BEACH CHANGE AT BENGELLO BEACH, EUROBODALLA SHIRE, NEW SOUTH WALES: 1972-2010

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Introduction

In late-May to mid-June 2010 beaches along the New South Wales coast were battered by wild winds, rough seas and heavy rainfall associated with three separate low pressure systems in the western Tasman Sea. Severe flooding and gale force winds (including a tornado at Lennox Head) caused much damage during the second and third storms along the north and central coasts, though these areas were not affected by the initial storm that developed off the south coast. This first low pressure cell formed on the night of 29th May 2010 and produced wind gusts in excess of 130 kph around Montague Island and Narooma and flash flooding in Bega and Eurobodalla Shires. Dangerous sea conditions were experienced in coastal areas with maximum wave heights off Eden reaching 10-12 m during 30th May. The Batemans Bay wave recorder failed during the night of 30-31 May though it recorded maximum wave heights of over 6 m and swell from the south to southeast both prior to and after the failure. Declining spring tides with a range of 0.2 to 1.4 m were predicted for 31 May 2010 at Moruya.

The response of Bengello Beach to this event was typical of such storms on open ocean beaches with lowering and landward displacement of the beach face, and erosion of the backshore and berm to produce a vertical scarp cut back into the incipient foredune (Figure 1).

Figure 1. Bengello beach Profile # 4 looking south before and after the May-June 2010 storm. Photograph on left taken 29 April and on right photo taken 29 June from approximately the same place. Note wooden post in both pictures. Scarp is 1.8 m high.

What occurred at Bengello beach during this storm was not particularly unusual, but it certainly does not compare with the impact of the series of storms in the mid-1970s, and specifically in May-June 1974. Those benchmark storms acted as a catalyst for state agencies to understand the characteristics of ocean conditions responsible for the widespread devastation of coastal buildings, facilities, infrastructure and environments, and since then monitoring of wave conditions along the New South Wales coast has improved significantly. In addition to port authorities, there is now a series of seven Waverider buoys from Byron Bay to Eden funded by the NSW Department of Environment and Climate Change and maintained by Manly Hydraulics Laboratory who provide real time data to the public.

In contrast to this continuous monitoring of wave and swell conditions, there is no equivalent centralised state system of beach monitoring. However, some beaches have been the subject of long-term study by independent researchers including Narrabeen to the north of Sydney (e.g. Short and Trembanis, 2004) and Bengello (Moruya) beach in Eurobadalla Shire. The purpose of the present report is to summarise, in a qualitative way, the first order changes that have occurred at Bengello beach during the last 38 years.

Field surveys and setting of Bengello beach

Bengello beach is located on the south coast of New South Wales, just to the northeast of the township of Moruya and about 250 km south of Sydney. Since January 1972, four beach profiles have been surveyed in the centre of the beach in a program established by Bruce Thom and Roger McLean while they were at the Australian National University. Surveys were initially undertaken at fortnightly intervals until January 1976, subsequently at monthly intervals through January 1989, and since then several times a year at approximately six-week intervals up to the present. The profiles are located in the most exposed central portion of the beach so as to receive waves from the greatest range of wave directions (Figure 2).

Bengello beach is a typical crescent-shaped beach compartment with Broulee Island and tombolo to the north, and the Moruya River training wall and headland at its southern end, a distance of approximately 5.5 km. The beach faces slightly south of east and is subjected to waves of an east coast swell environment. The offshore wave climate is both energetic and variable. Wave energy levels are moderate, though high waves (>4 m) and/or low swell may occur in any month. Off Batemans Bay, data from a Waverider buoy moored in water about 80 m deep and located 27 km northeast of Bengello beach has an average significant wave height (H sig) of 1.5 m and wave periods are typically in the range of 8 to 12 seconds (Lord and Kulmar, 2000). Based on five years of Batemans Bay Waverider data (from 2001) the average direction of swell waves is from the southeast and over 90 per cent of storm waves (>3 m H sig) come from the southeast and south (McInness *et al.,* 2007). Tides at Moruya are semi-diurnal with a mean spring range of about 1 m and mean neap of about 0.6 m.

The active beach at Bengello is backed by a succession of dune ridges, 5 to 8 m high which have developed as a transgressive-regressive sequence during the Holocene (Thom, 1984). The nearshore, beach, and dune sediments are quartzose-feldspathic sands with subtle differences in texture and composition between the three environments. Excluding the shell fraction, all are texturally mature and can be classified as very well to well sorted fine to medium sands with mean grain sizes from 1.7 phi to 2.5 phi.

