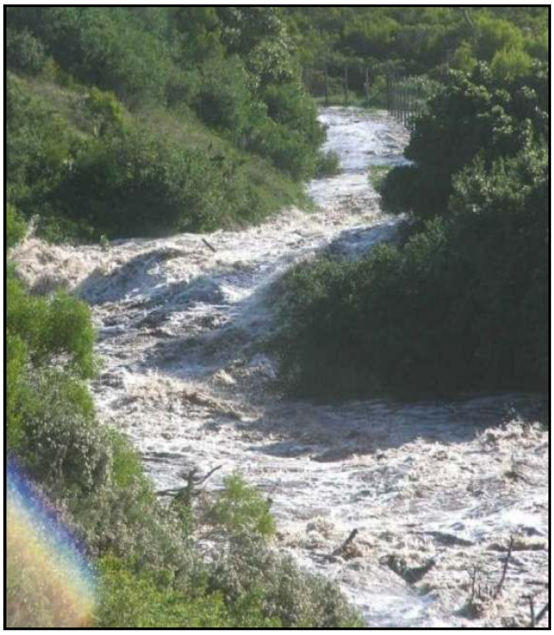
NUCLEAR POWER STATION ('NUCLEAR 1') AND ASSOCIATED INFRASTRUCTURE

Second Addendum to Dune Geomorphology Impact Assessment: New western access routes and 2011 - 2012 floods

June 2013



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DECLARATION OF INDEPENDENCE

I, Werner Kurt Illenberger as principal of Illenberger & Associates, hereby confirm my independence as a specialist and declare that I do not have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of which Arcus GIBB was appointed as environmental assessment practitioner in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), other than fair remuneration for worked performed, specifically in connection with the Environmental Impact Assessment for the proposed conventional nuclear power station (‘Nuclear 1’). I further declare that I am confident in the results of the studies undertaken and conclusions drawn as a result of it – as is described in my attached report.

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EXECUTIVE SUMMARY

This specialist study is the second Addendum Report to the Dune Geomorphology Report. It investigates new western access routes to the Thyspunt site, and the 2011 - 2012 floods.

The MSC thesis of Lauren Elkington was completed in June 2012. It represents the current state of research being conducted by Prof. Ellery of Rhodes University and his colleagues. The thesis was reviewed and relevant information has been incorporated into this report.

Available literature on the subject was perused, including diverse reports prepared for Eskom. Field visits were undertaken. Rainfall records were consulted. Various local residents and environmental specialists were consulted. Detailed contour maps and aerial photographs and images from 1942 to 2012 were analyzed to investigate the dynamics of the dunefields and the flood behaviour of the Sand River. A GIS was used to create digital overlays of the topographic data and images.

Dune morphodynamics in the Cape St Francis Headland-bypass dunefield

The headland-bypass dunefields at Cape St Francis have been cut off from their source beaches due to human activities. If there is no human intervention to counter this (other than continuing to stabilize the dune ridge along Oyster Bay beach), the dunefields will slowly be stabilized over the next 1000 years or so by natural re-vegetation processes and the continuing spread of invasive alien vegetation.

If the dune ridge along the Oyster Bay Village shoreline is allowed to become mobile and over-run the village, the feeder zone will revert to its natural state and eventually start feeding sand into the dunefield. However, if this dune ridge is managed and not allowed to remobilize, the sand supply to the dunefield will remain cut off. This is the more likely scenario.

If invasive alien species like rooikrans are cleared, natural re-vegetation will be slower, advancing dunefields will move faster, and the loss of mobile dunes due to encroachment by alien vegetation will stop. The dunefields will revert to their natural mobility.

It is predicted that if invasive alien species are kept in check the eastern margins of dunefields will continue to advance at their historic rates, i.e. the leading tongues of dunefields will move eastward at rates of 10 to 30 m/yr, and the trailing ends of dunefields will continue to be vegetated at about 5 m/yr.

The localities and nature of wetlands in the dune areas have changed very much over the life of the dunefields, corresponding to their dynamic nature. A large amount of active dune areas has been lost due to human impacts; the numbers of interdune wetlands are correspondingly reduced.

Assessment of access routes across the western end of the mobile Oyster Bay dunefield

The impacts are restricted to issues related to mobile dunes. The proposed routes cross the trailing (western) ends of patches of mobile dunefields, where dune movement is slowing down. The mobile dunes are moving along valleys that would be

filled to build the roads. As such the only viable option would be to stabilize the patches of mobile dunes to the west (upwind) of the proposed routes. The main consequence of this would be to lose a small area of mobile dunes. The environmental impact will be low.

As a mitigatory offset, Eskom could undertake to restore mobile dunes that are located within land that they own in the bulk of the Oyster Bay dunefield by removing alien vegetation. An area much larger than what would be stabilized could be re-mobilized.

Assessment of access routes across vegetated parabolic dunes and linear dune ridges

This entails crossing the vegetated dunes with a road that would need cut and fill to create a road with a smooth gradient. Terraforce or similar blocks must be used to stabilise the sides of the cut and fill, as rehabilitation by vegetating the slopes will be difficult and slow. There will thus be little effect on the stability of the dunes, apart from the risk of slumping during the construction phase. The environmental impact will be low.

The 2011 and 2012 floods and the Sand River

Flash-floods are caused by moving dunes that block the Sand River channel within the dunefield during dry periods. When the river flows again, water would pond against the dunes until the interdune ponds overflow and breach, causing a catastrophic flash-flood. Large amounts of sediment and plants may be transported by the high energy peak water flow.

The Santareme event of 15 September 2012 provides a dramatic example of the flash-flood that can result when an interdune pond breaches. This dunefield had been artificially stabilized, preserving the transverse dune topography that dams surface runoff. The flood resulted from the rupture of one of these ponds.

It often happens that there is not one big rainfall event, but a number of smaller events. The landscape became progressively saturated with water, so that there is less and less absorption capacity, and the proportion of runoff increases accordingly. A rainfall event of 100 mm or so at the end of a wet season can generate a flood with high peak flow that can cause significant damage. This happened in 2011 and 2012.

The largest event in 2011 was 123 mm on 2/3/4 July. After this rain, a large volume of water accumulated in the nose of the southern tongue of the Oyster Bay dunefield; flow was augmented by water from the cutoff canal. The southern tongue was artificially breached on 7 July. The Sand River culvert was washed away in the ensuing flash-flood, and the Sand River delta in the Kromme estuary gained about 80,000 m^3 of sediment.

The final rainfall event of 2012 was the largest event for that year: 113 mm fell from 17 to 20 October. It resulted in a flood that washed away the temporary Sand River culvert that had been built in August 2011.

The Sand River erodes dunes as it makes its way through the dunefield, entraining much sand. Large amounts of sand as well as plant debris are carried down the Sand River during floods. This is a normal fluvial process, not a debris flow. The sand is ultimately deposited in the Sand River delta in the Kromme estuary. This has been happening for hundreds of years.

Sand River delta in the Kromme Estuary

The Kromme estuary is typically sand-choked. The sand is derived from the Sand River and from tidal currents that carry sand into the estuary from the sea. The Sand River delta has never blocked the Kromme estuary completely, and it is not likely to do so.

Supposed debris flows

The supposed debris flow deposit is a bulldozer deposit.

Recommendations

Alien vegetation across the whole dunefield needs to be mapped to confirm and refine projected scenarios for future dunefield dynamics.

Interdune ponds should be monitored during periods of high rainfall to see if dangerous situations are developing. Aerial surveys from a small aircraft are an efficient way to do this.

The temporary Sand River culvert should be urgently replaced with a suitably designed permanent structure.

ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROPOSED NUCLEAR POWER STATION ('NUCLEAR-1') and ASSOCIATED INFRASTRUCTURE

Second Addendum to Dune Geomorphology Impact Assessment: New western access routes and 2011 - 2012 floods

CONTENTS

1 INTRODUCTION

1.1 Background

Eskom Holdings (Ltd) has proposed the construction of a nuclear power station on one of five alternative sites, located in the Northern, Eastern and Western Cape Provinces of South Africa, of which three sites (two in the Western Cape and one in the Eastern Cape) were carried forward to the EIA phase. GIBB (Pty) Ltd (GIBB) was appointed by Eskom Holdings (Pty) Ltd (referred to hereafter as Eskom) to undertake the Environmental Impact Assessment (EIA) for the proposed nuclear power station and its associated infrastructure at each site.

Further background information is in the Dune Geomorphology Report (Illenberger, 2010a) and Geomorphology Addendum Report (Illenberger, 2010b).

This report is the second addendum to the Dune Geomorphology Report. The terms of reference for this addendum are:

- Investigate newly proposed alternative western access routes past the settlements of Umzamawethu and Oyster Bay to the Thyspunt site. This will include a predictive model of the dynamics of dunes in the western end of the Oyster Bay Dunefield.

- An investigation of the 2011 and 2012 Sand River flood events as a second addendum to the Dune Geomorphology Report.

- Incorporation of relevant information from the recently completed (June 2012) MSc Thesis of Lauren Elkington and other new information from Prof. Fred Ellery of Rhodes University and his colleagues.

Many photographs, aerial photographs and images, topographic maps, reports, documents and rainfall data were examined in this investigation. Numerous people were consulted. A lot of information has been included in the report, for record purposes and to make future investigations easier.

1.2 Study Approach

Detailed contour maps and aerial photographs from 1942 to 2012 (Table 1.1) were analyzed to investigate the dynamics of the dunefields and the flood behaviour of the Sand River. A GIS was used to create digital overlays of the topographic data and images.

Rainfall records were consulted. Local residents were consulted to collect information about flood events, damage that resulted from floods, and other relevant information: Owen Putzier, Bart & Caryl Logie, Nevil Hulett, Nick Borman amongst others. Mike & Greg Miller supplied aerial photos taken on 7 July 2011, 11 August 2011, 9 February 2012 and 27 October 2012. The staff of Eskom supplied many photographs and information about flood events.

Various specialists familiar with the sites were consulted. These specialists include:

Specialists on the EIA team:

- Liz Day (The Freshwater Consulting Group): wetlands study;
- Barrie Low (Coastec): botanical study; and
- Dave Halkett: archaeology.

Table 1.1 Aerial photographs used in the investigation

Date	Job	Scale	Strip numbers	State of dunefield	Comments
1942	2/42	1:30 000	7, 8	wet	
1961-11		1:36 000	18, C1	wet	
1969-05-08	622	1:36 000	12	dry	
1971-11-21	622	1:36 000	C3	very wet	after 1971 floods
1975-07-06	498/71	1:30 000	6	dry	
1985-09-17	885	1:30 000	15, 16	wet	
1986-06-09	891	1:50 000		dry	
1994	973	1:50 000		dry	
1999-01	498/357	1:10 000		dry	1:10 000 orthophoto series
2000-09-05		1:50 000		dry	
2003	1076	1:50 000	16	wet	monochrome
2003	DWAF	75 cm res		wet	colour
2003-06-27	GoogleEarth			wet	GoogleEarth
2006	SPOT	5 m res			
2006-03-06	GoogleEarth			dry	GoogleEarth
2007-09-01	Eskom	15 cm res		wet	Only part of dunefield was flown.
2009-11-17	NGI*	50 cm res		dry	
2010-10-16	GoogleEarth			dry	GoogleEarth
2011-03-24	Eskom	15 cm res		dry	
2011-11-07	GoogleEarth			wet	GoogleEarth

*Chief Directorate – National Geo-spatial Information (formerly Department of Surveys & Mapping)

Various academic specialists familiar with the sites were consulted. These specialists include:

Frank Silberbauer, who has been a resident in St Francis Bay for many years, and who has compiled a number of documents recording flood events in the area.

Jenny Burkinshaw and Izak Rust. These specialists have extensive experience of coastal dunes, including inter alia the dunes in the area under investigation. Jenny Burkinshaw studied morphodynamics of headland-bypass dunefields, concentrating on the Cape St. Francis dunefields, in her PhD thesis.

1.2.1 Timing of site assessments

Field visits were conducted in July & August 2011 and May, October and November 2012.

2 ASSESSMENT OF MSC THESIS OF LAUREN ELKINGTON

Lauren Elkington completed her MSc thesis entitled “Morphology, patterns and processes in the Oyster Bay headland bypass dunefield, South Africa” in June 2012.

She did this thesis at the Department of Geography, Rhodes University. Quoting from the thesis:

> “The work described in this research project was carried out, over a period from 2008 – 2012, under the supervision of Ms Gillian McGregor (Geography Department, Rhodes University), Prof. Fred Ellery (Environmental Science Department, Rhodes University) and Prof. Richard Cowling (main funder, Department of Botany, Nelson Mandela Metropolitan University).”

It represents the current state of research being conducted by Prof. Ellery and his colleagues, and no further or new information was presented at the Southern African Society of Aquatic Scientists Annual Congress held in July 2012 (Ellery et at, 2012). (Prof. Ellery, e-mail and telephonic correspondence, December 2012 and January 2013.) Relevant aspects of her thesis and by default the state of research being conducted by Prof. Ellery and his colleagues are discussed below.

2.1 Introduction

The high sediment flux that accompanied the November 2007 flood (Elkington, 2012: Fig 1.4 & p 7) was not derived from the “mobile dunefield system”, and is in a drainage system completely unrelated to the Sand River. The November 2007 flood event is discussed in detail in the Geomorphology Addendum Report (Illenberger, 2010b).

2.2 Literature review

Various specialist reports from the Eskom Nuclear-1 EIA were not referred to at all: the Wetlands Report (Day, 2009), Botany Report (Low, 2009), Geohydrology Report (SRK, 2009), and Dune Geomorphology Report (Illenberger, 2010a). The Geomorphology Addendum Report (Illenberger, 2010b) is only referred to once, regarding textbook description of debris flows. Issues that are investigated in the latter report like debris flows and debris flow deposits, groundwater and dune wetlands, quicksands and liquefaction of sand, the November 2007 flood, and potential for flood damage where the R330 crosses the Sand River, are not referred to, even though they have direct bearing on the topic of the thesis. These omissions are severe deficiencies.

2.3 Study area

The study area only covers the central part of the Oyster Bay dunefield (Elkington, 2012: Chapter 2). It does not include the lower Sand River channel where the supposed debris flow deposits are located (Fig. 2.1), and where the character of the Sand River changes significantly. This restriction of the study area considerably reduces the value of all the data presented in the thesis, whether it be vegetation, topographic analysis, dune dynamics, groundwater or analysis of “drivers of change”.

