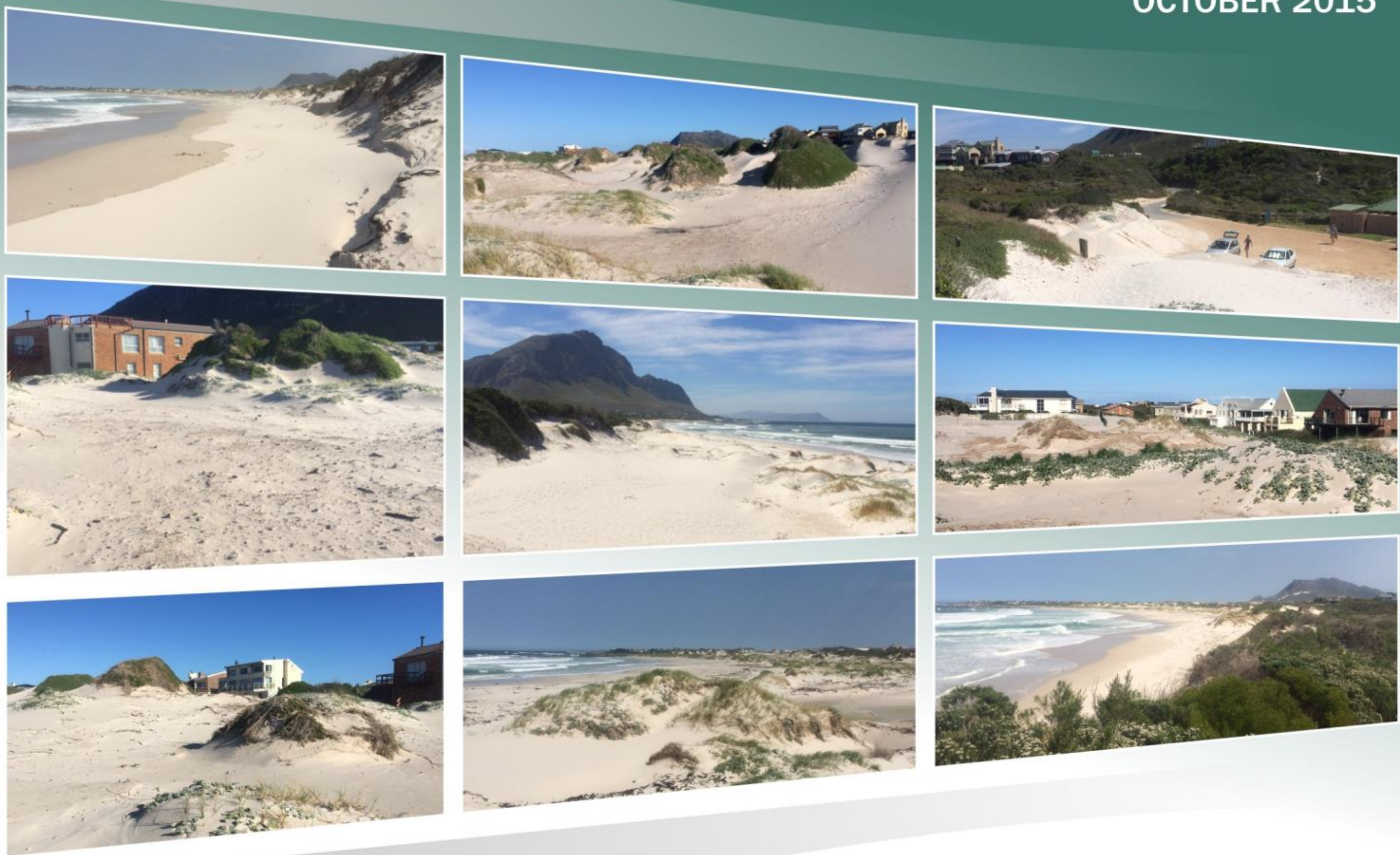
Betty's Bay Beachfront Management Plan

Prepared for:
OVERSTRAND MUNICIPALITY
the
Betty's Bay Ratepayers' Association
and the
Betty's Bay Dune Interest Group
by
LAURIE BARWELL & ASSOCIATES

OCTOBER 2015



BETTY'S BAY BEACHFRONT MANAGEMENT PLAN

Submitted to:

Overstrand Municipality, the Betty's Bay Ratepayers' Association and the Betty's Bay Dune Interest Group

Prepared by:

Laurie Barwell

Acknowledgments:

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Note: Photographs by L Barwell unless otherwise indicated

Frontispiece: Betty's Bay Beach (Photo: L Barwell - KiteCam February 2015)

The existing hummock dunes can form the core of a managed foredune at Betty's Bay (Photo: 23 September 2015)

SCOPE OF THIS REPORT

The Overstrand Municipality in partnership with the Betty's Bay Ratepayers' Association appointed Laurie Barwell & Associates (LB&A) to develop a Beachfront Management Plan for the beach and the foredune system at Betty's Bay.

The focus of this report is the area located seawards of the public parking area and municipal ablution facility, Moraea Road and Nerine Crescent. The study area comprises of a total alongshore distance of approximately 700 m.

The latest information, including available aerial images and a topographical survey, was used to quantify the dune and beach changes over the post development period 1977 to 2015. From the analysis it was concluded that the beachfront underwent a series of management interventions in the past. From a totally natural open beach in 1937 with a berm-overwash lagoon to a totally managed stabilized beach, foredune and backdune area by 1987. This was associated with the development of the infrastructure for the development of the beachfront area.

For the period 1987 to 2015 the upper beach (with the wetline used as proxy) was dynamically stable showing a seasonally horizontal positional fluxuation within a band of up to 25 to 35 metres over the 38 year period.

However, for the period 1987 to 2015 it is seen that wind-blown sand moved landwards off the beach, foredunes and the area immediate landwards of the natural foredune. The aerial photo analysis over the period shows that the edge-of-vegetation line advanced landwards onto the public parking area, Nerine Crescent and Moraea Road 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 a desired buffer dune system are put forward for the study area.

It is concluded that Betty's 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 (or exits) the system from adjacent areas and that any sand blown landwards off the beach and foredune is effectively lost to the natural littoral system. This compromises the function of the foredune as a natural buffering system between the sea storms and the natural assets (eg principally the freshwater backdune wetlands) and development (eg public amenities, infrastructure and private property).

The May 2015 topographic survey shows that there are currently low lying areas in the blow-out channels amoungst the hummock dunes where seawater from a high storm surge could overtop into the backdune wetland. This could change the essentially freshwater ecosystem to a saltwater regime.

The assessment of the current situation confirmed the need for a beach and dune management plan for the study area. Managing the buffer system is important to protect the Betty's Bay system from immediate storm sea impact and the effects of climate change in future. Of particular importance and a priority management objective is to return the 'lost' beach and foredune sand to the beach and to establish and maintain the buffering integrity of a managed foredune at a higher level and larger volume than at present so-as to keep the sand within the dynamic littoral zone.

Effective management of the storm water run-off in the backdune area along Nerine Crescent, Moraea Road and the parking area is also of importance. The reinstatement of a storm water detention area is therefore recommended.

The Management Plan allows for the reinstatement of the public parking area to its previous size and the establishment of a landscaped backdune grassed verge as an amenity. The possibility of constructing a raised boardwalk and viewing platform with access for disabled persons also becomes possible. A detailed phased implementation programme is proposed. If implemented properly the proposed actions will prevent the influx of sand into private property along Nerine Crescent and Moraea Road. 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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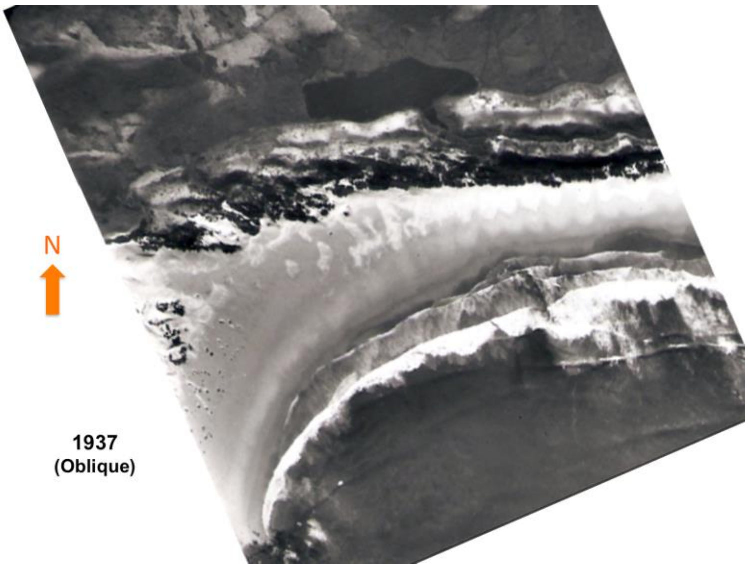
Figure 1: Locality Map (Google Earth™)



Betty's Bay: The 1937 photo shows a wide beach, beach berm and wash-over lagoon

1 INTRODUCTION

On-going challenges associated with managing the influx of wind-blown sand off the beach and dunes onto the municipal road infrastructure, public amenities and the private properties located along Nerine Crescent and Moraea Road at Betty's Bay have been experienced over a long period.

To resolve the situation the Betty's Bay Ratepayers Association in partnership with the Overstrand Municipality appointed Laurie Barwell & Associates (LB&A) to develop a Management Plan for the beach and the foredune at Betty's Bay. As is proved at, for example, Lappiesbaai (Stillbaai), Pringle Bay and along the Table View (Milnerton) beachfronts, the implementation of a well-designed management plan can turn a costly liability into an attractive asset.

1.1 Study area

Betty's Bay is located within the Overstrand Municipal area near to the coastal towns of Kleinmond and Pringle Bay at the southeastern edge of False Bay near Cape Town in the Western Province, Republic of South Africa (Figure 1)

1.2 The problem

The actual area of concern is the interface between the dynamic beach and the natural foredune at the main beach at Betty's Bay. As can be seen on the 1937 oblique aerial photograph (Appendix 1), prior to development the beachfront consisted of a wide sandy beach, a back-beach wash-over lagoon and a corridor of vegetated dunes (upon which houses are built today). The natural outlet from the extensive coastal wetland system that typifies Betty's Bay was located on the western side of the beach. The outlet from Malkopsvlei has essentially remained unchanged flowing between two high dune ridges and onto the beach at the eastern side of the beach.

Following the development of Betty's Bay into a large coastal town, the western wetland outlet was formalised, the beachfront stabilized and infrastructure such as roads and other municipal services established. The beachfront now consists of fixed dunes, coastal wetlands, a public car park, ablution facility and private houses.

From available aerial photographs it can be seen that a degree of beachfront management had occurred up to the late '80s but no formal management plan exists. The essence of the approach was to establish vegetation and maintain this to prevent wind-blown sand encroachment. This is depicted in the 1987 aerial photograph (Appendix 1). That situation is in contrast to the 1988 Management Plan for the adjacent coastal town of Pringle Bay where a formal plan was drawn up by the CSIR in 1988 (CSIR, 1988) and partially implemented with success in 1989. An updated management plan for Pringle Bay was completed in 2015 (Barwell, 2015).

Much of the management approach and practice detailed in the CSIR (1988) report is directly applicable to Betty's Bay and can (and should) be used as reference for implementation of the management plan for Betty's Bay.

As can be seen on the 1987 aerial photo (Appendix 1), a wide vegetated foredune system existed seaward of Nerine Crescent, Moraea Road and the public parking area. At that time sand blown off the beach during the spring and summer southeasterly winds was trapped within the foredunes close to the high water mark. However some blowouts in the foredune are noticeable on the 1987 photo. As can be seen on the Google Earth™ aerial images for 2005, 2011, 2013 and 2015, the exposed sand area gradually increased landwards and the current situation is very similar to that which existed in 1977 prior to the establishment of vegetation along the beachfront.

Wind-blown sand currently (2015) blows off the beach, through the blowouts in the hummock dune area and has resulted in the formation of mobile dunes that now reach levels of up to 10m above MSL in places. These dunes are slowly but surely impinging on the houses along Nerine Crescent and Moraea Road, the municipal ablution facility, the car park and the adjacent backdune wetland all of which are threatened with inundation by the advancing wind-blown sand.

1.3 Approach and process

The needs and focus of the management plan were determined through informal and formal consultation with a selection of people including current beach users, the Betty's Bay Ratepayers' Association and officials of the Overstrand Municipality.

It was concluded that there is a definite need and urgency to prevent the dunes from further advancing onto private and public property as well as into the backdune wetland. A further need was expressed for more parking and easier access to the beach via formalised pathways. A request to look into the possibility of providing easier access for disabled people was noted.

The requirement to consider the effects of climate change and specifically the impact of an increase in the sea level and storminess was emphasized.

The latest information, including available aerial images and a topographical survey was considered and used to quantify the dune and beach changes over time. Observations by the Consultant and his associates as well as knowledgeable local residents during occasional site visits over a number of years contributed to the available body of knowledge.

2 PHYSICAL ENVIRONMENT

2.1 Introduction

In order to ensure that the correct developmental and management decisions are taken and implemented, it is important to have a basic understanding of the physical environment at the study site. In particular, this involves having knowledge of the established biophysical processes and being able to predict the environmental consequences of management or developmental actions.

The coastline and foredunes at Betty's Bay are influenced by a complex interaction between several physical and biotic components. However it is the littoral and cross-shore sediment movement, the potential for the rip current channels to move alongshore, the prevailing wind regime and associated wind-blown sand budget that are most relevant to the solution. These aspects are discussed below.

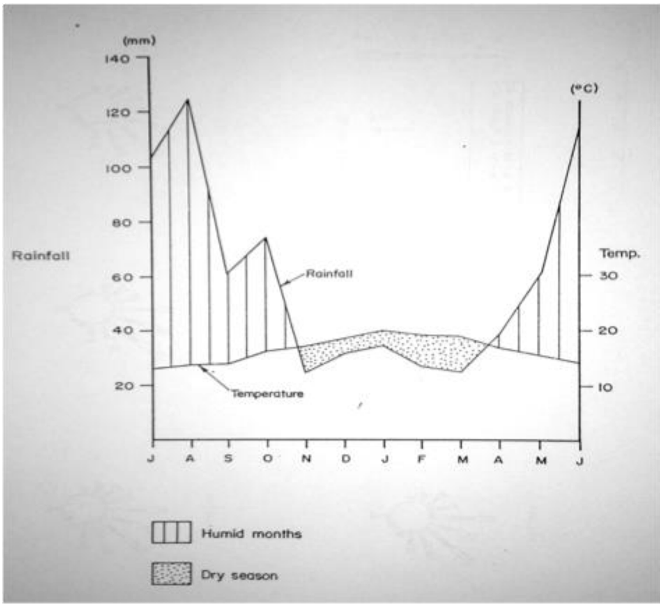


Figure 2: Climate diagramme for Betty's Bay (Heydorn & Tinley, 1980)

The climate at Betty's 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 southwestern Cape reflects a unimodal winter peak and summer dry season. The months with the highest recorded rainfall are June, July and August. (Boucher, 1978).

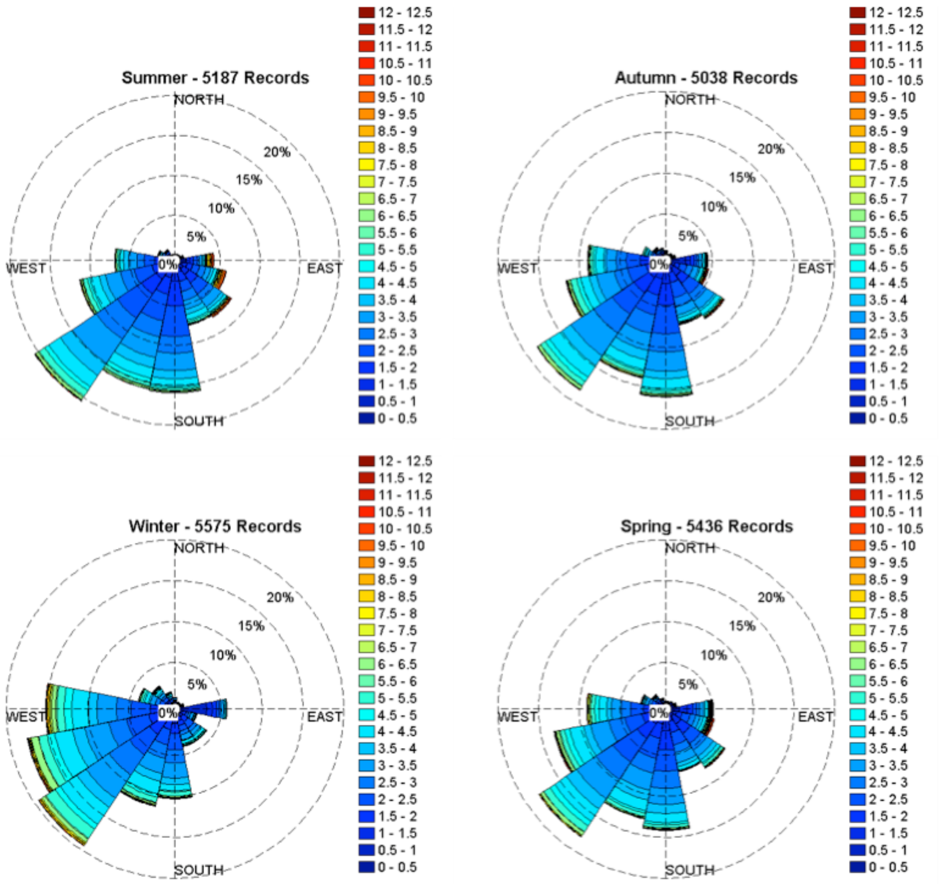
The monthly average temperature and rainfall data are depicted in a so-called climate diagramme (Figure 2). A humid period extends from April to October (where the rainfall line is above the temperature line). The arid period extends from November to March each year.

