Great Lakes Coastal Hazard Study

Appendix E – Jimmy's Beach Coastal Hazard Study

For: Great Lakes Council

Project Name:	Great Lakes Coastal Hazard Study
Project Number:	3001829
Report for:	Great Lakes Council

PREPARATION, REVIEW AND AUTHORISATION

Revision #	Date	Prepared by	Reviewed by	Approved for Issue by
1 (DRAFT)	24/02/12	A. Xiao, M. Glatz	C. Adamantidis	
2	22/08/12	E. Watterson	D. Messiter	D Messiter
3	18/10/13	H. Nelson	D Messiter	D Messiter

ISSUE REGISTER

Distribution List	Date Issued	Number of Copies
Great Lakes Council:	23/10/13	1 (E)
SMEC staff:		
Associates:		
Sydney Office Library (SMEC office location):		
SMEC Project File:	23/10/13	1 (E)

SMEC COMPANY DETAILS

SMEC Australia Pty Ltd
74 Hunter Street, Newcastle NSW 2300

Tel: **02 4925 9621**

Fax: **02 4925 3888**

Email: **Dan.Messiter@smec.com**

www.smec.com

TABLE OF CONTENTS

1 INTRODUCTION 1

2 SITE OBSERVATIONS AND DATA 3

2.1 Site Inspection 3

2.1.1 Jimmy's Beach – Winda Woppa 3

2.1.2 Barnes Rock to Carrie Island Entrance 4

2.1.3 Yacaaba Barrier 4

2.2 Sediment Sampling 5

2.3 Historical Aerial Photograph Analysis 10

2.4 Coastline Management at Jimmy's Beach 15

3 DATA COLLECTION AND REVIEW 17

3.1 Review of Past Studies 17

3.1.1 Gordon A.D. (1982) 17

3.1.2 Public Works Department (1985 – 1987) 17

3.1.3 Watson P. (1997) 18

3.1.4 MHL (2000 - 2002) 18

3.1.5 Sydney University, School of Geosciences (2007 – 2010) 19

3.1.6 WBM-BMT (2011) 21

3.2 Coastal Processes Data 21

3.2.1 Wave Climate 21

4 COASTAL PROCESSES ANALYSIS 34

4.1 Photogrammetric Data Analysis 34

4.1.1 Short Term Storm Erosion 36

4.1.2 Long Term Changes 40

4.2 Net Longshore Sediment Transport 47

4.3 Wave Inundation 48

4.3.1 Introduction 48

4.3.2 Ocean Inundation 48

4.4 Climate Change Impact 51

4.4.1 Bruun Rule 51

4.4.2 Determination of Bruun Rule Parameters 51

4.4.3 Beach Response 55

4.5 Analysis of Beach Nourishment Material 56

5 HAZARD DEFINITION AND MAPPING 60

5.1 Summary of Hazard Parameters 60

5.2 Hazard Mapping 60

6 CONCLUSION 62

7 REFERENCES 67

APPENDIX 1 – WAVE TRANSFORMATION MODELLING 69

LIST OF TABLES

Table 1: Results of Sediment sampling undertaken in 2000 (grain size, mm)

Table 2: Results of Sediment sampling undertaken in 2002 (grain size, mm)

Table 3: Historical evolution of the Winda Woppa Spit and Jimmy's Beach at Guyra Street (Vila Concejo et al., 2010)

Table 4: Summary of known nourishment volume estimates at Jimmy's Beach

Table 5: Locally generated sea waves under typical condition

Table 6: List of aerial photographs and accuracies used for photogrammetric analysis (MHL, 2000)

Table 7: Pre-nourishment long-term volume change rates for Jimmy's Beach (1963 – 1983)

Table 8: Long-term volume change rates (including Beach Nourishment) for Jimmy's Beach (1963 – 2008)

Table 9: Long-term volume change rates for Jimmy's Beach during beach nourishment (1983 – 2008)

Table 10: Pre-nourishment Long Term Dune Escarpment Movement Rate (1963-1983) One Beach and Boat Beach

Table 11: Long Term Dune Escarpment Movement Rate including Beach Nourishment (1963-2008)

Table 12: Long Term Dune Escarpment Movement Rate during Beach Nourishment (1983-2008)

Table 13: Adopted Beach Recession Rates for Coastal Hazard Assessment

Table 14: Adopted post-nourishment beach recession rates for Coastal Hazard Assessment (1983 – 2008)

Table 15: Sydney wave height occurrence by direction to December 2004 (Kulmar et al., 2005)

Table 16: Estimated potential longshore sediment transport using CERC (1984) formula in typical conditions

Table 17: Estimated potential longshore sediment transport using Kamphuis formula in typical conditions

Table 18: Present day, 2050 and 2100 wave runup levels for Jimmy's Beach,1% AEP storm event

Table 19: Determination of the berm height, the closure depth and the profile length per block and per continuous beach from bathymetric and topographic data

Table 20: Predicted beach erosion due to sea level rise

Table 21: Distribution parameters required to determine overfill ratio at the sampling locations

LIST OF FIGURES

Figure 1: *Locality Map*

Figure 2 *(a) Beach along The Boulevarde looking west; (b) Sand nourishment at Jimmy's Beach; (c) Wind-blown sand on The Boulevarde*

Figure 3: *(a) Remnant of large trees half-way between Myall River eastern entrance and Barnes Rock; (b) & (c) Extensive shoals located in front of Myall River eastern entrance; (d) Shoals located within Myall River eastern entrance*

Figure 4: *(a) Shoal south of Yacaaba Barrier; (b) Erosion scarp at the back of Beach at Yacaaba Barrier*

Figure 5: *Sediment sample sites at Winda Woppa, Jimmy's Beach and Yacaaba Head (MHL, 2000)*

Figure 6: *Sediment sample sites at Yacaaba Isthmus Borrow Area (Jelliffe Environmental Pty Ltd, 2003)*

Figure 7: *Sediment sieve analysis results at Winda Woppa, Jimmy's Beach and Yacaaba Isthmus between 2000 and 2002 (MHL, 2000 & Jelliffe Environmental Pty Ltd, 2003)*

Figure 8: *Evolution of Winda Woppa spit between 1795 and 1941 (Thom et al., 1992)*

Figure 9: *Winda Woppa shoreline long-term trend based on historical aerial photos (Sydney University Geoscience Research Project)*

Figure 10 *Historical evolution of a shore-attached sandwave along Yacaaba Head (Vila-Concejo et al., 2011)*

Figure 11: *Digital Terrain Model (DTM) from bathymetry and ALS data Delft-3D wave transformation model grids*

Figure 12: *Delft 3D wave transformation smaller model grids for Jimmy's Beach and the locations of Reference Points for Longshore Sediment Transport analysis*

Figure 13: *Significant wave height exceedance for NSW coast (Lord & Kulmar, 2000)*

Figure 14: *Storm wave height duration recurrence (Lord & Kulmar, 2000)*

Figure 15: *SWAN wave transformation model for swell wave Hs=1m, Ts=10s, offshore wave direction = SSE*

Figure 16: *Wave refraction coefficient at 1 m depth along Jimmy's Beach from west (Barnes Rocks) to east (erosion zone)*

Figure 17: *Annual wind rose for 9:00 am wind speed at Nelson Bay*

Figure 18: *Annual wind rose for 3:00 pm wind speed at Nelson Bay*

Figure 19: *SWAN wave transformation model for significant wind wave (Hs), Ts=3s, wind wave direction =W, wind speed = 5 ~ 6 m/s*

Figure 20: *Photogrammetry profile locations at Jimmy's Beach*

Figure 21: *Dune stability schema (after Nielsen et al., 1992)*

Figure 22: *Determination of Equivalent storm erosion, pre-storm and post-storm*

Figure 23: *Estimated Storm Erosion Demand for the consecutive storms at Jimmy's Beach*

Figure 24: *Cumulative change in beach volume in cubic metres per metre length of beach at Jimmy's Beach (pre nourishment)*

Figure 25: *Cumulative change in beach volume in cubic metres per metre length of beach at Jimmy's Beach (post nourishment)*

Figure 26: *Cumulative dune face movement in metres at Jimmy's Beach (pre-nourishment)*

Figure 27: *Cumulative dune face movement in metres at Jimmy's Beach (post-nourishment)*

Figure 28: *Runup Hazard Line – Jimmy's Beach Maximum Runup Line and Maximum 2% Runup Line*

Figure 29: *Concept of shoreline recession due to sea level rise*

Figure 30: *Suggested relationship for shape factor A vs. grain size D*

Figure 31: *Nearshore profile at Jimmy's Beach vs. idealised equilibrium profile*

Figure 32: *Isolines of the adjusted overfill ratio (RA) for values of mean difference and sorting ratio (Shore Protection Manual, 1984)*

Figure 33: *Beach Nourishment construction, Jimmy's Beach Port Stephens*

Figure 34: *Present Hazard Zones at Jimmy's Beach*

Figure 35: *Year 2050 Hazard Zones at Jimmy's Beach*

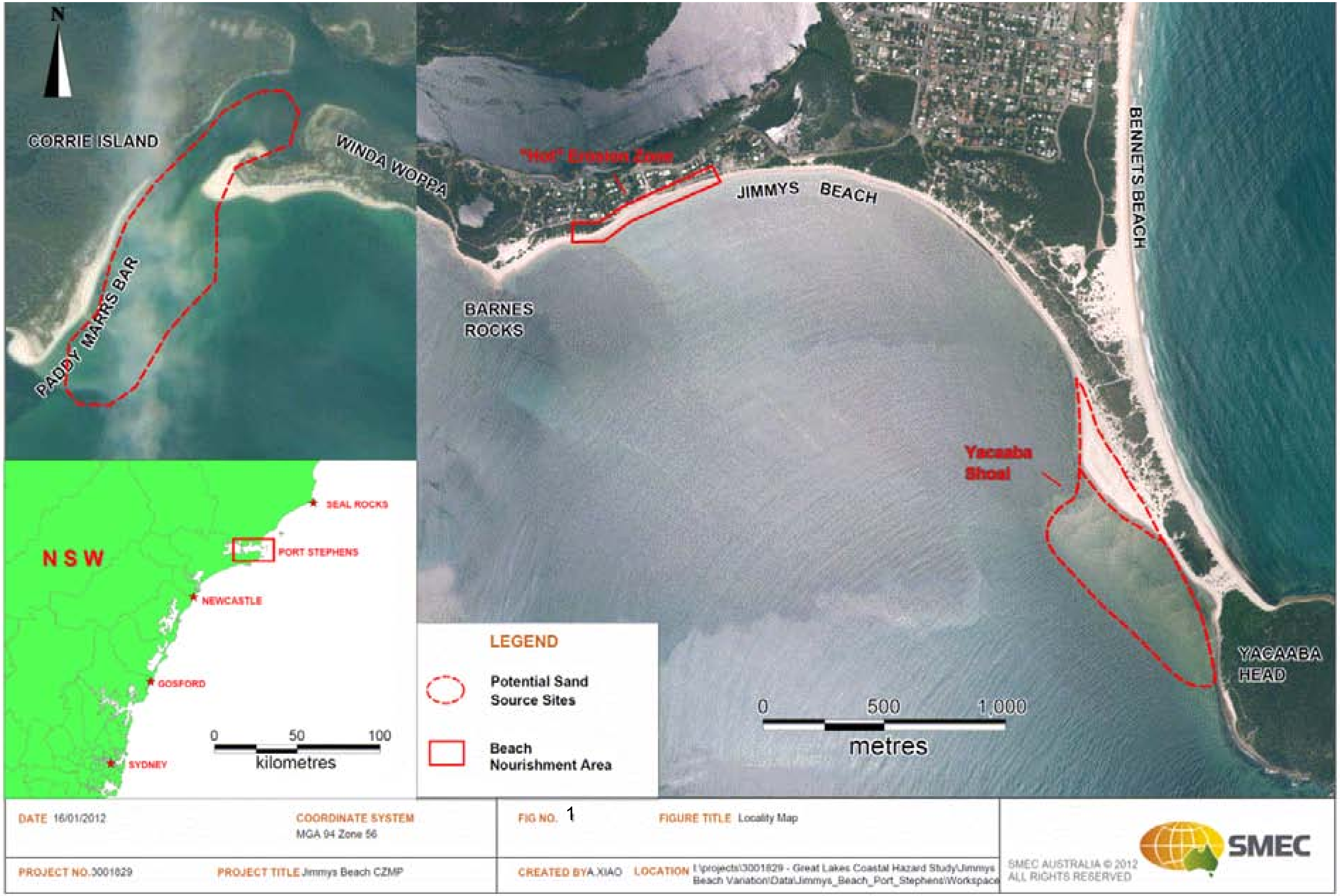
Figure 36: *Year 2100 Hazard Zones at Jimmy's Beach*

Figure 37 *Year 2060 Hazard Zones at Jimmy's Beach*

1 INTRODUCTION

Jimmy's Beach, located on the northern shoreline of Port Stephens, is a narrow reflective estuarine beach, parts of which have experienced recession during, at least, the past 30 years. Residential development behind Jimmy's Beach began in the 1960s (Watson, 2000), and has driven much of the concern about beach recession. Recession caused by an imbalance in the sediment budget has been managed by on-going beach nourishment to counteract the loss rates from this area. Beach nourishment sand was borrowed from the Corrie Island channel/Paddy Marrs Bar at the Myall River entrance between 1984 and 1998. However, in the mid 1990s it was suggested to dredge from the Yacaaba Shoal at the estuary entrance giving consideration to longshore sediment transport processes and sediment size. Figure 1 provides a locality map and shows the extent of the study area at Jimmy's Beach.

Jimmy's Beach has been the subject of several previous studies. It is understood that these studies need to be revised to take account of more recent survey and contemporary understanding of climate change, to derive updated coastal hazard mapping for Jimmy's Beach. This report documents this process and provides technical information regarding coastal processes and hazards at the site to inform the development of a Coastal Zone Management Plan (CZMP).


N
CORRIE ISLAND
WINDA WOPPA
PADDY MARRS BAR
"Hot" Erosion Zone
JIMMYS BEACH
BENNETTS BEACH
BARNES ROCKS
Yacaaba Shoal
YACAABA HEAD
N S W
SEAL ROCKS
PORT STEPHENS
NEWCASTLE
GOSFORD
SYDNEY
0 50 100
kilometres
LEGEND
Potential Sand Source Sites
Beach Nourishment Area
0 500 1,000
metres
DATE 16/01/2012
COORDINATE SYSTEM MGA 94 Zone 56
FIG NO. 1
FIGURE TITLE Locality Map
PROJECT NO.3001829
PROJECT TITLE Jimmys Beach CZMP
CREATED BY A.XIAO
LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\Jimmys Beach Variation\Data\Jimmys_Beach_Port_Stephens\Workspace
SMEC AUSTRALIA © 2012
ALL RIGHTS RESERVED
SMEC

2 SITE OBSERVATIONS AND DATA

2.1 Site Inspection

Site observations were made about Jimmy's Beach during a site visit that was conducted by SMEC's project team on 15 November 2011. Notes from that site visit are provided below.

2.1.1 Jimmy's Beach – Winda Woppa

The beach along The Boulevarde at Winda Woppa is relatively narrow (Figure 2a). Some beach nourishment has been undertaken along the section of the beach facing the road and the flat artificial berm is noticeable at the back of the beach (Figure 2b). The section of the beach located between Kururma Crescent and Guya Street is the most exposed to offshore swell. A buffer zone of 5 to 10 m has been fenced and vegetated along the road. Where there is a gap in the fencing and vegetation, some wind-blown sand was observed on the road (Figure 2c).

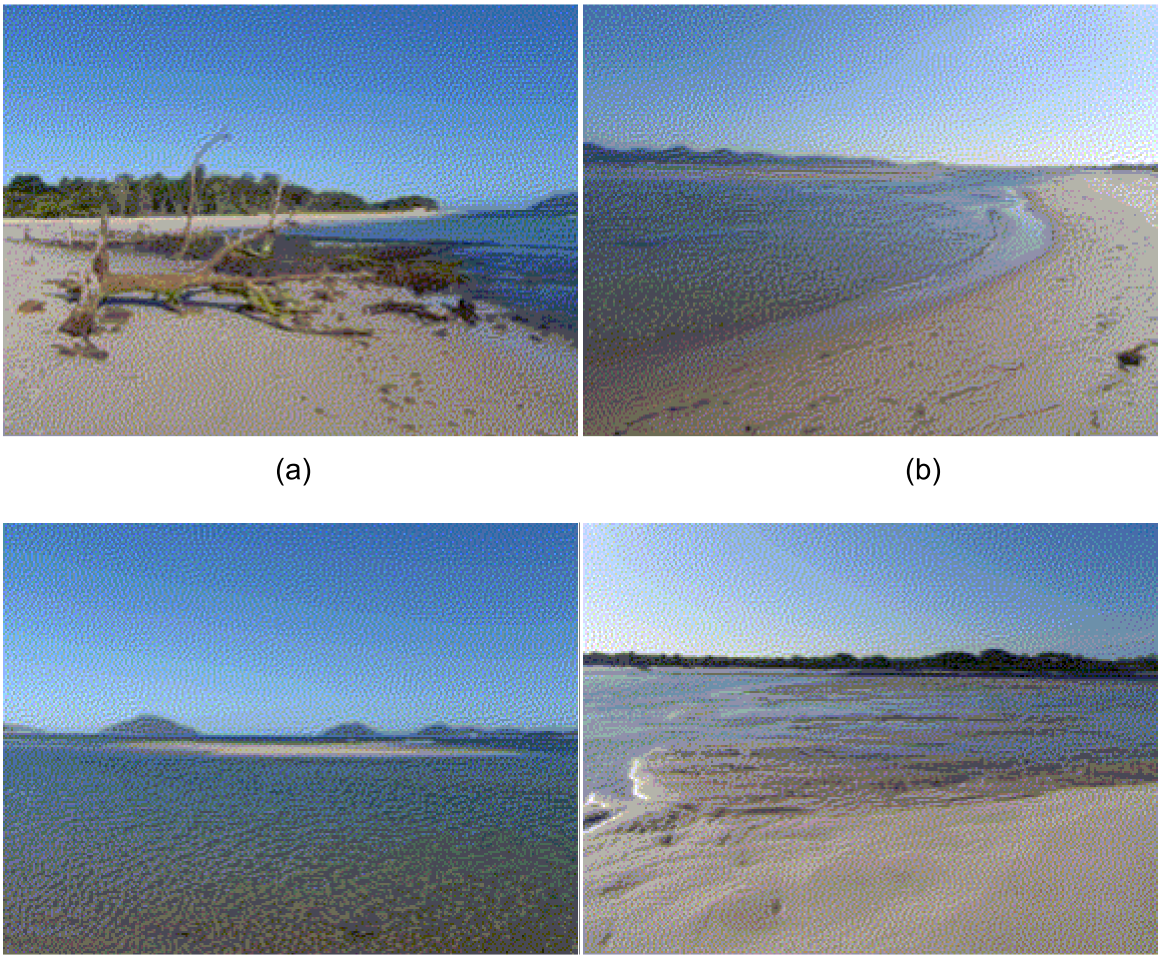
(a) (b)

(c)

Figure 2: (a) Beach along The Boulevarde looking west; (b) Sand nourishment at Jimmy's Beach; (c) Wind-blown sand on The Boulevarde

2.1.2 Barnes Rock to Carrie Island Entrance

The remnants of some large trees were observed half-way between Barnes Rock and the eastern Myall River entrance (Figure 3a), evidence of significant long-term recession of the coastline at this location. Some extensive shoals (Paddy Marrs Bar) are visible in front of (Figures 3b and 3c) and within (Figure 3d) the eastern entrance to Myall River. These shoals may potentially be used as sand sources for beach nourishment if the distribution of the local sediment matches Jimmy's Beach sand and if this sand is within the same littoral compartment as Jimmy's Beach.



(a) (b)

(c) (d)

Figure 3: (a) Remnant of large trees half-way between Myall River eastern entrance and Barnes Rock; (b) & (c) Extensive shoals located in front of Myall River eastern entrance; (d) Shoals located within Myall River eastern entrance

2.1.3 Yacaaba Barrier

Yacaaba Barrier has been the recent borrow location for beach nourishment occurring along Jimmy's Beach. The main source is the shoal that is located south of the discontinuity of the shoreline at Yacaaba Barrier (Figure 4a). Significant refraction occurs around the shoal as observed north of the shoal (Figure 4a). The planform of the shoreline is influenced by the complex wave processes caused by the offshore shoal.

A moderate scarp was observed at the back of the beach (Figure 4b).

(a) (b)

Figure 4: (a) Shoal south of Yacaaba Barrier;
(b) Erosion scarp at the back of Beach at Yacaaba Barrier

2.2 Sediment Sampling

The Public Works Department NSW (PWD) conducted sand sampling around the Myall River, the Paddy Marrs Bar and the south-east end of Jimmy's Beach, to examine suitable sand sources for the beach nourishment program in 1984. A total of 110 sand samples were taken both offshore and onshore to a maximum depth of 2 m below the surface. Sand samples were analysed for grain size using a settling tube. To determine the relative suitability of the sand source, the native system (Jimmy's Beach) was also sampled.

Wilson (1984) compared the empirical ratios between the native system and potential borrow materials and indicated that the most suitable material for sand nourishment at Jimmy's Beach would be the south-east end of Jimmy's Beach. Sand on the Paddy Marrs Bar was indicated to be finer than the native beach sand but still could be considered suitable. Sand in the Myall River was considered too fine inducing significant loss if used for nourishment.

PWD (1986) examined the sediment grain sizes throughout the Winda Woppa sand spit. A total of ten site samples were collected in water depths ranging from 0.65 m to 1.3 m. The survey indicated that the material would be suitable for sand nourishment of Jimmy's Beach.

In July 2000, sediment samples were taken by PWD from Winda Woppa, Jimmy's Beach, Yacaaba Isthmus and Bennetts Beach (refer to Figure 5) and in October 2002, sediment samples were taken by Jelliffe Environmental from Yacaaba Isthmus (refer to Figure 6). At each site, samples were collected by driving a polycarbonate pipe into the sand at the swash zone to 1 m, or refusal. Results of the averaged sample distribution are given in Table 1, Table 2 and Figure 7.

Sediments at Jimmy's Beach had an average median sand diameter D_{50} = 0.38 mm within a range of 0.30 mm to 0.40 mm. Samples from Yacaaba in both 2000 and 2002 were similar to sediments at Jimmy's Beach with an average D_{50} = 0.38 mm. However, the sediments collected in 2000 ranged between 0.30 mm and 0.55 mm which was coarser than the samples in 2002 which fell within a range of 0.36 mm to 0.42 mm. Sediments from Winda Woppa were finer with an average D_{50} = 0.35 mm and a range of 0.32 mm to 0.40 mm.

Table 1: Results of Sediment sampling undertaken in 2000 by PWD (grain size, mm)

Yacaaba	D5	D16	D50	D84	D95
Y1	0.170	0.220	0.350	0.460	0.700
Y2	0.200	0.295	0.400	0.600	1.000
Y3	0.155	0.200	0.340	0.520	1.400
Y4	0.155	0.195	0.320	0.460	0.870
Y5	0.160	0.215	0.340	0.420	0.720
Y6	0.290	0.355	0.470	0.700	1.100
Y7	0.150	0.260	0.390	0.530	0.700
Y8	0.180	0.310	0.390	0.530	0.760
Y9	0.180	0.370	0.540	0.870	1.100
Av	0.182	0.269	0.393	0.566	0.928
Jimmy	D5	D16	D50	D84	D95
J1	0.185	0.270	0.390	0.600	1.730
J2	0.185	0.280	0.390	0.570	1.190
J3	0.185	0.280	0.395	0.620	1.730
J4	0.175	0.245	0.370	0.510	0.750
J5	0.170	0.265	0.380	0.510	0.750
J6	0.165	0.215	0.350	0.490	0.700
J7	0.170	0.260	0.390	0.560	1.040
Av	0.176	0.259	0.381	0.551	1.127
Winda Woppa	D5	D16	D50	D84	D95
W1	0.160	0.240	0.350	0.415	0.510
W2	0.165	0.205	0.320	0.395	0.455
W3	0.170	0.220	0.340	0.415	0.505
W4	0.180	0.265	0.375	0.505	0.620
W5	0.165	0.240	0.350	0.525	0.755
W6	0.180	0.295	0.400	0.550	0.730
Av	0.170	0.244	0.356	0.468	0.596

Table 2: Results of Sediment sampling undertaken in 2002 by Jelliffe Environmental (grain size, mm)

Oct-02					
Yacaaba	D5	D16	D50	D84	D95
1	0.280	0.320	0.380	0.470	0.600
2a	0.265	0.315	0.370	0.445	0.530
2b	0.290	0.330	0.390	0.490	0.570
3	0.235	0.305	0.370	0.450	0.535
4	0.275	0.325	0.385	0.490	0.585
5	0.275	0.325	0.400	0.525	0.670
6	0.190	0.275	0.355	0.410	0.465
7	0.235	0.305	0.370	0.450	0.535
8	0.280	0.320	0.370	0.420	0.490
9	0.220	0.295	0.360	0.410	0.450
10	0.300	0.335	0.390	0.500	0.625
11	0.310	0.345	0.425	0.550	0.725
12	0.295	0.330	0.390	0.515	0.655
13	0.220	0.300	0.370	0.450	0.535
14	0.245	0.310	0.375	0.455	0.560
15	0.240	0.310	0.370	0.450	0.520
16	0.220	0.300	0.365	0.425	0.495
17	0.285	0.335	0.420	0.575	0.860
Av	0.259	0.316	0.381	0.471	0.578

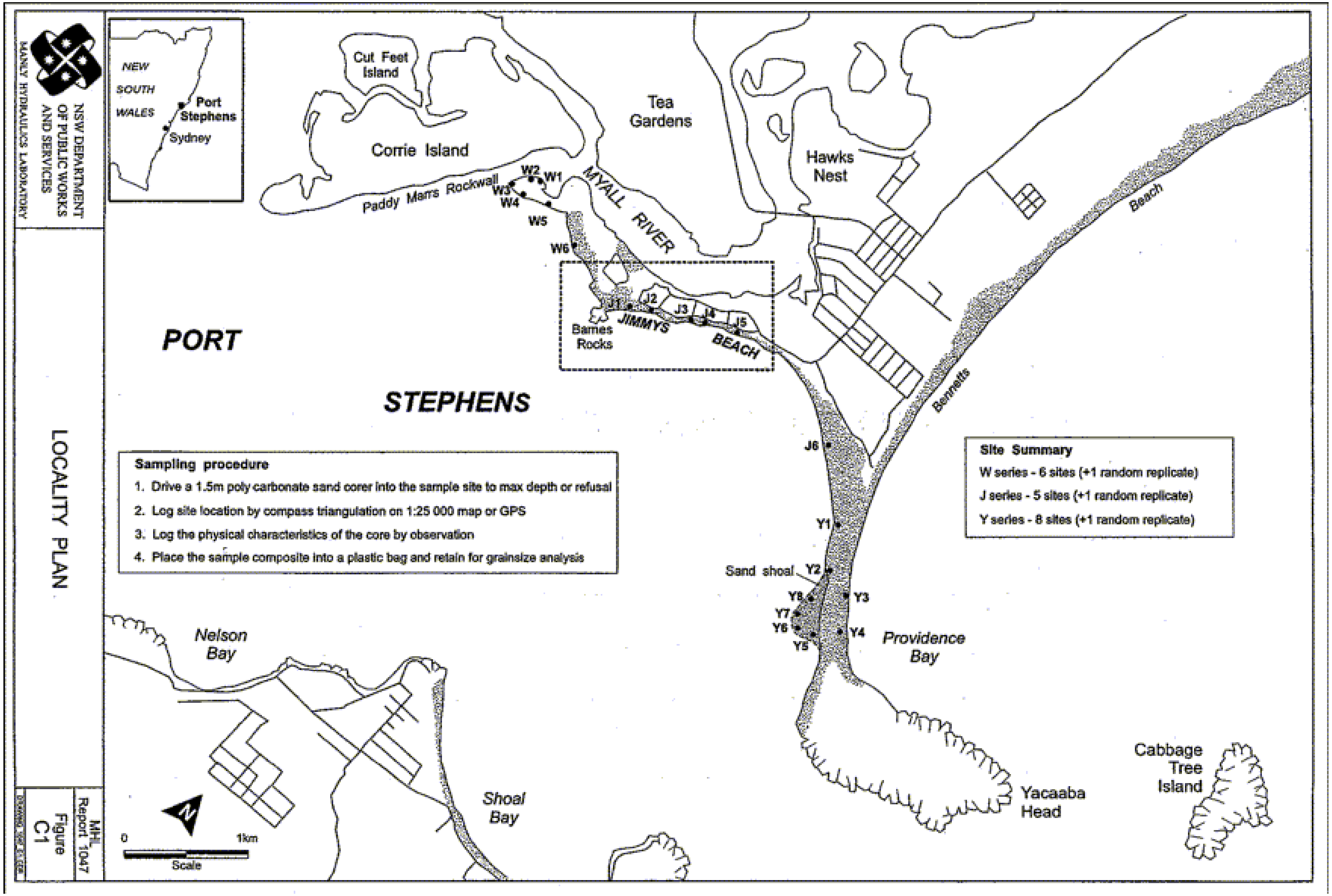


Figure 5: Sediment sample sites at Winda Woppa, Jimmy's Beach and Yacaaba Head (MHL, 2000)