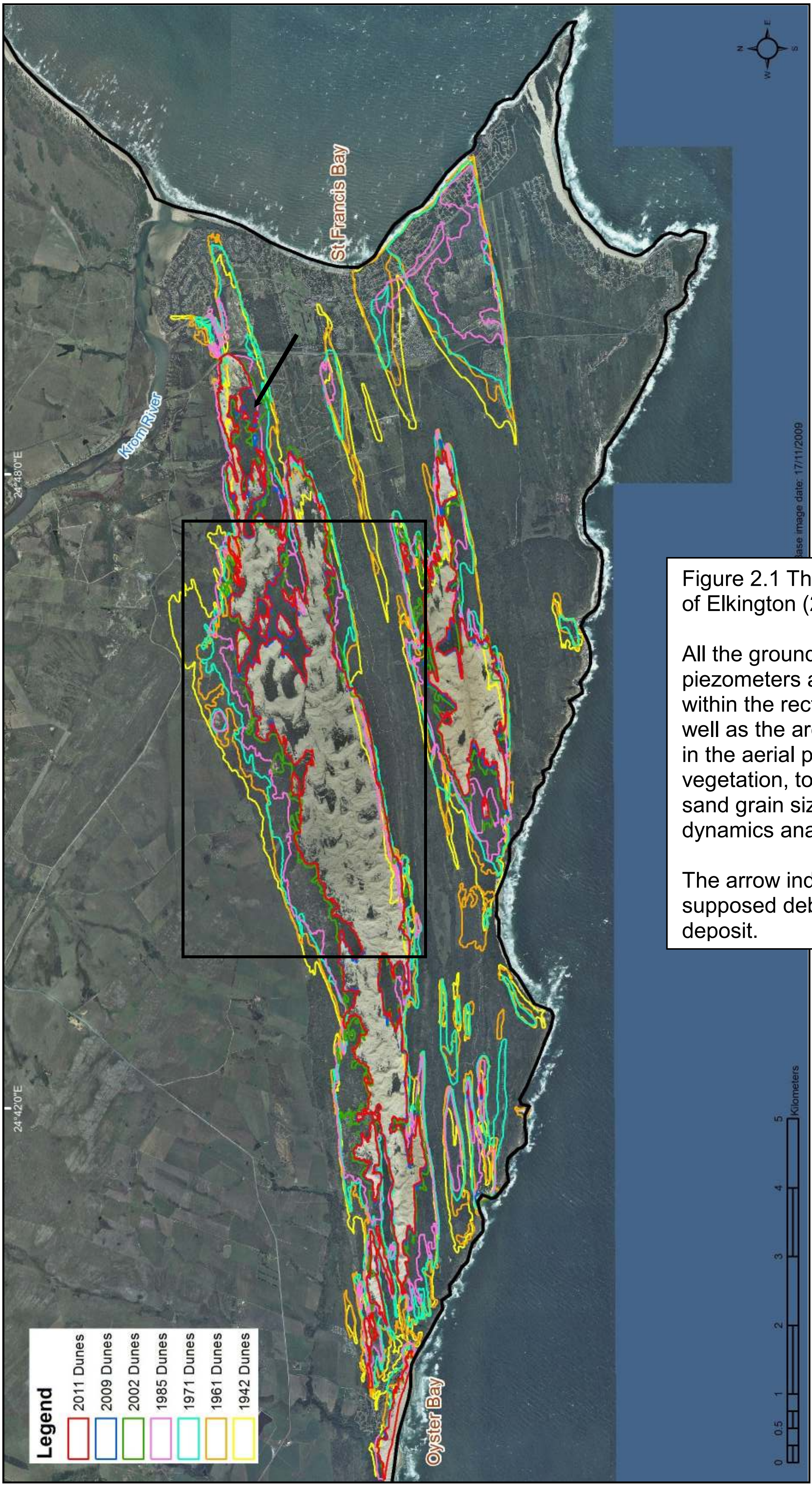


Figure 2.1 The study area of Elkington (2012).

All the groundwater piezometers are located within the rectangle, as well as the area covered in the aerial photo, vegetation, topographic, sand grain size and dune dynamics analyses.

The arrow indicates the supposed debris flow deposit.

The aerial photo analysis is similarly restricted. The very valuable 1942 photos were not used in the aerial photo analysis.

The restricted information available is of little use in the geomorphological investigations for this EIA.

2.4 Mapping of vegetation types

There is detailed information on vegetation types in the study area (Elkington, 2012: p 99), including maps showing vegetation changes over time. These should be incorporated into the Botany and Wetlands Reports if the appropriate specialists find it of value to their investigations.

2.5 Groundwater

The data collected on groundwater is of limited value because only pH and electrical conductivity were measured (Elkington, 2012: p 106). There is no chemical analysis of groundwater samples. Standard techniques for describing and characterising groundwater (e.g. Piper Diagrams and Durov Diagrams) are not used.

2.6 Debris flows

From Elkington, 2012: p 138:

> “The requirement that fine sediment is present to “lubricate” debris flows is difficult to demonstrate in the eastern region of the dunefield. It is possible that debris flows that develop under the circumstances described in this study (rapid filling behind a single narrow dune with a very steep slope on both the dune face and the water table, creating a massive head of water behind a singularly unconsolidated and unstable feature) do not require fine material in order for the sand to liquefy and produce a debris flow. *It would be anticipated that under these circumstances, debris flows would rapidly dewater* and therefore occur over a limited spatial extent.”

This is correct. Figure 2.2 illustrates this rapid de-watering that happens when one makes “drip-sand castles”, causing sand movement to freeze virtually instantaneously, so there is no flow. If water dams up behind a dune, the sideways pore pressure may liquidize the sand, causing slumping and piping resulting in catastrophic failure of the sandy “dam wall”. The sand is carried by flowing water, and not as a slurry, so it is not a debris flow (see Addendum Report for a detailed explanation; also standard textbooks, e.g. Hsu, 2004).

A mixture of mud and sand will produce a debris flow, as illustrated in Figure 2.3. The mixture flows easily to produce a deposit with a low angle of repose.

The conjectures in the thesis about the occurrence of debris flows and their possibly catastrophic consequences are rendered null and void, as the supposed debris flow deposits are bulldozer deposits created when Lionel Donnelly built a dam in the area (Chapter 10; Frank Silberbauer, pers. comm. 2012 & Silberbauer, 2011b: reproduced in Appendix A).

Figure 2.2 A “drip-sand castle”, as commonly built by children on a beach. The high porosity of sand allows the water to flow away rapidly, causing the sand to freeze into fascinating shapes. A debris flow is not created.

Figure 2.3 A mixture of mud and sand will produce a debris flow, and not a dripsand castle. The mud/sand mix flows away from the point of initiation and flow is sustained until the gradient is reduced to a low angle.

2.7 Conditions under which debris flows are likely to occur

From Elkington, 2012: 138

> "A possible agent that may "lubricate" debris flows, which has not been recognised before, is the presence of dissolved solutes. Calcium carbonate in the form of shell fragments, readily dissolves under prolonged saturation (Burkinshaw, 1998: p 121), and under conditions of capillary rise and evaporation, may increase to levels where the density of the remaining groundwater rises sufficiently to act as a lubricant. Individual measurements of groundwater electrical conductivity in this study suggest that locally, solute concentration may be sufficiently high to precipitate calcium carbonate from solution. Under these conditions calcium carbonate in solution may act a lubricant to sustain the more widespread occurrence of debris flows."

The logic propounded in this argument is flawed, since compounds that are in solution cannot act as lubricants.

2.8 Abstract and Conclusions

From Elkington, 2012: page i (Abstract):

> "The paradigm that sediment flux is entirely due to wind is almost certainly simplistic, and deeper understanding of these systems is needed."

The relative contributions made by wind and water to the sediment dynamics of the Oyster Bay Dunefield, and indeed deep understanding of the systems, are clearly demonstrated in the Dune Geomorphology Report, and further expanded upon in the Addendum Geomorphology Report. They were recognized and described long before Prof. Ellery and his colleagues first visited the area.

2.9 Conclusions

The MSc thesis of Lauren Elkington relies heavily on Jenny Burkinshaw's PhD and to some extent on the chapter on coastal dunes and dunefields in "The geomorphology of the Eastern Cape, South Africa" (Illenberger & Burkinshaw, 2008). The only substantial data used are aerial photographs of 1961 to 2011, and 2011 LIDAR elevation data of the dunefield supplied by Eskom. However, the very valuable 1942 photos were not used. The study area was restricted to the central part of the dunefield; in particular the lower Sand River channel where the supposed debris flow deposits are located and where the character of the Sand River changes significantly is excluded.

