Updated Management Plan for the Pringle Bay beach and adjacent dune area

Prepared for:
OVERSTRAND MUNICIPALITY
and the
Pringle Bay Ratepayers' Association
by
LAURIE BARWELL & ASSOCIATES

OCTOBER 2015









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UPDATED MANAGEMENT PLAN FOR THE PRINGLE BAY BEACH AND ADJACENT DUNE AREA

(This report is an update/revision of the 1988 CSIR REPORT: Pringle Bay Beachfront Management Plan. (C/SEA 8842) and should be seen as complementary)

Submitted to:

Overstrand Municipality & the Pringle Bay Ratepayers' Association

Prepared by:

Laurie Barwell

Acknowledgment:

Input to this report: Dr M. E. R. Burns and Dr A. E. F. Heydorn.

Authors of 1988 Report: M. E. R. Burns, L. Barwell, T. J. Heineken, P. Badenhorst, Dr D. H. Swart

Issued by:

Laurie Barwell & Associates
20 Simonsplein Centre
61 Plein Street
Stellenbosch
7600
lbarwell@gmail.com
+(27) 824622285

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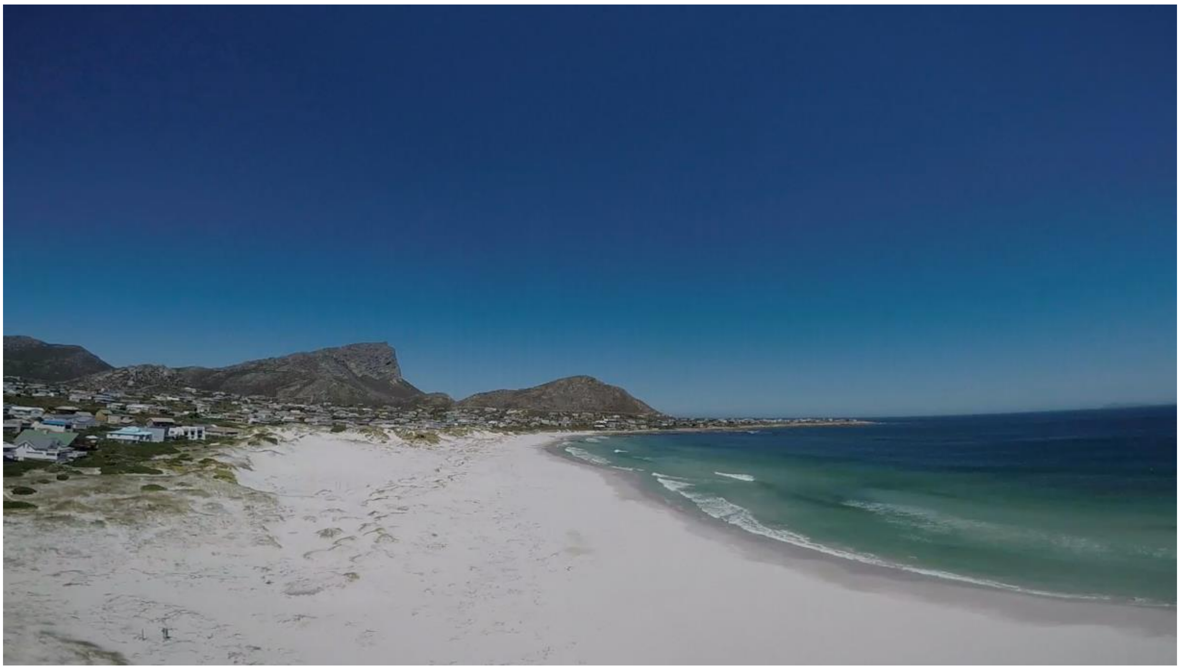

Frontispiece: Pringle Bay Beach (Photo: L Barwell - KiteCam February 2015)

Middle reaches of the beach and dune area at Pringle Bay

SCOPE OF THIS REPORT

The Overstrand Municipality in partnership with the Pringle Bay Ratepayers' Association appointed Laurie Barwell & Associates (LB&A) to update the 1988 Pringle Bay Beachfront Management Plan for the beach and the foredune located seaward of the houses west of the parking area (CSIR, 1988). A scanned copy of this report is available on request. Key information is included as Appendix 3.

An assessment of the implementation of the 1988 Management Plan has shown that the southern area of the bay (Area A in the Plan – Appendix 3) was successfully implemented and effectively managed. Unfortunately a lack of active management of the wind-blown sand in the middle (B) and northern (C) areas of the beach was not undertaken which has resulted in a dramatic build-up of the area behind the natural foredune.

Where-as the study area for the 1988 Management Plan included the whole beach and foredune area between the Buffels Estuary mouth southwards to the rocks at the boat launching site, the focus of this report is the managed buffer dune located seawards of the public parking area and the first row of privately owned houses located directly landwards of the shifting sand dunes both to the south and north of the parking area and municipal ablution facility. The study area comprises of a total alongshore distance of approximately 800 m southwards of the Buffels Estuary mouth.

The latest information, including available aerial images and topographical surveys, was used to quantify the dune and beach changes over the 76 year period (1938 to 2014) and to determinerequired updates of the 1988 plan. From the analysis it was concluded that since 1938 the the upper beach retracted landwards by up to 150 m due to the stabilisation of the natural dunefield carried out when the Pringle Bay town was established.

For the period 1989 to 2014 the upper beach has been dynamically stable showing a seasonally horizontal positional fluxuation within a band of up to 50 metres over the 25 year period.

However, for the same period it is seen that sand has been blown landwards off the beach and foredune and the area immediate landwards of the natural foredune. Using topographical surveys done in 2008 and in 2015 the rate of sand movement off the beach into thebackdune area has been calculated as between 16 and 20 m3/m/year. The aerial photo analysis over the same period shows that the edge-of-vegetation line advanced landwards at an average rate of 7 m per year.

The prevailing wind-blown sand potential and the effects of climate change and in particular sea level rise were taken into account and the dimensions of an effective buffer dune system are put forward for the study area.

It is concluded that Pringle Bay, as a 'pocket beach', has a finite amount of sand in the beach and dune system. This means that little (if any) new sand enters the system and that any sand blown landwards off the beach and foredune is effectively lost to the natural littoral system. This means that the function of the foredune as a natural buffer between the sea storms and the natural assets (eg climax coastal vegetation and wetlands) and development (eg public amenities, infrastructure and private property) will be compromised.

The assessment of the current situation concluded that the essence and recommendations of the 1989 management plan still hold, but that to counter the effects of climate change (in particular sea level rise) the managed foredune should be maintained at a higher level and larger volume than at present. Effective management of the storm water run-off from the parking area and town should also be enhanced through the provision of a water detention area behind the foredune.

A detailed phased implementation programme is proposed.

Improvements in the form of specific ongoing management actions that form the core of the management plan along with a user-friendly buffer dune integrity monitoring, evaluation and response guideline are provided

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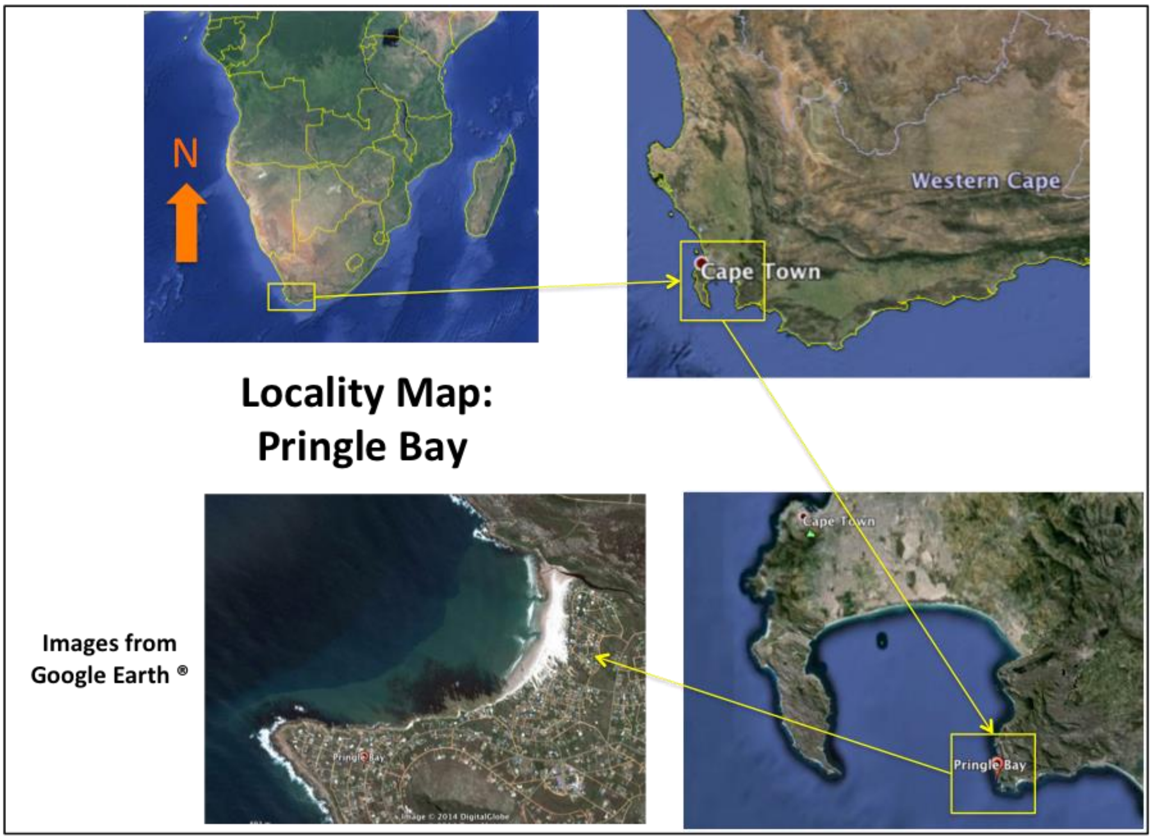


Figure 1: Locality Map

Pringle Bay: Beach berm and wash-over lagoon

1 INTRODUCTION

The Overstrand Municipality in partnership with the Pringle Bay Ratepayers Association appointed Laurie Barwell & Associates (LB&A) to update the 1988 Pringle Bay Beachfront Management Plan for the beach and the foredune located seaward of the houses west of the parking area (CSIR, 1988). A scanned copy of this report is available on request. Scanned copies of key information are included in Appendix 3 for easy reference.

1.1 *Study area*

Pringle Bay is located within the Overstrand Municipal area between the coastal towns of Rooi-els (5 km to the north) and Betty's Bay (9 km to the south) at the south-eastern edge of False Bay near Cape Town in the Western Province of the Republic of South Africa (Figure 1)

The actual area of concern is the interface between the dynamic beach, the Buffels Estuary mouth, a beach berm overwash lagoon area, the natural foredune, and the back-dune environment that consists of mobile and fixed dunes, coastal wetland, the public infrastructure including a car park, ablution facility and private houses that form the Pringle Bay coastal township.

Where-as the study area for the 1988 Management Plan (CSIR, 1988) included the whole beach and foredune area between the Buffels Estuary mouth southwards to the rocks at the boat launching site, the focus of this report is the managed buffer dune located seawards of the public parking area (and adjacent wetland) and the first row of privately owned houses located directly landwards of the shifting sand dunes both to the south and north of the parking area and municipal ablution facility. The study area comprises of a total alongshore distance of approximately 800 m southwards of the Buffels Estuary mouth (See Frontispiece, page (ii)).

1.2 *The (original) problem and implemented solution*

As can be seen on the series of historic photos (1938 to 2014, Appendix 1) the natural sediment pathway from the beach into the dune field has been altered and the sand dune fields stabilised. Residential development, roads and parking areas now occupy what was once an open sediment pathway between the beach and the dune field formed under the dominant onshore wind. The 1937 and 1938 aerial photographs show that an extensive dune field with back dune lagoon areas existed at the time. As can be seen on the 1961 aerial photo most of the dune field had been stabilised by then and the township infrastructure in an advanced stage of development.

A portion of the sand was blown back onto the beach by the opposing south-easterly winds when the dune field was exposed (as in 1938). The result of the stabilisation prevented this natural movement of wind-blown sand and a large volume of sand, estimated at between 10 and 20 m^3 per year per metre beach width (CSIR, 1988) is blown off the beach towards the eastern and south-eastern sector principally during winter westerly's and north-westerly's.

As was the case in 1988, wind-blown sand currently (2015) accumulates within the backdunes and the build-up of the sand in the back beach area resulted in the forming of mobile dunes that now reach a level of up to 12m above MSL in places. These dunes are slowly but surely impinging on the houses, municipal ablution facility, the car park and the adjacent backdune wetland all of which are threatened with inundation by the advancing wind-blown sand.

It is observed that some of the sand blown off the beach is trapped by kelp that had washed out onto the beach during seas storms. The kelp also traps seeds and plant material from adjacent dune vegetation and hummock dunes are formed. However the prevailing wind-blown sand and unfavourable climate prevents an effective vegetated foredune from naturally forming. The harvesting of kelp in the dune management area should be avoided to enable the continuation of this ecosystem service.

In essence, the 1988 Management Plan proposed to replace a previously natural process by a managed system where a buffer dune system needs to be maintained to prevent wind-blown sand from blowing into the established residential and public areas (CSIR, 1988) and to keep the sand on the beach within reach of the coastal processes that maintain the beach dynamics.

The 1988 Management Plan (CSIR, 1988) was developed through a facilitated process where intensive consultation took place via focus group discussions and workshops. As can be seen in the report (Extracts in Appendix 3) the 1988 Management Plan provides the conceptual design that addressed all of the issues identified in the consultation process. The portion of the plan that targeted the southern end of the beach and dune system was successfully implemented from 1989 and is still functioning satisfactorily.

The focus of the management activities on that area was due to the fact that the sand dunes had advanced significantly in that area and had already damaged a number of houses and inundated public roads and infrastructure. Unfortunately the management plan for the middle reaches of the beach was restricted to the provision of boardwalks and demarcated pathways across the dunes from the parking areas and the stabilisation of the exposed areas proved to be difficult and was unsuccessful.

Although the essence of the 1988 Management Plan is still valid, the design did not allow for the effects of climate change that recent knowledge has highlighted. The latest information on the projected climate change parameters, including an estimated rise in sea level of 1m by 2100 (and 0.35 m by 2050), necessitates the updating of the management plan. This includes the buffer dune design parameters to incorporate these aspects (included as Section 3 below). The 1988 plan also did not address the management of the significant volume of sand lost from the active littoral zone since 1988 and that is now contained in the migrating dunes. The updated plan addresses this important component of the pocket beach system.

1.3 Approach and process (this report)

The needs that formed the basis of the 1988 management plan were reassessed and there was informal and formal consultation with a selection of people including current beach users, property owners and officials of the Overstrand Municipality.

It was concluded that the original needs were still valid although the urgency to prevent the dunes from further advancing onto private and public property as well as the backdune wetland was emphasised. A further need was expressed for easier access to the beach via formalised pathways from the parking areas and a request to look into the possibility of providing easier access for disabled people was noted.

The latest information, including available aerial images and topographical surveys was considered and used to quantify the dune and beach changes over time. Observations by the Consultant and his associates during occasional site visits over a number of years since the 1988 study further contributed to the available body of knowledge.

2 CLIMATE

2.1 Introduction

The climate at Pringle Bay is influenced largely by the interaction between the east-moving cyclones of the circumpolar westerlies and the belt of subtropical anti-cyclonic cells of high pressure and the seasonal migration of these systems (Schultz, 1965, Heydorn and Tinley, 1980)

Available temperature records show the highest mean temperatures are recorded during January and February while July records the lowest values.

The annual rainfall distribution for the south-western Cape reflects a unimodal winter peak and summer dry season. The months with the highest recorded rainfall are June, July and August. (Boucher, 1978).

Combining the monthly average temperature and rainfall data results in a so-called climate diagramme (Figure 2). A humid period extends from April to October (where the rainfall line is above the temperature line). The arid period extends from November to March each year.

The implication of this information is that planting of vegetation in the dry period (November to April) should be avoided if no irrigation system is available. When relying on rain-fed gardening, it is clear from Figure 2 that the best time to establish dune vegetation is typically in August and September when the temperature is increasing and some 'follow-up' rainfall is still possible during October.

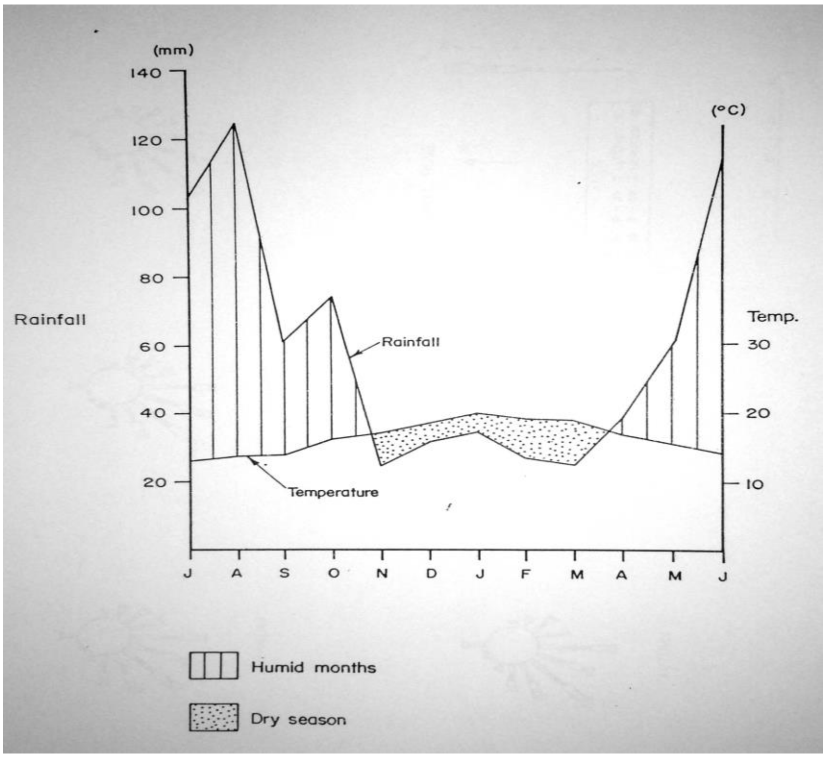


Figure 2: Climate diagramme for Pringle Bay (Heydorn & Tinley, 1980)

2.2 Wind climate and aeolian sediment movement

The seasonal wind-roses for the area are shown in Figure 3 and indicate a predominance of wind from the south-eastern sectors with apposing winds from the west and north-western sectors.

