A Review of Beach Erosion Vulnerability Estimation Methods in Queensland

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Abstract: Severe erosion of the Gold Coast beaches in the 1960's and 1970's caused extensive damage to inappropriately located infrastructure. A method to estimate the erosion vulnerability of beaches was required to assist in future planning for the coastal zone. The Queensland Government, through the Beach Protection Authority, developed the erosion prone area as a planning tool to control inappropriate development within the coastal zone.

The erosion prone area was intended to quantify the width of land considered vulnerable to erosion over a 50-year planning period based on long-term erosion trends, short-term erosion associated with a design storm event, beach recession due to climate change induced sea-level rise and dune scarping. For many beaches, erosion prone areas were calculated twenty to thirty years ago. However, the extent of observed shoreline recession suggests that the erosion prone area has overestimated the erosion vulnerability for many locations.

The aim of this paper is to determine whether the erosion prone area calculation method has the potential to over or underestimate beach erosion vulnerability. Historical aerial photographs, beach profiles and storm activity have been reviewed for the selected case sites to determine if there is any correlation between observed shoreline erosion and the erosion vulnerability estimated by the erosion prone area. The outcome of this review is to demonstrate that in many locations, there may be scope for variance of the erosion prone area, subject to detailed site specific studies.

It is acknowledged that the focus of coastal planning has widened considerably since the late 1960's and now considers economic, public access, water quality, cultural heritage, conservation and landscapes issues in addition to physical coastal processes. It is acknowledged that, as a planning tool, the erosion prone area continues to play an important role in the protection of values associated with the above issues.

1. INTRODUCTION

Gold Coast beaches experienced severe erosion during the 1960's and 1970's causing extensive damage to inappropriately located private and public infrastructure. In response to the erosion problem and rapid coastal development the Queensland Government formed the Beach Protection Authority (BPA) in 1968.

The BPA developed the erosion prone area as a method of estimating the erosion vulnerability of beaches over a fifty year planning period. The BPA also developed a buffer zone policy to provide guidance on development within the erosion prone area. For undeveloped sections of coast this policy advocated no permanent development within the erosion prone area, and for developed sections of coast, the policy recommended against increasing the level of development within the erosion prone area.

Legislative amendments to the *Coastal Protection and Management Act 1995* (Coastal Act) lead to the implementation of the State and Regional Coastal Management Plans. The erosion prone area subsequently became a physical coastal processes policy of the State and Regional Coastal Management Plans. Under the Coastal Act a condition can be applied to subdivision development approvals requiring the surrender of land within the erosion prone area to the State. Surrendered land is intended to act as a buffer between development and the shoreline allowing the continuation of natural coastal processes.

According to the Commonwealth Department of the Environment and Heritage (2001) approximately 75% of the Australian population lives within a few kilometres of the coast. In all States the growth rates occurring in coastal regions are higher than in other non-coastal regions indicating that the 'sea-change' trend is continuing. The erosion prone area is often the most valuable real estate and the over-estimation of the erosion prone area may result in significant financial loss for developments. Similarly, the under-estimation of the erosion prone area may result in the need for future property protection measures that are often funded by the Local Authority at considerable cost.

2. EROSION PRONE AREAS

The erosion prone area is intended to accommodate short-term storm erosion, dune scarping, long-term erosion trends, and sea level rise due to climate change over a set planning period. The calculation also included a 40% safety factor applied to the calculated erosion prone area width.

The EPA (2005a) information sheet, "Coastal erosion and assessment of erosion prone area widths" provides guidance on the preferred method for calculating the variables of the erosion prone area formula. The formula adopted for the erosion prone area calculation is:

$$E = [(N \times R) + C + G] \times (1 + F) + D \qquad \text{(Eqn. 1)}$$

Where E is the erosion prone area width (metres)
N is the planning period (years)
R is the rate of long-term erosion (metres/year)
C is the short-term erosion from the "design" storm event (metres)
G is the recession due to climate change induced sea-level rise (metres)
F is a factor of safety
D is the dune scarp component (metres)

In principle, the erosion prone area should determine a width of land sufficient to accommodate erosion from the design storm event at the end of the 50 year planning period. This also implies that for much of the 50 year planning period the erosion prone area can accommodate erosion from storms greater than the design event without significantly increasing the risk of erosion breaching the erosion prone area within the planning period.