The data collected on groundwater is of limited value because only pH and electrical conductivity were measured.

The current state of research being conducted by Prof. Ellery and his colleagues is of limited value, contains few hard facts and contains unsubstantiated and probably incorrect deductions and conclusions. The conjectures about the occurrence of debris flows and their possibly catastrophic consequences are rendered null and void as the supposed debris flow deposits are bulldozer deposits.

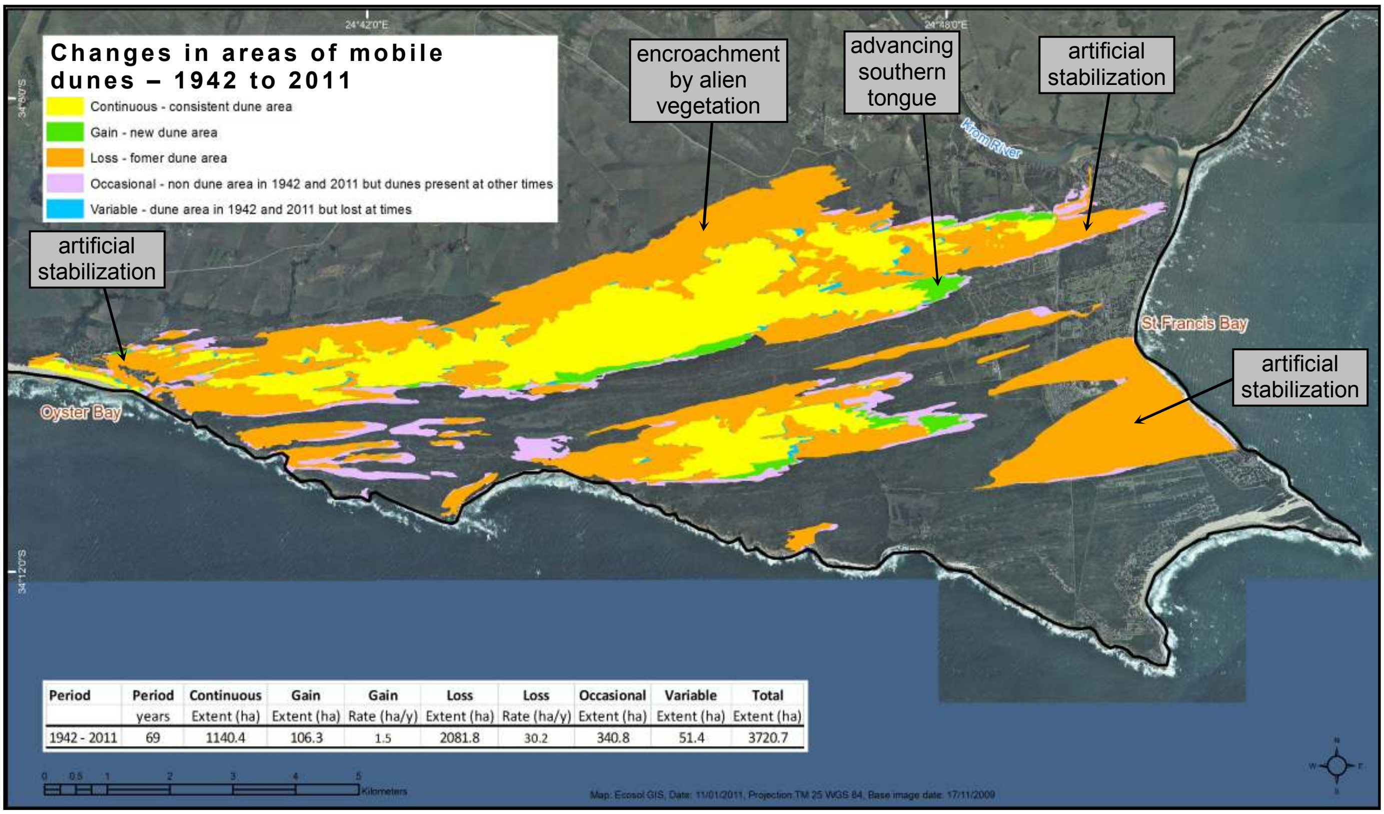
3 DUNE MORPHODYNAMICS IN THE CAPE ST FRANCIS HEADLAND-BYPASS DUNEFIELDS

Headland-bypass dunefields were defined in the Dune Geomorphology Report (Illenberger, 2010a). The definition is repeated here:

> "*A headland-bypass dunefield is a dunefield in which sand is blown from an upwind beach and transported across a low-relief headland to the downwind bay, bypassing the transport of sand by longshore drift around the headlands. These dunefields were recognised and defined by Ken Tinley in his seminal work on South African coastal dunes (Tinley, 1985, page 29). The coastline configuration, of the south Cape coast of South Africa together with the eastward transport of sand due to the prevailing west-south-westerly wave and wind regime, result in the formation of headland bypass dunefields whenever sandy beaches occur along the upwind shores of headlands.*"

Burkinshaw (1998) undertook a very detailed study of dune morphodynamics of the Cape St Francis headland-bypass dunefields in her PhD thesis. She used aerial photographs from 1942 to 1985; the 1985 aerial photographs were the most recent available when she did her research. In this report, her work has been extended using aerial photographs and images up to 2011, currently the most recent available. The whole of the Cape St Francis headland was mapped, using a Geographic Information System (GIS). Appendices B & C illustrate the changes in the areas of mobile dunes.

Figure 3.1 shows changes from 1942 to 2011. In the 43 years from 1942 to 1985, 30% of the originally active (mobile) dunefields had been stabilized, and in the 26



Period	Period years	Continuous Extent (ha)	Gain Extent (ha)	Gain Rate (ha/y)	Loss Extent (ha)	Loss Rate (ha/y)	Occasional Extent (ha)	Variable Extent (ha)	Total Extent (ha)
1942 - 2011	69	1140.4	106.3	1.5	2081.8	30.2	340.8	51.4	3720.7

Figure 3.1 Changes in the areas of mobile dunes between 1942 and 2011 on the Cape St Francis headland.

years from 1985 to 2011 a further 30% was stabilized. Part of this stabilization is natural, as happens at the down-wind end of a dunefield, where vegetation establishes itself when mobile sand movement ceases because all the sand has been blown away.

However, the largest part of the stabilization is due to artificial stabilization. The Department of Forestry started stabilizing dunes around Oyster Bay from 1917 to reclaim the active dune areas for farming purposes (Keet, 1936). Dunes in the area from Oyster Bay to Thysbaai were stabilized. The aerial photography of 1942 shows that the Oyster Bay dunefield had been cut off from its source of sand (the beach along Oyster Bay) by then (Appendix C & Figure 3.3).

Dune stabilization at St. Francis Bay started about 1960. The downwind nose of the Oyster Bay dunefield was stabilized by 1964, and is currently being mined for sand. The Santareme dunefield, which is situated along the eastern seaboard of the headland, was completely stabilized during the 1970's and 80's to enable the development of the southern part of St. Francis Bay village and Santareme.

In some areas, for example along the northern margin of the central and eastern portions of the Oyster Bay Dunefield, stabilization has largely resulted from birds, animals and wind dispersing the seeds of rooikrans (Figure 3.1). This encroachment by alien vegetation is occurring in many parts of the dunefields.