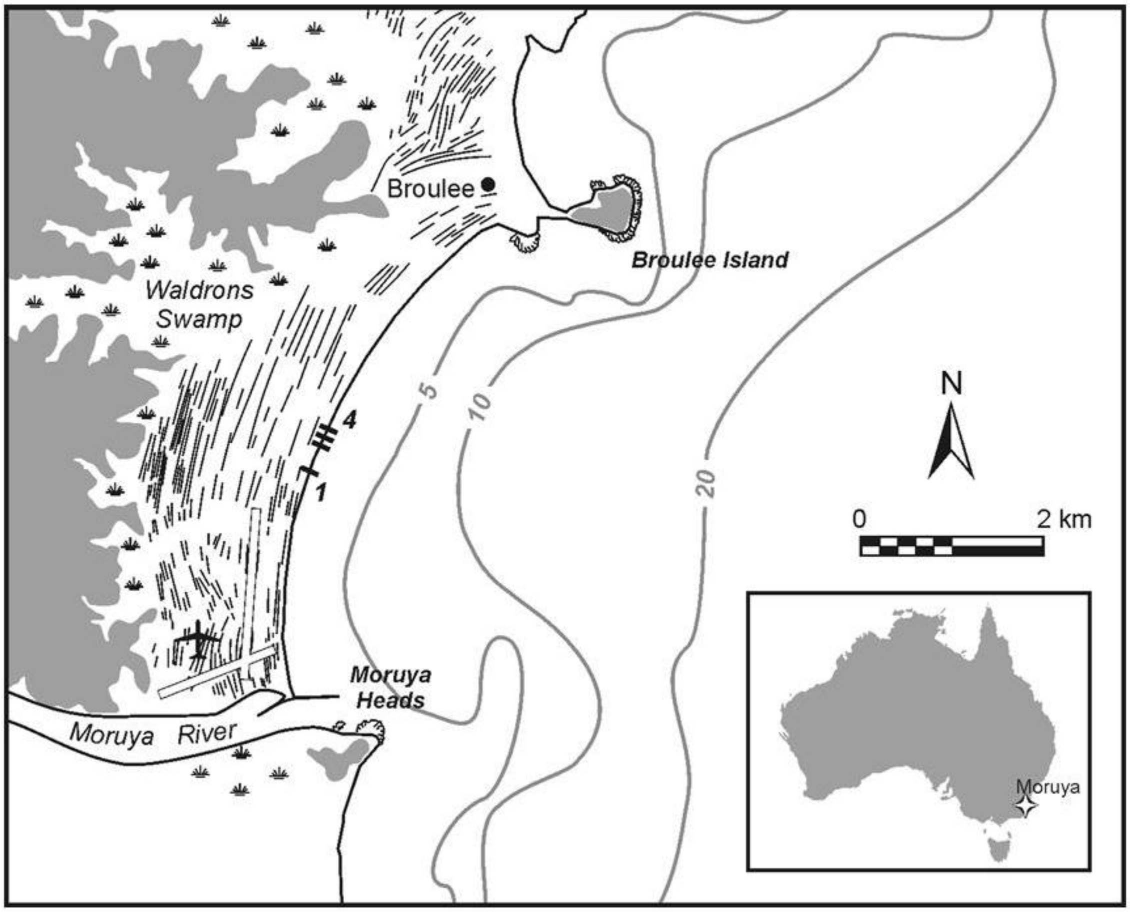

Figure 2. Location of Bengello Beach and four beach profiles. Profile benchmarks (BM) are located on the vegetated foredune some 100 to 120 m landward of the AHD intercept (approximately local mean sea level). The distance between BM 1 and BM 2 is 286 m, BM 2 and BM 3 69 m and BM 3 and BM 4 67 m. Broulee Island in the north is presently attached to the mainland by a tombolo.

Previous studies and present purpose

There have been a number of publications dealing with the morphodynamics of Bengello beach, which in the international scientific literature has been called Moruya beach because of its proximity to the township, airport and river all of that name. Wright *et al*., (1979) described it as a classic dissipative beach with a complex and varied topography that ranged through six beach types. Typically waves break 75-150 m offshore, often on a sand bar, and dissipate much of their energy before reaching the shore except during storms when waves extend across the beach face and on to the backshore. This occurred during the recent (May-June) 2010 storm.