A desktop study based on typical beach types was used to determine the erosion prone area for the majority of beaches. However, the erosion prone area width for beaches within the Capricorn Coast, Cairns, Hervey Bay and Mackay regions were determined through detailed site specific studies (BPA, 1979, 1984 and 1989, and EPA, 2005b).

For most beaches the erosion prone area was calculated over thirty years ago. However, for the majority of beaches the observed beach recession is significantly less than the estimated vulnerability provided by the erosion prone area. This suggests that the erosion prone area formula tends to overestimate the erosion vulnerability of beaches. This paper presents three case studies to examine the short and long-term erosion components of the erosion prone area and their effect on the over or underestimation of beach erosion vulnerability.

2.1. Short-Term Erosion Component (C)

The estimation of the short-term erosion component involves the selection of a design storm event and the estimation of shoreline recession associated with the design storm. Following statistical analysis of past meteorological events the EPA (2005a) recommends a 100 year ARI storm tide level combined with 50 year ARI wave conditions as the parameters for the design storm event.

There are various techniques for estimating the recession associated with the design storm event. The common assumption of the models is that a characteristic erosion profile is developed during a storm event that provides a volume balance between material eroded from the upper beach with material deposited further down the new profile in the nearshore zone.

The EPA (2005a) suggest that both the empirical Edelman (1972) and Vellinga (1983) methods predict a characteristic storm profile that is similar to observed post-storm surveys along the Queensland coast. Both these empirical methods evaluate the erosion distance assuming an equilibrium storm profile. The EPA (2005a) correctly emphasize that the development of an equilibrium profile is a gradual process that may not be reached for the design storm event. The EPA (2005a) also state that an additional factor of safety on the calculations is provided in assuming that an equilibrium profile develops during the design storm event.

This study has assessed the short-term erosion component for selected sites across Queensland using the empirical Vellinga (1983) method and the single line Storm-induced BEAch CHange (SBEACH) model. The SBEACH model was prepared by the United States Army Engineers Waterways Experiment Station. SBEACH simulates cross-shore beach, berm, and dune erosion produced by storm waves and water levels.

2.2. Long-Term Erosion Component (R)

Long-term erosion or accretion rates at any individual beach will vary depending on the period of the assessment and may also vary spatially along the beach. In selecting the long-term erosion rate the planning period for the erosion prone area calculation determines the time scale of interest. The selected long-term erosion rate must also be considered likely to occur for the duration of the planning period. The EPA (2005a) states that there are two basic approaches to obtaining an estimate of future long-term erosion:

- extrapolation of past erosion trends deduced from historical information; or
- calculation of the present sediment budget for the beach and conversion of any deficit into a horizontal movement of the shoreline extrapolated over the planning period.

There are limitations in the accuracy with which both approaches can estimate the magnitude of erosion rates and in the confidence with which the estimates can be projected into the future (EPA, 2005a). For this assessment historical aerial photographs of the study sites were rectified and the shoreline position was estimated using the seaward extent of vegetation. The long-term annual erosion or accretion rates were then extrapolated from the shoreline movements.

3. CASE STUDIES

Three sites have been selected to represent the variation in beach conditions across the State. The two southern Queensland sites are representative of wave dominated coastal systems, while the north Queensland site is representative of a low wave energy macrotidal coastal system with wide inter-tidal flats. Alternative methods of estimating the short-term erosion from the design storm event was undertaken for each site. The long-term erosion rate has also been extrapolated from historical aerial photographs for each site.

