Geomorphological evolution of the Prion Beach and New River Lagoon beach barrier system

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Tasmania

Explore the possibilities

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Cover Photo: Aerial photograph of prograded dunes supporting mature coastal rainforest inland from the shrub dominated shore parallel dune system, Prion Beach New River Lagoon. Photo Matt Dell.

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Introduction

Sandy beach/barrier systems make up a total of around 64km of the 250km of open ocean coastline around the Tasmanian Wilderness World Heritage Area (TWWHA) (Cullen 1998). The morphological diversity of these systems is considerable. Using the classification of Thom *et al.* (1978), Cullen (*opt. cit*.) recognized five different barrier types.

This coastline is of extremely high conservation significance. Apart from sea level rise caused by greenhouse gas induced climate change, human impacts are restricted to walking tracks and associated infrastructure, localized mining activities around Cox's Bight and Melaleuca, and anthropogenic fires which have burnt large areas of the hinterland and in some places coastal vegetation. To quote Sharples (2011):

> *A major geoheritage value of the TWWHA coastal landform systems as a whole is the fact that these comprise one of the longest temperate-zone wave-dominated coasts in the world having negligible disturbance from human activities other than global sea-level rise and associated climate change effect (Sharples 2003). This is a key element in the World Heritage Value of the TWWHA, giving these coasts outstanding universal value under Criterion 44(a) (i) of the UNESCO World Heritage criteria (UNESCO 1999). Apart from the intrinsic value of such a long stretch of essentially-undisturbed coast, this also gives the TWWHA coast important scientific value since it provides a rare opportunity to study coastal processes under conditions where anthropogenic influences (other than climate change) are negligible. Further study of these TWWHA shores could lead to a better understanding of the response of more heavily modified shores in settled regions elsewhere to sea-level rise.*

Furthermore, coastal barrier systems preserve evidence of their genesis and the past environmental conditions that impacted on their development. They can also be rich with cultural material which predates the arrival of Europeans to the island and the decimation of the original human inhabitants of the island. The work of Cullen (1998) indicates that the sandy barriers systems of the region evolved in a manner which broadly follows the evolution of barriers elsewhere in temperate Australia, this being a period of barrier progradation during the late Pleistocene and early Holocene, followed by either barrier stability, or regression since the middle Holocene up until the present.

If we are to use the barriers within TWWHA as 'benchmark' examples to compare with more heavily modified barriers elsewhere, in the manner suggested by Sharples (2011), it will be necessary to gain an understanding of their evolution up until now and to set up baseline monitoring to chart their development into the future. This report details the results of a project undertaken at Prion Beach/New River Lagoon to help achieve these ends. Commonwealth Government funds were provided for this work with the project managed by the Geoconservation Section of the Tasmanian Department of Primary Industries Parks Water and Environment.

The report has three parts:

1. an investigation into the morphology, dynamics and age of various parts of the barrier system;
2. an investigation of existing aerial photography to determine if trends or rates of dune erosion can be determined over recent years; and
3. the establishment of a series of transects to monitor further dune erosion and/or deposition.

The Study Area

Location

Prion Beach and New River Lagoon are situated between South Cape and South West Cape, on the south coast of Tasmania, within the TWWHA, and approximately 50 km south-west of Hobart (Figure 1). New River Lagoon has a catchment of around 28 900 ha. This catchment is bounded in the west by the Ironbound Range in the east by Precipitous Bluff, Mt Bisdee and Mt Bobs and extends many kilometres north to the southern slopes of Federation Peak. The beach and lagoon are regularly visited by bushwalkers as Prion Beach and the campsite on the eastern side of New River Lagoon form part of the South Coast Walking Track. Smaller numbers of walkers arrive at the lagoon via the Southern Range and Precipitous Bluff.

Figure 1. Prion Beach and New River Lagoon location.

General Climate

The region experiences a cool, super-humid, changeable, maritime climate, dominated by the passage of cold fronts associated with low pressure systems (Pemberton 1989). Much of the region, including the water catchment of the study area, experiences over 2000 mm of precipitation annually, with the higher ranges receiving in excess of 3500 mm. The coastline receives much less precipitation and the 1600 mm isohyet roughly follows it. The annual temperature regime for Maatsuyker Island (the closet weather station to the study site) is a July mean maximum of 10.9^{o}C and a mean minimum of 6.5^{o}C, and a February mean maximum of 17.2^{o}C and mean minimum of 11.0^{o}C. South-westerly to north-westerly winds are dominant. These winds are strongest near the coast and on the ranges. Winds of over 28 km/hr occur at Maatsuyker Island for 30—40% of the time.

Wave climate and tide regime

The southern coast of Tasmania is a high energy swell environment (Davies 1980). It is a very stormy region. Waves of less than 2 m occur only 2% of the time and waves greater than 5 m 40% of the time (Chelton *et al.* 1981). Waves of greater than 4 m regularly pound the coastline (Bureau of Meteorology 1995).

The study area has a micro-tidal regime with spring tides of <2 m. This tidal range is regularly amplified by high winds and large swells which cause areas of the beach and fore dunes that are normally beyond the reach of the tide and wave attack, to suffer significant erosion events.

The large and steep catchment area of the New River Lagoon causes the water level to rise substantially higher than the normal tidal levels after large rainfall events. This, when combined with a large storm surge, can maintain a high water level in the Lagoon for many days.

Geology and Geomorphology

Prion Beach is one of a number of large sandy barrier systems found on this coast and together with New River Lagoon is the largest sand spit/estuary system in the TWWHA and one of the largest in Tasmania. New River Lagoon has an area of approximately 1195 hectares and the Prion Beach spit is presently just over 6 km long comprising some 330 hectares.

New River Lagoon is surrounded by relatively mountainous topography formed by late Cambrian to early Ordovician, conglomerate, sandstone, and siltstone, Ordovician limestone, Precambrian quartzite, and Jurassic dolerite. The immediately adjacent piedmont zones of Precipitous Bluff and the Ironbound Range are formed by extensive colluviums and fan deposits (Baynes 1990, Pemberton 1989). The mountain peaks of the upper catchment of New River Lagoon supported small cirque glaciers during the late Holocene and peri-glacial activity would have been widespread at that time. This activity would have been the source of a considerable portion of the sediments in New River Lagoon and the Prion Beach barrier. During the last glacial the Lagoon and areas further out towards the edge of the continental shelf are likely to have been a broad plain with one or more river channels. Progressive sea level rise during the Post Glacial Marine Transgression (PGMT) would have caused the flooding of the area and the creation of the current barrier (Cullen 1998).

Methods

To assist with all three aspects of the project, a base map of the beach, dune and back barrier features was prepared using pre-existing aerial photographs, satellite imagery, and pre-existing LiDAR altimetry survey data (Table 1, data sources).

Two, five day field trips were undertaken between the 5/3/2012 and the 28/3/2012 to investigate barrier stratigraphy, obtain material for optically stimulated luminescence and radio carbon dating, and to establish dune erosion monitoring transects. Helicopter transport was utilised to access a base camp on the shores of the New River Lagoon and an inflatable boat used to access study sites.

Table 1. Data sources.

Data Type	Source	Date
1:25000 Aerial Photography	DPIPWE*	5/02/1988
1:24000 Aerial Photography	DPIPWE	17/09/2008
LiDAR DSM	ACE CRC**	5/11/210
1:5000 Aerial Photography	DPIPWE	6/03/2011

*Department of Primary Industries, Parks, Water and Environment

** Antarctic and Climate Ecosystems Cooperative Research Centre

Dune stratigraphy

Dune stratigraphy was studied either by locating and cleaning the faces of erosion scarps or by auguring holes into dunes with a hand auger. Primary soil profile data (McDonald *et al.* 1984) was recorded for each section investigated. The depth, Munsell colour and texture of each horizon was recorded at each site. Samples of each horizon were taken. The location of all auger holes and exposures investigated was recorded on a hand held GPS device. This data and all of the map and imagery data was loaded onto a GIS program for manipulation and map production.

At some locations sand samples were collected to enable the date of deposition to be determined using optically stimulated luminescence (OSL) techniques (Murray-Wallace *et al* 2002). This involved coring sandy deposits by driving 40 cm long, 5 cm diameter sections of steel tube into cleaned faces of the dunes (Photo 1). These tubes where plugged and wrapped to prevent mixing of the sand sample and light contamination. Samples from the surface and from a 40 cm radius surrounding the core locations where also taken. These samples were submitted for dating at the Victoria University of Wellington, School of Geography and Earth Sciences laboratory.

In places erosion has revealed peat deposits that occur at the base of dunes near current sea level. Samples were collected for radio carbon dating at some of these sites. These samples were submitted to the Australian National University, Radio Carbon Laboratory, School of Earth Sciences.

Photo 1. OSL dating sample collection showing steel tube in excavated dune profile.