Based on the profile survey data, Thom and Hall (1991) described the behaviour of beach profiles from 1972 to 1986, the survey record being extended out to 2000 by Shen (2002) and later to June 2004 by McLean and Shen (2006). In their analysis Thom and Hall (1991) identified three separate periods of beach condition: an accretion-dominated period (ADP) from 1972 to 1974; an erosion-dominated period (EDP) between 1974 and 1979, and a subsequent accretion-dominated period (ADP) from 1979 to 1986. They also defined a beach-width-shape index and identified four types of beach profile: (1) concave, (2) concave and berm, (3) concave with beach and dune, and (4) concave and dune, and suggested that under EDP conditions the beach fluctuates between profile types 1 and 2. Under ADP conditions profile types 3 and 4 prevail. Finally, they argued that changes between these four types of beach profile primarily result from the formation, accretion and erosion of the incipient foredune on the backshore (Thom and Hall, 1991).

In a subsequent paper the survey record was extended out to 2000 and a time series of foreshore sand volume change within the survey area (between profile 1 and profile 4) was analysed by Shen (2002). From the data set he identified three different morphodynamic conditions. An *erosional morphodynamic condition* dominated during 1972 to 1978, a period characterised by a high degree of beach change that includes the first ADP and the EDP of Thom and Hall (1991). During this period, the magnitude of short term erosion and accretion was much greater than during the subsequent *accretional morphodynamic condition*, which was separated into two phases, an *incremental accumulation phase* between June 1978 and January 1982, followed by a relatively *stable accretional phase* to 2000.

More recently McLean and Shen (2006) focussed on the morphodynamic pre-conditions that resulted in the development of a new frontal dune at Bengello beach. They argued that for this to happen two criteria had to be satisfied: first, the presence of a broad backshore berm at an elevation of 2.3 to 2.8 m above AHD or local mean sea level; and, second, the berm had to be at least 30 m wide (to allow wind deflation from backshore to dune to become effective). While the profile data from Bengello beach showed that the berm reached one or other of the required elevation (2.3 to 2.8 m) or the required width (>30 m) on several occasions, it was only when the beach achieved *both* conditions that an embryo dune developed into an incipient dune, that ultimately grew into the present frontal dune. That dune is now well vegetated and located some 20 to 30 m landward of the average high water mark.

In the present report we describe the major changes that Bengello beach has undergone since 1972, and comment, where appropriate on the foregoing studies. Our emphasis however, is on the changes in beach volume rather than beach morphology (though the two are closely related) and the qualitative relationship between beach volume change and ocean conditions, particularly storms.

Beach volume change data

Beach volume changes at Bengello beach are calculated using the cross-section areas of beach profiles at each bench mark (BM) multiplied by the distances between them. The area of a beach profile is enclosed by three lines: a vertical line at the BM location, the surface of the dune and beach seaward of the BM, and a horizontal line at the AHD intercept that extends landward to the BM vertical. This intercept approximates local mean sea level (MSL) and is called that in this report. Clearly, the morphology and elevation of the dune-beach surface varies through time and the position of the MSL intercept shifts horizontally with changes in beach condition, though on average it is presently some 100-120 m seaward of the BM**.** The volumetric data for the whole beach segment has been normalised as volume per unit length of beach and is presented in cubic metres per metre of beach length (m^3/m of beach length). That is, the total volume between profile 1 and profile 4 is divided by 422 m (the distance between BM 1 and BM 4).

