THE UNIVERSITY OF NEW SOUTH WALES
water research laboratory
Manly Vale N.S.W. Australia

UPDATE OF TWEED SHIRE COASTAL HAZARD LINES

by

J T Carley and M A Mole

Technical Report 2010/11
August 2010

THE UNIVERSITY OF NEW SOUTH WALES
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
WATER RESEARCH LABORATORY

UPDATE OF TWEED SHIRE COASTAL HAZARD LINES

WRL Technical Report 2010/11 August 2010

by

J T Carley and M A Mole

Water Research Laboratory
School of Civil and Environmental Engineering
University of New South Wales ABN 57 195 873 179
King Street
Manly Vale NSW 2093 Australia

Telephone: +61 (2) 8071 9800
Facsimile: +61 (2) 9949 4188

Technical Report No 2010/11
Report Status Final
Date of Issue August 2010

WRL Project No. 10061
Project Manager James Carley

Title	Update of Tweed Shire Coastal Hazard Lines
Author(s)	James Carley and Melissa Mole
Client Name	Tweed Shire Council
Client Address	Tweed Shire Council PO Box 816 MURWILLUMBAH NSW 2484
Client Contact	Ms Jane Lofthouse jlofthouse@tweed.nsw.gov.au
Client Reference	EQ2010-063

The work reported herein was carried out at the Water Research Laboratory, School of Civil and Environmental Engineering, University of New South Wales, acting on behalf of the client.

CONTENTS

LIST OF TABLES

1. INTRODUCTION

1.1 Overview

The NSW Government (1990) "Coastline Management Manual" identifies seven separate coastal hazards, namely:

- Beach erosion;
- Shoreline recession;
- Coastal entrance behaviour;
- Sand drift;
- Coastal inundation;
- Slope and cliff instability;
- Stormwater erosion.

The hazards of beach erosion and shoreline recession (due to ongoing underlying processes and future sea level rise) are generally combined into a "coastline hazard line" for various planning periods.

1.2 Coastline Hazard Lines for Tweed Shire

Within the Tweed Shire Council (TSC) area, coastline hazard lines were developed by WBM (2001) which were based on contemporary coastal engineering techniques. The WBM study was based on photogrammetry gathered between 1945 and 1999 and hazard lines were defined for present day (nominally the year 2000) and 2050 and 2100 scenarios. The WBM work used sea level rise projections (relative to 1990) of 0.2 m for 2050 and 0.5 m for 2100, based on mid range Intergovernmental Panel on Climate Change estimates from IPCC (1996).

The NSW Government Sea Level Rise Policy Statement (2009) is broadly based on IPCC (2007) and recommends the following allowances for coastal planning:

- 2050 up to 0.4 m;
- 2100 up to 0.9 m.

This recent policy necessitated an update of the WBM hazard lines, which was undertaken by WRL at the request of TSC.

At the request of TSC, figures are not provided in this report, but rather GIS shape files of the modified coastal hazard lines have been provided electronically to TSC.

With the exception of the revised sea level rise values, all other assumptions used previously by WBM were also adopted by WRL. The analysis was undertaken on the scale of typical values for embayments or sections of coast, and was not undertaken down to the level of individual properties. Therefore, a detailed analysis for a single property may produce a slightly different hazard line location due to site specific factors such as dune volume and height.

Future coastal behaviour will be dependent on the maintenance and preservation of entrance training works and bridge abutments, dredging of entrances, placement of dredged sand, protection works and future management strategies implemented. These are beyond the scope of this report. Coastal entrances in Tweed Shire are:

- Mooball Creek;
- Cudgera Creek;
- Cudgen Creek;
- Tweed River.

Coastal protection works in Tweed Shire are:

- Cudgen Headland SLSC;
- Kingscliff Bowls Club.