Recent erosion/barrier retreat

A series of aerial photographs from 1988, 2008 and 2011 (Table 1) where investigated to ascertain if there had been significant shore-face erosion during this period. These images were scanned and digitally rectified using the computer program Landscape Mapper to fit 1:25 000 scale base maps. The images where then visually compared to identify areas where erosion and/or deposition have occurred.

Erosion transects

Six erosion transects were established on the ocean face of the Prion Beach spit and a further four were located on the lagoon side of the spit. The ocean facing transects were located approximately every 400 metres along the spit (Figure 2). The location of the lagoon facing transects were constrained by suitable landing spots. They were placed about 1000 metres apart. Each transect consisted of five or six galvanized steel “droppers” (pegs) driven into the dune or swale surface. The pegs were located at the top of the dune escarpment on the shore face and at breaks of slope inland across the dune profile. The angle and distance between each successive peg was recorded with a clinometer and tape measure. The position of each peg was recorded with a hand held GPS.

The details of the transect profile measurements were plotted using Microsoft Excel. The angles were converted to radians to enable the trigonometric calculation of the planar distances and relative heights between the pegs. The profiles and associated tables are attached as Appendix 1.

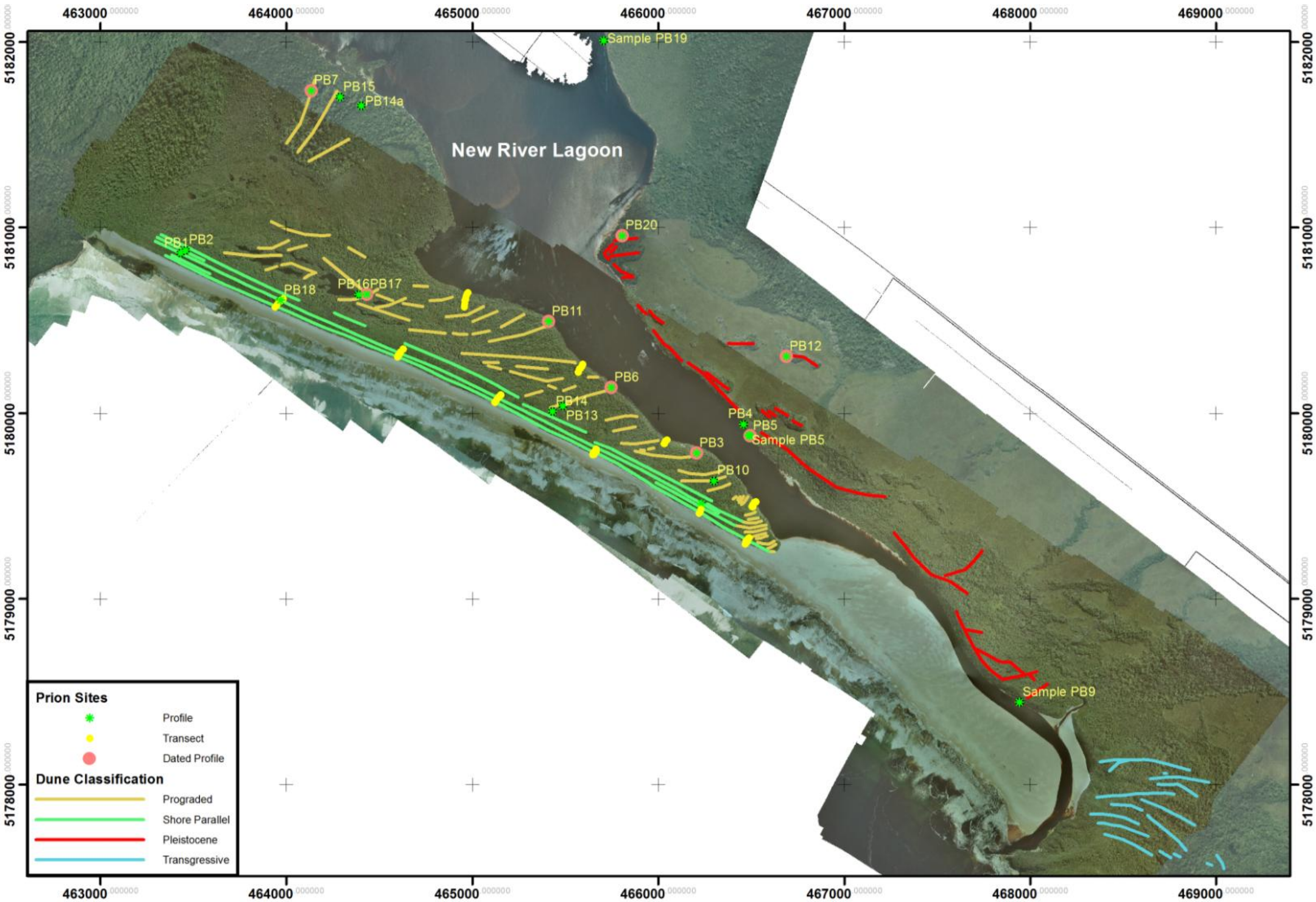


Figure 2. Site Locations and dune features along Prion Beach and New River Lagoon.

Results and Discussion

Base Map

The base map of the beach, dune and back barrier features are presented in Figure 3. The features identified on this map largely reflect those identified by Cullen (1998), however more recent imagery and LIDAR data yields greater detail of the Prion Beach barrier and back barrier geomorphic units. There appears to be at least six units.

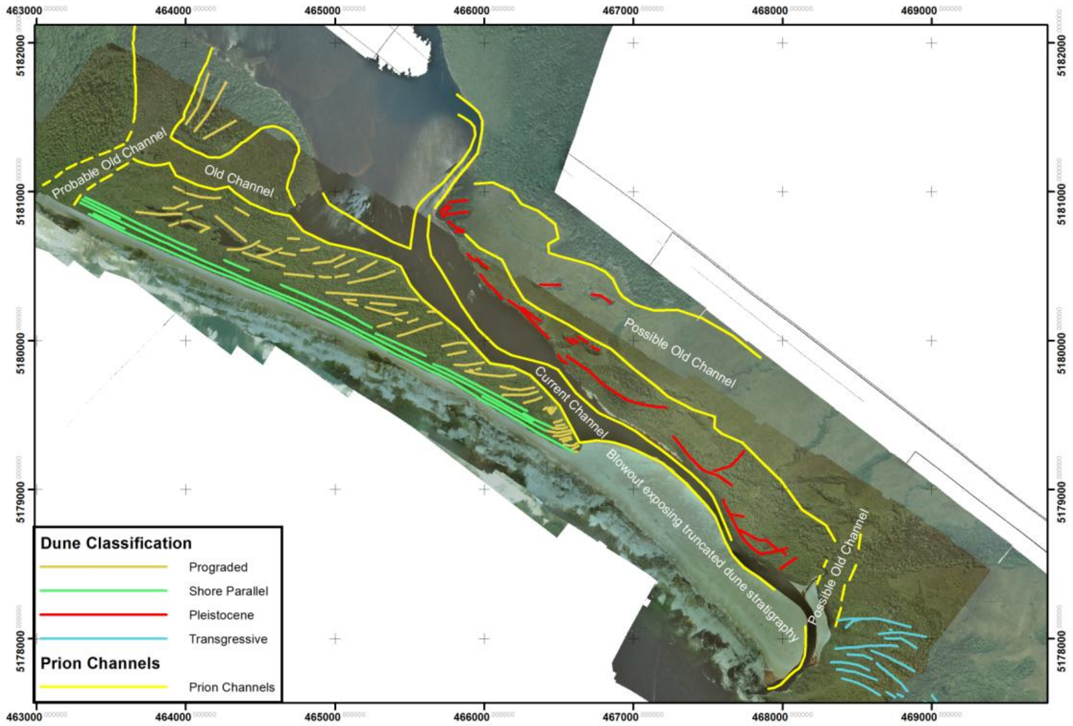


Figure 3. Dune classification and channel locations at Prion Beach and New River Lagoon.

Recent erosion/barrier retreat

A series of aerial images from 1988, 2008 and 2011 were ortho-rectified to assess erosion rates visually. The nature of the overhanging shoreline vegetation (Photo 2) and slumping of the dune faces on the beach and along the lagoon shore (Photos 3 and 4) and lack of accurate ground control in the area make an assessment of erosion trends difficult. Significant active slumping was observed along substantial sections of the ocean facing beach and at numerous localities on both sides of New River Lagoon. It is apparent from on-ground observations during the field trips that there has been considerable retreat on the ocean facing dunes since the 2011 aerial photographs were taken (see Photos 3 and 4).

Photo 2. Dense overhanging vegetation on the southern shore of New River Lagoon.

Photo 3. Slumping of foredunes on Prion Beach.

Photo 4. Slumping of aeolian dune sands on the northern bank of New River Lagoon.