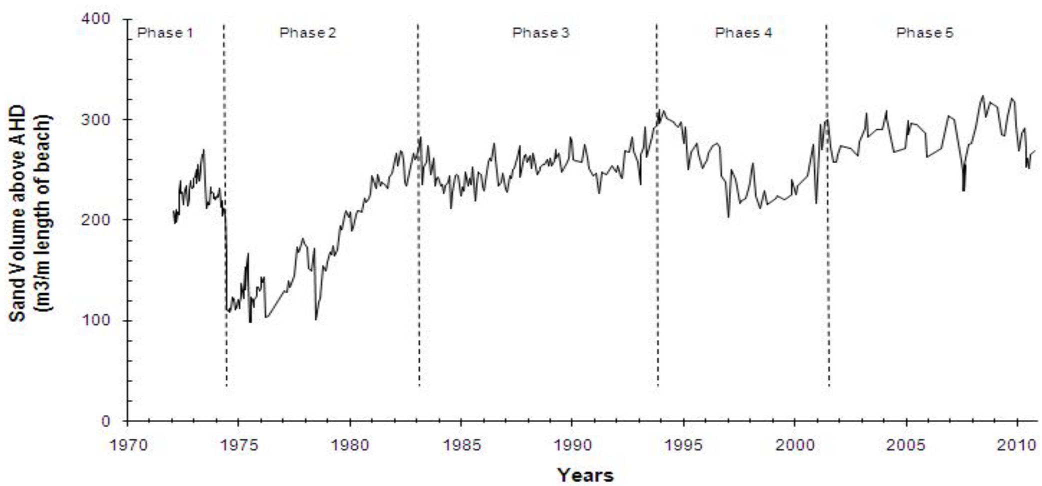

Figure 3. Time series of volume change at Bengello Beach, Moruya from January 1972 to October 2010. Normalised data (in m^3/m length of beach) based on the three-dimensional prism between Profile 1 and Profile 4, a distance of 422 m, and the AHD intercept with the profile at the time of survey. The position of the AHD intercept varies horizontally with erosion and accretion of the foreshore.

Beach volume changes 1972-2010

The magnitude of volume change over the last 38 years is shown in Figure 3. We distinguish five distinctive phases in the time series, details of which are described below. However at the outset, it is obvious that the mid-1970s stand out as a period of very substantial sand deficit the magnitude of which has not been duplicated again in the last three decades.

Phase 1 1972 to 1973: Accretion

During the first year of surveys the amount of sand above MSL increased incrementally from about 200 to 250 m^3/m of beach length. Broadening of the berm and development of an incipient foredune were the most evident morphological effects. But this trend was short-lived. In mid-June 1973, the beach was severely depleted by a storm and the accretionary phase was abruptly terminated reducing the volume back to 210 m^3/m of beach length. This event clearly shows on Figure 3. Elsewhere McLean and Thom

(1975) have suggested that the June 1973 storm represents a turning point in the beach system, from a constructional to erosional regime. They also suggest that this turning point reflects a subtle change in incident wave energy from a lower average in the year or so prior to the storm, to a higher average level in the following year (based on Waverider buoy data off Botany Bay and Port Kembla).

Phase 2 1974 to 1982: Severe erosion and gradual accretion

The second phase extends over several years and includes the most substantial fluctuations in the 38 year record. The first part is characterised by a severe reduction in beach volume (the EDP of Thom and Hall, 1991) and the second by a slow and episodic increase in volume (the ADP of Thom and Hall, 1991). The storms of May-June 1974 were primarily responsible for the initial change in beach state to an erosional condition that effectively lasted for three to four years. These storms which caused massive and widespread damage to coastal structures and beaches along the central and south coasts of New South Wales have been described by Foster *et al*., (1975) amongst others. There were two major storms, the first from 24 to 27 May, and the second of longer duration from 9 to 15 June. Both events were characterised by maximum wave heights of over 8 m (off Port Kembla) and by high tides and a substantial storm surge and wave set-up, especially in the early event.

At Bengello, the beach was combed down and trimmed back, initially with the removal of the backshore and incipient dune and swale, ultimately cutting into the stable, *Acacia* covered frontal dune itself. In the seven weeks from 6 May to 21 June 1974, the surveyed segment of the beach (422 m long) lost about 40,000 m^3 of sand, above MSL, or about 95 m^3/m of beach length, which if translated into a volume for the whole beach represents a total loss of about 520,000 cubic metres. The MSL intercept was displaced landward by 50 to 60 m and between the former MSL and high water marks the beach was reduced vertically by 3 m. In short, what was once the incipient foredune was now the beach foreshore. A 2 m high vertical scarp separated this new foreshore from the vegetated inland (see Figure 4).

By December 1974 there had been some recovery of the beach with a backshore ramp developing in front of the scarp. The backshore continued to build throughout the summer of 1974-75 adding about 40 m^3/m of beach length to the profiles. Throughout this time the scarp remained at the back of the beach, and this was freshened up during high seas in the first half of 1975, such that the beach lost all of the sand gained in the previous few months. This binary sequence of beach changes – erosion and scarping; accumulation and backshore ramp building – with the associated fluctuations in the volume of sand stored in the beach, was repeated on two further occasions during Phase 2, in 1976 and 1978, with the scale (both temporal and volume) increasing on each occasion as shown in Figure 3.

Although minor erosional episodes affected the beach from 1979 through 1982, this was a period of natural beach nourishment with over 150 m^3/m of beach length being added to the profiles and the MSL intercept advancing about 50 m seaward during this time. By mid-1982 the volume of sand above MSL was similar to that prior to the 1974 storms, eight years earlier.

