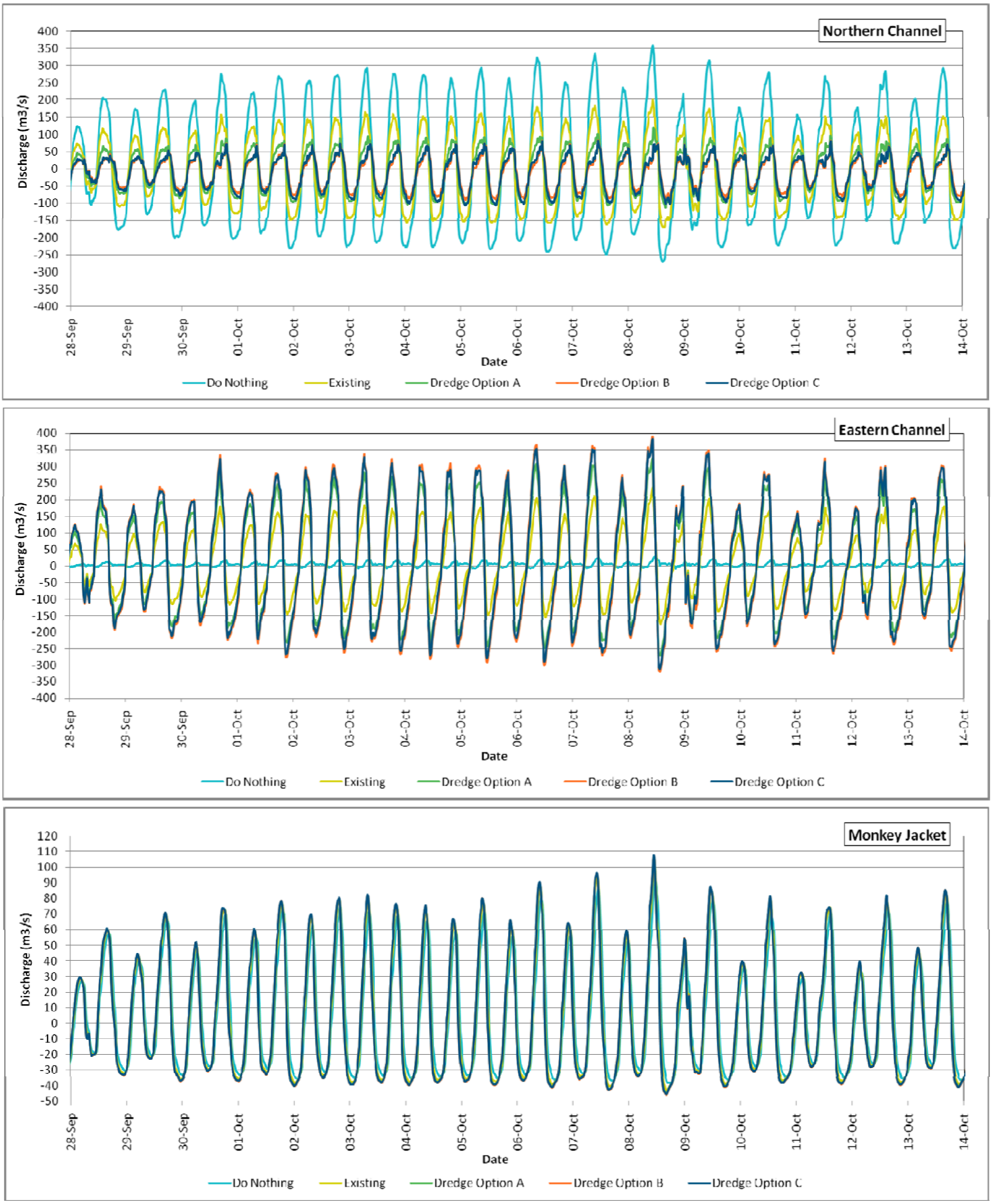


Figure 5-6 Simulated Change to Tidal Flows

5.5.5.2 Impacts on Oceanic Flushing

For the purposes of this assessment, oceanic flushing is assessed in terms of an e-folding[1] flushing time. The smaller the e-folding time, the better the efficiency of oceanic flushing and tidal exchange.

Changes in the e-folding time for the dredging options and comparative options are shown in Figure 5-7. The results show that e-folding times within the lower reaches of the Myall River would decrease (i.e. improved efficiency of oceanic flushing) with increased flow through the Eastern Channel compared to existing condition). E-folding time in the lower reaches is reduced from 20 days (existing) to less than 15 days (dredge options). As expected, for the condition of no flow through the Eastern Channel (i.e. 'do nothing' conditions), e-folding times in the river would increase, up to about 40 days.

Dredge Option B is predicted to result in marginally improved oceanic flushing compared to Dredge Option A although differences are minor and typically in the order of 2 days for areas including the confluence and Pindimar Bay. E-folding times for Dredge Option C are comparable to those predicted for Dredge Option B, while results for Option D would be the same as Option A.

Dredging in the Eastern Channel also improves tidal flushing within Pindimar Bay, as a proportion of the 'clean' seawater carried into the River through the Eastern Channel during the flood tide is then diverted through the Northern Channel and into Pindimar Bay during the subsequent ebb tide.

There is also a tidal lag between the Eastern Channel and Northern Channel meaning that, for between 1-2 hours during each tidal cycle, the Eastern Channel is flooding while the Northern Channel is still ebbing. This also facilitates the transfer of clean seawater to Pindimar Bay. Under existing conditions, e-folding time within Pindimar Bay exceed 25 days, however, with increased contribution of seawater via the Eastern Channel, e-folding time is reduced to approximately 15 days or less. For the 'do nothing' scenario, e-folding times in Pindimar Bay increase to about 30 days.

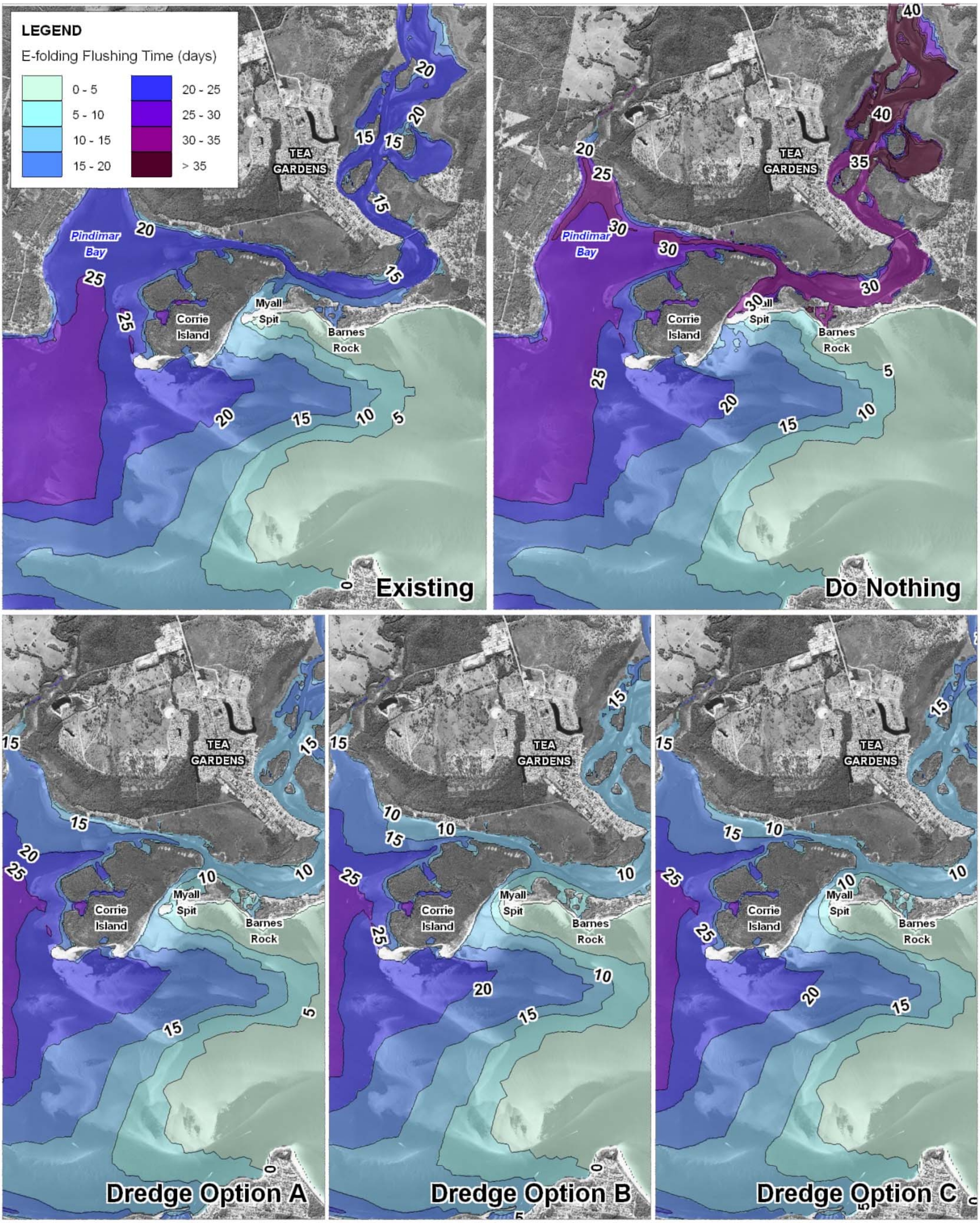
5.5.5.3 Impacts on Salinity

To determine potential impacts on salinity, a hypothetical scenario was constructed where an elevated water level was applied in Bombah Broadwater (Myall Lakes), generating a consistent freshwater discharge into the upper reaches of the Myall River. Changes in resulting salinity profiles along the river were determined for the different dredging options.

The elevated water level adopted in Bombah Broadwater for this assessment was determined by analysing historical data from Bombah Point (refer to Figure 3-2 for location). Three significant peaks in water level have been recorded over the last ten years. An initial water level of 0.84 m AHD within Bombah Broadwater (as recorded in June 2007) was chosen for modelling purposes. Resulting flows and water levels from Myall Lakes are shown in Figure 5-8 for the 100 day long simulation.

Salinity results have been examined for Brasswater, Monkey Jacket, Tea Gardens, Pindimar Bay and Corrie Island Confluence (refer to Figure 3-2 for locations) for the different dredging options. The results of the salinity analysis (daily averaged salinities) are presented in Figure 5-9.

[1] E-folding is a measurement of flushing. Starting with a concentration of 1.0 inside an estuary, the e-folding time is that time taken for tides to reduce the concentration to 1/e (or 0.37) at a particular location.



Title:

Simulated Changes to Tidal Flushing with and without dredging

Figure: **5-7**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in 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.

N

0 1.25 2.5km

Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_015_110218_TidalFlushingResults.WOR

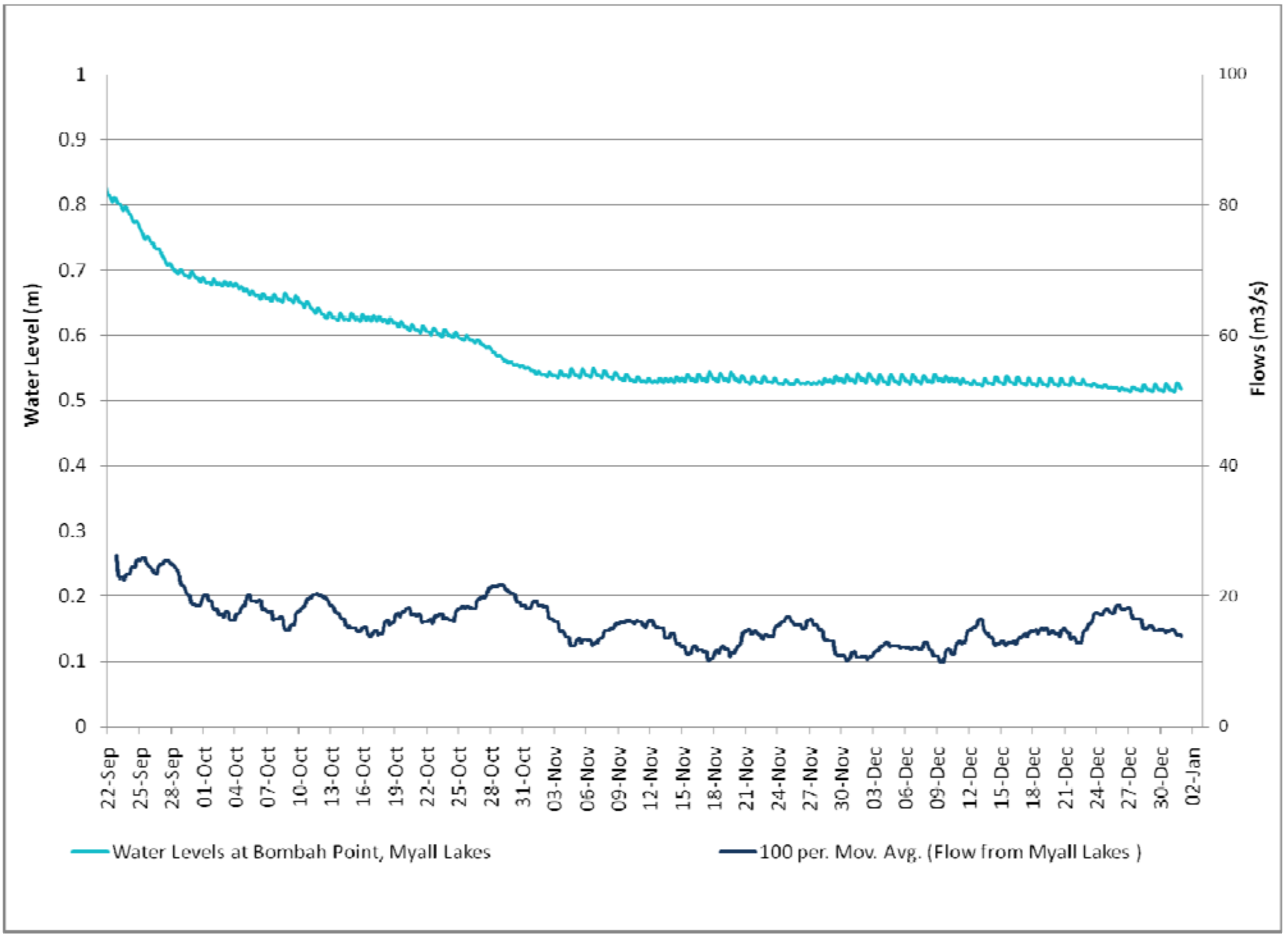


Figure 5-8 Simulated Water Levels and Flows from Myall Lakes for Salinity Analysis

The modelling results showed that there was no change in salinity at Brasswater (results not shown), while only small changes were observed at Monkey Jacket, highlighting the dominance of freshwater flows at the upstream end of the estuary. Similarly, in Pindimar Bay, at the downstream end of the estuary, there was relatively little difference in dredging scenarios considered.

The greatest difference was predicted at Tea Gardens, which is approximately mid-way along the estuary. At Tea Gardens, salinity can be impacted significantly by freshwater flows from Myall Lakes. As observed in Figure 5-9, dredging within the Eastern Channel could increase salinities by 20 – 40% compared to existing conditions, while complete closure of the Eastern Channel could reduce salinities by about 30% compared to existing levels. Dredge Options B & C showed marginally higher salinity levels at Tea Gardens compared to Dredge Option A, reflecting the larger tidal flows, and thus greater oceanic flushing, through the Eastern Channel.

Salinities at Tea Gardens also show a distinct spring-neap cycle, with higher salinities during spring tides, and lower salinities during neaps, reflecting the increased propensity of tides during springs.

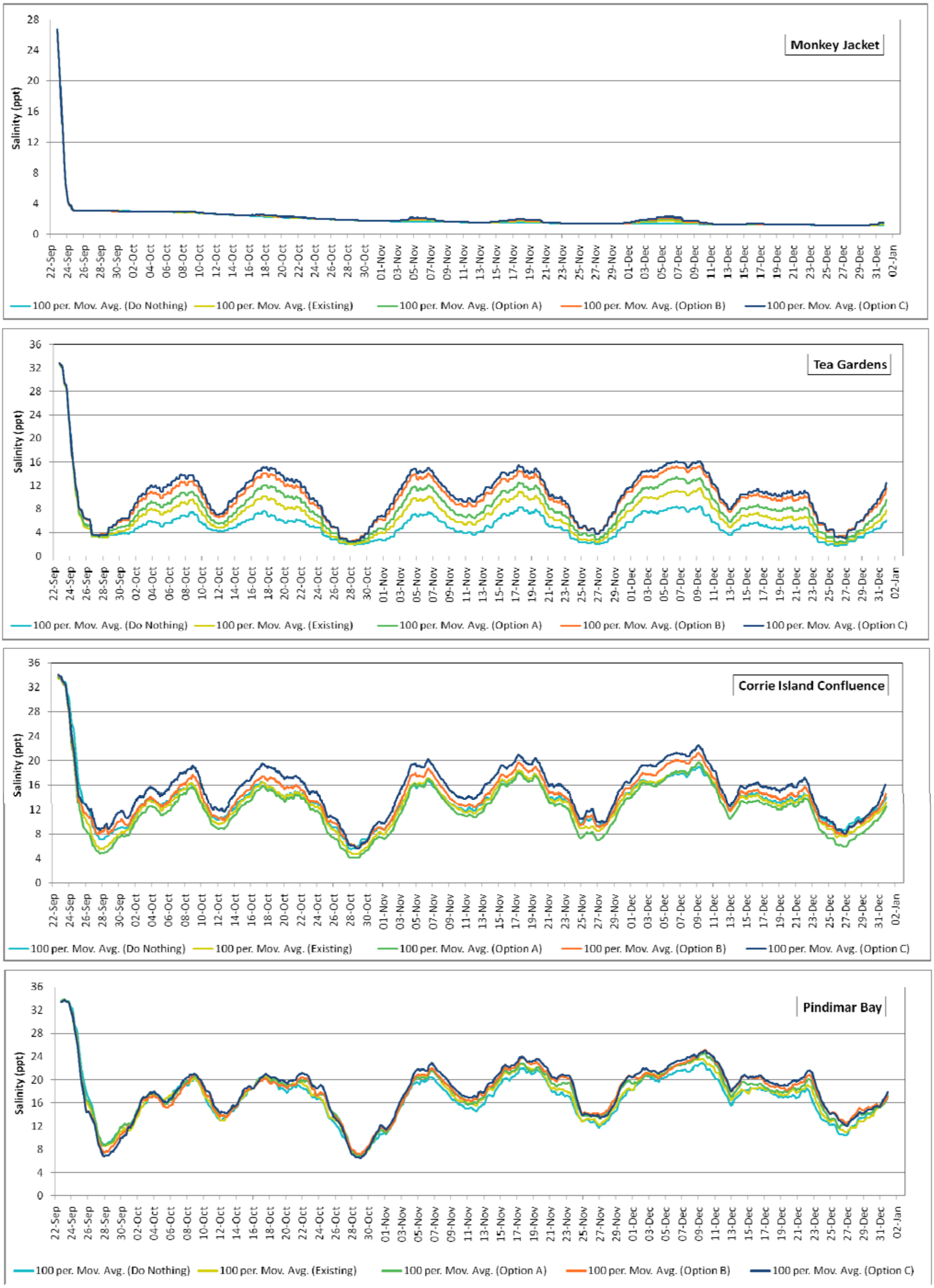


Figure 5-9 Simulated Changes to 24 hour Moving Average Salinity With and Without Dredging

5.5.5.4 Impacts on Entrance Morphology

The study region at the end of Winda Woppa spit comprises a complex interaction of geomorphologic features and different sediment transportation processes. One month long simulations involving waves, tides, wind and morphology were executed for the “existing condition” (for comparison) management Options A, B and C with results provided on Figure 5-10 through Figure 5-13 respectively. The do nothing scenario was not assessed for entrance morphology, as the Eastern Channel is fully closed under this scenario. Importantly, this month long period does not consider a full set of possible combinations of winds, waves and tides. Combined with limitations of the model in replicating beach face transport processes (refer Section 4.3.6.2) this means that the results need to be carefully interpreted.

For the Existing Condition, the month-long simulation indicates that the initial morphology is not “in equilibrium”, and that substantial changes would occur around the fringes of the main flow channel. Paddy Mars Bar in front of the Eastern Channel entrance would also be subject to varying degrees of erosion and accretion. When waves are present, such as on Paddy Mars Bar, sediment transport is considerably enhanced due to the sediment stirring action of the wave motions resulting in larger sediment concentrations, which are subsequently transported by the currents (generated by tides, waves and/or wind).

For Dredge Option A, the simulation indicates that the dredged channel would tend to widen, with the bar on the ocean side of the new channel scouring.

For Dredge Option B the simulation indicates that, like Option A, the dredged channel would tend to widen (migrating westward), while the area of extra dredging (i.e. the end of the spit) may also tend to scour. This becomes possible because tidal flows are now able to reach this area, which is shoaled above the high tide mark in Dredge Option B.

For Dredge Option C the fixed boundary of the groyne tends to force a more pronounced widening of the new channel to the west, with erosion of the bar at the ocean side of the channel.

For Dredge Option D, results would be the same as Option A.

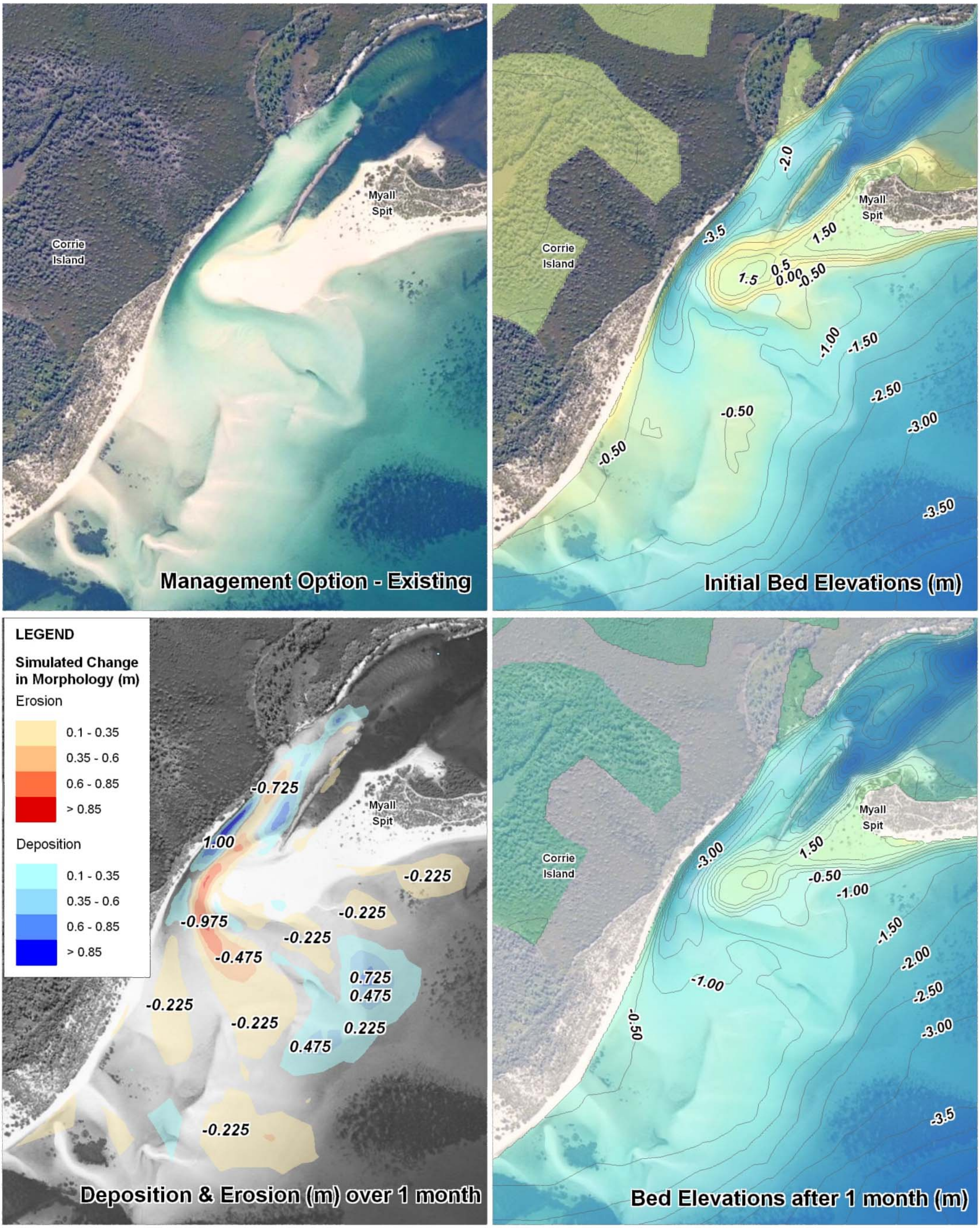
Accretion patterns for all simulations are reasonably consistent, showing deposition of eroded sediments on the ocean side of the shoals, in slightly deeper water. There was also little difference in erosion and accretion patterns on the river side of the entrance region, or within the broader Lower Myall River environs.

An alternative analysis, involving transects across the bed, has been undertaken. The locations of the adopted transects are shown on Figure 5-14. Charts showing the changes of bed elevations along those transects during the simulation are shown on Figure 5-15 through Figure 5-18 for transects 1 through 4 respectively.

This analysis also shows there is significant simulated re-adjustment in all of the dredging options, and the existing conditions scenario.

Furthermore, the entrance morphology response to episodic events has not been considered, and it is these extreme events that may be more significant in terms of the longevity of works.

Further afield, no significant changes to morphology were modelled for Dredge Option A or the existing scenario. In Dredge Options B and C, deposition and erosion was modelled at the end of the Northern Channel, on the southern corner of the Northern Channel where the channel enters Pindimar Bay. In addition deposition and erosion were also observed on the southern corner of the Northern Channel, where the channel enters the confluence region, and the northern corner of Winda Woppa Spit directly opposite the confluence, with similar rates. The patterns of erosion and accretion for all four areas are shown in Figure 5-19 for Option B. Similar values of erosion and accretion were simulated for Option C. These erosion and deposition patterns are related to the redistribution of tidal flows and velocities through entrance area.



