Coastal Risk Management Guide

Incorporating sea level rise benchmarks in coastal risk assessments

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Abbreviations

AHD	Australian Height Datum
ARI	Average recurrence interval
CSIRO	Commonwealth Scientific Industrial Research Organisation
DECC	Department of Environment, Climate Change NSW
DECCW	Department of Environment, Climate Change and Water NSW
ICOLL	intermittently closed and open lakes and lagoon
IPCC	Intergovernmental Panel on Climate Change

1 Introduction

The NSW Government has adopted a Sea Level Rise Policy Statement (NSW Government 2009) to support consistent adaptation to projected sea level rise impacts. The Policy Statement includes sea level rise planning benchmarks for use in assessing the potential impacts of projected sea level rise in coastal areas, including flood risk and coastal hazard assessments, development assessment, coastal infrastructure design processes and land-use planning exercises.

These benchmarks are a projected rise in sea level (relative to the 1990 mean sea level) of 0.4 metres by 2050 and 0.9 metres by 2100 (Department of Environment, Climate Change and Water (DECCW) 2009). The projections were derived from sea level rise projections by the Intergovernmental Panel on Climate Change (IPCC 2007) and the CSIRO (McInnes et al 2007). These benchmarks will be periodically reviewed.

The Coastal Risk Management Guide has been prepared to assist local councils, the development industry and consultants incorporate the sea level rise benchmarks in coastal hazard assessments. This includes coastal hazard assessments carried out as part of a coastal hazard definition study during a coastal zone management planning process or for assessing coastal hazard constraints for proposed coastal developments. The information in this guide updates the sea level rise information in the *NSW Coastline Management Manual* (NSW Government 1990).

The *NSW Coastal Planning Guideline – Adapting to Sea Level Rise* (Department of Planning 2010) provides detail about the consideration of this information in land-use planning and development assessment.

2 The impact of sea level rise in coastal areas

Of all the impacts from climate change, the projected rise in mean sea level is one of the most significant concerns for integrated coastal zone management. In addition to higher projected storm surge and oceanic inundation levels, a rise in the mean sea level will also result in landward recession of unconsolidated (sandy) shorelines (Figure 2.1).

Figure 2.1. Erosion at Belongil Spit, Byron Bay (2 June 2009).

Depending on the rate and scale of sea level rise, the environmental, social and economic consequences, in particular within low-lying intertidal areas, are expected to be significant. In addition to open coast recession and higher inundation levels, saltwater intrusion and landward advance of tidal limits within estuaries will have significant implications for freshwater and saltwater ecosystems and development margins, particularly building structures and foundation systems within close proximity to the shoreline. Existing coastal gravity drainage, stormwater infrastructure and sewerage systems may become compromised over time as the mean sea level rises. Sea level rise will also influence entrance opening regimes for intermittently closed and open lakes and lagoons (ICOLLs). The level of protection provided by existing seawalls and other hard engineering structures will decrease over time due to the increasing threat from larger storm surges and inundation at higher projected water levels.

This guide has been developed in recognition that adaptation to sea level rise will require careful planning and management now and into the future to minimise social, environmental and economic impacts.

3 Coastal hazard assessment

The *Coastline Management Manual* (NSW Government 1990) identifies a range of coastal hazards, two of which will be directly exacerbated by sea level rise – shoreline recession and coastal inundation (Figure 3.1).

Figure 3.1. Erosion at Old Bar, Taree (7 July 2008).

Coastal hazard studies or assessments commonly identify hazard limits or hazard areas, which define the estimated extent of land projected to be impacted upon by coastal processes and hazards over defined planning periods. These studies can be used to define coastal hazard areas which are used in land-use planning and development assessment. The immediate hazard area represents the landward extent of beachfront land that could be at direct threat from beach erosion resulting from a single extreme event or from several very severe beach erosion events in close succession with cumulative impacts, commonly referred to as ‘storm bite’. In addition to storm bite, an adjoining zone of reduced foundation capacity will exist landward of an erosion escarpment in sandy dunal systems, as described by Nielsen *et al* 1992 (see Figure 3.2).