Erosion transects

Ten transects to monitor ongoing dune erosion or deposition were established at Prion Beach (Figure 2). The details of each transect including a profile of the dunes at each location is presented in Appendix 1. The optimal time between successive re-measurements of the profile transects is yet to be determined. During installation the transect lines were cleared by hand. Each monitoring pin was located by hand held GPS. Vegetation recovery is likely to be relatively rapid and it would be prudent to precisely locate the transects and individual marker pins with a differential GPS before it becomes excessively difficult to achieve this.

This technique will enable a more accurate measure of dune retreat or growth than was possible with the initial aerial photography assessment. It would be prudent to re-measure any pegs on the actively slumping dune faces in the not too distant future.

Dune Mapping, Stratigraphy and Dating

Mapping from remotely sensed data, investigations of dune stratigraphy on erosion scarps and in augured holes, and dating of selected samples from some of the profiles investigated have revealed six distinct dune units. These units are described below.

Material suitable for OSL and radio-carbon dating was retrieved at a number of locations. The dates obtained from these samples are presented in Tables 2 and 3. The locations of these samples are shown in Figure 2. The location, extent, stratigraphy, age and relationships between these six units are described in the following sections.

Table 2. Dates from the Luminescence Dating Laboratory, Victoria University of Wellington Luminescence Ages (Wang, 2012).

Field Code	Laboratory Code	De(Gy)	Dose Rate (Gy/ka)	Luminescence Age (ka)
PB3	WLL1016	0.91±0.22	0.41±0.02	**2.2±0.5**
PB5	WLL1017	64.88±19.11	0.56±0.03	**116.8±34.8**
PB6	WLL1018	2.20±0.98	0.36±0.01	**6.2±2.8**
PB7	WLL1019	2.42±0.76	0.48±0.02	**5.1±1.6**
PB11	WLL1020	2.01±0.32	0.42±0.01	**4.8±0.8**
PB12	WLL1021	6.42±1.78	0.26±0.01	**24.8±7.0**
PB17	WLL1022	1.93±0.43	0.37±0.02	**5.2±1.2**
PB20	WLL1023	44.71±11.84	0.35±0.01	**126.2±33.8**

Table 3. Radio-carbon Centre Australian National University ^{14}C Results.

Sample Name	S-ANU#	other ID	$\delta^{13}C$	±	Percent Modern Carbon (pMC)	±	14C age	±
PB10a	30706	8843	-22.53	0.214	97.178	2.20E-01	**230**	**20**
PB11	30707	8841	-21.19	0.452	55.554	1.76E-01	**4720**	**30**

NOTES:

1) $\delta^{13}C$ values are the AMS machine quoted values and are used to correct the age. They can differ from IRMS results.

2) The quoted age is in radiocarbon years using the Libby half-life of 5568 years and following the conventions of Stuiver and Polach (Radiocarbon, v. 19, p.355, 1977, in Fallon *et al* (2010)).

3) Radiocarbon concentration is given as percent Modern Carbon and conventional radiocarbon age.

4) Sample preparation backgrounds have been subtracted, based on measurements of samples of 14C-free CO2

1. Transgressive dunes

There is a field of transgressive dunes on the eastern side of the mouth of New River Lagoon. Behind the beach, the foredune area of these dunes is devoid of vegetation and actively migrating in an easterly direction (Figures 2 and 3). This dune field receives windblown sand from Prion Beach. The sand which is derived from the beach and from actively eroding fore dunes is transported progressively to the east by wind and long-shore drift. These dunes also appear to cover much older barrier dunes along the eastern edge of the current lagoon mouth channel (see Section 5 below). No investigation of dune stratigraphy was made in this unit.

Cullen (1998) considered that these transgressive dunes were the product of late Holocene barrier recession. In his study, a sandy peat deposit exposed at the base of the foredune at the eastern end of the beach, near to the lagoon mouth entrance, yielded a date of 7450+/-70 years BP (Beta – 82648). The deposit is interpreted as having been deposited in a back barrier or dune swale wetland, which predated the current foredune and the transgressive dune field at the eastern end of the beach. This peat horizon appears to be relatively extensive as a similar deposit in the same stratigraphic position was recorded in the current study (PB8), a few hundred meters to the west. The date of the peat deposit coincides well with the end of the Holocene Post Glacial Marine Transgression. Subsequent barrier retreat and the development of the transgressive dune field at this end of Prion Beach, has buried this deposit. This scenario accords well with mid to late Holocene barrier evolution in south-eastern Australia (see Cullen 1998).

This would lend weight to the view that a palaeo-lagoon mouth/river channel flowed out at this point (Figure 2, and Sections 5 and 6 below). Closing of the mouth would have created a lagoon/wetland environment in which peat accumulation could proceed.

2. Shore parallel dune ridges on Prion Beach Spit

Figure 2 shows a series of well-developed, shore parallel, dune ridges which extend for about two thirds of the length of the Prion Beach Spit. There are three well developed ridges ranging up to around 30 m in height, with faces of up to 45 degrees. These dunes are well vegetated with coastal heath and scrub except for the eroding shore face. In many places this is actively slumping in response to wave attack. In others, low incipient foredunes are currently developing with some establishment of foredune vegetation. This mirrors the situation at many beaches on the south and west coasts of Tasmania and elsewhere in south-eastern Australia where episodic barrier retreat and the development of transgressive dunes has been a common phenomenon in the late Holocene (Sharples 2003, Cullen 1998, Pemberton and Cullen 1997).

Dune stratigraphy in this geomorphic unit was investigated with five auger holes; PB1, PB2, PB9, PB14 and PB18 (Figures 2 and 4). Dune profiles from these holes show only limited soil horizon development. In some auger holes there may be evidence of previous periods of dune mobilization in the form of buried A1 horizons. This interpretation is consistent with a relatively deep foredune profile described by Cullen (1998) for Prion Beach and at other sites in the TWWHA. Alternately weakly developed (slightly darker) horizons may represent the beginnings of B2 horizon and podzol development (PB14 and PB18). In all of these profiles a bleached A2 horizon is either absent or only weakly developed (PB9, and PB14), that is shallow and not strongly bleached. This contrasts strongly with the profiles recorded in dunes that lie directly inland, which by their location, must be older than these shore parallel dunes (see Section 3 below).

No material from this unit was submitted for dating. However, the position of these shore parallel dunes, their morphology, and their stratigraphy, suggest that they have developed in the mid to late Holocene, with a period of shore parallel dune progradation followed by limited episodes of dune recession, as described by Thom (1983). Sharples (2003) considers that the current erosion phase is in response to the impacts of recent sea-level rise caused by a warming climate.

3. Eastward trending prograded dune ridges on the Prion Beach Spit

The development of the current spit at Prion Beach appears to have been initiated by the development of a series of parallel dunes orientated at around 20 to 45 degrees to the shore face (Figures 2 and 3, and photo 5). Some dune swales on the western half of the spit support small lakes and wetlands. The dunes are more or less of the same height and steepness as the shore parallel dunes described in the previous section. The New River Lagoon end of these dunes is currently eroding in response to attack by waves generated on the lagoon and perhaps as a result of recent sea level rise. This erosion has caused an extensive escarpment to develop along this shoreline which is actively slumping along much of its length. This shoreline shows evidence of differential rates of erosion, possibly caused by the migration of the primary tidal channel in the lagoon.

Dune profiles were investigated along the eroding escarpment at sites PB3, PB6 and PB11 (Figures 2 and 4). Dune stratigraphy was also investigated with three auger holes (PB10, PB13 and PB 17) (figures 2 and 4).

Sand samples from A2 and B2 horizons where collected for dating by OSL techniques from profiles PB3, PB6, PB11, and PB17. These samples returned dates ranging from 2.2+/-0.5 to 6.2+/-2.8 ka BP (Table 2). The dates obtained from PB 6 (6.2+/-2.8 ka BP), PB 11 (4.8+/-0.8 ka BP), and PB 17 (5.2+/-1.2 ka BP) all overlap within their error margins and must be considered to be more-or-less contemporaneous.

Therefore the spit appears to have developed relatively rapidly to a point at, or to the east of PB6, at a time around the end of the Post Glacial Marine Transgression (PGMT). The PGMT is dated to somewhere between 6 and 6.5 ka BP (Thom and Chappell 1975) with sea level remaining more or less stable (+/- 1m) since then (Thom and Roy 1983). The OSL date from site PB3 suggests that the process of progradation continued, not necessarily continuously, into the late Holocene at 2.2+/-0.5 ka BP and possibly later.