Title:

Management Option Existing Case - Simulated Changes to Morphology

Figure: **5-10**

Rev: **A**

N

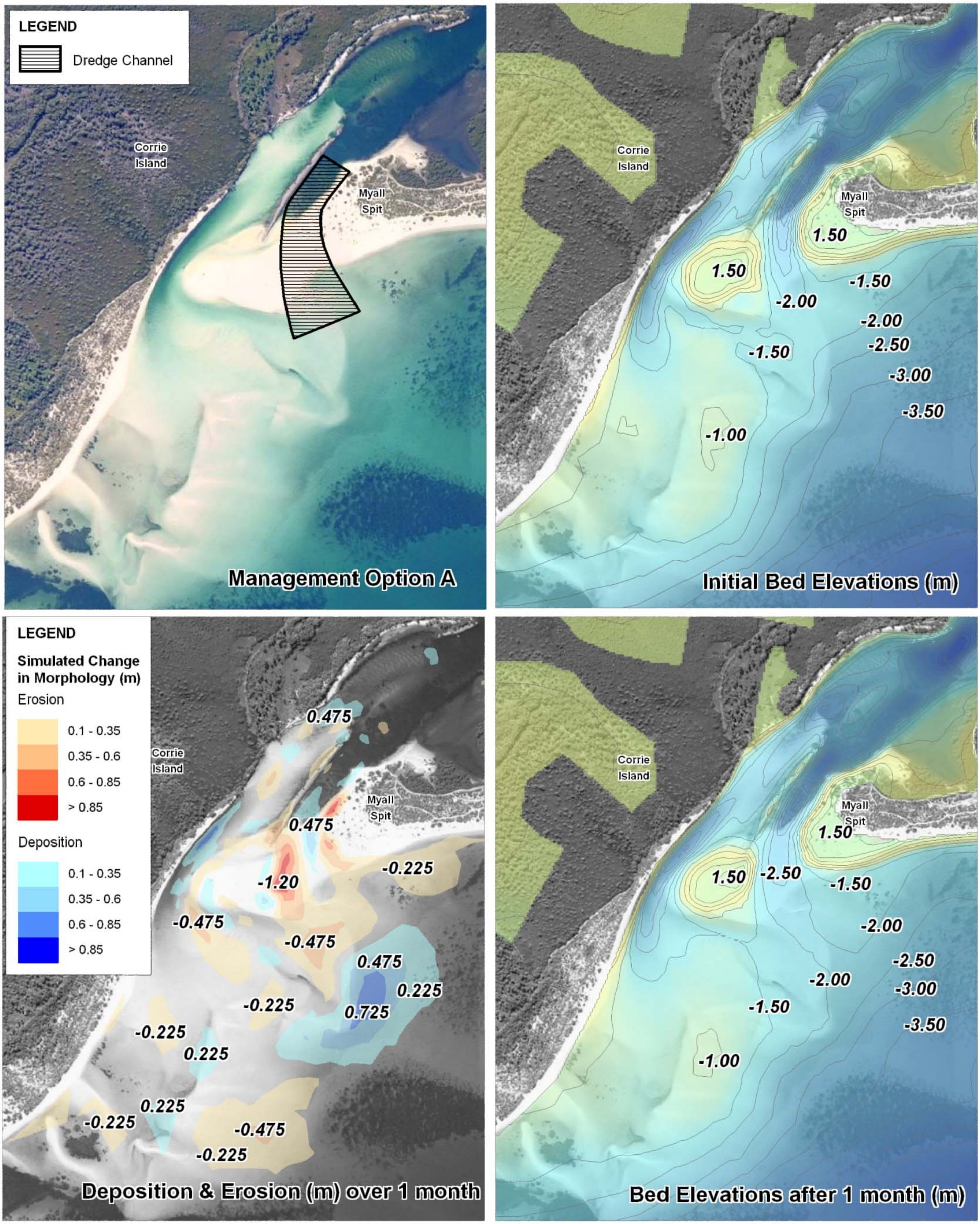
0 250 500m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure 5-9_ExistingConditions_MorphResults.WOR



Title:

Management Option - Dredge Option A Simulated Changes to Morphology

Figure: 5-11

Rev: A

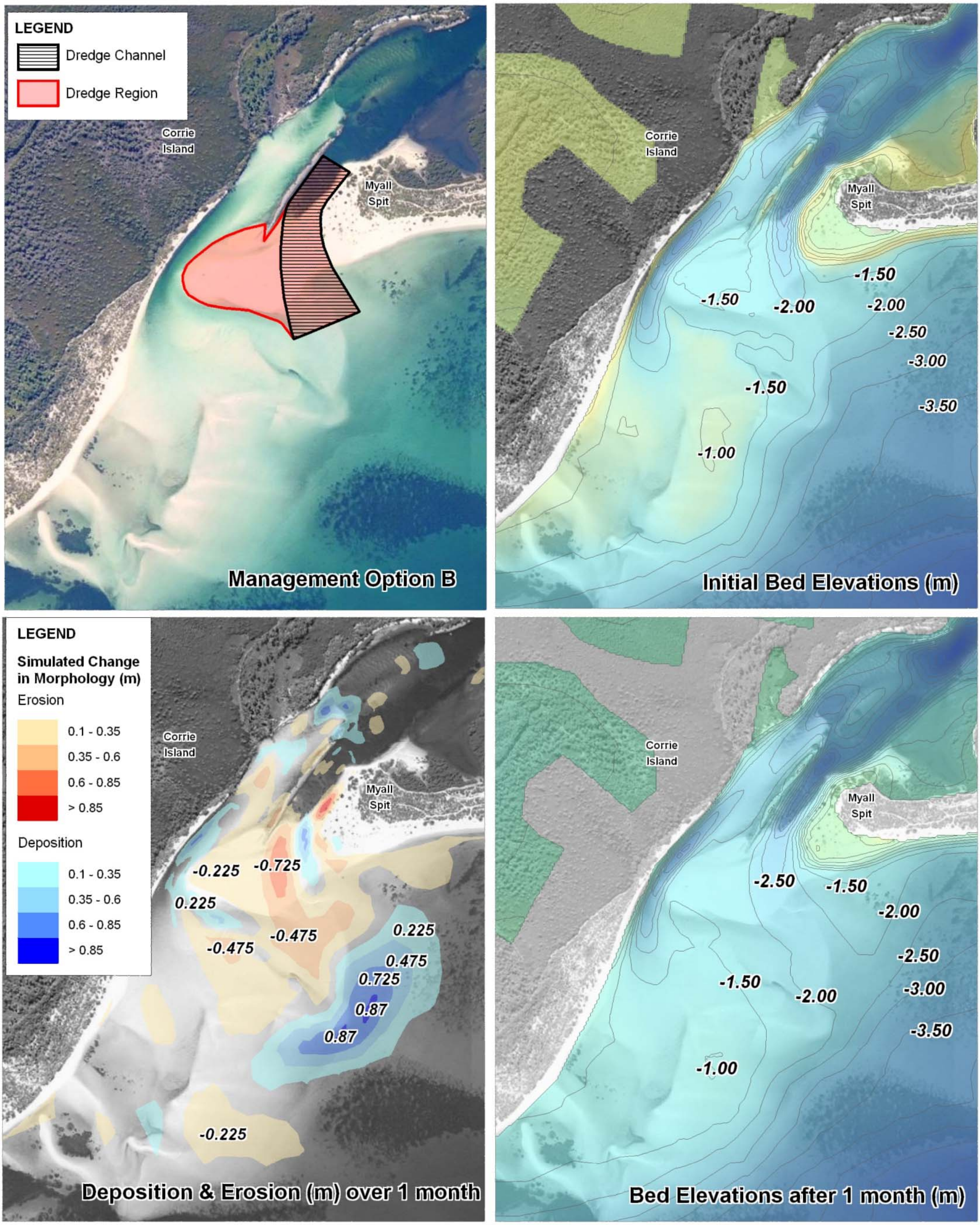
N

0 250 500m

Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure 5-10_OptionA_MorphResults.WOR



Title:

Management Option - Dredge Option B
Simulated Changes to Morphology

Figure: **5-12**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in 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.

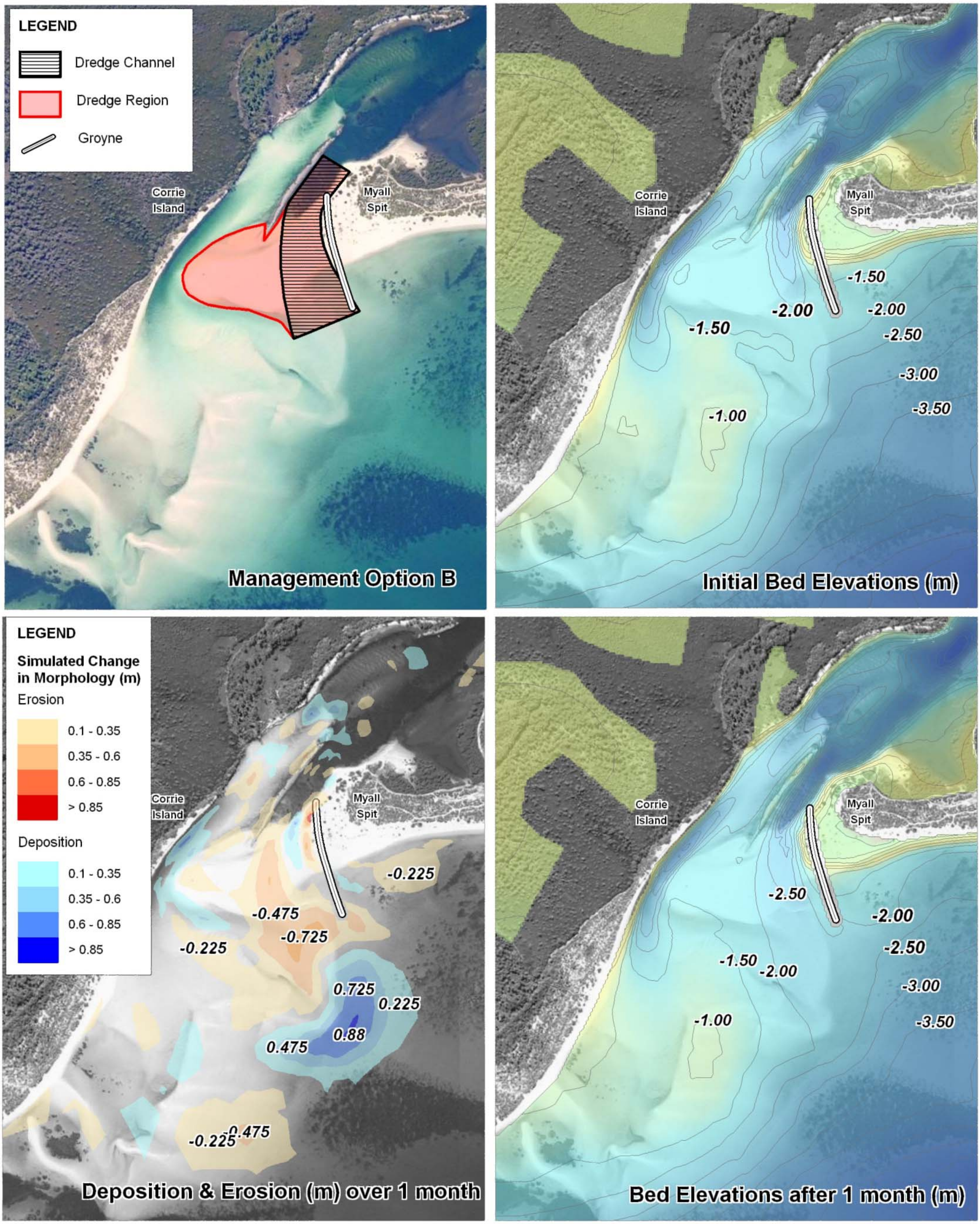
N

0 250 500m

Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure 5-11_OptionB_MorphResults.WOR



Title:

Management Option - Dredge Option C
Simulated Changes to Morphology

Figure: **5-13**

Rev: **A**

N

0 250 500m

Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure 5-12_OptionC_MorphResults.WOR

Title:
Transect locations for morphology modelling results

Figure: 5-14

Rev: A

N

0 250 500m

Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_011_101018 Community Concerns.WOR

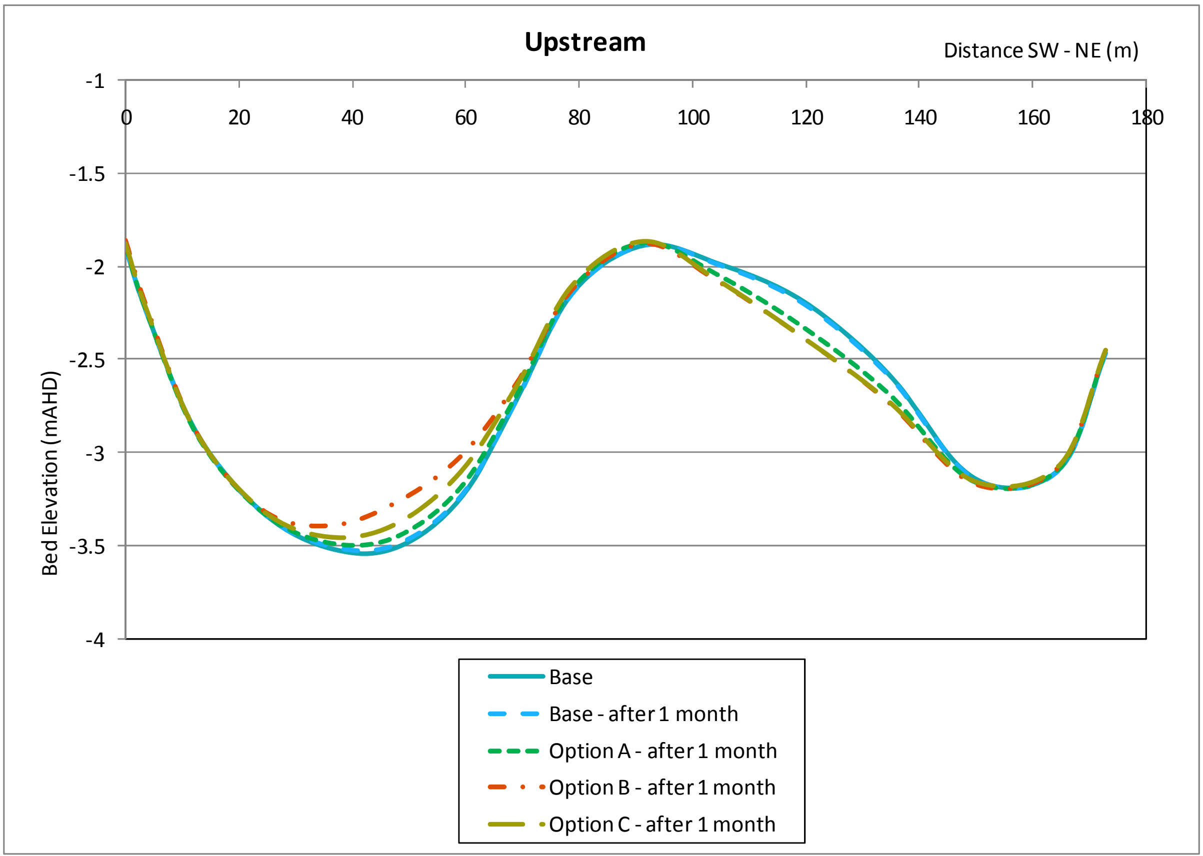


Figure 5-15 Changes to bed elevations at Transect 1

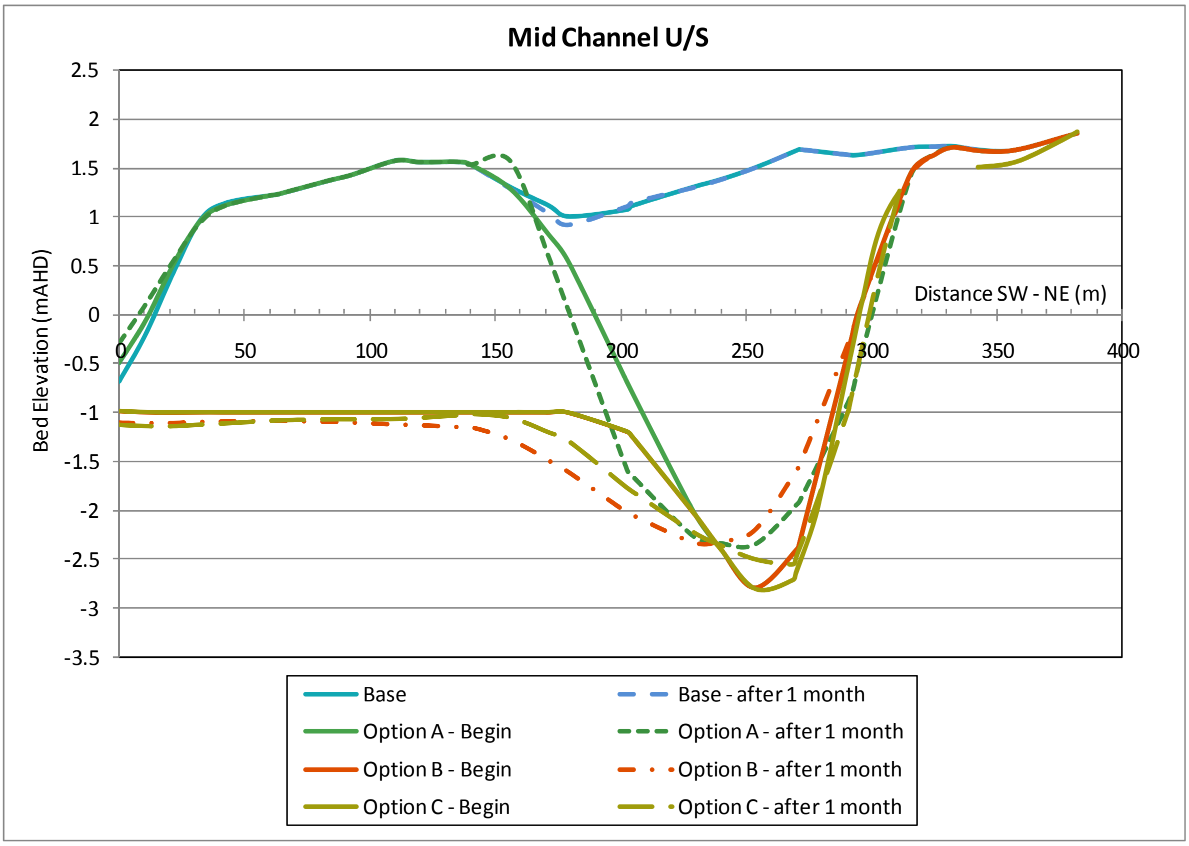


Figure 5-16 Changes to Bed Elevations at Transect 2

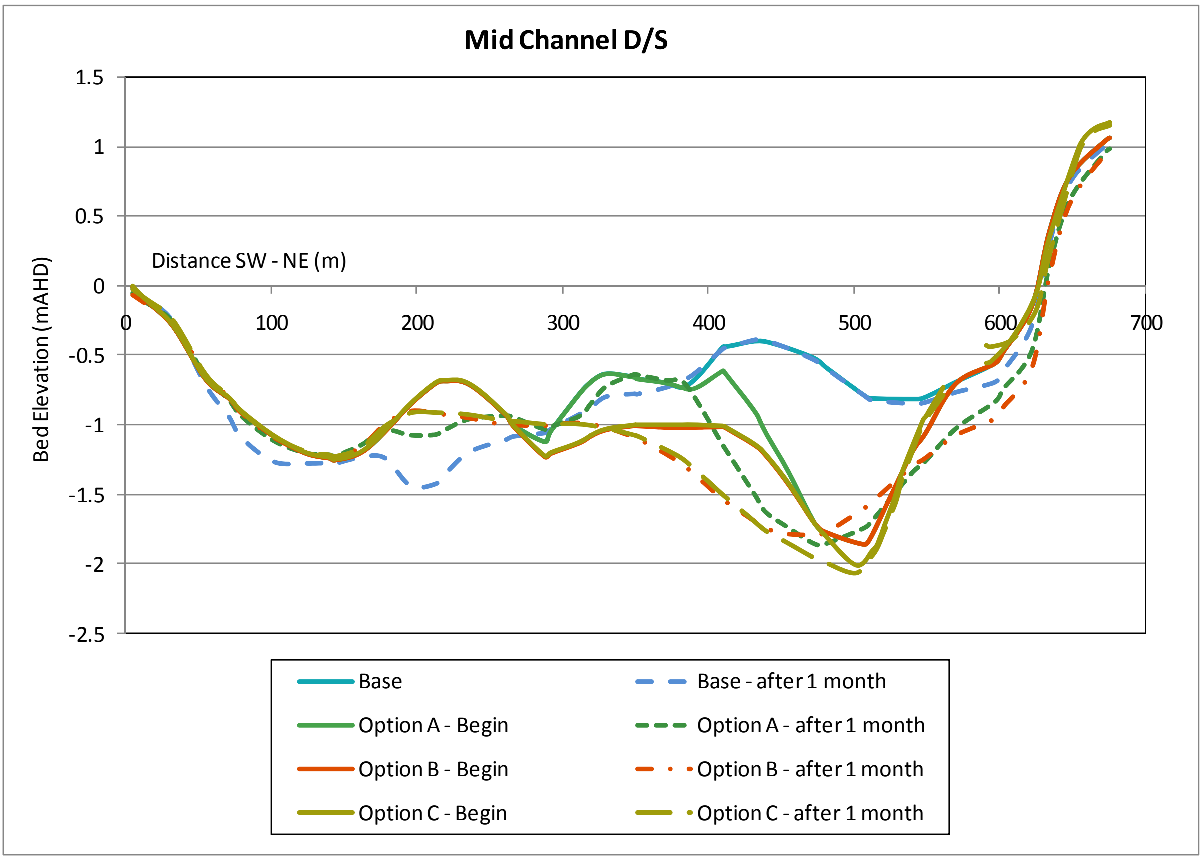


Figure 5-17 Changes to Bed Elevations at Transect 3

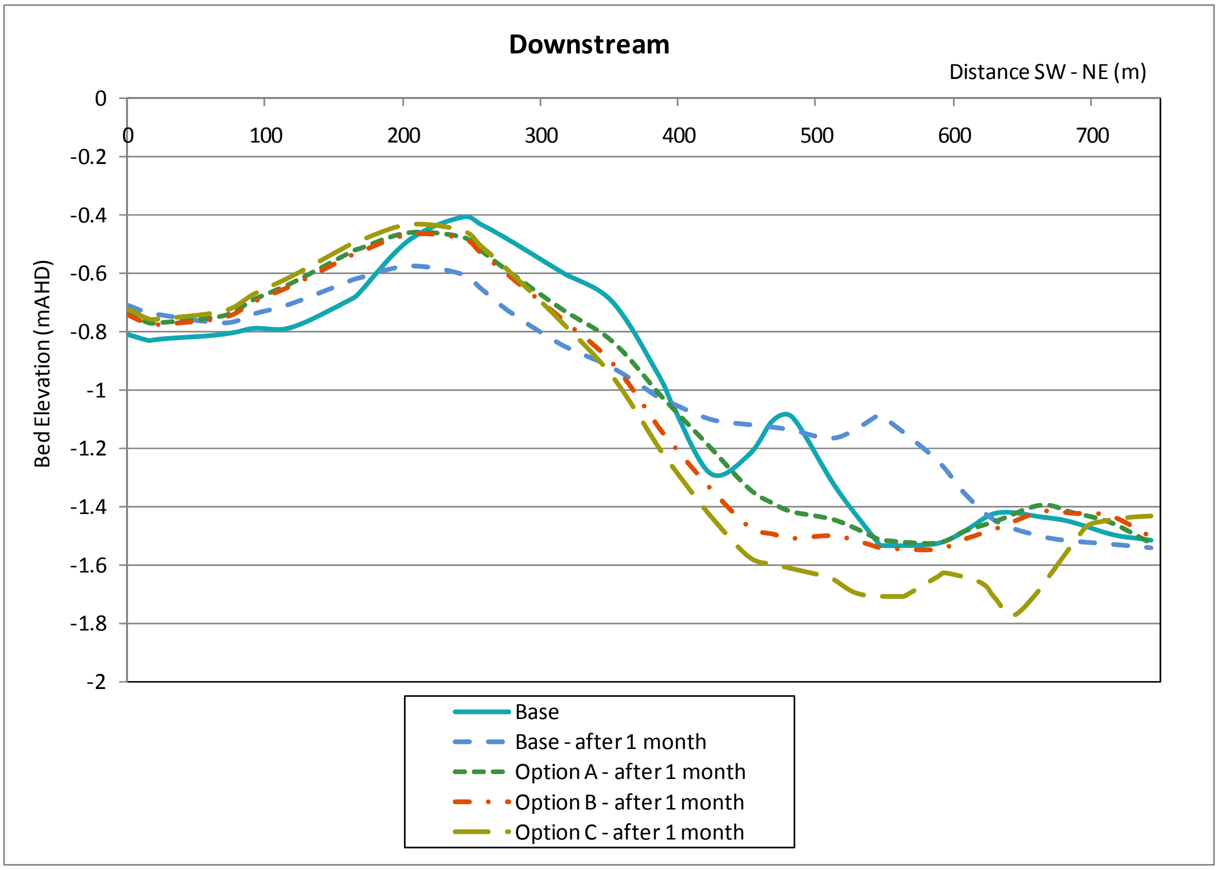
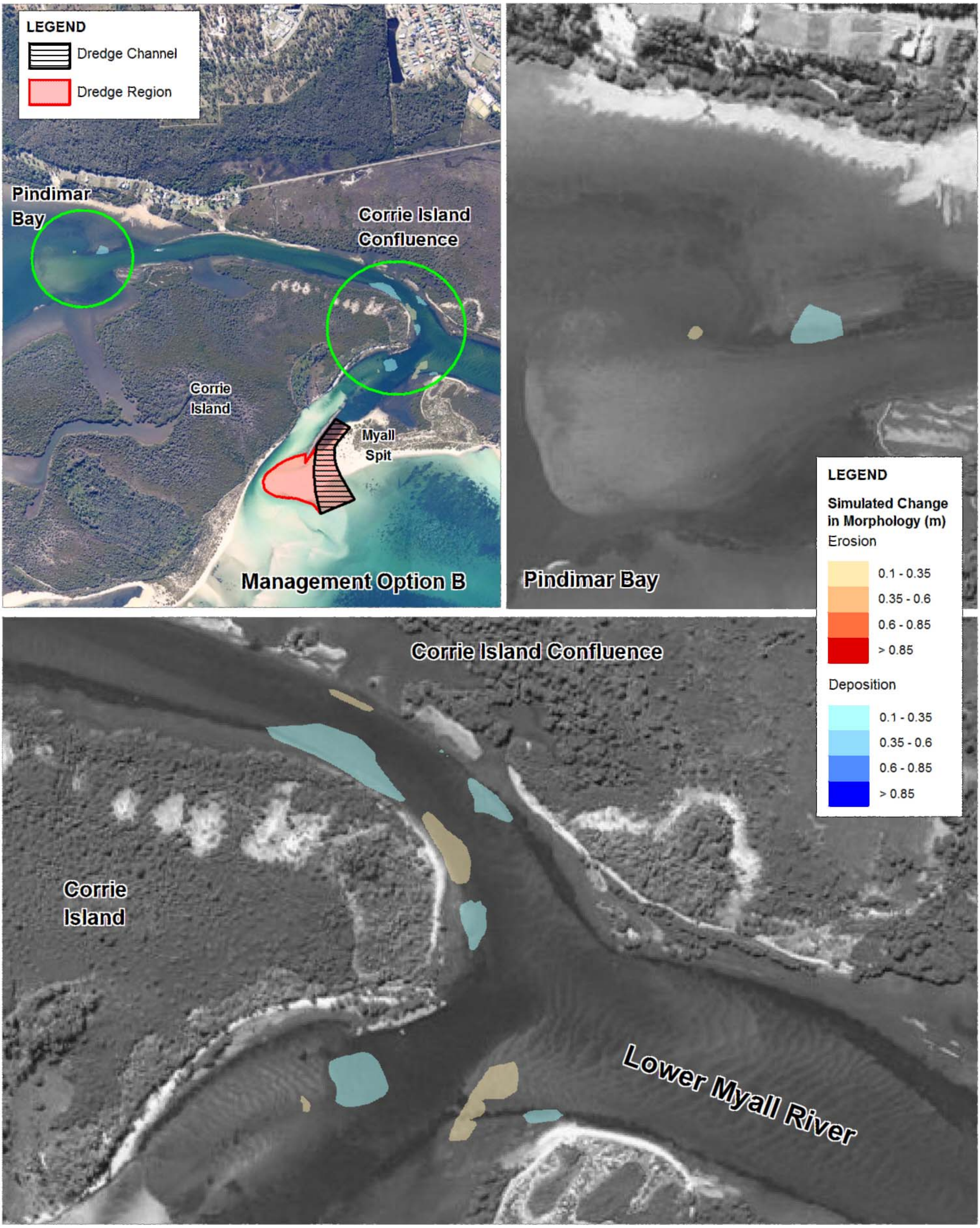


Figure 5-18 Changes to Bed Elevations at Transect 4



Title: **Simulated Morphological Changes further afield**

Figure: 5-19

Rev: A

N

0 125 250m

Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure 5-10_OptionA_MorphResults.WOR

5.5.5.5 Impacts on Longshore Drift

Dredging of the Eastern Channel will not have any direct effect on longshore drift along the Winda Woppa spit shoreline, however, the options involving construction of a groyne and placement of dredged material on the shoreline west of Barnes Rock are expected to impact on longshore transport rates.