Southerly to south-easterly winds dominate in frequency of occurrence and velocity throughout the year, but are more significant during summer, spring and autumn. Westerly (onshore) winds occur throughout the year and the velocity range remains relatively constant for all seasons. The data used to compile the wind-roses originate from voluntary observing shipping (VOS) and provide a good first estimate of the long-term wind climate in the area. However, possible wind funnelling or sheltering effects by the local mountainous topography is not taken into consideration. The VOS data can only be improved upon by continuous on-site wind measurements over a period of at least three years.

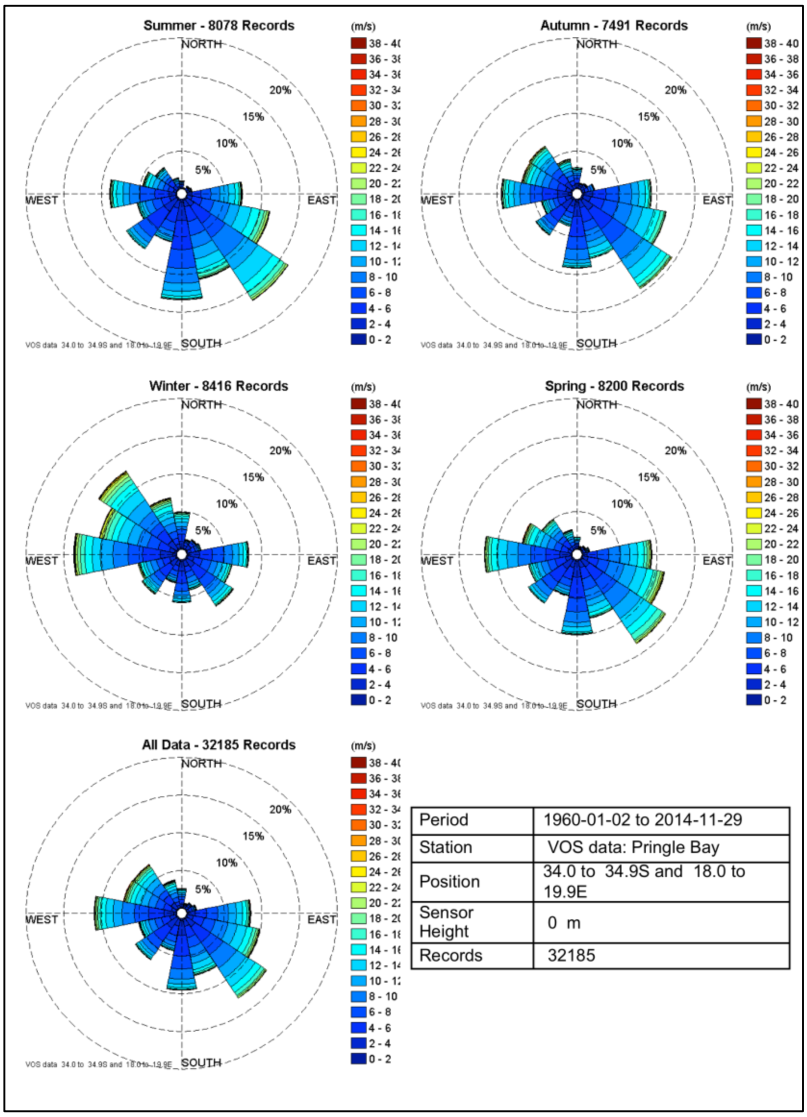


Figure 3: Seasonal wind roses for the offshore area

The VOS wind data were analysed and a set of aeolian creep diagrams (Figure 4) was deduced for the beach and foredune at the study site (after Swart, 1986). The aeolian creep diagrams (scan-copied from CSIR, 1988) indicate how wind-blown sand would encroach from different directions towards the centre of an imaginary circle on the ground. The equivalent volumes of sand blown seasonally in the specified directions by the prevailing winds are shown in Table 1 (CSIR, 1988). The predictive aeolian transport calculations are based on formulae derived for dry, cohesionless sand of unlimited quantity blowing across a flat, unvegetated surface under constant wind conditions. Since these criteria are seldom met in practice, only the *potential* transport rates are calculated.

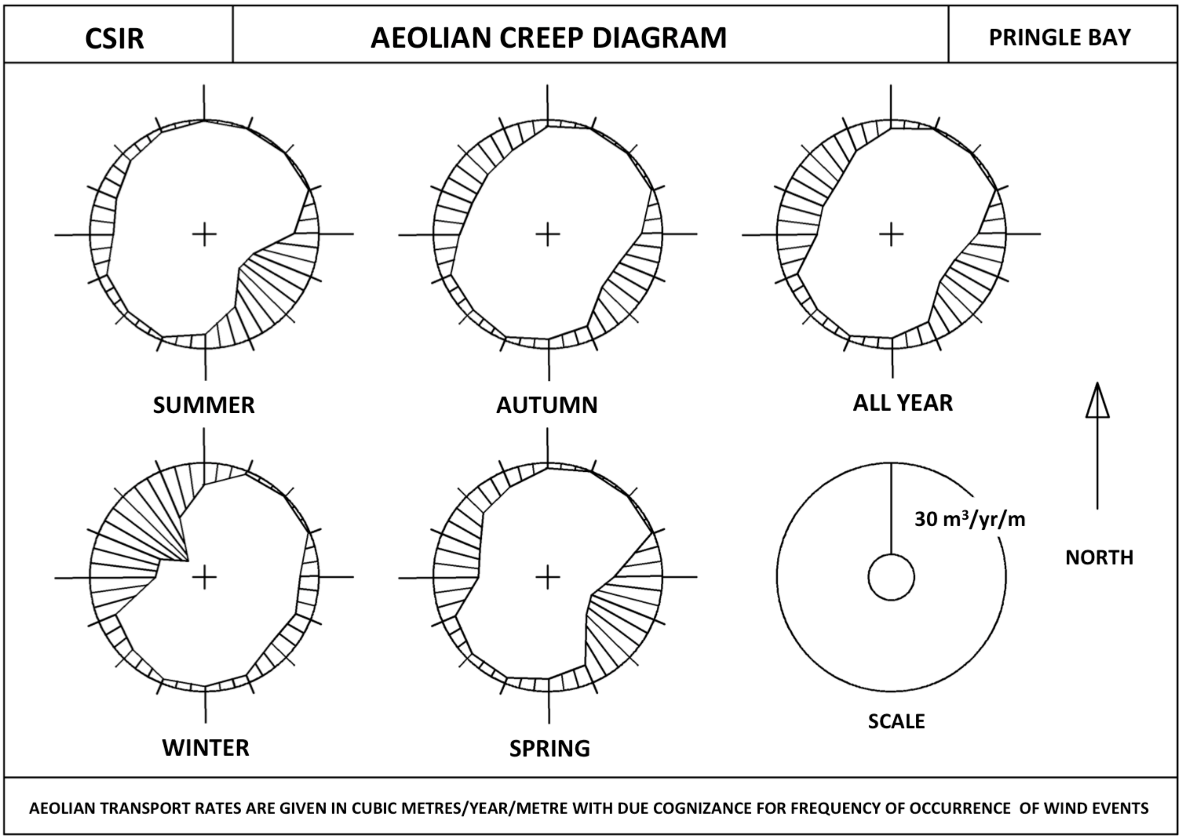


Figure 4: Aeolian creep diagrams for the area at Pringle Bay (CSIR)

Table 1: Potential Aeolian transport rates (m^3/m/yr.)

DIRECTION	ALL YEAR	Net potential
N – BOUND:	2.8	1
S – BOUND:	1.8	
E – BOUND:	10.9	3.7
W – BOUND:	7.2	
SE – BOUND:	9.2	
NW – BOUND:	10.4	1.2

It is clear from Figure 4 and Table 1 that the largest potential net movement of sand at the study site is onshore (east-southeast-bound) with the net annual average potential rate calculated as 3.7 m^3/m/yr. (all seasons). This formed the dunefield located to the east of the study area when the area was unvegetated. The orientation of the dunes confirms the dominant winds from the west to north-western sectors. Of importance for the buffer management at the study site is that a significant amount of sand can be blown off the beach and into the dunes when the beach is wide and the sand is dry. This has two implications (1) positive in that the area in front of the buffer system can build up and thereby add volume to the buffer, and (2) negative in that sand can move onto the private and public property should the dunes be unvegetated. Maintaining the dune vegetation within the foredune system is therefore a critical management action.

3 CLIMATE CHANGE AND SEA LEVEL RISE

3.1 Introduction

As was noted in IPCC (2001) climate change is expected to have a number of consequences that will detrimentally affect coastal resources. These are, amongst others: higher sea levels; higher sea temperatures; changes in precipitation patterns and sediment fluxes from rivers; changed oceanic conditions; as well as changes in storm tracks, frequencies and intensities. The apparent increase in storm activity and severity will be the most visible impact and the first to be noticed, since higher sea levels will require smaller storm events to overtop existing storm protection measures.

3.2 Climate change scenarios

As discussed in Appendix 4, which is a direct extract from report (CSIR, 2012), it is concluded that the best estimate ("mid scenario") of sea level rise (SLR) by 2100 is around 1m, with a plausible worst case scenario of 2m, and a best case scenario of 0.5 m. The corresponding best estimate ("mid scenario") projection for 2050 is assumed to be 0.35 m.

3.3 Sea storms and climate change

Changes in the shape of sandy coastlines depend on a number of factors of which the most important is the availability and distribution of sediment (sand). Sand along the coast is moved mostly by waves, while the waves approaching the coast are in turn affected by, inter alia, the bottom topography (SPM, 1981 and CEM, 20..). As the sea level rises, existing topographic features will be located in deeper water and will have a different effect on waves approaching the coast (CSIR, 2012).

Features landward of the breaker zone will be in deeper water and will either have an amplified or dampened effect on the wave climate compared to the present. Deep-water features (e.g. submerged and partially submerged reefs) may deepen to the degree that their effect on the wave climate is negligible. The points of wave energy convergence and divergence will change. The new locations of wave energy convergence could be expected to experience an increase in erosion while those locations currently subject to energy convergence could accrete if they are exposed to less energy in future. Changes in wave approach will change longshore currents and longshore sediment transport.

In conclusion, the primary hazards to physical (abiotic) coastal infrastructure related to sea storms and climate change are (CSIR, 2012):

- Extreme inshore sea water levels resulting in flooding and inundation of low-lying areas.
- Changes in storm system characteristics, winds and local wave regime resulting in direct wave impacts.
- Coastal erosion, removal of dunes and subsequent under-scouring of, for example, foundations and structures.
- System complexities, thresholds and non-linarites, for example related to sand transport.
- A combination of extreme events, such as sea storms during high tides plus sea level rise, will have the greatest impacts and will increasingly overwhelm existing infrastructure as climate change related factors set in in time.
- Areas located adjacent to river mouths have the additional effect of possible higher water levels in the estuary and foredune wash-away due to the river mouth changing direction, often alongshore to the sand spit.

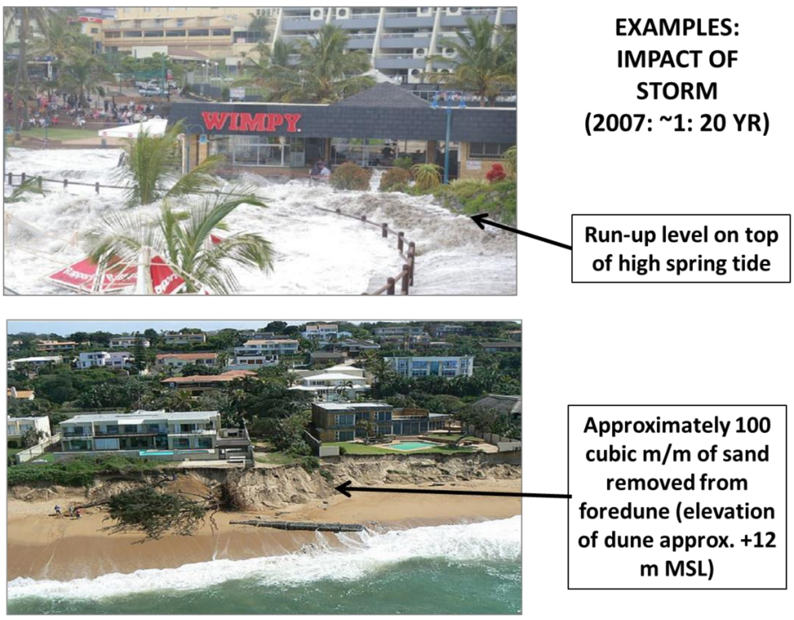
The main metocean drivers related to the above are thus waves and sea water levels (and to a lesser extent winds and currents).

The example shown in Figure 5 indicates the effect of run-up during a large sea storm in South Africa. Note that the return period for that particular storm is estimated to be in the region of 1:20 years. Noteworthy is that in South Africa the 1:50 yr. return period event is normally specified for the location and design of houses and infrastructure. It is important to realise that South Africa has not yet experienced a 1:50 yr. magnitude sea storm since wave recordings began some 30 years ago!

3.4 *Extreme inshore sea water levels*

The background discussion to extreme inshore sea water levels is provided in Appendix 4.

The key (abiotic) aspects when considering the potential impact of climate change on coastal development are consolidated in the 'hazard level' as discussed below.



Storm run-up along the KwaZulu-Natal coast resulted in damage to property and erosion along large sections of the coastline when high waves coincided with a very high spring tide (Ethekwini Municipality, 2007)

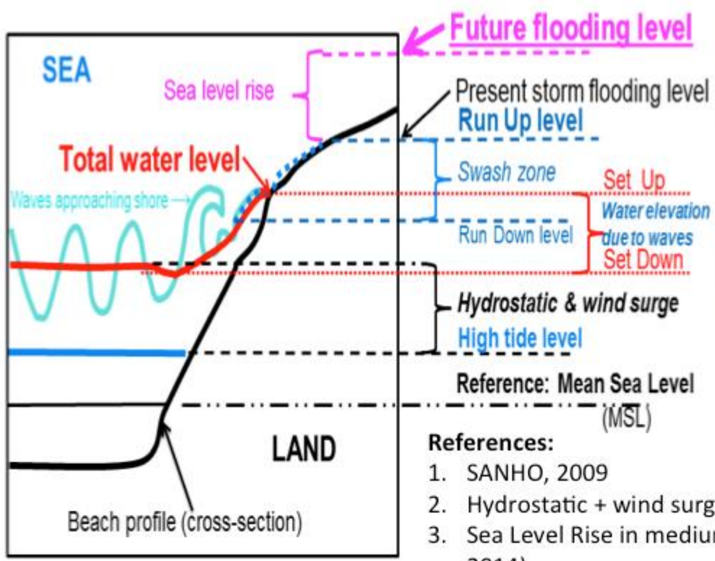
Figure 5: Examples of the effect of a large storm coinciding with a high tide level

Figure 6 shows the extreme inshore sea water levels calculated for Pringle Bay (using the tidal information available for Hermanus at http://www.sanho.co.za) and combine the various contributing components as shown (CSIR, 2014). Thus, the figure shows the following increasing water levels relative to Mean Sea Level (MSL) which is at approximately 0 m elevation:

- Mean High Water Spring tide (MHWS, occurring every 14 days) = 0.99 m above MSL.
- Highest Astronomical Tide (HAT, highest level that *ordinary* tides will reach under average meteorological conditions, which has a 19 year cycle) = 1.28 m above MSL.
- A low-pressure weather system ('cold front') passing the coast results in an additional local set-up (increase) of the sea water level due to strong onshore winds causing a surge and a rise in sea level due to the low barometric pressure. The combined wind and "barometric" set-up is estimated at an additional 0.5 m. Thus, at present, a coastal low pressure system passing the southern Cape coast during spring tide (which occurs every 2 weeks) could result in a sea water level of about +1.49 m above MSL which is worked out as +0.99 m (MHWS) + 0.5 m (wind & barometric set-up).
- The mid scenario (best estimate) for Sea level Rise (SLR) due to climate change) is 1 m by 2100, and 0.35 m by 2050 (CSIR, 2014)[1]. For the type of development and infrastructure at Pringle Bay a medium term planning timeframe up to 2050 is assumed. Thus, the extreme future scenario in the *medium* term for a coastal low pressure system occurring during spring tide could result in flooding levels of about 1.84 m above MSL, calculated as +1.49 m + 0.35 m (SLR).

The above elevations all relate to the "still-water" level at the shoreline. This should not be

HAZARD LEVEL (including climate change)



Haz level		6.2
RunUp[4]	4.36	6.2
SLR[3]	0.35	1.84
Residual[2]	0.5	1.49
MHWS[1]	0.99	

References:

1. SANHO, 2009
2. Hydrostatic + wind surge – 1:10 yr (CSIR, 2014)
3. Sea Level Rise in medium term – by 2050 (CSIR, 2014)
4. Exposed beach – 1:30 yr (CSIR, 2014)

Figure 6: Estimated hazard level for 2050 at Pringle Bay

confused with the additional effect of wave setup and wave run-up, which can reach even higher elevations. (Wave setup is the effect of water build-up against the shore due to wave breaking and wave run-up is the rush of water in the swash zone up the beach slope above the still-water

[1] Note that this figure relates to the still-water level so the effects of tides, of wave setup and of wave run-up are excluded.

level). Based on wave set-up and wave run-up modelling, the additional height so reached would be another 4.36 m in addition to the 'still-water' level calculated above as +1.84 m MSL at Pringle Bay.

Thus, the total elevation (including the effect of climate change) that may be reached by storm waves during the passing of a low pressure system at spring high tide could be in the order of 1.84 m + 4.36 m = + 6.2 m MSL. This level is also known as the Hazard Level.

4 BEACH AND FOREDUNE STABILITY

It is a well-known fact that Pringle Bay is a typical 'pocket-beach' system where the sediment (sand) forms a closed system (Heydorn & Tinley, 1980). The implication is that no significant volume of 'new' sand enters the system from adjacent areas along the shore or from the mountains via the river and estuary. The sand on the beach and dunes is therefore a scarce resource and is continuously moved around within the confined area by the coastal processes as described above.

The sand in the nearshore (in the form of underwater sand banks), the sand on the beach and those that form the coastal foredunes collectively provide a service to the areas located landward of the foredune. This so-called ecosystem service, takes the form of a natural storm buffer that protects both the built and natural environments located landwards of the foredune.

In the absence of a naturally formed foredune, a constructed foredune can be established and managed to perform this buffering service. This can be seen as a 'soft-engineering' solution. A constructed buffer dune system typically has two broad objectives: (1) managing the system to maintain the natural functionality of the prevailing coastal processes including the integrity of the backdune area of the ecosystem; and (2) protecting the interests of property owners (private and public) against the impact from the natural processes. An associated objective is to enhance the recreational and aesthetic qualities of the area.

