Moquini Beach Buffer Dune Maintenance Management Plan

Prepared by
Mr Laurie Barwell

and the
Moquini Dune Management Team

DRAFT FEBRUARY 2021
(FOR DISCUSSION)

Submitted to:	Moquini Beach Home Owners
Prepared by:	Laurie Barwell
Issued by:	Laurie Barwell & Associates (Pty) Ltd (LB&A)
Keywords:	Dune Management Soft Engineering Climate Change Sea Level Rise
Date:	February 2021

Note: Photographs by Laurie Barwell unless otherwise indicated

Photo: KiteKam 05-2019

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Limitations of the study

The aerial image and photographic analysis that forms the basis of the shoreline stability assessment, conclusions and recommendations are based on the availability of historical and recent data and information. Due to poor resolution of such historic material it is required to make use of much intepretation of landscapes and features as well as the technical skill to undertake comparitive image analysis that is shaped via experiential learning. As such only a broad idea of the relevant dynamics can be reached. However this approach has proven to be useful in identifying long-term trends that are important when attempting to understand natural processes and their potential impact on and potential response to developmental and / or management actions.

Author

The author (Mr Laurie Barwell) has a B.Eng Civil and an MSc.Eng degree in Coastal Engineering, specializing in coastal environmental assessment and engineering with specific reference to beach and dune management, and climate change risk and vulnerability assessment and response strategies. Having retired from the CSIR in 2014, the author has 40 years of experience related to water and coastal environmental engineering and coastal zone management practices.

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Figure 1: Moquini Beach is located 2 km east of the Goukou Estuary mouth at Stilbaai within the Hessequa Municipality in the Garden Route District of the Western Cape province in South Africa.

1. INTRODUCTION

The Moquini Home Owners Association wishes to implement a dune maintenance management plan (DMMP) for the existing buffer dune system along the seafront of the Moquini residential area at Stilbaai.

This report (the DMMP) is based on input provided by Mr Laurie Barwell, specialist coastal environmental engineer.

The DMMP should be read as complementary to the CSIR report on the recommended development setback line that was published in 1994[1].

The DMMP includes recent information that updates the CSIR report to allow for the projected climate change related sea level rise (SLR). Included are the following:

i. The physical environmental context.
ii. The coastline stability over the period 1965 to 2020 using available aerial images and topographical surveys.
iii. Assessment of the potential short term cross-shore erosion due to seasonal storms.
iv. An assessment of the implication of climate change on the coastline stability and in particular the implications of the projected rise in sea level.
v. The deduction of the 1:50 yr storm erosion line and associated setback as compared to that in the CSIR 1994 report.
vi. Consideration of the information reflected in the draft reports on the Coastal Management Lines for Eden District (now Garden Route)[2].
vii. An assessment of the current buffer dune integrity.

Site-specific dune maintenance management actions in the form of appropriate methodology statements form the core of the DMMP.

[1] CSIR, 1994. Setback line at Still Bay beteen Lappies Bay and Preekstoel.
[2] Eden District Coastal Processes and Risk Modelling (v.2). Royal HaskoningDHV, UK Ref.:MD2368. Draft May 2017.

1.1 Study area

Moquini Beach residential area is located approximately 2 km east of the Goukou Estuary mouth at Stilbaai in the Hessequa Municipality within the Garden Route District of the Western Cape province in South Africa (Figure 1).

The Moquini Beach beach and dune area has been devided into five specific Coastal Management Units (CMU1 to CMU6, Figure 2), catogarised ito three management zones (A, B and C, Figure 3), each requiring specific maintenance activities. The houses closest to the setback line have been numbered to enable identification for the development and implementation of site specific maintenance activities.

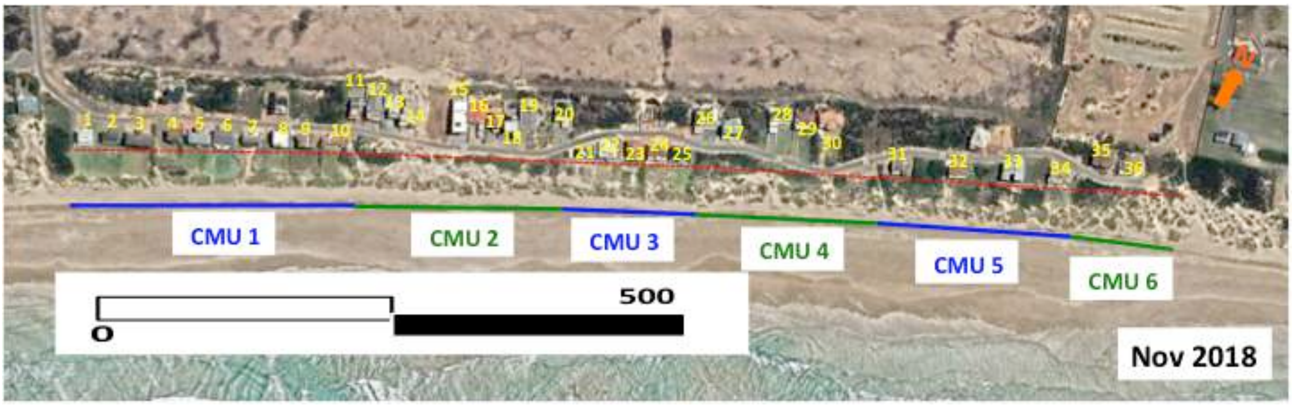
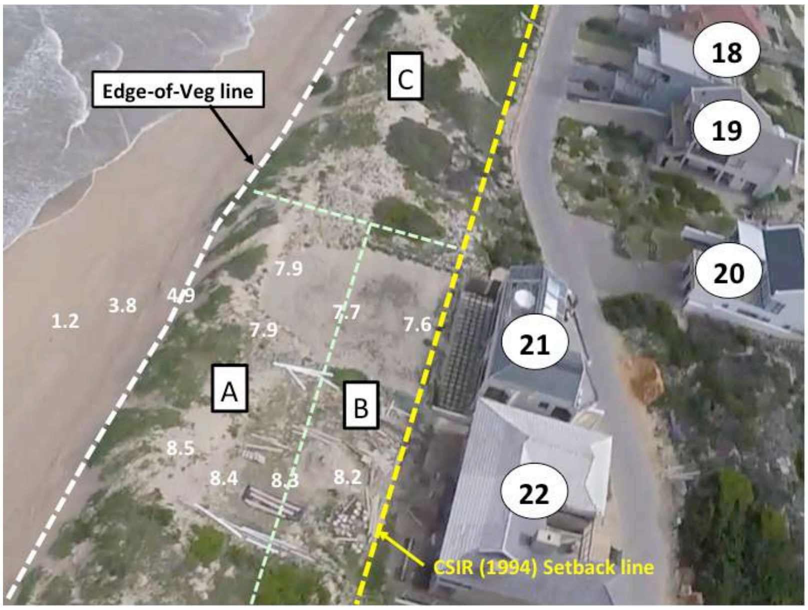


Figure 2: Moquini Beach is catagorised into six coastal management units (CMUs)



Note: The white figure indicate the elevation (m) to MSL.

Figures 3: The Moquini Beach dune management area consists of three zones (A, B and C), each requiring specific maintenance activities.

1.2 Approach and process

An analysis of available information, including historic aerial images (from 1965 to 2019), and topographical and cross-sectional surveys done in 1994 and 2020, assisted in understanding the coastal processes and in particular the historic stability of the coastline at the sites. The results were used to determine the dune and beach changes over the 54 year period.

A statistical analysis of the historic position of the wave run-up line on the beach, the horizontal changes in the Edge-of-Veg line over the analysis period, and the projected sea level rise (SLR) along with the surveyed beach slope, provide input to enable the calculation of the 50 yr and 100 yr erosion potential. This leads to the recommended position of the 50 yr and 100 yr setback line. The assessment results were considered in the context of the existing CSIR setback requirement that forms part of the original development approval conditions.

A site visit, topographical survey and buffer dune integrity assessment was undertaken by the author in October 2020. A KiteKam aerial survey done in May 2019 is used to illustrate the spatial elements of the DMMP.

2. RELEVANT LEGISLATION AND POLICIES

Implementing dune maintenance within a buffer dune system, by definition, requires physical activities within the area seawards of a demarcated setback line, thus within the littoral active zone and within a sensitive dune system.

The following legislation needs to be taken into account when planning activities within the littoral active zone or within sensitive dune systems. So the proposed maintenance related works are being undertaken in terms of the applicable listed activities and sections contained within:

Government Gazette No 38282, 04 December 2014 – NEMA EIA Regulations, GN No. R 983 of Listing Notice 1:

- **Listed Activity 18:** The planting of vegetation or placing of any material on dunes or exposed sand surfaces of more than 10 square metres, within the littoral active zone, for the purposes of preventing the free movement of sand, erosion or accretion, excluding where—

(i) the planting of vegetation or placement of material relates to restoration and maintenance of indigenous coastal vegetation undertaken in accordance with a maintenance management plan; or

(ii) such planting of vegetation or placing of material will occur behind a development setback.

- **Listed Activity 19:** The infilling or depositing of more than 5 cubic metres into, or the dredging, excavation, removal or moving of soil, sand, shells, shell grit, pebbles or rock of more than 5 cubic metres from—

(i) A watercourse;

(ii) The seashore; or

(iii) The littoral active zone, an estuary or a distance of 100 metres inland of the high-water mark of the sea or an estuary, whichever distance is the greater—

but excluding where such infilling, depositing, dredging, excavation, removal or moving—

(a) will occur behind a development setback;

(b) is for maintenance purposes undertaken in accordance with a maintenance management plan; or

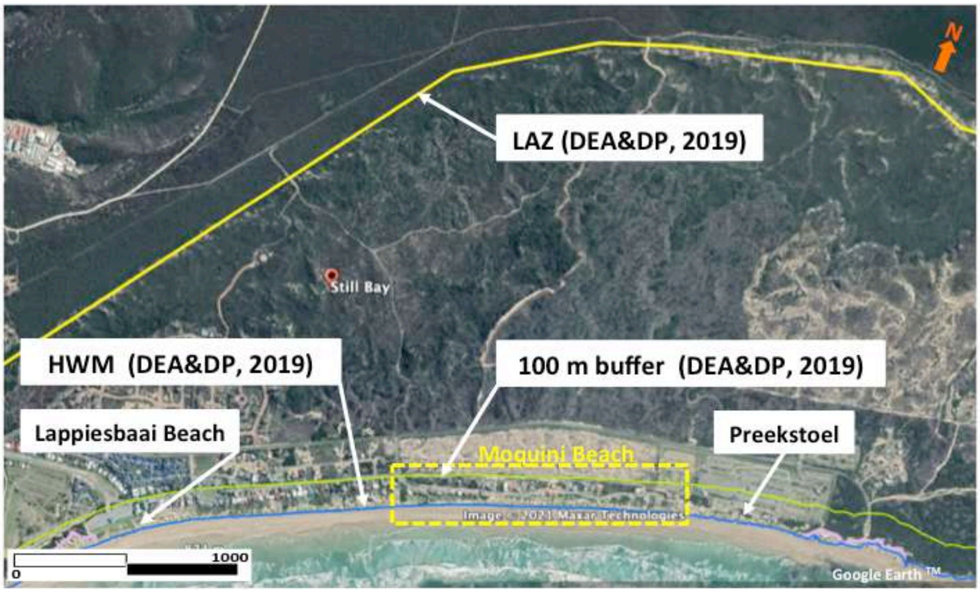
(c) falls within the ambit of activity 21 in this notice, in which case that activity applies.

Furthermore, the following sections of the relevant legislation are considered:

Section 1:	National Environmental Management Act No 107 of 1998
Section 2:	National Environmental Management Act No 107 of 1998
Section 28:	National Environmental Management Act No 107 of 1998
Section 6:	'ORV Regulations' Regulations for the Management of Vehicles in the Coastal Zone
Section 1:	NEM: Integrated Coastal Management Act
Section 7:	NEM: Integrated Coastal Management Act (Composition of Coastal Public Property)
Section 13:	NEM: Integrated Coastal Management Act (Access to coastal public property)
Section 16:	NEM: Integrated Coastal Management Act (Composition of the Coastal Protection Zone)
Section 17:	NEM: Integrated Coastal Management Act (Purpose of the Coastal Protection Zone)
Section 18:	NEM: Integrated Coastal Management Act (Coastal Access Land)
Section 20:	NEM: Integrated Coastal Management Act (Responsibilities of Municipalities with respect to Coastal Access Land)

2.1 Coastal Management lines

The Eden District Coastal Management lines[3] for the 50yr and 100yr run-up are shown in Figures 4 and 5a to 5d.

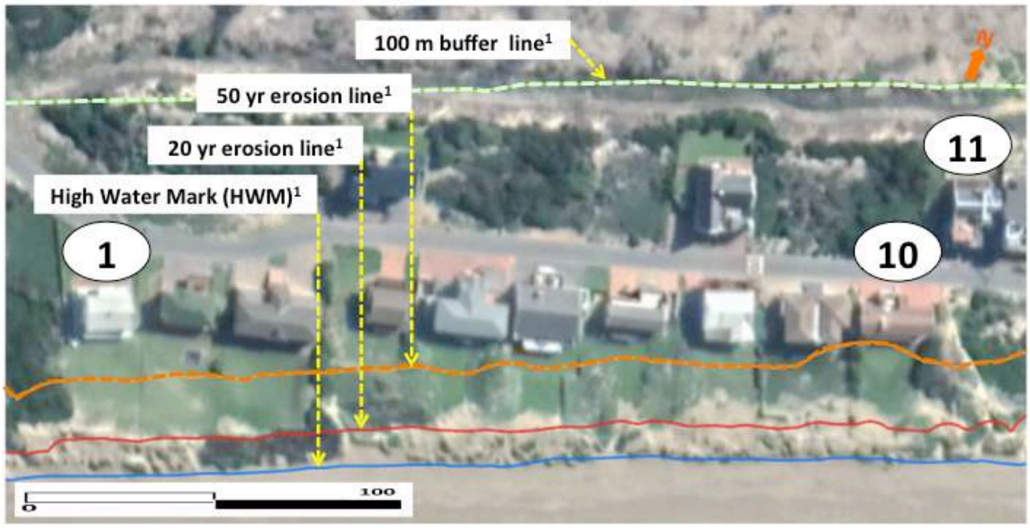


Figures 4: The Moquini Beach dune management area falls well within the Littoral Active Zone (LAZ) and within the 100 m coastal buffer area as defined by relevant legislation.[4]

[3] Eden District Coastal Processes and Risk Modelling (v.2). Royal HaskoningDHV, UK Ref.:MD2368. Draft May 2017.