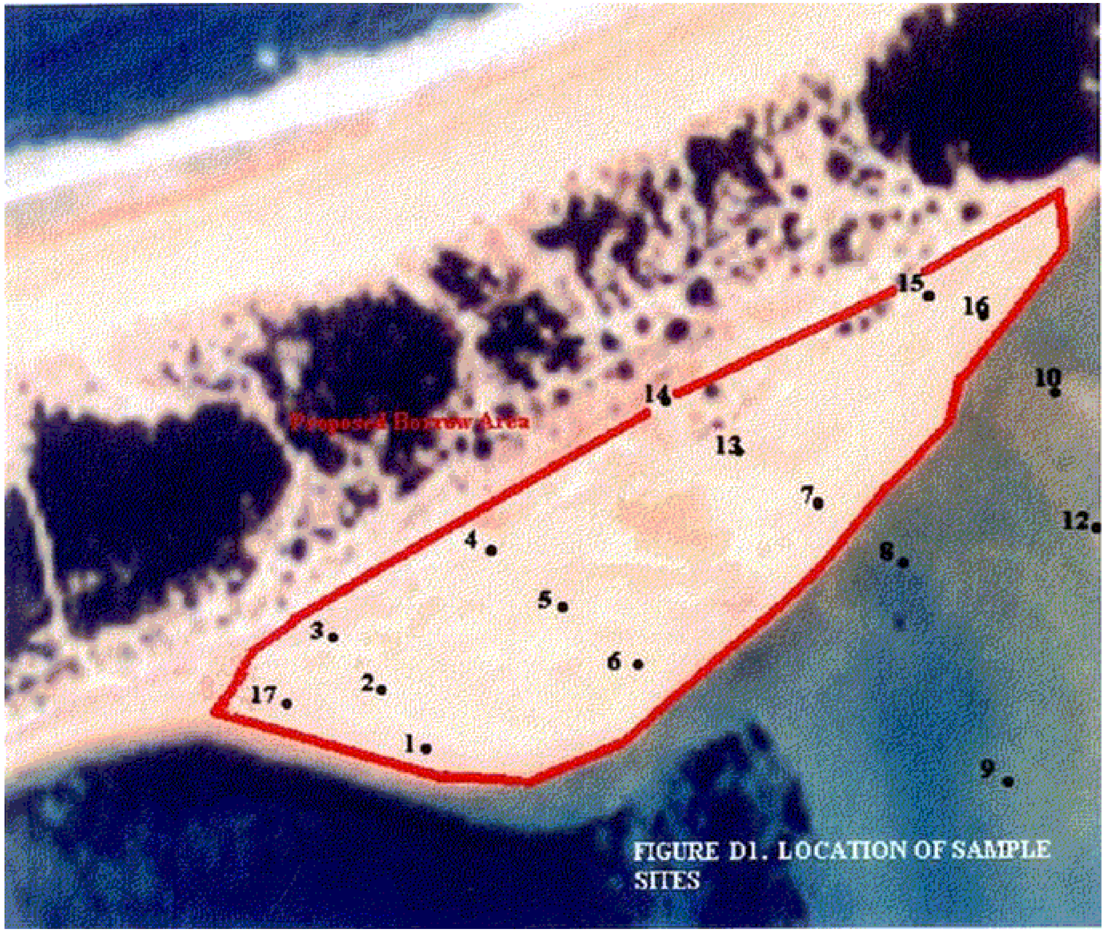


Figure 6: Sediment sample sites at Yacaaba Isthmus Borrow Area (Jelliffe Environmental Pty Ltd, 2003)

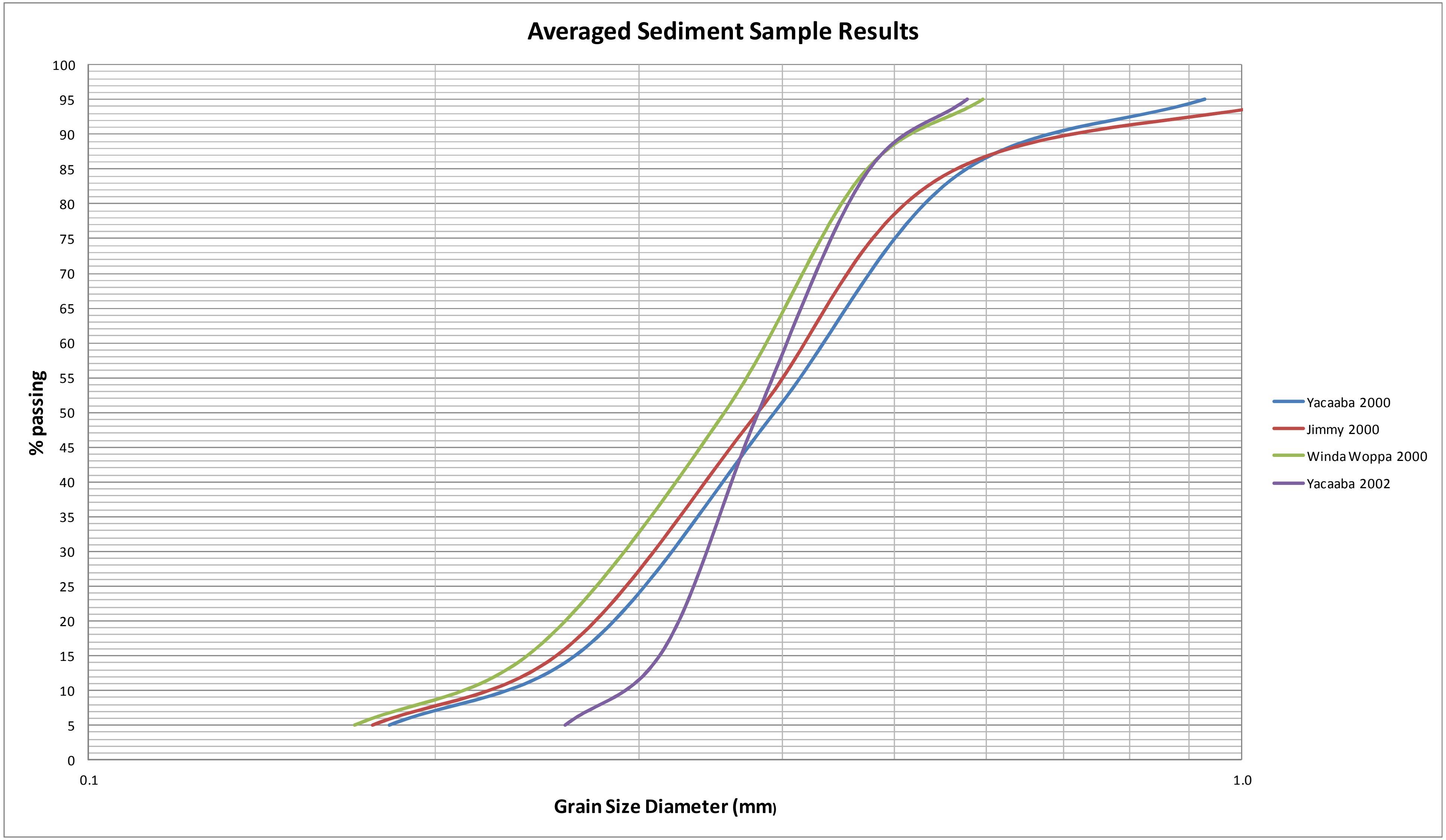


Figure 7: Sediment sieve analysis results at Winda Woppa, Jimmy's Beach and Yacaaba Isthmus between 2000 and 2002 (MHL, 2000 & Jelliffe Environmental Pty Ltd, 2003)

2.3 Historical Aerial Photograph Analysis

According to historical records, several areas in Port Stephens have been losing sediment for at least the last few decades: the flood-tide delta (FTD), Jimmy's Beach, Shoal Bay and Nelson Bay. Only two areas, a sandwave attached to Yacaaba Head and the sand spit associated with the tidal inlet at the Myall River entrance, have been identified as gaining sediment. Sand accumulation in the sandwave is linked to high-energy storm waves while the sand spit traps sediment that cannot bypass the river entrance (Vila-Concejo *et al*, 2011).

Winda Woppa Spit

According to Thom *et al*. (1992*) "Winda Woppa spit was initiated about 1820 and reached its maximum length about 1910; a storm in 1927 caused the breaching of the spit some 1300 m from its end, creating a sand bank that migrated landwards to form a beach on Corrie Island. Winda Woppa spit has continued to extend westwards ever since but engineering interventions in the area have not allowed extension further than its present position" (refer to Figure 8).*

Vila-Concejo *et al*. (2006) proposed a hypothesis that "*the spit and entrance to the Myall River represents a migrating tidal inlet system where the inlet opens somewhere along the Winda Woppa spit then migrates downdrift."*

From historical aerial photos by tracing the position of the shoreline in a GIS system (Figure 9), it was found by the Sydney University Geosciences Group that Winda Woppa shoreline is highly dynamic and geometrically unstable with a growing spit trapping large amounts of sediment over the long-term. Table 3 summarises the historical evolution of Winda Woppa Spit and Jimmy's Beach at Guya Street.

Table 3: Historical evolution of the Winda Woppa Spit and Jimmy's Beach at Guya Street (Vila-Concejo et al., 2010)

Time Frame	Winda Woppa Spit	Jimmy's Beach shoreline at Guyra Street
1972 – 1986	90 m westward extension	10 m retreat
1986 – 1993	100 m eastward extension	10 m retreat
1993 – 2001	60 m westward extension	small retreat
2001 – 2006	60 m westward extension	small retreat
2006 – 2008	140 m westward extension	10 m retreat
2008 – 2009	no obvious extension	small retreat
Total (including 1951)	~800 m westward extension	up to 95 m retreat

Yacaaba Sandwave

Forcing mechanisms and morphologic evolution of the northern shoreline sandwave were investigated by Vila-Concejo *et al.* (2011) based on the historical aerial photos from 1968 to 2008 and topographic measurements between March 2007 and April 2008. Decadal studies show that the sandwave was first observed in the 1980s and that there was a period up until mid 1990s where westward sediment transport caused sandwave formation and migration towards the inner parts of the estuary. Since then, the sandwave migration has slowed down, remaining relatively stable with some further migration between 2006 and 2008 (as shown in Figure 10).

There have been several artificial engineering interventions on Jimmy's Beach. Since the commencement of beach nourishment in 1984, there have been morphological changes in the vicinity of Yacaaba Isthmus and the offshore shoals. The first nourishment intervention was undertaken between March 1984 and 1998, with a total sand placement of 372,000 m^3 (from Corrie Channel) in the erosion zone of Jimmy's Beach. A nourishment program that involves dredging of sediment from the sandwave and placement on the erosion zone of Jimmy's Beach through buried pipeline was commenced in February 2008. Sand (volume of 50,000 m^3) was borrowed from the sandwave along Yacaaba Barrier on the eastern end of Jimmy's Beach as emergency nourishment material.

Previous studies (DPWS, 1999, 2000; PWD, 1985, 1987) state that beach nourishment on Jimmy's Beach enhanced eastward sediment transport by locally generated westerly waves causing progradation of the sandwave at Yacaaba Barrier. However, Vila-Concejo *et al.* (2010, 2011) postulated that sandwave accretion episodes occur under severe to extreme SE storms. Given the location of the sandwave at the entrance of the estuary, the orientation of the estuary and the dominant wave climate, it is inferred that the morphology and evolution of the sandwave is related to high angle waves propagating from the ocean and high angle waves locally generated by westerly winds. (Vila-Concejo *et al.* 2009).

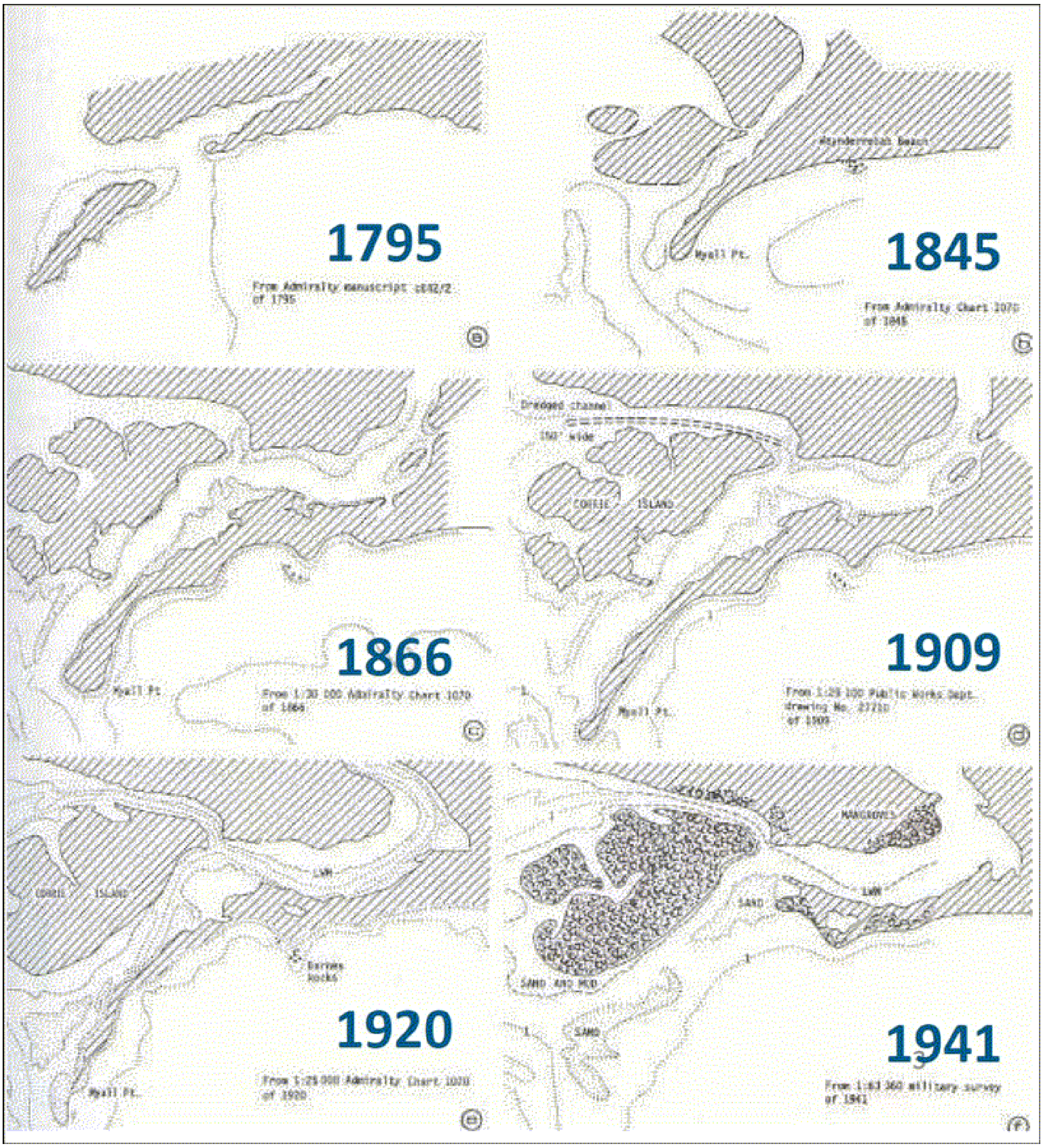


Figure 8: Evolution of Winda Woppa spit between 1795 and 1941 (Thom et al., 1992)

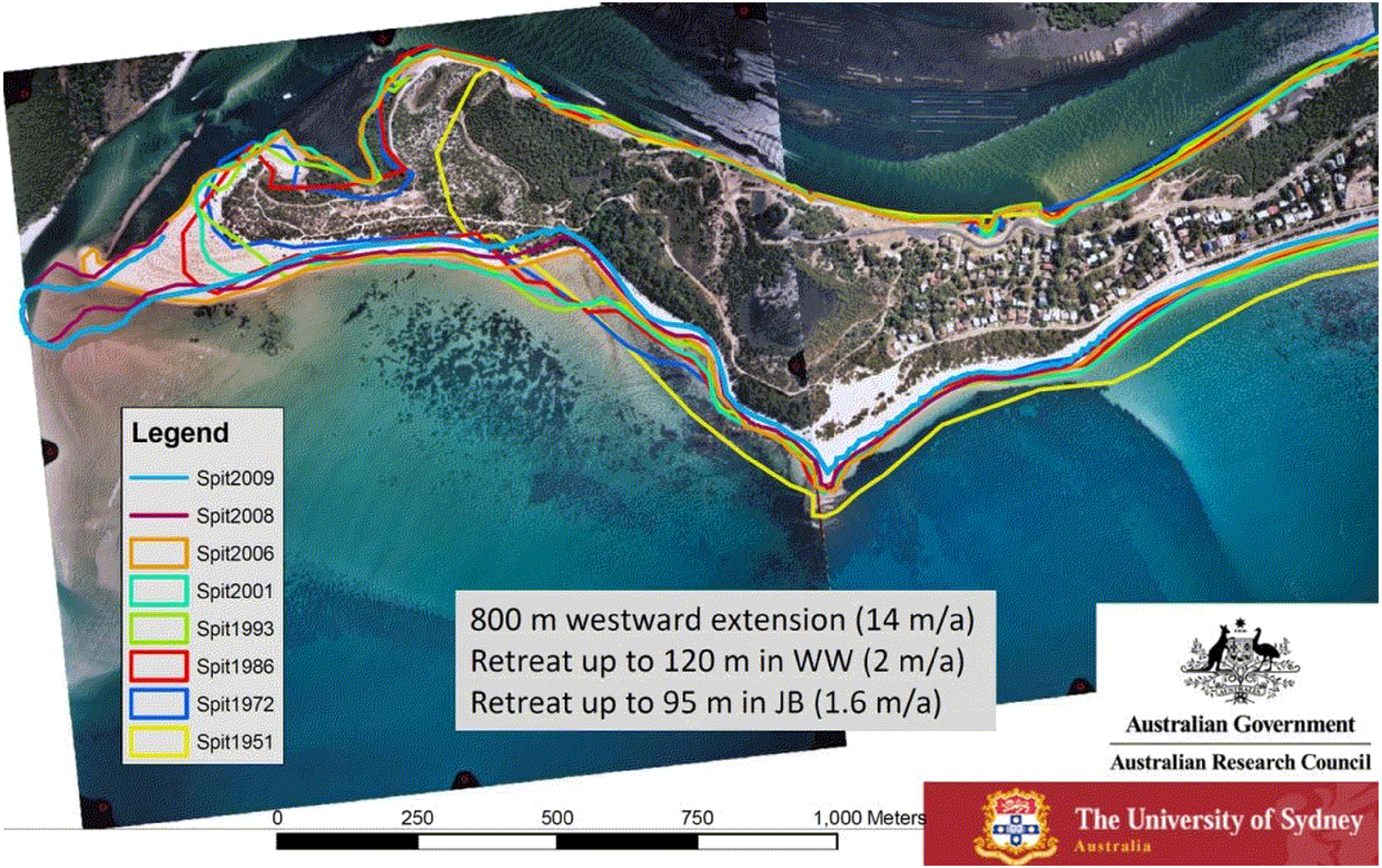


Figure 9: Winda Woppa shoreline long-term trend based on historical aerial photos (Sydney University Geoscience Research Project)

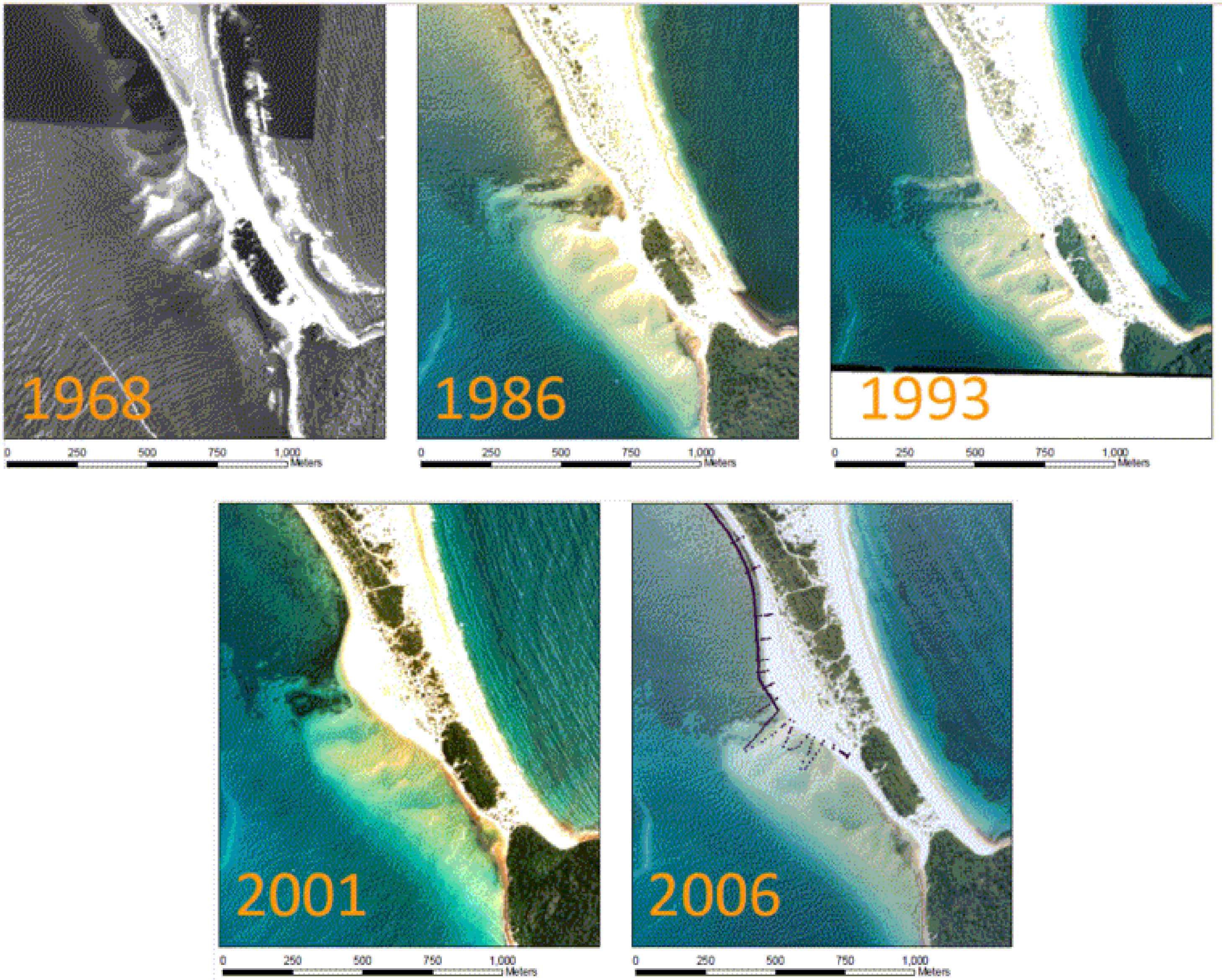


Figure 10: Historical evolution of a shore-attached sandwave along Yacaaba Head (Vila-Concejo et al., 2011)

2.4 Coastline Management at Jimmy's Beach

In response to coastline hazards at Jimmy's Beach, Council has implemented periodic beach nourishment since 1984. Beach nourishment has been the formal long term coastline management plan for Jimmy's Beach since 1990 having been the primary recommended management option in the previous Coastline Management Reviews (PWD 1987 and MHL 2001). Watson (1992) and Watson (2000) provide a summary of the effectiveness of this policy. In general Council are satisfied with the outcomes of the beach nourishment implemention to-date.

According to the Jimmy's Beach Emergency Action Sub Plan (GLC, 2011), nourishment of the beach has taken two principle forms, being staged and premeditated renourishment (primarily from Corrie Channel an adjacent tributary) and emergency sand placements. These emergency works were undertaken during storm events as a final measure to protect public infrastructure located between the foreshore and the residential development.

Beach nourishment at Jimmy's Beach has historically been undertaken, as required, to maintain a minimum setback from the dune crest to The Boulevarde. MHL (2000) recommended a minimum setback of 15 m. Emergency works (sand dumping) are commenced when the top of the erosion scarp is 10 m from the road reserve (GLC, 2011).

Between 1996 and 2008, nourishment was mainly in the form of emergency works with sand sourced from two terrestrial 'stockpiles'. The first, and most used, was the back dune system at the end of Beach Street known as 'Dead Mans'. The second less frequently used site, was at the western end of The Boulevarde. Both sites are now depleted of material and present little opportunity as a source for any future renourishment (GLC, 2011).

In February 2008, pipelines were buried along Jimmy's Beach to facilitate pumping of nourishment sand from the sandwave located at the Yacabba Isthmus to Jimmy's Beach East. This pipeline was to be used to provide a return to premeditated (or planned) nourishment. It is understood that these pipelines have remained in place and may be used to facilitate future nourishment.

Table 4 provides a summary of the known beach nourishment works undertaken, the information presented in this table has been sourced from the available literature. From the available information it is estimated that a total of just under 550,000 m^3 has been placed on Jimmy's Beach for a total estimated cost of approximately $3.2 million. The average rate of nourishment has been approximately 21,000 m^3/year, with an average cost of $5.80/ m^3.

It is noted that the estimates of nourishment volumes presented in Table 1 are based on a range of sources of variable reliability. Actual nourishment estimates are difficult to determine particularly given the emergency dumping nature of much of the nourishment works. As such, the annual rate of nourishment of 21,000 m^3/yr is expected to be a best estimate with considerable uncertainty.

Table 4: Summary of known nourishment volume estimates at Jimmy's Beach

Year	Volume (m³)	General Nourishment Location	Sand Source	Cost ($/m³)	Source of Information
1984	43,000	-	Paddy Mars Bar	$ 5.80	PBP 2005
1987	20,000	Vicinity of Guya Street	Paddy Mars Bar	$ 6.30	PBP 2005
1988	80,000	Between Fisherman's Walk and Gemalla Street	Western Corrie Island Channel	$ 6.00	Watson 1997
1992	48,000	Between Kururma Crescent and Gemalla Street	Northern Corrie Island Channel	$ 8.00	PBP 2005
1995	69,000	Between Kururma Crescent and Gemalla Street	Paddy Mars Bar	$ 4.60	PBP 2005
1998	100,000	N/A	Western Corrie Island Channel	$ 4.30	PBP 2005
1998 - 2008	100,000[1]	Emergency nourishment area (Jimmy's Beach East erosion hot-spot)	Terrestrial stockpiles mainly 'Dead Mans' area	N/A	GLC 2011
2007	6,000	Emergency nourishment area (Jimmy's Beach East erosion hot-spot)	Na	N/A	Vila-Concejo *et al* (2008)
2008	50,000	N/A	Sandwave adjacent to Yacabba Head. Permanent pipeline used	N/A	Vila-Concejo *et al* (2010)
2009	10,000	N/A	Unknown	N/A	Vila-Concejo *et al* (2010)
2010	5,000[2]	Jimmy's Beach East nourishment area	Corrie Channel	N/A	Tattersalls Lander
2010	23,000[3]	Jimmy's Beach East nourishment area	Yacabba sandwave	N/A	Tattersalls Lander

[1] This estimate appears to be based on the number of emergency nourishment interventions and the estimated volume of a typical emergency intervention it is subject to considerable uncertainty. It is considered that future studies should seek more reliable information on these nourishment volumes.
[2] This estimate is based on the volume of the dump truck hoppers used in the works and the number of trips made.
[3] This estimate (rounded up from 22,982m³) was provided by Rob King (Principal) from the dredging contract (National Dredging Services) who undertook the 2010 works (pres. comms. Bob Lander).

3 DATA COLLECTION AND REVIEW

A number of documents prepared in recent years describe coastal processes and coastal management actions at Jimmy's Beach. This section provides a summary of relevant aspects of these documents related to the understanding of coastal erosion and sediment transport within the study area.

3.1 Review of Past Studies

3.1.1 Gordon A.D. (1982)

An assessment of Beach Processes in the Hawks Nest Region. Coastal Engineering Branch Working Paper, Public Works Department New South Wales, November.

Gordon (1982) presents a conceptual coastal sediment model for three inter-related systems: the ocean beach (Bennetts Beach), the estuary beach (Jimmy's Beach) and the aeolian processes of the Yacaaba Isthmus to understand how each discrete process system provides feedback to the other systems. A summary of key conclusions are outlined below:

- The system, especially the areas surrounding Jimmy's Beach and the Myall River entrance, is in a state of disequilibrium, due to the fickle behaviour of the Myall entrance and is in a phase of readjustment. The dominance of any entrance and entrance switching/modification behaviour is event (storm) related.

- A combination of swell and sea factors point to a dominant westerly sea condition due to the fetch of Port Stephens. The westerly wind induced high occurrence seas dominate the lower occurrence but higher instantaneous energy swell events. However, the south-easterly sea/swell entering the Port may have a significant impact on the littoral processes of Jimmy's Beach.