It is also important to estimate the extent of land that could be impacted upon by coastal processes and hazards (including sea level rise) over longer-term planning horizons (such as 2050 and 2100). These areas encompass the immediate hazard area whilst incorporating allowances for underlying long-term recession of the shoreline that could result from long-term sediment imbalance within the active beach system or from measured and projected sea level rise.

In addition to underlying recessionary trends, sea level rise will increase the predicted recession over the adopted planning period (see section 4.3), resulting in a landward movement of coastal hazard areas over time (see Figure 3.3).

Previous coastal hazard studies have commonly determined 2050 and 2100 coastal hazard lines or areas incorporating projected sea level rise (see Figure 3.3). Where these studies have considered sea level rise allowances other than the planning benchmark figures advised in the *NSW Sea Level Rise Policy Statement* (2009), the hazard lines should be recalculated through a revised hazard definition study to reflect the benchmark allowances.

Coastal inundation assessments should also incorporate increased still water levels resulting from sea level rise projections (see section 4.2). In most instances, dunal systems along the open coastline are sufficiently elevated that episodic threat from oceanic inundation due to wave runup and overtopping of coastal dunes or barriers is negligible. Notwithstanding, the threat of oceanic inundation along the open coast in the vicinity of low-crested dunal barriers (less than 5 metres Australian Height Datum (AHD)) should also be considered where this is relevant. Around lower lying estuarine foreshores, the threat from tidal inundation will be significantly exacerbated with a projected rise in mean sea level. The interaction between this issue and catchment flooding is particularly important for coastal councils and has been considered in the companion document *Flood Risk Management Guide – Incorporating sea level rise benchmarks in flood risk assessments* (DECCW, 2010)

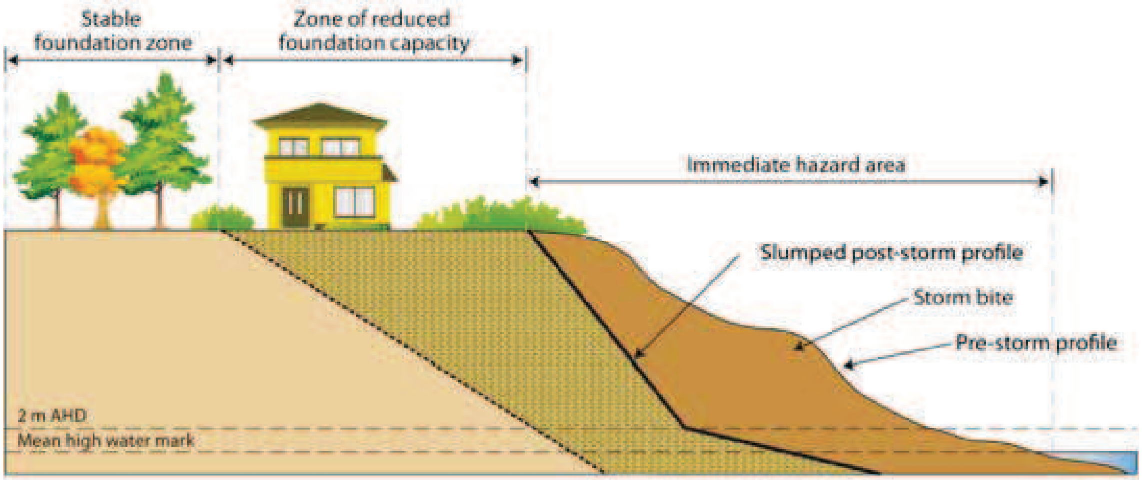

Figure 3.2. Idealised schematic of a dune profile depicting the immediate hazard area and associated zone of reduced foundation capacity (after Nielsen et al 1992).

