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Coastal Management/Set-back Lines for the Overberg District

Coastal Processes and Risk Modelling

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1 INTRODUCTION

With climate change and the dynamic nature of coastal zones in mind, the prediction of sea level changes and calculation of the related coastal risk to coastal communities have become a necessity in the face of the potentially extensive impact of sea level rise-related storms and increase in storm surges on the coastal zone. The Western Cape Government Department of Environmental Affairs & Development Planning (WCG) proposes to delineate coastal management (set-back) lines for the Overberg District as one strategy through which responsible coastal management can be ensured. A process of determining such lines was initiated in 2011/2012 (WCG, 2012), and this is now being revisited following further refinement of the approach and methodology.

Delineation of coastal management (set-back) lines must be undertaken in accordance, or in alignment with, a number of legislative tools. This includes the National Environmental Management: Integrated Coastal Management Act (Act No. 24 of 2008) and the National Environmental Management: Integrated Coastal Management Amendment Act (Act No. 36 of 2014)(ICM Act), the National Environmental Management Act (Act No. 107 of 1998)(NEMA), NEMA Environmental Impact Assessment (EIA) Regulations, 2014, the Draft Western Cape Provincial Coastal Management Programme as well as the Western Cape Provincial Spatial Development Framework (PSDF). Furthermore, coastal management zones are proposed as a means to facilitate improved planning and management of sensitive and often vulnerable coastal areas. The process outcomes will therefore need to filter into municipal planning through Integrated Development Plans (IDP's) and Land Use Management Schemes (LUMS).

The project consists of two main components – modelling of coastal processes on the one hand and determination of management guidelines on the other. The technical modelling includes the determination of a refined high water mark (HWM), and various lines describing natural coastal processes in respect to short, medium and long term risks. Management guidelines are then derived by means of a stakeholder engagement process which is based on the technical information.

It is envisaged that at the end of the project, the following would be available:

- a delineation of the high-water mark as defined by the ICM Act
- lines demarcating physical processes or sea-based risk in the short, medium and long term (1:20, 1:150 and 1:100)
- a coastal management line that can be used to manage development along the coast
- a line demarcating the Coastal Protection Zone (CPZ) (as required by the ICM Act)

This report deals with the first component of the project, namely the modelling of coastal risk and associated mapping of different risk zones along the coastline.

2 COASTAL MANAGEMENT (SET-BACK) LINES IN TERMS OF THE ICM ACT

Coastal management (set-back) lines, as detailed in the ICM Act, are prescribed boundaries that indicate the limit of development along ecologically sensitive or vulnerable areas, or an area that poses a hazard or risk to humans. These lines referred to by the ICM Act are different both in origin and application to development set-back lines used within the EIA regulatory scheme, but could in future potentially be used as such.

The coastal management line prohibits or restricts the construction, extension or repair of structures that are either wholly or partly seaward of the line, and may even be situated outside the coastal zone. The ultimate intention of the coastal management line, as defined in the ICM Act, is to protect or preserve:

- coastal public property such as beach amenities and other infrastructure such as parking
- coastal private property such as private residences and business properties
- public safety in the face of extreme climate and other natural events
- the coastal protection zone
- the aesthetics or "sense-of-place" of the coastal zone

The establishment of coastal management lines is a provincial responsibility but a relevant Member of the Executive Council (MEC) can only establish such a line(s) after consultation with Municipalities and interested and affected parties (I&AP's). The MEC must communicate this by publishing regulations or a notice in the Gazette (as per the ICM Amendment Act). Once determined, this line must be delineated on the map or maps that form part of the municipal zoning scheme. This is done so that the public may determine the position of the set-back line in relation to existing cadastral boundaries (Celliers *et al.,* 2009).

The coastal management line is proposed to give specific direction in respect to locating the future development footprint, whilst the information on coastal risk can be used in coastal planning schemes to inform future activities and land use. Effective coastal governance structures should ensure that future decision making is in line with the National, Provincial and Municipal Coastal Management Programmes (CMP) and any related norms and standards to assist decision makers in respect to best practice.