These dunes, at least at their northern/ New River Lagoon end, overlie sandy peat deposits. Some of this material was collected for dating (PB10a and PB11) (Figure 2). PB10a returned a date of 230+/-20 BP and PB11 a date of 4720+/-30 BP (Table 3). PB10a appears to be contaminated with modern material. It is very unlikely that a deposit of this nature could develop in such a short time. However, the date of 4720 BP for PB11 coincides remarkably closely with the OSL date from the overlying sands (PB11, 4800+/-800 years BP). The peat deposits or PB10a and PB11 are interpreted as being either back barrier or dune swale deposits wetlands, like those which currently occur elsewhere in this dune unit (Figure 2 and photo 5). This indicates that the spit has been relatively stable at least in the area around PB11, since the formation of the dunes that buried the peat deposits up until the present.

All of the profiles investigated in this geomorphic unit show considerable horizon development. The profiles exhibit A1, bleached A2, and light and dark banded B2 horizons. This contrasts to the shore parallel dunes where A2 horizons are either absent or only weakly developed and B2 horizons show little organization into bands. This supports the conclusion that this series of dunes formed prior to the shore parallel dune unit. Dunes with similar profile development on other barrier systems in the TWWHA have returned thermo-luminescence dates of between 5.2 +/- 1.7 ka BP and 13.5 +/- 3.4 ka BP (Cullen 1998), that is anywhere between the late Pleistocene and around the end of the PGMT.

4. Remnant parallel dunes

A small area of parallel dunes is located behind the current spit and low lying, back barrier, swamp areas (Figure 3 and Photo 6). These dunes are surrounded by wetlands and backwater reaches of New River Lagoon. They appear to be remnants of what was probably a more extensive system. There are at least three dune ridges in this unit and they are oriented at right angles to the current beach. They can be seen in Photo 6 and are indicated by the taller, lighter green *Eucalyptus* trees evident in the photo. The dunes are not as high as those described in Sections 2 and 3 (above) and the dune faces are not as steep. The stratigraphy of these dunes and intervening swales was investigated at three sites using auger holes (PB7, PB14a, and PB15, Figures 2 and 4). PB7 and PB15, both located on the face of dunes revealed very well developed profiles. At both sites A2 horizons were deep (> 1 m) and very pale in colour (values of 7 or 8 and Chroma's of 1 or 2). The B2 horizons were also well developed with sharply contrasting bands of light and dark sands. Both the morphology (height and slopes) and the stratigraphy of these dunes suggest that they are possibly older than the dunes of the main spit (Sections 2 and 3). However, an OSL date obtained from the A2 horizon at PB7 (5.1+/-1.6 ka BP) (Table 2) indicates that the material is of a similar age to the parallel dunes of unit 3 (see above).

Photo 5. Prograded dunes supporting mature coastal rainforest inland (left) from the shrub dominated shore parallel dune system (behind the beach on the right). Swales support small wetlands.

Photo 6. Parallel dunes perpendicular to current beach which support tall eucalypt forests. Swales are dominated by peaty soils.

The dune swales in this unit tend to be wide and flat and were comprised of deep peat horizons overlying sandy horizons. These peats were probed at a number of locations and a profile recorded (PB14a). The flats currently support swamp forests of *Nothofagus, Atherosperma* and *Acacia* species or low forest and scrub of *Melaleuca sp.* Some of these low lying areas may have been inter-dune lakes in the past, similar to those found in unit 3 (Figure 3). Although not visited during the survey, there appears to be open water to the west of the PB7. This maybe a former swale or perhaps an old river channel (see Section 6). The depth and extent of these peat deposits suggest that there has been a long period of paludification in the area. Peat deposits rarely exceed 1 to 2m in any but the deepest lakes in Tasmania (Ian Thomas pers. com.)

If the dunes are of the same age as those in the main spit as the OSL dates suggest, then it seems likely that they have formed as part of the spit but have since been isolated by erosion caused by migration of the channel that drains the lagoon. If so differences in dune profile development can most likely be attributed to differences in hydrology rather than longer time since deposition.

5. Pleistocene dunes on the eastern shore of New River Lagoon

A series of dunes extends along the eastern shore of New River Lagoon from a prominent headland (PB20) towards the lagoon entrance to at least the position of site PB5. Generally these dunes parallel the shoreline but around PB20 some are oblique to the shore. There are at least two dunes which lie inland of and disjunct from the main body of dunes along the shore (Figure 2 and 3).

Dune stratigraphy was investigated at four locations (PB4, PB5, PB12 and PB20, Figures 2 and 3). In all cases very well developed soil profiles were revealed. These profile consisted of deep (> 2m), heavily bleached (values of 7 or 8 and Chroma's of 1) A2 horizons. The A2 horizon was not bottomed at PB12 and at the other sites the A2 horizon is underlain by banded B2 fine sands and dark semi-consolidated, ferruginised B2.2 beds. This suggests that all of these dunes are of considerable age.

The A2 horizon at PB20 yielded a date of 126.2+/-33.8 ka BP. At PB5 the A2 horizon was dated at 116.8+/-34.8 ka PB. These are much older than any other dunes investigated in this study or elsewhere on the coastline of the TWWHA (Cullen 1998, Pemberton and Cullen 1997). Given the error margins associated with the dates from PB5 and PB20 it is reasonable to assign them to the same phase of dune building. The A2 horizon at PB12 returned a date of 24.8+/-7.0 ka BP.

These features are interpreted as belonging to two dune building episodes: a coastal barrier formed in response to the marine transgression leading up to the last interglacial sea level maximum, the remnants of which now occur along the eastern shore of New River Lagoon (Figure 2 and 3); and terrestrial aeolian dunes derived from the erosion of this coastal barrier around the time of the last glacial maximum when colder and drier climatic conditions than at present prevailed (Figure 2 and 3).

5.1. Last interglacial Pleistocene barrier dunes

Based on the limited investigations of this study, it is suggested that the dunes investigated at PB4 and PB5 are the remnants of a barrier system that developed in response to the marine transgression leading up to the last interglacial sea level maximum at around 120 ka BP. Globally widespread evidence from raised marine terraces and oxygen isotopes indicates that this event occurred at about 120 ka BP and at a level of around +6m (from +2m to +9m) above current mean sea level (Murray-Wallace 2007, Williams *et al.* 1998). Further investigations of dune stratigraphy are required to test this hypothesis. It is not possible to ascribe a barrier morphology to this system with any certainty. Generally these dunes are orientated parallel to the shore of New River Lagoon (Figure 3), tentatively suggesting that they were part of a prograded barrier similar to the current Holocene spit (see Sections 2 to 4). In places these dunes are currently being eroded by wave action and perhaps channel flow in the lagoon. There is also evidence that they have suffered deflation (see Section 5.2 below). South of a point near to the current campsite, these dunes appear to have either been buried by or eroded by mid to late Holocene transgressive dunes (Section 1 above).

It is interesting to note that the ferruginised B2.2 horizons at the base of dunes at PB4 and PB5 lie close to the current mean sea level and not at +6 m or even +2 m. The elevation of the B2.2 horizon at PB20 was not determined. Palaeo-coastlines in Tasmania, that are considered to be of last interglacial age, are found between +11 m and +32 m above mean sea level and there is evidence that there has been considerable uplift of at least some of these sites (Bowden and Colhoun 1984, Murray-Wallace and Goede 1995). This uplift has been attributed to neo-tectonism due to crustal hotspot activity. However, based on investigations of cave deposits at New River Lagoon, Kiernan and Lauritzen (2001) concluded that uplift in the region since the last interglacial maximum was constrained to <10 m. and possibly <2 m. above current mean sea level. Dunes which can be ascribed to the last interglacial sea level maximum have not been found elsewhere along the TWWHA coastline.

5.2. Last glacial aeolian terrestrial dunes

The dune investigated at PB12 is one of a number of dunes located on a plain occupied by buttongrass moorland to the east of the last interglacial dunes described above (Figure 2 and 3). This moorland may have been a past river channel or lagoon (Figure 2, Section 6). The date for A2 horizon material at PB12 correlates with a phase of terrestrial aeolian dune development in Tasmania that occurred just before and during the last glacial maximum in response to a much colder and drier climate (Bowden 1983, Duller and Augustinus 2006, McIntosh *et. al.* 2009). Donaldson (2010) recorded a phase of aeolian terrestrial dune building at 26.1 +/- 3.5 ka BP inland of Holocene Barrier dunes on the Seven Mile Beach sand spit. It seems plausible that the prevailing climatic conditions at New River Lagoon during the last glacial maximum would have contributed to the deflation of the Pleistocene barrier dunes immediately to the west. Aboriginal burning may also have been a contributing factor. A prominent charcoal layer was recorded 3.25 m from the surface at PB5. This material was not collected for dating.

6. Palaeo-river channels and/or lagoon areas

Aerial imagery reveals two areas which may have been past river channels or lagoons (Figure 2). The first, lying to the east of the current lagoon, has been discussed in Section 5 above. This area is currently occupied by buttongrass moorland, heathland and limited areas of forest and scrub. The stratigraphy of the area was not investigated during this study. However, vegetation of this type is usually underlain by well-developed peat horizons over sands or gravels (Pemberton 1989).