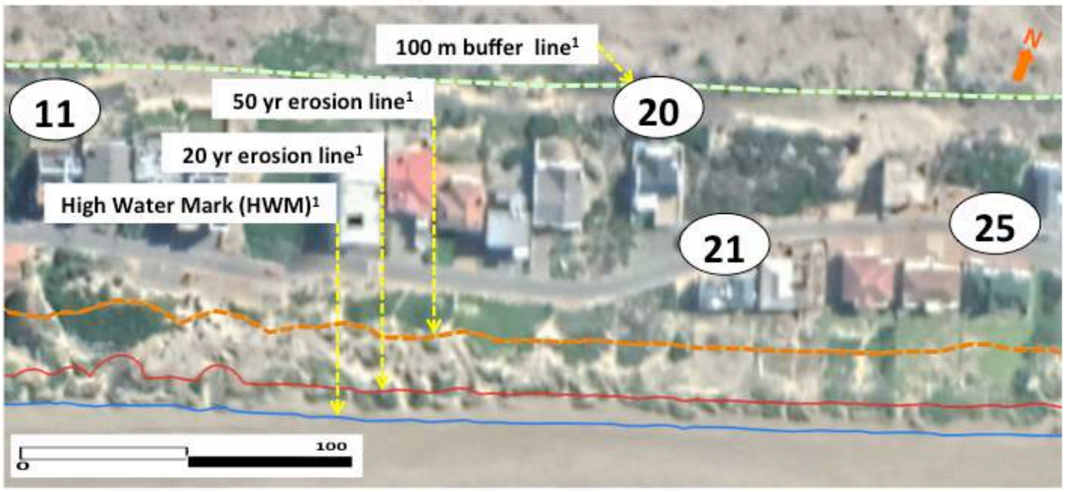
[4] Government Gazette No 38282, 04 December 2014 – NEMA EIA Regulations, GN No. R 983 of Listing Notice 1

MOQUINI BEACH: CMU 1

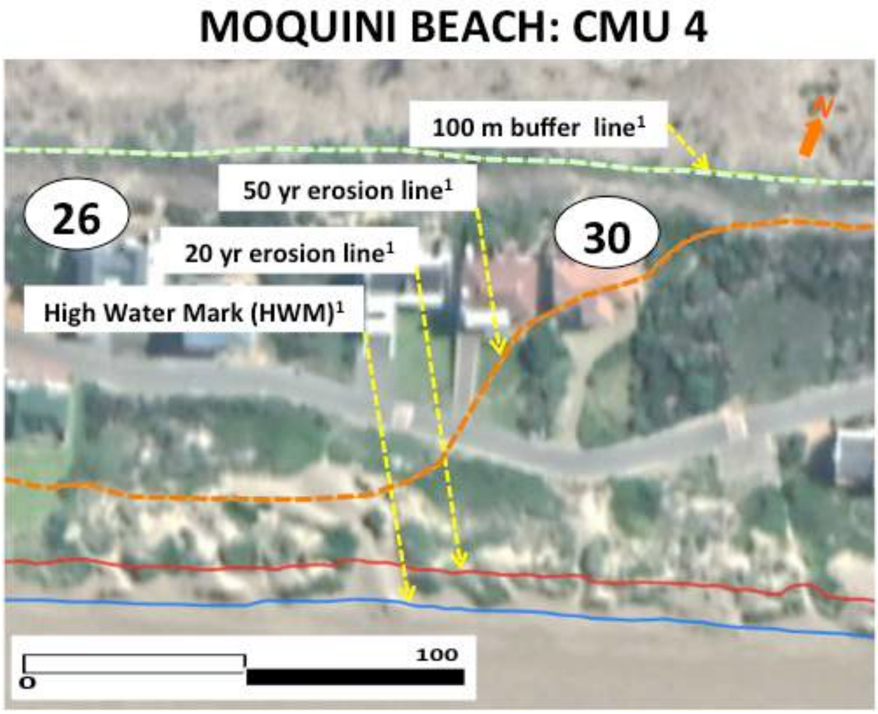


Figures 5a: DEA&DP management lines in CMU 1

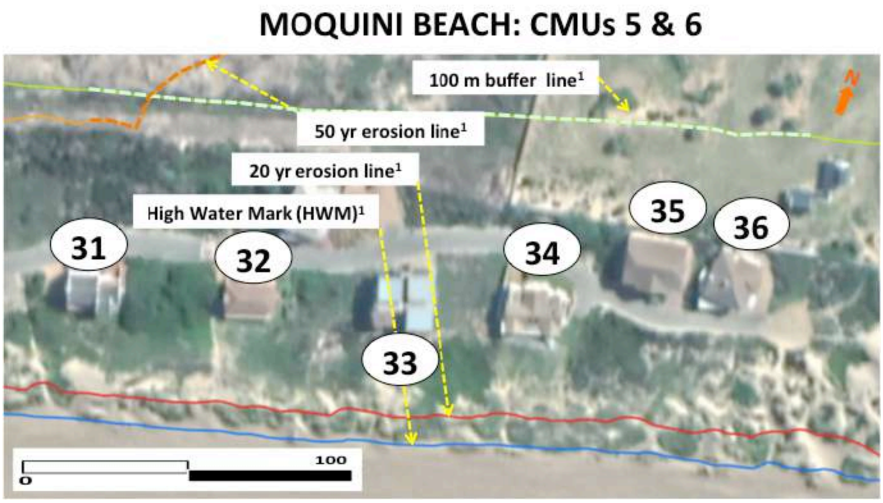
MOQUINI BEACH: CMUs 2 & 3



Figures 5b: DEA&DP management lines in CMUs 2 & 3



Figures 5c: DEA&DP management lines in CMU 4[5].



Figures 5d: DEA&DP management lines in CMU 4.

[5] Note the non-sensical positioning of the 50 yr erosion line on both Figures 5c and 5d.

3. PHYSICAL ENVIRONMENT

3.1 Introduction

In order to ensure that the correct 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 abiotic processes and being able to assess the environmental consequences of management or developmental actions.

The coastline and foredune within Still Bay and in particular at Moquini Beach are influenced by a complex interaction between several physical and biotic components. However it is the littoral and cross-shore sediment movement (under existing and future climate scenarios), the prevailing wind regime and associated aeolian sand movement, and the management of storm-water off the landward development (in particular solid surfaces such as roofs, paving, roads and parking areas) that are most relevant to the stability of the coastline in the short- and long terms. These aspects are discussed below.

3.2 Coastal processes and the sediment budget

Moquini Beach is located approximately 2 km east of the Goukou Estuary mouth within the Still Bay bay in the middle reaches of a logarithmic spiral-shaped (crenulated) embayment that stretches along a 4 km long sandy shore eastwards to Preekstoel and beyond. (Figures 1 and 3).

The physical processes that have caused the log-spiral equilibrium shape of the bay to be formed between the two fixed points (Morris Point) to the southwest and the rock cliffs east of Preekstoel are governed by the sea swells reaching the coastline and the resultant longshore and cross-shore currents; the availability of sediment within the beach and dune system along the coastline as well as those flushed from the Goukou river during large floods; the effect of prevailing winds; and the underlying geology. 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 that is termed the local sediment budget.

A comprehensive description of these processes is provided in inter alia the CSIR (1994, 1989[6], 1992[7]) reports and the Part 2 green reportand is not repeated here. The deep sea swell directions offshore of the study site vary between the south-western, southern and south-eastern sectors. Most of the severe storms originate in the south-west of South Africa and the study area is only partially protected by Morris Point[8] By definition it is located just within the wave 'shadow area' and the wave energy is close to those along the open coastline.

No accurate estimate of the longshore sediment transport potential has been done, although the CSIR reports provide adequate contectual information to serve a DMMP.

[6] CSIR, 1989. The dynamics of the Duiwenhoks and Kafferkuils Estuaries. By Dr G A W Fromme. CSIR report EMA-T 8901, Stellenbosch

[7] CSIR, 1992. Estuaries of the Cape: Part II. Report no 34 – Kafferkuils and Duiwenhoks. CSIR Research Report 433, Stellenbosch.

[8] Barwell, L. 2011. Integrity Assessment Procedure for Buffer Dune Systems on the Cape South Coast, South Africa. MSc Thesis. Faculty of Engineering, Stellenbosch University. December 2011.

3.3 Wind climate and aeolian sediment movement

Of importance for the buffer management at the study site is that although a limited volume of sand can be blown off the beach and into the dune during the summer and autumn seasons when the beach is typically wide and the sand is dry, this volume of sand will form a natural foredune that enhances the buffering ability against the forces of the sea. This is discussed in the next section of this report.

The seasonal wind-roses, derived from Voluntary Ship data (VOS), for the offshore region are shown in Figure 6. Indicated are sustained onshore winds from the southwestern and eastern sectors all year round.

From a sand movement point of view, it is the prevailing onshore winds relative to the SW-NE orientation of the Stilbaai Bay coastline at Moquini Beach. that are of importance as they bring sand into the dune area.

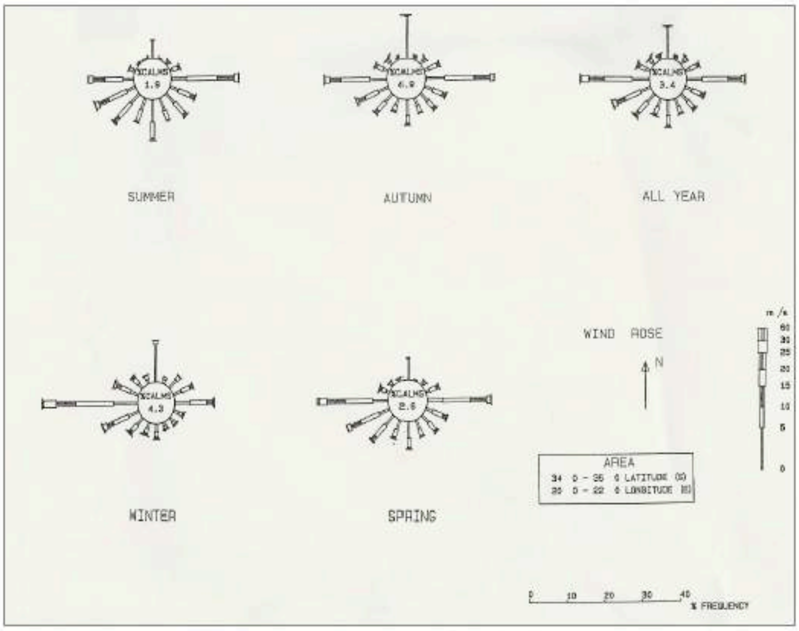


Figure 6: Wind roses for the area as published for Still Bay (in CSIR, 1986[9]).

The wind data were analysed and a set of aeolian creep diagrams (Figure 7) was deduced for the beach and foredune at the study site (after Swart, 1986[10]). 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 natural system as prevailed in 1954 reflects these uninhibited processes (Figure 7). The long-term net wind-blown sand pathways can be derived from the orientation of the longitudinal sand dune ridges in the dune system[11]. These confirm the information depicted in the creep diagrams.

[9] CSIR, 1986. Waaisand problem by Lappiesbaai, Stilbaai-Oos. By Mr L. Barwell. Submitted to Dept of Environmental Affairs, CSIR Report OX/C/CSW/ 24/6, Stellenbosch.

[10] Swart, D. H. (1986). Prediction of wind-blown sediment transport rates. Proc. 20th International Conference on Coastal Engineering, Taiwan

[11] Heydorn, A E F and Tinley, K L, 1981. Synopsis of the Cape Coast. Part 1, Natural features, dynamics and utilization. Estuaries of the Cape series, CSIR Research Report No. 380. Stellenbosch

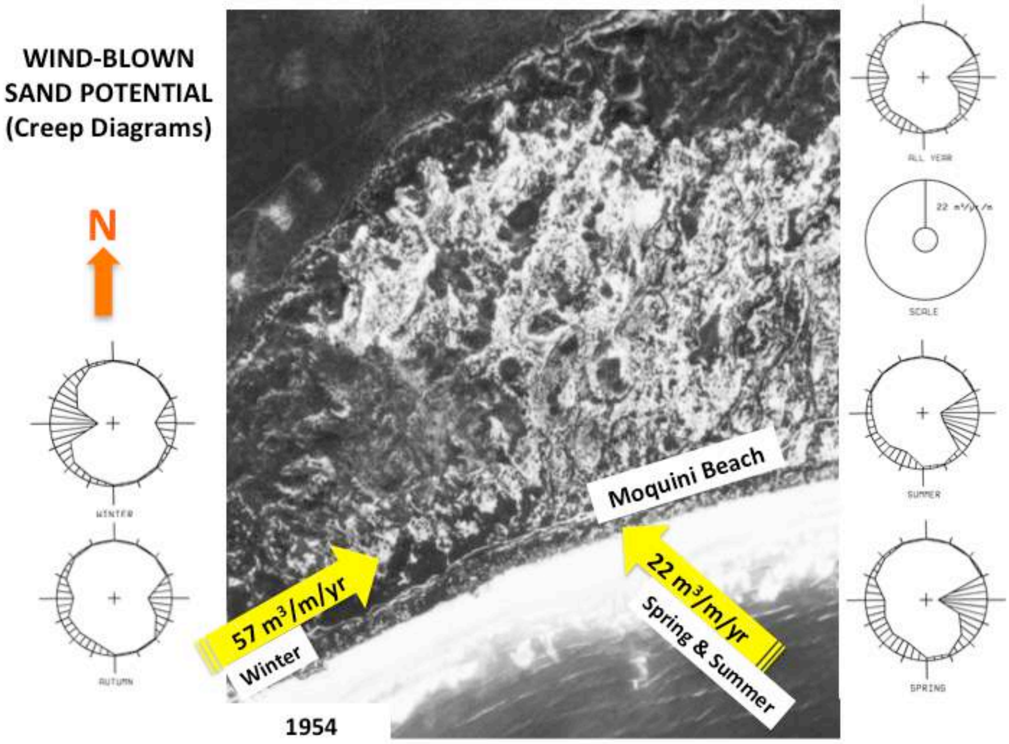


Figure 7: 1954 aerial photo and aeolian creep diagrams

The equivalent volumes of sand blown seasonally in the specified directions by the prevailing winds are calculated using the method devised by Swart (1986). The grain size of the sand is based on an analysis of sand samples taken in the area. 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. The predicted transport rates for the different seasons and wind directions are shown in Table 3.1

Table 3.1: Potential Aeolian transport rates ($m^3/m/yr$) for the study area

DIRECTION	Rate ($m^3/yr/m$)					Net rate ($m^3/yr/m$)				
	SUM	AUT	WIN	SPR	ALL YEAR	SUM	AUT	WIN	SPR	ALL YEAR
N – BOUND:	14	11	15	15	14	12	6	7	12	10
S – BOUND:	2	5	8	3	4					
NE – BOUND:	17	27	57	40	39	14	12	49	22	25
SW – BOUND:	31	15	9	17	14					
E – BOUND:	33	32	74	48	47	7	11	62	22	26
W – BOUND:	26	21	12	26	21					
SE – BOUND:	18	22	51	29	30		4	40	7	12
NW – BOUND:	22	18	11	22	18	4				

It is seen in Table 3.1 and Figure 7 that the net movement of sand at the study site is oblique onshore to the shoreline (NE-bound) with the net potential rate[12] calculated as 25 $m^3/m/yr$ (All

[12] The net potential rate is calculated as the difference between the two wind directions, eg for the 'All Year' case, the NE-bound (onshore) of 39 $m^3/m/yr$ minus the apposing (SW-bound) wind transport (14 $m^3/m/yr$). This equals a net onshore (NE-bound) potential of 25 $m^3/m/yr$. Of course if the dune vegetation is so dense that very little sand can blow back onto the beach, the net onshore (NE-bound) rate will be close to the full amount of 39 $m^3/m/yr$.