Longshore sediment transport generated by swell waves on Jimmys Beach and the foreshore west of Barnes Rock has been calculated to be an order of magnitude larger than longshore transport under the action of wind generated waves. Furthermore, wind-generated longshore transport can occur in both directions, depending on prevailing wind conditions, whereas swell-generated transport is largely from the one direction given the limited window of exposure to swell through the entrance to Port Stephens.

For Options A, B & D, the longshore drift would not be notably different than under existing conditions. For Option C, however, the construction of the groyne will result in shoreline deposition on the updrift (eastern) side of the structure, which will realign the shoreline more perpendicular to the direction of the incoming swell waves. This will reduce the rate of longshore transport along the shoreline. Based on estimated longshore transport rate of up to 15,000m^3/yr, the groyne could reach a maximum sand volume within about 4 – 5 years, after which time the groyne would bypass and deliver sand into the entrance channel. However, as the shoreline adjusts, it will align itself more to the incoming swell wave direction, and transport rates will decrease. For this reason the time taken to bypass the groyne may be somewhat longer, although this depends significantly on the frequency and nature of coastal storms and large winds over the years following construction. Analysis of the probabilities related to various bypassing times would need to be undertaken using a model of shoreline evolution, during detailed design of the groyne, if required.

Placement of sand onto Jimmys Beach is unlikely to have a significant impact on the longshore drift occurring west of Barnes Rock and into the Eastern Channel. Whilst there may be some scope for small amounts of westerly sand migration behind Barnes Rock (Vila-Concejo et al, 2007), this study considers that the sediment processes on Jimmys Beach are largely disconnected from the Myall River entrance.

Placement of dredged sands onto the foreshore west of Barnes Rock is expected to have an impact on local longshore drift. Any changes to alignment of this section of the shoreline would alter the obliquity of waves as they strike the shoreline. This wave obliquity is the primary driver for longshore transport. Placement of sand on this section of the shoreline would at least maintain existing rates of longshore transport (i.e. up to 15,000m^3). Given the unconsolidated and unvegetated nature of the deposited spoil, transport rates could be higher.

5.5.5.6 Impacts on Aquatic Ecology

Direct impacts of the dredging options would be restricted to the immediate areas of dredging and placement activities. Most of the dredge footprint comprises unvegetated sand (both subaqueous and subaerial). Benthic fauna present within the sandy material would be directly impacted. Similarly, for the proposed placement areas, which again contain mostly unvegetated sand, existing benthic fauna would be smothered by the nourishment works. It is expected that mortality rates would be high for benthic fauna directly impacted, however, as the dredging and placement footprints are relatively small in a local context, this loss would not be considered detrimental. There may also be some loss of small patches of existing seagrass (refer previous discussion in Section 2.1.6 and Figure 2-5). These impacts would need to be confirmed through the course of a more detailed environmental impact assessment for any proposed works.

5.5.5.7 Impacts on Terrestrial Ecology

Possible dredging or nourishment works would not have any direct impact on fringing terrestrial ecology. When considering indirect effects, however, impacts on terrestrial habitats will occur associated with continuing recession of foreshores west of Barnes Rock and the eastern shore of Corrie Island. The 'do nothing' option is expected to have continuing erosion of both these areas. All channel dredging options (A, B, C & D) are expected to relieve erosional stress on the Corrie Island foreshore, which should reduce future recession. Options that involve placement of sand on the foreshore west of Barnes Rock would additionally relieve erosional stress on this section of the foreshore.

5.5.5.8 Impacts on Ecosystem Health and Community Structure

As outlined previously, DECCW (2010) concludes that the existing shoaled condition of the Eastern Channel has not had a detrimental effect on the water quality and overall condition or health of the Lower Myall River. As such, improvements in the degree of oceanic flushing of the River borne out by the various dredging options for the Eastern Channel would not necessarily improve the already healthy condition of the estuary. The impact of the 'do nothing' option, which assumes complete closure of the Eastern Channel, on ecosystem health of the Lower Myall River, is not known. Based on comparable locations elsewhere in Port Stephens, it can be hypothesised that the impacts of channel closure would be limited. Nonetheless, if such circumstances occur, then further ecological investigations should be carried out and compared with the DECCW (2010) study, to quantify any impacts.

As outlined in Section 5.5.5.3, the dredging options could potentially modify the salinity structure of the lower sections of the River, with slightly more saline conditions with the Eastern Channel dredged, and less saline conditions if the Eastern Channel closes. Salinity within the Lower Myall River is already variable, with communities adapted to such conditions. It is expected therefore that the overall tendency for more saline conditions in the River associated with the dredging options would not have a significant impact on the estuarine community structure, although it may tend to be slightly more favourable for marine species if dredged, and less favourable for such species if left to close.

It should be recognised that marine species would occupy the Lower Myall River opportunistically only, when conditions are suitable within the estuary.

5.5.5.9 Other Considerations

<u>Option C: Construction of a Groyne</u>

The construction of a hard structure, such as a groyne, within an environment as dynamic as the Lower Myall River will invariably have impacts that are not readily apparent. History shows that most coastal structures have resulted in unintended consequences in the form of erosion or changes to sediment dynamics and morphological responses.

Hard structures tend to be easily placed but notoriously difficult to remove. As such, the construction of a groyne at the end of Winda Woppa Spit would have to be considered in a permanent context. As the local sediment dynamics and hydrodynamic environment changes with time, the influence of the groyne will also change. Thus, the construction of a permanent structure is a 'leap of faith' that the environment in the future will be largely similar to that experienced today. In such a dynamic location, and considering the potential for future climate change, there is much uncertainty regarding the future environment. Such a 'leap of faith' may be unsupported.

Options A – D: Nourishment of Jimmy's Beach

As outlined previously, the sediment processes acting on Jimmy's Beach are largely independent of the sediment processes acting within the Eastern Channel and along the foreshore west of Barnes Rock. Placement of sand from the channel onto Jimmy's Beach would represent an 'external' source of sand to the Jimmy's Beach sediment cell. While nourishment has occurred on Jimmy's Beach for several decades, there is still significant uncertainty regarding the fate of such nourishment material.

Options involving the placement of sand on Jimmy's Beach should be approached with caution and should be accompanied by a detailed sediment dynamics assessment for the Jimmy's Beach sediment cell. It is understood that the NSW Government has allocated funds for further investigations into the long-term management plan of Jimmy's Beach, including nourishment sources and fate of sediments. Any assessment undertaken by the NSW Government should include the option of sand extraction from the Eastern Channel, either as one-off dredging campaigns, or as an 'on-demand' sand pumping system (e.g. sand shifter). The assessment should also consider the same approach and configuration (including a fixed in place sand pumping system) for extraction from alternative sand sources, including the Yacaaba sand deposit currently used for nourishment purposes.

5.5.6 Evaluation of Longevity of Works

The morphodynamic assessment (refer Section 5.5.5.4) highlights the dynamism of the area, with significant areas of sediment erosion and accretion under all modelled scenarios, including the existing conditions (emphasising a near-constant imbalance given the ever-changing influences of waves, tides, wind and floods). It is therefore very difficult to determine the expected longevity of any dredging and nourishment works undertaken.

In order to provide a ball park indication of longevity, the longshore transport rates west of Barnes Rock have been used to determine approximate rates of channel infill. This is considered reasonable in the first instance, as this mechanism is introducing an external source of sand to the entrance area.

Longshore sediment transport potential has been estimated to be up to about 15,000m^3. For nourishment onto Jimmys Beach, and in the absence of a groyne at the end of Winda Woppa spit (i.e. Dredge Options A, B & D), it can be assumed that sediment would be reworked into the Eastern Channel at a rate of about 10 – 12,000m^3 per year. For nourishment onto the shoreline west of Barnes Rock, this could increase up to the maximum potential of around 15,000m^3. Following an initial readjustment period, Dredge Option D would aim to extract sand at a rate in the order of 10,000m^3 per year, and place the material on Jimmys Beach as well as the foreshore west of Barnes Rock, as required.

If a groyne is constructed, then there would be a period of time that the groyne would fill before bypassing of sand into the Eastern Channel. The potential volume of sand that can be stored by the groyne is approximately 70,000m^3.

Approximate estimates of durations for 50% infill of the dredged volume are presented in Table 5-3. These durations should be interpreted with caution, and are provided mostly for comparative purposes.

Table 5-3 Approximate Longevity of Short-Listed Options to Reach 50% Infill of Dredging

	Jimmys Beach nourishment	West of Barnes Rock nourishment
Dredge Option A (55,000m^3)	2.5 – 3 yrs.	2 yrs.*
Dredge Option B (95,000m^3)	4.5 – 5 yrs.	3 yrs.*
Dredge Option C (95,000m^3 + groyne)	11.5 – 12 yrs.	8 yrs.*
Dredge Option D (55,000m^3 + pumping)	Would not reach 50% infill if sand is regularly pumped ashore	

Note

* Sand placed on the foreshore west of Barnes Rock will be influenced by swell waves and will be eroded and reworked back into the Eastern Channel. As such, the longevity of dredging works that involve placement of sand onto this foreshore would is lower than if the sand was placed external to the 'sediment cell' (e.g. onto Jimmy's Beach, where sand is not reworked back into the Eastern Channel).

5.5.7 Evaluation of Economic Impacts

5.5.7.1 Benefits

Economic benefits of the short-listed options are difficult to calculate. Rather than enhancing the local economy, the potential works may simply maintain status quo. But this would need to be compared to the 'do nothing' scenario, whereby the continuing shoaling and potential closure of the channel may have an adverse impact on tourism and boating related income in Tea Gardens, and particularly if the River continues to deteriorate in clarity and amenity.

The significance of the River to the local community also incorporates a range of intangible factors, which cannot easily be evaluated purely on an economic scale.

5.5.7.2 Capital Costs

Approximate capital costs for the short-listed options are presented in Table 5-4. Cost differential between nourishment on Jimmys Beach versus nourishment west of Barnes Rock relates to the additional pumping distance for the dredged material.

Table 5-4 Approximate Capital Costs for Short-listed Options

CAPITAL COSTS	Jimmys Beach nourishment	West of Barnes Rock nourishment
Dredge Option A (55,000m^3)	$2.0 m *	$1.5 m
Dredge Option B (95,000m^3)	$3.2 m *	$2.5 m
Dredge Option C (95,000m^3 + groyne)	$6.2 m *	$5.5 m
Dredge Option D (55,000m^3 + Sand Shifter)	$2.8 m*	$2.3 m

** There is potential for these costs to be offset by separate funding for Jimmys Beach nourishment works.*

5.5.7.3 Maintenance Costs

Estimated on-going costs for maintaining an open entrance through the Eastern Channel are provided in Table 5-5. Although transportation to Jimmys Beach would involve a longer distance, and hence higher costs, if the shoreline west of Barnes Rock was nourished, then the demand for maintenance would be greater, and the longshore transport rate would be higher.

Table 5-5 Approximate Maintenance Costs for Short-listed Options

MAINTENANCE COSTS	Jimmys Beach nourishment	West of Barnes Rock nourishment
Dredge Option A (55,000m^3)	$280,000 * p.a.	$360,000 p.a.
Dredge Option B (95,000m^3)	$300,000 * p.a.	$380,000 p.a.
Dredge Option C (95,000m^3 + groyne)	$130,000 * # p.a. for 10yrs, then $300,000 p.a. thereafter	$160,000 # p.a. for 6yrs, then $380,000 p.a. thereafter
Dredge Option D (55,000m^3 + Sand Shifter)	$150,000 * p.a.	$150,000 p.a.

** There is potential for these costs to be offset by separate funding for Jimmys Beach nourishment works.*

 # Maintenance works may involve extracting material in the dry from in front of groyne instead of waiting for channel to infill. This would require a more frequent (but potentially cheaper) program of maintenance works.

Costs are estimates only and are provided in present dollar terms. Lower maintenance costs are achieved for Dredge Option C only until the groyne fills and starts to bypass sand directly into the channel. The construction of a groyne does introduce the ability to extract sand on the shoreline (i.e. remove sand trapped in front of the groyne) as an alternative to removing sand accumulated within the channel, however, this would need to happen before the sand starts to bypass the groyne in order to avoid accumulation within the channel. Removal of sand from the shoreline could potentially save significant effort and costs (especially mobilisation costs) for on-going dredging within the channel. It is expected, however, that the dynamics of sediment within the channel and entrance area would still require some degree of channel dredging from time to time.

As discussed previously, the installation of a Sand shifter sand pumping system would provide a relatively low-cost mechanism for maintenance works within the channel.

5.5.7.4 Total Cost Comparison

A rudimentary total cost comparison has been carried out to provide an indication of the relative value of the different options presented, including the ‘do nothing’ option. Costs over 10 year and 20 year periods have been considered, based on present dollar value (Table 5-6). Costs compared also include the costs of managing of Jimmys Beach through on-going nourishment.

This cost comparison shows that over 20 years, Option D with nourishment of Jimmys Beach would have approximately the same cost as the expected costs of nourishing the beach irrespective of any Eastern Channel dredging works. That is, for little or no additional cost, the Eastern Channel can be used as an alternative source of nourishment material for Jimmys Beach, while providing the additional benefit of maintaining a more open channel configuration.

5.5.8 Evaluation of Social Impacts

Benefits and costs associated with the social and community aspects of the short-listed options have not been evaluated in detail. Engagement with the MRAG during the project has provided an indication of preferences for particular solutions, however, it is envisaged that more extensive consultation during the public exhibition of this document will reveal a wider community perspective.

From discussions to date with community members, an important element of the Lower Myall River entrance solution would be integration with the wider issues of Jimmys Beach. Although there may not be a strong connection between the processes causing erosion of Jimmys Beach and the processes causing shoaling in the Eastern Channel, the opportunity to address both issues in tandem is particularly attractive.

Table 5-6 Total Costs Comparison after 10 Years and 20 Years (Present Dollar Value)

	$ '000,000s			
	After 10 years		After 20 years	
	Eastern Channel only	Eastern Channel and Jimmys Beach Combined	Eastern Channel only	Eastern Channel and Jimmys Beach Combined
Do nothing	0	2.5 *	0	5.0 *
Option A: Jimmys nourish	4.8	4.8	7.6	7.6
Option A: west of Barnes Rk	5.1	7.6	8.7	13.7
Option B: Jimmys nourish	6.2	6.2	9.2	9.2
Option B: west of Barnes Rk	6.3	8.8	10.1	15.1
Option C: Jimmys nourish	7.5	7.5	10.5	10.5
Option C: west of Barnes Rk	7.1	9.6	10.9	15.9
Option D: Jimmys nourish	4.3	3.8 #	5.8	5.3 #
Option D: west of Barnes Rk	3.8	6.3	5.6	10.6

** Assumes an on-going demand of 15,000m^3 per annum at a cost of approx. \$15/m^3, based on historical rates of nourishment and most recent costs.*

 # Assumes that the first 3 years do not require on-going costs, as Jimmys Beach nourishment demand is met by the placement (and possible storage) of material from the initial capital dredging works.

5.6 Summary of Options Assessment

A summary of the options considered as part of this assessment is provided in Table 5-7. This table recaps the environmental, social and economic impacts of Dredge Options A to D, compared with the 'Do Nothing' scenario.

As presented in the table, the 'do nothing' option may have some environmental and social consequences that could be overcome by the dredging options (particularly A, B and D). When considered in combination with the costs for on-going nourishment of Jimmys Beach, Dredge Option D is comparable to the 'do nothing' option, while all other dredging options are notably more expensive. Subject to more detailed assessments, Dredge Option D would appear to be virtually a no-regrets option when considered over a longer time period (20 + years).

Table 5-7 Summary of Options Assessment

Options	Environmental	Social	Economic
Do nothing	Eastern Channel will eventually close, and oceanic flushing in the river will be reduced. The resulting change to ecosystem health of River is unknown, but is likely to be limited. There will be continued shoreline recession west of Barnes Rock, while Corrie Island will likely continue to erode until the channel closes.	When the Eastern Channel closes, there may be a reduction in aesthetics (water clarity) and amenity of river, while navigation through the channel will be prevented. There may be some community backlash when the channel closes.	If the channel closes, there may be economic loss associated with tourism and boating industry. Costs for doing nothing range from $0 to $5m over the next 20 years, depending on whether on-going costs for nourishing Jimmys Beach are included.
Dredge Option A ($55,000m^3$)	There would be no significant improvement in environmental conditions compared to existing. The works may reduce the propensity of future shoreline recession and associated vegetation and habitat loss on Corrie Island and west of Barnes Rock.	The amenity and aesthetics of the river (water clarity) may be improved compared to existing conditions. There would be the potential for improved navigation through the channel, but not assured.	Costs of capital dredging and on-going maintenance dredging to keep the channel open would cost between $7.6m and $8.7m over the next 20 years, depending on where the sand is placed. If sand is not placed on Jimmys Beach, then the on-going cost of nourishing Jimmys Beach would be additional.
Dredge Option B ($95,000m^3$)	As above for Dredge Option A	As above for Dredge Option A	Costs of capital dredging and on-going maintenance dredging to keep the channel open would cost between $9.2m and $10.1m over the next 20 years, depending on where the sand is placed. If sand is not placed on Jimmys Beach, then the on-going cost of nourishing Jimmys Beach would be additional.
Dredge Option C ($95,000m^3$ + groyne)	As above for Dredge Option A. There may be some detrimental effects of on the environment associated with construction of a hard groyne structure. There is also a high degree of uncertainty regarding the potential impacts given the dynamism of the coastal environment.	As above for Dredge Option A. Visual amenity may be impacted by the groyne structure, affecting the 'natural' feel of the area.	Costs of capital dredging and on-going maintenance dredging to keep the channel open would cost between $10.5m and $10.9m over the next 20 years, depending on where the sand is placed. If sand is not placed on Jimmys Beach, then the on-going cost of nourishing Jimmys Beach would be additional.

Options	Environmental	Social	Economic
Dredge Option D ($55,000m^3$ + Sand shifter)	As above for Dredge Option A	As above for Dredge Option A	Costs of capital dredging and on-going maintenance dredging to keep the channel open would cost between $5.3m and $5.8m over the next 20 years, depending on where the sand is placed. If sand is not placed on Jimmys Beach, then the on-going cost of nourishing Jimmys Beach would be additional.

5.7 Further Considerations

The evaluation of short-listed options presented in this report represents a preliminary or first-pass assessment of somewhat idealised conditions (both in terms of dredging and placement). It is envisaged that if any options are to be pursued further, then additional investigations would be required to address various unknowns, including:

- The ideal size of channel to optimise tidal flows and self-scour (to minimise channel infill). It is noted that the morphodynamic simulations suggest a widening of the dredged channel within a relatively short period of time. Therefore, there may be consideration of having a wider channel initially.
- A suitable amount of over-dredging, or "insurance dredging", to cater for a certain degree of channel infill without compromising the objectives of the channel. It is considered, however, that excessive over-dredging will simply promote more rapid infill of the channel, so detailed analysis will be required to optimise design.
- Consideration of land-based operations for dredging, including suitable dredge settlement ponds, and return flows to the waterway, if the material is not to be placed directly onto foreshores (either on Jimmys Beach, or west of Barnes Rock).
- The suitability of the sand for placement on Jimmys Beach. There may be some minor difference in sediment characteristics, however, the consequence of any difference on the response of the shoreline profile would need to be assessed.
- The potential impacts of placement of 'external' sand on Jimmy's Beach, as discussed in Section 5.5.5.9.

6 RECOMMENDED NEXT STEPS

6.1 Overview

Table 6-1 provides a quick reference summary of the major issues that affect the Lower Myall River entrance both now, and theoretically once the Eastern Channel closes.

Jimmys Beach nourishment is an on-going issue for Council and the State Government. Although not directly affecting the Lower Myall River entrance, there is potential that sand build-up within the Eastern Channel can be used as a source of nourishment sand. Sediment processes on Jimmys Beach and the Lower Myall River are essentially disconnected. Therefore, closure of the Eastern Channel would have no impact on the demand for nourishment on Jimmys Beach.

As explained previously in this report, DECCW (2010) concluded that water quality and ecosystem health of the Lower Myall River is not currently degraded. It is uncertain whether this would still be the case when and if the Eastern Channel closes, given the changes in oceanic flushing that would result.

Aesthetics and amenity of the river are expected to be lower than in the recent past due to poorer water clarity (most likely resulting from reduced oceanic flushing). The lower reaches of the River were previously quite marine, with clear waters and a sandy bed. Higher levels of tannin are now present in the river, indicating more estuarine conditions with more prominent freshwater and groundwater influences. When and if the Eastern Channel closes, it is expected that water clarity would be reduced further, given the predicted reduction in oceanic flushing.

Shoreline erosion is a current issue both on the eastern foreshore of Corrie Island, and west of Barnes Rock. In both these locations, erosion is currently impacting on vegetation and degrading local wetland habitat values. Corrie Island is a Ramsar-listed wetland, and will continue to erode until the Eastern Channel closes. Meanwhile, erosion west of Barnes Rock will continue irrespective of the condition of the Eastern Channel. Erosion in this area is in response to the natural realignment of the shoreline based on the approaching dominant ocean swell waves. Much greater erosion of this shoreline can therefore be expected in the future, including a potential breakthrough across the Winda Woppa Spit into the Myall River.

Table 6-1 Relevance of Issues

Issue	Now ?	When Eastern Channel closes ?
Water quality & ecosystem health	No	Don't know
Water clarity and aesthetics	Maybe	More likely
Shoreline erosion	Yes	Yes, but less likely on Corrie Island foreshore
Jimmys Beach nourishment	Yes	Yes

Recommended next steps for management of the Lower Myall River entrance area are outlined in the decision support framework given in Figure 6-1.

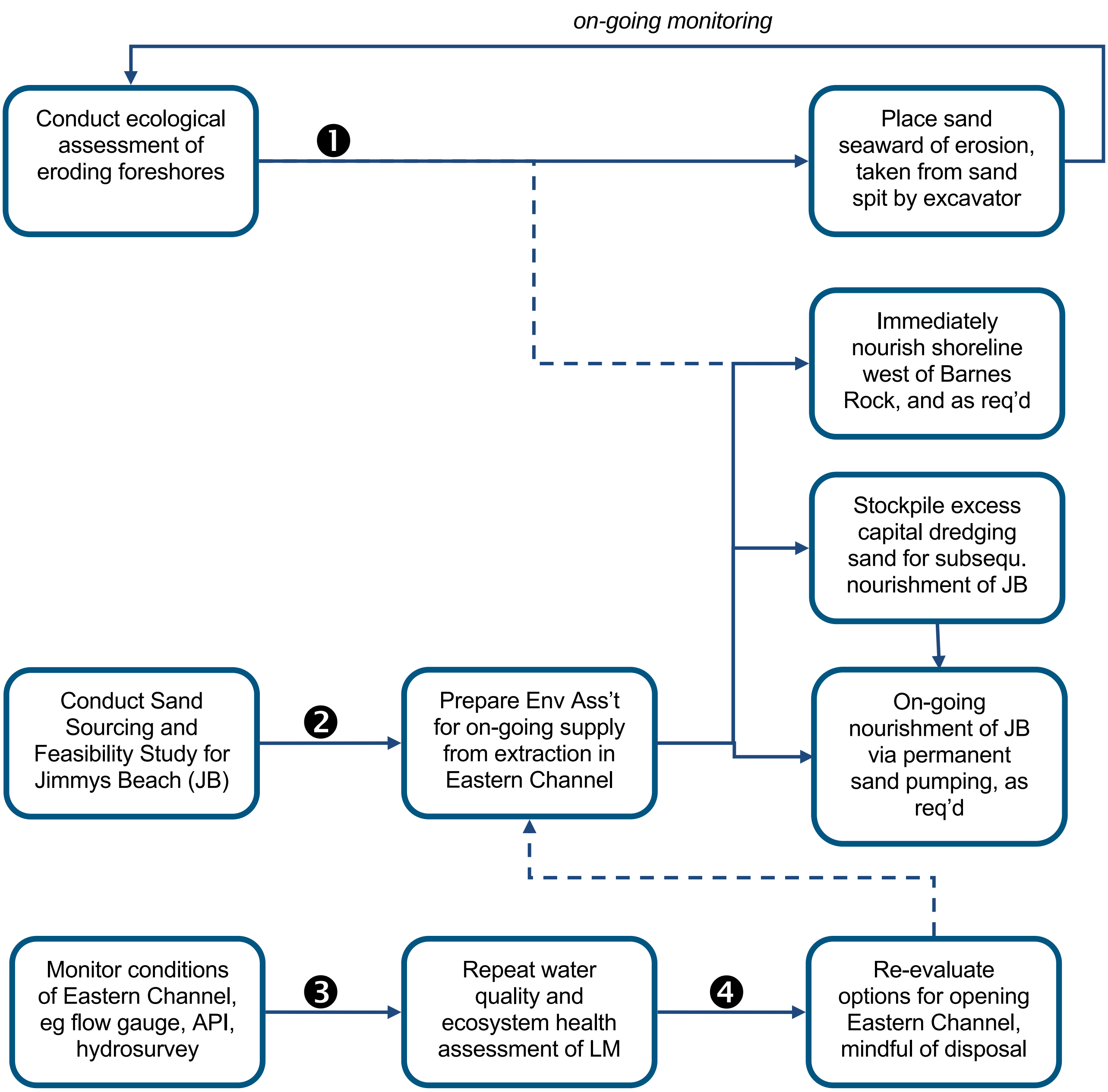


Figure 6-1 Recommended Decision Support Framework

Progression through the Decision Support Framework (Figure 6-1) is controlled by a series of gates, or 'triggers', identified as ❶❷❸❹, which are described further below.