The presence of underlying rock may also alter the hazard line location. The protection works (Kingscliff Bowls Club and Cudgen Headland SLSC) were not considered in the updated hazard lines. Both ad-hoc and formal protection works will also have a localised end effect of increased erosion over a short distance (tens to hundreds of metres). In Tweed Shire this end effect will be predominantly to the north. Such end effects have not been considered in the hazard lines.

Duranbah beach was not included in the WBM (2001) study as it is subject to artificial nourishment and adaptive management by the Tweed River Entrance Sand Bypass Project and Council. Duranbah has not been included in this study.

The purpose of this study was to provide revised coastal hazard lines for TSC using the latest sea level projections from the NSW Government (2009). This report is limited to the hazards of beach erosion and shoreline recession – both ongoing underlying, and due to future sea level rise.

2. COASTLINE SETBACK COMPONENTS

2.1 Setback Components

2.1.1 List of Setback Components

There are five key components of coastal setback defined by WRL in studies of this type, namely:

S1: Allowance for short term storm erosion;

S2: Allowance for ongoing underlying recession;

S3: Allowance for recession due to future sea level rise;

S4: Allowance for dune stability (*Zone of Reduced Foundation Capacity - ZRFC*);

S5: Allowance for beach rotation.

For the purposes of this study only components S1 to S3 were incorporated into the hazard line, with S4 presented separately, and S5 not considered as beach rotation is not quantifiable with the data presently available. Further details on this are presented below.

2.1.2 Brief Description of Setback Components

S1: ***Allowance for short term storm erosion***, is for erosion due to an oceanic storm or series of storms. In NSW it is generally calculated using the work of Gordon (1987) as a basis, together with photogrammetric survey data, ground surveys and/or numerical modelling for the subject beach, and an adjustment for wave exposure and erosion potential. It is generally expressed in m^3/m above Australian Height Datum (AHD). The maximum value measured in NSW is 320 m^3/m (NSW Government, 1990).

S2: ***Allowance for ongoing underlying recession***, is a long term trend in the beach planform, which may be receding or accreting. It is generally estimated from photogrammetric survey data extending over approximately 50 years. It is generally expressed in terms of m/year. On the northern NSW coast, recession rates are generally higher near the southern hooks of bays.

S3: ***Allowance for recession due to future sea level rise***, is a projection of future shoreline recession due to a rise in mean sea level. It is usually calculated with the Bruun Rule (Bruun, 1962, 1988). A rule of thumb is that on open coasts, the Bruun Factor is typically in the range 50 to 100. That is, coastal recession will be 50 to 100 times the sea level rise.

Specific calculations taking account of the measured profile, wave climate and sand characteristics are preferred. There is considerable controversy regarding the Bruun Rule, however, there are few alternatives which can provide an immediate answer. Obviously, long term monitoring is preferable, but is not feasible if an answer is required in the short term.

S4: ***Allowance for dune stability***, encompasses an additional setback component relating to the geotechnical stability of dunes as described in: Nielsen *et al.* (1992). This method delineates a *Stable Foundation Zone* and a *Zone of Reduced Foundation Capacity.* In this method, buildings constructed seaward of the *Stable Foundation Zone* (SFZ) need to be constructed on piles due to the reduced bearing capacity in the *Zone of Reduced Foundation Capacity* (ZRFC).

S5: ***Allowance for beach rotation***, involves either a cyclic or one way change in the alignment of a beach's planform due to changes in the wave direction over medium (weeks to months) to long (decades) term time scales. It is a well known seasonal phenomenon in Perth WA, where the beach planform alignment is influenced by north-west storms in winter and south-west seabreezes in summer. The work on beach rotation presented by Short *et al.* (2000) involved more than 20 years of ongoing monthly surveys at Narrabeen NSW, which is approximately 3.6 km long. Short *et al.* found that beach rotation accounted for about 30% of beach width variation (along the 3.6 km long Narrabeen Beach). Regular long term monitoring is the only method available to properly track beach changes, so that extremes, averages, cycles and rotation can be properly identified. It was not considered by WBM (2001) or this report.