Figure 4. Bengello beach in 1974 from Profile # 3 looking north showing planar beachface, erosion scarp cut into swale between former incipient dune and established frontal dune. Photograph taken 25 May 1974 towards the end of the first May-June 1974 storm series. In the following weeks seas eroded the remainder of the swale and the scarp cut back further into the vegetated foredune to left.

Phase 3: 1983 to 1993: Beach ‘stability’ and low variability

In contrast to the previous phase, the eleven year period from 1983 to the end of 1993 is characterised by relatively small fluctuations in volume, typically of the order of 5 to 20 m^3/m of beach length between surveys. There were, however, several occasions when the beach was impacted by stormy seas most notably in August 1986, and again in 1990 and 1992. These events had a similar effect to those described earlier for the May-June storms of this year (2010). Recovery and return to pre-storm volume for these events was much more rapid than during Phase 2. By this time the beach was in a ‘well nourished’ state and possessed all of the morphologic components of the classical open ocean beach profile; a developing foredune, broad backshore and berm and gently sloping foreshore. In fact, by the end of this phase Bengello beach contained more sand (above MSL) than at any time in the previous two decades.

Phase 4: 1994 to 2001: Gradual erosion and gradual accretion

This phase, like Phase 2 contains two quite distinct periods, though the magnitude of volumetric change is much less than in the earlier phase. Nevertheless, from the beginning of 1994 to 2000 over 100 m^3/m of beach length had been removed from above MSL. Whilst there was little change in the horizontal position of the MSL intercept throughout the period, a series of high waves in 1994 and particularly in August/September 1996 and during the winter of 1998 trimmed back the shoreline, removed the incipient foredune and again created a simple 2-D erosional profile comprising a concave or planar foreshore backed by an erosional scarp 1.5 to 2 m high.

However, recovery from these erosional events was quite rapid and by the end of 2001 all of the diminished sand volume had returned to the beach. Although these high frequency episodes of sand volume reduction and expansion show on figure 3, the most obvious trends illustrated in the figure are the gradual sand loss through 1999 and the subsequent gain from 2000 to mid-2001. There is no simple explanation (e.g sea-level or wave energy variation) for these trends.

Phase 5: 2002 to 2010: Beach 'stability' and high variability

Throughout the last few years Bengello beach has maintained a 'well-nourished' state. The total amount of sand stored above MSL has been, on average, greater than at any time since surveys began in 1972. On the other hand, this most recent phase has been characterised by high variations in sand volume, *albeit* around a rather consistent average. In this sense Phase 5 is distinguished from Phase 3 which also had a consistent mean volume, but had lower inter-survey variability. Another difference is that since 2002 the average volume of sand above MSL has been at least 40 m^3/m of beach length greater than that during Phase 3. Morphologically this difference is very clear in that there is now a well established vegetated foredune that reaches an elevation of over 5 m above MSL and is located 40 to 50 m seaward of the profile benchmarks and some 50-60 m landward of the average position of the MSL intercept, whereas during Phase 3 the foredune was just developing and subject to episodic erosion and accumulation. There is also an incipient dune some 10-15 m seaward of the vegetated frontal dune and separated from it by a narrow 'swale'.

Inspite of this 'healthy' state Bengello beach has not been immune from the effect of several east coast storms. These have had a similar impact to that of May-June 2010 (see Figure 1). Important erosional events happened in July 2001, October 2004 and July 2005, though the most significant occurred in June-July 2007. This 2007 series of storm systems impacted the central and southern NSW coastal regions and have been described by BOM (2009) and Watson *et al.,* (2009) amongst others.. The first event which occurred over Queen's Birthday weekend (June 8 and 9) was the most serious, grounding the bulk coal ship *Pasha Bulker* on the beach at Newcastle, and being likened to the May 1974 storm that grounded the *Sygna* on nearby Stockton Beach.

During the June 2007 long weekend the Sydney directional Waverider buoy recorded the highest waves along the NSW coast. Significant wave heights (H sig) reached 6.87 m, with a maximum individual wave height of 14.13 m. Throughout June H sig exceeded 3 m for a total of 208 hours, some 29 percent of the month. This sustained swell wave activity together with tide levels at least 20 cm above normal, had a cumulative impact on eroding many NSW beaches (Watson *et al.,* 2009). Whilst the Waverider buoy off Batemans Bay, 27 km north of Bengello beach recorded lower wave heights than at Sydney, H sig still exceeded 4m on several occasions during the month and the impact on Bengello beach was dramatic.