Key to understanding the functioning of the prevailing coastal system at the site as well as determining the risk to public infrastructure and private property is gaining an understanding of any trends in the short (seasonal) and long-term (decadal) beach and dune stability.

Such understanding of the prevailing coastal processes also forms a critical basis for determining the influence of a proposed development on the processes. These factors are ignored at peril.

Undertaking an analysis of available historic aerial photographic and satellite imagery complemented by periodic topographic surveys if, these are based on a common survey datum, effectively determines the degree of long-term stability at the site.

4.1 Aerial image analysis

The 1988 CSIR report described the analysis of available maps and aerial photographs to determine the historical changes within the study area. The changes over the period between 1938 and 1988 were discussed in detail in the 1988 report and are not repeated here.

As part of this report the analysis is updated to include aerial photographs (from the South African Surveyor-general) and satellite imagery (available via Google Earth™) for the subsequent period up to 2014 in order to obtain information on the stability of the coastline at Pringle Bay over the period post 1989 when (portions of) the foredune and beach were managed according to the management plan. The images that were analysed are shown in Figure 1.1 (Appendix 1).

Figure 7 shows the 'edge-of-vegetation' line, which is relatively easy to observe on aerial images as the boundary between the dark areas (vegetation) and the light area (beach sand) and is used as an indicator of beach stability when tracked over time.

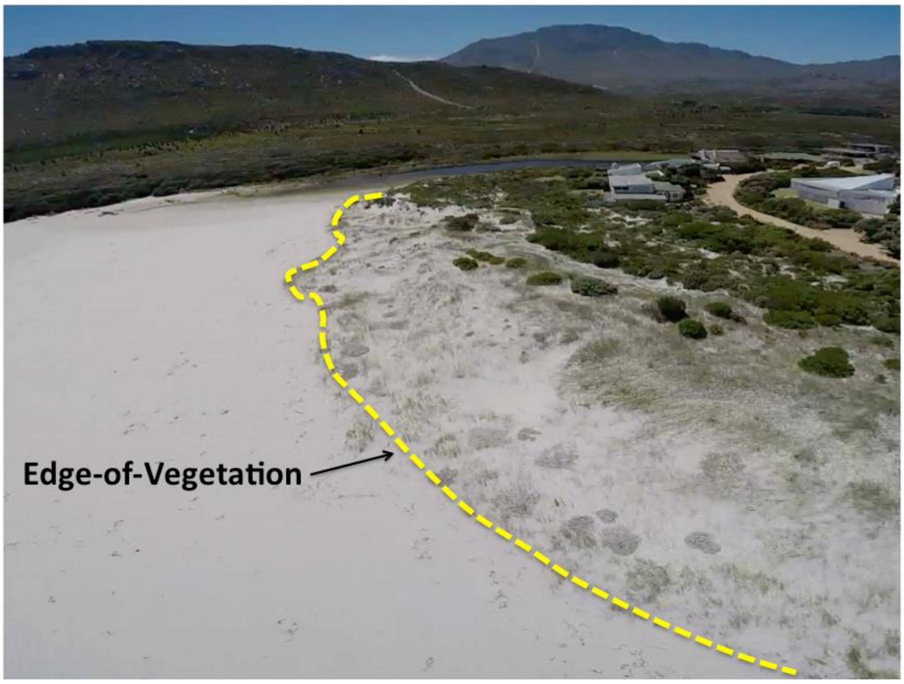


Figure 7: Definition of the 'Edge-of-vegetation' line

A comparative analysis of the available images for 1938, 1987, 2005 and 2014 is shown in Figure 8. The 1938 line shows the 'edge-of-veg' line before any development and the 1987 line shows the situation before the implementation of the management plan in 1989. Figure 9 shows the calculated horizontal variation of the 'edge-of-veg' lines compared to the baseline position of 1987 along the four reference lines (A, B, C and D) shown in Figure 8. It is important to note that the error band of this type of analysis is in the order of ±15 m due to the distortion and low resolution of the earlier images. The improvement in imaging technology in recent years has decreased this error band significantly to ±5 m. The 2014 image for example has a very low error margin and future analyses will prove to be significantly more accurate. Having said this, the technique has a high confidence level for reaching conclusions on the overall trend in the stability of the coastline, especially over longer periods (L Barwell, pers. obs.)

Referring to Figure 9, it can be seen that the 'edge-of-vegetation' line at Line A had remained unchanged between 1987 and 2005 but had moved seawards by 71 m due to active management of the wind-blown sand as per the management plan. The foredune along Line C remained 'natural' and the position of the 'edge-of-vegetation' line was unchanged over the whole period between 1987 and 2014. The edge-of-vegetation' line at Line B underwent a period of stability between 1987 and 2005, but a shift landward occurred between 2005 and 2014.

Since the north-westerly winds blow obliquely onshore (along Line D, Figure 8) the changes along this line provide a good measure of the prevailing trends. As seen in Figure 9, the position of the 'edge-of-vegetation' line at Line D moved south-eastwards by 103 m over the period 1987 to 2005 (at a rate of 6m/yr.) and 71m south-eastwards between 2005 and 2014 (at 8m/yr.).

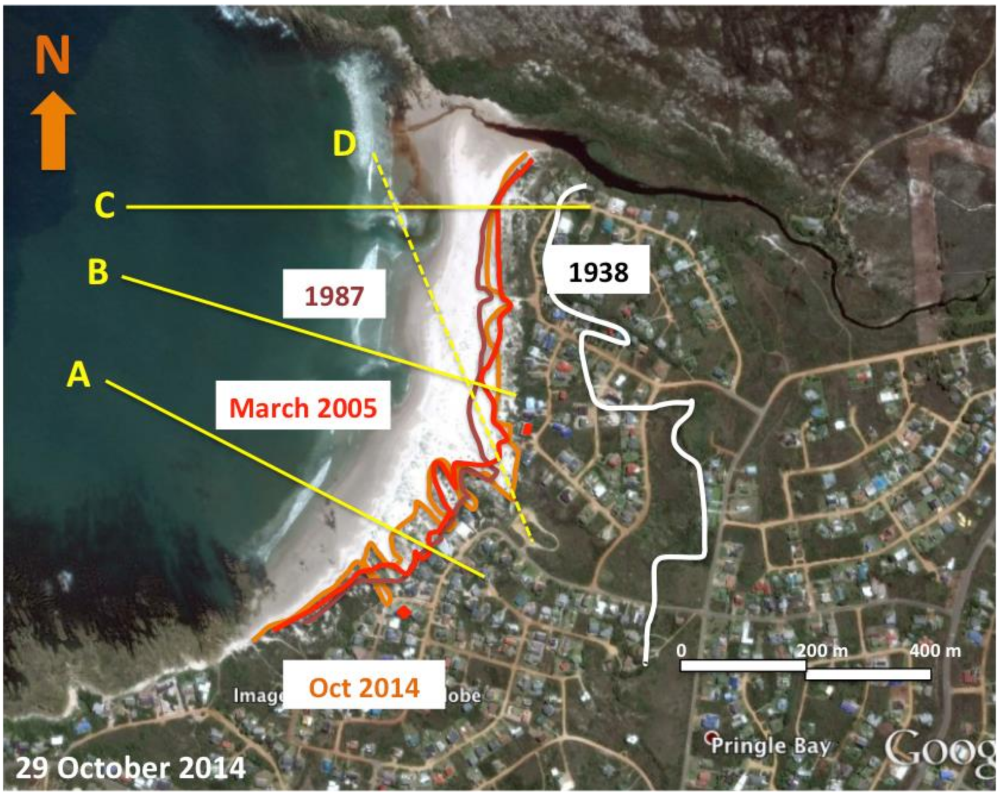


Figure 8: **Positional change in the seaward 'edge-of-vegetation' line within the study area**

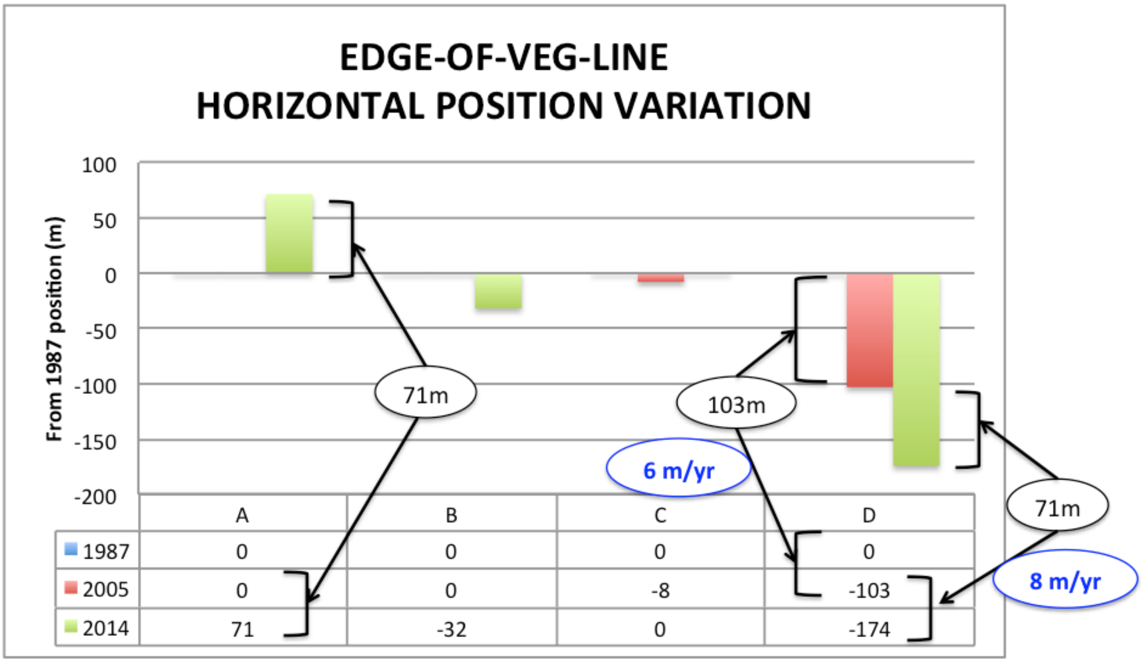


Figure 9: **Horizontal variation in the position of the seaward 'edge-of-vegetation' line over the period 1987 to 2014 for positions A to D shown on Figure 8**

4.2 Comparative surveys

A topographical survey of the study area done by the CSIR in 1988 is included in the 1988 Management Plan report (CSIR, 1988). Unfortunately the 1988 data are not available in a compatible digital format. However it is possible to interpret the contours on the scanned copy of the report and is discussed below.

More recent topographical surveys of the management area at Pringle Bay are available for 2008 and 2015. This allows for the comparison of cross-sectional data and provides the opportunity for calculating actual volumetric changes over the period between the surveys. The 2015 survey also provides an excellent baseline for future post-management comparative studies. The positions of the selected survey lines are shown in Figures 10 and 11. The spot heights surveyed in February 2015 and the contours taken from the 2008 aerial survey are shown in Figure 11. The contour and topographical spot heights are given to MSL (Mean Sea Level).

Figure 10: Position of survey lines (on the October 2014 Google Earth™ image)

The existing Life Savers' Facility is positioned on Line LS13
Photo: L Barwell (November 2014)

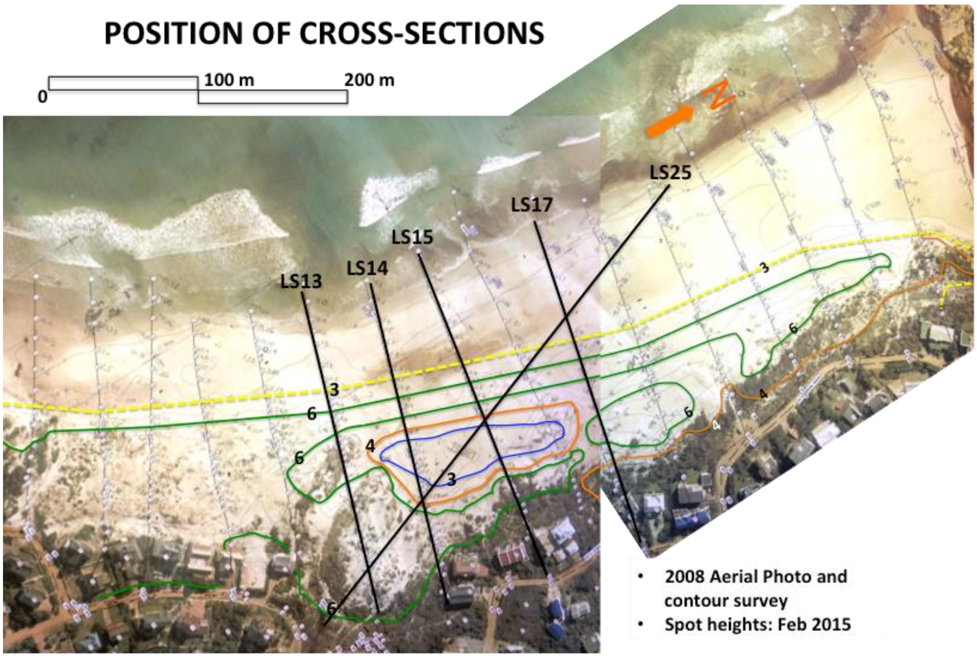


Figure 11: Position of February 2015 survey lines shown on the July 2008 aerial photograph (also shown are the proposed new contours – also see Figure 22)

In Figure 12 the topographical heights as surveyed in 2008 and those from the 2015 survey are plotted along Section LS13 (Figure 11). The zero point along the x-axis is taken as the point where Section LS13 crosses Section LS25.

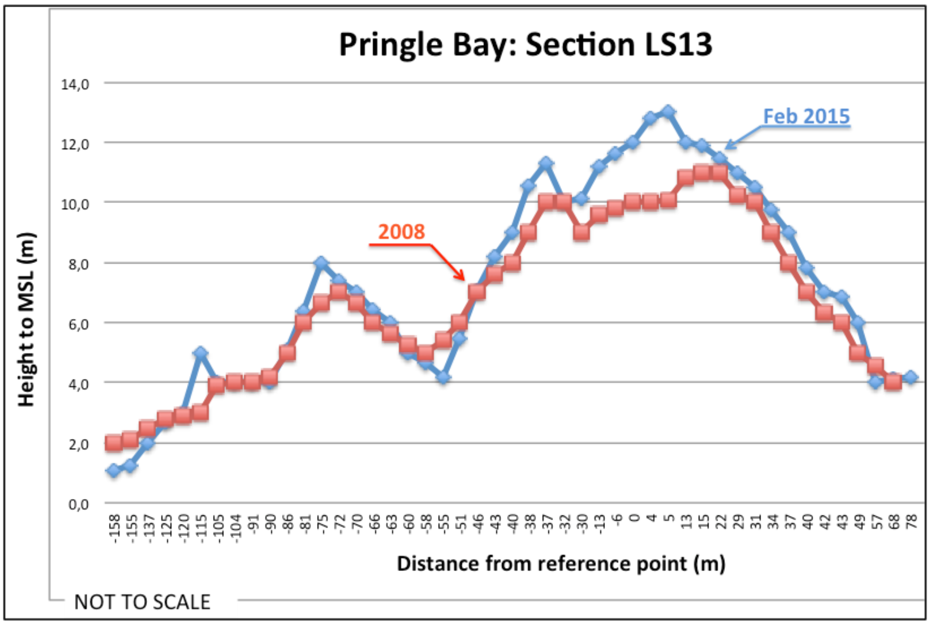


Figure 12: Comparative cross section of beach and dunes (Section LS13)

The frontal dune system showed little change as the area is partially vegetated and the Life Savers' hut is placed on the foredune and thus benefits from active management to prevent damage to the area around the facility.

Shown in Figure 13, Section LS14 (Figure 11) is located in the area where a significant volume of wind-blown sand has accumulated due to an influx of sand removed from the deflation area located west along Section LS14 and north-west along Section LS25 (Figure 15). This principle is illustrated in Figures 13 and 15. The calculated average rate of accumulation is around 60 $m^3/m/yr$. (Figure 13) to 16 $m^3/m/yr$. (Figure 15) over the period between surveys.