2.2 Design Setbacks

The total design setback (S) for three planning horizons comprises:

- Present day S = S1
- 2050 S = S1 + S2 + S3
- 2100 S = S1 + S2 + S3.

The S4 component needs to be added to the above for unpiled buildings.

3. PREVIOUS COASTLINE HAZARD LINES

The previous WBM (2001) study was utilised to define the components shown in Section 2 or the methodology for their derivation.

The *allowance for short term storm erosion* (S1) was obtained directly from WBM (2001) and is shown in Table 3.1.

Table 3.1
Allowance for Short Term Storm Erosion (S1) (WBM, 2001, chapter 8)

Precinct	S1: WBM allowance for short term storm erosion		
	Erosion volume (m^3/m) relative to 1999 erosion scarp (1)	Average dune height (m AHD)	Equivalent horizontal distance relative to 1999 erosion scarp (4) (m)
Wooyung to Hastings Point	160	(2) 5.5	30-40 in places (5) 50
Hastings Point to Norries Head	160	7	30 - 40
Cabarita / Bogangar / Casuarina Beach	200	6 - 8	40 - 50
Kingscliff / Dreamtime Beach (most)	160	6	30-40
Kingscliff near Cudgen Headland SLSC	200	5	50
Letitia Spit	200	(3) 6	(2) 30-40

Notes
(1) Referenced from a regionally smoothed alignment of the 1999 erosion scarp.
(2) WBM (2001) noted this height was for 1947 – 1962 (pre-mining).
(3) Not stated in WBM (2001) obtained by WRL from LIDAR survey data provided by TSC.
(4) Horizontal distance is subject to dune height and volume.
(5) Where dune is low.

The *allowance for ongoing underlying recession* (S2) was obtained directly from WBM (2001) and is shown in Table 3.2. Table 3.2 presents the minimum, maximum and best estimate recession rates determined by WBM.

Table 3.2
Allowance for Ongoing Underlying Recession (S2) (WBM, 2001)

Precinct	S2: WBM allowance for ongoing underlying recession		
	Low (m/yr)	Mid (m/yr) (best estimate)	High (m/yr)
Wooyung to Hastings Point:			
Wooyung to Pottsville	0.075	0.10	0.20
Pottsville (South)	0.075	0.10	0.20
Pottsville (North) to Hastings Pt	0.04	0.05	0.10
Hastings Point to Norries Head:			
South	0.075	0.10	0.20
North	0.04	0.05	0.10
Norries Head to Sutherland Point:			
Cabarita Township	0.10	0.15	0.25
Casuarina Beach (Central)	0.075	0.10	0.20
Sutherland Point	0.04	0.05	0.10
Sutherland Point to Fingal:			
Kingscliff (South)	0.15	0.20	0.30
Dreamtime Beach (Central)	0.075	0.10	0.20
Fingal to Tweed River:			
Fingal	0.04	0.05	0.10
Letitia Spit (2)	(2) 0.00	(2) 0.00	(2) 0.00

Notes
(1) Indurated sand (coffee rock), rock, protection works and future management not considered.
(2) The effects of the sand bypassing were expected by WBM (2001) to include a one-off retreat which will be dependent on strategies adopted.

The *allowance for recession due to sea level rise* (S3) was determined by use of the Bruun Rule. The Bruun Factor (BF) used to determine the setback allowance for Sea Level Rise (SLR) was determined from WBM (2001) and is shown in Table 3.3). The *allowance for recession due to sea level rise* is defined by S3=BF × SLR.

Table 3.3
Bruun Factor used for Recession due to Sea Level Rise (S3) (WBM, 2001)

Precinct	S3: WBM allowance for recession due to sea level rise (Bruun Factor)
All of Tweed Shire	(1) 50

Note
(1) This value fits within the "rule of thumb" range of 50 to 100.