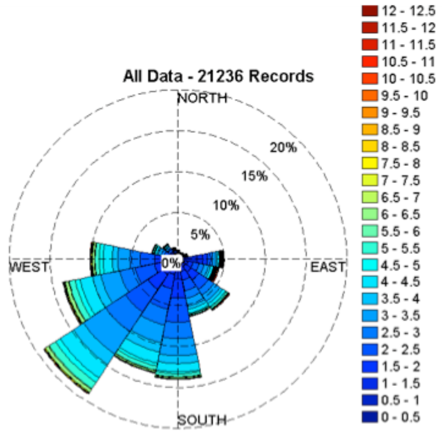
The implication of this information is that planting of dune vegetation in the dry period (November to April) should be avoided if no irrigation system is available. When relying on rain-fed 'gardening', it is clear from Figure 2 that the best time to establish dune vegetation is typically in August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

2.2 Coastal processes and the nearshore sediment budget

The small half-heart shaped bay at Betty's Bay falls within the larger log-spiral shaped Bay that extends from Cape Hangklip to Danger Point at the eastern edge of Walker Bay as can be seen on the locality map (Figure 1).

The physical processes that have shaped the bay and coastline are governed by the sea swells reaching the beach and the resultant longshore and cross-shore currents, the availability of sediment within the beach and dune system and the effect of prevailing winds that blow obliquely onshore. The availability of sediment in the nearshore and onshore areas plays a significant role and it is this quantified interaction of the movement of the available sediment by nearshore currents and the wind-blown sand potential that is termed the local sediment budget.





Period	1960-01-02 to 2014-11-29
Station	VOS data: Off Betty's Bay
Position	34 to 34.9 S, 18 to 19.9 E
Instrument Depth	0 m
Water Depth	0 m
Instrument Type	VOS
Records	21236

Figure 3: Deep-dea wave regime off Betty's Bay (source: SADCO (CSIR))

The prevailing deep sea waves that arrive from the south-western sector (Figure 3 and CSIR, 2014) are refracted (bent) around the point at Cape Hangklip and then further locally by the reefs and rocky promontory at the south-western end of Betty's Bay beach. The wave energy and induced alongshore currents shape the soft sandy coastline to form the typical half-heart bay resulting in a coastline with an average west-southwest / east-northeast orientation.

The wind rose for summer for the area at Betty's bay is included in Figure 4 since the local southeasterly winds generate large wind-waves that also shape the beach. The southwestern side of the bay will experience cross-shore sediment movement due to the wind-waves. An alongshore current and southwestward alongshore sediment movement is expected to occur and could be the source of the wider beach along the western side of the bay.

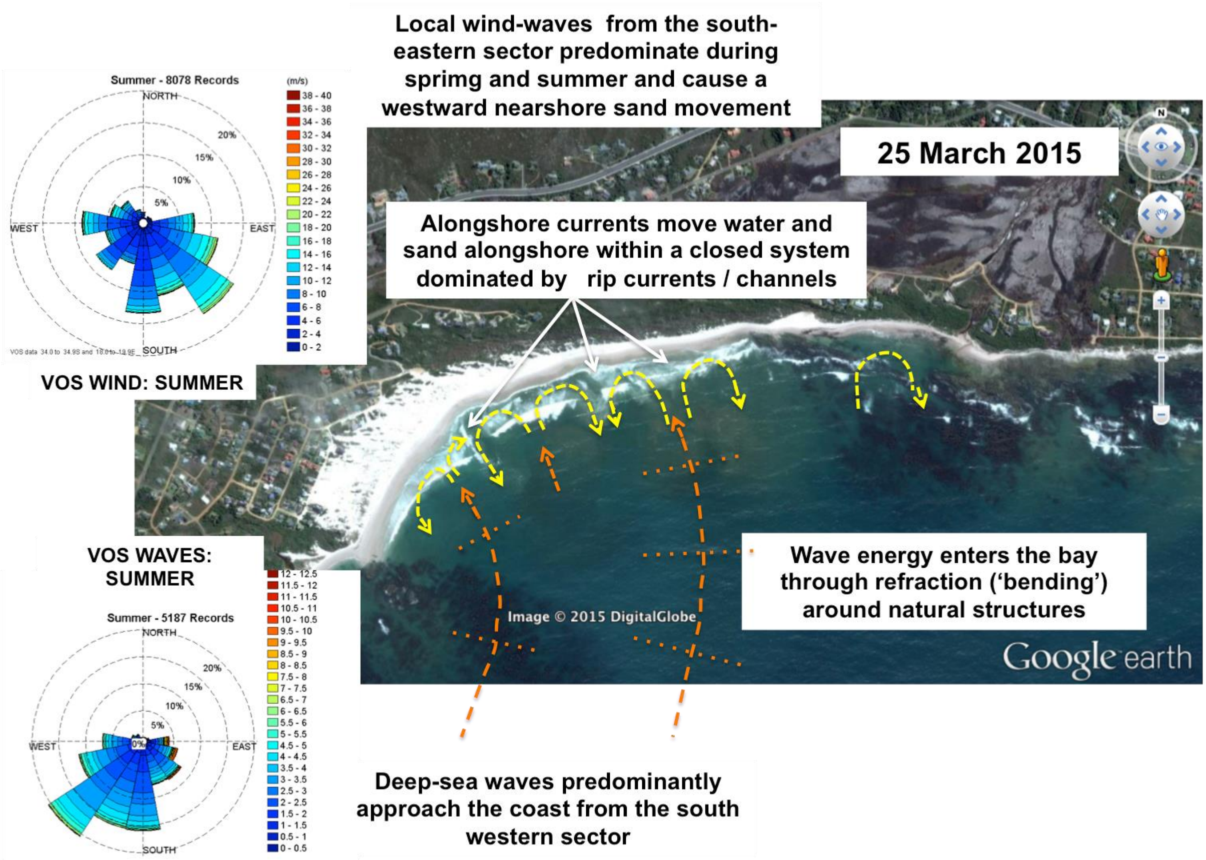


Figure 4: The nearshore currents are caused by both deep-sea wave energy and local wind-waves

From the series of available aerial photographs and Google Earth™ images it can be seen that a number of rip channels occur along most of the beach. These form in summer and winter seasons. A summary of the typical nearshore currents is depicted in Figure 4. By implication there is no dominant longshore current and associated sediment movement and the configuration is typical of a closed system pocket beach where the existing sediment is continuously recycled amongst the foredunes, beach and nearshore areas, no significant 'new' sediment (sand) enters or leaves the system. The existing volume of sand in the system is therefore finite and should be seen as a scarce resource. As can be seen in Figures 5 & 6, the traces of the historic wetline over the years show that the horizon position remained within a band of 35 m. This shows that there is no erosional or accreting trend and the only variation is due to the changing beach dynamics as the coastal processes differ for the various seasons and often in response to the formation of a rip channel.

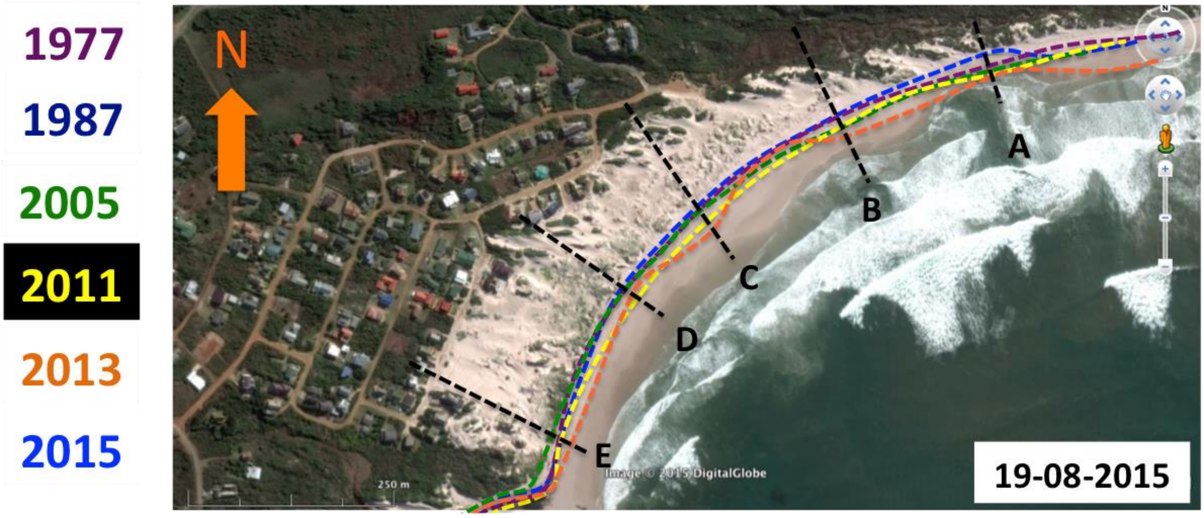


Figure 5: The horizontal position of the observable wetline (or wave run-up line) has moved within a band of 25 m to 35 m over the 38 years.

Concern that the dune erosion observed on the eastern side (close to Section A on Figure 5) was the result of the coastline retreating over time was expressed during a public consultation workshop. An analysis in more detail of the area to the east of Section A is shown in Figure 6. It can be seen that the position of the edge-of-vegetation line had fluctuated in a band between 8 m and 10 m. The dune directly west of the Malkopsvlei outlet had moved landwards by 20 m from the 2005 position. This is to be expected as the water from the outlet can be observed on the aerial images to meander within that 'mouth' area.

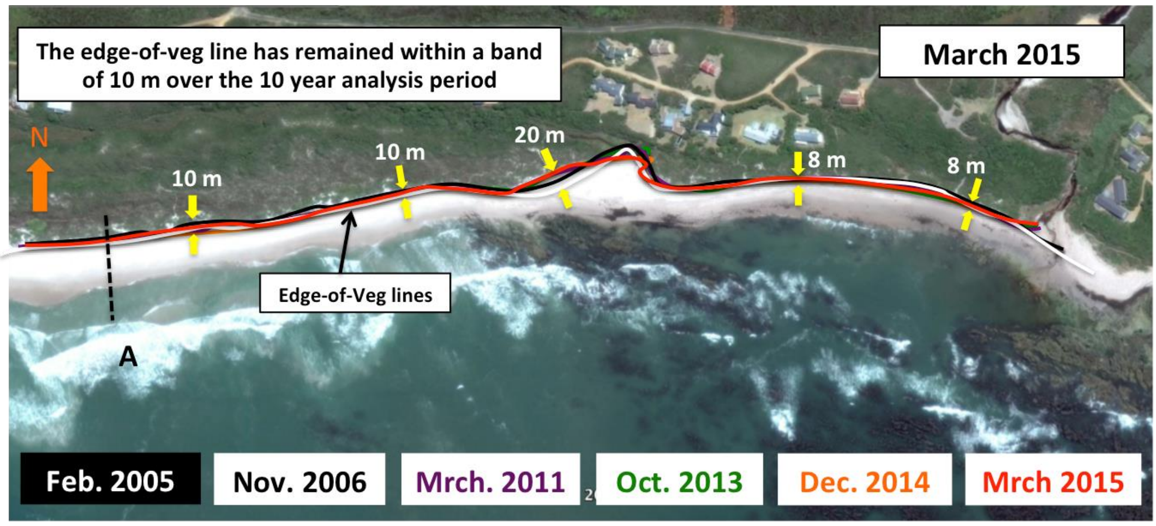


Figure 6: No erosional or accretion trend in the horizontal position of the edge-of-veg line within the eastern side of Betty's Bay beach is seen.

2.3 Wind climate and aeolian sediment movement

The seasonal wind roses for the area are shown in Figure 7 and were obtained from the South African Data Centre of Oceanography (SADCO) hosted at the CSIR. It can be seen that 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 (alongshore) winds occur throughout the year and the velocity range remains relatively constant during spring, summer and autumn but are dominant during winter.

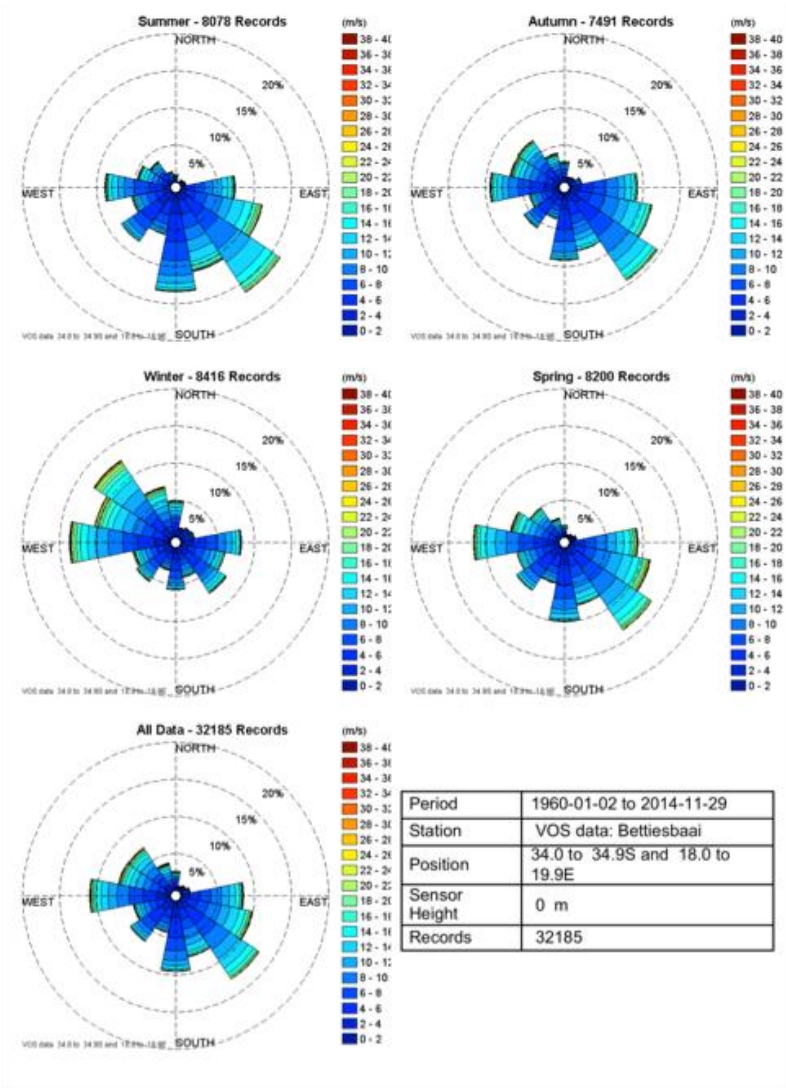


Figure 7: Seasonal wind roses for the offshore area at Betty's Bay

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.

The VOS wind data were analysed and a set of aeolian creep diagrams (Figure 8) was deduced for the exposed beach and backdune areas at the study site (after Swart, 1986). The aeolian creep diagrams 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, exposed surface under constant wind conditions. Since these criteria are seldom met in practice, only the potential transport rates are calculated. As found for Pringle Bay (Barwell, 2015) the actual wind-blown sand transport rates could be significantly higher due to the wind funnelling effect through blow-outs in dunes or around structures, for example.

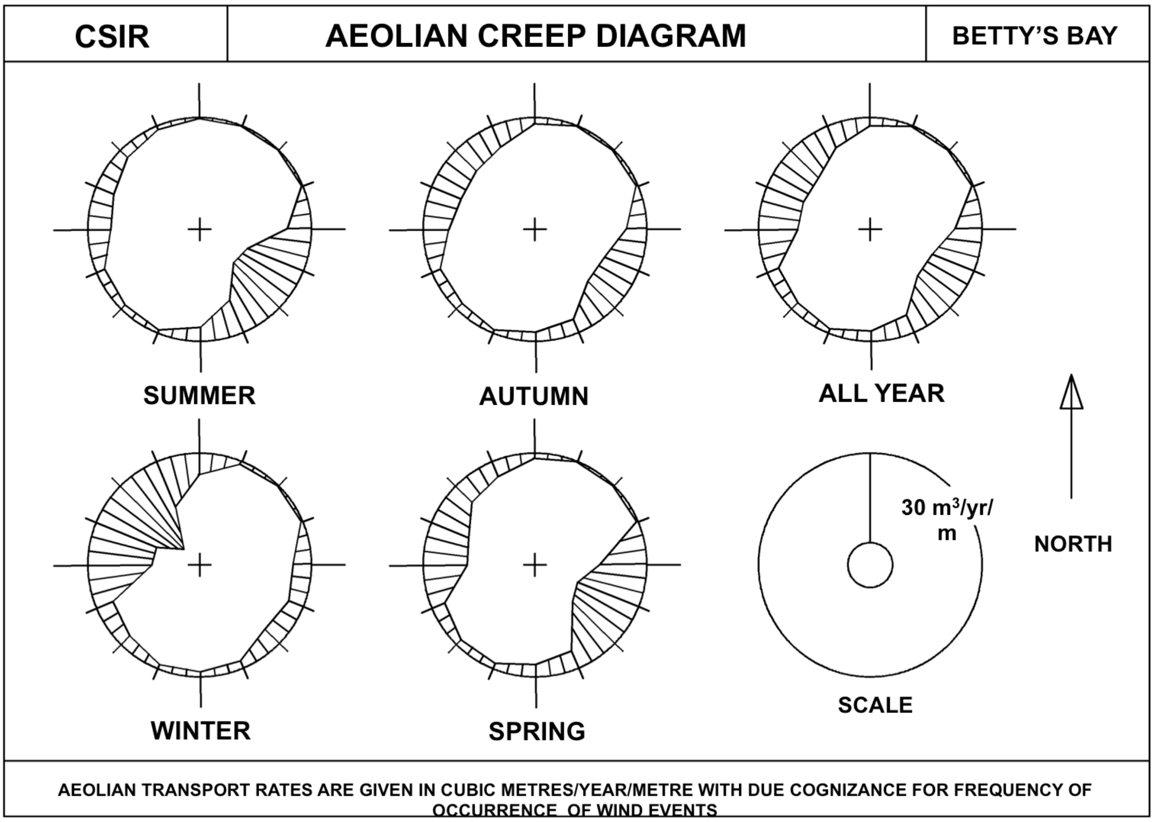


Figure 8: Aeolian creep diagrams for the area at Betty's Bay (CSIR)

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

Due to orientation of the coastline at Betty's Bay and the associated exposed beach area it is clear from Figure 8 and Table 1 that the south-easterly onshore winds have the potential to transport about 10.4 m^3/m/yr. as calculated for all seasons. Of course the potential will be a lot higher during the spring and summer months. However, the apposing northwesterly winds throughout the year (but especially in winter) have the potential to return 9.2 $m^3/m/yr$. back to the beach. Unfortunately a large percentage of northwest bound wind-blown sand is 'trapped' in large vegetated dunes and amongst the private houses and public roads. The high houses along the beachfront also have an effect on the north-westerly windfield and wind dynamics modelling done by Engineers have shown a drastic increase in turbulence (G van der Merwe, pers. comm.) and an associated reduction of effective ground level shear-forces thereby reducing the wind-blown sand transport potential towards the south-east (i.e. back onto the beach).