Trigger ➊: If the ecological assessment indicates that the wetland habitats are being impacted significantly, then proceed to the next step, otherwise stop.

Trigger ➋: If the Sand Sourcing and Feasibility Study shows that dredging from the Eastern Channel is a viable and preferable long-term option for nourishing Jimmys Beach (both from an economic and environmental impact perspective), then proceed to the next step, otherwise stop.

Trigger ➌: If monitoring shows that the Eastern Channel has closed completely, then proceed to the next step, otherwise continue monitoring.

Trigger ➍: If the water quality and ecosystem health assessment of the Lower Myall River indicates that the health or condition of the river system has been degraded as a result of the closed channel, then proceed to the next step, otherwise stop.

If sourcing of sand for nourishment of Jimmys Beach from the Eastern Channel is indeed viable and a preferable option (i.e. Trigger ➋ is open), then a detailed *Eastern Channel Sand Sourcing Strategy* should be prepared, which aims to optimise the methods of extraction, delivery and placement of sand, as well as the location and size of extraction areas, and frequency of extraction. Placement of sand at multiple locations should be accommodated through various outlets within the discharge pipelines. The Strategy should also describe the conditions required for on-going extraction, triggered by a need for nourishment on Jimmys Beach, or possibly the need for nourishment west of Barnes Rock to protect existing wetlands (if determined to be a significant issue, as per Trigger ➊) or to maintain access to the end of Winda Woppa Spit to support sand sourcing infrastructure. In combination with the Strategy, relevant environmental assessment documents and approvals / consents should be obtained, so that there is minimal delay in providing nourishment when required by Jimmys Beach (noting that a single storm event could deplete the beach of significant sand volume).

Monitoring of the success of the overall system would also need to be carried out to determine if operational changes to the on-going strategy are required.

6.2 Approvals and Consents

Any works associated with extraction of material from the Eastern Channel would require various approvals and consents from a range of authorities. The works would be carried out within the Port Stephens Marine Park, and near Ramsar-listed wetlands. A full Environmental Impact Statement (EIS) would be required, fully documenting the impact of the works to all physical, chemical, sedimentological and ecological processes. The EIS would also need to justify the works from an Ecologically Sustainable Development (ESD) perspective, as espoused by various Council, State and Federal Policies, as well as from an economic perspective. In this regard, consideration of the ‘do nothing’ scenario will be important, as a baseline comparison for the works.

It is envisaged that sea level rise and other climate change impacts would also need to be considered as part of the EIS. In this regard, adaptable and reversible options such as the Sand shifter, are particularly attractive when compared to other fixed hard engineering structures, such as groynes and seawalls.

7 REFERENCES

Austin, T.P., Short, A.D., Hughes, M.G., Vila-Concejo, A. and R. Ranasinghe, (2009) Tidal Hydrodynamics of a Micro-tidal, Wave Dominated Flood-tide Delta: Port Stephens, Australia, *Journal of Coastal Research*, **SI 56** (Proceedings of the 10th International Coastal Symposium), Lisbon, p 693-697

Dean, R.G. and Dalrymple, R.A. (2002) Coastal Processes with Engineering Applications, Cambridge University Press

Floor Anthoni, J (2010) http://www.seafriends.org.nz/oceano/beach, accessed 12th October, 2010

Jiang, A.W., Allery, C., Vila Concejo, A., Cowell, P. And Ranasinghe, R. (2009) Dominant hydrodynamic processes at Jimmy's Beach, port Stephens, Australia: A numerical modelling study, Australasian Ports and Coasts Conference, Museum of New Zealand Te Papa Tongarewa, Wellington, NZ, 14th – 18th September, 2009

Komar, P.D. (1976) Beach Processes and Sedimentation, Prentice-Hall, Inc. Englewood Cliffs, New Jersey

Masselink, G. and Hughes, M.G. (2003) Introduction to Coastal Processes and Geomorphology, Hodder – Arnold Publishers, London

MHL (1998) Port Stephens Tidal Data Collection September 1993, prepared by the NSW Department of Public Works and Services Manly Hydraulics Laboratory, February 1998, Report No. MHL716.

MHL (1999) Port Stephens/Myall Lakes Estuary Processes Study, prepared by Manly Hydraulics Laboratory (MHL), Report No. MHL913, January 1999

MHL (2010) DECCW Myall River Data Collection, September 2008 – September 2009. *Report MHL 1943 prepared for Department of Environment, Climate Change and Water, June*.

Department of Primary Industries (DPI) (2006) Estuarine Resources of New South Wales, Project Summary Sheet CCA04 *Comprehensive Coastal Assessment: Better Planning for Coastal NSW*

PWD (1981) Lower Myall River Processes Study Datum Establishment, September 1979, Public Works Department, Manly Hydraulics Laboratory, Report MHL227 and 227 Supplementary

PWD (1982) Myall River Tidal data Collection, 22.10.1975, Report No. 350, August 1982, Public Works Department, Manly Hydraulics Laboratory, NSW

PWD (1998) Port Stephens Tidal Data Collection, September 1993, Department of Land and Water Conservation, Manly Hydraulics Laboratory, NSW, Report No. CFR97/7, MHL716, DPWS Report No. 95053

Sanderson, B.G. (2008) Circulation and the Nutrient Budget in Myall Lakes *Hydrobiologia (2008) 608:3-20*

Scanes, P., McCartin, B., Kearney, B., Coade, G., and Floyd, J (2010) Ecological Condition of the Lower Myall River Estuary, *Draft Report Prepared for Great Lakes Council by the Coastal Waters Science Unit of the Department of Environment, Climate Change and Water,* September.

Short, A.D., (2007) Beaches of the New South Wales Coast A guide to their nature, characteristics, surf and safety, 2nd Edition, February, 398p

Soulsby, R (1997) Dynamics of marine sands, A manual for practical applications. Thomas Telford Books

Thom, B.G., Shepherd, M., Ly C.K.,Roy, P.S., Bowman, G.M., and Hesp, P.A. (1992) Coastal Geomorphology and Quaternary Geology of the Port Stephens-Myall Lakes Area *Australian National University, Canberra*

Umwelt (2000) Port Stephens and Myall Lakes Estuary Management Plan, prepared for Great Lakes Council by Umwelt (Australia) Pty Ltd

University of Sydney (2010) Flood Tide Delta Morphodynamics and shoreline implications in Port Stephens, http://www.geosci.usyd.edu.au/research/re_portstephens.shtml accessed 18/10/2010, Last Updated 07/07/2010

Van Rijn, L.C. (1993) Principles of Sediment Transport in Rivers, Estuaries and Coastal Seas, Aqua Publications

van Rijn, L.C. (2007a) Unified View of Sediment Transport by Currents and Waves I: Initiation of motion, bed roughness and bed load transport. Journal of Hydraulic Engineering – ASCE v133 pp. 649-667 June

van Rijn, L.C. (2007b) Unified View of Sediment Transport by Currents and Waves II: Suspended transport Journal of Hydraulic Engineering – ASCE v133 pp. 668-689 June

van Rijn, L.C. (2007c) Unified View of Sediment Transport by Currents and Waves III: Graded beds. Journal of Hydraulic Engineering – ASCE v133 pp761-775 July

van Rijn, L.C. (2007d) Unified View of Sediment Transport by Currents and Waves IV: Application of Morphodynamic Model. Journal of Hydraulic Engineering – ASCE v133 pp 776-793, July

Vila-Concejo, A., Short, A.D., Hughes, M.G. and R. Ranasinghe, (2007) Flood-tide Delta Morphodynamics and Management Implications, Port Stephens, Australia, *Journal of Coastal Research*, SI 50 (Proceedings of the 9th International Coastal Symposium), Gold Coast, p705-709.

Vila-Concejo, A., Hughes, M.G., Short, A.D. and R. Ranasinghe (2008) Estuarine shoreline processes: a dynamic low energy system, Proceedings of the 14th Biennial Physics of Estuaries and Coastal Seas Conference, Aug 25-59 2008, Liverpool, UK.

Vila-Concejo, A., Short, A.D., Hughes, M.G. and R. Ranasinghe, (2009) Formation and Evolution of a Sandwave on an Estuarine Beach, *Journal of Coastal Research*, SI 56 (Proceedings of the 10th International Coastal Symposium), Lisbon, p 153-157.

Watson, P. (2008) Port Stephens: Sand Transport and Shoreline Evolution, presentation to the Great Lakes Stakeholder Forum, Great Lakes Council, DECC.

Watson, P. (2000) Jimmys Beach, Port Stephens, NSW: An Expensive Learning Experience in Coastal Management, in *Coastal Engineering 2000, Volume Four,* Edited by Bill L. Edge, ASCE

You, Z. and D. Lord, (2008) Influence of the El-Nino-Southern Oscillation on NSW Coastal Storm Severity, *Journal of Coastal Research*, 24, 2B, 203-207.

APPENDIX A: HISTORICAL HYDROGRAPHIC SURVEYS
SOURCE: WATSON, 2008

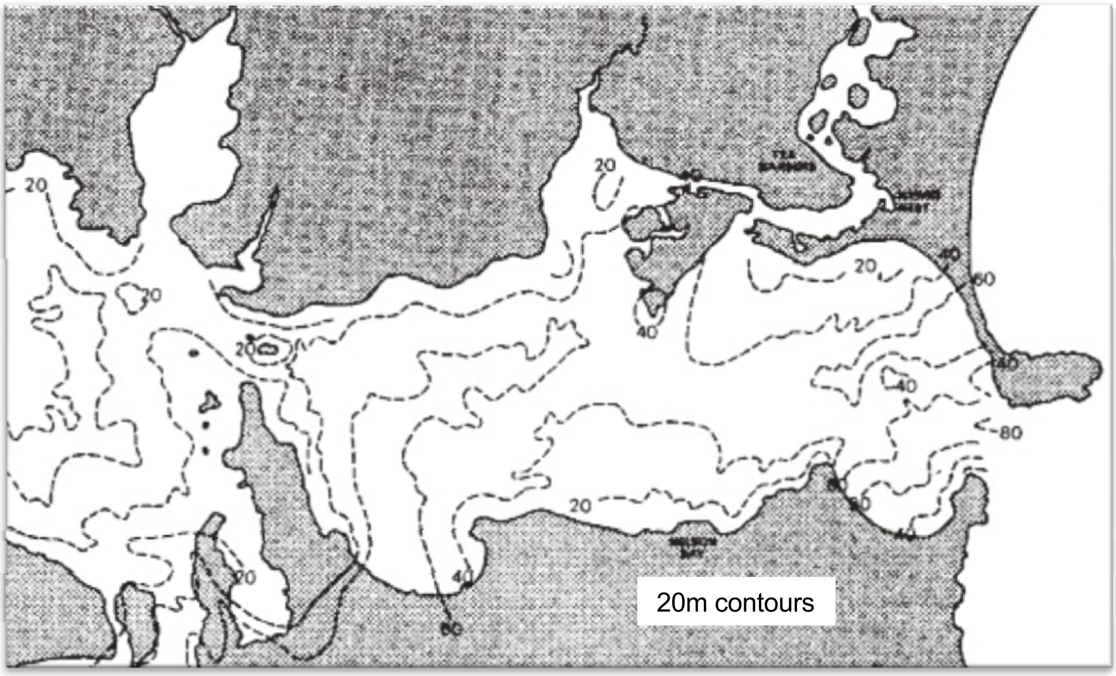
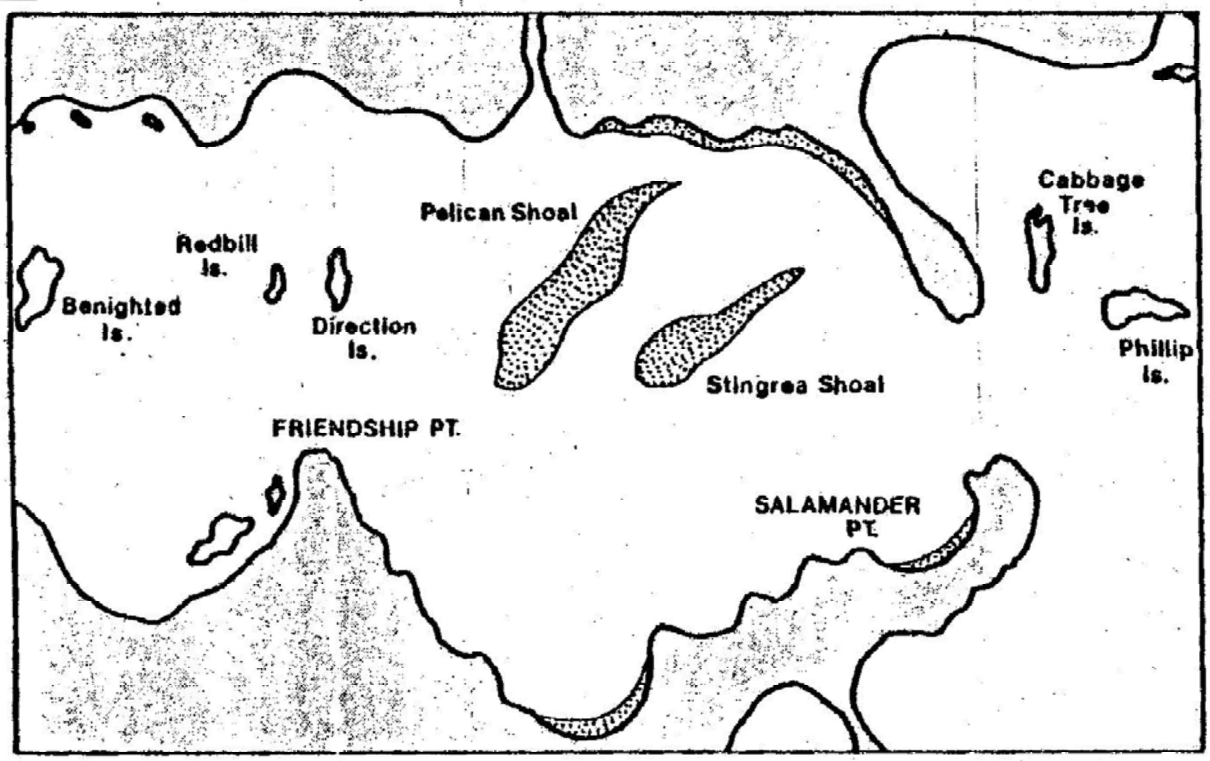
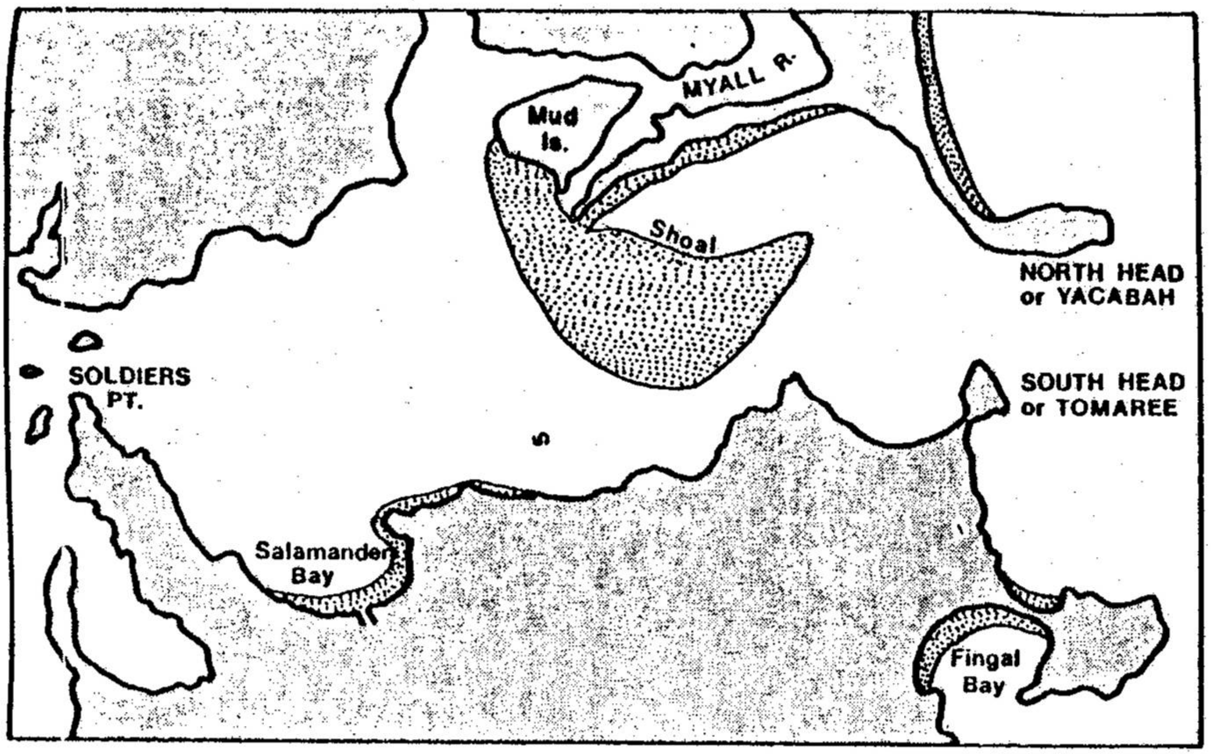


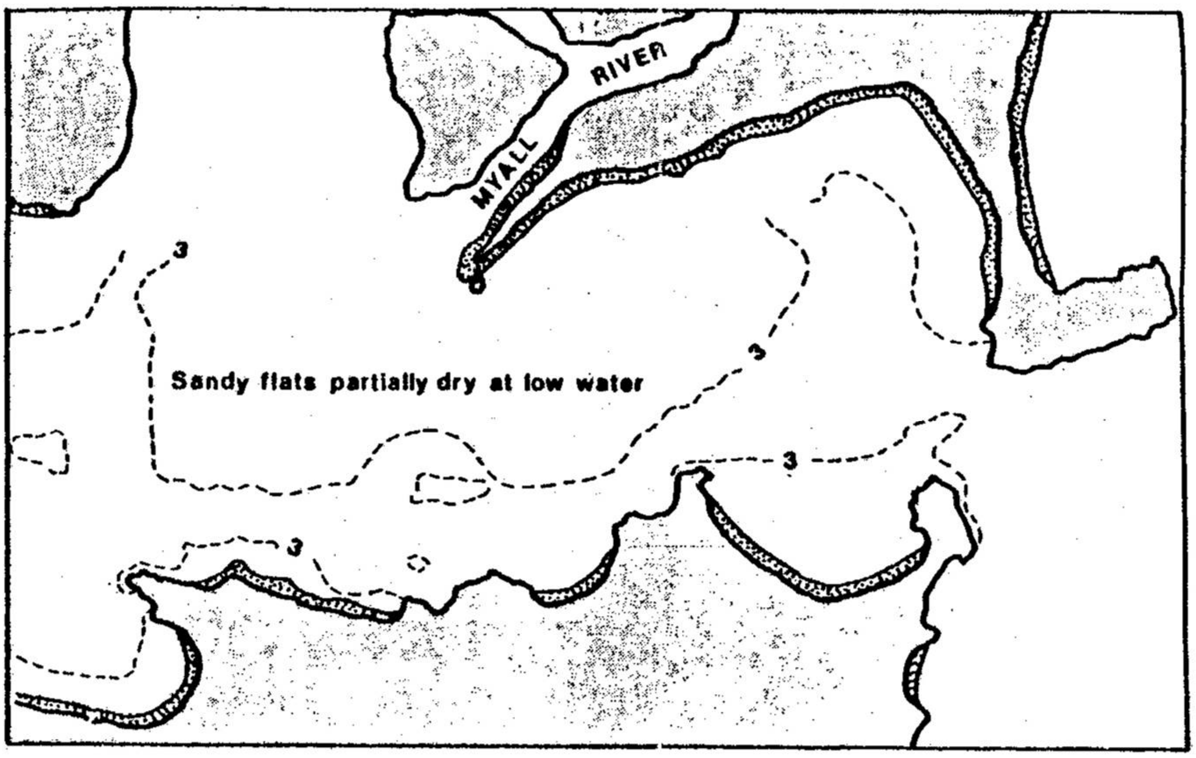
Figure A-1 Bedrock Topography of Port Stephens Source: Thom et al 1992



1792 - WATLING

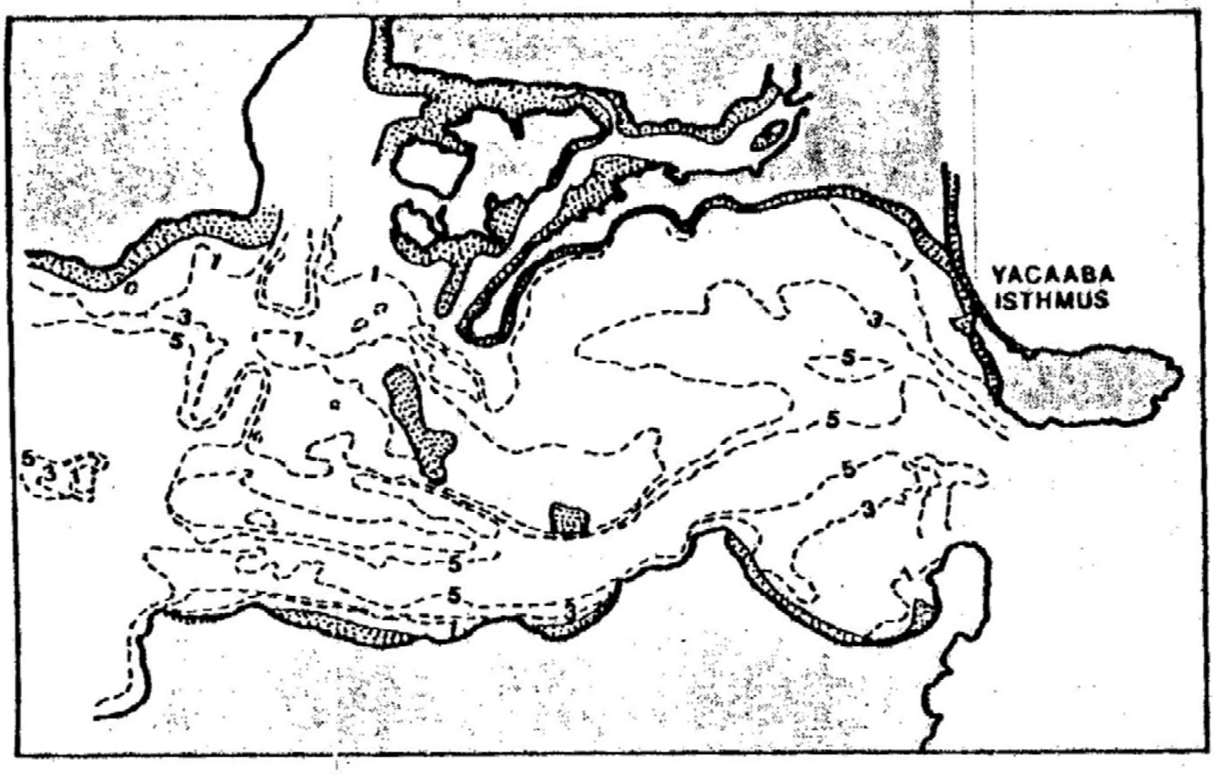


1828 – WILLIAM JOHNS

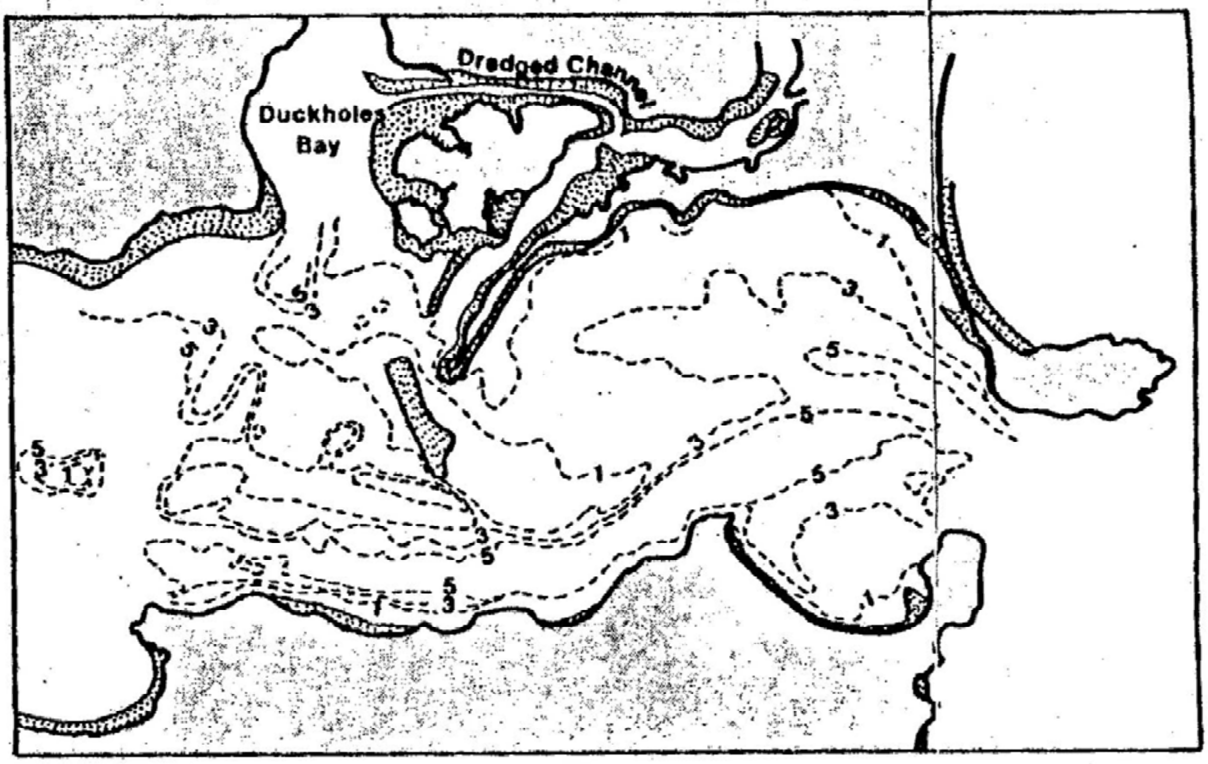


1838 – JOHNSON

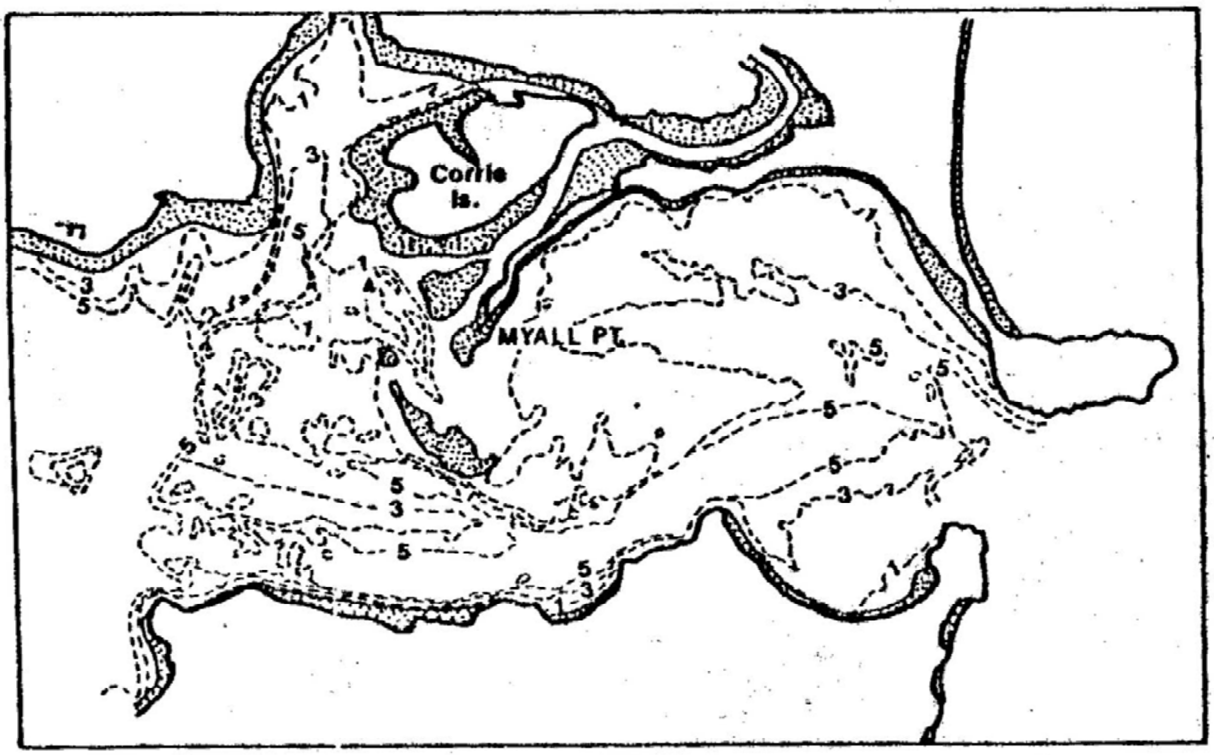
(DEPTH IN FATHOMS)