The allowance for dune stability (S4) was obtained from WBM (2001) and reproduced in Table 3.4. This setback component is not required for piled buildings and is dependent on dune elevation. It was not incorporated in the hazard lines presented in WBM (2001). Due

to these factors, TSC requested that the dune stability (S4) component not be incorporated in the revised hazard lines, but will be incorporated in a future DCP.

Table 3.4
Allowance for Dune Stability (S4) (WBM, 2001)

S4: WBM allowance for dune stability (width of Zone of Reduced Foundation Capacity)	
Average Dune Height (m AHD)	**Indicative width of Zone of Reduced Foundation Capacity (m)**
4	9.3
5	10.7
6	12.2
7	13.6
8	15.0
9	16.4
10	17.9

4. UPDATED COASTLINE HAZARD LINES

4.1 Shire Wide Coastline Hazard Lines

Hazard lines (excluding the *Zone of Reduced Foundation Capacity,* S4) represent the idealised upper edge of a dune erosion scarp at the end of the planning period and following a major storm erosion event. The values for the components derived by WBM (2001) represent contemporary coastal engineering practice and were peer reviewed.

The values for S1 and S2, and the methodology for S3 (Tables 3.1 to 3.3) were obtained from WBM (2001). The adopted values which were used to determine the revised hazard lines are summarised in Table 4.1.

A range of ongoing underlying recession rates (S2) were outlined by WBM (2001), with a low, mid (best estimate) and high rate for each precinct presented in Table 3.2. At the request of TSC, the high S2 values were incorporated into the revised 2050 and 2100 hazard lines. Both mid and high S2 values are plausible choices and do not constitute a large proportion of the total setback distance.

The allowance for Dune Stability (width of *Zone of Reduced Foundation Capacity*), in component S4, was not included in the final hazard lines at the direction of the TSC. This component only applies to unpiled buildings and is often considered on a case by case basis, depending on the site specific conditions. WBM (2001) outlined general values for Tweed Shire based on average dune height (Table 3.6). Council has commenced a Development Control Plan (DCP) for Coastal Erosion. It is important for an allowance for dune stability to be incorporated into the DCP in the consideration of suitable responses for development within the coastal risk planning area.

As discussed in Section 1.2, the updated setback lines don't consider coastal protection works or their end effects. Likewise, except for emergent natural headlands, underlying rock or indurated sand was also not considered. After modification to include the NSW Government Sea Level Rise Policy Statement (2009) values of 0.4 m (2050) and 0.9 m (2100) SLR, the present day, 2050 and 2100 hazard line calculations are shown in Tables 4.2, 4.3 and 4.4, and summarised in Table 4.5. The additional setback required for an unpiled building due to the S4 component is shown in Table 4.6, and as stated above, this component will be incorporated into a forthcoming Council DCP.

Table 4.1
Summary of Adopted Allowances for Hazard Lines

Precinct	S1: allowance for short term storm erosion (m^3/m)[1]	S2: allowance for ongoing underlying recession (m/yr) for 2050 and 2100 [2]	S3: allowance for recession due to sea level rise (Bruun Factor)	S4: typical allowance for dune stability (ZRFC) (m) [3]
Wooyung to Pottsville	160	0.20	50	12
Pottsville (South)	160	0.20	50	12
Pottsville (North) to Hastings Pt	160	0.10	50	12
Hastings Pt to Norries Head (South)	160	0.20	50	12
Hastings Pt to Norries Head (North)	160	0.10	50	12
Cabarita Township	200	0.25	50	12
Casuarina Beach (Central)	200	0.20	50	12
Sutherland Point	200	0.10	50	12
Kingscliff (South)	160	0.30	50	12
Kingscliff near Cudgen Headland SLSC	200	0.30	50	12
Dreamtime Beach (Central)	160	0.20	50	12
Fingal	200	0.10	50	12
Letitia Spit [4]	200	0.00	50	12

Notes
(1) The values above were adopted from WBM (2001).
(2) High recession rate adopted for the 2050 and 2100 hazard lines from the values presented by WBM (2001).
(3) A shire wide typical dune height of 6 m AHD was adopted and the associated S4 value from WBM (2001). This component should be assessed where the dune height varies significantly from 6 m AHD.
(4) The effects of the sand bypassing were expected by WBM (2001) to include a one-off retreat which will be dependent on strategies adopted..