Surveys in February 2007 showed the beach prior to the storms comprised a wide foreshore, broad berm and a backshore ramp that linked to an incipient dune seaward of the established foredune and swale. During the storms in June 2007 the MSL intercept was displaced landwards by 20 to 30 m, the berm and backshore together with much of the incipient dune was eroded away forming a vertical scarp 1.5 to 2 m high (Figure 5).

Figure 5. Bengello beach from Profile # 4 looking north. Photograph taken 30 June 2007 after erosion of berm, backshore and incipient dune. Scarp 1.5 to 2 m high. Arrows indicate frontal dune and degraded and vegetated scarp associated with the storm events of 1996-98 (right arrow) and 1974-76 (left arrow). Note that the beach has prograded some 50 to 60 m since the 1970s and is now in a comparable position to where it was at the start of our survey program in 1972. See also Figure 4 for the view from the left arrow position on 25 May 1974.

Within a year the beach had recovered from its erosional state and had a morphology similar to that prior to the June storms. It also had the highest sand volume recorded at over 300 m^3/m of beach length. However, since the beginning of 2009 the most recent trend has been a reduction in the amount of sand emphasised by two more erosional events in October 2009 and May-June 2010. In all about 40-50 m^3/m of beach length has been removed in the last 18 months or so, a sand volume not dissimilar to the amounts eroded in 1973 and 1996, prior to the major erosional events of 1974 and 1996 . At the present time (October 2007) it is not clear whether the general erosional trend will continue or be reversed.

Discussion and conclusions

Episodically there is significant beach erosion along the NSW coast, most frequently, though not exclusively, associated with east coast cyclones or east coast low pressure systems (ECL). These storms are one of the more dangerous weather systems to affect the NSW coast, because they intensify rapidly and can generate gale or storm force winds, heavy widespread rainfall leading to river floods, and, very rough seas and prolonged heavy swells which can cause considerable damage to the coastline (BOM, 2009).

At Bengello beach such storms are relatively common. They result in combing down of the beachface, landward displacement of the shoreline and the development of a scarp that separates the active beach from the vegetated hinterland. Replenishment of the lost sand back to the beachface and berm is an equally common response during fair weather conditions that follow such events. This rhythmic, though not regular, pattern of erosion and accretion is clearly evident in the record of beach change described in the present report. Typically shifts of some 20 to 40 m^3/m of beach length are characteristic of this particular beach system, though replacement of the lost sand normally takes much longer (weeks or months) than its removal (hours or days). This temporal asymmetry in volume loss and gain is well shown in the Bengello data (Figure 3) and suggests that for most of the last three decades Bengello could be regarded as an ‘equilibrium beach’. The record also suggests that from mid-1974 to 1978 the beach was not in ‘equilibrium’ as a consequence of the massive impact of the May-June storms of 1974.

The 1974 storms were clearly exceptional, but not unprecedented (Thom, 1974), and as Jeans and Davies (1984) pointed out a decade later: “It now appears likely that an ‘event’ of this magnitude has a recurrence interval of about 100 years”. Since then the 1974 storms have been revisited by Lord and Kulmar (2000) who, based solely on wave height and duration data, suggest that the 1974 events would more properly be assigned a return interval of 50 years rather than 100 years. Regardless of such detail, it is obvious from our data that the beach response to the 1974 storms has not been matched since that date, even though it has been argued that the scale of the June 2007 storms was roughly comparable to 1974 (Watson *et al.,* (2009). At Bengello however, the antecedent beach conditions were quite different between 1974 and 2007 (‘under-nourished’ versus ‘well-nourished’) and this may well be the most important factor in contributing to the different responses.

Since the 1974 storms, Bengello beach has prograded some 60-80 m, adding about 200 m^3/m of beach length to the shore. But, it must be emphasised that such progradation only takes the beach back to its pre-1974 position, that is where it was in the early 1970s at the beginning of our survey program. Vestiges of the 1974-76 erosional shoreline (and that of 1996-98) are still quite evident in the ridge-swale landscape at the back of Bengello beach (see Figure 5). The presence of such features provides clear evidence, and a timely reminder, of the scale of change that natural or little modified beaches along the NSW coast can undergo. The present study has provided a perspective on the magnitude and frequency of shoreline movements at one New South Wales beach over nearly four decades. These movements, and the morphological changes associated with them, are unlikely to lessen in the years ahead, though they may well increase if boundary conditions change.

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