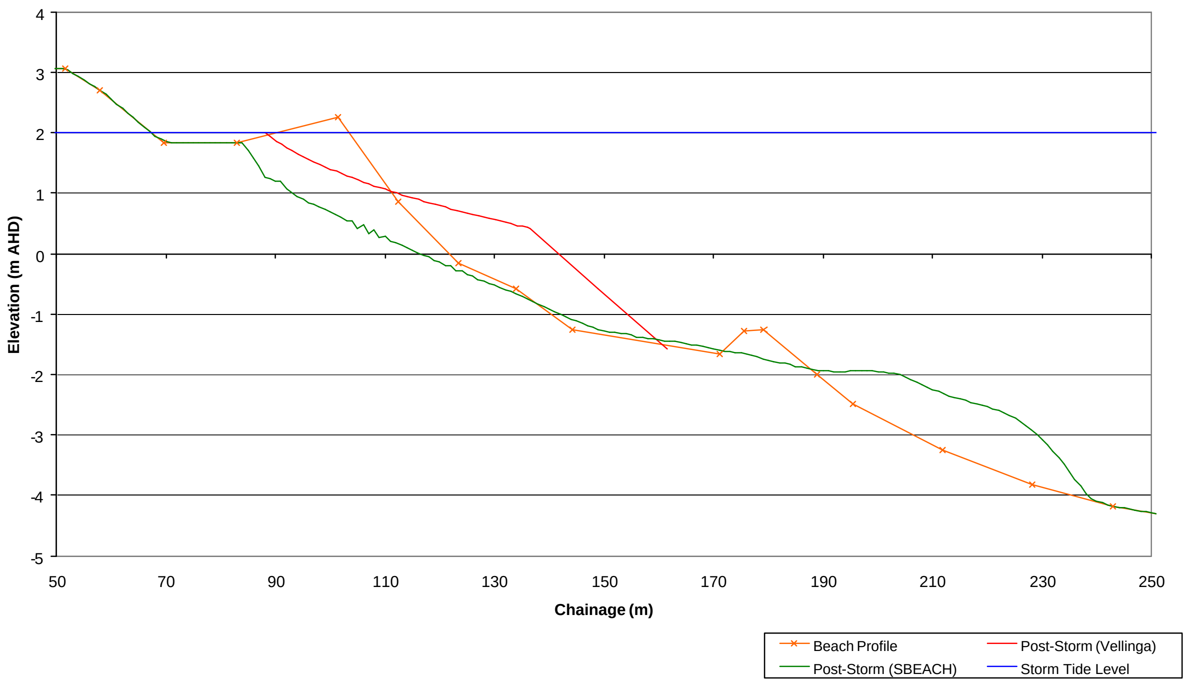
3.1. Palm Beach, Gold Coast

Palm Beach is approximately 4.2km in length and is located between Currumbin Creek to the south and Tallebudgerra Creek to the north. A seawall buried beneath the dune system protects development along Palm Beach. In addition the Currumbin and Tallebudgerra Creek mouths are trained and two rock groynes are located on the beach.

Wave data obtained from the EPA’s Gold Coast wave recording site was analyzed to obtain extreme wave heights for various return intervals using the Automated Coastal Engineering System (ACES) created by the United States Army Engineers Waterways Experiment Station. Linear wave transformations were used to obtain appropriate boundary conditions.

The analysis provided a significant wave height (H_s) of 2.49m and wave period (T_p) of 8.8 seconds. The adopted 100 year ARI storm tide level for this assessment is 2m AHD (DEH, 1998). Beach profiles were obtained from Gold Coast City Council. The design wave parameters, water level and beach profiles were input into the Vellinga and SBEACH models. Figure 1 shows a plot of the estimated shoreline recession results.

Figure 1: Results of Short-term Erosion Estimation



Dune crest recession of approximately 12m and 17m was predicted by the Vellinga and SBEACH models, respectively. The SBEACH model also predicts accretion further offshore than that predicted by the empirical Vellinga model.

A comparison of aerial photographs from 1982 and 2004 indicates that an average annual accretion of 0.62m has occurred in this period. Figure 2 presents the aerial photograph comparison along with the 1982 and 2004 vegetation lines.

Figure 2: Palm Beach Shoreline Comparison of Aerial Photographs from 1982 and 2004

The existing erosion prone area width for Palm Beach is 40m and based on the long and short-term erosion components assessed above this width seems to reasonably reflect the erosion vulnerability of Palm Beach.