The orientation of the sand blowouts and the associated dune slip-faces confirms the dominant winds from the southeasterly sectors. The actual net transport rates can only be determined through comparative analysis based on periodic topographic surveys.

Of importance for the buffer dune management at the study site is that a significant amount of sand can (and will) be blown off the beach and into the established foredunes when the beach is wide and the sand is dry. This has two implications (1) positive in that the area in front of the managed 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 destabilized (i.e. the dune vegetation removed). Maintaining the dune vegetation within the foredune system is therefore a critical management action. This is addressed in Section 7.

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

As introduced in the previous section, 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, 2002). As the sea level rises, existing topographic features (such as nearshore reefs and rocks) 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 a 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 becomes 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.

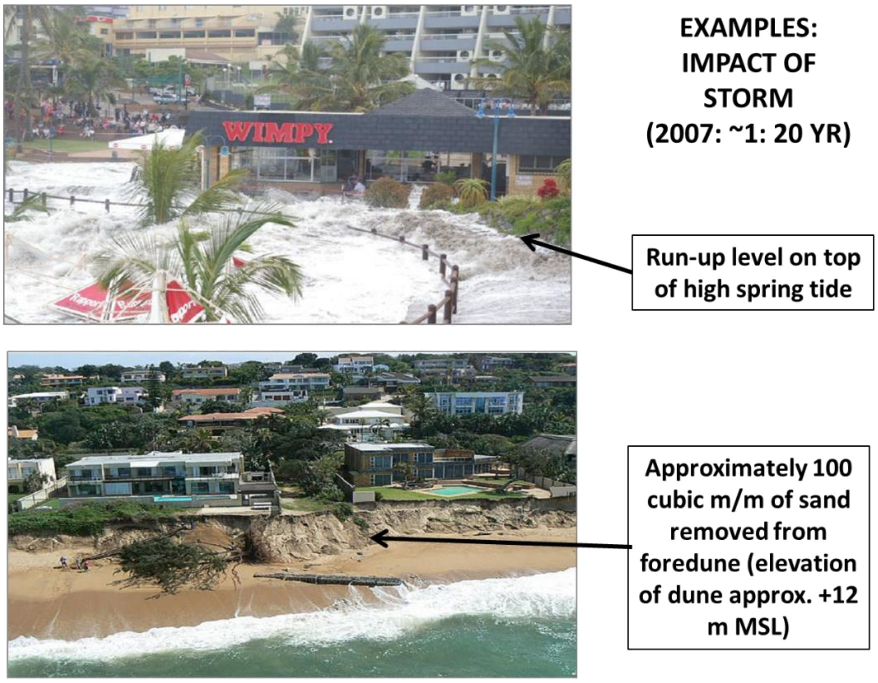
The main metocean drivers related to the above are thus waves and sea water levels (and to a lesser extent winds and currents).

The examples shown in Figure 9 indicate 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 9: Examples of the effect of a large storm coinciding with a high tide level

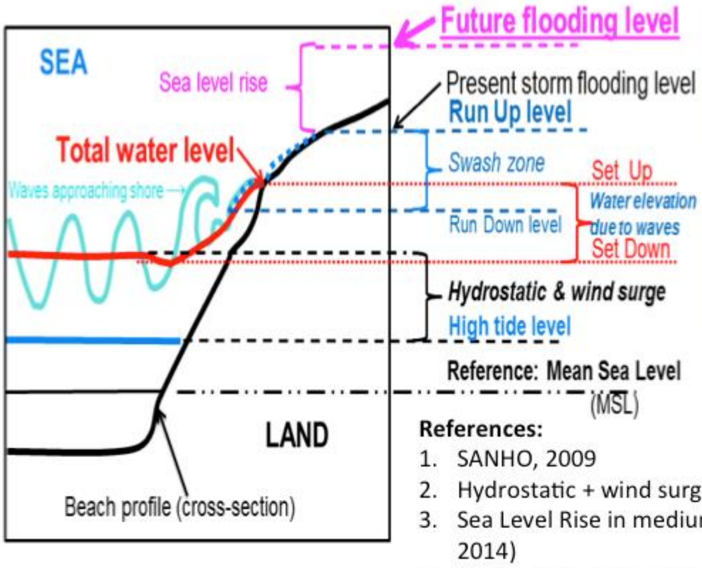
Figure 10 shows the extreme inshore sea water levels calculated for Betty's Bay (using the tidal information available for Hermanus at http://www.sanho.co.za) and combining the various contributing components as shown (CSIR, 2014). Thus, the figure shows the following increasing water levels relative 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). For the type of development and infrastructure at Betty's 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 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 level). Based on wave set-up and wave run-up modelling, the additional height so reached would be another 3.96 m in addition to the 'still-water' level calculated above as +1.84 m MSL at Betty's 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 + 3.96 m = + 5.8 m MSL. This level is also known as the Hazard Level. Rounding up, the recommended height of the top of the foredune is thus +6.0 m MSL.

HAZARD LEVEL (including climate change)



Haz level		5.8
RunUp[4]	3.96	5.8
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. Partially exposed beach – 1:30 yr (CSIR, 2014)

Figure 10: Estimated hazard level for 2050 at Betty's Bay

4 BEACH AND FOREDUNE STABILITY

As was discussed above, Betty's 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 streams and river. The sand on the beach and dunes is therefore a scarce resource and is continuously moved around within the confined bay 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

As was discussed in Section 2.2, the 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

An analysis of available aerial photographs (sourced from the South African Surveyor-general) and satellite imagery (available via Google Earth™) for the period up to 2015 was done.

The objective was to obtain information on the stability of the coastline at Betty's Bay over the chosen period post 1977 when (portions of) the foredune and beach were informally managed up to 1987. The images from 2005 to 2015 show the result of no (or little) formalized management. The images that were analysed are shown in Appendix 1. The results of the analysis are discussed below.

Figure 11 shows the 'edge-of-vegetation' line, which is relatively easy to observe on aerial images as the smoothed 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.

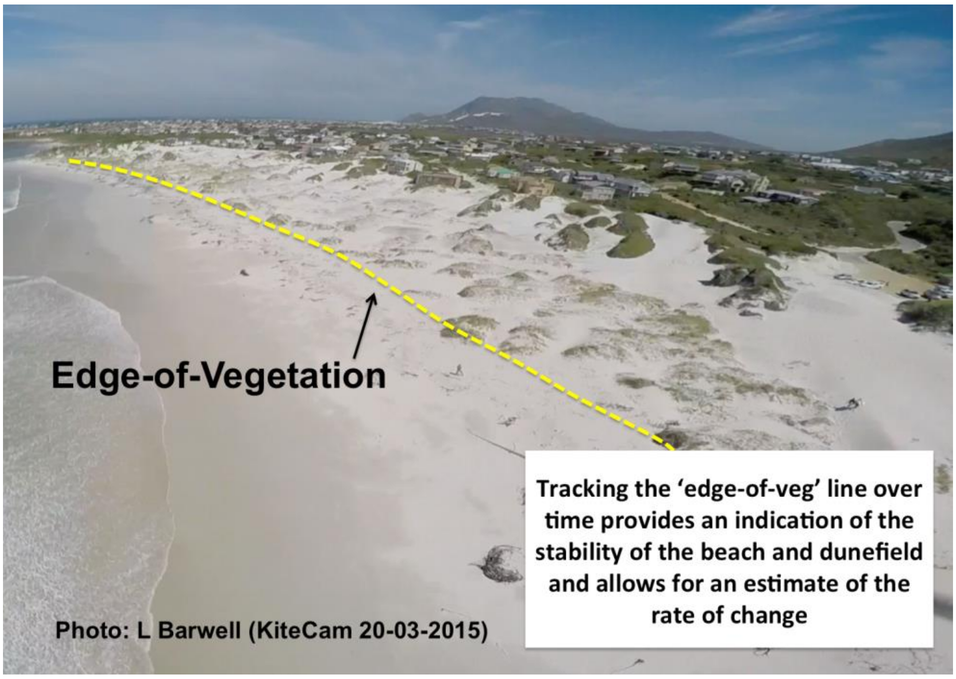


Figure 11: Definition of the 'edge-of-vegetation' line

A comparative analysis of the available images for 1977, 1987, 2005, 2011, 2013, 2014 and 2015 is shown in Figure 12. The 1977 line shows the 'edge-of-veg' line before any development and the 1987 line shows the situation at the end of the informal management period. Figure 13 shows the calculated horizontal variation of the 'edge-of-veg' lines compared to the baseline position of 1987 along the five reference lines (A, B, C, D and E) shown in Figure 12. The lines are overlain on the Google Earth™ image of 19 August 2015.

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 aerial photographs (1977 and 1987). The improvement in imaging technology in recent years has decreased this error band significantly to ±5 m for the Google Earth™ images from 2005. The 2015 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 12, it can be seen that the 'edge-of-vegetation' line at Lines A and B remained relatively unchanged during the stabilization period between 1977 and when the informal dune management programme at Betty's Bay reached a peak in 1987. Although a number of large blowouts remained unmanaged in the area to the east of the car park (Lines A and B). The position of the edge-of-veg at Lines A and B remained stable over the 38 years.

The foredune and back-beach areas seaward of Nerine Crescent, Moreae Road and the public car park at Lines C, D and E were successfully stabilized during the period 1977 to 1987. As can be seen in Figure 13, the edge-of-veg line moved seawards at an average rate of 17 m/yr. during the10-year analysis period.

Unfortunately this informal / unofficial management of the stabilized area changed and the area became destabilized at an average rate of 7 m/yr. over the 28 years between 1987 and 2015 as can be seen in Figures 12 and 13.

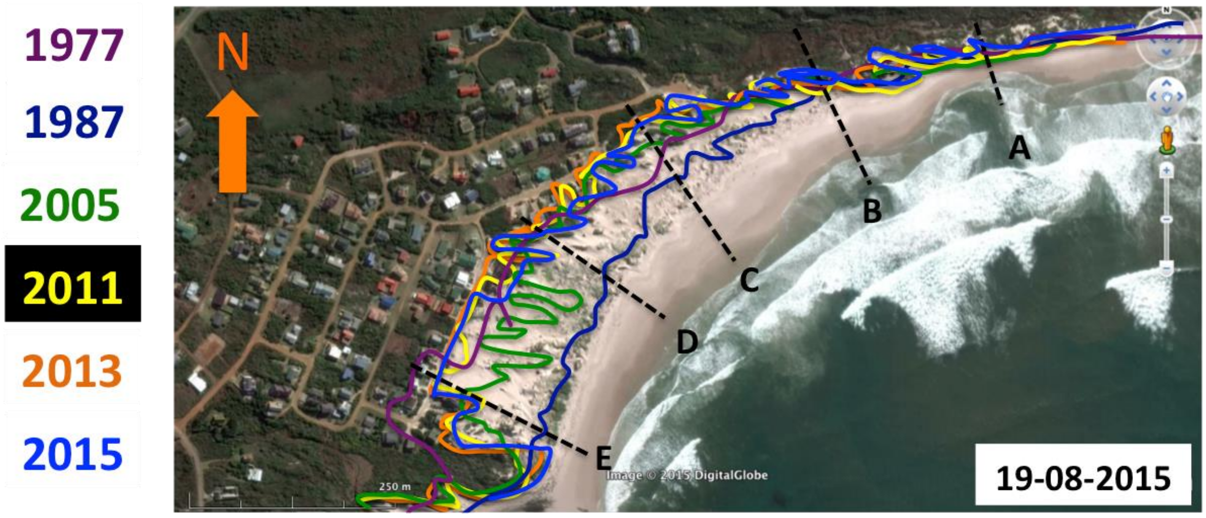


Figure 12: Positional change in the seaward 'edge-of-vegetation' line within the study area

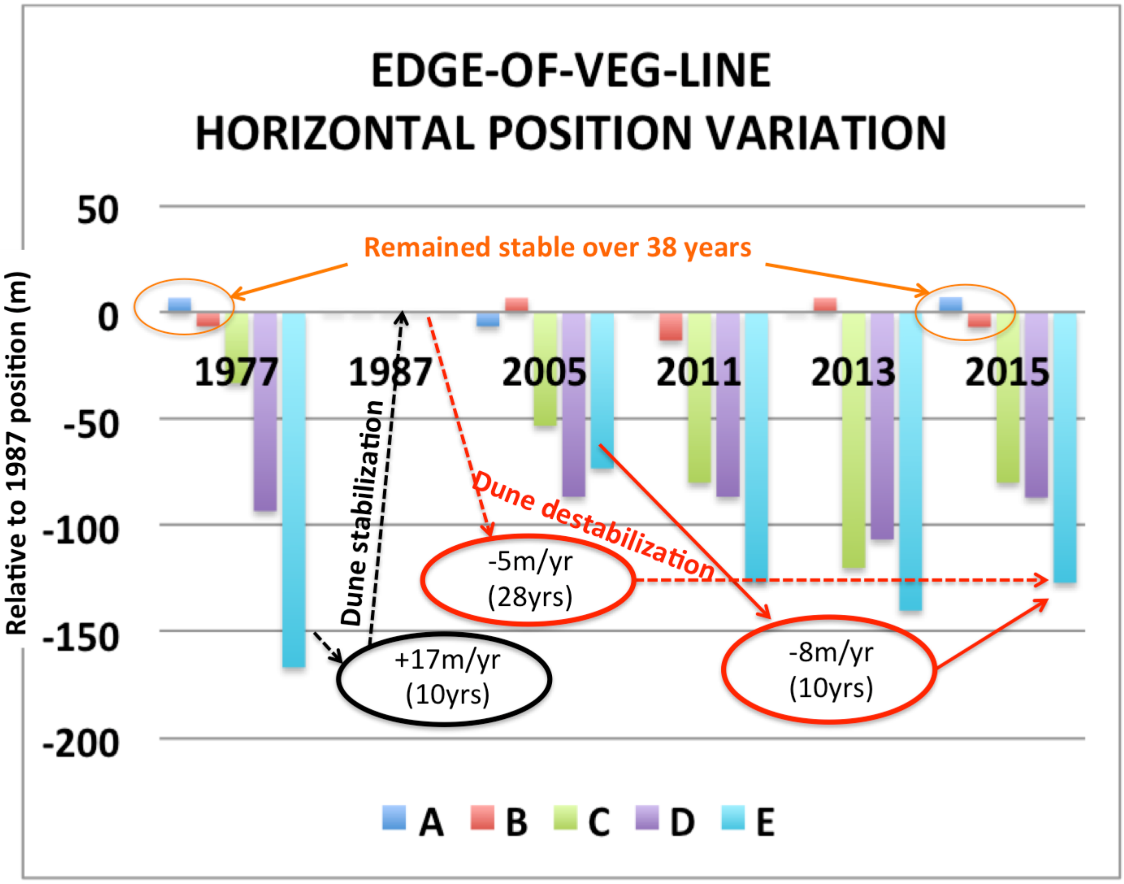


Figure 13: Horizontal variation in the position of the seaward 'edge-of-vegetation' line over the period 1987 to 2014 for positions A to D shown on Figure 8

4.2 Topographical surveys

The Overstrand Municipality commissioned a topographical survey of the management area at Betty's Bay. The survey was done in May 2015 and the data form the basis of this management plan. Ideally the same area should be resurveyed after the management plan is implemented and then at least again every 5 years.

The 2015 survey thus provides an excellent baseline for future post-management comparative studies. The positions of the survey lines are shown in Figures 14 and 15. The full record of the survey data is stored on a DVD and archived at the CSIR in Stellenbosch. The contour and topographical spot heights are given to MSL (Mean Sea Level).

Of importance is that the Google Earth™ image of 2 March 2015 (Figure 14), the KiteCam oblique photo taken on 20 March 2015 (Figure 15) and the topographical survey done in May 2015 provide excellent visual and quantifiable cross-reference data of the study area.