Perusal of the changes in the areas of mobile dunes between 1942 and 2011 (Figures 3.3, 3.7 and Appendices B & C) reveals that:

- There have been hardly any gains of new active dune areas; the gains are mostly in areas where there has been little or no human impacts and intervention, e.g. the advancing southern tongue of the Oyster Bay dunefield, although the tip is now being stabilized, since the Links Golf Course has been built in the area downwind of the southern tongue.

- There have been wholesale losses of active dune areas.

- Overall the active dunes are moving eastward, but there are complex changes along the southern margin of the Oyster Bay dunefield in some areas. Growth and shrinkage pockets are found, albeit on a small scale. These occur at intervals throughout the dunes and seem to be ad hoc rather than driven by any one set of factors.

3.1 Dynamics of dunes in the western end of the Oyster Bay Dunefield

The Oyster Bay Dunefield is a headland-bypass dunefield. Sand used to blow off the Oyster Bay beach, initially as parabolic dunes that then developed into transverse dunes, which moved eastward across a relatively flat area (where Oyster Bay Village is now located), until they reached three large ridges (Figure 3.2). Here dunes were channelled and constricted into the valleys between the ridges, causing sand to pile up and form large transverse dunes. These dunes continued to move up-gradient towards the east. The large ridges peter out towards the east, and the transverse dunes spread out and merge, becoming lower, to form a wide dunefield of mobile dunes in the central Oyster Bay Dunefield.

As discussed above, the Department of Forestry embarked on a program of stabilization in the area around Oyster Bay from 1917. Stabilization consisted of building drift fences along the shore and planted with alien vegetation, mostly rooikrans (*Acacia cyclops)*. This resulted in the accumulation of sand to form an artificial dune ridge parallel to the shore. Because of the high wind energy, blowouts and parabolic dunes initiated along the ridge, and constant maintenance was required to keep the ridge stabilized. The ridge became higher and wider with time, because sand was constantly being fed off the beach onto the ridge. The ridge was flattened in the 1960's by bulldozing the sand into the sea (Figure 3.4) and again in the 1970's. (Nick Borman, pers. comm., 2012). The dune ridge is no longer being stabilized routinely, and is currently engulfing roads and houses in Oyster Bay Village (Figure 3.5).

Currently the transverse dunes that formed when sand was last channelled into the valleys between the ridges continue to be blown eastward. The up-wind (western) ends of the valleys become depleted from sand as the dunes move, and pioneer dune vegetation establishes itself in the depleted areas; both indigenous and alien vegetation. Thus the dunefield gradually becomes vegetated from the west. There are a few exceptions to this, in areas that are currently protected from the dominant westerly winds but exposed to easterly winds. Smaller parabolic dunes that advance westward are formed in these areas, e.g. Figure 3.6.

The transverse dunes in the central Oyster Bay Dunefield continue to be blown eastward. In areas where the dunefield front is advancing into vegetated areas, parabolic dunes form. As these dunes invade an area, their trailing arms tend to merge and transverse dunes form behind the advancing front of parabolic dunes. Illenberger (1988: Fig 2) illustrates the processes and distinctive dune patterns that form.

Figure 3.2 Oyster Bay area on 24 March 2011 with contours at 1 metre intervals.

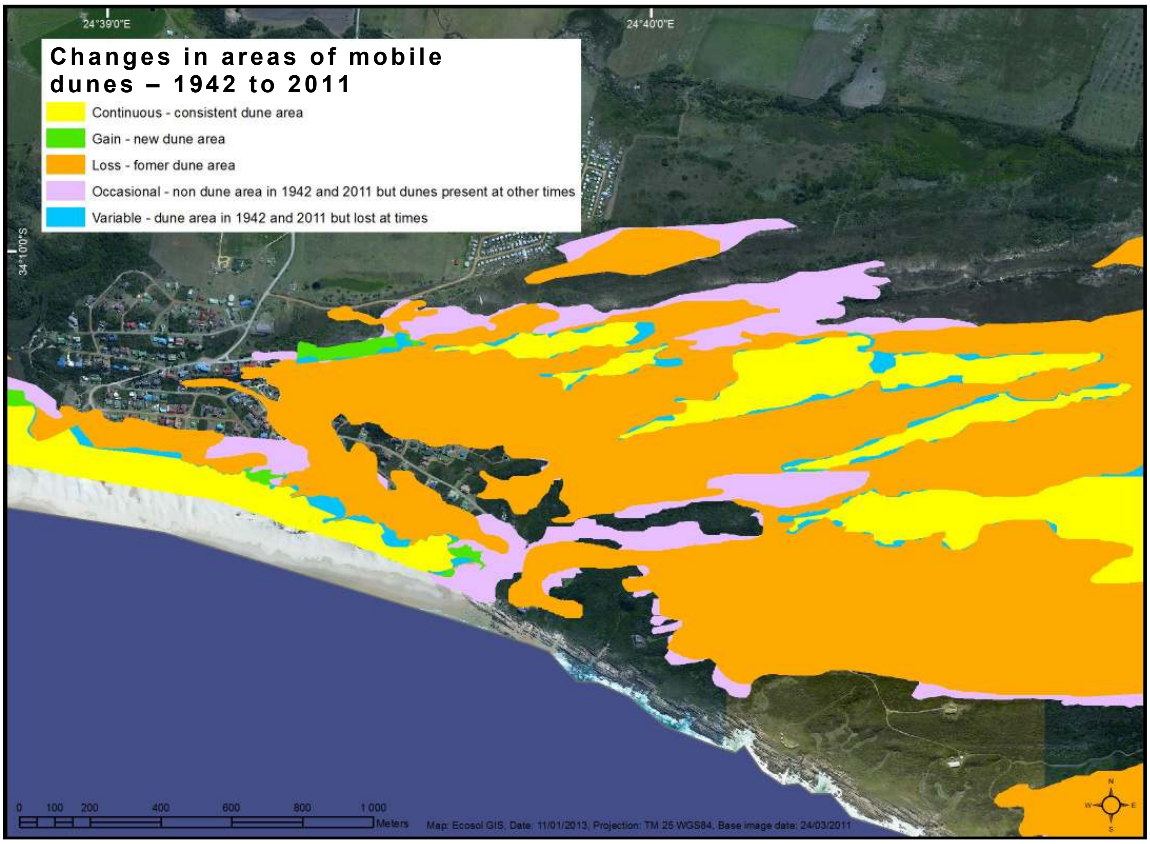


Figure 3.3 Changes in the areas of mobile dunes between 1942 and 2011 in the Oyster Bay area

Figure 3.4 Oyster Bay Village in the 1960's, shortly after the artificial dune ridge had been partially flattened. Photograph supplied by Nick Borman, Oyster Bay Beach Lodge.

Figure 3.5 The artificial dune ridge along the Oyster Bay beach is no longer being stabilised routinely, and is currently engulfing roads and houses in the village.