- Tidal currents would not significantly influence beach processes at Jimmy's Beach. While flood flows from the Myall River may modify the quasi-normal current patterns, the impact of these events on Jimmy's Beach littoral system is likely to be small, infrequent and of short duration.

- Although short term fluctuations in beach width and storm induced recession of the erosion scarp is the case at Jimmy's Beach, the long-term shoreline realignment will be dominated by the westerly seas which result in a west to east movement of sand on Jimmy's Beach and the development of a sand sink immediately west of Yacaaba Head. South-easterly waves would also reverse sand movement direction to deposit sands onto Paddy Marrs Bar to depth without re-entraining by westerly winds. Jimmy's Beach can conceivably lose sand in both directions.

- It is estimated that there is about 10,000-15,000 m^3/yr of easterly drift conveying sand from Jimmy's Beach to Yacaaba headland.

3.1.2 Public Works Department (1985 – 1987)

Jimmy's Beach Erosion Study, Report No. 85042

PWD (1987) produced a detailed description of the physiographic setting, the geomorphology and land use changes at Myall Point and Corrie Islands, Yacaaba Isthmus and Winda Woppa Spit by examining historical hydrographic charts. In addition to reviewing the historical data, a detailed photogrammetric analysis (1951, 1965, 1968, 1975, 1983 and 1984) was conducted to examine coastal processes. The environmental factors including the wind, waves and currents were measured to develop a numerical sediment transport model for sand budget estimation. A summary of key conclusions are outlined below:

- The periods of wind waves were measured between 1.5 and 2.5 seconds with a predominant wave direction from SSW. A relationship between wind wave heights H_s at Jimmy's Beach and mean hourly wind velocity for various wind directions was developed;
- Refraction effects play an important role in turning the offshore swell into the shallower water and focussing wave energy onto the foreshore areas, such as Jimmy's Beach fronting area near Guyra Street. A relationship between extreme storm return events and total nearshore significant wave height H_s (wind waves superimposed on ocean swell waves) at Jimmy's Beach was developed;
- Design water levels were determined at the beach of 2.6 m AHD (tidal level 1.1 m AHD, storm surge 0.5 m, wind setup 0.3 m and wave setup 0.7 m) and several hundred metres off the beach of 1.8 m AHD (tidal level 1.1 m AHD, storm surge 0.5 m, wind setup 0.2 m and wave setup 0.0 m);
- Current data was collected for the near bed currents (0.3 m above bed), near surface currents over flood and ebb tide cycles and surf zone longshore currents. Surf zone currents are alongshore and primarily wind induced. Depth averaged current velocities in the surf zone at Jimmy's Beach for different wind conditions were provided in the report;
- Sand erosion and foreshore recession was estimated by measuring bed level changes and a temporary groyne. Long term recession at Jimmy's Beach was reported as been a maximum near Guyra Street with an average long-term recession rate of 1.1 m/yr. The average rate of removal of sand from Jimmy's Beach between Barnes Rocks and Tuloa Avenue was calculated at about 8,000 m^3/yr from west to east, including 5,000 m^3 from fair weather and 3,000 m^3 from storm erosion.

3.1.3 Watson P. (1997)

Port Stephens Nourishment Projects Evaluation, Monitoring & Sustainability, 13th Australasian Coastal Conference Proceedings 1997

Watson (1997) provided more recent survey data along Jimmy's Beach between November 1991 and May 1997 to monitor both the January 1992 and August to November 1995 beach nourishment exercises. It was shown that very high loss rates of nourishment sand about 17,500 m^3/yr (after readjustment) was observed with minor increases in sand reserves east of the nourished portion of the beach and negligible variation in sand reserves west of the nourished area.

Detailed consideration of photogrammetric data for the period 1963 to 1997 was undertaken by DLWC to assess historical sand loss rates at Jimmy's Beach. This indicated an increase in accumulation rate since commencement of nourishment of about 11,900 m^3/yr along Yacaaba Isthmus.

3.1.4 MHL (2000 - 2002)

Jimmy's Beach Coastline Management Review – Conceptual Sediment Budget and Beach Nourishment Practices, Stage 1 and 2 (MHL1041, April 2000)

This paper reappraised the coastal processes and coastline hazards at Jimmy's Beach. A detailed data review was performed to understand pre- and post-nourishment loss rates from Jimmy's Beach and to estimate a sand budget for the Jimmy's Beach/ Winda Woppa compartment including the Corrie Island eastern channel, the southern channel of Port Stephens, Yacaaba Headland and Yacaaba Isthums. A long-term landward recession of the dune scarp of 0.4 m/yr was estimated from pre-nourishment photogrammetric data. The storm bite demand was reported as some 70 m^3/m length of beach. A 50-year coastal hazard zone was defined by a combination of long-term recession, storm bite and sea level rise effect. Under this assessment, all foreshore property structures between Kurkurma and Gemalla Streets and two lots east of Gemalla Street would be directly affected by coastal erosion.

It was found that following placement (dredging from Corrie Island eastern channel and the Paddy Marrs Bar) of 47,000 m^3 in Jan 1992 and 67,000 m^3 in August 1995 on the beach face at Jimmy's Beach, the sediment loss rates increased substantially compared to the historical rate of 8,000 m^3/yr and the sand shoal grew proportionally on the western side of Yacaaba Head. The beach area fronting The Boulevarde is estimated to contribute approximately 20,000 m^3/yr to the alongshore sand budget as a result of beach nourishment practices. The reason for high recession of the artificially nourished beachfront was thought to be due to either; the placement of sands on the active profile, or the use of finer material size than the native beach material.

Nourishment practices to that date had been constrained by source selection and the need to consider increases in Jimmy's Beach sediment transport rates following nourishment. Sand dredged from Paddy Marrs Bar and placement to the east of Jimmy's Beach was reported to possibly cause sediment transport back to Yacaaba Isthums and a build-up of offshore 'focusing' shoals which caused swell focus and higher erosion rates surrounding Guyra Street.

3.1.5 Sydney University, School of Geosciences (2007 – 2010)

General Overview of University of Sydney University Work

Between 2005 and 2010, a detailed investigation of estuarine processes was undertaken at Port Stephens as part of an Australian Research Council (ARC) funded project. This research project has resulted in a number of peer reviewed papers (Vila-Concejo *et al*, 2010, Pereira *et al*, 2011 and Vila-Concejo *et al*, 2009). In general, these studies have used a wide range of analysis methods including wave and current monitoring in the surf zone. The results of these investigations lead researchers to state that:

- Sediment transport in the entire lower estuary to be mostly westward directed and more related to wave propagation into the estuary than tidal circulation.
- According to Vila-Concejo *et al* (2010) the northern shoreline can be divided into four contiguous zones (east to west along the foreshore) with regard to long-term net sediment transport: 1) an area with a shoreline attached sandwave near the entrance that accumulates large volumes of sediment (from the south-east); 2) a relatively stable area between the sandwave and an erosion zone; 3) at Jimmy's Beach undergoing shoreline retreat; and 4) the western end of the system comprised of a mobile sand spit, Winda Woppa, that has been prograding westward since at least 1951.
- A westward net transport was concluded based on results that showed that the sandwave received sediment from the south east and that 'while there is no clear direction of longshore transport in the erosion zone, the fact that Winda Woppa is extending rapidly to the west seems to indicate an overall westward transport along the northern shoreline'.
- Vila-Concejo *et al* (2011) states that propagation of SE waves into the estuary is the dominant forcing mechanism for sediment transport and drives westward transport. This is in direct contrast to all previous engineering studies that stated the importance of eastward sediment transport caused by locally generated wind waves.

A flood tide delta which has been propagating landward with deposition at the landward end and erosion of the seaward end was not thought to play a significant role in shoreline processes.

More detail on the specific papers is provided below.

Estuarine beach evolution in relation to a flood-tide delta (Vila-Concejo et al., 2011)

A detailed estuarine processes investigation with the aim of investigating the causes of shoreline erosion was undertaken from March 2007 to March 2010, including topography, bathymetry and hydrodynamic variables measurement between shorelines and the flood-tide delta. Results show that high energy swell waves (SE storms) dominate the overall estuary system undergoing westward sediment transport and floods dominate the outer estuary including areas near the estuary entrance and near the ebb channel.

Alongshore currents measured during the study period showed that both westerly wind waves and SE swell waves caused westward currents with a large percentage of sediment entrainment along Yacaaba Barrier. The Jimmy's Beach erosion zone was dominated by SE incident waves while the alongshore current direction was not clear. There is no prevailing current around Winda Woppa to induce sediment movement.

Volumetric changes at the erosion zone of Jimmy's Beach and Yacaaba Barrier including several engineering interventions during 2007 – 2010 were calculated using detailed bathymetric measurements. Before the largest intervention undertaken in 2008, a loss of 53,000m^3 from the beach and a gain of 8,000 m^3 was found at Yacaaba Barrier. Following a volume of 50,000m^3 of sand transported from Yacaaba Barrier to Jimmy's Beach, volumetric calculations showed that between 2007 and March 2009, a net loss of 33,000m^3 from the beach and a net rebuild of 22,000m^3 at the sandwave occurred.

It was pointed out that there is no evidence supporting the former studies about westerly wind waves dominating longshore sediment transport from west to east. It was mentioned that the sandwave receives sediment from the southeast transverse bars rather than from the erosion zone on Jimmy's Beach and no clear longshore sediment transport direction was found. The whole system, especially the Winda Woppa spit and southern shoreline indicates a westward transport direction.

Influence of high-energy conditions on beach changes in tide-dominated (Amazon, Brazil) and wave-dominated (NSW, Australia) coastal environments (Pereira et al., 2011)

The aim of this paper was to compare two different wave-tide system evolutions between tide-dominated Sao Luis' Beach on the Amazon coast and wave-dominated Jimmy's Beach on the SE coast of Australia. The sources of sediment in the Port Stephens estuary are linked to the dynamics of the outer sections of the flood-tide delta which transported "new" sediments into the estuary by severe and extreme storms. High-frequency (low energy) storms cause acute erosion at Jimmy's Beach while low-frequency (high energy) storms cause sediment accumulation in the outer parts of the beach, near the estuary entrance.

Estuarine shoreline processes: a dynamic low energy system (Vila-Concejo et al., 2010)

Over 50 aerial photographs taken since 1951 were rectified and analysed to establish medium to long-term trends of shoreline evolution. The northern shoreline of the Port Stephens estuary was divided into four contiguous zones with regard to sediment transport. Beginning from the estuary entrance these are:

1) an area with a shoreline-attached sandwave (Yacaaba Head) that migrates westward with several cycles of formation/destruction;

2) a relatively stable area between the sandwave and an erosion zone;

3) an erosion zone undergoing 50-80 m shoreline retreat (Jimmy's Beach) which suggested a 1 m/yr shoreline retreat rate; and

4) a sand spit (Winda Woppa) that is extending ~800 m westward and 50-100 m retreat in some sections.

Long term accretion was only measured in section 1 and section 4 which both indicate westward sediment transport along the northern shorelines of Port Stephens. During the study period (March 2007 – Feb 2010), a net annual erosion of 42,000 m^3 on the northern shorelines was estimated and maximum erosion occurred in May 2007 subsequently followed by emergency nourishment of 6,000 m^3. The storm cluster in 2007 caused extensive damage to the study region and transported sand to the sandwave area.

3.1.6 WBM-BMT (2011)

Sediment and Hydrodynamic Assessment of the Lower Myall River Estuary and Preparation of Management Recommendations (2011)

In a recent engineering investigation into the shoaling of the eastern Myall River entrance channel, WBM (2011) concluded that 'shoaling of the Eastern Channel is unlikely to be linked to erosion on Jimmy's Beach'. This conclusion was reached on the basis of longshore transport calculations and comparison of topographic and bathymetric surveys (see Appendix D, WBM, 2011) to infer that sediment inputs causing the elongation of the spit and shoaling of the Eastern Channel could be primarily attributed to erosion of the shoreline along Winda Woppa peninsula west of Barnes Rock. And thus by deduction, that westward sediment transport around Barnes Rock (i.e. from Jimmy's Beach) is not a significantly factor in the elongation of Winda Woppa spit.

3.2 Coastal Processes Data

3.2.1 Wave Climate

An important step in understanding the coastal processes at Jimmy's Beach is to develop an understanding of the wave climate.

Port Stephens is a drowned river valley microtidal estuary located on a wave dominated coast. Local wave climate is comprised of both ocean swell waves and local wind waves. The ocean swell waves entering Port Stephens between Yacaaba Head and Tomaree Head undergo diffraction, reflecting, refracting, shoaling and breaking before arriving at Jimmy's Beach. It is only waves from the ESE to S direction that are able to penetrate into Port Stephens without significant loss of energy (PWD,1987). However, the predominant wave climate offshore of NSW is from this direction, particularly for storm waves (Lord and Kulmar, 2005).

To examine this understanding of the wave climate in sufficient detail for longshore sediment transport analysis, a wave transformation model was set up, with detailed bathymetry provided by a combination of survey data at the site and bathymetric soundings from Admiralty Charts.

3.2.1.1 SWAN Model

The wave refraction predictions were obtained by using the numerical model SWAN (acronym for **S**imulating **WA**ves **N**earshore – Cycle III version 40.11). The refraction model SWAN was executed within the Delft3D-WAVE environment which provides a convenient interface for pre- and post-processing of the results.

The SWAN model can account for refractive propagation and shoaling due to spatial variations in bottom topography and currents. The model also represents the process of wave generation by wind, dissipation by white capping, bottom friction, obstacles, depth-induced wave breaking and non-linear wave-wave interactions (quadruplets and triads) explicitly with state-of-art formulations. Wave blocking and reflections by opposing currents is also represented in the model. Diffraction is not modelled in SWAN, so SWAN cannot be used in areas where variations in wave height are large within a horizontal scale of a few wavelengths.

Configuration data to set up the wave transformation model include:

- Bathymetry
- Shoreline
- Bottom friction characteristics
- Structures
- Sediment characteristics

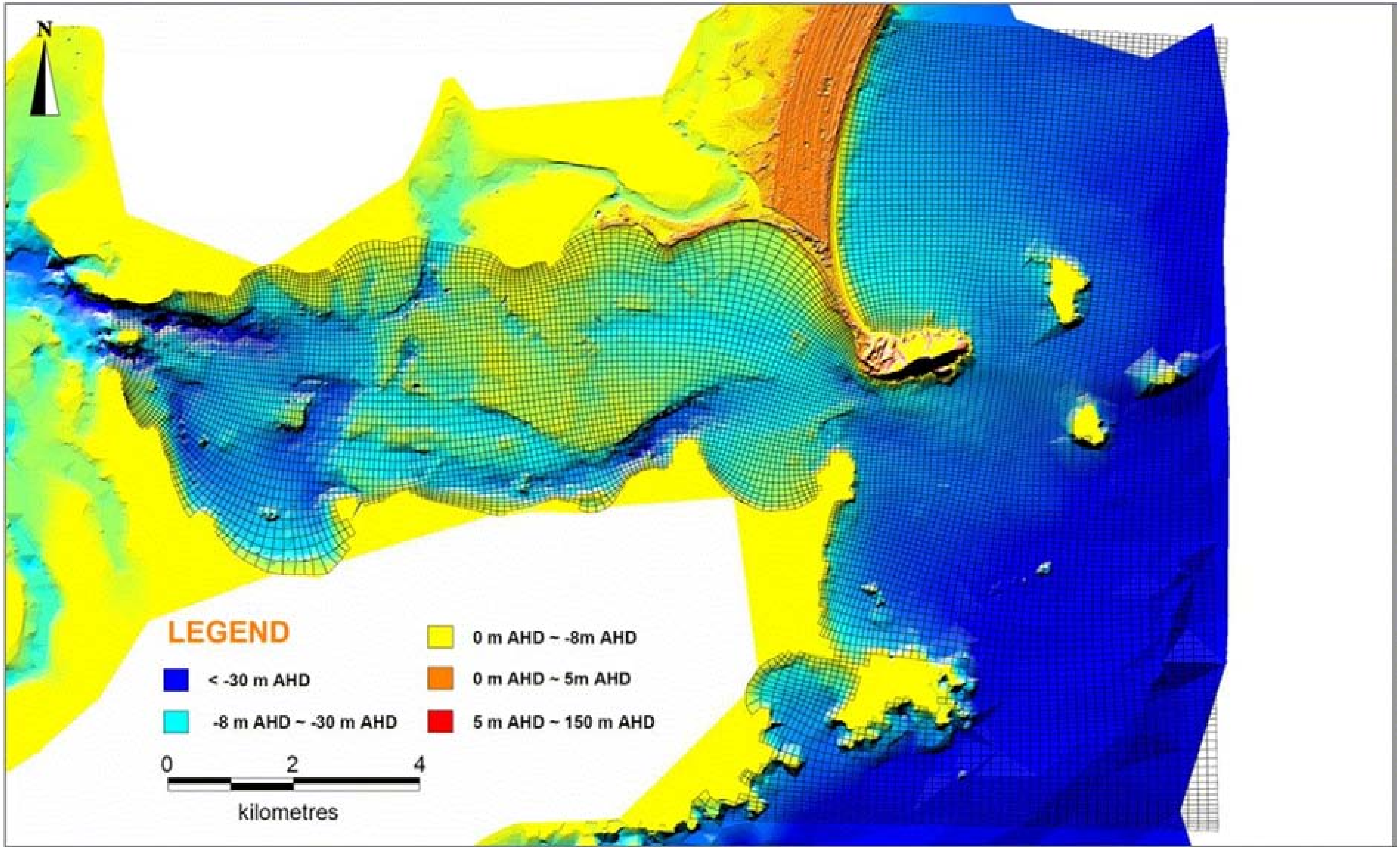
Forcing data to simulate wave transformation model include:

- Wave radiation stress data
- Wind data
- Offshore tide (surge) data

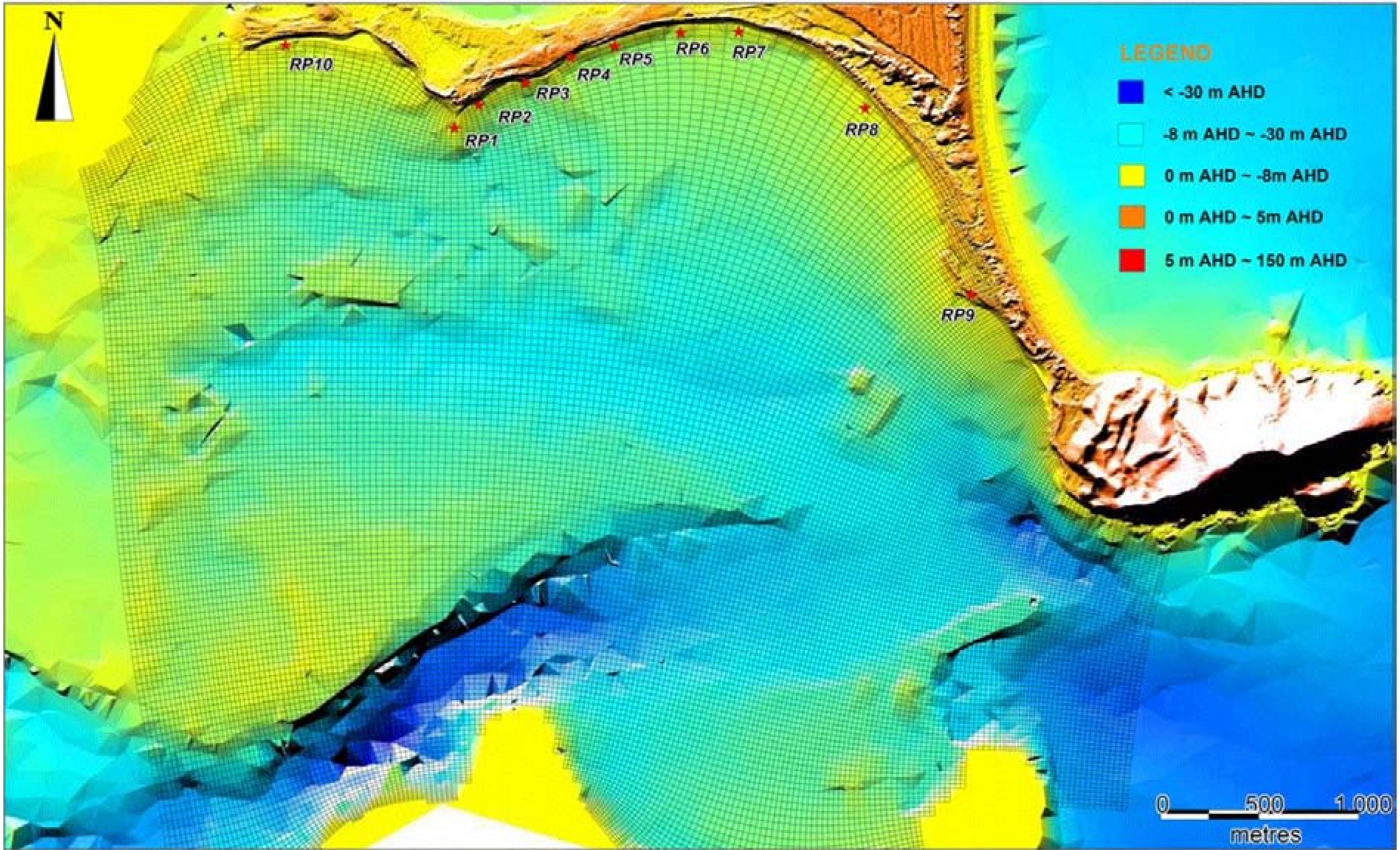
Bathymetric data for the model comprised:

- digitised soundings on a 1 km grid as provided by Geoscience Australia (Petkovic & Buchanan, 2002)
- digitised soundings and contours from the Admiralty Chart Aus 209 (published 5/9/77, edition 27/4/2001), Australia East Coast – New SouthWales – Port Stephens, scale1:25000
- digitised soundings and contours from Hydrographic Survey in 1969 by Department of Public Works NSW, Port Stephens, scale 1:12000

The domain of the wave transformation model extended from Bennetts Beach in the north to One Mile Beach in the south, extending some 5 km offshore into water depths in excess of 50 m (Figure 11 and Figure 12). This region was schematised onto a curvilinear, boundary fitted orthogonal grid derived from the detailed soundings and contours that has the advantage of a better representation of complex coastline configuration. Compared to the traditional rectilinear grid arrangement, the number of grid points to cover the same model domain can be reduced while maintaining a high resolution for the area of interest. The lateral boundaries were also located far from the region of interest to prevent inaccuracies in boundary conditions affecting the calculations in the area of interest.



DATE 18/01/2012	COORDINATE SYSTEM MGA 94 Zone 56	FIG NO. 11	FIGURE TITLE Digital Terrain Model (DTM) from bathymetry and ALS data Delft-3D wave transformation model grids
PROJECT NO. 3001829	PROJECT TITLE Jimmys Beach CZMP	CREATED BY A.XIAO	LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\Jimmys Beach Variation\Data\Jimmys_Beach_Port_Stephens\Workspace



DATE 18/01/2012	COORDINATE SYSTEM MGA 94 Zone 56	FIG NO. 12	FIGURE TITLE Delft-3D wave transformation smaller model grids for Jimmys Beach and the locations of Reference Points for Longshore Sediment Transport analysis	SMEC
PROJECT NO.3001829	PROJECT TITLE Jimmys Beach CZMP	CREATED BY A.XIAO	LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\Jimmys Beach Variation\Data\Jimmys_Beach_Port_Stephens\Workspace	SMEC AUSTRALIA © 2012 ALL RIGHTS RESERVED

3.2.1.2 Offshore wave climate

Summary wave statistics are available from the Manly Hydraulics Laboratory (*e.g.*, as published in Lord and Kulmar, 2000). MHL (1997) compared wave data from the Sydney buoy with measurements at Jimmy's Beach in Port Stephens, and found the Sydney data to be sufficiently similar to represent the offshore wave climate at Port Stephens. The offshore wave data show that the predominant swell wave direction is south-southeast (SSE, 157.5°TN) with over 70% of swell wave occurrences directed from the SE quadrant. The average deep water *significant* wave height (Hs), as measured at Sydney, is around 1.5 m (Figure 13) and the average wave period is around 10 s. Analysis of storms recorded at Sydney has provided wave height/duration data for various annual recurrence intervals, which are presented in Figure 14.

The transformation of offshore swell waves to the area of Jimmy's Beach was undertaken to get an indication of the range of wave conditions that are most likely at the site. The model was forced by average offshore wave conditions, which are defined at the offshore boundary with a wave height (Hs) of 1.5 m, a wave period of 10 seconds and a wave direction (φ) in a range between 67.5°TN (ENE) and 180°TN(S).