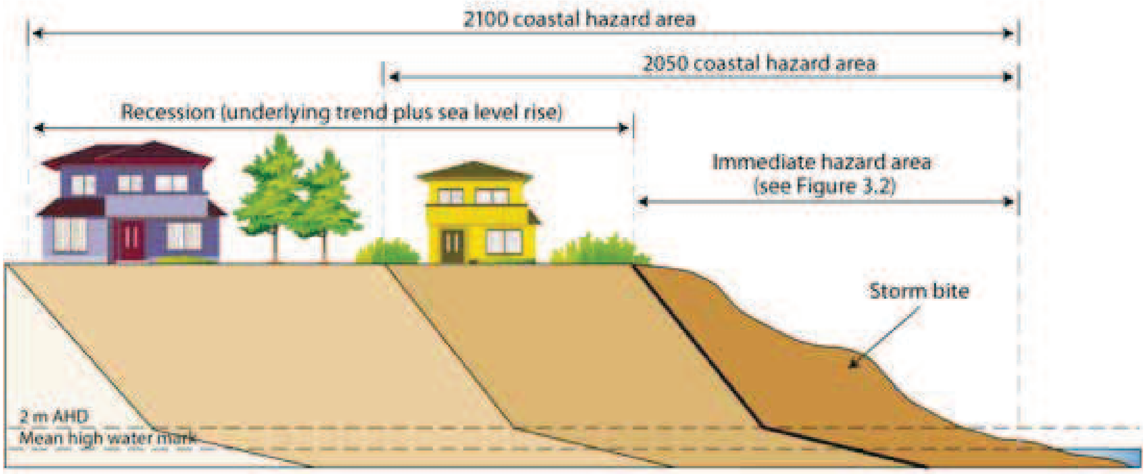

Figure 3.3. Idealised schematic of a dune profile depicting the high hazard area, 2050 coastal hazard area and 2100 coastal hazard area.

4 Application of sea level rise planning benchmarks

4.1 Sea level rise benchmarks

Increasing mean sea level over time will have two primary impacts within and adjacent to tidal waterways:

- increasing still water levels over time and
- subsequent recession of unconsolidated shorelines.

In circumstances where it is necessary to consider physical coastal processes and/or the influence of tidal waters, it is recommended that the additional impact of projected sea level rise up to the planning benchmarks be considered. This will enable sea level rise to be appropriately considered in planning decisions, hazard mitigation strategies and infrastructure design.

Figure 4.1. Erosion at North Entrance, Wyong Shire (12 June 2009).

For land-use planning purposes, 2050 and 2100 sea level rise benchmarks should be used. For other purposes (e.g. infrastructure design), linear interpolation between the 1990 base sea level and the 2050 and 2100 sea level rise benchmarks can be used to estimate projected sea level rise for coastal planning horizons or asset life other than those corresponding to the benchmark years.

For consideration of sea level rise beyond 2100, an additional 0.1 metres per decade allowance can be used above the 2100 benchmark level. This approach assumes a linear rise beyond 2100 at rates equivalent to that projected for the last decade of the twenty-first century (2090–2100). These sea level rise projections will need to be discounted to accommodate the sea level rise measured between 1990 and present. This can be assumed to be approximately 3 millimetres/year from 1990 (CSIRO, 2009).

For practical implementation, sea level rise benchmarks, which are generally referenced to 1990 mean sea levels, can be broadly related to the AHD. Analysis of hourly water levels at Fort Denison (Sydney Harbour) over the period from January 1989 to December 1990 indicates a mean sea level over this period of approximately 0.06 metres AHD.

4.2 Design still-water levels

Table 4.1 provides an estimate of design ocean still-water levels at Fort Denison for varying average recurrence interval (ARI) events in 2050 and 2100 that incorporate provision for sea level rise. It is recommended that these levels be used in the Newcastle–Sydney–Wollongong area for the design of maritime structures, determining oceanic inundation/wave runup levels and for oceanic and hydrodynamic modelling processes where full oceanic tidal conditions are expected. In other locations (e.g. NSW North and South coasts), analysis of local tidal records will be needed to develop this information.