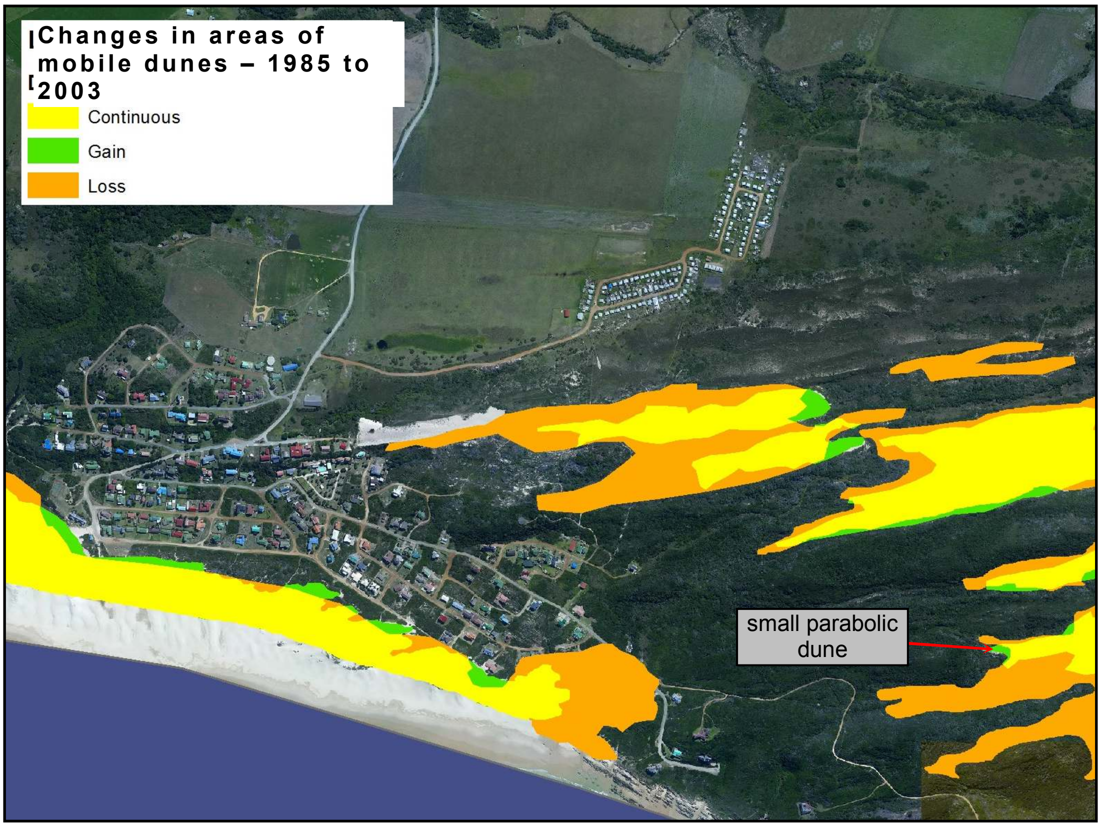


Figure 3.6 Changes in the areas of mobile dunes between 1985 and 2003 in the Oyster Bay area. Note a small parabolic dune that is advancing westward, driven by easterly winds.

3.2 Predictive model of dunes dynamics in the western end of the Oyster Bay Dunefield

If the dune ridge along the Oyster Bay Village shoreline is allowed to become mobile and over-run the village, it will revert to its natural state and eventually start feeding sand into the dunefield, as described in Section 3.1. The dunes at Sardinia Bay, Port Elizabeth are an exact analogy, as these dunes have been allowed to return to their natural state. Appendix D illustrates the sequence of events. This area is the feeder zone for the Cape Recife headland-bypass dunefield, which was artificially vegetated over 100 years ago (Lord, Illenberger & McLachlan, 1985).

If natural processes are allowed to continue unencumbered, the first parabolic dunes at Oyster Bay would reach the area between the middle and southern ridges (Fig.3.2) in about 50 years and the area between the northern and ridges middle would be reached in about 100-200 years. It would take many years for the feeder zone to become fully operational.

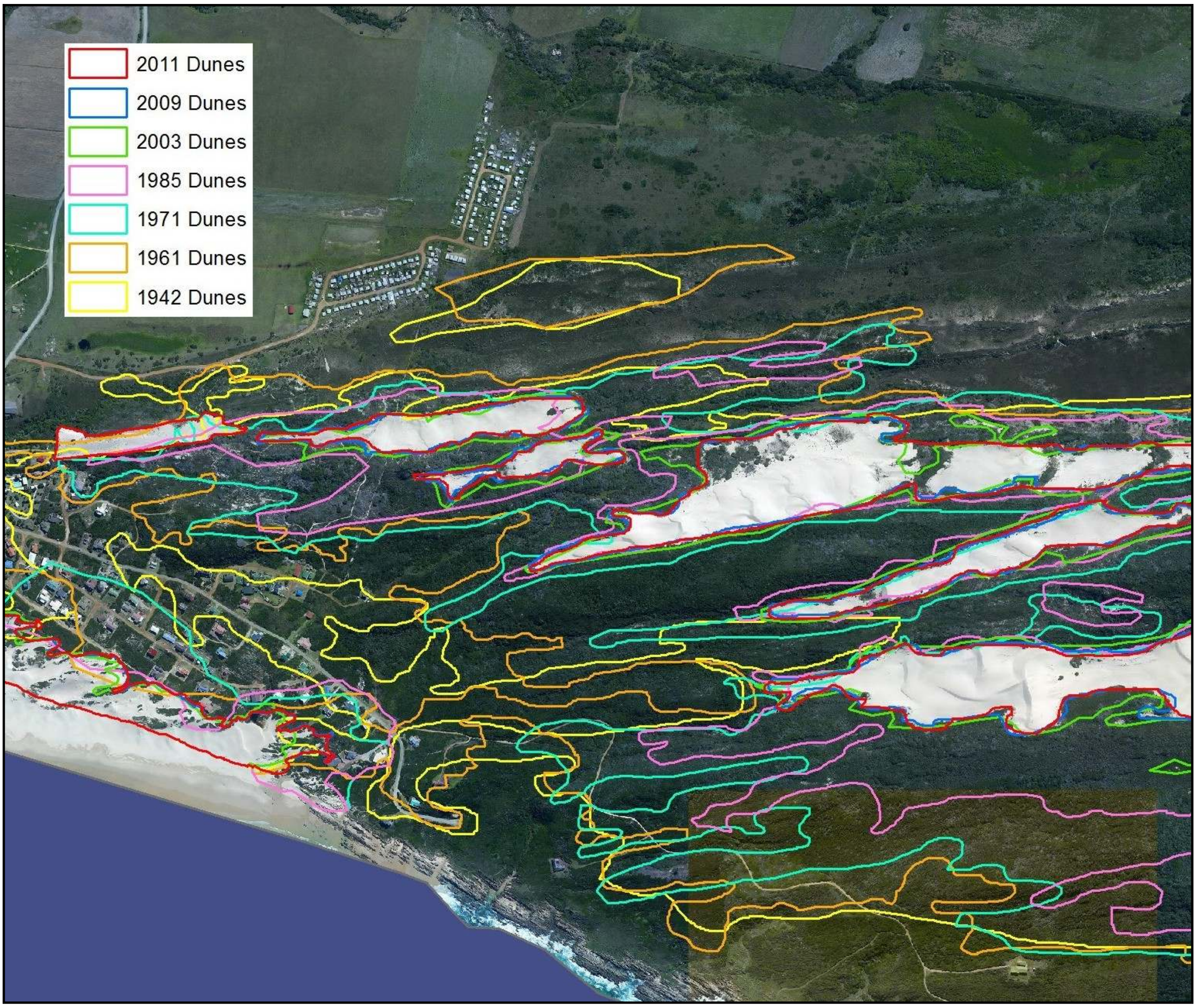


Figure 3.7 Changes in dunefield margins from 1942 to 2011 in the western end of the Oyster Bay dunefield. Base image 24 March 2011

It this dune ridge is managed to prevent impacts on Oyster Bay and not allowed to remobilize, the sand supply to the dunefield will remain cut off. This is the more likely scenario.

If invasive alien species like rooikrans are cleared, natural re-vegetation will be slower, advancing dunefields will move faster as the vegetation is easier to overcome and the loss of mobile dunes due to encroachment by alien vegetation will stop. The area of active dunefield will increase and the dunefields will revert to their natural mobility, as is happening at Koeberg. Alien vegetation across the whole dunefield area needs to be mapped to refine projected scenarios for future dunefield dynamics.