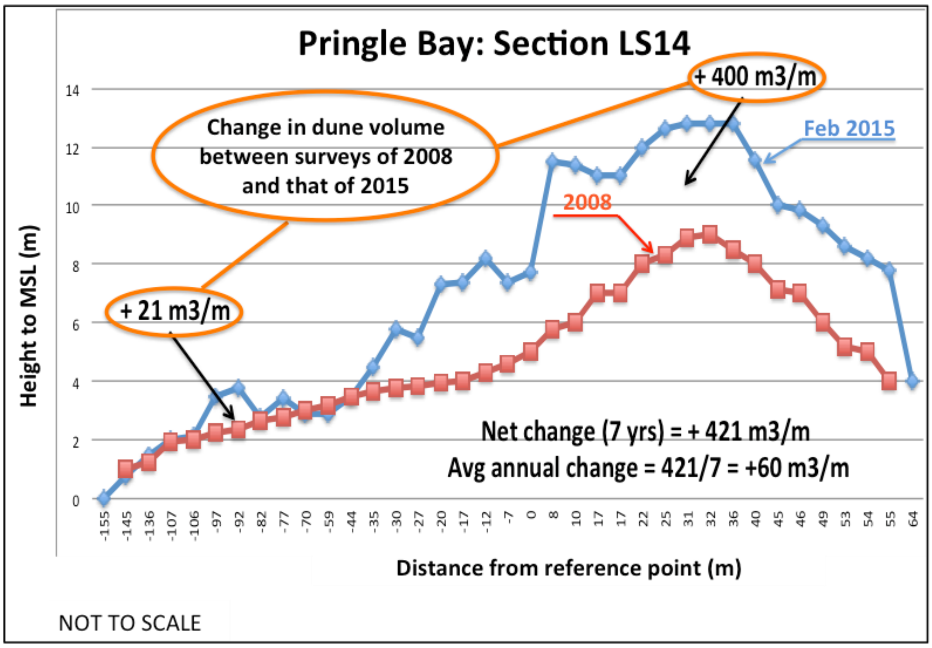


Figure 13: Comparative cross section of beach and dunes (Section LS14)

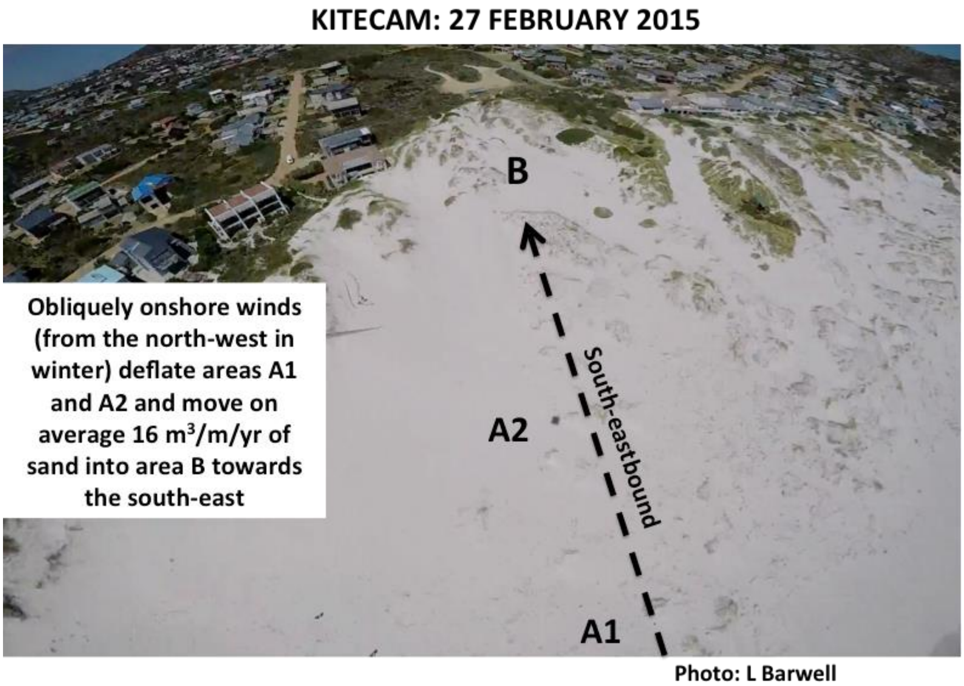


Figure 14: Wind-blown sand along Section LS25

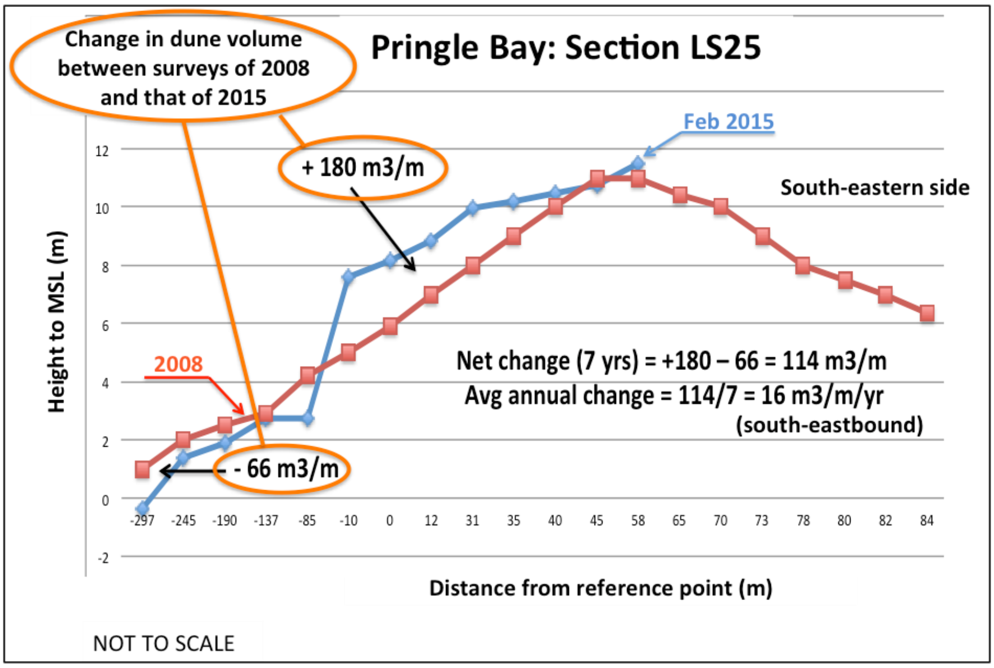


Figure 15: Comparative cross section of beach and dunes (Section LS25)

4.3 Conclusion on the beach and foredune stability analysis

From the aerial photo/image analysis (Figure 9), it can be seen that the 'edge-of-vegetation' line at Line A (south of the 'problem' area) had remained unchanged between 1987 and 2005 and had moved seawards by a significant amount due to active management of the wind-blown sand as per the 1988 management plan (CSIR, 1988). Similarly the edge-of-vegetation' line at Line B underwent a period of stability between 1987 and 2005, and only a slight landward shift occurred between 2005 and 2014.

The foredune along Line C (northern end of the beach) next to the estuary mouth remained 'natural' and the position of the 'edge-of-vegetation' line was unchanged over the whole period between 1987 and 2014. This is due to the fact that the 'dry' beach width is relatively narrow due to the influence of the estuary mouth and thus there is a limit to the amount of dry sand available to be blown off the beach. There is also a limited amount of pedestrian traffic across the dunes which limiting the potential for blow-outs to form. The formalised pathway from the parking area to the beach, part of the 1989 management plan, probably played a role in guiding pedestrians away from the foredune.

As discussed above a trend along Line D in wind-blown sand movement of an average of $7m^3/m/yr$. was calculated for the period 1987 to 2014. This is also the area where the most pedestrian traffic from beach-goers occurs from the parking area and public ablution facility across the (high) dunes to the beach. A significant number of blow-outs orientated in a north-west / south-east direction have formed with the associated dune slipface advancing onto the public and private land.

The analysis of the topographical surveys provides an opportunity to quantify the actual volumetric change and rate of change of the dunes in the 'problem' area. As stated above the 1988 survey data (included in CSIR 1988) are not available in a compatible digital format so it is difficult to make a direct comparison. However a visual interpretation of the 1988 contour map enables the following conclusions:

- In 1988 the highest dunes near the public parking area reached an average level of +5.5 m MSL. Compare this to the average height of +10.5 m MSL in 2008 and +13 m MSL in 2015 (Figures 7, 8 and 10 and Area B, Figure 9). As is discussed in Section 7, it is planned to reduce this level to between +6 m MSL and +8 m MSL (Figures 18 to 22);

- The average level in the area close to the existing storm water outlet pipe was +1.5 m MSL in 1988 and +3.0 m MSL in both 2008 and 2015 (Figure 8). The planned level is to remain at the existing level of the storm water pipe outlet (estimated at +3.0 m MSL) since this is a fixed structure (Figure19);

- The level of the storm water detention area behind the foredune was at +1.0 m MSL in 1988 and +3.5 m MSL in 2008 and 2015. The planned level has to tie in to the level of the existing storm water outlet pipe to allow effective drainage from the parking area. (Figures 19 to 22).

The above analysis is typical of a closed pocket beach / bay where no 'new' sand enters the system from adjacent areas. The fact that the volume of sand is limited to that within the existing active system (i.e. the nearshore area, the beach, foredunes and the backdune area) creates the opportunity to manage the system in a fairly cost-effective manner into perpetuity.

Unfortunately the opposite is also true should no or a limited maintenance be undertaken. The measured (and observed) high wind-blown sand transport rate means that the finite volume of sand that makes up the natural buffer against the forces of the sea is rapidly getting lost off the beach. This is not only causing a current to medium term impact on the backdune wetland ecosystem, but also municipal infrastructure (ablution facility, parking area and storm water management system) and the high value private properties. The loss of sand is also foreclosing on the beach and foredune buffer system ability to buffer against the projected impacts of climate change in the form of sea level rise and increased storminess.

Kelp traps sand and provides natural fertilizer thus creating suitable environment for pioneer dune vegetation to grow and form the core of the foredune system.
Photo: L Barwell (November 2014)

5 FOREDUNE INTEGRITY

Maintaining the integrity of the buffer dune system to provide the ecosystem service it is designed for is the key and critical aspect for safeguarding the backdune ecosystem and the public and private property located landwards of the buffer dune system against the influence of present and future coastal processes.

The basic principles of buffer dune integrity can be summarised as *the ability of a vegetated foredune to prevent movement of wind-blown sand and to secure a large enough volume of sand to effectively counter the offshore erosion due the design sea-storm.*

The reduction of foredune integrity can occur as a result of vegetation removal, trampling or die-off, often due to poor management. Naturally occurring kelp washed up onto the beach forms the core of a natural windblown sand management mechanism. Sand and seeds are trapped amongst the kelp, thereby forming a sheltered micro-climate where pioneer dune vegetation can establish. Nutrients are released as the kelp naturally decays thereby assisting the vegetation to grow and trap more wind-blown sand until a series of hummock dunes are formed. More kelp washed into the gaps between the hummocks and the process repeats until a foredune is formed. The removal of washed up kelp should therefore be discouraged within the dune management area.

From the CSIR (1988) study and the previous section above, it was shown that there is a high potential of a net landwards movement of wind-blown sand under the prevailing wind regime. In fact it is recommended that a net annual rate of 20 m^3/m towards the south-eastern to eastern sector be used to design the buffer dune. To manage this potential it is essential that, for example, the dune vegetation component of the buffer dune system be maintained at a high level of integrity.

A good practice guideline to buffer dune management is provided as Appendix 5. The Overstrand Municipal Environmental Managers are encouraged to apply the guidelines to the specific management area and to keep a strict record of the assessment, as they take place.

Please note that the essence of this management action holds true for the whole buffer dune system at Pringle Bay.

6 FINDINGS AND CONSIDERATIONS

The findings from the analyses in the sections above lead to the following findings that should be considered in the design of the updated management plan for Pringle Bay:

- The upper beach and foredune are dynamically stable (see Section 4) in the areas where active management has taken place.
- In the middle reaches of the study area (the ‘problem’ area) the ‘edge-of-veg line’ has moved landwards at an average rate of around 7 m per year over a period of 25 years due to a lack of active management of the foredune integrity.
- A net potential wind-blown sand movement rate of 20 $m^3/m/year$ is estimated for the study area. This means that the management plan and foredune design should cater for an anticipated annual volume influx of 20 m^3 per metre of beach width perpedicular to the wind direction. This means the vegetated foredune basewidth should not be less than 45 m. A further (positive) implication of this is an expected equivalent net dune volume

increase over the seaward 10 to 15 m of the foredune can occur, thereby 'keeping the sand on the beach' and providing an effective buffer against large storms.

- A hazard level that includes the anticipated effects of climate change in the medium term (by 2050) is estimated to be at +6.2 m MSL at Pringle Bay. This means that the foredune should be maintained at a minimum of +6m MSL at all times.
- Sea Level Rise could potentially cause a landwards movement of about 20 m to 50 m over the next 50 years (according to Bruun's theory (Bruun 1988). A larger dune volume would tend to reduce the potential horizontal landward reach during cross-shore erosion caused by SLR.
- Exposed blow-outs will rapidly move sand inland. To prevent the landward loss of sand, the impact on backdune vegetation and specifically to limit an increase in dune height, the foredune integrity should be maintained at all times. For example blowouts should be actively managed by packing of branches according to a pro-active plan. A pro-active 'good practice guideline' is included in Appendix 3).
- The site is suitable for appropriate raised boardwalks and an opportunity exists to provide a viewpoint and beach access for disabled citizens (see Appendix 2).

7 MANAGEMENT PLAN

7.1 The 1988 Management Plan

From the above it is concluded that the 1988 management plan (CSIR, 1988) is still valid and can be used as the baseline for the development of the updated plan which brings into consideration the influence of climate change and specifically the potential effect of sea level rise. Specific layout and management refinements are, however, recommended based on the results of the analyses presented above.

Whereas a scanned copy (of poor print quality) of the document is available on request, key information is extracted and presented in Appendix 3 for easy reference.

7.2 The updated management plan for the Pringle Bay beach area

The Management Objective is to keep the limited beach sand resource within the dynamic beach and foredune system by preventing the sand from blowing out of the 'pocket-beach' system.

To this end the Management Plan has five key components:

1. Returning to the beach (A1, Figure 16) as much of the sand now 'stored' in the large backdunes, and stabilizing Area A2 so-as to prevent further landward migration of the sand;
2. Ensuring that a functioning vegetated foredune (on the seaward interface between Areas A1 and A2) is maintained to form the core of the buffer system;
3. Allowing for effective storm water management from the parking area (B) through the backdune into a detention area within Area A2 and located directly landward of the vegetated foredune;
4. Providing effective and safe beach access pathways and boardwalks through and across the vegetated dune area (Points marked as C); and
5. Carrying out an effective communication and education process to encourage buy-in from beach users to understand the system and assist with preserving its integrity.

Each of these components is discussed below.

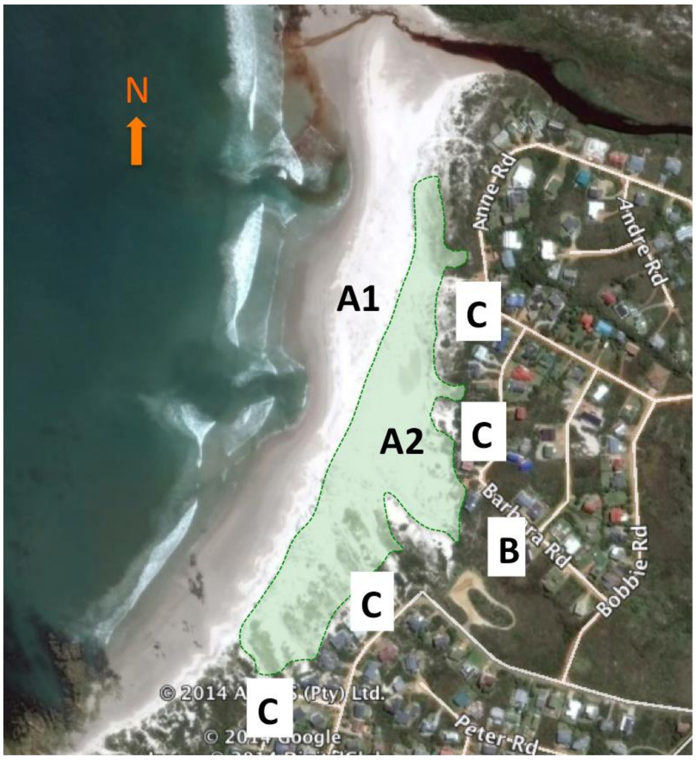


Figure 16: Components of the beach and dune at Pringle Bay

Figure 17: Details of the managed areas within the beach and dune areas

With reference to Figure 17 the following approach to implementing the management plan is recommended:

- Move the 'lost' sand from the high dunes (1) back onto the beach and to form a new foredune (2);
- Maintain a vegetated foredune (2) through effective and ongoing management;
- Establish suitable dune vegetation in Areas 1 and 3;
- Maintain the integrity of the vegetated dune to prevent exposed areas from forming as this causes 'blow-outs' and a subsequent loss of sand from the buffer dune;
- Landscape Area 4 to allow for the accumulation / detention of storm water draining off the public parking area (5) and adjacent wetland via the existing storm water drainage pipe;
- Formalize the walkway access to the beach at the position marked as 6;
- Prevent informal paths from forming within the rehabilitated area;
- Implement a structured seasonal management and maintenance programme; and
- Implement a public information and progress feedback programme.

7.3 Reshape the area to form new dune profiles

As summarised above, the first component is to move the sand from the high dunes back onto the beach so-as to reinstate the buffering system. This is best achieved by mechanical means. As depicted in Figures 18 to 21 the area is reshaped to ultimately reflect the topography represented by the new contours shown in Figure 22.

The positions of the cross-sections are shown in Figure 8.

The existing Life Savers' Facility is located behind and above the new foredune at Section LS13 (Figure 18). The backdune area is reshaped to still form the highest point (at +8.0 m MSL) thereby creating a wind-free area on the southern side to allow the establishment of a new boardwalk and pathway from the parking area to the beach. This is discussed in Section 7.6 below. All exposed areas are to be stabilized as soon as possible after the buldozing has taken place. This is discussed in Section 7.5 below.

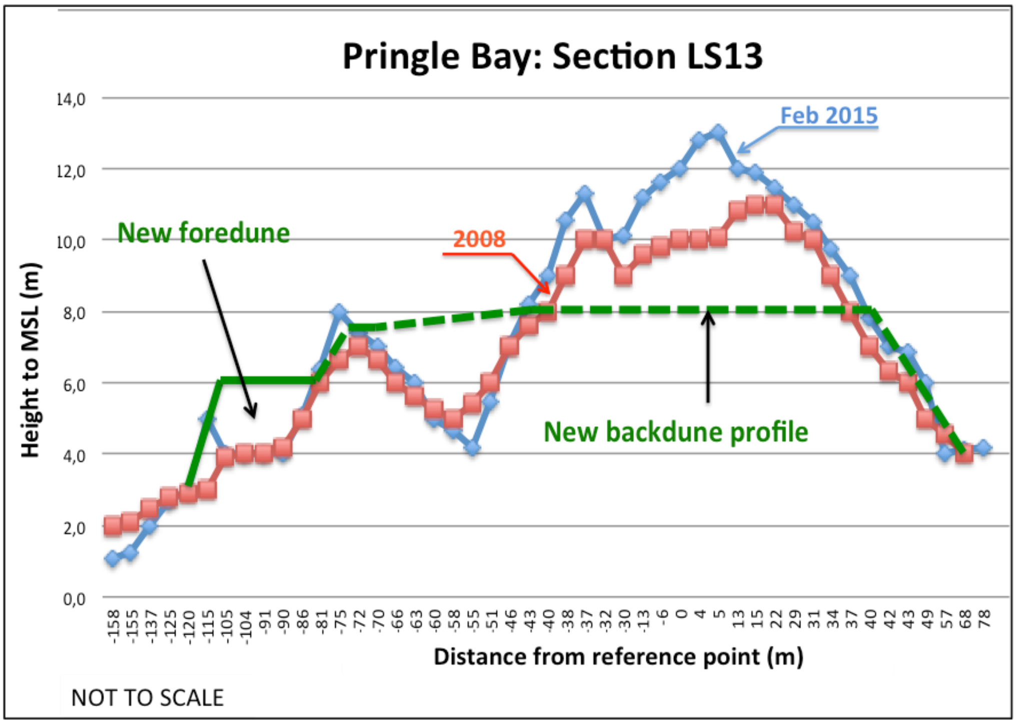


Figure 18: The new backdune profile along Section LS13 (refer to Figure 10)

For the area represented by Section LSA14 (Figure 19), sand from the backdune area is buldozed all the way onto the beach and the backdune area is contoured to a level of +6.0 m MSL. The natural stormwater detension area is reinstated at a level low enough to allow the stormwater to drain into it from the existing stormwater drainpipe outlet. This level is estimated at +3.0 m MSL but can only be established once the pipe is exposed during the reshaping exercise. The area between the detension pond area and the beach is reshaped to form a new foredune with a top level of +6.0 m MSL.