Year). The net potential rate for summer is 14 m^3/m/yr towards the northeast. The net potential rate for winter is 62 m^3/m/yr towards the east. Due to the orientation of the shoreline, the important direction is NE-bound (Oblique onshore and normal to the longitudinal dune ridges) where the net potential rate for winter is 49 m^3/m/yr.

Taking the worst case as being the maximum potential rate in the dune field (without any returning transport by opposing wind transport), the figures show E-bound rates of 74 m^3/m/yr during winter and 48 m^3/m/yr during spring respectively. Looking at all seasons the maximum 'All Year' rate of 47 m^3/m/yr is towards the eastern sector when there is no returning transport due to the vegetation.

Furthermore, the maximum west- and northwest bound wind-blown sand rate is 26 m^3/m/yr during spring and summer. The all seasons rate is 21 m^3/m/yr is towards the west-north-western sector, thus obliquely onshore.

The following conclusions can be drawn from these results:

(1) The orientation of the coastline along Moquini Beach is WSW to ENE.
(2) Sand is therefore blown north-eastwards (obliquely onshore) along the narrow beach due to the dominant south-westerlies throughout the year.
(3) During the hot and dry spring and summer months, the dry beach is at its widest and the frontal dune vegetation is sparse. This allows the prevailing easterly winds to move sand at a potential rate of 26 m^3/m/yr obliquely onshore towards the W. Once the sand is blown beyond the natural foredune, the exposed sand is available to be blown to the eastern sector (i.e. NE and E) at the maximum potential rate of 74 m^3/m/yr during both winter and summer months.
(4) The orientation of the blow-outs that have formed within the foredune at Moquini confirms this net directional trend. It also explains the ENE extension of the relict dunefield (Figure 7) as sand deposited at the mouth of the Goukou river blows inland.
(5) The prevailing onshore wind-blown sand has formed a foredune along the Moquini Beach area that has reached elevations of up to +10 m MSL in places where unmanaged blow-outs have formed.

4. BEACH AND FOREDUNE STABILITY

Coastal foredunes typically provide a valuable service to the areas located landward of the dune system. This so-called ecosystem service, takes the form of a natural buffer dune system (Heydorn & Tinley, 1980[13]). The key factor is the existence of a sufficient volume of sand in the area between the back dune area and the beach. Part of this volume of sand is eroded and washed offshore under stormy conditions. The sand is returned to the beach during subsequent calm periods to rebuild the beach and blown into dunes by onshore winds.[14]

If this beach-dune system is allowed to maintain its natural integrity, the ecosystem service is capable of forming an effective and enduring protection of the back dune area against the forces of the sea. This is particularly valid when development is located beyond the reach of the coastal processes, i.e. behind the setback line.

[13] Heydorn, A. E. F. and Tinley, K. L. (1980). Estuaries of the Cape. Part I. Synopsis of the Cape coast. Natural features, dynamics and utilization. Stellenbosch. CSIR Research Report 380.
[14] A video illustrating these processes can be viewed on You Tube (https://www.youtube.com/watch?v=FqT1g2riQ30)

Where historic human intervention has taken place (i.e. the foredune system has been reshaped to accommodate development (such as at Moquini Beach), ongoing management is required to maintain the modified ecosystem service. Unfortunately the effects of human activities (for example people walking across the dunes) can result in the destruction of the fragile dune vegetation. This in turn leads to the formation of informal pathways that can result in sand blowouts under prevailing onshore winds. Sand blown landward off the foredune is lost to the buffering mechanism. Not only can the advancing wind-blown sand pose a nuisance and costly problem to coastal development, it also means the dune is unable to effectively buffer against the erosional effect of sea storms. This puts the development at risk of undercutting foundations and damage by wave action.

Establishing a sustainable and durable coastal buffering system is dependent on meeting two broad managing objectives: (1) managing the system to maintain the functionality of the prevailing coastal processes including the integrity of the buffer dune area of the ecosystem; and (2) protecting the interests of property owners (private and public) against the impact from the natural processes as well as to enhance the recreational and aesthetic qualities of the area.

Key to maintaining the functioning of the prevailing coastal system at the site and to determine 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.

By 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 carries out the historic trend analysis as discussed in the next section.

4.1 Aerial photograph and image analysis

Useable aerial photographs (sourced from the Surveyor-General, Mowbray, Cape Town) and downloaded Google Earth™ images are available of the study area for the period 1965 to 2020.

Figure 8 shows the 'edge-of-vegetation' line that is relatively easy to observe on aerial images as the boundary between the dark areas (vegetation) and the light area (beach sand). The seaward beach area typically has very little (if any) dune vegetation present. This means that seawater had at times reached the 'edge-of-veg' line thus removing any dune vegetation. This shows that this area is highly dynamic. Also shown on Figure 6 is the wave run-up line, which demarcates the highest point along a beach where waves reached during a recent (seasonal) event. Tracking the wave run-up lines over time provides a useful indicator of beach stability as discussed in the next section.

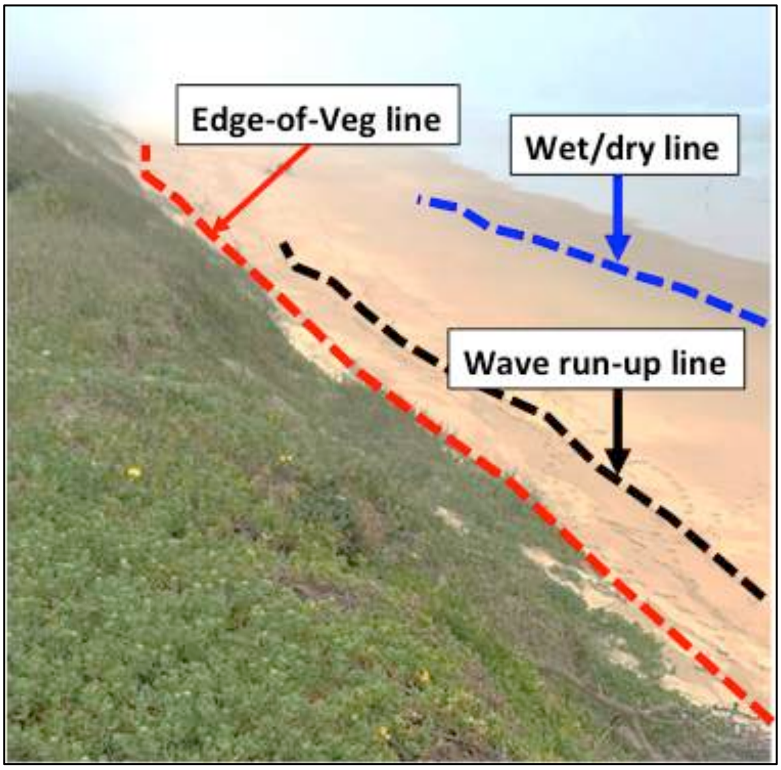


Figure 8: Definition of the 'edge-of-vegetation' and wave run-up lines

The results of accurate topographic surveys15 along the Garden Route coastline has shown that the 'edge-of-vegetation' line can be seen as a proxy for the long-term position of the high water mark (HWM).

Note that the wave run-up line should not be confused with the wet/dry line (also shown in Figure 8). The wet/dry line is closely related to the state of the tide at the time of the photograph whereas the wave run-up line is an indication of the position of the highest point on the beach where the waves reached during a previous event (storm or the high tide).

Theron (2016)[16] researched various methods to determine the coastal development setback within South Africa. He concluded that the use of the 'normal distribution' method provides an acceptable outcome. A variation of this method was used during the CSIR setback report for Moquini and at Lappiesbaai[17] along the Still Bay coastline. In both of these studies it was found that there was no long-term trend in the position of the HWM over the study periods.

The stability of the coastline at Moquini Beach was analysed using a similar method, and the results are further discussed below. There are limitations in using aerial photos to determine the shoreline variation and stability over time. These include the availability of a sufficient time spread of photos as well as the level of accuracy of determining the position of the edge-of-veg line, the high water mark (HWM) and/or the wave run-up line due to the resolution of especially the earlier aerial photos. It has been shown that the accuracy of determining the position of the run-up line off the

[15] Seasonal topographical surveys along beaches in the Garden Route District coastline. Barwell, L, 2017. (in press).

[16] Theron, A.K. (2016): Methods for Determination of Coastal Development Setback Lines in South Africa. PhD Thesis. Stellenbosch University.

[17] CSIR, 2014. Updated management plan for the Lappiesbaai Beach and adjacent area at Stilbaai. CSIR Report January 2014. Stellenbosch

older aerial photos can be in the order of 10 m to 15 m. Results are, however deemed to be acceptable for the intended purpose.

The available aerial photographs and images were used to determine and assess the historical changes that have occurred within the study area.

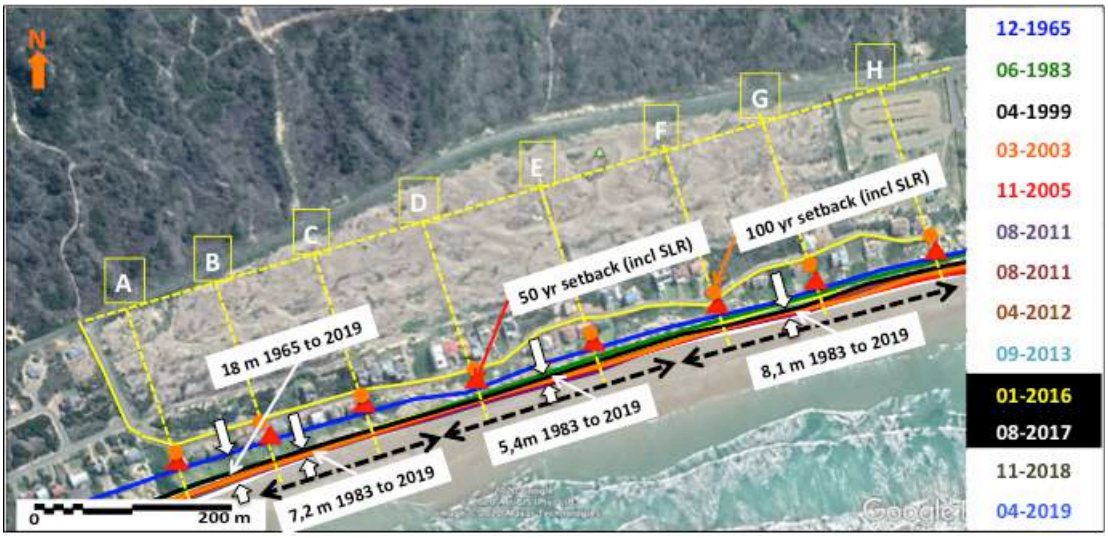


Figure 9: The position of the reference lines (A to H) and positions of the wave run-up line for the period 1965 to 2019 at Moquini Beach. The lines are superimposed at a common scale on the 2019 aerial image (Google Earth™)

As shown in the Figures 9, reference lines (A to H) spaced on average 120 m alongshore (similar to the CSIR 1994 report), were defined as the reference.

The analysis showed that for the period 1965 to 2019 the horizontal position of the wave run-up lines varied on average over distance of 13 m for the 8 lines. The variation envelopes are shown in Figure 9. The dimensions of the frontal dune system had stabilised by 1983 and the average movement of the position of the wave-runup line was over a distance of 6,9 m for the period 1983 to 2019. The standard deviation for the latter period is 2,7 m.

Using the 1983 baseline and applying the normal-distribution method, the calculated short-term erosion distance with a 1:100 year probability is on average 6,2 m landwards of the mean position of the run-up lines at Moquini Beach. These values are included in the setback summary table (Table 6.1).

The results further show that, although the position of the wave run-up fluctuated within an envelope of 5,4 to 10,8 m over the 36 year period, no erosional or accretional trend can be seen. It is therefore concluded that the shoreline at Moquini Beach is in a state of dynamic equilibrium. This implies that the long-term erosion at the site is nil. From the available information it can be concluded that the middle reaches of the Still Bay crenelated bay is in dynamic stability. There is therefore no long-term erosional or accretion trend at the study site, although a conservative 0,05 m/yr coastline retreat rate is accepted to allow for potential errors in the photo analyses.

This conclusion ties in with that found for the CSIR studies at Lappiesbaai and the 1994 study at Moquini Beach.

4.2 Topographical surveys

Beach and dune profile surveys[18] in the study areas were carried out in April 1994 and in October 2020 at the Moquini Beach site. The profiles are shown in Section8. The surveys reflects the form and position of the beach and foredune at the time of the survey and provides valuable comparative information that enables the assessment of possible future changes. The profiles are used as the basis for the management actions as discussed later.

The results show that the seaward position of the +3.5 m MSL contour can be taken as the 'edge-of-veg line' at Moquini and is a useful proxy for the long-term position of the High Water Mark (HWM) at this site.

Of importance is that the upper beach is at an average slope of 1:15 between the 0 MSL contour, the +2 m MSL contour and even up to the + 3 m MSL level and is valid for all the CMUs along Moquini Beach. This information is used to determine the effect of the projected sea level rise component on the long-term setback.