Where tidal conditions less than the oceanic range prevail (e.g. inside constrained estuarine environments), Table 4.1 does not apply and locally derived design still water levels would be determined on a site-specific basis, taking into consideration the sea level rise benchmarks for oceanic conditions.

Table 4.1. Design ocean still water levels at Fort Denison for 2010 and predicted levels for 2050 and 2100 incorporating projected sea level rise.

Average Recurrence Interval (years)	2010 design still water levels (1) (metres AHD)	2050 design still water levels (2) (metres AHD)	2100 design still water levels (2) (metres AHD)
0.02	0.97	1.31	1.81
0.05	1.05	1.39	1.89
0.1	1.00	1.44	1.94
1	1.24	1.58	2.08
10	1.35	1.69	2.19
50	1.41	1.75	2.25
100	1.44	1.78	2.28

Notes: The design still water levels are only relevant where full ocean tide conditions prevail. (1.) Design still-water levels for 2010 were derived from extreme value analysis of Fort Denison tide gauge data from June 1914 to December 2009 (after Watson and Lord, 2008). There are negligible tidal friction losses between the ocean and Fort Denison within Sydney Harbour; therefore, Fort Denison data provides an indicative representation of oceanic still-water levels. The design still-water levels inherently incorporate allowance for all components of elevated ocean water levels experienced over this timeframe (including tides, meteorological influences and other water level anomalies); however, they exclude wave setup and wave runup influences. (2.) Design still-water levels for 2050 and 2100 incorporate planning benchmark allowances for sea level rise with a reduction of 60 millimetres to accommodate the estimated amount of global average sea level rise that has occurred between 1990 and present. From satellite altimetry, this is estimated to be 3 millimetres/year (CSIRO, 2009). These design levels are indicative and provided for guidance only.

4.3 Recession of unconsolidated shorelines

It is widely acknowledged that the projected sea level rise will result in recession of unconsolidated (sandy) shorelines (Figures 4.1 and 4.2). The simple two-dimensional model, known as the *'Bruun Rule'* (Bruun 1962, 1988), can be used as a coarse first-order approximation for determining sea level rise induced recession for planning purposes along the open coast. Using the *Bruun Rule*, recession due to sea level rise can be estimated simply as the product of the sea level rise (over the planning timeframe of interest) multiplied by the inverse of the active profile slope (see 'X' in Figure 4.3).

Figure 4.2. Coastal erosion at Collaroy/Narabeen beach (June 2007).

It should, however, be clearly understood that there are limitations with the *Bruun Rule* for use throughout the coastal zone in determining foreshore recession due to sea level rise (Ranasinghe et al 2007). Improved three-dimensional modelling methodologies for estimating the shoreline response to sea level rise are currently being developed to incorporate a broader suite of natural processes and physical attributes on a site-specific basis (see Patterson 2009 and Huxley 2009). These shoreline evolution modelling tools have the additional advantage of being able to consider the sensitivity of shorelines to other less certain climate change projections, such as changes to predominant wave directions.

When using the *'Bruun Rule',* use of the lower limit of profile closure (seaward limit of the Shoal Zone) as prescribed by Hallermeier (1981) is recommended in the absence of readily available information on active profile slopes at a location under consideration. It has been common practice along the NSW coastline to generically adopt active profile slopes in the range of 1:50 to 1:100; however, because of the intraregional variability in slope that exists across the offshore NSW shelf, more rigorous site-specific analysis is recommended to justify the use of a selected active profile slope for use in a *'Bruun Rule'* assessment. For planning purposes on estuarine foreshores, in the absence of better information, it is recommended that estimations of recession due to sea level rise use the same *'Bruun Rule'* approach with relevant average foreshore slopes inferred or estimated from survey information.