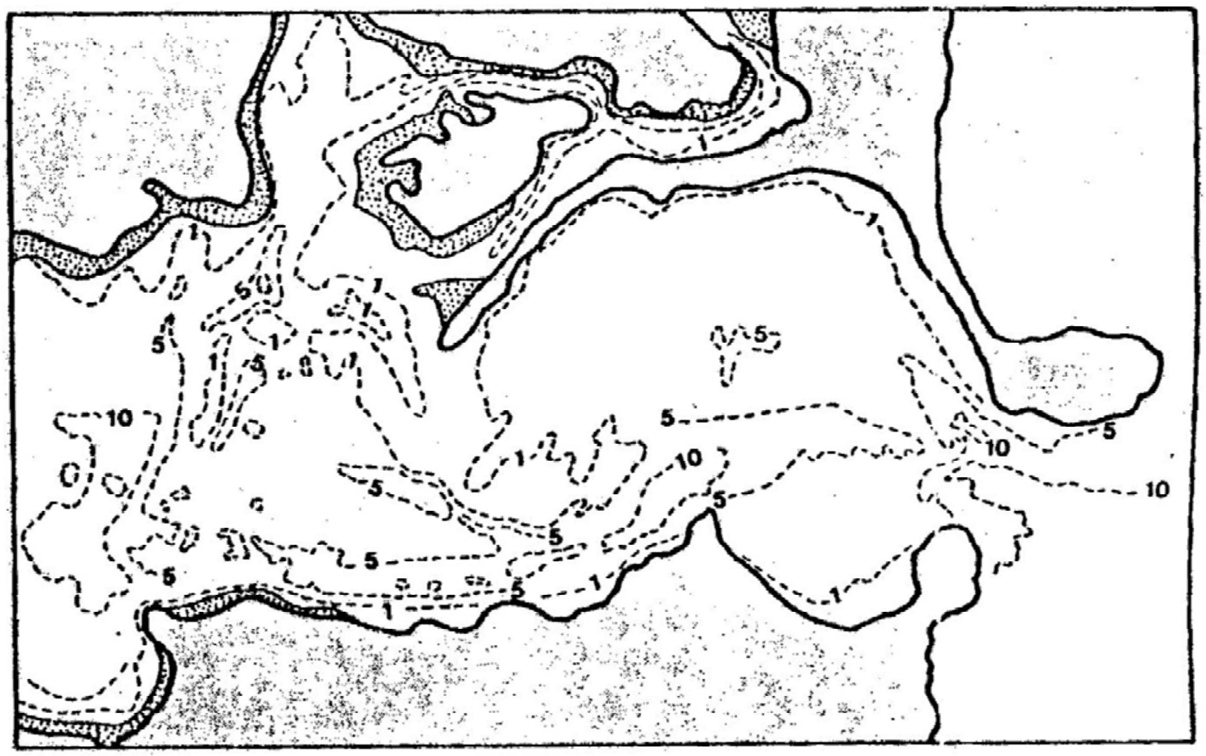
1866 – F.W. SIDNEY R.N.
(DEPTH IN FATHOMS)



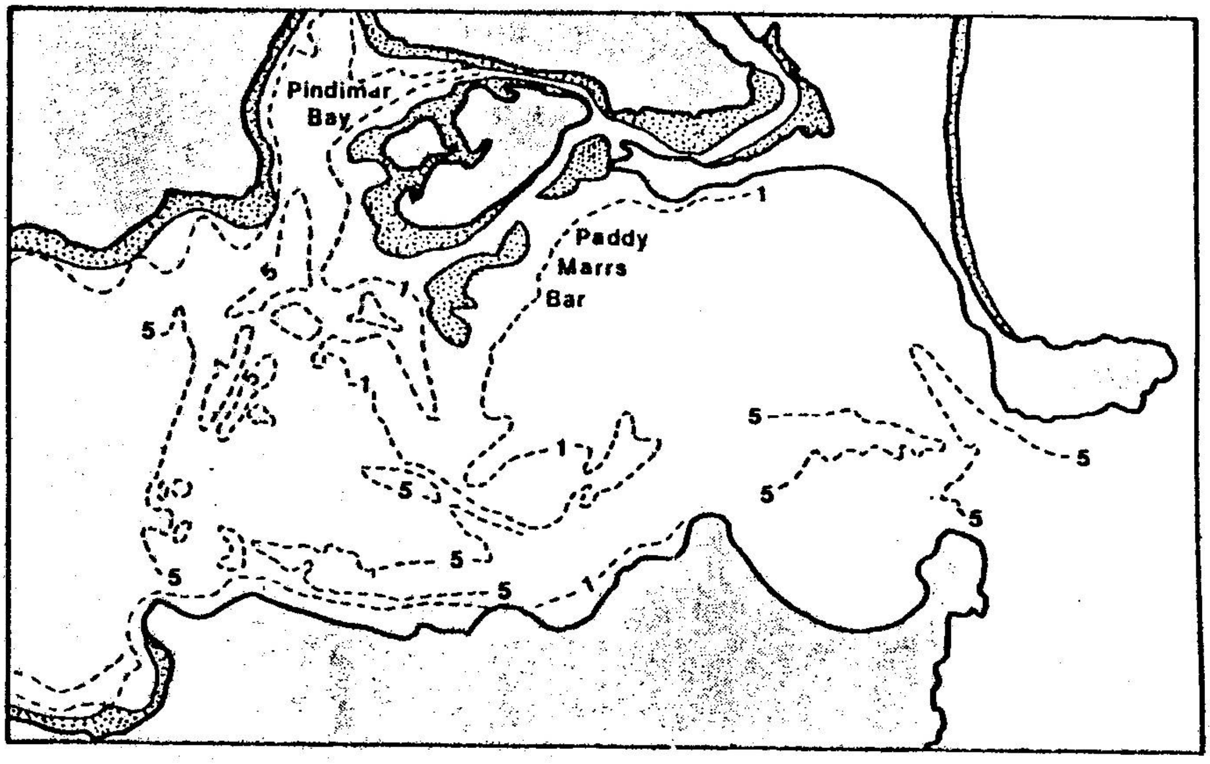
1909 – F.W. SIDNEY
(CORRECTIONS BY G.H. HALLIGAN)



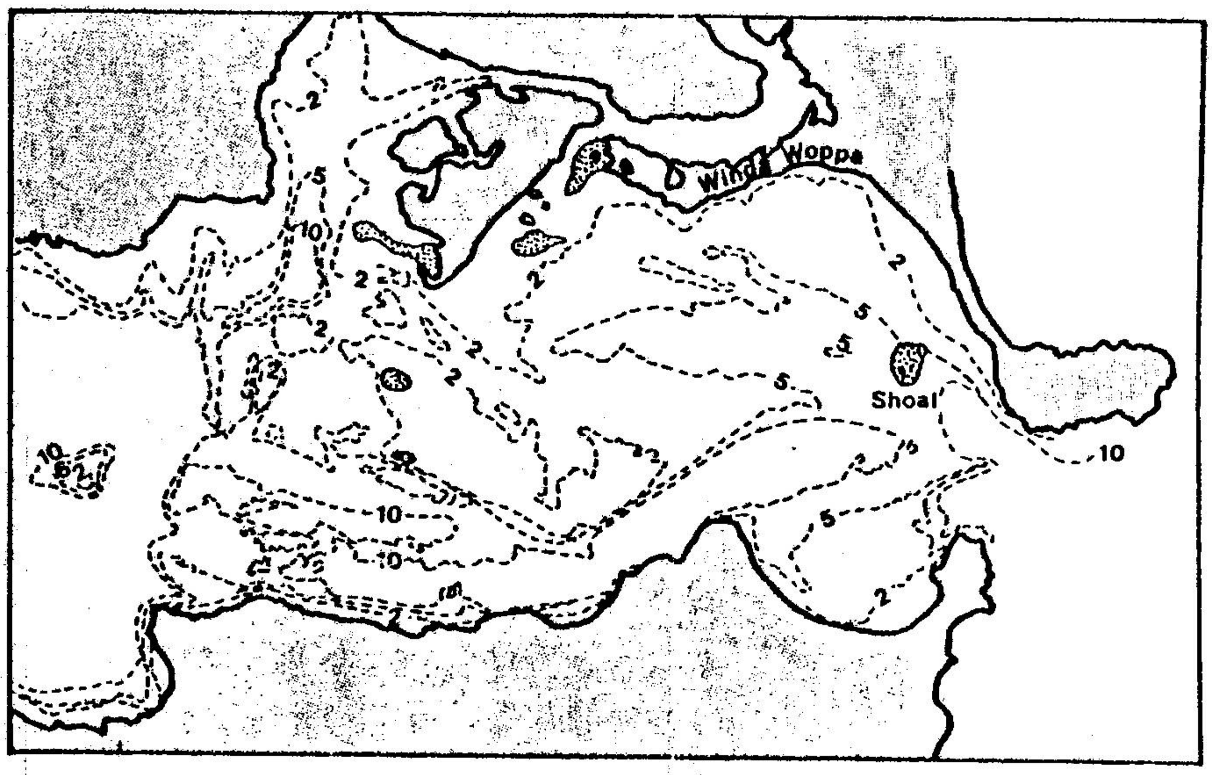
1920 – C.M.L. SCOTT
(DEPTH IN FATHOMS)



1922 – SOURCE OF BATHYMETRY UNKNOWN
(DEPTH IN FATHOMS)



1941 – SOURCE OF BATHYMETRY UNKNOWN
(DEPTH IN FATHOMS)



1969 – P.W.D. SURVEY
(DEPTH IN METRES)

APPENDIX B: WIND AND WAVE DATA

Table B-1 Percentage Occurrence Wave Height, Sydney March 1992 to June 2009

H_s (m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
0 – 0.49	100	100	100	100	100	100	100	100	100	100	100	100	**100**
0.5 – 0.99	99.96	99.99	100	99.9	99.61	99.54	99.71	99.43	99.95	99.84	99.89	99.91	**99.803**
1 – 1.49	89.44	88.99	91.98	87.62	79.15	77.68	79.34	77.75	79.85	85.05	87.56	84.13	**83.784**
1.5 – 1.99	47.28	49.75	52.45	49.23	50.31	49.05	46.83	43.07	41.47	45.35	46.61	44.63	**47.12**
2 – 2.49	18.65	21.05	24.41	25.67	27.42	27.75	26.28	21.73	19.74	18.82	21.45	18.89	**22.777**
2.5 – 2.99	6.43	8.3	10.78	11.82	12.65	15.69	14.53	10.29	9.1	8.15	10.54	7.36	**10.595**
3 – 3.49	2.72	2.94	5.19	6.02	6.48	9.42	7.61	5.47	4.49	4.05	5.69	2.99	**5.349**
3.5 – 3.99	1.03	1.22	2.71	3.14	2.67	5.72	3.96	2.63	1.88	2.15	3.22	1.18	**2.676**
4 – 4.49	0.3	0.51	1.04	1.52	1.16	3.45	2.32	1.56	0.86	1.16	1.59	0.44	**1.361**
4.5 – 4.99	0.07	0.22	0.53	0.67	0.7	1.97	1.38	0.81	0.47	0.43	0.89	0.16	**0.714**
5 – 5.49	0	0.05	0.33	0.25	0.59	1.13	0.62	0.37	0.08	0.12	0.42	0.04	**0.345**
5.5 – 5.99	0	0.01	0.2	0.08	0.37	0.68	0.3	0.13	0.03	0.06	0.18	0	**0.177**
6 – 6.49	0	0	0.08	0.03	0.19	0.27	0.18	0.02	0	0	0.03	0	**0.071**
6.5 – 6.99	0	0	0.01	0	0.15	0.03	0.07	0	0	0	0	0	**0.023**
7 – 7.49	0	0	0	0	0.11	0	0	0	0	0	0	0	**0.01**
7.5 – 7.99	0	0	0	0	0.05	0	0	0	0	0	0	0	**0.004**
8 – 8.49	0	0	0	0	0.04	0	0	0	0	0	0	0	**0.003**
8.5 – 8.99	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Average (m) :	1.57	1.62	1.79	1.63	1.67	1.73	1.66	1.55	1.54	1.58	1.61	1.54	1.63
Maximum (m) :	4.92	5.53	6.61	6.18	8.43	6.87	6.96	6.09	5.78	5.81	6.22	5.49	8.43
Minimum (m):	0.48	0.5	0.59	0.38	0.4	0.39	0.39	0.4	0.45	0.43	0.38	0.46	0.38

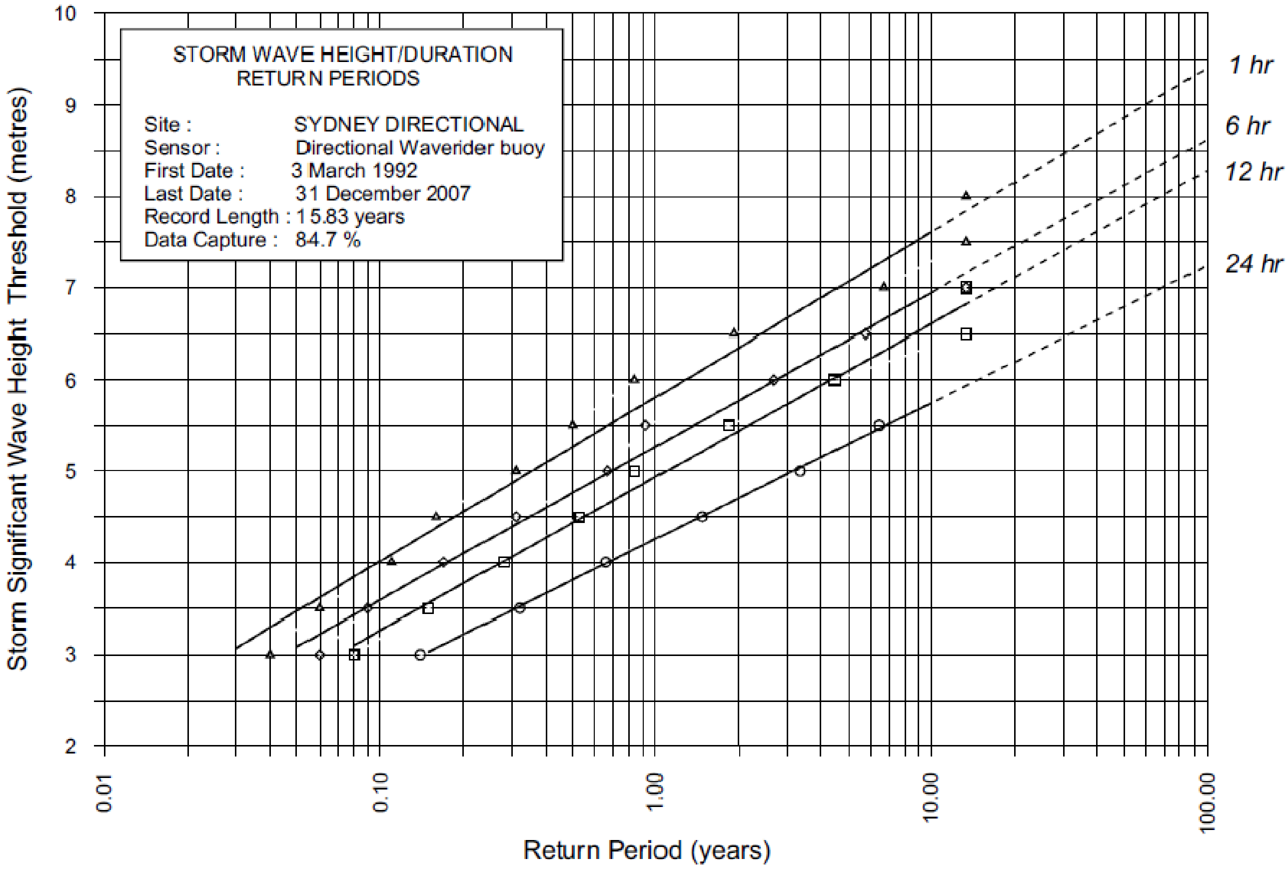


Figure B-1 Wave Height / Duration Curves for Sydney (MHL, 2009)

Table B-2 Percentage Occurrence Wave Direction, Sydney, March 1992 – June 2009

DIR	DEGREES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
N	*348.75 - 11.24*	0	0	0	0	0	0	0	0	0	0	0	0	**0**
NNE	**11.25 - 33.74**	0.16	0.01	0.06	0.1	0.06	0.05	0.04	0.11	0.09	0.26	0.04	0.09	**0.091**
NE	**33.75 - 56.24**	4.4	2.87	2.66	2.06	1.37	1.07	0.87	1.63	4.94	5.83	4.4	5.15	**3.057**
ENE	**56.25 - 78.74**	16.62	14.07	9.77	6.51	6.33	3.54	3.5	4.7	9.85	11.19	13.77	11.72	**9.033**
E	**78.75 - 101.24**	18.83	17.68	16.74	11.56	9.67	8.6	9.48	5.64	7.66	9.3	9.85	10.56	**11.086**
ESE	**101.25 - 123.74**	11.05	13.32	12.73	13.68	10.25	9.98	12.51	7.46	6.77	7.63	8.66	9.11	**10.227**
SE	**123.75 - 146.24**	11.98	12.16	17.1	18.86	18.22	17.03	19.38	20.21	17.32	13.08	14.18	14.36	**16.312**
SSE	**146.25 - 168.74**	18.82	20.18	24.59	30.03	34.13	40.23	35.74	39.73	32.94	29.35	24.22	24.93	**29.998**
S	**168.75 - 191.24**	16.9	19.07	15.26	16.41	18.91	18.7	16.59	19.09	18.81	21.67	23.02	22.59	**18.884**
SSW	**191.25 - 213.74**	1.22	0.65	1.06	0.64	0.52	0.41	0.76	0.84	0.85	1.41	1.82	1.39	**0.954**
SW	**213.75 - 236.24**	0	0	0.03	0.1	0.11	0.05	0.22	0.03	0.15	0.07	0	0.02	**0.067**
WSW	*236.25 - 258.74*	0	0	0	0	0.03	0.03	0.1	0.05	0.16	0.05	0.03	0.01	**0.04**
W	*258.75 - 281.24*	0.01	0	0	0.04	0.05	0.12	0.27	0.12	0.15	0.05	0.01	0.02	**0.073**
WNW	*281.25 - 303.74*	0	0	0	0	0.1	0.07	0.28	0.1	0.17	0.1	0.01	0.03	**0.077**
NW	*303.75 - 326.24*	0	0	0	0	0.16	0.08	0.15	0.19	0.08	0.02	0	0.02	**0.062**
NNW	326.25 - 348.74	0	0	0	0	0.06	0.03	0.08	0.08	0.01	0	0	0.01	0.024
	Average :	120.37	123.6	128.12	135.53	138.79	144.56	142.69	144.96	136.64	134.06	132.3	133.07	134.87
	Maximum :	277	208	221	281	351	357	358	355	356	325	297	330	358
	Minimum :	21	33	21	3	20	10	23	15	0	20	33	7	0

Table B-3 Percentage Occurrence Wave Period, Sydney March 1992 to June 2009

T_P (s)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
0.00 - 1.99	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00 - 3.99	0.08	0.05	0.06	0.17	0.46	0.51	0.72	0.66	0.59	0.35	0.14	0.27	0.353
4.00 - 5.99	8.56	7.44	4.03	5.38	3.13	2.34	3.2	4.21	6.05	9.1	9.59	9.88	5.962
6.00 - 7.99	27.13	23.32	13.87	10.85	8.37	8.43	6.37	10.75	15.04	20.56	25.38	25.23	15.848
8.00 - 9.99	31.15	28.89	30.23	26.01	26.74	21.43	22.33	22.32	27.76	26.59	29.9	26.91	26.513
10.00 - 11.99	26.1	25.68	32.01	34.01	38.84	37.5	41.89	37.33	33.76	29.16	27.3	26.91	32.884
12.00 - 13.99	6.13	12.71	16.82	19.13	17.68	23.36	20.06	18.92	12.53	10.28	7.08	9.48	14.759
14.00 - 15.99	0.71	1.72	2.72	3.64	3.96	5.31	4.84	4.7	3.5	2.76	0.61	1.24	3.067
16.00 - 17.99	0.14	0.19	0.24	0.7	0.74	1.09	0.54	1.08	0.68	1.01	0.01	0.06	0.56
18.00 - 19.99	0	0	0.02	0.09	0.07	0.04	0.05	0.03	0.11	0.14	0	0.02	0.049
20.00 - 21.99	0	0	0	0.02	0	0	0	0	0	0.05	0	0	0.006
Average (s) :	8.81	9.29	10.03	10.28	10.32	10.81	10.56	10.33	9.77	9.38	8.88	9.04	9.78
Maximum (s) :	17.1	17.1	19.7	20	19.7	19.7	18.18	18.18	19.7	20	17.1	19.7	20
Minimum (s):	3.33	3.8	3	2.8	2.77	2.8	2.85	2.77	3	2.6	3.4	2.6	2.6

Table B-4 Maximum Yearly Wind Speeds for Wind Direction Octants (Williamtown)

Year	NN	NE	EE	SE	SS	SW	WW	NW
1989	31	39	48	46	48	55	50	55
1990	26	44	48	52	59	46	63	65
1991	30	44	46	42	50	48	67	65
1992	33	42	44	50	54	52	65	61
1993	41	37	39	46	50	48	63	63
1994	37	46	44	57	57	41	70	65
1995	37	39	41	48	55	54	57	55
1996	35	44	37	55	55	37	55	59
1997	28	39	48	39	55	44	55	46
1998	22	35	33	44	48	52	63	74
1999	18	33	35	42	46	59	59	57
2000	26	37	39	44	46	41	59	50
2001	30	39	41	48	57	41	50	61
2002	24	37	42	39	44	41	50	59
2003	35	39	39	41	50	46	57	72
2004	35	35	37	44	46	48	57	63
2005	28	33	39	46	54	52	65	54
2006	28	35	52	52	50	52	52	44
2007	28	33	39	67	42	37	57	55
2008	28	31	37	44	48	52	59	57
2009	33	33	41	46	50	39	63	65
MAX	**41**	**46**	**52**	**67**	**59**	**59**	**70**	**74**

APPENDIX C: SCENARIO SELECTION FOR MORPHOLOGICAL MODELLING

To assess the impacts of dredging options on the morphology of the Eastern Channel and Myall Spit data were required that would generate a reasonable sediment transport. Historical aerial photographs were examined to identify periods when the Eastern Channel experienced significant infilling Myall Spit grew notably.

- The Spit extended significantly between 2001 and 2009;
- A review of SPOT imagery for years 2005 and 2007 showed that a navigable channel was still present in February 2005 although the western extent of the spit was beginning to encroach on the eastern side of the channel;
- Aerial photos (DECCW) from April 2006 show that the east side (i.e. east of the pile of rock 'ballast' in the centre of the channel) of the channel was blocked by westward migration of the spit at that time.

Based on the timing of these features we examined wave data between February 2005 and April 2006.