The elevation of the foredune is on average + 8,9 m MSL over a dune width of about 20 m. The dynamic (ever-changing) sea facing portion of the dune is at an average slope of 1:2,4 and has an average width of 12 m measured horizontally landwards from the 'Edge-of-Veg' line. Typically the seaward 6 m will always consist of exposed sandy areas with small hummock dunes and erosion scarps.

4.3 Conclusion on the beach and foredune stability analysis

As discussed above, an assessment was conducted of the beach and foredune stability over the 54 years between 1965 and 2019. The assessment was done using available historic aerial photos images and topographical surveys.

From the above it is concluded that the beach and foredune within the study area can be categorised as being 'dynamically stable' in the long-term at present. This means that there is a balance between the sand that enters the system (via the river, from dune erosion and as moved alongshore) and that leaving the dune-beach system (cross-shore and alongshore due to wave action; onshore due to low energy waves; and wind across the dry parts of the beach). This also means that there is no evidence of a trend of coastline retreat (erosion) or build-out (accretion) at the study site during the period of 36 years since 1983. The beach accreted between the period 1965 and 1983 as the managed dune system stabilised.

However, it is important to understand that the beach and foredune undergo periodic changes that result in the upper (dry) beach being narrow at times and wider at other times. For the Garden Route District, this variation often aligns to the summer and winter periods.

From the surveys and on-site observations can be concluded that there is a large volume of dune sand stored in the buffer dune system, and that maintaining this buffer volume should be the goal of the DMMP.

[18] CSIR in 1994 and LB&A in 2020

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 properties and infrastructure located landwards of the buffer dune system against the influence of present and future coastal processes.

The basic principles of foredune integrity can be summarised as:

The ability of a vegetated foredune to prevent movement of wind-blown sand due to vegetation removal, trampling or die-off as a result of poor management. Furthermore a well functioning foredune also stores a large enough volume of sand to effectively counter the offshore erosion due the design sea-storm.

As discussed in Section 3, the local wind statistics (Figure 6) and the associated calculated wind-blown sand potential (Figure 7) show that there is a potential of a net landwards movement of wind-blown sand at the study site during all seasons but especially during spring and summer. The risk of wind-blown sand being mobilised under onshore winds is high enough to justify an active effort to, for example, maintain the dune vegetation component of the buffer dune system at a high level of integrity.

The critical factors to identify and manage are: (1) exposed sand areas in excess of 1 m^2; and (2) the forming of blow-outs within the foredune and specially associated with informal and formal access pathways to the beach.

A good practice guideline[19] to buffer dune management is available and forms a useful aid to the MMP for the buffer dune at Moquini Beach.

6. CLIMATE CHANGE AND SEA LEVEL RISE

6.1 Introduction

As was noted in IPCC (2001) climate change is expected to have a number of consequences that could detrimentally affect coastal resources. The consequences 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 or erode existing storm protection measures.

The current knowledge and potential impacts are discussed in Appendix 1.

[19] Barwell, L (2013). Generic Guidelines to Buffer Dune Maintenance as an aid to decision making at municipal level. Stellenbosch. (unpublished technical paper).

6.2 Climate change scenarios

As discussed in Appendix 1, which is a direct extract from a CSIR report (CSIR, 2012), it is concluded that the best estimate ("mid scenario") of sea level rise (SLR) by 2100 is around 1 m, with a plausible worst case scenario of 2 m, 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. A value of 0,35 m by 2050 is commonly used in South Africa. The latter scenario is considered relevant to DMMPs.

6.3 Sediment movement and climate change

In general, changes in the shape of sandy coastlines depend on a number of factors of which the availability and distribution of sediment (sand) within a particular system is important. The waves approaching the coast are in affected by, inter alia, the bottom topography, resulting in the waves breaking within the surfzone. Sand along the coast is moved mostly by the breaking waves and associated nearshore currents[20].

Complex interaction amongst the approaching waves and the nearshore movement of water and sediment form alongshore and cross-shore channels in the surfzone. Where the cross-shore rip current channels become deep and close inshore a higher risk of landward erosion of the foredune occurs.

When the dry beach area is wide, typically in the summer months, onshore winds move the dry beach/sand into the foredune area, increasing the risk of wind-blown sand inundation into developed areas.

It can thus be concluded that the primary hazards to physical (abiotic) coastal infrastructure related to waves, winds and climate change induced SLR (and/or wave direction) are:

- 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 and wind-blown sand impacts.
- Coastal erosion, removal of dunes and subsequent under-scouring of, for example, foundations and structures located too close the (new) shoreline.
- A combination of extreme events, such as sea storms during high tides plus sea level rise, will have the greatest impacts and will increase erosion of foredunes and increasingly overwhelm existing wrongly-positioned infrastructure as climate change related factors set in in time.

The main metocean drivers related to the above are thus waves and sea water levels (and to a lesser extent winds and currents). The landward drivers include flash floods that create higher storm water levels in low lying areas, especialy along estuaries. The storm water discharging onto the dunes and beach result in wash-aways and lower beach levels resulting in an increase risk of dune erosion.

The implication of the extreme inshore water levels due to storm surge and sea level rise on the Moquini Beach area is discussed in the next section.

[20] A video illustrating these processes can be viewed on You Tube (https://www.youtube.com/watch?v=FqT1g2riQ3o)

6.4 Site-specific hazard level

The background discussion to determining the site specific extreme inshore sea water levels (or the hazard level) is provided in the previous section and in Appendix 1.

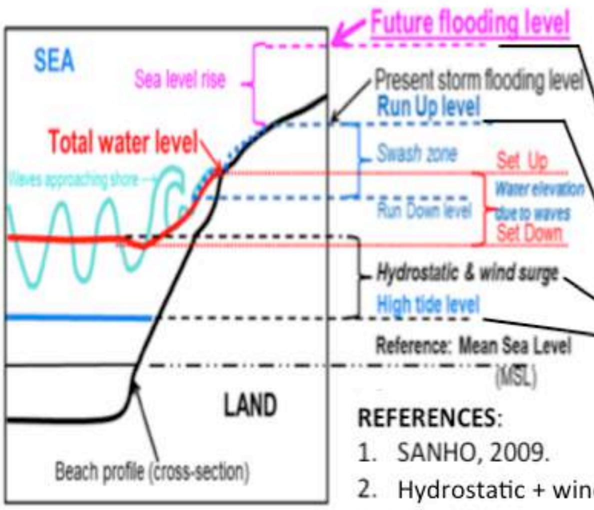
Commissioned by the national Department of Environmental Affairs (DEA), the CSIR produced a research report that summarised the state of knowledge (in 2014). The report still forms the basis of coastal hazard and vulnerability assessments of the South African coastal region.[21] However, some refinement has taken place and regional information now exists and has been included in demarcating coastal management lines[22] as discussed in Section 2.

The CSIR report produced estimates of extreme values for realistic combinations of the inshore seawater level components as applicable to each SA coastal region. Based on these calculations and the wave conditions, robust first-order (coarse) storm surge levels estimates are provided of the regional storm surge levels around the South African coast for the offshore wave regime.

Stated clearly, therefore, is the reality that although it is at present not possible to reliably estimate changes in storm patterns, windiness, wave energy or direction, the increase in storm activity and severity will probably be the most visible impact as a risk to vulnerable properties.

The analysis method described in detail in CSIR (2014) was used to determine a hazard level (m to MSL) at Moquini Beach as illustrated in the figure below.

HAZARD LEVEL (INCLUDING CLIMATE CHANGE)



REF	1 DRIVER	2 CALC. PROCESS	3 INCREM. COMP. (m)	4 ACCUMM. LEVEL (m MSL)
E	Hazard Level	(D4)		7.0
D	SLR[4]	(C4 + D3) = D4	0.35	6.9
C	Run-Up[3]	(B4 + C3) = C4	4.55	6.55
B	Residual[2]	(A4 + B3) = B4	0.83	2.0
A	MHWS[1]	(A4)		1.17

REFERENCES:

1. SANHO, 2009.
2. Hydrostatic + wind surge (1:10 yr). CSIR, 2014
3. Run-up for mostly exposed bay (1:30 yr). CSIR, 2014
4. Sea Level Rise in medium term (by 2050). CSIR, 2014.

Figure 10: Extreme still water level & wave run-up within the mostly exposed section of coastline in the Still Bay bay, including the Moquini Beach area.

[21] CSIR (Council for Scientific and Industrial Research). 2014. *Determination of the inshore wave climate along the South African coast – Phase 1 for coastal hazard and vulnerability assessment*. CSIR Report CSIR/NRE/ECOS/ER/2014/0037/A, Stellenbosch.

[22] Eden District Coastal Processes and Risk Modelling (v.2). Royal HaskoningDHV, UK Ref.:MD2368. Draft May 2017.

Figure 10 shows the extreme inshore sea water levels calculated for the study site (using the tidal information available for Mossel Bay (http://www.sanho.co.za) due to the combination of the various contributing components. The figure shows the increasing water levels all relative to Mean Sea Level (MSL) which is at 0 m elevation:

- Mean High Water Spring tide (MHWS) = 1,17 m above MSL (see Cell A4 in Figure 10).

- Storm surge as estimated for a 1:10 year return period = 0,83 m. (Cell B3). If added to the MHWS level the storm surge level can reach +2,0 m MSL. (without wave run-up) – see Cell B4). The storm surge amount includes the effect of a low-pressure weather system ('cold front') passing the coast that results in a local set-up (increase) of the sea water level due to strong onshore winds and low barometric pressure, known as the residual component – Cell B3. Thus, at present, a coastal low pressure system passing the coast during spring tides (which occur every 2 weeks) could result in sea water levels of about +2,0 m above MSL.

- The above elevations all relate to the still-water level at the shoreline. This should not be confused with the additional effect of wave run-up, which can reach even higher elevations. (Wave run-up is the rush of water in the swash zone up the beach slope above the still-water level. Figure 11 illustrates this phenomenon on an open coast). Based on wave and run-up modelling (CSIR, 2014), the additional height reached by wave run-up would be in the order of 4,55 m (Cell C3) for the mostly exposed are at the study site. If a 1:30-yr storm occurs during a spring high tide the wave run-up level at the study site is therefore +6.55 m MSL at present (without sea level rise) (Cell C4).

- The mid scenario (best estimate) for Sea level Rise (SLR) due to Climate Change) is +1 m by 2100, or in the order of 0,35 m by 2050 (see Appendix 1). Thus, the total elevation reached by storm waves during a low pressure system at spring high tide could be in the order of +6,55 m +0,35 m = +6,9 m above Mean Sea Level (MSL) for the 2050 SLR scenario. Rounded up to + 7,0 m MSL this level is known as the 'Hazard Level' at the site and should be taken into consideration when designing the location and level of coastal infrastructure such as access steps along the beachfront. The hazard level also forms a critical factor in determining the required buffer dune volume.

Figure 11: Examples of the effect of a large storm coinciding with a high tide level on an open coastline. (Photo: Ethekwini Municipality)

6.5 Setback distance due to sea level rise (SLR)

The net alongshore sediment transport direction at Moquini Beach area is predominantly towards the east, with occational westward movement during easterly wave and wind conditions. Sediment within the Moquini Beach stretch of coastline is moved around via a series of alongshore and cross-shore current channels which effectively keeps the sediment within the local system.

The eastbound alongshore movement happens during large storms originating from the southwestern sector. Sediment flushed out of the Goukou estuary at times feeds sand into the system from the western side of the crenulated bay to replace that moved out of the system to the east. This, along with the managed foredune system could explain the reason for the long-term dynamic stability of this section of coastline. No specific research has been done on this hypothesis, however an understanding of nearshore processes makes it credible. A further deduction leads to the assertion that SLR will not change the sediment movement system in any significant manner.

The previous discussion concluded that the projected SLR is +0,35 m by 2050 and +1,0 m by 2100. This reduces to a SLR rate of 9 mm / yr for the 40 years from 2010 to 2050 and then 13 mm / yr from 2050 to 2100.

Using the surveyed beach slope (an average of 1:15), the horizontal distance setback at Moquini Beach due to SLR by 2050 is calculated to be on average 3,3 m; and 9,4 m by 2100.

6.6 Total setback distance due to coastal processes

The total setback due to coastal processes at Moquini Beach is therefore the sum of the components dicussed above and reflected in the table below. The positions of the analysis lines are shown on Figure 8.

Table 6.1: Total development setback at Moquini Beach

Component	Distances (m)								
	Lines	AA	BB	CC	DD	EE	FF	GG	HH
	CMU	1	1	1	2	3	4	5	6
Short-term erosion	1:100	14	12	12	7	8	9	8	9
Dynamically stable	2050	2	2	2	2	2	2	2	2
	2100	4	4	4	4	4	4	4	4
SLR setback	2050	3	3	3	3	3	3	3	3
	2100	9	9	9	9	9	9	9	9
Wind-blown sand buffer	2050	15	15	15	15	15	15	15	15
	2100	15	15	15	15	15	15	15	15
Total development setback	2050	34	32	32	27	28	29	28	29
	2100	42	40	40	35	36	37	36	37

The calculated setback distance correlates well to that determined by the CSIR in 1994, and thus confirms the development setback line for Moquini Beach.

7. FINDINGS AND CONSIDERATIONS

The findings and considerations based on the analyses in the sections above lead to the following conclusions pertaining to the design parameters of an effective buffering system and maintenance management plan for the seaward interface between the Moquini Beach development, including roads and parking areas and the current and future coastal processes:

- The coastline at the site is in a state of dynamic equilibrium with no long term trends noticeable during the analysis period of 54 years (1965 to 2019). A conservative long-term erosion rate of 0,05 m/yr in the reorientation of the crenulated bay configuration is recommended to allow for possible errors due to the poor resolution of the earlier aerial photography. Working off the CSIR (1994) configuration baseline, this translates to an incremental setback distance of 2 m by 2050 and 4 m by 2100, and can be seen as a safety margin.
- The wave run-up line (i.e. shoreline stability) has moved within a range of up to 13 m over the period of 54 years (1965 to 2019) at Moquini Beach (Figure 9). This reflects the net influence due to seasonal changes, including storms. It translates to a 1:100 yr short-term erosion potential of an average of 9 m and 14 m. The earlier situation (pre-1963) is ignored due to the major human-induced modification to the foredune area that took place in the late 1950s.
- A SLR of 0,35 m by 2050 can result in the HWM moving landward on average by 3 m based on the assumption that the upper beach slope will remain in the order of 1:15 as seen at present. This value is 9 m by 2100 (Table 6.1).