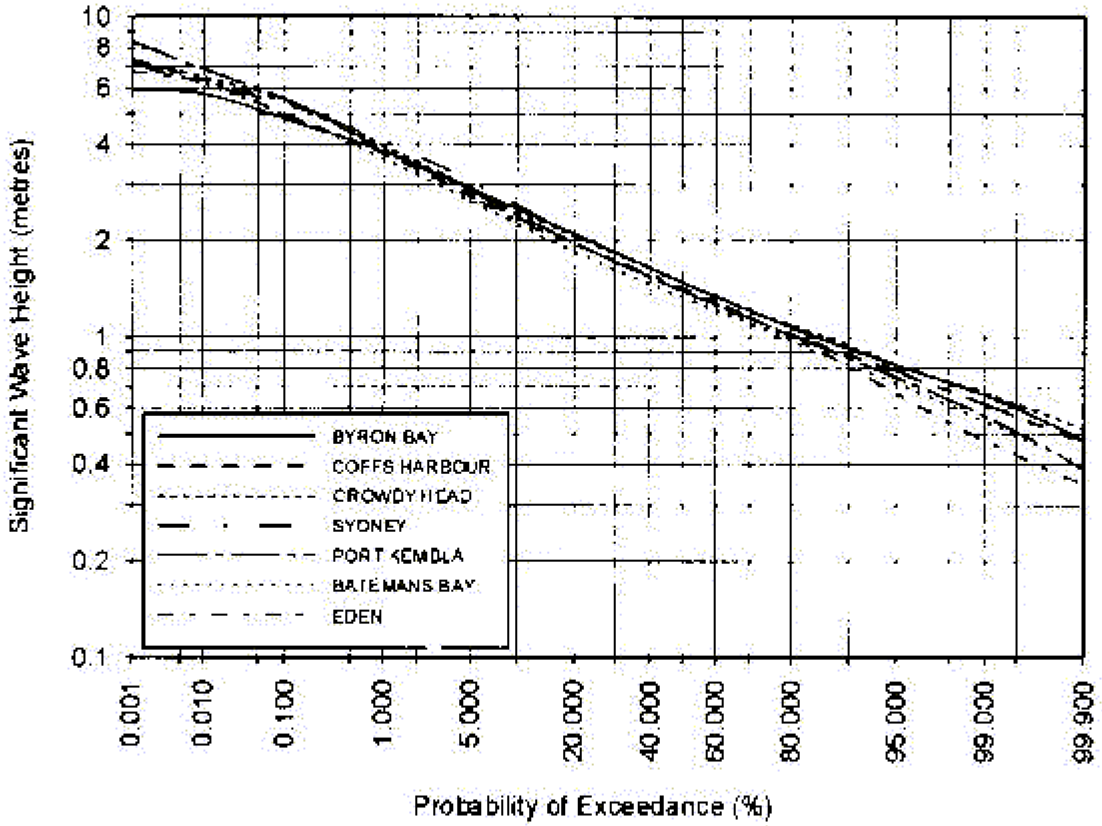
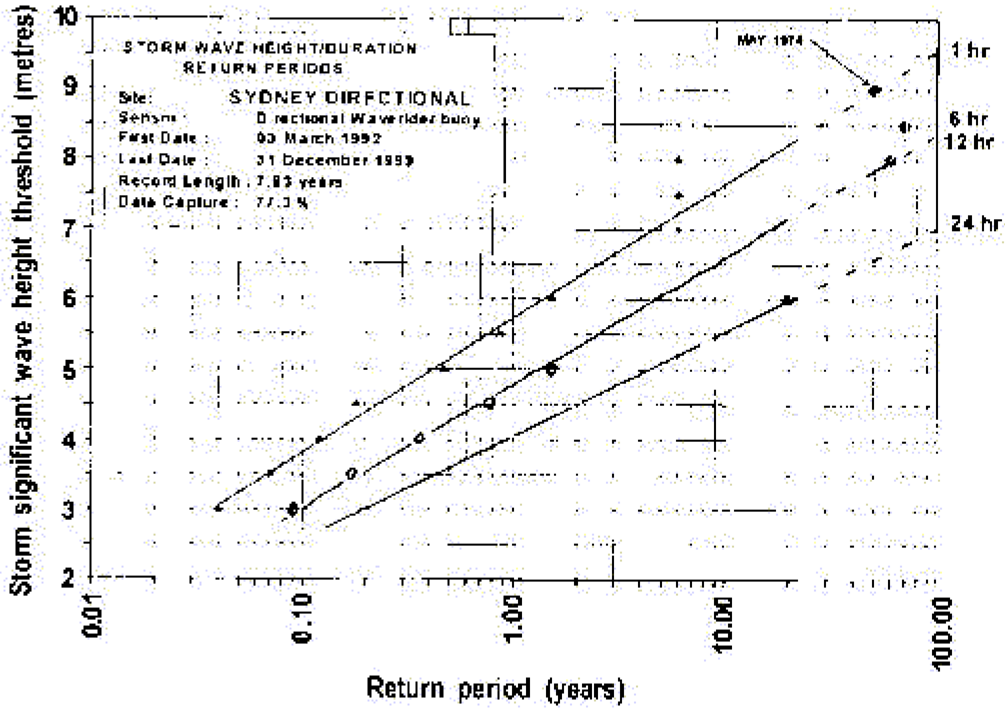


Figure 13: Significant wave height exceedance for NSW coast (Lord & Kulmar, 2000)



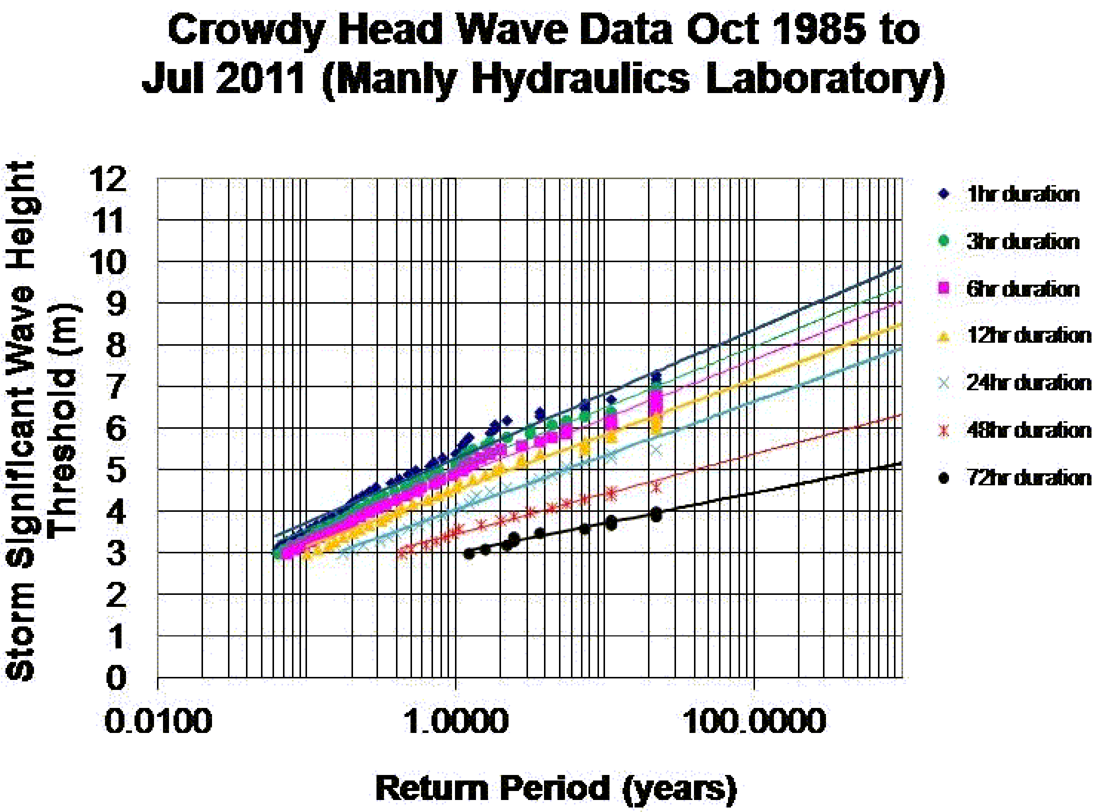
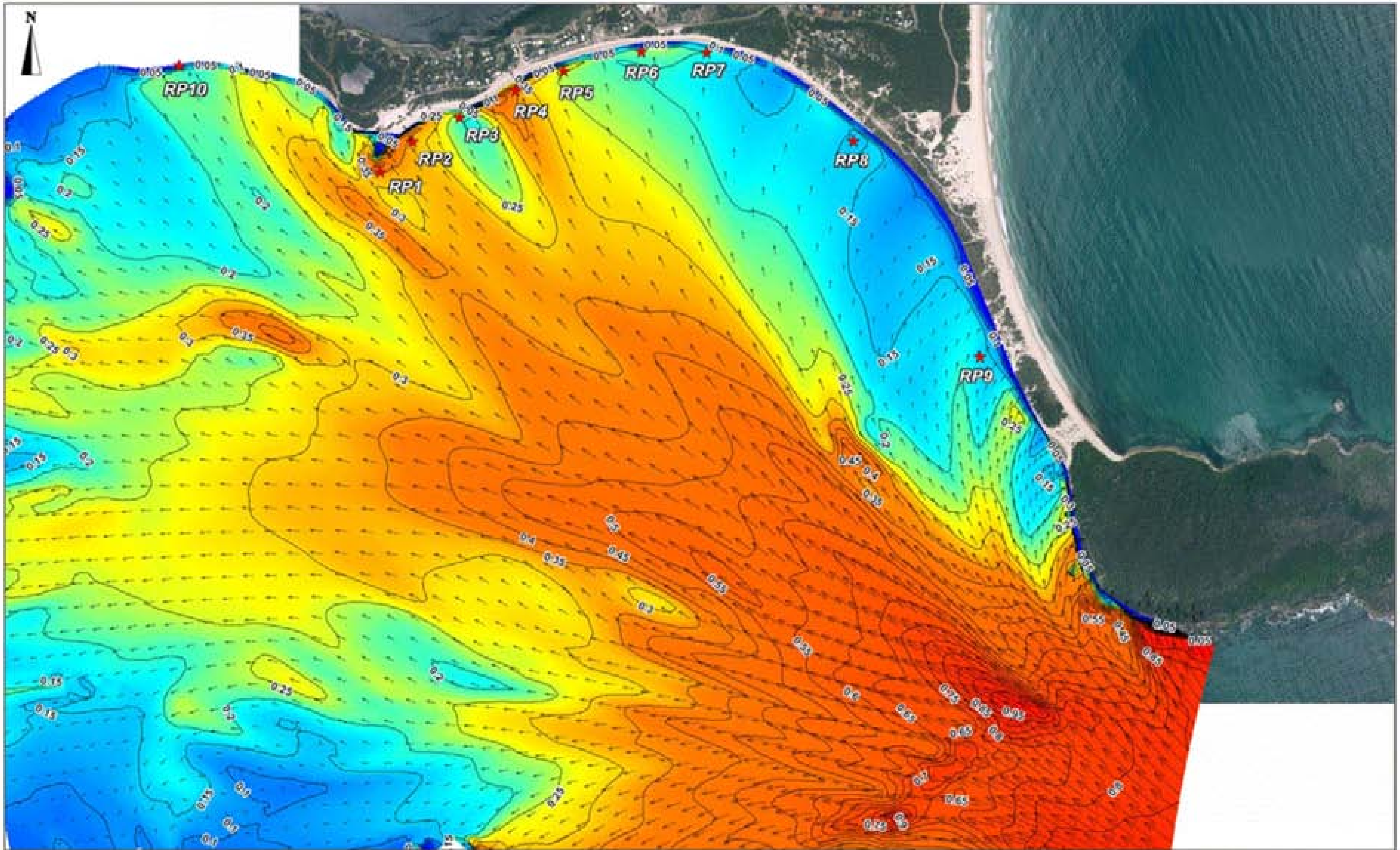


Figure 14: Storm wave height duration recurrence
top: Sydney (Lord & Kulmar, 2000)
bottom: Crowdy Head (from MHL data to July 2011)

Model output for offshore waves approaching from the SSE (over 70% of swell wave occurrences) with a 10s wave period is presented in Figure 15. Wave energy tends to focus on the western end of Jimmy's Beach around Barnes Rocks and Guyra Street. Nearshore wave approach angles from the model output indicate that westerly sediment transport may be favoured under swell conditions. However, complex nearshore wave processes (e.g. wave breaking, longshore currents induced by wave setup) are not accurately represented by the SWAN model. Due to wave focusing that is evident along the shoreline, during larger swell events the effects of differential wave heights (and therefore wave setup) driving alongshore currents (from areas of high wave energy to low wave energy) may have a significant influence in driving sediment transport.

Model output indicating the refracted wave paths and wave transformation coefficients due to wave refraction of average swell waves (Hs offshore = 1 m, offshore wave direction from ENE, ESE, E, SE, S) at Jimmy's Beach are provided in Appendix 1. Figure 16 shows offshore swell waves (ENE67.5° - S.180°TN) approaching Jimmy's Beach along the 1 m depth contour from the western end to the eastern end of Jimmy's Beach have a wave refraction coefficient in a decreasing trend. It indicates that extensive wave energy is refracted towards the nearshore areas along western corner of Jimmy's Beach, resulting in a higher wave climate. Wave focusing occurs around Guyra Street which is the location where photogrammetric profiles indicate storm erosion has been the greatest. These coefficients can be applied to the offshore wave heights to determine nearshore *design* significant wave heights.



DATE 16/01/2012 0 300 600 metres	COORDINATE SYSTEM MGA 94 Zone 56	FIG NO. 15	FIGURE TITLE SWAN wave transformation model for swell wave Hs=1m,Ts=10s,offshore wave direction = SSE
PROJECT NO. 3001829	PROJECT TITLE Jimmys Beach CZMP	CREATED BY A.XIAO	LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\Jimmys Beach Variation\Data\Jimmys_Beach_Port_Stephens\Workspace

SMEC

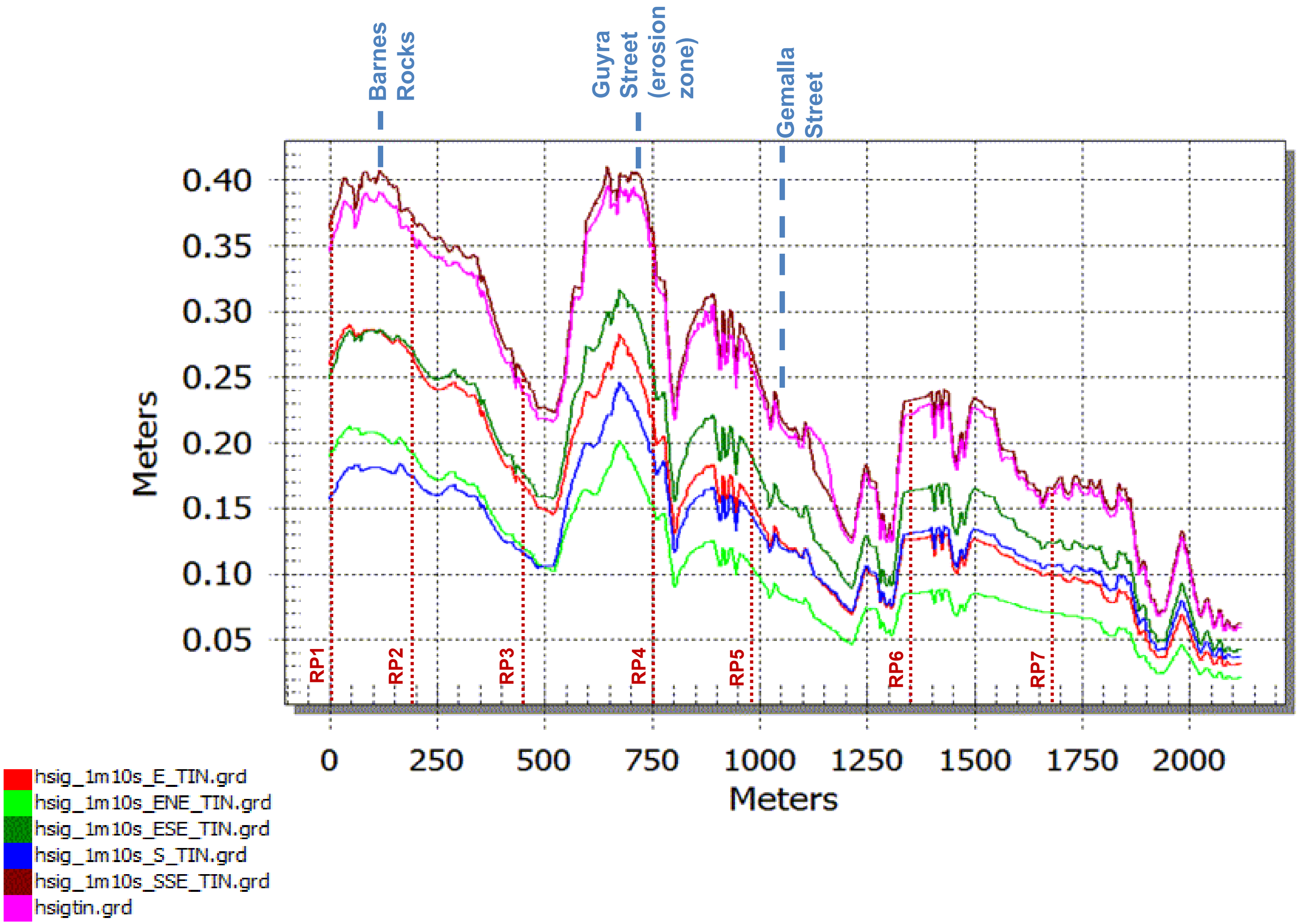


Figure 16: Wave transformation coefficient at 1 m depth along Jimmy's Beach from west (Barnes Rocks) to east

3.2.1.3 Locally Generated Seas

Waves generated by local winds depend on the fetch length, depth of water and the wind speed, direction and duration. Wind waves are generally relatively small in height, short in wave length and with a wave period of 2 to 4 seconds.

An assessment of the wave climate due to waves generated locally along Jimmy's Beach was also made. Wind data at Nelson Bay provided by the Bureau of Meteorology for 10 minute averaged wind speeds at 9:00 am and 3:00 pm, was available between 1968 and 2010. From the wind roses of the Bureau of Meteorology (see Figure 17 and Figure 18), typical condition wind speed was observed to be around 15-20 km/h (i.e. 5-6m/s) for the different wind directions.

As these locally generated waves have a much shorter wavelength than the offshore swell waves, they would undergo less severe refraction on the nearshore zones along Jimmy's Beach. The locally generated wave height and direction at Jimmy's Beach was transformed using the SWAN model by driving the model with winds applied as the boundary condition. Model output of westerly wind-generated waves approaching from the west for typical wind speeds of 5-6 m/s is presented in Figure 19. Results of the SWAN model for wind wave transformation are illustrated in Appendix 1. They show that locally generated seas are always oblique to the shoreline, generating an eastward sediment transport potential by westerly to southerly winds. Wind wave energy focus on the sandwave and estuary entrance under westerly winds and high wave energy on Jimmy's Beach was observed under south-westerly and southerly winds. It can be seen that *significant* wave heights could reach up to 0.3 m for typical conditions under westerly wind around the sandwave along Yacaaba Head, and 0.23 m at the erosion zone of Jimmy's Beach. The wind wave climate derived by the SWAN model for typical conditions is shown in Table 5.

Table 5: Locally generated sea waves under typical conditions

Wind Direction	Wind Speed (m/s)	Peak Period Tp (s)	Significant Wave Height Hs (m) along Jimmy's Beach	Significant Wave Height Hs (m) at Yacaaba sandwave
W wind	5 ~ 6	2.1	0.14 ~ 0.22	0.25 ~ 0.3
SW wind	5 ~ 6	2.1	0.18 ~ 0.23	0.21 ~ 0.23
S wind	5 ~ 6	1.9	0.21 ~ 0.23	0.18 ~ 0.23

3.2.1.4 Summary of Wave Climate

From the above analysis of the wave climate for Jimmy's Beach, it was found that:

- Nearshore swell wave energy is from the southeast to southwest (range 130°TN - 220°TN) based on wave transformation modelling;
- Swell wave heights under typical conditions (offshore Hs=1.5 m, Tp=10 s) can reach up to Hs=0.6 m at Barnes Rock and in front of Guyra street;
- Locally generated waves by westerly, south-westerly and southerly winds can reach up to Hs = 0.3 m, Tp = 2.1 s in typical conditions with wave energy focussing around the sandwave and along Jimmy's Beach.

- The direction of approach of wave energy at Jimmy's Beach may favour westward longshore sediment transport for swell waves while wind waves generate eastward sediment transport.
- Wave focusing, differential wave setup and lateral expansion currents during large swell events may counteract westerly sediment transport in some areas.

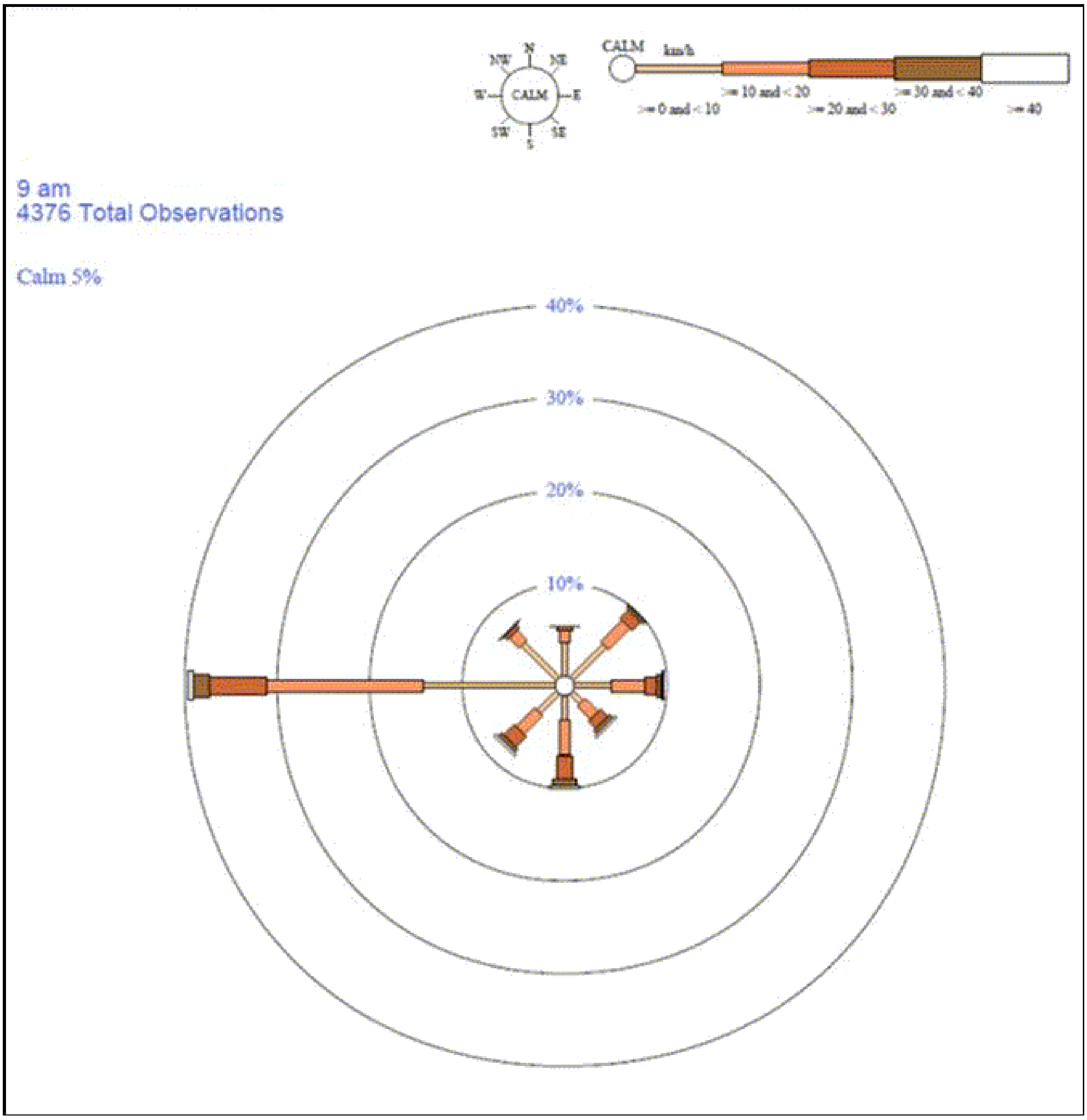


Figure 17: Annual wind rose for 9am wind speed at Nelson Bay

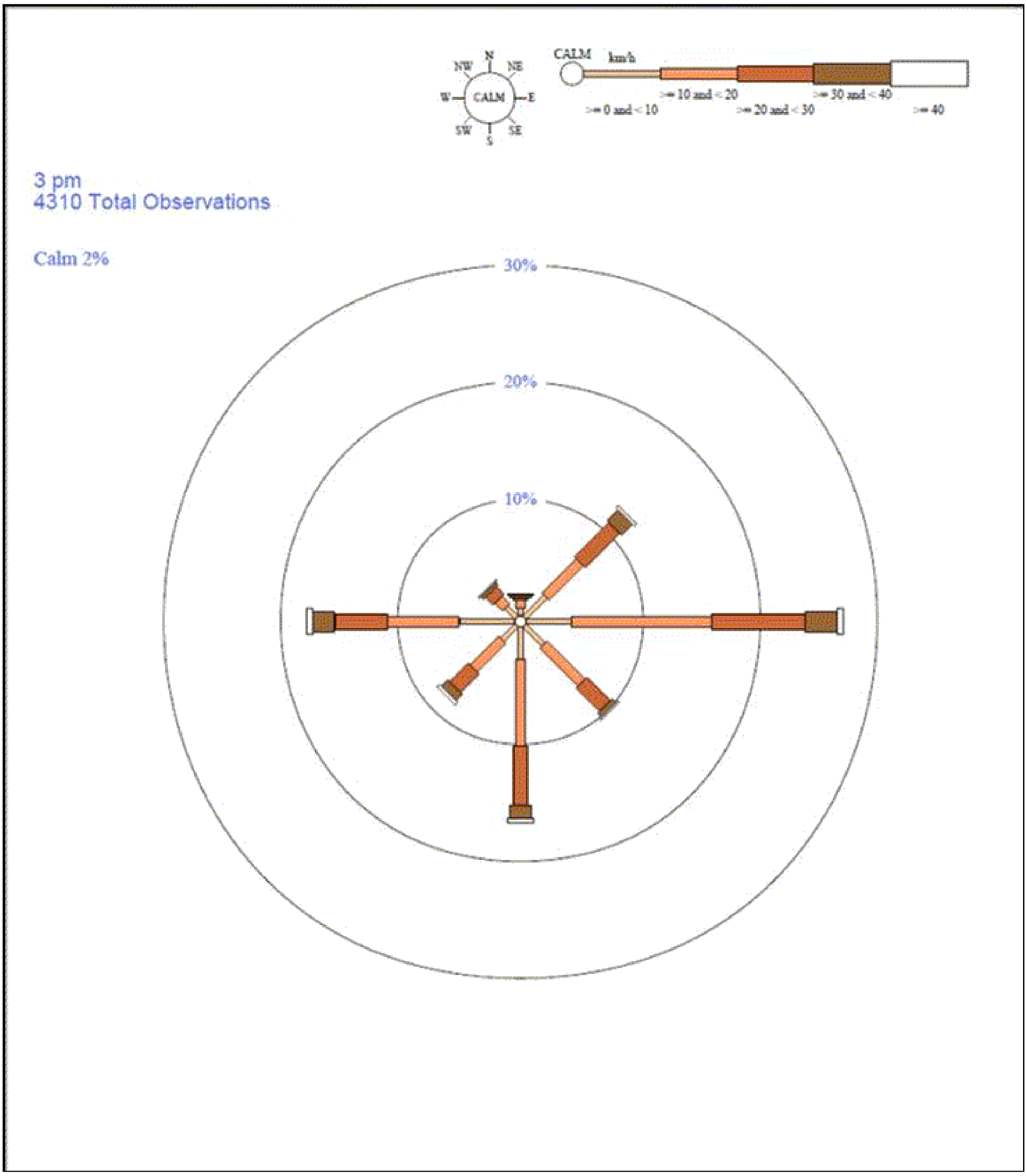
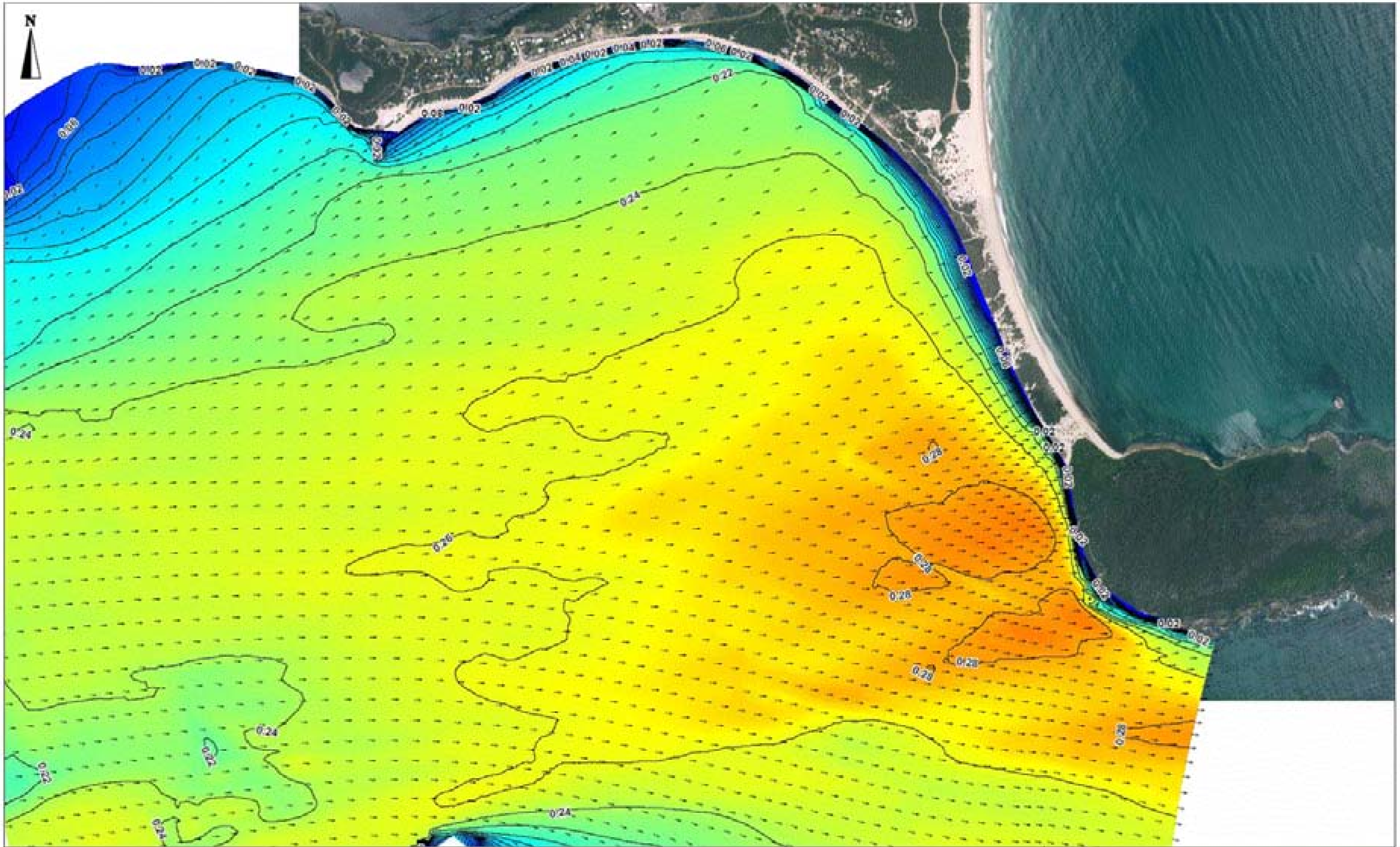


Figure 18: Annual wind rose for 3pm wind speed at Nelson Bay



DATE 16/01/2012	0 300 600 metres	COORDINATE SYSTEM MGA 94 Zone 56	FIG NO. 19	FIGURE TITLE SWAN wave transformation model for wind waves wind wave direction = W, wind speed = 5 ~ 6 m/s
PROJECT NO.3001829	PROJECT TITLE Jimmys Beach CZMP		CREATED BY A.XIAO	LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\Jimmys Beach Variation\Data\Jimmys_Beach_Port_Stephens\Workspace

4 COASTAL PROCESSES ANALYSIS

4.1 Photogrammetric Data Analysis

Photogrammetric data along Jimmy's Beach shoreline from Winda Woppa spit to Yacaaba Head was provided by the Office of Environment and Heritage (OEH) based on aerial photographs dating from 1951 to 1999. This enabled long term recession rates and storm erosion demand to be assessed. The photogrammetry data consisted of 128 cross shore profiles in six blocks covering a total coastline length of approximately 6.3km. Digital files contain the geographic locations and elevations of transects at 50m intervals. Figure 20 illustrates the block divisions along the beach and the location of each cross shore profile within each of the blocks.