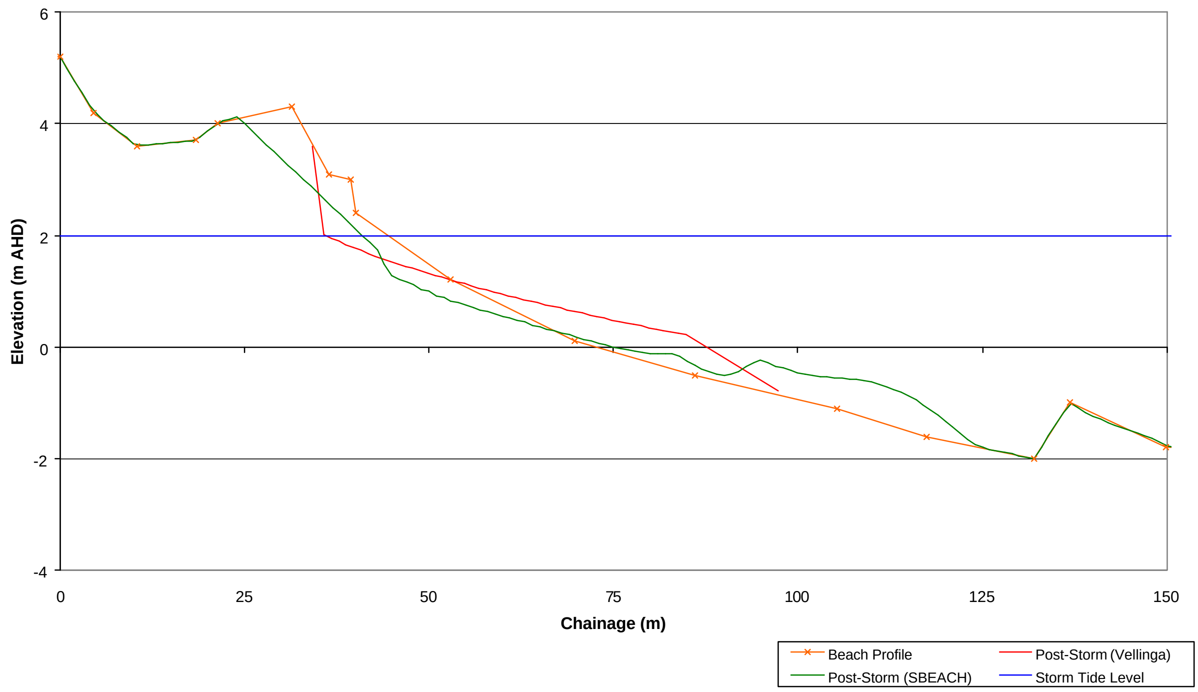
3.2. Peregian Beach, Noosa

Peregian Beach is located at the southern boundary of Noosa Shire and is located between Coolum 6km to the south and Noosa Heads 9km to the north. The section of coast between Coolum and Noosa Heads is straight sandy beach approximately 15km in length.

Wave data obtained from the EPA's Mooloolaba wave recording site was analyzed to obtain extreme wave heights for various return intervals using ACES. The water depth at the Mooloolaba wave recording site is 32m and linear wave transformations were used to obtain the appropriate boundary conditions for the models. The analysis provided a H_s of 6.31m and T_p of 13.3 seconds. The adopted 100 year ARI storm tide level for this assessment is 2m AHD (DEH, 1998). Beach profiles were obtained from the EPA.

The design wave parameters, water level and beach profiles were input into the Vellinga and SBEACH models. Figure 3 shows a plot of the estimated shoreline recession results.

Figure 3: Results of Short-term Erosion Estimation



Shoreline recession of approximately 8m and 3m was predicted by the Vellinga and SBEACH models, respectively. The SBEACH model also predicted accretion further offshore than that predicted by the empirical Vellinga model.

A comparison of aerial photographs from 1982 and 2004 indicates that an average annual accretion of 0.67m has occurred in this period. Figure 4 presents the aerial photograph comparison along with the 1982 and 2004 vegetation lines.

Figure 4: Peregian Beach Shoreline Comparison of Aerial Photographs from 1982 and 2004

The existing erosion prone area width for Peregian Beach is 125m. Given the accretion that had occurred between 1982 and 2004 and the estimated short-term erosion it appears that the current erosion prone area width overestimates the erosion vulnerability of Peregian Beach.