3 PHYSICAL PROCESSES MODELLING

The determination of risk zones or areas where coastal processes are active along the Overberg District coastline is based on the application of a consistent delineation methodology applied along the study area. The process is shown in Figure 1, and described in more detail below.

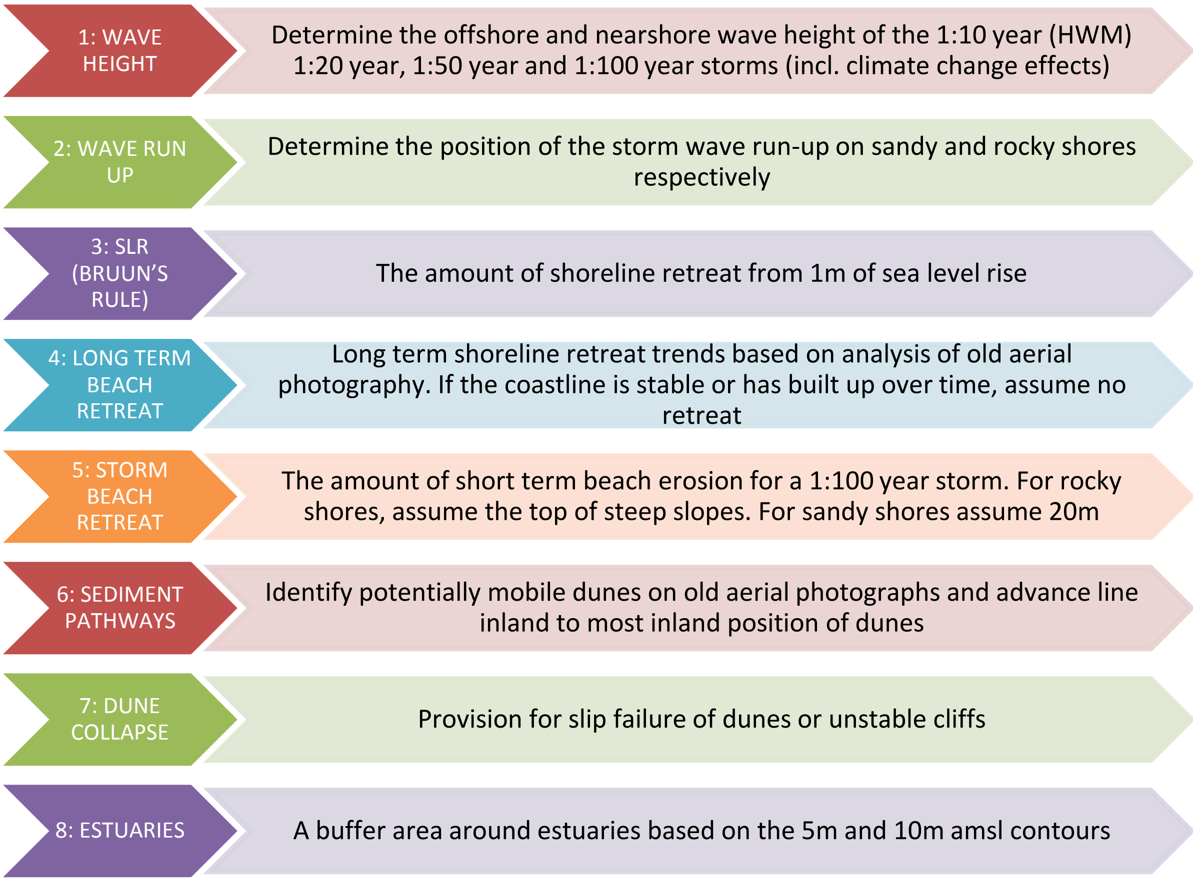

Figure 1: Procedural Steps for Determining the Coastal Processes/Risk Lines

3.1 Data Sources

The data used for the various modelling processes in this study were sourced as:

3.1.1 Aerial photography

Historical aerial photographs covering the study area or a portion thereof were obtained from the National Geo-spatial Information (NGI), a component of the national Department of Rural Development and Land Reform (DRDLR) (previously the Chief Directorate: Surveys and Mapping). All photography of the coastline was geo-referenced where necessary with particular emphasis placed on sections of sandy shoreline, where trends in long-term beach retreat or accretion were identified.