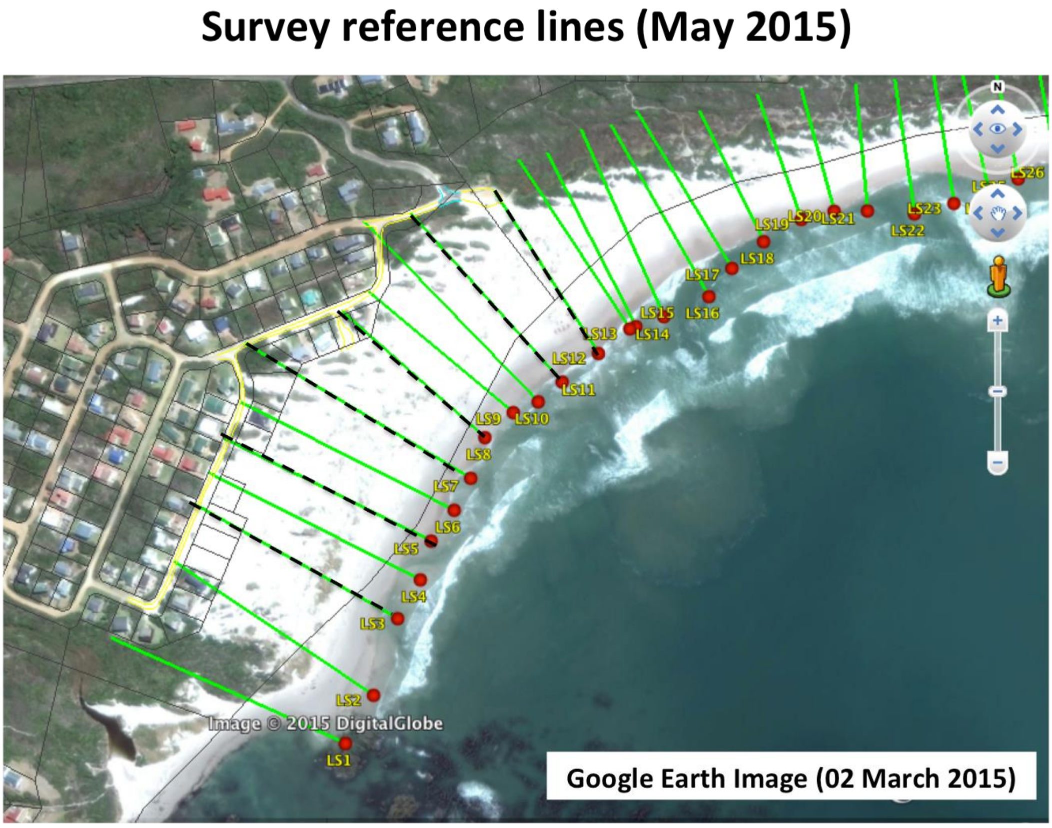


Figure 14: Position of the May 2015 survey lines (overlain on the March 2015 Google Earth™ image)

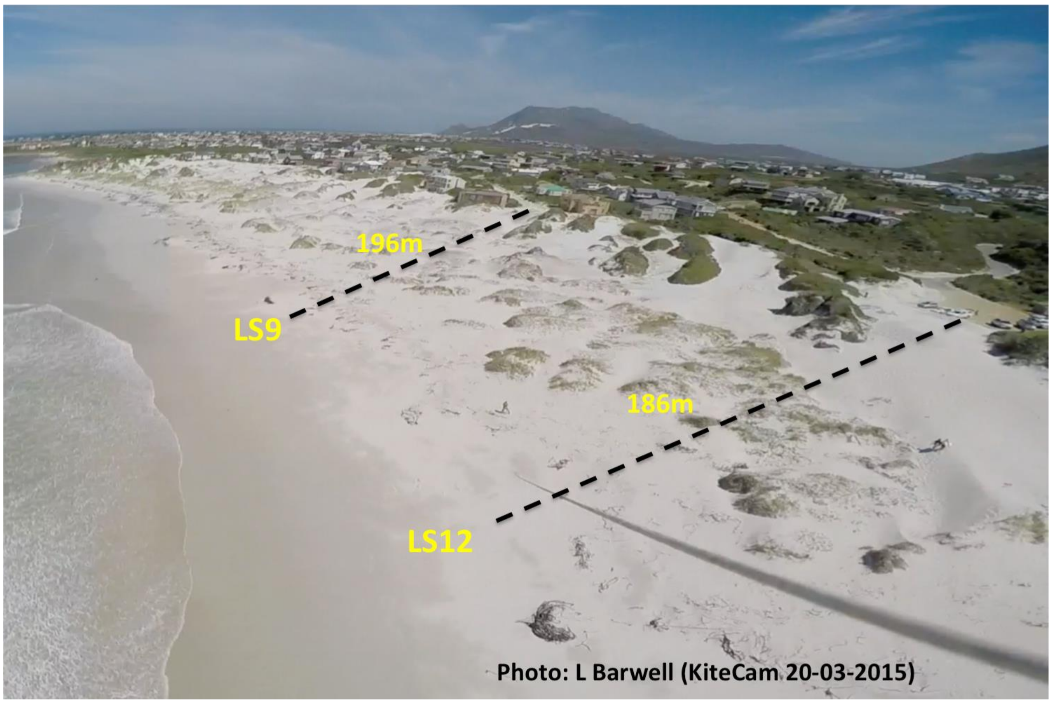


Figure 15: Oblique perspective of the positions of May 2015 survey lines LS9 and LS12

In Figure 16 the topographical heights as surveyed in May 2015 are plotted along Sections LS3, LS5 and LS7 (marked in black in Figure 14). The zero point along the x-axis is taken at the seaward edge of the road.

The following observations are of relevance:

- LS3: The current 'natural' foredune has two peaks at + 5 m MSL with a lower blowout deflated area at +3 m MSL. The total base width of the natural foredune is in the order of 50 m measured landwards of the edge-of-veg line that is taken as at +3 m MSL at Betty's Bay. The back dune reaches a level of +7 m MSL tapering down over a distance exceeding 50 m to +6 m close to the edge of the road (Nerine Crescent).
- LS5: The current 'natural' foredune has one peak at almost + 7 m MSL. The deflated areas are at +2 m and +3 m MSL. The total base width of the natural foredune is in the order of 40 m measured landwards of the edge-of-veg line. The back dune reaches a level of +8 m MSL tapering down over a distance of 50 m to +7 m close to Nerine Crescent.
- LS7: The current 'natural' foredune has two peaks at + 4 m and + 5 m MSL with a trough at +2 m MSL. The total base width of the natural foredune is in the order of 40 m measured landwards of the edge-of-veg line. The back dune reaches levels of +7 and +10 m MSL dropping steeply down to +5 m forming a flat area of about 30 m up to the edge of Moraea Road.

Figure 13 shows the cross-sections for LS7, LS9 and LS11. Sections LS7 and LS9 both end at Moraea Road. Section LS11 traverses the high dune seawards of the wetland.

- LS9: The current 'natural' foredune has peaks at + 5.5 m MSL with troughs at +3.8 and 4.5 m MSL. The total base width of the natural foredune is in the order of 40 m measured landwards of the edge-of-veg line. The deflation area is at +3 m MSL. The back dune reaches a level of +8 m MSL dropping steeply down to +4 m within the vegetated corner erf which has a narrow channel base at + 3.8 m MSL sloping up to a bank at +6 m MSL at the edge of Moraea Road which is at +4 m MSL.

- LS11: The current 'natural' foredune has peaks at + 5 m MSL. The total base width of the natural foredune is in the order of 20 m measured landwards of the edge-of-veg line. The deflation area is about 40 m wide and is at +3 m MSL. The back dune reaches levels of +6 and 9m MSL dropping steeply down to +5 m forming the existing wetland which has a narrow channel base at + 5 m MSL sloping up to a bank about 20 m wide at +6 m MSL at the edge of Moraea Road which is at +4 m MSL.

Figure 18 shows the cross-sections for LS11 and LS12. Section LS12 ends at the public parking area.

- LS12: The current 'natural' foredune peaks at + 5 m MSL. The total base width of the natural foredune is in the order of 20 m measured landwards of the edge-of-veg line. The deflation area is at +3 m MSL. The back dune reaches levels of +6 and +9 m MSL dropping steeply down to +5 m and +6 m MSL before sloping down to the car park.

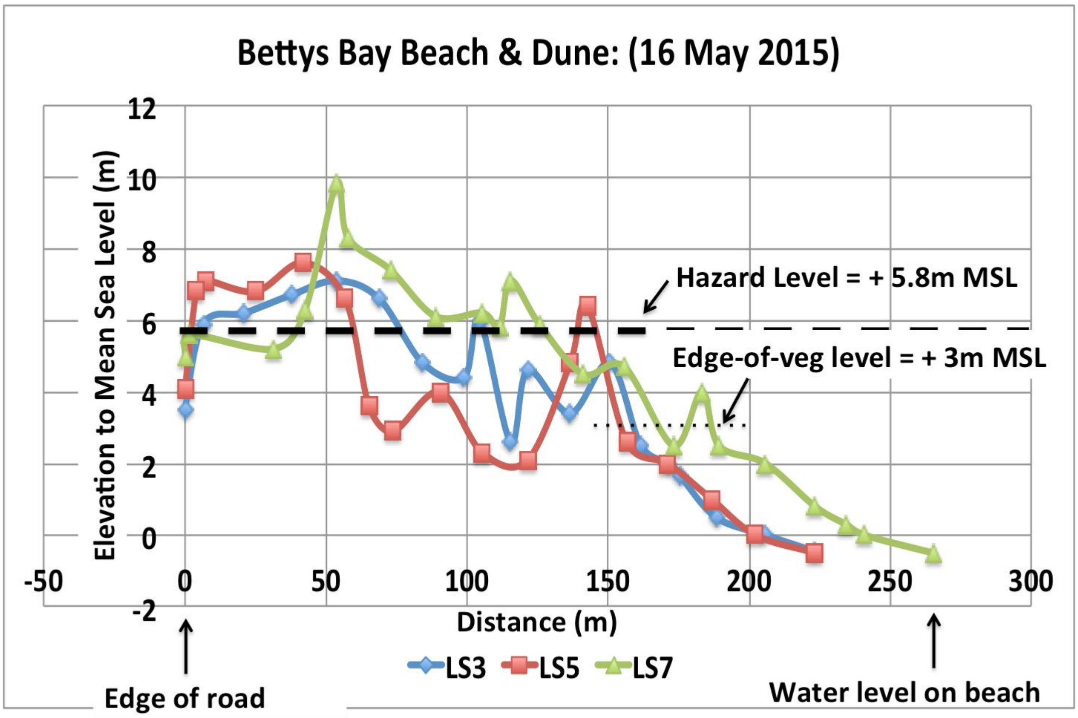


Figure 16: Cross sections LS3, LS5 and LS7 as surveyed in May 2015

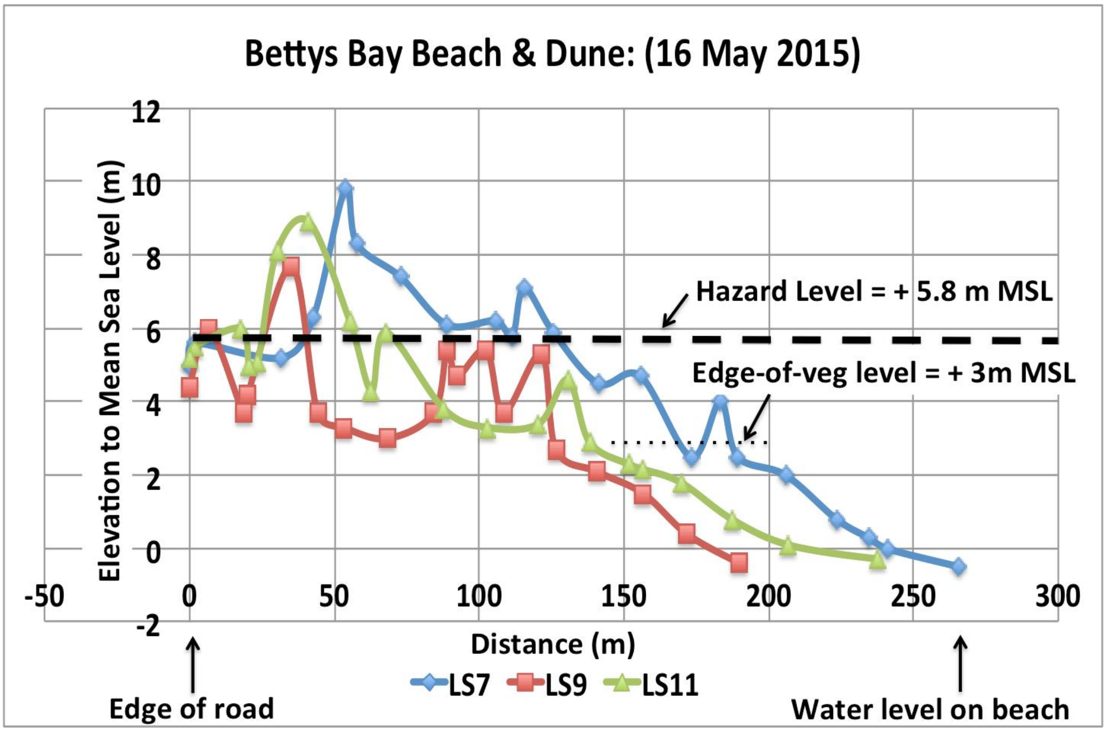


Figure 17: Cross sections LS7, LS9 and LS11 as surveyed in May 2015

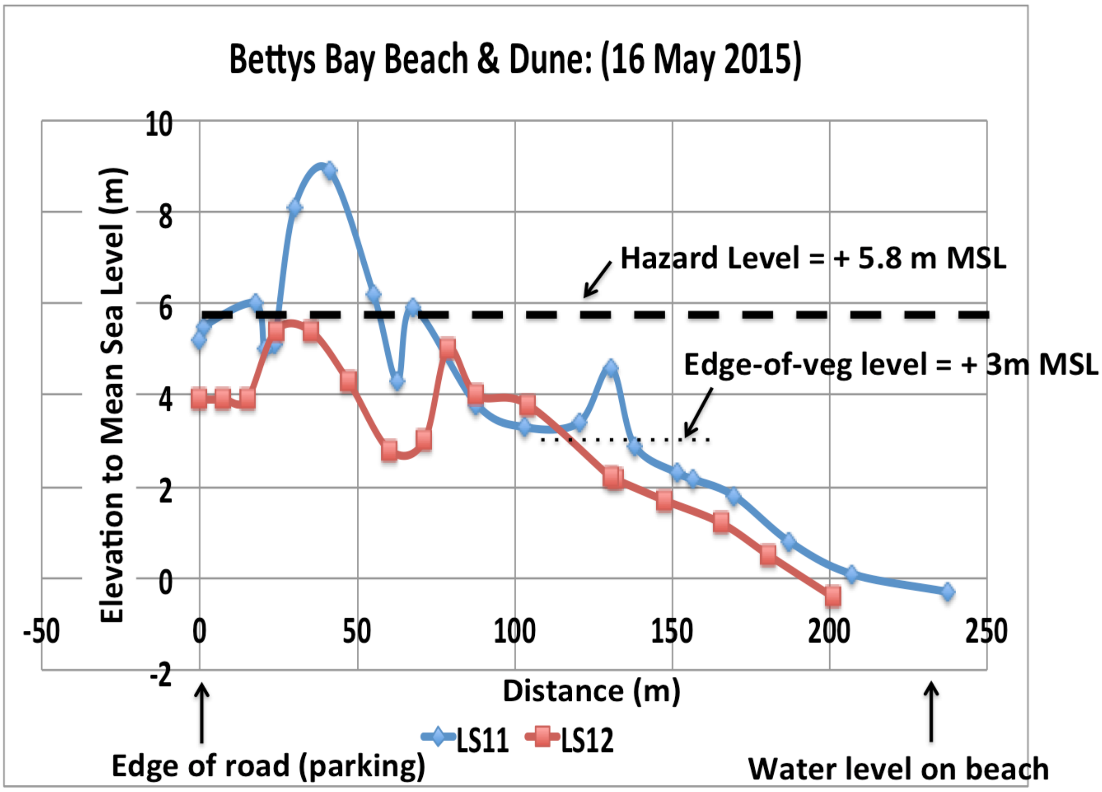


Figure 18: Cross sections LS11 and LS12 as surveyed in May 2015

4.3 Conclusion on the beach and foredune stability analysis

The 'unofficial' sand stabilization and management of the Betty's Bay backdune area between 1977 and 1987 was successful in keeping the beach sand within a functional foredune and preventing blow outs and subsequent movement of wind-blown sand north-westwards towards the developed area.

The integrity of the integrated beach, foredune, vegetated backdune and wetland systems was compromised in the period after 1987 and the 2015 situation is essentially similar to that in 1977 except that there would have been less sand trapped in the backdunes near to the roads and parking area.

The analysis of the coastal processes and sediment movement patterns facilitates a conclusion that Betty's Bay is a small half-heart shaped pocket beach / bay with a closed (and finite sediment resource) where no 'new' sand enters the system from adjacent areas. There is also no real evidence that alongshore sediment leaves the system other than possibly westwards due to a local longshore transport current generated by the prevailing south-easterly wind-waves.

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.

Unfortunately the opposite is also true should no or limited maintenance be undertaken. The measured (and observed) impact of the 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 short to medium term impact on the backdune wetland ecosystem, but also on municipal infrastructure (roads, parking areas, ablution facility and storm water management system) and the high value private properties.

As evidenced by the topographical survey data the existing natural foredune is in places lower than the current storm-surge hazard level of +5.4 m MSL.

It is thus possible for a high storm surge to wash over into the Nerine Crescent, Maraea Road and public parking areas if the situation remains unchanged. This would have a high impact on the existing backdune wetland system as well as cause damage via salt-water intrusion into municipal services as well as damage to private property.

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.