The data revealed that notable swell wave events occurred between March-April 2005 and June-July 2005. The south east facing alignment of shorelines within the study region is most vulnerable to swell waves originating from the south-east (SE). The March-April event had the more significant south-easterly waves and that event was subsequently chosen for analyses. This event was not responsible for all of the spit extension and channel infilling present between February, 2005 and April, 2006, but would have contributed a significant proportion. The time series of ocean wave heights and identification of those originating from the south east in shown on Figure D-1.

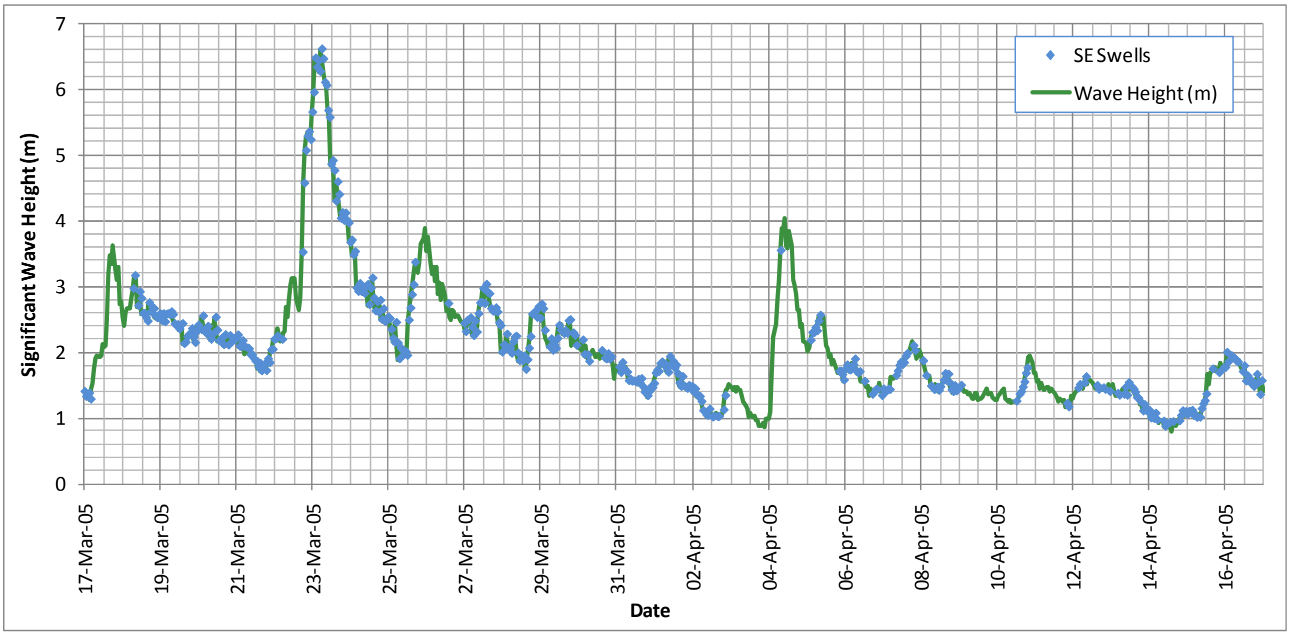


Figure C-1 Wave Climate for Sydney from 17th March to 17th April 2005

APPENDIX D: LONGSHORE SEDIMENT TRANSPORT CALCULATIONS

D.1 Types of Waves

Longshore sediment transport rates were calculated separately for the following two different types of waves impacting on Winda Woppa:

- Local wind waves caused by winds blowing over the surface of Port Stephens; and
- Ocean Swell waves propagating in through the entrance of Port Stephens.

D.2 Transects used for Calculation

Longshore Transport rates were calculated at three transects established along Winda Woppa spit, as shown on Figure D.2. For longshore transport calculations, it is necessary to examine the characteristics of breaking waves. SWAN was used to determine breaking wave directions and heights along these transects for numerous local wind wave and ocean swell wave conditions.

D.3 Wind Speed Statistics and Local Wind Wave Simulations

Wind statistics were derived from the 20 year wind record collected at Williamtown, and data organised into 45 degree bins. The proportion of time wind occurred from each direction is charted on Figure D.1.

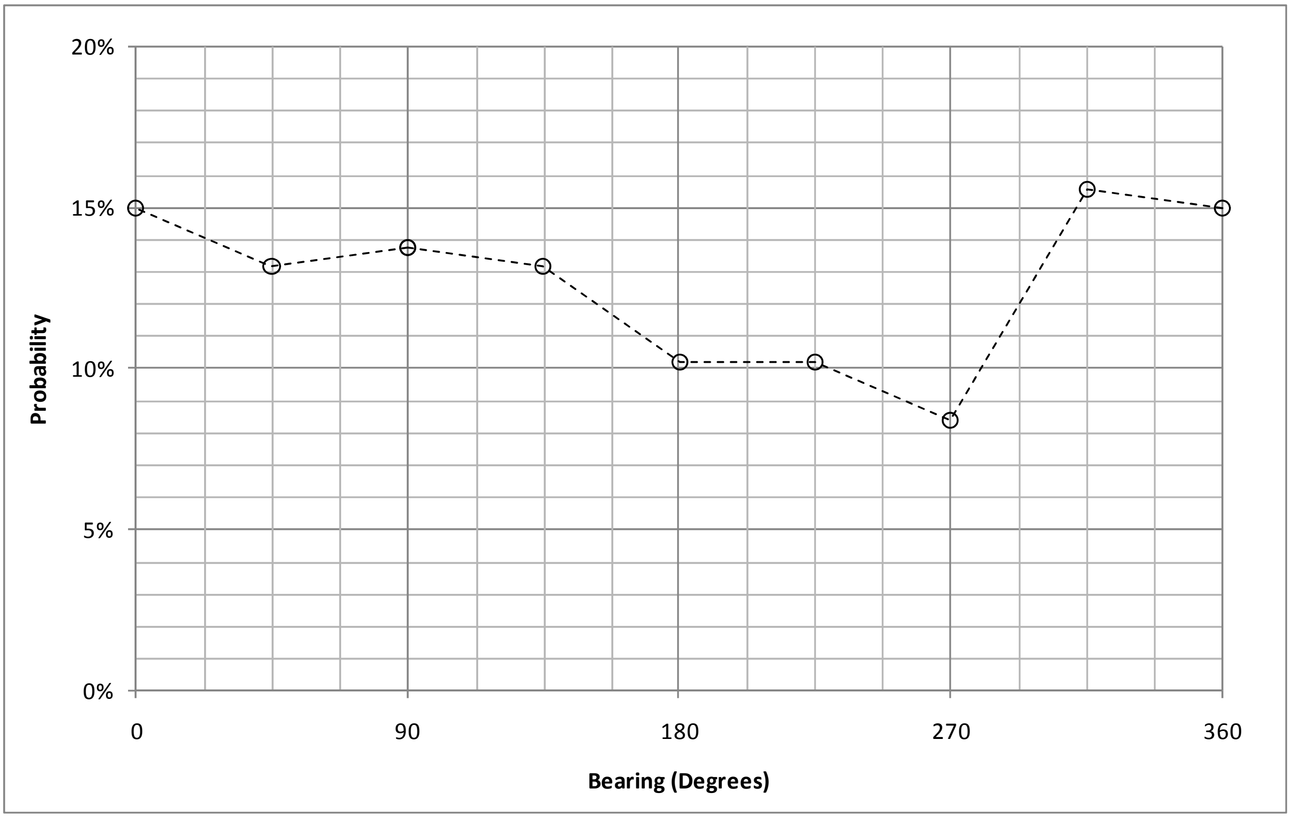
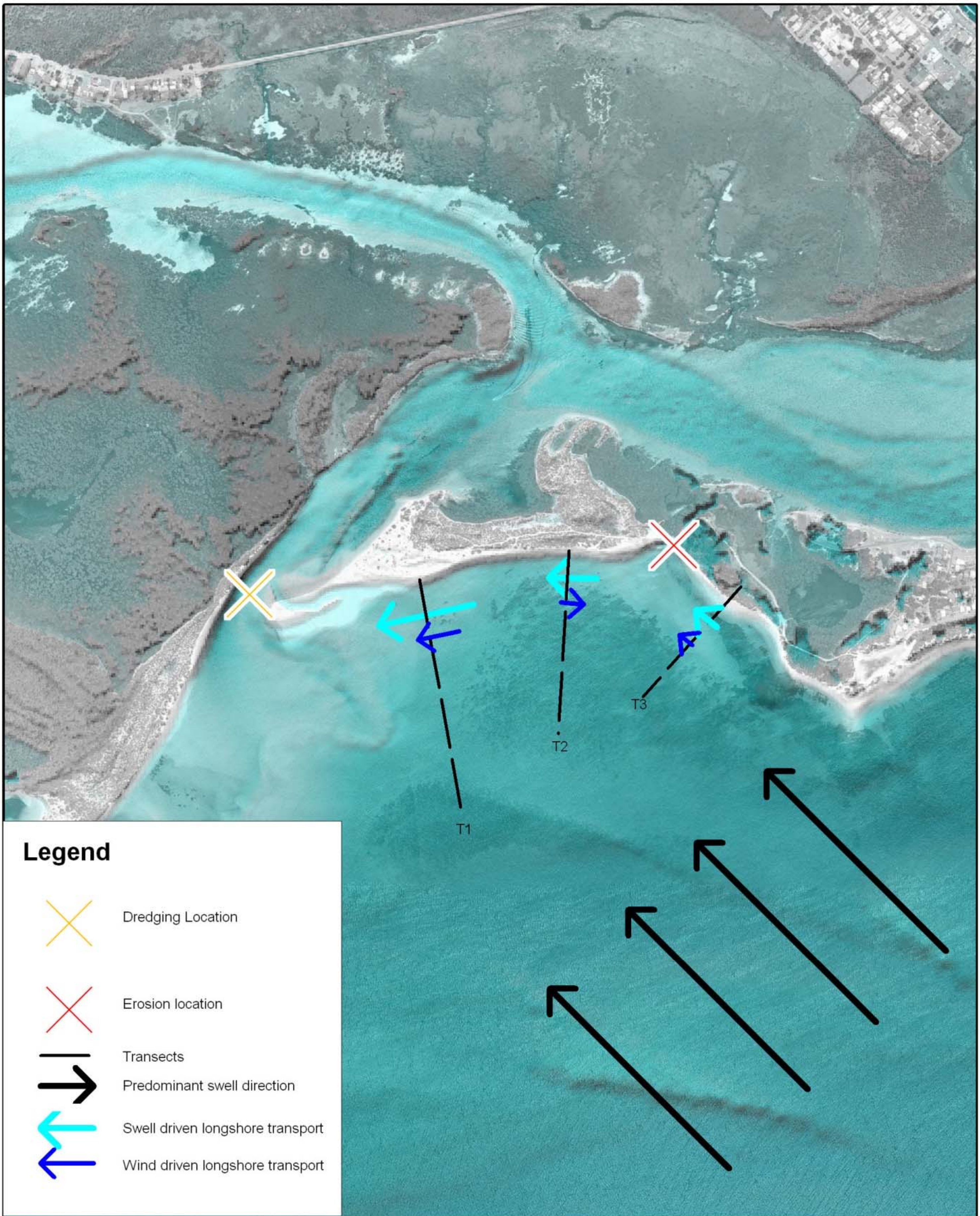


Figure D-1 Prevalence of Winds from each direction



Title:
Dredging option through deposition near Winda Woppa

Figure: D-2

Rev: A

N

0 250 500m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\docs\Figures\Figure_D-2.WOR

The data in each directional bin were subsequently subdivided into bins based on ranges in wind speed of 2 km☺h^{-1}. Wind data from each directional bin was ranked in order of probability based on the statistical analysis previously undertaken. All bins with a probability greater than 0.3 percent were considered as separate scenarios. All other cases were considered to be statistically insignificant.

A SWAN wave model simulation was executed for each case, using a direction and wind speed from the representative bins. The height and direction of the resultant breaking waves was determined and used in the longshore transport calculation.

The resulting longshore transport rates are assumed to occur for the same proportion of time as the corresponding wind condition when deriving annualised (average) longshore transport rates.

D.4 Ocean Swell Statistics and Swell Propagation Simulations

Ocean swell statistics were derived by analysing the WaveRider data from Sydney over a period of 15 years. Data were organised into 22.5 degree bins. Swell occurred between bearings of 45 and 225 degrees (NW to SE) due to the orientation of the coastline. The proportion of time swell occurs from each direction is charted on Figure D.3.

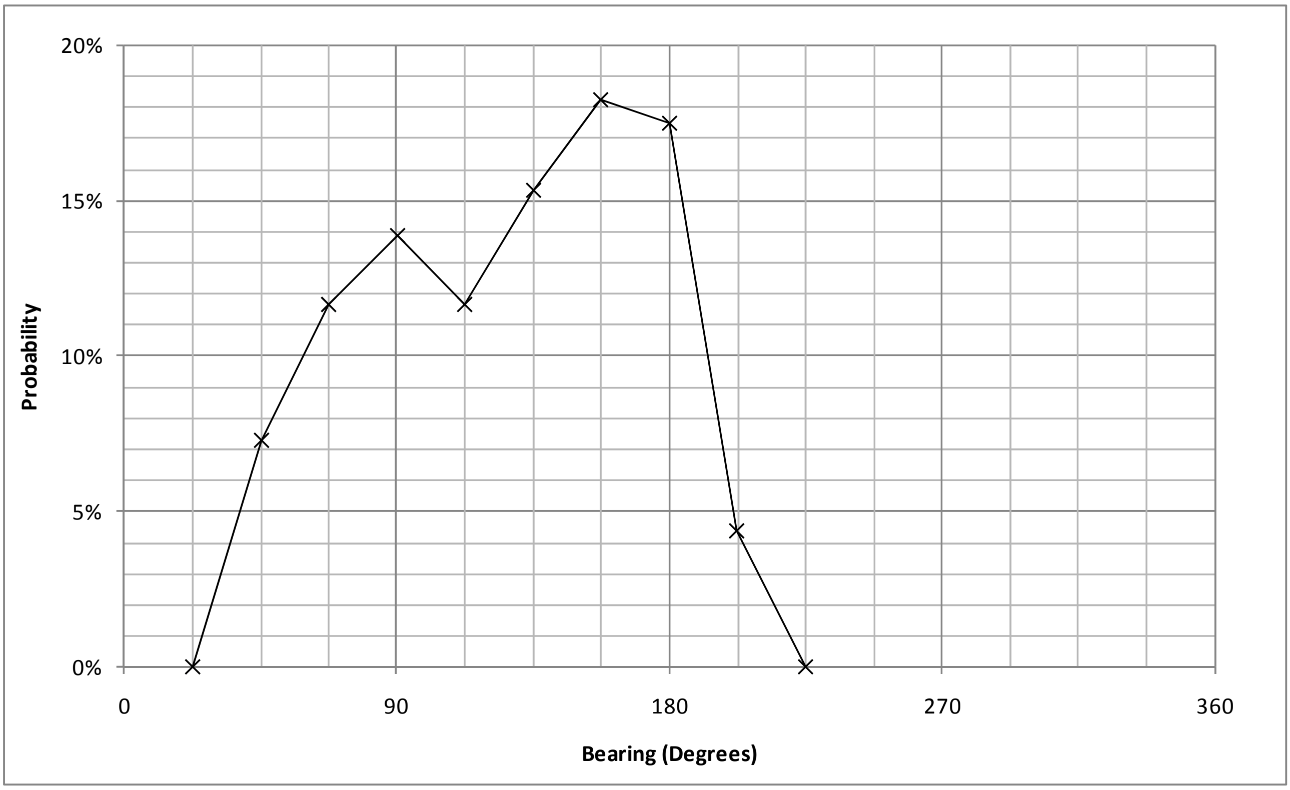


Figure D-3 Prevalence of Ocean Swell from each direction

The data in each directional bin was further subdivided into bins based on the wave period which ranged between 4.5 and 17 seconds. Each of the direction/wind speed bins was assigned a probability based on the proportion of time winds fell within that bin in the wave record. Bins with a probability of less than 0.01 percent were considered to be statistically insignificant.

Probability distributions of swell wave heights for each of these bins were obtained though statistical analysis. Wave height cases were defined for each bin representing an exceedance probability of 20, 40, 60 and 80 percent.

A SWAN wave model simulation was subsequently executed for each case, using a direction, period and wave height representative of that case. The height and direction of the resultant breaking wave was determined and used in the longshore transport calculation.

The resulting longshore transport rates are assumed to occur for the same proportion of time as the corresponding wind condition when deriving annualised (average) longshore transport rates.

D.5 Longshore Transport Calculations

Sediment transport in water can be represented in terms of scouring and advection dispersion processes. In the surf zone both current and wave action significantly alter the scouring and transport processes. The calculation of Longshore Transport Rates is relatively inaccurate. Therefore, three different methods for calculating the longshore transport were used for comparison and consideration in deriving a representative number.

The CERC, Kamphuis and Van Rijn LT Formulas have been used to calculate approximations of longshore sediment transport based on the statistically weighted wind wave and swell conditions described in preceding sections. Longshore sediment transport is greatest when waves approach the shore at an angle of 45 degrees.

While small in magnitude, tidal current velocities are also important, particularly as the tidal hydrodynamics tend to drive currents from east to west for the majority of the tidal cycle. During the flood tide, the TUFLOW-FV model indicates that sand is dragged towards the eastern channel under the effect of the prevailing current. However, during the ebb current, TUFLOW-FV indicates a counter clockwise eddy forms between the main ebb jet of the tide and the shoreline along Winda Woppa. This causes currents adjacent to the shoreline to be from east to west during most of the ebb tide as well.

The CERC Formula is commonly applicable to high energy storm conditions, in which it over predicts by an order of magnitude of approximately two. However, the degree of over prediction is significantly higher for standard wave conditions (as applied for this assessment). The CERC Formula has been used in this instance as a benchmark, as it has a longer track record of application for longshore sediment transport calculation.

The Kamphuis equation has generally been considered an underestimate of longshore sediment transport; however for low wave breaking wave heights it can also over estimate rates. The Kamphuis method always calculated lower transport rates than with Van Rijn's equation in this assessment.

The van Rijn LT formulation has an advantage over the other formulations in that the tidal current (as opposed to the current generated by waves) is an input to the calculation.

D.6 Longshore Transport Due to Swell - Results

The resulting breakdown of swell related annualised sediment transport rates at Transect 1 plotted against offshore swell direction is presented on Figure D.4. Transect 1 has been presented, as results at this transect best represent the measured deposition in the eastern channel over the past 10 years.

Transport is maximised for swell bearings between 90 and 135 degrees (i.e. swell arriving from the east through to south). At this approach angle, swell waves have a more direct line of attack to the foreshore at Winda Woppa.

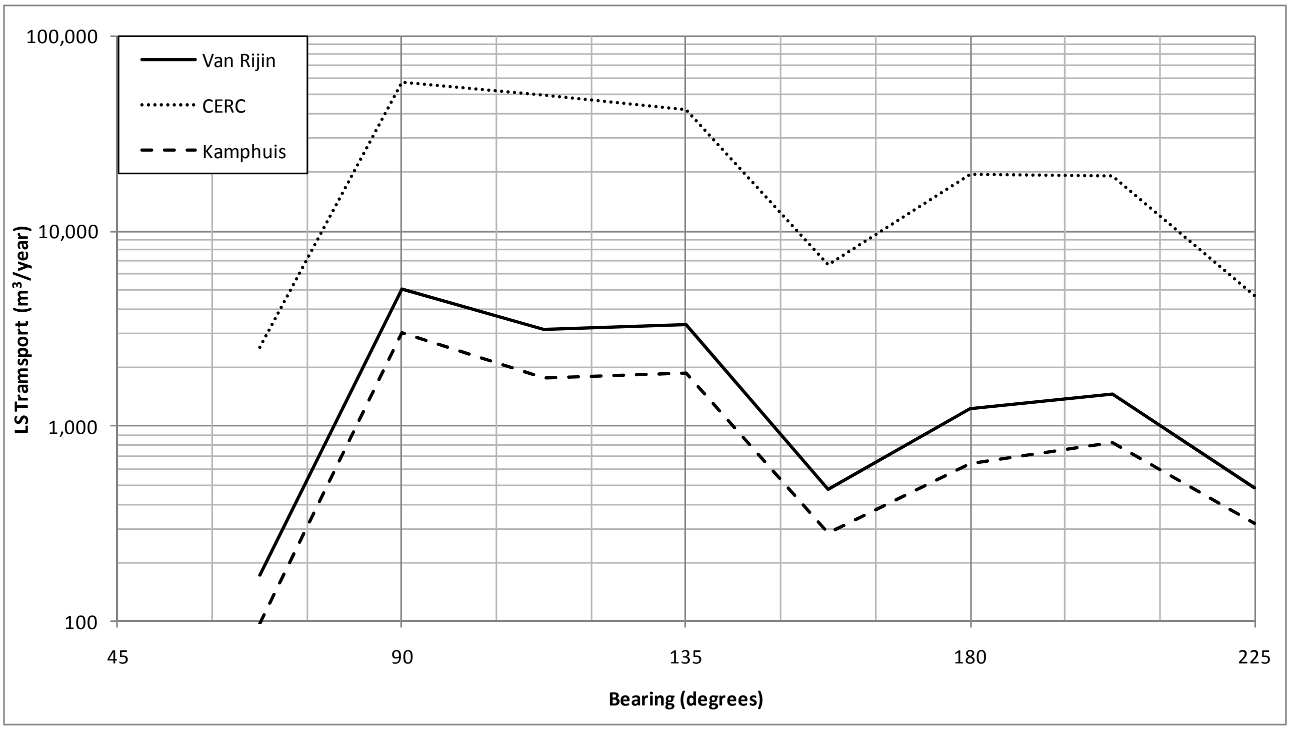


Figure D-4 Relative Rates of Longshore Sediment Transport Volumes Expected for Specific Offshore Swell Directions

D.7 Longshore Transport Due to Wind - Results

Longshore transport rates are the greatest for winds approaching from between 90 and 180 degrees (E to S winds). This is because the direction of the wind generated waves are oblique to the shoreline in at Winda Woppa For wind bearings greater than 180 degrees transport is either negative (indicating transport away from the river mouth) or very low as it tends to push sand towards the east.. However, the overall annualised magnitude of transport due to wind waves remains positive. Overall, wind wave induced longshore transport at this location is around an order of magnitude less than that caused by ocean swell.

D.8 Net Transport and Comparison to Hydrosurvey Data

The total transport rate was considered to result from both wind and swell generated waves. A summary of net long shore transport rates, from both Swell and wind waves are presented in Table D-1. These values are an average of the Kamphuis and Van Rijn computations. Figure D-2 schematically illustrates the LS sediment transport occurring at each transect.

Table D-1 Contributors to Net Annualised Longshore Transport Rate

Transect	Annualised Swell Related Transport	Annualised Wind Wave Related Transport	Annualised 'Total' Transport
1	12 100	250	12 350
2	2 000	40	2 040
3	1 300	90	1 390
+ve Transport rates indicate transport from east to west (i.e. towards the eastern channel)			

Tables D-2 to D-19, at the end of this Appendix show this data further broken down for each computation method. These Tables help illustrate the variation in transport that occurs along this shore, due to the variable orientation to incoming waves.

By comparing the differences in volume between the 2009 and 2001 hydrosurveys, it is clear that around 100 000 m^3 of sand has deposited at the end of Winda Woppa Spit. This is consistent with an annualised total transport of around 12 000 m^3/yr, consistent with the eastern most transect (Transect 1). The fit between the measured and modelled results is remarkable, given the uncertainties associated with longshore transport calculations. In interpreting this information, it should be noted that there are errors inherent in both the longshore transport calculations, and the comparison of hydrosurvey data. Transport in the area is complex and the ultimate fate of sand transported along Winda Woppa may be dictated by tides, wind and other factors.

D.9 Where did the sand come from?

From examination of aerial photography, it is clear that the shoreline to the west of Barnes Rock has receded significantly over the past decade.

Again, using the digital elevation models available, the volume represented by that recession has been estimated. This is somewhat difficult, as we do not have ground survey data for the dunes in this area from 2001.

Based on Lidar data, we note that the dunes in this area have crest levels of around 3.0 m. Comparing the bathymetries of 2001 and 2009, we note that the relatively inactive bed level (i.e. minimal change between 2001 and 2009) is at around -1.0 m AHD.

Considering a number of transects across the area of recession, we have determined that the linear amount of recession (based on location of the front edge of any visible foredune vegetation from aerial photographs) as measured in GIS averages around 70 m. This occurs over around 300 m of foreshore.

The length of foreshore subject to recession is around 300 m. Assuming similar dune and beach profiles existed in 2001, our estimate is based on a 4.0 m high dune receding by 70 m. This results in a volume of sand loss of around 84,000 m^3.

The calculated eroded volume is similar to that calculated as depositing at the end of Winda Woppa from the comparison of hydrosurveys. However, the available data is limited, and is possible that the estimates could vary by +/- 30%

Nevertheless, it is fair to conclude, on the basis of this calculation, and the apparent relative stability of shorelines immediately to the north of Barnes Rock (i.e. south of the main area of erosion) that the sand removed from this area by wave action supplied most of the sediment needed to grow Winda Woppa spit.

It follows that the amount of sediment transported around Barnes Rock (i.e. from Jimmy's Beach) is not likely to be a significant factor in causing the elongation of Winda Woppa spit.