3.1.2 LIDAR

Existing ground topography information was not considered accurate enough to determine the beach and rocky shore slopes, and therefore a LIDAR survey was undertaken. This laser based technology provides for an accuracy of 20-50cm in modelling. The LIDAR information is used to determine the wave run-up element of the analysis as well as to create the accurate digital elevation model upon which the simulation results are modelled upon.

3.1.3 Wind and Wave data for the region

Wind and wave data was sourced for the study area.

Wave data was obtained from actual and virtual wave buoys in the area, and analysed to determine wave heights, wave period, extreme (storm) values and wave direction. The results were then used in a SWAN model to determine inshore (15m depth) wave characteristics.

3.1.4 Bathymetry

Bathymetric maps were obtained from the South African Navy and converted into a digital format compatible with CAD and ESRI computer applications. Specifically, the minus 15m depth contour was digitized from the South African Navy charts "SAN 120 and 121" and added to a digital terrain model.

3.2 Determining the physical processes line (risk zone)

3.2.1 Step 1: Determine the 1:10. 1:20, 1:50 and 1:100 year storm off-shore wave height

The 1:10 (current HWM), 1:20 (short term), 1:50 (medium term) and 1:100 (long term) year storm wave heights and periods (see Figure 2) were determined using available wave statistics.

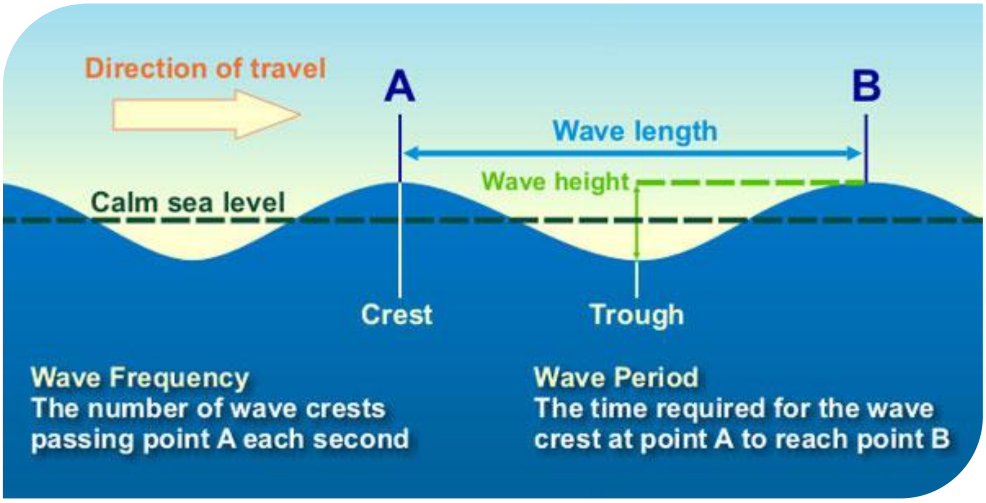

Figure 2: Wave characteristics and terminology (credit: US National Oceanic and Atmospheric Administration (NOAA) Ocean Service)

There are a number of wave recording locations in the region as shown in Figure 3. The period of data varies between the sites and as a result the wave height statistics vary slightly.