The volume and shape of the existing foredune can be enhanced by packing branches in a well planned manner
Photo: L Barwell (November 2014)

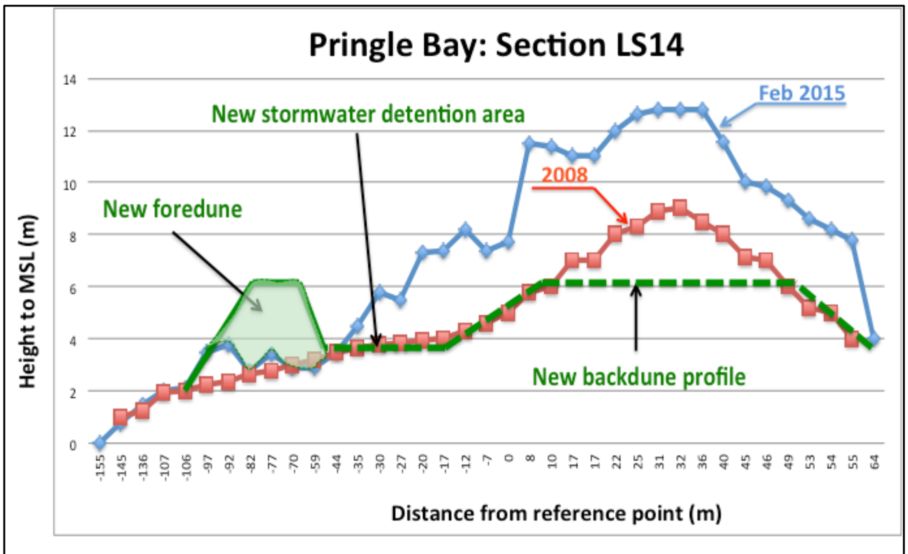


Figure 19: The new backdune profile along Section LS14 (refer to Figure 10)

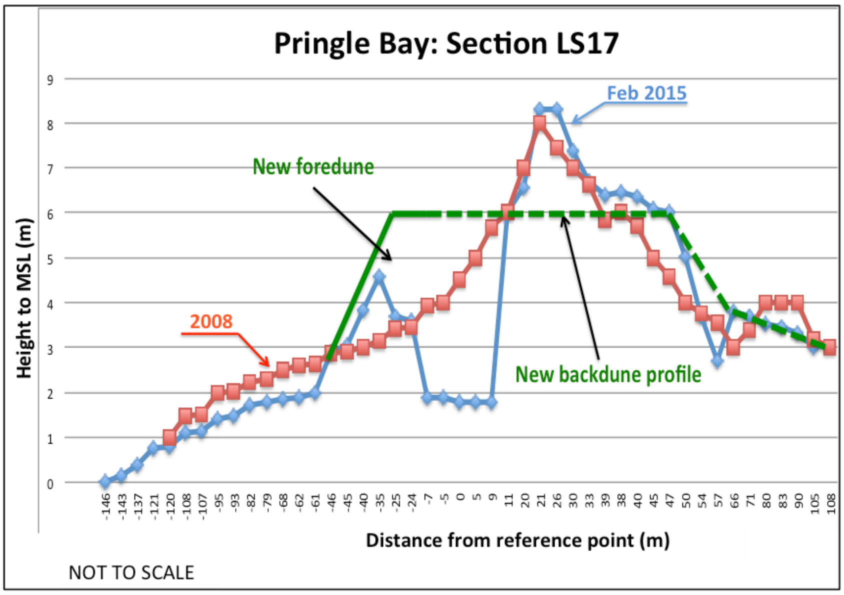


Figure 20: The new backdune profile along Section LS17 (refer to Figure 10)

At Section LS17 (Figure 20) sand from the backdune area is used to fill in and reform the foredune to a top level of +6.0 m MSL. This forms the northern edge of the reinstated stormwater detension pond. Figure 21 reflects the reshaped Section LS25 showing the new foredune, the stormwater detension area and the reprofiled backdune area.

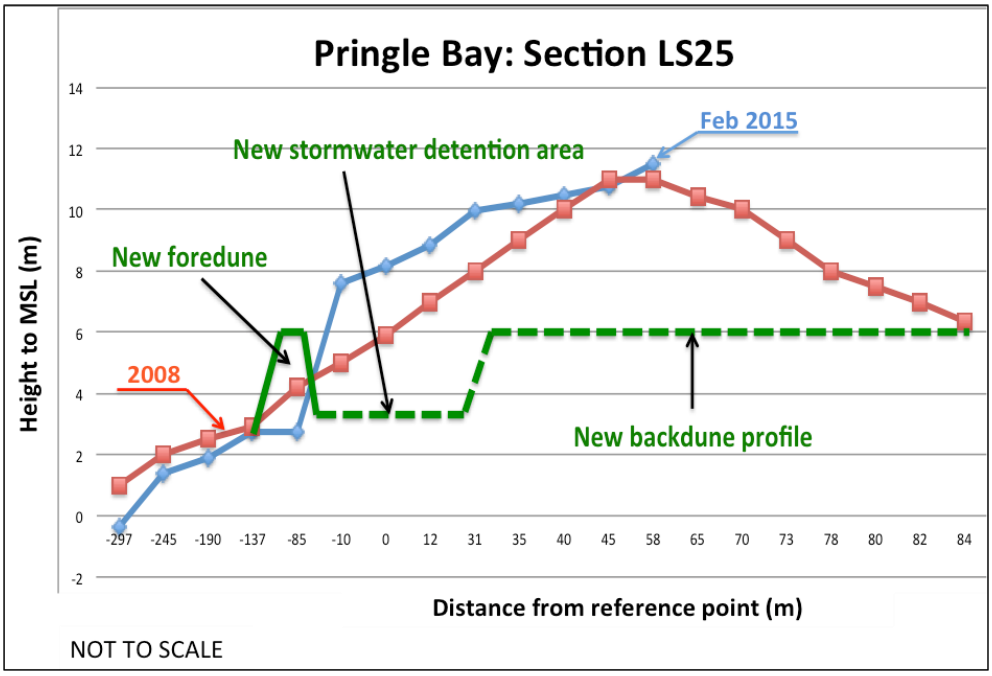


Figure 21: The new backdune profile along Section LS25 (refer to Figure 10)

The landscaping is summarized in the form of a new contour map shown in Figure 22.

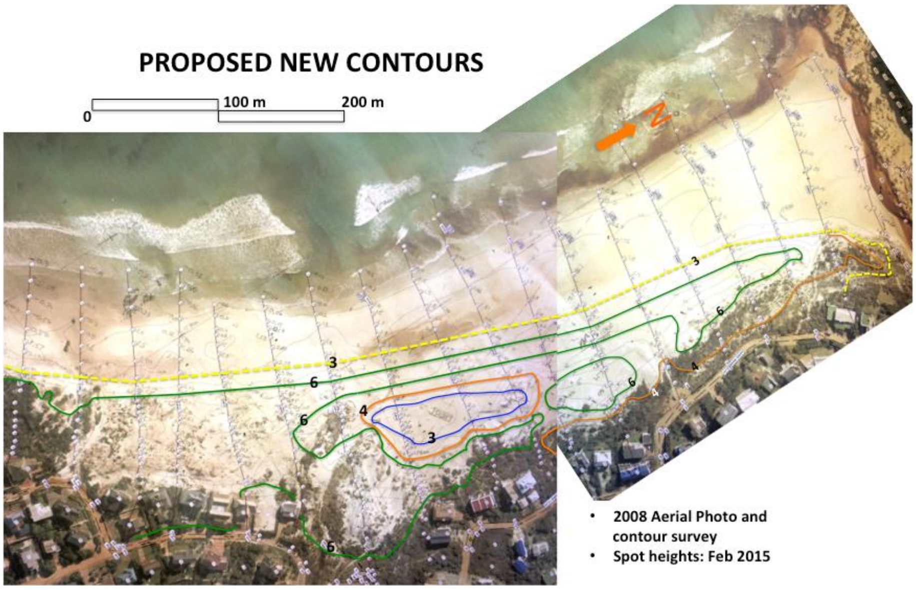


Figure 22: The proposed new contours after the area is reshaped accoruding to the management plan

Photo: L Barwell (November 2014)

The backdune area needs to be reshaped to allow for an effective storm water detention area
Photo: L Barwell (November 2014)

7.4 Sand stabilization

A key element to the management plan and critical to the success and sustainability of the intervention is the effective and rapid stabilization of exposed sand areas. As seen in Figures 18 to 21, using a bulldozer will reshape large areas of the dunes.

These sandy areas need to be stabilized by spreading and working in straw in the exposed areas as a first measure. This approach is then complemented by the packing of seedless branches in identified parts of the dune area. Branches create a suitable environment that limits the ability of wind to move sand. They also establish suitable conditions for the natural growth of dune vegetation over time.

Due to the prevailing high wind-blown sand potential it is necessary to plant rapid and strong growing dune pioneer vegetation on the newly established foredune. As recommended by the 1988 Management Plan and proven to have successfully maintained the integrity of the beach-foredune-backdune system in the southern parts of the Pringle Bay beach the use of the non-invasive Marram grass is encouraged.

The identified key elements of the updated management plan are illustrated in Figure 23. The middle reaches of the beach between Section LS13 and to the north of Section LS17 form the core of the plan. This area needs to be reshaped by means of a bulldozer. As indicated a new foredune needs to be built using sand 'brought back' from the existing high dunes on the eastern side of the core area. A new landscaped storm water detention area is also shown. This area will in time become an effective backdune wetland system that reinstates the situation that prevailed before the Pringle Bay town was developed.

The areas to the south and north of the core area will be left undisturbed with only branch packing required to encourage natural vegetation growth. A vegetated foredune along the seaward edge of these areas will be facilitated by means of branch packing to firstly trap wind-blown sand off the beach and when the desired foredune shape is thereby obtained suitable pioneer vegetation will be planted. This is essentially 'coastal gardening' by a dedicated team of 'coastal gardeners'.

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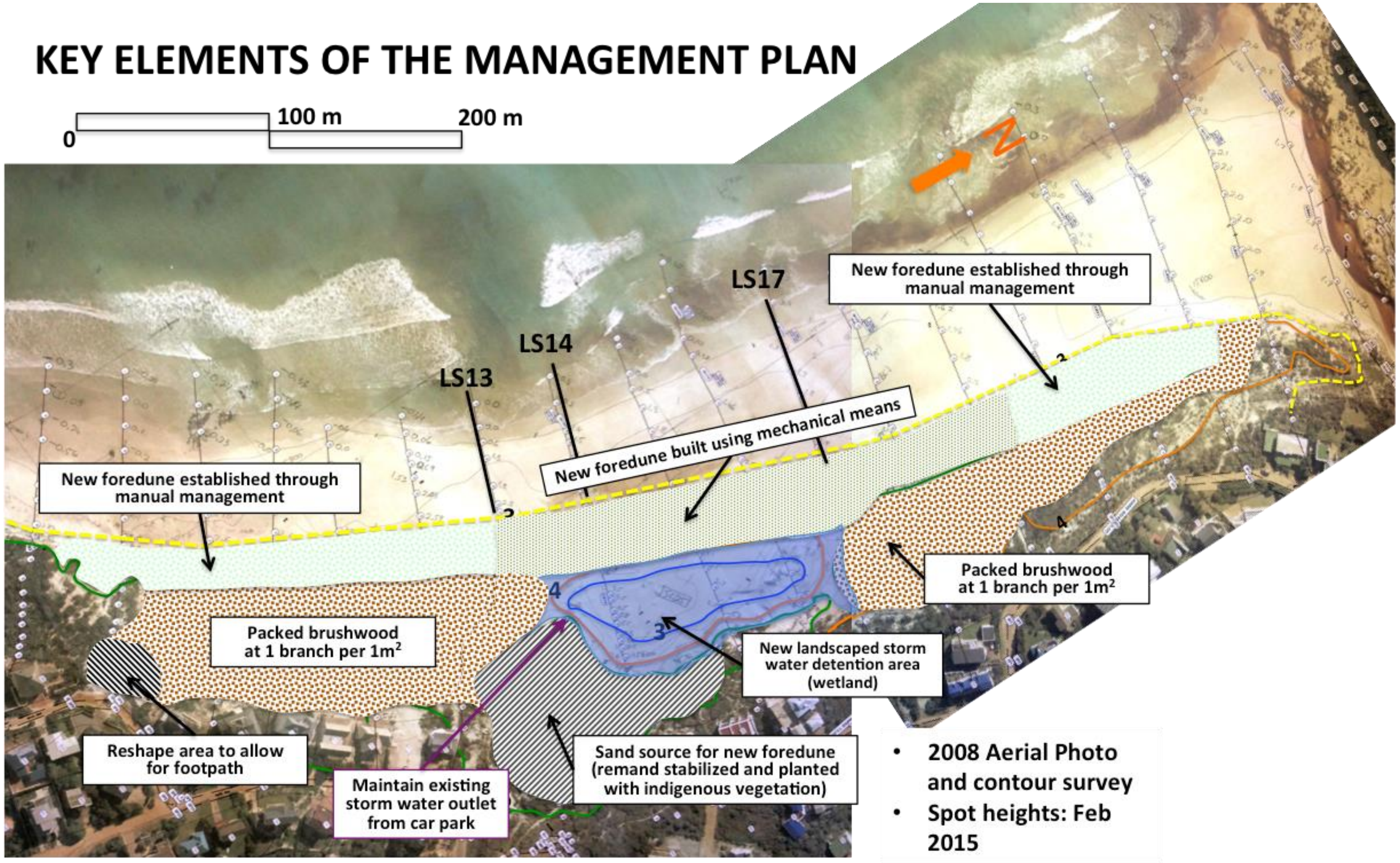

Figure 23: Key features and tasks associated with the updated management plan (not to scale)

7.5 Beach access pathways

Figure 24 illustrates the beach access boardwalks and pathways recommended as part of the updated management plan. The design and management options consist of a combination of raised boardwalks constructed up and over the steep backdune. A managed footpath is then maintained through the vegetated dune area leading up to raised boardwalks over the foredune. The design of the foredune boardwalks need to be done in a way that the front 30% is constructed as a sacrificial portion to allow for the natural dynamic nature of the foredune.

A special feature is the location of a managed footpath along the south-eastern edge of the new detention area which can be used as an educational feature with suitable information signage overlooking what will become a backdune wetland.

Wind-blown sand has overwhelmed access pathways installed as part of the 1988 Management Plan
Photo: L Barwell (November 2014)

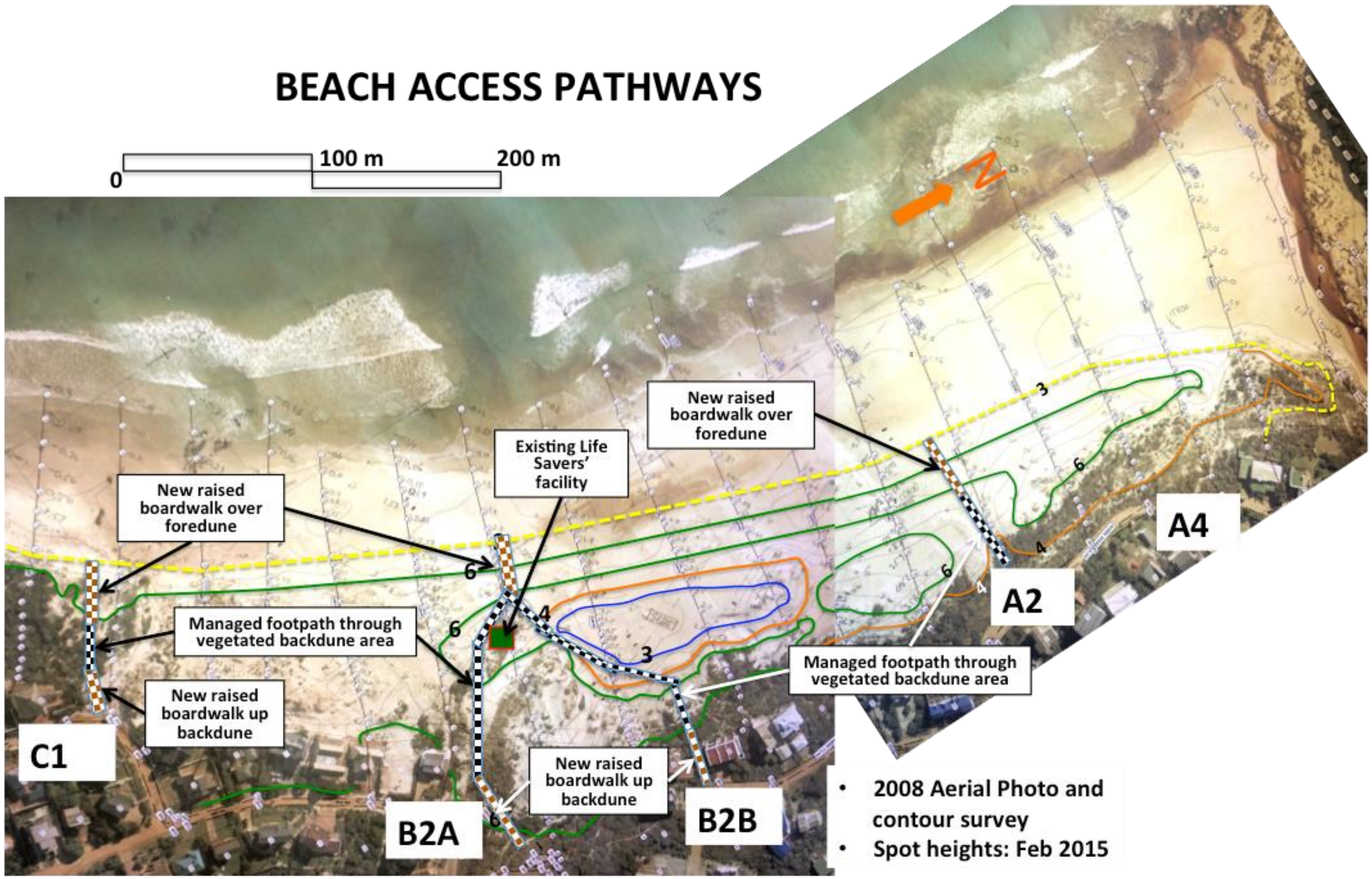

Figure 24: Beach access baordwalks and pathways (not to scale)

8 MANAGEMENT ACTIONS

8.1 General

The following list of management actions reflect the recommended steps in the implementation of the management plan as depicted in this report:

1. Secure an annual budget for managing the integrity of the system.
2. Appoint a dedicated 'dune gardening / management workforce'.
3. Implement the phased management actions (see next section).
4. Maintain the buffer dune integrity (use the Generic Guideline – Appendix 5) and apply the relevant management actions as described. Keep records of all activities associated with the maintenance of the buffer dunes as recommended. Keeping an associated photographic record (date and time important!) will assist in making any required adjustments to the management plan when required.
5. Prepare a stockpile of seedless branches to be used for blow-out prevention / management, especially before, during and after the dry summer and autumn months.
6. Communicate effectively, for example by publishing a seasonal news article on the dune integrity status, especially during vacation periods. This will go a long way to secure cooperative management of the dune integrity.