- During the hot and dry spring and summer months, the dry beach is at its widest and the frontal dune vegetation is sparse. This allows the prevailing south-easterly winds to move sand at a potential rate of 26 m^3/m/yr obliquely onshore towards the NW. (See Section 3.3). Once the sand is blown beyond the natural foredune, the exposed sand is available to be blown to the eastern sector (i.e. NE and E) at the maximum potential rate of 74 m^3/m/yr during both winter and summer months.

- An allowance of 15 m for a vegetated buffer to manage wind-blown sand influx is considered to be adequate for the wind-blown sand potential. The edge-of-veg position is typically used as the seaward reference point for this component.

- The total development setback due to coastal processes for 2050 is estimated to be an average of 30 m landwards of the long-term mean of the position of the wave run-up line at Moquini Beach (Table 6.1). By 2100 this distances is an average of 38 m. This confirms the setback line established by the CSIR In 1994.

- A seastorm hazard level of +7,0 m MSL is determined for the site by 2050. The implication is that the wave run-up during a significant seastorm occurring at spring high tide can reach a level of +7,0 m MSL. Adding a further 2,0 m horisontal retreat due to post-storm slumping of the dune to the natural angle of repose, the 50-yr erosion level is taken as + 8 m MSL. The implication is that the minimum foredune elevation should be maintained at + 8 m MSL to be safe.

8. MAINTENANCE MANAGEMENT REQUIREMENTS FOR MOQUINI BEACH

8.1 Introduction

In the previous section it is concluded that the 2050 hazard level is at +7,0 m MSL which includes a projected sea level rise of 0,35 m for the Moquini Beach area. Allowing for further post-storm dune slumping, a minimum foredune elevation of + 8 m MSL is recommended.

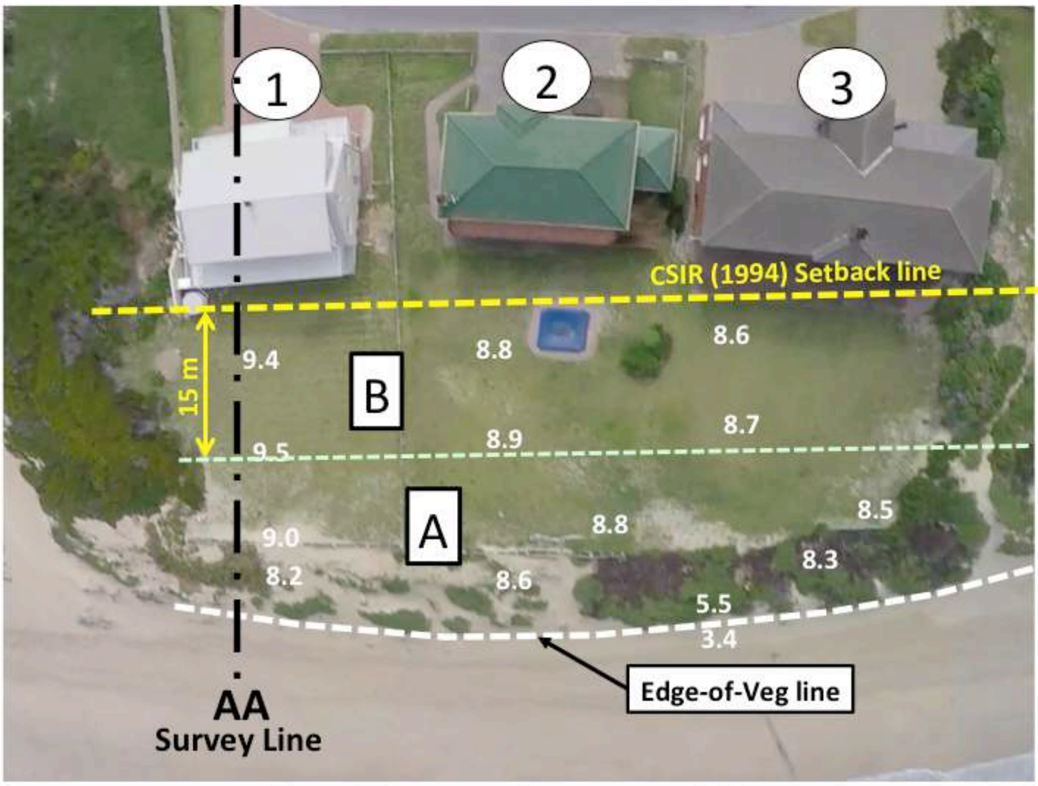


Figure 12a: Overview of Maintenance Management Requirements for the SW part of CMU! 1at Moquini Beach

In Management Zone A (Figure 12a) it is assumed that a band of up to 5 m landwards of the edge-of-veg line will always be in a state of dynamic change due to the influence of waves and wind. This means that the active maintenance ativities are to be concentrated on the rest of the area of Zone A.

As discussed in the methodology statements (Section 8.2) the management objectives for Zone A are to prevent landward wind-blown sand movement in exposed areas and the prevention of blow-outs.

In Managenent Zone B active coastal gardening can be promoted using suitable indigenous vegetation. The planting of suitable indigenous lawn grass should be restricted to the area within 5 m seawards of the CSIR Setback line..

No permanent hard structures should be placed in either Zones A or B. This includes, e.g. swimming pools, fish ponds, built seating and concrete/brick steps and footpaths to to the beach.

The identification and demarcation of suitable beach access points is critical. Active management of these areas will be required to prevent blow-outs from forming.

Boardwalks and pathways made from timber and not placed on concrete footings or foundatons can be used to cross the Zone B and the first 10 m of Zone A when looking seawards from Zone B.

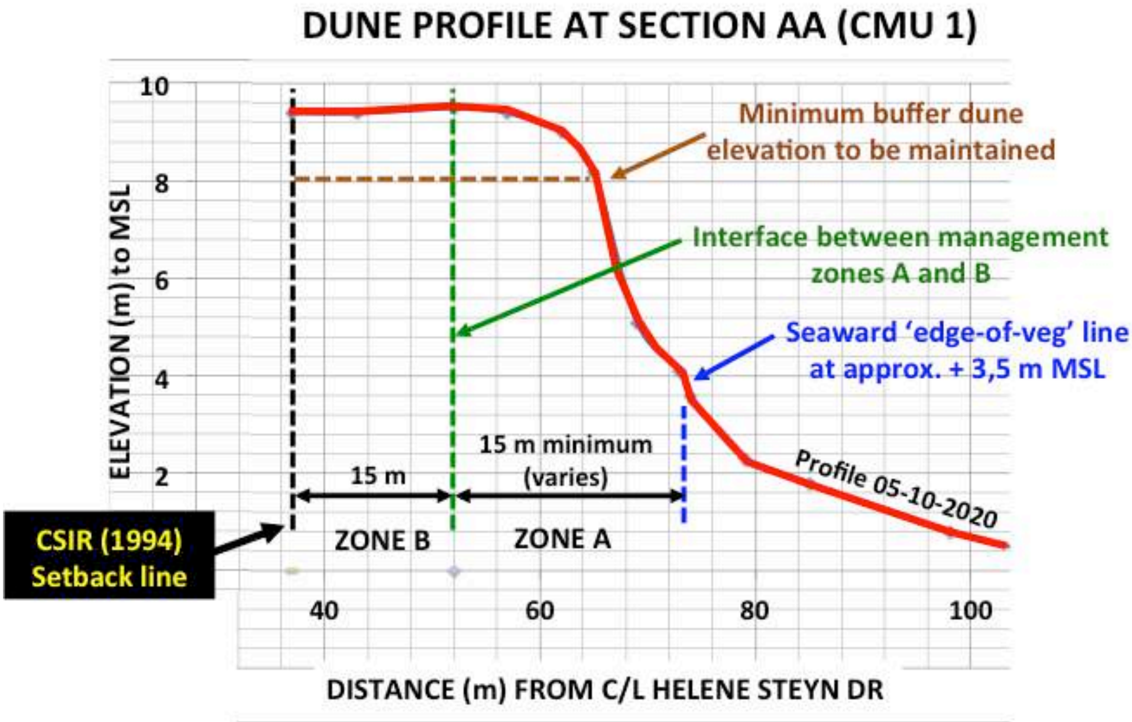


Figure 12b: Overview of Maintenance Management Requirements for the SW part of CMU! 1at Moquini Beach