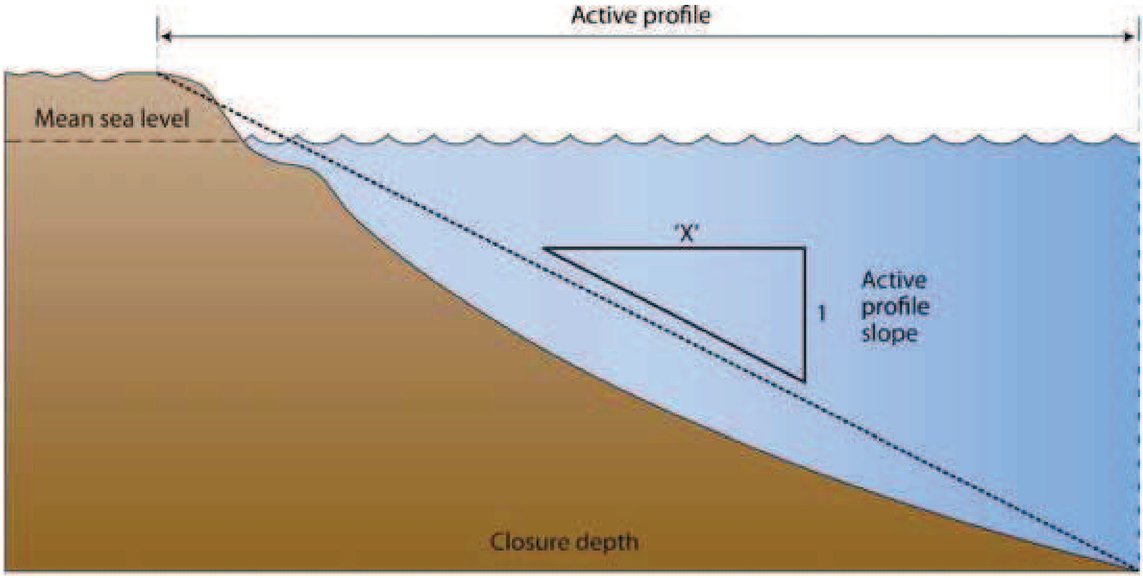

Figure 4.3. This diagram represents as idealised schematic of the active profile for consideration in *'Bruun Rule'* applications.

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6 Glossary

active profile slope	The average slope of the portion of a beach system (including the underwater section) which extends seaward to a point beyond which active sediment movement is largely immeasurable.
Australian Height Datum	A common national surface-level datum approximately corresponding to mean sea level.
oceanic inundation	A natural process whereby elevated ocean water levels combined with wave runup along beaches result in seawater overtopping frontal dune systems and coastal barriers during storm events. This process is generally rare and episodic, occurring principally around the peak of a high tide, creating a hazard mainly where frontal dunes or coastal barriers along the NSW coastline are crested below about 5 metres AHD.
shoreline recession	A net long-term landward movement of the shoreline caused by a net loss in the sediment budget.
storm surge	An increase in coastal water level caused by the effects of storms. Storm surge consists of two components: an increase in water level caused by a reduction in barometric pressure (barometric setup) and an increase in water level caused by the action of wind blowing over the sea surface (wind setup).
still water levels	Average water-surface elevation at any instant, excluding local variation due to waves and wave set-up, but including the effects of tides and storm surges.
tidal inundation	The submergence of land by seawater due mainly to the action of very high tides. This process is predominantly a hazard for low-lying estuarine foreshores and is exacerbated by coincidence of elevated ocean water levels during storms and catchment flooding.
wave runup	The vertical distance above mean water level reached by the uprush of water from waves across a beach or up a structure.
wave setup	The increase in water level within the surf zone above mean still water level caused by the breaking action of waves.
zone of reduced foundation capacity	Zone located adjacent to and landward of an erosion escarpment in unconsolidated dunal systems where load bearing capacity is reduced (see Nielsen *et al*, 1992).