It is predicted that the eastern margins of the dunefields will continue to advance at their historic rates, i.e. the leading tongues of dunefields will move eastward at rates of 10 to 30 m/yr (Burkinshaw, 1998). In the Oyster Bay area there will be no further input of wind-blown sand, and the trailing ends of dunefields will continue to be vegetated at about 5 m/yr. These rates are unlikely to change significantly with time.

3.3 Impacts on dune wetlands related to dune dynamics

As documented in the Dune Geomorphology Report (Illenberger, 2010a) and the Wetlands Report (Day, 2009), within areas of mobile dunes the wetlands move with dunes and may cease to exist if a dune moves into an area where the groundwater table is close to the surface. Conversely, a wetland may be created if wind erodes the interdune area behind an advancing transverse dune low enough to expose the groundwater table. A wetland may also be created if an advancing parabolic dune blocks off a river or stream. The advancing tongue of a dunefield may create a whole new interdune wetland system.

It follows that the localities and nature of wetlands in the dune areas have changed very much over the life of the dunefields, i.e. the past 6000 years odd.

Considering the large active dune area that has been lost due to human impacts, the number of interdune wetlands would have been reduced. This would translate to habitat loss for this type of wetland.

3.4 Conclusions

The headland-bypass dunefields at St. Francis have been cut off from their source beaches due to human activities. If there is no human intervention to counter this (other than continuing to stabilize the dune ridge along Oyster Bay beach), the dunefields will slowly be stabilized over the next 1000 years or so by natural re-vegetation processes and the continuing spread of invasive alien vegetation.

If the dune ridge along the Oyster Bay Village shoreline is allowed to become mobile and over-run the village, the feeder zone will revert to its natural state and eventually start feeding sand into the dunefield. However, if this dune ridge is managed and not allowed to remobilize, the sand supply to the dunefield will remain cut off. This is the more likely scenario.

If invasive alien species like rooikrans are cleared, natural re-vegetation will be slower, advancing dunefields will move faster as the vegetation is easier to overcome, and the loss of mobile dunes due to encroachment by alien vegetation will stop. The dunefields will revert to their natural mobility.

It is predicted that the eastern margins of dunefields will continue to advance at their historic rates, i.e. the leading tongues of dunefields will move eastward at rates of 10 to 30 m/yr. The trailing ends of dunefields will continue to be vegetated at about 5 m/yr. These rates will not change significantly with time.

The localities and nature of wetlands in the dune areas have changed very much over the life of the dunefields. Large active dune areas have been lost due to human impacts and the numbers of interdune wetlands have been correspondingly reduced.

4 ENVIRONMENTAL ASSESSMENT & MITIGATION: NEW ALTERNATIVE WESTERN ACCESS ROUTES

The newly proposed alternative western access routes pass to the east of the settlements of Umzamawethu and Oyster Bay to the Thyspunt site, and include an inland alternative to CR-1 (Fig. 4.1).

There are five possible combinations currently under consideration:

1) Coastal Route (CR-1 & CR-2): NPS to Humansdorp Road, between Oyster Bay and Umzamawethu; three alternatives at western end.
2) Inland Route 1 (IR-1): NPS to west of Umzamawethu.
3) Inland Route 2 (IR-2): NPS to west of Umzamawethu.
4) Coastal to Inland Route 1, alternative 1 (CR-1 to IR-1).
5) Coastal to Inland Route 2, alternative 2 (CR-1 to IR-2).

The first route (CR-1 & CR-2) was the one originally proposed and was assessed in the Dune Geomorphology Report (Illenberger, 2010a).

The middle parts of IR-1 and IR-2 cross the mobile Oyster Bay dunefield characterised by transverse dunes, including both artificially and naturally vegetated dune areas. These parts are assessed in Section 4.1. The assessment is similar to the Dune Geomorphology Report.

The remaining parts of all the routes to the south of where they cross the Oyster Bay dunefield traverse parabolic dunes; both artificially and naturally vegetated; and linear vegetated dune ridges, as described and assessed in the Dune Geomorphology Report. The assessment of impacts and mitigations is exactly as in the Dune Geomorphology Report. This assessment is repeated in Section 4.2.

4.1 Inland Route 1 (IR-1) and Inland Route 2 (IR-2) across mobile dunes

The assessment is similar to the Dune Geomorphology Report, except that there are no interdune wetlands in the areas traversed by IR-1 and IR-2. The impacts are thus restricted to issues related to mobile dunes. Both routes cross the trailing (western) ends of patches of mobile dunefields, where dune movement is slowing down. The mobile dunes are moving along valleys that would be filled if the roads are built according to the “Cut and Fill Diagrams” supplied by Eskom. As such the only viable option would be to stabilize the patches of mobile dunes to the west (upwind) of the proposed routes. The main consequence of this would be to lose a small area of mobile dunes.

Mitigation/special measures:

- *Use only indigenous dune vegetation. Weed out alien vegetation routinely.*
- *Monitoring and repair of possible blowouts or water erosion that may occur as a result of windy or rainy periods during rehabilitation and recovery phases must be undertaken.*

- *A suitably qualified ECO is needed to supervise the construction phase and operational phase.*

This will reduce the impact to low.

As a mitigatory offset, Eskom could undertake to restore mobile dunes in the bulk of the Oyster Bay dunefield which they currently own, by removing alien vegetation, as per the scenarios in Chapter 3. An area much larger than what would be stabilized could be re-mobilized.