8.2 Phasing of implementation

Whereas it would be ideal to implement the dune management plan as a 'turnkey' contract through a specialised contractor, the costs are probably beyond the means of a local municipality. An alternative approach is for local labour to carry out the work in a phased manner over a number of seasons thereby spreading the costs across financial years. However, this approach can only succeed through and effective, efficient and continuous collaboration between the Municipality and residents.

A possible phased approach is presented below. It is important to understand that to limit the costs the phasing of some of the activities is dependent on the seasons (mainly due to rainfall and the dominant wind regime).

Phase I: Prevent further south-eastward wind-blown sand movement (May/June 2015)

Whatever the timeframe for the future phases (depending on available funding), it is absolutely critical to prevent any further loss of beach and foredune sand from the system. As seen in Section 2 it is the dominating onshore winter wind regime that holds the greatest risk to beach sand losses and the associated impact of the advancing dune fronts on the backdune ecosystem, public infrastructure (parking area, ablution facility and beach access pathways) and private property (beachfront houses and gardens).

Phase 1 is therefore designed to 'freeze' the current situation so-as to allow time to find funding for the phased implementation of the management plan.

As seen in Figure 25, the required action is to pack seedless branches in the blow-outs and exposed dune areas as indicated. This eastern area will arrest sand blowing south-eastwards off the beach and backdune area. The actual rate of wind-blown sand may require the branches to be buried within a short timeframe and it will then be necessary to place further layers of branches until the winter and spring wind regime changes.

Packing branches along the upper beach area as indicated in Figure 25 traps sand blown off the beach in the area where the natural foredune will form. As the sand builds up within the branches the core of the new foredune will form. Once the summer south-easterly wind regime kicks in (December to March) the branches will also trap sand blowing north-westwards off the backdune and water detention areas.

Implementing Phase 1 will not only reduce the rate of encroachment of wind-blown sand on the backdune properties but also reduce the volume of sand that bulldozing will have to move back onto the beach and foredune.

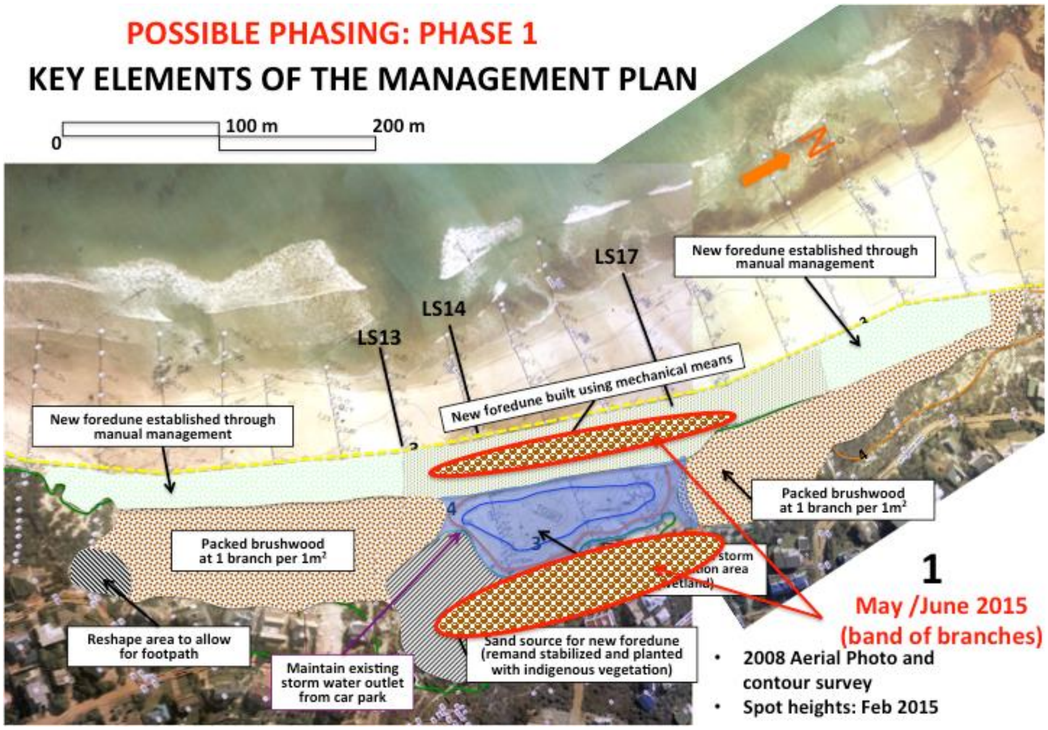

Figure 25: Phase 1 of implementation of the management plan

Phase II: Mechanical shaping (Year 1: August to November or Year 2: March to May)

Phase 2 is the most expensive part of implementing the management plan as it has to be done by a specialist contractor using machinery. It also will require a dedicated labour force to stabilize the exposed sand areas as soon as possible to prevent indirect impacts on adjacent properties and established climax backdune vegetation.

The work will have to be carried out by experienced sand moving contractors and supervised by a coastal environmental engineer experienced in this work.

Ideally a local labour force should harvest as much of the existing pioneer and secondary dune vegetation before bulldozing commences. These plants should be cared for in a temporary nursery to prepare for re-planting within the new foredune. The possibility of getting the local residents involved by inviting them to volunteer to harvest and 'host' these plants on their properties for the required period may be a worthwhile exercise to encourage buy-in to 'their' foredune!

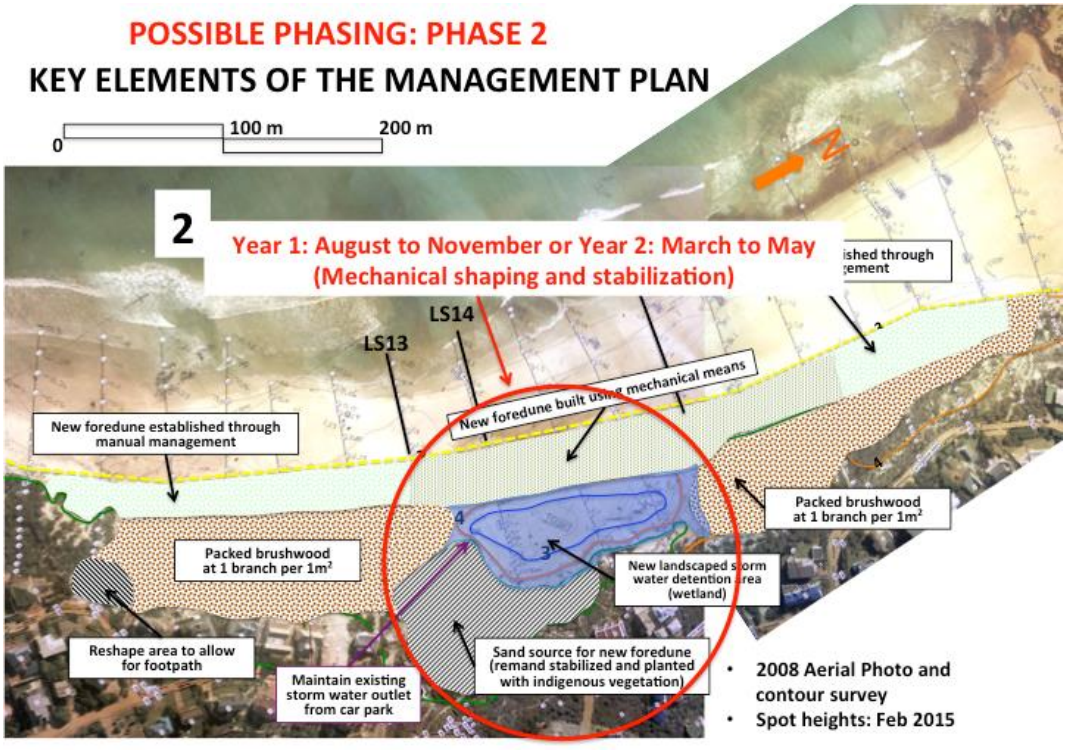

Figure 26: Phase 2 of implementation of the management plan

Phase III: Build main access walkways (In November of Year 1 and/or Year 2)

Establishing fit-for-purpose access pathways from the public parking area to the beach is an important management action. Since most beach-going pedestrian activities take place during the December and January summer holiday period, it is essential to have such dedicated facilities in place by mid December if possible.

The ideal is to construct the boardwalks and pathways after Phase 2 is completed. However this may not be possible due to time and financial constraints. It is therefore recommended that the landward portions of access pathways B2A and C1 (Figure 24) be formalised in 2015 to the best means possible. The placing of the actual pathway route and construction of the raised boardwalk portions need to be done in close consultation with experienced coastal environmental engineers.

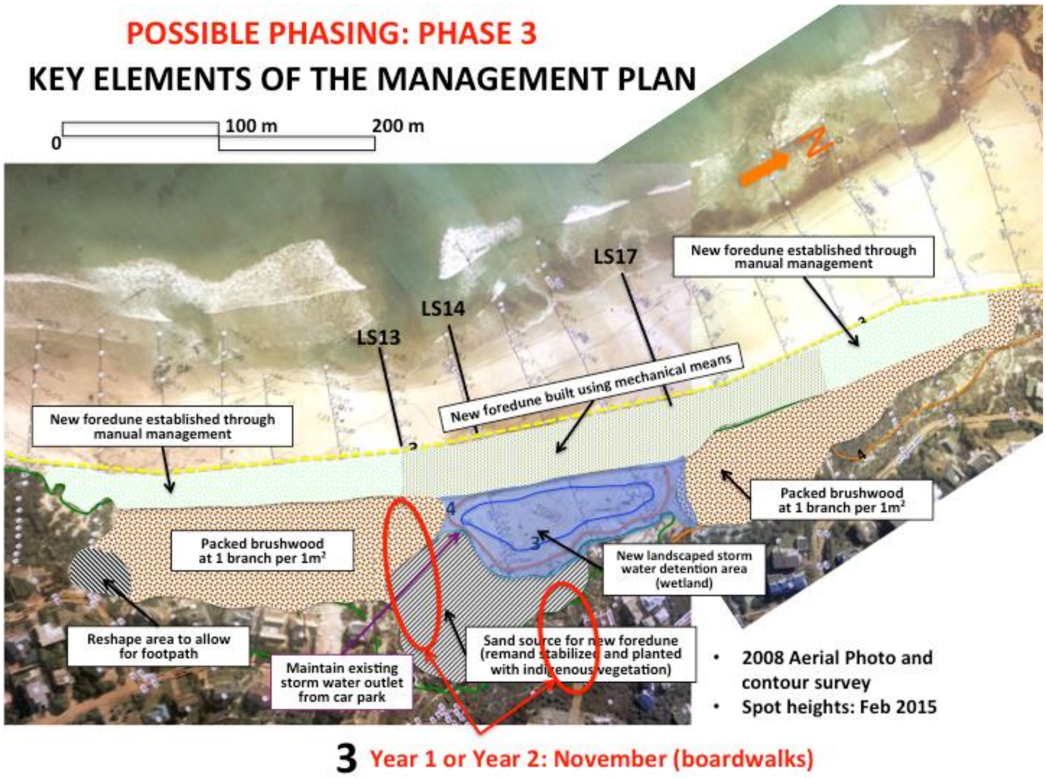

Figure 27: Phase 3 of implementation of the management plan

Phase IV: Stabilize southern and northern areas (Year 2: April & May)

Packing branches in the exposed areas to prevent wind-blown sand movement can stabilize the areas indicated as 4 in Figure 28. Since both these areas are already partially covered by pioneer dune vegetation, the packed branches will create a stable environment where the existing dune vegetation will soon establish itself and thus stabilize the areas. Implementing the maintenance guidelines will assist in keeping the integrity of the foredune and adjacent area.

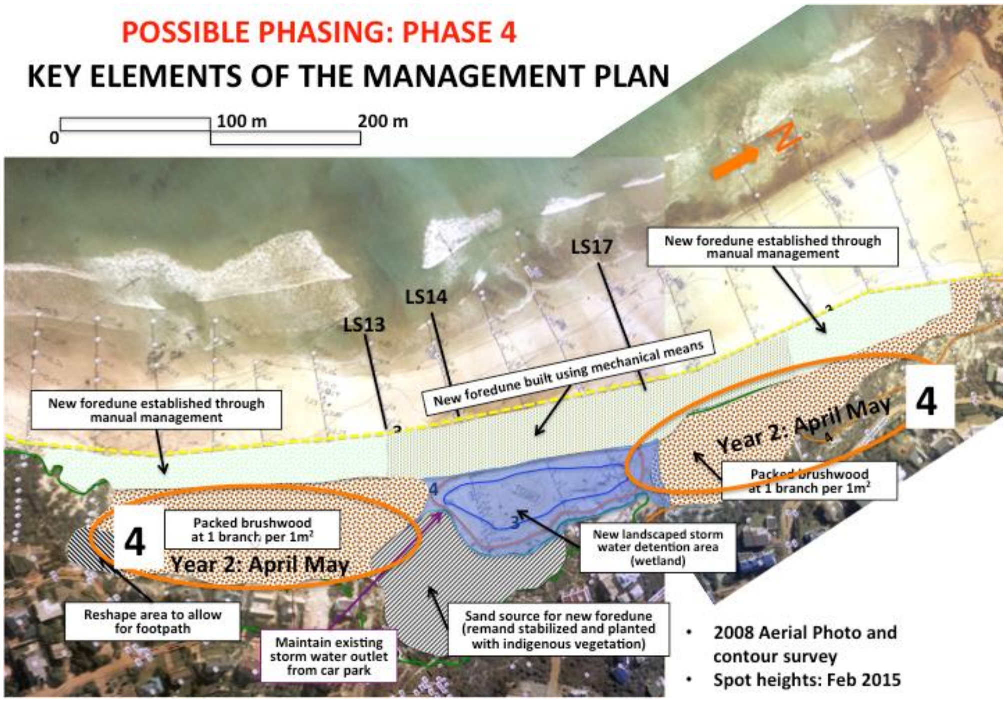

Figure 28: Phase 4 of implementation of the management plan

Phase V: Manually establish the southern and northern foredune sections (Year 2: July to October)

The required foredune will be established by a structured regime of packing branches to build up the required width and height of the foredune over time. The branches will trap wind-blown sand coming off the beach (in winter). Once the required dimensions are achieved the dune can be planted with pioneer vegetation harvested from adjacent stable dune areas as well as from the 'nursery' established prior to Phase 2.

Phase V1: Completion of the access pathways (before December)

The required boardwalks and pathways are shown in Figure 24. Once the foredunes are established and funding is available the rest of the access infrastructure should be installed.

The option exists to construct a beach access and viewing platform that can also allow disabled people to experience the beach and sea views. A suitable place for this could either be at positions C1 or A2 (Figure 24). An example of this structure is shown in Appendix 2.

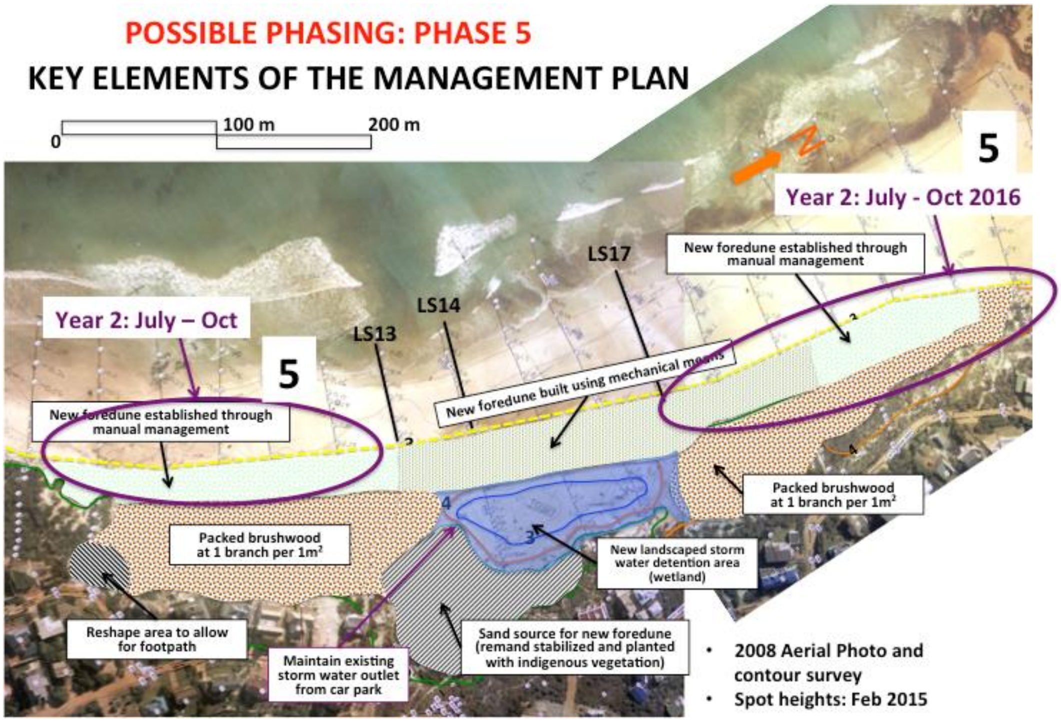

Figure 29: Phase 5 of implementation of the management plan

The high dunes advancing south-eastwards towards the public car park and ablution facility (green roof)

Photo: L Barwell (November 2014)