Table 6 lists the aerial photographs analysed. From Table 6, it can be seen that earlier photography was at a smaller scale and later photography, being clearer and at a larger scale, allowed the technique to bear more accurate results.

Checking of each profile data set was carried out, to ensure that the estimated erosion for the major storms was reasonable and suitable for use in the analysis.

Table 6: List of aerial photographs and accuracies used for photogrammetric analysis (MHL, 2000)

Date	Scale (1:X)
18 August 1963	40,000
19 January 1968	21,000
19 September 1974	40,000
27 March 1979	15,000
20 January 1983	16,000
20 May 1986	16,000
2 March 1993	25,000
22 June 1994	6,000
6 December 1996	6,000

Generally, for photography scales of up to 1:12000, RMS (Root Mean Square) values of the residuals of 0.25 m for elevation and 0.35 m in plan are considered to be acceptable. The maximum and RMS residual errors for ground co-ordinates for each photogrammetric model setup reported within the standard adopted tolerance (MHL, 2000).

The photogrammetric analysis undertaken for this study had two principal objectives: to determine the storm erosion demand and quantify any historical long-term recession rate. Details on the analysis completed is provided in Section 4.1.2 .

DATE 13/01/2012	COORDINATE SYSTEM MGA 94 Zone 56	FIG NO. 20	FIGURE TITLE Photogrammetry profile locations at Jimmys Beach
PROJECT NO. 3001829	PROJECT TITLE Jimmys Beach CZMP	CREATED BY A.XIAO	LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\Jimmys Beach Variation\Data\Jimmys_Beach_Port_Stephens\Workspace

4.1.1 Short Term Storm Erosion

4.1.1.1 Storm Erosion

The amount of sand eroded from the beach during a severe storm will depend on many factors including the state of the beach when the storm begins, the storm intensity (wave height, period and duration), direction of wave approach, the tide levels during the storm and the occurrence of rips. Storm bite is the volume of beach sand that can be eroded from the subaerial (visible) part of the beach and dunes during a *design* storm. Usually, it is defined as the volume of eroded sand as measured above mean sea level (~ 0 m AHD datum). Usually, the storm bite (or storm erosion demand) has been quantified empirically with data obtained from photogrammetric surveys. For a particular beach, the storm bite may be quantified empirically with data obtained from photogrammetric surveys, or it may be quantified analytically using a verified numerical model.

For Jimmy's Beach, details of the empirical analysis are given below.

4.1.1.2 Quantifying Storm Erosion Demand From Historical Storms

The available photogrammetric data at Jimmy's Beach does not generally allow an estimate of storm demand to be made, because the photographs were not always taken immediately before and after a storm event. The lack of suitable pre-storm and post storm photographs mean that the real dune erosion would already have undergone recovery and the estimation of dune volume changes would be incorrect.

MHL (2000) estimated a storm demand of 70 m^3/m, at Jimmy's Beach, which they considered to be conservative. However, this estimate was limited by the lack of pre and post storm sequences in the photogrammetric record. This storm demand is based on the analysis of beach changes between each date of aerial photography, and derivation of a storm demand estimate reflecting the maximum changes between consecutive dates.

PBP (2005) used evidence from historical measurements, wave energy considerations and storm bite numerical modelling to suggest a storm demand of 50 m^3/m above 0m AHD at Barnes Rocks at the western end of Jimmy's Beach should be adopted.

All blocks of the photogrammetric data used by MHL (2000) were reanalysed as outlined below. The dates of the most appropriate photogrammetric data to compare to quantify the *equivalent* storm erosion demand for Jimmy's Beach are between 1968 and 1974, which allows an estimation of the storm bite of the May–June 1974 storms. Photogrammetry data from after 1984 are influenced by beach nourishment which masks the underlying storm erosion demand. The protocol applied to calculate *equivalent* storm erosion demand is described in Nielsen *et al.* (1992) and outlined in following section.

4.1.1.3 Storm Erosion / Dune Stability Schema

A generalised dune stability schema relating to storm erosion is presented schematically in Figure 21. The following four stability zones (*Zone of Wave Impact*, *Zone of Slope Adjustment*, *Zone of Reduced Foundation Capacity* and *Stable Foundation Zone*) have been delineated as follows (after Nielsen *et al*., 1992):

- The *Zone of Wave Impact* delineates an area where any structure or its foundations would suffer wave attack during a severe storm. It is that part of the beach that is seaward of the dune erosion escarpment.

- A *Zone of Slope Adjustment* was delineated to encompass that portion of the seaward face of the dune that would slump to the natural angle of repose of the dune sand following removal by wave erosion of the *Design Storm Erosion Demand*. That presents the steepest stable dune profile under the conditions specified.

- A *Zone of Reduced Foundation Capacity* for building foundations was delineated to take account of the reduced bearing capacity of the sand adjacent to the dune erosion escarpment. It was considered that structural loads should be transmitted only to soil foundations outside the zone within which the *Factor of Safety* was less than 1.5 during extreme scour conditions at the face of the dune. This allows for the design assumption that the soil may develop its full bearing capacity.

- The *Stable Foundation Zone* is that portion of the dune that is unaffected by the wave erosion processes and within which no special foundation requirements need to be made.

To determine the impact of storm erosion on a homogeneous sand dune, the *design storm erosion demand* is subtracted from the available sand storage on the beach. The slumped storm erosion profile is idealised as comprising a steep dune escarpment at a slope (i) equal to the natural angle of repose of dune sand (φ) to the top of the swash zone at low tide, taken to be 2 m AHD, then a steep nearshore beach face of slope 1:10 down to RL 0 m (AHD – the datum for the reference volume calculations; see Figure 22). A flatter slope (α) extending landward from the limit of beach scour and incorporating a Factor of Safety of 1.5 ($\tan\alpha = \tan\varphi/1.5$) defines the limit of the *Zone of Reduced Foundation Capacity* beyond which surface footings can be used safely.

For the assessment of slope stability of eroded dunes, a value of 35° has been adopted for the angle of internal friction for dune sands.

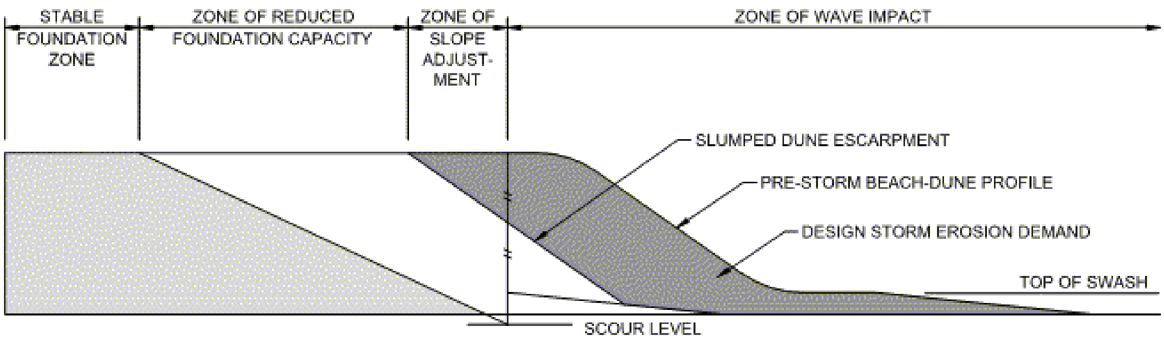


Figure 21: Dune stability schema (after Nielsen et al., 1992)

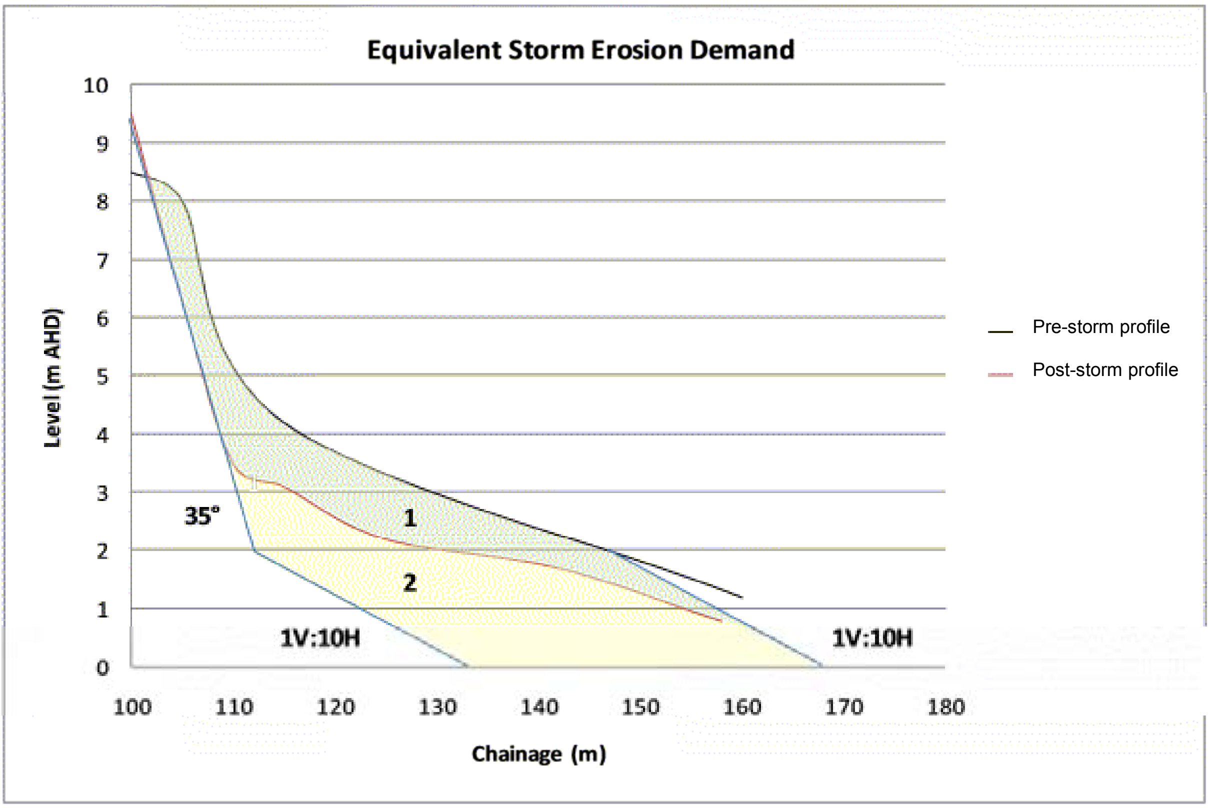


Figure 22: Determination of Equivalent storm erosion, pre-storm and post-storm

4.1.1.4 Estimation of Storm Erosion Volumes

The equivalent storm erosion volumes were assessed for Jimmy's Beach, with site specific conditions being taken into account when considering the impact along different sections of the beach.

The estimated storm erosion demands between consecutive dates of available aerial photographs are plotted in Figure 23 and the *design* storm demand for coastal hazard assessment was determined based on the photogrammetric data between 1968 and 1974 to encompass May-June 1974 storms. From this analysis, a maximum loss of sand volume of 50 m^3/m has been assessed at the location of profile 1 – 8 of Block 1 and 70 m^3/m for profile 9 – 30 of Block 1 and Block 2. A lower storm demand value of 40 m^3/m can be attributed to Block 3 and profile 1 – 17 of Block 4 which are areas sheltered from SE storms by the Yacaaba Head sandwave. The location of profile 18-26 of Block 4 is slightly exposed to offshore swell waves near the estuary entrance, so a value of 50 m^3/m was adopted.

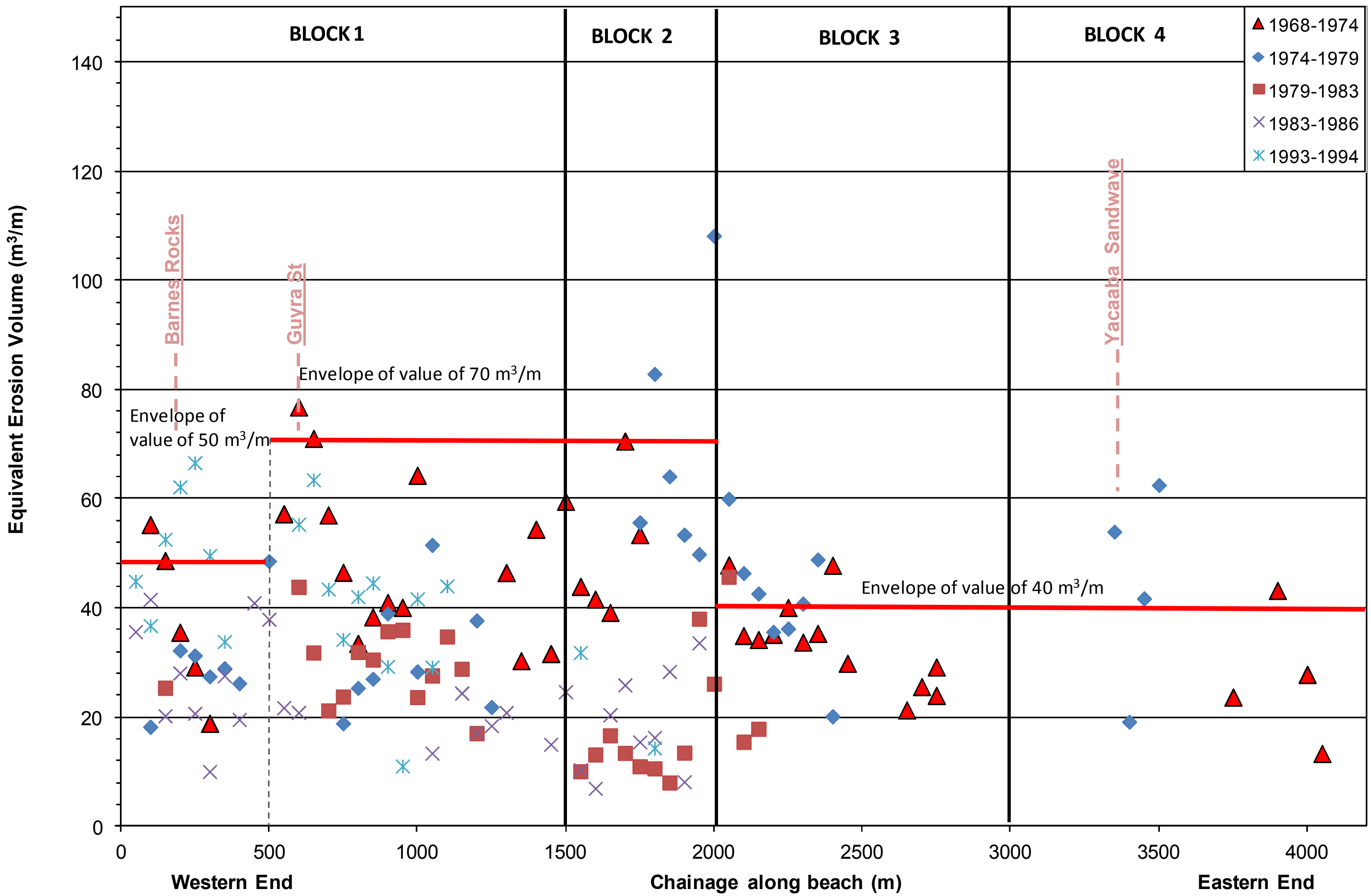


Figure 23: Estimated Storm Erosion Demand for the consecutive storms at Jimmy's Beach

4.1.2 Long Term Changes

4.1.2.1 Volumetric Analysis of Profiles

The photogrammetric data were analysed for volume change to determine trends in beach erosion or accretion over time along the beachfront.

The digital photogrammetry files were processed and analysed using the software program, Beach Morphology Analysis Package (BMAP). BMAP consists of automated and interactive procedures to analyse morphologic and dynamic properties of beach profiles (Sommerfeld *et al.,* 1994).

All the profiles from each block along Jimmy's Beach were read into the program BMAP, which is able to calculate volumes under specific beach profiles or the average over multiple profiles. It should be noted that the volume considered was that above 0.0 m AHD landward of the 2.0 m AHD contour. The profile volumes were taken to a point just on the landward side of the dune to minimise errors in the volume calculations due to discrepancies in the vertical datum for different years of photography.

Pre-nourishment Long Term Recession

Beach nourishment commenced in 1983, therefore in determining natural long term recession rates, the 1963-1983 period of photogrammetric data was used. Figure 24 illustrates the pre-nourishment cumulative change in beach volume in cubic metres per metre length of beach, for Block 1 – 4 over time. From this plot it can be seen that for the main section of Jimmy's Beach (Block 1 – 3), there has been a steady decline in subaerial beach volumes between 1963 and 1983, with an average decline of 40 m^3/m at Block 1, 70 m^3/m at Block 2 and 10 m^3/m at Block 3. Yacaaba sandwave at Block 4 was prograding with a net increase of 90 m^3/m over the same period.

The long term erosion and recession rate for Jimmy's Beach is summarised in Table 7.

Table 7: Pre-nourishment long-term volume change rates for Jimmy's Beach (1963 – 1983)

Long term volumetric change rate (m^3/m/yr)				
Block 1(p1-p8)	**Block 1(p9-p30)**	**Block 2**	**Block 3**	**Block 4**
-2.62	-1.95	-3.82	-0.48	4.92
Long term dune progradation or recession rate estimated from volume change (m/yr)				
Block 1(p1-p8)	**Block 1(p9-p30)**	**Block 2**	**Block 3**	**Block 4**
-0.58	-0.43	-0.85	-0.13	1.0

Photogrammetric data for Winda Woppa at Block 5 between 1963 and 1983 showed a net volume increase of around 20 m^3/m during that period indicating general progradation of the Winda Woppa Spit. However, during SMEC's site visit on 15 November 2011, there was clear evidence of significant long-term recession along a discrete section of Winda Woppa spit. This long term erosion was identified by Sydney University in their analysis of historical aerial photographs (refer to Figure 9). This local recession is offset in the numerical analysis by the westward progradation of the spit.

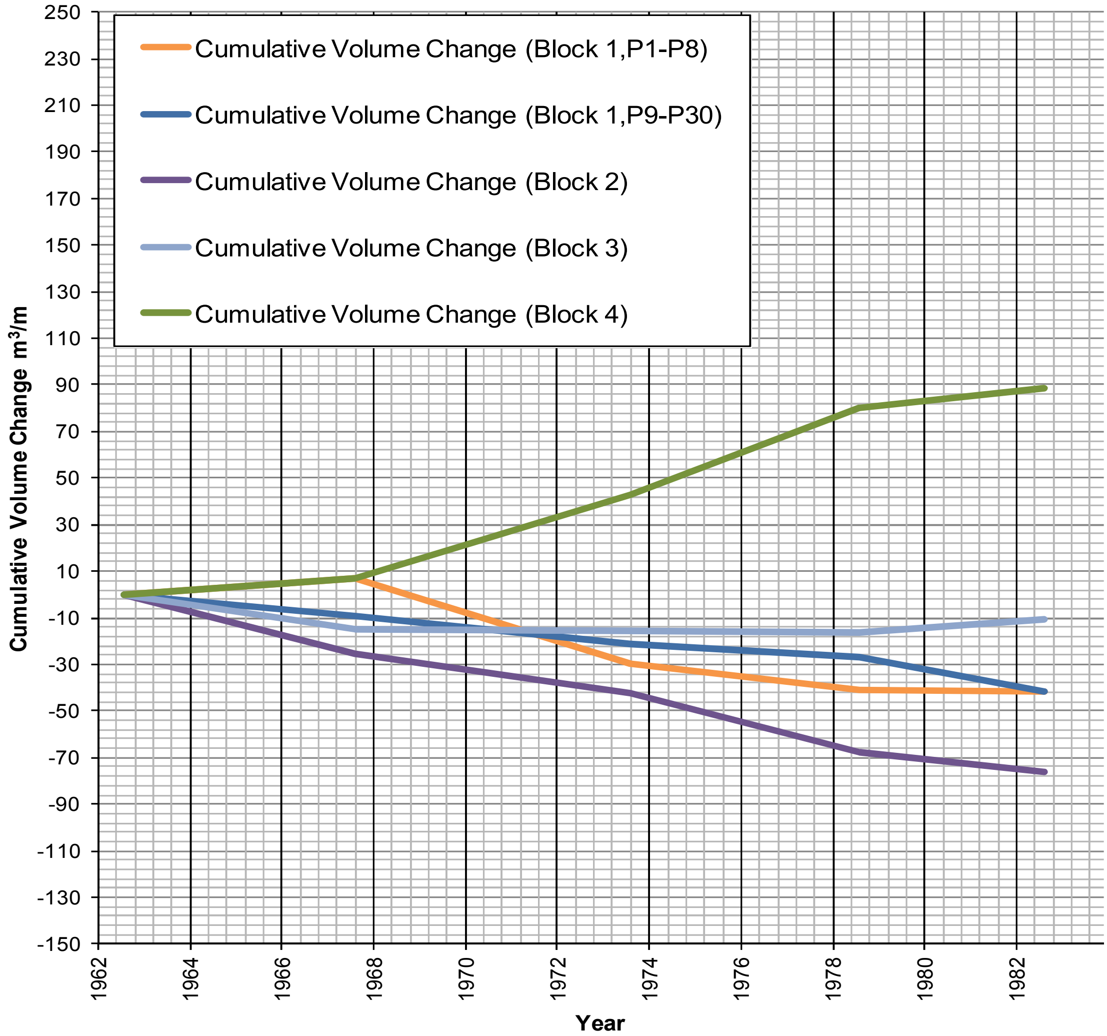


Figure 24: Cumulative change in beach volume in cubic metres per metre length of beach at Jimmy's Beach (pre nourishment)

Long Term Recession (including Beach Nourishment)

It is evident that long term recession rates have reduced since the commencement of beach nourishment (and the rate of progradation for Block 4 has increased). This is especially noticeable at Block 1, where nourishment has been concentrated (see Figure 25).

It was found that Yacaaba Head at Block 4 had experienced significant progradation between 1963 – 1978, 1986 – 1992 and 1999 – 2008, with a sharp decrease in sand volume of around 40m^3/m between 1992 and 1994 showing the effect of sand dredging at the Yacaaba sandwave for Jimmy's Beach emergency nourishment in January 1992. A net increase of 320 m^3/m at Block 4, 50 m^3/m at Block 3 and a net decrease of 30 m^3/m at Block1 and 100 m^3/m at Block 2 were observed over the 45 year period of photogrammetric data (refer to Figure 25).

The long term recession rate (including beach nourishment effects) for Jimmy's Beach is summarised in Table 8. The rate of recession or progradation following adoption of regular beach nourishment (1983 – 2008) is summarised in Table 9.

Table 8: Long-term volume change rates (including Beach Nourishment) for Jimmy's Beach (1963 – 2008)

Long term volumetric change rate (m3/m/yr)				
Block 1(p1-p8)	**Block 1(p9-p30)**	**Block 2**	**Block 3**	**Block 4**
-0.27	-0.60	-2.32	1.25	6.36
Long term dune progradation or recession rate estimated from volume change (m/yr)				
Block 1(p1-p8)	**Block 1(p9-p30)**	**Block 2**	**Block 3**	**Block 4**
-0.06	-0.13	-0.52	0.37	1.31

Table 9: Long-term volume change rates for Jimmy's Beach during beach nourishment (1983 – 2008)

Long term volumetric change rate (m^3/m/yr)				
Block 1(p1-p8)	**Block 1(p9-p30)**	**Block 2**	**Block 3**	**Block 4**
1.08	0.04	-0.85	2.08	6.47
Long term dune progradation or recession rate estimated from volume change (m/yr)				
Block 1(p1-p8)	**Block 1(p9-p30)**	**Block 2**	**Block 3**	**Block 4**
0.24	0.008	-0.19	0.61	1.33

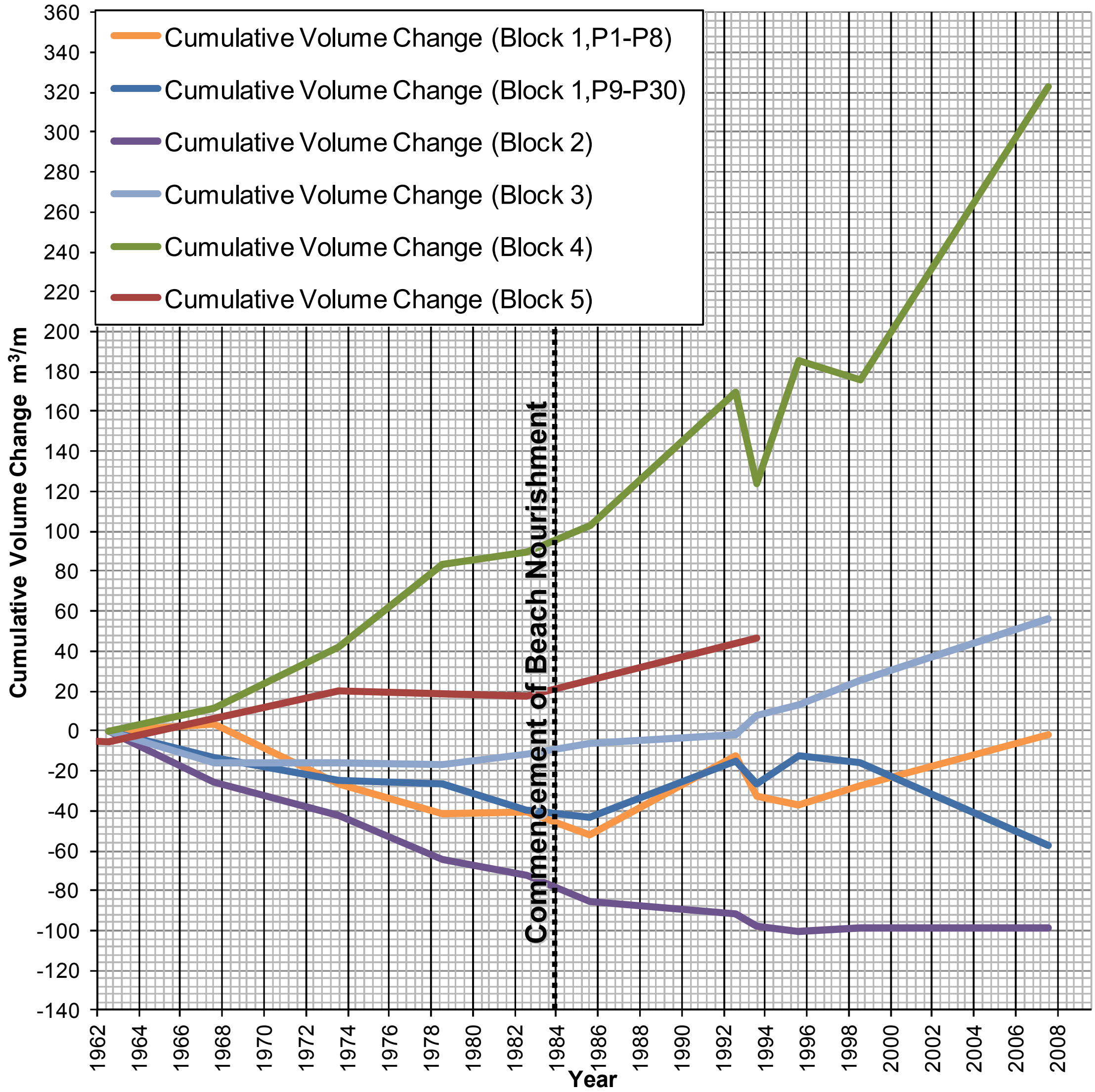


Figure 25: Cumulative change in beach volume in cubic metres per metre length of beach at Jimmy's Beach (post nourishment)

4.1.2.2 Translation of Dune Escarpment

As the natural short-term fluctuations of a beach and dune are large compared with any underlying long term trend in beach change, sometimes it can be difficult to quantify an accurate rate of recession or progradation. Often it can be more accurate to measure beach recession by mapping the response of a consistent or readily identifiable feature such as the dune erosion escarpment over time. This can be done by measuring the location of the dune face along each profile, by selecting a representative contour level and measuring the chainage along each profile of the toe, or the crest of the dune.

By inspection of the profiles at Jimmy's Beach, it was determined that from these data the location of the RL3.0 m AHD contour best represented the location of the front face of the dune along Jimmy's Beach.

Pre-nourishment Dune Face Movement

Figure 26 shows the pre-nourishment (1963 – 1983) cumulative movement of the 3.0 m AHD contour over time, for Block 1 – 4 along Jimmy's Beach. Negative values represent dune recession. Block 1 – 3 showed dune face recession between -7 m and -17 m while Block 4 showed dune face propagation extent up to 30 m. The location of the dune face at Block 2 was estimated to have a maximum recession rate of 0.87 m/yr and a propagation rate of 1.55 m/yr was observed at Yacaaba sandwave within Block 4. Table 10 shows the long term dune escarpment movement rate at Jimmy's Beach.