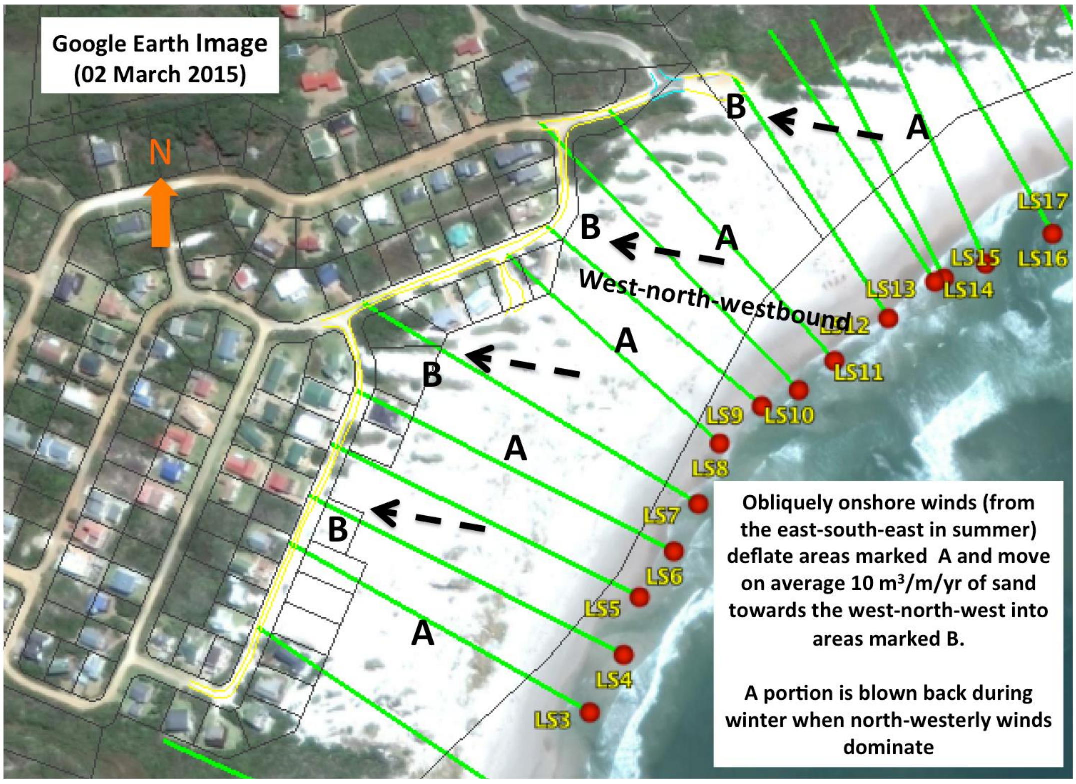


Figure 19: Wind-blown sand pattern within the study area

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 and is often the result of poor management.

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 10 m^3/m towards the northwestern 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 Betty's Bay.

6 FINDINGS AND CONSIDERATIONS

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

- The integrity of the natural foredunes along the beachfront is compromised and the system is thus unable to function as an effective buffer to prevent wind-blown sand from encroaching into the backdune areas.
- The volume of sand in the current foredunes is not enough to form an effective buffer against stormsea erosion and surges. This puts the backdune development, infrastructure and the natural wetland ecosystem at risk of seawater intrusion and storm damage.
- The 'edge-of-veg line' has moved landwards at an average rate of around 7 m per year over a period of 28 years due to a lack of active management of the foredune integrity since 1987.
- A net potential wind-blown sand movement rate of 10 $m^3/m/year$ towards the north-western sector is estimated for the study area. This means that the management plan and foredune design should cater for an anticipated annual volume influx of 10 m^3 per metre of beach width perpedicular to the wind direction. To manage this rate the vegetated foredune basewidth should not be less than 60 m. A further (positive) implication of the rate 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.
- To form an effective buffer against storm surges a foredune top level of at least + 6 m MSL should be maintained.
- The volume of sand 'trapped' in the high backdunes is a valuable resource for re-establishing an effective beach and foredune buffer ecosystem service and should be returned to the beach and foredune system.
- Reshaping the backdune area creates the opportunity to establish an attractive and well functioning backdune ecosystem comprising of wetland habitat as well as functioning public amenities in the form of parking, stormwater management, easy pedestrian access to the beach, educational opportunities and job creation (as ongoing maintenance is required).
- Sea Level Rise could potentially cause a landwards movement of about 20 m to 50 m and sufficient space and dune sand volume needs to be maintained for the long term.
- 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 management plan for the Betty's 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 six key components:

1. Returning to the beach as much of the sand now 'stored' in the large backdunes, and stabilizing the areas thus exposed so-as to prevent further landward migration of the sand;
2. Ensuring that a functioning vegetated foredune is maintained to form the core of the buffer system;
3. Stabilizing the area landward of the new foredune so-as to prevent wind-blown sand movement. The medium-term goal is to reinstate indigenous coastal fynbos in the backdune area.
4. Allowing for effective storm water management from the roads and parking area by providing detention areas in the backdune area.
5. Providing effective and safe beach access pathways and boardwalks through and across the vegetated dune area and over the foredune; and
6. Carrying out an effective and on-going communication and education process to encourage buy-in from beach users to understand the system and to assist with preserving its integrity.

Each of these components is discussed below.

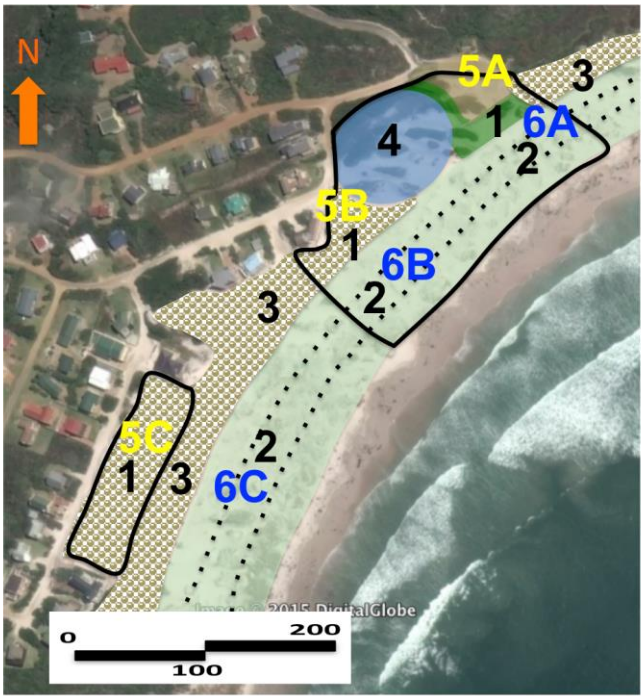


Figure 20: Details of the managed areas within the beach and dune areas

With reference to Figure 20 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 on-going management;
- Establish suitable dune vegetation in Areas 1 and 3;
- Maintain the integrity of the vegetated areas 1, 2 & 3) to prevent exposed areas from forming as this causes 'blow-outs' and a subsequent loss of sand from the buffer system;
- Landscape Area 4 to allow for the accumulation / detention of storm water draining off the roads and the public parking area (5A) and adjacent wetland via the existing storm water drainage ditches and pipes;
- Improve parking areas (5B & 5C) through landscaping and the provision of grassed verges;
- Formalize the walkway access to the beach at the positions marked as 6A, 6B & 6C;
- 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.

7.2 Reshape the area to form new dune profiles

As summarised above, the first component is to return the sand from the high back dunes to the beach so-as to reinstate the buffering system. This is best achieved by mechanical means.

As depicted in Figures 21 to 25 the area is reshaped to ultimately reflect the topography represented by the new contours shown in Figure 26.

The positions of the cross-sections are shown in Figure 14.

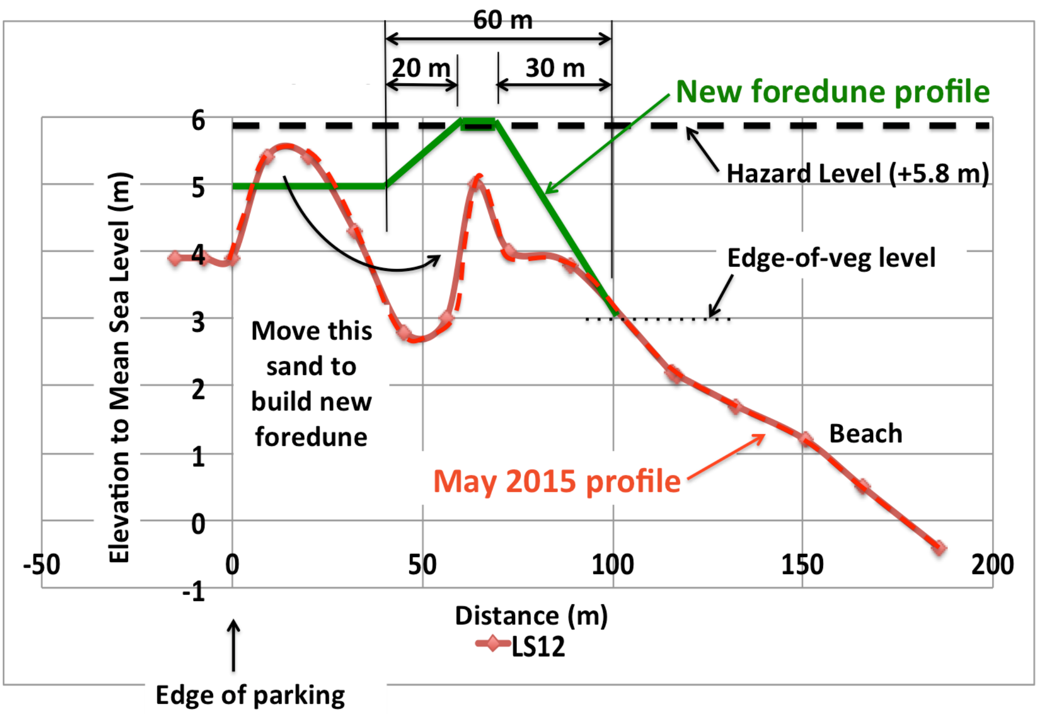


Figure 21: The new backdune profile along Section LS12 (refer to Figure 14)

For the area represented by Sections LS11 and LS12 (Figures 21 and 22), sand from the backdune area is bulldozed all the way onto the beach and new foredune. A larger parking area and grassed verge can be landscaped and the rest of the backdune area is contoured to a level of +5.0 m MSL. The natural storm water detention area is reinstated at a level low enough to allow the storm water to drain into it from the existing storm water drains. This level is estimated at +3.0 m MSL but can only be established once the area is cleared during the reshaping exercise. The area landward of the +3 m MSL line on the beach is reshaped to form a new foredune with a base width of 60 m and top level of +6.0 m MSL as indicated.

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

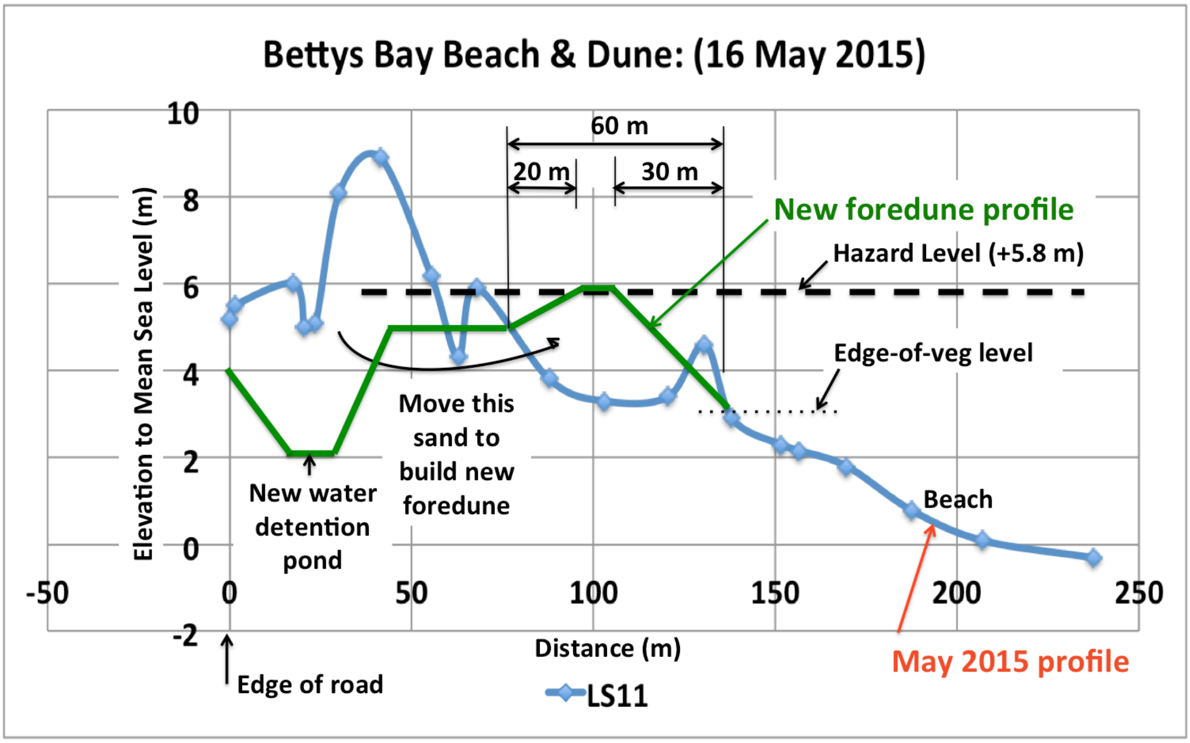


Figure 22: The new backdune profile along Section LS11 (refer to Figure 14)

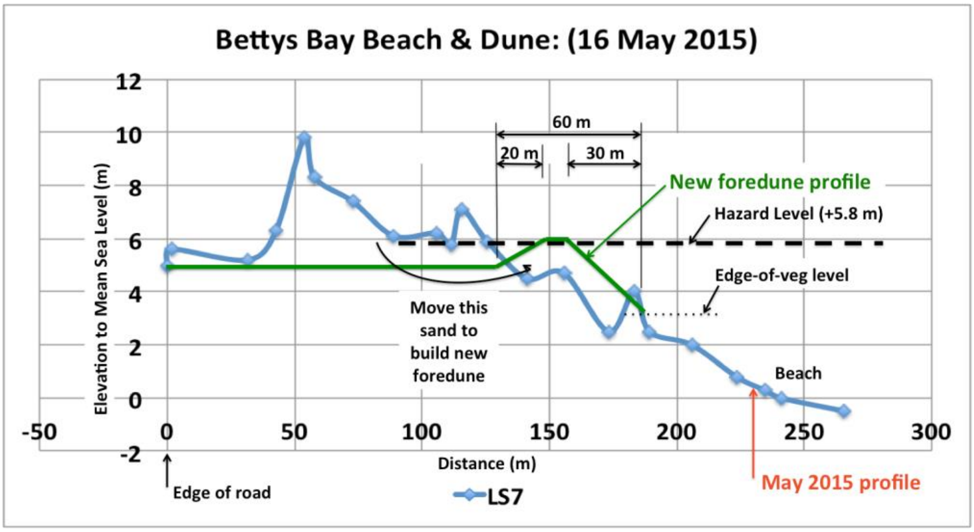


Figure 23: The new backdune profile along Section LS7 (refer to Figure 14)

At Section LS7 (Figure 23) sand from the backdune area is used to fill in and reform the foredune to a top level of +6.0 m MSL. Figures 24 and 25 reflect the reshaped Section LS5 and LS3 showing the new foredune.

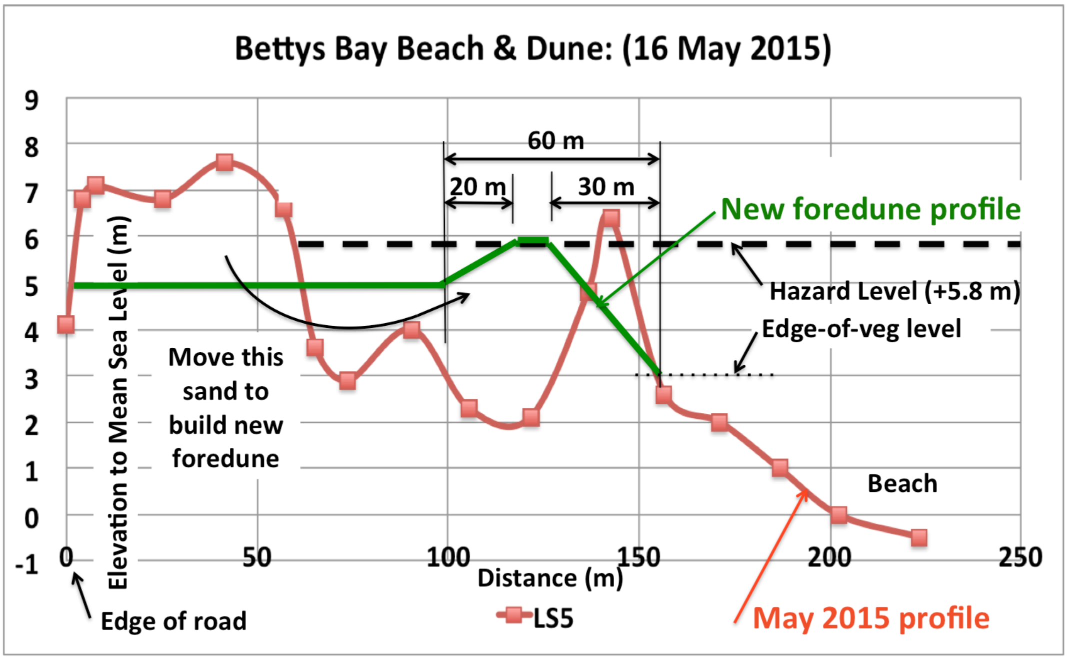


Figure 24: The new backdune profile along Section LS5 (refer to Figure 14)

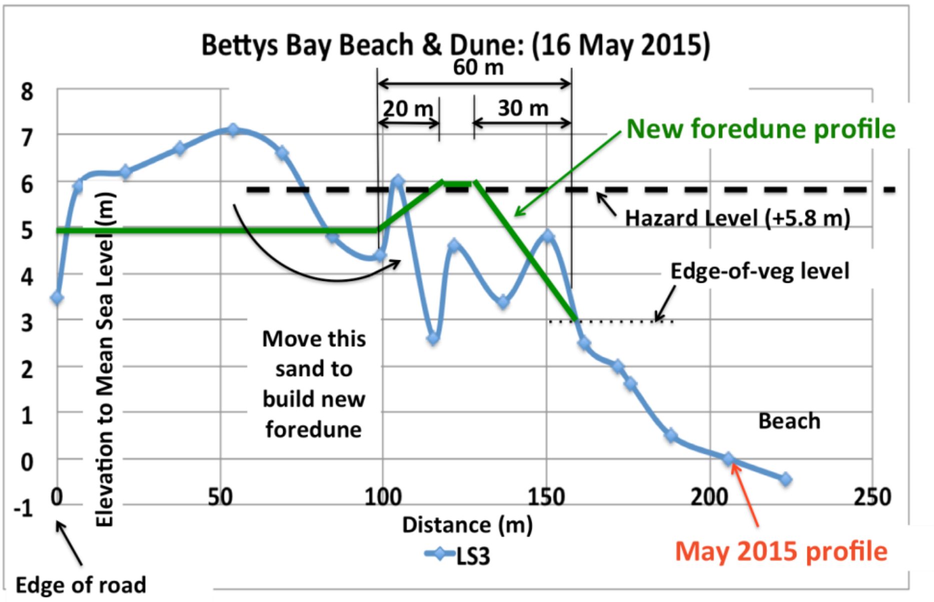


Figure 25: The new backdune profile along Section LS3 (refer to Figure 10)

Figure 26 shows the new contours after the sand is moved and the landscaping done.