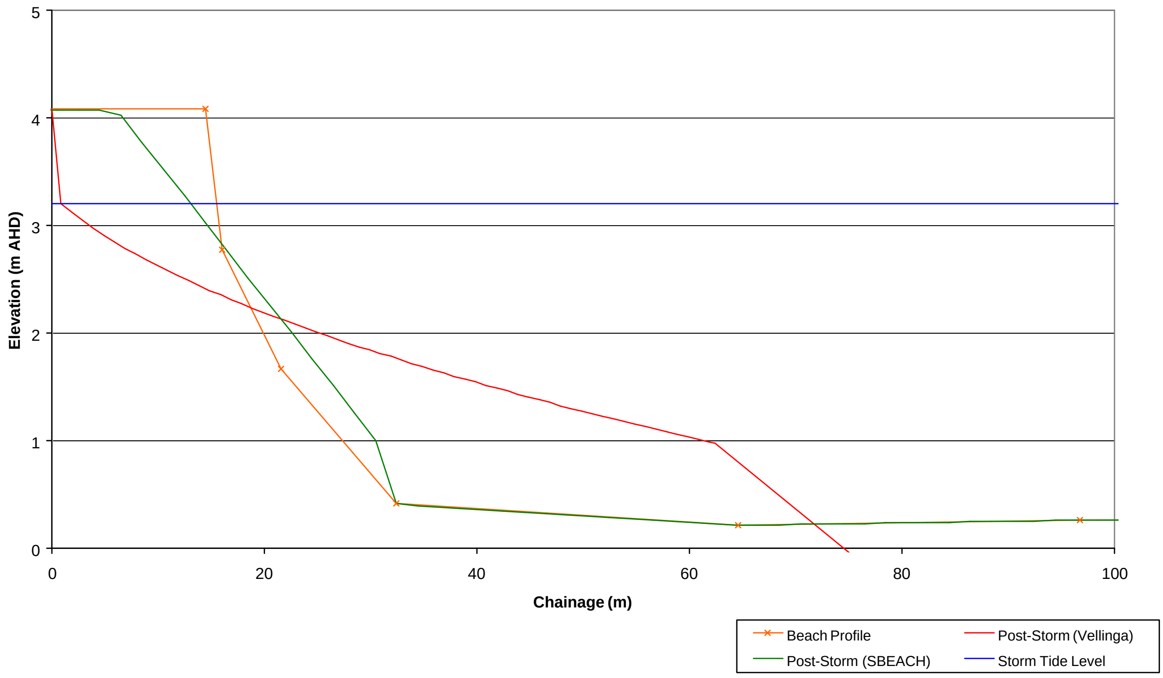
3.3. Bushland Beach, Thuringowa

Bushland Beach is approximately 15km northwest of Townsville and located between the Bohle and Black Rivers. Bushland Beach is a typical north Queensland macrotidal beach consisting of a low frontal sand dune, narrow beach face, and wide intertidal zone.

For this case the extreme wave analysis for a previous study undertaken by Cardno Lawson Treloar was used and appropriate boundary conditions were obtained using linear wave transformations. The analysis provided a H_s of 0.93m and T_p of 5.2 seconds. The adopted 100 year ARI storm tide level for this assessment is 3.2m AHD (DEH, 1998). Beach profiles were obtained from the previous Cardno Lawson Treloar study.

The design wave parameters, water level and beach profiles were input into the Vellinga and SBEACH models. Figure 5 shows a plot of the estimated shoreline recession results.