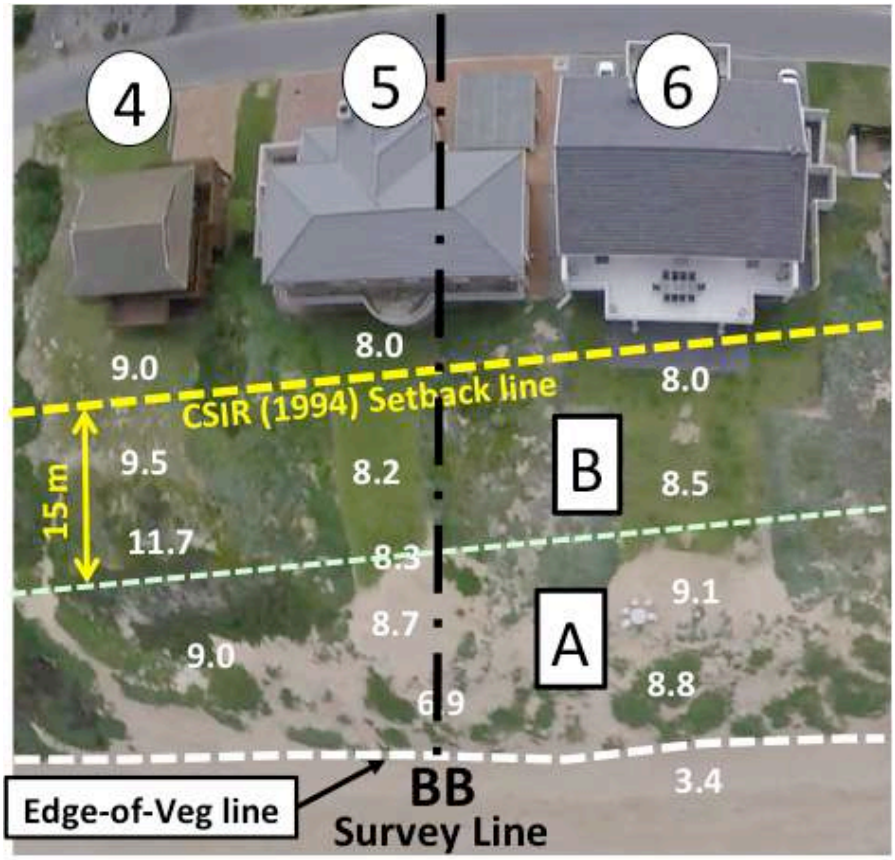


Figure 13a: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

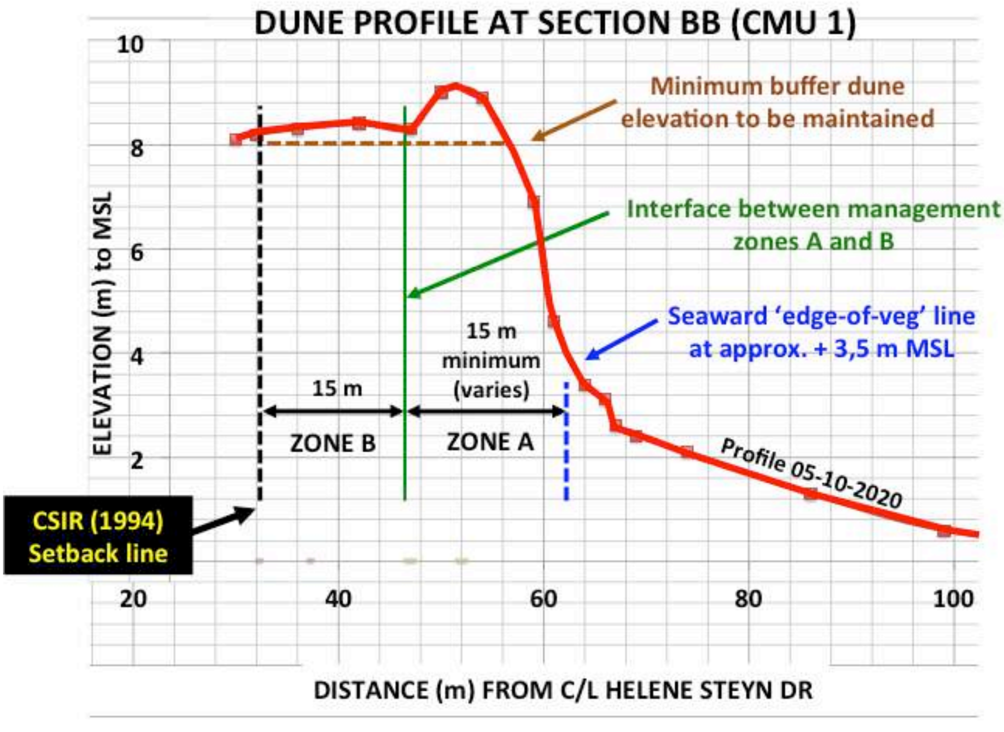


Figure 13b: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

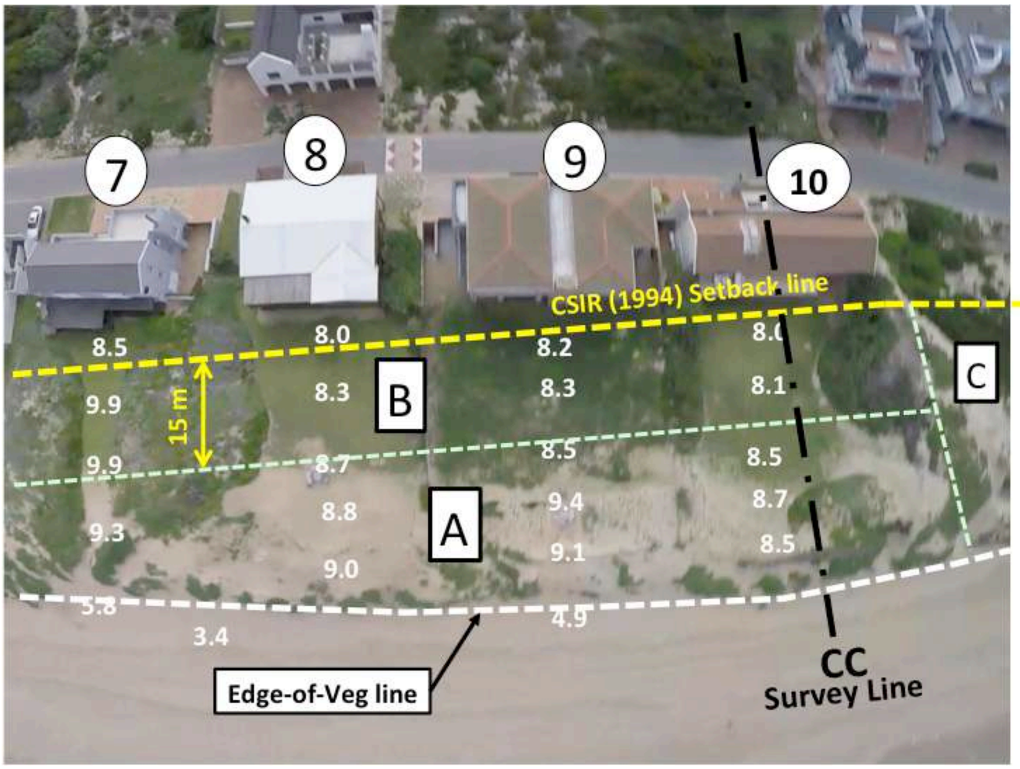


Figure 14a: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

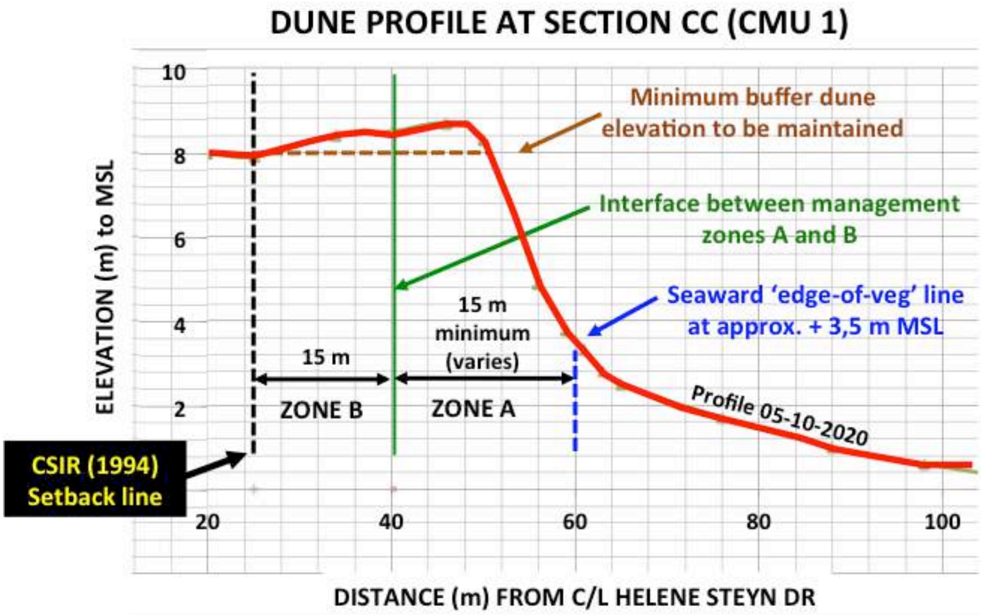


Figure 14b: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

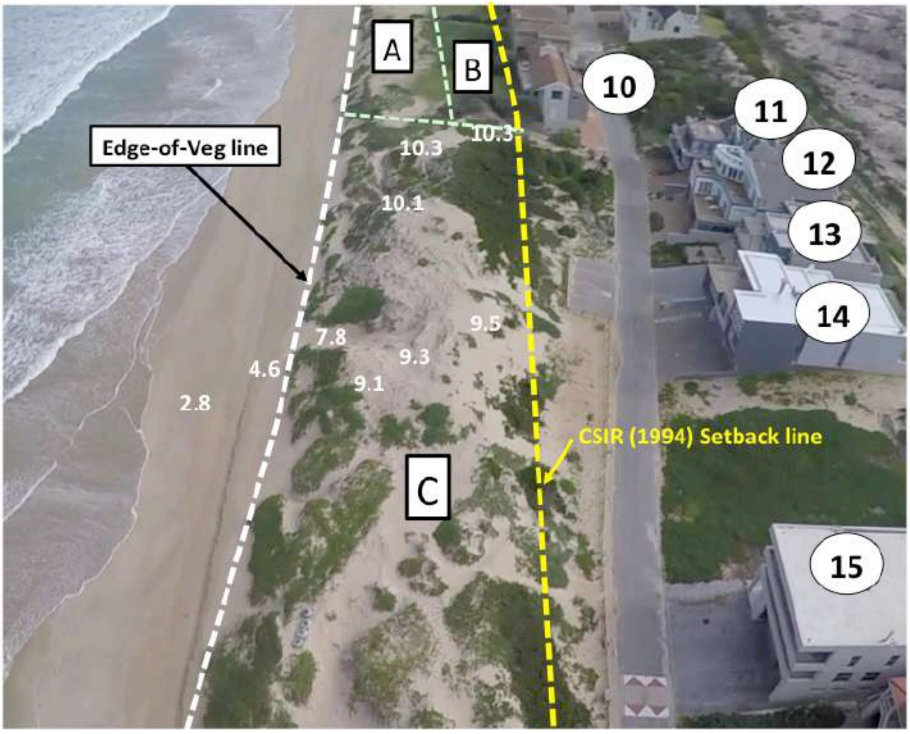


Figure 15: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

The maintenance management of Zone C is similar to those for Zone A, but activities extend all the way landwards up to the road and parking areas.

The dune height can be topped to the +8,0 m MSL minimum level by bulldozing the sand seawards onto the beach. The sand areas exposed by the topping activities should be stabilized by brushwood planting and revegetation. The details are provided in the methodology statements in Section 8.2.