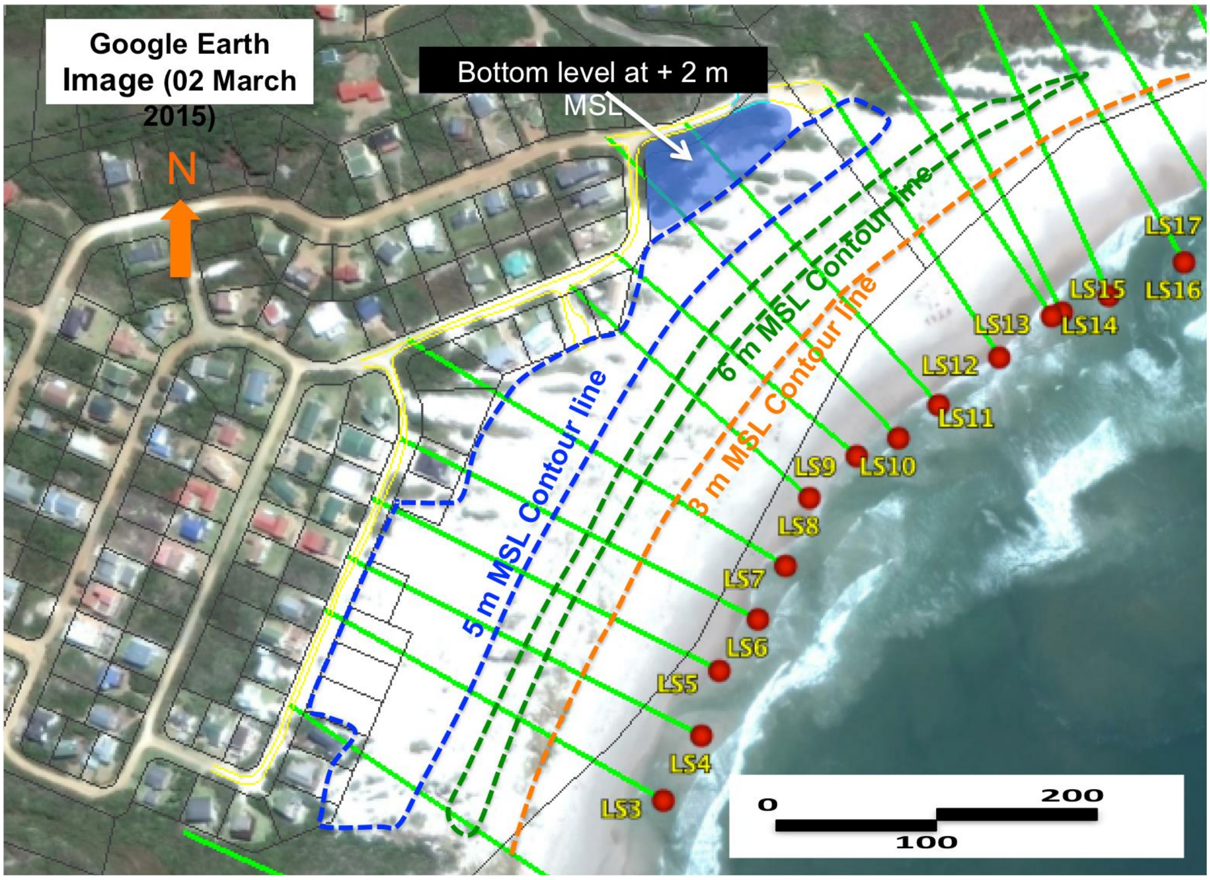


Figure 26: The proposed new contours after the area is reshaped according to the management plan

The key features of the Management Plan are shown in Figures 27 to 29.

The car park area needs landscaping to allow for more efficient use and easier access for pedestrians to the beach , Photo: (November 2014)

The area seawards of Nerine Crescent needs to be landscaped and stabilized to prevent wind-blown sand from encroaching onto the road and private propert

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)

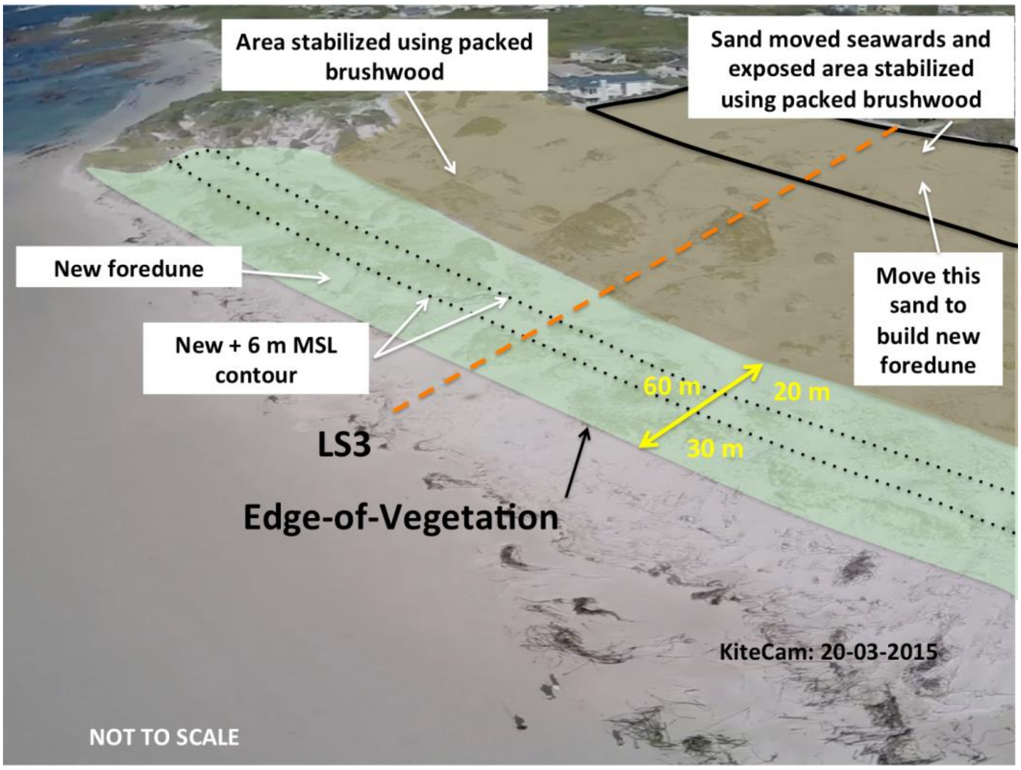


Figure 27: Key features and tasks associated with the updated management plan (not to scale)

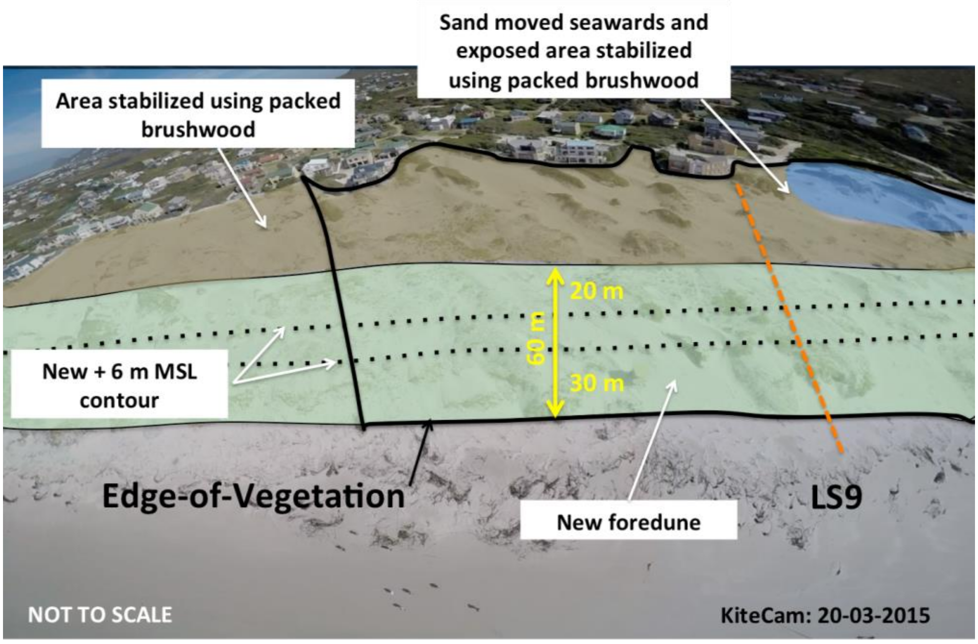


Figure 28: Key features and tasks associated with the updated management plan (not to scale)

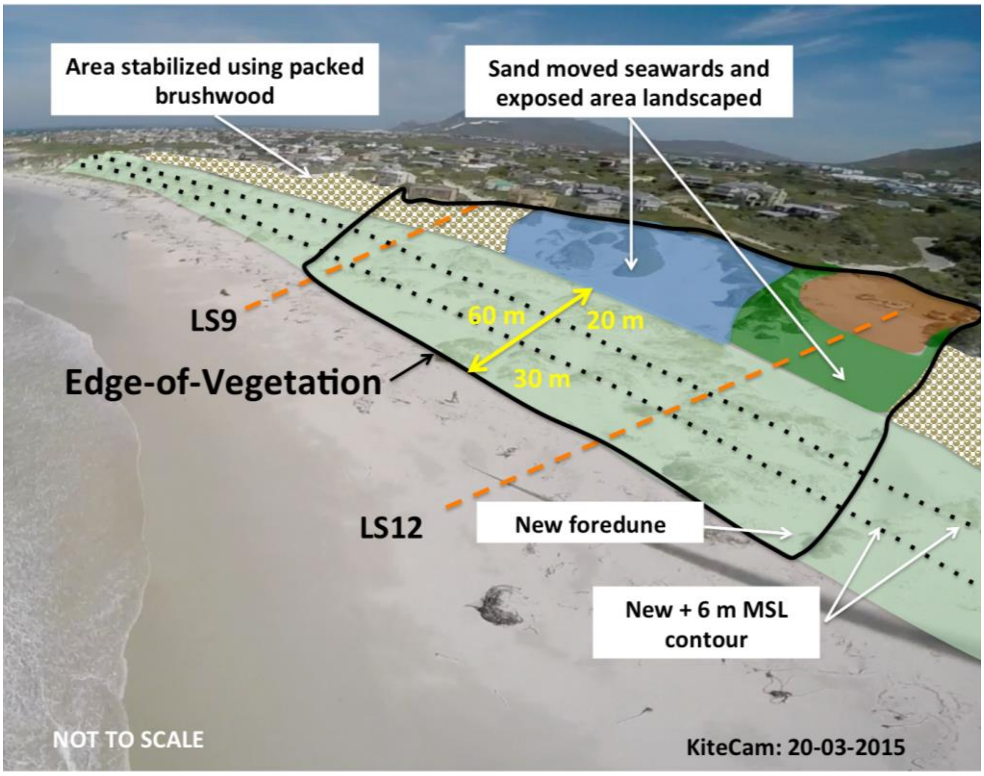


Figure 29: Key features and tasks associated with the updated management plan (not to scale)

Formal access pathways should be installed across the dunes to prevent blowouts

7.3 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 proven at Pringle Bay (CSIR. 1988) to have successfully maintained the integrity of the beach-foredune-backdune system, the use of the non-invasive Marram grass is encouraged at Betty's Bay.

7.4 Beach access pathways

Figure 30 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.

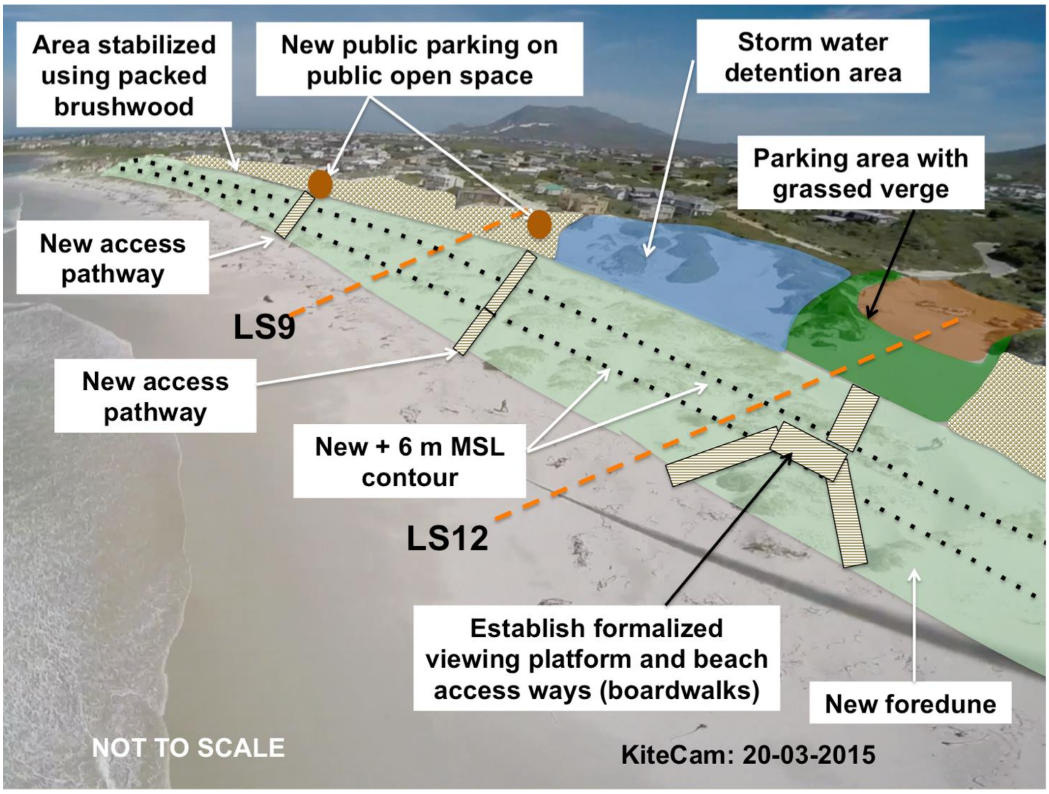


Figure 30: Beach access boardwalks and pathways (not to scale)

Figure 31: Outline of Erf 3784 is Public Space managed by the Overstrand Municipality (Source: Surveyor General)

As can be seen in Figure 31, Erf 3784 is 'Public Space' and therefor under the management of the Local Authority. The seaward boundary is the High Water Mark as determined by the Surveyor General from time to time. The figure also shows that the area to the NE of Erf 3766 forms part of Erf 3784, as is the area between Erven 3773 and 3774. As illustrated in Figure 30, this fact provides the opportunity to reinstate the public parking and formalise public beach access pathways.

8 MANAGEMENT ACTIONS

8.1 General

The following list of management actions reflects 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 blowout prevention / management, especially before, during and after the dry spring and summer 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 stages thereby spreading the costs across financial years. However, this approach can only succeed through an effective, efficient and continuous collaboration between the Municipality and residents.

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

Stage 0: Prevent further northwestward wind-blown sand movement (December 2015 to March 2016)

Whatever the timeframe for the future implementation stages (dependant 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 spring and summer wind regime that holds the greatest risk to beach sand losses and the associated impact of the advancing dune fronts towards the backdune ecosystem, public infrastructure (parking areas, ablution facility, roads and storm water detention area) and private property (beachfront houses and gardens along Nerine Crescent and Moraea Road).

An initial (temporary) option (Stage 0) is therefore designed to 'freeze' the current situation so-as to allow time to find funding for the implementation of the management plan.

As seen in Figure 32, the required action is to pack seedless branches in the blowouts and exposed dune areas as indicated. This action will arrest sand blowing northwestwards off the beach and back-beach area. The actual rate of wind-blown sand may result in the seaward edge of the branches being buried within a short timeframe and it will then be necessary to place further layers of branches until the season changes or the actions under Stage 1 are started.