Table 4.2
Present Day Horizontal Setback Distances (from 1999 Scarp)

Precinct	S1: allowance for short term storm erosion (m)[(1)]	S: total horizontal setback (m) S1 (excludes S4)
Wooyung to Pottsville	30-40 in places 50	30 - 50
Pottsville (South)	30-40 in places 50	30 - 50
Pottsville (North) to Hastings Pt	30-40 in places 50	30 - 50
Hastings Pt to Norries Head (South)	30-40	30 - 40
Hastings Pt to Norries Head (North)	30-40	30 - 40
Cabarita Township	40-50	40 - 50
Casuarina Beach (Central)	40-50	40 - 50
Sutherland Point	40-50	40 - 50
Kingscliff (South)	30-40	30 - 40
Kingscliff near Cudgen Headland SLSC	50	50
Dreamtime Beach (Central)	30-40 in places 50	30 - 50
Fingal	40-50	40 - 50
Letitia Spit	40-50	40 - 50

Notes
(1) Allowance for short term erosion depends on dune height and varies within each precinct, values adopted from WBM (2001).

Table 4.3
2050 (SLR = 0.4 m) Horizontal Setback Distances (from 1999 Scarp)

Precinct	S1: allowance for short term storm erosion (m)[1]	S2: allowance for ongoing underlying recession (m) [2]	S3: allowance for recession due to sea level rise (m)	S: total horizontal setback (range) (m) S1+S2+S3 (excludes S4)
Wooyung to Pottsville	30-40 in places 50	10	20	60 - 80
Pottsville (South)	30-40 in places 50	10	20	60 - 80
Pottsville (North) to Hastings Pt	30-40 in places 50	5	20	55 - 75
Hastings Pt to Norries Head (South)	30-40	10	20	60 - 70
Hastings Pt to Norries Head (North)	30-40	5	20	55 - 65
Cabarita Township	40-50	13	20	73 - 83
Casuarina Beach (Central)	40-50	10	20	70 - 80
Sutherland Point	40-50	5	20	65 - 75
Kingscliff (South)	30-40	15	20	65 - 75
Kingscliff near Cudgen Headland SLSC	50	15	20	85
Dreamtime Beach (Central)	30-40 in places 50	10	20	60 - 80
Fingal	40-50	5	20	65 - 75
Letitia Spit [3]	40-50	[3] 0	20	60 - 70

Note
(1) Allowance for short term erosion depends on dune height and varies within each precinct, values adopted from WBM (2001).
(2) Highest recession rate adopted from WBM (2001).
(3) The effects of the sand bypassing were expected by WBM (2001) to include a one-off retreat which will be dependent on strategies adopted.

Table 4.4
2100 (SLR = 0.9 m) Horizontal Setback Distances (from 1999 Scarp)

Precinct	S1: allowance for short term storm erosion (m)[1]	S2: allowance for ongoing underlying recession (m) [2]	S3: allowance for recession due to sea level rise (m)	S: total horizontal setback (range) (m) S1+S2+S3 (excludes S4)
Wooyung to Pottsville	30-40 in places 50	20	45	95 - 115
Pottsville (South)	30-40 in places 50	20	45	95 - 115
Pottsville (North) to Hastings Pt	30-40 in places 50	10	45	85 - 105
Hastings Pt to Norries Head (South)	30-40	20	45	95 - 105
Hastings Pt to Norries Head (North)	30-40	10	45	85 - 95
Cabarita Township	40-50	25	45	110 - 120
Casuarina Beach (Central)	40-50	20	45	105 - 115
Sutherland Point	40-50	10	45	95 - 105
Kingscliff (South)	30-40	30	45	105 - 115
Kingscliff near Cudgen Headland SLSC	50	30	45	125
Dreamtime Beach (Central)	30-40 in places 50	20	45	95 - 115
Fingal	40-50	10	45	95 - 105
Letitia Spit [3]	40-50	[3] 0	45	85 - 95