D.10 Longshore Computation Tables

D.10.1 Transect 1

Swell waves

Table D-2: Swell generated annual longshore transport rates at Transect 1 calculated using the Kamphuis Method

KAMPHUIS		Bearing (degrees)								
		45	62.5	90	112.5	135	157.5	180	202.5	Total
		Longshore Transport rates (m^3/year)								
Period (sec)	<6	19	78	4	5	64	93	103	11	378
	6-8	78	555	380	6	8	27	517	294	1,864
	8-10	0	1,159	671	193	45	105	167	10	2,350
	10-12	0	1,110	563	1,445	71	408	28	0	3,625
	12-14	0	99	49	221	93	7	0	0	470
	>14	0	0	118	10	0	0	0	0	128
	Total	97	3,001	1,785	1,879	281	640	816	316	**8,816**

Table D-3: Swell generated annual longshore transport rates at Transect 1 calculated using the CERC Method

CERC		Bearing (degrees)								
		45	62.5	90	112.5	135	157.5	180	202.5	Total
		Longshore Transport rates (m^3/year)								
Period (sec)	<6	999	2,528	110	104	735	1,657	1,652	236	8,022
	6-8	1,536	11,107	5,500	340	301	1,378	11,742	4,265	36,168
	8-10	0	22,578	14,770	4,348	1,780	2,773	5,239	150	51,639
	10-12	0	17,791	24,411	32,297	2,313	13,373	544	0	90,729
	12-14	0	3,292	2,020	4,107	1,554	374	9	0	11,356
	>14	0	7	2,472	203	0	7	0	0	2,689
	Total	2,535	57,303	49,283	41,399	6,684	19,563	19,186	4,650	**200,603**

Table D-4: Swell generated annual longshore transport rates at Transect 1 calculated using the Van Rijn Method

Van Rijn		Bearing (degrees)								
		45	62.5	90	112.5	135	157.5	180	202.5	Total
		Longshore Transport rates (m^3/year)								
Period (sec)	<6	46	150	7	7	93	148	153	18	621
	6-8	128	969	585	12	14	58	940	455	3,161
	8-10	0	1,981	1,115	313	86	184	332	14	4,025
	10-12	0	1,774	1,187	2,623	132	833	44	0	6,594
	12-14	0	192	97	372	148	16	0	0	825
	>14	0	36	197	22	0	0	0	0	255
	Total	173	5,102	3,187	3,349	473	1,239	1,470	488	**15,480**

Wind waves

Table D-5: Wind generated annual longshore transport rates at Transect 1 calculated using the Kamphuis Method

Kamphuis		Direction (Bearing) 0	45	90	135	180	225	270	315	Total
Longshore Transport rates (m^3/year)										
Speed ($m \cdot s^{-1}$)	**0-4**	0.00	0.00	0.21	0.42	-0.18	-1.39	-0.11	0.00	**-1.04**
	4-8	0.00	0.06	8.36	26.29	7.97	-8.05	-0.71	0.00	**33.92**
	8-12	0.00	0.10	8.19	32.35	18.10	-6.19	-1.00	0.00	**51.54**
	12-16	0.00	0.00	0.00	4.74	4.67	-0.77	-0.38	0.00	**8.26**
	Total	**0.00**	**0.16**	**16.75**	**63.80**	**30.56**	**-16.40**	**-2.19**	**0.00**	**92.68**

Table D-6: Wind generated annual longshore transport rates at Transect 1 calculated using the CERC Method

CERC		Direction (Bearing) 0	45	90	135	180	225	270	315	Total
Longshore Transport rates (m^3/year)										
Speed ($m \cdot s^{-1}$)	**0-4**	0.00	10.88	183.64	327.31	116.39	-110.62	-7.27	0.00	**520.32**
	4-8	-0.01	72.50	2260.22	5708.47	3576.89	-540.22	-43.56	0.00	**11034.29**
	8-12	0.00	56.49	1592.50	4725.18	5360.66	-340.76	-55.77	0.00	**11338.29**
	12-16	0.00	0.00	0.00	471.08	943.89	-33.90	-19.00	-0.01	**1362.06**
	Total	**-0.01**	**139.88**	**4036.36**	**11232.04**	**9997.83**	**-1025.50**	**-125.61**	**-0.01**	**24254.97**

Table D-7: Wind generated annual longshore transport rates at Transect 1 calculated using the Van Rijn Method

Van Rijn		Direction (Bearing) 0	45	90	135	180	225	270	315	Total
Longshore Transport rates (m^3/year)										
Speed ($m \cdot s^{-1}$)	**0-4**	0.00	0.03	1.01	2.07	0.71	-0.28	-0.01	0.00	**3.52**
	4-8	0.00	0.31	30.14	91.01	34.62	-2.52	-0.09	0.00	**153.46**
	8-12	0.00	0.39	27.60	103.20	71.44	-2.18	-0.17	0.00	**200.29**
	12-16	0.00	0.00	0.00	14.04	16.96	-0.30	-0.08	0.00	**30.61**
	Total	**0.00**	**0.72**	**58.75**	**210.31**	**123.73**	**-5.28**	**-0.34**	**0.00**	**387.88**

D.10.2 Transect 2

Swell waves

Table D-8: Swell generated annual longshore transport rates at Transect 2 calculated using the Kamphuis Method

KAMPHUIS		Bearing (degrees)								
		45	62.5	90	112.5	135	157.5	180	202.5	Total
		Longshore Transport rates (m^3/year)								
Period (sec)	<6	5	17	1	1	11	17	21	2	75
	6-8	15	99	62	1	1	4	98	53	333
	8-10	0	206	157	43	7	16	34	2	466
	10-12	0	200	108	273	12	84	4	0	682
	12-14	0	22	9	39	17	1	0	0	88
	>14	0	0	21	2	0	0	0	0	23
	Total	20	545	359	358	48	123	157	57	1,667

Table D-9: Swell generated annual longshore transport rates at Transect 2 calculated using the CERC Method

CERC		Bearing (degrees)								
		45	62.5	90	112.5	135	157.5	180	202.5	Total
		Longshore Transport rates (m^3/year)								
Period (sec)	<6	305	632	25	16	138	406	351	39	1,912
	6-8	401	2,148	971	45	47	254	2,407	848	7,120
	8-10	0	4,442	3,673	1,058	308	499	1,209	25	11,215
	10-12	0	3,518	4,743	6,726	476	3,094	91	0	18,648
	12-14	0	833	433	783	305	73	1	0	2,428
	>14	0	2	469	37	0	2	0	0	509
	Total	706	11,575	10,315	8,666	1,274	4,328	4,058	912	41,833

Table D-10: Swell generated annual longshore transport rates at Transect 2 calculated using the Van Rijn Method

Van Rijn		Bearing (degrees)								
		45	62.5	90	112.5	135	157.5	180	202.5	Total
		Longshore Transport rates (m^3/year)								
Period (sec)	<6	11	27	1	1	13	24	25	2	104
	6-8	22	139	77	1	1	8	143	66	456
	8-10	0	284	209	56	11	23	57	2	642
	10-12	0	257	177	404	19	144	5	0	1,006
	12-14	0	36	15	52	21	2	0	0	126
	>14	0	6	28	3	0	0	0	0	36
	Total	32	749	507	517	65	200	230	70	2,370

Wind waves

Table D-11: Wind generated annual longshore transport rates at Transect 2 calculated using the Kamphuis Method

		Direction (Bearing)								
Kamphuis		**0**	**45**	**90**	**135**	**180**	**225**	**270**	**315**	**Total**
Longshore Transport rates (m^3/year)										
Speed ($m \cdot s^{-1}$)	**0-4**	0.00	0.00	0.10	0.32	-0.43	-2.01	-0.15	0.00	**-2.16**
	4-8	0.00	0.01	3.54	13.65	-1.80	-13.30	-1.36	0.00	**0.73**
	8-12	0.00	0.03	3.44	14.59	-20.32	-11.75	-2.30	0.00	**-16.31**
	12-16	0.00	0.00	0.00	1.87	-3.72	-1.35	-0.98	0.00	**-4.18**
	Total	**0.00**	**0.03**	**7.08**	**30.43**	**-26.26**	**-28.41**	**-4.80**	**0.00**	**-21.92**

Table D-12: Wind generated annual longshore transport rates at Transect 2 calculated using the CERC Method

		Direction (Bearing)								
CERC		**0**	**45**	**90**	**135**	**180**	**225**	**270**	**315**	**Total**
Longshore Transport rates (m^3/year)										
Speed ($m \cdot s^{-1}$)	**0-4**	0.00	1.78	110.84	257.48	32.63	-161.99	-9.99	0.00	**230.74**
	4-8	0.00	11.43	1113.62	3494.79	1303.41	-964.00	-79.76	0.00	**4879.48**
	8-12	0.00	13.81	744.01	2610.14	-640.99	-775.09	-132.76	0.00	**1819.11**
	12-16	0.00	0.00	0.00	194.60	-150.63	-76.77	-54.67	0.00	**-87.47**
	Total	**0.00**	**27.02**	**1968.48**	**6557.00**	**544.42**	**-1977.86**	**-277.19**	**0.00**	**6841.87**

Table D-13: Wind generated annual longshore transport rates at Transect 2 calculated using the Van Rijn Method

		Direction (Bearing)								
Van Rijn		**0**	**45**	**90**	**135**	**180**	**225**	**270**	**315**	**Total**
Longshore Transport rates (m^3/year)										
Speed ($m \cdot s^{-1}$)	**0-4**	0.00	0.00	0.45	1.36	0.15	-0.61	-0.02	0.00	**1.33**
	4-8	0.00	0.03	11.38	42.66	12.56	-6.69	-0.30	0.00	**59.64**
	8-12	0.00	0.08	10.28	42.81	-5.14	-7.63	-0.70	0.00	**39.70**
	12-16	0.00	0.00	0.00	4.77	-2.36	-1.05	-0.39	0.00	**0.97**
	Total	**0.00**	**0.11**	**22.12**	**91.60**	**5.21**	**-15.99**	**-1.41**	**0.00**	**101.65**

D.10.3 Transect 3

Swell waves

Table D-14Swell generated annual longshore transport rates at Transect 3 calculated using the Kamphuis Method

KAMPHUIS		Bearing (degrees)								
		45	62.5	90	112.5	135	157.5	180	202.5	ALL
		Longshore Transport rates (m^3/year)								
Period (sec)	<6	0	0	0	6	0	0	0	0	7
	6-8	0	0	5	46	6	1	1	0	60
	8-10	0	2	55	231	20	3	1	0	312
	10-12	0	5	126	274	25	4	1	0	436
	12-14	0	2	70	80	5	2	0	0	158
	>14	0	2	52	14	0	1	0	0	69
	ALL	0	12	308	652	56	11	4	0	**1,042**

Table D-15: Swell generated annual longshore transport rates at Transect 3 calculated using the CERC Method

CERC		Bearing (degrees)								
		45	62.5	90	112.5	135	157.5	180	202.5	ALL
		Longshore Transport rates (m^3/year)								
Period (sec)	<6	1	5	17	486	36	18	31	1	595
	6-8	5	50	382	2,504	422	92	133	4	3,593
	8-10	0	157	2,340	7,892	990	193	95	3	11,670
	10-12	0	202	3,774	7,032	931	189	52	0	12,181
	12-14	0	72	1,627	1,623	126	51	5	0	3,504
	>14	0	45	952	249	0	16	0	0	1,263
	ALL	6	531	9,093	19,786	2,505	559	316	9	**32,805**

Table D-16: Swell generated annual longshore transport rates at Transect 3 calculated using the Van Rijn Method

Van Rijn		Bearing (degrees)								
		45	62.5	90	112.5	135	157.5	180	202.5	ALL
		Longshore Transport rates (m^3/year)								
Period (sec)	<6	0	0	0	13	1	0	0	0	15
	6-8	0	1	9	87	11	2	2	0	111
	8-10	0	3	83	372	32	4	2	0	497
	10-12	0	6	177	401	37	6	1	0	629
	12-14	0	3	90	108	6	2	0	0	209
	>14	0	2	74	30	0	1	0	0	108
	ALL	0	15	434	1,011	86	15	6	0	**1,568**

Wind waves

Table D-17: Wind generated annual longshore transport rates at Transect 3 calculated using the Kamphuis Method

Kamphuis		Direction (Bearing) 0	45	90	135	180	225	270	315	Total
Longshore Transport rates (m^3/year)										
Speed ($m \cdot s^{-1}$)	**0-4**	0.00	0.00	0.03	0.18	0.21	0.06	0.00	0.00	**0.48**
	4-8	0.00	0.00	1.28	4.72	7.51	1.50	0.04	0.00	**15.05**
	8-12	0.00	0.01	1.38	10.37	16.64	2.77	0.10	0.00	**31.25**
	12-16	0.00	0.00	0.00	0.87	4.07	0.54	0.07	0.00	**5.55**
	Total	**0.00**	**0.01**	**2.68**	**16.14**	**28.43**	**4.86**	**0.20**	**0.00**	**52.33**

Table D-18: Wind generated annual longshore transport rates at Transect 3 calculated using the CERC Method

CERC		Direction (Bearing) 0	45	90	135	180	225	270	315	Total
Longshore Transport rates (m^3/year)										
Speed ($m \cdot s^{-1}$)	**0-4**	0.00	-0.04	20.89	126.93	198.27	38.60	1.30	0.00	**385.96**
	4-8	0.01	2.22	386.08	2247.21	3458.71	571.48	19.39	0.00	**6685.09**
	8-12	0.01	3.34	320.34	2113.62	5132.71	747.76	39.57	0.00	**8357.36**
	12-16	0.00	0.00	0.00	162.71	858.06	109.53	24.20	0.01	**1154.52**
	Total	**0.01**	**5.51**	**727.32**	**4650.48**	**9647.76**	**1467.38**	**84.46**	**0.02**	**16582.93**

Table D-19: Wind generated annual longshore transport rates at Transect 3 calculated using the Van Rijn Method

Van Rijn		Direction (Bearing) 0	45	90	135	180	225	270	315	Total
Longshore Transport rates (m^3/year)										
Speed ($m \cdot s^{-1}$)	**0-4**	0.00	0.00	0.04	0.56	0.79	0.05	0.00	0.00	**1.44**
	4-8	0.00	0.00	2.95	15.58	27.13	3.17	0.02	0.00	**48.85**
	8-12	0.00	0.02	3.29	29.30	56.56	6.88	0.10	0.00	**96.15**
	12-16	0.00	0.00	0.00	2.58	12.99	1.38	0.12	0.00	**17.07**
	Total	**0.00**	**0.02**	**6.29**	**48.01**	**97.46**	**11.48**	**0.24**	**0.00**	**163.51**

APPENDIX E: MODELLING SOFTWARE AND MODEL ESTABLISHMENT

E.1 Model Selection

Development of the coastal hydrodynamic model requires a considerable amount of data to adequately represent hydrodynamic, advection / dispersion, waves and sediment transport processes occurring within the study area. The numerical model therefore requires the following datasets to simulate and / or calibrate hydrodynamics:

- **Bathymetric survey data** – used to describe the topography of the bed and coastline over the domain of a numerical model incorporating the full tidal extents of the estuary;
- **Wave, Water level and flow data** – used to calibrate and / or validate model predictions. Wave, Water level and flow data are most commonly used to ensure the model adequately represents the tidal prism of a waterway; and

For the present study, the two-dimensional hydrodynamic model (TUFLOW-FV), coastal wave model (SWAN) and sediment morphology model (TUFLOW-MORPH) were selected to satisfy the modelling scope and objectives. An overview of the selected models is provided in Figure E.1, with further details of model bathymetry, model geometry and boundary condition data adopted for each provided in the following sections.

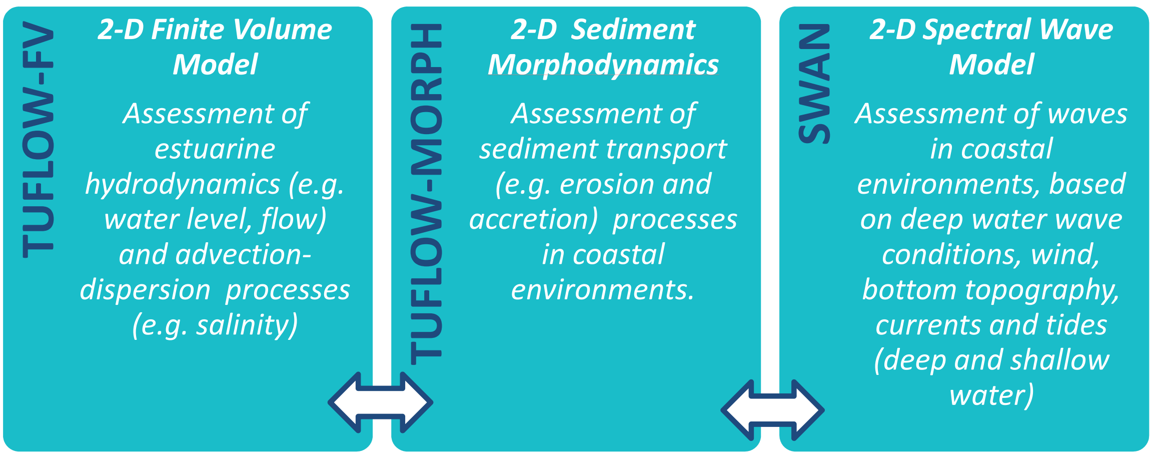


Figure E-1 Numerical Models Adopted for the Investigations

For numerical modelling investigations, tidal flows occurring within the study area are predicted by the hydrodynamic model (TUFLOW-FV) with the effect of waves introduced from the wave model (SWAN). Sediment supply to the entrance may result from the combined effects of waves and tidal flows. As waves approach the coast, they refract, diffract, shoal (rear up) and break. These processes generate forces which act to:

- Drive longshore currents; and
- Set up the water level at the shoreline.

In order to properly model coastal sediment transport processes, it is important to provide the resulting wave forces (also known as wave radiation stresses) to the hydrodynamic model. The waves also have a direct effect in stirring sediment from the bed and thus making it more available for transport by the currents. For this reason the spatial wave field needs to be supplied to the sand transport model (TUFLOW-MORPH) as well.

Using the numerical models outlined above, the overall morphological modelling process, including the effects that waves and tidal flows have on sediment transport, follow the structure outlined in Figure E-2. In all cases, the TUFLOW-FV hydrodynamic model is linked with the SWAN wave model, allowing the passage of wave stresses and the wave field to the hydrodynamic and sediment transport model, and bed elevations / current fields back to the wave model. This approach incorporates the important coastal processes occurring within the Estuary that influence its environmental condition and introduce changes to bathymetry over time.

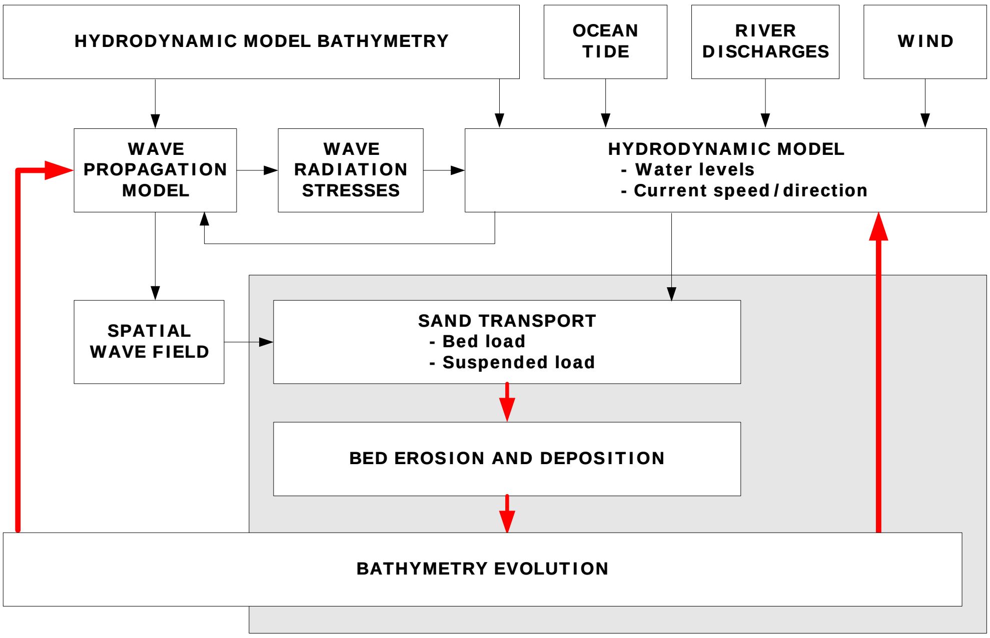


Figure E-2 Combined Hydrodynamic, Wave and Morphological Modelling

E.2 Hydrodynamic modelling (TUFLOW-FV)

TUFLOW-FV is a two dimensional finite volume model code that solves the conservative integral form of the non-linear shallow water equations (NLSWE) (i.e. assuming that pressure varies hydrostatically with depth), including viscous flux terms and source terms for Coriolis force, bottom-friction and various surface and volume stresses. The model is currently fully operational as a 2-dimensional NLWSE solver, and development work to extend the model to a 3-dimensional NLSWE solver including baroclinic forcing is almost complete.

The scheme is also capable of simulating the advection and dispersion of multiple scalar constituents (e.g. salinity, temperature) within the model domain. Bed friction is modelled using a Manning's roughness formulation and Coriolis force is also included in the model formulation. The spatial domain (or study area extents) is discretised using contiguous, non-overlapping irregular triangular and quadrilateral "cells". Advantages of an irregular flexible mesh include:

- The ability to smoothly resolve bathymetric features of varying spatial scales (e.g. dredged channels adjacent to broad shoaled areas);
- The ability to smoothly and flexibly resolve boundaries such as coastlines; and
- The ability to adjust model resolution to suit the requirements of particular parts of the model domain without resorting to a “nesting” approach.

The flexible mesh approach has significant benefits when applied to study areas involving complex coastlines and embayments, varying bathymetries and sharply varying flow and scalar concentration gradients. TUFLOW-FV presently accommodates a wide variety of boundary conditions, including those necessary for modelling the processes of importance to the present study including water level and flow variations, wind stress and wave radiation stress, salinity and temperature. The assumption of a vertically well mixed water body means that the two-dimensional TUFLOW-FV is suitable. It is considered that three dimensional processes driven by salinity and / or thermal stratification are not significant issues for the study area, even though they might occur from time to time at some locations in response to fluvial inputs from the Myall Lakes. Sediment transport (erosion / accretion), water quality and tidal flushing are influenced by currents generated from a combination of tides and wave conditions and have been identified as the primary drivers influencing the issues of concern for the study area.

E.2.1 Model Application

Figure E.2 shows the hydrodynamic model requires a combination of bathymetry, ocean tide, flow discharges, wind and wave stresses, as relevant, to calculate water level, current speed and direction. The transport and fate of constituents such as temperature and salinity (both conservative constituents) may also be included in a coupled advection-dispersion transport model. For the present study, salinity has been used as an indicator of flushing potential and expected water quality.

E.2.2 Model geometry

The TUFLOW-FV numerical model geometry consists of nodes interconnected by a series of triangular and quadrilateral cells to form a two-dimensional mesh of the waterway system. The model geometry has been developed to capture the level of detail required to model important coastal estuarine processes while minimising model runtimes. The primary advantage of using a flexible mesh system is that it provides an accurate representation of the tidal prism without the need to define bathymetric conditions using a high resolution grid.

The model geometry includes the full tidal prism of the Port Stephens / Myall Lakes estuary with upstream extents defined by the tidal excursion limits of Tilligerry Creek, Myall River, Karuah River and the Bombah Broadwater. Furthermore, the entire Myall Lakes System is incorporated to represent the storage present in the system for simulations examining drainage of the Upper Lakes following a significant catchment runoff event. The model geometry includes increased detail to define the waterway areas of the Lower Myall River and channel connections in the vicinity of Corrie Island, i.e. the sand spit, the Northern Channel, Eastern Channel etc., which has been provided through increased spatial resolution where abrupt changes to bathymetry occur. Detailed geometry was extended upstream to ensure hydraulic properties of the Myall River are adequately represented by the model. The Lakes are located sufficiently upstream from the study area that a relatively coarse geometry is reasonable to capture the approximate storage property of the lake system.

For the remainder of the Port Stephens Estuary, the spatial resolution of model geometry was configured to capture other important bathymetric features including the shallow intertidal areas, tidal deltas and other flow connections present beyond the immediate study area. These are important to suitably represent tides propagating across the Port, towards the mouth of the Lower Myall River.

The model geometry was also extended beyond Yacaaba and Tomaree Headlands to include nearshore areas to a depth of approximately 50 metres which are important for ocean wave processes (i.e. wind and swell generated waves). The model geometry used to assess tidal hydrodynamics is shown in Figure E.3.

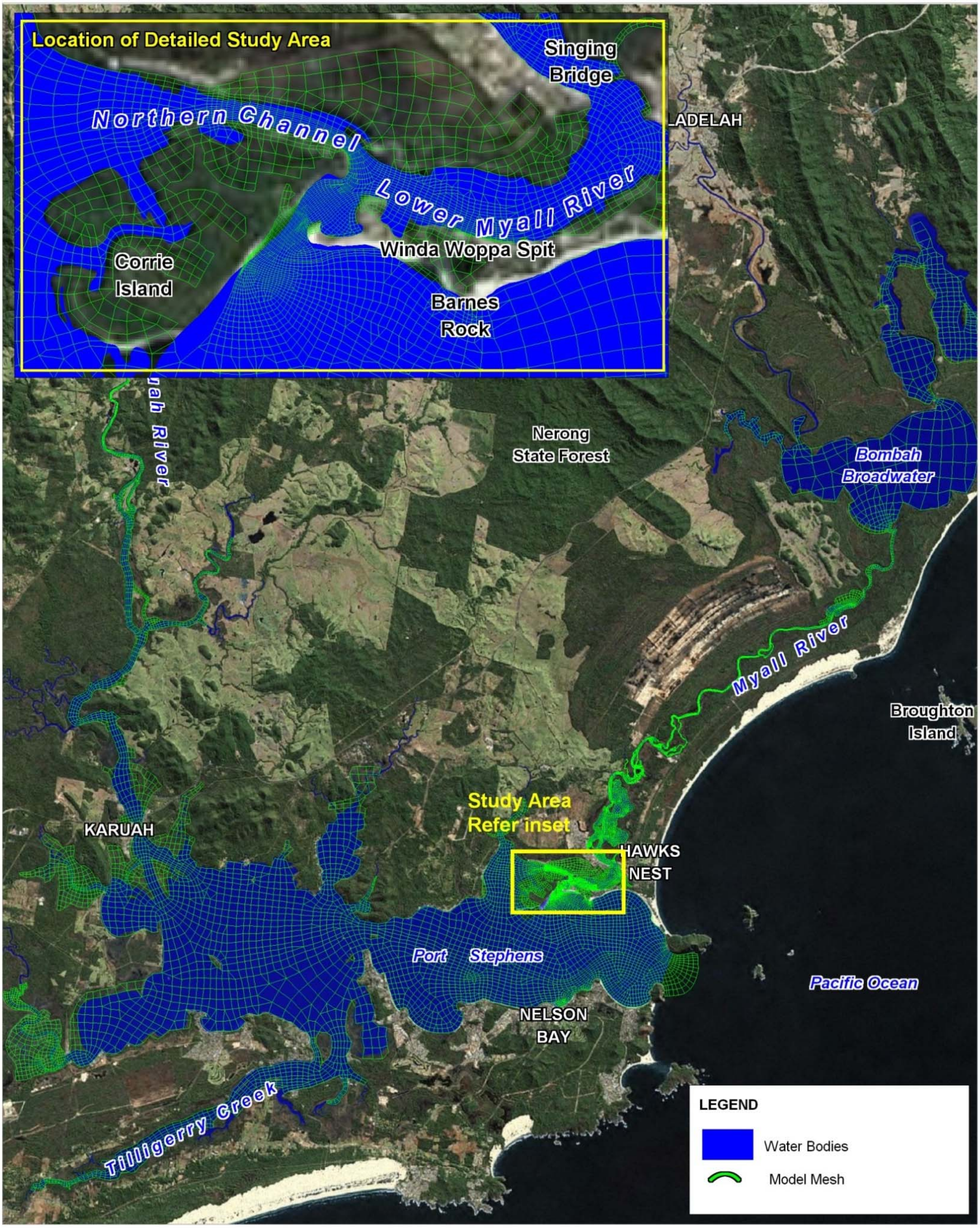
E.2.3 Model bathymetry

Hydrosurvey has previously been collected for the study area on a number of occasions (refer Section 3.1). The most recent data collection campaigns include hydrosurvey collected for the Myall River Entrance as part of the intensive tidal gauging exercise undertaken by DECCW in September 2009 and the more extensive hydrosurvey collected in 2001 which covers the eastern and central basin regions of Port Stephens. These two data sources form the basis of bathymetry data adopted by the numerical model along with additional hydrographic survey collected in 2001/2002 which has been incorporated to define bathymetric conditions for the Myall Lake (Bombah Broadwater) and the upper reaches of the Myall River.