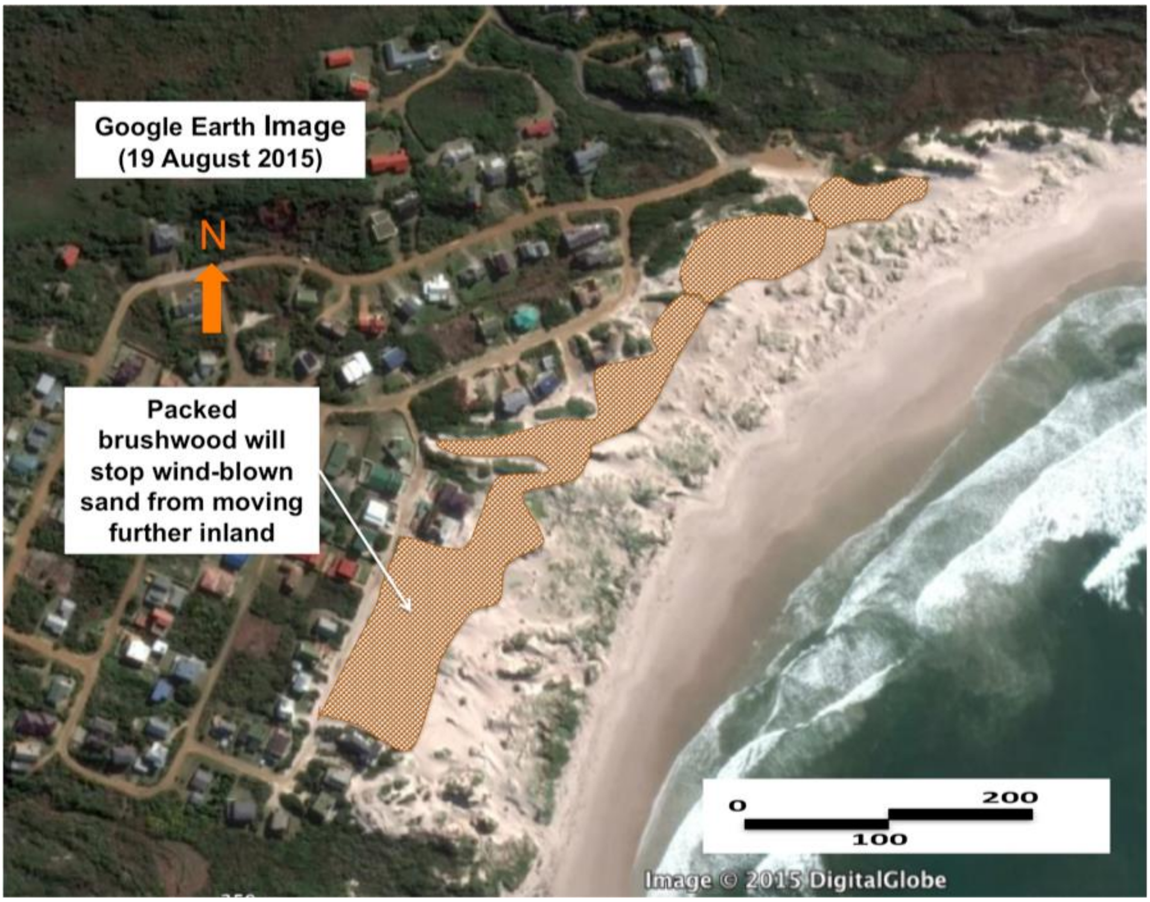


Figure 32: Implementing Stage 0 will prevent further north-westward sand movement

Implementing Stage 0 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 new foredune in the subsequent stages.

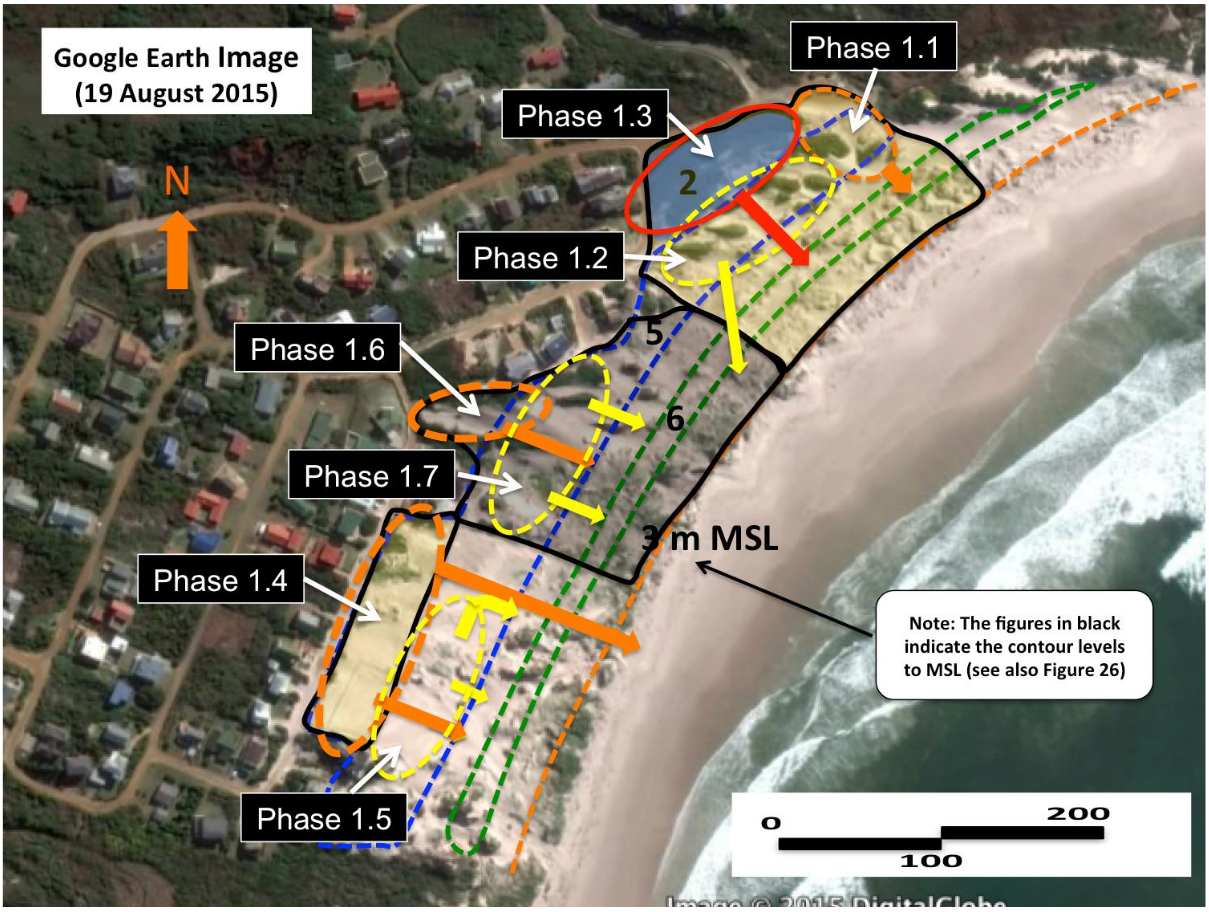


Figure 33: Phases within Stage 1 of implementation of the management plan

Stage 1: Mechanical shaping (Year 1: March to May)

Stage 1 is divided into various sub-parts or Phases and 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 after bulldozing to prevent indirect impacts on adjacent properties and already established climax backdune vegetation.

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

Referring to Figure 33, the recommended actions are discussed below. Note that the activities are prioritised using colour coding (1) Orange first; (2) Yellow second; and (3) Green third. This prioritising will be needed to allow the branch-packing activity to proceed directly after the bulldozing.

Phase 1.1: The sand accumulated in the area on and seaward of the public parking area should be bulldozed onto the beach and into the area where the new foredune is needed to eventually realise the cross-section depicted in Figure 21. The reinstated public parking area and verge should be landscaped at the same time.

Phase 1.2: The sand accumulated in the high dunes seaward of the existing storm water detention area at the corner of Myrica and Moraea Roads should be bulldozed into the area where the new foredune is needed.

Phase 1.3: As depicted in Figure 33, the shaping of the new storm water detention area will require moving excess sand seawards to allow the whole area to be landscaped to realise the cross-section depicted in Figure 22 and the contours shown in Figure 26.

Phases 1.4 & 1.5: The sand accumulated in the area directly seaward of Nerine Crescent and Erven 3771 & 3779 should be bulldozed into the area where the new foredune is needed to eventually realise the cross-section depicted in Figures 24 & 25 and the contours shown in Figure 26. Close liaison with the owners of these erven will be required to agree on the amount of sand to be removed from their properties.

Phases 1.6 & 1.7: The sand accumulated in the area directly seaward of Nerine Crescent (e.g. on Erven 3770 to 3772) should be bulldozed into the area where the new foredune is needed to eventually realise the cross-section depicted in Figure 23 and the contours shown in Figure 26. Close liaison with the owners of these erven will be required to agree on the amount of sand to be removed from their properties.

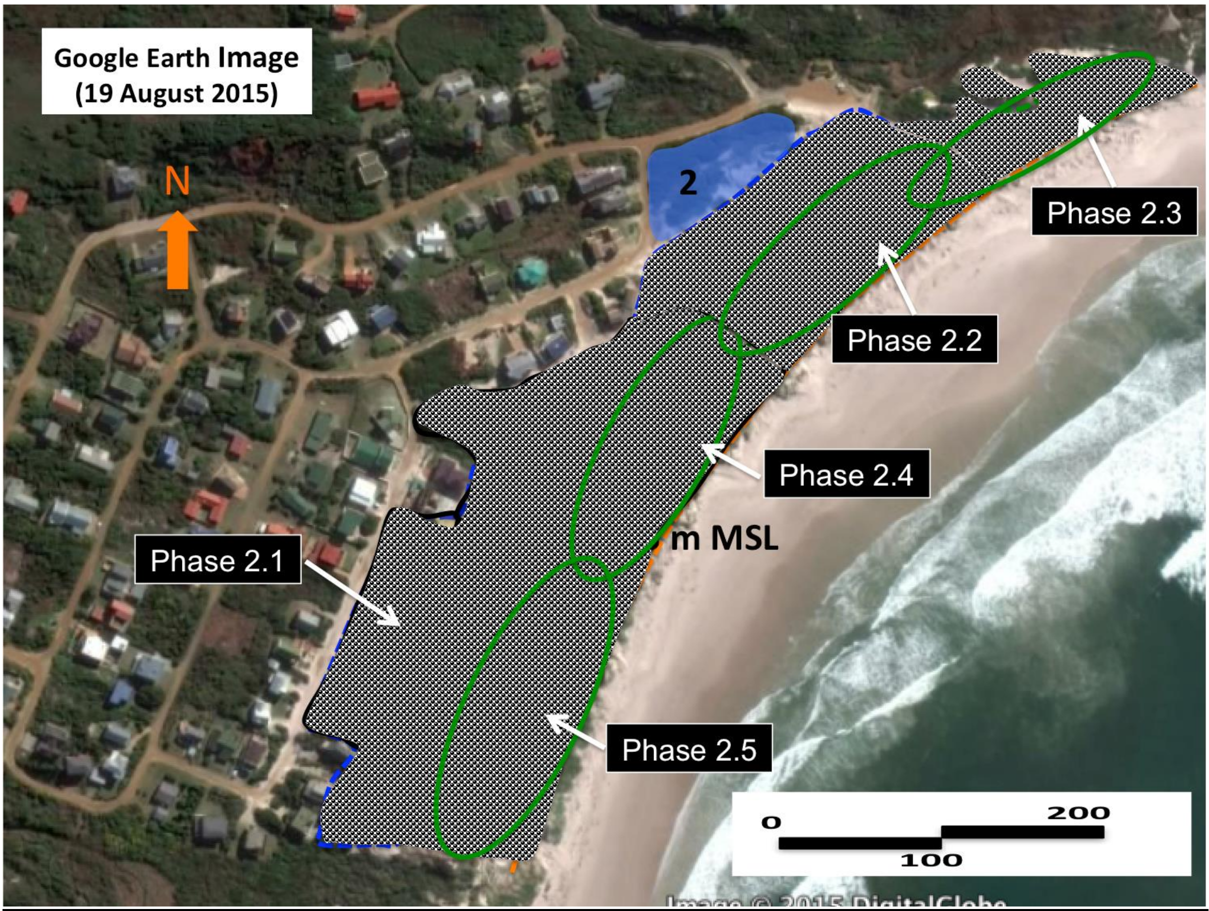


Figure 34: Stage 2 of implementation of the management plan

Stage 2: Branch-packing to naturally build the new foredune

As depicted in Figure 34, Stage 2 is focused on using the packing of seedless branches in a strategic manner to trap wind-blown sand in predetermined areas in blowouts and exposed areas amongst the hummock dunes to naturally build-up the desired foredune in the specified position.

Phase 2.1: The areas covered by branches or straw to stabilize the exposed sand areas during Stage 1 need to be reinforced to prevent any blowouts from occurring.

Phase 2.2 to 2.5: Branches and washed up kelp are packed in strategic positions, patterns and sequences on the newly formed foredunes and in exposed areas amongst the existing hummock dunes to trap sand blown off the beach. This method results in time results in the natural build-up of the desired height and form of the desired foredune.

Figure 35: Stage 3 of implementation of the management plan

Stage 3: Build main access walkways (In November)

Establishing fit-for-purpose access pathways from the public parking areas 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 Stage 1 is completed. 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.

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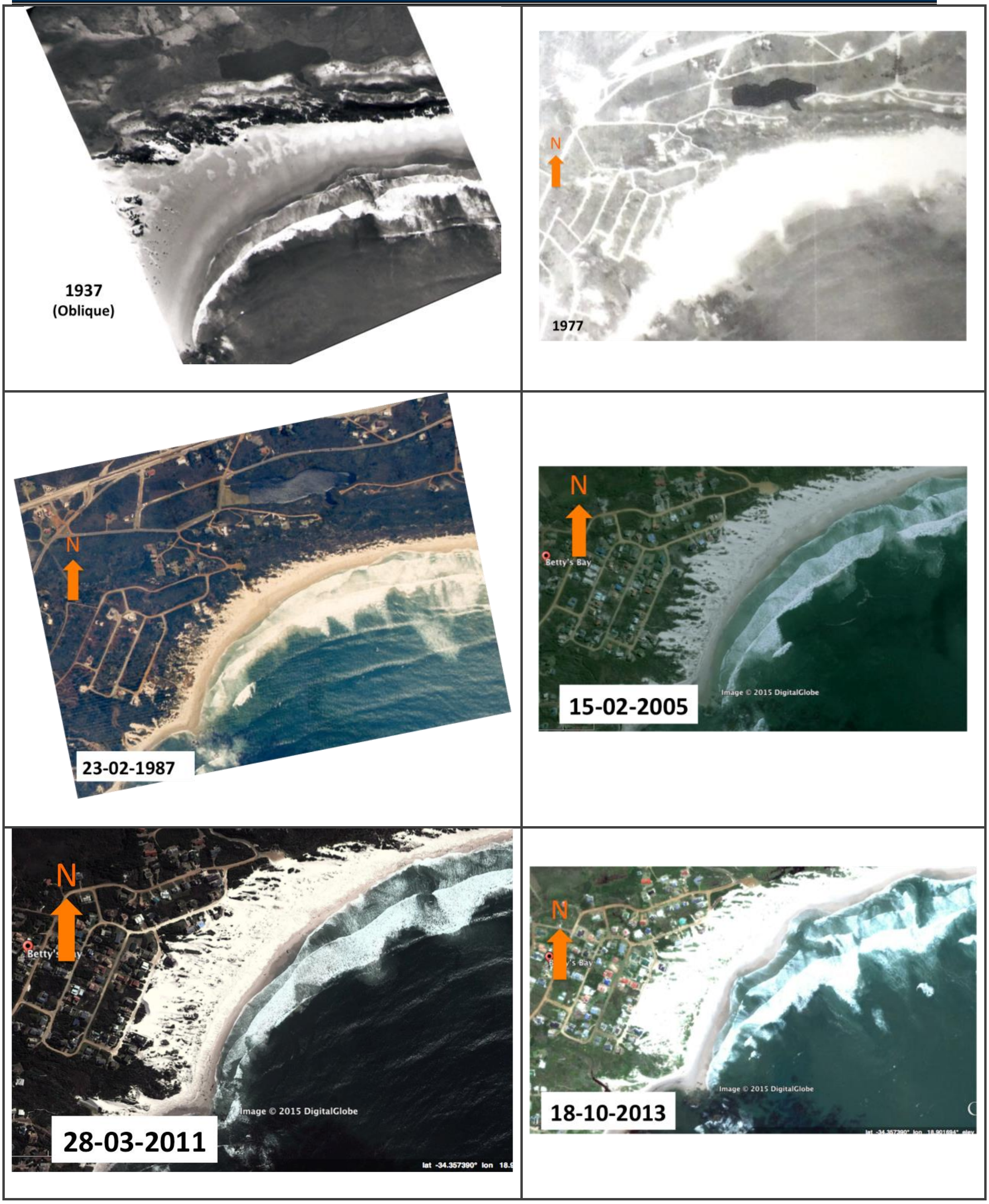
APPENDIX 1: Aerial images 1937 to 2013



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.

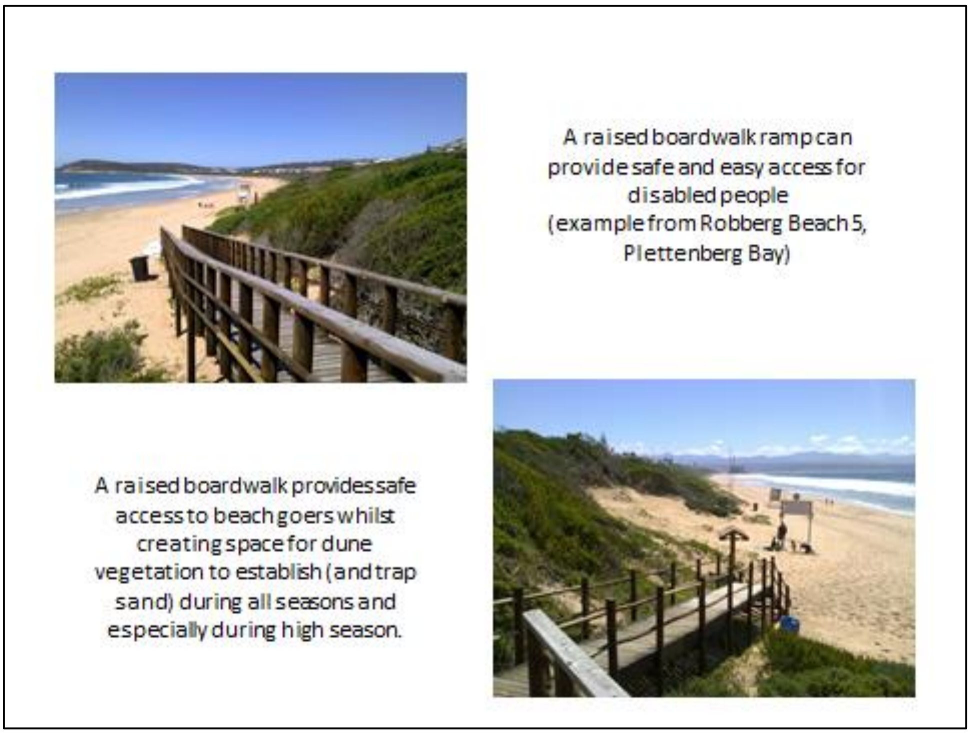


Figure A2.2: Examples of raised viewing platform, access boardwalk and wheelchair friendly ramp. (Blue Flag Beach, Plettenberg Bay)

EXAMPLE

APPENDIX 3: Examples of dune stabilization activities

The Table View, Milnerton Management Plan under constuction

Marram tufts are planted to establish a foredune at Hout Bay Beach

APPENDIX 4: Extreme inshore seawater 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.