Note
(1) Allowance for short term erosion depends on dune height and varies within each precinct, values adopted from WBM (2001).
(2) Highest recession rate adopted from WBM (2001).
(3) The effects of the sand bypassing were expected by WBM (2001) to include a one-off retreat which will be dependent on strategies adopted.

Table 4.5
Summary of Setback Distances (from 1999 Erosion Scarp)

Precinct	Present Day (m) S = S1 (Excludes S4)	2050 (m) S = S1+S2+S3 (High S2, excludes S4)	2100 (m) S = S1+S2+S3 (High S2, excludes S4)
Wooyung to Pottsville	30 - 50	60 - 80	95 - 115
Pottsville (South)	30 - 50	60 - 80	95 - 115
Pottsville (North) to Hastings Pt	30 - 50	55 - 75	85 - 105
Hastings Pt to Norries Head (South)	30 - 40	60 - 70	95 - 105
Hastings Pt to Norries Head (North)	30 - 40	55 - 65	85 - 95
Cabarita Township	40 - 50	73 - 83	110 - 120
Casuarina Beach (Central)	40 - 50	70 - 80	105 - 115
Sutherland Point	40 - 50	65 - 75	95 - 105
Kingscliff (South)	30 - 40	65 - 75	105 - 115
Kingscliff near Cudgen Headland SLSC	50	85	125
Dreamtime Beach (Central)	30 - 50	60 - 80	95 - 115
Fingal	40 - 50	65 - 75	95 - 105
Letitia Spit	40 - 50	60 - 70	85 - 95

Note: S4 component not included in final WRL lines by request of TSC.

Table 4.6
Width of Zone of Reduced Foundation Capacity (WBM, 2001)

S4: allowance for dune stability (Zone of Reduced Foundation Capacity)	
Average Dune Height (m AHD)	**Indicative width of Zone of Reduced Foundation Capacity (m)**
4	9.3
5	10.7
6	12.2
7	13.6
8	15.0
9	16.4
10	17.9

4.2 Coastline Hazard Lines for Fingal Head Beach – Letitia Beach

The stretch of coastline from Fingal Head to the Tweed River southern breakwater is approximately 3.5 km long. The hazard lines in this report cover the southern 2.3 km of Fingal Head Beach towards Letitia Spit. The Tweed River Entrance Sand Bypassing Project (TRESBP) commenced bypassing sand from the northern end of Letitia Spit to the southern Gold Coast in March 2001.

Due to a combination of the operation of TRESBP and precedent coastal conditions, the coastline along Letitia Spit has changed since the WBM (2001) report. North of the Fingal Head Holiday Park, Letitia Spit is currently undeveloped in the vicinity of the hazard lines.

The location of revised hazard lines is dependent on future operation and adaptive management associated with TRESBP and would require a detailed reassessment beyond the scope of this report. In this WRL study, the hazard lines have been revised based only on revisions to sea level rise benchmarks. Due to uncertainty of the overall impact on beach recession rates from operation of TRESBP, the northern most 1 km (that is, the area from 1.3 to 2.3 km from the southern end) of coastal hazard lines derived by WRL for Fingal Head Beach/Letitia Beach are indicative only. The position of the hazard lines in this area will be reassessed (in a future study) as information regarding longer term beach stability becomes evident.