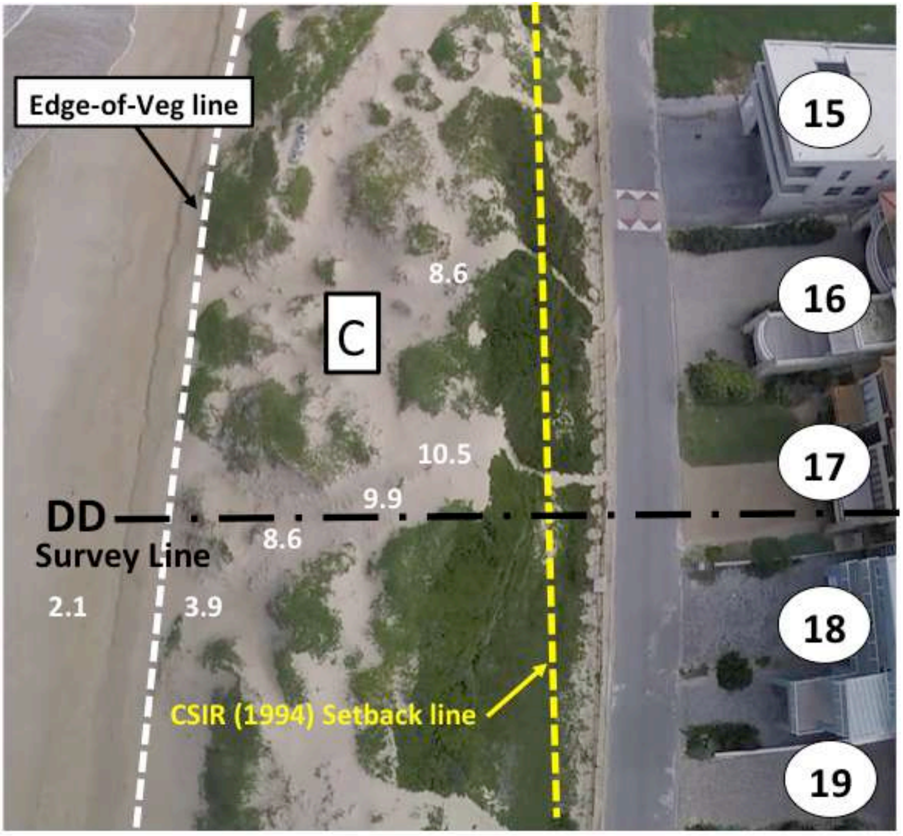


Figure 16a: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

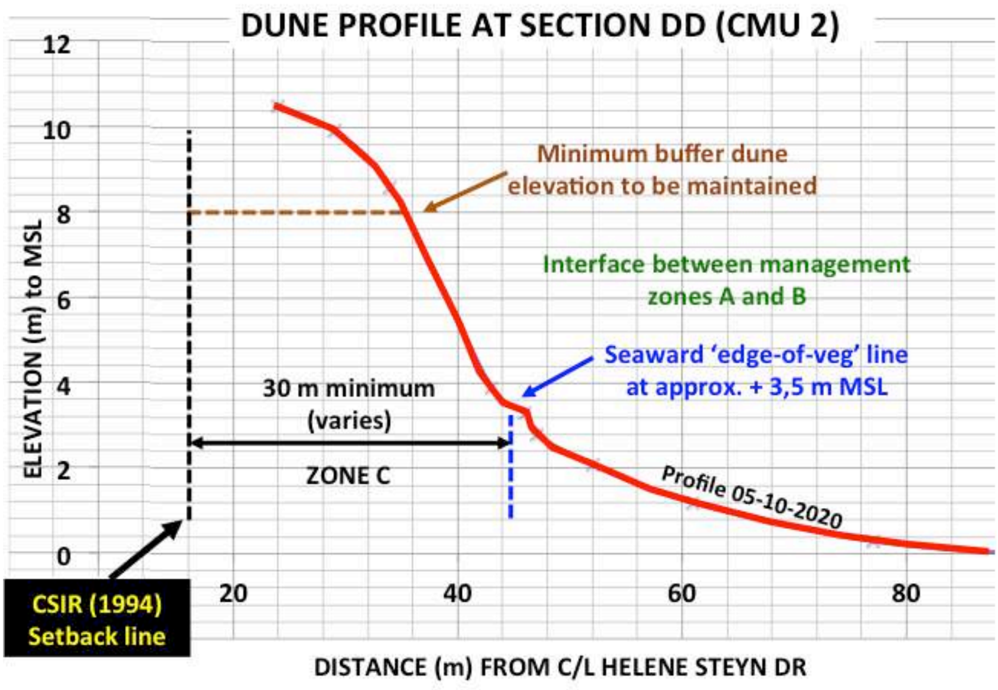


Figure 16b: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

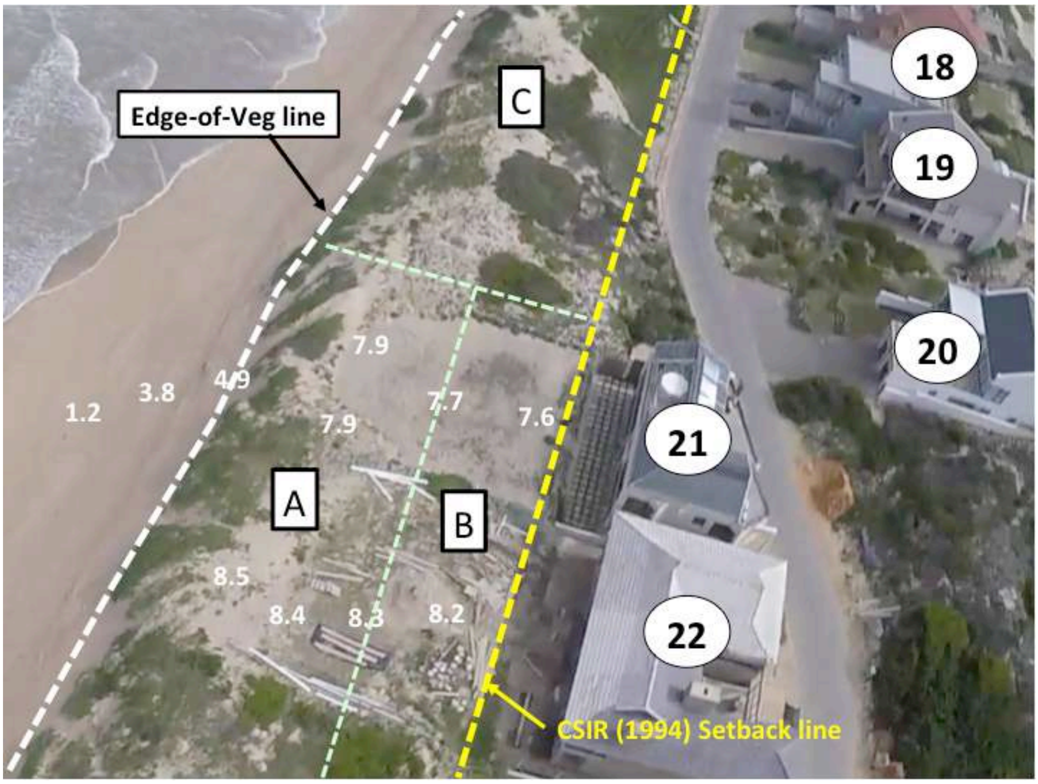


Figure 17: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

Figure 18a: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

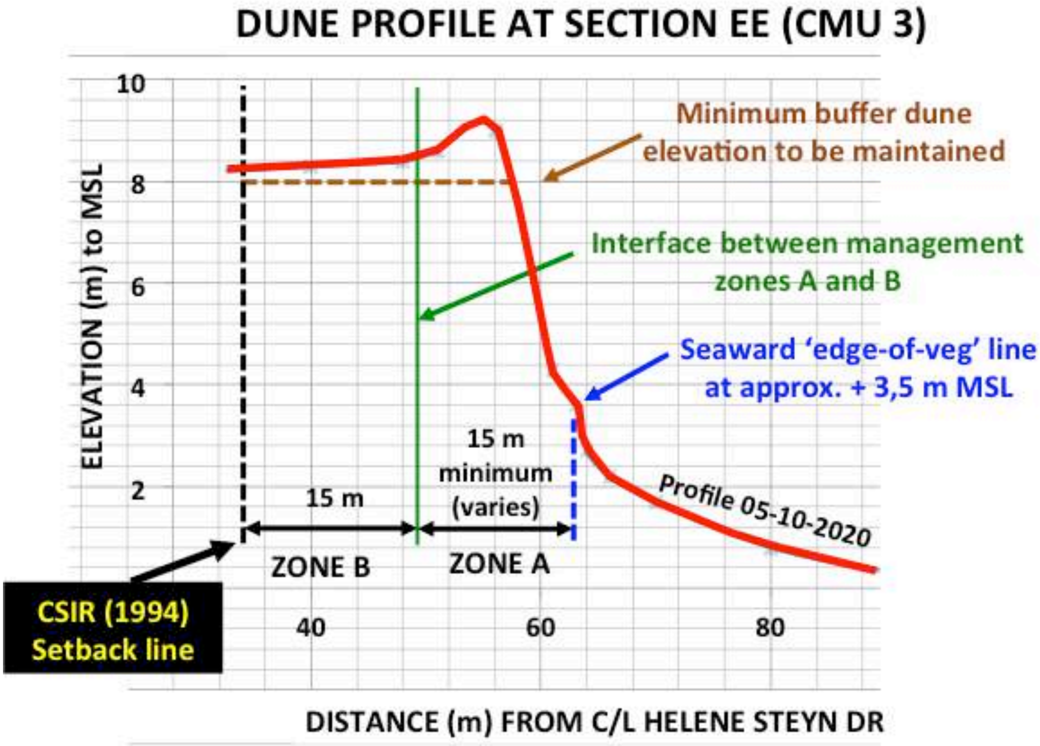


Figure 18b: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

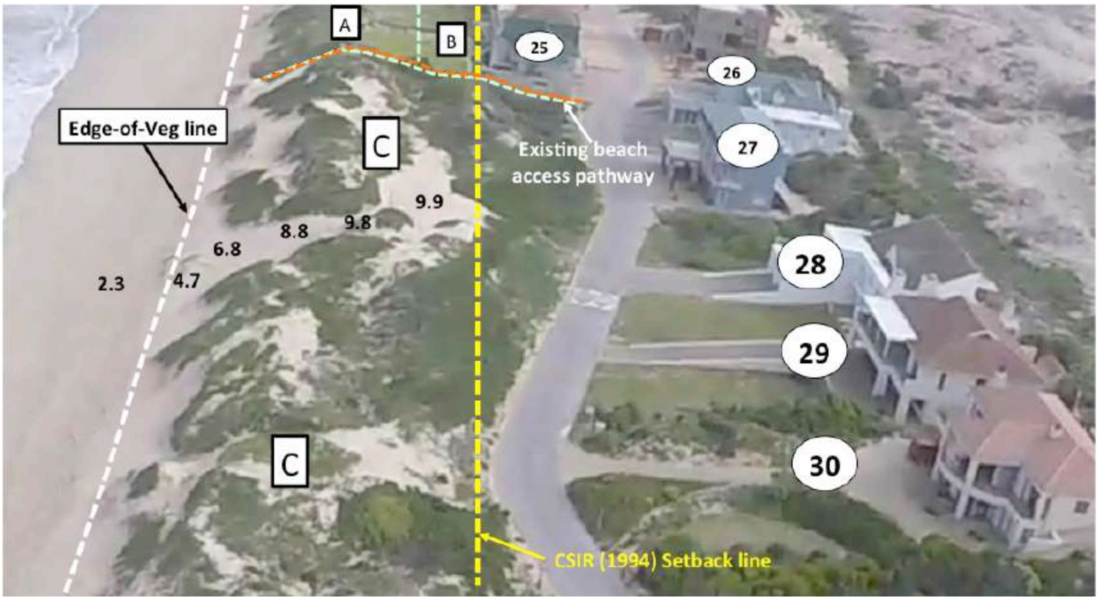


Figure 19: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

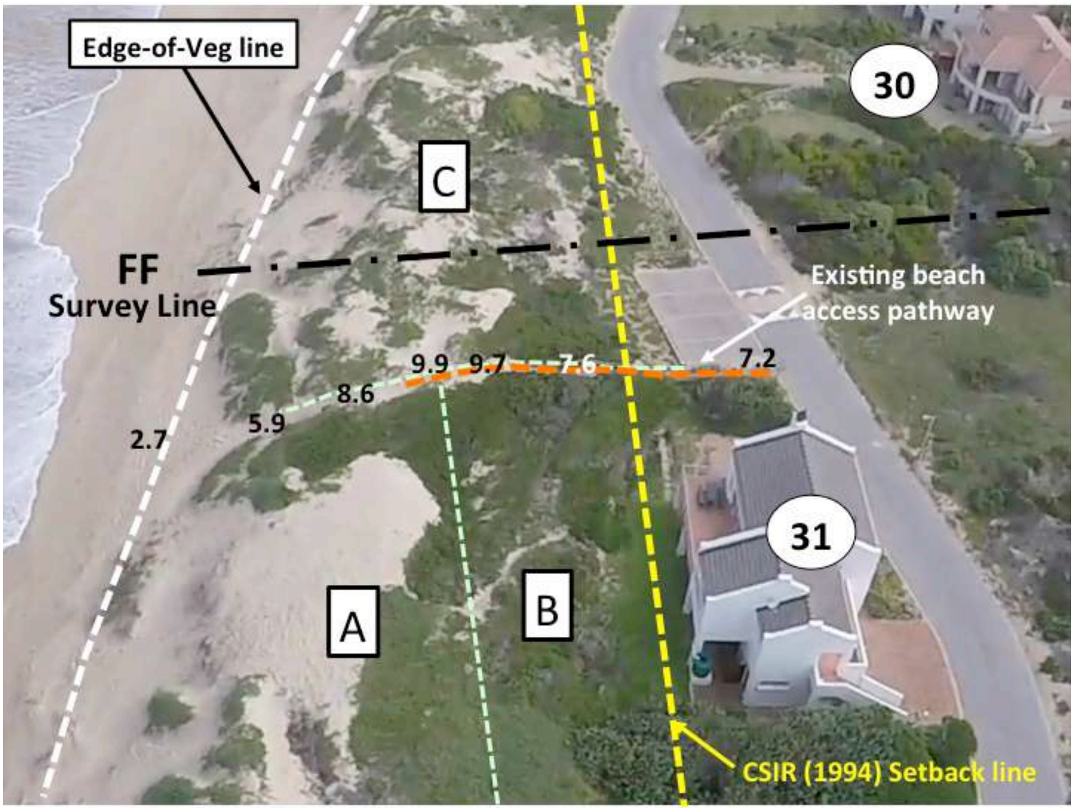


Figure 20a: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

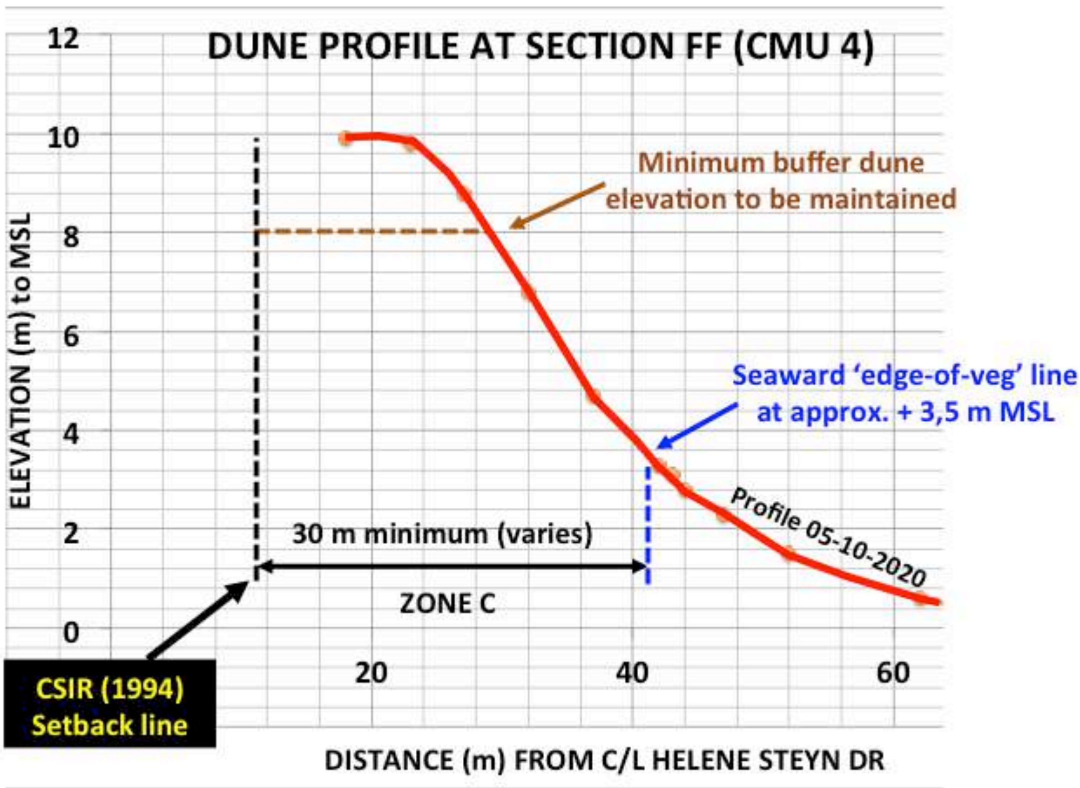


Figure 20b: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

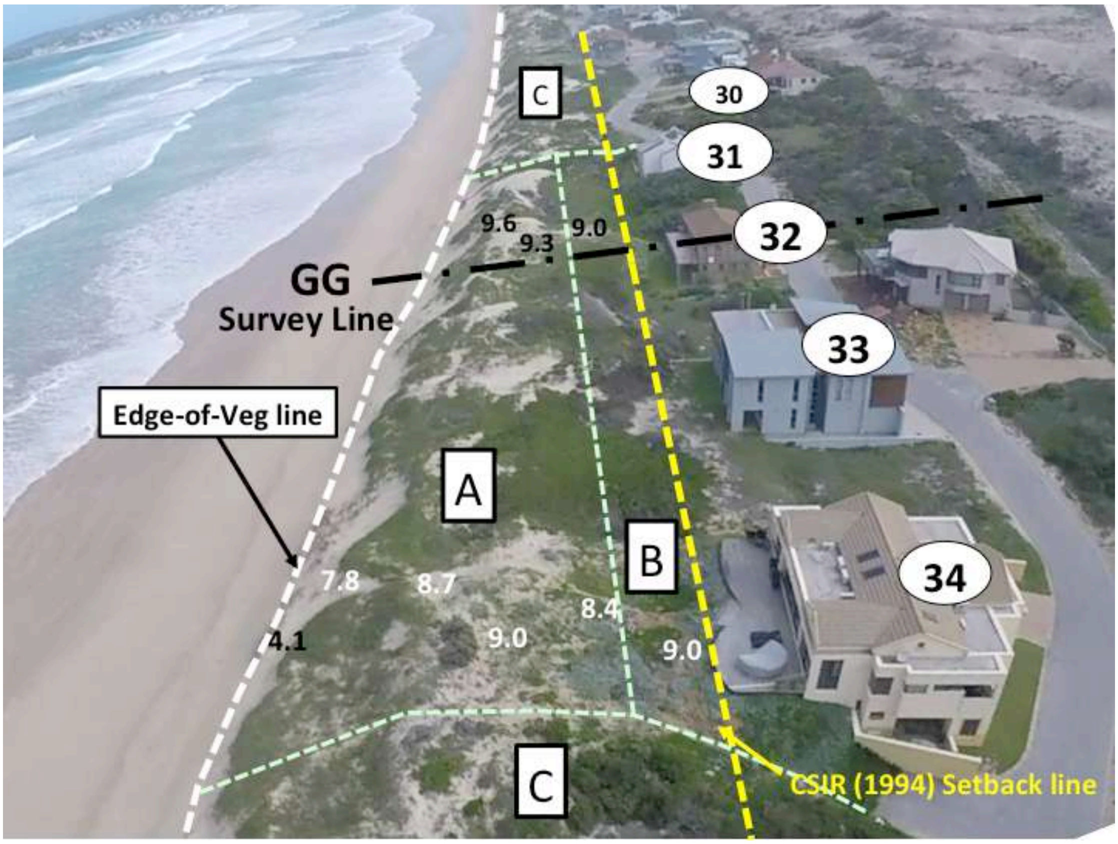


Figure 21a: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

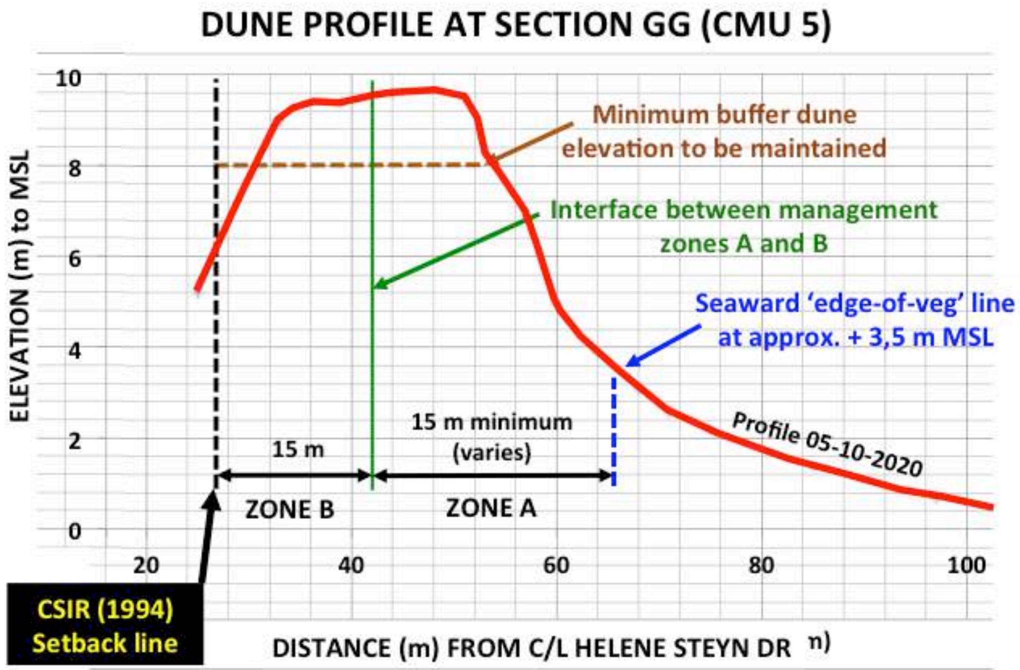


Figure 21b: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

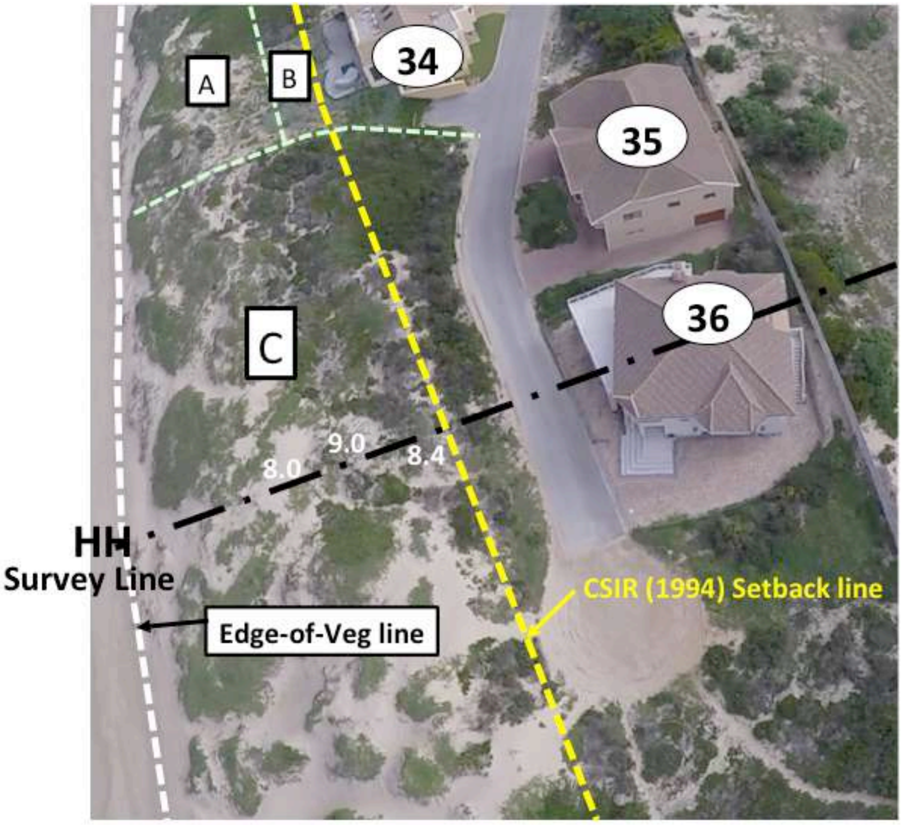


Figure 22a: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

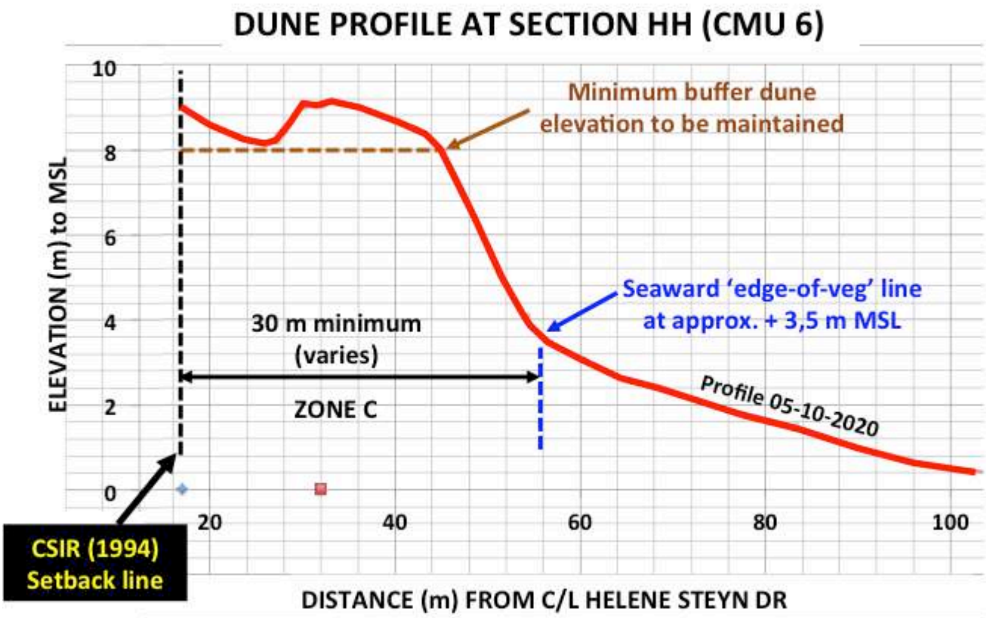


Figure 22b: Overview of Maintenance Management Requirements for Sections B and D at Moquini Beach

8.2 Description of Specific Maintenance Activities

8.2.1 Description of Specific Maintenance Activities for Management Zone A

Method Statement 1: Maintain the buffer dune volume at the recommended amount. By definition this means managing the minimum height of the dune as well as the minimum width relative to the recommended setback line as indicated for the CMUs.

Action 1.1
The minimum design area and elevation (+ 8 m MSL) for the buffer dune is indicated by a system of reference points established on the buffer dune to indicate the minimum level to which the buffer dune is to be managed.

Action 1.2
Indicate the boundaries of the various zones relative to the setback line by a system of clearly marked refence points. The minimum height should be indicated in an appropriate way to allow effective dune height management.

Method Statement 2: To prevent onshore encroachment of wind-blown movement of sand

Action 2.1
The Dune Management Team (DMT) should Identify blow-outs and areas where dune sand is exposed. The ***Good Practice Guide and DSS*** tool (Appedix 2) can be applied to identify the appropriate maintenance responses.

Action 2.2
Stockpile seedless branches in an appropriate place where it does not pose a fire hazard. This will be done under supervision of the Dune Management Team in collaboration with the Working on Fire and specific worker teams set up by the DMT. The material will be used for brush packing and will be gathered from road verges and the clearing of fire breaks. The brush pack material will comprise a variety of natural vegetation and seedless Rooikrans. The collected material will be temporarily stored at the designated hoarding sites situated along Helene Meyer Drive. The Dune Management Team will ensure that the material does not pose a fire risk and/or threat to the private and municipal property. This will be done by stacking the branches in small heaps within the designated hoarding sites.

Action 2.3
Pack seedless brushwood on the minor blowouts and all exposed areas as identified during the seasonal assessment using the ***Good Practice Guide and DSS*** tool. The dune rehabilitation worker team will dig holes / trenches of up to 40 cm deep and plant and pack the brushwood in staggered rows that are about 40 cm apart. The overall goal is to establish a suitable micro-climate that would result in the reinstatementof indigenous coastal vegetation in the identified dune areas.

Action 2.4
Plant appropriate indigenious dune vegetation in the exposed sand areas. Plants or cuttigs can be sourced from identified areas within the adjacent managed foredune areas.