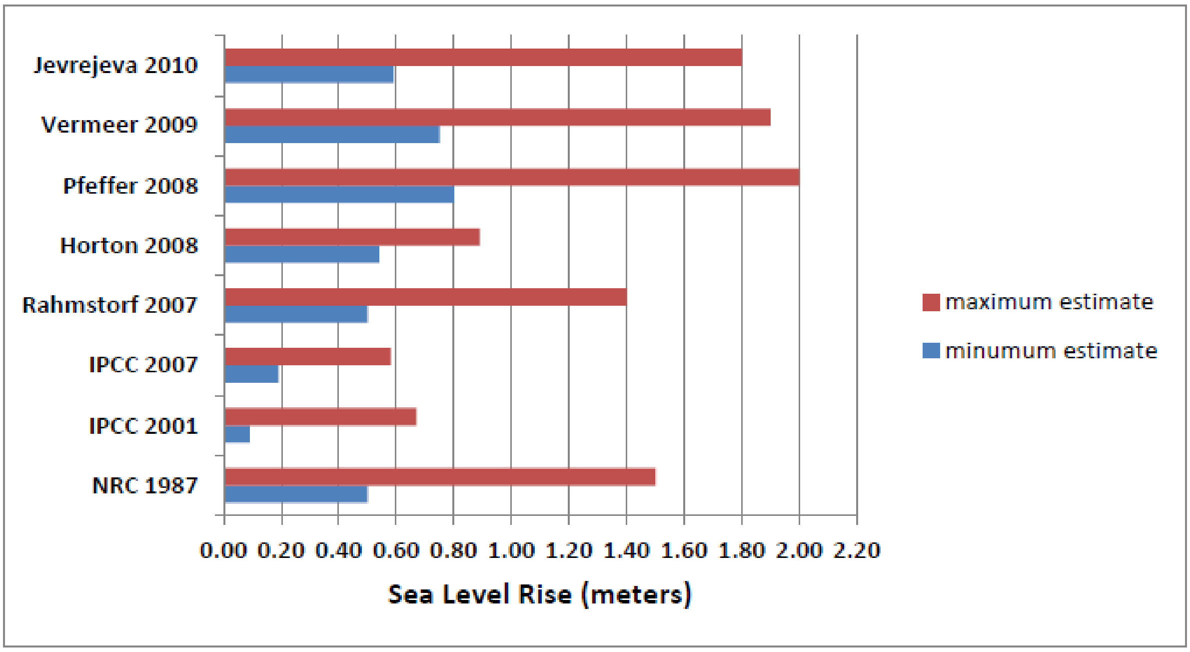


Figure A6.1: Comparison of minimum and maximum estimates of global SLR by year 2100 (USACE, 2011)

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.

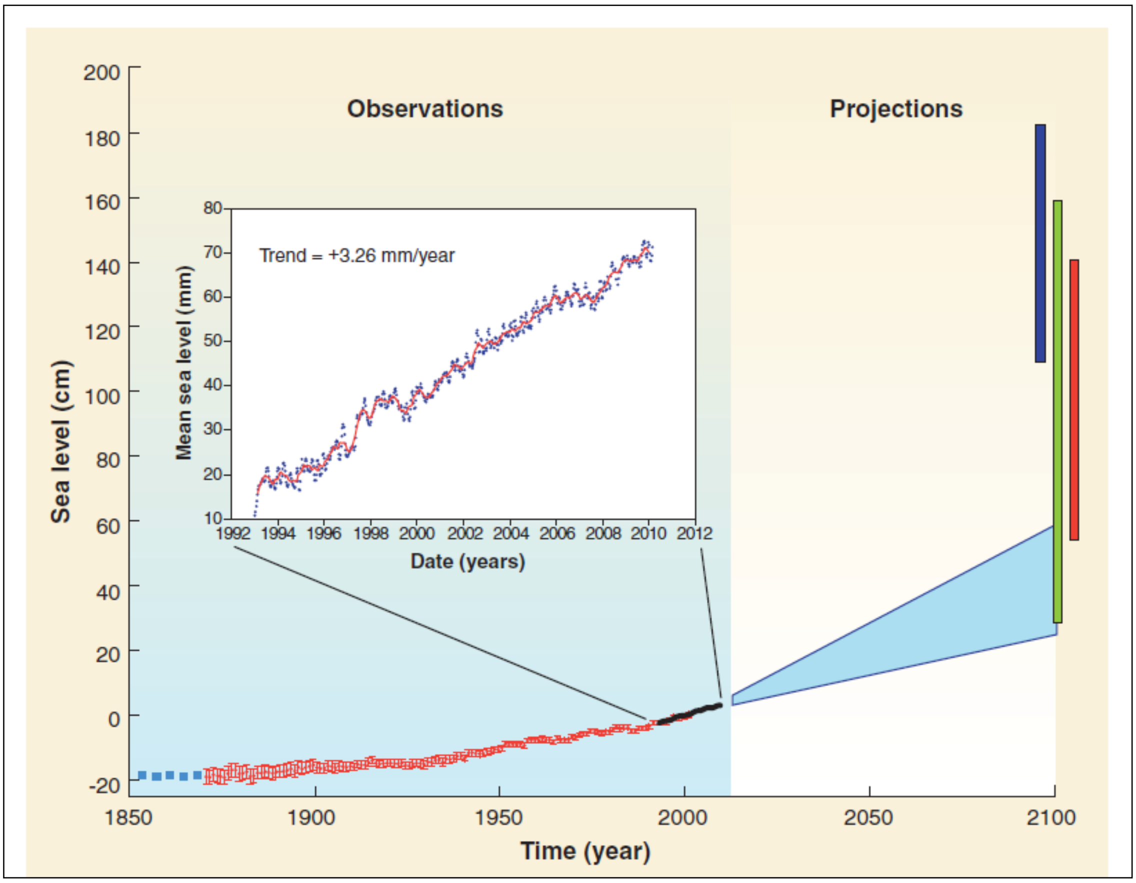


Figure A6.2: Measured and project sea level rise (Nicholls and Cazenave 2010). (The blue, green and red bars are projections from different authors.)

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 blowouts, 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 blowouts.** It is particularly important to stabilize the blowouts occurring at the top of the foredunes for the reasons mentioned above. Planting clumps of pioneer dune vegetation appropriate to the specific wind-blown sand regime and the packing of brushwood in between can do this. In addition, blowouts 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 sea will erode the seaward toe of the dunes 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. Guiding fencing on the landward side along with information boards explaining the importance and sensitivity of the dunes are recommended to assist in obtaining the support of beach users to use the footpaths and to refrain from trampling the dune vegetation.

- **The removal of alien vegetation.** The tops and landward slopes of foredunes are often colonized by alien invasive vegetation. These alien plants often deplete the groundwater resource and thereby deprive the indigenous dune vegetation of water. 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 blowouts. For ecological reasons, it is also recommended that the management plan include 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 blowouts and by cropping the dune vegetation during the appropriate season. However, owners of seafront properties often prefer the safety of a well-vegetated foredune of sufficient volume to effectively buffer against the wind-blown sand and the forces of the sea to a sea view.

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 blowouts 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 is 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 blowouts 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, lookout 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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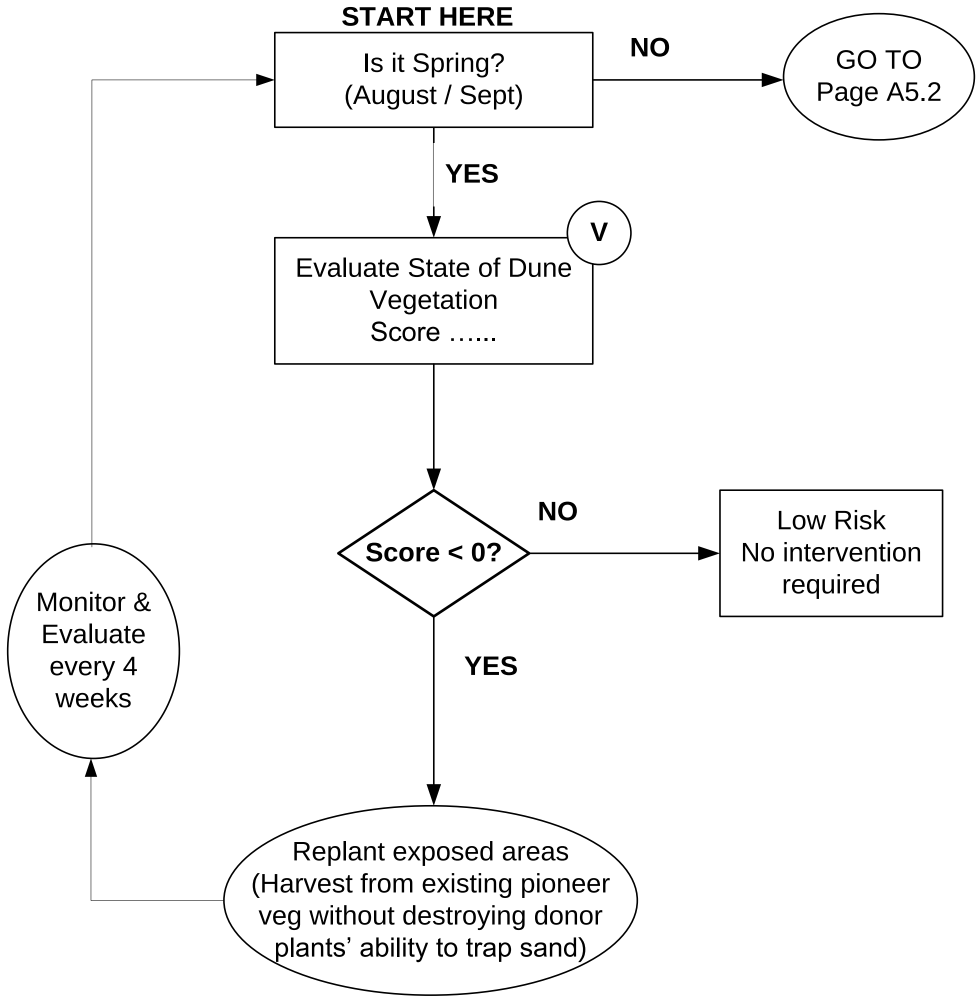
Decision Tree for the Maintenance of Buffer Dunes: SPRING

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

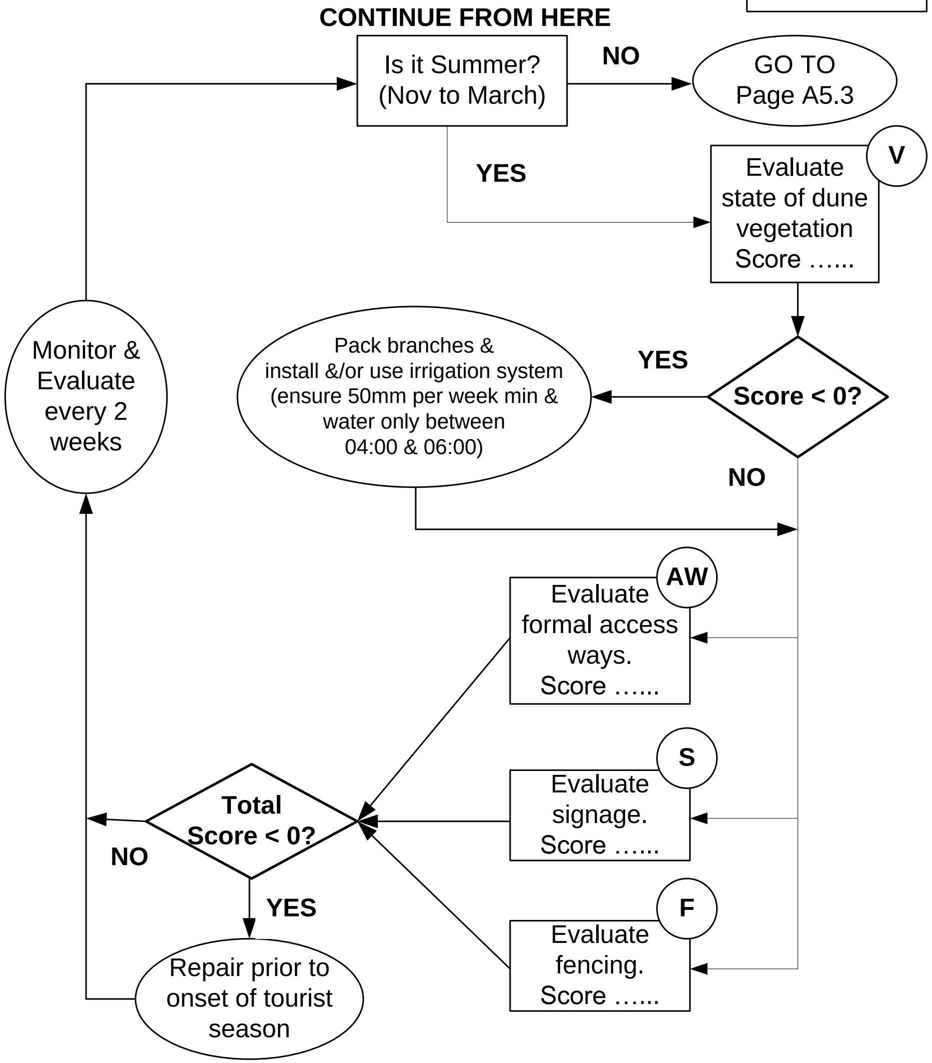
Note: Circle the appropriate score value

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

ASSESSOR: ………………………………

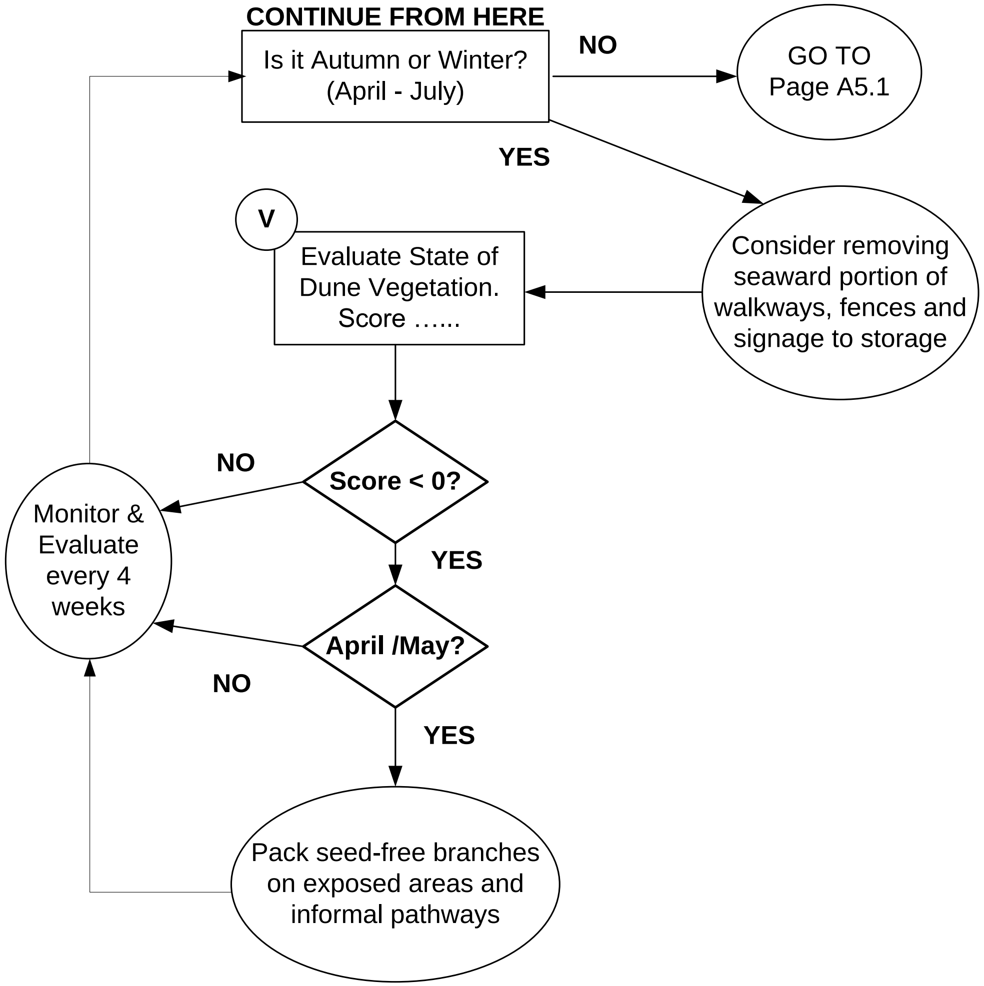
ACTION TAKEN: ……………………………………

…………………………………………………………….



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: …………………………………………

……………………………………………………………