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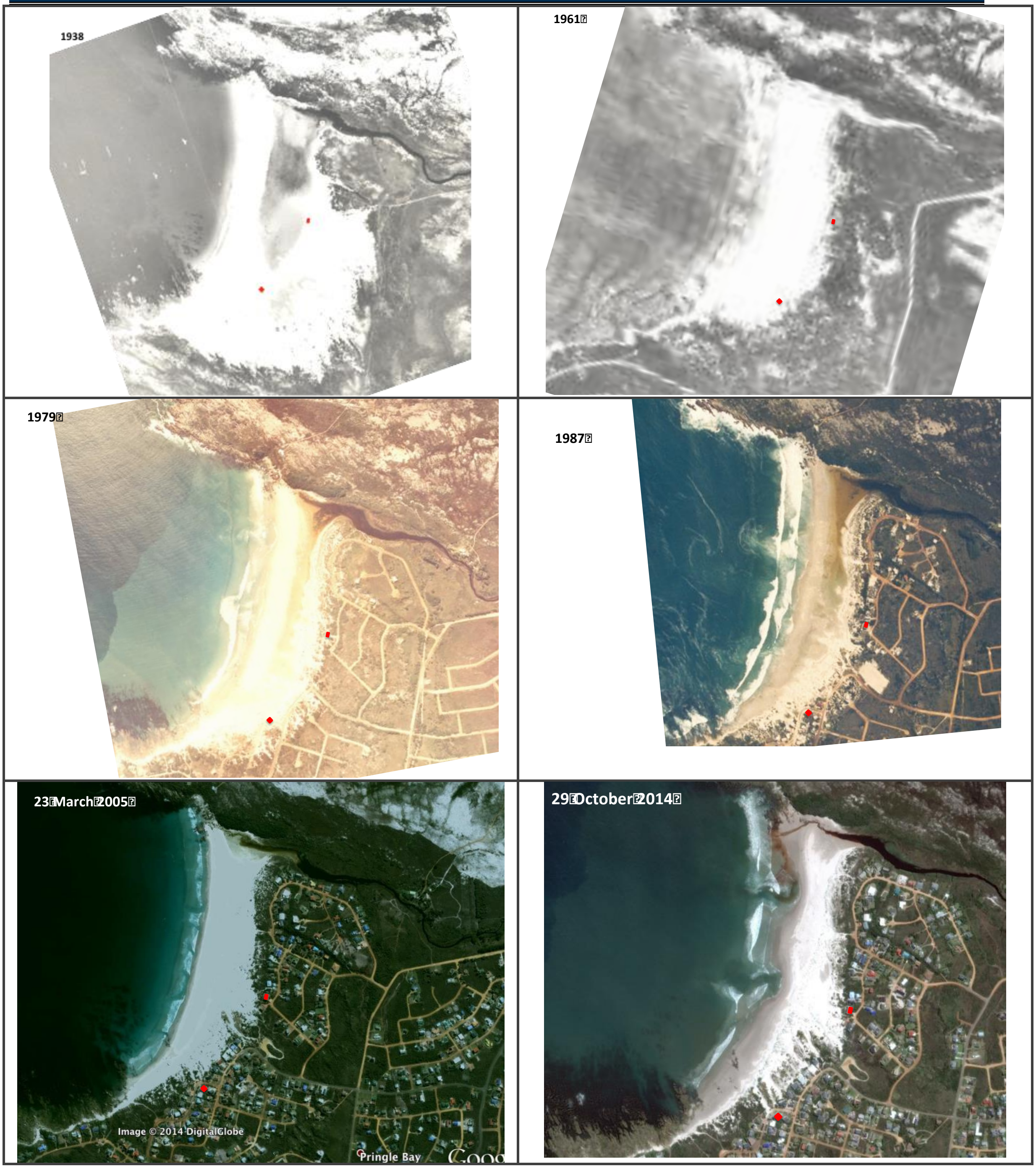
APPENDIX 1: Aerial images 1938 to 2014



Note: The red dots indicate the positions of the same two buildings

APPENDIX 2: Example of raised boardwalk

Figure A2.1: An example of a functional raised viewing deck and beach access walkway. The floor levels allow sand to move freely beneath the structure and enough sunlight allows for vegetation growth.

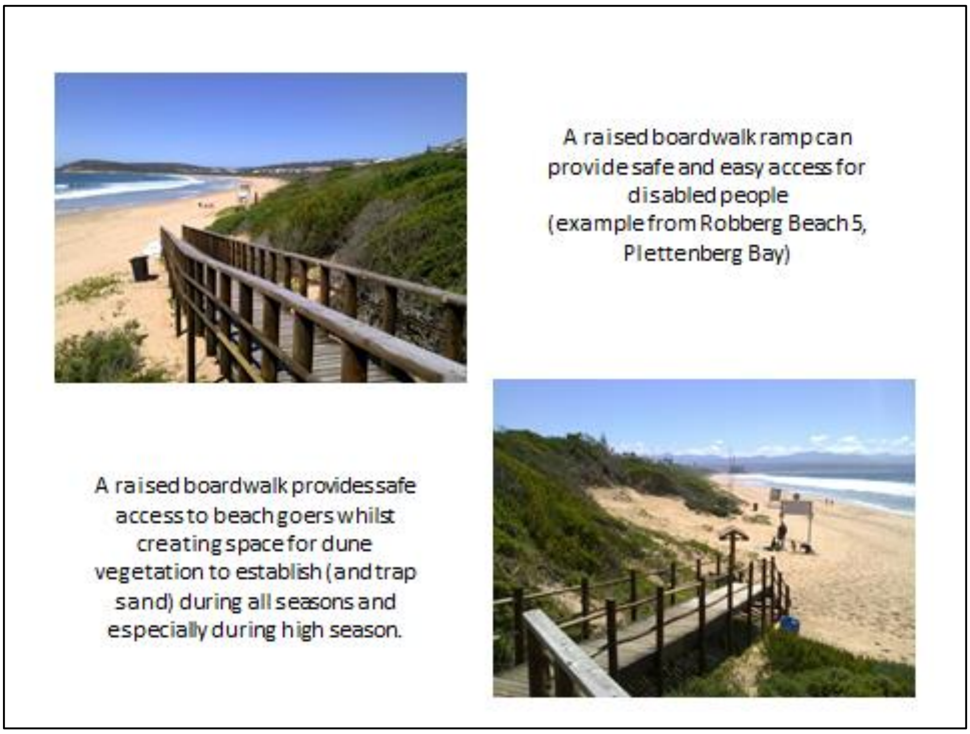


Figure A2.2: Examples of raised viewing platform, access boardwalk and wheelchair friendly ramp. (Blue Flag Beach, Plettenberg Bay)

APPENDIX 3: Extracts from 1988 Management Plan

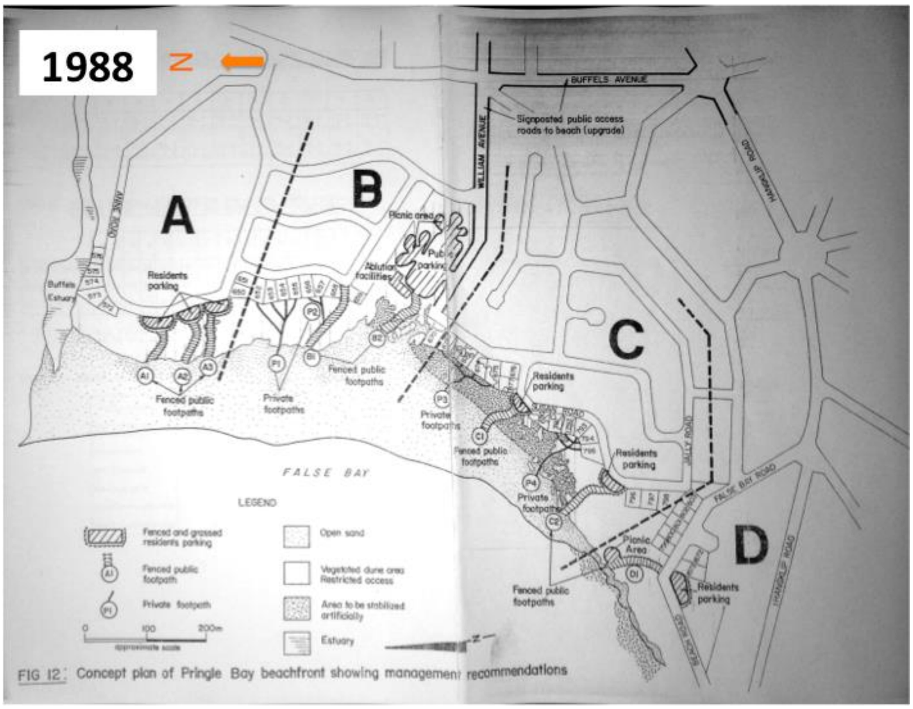


Figure A3.1: The 1988 Management Plan differentiated actions for 4 areas as indicated (CSIR, 1988).

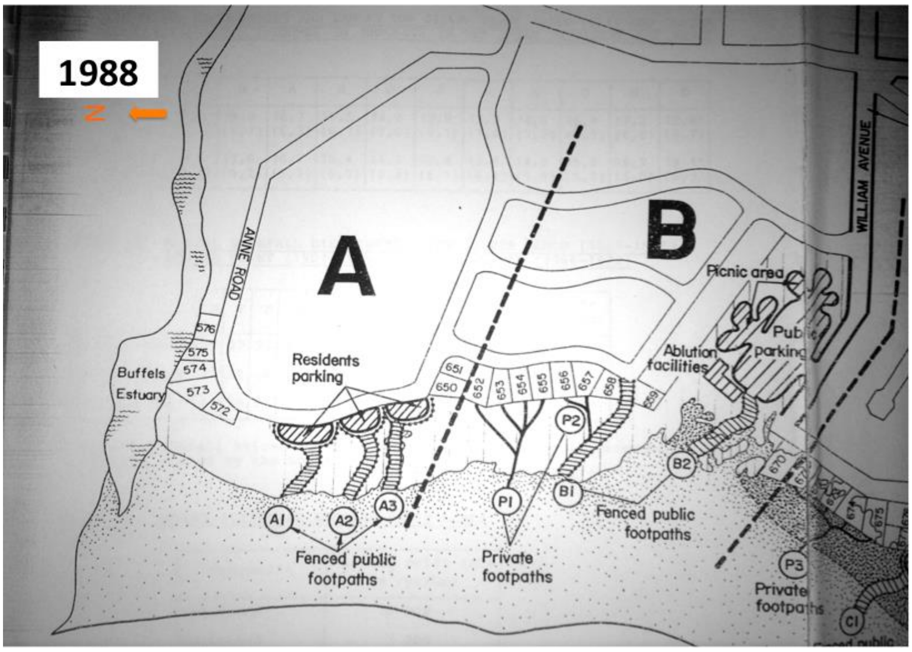


Figure A3.2: The focus of the updated management plan is on Area B (CSIR, 1988)

APPENDIX 4: Extreme inshore sea water levels

(Extract from CSIR, 2012, written by Theron, A.T.)

Significant drivers of high inshore sea water levels are tides, wind set-up, hydrostatics set-up, wave set-up and, in future, sea-level rise due to climate change (Theron, *et al* 2010). These drivers all affect the still-water level at the shoreline.

The drivers/components of extreme inshore sea water levels most significant to the Southern African context are the tides (South African spring tides are about 1 m above mean sea level (MSL)), potential SLR, and wave run-up. Theron (2007) has estimated that in the South Africa (SA) setting during extreme events, these components could each contribute additional amounts (heights) of between about 0.35 m to 1.4 m to the inshore sea water level. Note that potential additional impacts of climate change (e.g. more extreme weather events) on wind-, hydrostatic- and wave set-up are not included in the above range of increase.

Recent observations from satellites, very carefully calibrated, are that global sea level rise over the last decade has been 3.3 +/- 0.4 mm/y (Rahmstorf *et al.* 2007)). The IPCC AR4 Report (IPCC 2007) concludes that anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilised. Comparisons between about 30 years of South African tide gauge records and the longer term records elsewhere, show substantial agreement. A recent analysis of sea water levels recorded at Durban confirms that the local rate of sea level rise falls within the range of global trends (Mather 2008). Present SA SLR rates are: west coast +1.87 mm/y, south coast +1.47 mm/y, and east coast +2.74 mm/y (Mather *et al.* 2009).

The probability of sudden large rises in sea level (possibly several metres) due to catastrophic failure of large ice-shelves (e.g. Church and White 2006) is still considered unlikely this century, but events in Greenland (e.g. Gregory 2004, Overland, 2011) and Antarctica (e.g. Bentley 1997; Thomas *et al.* 2004) may soon force a re-evaluation of that assessment. In the longer term the large-scale melting of large ice masses is inevitable. Recent literature (since IPCC 2007) gives a wide range of SLR scenarios, as indicated in Figure A6.1.

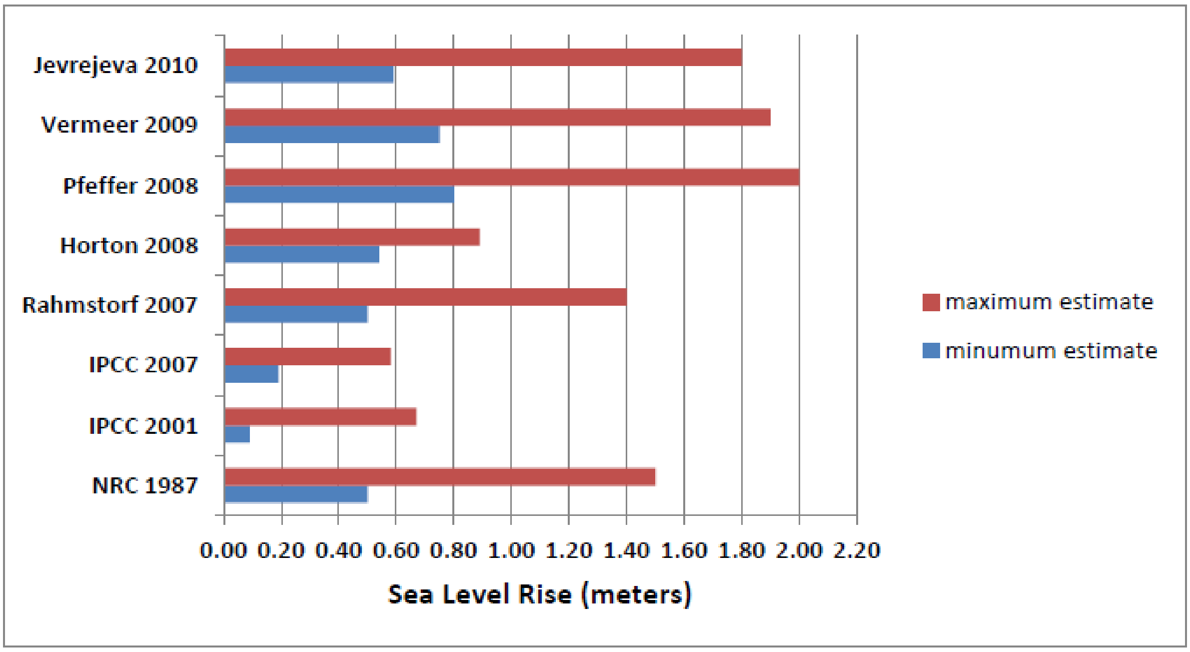


Figure A6.1: Comparison of minimum and maximum estimates of global SLR by year 2100 (USACE, 2011)

Some projections and scenarios are even higher, but most "physics/process based" projections (e.g. Nicholls and Cazenave 2010; Pfeffer *et al* 2008; Milne *et al* 2009; SWIPA 2011) for 2100 are in the 0.5 m to 2 m range, (Fig A6.2) as is also concluded in various reviews (e.g. Theron and Rossouw 2009; Fletcher 2009). It is concluded that the best estimate ("mid scenario") of SLR by 2100 is around 1m, with a plausible worst case scenario of 2m, and a best case scenario of 0.5 m. The corresponding best estimate ("mid scenario") projection for 2050 is 0.3 m to 0.5 m.

The drivers of inshore water levels should not be confused with the added effect of wave run-up, which can reach even higher elevations. Wave run-up is the rush of water up the beach slope beyond the still-water level in the swash zone. According to surveyed elevations (Smith *et al*. 2010), maximum run-up levels on the open Kwazulu-Natal (KZN) coast near Durban during the March 2007 storm (which coincided with highest astronomical tide) reached up to about +10.5 m MSL. Note that wave set-up and run-up are both accounted for in these levels. The maximum wave run-up alone during the 2007 KZN storm is estimated to have been up to about 7 m (vertical), resulting from significant nearshore wave heights of about 8.5 m.

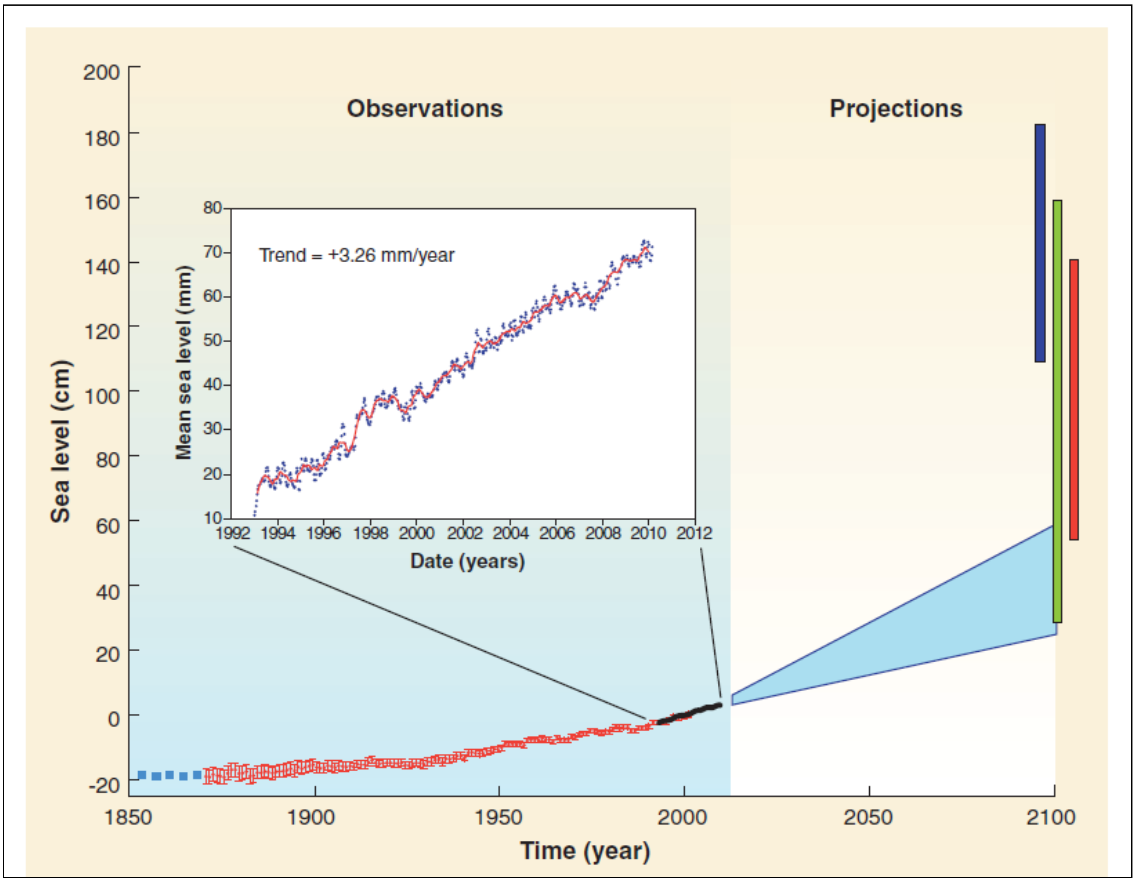


Figure A6.2: Measured and project sea level rise (Nicholls and Cazenave 2010).
(The blue, green and red bars are projections from different authors.)