Table 10: Pre-nourishment Long Term Dune Escarpment Movement Rate (1963-1983)

Dune escarpment movement rate (m/yr)				
Block 1 (p1-p8)	**Block 1 (p9–p30)**	**Block 2**	**Block 3**	**Block 4**
-0.64	-0.36	-0.87	-0.45	1.55

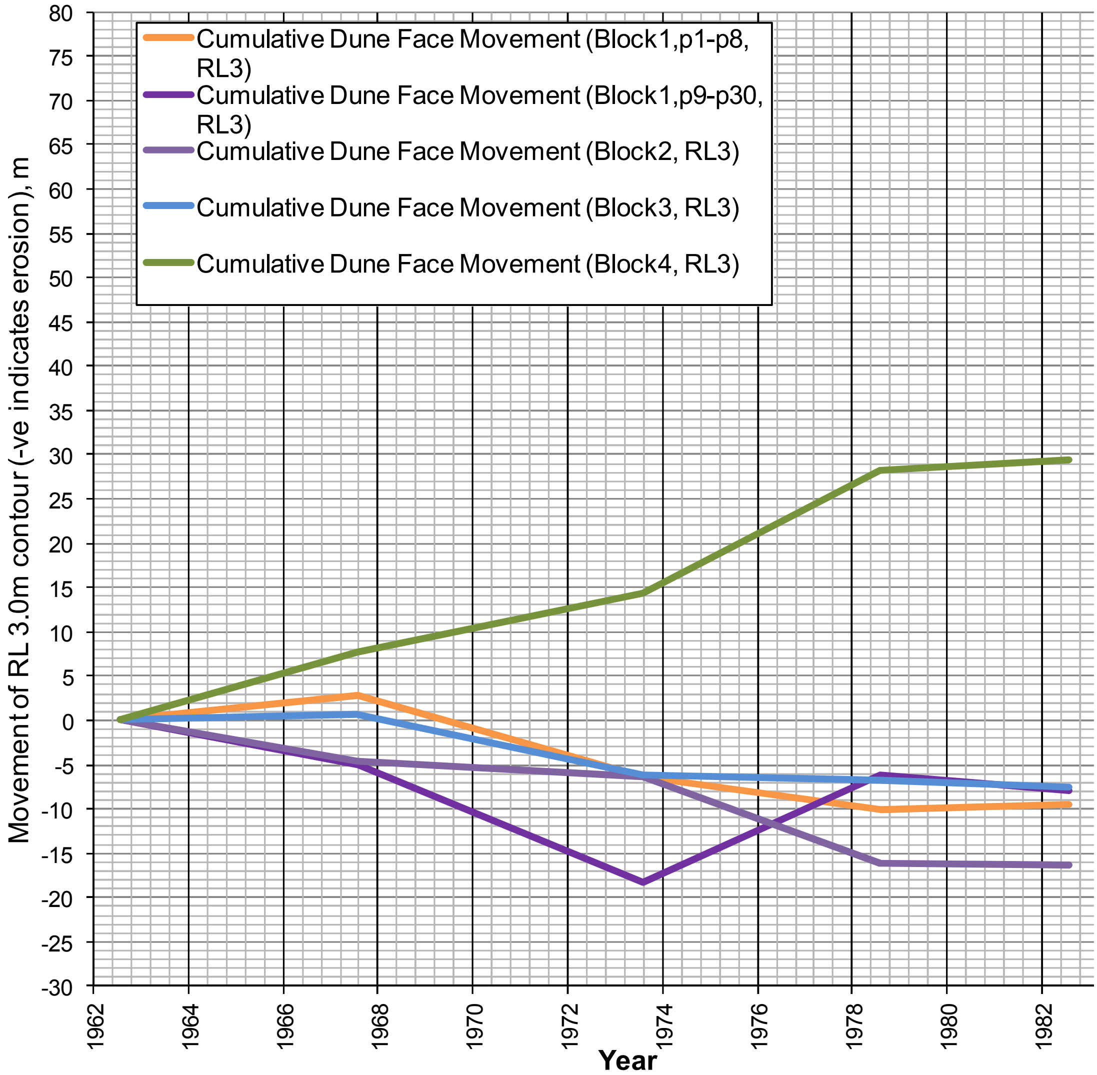


Figure 26: Cumulative dune face movement in metres at Jimmy's Beach (pre-nourishment)

Dune Face Movement (including Beach Nourishment)

Figure 27 shows the cumulative movement of the 3.0 m AHD contour over time between 1963 and 2008 taking account of the influence of beach nourishment, for Block 1 – 4 along Jimmy's Beach. Negative values represent dune recession. The recession rate of dune face at Block 2 was not reduced significantly, around -0.6 m/yr and the progradation rate at Yacaaba Head in Block 4 remained a rate of 1.58 m/yr. Block 2 showed dune face recession extent up to 25 m between 1963 and 2008 while Block 4 showed dune face propagation extent up to 90 m over 45 years, illustrating the growth of the sand wave in this area (Table 11). Table 12 presents the long term dune escarpment movement since 1983, incorporating the effects of beach nourishment.

Table 11: Long Term Dune Escarpment Movement Rate including Beach Nourishment (1963-2008)

Dune escarpment movement rate (m/yr)				
Block 1 (p1-p8)	**Block 1 (p9–p30)**	**Block 2**	**Block 3**	**Block 4**
-0.25	-0.06	-0.60	-0.04	1.58

Table 12: Long Term Dune Escarpment Movement Rate during Beach Nourishment (1983-2008)

Dune escarpment movement rate (m/yr)				
Block 1 (p1-p8)	**Block 1 (p9–p30)**	**Block 2**	**Block 3**	**Block 4**
0.03	-0.045	-0.26	0.31	1.67

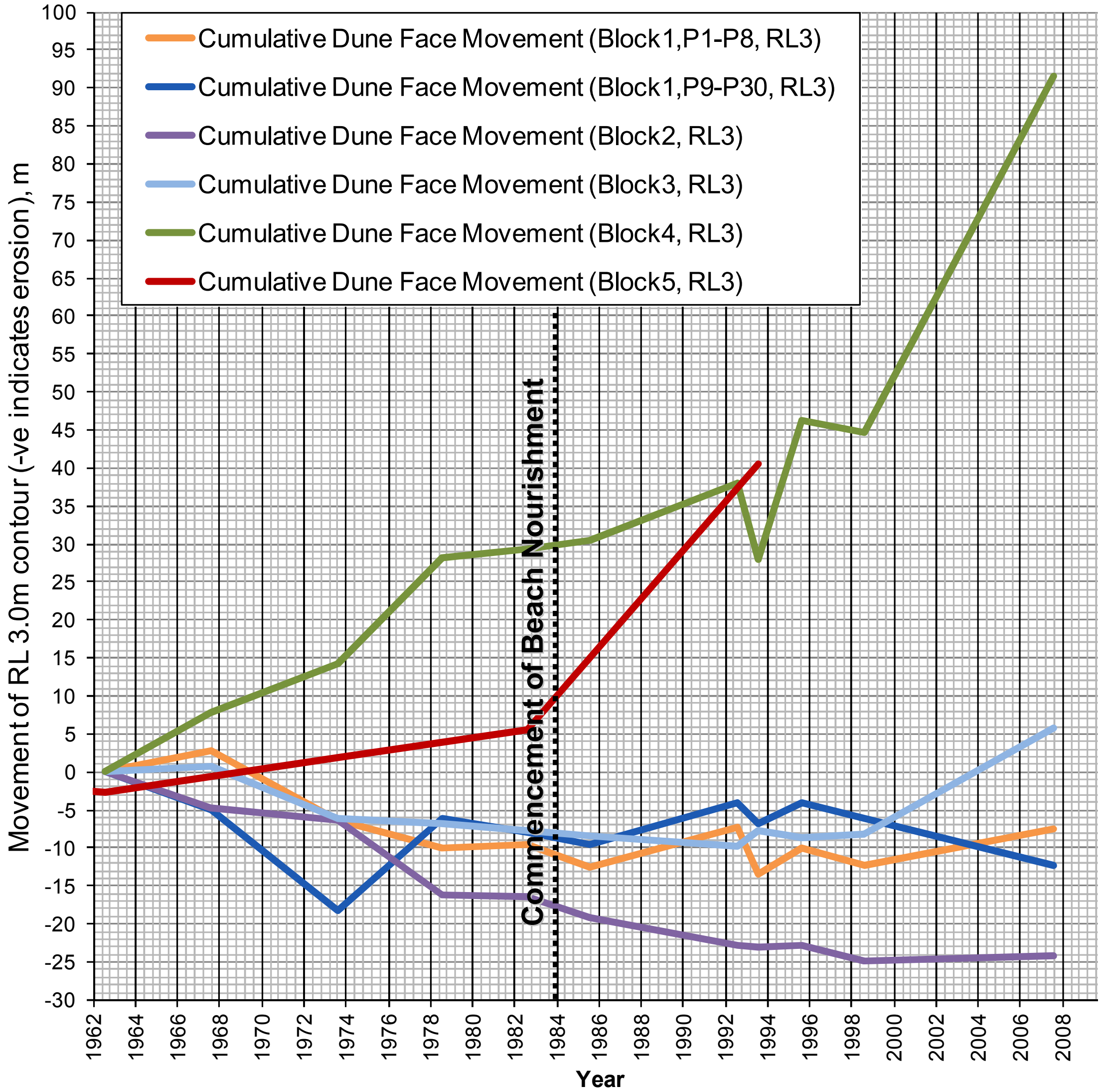


Figure 27: Cumulative dune face movement in metres at Jimmy's Beach (post-nourishment)

4.1.2.3 Summary of Photogrammetry Analysis and Adopted Long-term Recession Rates

The translation of dune escarpment analysis was consistent with the volumetric photogrammetry analysis. Table 13 summarises the pre-nourishment long term recession rates at Jimmy's Beach for coastal hazard assessment, assuming beach nourishment is not continued into the future.

Table 13: Adopted pre-nourishment beach recession rates

	Block 1 (p1-p8)	Block1 (p9 – p30)	Block 2	Block 3	Block 4
Pre- nourishment Long Term Recession Rate (m/yr)	-0.6	-0.4	-0.9	-0.1	0

Should beach nourishment continue into the future, adopted long term recession rates based on historical measurements between 1983 and 2008 are provided in Table 14.

Table 14: Adopted post-nourishment beach recession rates

	Block 1 (p1-p8)	Block1 (p9 – p30)	Block 2	Block 3	Block 4
Post – nourishment Long Term Recession Rate (1983 – 2008) (m/yr)	0	0	-0.3	0	0

Previous coastal assessments of Jimmy's Beach have recommended the following long term recession rates of:

- MHL (2000) used a 0.4 m/yr for Block 1 – 3 based on the most conservative result from a block averaged volume analysis and adopted average dune heights.
- PBP (2005) reassessed long term recession as part of a coastal engineer's report for a property located along western end of Block 1 and found a positional rate of 0.5 m/yr and volumetric rate of 2 m^3/m/yr.

The photogrammetric data analysed here could not be used to quantify storm erosion volume demand accurately, as this would require photography to be taken at least immediately after a major storm. However, it has allowed an estimate of storm bite as well as long term beach recession rates.

In summary, the trend for long term beach change for Jimmy's Beach was one of clear long term recession, with an average underlying pre-nourishment recession rate of around 0.4 m/yr along Jimmy's Beach and a pre-nourishment progradation rate of around 1 m/yr along Yacaaba Shoal. It represents a loss of sand of around 2 m^3/m/yr along Jimmy's Beach and accumulation of sand of around 5 m^3/m/year along Yacaaba Shoal. Following commencement of beach nourishment in 1983, the long term change at Jimmy's Beach has been significantly less and the beach has been relatively stable. The accuracy of this estimate depended on the horizontal and vertical accuracy of the photogrammetry, as well as the period of time over which the photogrammetry was carried out. This estimate is based on the existing photogrammetric data and may be subject to change in the future as more data is collected.

4.2 Net Longshore Sediment Transport

The issue of erosion management at Jimmy's Beach has been contentious for several decades. In particular there have been conflicting conclusions reached about the direction of net alongshore sediment transport at Jimmy's Beach. The School of Geosciences, Sydney University, more recently suggested that the net alongshore movement of sand along Jimmy's Beach is from east to west (see Section 3.1.5), at odds with the conclusions of all previous detailed studies and survey monitoring exercises (MHL, 2000). While both the previous detailed studies included monitoring, eth PWD/DLWC program was significantly more extensive, covering a similar plan area but using a registered surveyor and conducting regular surveys along closely spaced preset shore normal survey lines out to the seaward limit of the assumed depth of closure (>> 3 m AHD). These surveys charted the movement of several large nourishment volumes at Jimmy Beach over time from west to east ending up at the sandwave feature along the Yacaaba Isthmus.

The University of Sydney present the hypothesis that the net sediment transport direction along the entire northern foreshore of Jimmy's Beach is from east to west. It can be inferred from this that at least 500,000 m^3 of nourished material (see Section 2.4) would have been transport west along with additional volumes of existing shoreline and nearshore material (e.g. material eroded from Winda Woppa peninsula's southern shoreline). The following arguments have been presented to dispute this hypothesis:

- The embayment immediately to the west of Guya Street to Barnes Rocks would show evidence of this vast sediment supply over the past 50 years. In all surveys conducted by DLWC (which included this embayment for completeness) there was no evidence of change from one survey to the next with all sand movements measured eastward and at dynamic rates from the shoreline perturbation opposite Guya Street. Aerial photos similarly show no evidence of embayment widening or change over the past 50 years.

- There was a relatively sharp deepening of the nearshore profile west of the shoreline perturbation opposite Guya Street evident in all DLWC surveys conducted over many years. This area notably from the early surveys contains brick size rocks on the seabed commencing at depth of approximately -1.5 to 2.0 m AHD that were never buried with sand at any stage throughout the lengthy period of survey monitoring. If the alongshore sediment transport was from the east to west beyond Guya Street, then it is likely that these deeper nearshore areas would have been readily filled given the large quantities of sand transported.

- The aggregation of and growth of the sandwave feature along Yacaaba isthmus accords closely with the artificial nourishment volumes added since the mid 1980s based on detailed photogrammetric data analysis by DLWC.

- Inspection of planform alignments and assumed zeta formations in alongshore direction do not support the direction of net east to west sediment transport proposed by Sydney University.

- In a recent engineering investigation into the shoaling of the eastern Myall River entrance channel, WBM (2011) concluded that *'shoaling of the Eastern Channel is unlikely to be linked to erosion on Jimmy's Beach*'. This conclusion was reached on the basis of longshore transport calculations and comparison of topographic and bathymetric surveys (see Appendix D, WBM, 2011) to infer that sediment inputs causing the elongation of the spit and shoaling of the Eastern Channel could be primarily attributed to erosion of the shoreline along Winda Woppa peninsula west of Barnes Rock. And thus by deduction, that westward sediment transport around Barnes Rock (i.e. from Jimmy's Beach) is not a significantly factor in the elongation of Winda Woppa spit.

As no significant independent field measurement has been undertaken for this assessment, SMEC are unable to resolve conflicting conclusions about net sediment transport direction along Jimmy's Beach. However, based on our review of the previous investigation and existing coastal processes it is considered likely that the majority of the sand eroded from the 'hot spot' is transported to the east while a smaller proportion 'leaks' past Barnes Rocks and is transported west to the Connie Channel.

4.3 Wave Inundation

4.3.1 Introduction

Coastal inundation at Jimmy's Beach would occur if the frontal dune is low enough to allow overtopping during a major storm. It was found that wave runup levels can vary at different locations along the beach, due to varying beach slopes. Wave runup levels on Jimmy's Beach were estimated using parameters from long term wave statistics at the Sydney and Crowdy Head directional Waverider buoys.

4.3.2 Ocean Inundation

From previous studies at Jimmy's Beach, it was pointed out that the dune in some areas has been previously overtopped and large scale inundation of the low-lying land surrounding the lagoon behind the beach area was recorded (MHL, 2000). A design wave runup value of 3.1 m AHD was adopted for Jimmy's Beach as a sheltered coast.

Wave runup levels at Jimmy's Beach were estimated using the Automated Coastal Engineering Software (ACES) using the value of the nearshore significant wave height calculated with the SWAN model and SBEACH software. The wave runup module of ACES was used to determine the levels, which assumes a smooth sloped, linear beach.

Design incident wave conditions for the assessment of wave runup were determined for a maximum deepwater offshore wave height corresponding to the 1% AEP (Annual Exceedance Probability). From long term wave statistics as measured at the Sydney directional Waverider buoy (which is representative of the study region), this corresponds to an offshore deepwater significant wave height of around 9.5 m. The wave transformation coefficient from the SWAN model was used as a boundary condition to drive the SBEACH model.

SBEACH (Storm-induced BEAch CHange 32) is an empirically based, two-dimensional, morphological, numerical model. The model is founded on extensive large wave tank and field data measurements and analysis (Larson *et al.*, 1990; Rosati *et al.*, 1993). The model accepts as data:

- surveyed beach profiles
- time-varying water levels
- regular or irregular wave heights and periods
- wave angles
- wind speeds and wind directions
- an arbitrary grain size in the fine-to-medium sand range

The nearshore boundary conditions for ACES that have been adopted for Jimmy's Beach are shown in Table 15. The assumed nearshore beach profile is measured from Port Stephens estuary entrance to the top of the dune of Jimmy's Beach, to obtain a beach slope for use in the wave runup calculation. The runup was added to the nearshore water level, which included an allowance for wave setup and wind setup. The maximum expected wave runup and 2% wave runup (runup level exceeded by 2% of waves) is given in Table 15. The runup level has been calculated by adding up the runup calculated by ACES to the nearshore design water level (Kulmar and Nalty, 1997).

Following future sea level rise, maximum runup levels would be expected to increase by at least the value of future sea level rise. As the shoreline alignment will be expected to change in the future along sandy shorelines, it is not possible to accurately predict the future limits of inundation due to wave runup. However, a future runup level for 2050 and 2100 has been indicated in Table 15, assuming that the nearshore beach slopes and wave climate are unchanged.

Based on ALS data, the analysis indicates that some overtopping could occur along The Boulevarde and the low-lying area surrounding the lagoon behind the beach area. The map of the maximum wave runup levels are represented in Figure 28.

Table 15: Present day, 2050 and 2100 wave runup levels for Jimmy's Beach,1% AEP storm event

Location	Nearshore Water Level (incl. Tide, Wind and Wave Setup)	2% Wave RunUp Level	Maximum Wave RunUp Level	Maximum 2% Wave RunUp	Maximum RunUp	2050 Maximum Runup	2100 Maximum Runup
	m AHD	m	m	m AHD	m AHD	m AHD	m AHD
Jimmy's Beach East	1.45	2.33	2.77	3.78	**4.22**	**4.66**	**5.06**
Jimmy's Beach Centre-East	1.55	3.72	4.54	5.27	**6.09**	**6.53**	**6.93**
Jimmy's Beach Centre-West	1.57	3.10	3.74	4.67	**5.31**	**5.75**	**6.15**
Jimmy's Beach West	1.58	1.83	2.10	3.41	**3.68**	**4.12**	**4.52**

DATE 06/12/2011	COORDINATE SYSTEM MGA 94 Zone 56	FIG NO. 28	FIGURE TITLE Runup Hazard Line - Jimmys Beach Maximum Runup Line and Maximum 2% Wave Runup Line
PROJECT NO. 3001829	PROJECT TITLE Great Lakes Coastal Hazard Study	CREATED BY A.XIAO	LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\009DATA\GIS\Great Lakes Overall.wor

SMEC Great Lakes COUNCIL

4.4 Climate Change Impact

4.4.1 Bruun Rule

The most widely accepted method of estimating shoreline response to sea level rise is the Bruun Rule (Bruun, 1962; 1983). Bruun (1962, 1983) hypothesised that the beach assumed an *equilibrium profile* that kept pace with the rise in sea level without changing its shape, by an upward translation of sea level rise (S) and shoreline retreat (R).

Figure 29 illustrates the concept of the Bruun Rule. The Bruun Rule equation is given by:

$$R = \frac{S}{(h_c + B)/L}$$

where: *R* = shoreline recession due to sea level rise;

S = sea level rise (m)

h_c = closure depth

B = berm height; and

L = length of the active zone.

The Bruun model assumes that the beach profile is in an equilibrium state. Berm height is taken to be the average height of the dune along the beach, and closure depth is the depth at the seaward extent of measurable sand movement. The length of the active zone is the distance offshore along the profile in which sand movement still occurs.

4.4.2 Determination of Bruun Rule Parameters

Several schemas exist, based on analytical and laboratory studies, to determine closure depth and length of the active zone, including those of Swart (1974) and Hallermeier (1981, 1983).

Hallermeier (1981, 1983) defines a simple zonation of an onshore-offshore beach profile consisting of a *littoral* zone, *shoal* zone or buffer zone, and offshore zone where surface wave effects on the bed are negligible.

Based on an analytical approach, supported by laboratory data and some field data, the two water depths bounding the shoal zone, defined by d_s and d_o are given by:

$$d_s = \frac{2.9H}{(S-1)^{0.5}} - \frac{110H^2}{[(S-1)gT^2]}$$

where d_s = water depth bounding the littoral and shoal zones

H = significant wave height *exceeded 12 hours per year*

T = associated wave period

S = specific gravity of the sediment, and

G = acceleration due to gravity; and

$$d_o = 0.018 H_{med} T_{med} \left[\frac{g}{(S-1)D_{50}} \right]^{0.5}$$

where d_o is the depth at the boundary of the offshore zone, H and T are the median *significant* wave height and period parameters and D_{50} is the median grain size. For Jimmy's Beach, H_{med} = 0.6 m; T_{med} = 9.5 s; H = 2 m and T_p = 12 s based on factoring median wave height values for open coast beaches by the wave transformation coefficients from the results of the SWAN modelling (*"Future Directions for Wave Data Collection in New South Wales"*, Kulmar & Lord, 2005).

Typical beach sand characteristics give S = 2.65, and median grain size along Jimmy's Beach shoreline varies between D_{50} = 0.37 mm and D_{50} = 0.39 mm as illustrated in Figure 7. Using these values, Hallermeier equation gives:

d_s = 4.3 m and

d_o = 13.0 m

Bruun (1954) proposed a simple power law to describe the relationship between water depth, *h*, and offshore distance, *x*, measured at the mean sea level:

$$h = Ax^{\frac{2}{3}}$$

where *A* is a dimensional shape factor, mainly dependent on the grain size. Figure 30 (from Dean, 1987) gives an empirical relationship between *A* and grain size, D. This gives a value of *A* for Jimmy's Beach, based on a measured median grain size of around 0.37-0.39 mm, of approximately 0.15 to 0.20.

Analysis of data from the digitised soundings from:

- the Australian and Admiralty Chart AUS 219 *Sugarloaf Anchorage* and *Cape Hawke Harbour;*
- geological map *SI 56-2 Newcastle;*
- bathymetric survey data of Port Stephens; and,
- topographic data from the Aerial Laser Survey (ALS) provided by Great Lakes Council,

indicates that the nearshore profile is in equilibrium down to a depth of up to 5 m with a profile length varying between 100 and 200 m (Table 19).

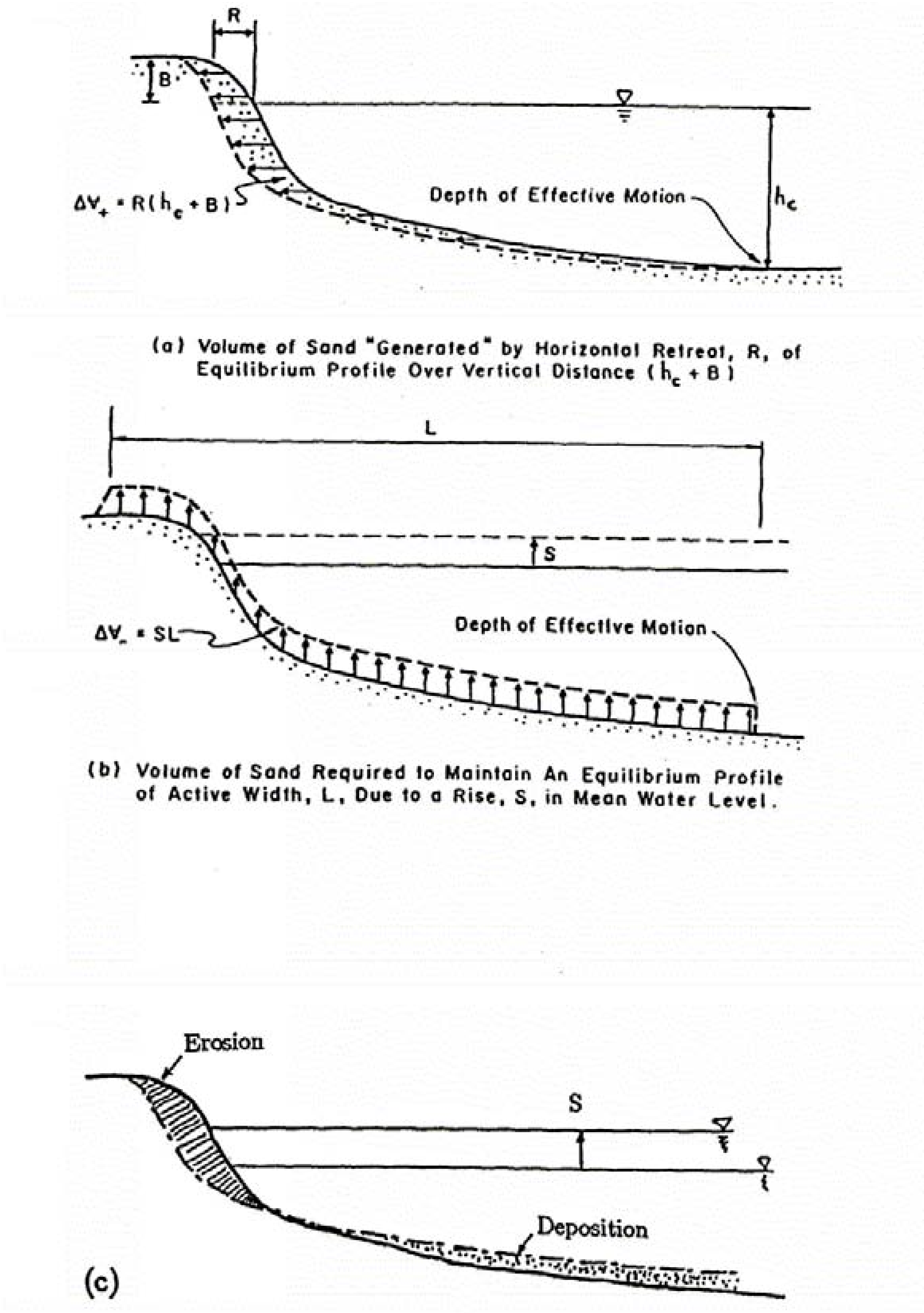


Figure 29: Concept of shoreline recession due to sea level rise

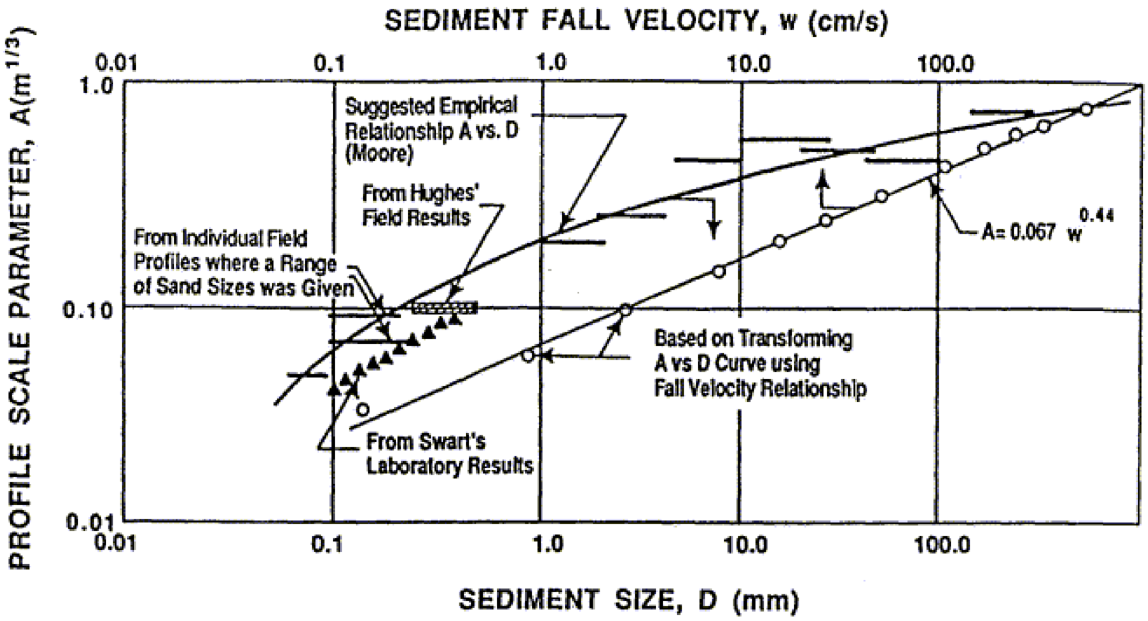


Figure 30: Suggested relationship for shape factor A vs. grain size D

Table 19: Determination of the berm height, the closure depth and the profile length per block and per continuous beach from bathymetric and topographic data

Beaches Name	Av. Dune height B (m)	Av. d_s from Hallermeier (m)	Adopted Av. Closure depth h_c (m)	Av. Profile length L (m)	Average slope per block (1:X)
Jimmy's Beach East	4.6	4.3	-2.2	100	15
Jimmy's Beach Centre-East	5.4	4.3	-3.6	160	18
Jimmy's Beach Centre-West	5.4	4.3	-2.5	135	17
Jimmy's Beach West	7.6	4.3	-4.4	208	17

The closure depths and the equilibrium profile lengths have been assessed from the beach profile graph as the profile is not in equilibrium below these depths. These two characteristics are the coordinates of the last point fitting with the equilibrium profile.