Method Statement 3: Refill blow-outs by returning sand that has been blown out of disturbed areas within Management Zone A. The purpose is to maintain the volume of sand in the buffer dune.

Action 3.1
Sand blown landwards from existing and newly formed blow-outs is returned to the blow-out depression by using manual labour. Supervised by the Dune Management Team, this activity will be followed by Actions 2.3 and 2.4 and result in the integrity of the foredune being re-established and maintained.

8.2.2 Description of Specific Maintenance Activities for Management Zone B

8.2.3 Description of Specific Maintenance Activities for Management Zone C

9. MANAGEMENT RECOMMENDATIONS

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

1. Appoint a dedicated Dune Management Team
2. Secure a budget.
3. Install a series of dune height and zone indicator reference poles within each CMU to indicate the minimum dune crest height (+8,0 m MSL) and the boundaries of the various management zones. Use the reference poles as an educational topic for current and future home owners and their children.
4. Note that there are different guidelines for maintaining Zones A, B and C respectively.
5. Assess the buffer dune integrity (use the ***Good Practice Guide and DSS*** – Appendix 1) 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.
6. Top the buffer dune to the predetermined minimum level (+8,0 m MSL) when required. Such activities should be planned for July and can be done by mechanical means or via manual labour. Note, a special permit needs to be obtained from DEA if it is required for vehicles to drive on the beach. Te need for beach driving is not foreseen for Moquini Beach.
7. It is anticipated that a height control intervention will be required on average every 4 to 5 years. However if the dune integrity is managed diligently (Step 5) and all 'blown-out' dune sand placed back into the blow-outs and the excess placed back onto the beach (as this is an important natural source of sand that maintains the beach dynamics) it is foreseen that the dune crest height should naturally be maintained at or close to the minimum level.

8. Plan the topping exercise properly which includes the re-establishment of the dune vegetation during late winter and spring only.
9. Prepare a stockpile of seedless branches to be used for blow-out prevention / management, especially during summer and autumn.
10. Communicate effectively (seasonal news article on dune integrity status, especially during vacation periods) to secure cooperative management of the dune integrity.

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APPENDIX 1: Extreme inshore sea water levels

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

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.

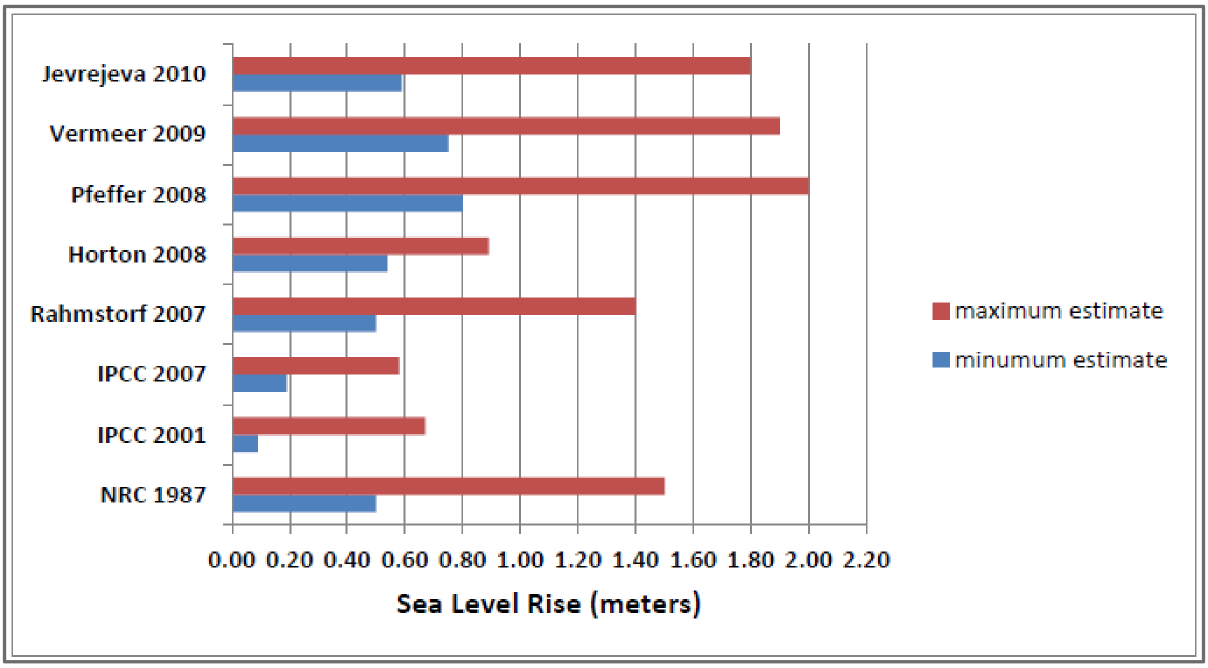

Figure A6.1: Comparison of minimum and maximum estimates of global SLR by year 2100 (USACE, 2011)

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.

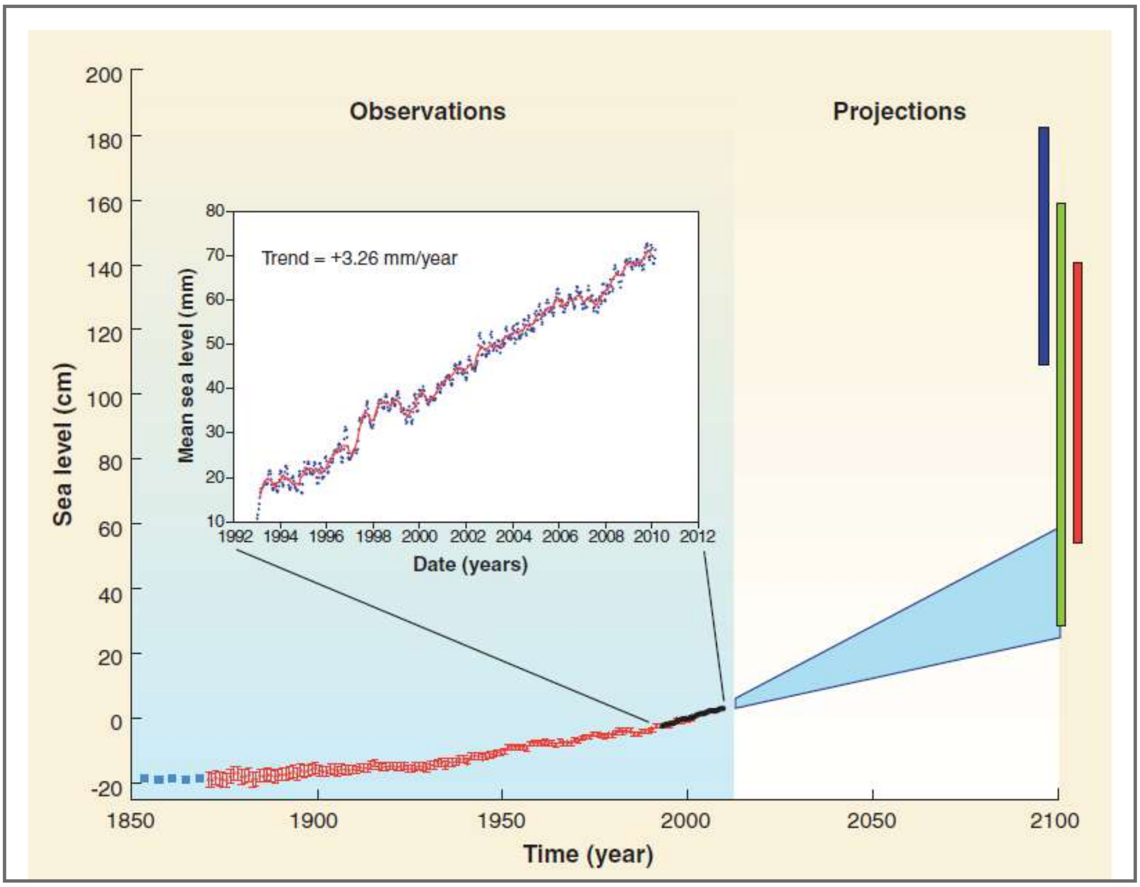

Figure A6.2: Measured and project sea level rise (Nicholls and Cazenave 2010). (The blue, green and red bars are projections from different authors.)

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 2: Good practice guide and Decision Support System for buffer dune maintenance 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 to the indigenous plant species and would leave large areas exposed and therefore open 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 establish indigenous 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 topping the dune and/or 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. 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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