Around southern Africa wave run-up is thus an important factor, which may be considerably exacerbated by tides and future SLR (Theron, *et al* 2010).

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APPENDIX 5: Good practice guide to buffer dune management

(Extract from Barwell, (2013)

Three seasonal rule-based Decision Trees for the maintenance of buffer dune systems (DTMBD) are discussed below. This model is mainly designed for areas where little rain and persistent onshore winds occur during the summer months.

The following environmental aspects are important to a management plan:

- **The protection and enhancement of the supply of sand** available for erosion during storms. This can be achieved by creating a supply of sand close to the shoreline.

- **The prevention of inland encroachment of foredunes.** Encroachment occurs through blow-outs, where sand blows over the foredunes and accumulates on the landward side. This poses a threat to any development located downwind of the dunes.

- **The stabilization of blow-outs.** It is particularly important to stabilize the blow-outs occurring at the top of the foredunes for the reasons mentioned above. This can be done by planting clumps of pioneer dune vegetation appropriate to the specific wind-blown sand regime and the packing of brushwood in between. In addition, blow-outs occurring in the middle and lower reaches of the dunes should also be stabilized in the same manner.

- **The appropriate layout and design of footpaths and beach access ways.** Appropriately designed boardwalks that allow for changes in the beach profile, the dominant winds with measures to allow for vegetation growth underneath if required. The fact that the seaward toe of the dunes will be eroded by the sea should be provided for.

- **The protection of the dunes from being trampled by humans.** Development always results in an increase in human pressure on the dunes and the likelihood of the dune vegetation being trampled. Therefore an appropriate layout of footpaths and fences is required that keep people off the dunes by providing effective access from properties and parking areas to and from the beach. Fences along the seaward side of the dune are often required to discourage people from taking short-cuts over the dunes. Information boards explaining the importance and sensitivity of the dunes are recommended to assist in obtaining the support of beach users.

- **The removal of alien vegetation.** The tops and landward slopes of foredunes are often colonized by alien invasive vegetation. In the event of fire, such vegetation is often less resistant than the indigenous plant species and would leave large areas exposed. This will increase the vulnerability to wind erosion and the formation of blow-outs. For ecological reasons, it is also recommended that the management plan includes a programme to remove alien invasive vegetation and to establish indigenous coastal dune vegetation.

- **The provision of a sea view.** Although not an important aspect of the biotic environment, the aesthetic benefits of providing the properties with a sea view should be considered in the development of the management plan where possible. This can be achieved by limiting the growth of the dune height to the set minimum height by preventing blow-outs and by cropping the dune vegetation during the appropriate season.

Specific management activities shown in the Figures on pages A5.1 to A5.3 are aligned to the seasons each year and are discussed below.

The ideal recovery time: SPRING (Figure on Page A5.1)

Dune vegetation recovery usually starts during spring and early summer when the soil warms up and plants grow if water is available. This allows for exposed sandy areas to be re-vegetated before the hot and dry summer season. There is also typically less impact from people at this time.

The key objective is thus to start the preparation of the Buffer Dune System for the summer holiday season by covering exposed sandy areas, closing off informal pathways and replacing or assisting recovery of dead or stressed dune vegetation.

Managers are encouraged to make copies of the form shown on Page A5.1 and to complete and sign the form and keep on file so-as to gain an understanding of the actual time and costs involved with the maintenance programme.

The Challenge: SUMMER (Figure on Page A5.2)

Vegetated foredunes often undergo a lot of abuse and stress during the summer months of November to March including the Easter Holiday period. People spend a lot of time on the beach during summer and the reality is that when the wind blows it is often more comfortable to seek shelter in the dunes and this is when informal pathways and exposed sand areas are started. The risk of fires also increases at this time.

People management through education (signage) and guiding (pathways and fencing) form the key management activities during summer. If an irrigation system is installed, irrigating the foredunes during the early hours of the morning will also assist in the ability of the dune vegetation to recover from human trampling and to prevent blow-outs and sand encroachment. Experience has shown that irrigation systems are broken if they operate during the day or night up to about 02:00. This could be due to the fact that people use these dune and back-beach areas for recreational activities from about 06:00 to 02:00 the next day and a sudden burst of water from an automatic irrigation system often results in irritation and subsequent vandalism.

Managers are encouraged to make copies of the form shown on Page A5.2 and to complete and sign the form and keep on file so-as to gain an understanding of the actual time and costs involved with the maintenance programme.

The Stormy period: AUTUMN & WINTER (Figure on Page A5.3)

During autumn and winter it is wise to monitor and evaluate the state of the Buffer Dune System, including the boardwalks at least once a month. Removal of the seaward fencing and signage along high energy coastlines prior to the onset of winter may save on replacement or repair costs since the seaward side of the foredunes are likely to be eroded during storms.

The effort to remove these in autumn and replace them just before the summer season is often much less of an issue than having to purchase or construct replacements. The latter often is not budgeted for and then never gets done, resulting in larger expenses later on.

Replanting vegetation during autumn and winter is unnecessary since plants tend to grow slowly and often don’t survive. Packing brushwood in exposed areas will prevent blow-outs and assist in the rehabilitation of the dune during spring and early summer.

Managers are encouraged to make copies of the form shown on Page A5.3 and to complete and sign the form and keep on file so-as to gain an understanding of the actual time and costs involved with the maintenance programme.

Public Education and Involvement

Although beaches are utilized by a far wider public than just the residents in the immediate vicinity of the beaches, it is very important that the local population is intimately involved with the planning, execution and maintenance of the planning, implementation and maintenance of Buffer Dune Systems.

An important part of this process is the development of a public education programme which will encourage the best use of the coastal resources. In order to do this it is also important that the public is aware of and understands the natural processes in the coastal environment. This will give them a far greater appreciation of the reasons for the Buffer Dune System and the need to protect and maintain vegetation on the frontal buffer dune.

Some of the ways in which the above-mentioned objectives can be achieved are as follows:

- Information meetings with Ratepayers' Association, businesses, schools and interest groups, particularly those located in the immediate vicinity of the specific beach.

- Production of an information brochure which outlines the beachfront management plan and gives details of the access paths, amenities, look-out points etc.

- Publishing an annual "State of our Beaches" report / article in a local newspaper during December where the activities as captured by means of the forms kept on file are discussed and future activities highlighted.

- The erection of a number of well-designed and durable information signs encouraging public co-operation and explaining what is being done and why it is being done.

- Maintenance of continuous close contact between the authorities and the public. The Local Authority must be seen to be responding to all reasonable requests and queries from the public.

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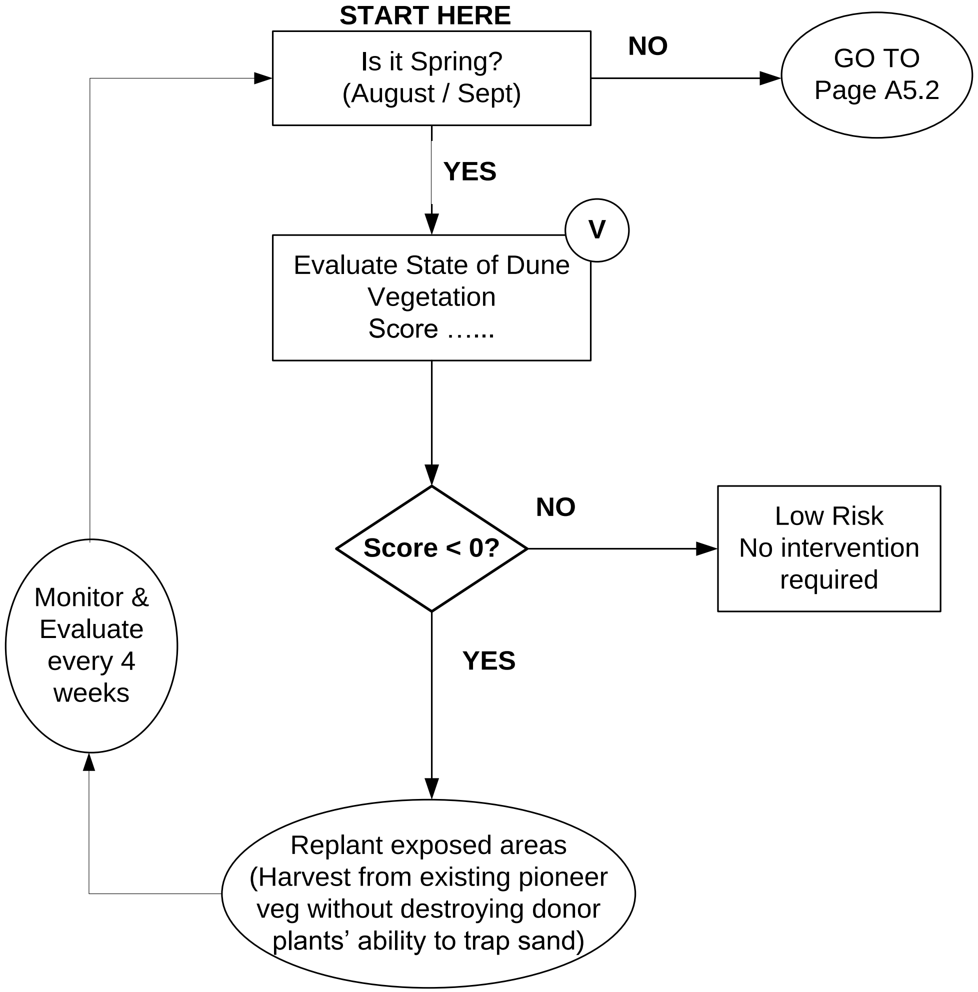
Decision Tree for the Maintenance of Buffer Dunes: SPRING

PAGE A5.1

V

Criteria for Early Spring	**Score Yes or No**
* Exposed sandy area? ……..……..-4	or +4
* Informal pathways? ……………….-3	or +3
* Burnt or stressed/dead veg?........-3	or +3

Note: Circle the appropriate score value



SITE: ……….……………………...
DATE: ……../…../……

ASSESSOR: ……………………………….

ACTION TAKEN: ...…………………………………

……………………………………………………………

Decision Tree for the Maintenance of Managed Buffer Dunes : SUMMER

PAGE A5.2

V

Criteria for Summer	Score Yes or No
* Exposed sandy area? ………..…..	-4 or +4
* Informal pathways? …………...	-4 or +4
* Burnt or stressed/dead veg?....	-2 or +2

Note: Circle the appropriate score value

AW

Criteria for Access Ways	Score Yes or No
* Formal accesses? ……………...	0 or -4
* Walkway above sand level?.	.+2 or -4
* Safe & easy to use?....................	+2 or -4

Note: Circle the appropriate score value

S

Criteria for Signage	Score Yes or No
* All required signage up & clear to read…..	+3 or -4

Note: Circle the appropriate score value

F

Criteria for Fencing	Score Yes or No
* Intact?	+3 or -4

Note: Circle the appropriate score value

SITE: ………..………………….…..
DATE: ….…./…..../……

ASSESSOR: …………………………….

ACTION TAKEN: ………………………………….

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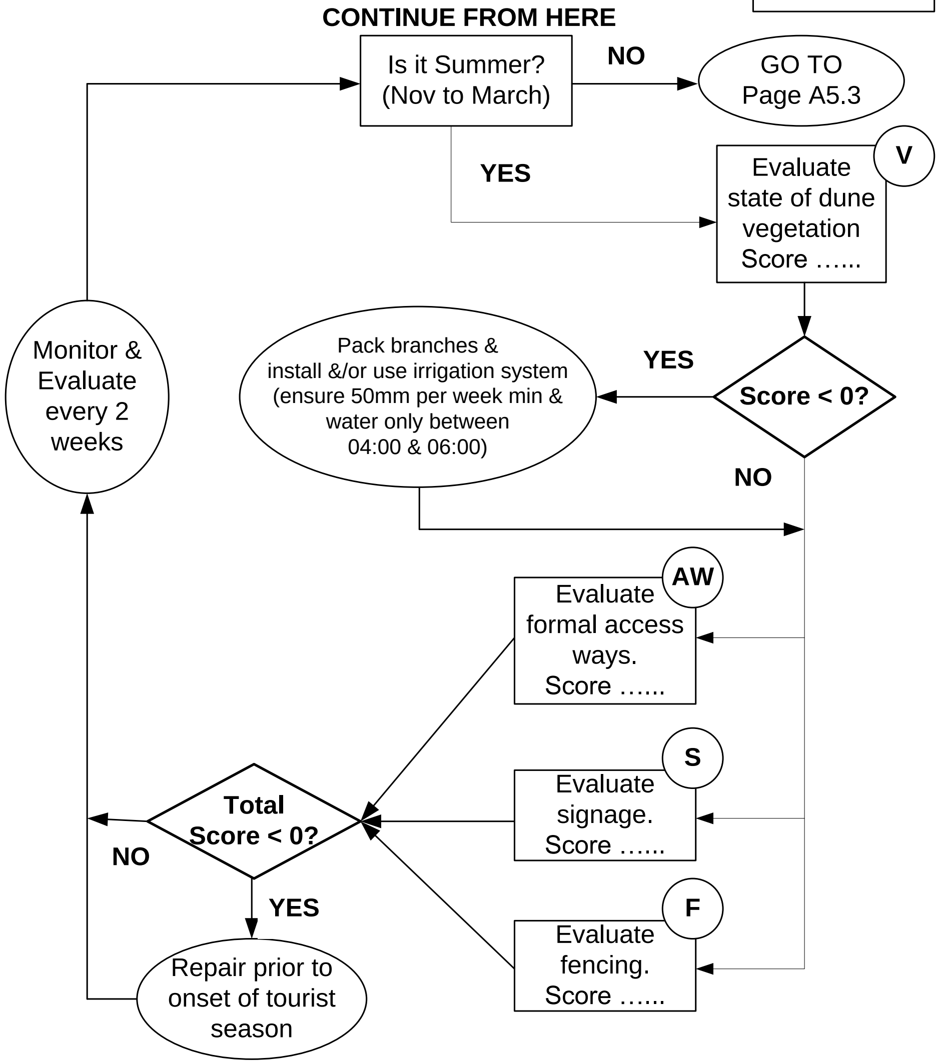


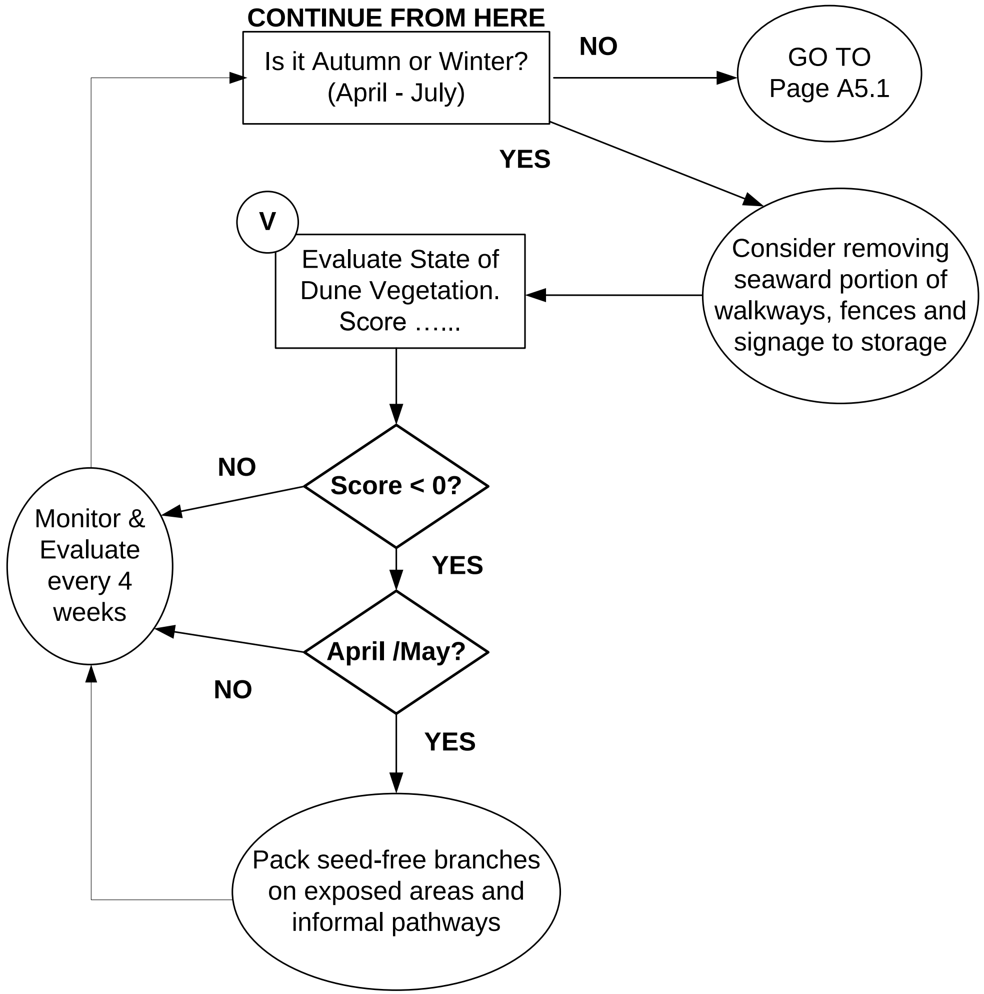
Decision Tree for the Maintenance of Buffer Dunes: AUTUMN / WINTER

PAGE A5.3

V

Criteria for Autumn	Score Yes or No
* Exposed sandy area? …………..-1 or +1	
* Informal pathways? ……………..-1 or +1	
* Burnt or stressed/dead veg?.......-1 or +1	

Note: Circle the appropriate score value



SITE: ………..…………………...
DATE: ……../…..../……

ASSESSOR: ………………………………

COMMENTS: …………………………………………

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