(Image: © 2011 Google, © 2011 GeoEye, © 2011 Europa Technologies, © 2011 AfriGIS (Pty) Ltd.)
(Data: SIO, NOAA, U.S. Navy, NGA, GEBCO)

Figure 3: Wave Recording Stations along the Southern Cape Coastline

Extreme wave analysis statistics from recent coastal engineering and oceanographic studies were also reviewed. The results of several available studies are presented in Table 1, Table 2 and Table 3:

Table 1: Extreme Wave Analysis at Slangkop, Statistical Methods and Source

Wave return period (1 in x years)	Recorded Significant Wave Height (m)	Method	Report
1:10	10.0	Extreme 1	(MacHutchon, 2006)
1:20	10.2		
1:50	11.1		
1:100	11.7		

Table 2: Extreme Wave Analysis at Cape Town (NCEP and Slangkop), Statistical Methods and Source

Wave return period (1 in x years)	Recorded Significant wave height (m)	Method	Report
1:1	9.1	Fisher-Tippet	(Theron *et al.* 2010)
1:5	10.4		
1:10	11.2		
1:30	12.1		
1:50	12.6		
1:100	13.2		

Table 3: Extreme Wave Analysis at Mossel Bay (NCEP), Statistical Methods and Source

Wave return period (1 in x years)	Recorded Significant wave height (m)	Method	Report
1:1	8.7	Fisher-Tippet	(Theron *et al.* 2010)
1:5	10.1		
1:10	10.6		
1:30	11.6		
1:50	12		
1:100	12.6		

From the evaluation of the results of extreme wave statistics presented in Table 1, Table 2 and Table 3 above, it was decided that due to the conservative approach of this study, the effects of climate change should be incorporated and thus the extreme 1:100 year offshore wave conditions used were H_o = 15.4m. The 1:10 year offshore wave height used to determine the current High Water Mark was 11.2m. This is summarised in Table 4 below.

Table 4: Wave heights selected for the study

Wave return period (1 in x years)	Cape Town Recorded Significant wave height (m)	Mossel Bay Recorded Significant wave height (m)	1 in 10 year wave height selected for this study (m)	1 in 100 year wave height increase for Climate Change (17%) (m)
1:1	9.1	8.7		
1:5	10.4	10.1		
1:10	11.2	10.6	11.2	
1:30	12.1	11.6		
1:50	12.6	12		
1:100	13.2	12.6		15.4

3.2.2 Step 2: Determine the HWM based on wave run-up models

Wave run-up heights are determined using the models of Mather *et al.* (Mather, Stretch, & Garland, 2010) for sandy shorelines and the Eurotop manual for rocky shorelines (Pullen, 2008). The different run-up heights for future wave height scenarios of 1:10 (current HWM), 1:20 (short term), 1:50 (medium term) and 1:100 (long term) year inshore wave heights were used to determine different coastal risk areas. The run-up of the 1:10 year storm wave height also doubles as demarcation of the current high water mark, in accordance with the prescriptions of the ICM Act.

Accordingly, the coastline was divided into sections that had one of four consistent profiles, namely:

- Small sandy embayment's where urban development had taken place;
- Large open sandy stretches of coastline;

- Steep rocky shorelines; or
- Rocky promontories.

These locations were determined at positions where the water depth was 30m and 15m. The design wave heights determined in Table 4 were transformed to a water depth of 30m and 15m respectively using the SWAN model. SWAN is the most widely used computer model to compute irregular waves in coastal environments, based on deep water wave conditions, wind, bottom topography, currents and tides (deep and shallow water). SWAN explicitly accounts for all relevant processes of propagation, generation by wind, interactions between the waves and decay by breaking and bottom friction. Diffraction is included in an approximate manner in SWAN. For further information see www.swan.tudelft.nl/.

As part of the refinement of the modeling work that took place during the initial Overberg Coastal Set-back Lines project in 2011/2012 (WCG, 2012), the modeled current HWM was revisited and significantly revised in certain locations. Inaccuracies in the initial HWM demarcation were likely due to submerged reefs that do not appear on the bathymetric charts, but that reduce the run-up height of incoming waves.

The revision process compared the modeled HWM to current physical indicators such as a wetline or vegetation boundary. Where a significant discrepancy was present, the HWM was revised downward to the more accurate real-world position. This revised position was then used to also revise the risk projections for 1:20, 1:50 and 1:100 year return periods.

Additionally, certain sections of the coastline were identified where the original modeling outputs from the previous study could be improved through refined run-up projections. The areas affected by the modeling refinements are indicated on Figure 4, and as is quite evident, most of these areas were located in the Overstrand Local Municipality.