The application of the Bruun Rule is limited to the portion of the profile in equilibrium. The computed nearshore profile slope is within the range of 1:15 to 1:18 for Jimmy's Beach.

A comparison plot of the shore-normal profile at the central-eastern end of Jimmy's Beach and the estimated equilibrium profile is given in Figure 31. It should be noted that the nearshore profile is based on limited data.

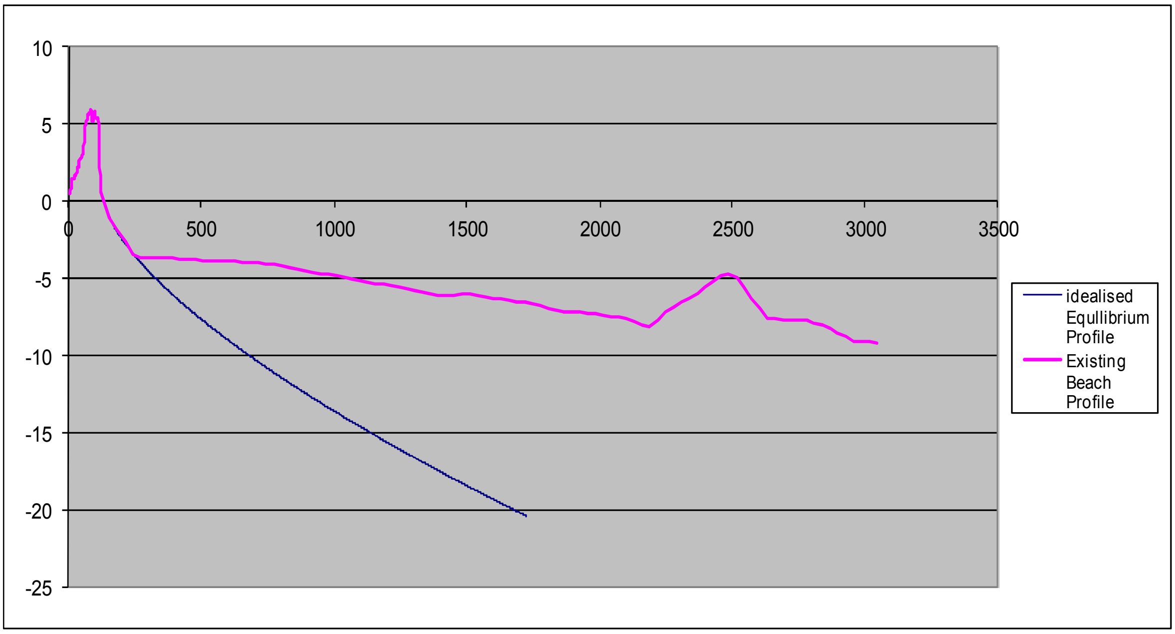


Figure 31: Nearshore profile at Jimmy's Beach vs. idealised equilibrium profile

4.4.3 Beach Response

Results of the Bruun analysis are given in Table 20. The 2050 and 2100 sea level rise benchmark of 0.40 m and 0.90 m from 1990 respectively (2009 *NSW Government Sea Level Rise Policy Statement* benchmarks for planning purposes), were adapted to include the measured sea level rise that already occurred between 1990 and 2011, which is around 0.06 m. Therefore values of 0.34 m by 2050 and 0.84 m by 2100 were used in the sea level rise calculation. For the 2060 beach response assessment, an interpolated value of 0.44 m was used.

Table 20: Predicted beach recession due to sea level rise

Location	Slope	Climate Change Impact from 2010 (taking account of SLR since 1990)								
		Sea Level Rise (m)			Total Recession (m)			Total Sand Vol (m^3/m)		
		2050	2060	2100	2050	2060	2100	2050	2060	2100
Jimmy's Beach East	15	0.34	0.44	0.84	5.0	6.5	12.4	23.0	29.8	56.8
Jimmy's Beach Centre-East	18	0.34	0.44	0.84	6.0	7.8	14.9	32.6	42.2	80.6
Jimmy's Beach Centre-West	17	0.34	0.44	0.84	5.8	7.5	14.4	31.4	40.6	77.5
Jimmy's Beach West	17	0.34	0.44	0.84	5.9	7.6	14.6	44.8	58.0	110.7

It should be noted that these recession rates assume that the dune is composed entirely of erodible material.

4.5 Analysis of Beach Nourishment Material

Two main locations have been identified and used in the past as beach nourishment sources for Jimmy's Beach. Based on the grain size analysis presented in Section 2.2 (PWD, 2000), the overfill ratio for sand nourishment has been determined.

Beach nourishment involves placement of sand onto the beach to create a dune, which provides a buffer against erosion due to storms. Such nourishment depends on locating a suitable source of sand, such as a nearby estuary. Nourishment is most effective when the sand placed on the beach closely matches the grain size and characteristics of the native beach sand, or when the sand is sourced from within the same coastal sediment compartment as the beach.

When the borrowed sand distribution does not match the native sand distribution, an overfill ratio (R_A) is applied to determine the required nourishment volume. For example, if the overfill ratio between the existing sand and the selected source of sand is 1.1, a volume of 1,100 m^3 of borrow sand would be required to act as efficiently as a volume of 1,000 m^3 of native sand.

After Coastal Engineering Manual (CEM, 2003), a nourishment project should use fill material with a composite median grain diameter equal to that of the native beach material, and with an overfill ratio within the range of 1.00 to 1.05. This is the optimal level of sediment compatibility. Both the overfill ratio and equilibrium beach profile concepts indicate that sediment compatibility is sensitive to the native composite median grain diameter. Accordingly, the compatibility range varies depending on the characteristics of the native beach material, with coarse material being less sensitive to small variations between the native and borrow sediments than fine material.

As a rule of thumb, for native beach material with a composite median grain diameter exceeding 0.2 mm, borrow material with a composite median diameter within plus or minus 0.02 mm of the native median grain diameter is considered compatible. For native beach material with composite median diameter between 0.15 and 0.2 mm, borrow material can be considered compatible if its composite median diameter is within plus or minus 0.01 mm of the native diameter. For native beach material with a composite median diameter less than 0.15 mm, use of material at least as coarse as the native beach is recommended. Even though material is deemed compatible based on these rules, grainsize differences should be factored into estimates of required fill volume through use of equilibrium beach profile methods, or the overfill ratio, or both.

The overfill ratio can be calculated using the following criteria (CEM, 2003):

$$\frac{\sigma_{\varphi b}}{\sigma_{\varphi n}} = \frac{\left[\frac{(\varphi_{84}-\varphi_{16})}{4} + \frac{(\varphi_{95}-\varphi_{5})}{6}\right]_b}{\left[\frac{(\varphi_{84}-\varphi_{16})}{4} + \frac{(\varphi_{95}-\varphi_{5})}{6}\right]_n}$$

$$\frac{M_{\varphi b} - M_{\varphi n}}{\sigma_{\varphi n}} = \frac{\left[\frac{(\varphi_{16}+\varphi_{50}+\varphi_{84})}{3}\right]_b - \left[\frac{(\varphi_{16}+\varphi_{50}+\varphi_{84})}{3}\right]_n}{\left[\frac{(\varphi_{84}-\varphi_{16})}{4} + \frac{(\varphi_{95}-\varphi_{5})}{6}\right]_n}$$

Where:

φ_x = $-\log_2 D_{(100-x)}$ = X^{th} percentile of the sediment diameter (phi unit)

$D_{(100-x)}$ = sediment diameter exceeded X percent of the time (mm)

$\sigma_{\varphi b}$ = estimated standard deviation for borrow material (phi unit)

$\sigma_{\varphi n}$ = estimated standard deviation for native material (phi unit)

$M_{\varphi b}$ = estimated mean grain size for borrow material (phi unit)

$M_{\varphi n}$ = estimated mean grain size for native material (phi unit)

Once these two criteria are calculated, the overfill ratio can be read from the diagram shown in Figure 32.

At Jimmy's Beach, the sandwave at Yacaaba Barrier and the spit at Winda Woppa have been accumulating sand for a long period. Sand from these locations has been transported to Jimmy's Beach as beach nourishment sources since 1984. The average grain size distribution at different sampling locations (and different years for the Yacaaba sandwave) is illustrated in Figure 7 and the values required in the above criteria for each location, based on sampling in the same year (2000), are provided in Table 21.

From Table 21 and Figure 32, the sandwave located along the Yacaaba Barrier has a similar distribution of fine sediment as the native sand from Jimmy's Beach. The Winda Woppa spit area contains fine sediments from the river entrance. Further sampling and analysis prior to beach nourishment campaigns would be necessary to characterise sediments from the borrow area and calculate the overfill ratio and hence volume of nourishment sand required.

Table 21: Distribution parameters required to determine overfill ratio at the sampling locations

Location Diameter	Yacaaba sandwave (2000)	Jimmy's Beach Native (2000)	Winda Woppa spit (2000)
D5 (mm)	0.182	0.176	0.17
D16 (mm)	0.269	0.259	0.244
D50 (mm)	0.393	0.381	0.356
D84 (mm)	0.566	0.551	0.468
D95 (mm)	0.928	1.127	0.596
Overfill Ratio for Jimmy's Beach	***1.02***	**-**	***1.75***

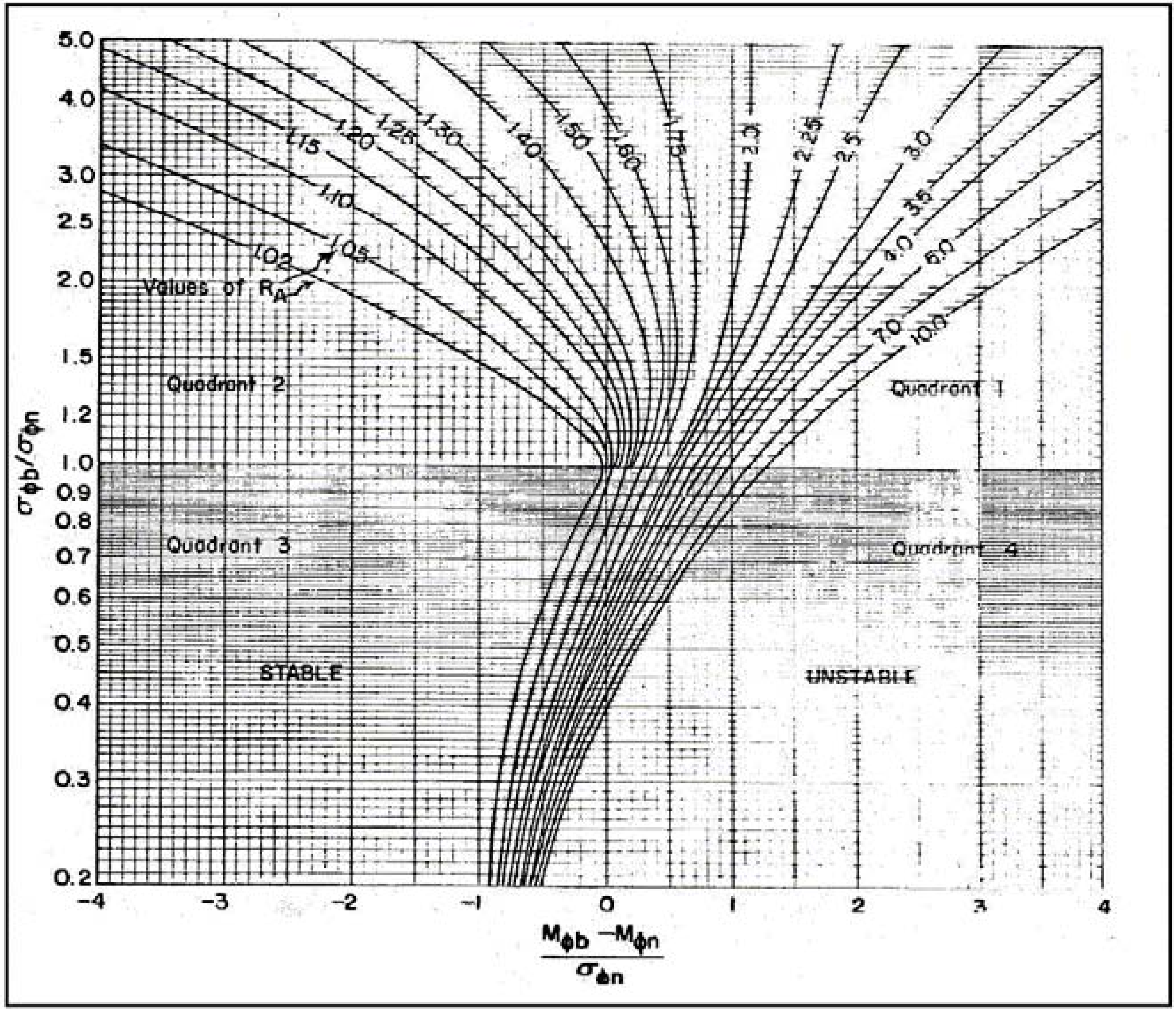


Figure 32: Isolines of the adjusted overfill ratio (RA) for values of mean difference and sorting ratio (Shore Protection Manual, 1984)

Nourishment work would also involve dune management techniques to revegetate the dune with native species, stabilising the dune sands and improving the ecology and recreational amenity of the beach.

Typically, a sand bund is constructed at the seaward end of the proposed beach nourishment profile, and a slurry of sand mixed with water is pumped onto the beach. An example of the process of placing beach nourishment at Jimmy's Beach with sand pumped from Winda Woppa is shown in Figure 33.

Figure 33: Beach Nourishment construction, Jimmy's Beach Port Stephens

.

5 HAZARD DEFINITION AND MAPPING

5.1 Summary of Hazard Parameters

Table 22 summarises each component of the immediate, 2050 and 2100 hazard lines. The storm demand volumes were applied as per Nielsen *et al.* (1992) on a profile by profile basis. Long-term recession components are applied as a landward shift of the immediate hazard line.

Table 22: Key parameters used in determining immediate, 2050 and 2100 hazard lines

Beach Section	Storm Demand (m^3/m)	Adopted long term recession rate due to sediment loss (m/yr)	Long term recession due to sea level rise (m)	
			2050	2100
Block 1 (Jimmy's Beach West)	50	0.6	5.9	14.6
Block 1 (Jimmy's Beach Centre-East)	70	0.4	6	14.9
Block 2 (Jimmy's Beach East)	70	0.9	5	12.4
Block 3 (Jimmy's Beach East)	40	0.1	5	12.4
Block 4 (Yaccaba Isthmus East)	20	0	5	12.4
Block 4 (Yaccaba Isthmus West)	50	0	5	12.4
Block 5 (Winda Woppa)	20	0	5	12.4

5.2 Hazard Mapping

The limits of the *Zone of Wave Impact and Slope Adjustment* and the *Zone of Reduced Foundation Capacity* have been calculated using the values for design storm erosion demand, for the 2050, 2060 and 2100 planning periods, adding the estimated recession associated with the sea level rise benchmarks and historical long term recession.

To obtain the location of the various zones, average values of the different profiles would normally have been used. However, several anthropogenic influences (beach nourishment, dune stabilisation, etc.) would have distorted the average result. The ALS data, which provides a greater density of data (dated from 2006) was used to define the hazard lines.

The immediate hazard limits due to the design storm erosion volume are shown in Figure 34 for the Jimmy's Beach coastline. It can be seen that there is no private property at immediate risk of storm damage. However parts of The Boulevarde in front of the residential development between Kururma Crescent and Guyra Street lie within *the Zone of Slope Adjustment*.

For the 2050 and 2100 planning periods, long term beach recession and sea level rise limits were added to the design storm recession for several locations along the beach, to estimate the seaward limits of the *Zone of Reduced Foundation Capacity*. Figure 35 illustrates the hazard limits for 2050 and Figure 36 illustrates the hazard limits for 2100. For the 2050 planning period, there would be about 16 properties landward of The Boulevarde affected by the *Zone of Slope Adjustment*. For the 2100 planning period, there would be about 25 more properties along The Boulevarde affected by the *Zone of Slope Adjustment* with a breakthrough in the back beach area into the Myall River channel.

For the 2060 planning period, there would be about 18 properties affected by the *Zone of Slope Adjustment* and 11 additional properties affected by the *Zone of Reduced Foundation Capacity* (refer to Figure 37).

It should be noted that the hazard mapping assumes that the dune is composed entirely of erodible material and that the nearshore beach profile is in equilibrium with the wave climate. It also assumes that present day management practices, such as beach nourishment, are discontinued.

6 CONCLUSION

Technical studies using an updated empirical database have allowed for the quantification of the coastal hazards at Jimmy's Beach. The assessment has been made on the basis of detailed photogrammetric survey data, sand sampling, wave transformation modelling and review of existing studies.

AS4997-2005 "*Guidelines for the design of maritime structures*" (AS, 2005) recommends that a storm event having a 5% probability of being exceeded over a 50 year period be adopted for risk analyses. Several large storm events occurred over the period of the photogrammetric data record, including a major storm in May-June 1974. The exceedance probability of these storms at Great Lakes is not known, but as they are the largest storms to have occurred over the period of the photogrammetric record, they were adopted for analysis for Jimmy's Beach. The maximum estimated erosion between consecutive dates of photogrammetric data which encompasses these large storm events, were adopted as the design storm erosion demand.

The available photogrammetric data has indicated that Jimmy's Beach had been undergoing long term recession prior to beach nourishment commencing in 1983. Following the use of beach nourishment as a management technique, the beach has been relatively stable as indicated in the photogrammetric data between 1983 and 2008.

As no significant independent field measurements has been undertaken for this assessment SMEC are unable to resolve conflicting conclusions about net sediment transport direction along Jimmy's Beach. However, based on our review of the previous investigations and existing coastal processes it is considered likely that the majority of the sand eroded from Jimmy's Beach is transported to the east while a smaller proportion 'leaks' past Barnes Rocks and is transported west to the Corrie Channel.

The prognosis for a future sea level rise, as a result of global warming, could increase the rate of long term recession. High estimate sea level rise scenarios in line with the 2009 *NSW Sea Level Rise Policy Statement*, indicated a sea level rise from the 1990 sea level of 0.40 m by 2050, and 0.90 m by 2100. A Bruun analysis was undertaken to estimate the sea level rise induced shoreline recession at Jimmy's Beach, based on estimates of the active beach slope undertaken using Hallermeier and by examination of bathymetric profiles.

Wave runup analysis for the design storm has indicated that maximum wave runup levels may create some inundation hazard for the properties located along Jimmy's Beach as the dune height is lower than the runup level in some locations. This is especially true at the eastern end of The Boulevarde. The inundation zone would likely increase based on current predictions for future sea level rise.

The two potential sand sources for beach nourishment at Winda Woppa and Yacaaba were assessed for suitability based on their grain size characteristics. It was found that the sand source at Yacaaba is more suitable as the grain size characteristics of this source are more compatible with those of the native beach sand that the source at Winda Woppa.

DATE 06/12/2011 | 0 200 400 metres | COORDINATE SYSTEM MGA 94 Zone 56

FIG NO. 34 | FIGURE TITLE Present Hazard zones at Jimmys Beach

PROJECT NO. 3001829 | PROJECT TITLE Great Lakes Coastal Hazard Study

CREATED BY A.XIAO | LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\009DATA\GIS

SMEC | Great Lakes COUNCIL

DATE 06/12/2011

COORDINATE SYSTEM MGA 94 Zone 56

FIG NO. 35

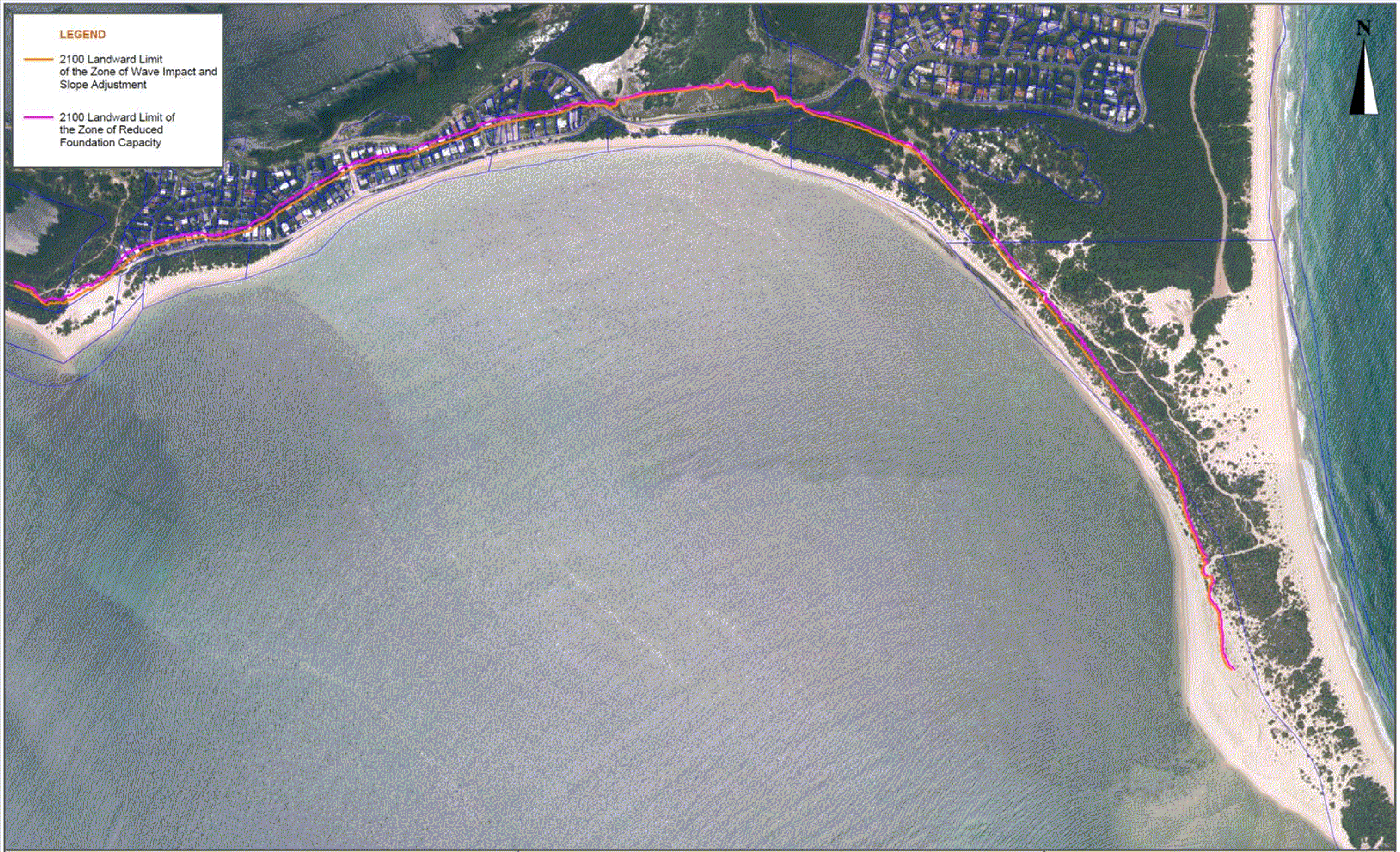
FIGURE TITLE Year 2050 Hazard Zones at Jimmys Beach

PROJECT NO. 3001829

PROJECT TITLE Great Lakes Coastal Hazard Study

CREATED BY A.XIAO

LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\009DATA\GIS



DATE 06/12/2011	0 200 400 metres	COORDINATE SYSTEM MGA 94 Zone 56	FIG NO. 36	FIGURE TITLE Year 2100 Hazard Zones at Jimmys Beach
PROJECT NO. 3001829	PROJECT TITLE Great Lakes Coastal Hazard Study		CREATED BY A.XIAO	LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\009DATA\GIS

SMEC Great Lakes COUNCIL

DATE 06/12/2011	0 200 400 metres	COORDINATE SYSTEM MGA 94 Zone 56	FIG NO. 37	FIGURE TITLE Year 2060 Hazard Zones at Jimmys Beach
PROJECT NO. 3001829	PROJECT TITLE Great Lakes Coastal Hazard Study		CREATED BY A.XIAO	LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\009DATA\GIS

SMEC Great Lakes COUNCIL

7 REFERENCES

Austin, T.P., 2011. The role of wave-tide interactions on floodtide delta morphodynamics and the impact on estuarine beaches: Port Stephens, N.S.W., The University of Sydney, Sydney.

Bruun, P.M. (1954). "Coast erosion and the development of beach profiles", Technical Memorandum 44, US Army Beach Erosion Board, June 1954.

Bruun, P.M. (1962). "Sea-Level rise as a cause of shore erosion", Jnl. Waterways, Harbour & Coastal Engg. Div., ASCE, Vol. 88, No. WW1, pp 117-130.

Bruun, P.M. (1983). "Review of conditions for uses of the Bruun Rule of erosion", Jnl. Coastal Engg., Vol 7, No. 1, pp 77-89.

CERC (1984). "Shore Protection Manual", U.S. Army Corps of Engineers, Coastal Engineering Research Centre, Waterways Experiment Station, Vicksburg, Miss.

Coastal Engineering Manual (2003). "Part V Chapter 3 – Shore Protection Projects", U.S. Army Corps of Engineers, EM 1110-2-1100, 31 July 2003.

Dean, R. G. (1987) "Coastal sediment processes: toward engineering solutions." In Nicholas C. Kraus, editor, Coastal Sediments '87, volume 1, pp 1 – 24, New Orleans, Louisiana, May 1987. ASCE. Proceedings of a Specialty Conference on Advances in Understanding of Coastal Sediment Processes.

DPWS, 1996. Port Stephens Flood Study-Stage 2: Design Water Levels and Wave Climate.

DPWS, 1999. Port Stephens/Myall Lakes Estuary Processes Study.

Jelliffe Environmental Pty Ltd, 2003. An Environmental Impact Statement for the proposed Jimmy's Beach sand extraction and beach nourishment scheme.

Flood-tide Delta Morphodynamics and Management Implications, Port Stephens, Australia. (Vila-Concejo et al., 2007)

Formation and Evolution of a Sandwave on an Estuarine Beach (Vila-Concejo et al., 2009)

Gordon, A.D. 1982, An Assessment of Beach Processes in the Hawks Nest Region, Coastal Engineering Branch Working Paper, Public Works Department New South Wales.

Hallermeier, R. J. (1981) "A profile zonation for seasonal sand beaches from wave climate" Coastal Engg., Vol. 4, pp 253-277.

Hallermeier, R. J. (1983) "Sand Transport limits in coastal structure design", Proc. Coastal Structures '83, ASCE, pp 703-716.

Jimmy's Beach – Investigation of Sand Source off Winda Woppa (PWD, 1986)

Kamphuis, J. W. (1991). "Alongshore sediment transport rate," Journal of Waterways, Port, Coastal and Ocean Engineering ASCE, 117(6), 624-641.

Kulmar, M. and Nalty, C. (1997), "New South Wales Coast, May 1997 Storm Analysis" Report MHL886, December 1997.

Kulmar, M., Lord, D., Sanderson, B. (2005), Future Directions for Wave Data Collection in New South Wales, 2005 Coasts and Ports Australasian Conference.

Lord, D.B. & M. Kulmar (2000). "The 1974 storms revisited: 25 years experience in ocean wave measurement along the south-east Australian coast", Proc. 27th ICCE, ASCE, Sydney, July, 2000, 559-572.

Manly Hydraulic Laboratory [MHL] (2000) Jimmy's Beach Coastline Management Review, Conceptual Sediment Budget and beach Nourishment Practices, Report No MHL 1041, NSW Department of Public Works and Services, DPWS Report No 00005, Prepared for Great Lakes Council.

Manly Hydraulic Laboratory [MHL] (2001) Jimmy's Beach Coastline Management Review, Stage 3, Management Options and Impacts, Report No MHL 1047, NSW Department of Public Works and Services, DPWS Report No 000022, Prepared for Great Lakes Council.

MHL (1997), Port Stephens Flood Study – Stage 2, Design Water Levels and Wave Climate, Final Draft Report MHL 759, Department of Public Works and Services, PW Report No. 96008, February, for Port Stephens and Great Lakes Councils, ISBN 0 310 6813 0.

Nielsen, A.F., D.B.Lord & H.G. Poulos (1992). "Dune Stability Considerations for Building Foundations", ", IEAust., Aust. Civ. Eng. Trans., Vol. CE 34, No. 2 pp 167-173.