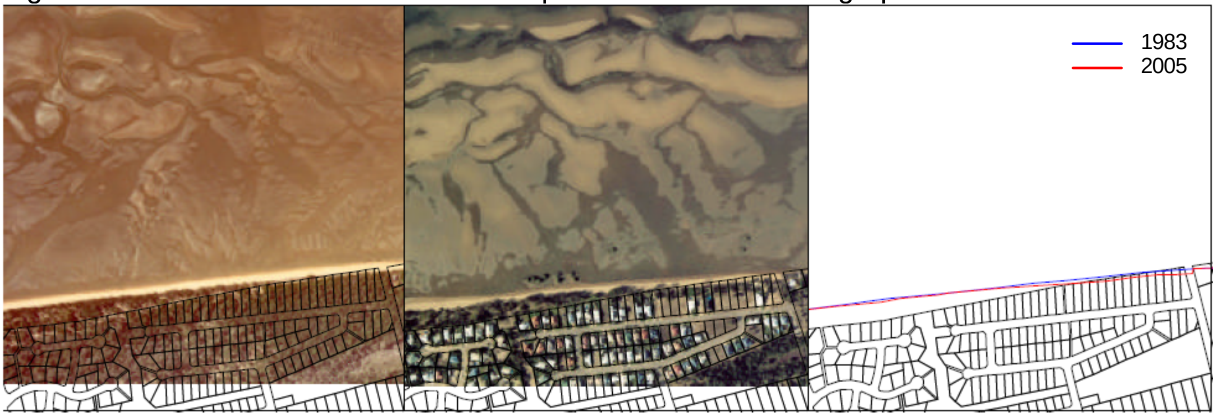
Figure 5: Results of Short-term Erosion Estimation



Dune crest recession of approximately 14m and 10m was predicted by the Vellinga and SBEACH models, respectively. The empirical Vellinga model predicted accretion further offshore than that predicted by the SBEACH model. The Vellinga method assumes an equilibrium storm profile develops and this may not be an appropriate assumption. In macrotidal systems, time dependence models are likely to provide more reliable results.

A comparison of aerial photographs from 1983 and 2005 indicates that shoreline position has been relatively stable during this period. Figure 6 presents the aerial photograph comparison along with the 1982 and 2004 vegetation lines.

Figure 6: Bushland Beach Shoreline Comparison of Aerial Photographs from 1983 and 2005



The existing erosion prone area width for the section of beach shown in Figure 6 is 80m. Given the long-term stability of Bushland Beach and the estimated short-term erosion it appears that the current erosion prone area width overestimates the erosion vulnerability of Bushland Beach.

4. CONCLUSIONS

This study has shown that the existing erosion prone area tends to overestimate the erosion vulnerability of beaches and in most cases there is scope for reduction. A conservative estimate of erosion vulnerability is preferable. However, an estimate that is overly conservative may result in economic loss through reduced development potential.

Historical aerial photograph analysis has shown that shoreline of the study beaches has been static or has accreted over the period assessed. The assessment of the short-term erosion associated with a design storm event has shown that the Vellinga and SBEACH models produce estimates that vary considerably. However, there are obvious differences between the results obtained for the wave dominated beach systems and the low wave energy macrotidal beach system.

The long-term erosion component assumes beaches are either static or in long term recession. The erosion prone area formula does not allow for long term accretion. In fact, the factor of safety applied to the erosion prone area formula would result in an overestimation of the accretion rate.

A comparison of the results obtained for the short-term erosion models has shown that the SBEACH model predicts greater shoreline recession for the wave dominated beaches and less shoreline recession for the low wave energy macrotidal beach than the Vellinga model. Further assessment is required to determine which method provides the most reliable results for the different coastal systems. On macrotidal beaches it is likely that an equilibrium beach profile will not have time to develop. Therefore empirical methods that assume development of an equilibrium profile overestimate the short-term erosion during storm events on macrotidal beaches.

5. TAKE HOME MESSAGE

The erosion prone area provides a simple method for estimating beach erosion vulnerability to assist in coastal planning. However, over or underestimation of the erosion prone area may have significant environmental and economic consequence. A reduction of the erosion prone area is likely to be possible for most beaches due to greater data availability. This study focused on the long and short-term components of the erosion prone area.

In relation to the long-term erosion component the erosion prone area formula needs to be amended to allow for a long-term annual accretion rate. This can be achieved by not applying a factor of safety to this component of the erosion prone area formula when there is an observed long-term accretion of the beach.

In relation to the short-term erosion component further work is needed to determine the most appropriate model for various coastal systems throughout the State. In this respect, calibration of the models was hindered by insufficient pre- and post-storm beach profile surveys. The lack of beach profile surveys in north Queensland was particularly evident. Due to the difficulty in obtaining adequate survey information laboratory investigations may provide an alternative method of validating the models.

6. REFERENCES

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