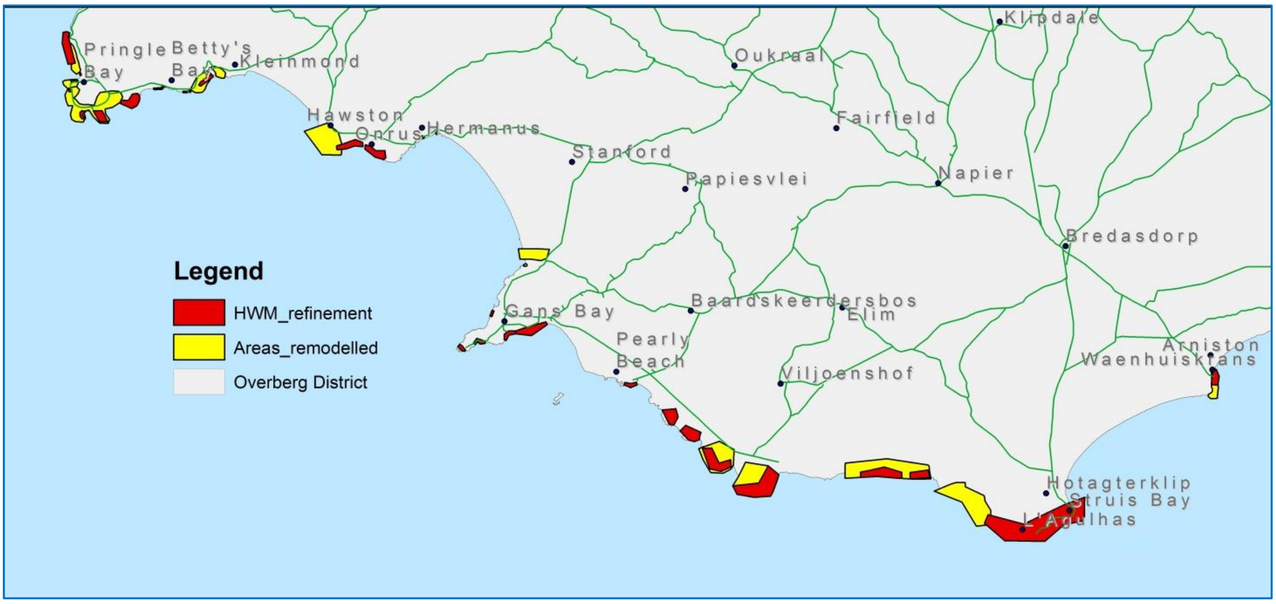

Figure 4: Areas where the high-water mark and risk projections were refined

3.2.3 Step 3: Determine the predicted future shoreline regression due to sea level rise

Where beach retreat takes place, the physical processes modelling needs to accommodate the accumulated future retreat for the various time horizons. For the purposes of this study, short, medium and long term time horizons are designated as 20, 50 and 100 years respectively, and the associated retreat (in metres) is added to the modelling.

Climate change related sea level rise is predicted to result in the shoreline moving inland due to inundation as well as increased sediment losses from increased wave energy at the shoreline. To model this anticipated change, the most commonly applied model used is the Bruun Rule (Bruun, 1962).

The amount of shoreline regression will depend on the amount of sea level rise expected. As sea level rise will vary into the future, approximate sea level rise amount for each wave return heights was predicted. This is an attempt to match scenarios of similar risk of occurrence to each other. Therefore the maximum expected sea level rise of 1 000 mm was equated to the 1:100 year horizon and a straight linear distribution was applied to the lesser return periods as shown in Table 7. It must be noted that wave height and sea level rise are completely independent of each other, i.e. a 100 year wave event can occur with no sea level rise.

Table 5: Combinations of wave height returns and sea level used in the three scenarios

Scenario	Sea level rise (mm)	Wave height return (years)
Short term	200	1:20
Medium term risk	500	1:50
Long term risk	1000	1:100

For each wave run-up scenario, the corresponding sea level rise was used to calculate the amount of long term retreat of sandy sections of the shoreline in accordance with the Bruun's Rule. On rocky shorelines, the line demarcating the maximum extent of physical processes is easier to define as no calculation of beach retreat is required. In this case the additional 20cm, 50cm or 1m of sea level rise (depending on the risk projection) is simply added to the wave run-up positions.