Patterson Britton & Partners [PBP] (2005), Coastal Engineering Assessment 0- Lot, DP 739877, The Boulevarde, Hawkes Nest, report prepared for Tattersal Surveyors March 2005

Pereira, LCC, Vila-Concejo, A, Trindade, WN, Short, AD, 2011. Influence of high-energy conditions on beach changes in tide-dominated (Amazon, Brazil) and wave-dominated (NSW, Australia) coastal environments. Journal of Coastal Research SI(64): 115-119.

Petkovic, P., Fitzgerald, D., Brett, J., Morse, M., Buchanan, C. (2001), Potential field and bathymetry grids of Australia's margins . Australian Society of Exploration Geophysicists 2001 Conference, Extended Abstracts.

PWD 1993. Port Stephens Flood Study Stage 1: analysis and review of existing information MHL 623.

PWD, 1985. Jimmy's Beach Management Report. 85012

PWD, 1986, Jimmy's Beach Erosion Study, Report No. 85042.

PWD, 1987. Jimmy's Beach Erosion Study. 85042

Sommerfeld, B. G., Mason, J. M., Kraus, N. C., Larson, M. (1994) "BFM: Beach Fill Module – Report 1 Beach Morphology Analysis package (BMAP) – User's Guide, U.S. Army Corps of Engineers.

Swart, D. H. (1974), "Offshore Sediment Transport and Equilibrium Beach Profiles", Delft Hydraulics Laboratory, Publn. No. 131.

Thom, B.G., Sheperd, 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. Dept. of Biogeography and Geomorphology, Australian National University, Canberra, 407 pp.

Vila-Concejo, A, Austin, TP, Harris, DL, Hughes, MG, Short, AD, Ranasinghe, R, 2011. Estuarine beach evolution in relation to a flood-tide delta. Journal of Coastal Research SI(64): 190-194.

Vila-Concejo, A., Hughes, M.G., Short, A.D. and Ranasinghe, R., 2010. Estuarine shoreline processes in a dynamic low-energy system. Ocean Dynamics, 60(2): 285-298.

Vila-Concejo, A., Matias, A., Pacheco, A., Ferreira, Ó. and Dias, J.A., 2006. Quantification of inlet-related hazards in barrier island systems. An example from the Ria Formosa (Portugal). Continental Shelf Research, 26(9): 1045-1060.

Vila-Concejo, A., Short, A.D., Hughes, M.G. and Ranasinghe, R., 2009. Formation and evolution of a sandwave on an estuarine

Vila-Concejo, A., Short, A.D., Hughes, M.G. and Ranasinghe, R., 2007b. Shoreline implications of flood-tide delta morphodynamics. The case of Port Stephens (SE Australia). In: Coastal Sediments, New Orleans, ASCE, 1417-1430

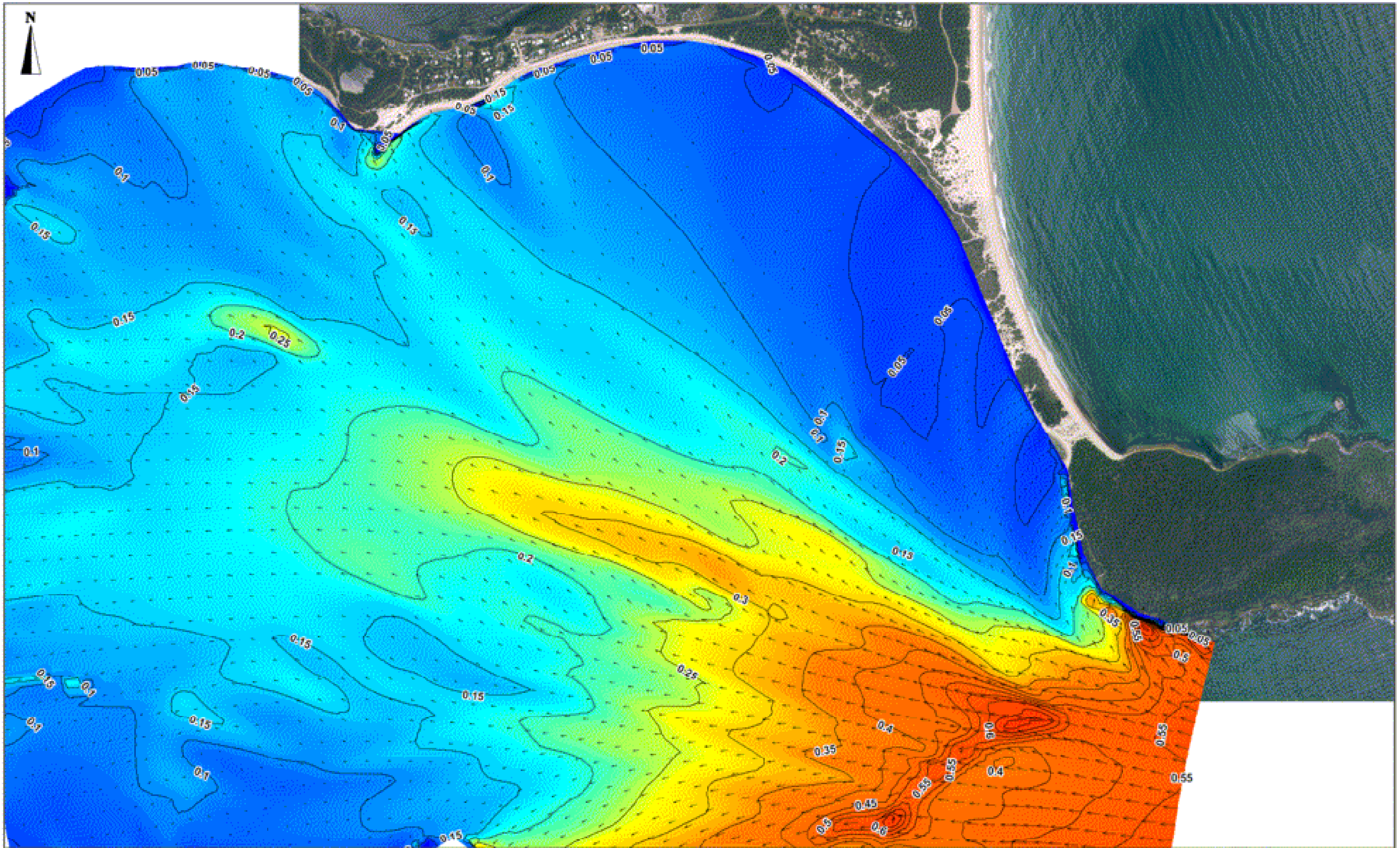
Vila-Concejo, A., Short, A.D., Hughes, M.G. and Ranasinghe, R., 2007a. Flood-tide delta morphodynamics and management implications, Port Stephens, Australia. Journal of Coastal Research, SI(50): 705-709.

Watson, P.J., 1997. Port Stephens Sand Nourishment Projects - Evaluation, Monitoring & Sustainability. In: 13th Australasian Coastal & Ocean Engineering Conference, Christchurch, New Zealand, Centre for Advanced Engineering, 1, 453-458

Watson, P.J., 2000. Jimmy's Beach, Port Stephens, N.S.W. An expensive learning experience in coastal management. In: (B.L. Edge)B.L. Edges), International Conference on Coastal Engineering Sydney, Australia, American Society of Civil Engineers, 4, 3566-3579

Wilson J. 1985, in conjunction with Public Works Department, New South Wales Coastal Branch Working Paper, Jimmy's Beach Erosion Management Options.

APPENDIX 1 – WAVE TRANSFORMATION MODELLING



DATE 16/01/2012

0 300 600
metres

COORDINATE SYSTEM MGA 94 Zone 56

FIG NO. A1

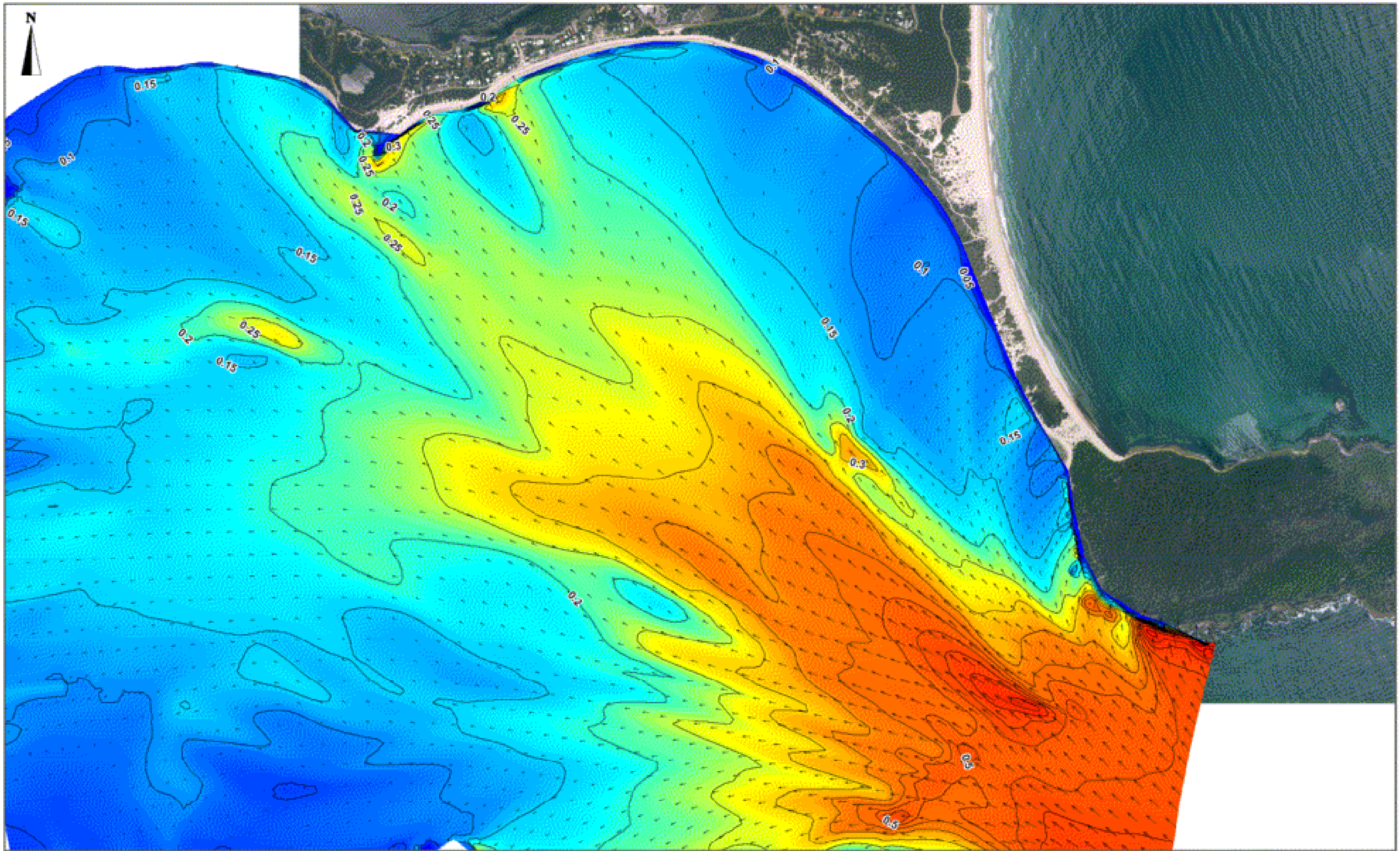
FIGURE TITLE SWAN wave transformation model for swell wave Hs=1m,Ts=10s,offshore wave direction = ENE

PROJECT NO. 3001829

PROJECT TITLE Jimmys Beach CZMP

CREATED BY A.XIAO

LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\Jimmys Beach Variation\Data\Jimmys_Beach_Port_Stephens\Workspace



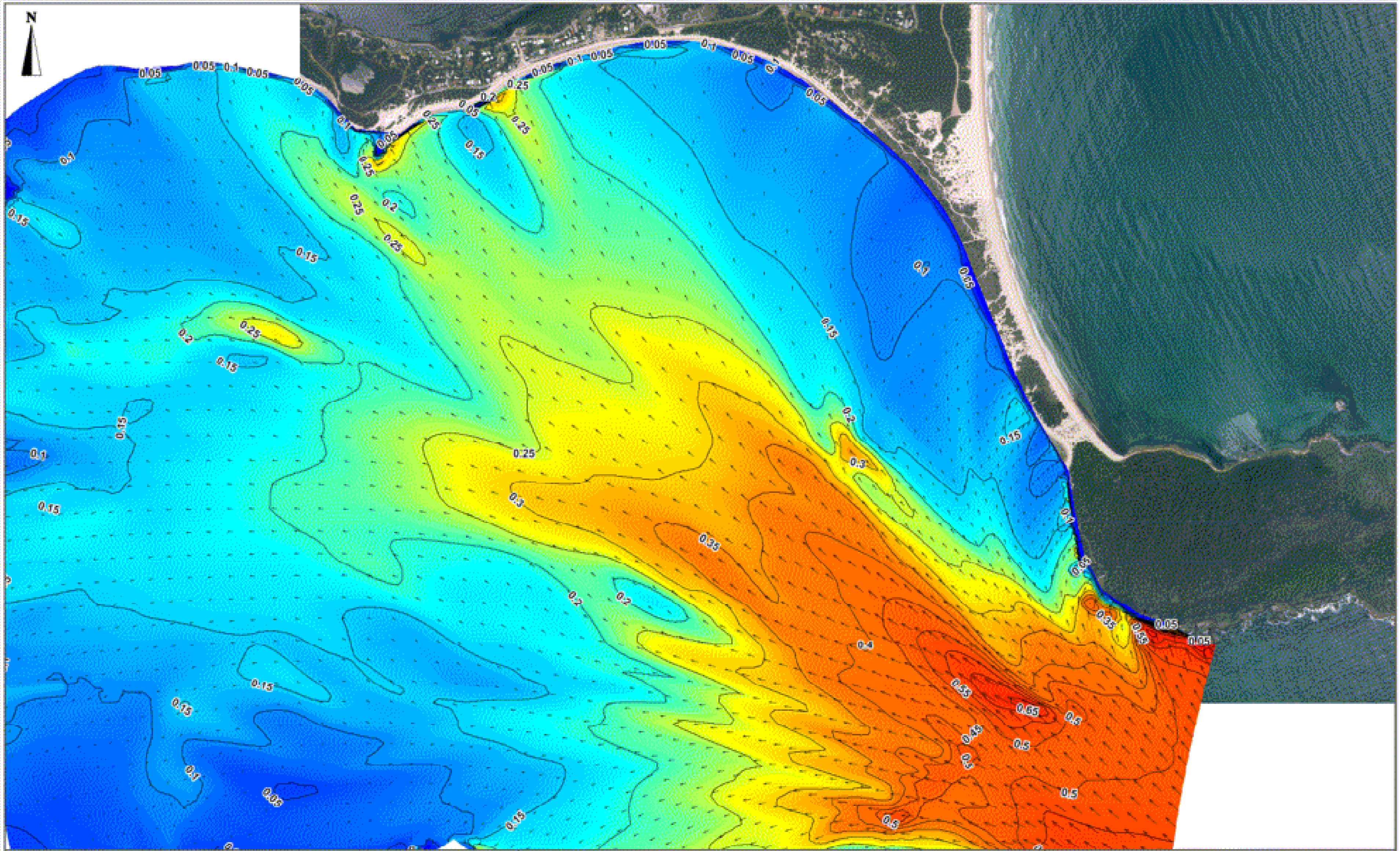
DATE 16/01/2012 | 0 300 600 metres | COORDINATE SYSTEM MGA 94 Zone 56

FIG NO. A2 | FIGURE TITLE SWAN wave transformation model for swell wave Hs=1m,Ts=10s,offshore wave direction = ESE

PROJECT NO. 3001829 | PROJECT TITLE Jimmys Beach CZMP

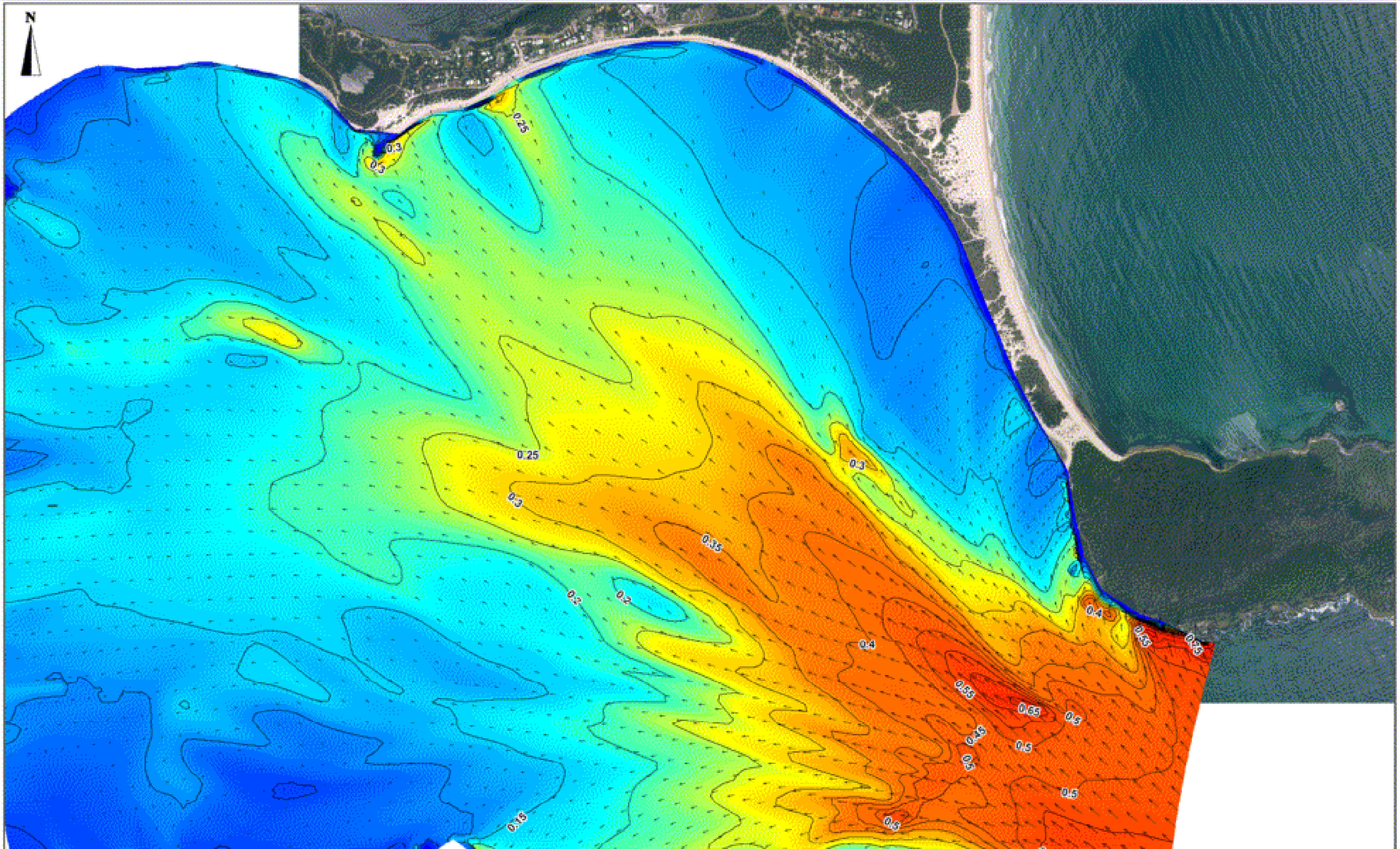
CREATED BY A.XIAO | LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\Jimmys Beach Variation\Data\Jimmys_Beach_Port_Stephens\Workspace

SMEC



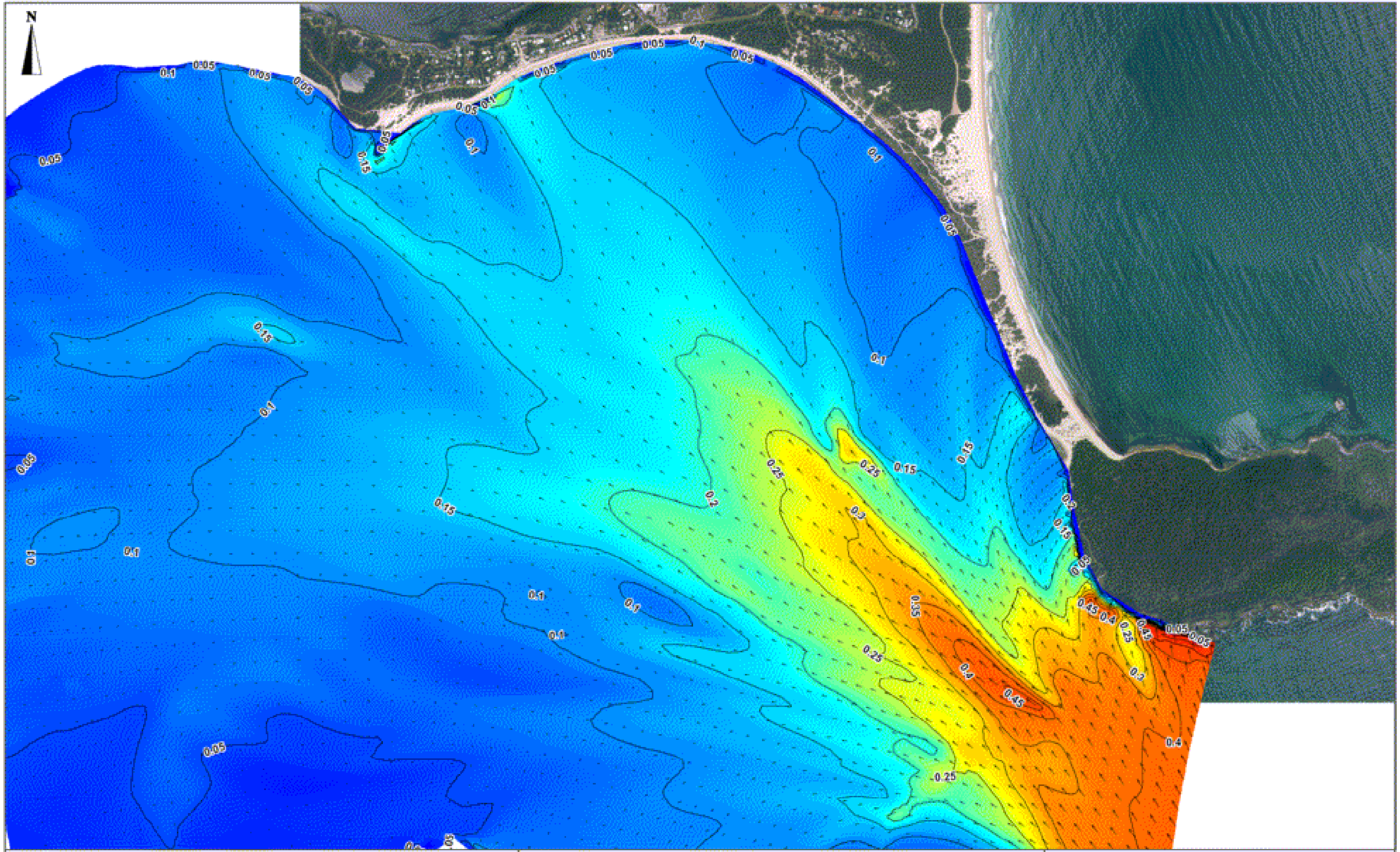
DATE 16/01/2012	0 300 600 metres	COORDINATE SYSTEM MGA 94 Zone 56	FIG NO. A3	FIGURE TITLE SWAN wave transformation model for swell wave Hs=1m,Ts=10s,offshore wave direction = E
PROJECT NO. 3001829	PROJECT TITLE Jimmys Beach CZMP		CREATED BY A.XIAO	LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\Jimmys Beach Variation\Data\Jimmys_Beach_Port_Stephens\Workspace

SMEC



DATE 16/01/2012 0 300 600 metres	COORDINATE SYSTEM MGA 94 Zone 56	FIG NO. A4 FIGURE TITLE SWAN wave transformation model for swell wave Hs=1m,Ts=10s,offshore wave direction = SE
PROJECT NO. 3001829	PROJECT TITLE Jimmys Beach CZMP	CREATED BY A.XIAO LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\Jimmys Beach Variation\Data\Jimmys_Beach_Port_Stephens\Workspace

SMEC



DATE 16/01/2012 | 0 300 600 metres | COORDINATE SYSTEM MGA 94 Zone 56

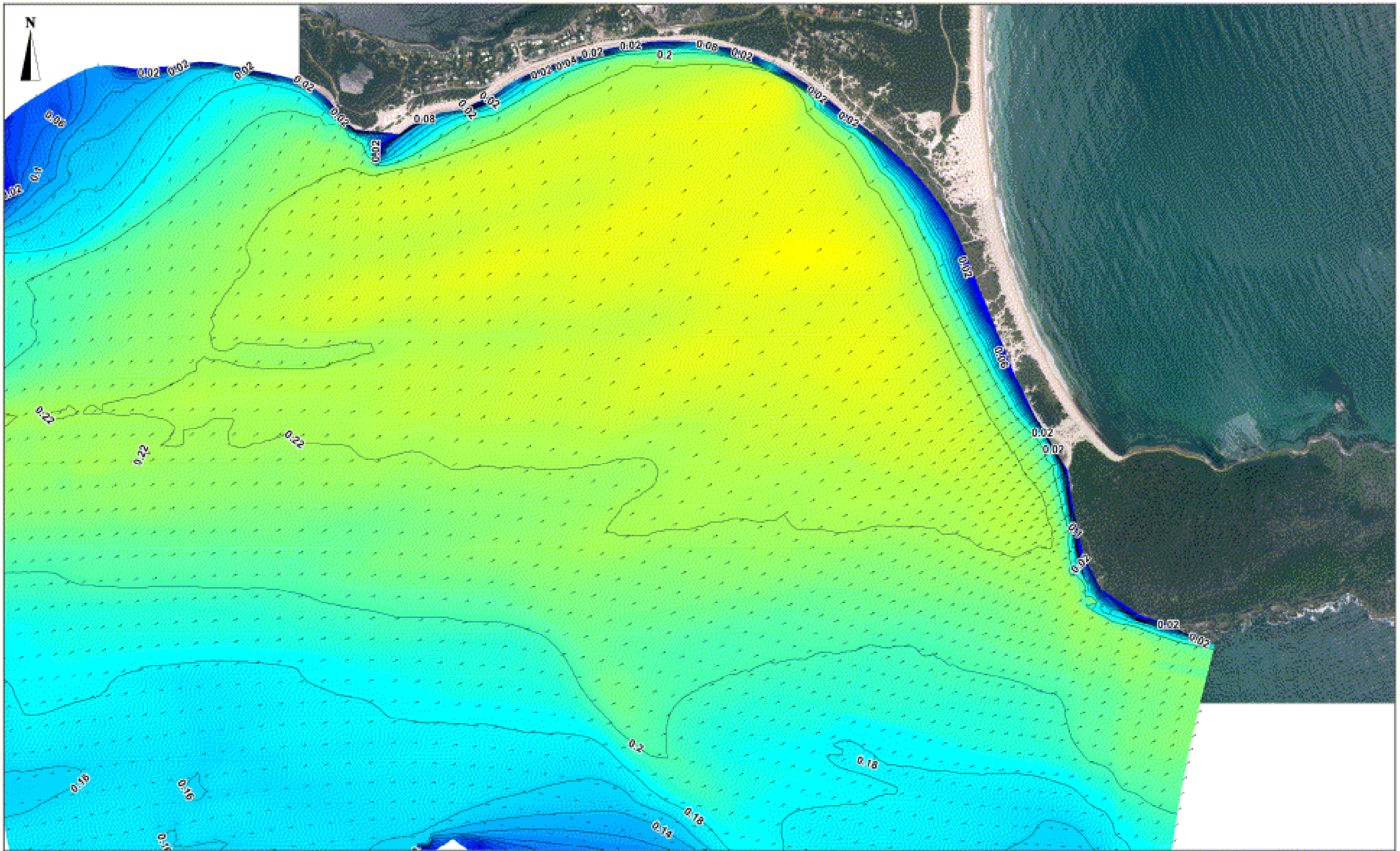
FIG NO. A5

FIGURE TITLE SWAN wave transformation model for swell wave Hs=1m,Ts=10s,offshore wave direction = S

PROJECT NO.3001829 | PROJECT TITLE Jimmys Beach CZMP

CREATED BY A.XIAO

LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\Jimmys Beach Variation\Data\Jimmys_Beach_Port_Stephens\Workspace



DATE 16/01/2012 | 0 300 600 metres | COORDINATE SYSTEM MGA 94 Zone 56

FIG NO. A6

FIGURE TITLE SWAN wave transformation model for wind waves, wind direction = SW

PROJECT NO. 3001829

PROJECT TITLE Jimmys Beach CZMP

CREATED BY A.XIAO

LOCATION I:\projects\3001829 - Great Lakes Coastal Hazard Study\Jimmys Beach Variation\Data\Jimmys_Beach_Port_Stephens\Workspace

SMEC