A second river channel or lagoon area is apparent on the aerial imagery at the western end of the current spit. It appears that the lagoon/river may have flowed out close to the base of bedrock hills and associated colluvium. The timing of this is uncertain. If the remnant parallel dunes described in Section 4 above represent the base of the current Holocene spit as dating suggests, it is likely that the channel post-dates the formation of these dunes and has been responsible for their isolation from the main spit. Growth of the current spit would have diverted the channel progressively to the east, with the mouth of the channel migrating eastward as the spit extended. At some point during this progression the main lagoon channel has shifted to the current location. Sediment deposition and paludification have subsequently occurred to form the low lying wetland areas to the west, south and east of the remnant parallel dunes (Section 4 and Figure 3). Given that the current spit at Prion Beach is of mid to late Holocene age, then these channels and wetlands would date to this period also.

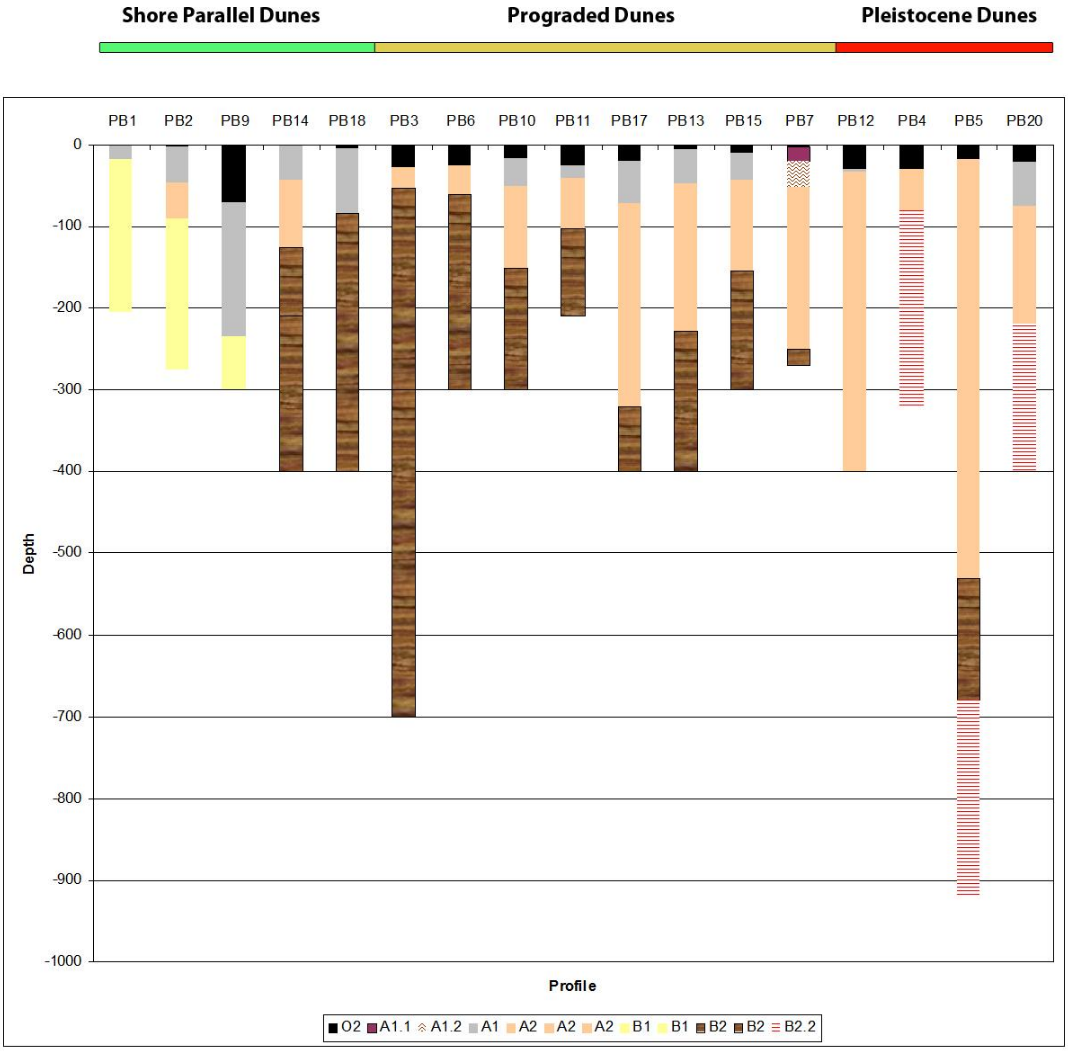


Figure 4. Dune stratigraphy at sample sites.

General Discussion and Conclusion

The preceding sections seek to describe the morphology of, and to explore the relationships between, the geomorphic units identified in this study. Figure 5 presents a possible scenario for the evolution of the Prion Beach barrier system. This scenario is based on the evidence uncovered by mapping and stratigraphic investigations of this and other studies. The exact morphology of the last interglacial maximum sea level barrier and the position of the New River during the last glacial is highly speculative. However this study shows that the current Prion Beach Spit developed from the mid to late Holocene and that the western two thirds of it have remained relatively stable. This development during the Holocene accords well with evidence from other beach/barrier systems in the TWWHA and elsewhere in south eastern Australia (Cullen 1998).

The Prion Beach spit is one of the largest spits in Tasmania and certainly the most pristine. Possible barrier dunes dating to the last interglacial sea level maximum have not previously been positively identified in the region or elsewhere in Tasmania. Likewise terrestrial aeolian dunes dating to around the last glacial maximum have not been identified in the region before. For these reasons it is recommended that the Prion Beach Spit, other dunes and associated features identified in this study be listed in the Tasmanian Geoconservation Database.

Although the ages of, and the relationship between the various geomorphic units described in the previous sections are not completely understood, one feature of the Prion Beach/New River Lagoon barrier system is abundantly clear, that is the dynamic nature of the system from what appears to be at least the late Pleistocene onwards. This dynamism is largely attributable to climatic change and consequent changes (rises) in sea level and water and sediment flow from the lagoon. The system is currently in a state of flux. Sharples (2003) argues that this can be attributed to a currently rising sea level caused by climatic warming.

In July 2011 there was a very large one in 75 year storm event which caused significant foredune and associated coastal erosion at Prion Beach and elsewhere throughout south-eastern Tasmania. Much of the foredune at Prion Beach is still actively eroding and in other sections incipient foredunes are developing. It is not clear whether this is evidence of ongoing erosion attributable to sea level rise or whether the current erosion is part of year to year cycles of erosion and deposition. What is clear is that sand currently in the surf-zone may either end up back on the beach and foredunes or will join the considerable volumes of this sand that are being transported from Prion Beach eastward towards the transgressive dune field at the eastern end of the beach. All this suggests that barrier retreat is continuing at the present.

Without a detailed analysis of future and all available historical aerial photogrammetry, ongoing monitoring of the transects, a study of the wave climate and run-up, and a detailed sediment budget it is difficult to directly proportion the recession purely to the effects of sea level rise.

Indeed the periods of strong La Nina' phase in the Southern Oscillation Index correlates very strongly to major coastal erosion events in Eastern Australia. The 2011 erosion event mentioned previously correlates well with a similar strength La Nina event in 1974 which was responsible for significant coastal erosion and flooding throughout eastern Australia (Short and Trembanis 2000).

The Prion Beach/New River Lagoon system provides a relatively undisturbed baseline monitoring site to assess changes in similar systems throughout Tasmania and elsewhere. This may prove particularly useful in untangling the impacts of sea level rise and coastal erosion caused by climate change from those imposed by other agents such as coastal development. However, if this is to be realised, then considerable effort combined with relatively low levels of funding will be needed to monitor changes in the system into the future and to capitalise on the results of the current study.