3.2.4 Step 4: Determine the short-term storm erosion risk along the coastline

During storm events sandy shorelines recede temporarily, as sand is lost, but soon recover to the pre-storm position. This short-term loss is an important factor in the determination of risk lines. Usually this is done using measurements taken from shoreline surveys but, as there was no such data available for the study area, an average short term shoreline retreat of

20m was applied along sandy sections.

3.2.5 Step 5: Determine long-term beach retreat due to natural sand movement

Historical aerial photography is used to determine if any long term beach regression is taking place. Beach regression can be the result of natural variability in coastal circulation patterns, changes to wind-blown sand movement or due to disruptions of natural patterns. Of concern are instances where sand deposition decreases or erosion increases along sandy sections of the coastline. A nett reduction in the amount of sand being delivered to beaches means that over time, the beach will recede landward along with the high water mark.

The approach taken to determine long term erosion trends is based on detail analysis of the historical shoreline positions from available aerial photography for sandy shorelines. The historical imagery were georeferenced, and common points of reference used to align the images, whereafter the relative movement of the shoreline was measured.

The earliest set of photographs was the 1938 series, which was very sparse. The next was dated 1961 but, and while it had improved coverage, the quality of the black and white imagery was extremely poor and it was extremely difficult to reconcile topographic details. The next complete set of imagery was the 1973 set followed by 2005 imagery.

Due to the fact that only two aerials of suitable quality were available for this study, namely 1973 and 2005 (with a resultant span of 32 years), the calculated regression trends period was not ideal but does provide a reasonable indication of the erosional trends in the study area.

The long term erosion trend at Betty's Bay is found to be just less than 2m per year based on the difference between the aerial photography of 1973 and 2005. Based on the annual long term erosion of 2m per year the 100 year trend is therefore in the order of 200m.

3.2.6 Step 6: Determination of a final physical processes line

In order to generate single lines denoting a zone where dynamic coastal processes will impact on development in future, only the highest of the 'stacked' wave run-up lines are considered along with littoral active zones. Littoral active zones were identified based the presence of windblown sand furrows indicating currently active sand belts on the most recent aerial photographs (2012/2013) and otherwise historically active zones as could be ascertained from historical imagery.

As a final step, joins are created between the modelling for rocky and sandy sections of the shoreline. The resultant unbroken lines are used and referred to as Physical Processes or Risk Lines – respectively for the current, short, medium and long terms. An example of the lines is shown in Figure 5.