5. SUMMARY

This report provides an update to the Tweed Shire coastal hazard lines. At the request of Council, there are no figures with this report, with the updated hazard lines provided as GIS shape files. The original lines were derived in WBM (2001) based on work undertaken in 2000-2001. The values and methodology from WBM (2001) were adopted by WRL, and the hazard lines updated in line with the NSW Government (2009) sea level rise policy, which recommends the following allowances for coastal planning:

- 2050 up to 0.4 m;
- 2100 up to 0.9 m.

There are five key components of coastal setback hazard lines defined by WRL, namely:

S1: Allowance for short term storm erosion;
S2: Allowance for ongoing underlying recession;
S3: Allowance for recession due to future sea level rise;
S4: Allowance for dune stability (*Zone of Reduced Foundation Capacity - ZRFC*);
S5: Allowance for beach rotation.

For this study, a high value of S2 was used for 2050 and 2100. The S4 and S5 components were not incorporated in the hazard lines. The following provides a range of coastal setbacks relative to the 1999 erosion scarp, with details provided in the body of the report:

- Present day (S = S1) 30 to 50 m;
- 2050 (S = S1 + S2 + S3) 55 to 85 m;
- 2100 (S = S1 + S2 + S3) 80 to 115 m;
- The S4 component needs to be added to the above for unpiled buildings (range 9 to 18 m) and will be incorporated in a forthcoming Council DCP.

Future coastal behaviour will be dependent on the maintenance and preservation of entrance training works and bridge abutments, dredging of entrances, placement of dredged sand (Mooball Creek, Cudgera Creek, Cudgen Creek, Tweed River), protection works (Cudgen Headland SLSC, Kingscliff Bowls Club), and future management strategies implemented, which are beyond the scope of this report. It is recommended that the coastal hazard lines be updated within 10 years, or with major revisions in sea level rise projections or coastal policy.

6. REFERENCES AND BIBLIOGRAPHY

Bruun, P (1962), "Sea Level Rise as a Cause of Beach Erosion", *Proceedings ASCE Journal of the Waterways and Harbours Division,* Volume 88, WW1, pp 117-130, American Society of Civil Engineers.

Bruun P, (1988), "The Bruun Rule of Erosion by Sea-Level Rise: A Discussion on Large-Scale Two- and Three-Dimensional Usages", *Journal of Coastal Research,* 4(4), 627-648.

Gordon, A D (1987), *Beach Fluctuations and Shoreline Change – NSW,* Proceedings of 8th Australasian Conference on Coastal Engineering, Launceston, The Institution of Engineers Australia, 103-107.

IPCC (1996), Climate Change 1995 – The Science of Climate Change, Intergovernmental Panel on Climate Change, Working Group 1, June.

IPCC (2007), *Climate Change 2007 - The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* (ISBN 978 0521 88009-1 Hardback; 978 0521 70596-7 Paperback), [Solomon, S, D Qin, M Manning, Z Chen, M Marquis, K B Averyt, M Tignor and H L Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

Nielsen, A F, Lord, D B and Poulos, H G (1992), "Dune Stability Considerations for Building Foundations", *Engineers Australia, Vol CE34 No 2, June.*

NSW Government (1990), *NSW Coastline Management Manual.*

NSW Government (2009), *NSW Sea Level Rise Policy Statement,* Department of Environment and Climate Change NSW, ISBN 978-1-74232-464-7 DECCW 2009/708, October 2009.

Short, A D, Trembanis, A C and Turner, I L (2000), *Beach Oscillation, Rotation and the Southern Oscillation, Narrabeen Beach, Australia,* Proceedings Coastal Engineering 2000, ASCE, 2439-2452.

WBM (2001), “Tweed Shire Coastline Hazard Definition Study” – Final Report, Brisbane. (Revision 3)”. Issued 22/10/01 (Council has advised that the stated year of 2007 is a typographical error, with 2001 being the correct year of issue).