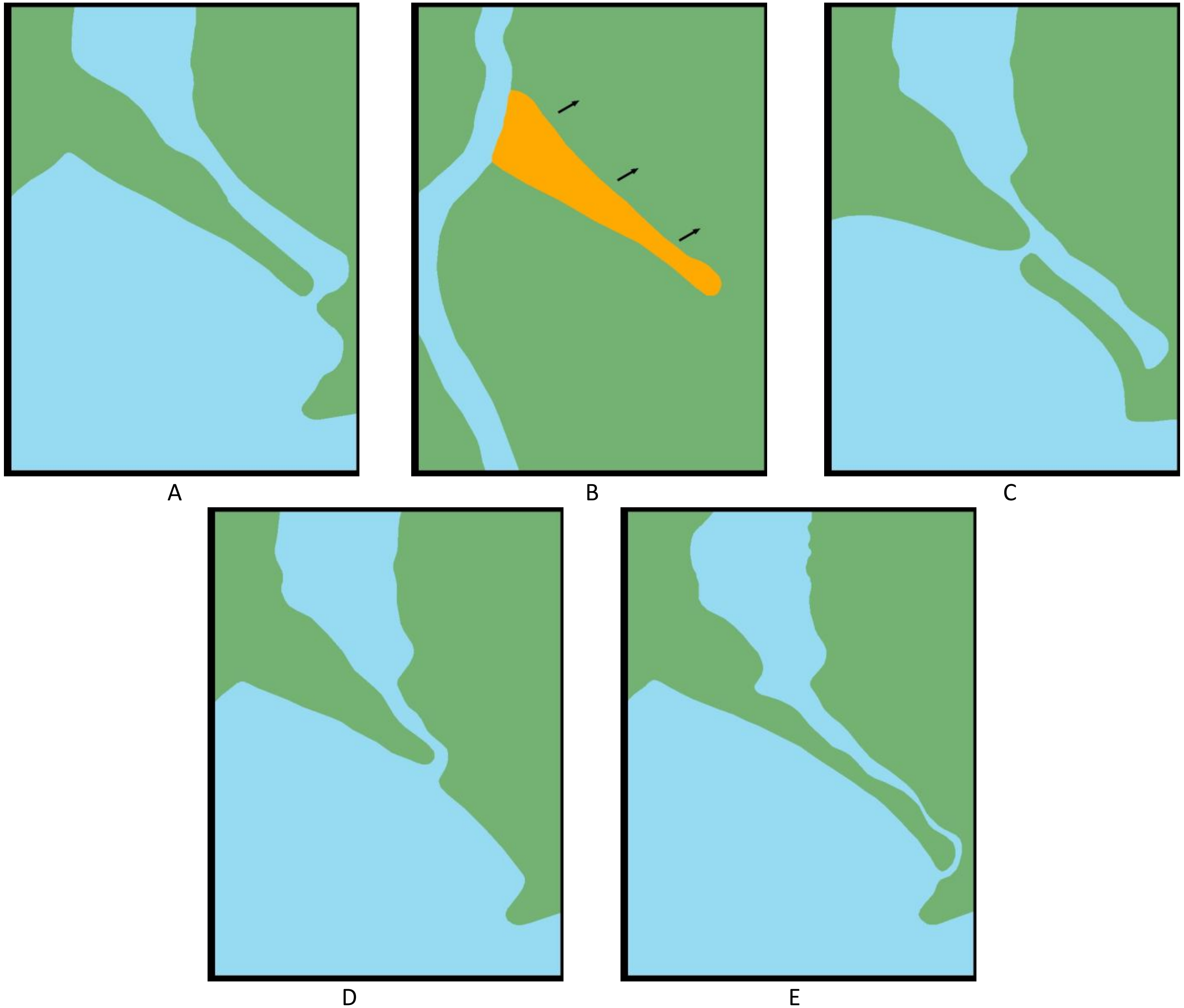


Figure 5. Possible evolution of the spit at Prion Beach: **A**. Initial spit formation (125 ka BP) **B**. Barrier deflation during last glacial maximum (25 ka BP) **C**. Initial Spit development post glacial marine transgression (@ 5 ka BP). **D**. Late Holocene spit progradation (2.2 ka BP). **E**. Current Spit with frontal parallel dunes.

References

Baynes, F. 1990. A preliminary survey of the coastal geomorphology of the World Heritage Area, South West Tasmania. Vols 1 and 2. Fred Baynes, Consulting Engineering Geologist Report No.013.

Bureau of Meteorology 1995. Tasmanian boating weather guide.

Bowden, A.R. 1983. Relict terrestrial dunes: legacies of a former climate in coastal northeastern Tasmania. Z. Geomorph. N. F. 45: 153-174.

Bowden, A.R. and Colhoun, E.A., 1984. Quaternary emergent shorelines of Tasmania. In B.G. Thom, Coastal Geomorphology in Australia, Academic Press, Sydney. Pp.313-342

Chelton, D.B., Hussey, K.J. and Parke, N.E. 1981. Global satellite measurements of water vapour, wind speed and wave height. *Nature.* 294; 529-532.

Cullen, P.J. 1998. Coastal dune systems of south-western Tasmania: their morphology, genesis, and conservation. Parks and Wildlife Service, Tasmania, Nature Conservation Report No 98/1.

Davies, J.L. 1980. Geographical variation in coastal development. (2nd ed.), Longmans, London.

Donaldson, P. 2010. Facies architecture and radar stratigraphy of the Seven Mile Spit complex, Tasmania. B.Sc. Honors Thesis, School of Earth Science, University of Tasmania.

Duller, G.A., and Augustinus, P. 2006. Reassessment of the record of linear dune activity in Tasmania using optical dating. Quaternary Science Reviews, vol. 25, pp. 2608-2618.

Fallon, S.J., Fifield, L.K. and Chappell, J.M. 2010. The next chapter in radiocarbon dating at the Australian National University: Status report on the single stage AMS, Nuclear Instruments and Methods in Physics Research B 268 898–901.

Kiernan, K., and Lauritzen, S.E. 2001. Dated speleothem evidence for uplift rates and terrace ages on the Tasmanian south coast. Zeitschrift fur Geomorphologie, 45 (2). pp. 159-176.

McIntosh, P. D., Price, D. M., Eberhard, R. and Slee, A. J. 2009. Late Quaternary erosion events in lowland and mid-altitude Tasmania in relation to climate change and first human arrival. Quaternary Science Reviews, 28 (9/10), 850-872.

McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S. 1984. Australian soil and land survey: Field handbook. Inkarta Press, Melbourne.

Murray-Wallace, C.V. 2007. Eustatic sea-level changes since the Last Glaciation. In, Elias, S. (Ed). Encyclopedia of Quaternary Science, Elsevier, Vol. 4, pp. 3034-3043.

Murray-Wallace, C.V., Banerjee, D., Bourman, R.P., Olley, J.M., and Brooke, B.P., 2002. Optically stimulated luminescence dating of Holocene relict foredunes, Guichen Bay, South Australia. *Quaternary Science Reviews* 21, 1077-1086.

Murray-Wallace and Goede, A. 1995. Aminostratigraphy and electron spin resonance dating of Quaternary coastal neotectonism in Tasmania and the Bass Strait Islands. Aust. J. Earth Sci. vol. 42, No. 1, pp. 51-67.

Pemberton, M. 1989. Land systems of Tasmania. Region 7. South West. Department of Primary industry, Tasmania.

Pemberton, M. and Cullen. P.J. 1997. Soils, stratigraphy, and shells: Coastal dune development in parts of western Tasmania; in: J. Hall and I.J. McNiven (eds.): *Australian Coastal Archaeology*, Research Papers in Archaeology and Natural History, No. 31 , ANU Publications, Australian National University, Canberra, p. 271-277.

Sharples, C. 2003. A Review of the Geoconservation Values of the Tasmanian Wilderness World Heritage Area; Nature Conservation Report 03/06, Nature Conservation Branch, Department of Primary Industries, Water and Environment, Tasmania, 219 pp.

Sharples, C. 2011. Potential climate change impacts on geodiversity in the Tasmanian Wilderness World Heritage Area: A management response position paper. Resource Management and Conservation Division, Department of Primary Industries Parks Water and Environment, Hobart, Nature Conservation Report Series 11/04.

Short, A.D., and Trembanis, A. 2000. Beach oscillation, rotation and the Southern Oscillation, Narrabeen Beach, Australia. Proceedings of the 27th International Conference on Coastal Engineering. Sydney 16-21, July 2000, Vol. 1, Paper no. 4.

Thom. B.J. 1983. Transgessive and regressive stratigraphies of coastal barriers in south-eastern Australia. *Marine Geol.* 56:137-150.

Thom, B.G. and Chappell, J. 1975. Holocene sea levels relative to Australia. Search 6, 90 – 93.

Thom, B.G., Polach, H.A. and Bowman, G.M. 1978. Holocene structure of coastal sand barriers in New South Wales, Australia. Technical report. Univ. N.S.W., Faculty of Military Studies, Department of Geography, R.M.C., Duntroon, A.C.T.

Thom, B.G. and Roy, P.S. 1983. Sea level change in New South Wales over the past 15 000 years. In: Hopley, D. (Ed.), Australian Sea Levels in the Last 15,000 Years: A review. James Cook University of North Queensland, Department of Geography Monograph Series, Occasional Paper No. 3. James Cook University of North Queensland, Department of Geography, Townsville, Qld., pp. 64 – 84.

UNESCO. 1999. Operational Guidelines for the Implementation of the World Heritage Convention; Revision adopted by the World Heritage Committee at its 22nd Session, December 1998, World Heritage Centre, Intergovernmental Committee for the Protection of the World Cultural and Natural Heritage, United Nations Educational, Scientific and Cultural Organisation, Paris.