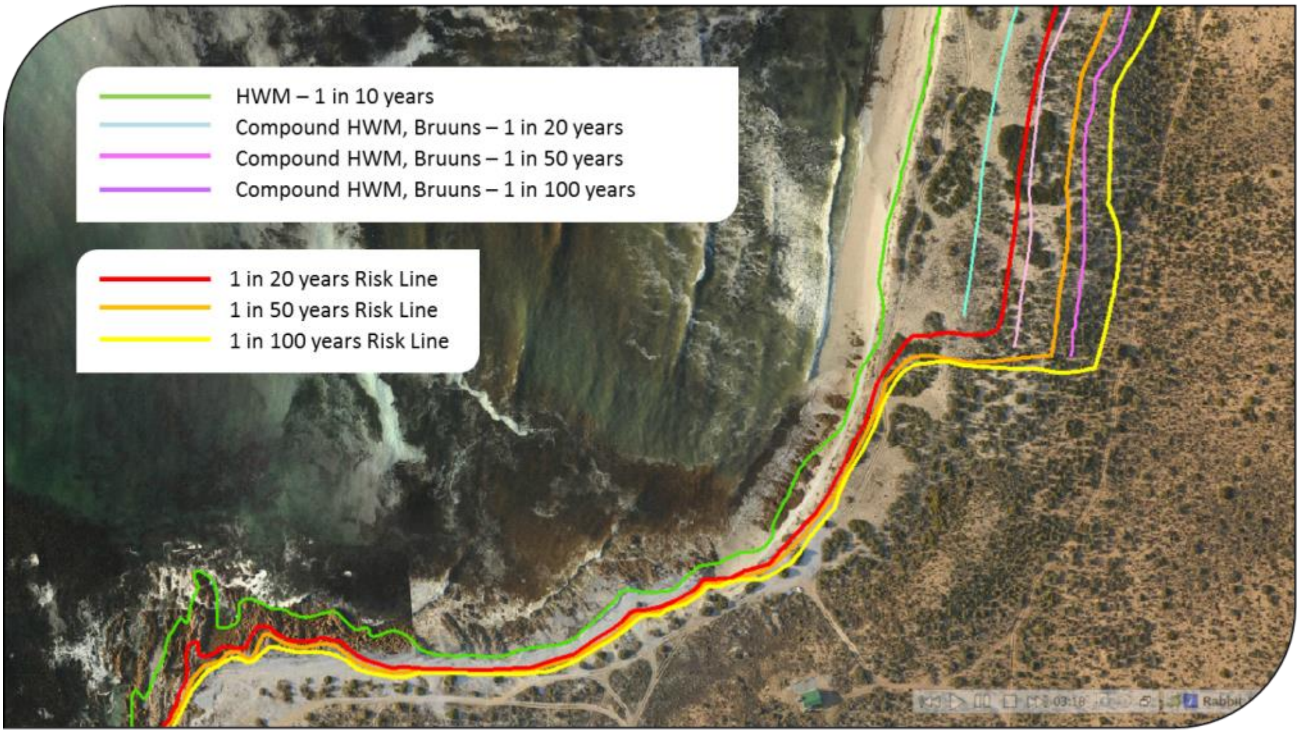

Figure 5: All scenarios modelled for sea level rise, short term erosion and wave run-up

3.3 Estuaries

Estuaries are particularly dynamic ecological systems that display characteristics of both terrestrial and marine systems. This makes estuaries extremely complex and sensitive, and consequently also challenging to manage. Nevertheless, degradation of estuaries often results from increasing coastal development and the impact of human activities. In order to preserve the remaining ecological functioning, biodiversity, and sustainable use of these sensitive coastal resources, effective co-operative and integrated management is essential.

Since inundation in estuaries represents the primary risk, floodline determination that can anticipate flood events with different return periods will be valuable in understanding how flood dynamics will impact on existing and future development. Unfortunately, to generate the necessary information within the scope of a regional coastal management line (set-backs) demarcation project will be prohibitively expensive. Consequently an approach is adopted that will use a simple contour height line to inform coastal management/set-back lines for estuaries, but with the option to defer to existing fine-scale management plans where such have been prepared. Additionally, some indication of recurring inundation can be gleaned from an assessment of the vegetation surrounding estuaries.

For the purposes of this project, the 5m and 10m amsl contours are used as reference lines to determine or inform development of coastal management (set-back) lines, until such time as an adopted Estuary Management Plan and zonation plan delineates an appropriate coastal development set-back for individual estuaries based on detailed floodline modelling.

In a similar study in the West Coast District (WCG, 2014), it was found that the 5m and 10m contour heights correspond well with immediate and occasional flood zones. Verification against anecdotal evidence from members of the public in the Overberg indicates that although these levels give a general indication of the extent of the functional estuarine zone, the two contours do not necessarily correspond exactly with estuary flood zones. This is especially true in cases where specific strong influences, such as a high river runoff volume (Breede River) or particularly flat floodplain (Heuningnes) are present.

Floodline studies are therefore strongly recommended in order to improve on the accuracy of the risk projections.

4 CONCLUDING STATEMENT

The contents of this report form the groundwork on which the delineation of risk zones, coastal management/set-back lines and the Coastal Protection Zone can be based. Detail of these delineations and the determination of an associated management scheme are contained in the main report that this report is appended to.

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