Although these hydrosurvey data provide detailed coverage of the study area and a majority of the Port Stephens embayment, there are some locations west of study area that have not been covered by any previous data collection or survey campaigns, namely Tilligerry Creek, the western fringe of Port Stephens and Karuah River. A Digital Elevation Model (DEM) of bathymetric conditions derived from the various sources of hydrosurvey data has been refined with additional data sources including:

- Australian Hydrographic Service bathymetric chart (AUS809) of the western portion of Port Stephens absent from previous hydrosurvey;
- Light Detection And Ranging (LiDAR) data for definition of fringing saltmarsh and wetland overbank areas (i.e. inter-tidal areas beyond the extent of hydrosurvey with main channel that regularly wet and dry during a tidal cycle); and
- Rectified aerial photography to assist with definition and alignment of foreshore areas and extent of low lying vegetation species that are often associated with these low-lying intertidal areas.

The hydrodynamic model was constructed to include the full tidal prism of the Port Stephens/ Myall Lake Estuary using the various bathymetry data sources described above. Areas seaward of entrance headlands were also included to account for the influence of waves propagating into the estuary. Bathymetry data for coastal / ocean areas seaward of the entrance was approximated by digitising depth contours from a 1:150,000 topographic chart (AUS00809 Port Jackson to Port Stephens derived from Australian Hydrographic Service). Ocean bathymetry in the vicinity of Port Stephens entrance was subsequently derived from digitised depth contours and incorporated within the DEM used to define bathymetry for the numerical model. The bathymetry used by the numerical model is shown in Figure E.4.



Title:

Model Mesh for Port Stephens and the Lower Myall River

Figure: E-3

Rev: A

N

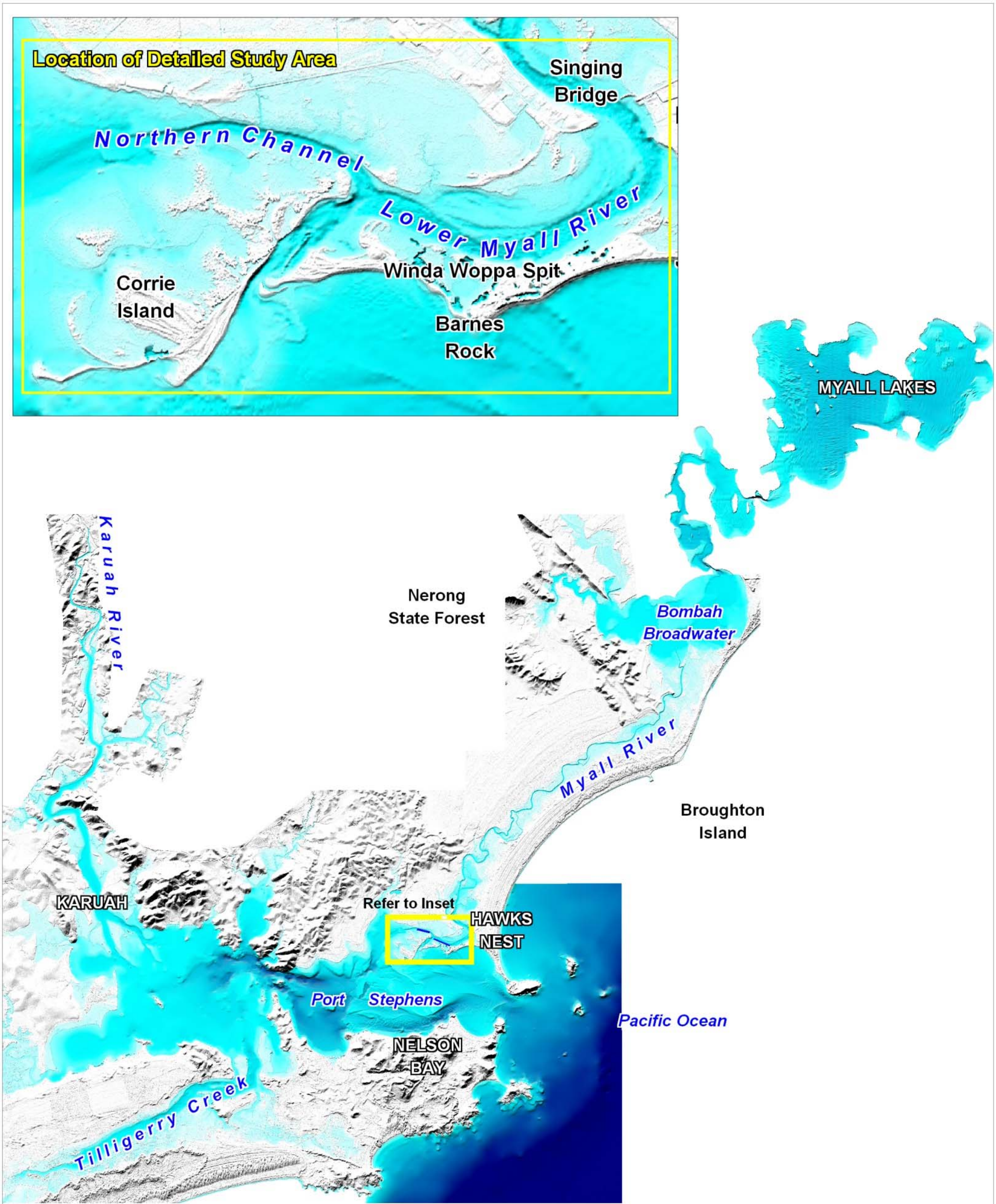
0 5 10km

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\DRG_012_110202 Model Extents.WOR



Title:
Hydrodynamic Model Bathymetry

Figure: **E-4**

Rev: **A**

N

0 5 10km
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure 4-5 Model Bathymetry.WOR

E.2.4 Model configuration

The hydrodynamic model was configured to account for tidal hydrodynamics in response to tidal water level variations and wave stresses. The model was configured using the hydrostatic assumption (i.e. vertical momentum not solved) and depth averaged approximation of the governing Navier Stokes Equations. The influence of the Coriolis force was calculated with latitude of -32.7°S. Salinity was modelled as a passive transport scalar (i.e. uncoupled from temperature and density effects).

The scalar mixing model adopted was the Elder model which calculates non-isotropic diffusivity using coefficients for longitudinal and transverse directions. The momentum mixing model adopted was the Smagorinsky formulation with a coefficient of 0.2. TUFLOW-FV has an adaptive timestep algorithm which automatically adjusts the model timestep to resolve hydrodynamic and advection dispersion processes based on a user specified Courant-Friedrichs-Lewy (CFL) stability criterion.

TUFLOW-FV accounts for wetting and drying dynamically based of cell depths of 0.005 m and 0.05 m respectively. The drying value corresponds to a minimum depth below which the cell is dropped from computations (subject to the status of surrounding cells). The wet value corresponds to a minimum depth below which cell momentum is set to zero, in order to avoid unphysical velocities at very low depths. Bottom drag or bed roughness is specified as a spatially varying Manning's *n* roughness value, which is standard for many two-dimensional hydrodynamic models.

E.2.5 Boundary forcing

In order to simulate tidal hydrodynamics, a variable water level was applied to the ocean boundary to represent tide conditions. The water levels were those measured at the MHL ocean tide station at Tomaree. Recent measurements of ocean tide at Tomaree since January 2008 are presented in Figure E-5, which illustrates the occasional elevation of peak tidal water levels above normal astronomical tide levels (i.e. often peaks at ~ 1.2 m AHD, which is higher than peak astronomical tide levels of ~1.0 m AHD).

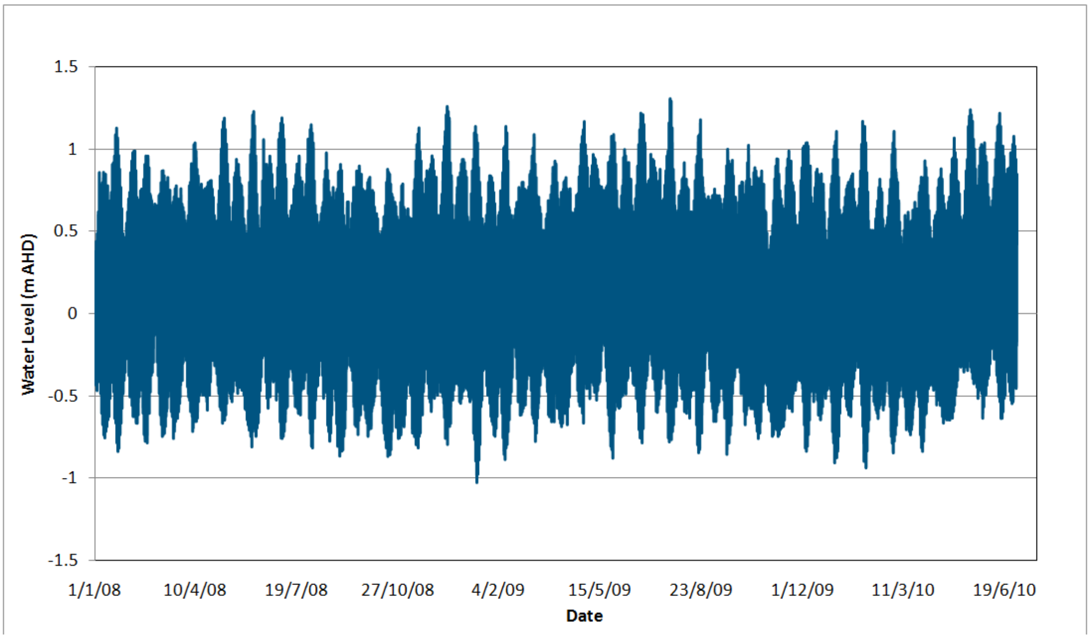


Figure E-5 Ocean Tide Conditions, Port Stephens

Where required, rainfall and evaporation were applied to the surface of the model explicitly as a global rate derived from the net daily rainfall and evaporation. No other boundary forcing (e.g. freshwater flows or groundwater) was applied to the model during stages of model development, calibration or scenario modelling. Separate boundary forcing data were however applied to the wave model and morphodynamic model, as discussed below.

E.3 Wave modelling (SWAN)

The Simulating WAves Nearshore (SWAN) model is a spectral coastal wave model code developed by the Technical University of Delft in the Netherlands.

The computer model developed for the Port Stephens / Myall Lakes Estuary adopts the SWAN spectral wave model to compute irregular waves in nearshore areas, based on variables such as deep water wave conditions, wind, bottom topography, currents and tides. SWAN may be configure to explicitly account for all relevant processes of propagation, generation by wind, interactions between the waves and decay by breaking and bottom friction with diffraction being included in an approximate manner (DHH, 2010).

Wave data, as represented by the significant wave height, period and mean direction of the two-dimensional wave spectrum is often required at a coastal locations for coastal applications and modelling investigations. As discussed in Section E.1, the TUFLOW-FV hydrodynamic model is linked with the SWAN wave model to allow the passage of wave stresses to the hydrodynamic and sediment transport model to account for wave setup and longshore sediment transport, which influence the environmental condition and introduce changes to bathymetry within the Estuary.

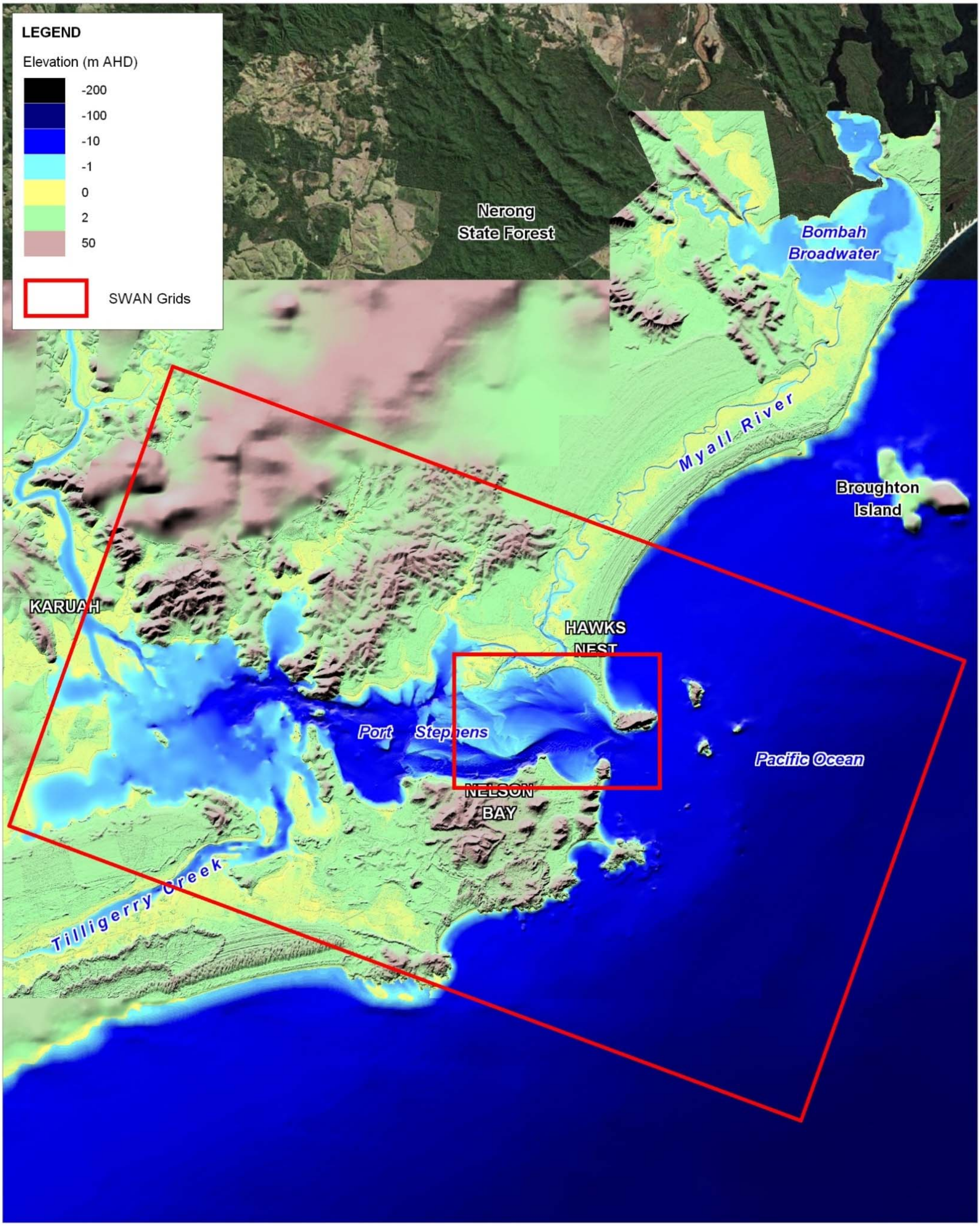
The wave model has been used to propagate "deep water" data measured at the WaveRider buoys inshore to the area of interest for the present study.

For the current study, a nonstationary two-dimensional SWAN model was developed to provide inputs to the hydrodynamic (TUFLOW-FV) and sediment transport (TUFLOW-MORPH) numerical models. Further details of the wave model development including bathymetry, geometry and boundary conditions are provided in the following sections.

E.3.1 Model geometry

The SWAN wave model consists of two grids, i.e. a coarse (larger) grid and a nested (smaller) grid with square cell sizes of 100 metres and 30 metres respectively. The extents of the coarse and nested grids are shown on Figure E-6

The purpose of the coarse grid wave model was to define offshore areas to a depth of approximately 100 metres (i.e. approximately 25 to 30 km from the coastline) to ensure that waves entered at the boundary were in similar depths to the waves measured at the WaveRider buoys. The coarse grid was orientated 70° in a counter clockwise direction from the positive (easterly) horizontal axis and was extended to the northern extent of Hawks Nest beach, as far south as Fingal Bay and as far west to cover all of Port Stephens.



Title:
SWAN Model Grid extents

Figure: **E-6**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in 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.

N

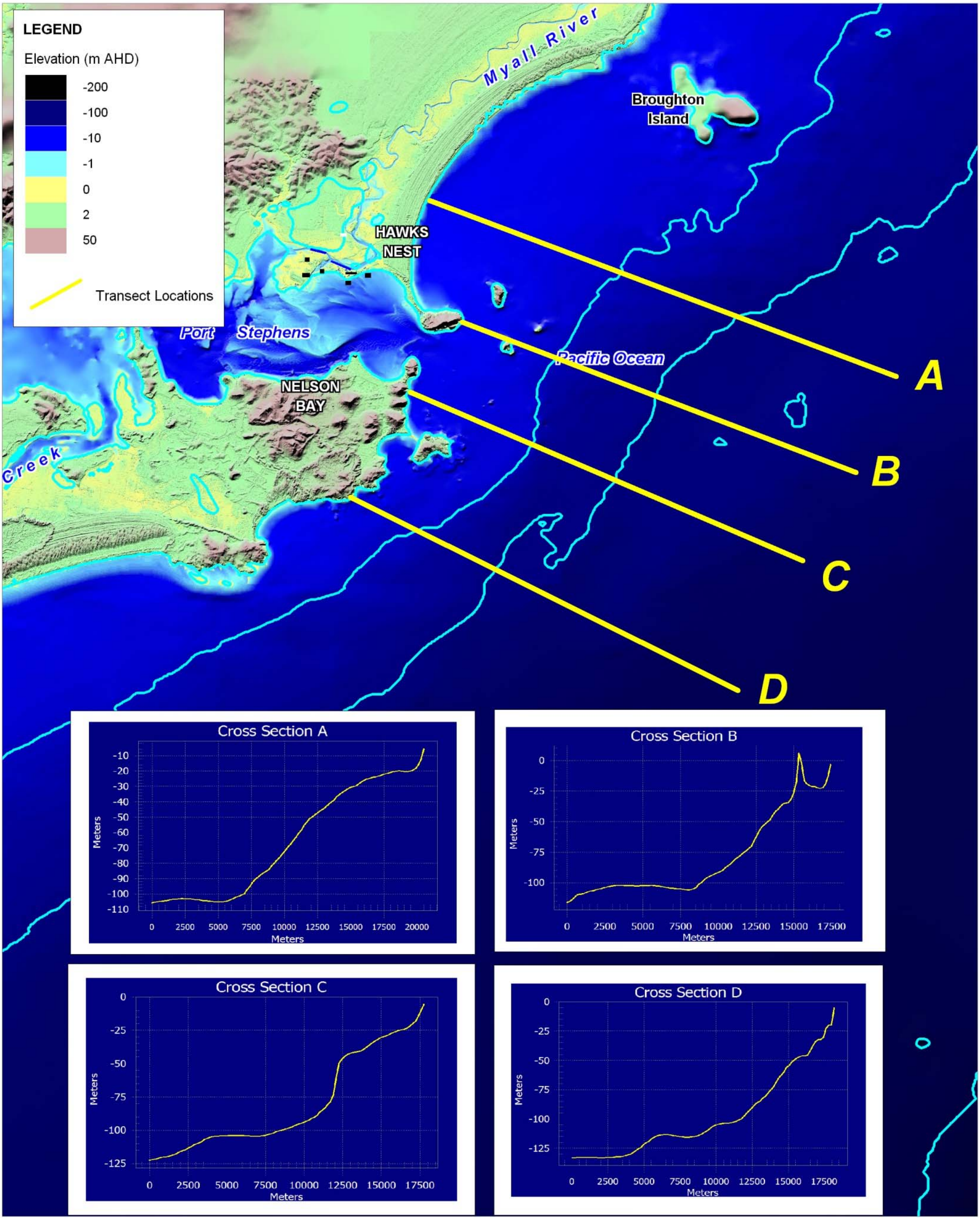
0 5 10km

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure 4-6 SWAN Model Grid extents.WOR



Title:

Offshore Bathymetry Transects

Figure: E-7

Rev: A

N 0 5 10km
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1926_Lower_Myall_River_Sediment_Hyrodynamic_Assessment\MI\Workspaces\Figure 4-7 Offshore Bathymetry Profiles.WOR

The nested grid was used to calculate higher resolution wave information within the bounds of the hydrodynamic model. The nested grid covers the flood tide delta region of Port Stephens and was orientated such that the y-axis is aligned in the north-south direction and the x-axis aligned in the east-west direction (i.e. model grid was not rotated).

E.3.2 Model bathymetry

Bathymetry or bottom topography required for development of the SWAN wave model includes ocean areas seaward of the entrance to a depth of approximately 100 metres. A DEM of nearshore and offshore bathymetry was estimated using depth contours digitised from a 1:150000 navigation chart for the east coast of Australia between Port Jackson and Port Stephens. These data were subsequently merged with other bathymetry data sources including that used for development of the hydrodynamic model to provide complete coverage for both wave model grids. The DEM of offshore bathymetry used by the SWAN wave model and some sample cross section profiles are shown in Figure E-7.

E.3.3 Model configuration

SWAN models were run in a two dimensional and stationary (i.e. each computation of wave spectra is used as an initial condition for the next set of boundary conditions) mode. Processes included within the model were depth induced breaking (constant) and dissipation by bottom friction (using the standard friction Collins coefficient of 0.015). Spectral wave directions were only considered from the sector between 52° and 262° (i.e. the model only considers waves between the north-easterly and southerly aspects). The computation grid adopted for both coarse and nested grids was equivalent to the resolution and extents of the input bathymetric grid (i.e. no interpolation of bathymetry was required). Outputs from the model include, wave induced force, spectral peak period, peak wave direction, significant wave height and water depth.

E.3.4 Boundary forcing

The WaveRider buoy data from Sydney were used as a boundary forcing for the coarse grid wave model, including temporal variations of significant wave height, wave period and wave direction. Wave data measured at Sydney for the period 1st to 30th September 2009 are shown in Figure 3-5, Figure 3-6 and Figure 3-7. In turn, the nested model was run interactively with TUFLOW-FV and used boundary conditions (i.e. wave spectra) calculated by the coarse wave model..

Local wind waves typically have shorter wave periods than ocean swell. It is generally 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.

E.4 Morphodynamic modelling (TUFLOW-MORPH)

The morphodynamic model, TUFLOW-MORPH, is an extension of the hydrodynamic model TUFLOW-FV (described in section). The morphodynamic component simulates patterns of sediment transport as governed by the hydrodynamics and applied boundary forcing. The processes and characteristics incorporated into the model include:

- Sediment transport and bed-evolution (sedimentation and erosion);

- Slumping of unstable slopes (both underwater and adjacent to water bodies);
- Sediment classes and ability to spatially vary sediment properties according to material type;
- Transport rates calculated using recent methods proposed by van Rijn's (van Rijn 2007a, 2007b, 2007c, 2007d); and
- Threshold velocity calculations using a shields criterion; and
- Option to calculate transport based on Particle size distribution parameters (D_{10}, D_{50} and D_{90}).

E.4.1 Model bathymetry

TUFLOW-Morph uses the same geometry as the TUFLOW-FV hydrodynamic model. The morphological model uses the same. The calculated sediment transport rates at each cell are applied within the finite volume scheme, utilising an upwind scheme to solve the sediment mass balance equation.

Sediment transport rates are calculated utilising a morphological time step which is larger than the hydrodynamic time step. Following testing, the morphological time step was set to 60 seconds.

While sediment transport is not calculated every hydraulic time step, the mass of sand within the bed is updated every time step. Consequently, the changes to bathymetry caused by erosion and scour have direct feedback to hydrodynamic processes every time step.

E.4.2 Model configuration

The morphodynamic model requires the input of sand grain sizes. The area of most significance to the study is located in and around the Eastern Channel. Section 3.6 provides data on sediments collected from the Myall. Based on that data the following sediment characteristics were applied in that area:

- D_{10} = 0.16 mm;
- D_{50} = 0.41 mm; and
- D_{90} = 0.70 mm;

While the sand in this area does moderately well sorted marine sands, there are some areas of known Coffee Rock (e.g. eastern edge of Corrie Island). It was assumed that the in-situ bed material had a dry density of 1850 kg/m^3 (approximately equals sediment with a solid density of 2650 kg/m^3 and a void ration of 0.4.

Currents generated by ocean tide and swell waves are used by the morphodynamic model to drive sediment transport processes. No other specific boundary forcing data are required by the morphodynamic model other than the initial model bathymetry.

BMT WBM Brisbane	**Level 11, 490 Upper Edward Street Brisbane 4000** **PO Box 203 Spring Hill QLD 4004** **Tel +61 7 3831 6744 Fax +61 7 3832 3627** **Email wbm@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Denver	**14 Inverness Drive East, #B132** **Englewood Denver Colorado 80112 USA** **Tel +1 303 792 9814 Fax +1 303 792 9742** **Email wbmdenver@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Melbourne	**Level 5, 99 King Street Melbourne 3000** **PO Box 604 Collins Street West VIC 8007** **Tel +61 3 9614 6400 Fax +61 3 9614 6966** **Email wbmmelbourne@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Morwell	**Cnr Hazelwood Drive & Miners Way Morwell 3840** **PO Box 888 Morwell VIC 3840** **Tel +61 3 5135 3400 Fax +61 3 5135 3444** **Email wbmmorwell@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Newcastle	**126 Belford Street Broadmeadow 2292** **PO Box 266 Broadmeadow NSW 2292** **Tel +61 2 4940 8882 Fax +61 2 4940 8887** **Email wbmnewcastle@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Perth	**1 Brodie Hall Drive Technology Park Bentley 6102** **Tel +61 8 9328 2029 Fax +61 8 9486 7588** **Email wbmperth@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Sydney	**Suite 206, 118 Great North Road Five Dock 2046** **PO Box 129 Five Dock NSW 2046** **Tel +61 2 9713 4836 Fax +61 2 9713 4890** **Email wbmsydney@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Vancouver	**1190 Melville Street #700 Vancouver** **British Columbia V6E 3W1 Canada** **Tel +1 604 683 5777 Fax +1 604 608 3232** **Email wbmvancouver@wbmpl.com.au** **Web www.wbmpl.com.au**