Wang, N. 2012. Luminescence Technical Report No. 12/12. Luminescence Dating Laboratory. School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.

Williams, M., Dunkerley, D., De Deckker, P., Kershaw, P., and Chappell, J. 1998. Quaternary environments. Publisher Arnold, London 1998.

Appendix 1 – Erosion transect measurements, profiles and locations

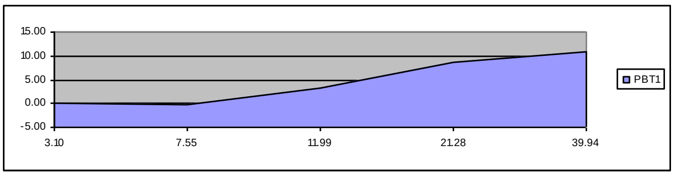
Erosion transect measurements

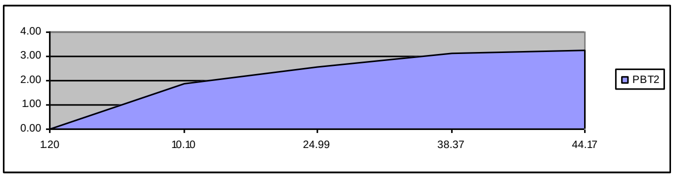
Transect	Peg	Distance	Angle	Radians	Cos	Sin	Length	Cum. Length	Height	Relative height	Derived Distance	Comments
PBT1	1	3.1	0	0.00	1.00	0.00	3.10	3.10		0.00		Distance to top of scarp
PBT1	2	4.45	0	0.00	1.00	0.00	4.45	7.55	0.00	0.00	4.45	
PBT1	3	5.8	40	0.70	0.77	0.64	4.44	11.99	3.73	3.73	5.8	
PBT1	4	10.72	30	0.52	0.87	0.50	9.28	21.28	5.36	9.09	10.72	
PBT1	5	18.8	7	0.12	0.99	0.12	18.66	39.94	2.29	11.38	18.8	
PBT2	1	1.2	0	0.00	1.00	0.00	1.20	1.20	0.00	0.00	1.2	Distance to top of scarp
PBT2	2	9.1	12	0.21	0.98	0.21	8.90	10.10	1.89	1.89	9.1	
PBT2	3	14.9	2.5	0.04	1.00	0.04	14.89	24.99	0.65	2.54	14.9	
PBT2	4	13.4	2.5	0.04	1.00	0.04	13.39	38.37	0.58	3.13	13.4	
PBT2	5	5.8	1	0.02	1.00	0.02	5.80	44.17	0.10	3.23	5.8	
PBT3	1		0	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0	
PBT3	2	9.56	10	0.17	0.98	0.17	9.41	9.41	1.66	1.66	9.56	
PBT3	3	7	0	0.00	1.00	0.00	7.00	16.41	0.00	1.66	7	
PBT3	4	9.06	45	0.79	0.71	0.71	6.41	22.82	6.41	8.07	9.06	
PBT3	5	5.6	-45	-0.79	0.71	-0.71	3.96	26.78	-3.96	4.11	5.6	
PBT3	6	2.79	-45	-0.79	0.71	-0.71	1.97	28.75	-1.97	2.13	2.79	
PBT4	0	0	0	0.00	1.00	0.00	0.00	0.00	0.00	0.00		
PBT4	1	11.05	32	0.56	0.85	0.53	9.37	9.37	5.86	5.86	11.05	Distance to dune face
PBT4	2	14.82	10	0.17	0.98	0.17	14.59	23.97	2.57	8.43	14.82	
PBT4	3	17.6	20	0.35	0.94	0.34	16.54	40.50	6.02	14.45	17.6	
PBT4	4	8.97	-3	-0.05	1.00	-0.05	8.96	49.46	-0.47	13.98	8.97	

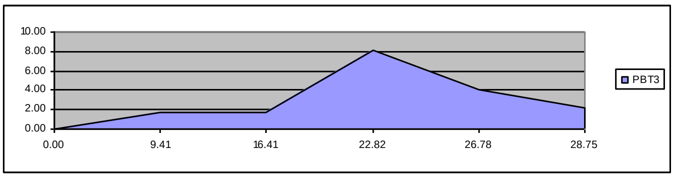
PBT4	5	10.58	-16	-0.28	0.96	-0.28	10.17	59.63	-2.92	11.06	10.58	
PBT5	0	0	0	0.00	1.00	0.00	0.00	0.00	0.00	0.00		
PBT5	1	12.43	40	0.70	0.77	0.64	9.52	9.52	7.99	7.99	12.43	Distance to dune face
PBT5	2	8.03	-25	-0.44	0.91	-0.42	7.28	16.80	-3.39	4.60	8.03	
PBT5	3	7.95	1	0.02	1.00	0.02	7.95	24.75	0.14	4.73	7.95	
PBT5	4	13.4	11	0.19	0.98	0.19	13.15	37.90	2.56	7.29	13.4	
PBT5	5	24.8	9	0.16	0.99	0.16	24.49	62.40	3.88	11.17	24.8	
PBT6	0	0	0	0.00	1.00	0.00	0.00	0.00	0.00	0.00		
PBT6	1	10.52	-2	-0.03	1.00	-0.03	10.51	10.51	-0.37	-0.37	10.52	Distance to dune face
PBT6	2	13	-12	-0.21	0.98	-0.21	12.72	23.23	-2.70	-3.07	13	
PBT6	3	15.32	16	0.28	0.96	0.28	14.73	37.96	4.22	1.15	15.32	
PBT6	4	8.27	11	0.19	0.98	0.19	8.12	46.07	1.58	2.73	8.27	
PBT6	5	10.9	0	0.00	1.00	0.00	10.90	56.97	0.00	2.73	10.9	
PBLT1	1	4.95	50	0.87	0.64	0.77	3.18	3.18	3.79	0.00	4.95	Distance to waters edge
PBLT1	2	7.3	35	0.61	0.82	0.57	5.98	9.16	4.19	7.98	7.3	
PBLT1	3	9.3	30	0.52	0.87	0.50	8.05	17.22	4.65	12.63	9.3	
PBLT1	4	10.95	-22	-0.38	0.93	-0.37	10.15	27.37	-4.10	8.53	10.95	
PBLT1	5	7.76	2	0.03	1.00	0.03	7.76	35.12	0.27	8.80	7.76	
PBLT2	1	4.08	0	0.00	1.00	0.00	4.08	4.08	0.00	0.00	4.08	Distance to waters edge
PBLT2	2	11.21	47	0.82	0.68	0.73	7.65	11.73	8.20	8.20	11.21	
PBLT2	3	5.02	-5	-0.09	1.00	-0.09	5.00	16.73	-0.44	7.76	5.02	
PBLT2	4	5.91	-4	-0.07	1.00	-0.07	5.90	22.62	-0.41	7.35	5.91	
PBLT2	5	11.5	7	0.12	0.99	0.12	11.41	34.04	1.40	8.75	11.5	
PBLT3	1	5.15	0	0.00	1.00	0.00	5.15	5.15	0.00	0.00	5.15	Root mat edge
PBLT3	2	17.58	44	0.77	0.72	0.69	12.65	17.80	12.21	12.21	17.58	
PBLT3	3	8.52	-4	-0.07	1.00	-0.07	8.50	26.30	-0.59	11.62	8.52	
PBLT3	4	5.48	-24	-0.42	0.91	-0.41	5.01	31.30	-2.23	9.39	5.48	
PBLT3	5	15.45	-22	-0.38	0.93	-0.37	14.32	45.63	-5.79	3.60	15.45	

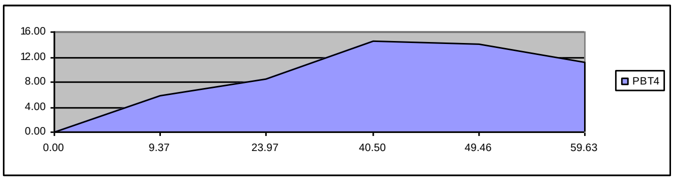
PBLT4	1	7.14	0	0.00	1.00	0.00	7.14	7.14	0.00		7.14	Edge of Marsupial lawn
PBLT4	2	14.5	0	0.00	1.00	0.00	14.50	21.64	0.00	0.00	14.5	
PBLT4	3	18.32	28	0.49	0.88	0.47	16.18	37.82	8.60	8.60	18.32	
PBLT4	4	13.5	20	0.35	0.94	0.34	12.69	50.50	4.62	13.22	13.5	
PBLT4	5	9.84	-5	-0.09	1.00	-0.09	9.80	60.30	-0.86	12.36	9.84	
PBLT4	6	12.12	-20	-0.35	0.94	-0.34	11.39	71.69	-4.15	8.22	12.12	

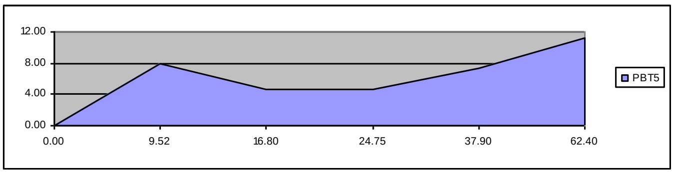
Dune profiles

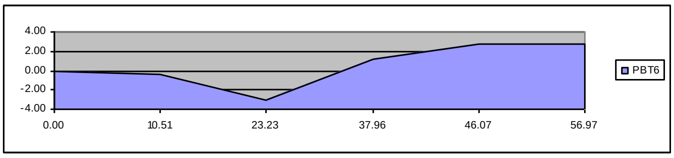


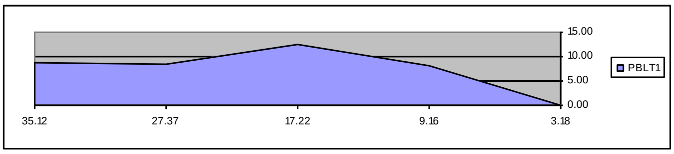


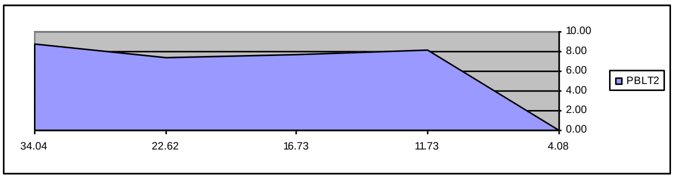


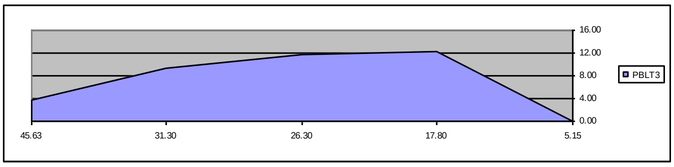


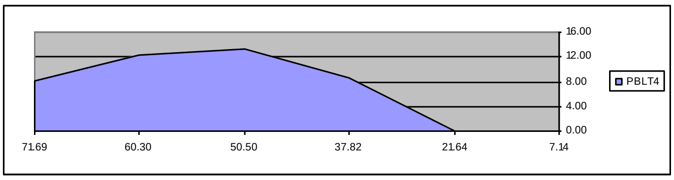












Waypoint, transect and boat landing locations

TYPE	Waypoint	Easting	Northing	Date-Time	ALTITUDE	SITE
Transect	419	5179469.62780517	466225.82154885	08-MAR-12 09:45	15.00	PBT1-1
Transect	420	5179460.26967252	466219.84111995	08-MAR-12 09:58	14.00	PBT1-2
Transect	422	5179482.84750589	466231.57251810	08-MAR-12 12:19	19.00	PBT1-5
Transect	423	5179310.96535292	466471.62966151	08-MAR-12 13:25	19.00	PBT2-2
Transect	424	5179326.74961900	466483.91018011	08-MAR-12 13:35	22.00	PBT2-3
Transect	425	5179328.73286373	466489.63676324	08-MAR-12 13:40	22.00	PBT2-4
Transect	426	5179309.97362251	466478.09580110	08-MAR-12 13:55	20.00	PBT2-5
Transect	427	5179294.38697079	466468.02812429	08-MAR-12 14:11	15.00	PBT2-1
Transect	431	5179806.61180885	465666.33025441	09-MAR-12 13:22	42.00	PBT3-1
Transect	432	5179797.75698061	465664.18092728	09-MAR-12 13:28	18.00	PBT3-2
Transect	433	5179791.60565528	465660.99565934	09-MAR-12 13:36	18.00	PBT3-3
Transect	434	5179787.89020409	465649.82611502	09-MAR-12 13:40	12.00	PBT3-4a
Transect	435	5179785.17762078	465652.77952120	09-MAR-12 13:41	11.00	PBT3-4
Transect	436	5179778.36132775	465654.21625226	09-MAR-12 13:47	7.00	PBT3-5
Transect	437	5179776.58594626	465649.31505068	09-MAR-12 13:52	6.00	PBT3-6
Landing	438	5179524.71452146	466524.62096411	24-MAR-12 14:24	21.00	PBLT1_Landing
Transect	439	5179493.03578914	466507.77979772	24-MAR-12 15:13	32.00	PBLT1-5
Transect	440	5179499.02772331	466503.35455419	24-MAR-12 15:19	33.00	PBLT1-4
Transect	441	5179506.92454692	466507.65644659	24-MAR-12 15:21	26.00	PBLT1-3
Transect	442	5179514.81159831	466513.78684867	24-MAR-12 15:31	19.00	PBLT1-2
Transect	443	5179519.71246083	466516.40370601	24-MAR-12 15:40	14.00	PBLT1-1
Transect	444	5179855.71367345	466046.80894505	24-MAR-12 16:02	9.00	PBLT2-1
Transect	445	5179855.66675026	466017.30681596	24-MAR-12 16:15	9.00	
Transect	446	5179837.89908145	466032.68270164	24-MAR-12 16:29	21.00	PBLT2-3
Transect	447	5179839.49993431	466034.53062493	24-MAR-12 16:30	20.00	
Transect	448	5179840.38286442	466034.30880658	24-MAR-12 16:32	20.00	PBLT2-4
Transect	449	5179845.65062301	466035.86751529	24-MAR-12 16:48	14.00	PBLT2-2
Landing	450	5180264.92504191	465593.41969901	25-MAR-12 09:43	0.00	PBLT3_Landing
Transect	451	5180253.67557277	465588.85755993	25-MAR-12 10:04	-2.00	PBLT3_1
Transect	452	5180243.01302059	465582.87750827	25-MAR-12 10:08	9.00	PBLT3_2
Transect	453	5180238.89998429	465575.85466228	25-MAR-12 10:16	12.00	PBLT3_3
Transect	454	5180236.45269958	465575.95527423	25-MAR-12 10:20	12.00	PBLT3_4
Transect	455	5180221.65777430	465570.02309082	25-MAR-12 10:25	5.00	PBLT3_5
Landing	467	5180645.19057106	464973.02159402	26-MAR-12 10:01	8.00	PBLT4_Landing
Transect	468	5180634.33223422	464968.79112285	26-MAR-12 10:11	10.00	PBLT4_1
Transect	469	5180619.97538144	464964.76072314	26-MAR-12 10:22	12.00	PBLT4_2
Transect	470	5180607.43087818	464960.05743613	26-MAR-12 10:28	22.00	PBLT4_3a
Transect	471	5180593.22733517	464960.51127822	26-MAR-12 10:38	28.00	PBLT4_3a
Transect	472	5180572.81358006	464958.90368256	26-MAR-12 10:46	22.00	PBLT4_6
Transect	473	5180580.18241155	464958.24222269	26-MAR-12 10:56	28.00	PBLT4_5
Transect	474	5180610.68613140	464964.96509874	26-MAR-12 11:04	20.00	
Transect	479	5180098.70630168	465153.30855627	27-MAR-12 10:32	24.00	PBT4_5
Transect	480	5180088.80615741	465143.43705049	27-MAR-12 10:36	29.00	PBT4_4
Transect	481	5180080.00000000	46514.00000000	27-MAR-12 10:36		PBT4_3
Transect	481	5180074.31599442	465131.67350515	27-MAR-12 11:08	24.00	PBT4_2
Transect	482	5180059.61269948	465121.86092834	27-MAR-12 11:17	25.00	PBT4_1
Transect	483	5180348.03635060	464628.43690053	27-MAR-12 12:46	22.00	PBT5_5
Transect	484	5180330.25101091	464613.26346515	27-MAR-12 12:52	21.00	PBT5_4
Transect	485	5180314.98489429	464608.07436315	27-MAR-12 13:05	19.00	PBT5_3

Transect	486	5180311.71828376	464601.27140093	27-MAR-12 13:21	18.00	PBT5_2
Transect	487	5180305.80096000	464598.32884468	27-MAR-12 13:23	21.00	PBT5_1
Transect	488	5180582.44458213	463947.70011220	27-MAR-12 15:11	18.00	PBT6_1
Transect	505	5180594.69800299	463956.80565458	27-MAR-12 15:37	19.00	PBT6_2
Transect	506	5180601.92650627	463966.44646642	27-MAR-12 15:51	17.00	PBT6_3
Transect	507	5180609.32938293	463970.28815406	27-MAR-12 15:55	19.00	PBT6_4
Transect	508	5180618.25431638	463983.76006977	27-MAR-12 16:29	25.00	PBT6_5
Transect	509	5180571.13121479	463940.13385583	27-MAR-12 16:48	21.00	PBT6_Dune Face