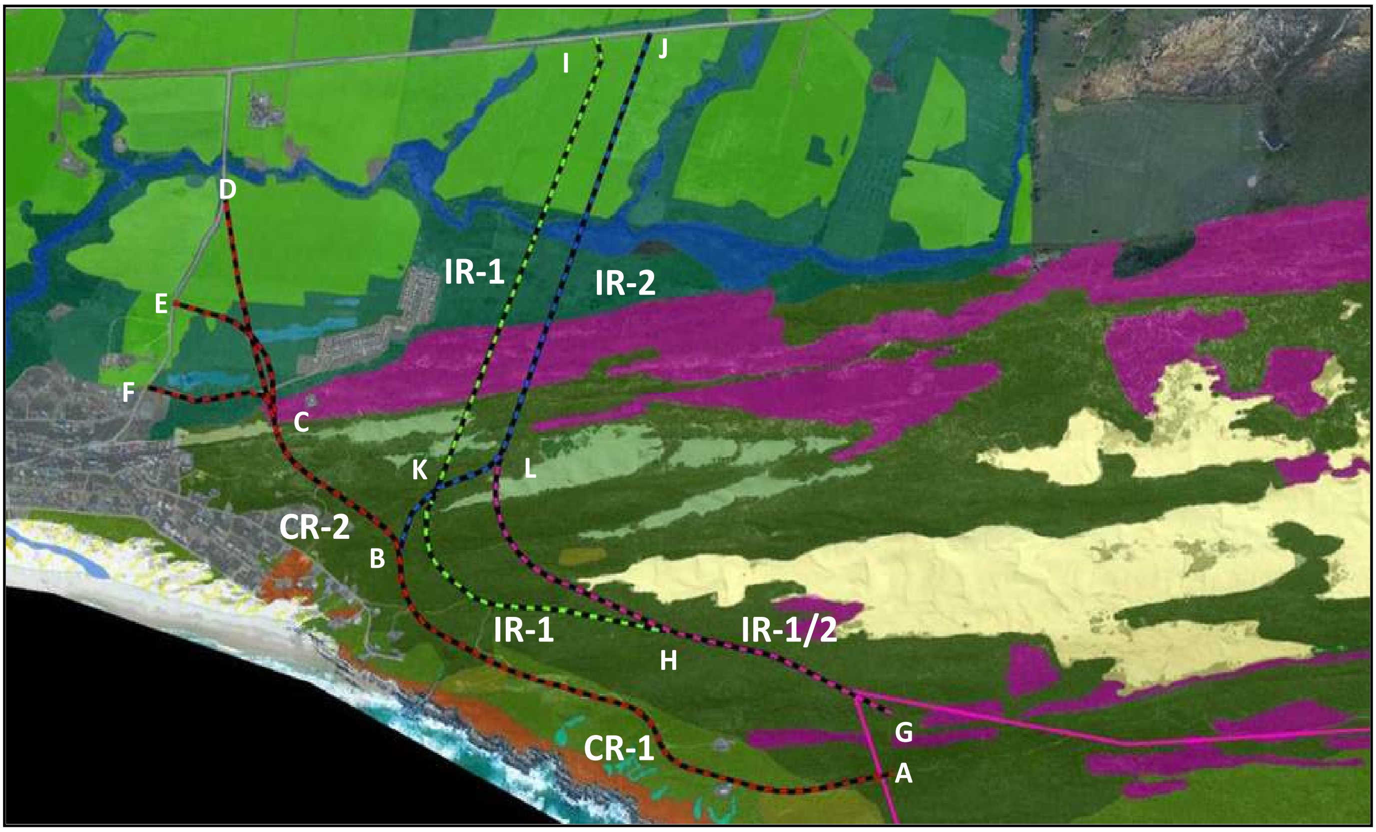


Figure 4.1 The five possible western access routes currently under consideration:

1) **Coastal Route** (CR-1 & CR-2): NPS to Humansdorp Road, between Oyster Bay and Umzamawethu; three alternatives at western end: A-B-C-D/E/F
2) **Inland Route 1** (IR-1): NPS to west of Umzamawethu: G-H-I
3) **Inland Route 2** (IR-2): NPS to west of Umzamawethu: G-H-J
4) **Coastal to Inland Route 1, alternative 1** (CR-1 to IR-1): A-B-K-I
5) **Coastal to Inland Route 2, alternative 2** (CR-1 to IR-2): A-B-L-J

4.2 Parabolic dunes and linear vegetated dune ridges

This entails crossing the vegetated dunes with a road that would need cut and fill to create a road with a smooth gradient. Terraforce or similar blocks must be used to stabilise the sides of the cut and fill, as rehabilitation by vegetating the slopes will be difficult and slow. There will thus be little effect on the stability of the dunes, apart from the risk of slumping during the construction phase. The environmental impact will be low.

Mitigation: None.

Blowouts may form during construction when bare sand is exposed. The environmental impact will be moderate.

Mitigation:

- *Blowouts can be repaired by placing brushwood or using drift fences on the bare sand surfaces, and then re-vegetating the bare sand with suitable pioneer species.*

- *Terraforce or similar blocks must be used to stabilise the sides of the cut and fill as quickly as possible.*

This will reduce the impact to low.

5 SUMMARY TABLES — ENVIRONMENTAL ASSESSMENT AND MITIGATION MEASURES

5.1 Environmental assessment and mitigation measures

Summary tables of environmental assessment and mitigation measures for the three sites are presented below in Table 5.1. Very low negative (~virtually insignificant) impacts are indicated with “neutral”.

5.2 Recommended monitoring and evaluation programme

The dynamics of mobile and vegetated dunes are well-understood at all three sites, and no periodic monitoring or measurements of dunes are required to gather further background information.

Mobile dunes in the vicinity of any construction activities must be monitored by a suitably qualified ECO, particularly within the Oyster Bay dunefield. Monthly visits are required. Any ad-hoc issues that crop up such as obstruction of moving dunes must be addressed.

Vegetated dunes in the vicinity of any construction activities must be monitored on a monthly basis by a suitably qualified ECO to address any ad-hoc issues that crop up. Rehabilitation of vegetation will require monitoring as specified in the botany specialist report.

The vegetated dunes in the vicinity of completed roads must be monitored at 3-monthly intervals by a suitably qualified dune specialist to check that there is no de-stabilization. The monitoring frequency can be reduced to six-monthly after 3 years, and annually after 6 years.

Environmental audits must be undertaken by a specialist auditor.

Table 5.1. Eskom Nuclear-1: assessment of impacts of new western access routes at Thyspunt

Impact	Nature	Extent	Intensity	Duration	Conse-quence	Probability	Signifi-cance	Revers-ibility	Irreplaceable resources	Cumulative impact	Confidence level
Access road across mobile dunes at the western end of the Oyster Bay dunefield - construction phase											
constructing access roads	negative	local	high	short-term	high	highly probable	high	high	yes	no	high
mitigation: repair of blowouts or water erosion	negative	local	low	short-term	low	definite	low	high	-	no	high
mitigation: ECO and *special rehabilitation techniques*	negative	local	low	short-term	low	definite	low	high	yes	no	high
Access road across mobile dunes at the western end of the Oyster Bay dunefield - operation phase											
constructing access roads	negative	local	high	short-term	high	highly probable	high	high	yes	no	high
mitigation: repair of blowouts or water erosion	negative	local	low	short-term	low	definite	low	high	-	no	high
mitigation: ECO and *special rehabilitation techniques*	negative	local	low	short-term	low	definite	low	high	yes	no	high
Access road across vegetated dunefield – construction phase											
formation of blowouts	negative	local	medium	short term	low	probable	low	high	no	no	high

Impact	Nature	Extent	Intensity	Duration	Conse-quence	Probability	Signifi-cance	Revers-ibility	Irreplaceable resources	Cumulative impact	Confidence level
mitigation: stabilise, rehabilitate	negative	local	low	medium term	low	definite	very low	high	no	no	high
Access road across vegetated dunefield – operation phase											
access roads	negative	local	low	permanent	low	definite	low	high	no	no	high
mitigation: ECO and *special rehabilitation techniques*	negative	local	low	short-term	low	definite	low	high	yes	no	high

6 THE CATCHMENT AND FLOW OF THE SAND RIVER

The eastern half of the dunefield that is currently still mobile is drained by the Sand River, which flows episodically during periods of high rainfall. When the Sand River floods it transports appreciable volumes of sand to the Kromme River estuary

6.1 Farmland catchment

About half of the catchment of the Sand River is farmland to the north of the dunefield; the remainder is within dunefields and wetlands. The Sand River farmland catchment is very flat for the most part; the average gradient is 1:200. Most of the valley floors have wetland vegetation (Figure 6.1). In flood hydrology terms the “time of concentration” (TC) is low, and the valley floor wetlands further attenuate flow.

John Hay, a local resident who owns the farm at the lowermost end of the Sand River farmland catchment, just before it enters the dunefield, has never observed flash-floods in the Sand River at this point. During high rainfall events, the river rises slowly and flow continues for days after rainfall events, tapering off to normal flow level over a number of weeks. (John Hay, pers. comm. 2012). These observations are in keeping with flood hydrology theory.

6.2 Flow along quartzite ridge

In the next part of the Sand River course, where it turns south-eastward to flow along and against a quartzite ridge the gradient is low, 1:150. There used to be active transverse dunes that ran obliquely across the channel, regularly blocking the channel, as can be seen on the aerial photos of 1942 (Fig 6.2). Water would find its way through the dunes, often being diverted along the dune axes. Moving dunes could block the river channel during dry periods. When the river flows again, water would pond against the dunes until the interdune pond overflows, causing a flash-flood. This phenomenon can occur in any part of the dunefield; one such event is described in Chapter 5 of the Addendum Report (Illenberger, 2010b).

The northern part of the dunefield was gradually vegetated, probably for the most part by the natural spread of alien vegetation, mostly rooikrans. The river channel gradually vegetated with dense wetland vegetation, as can be seen on the aerial photos of 2009 (Fig 6.3). Fig. 4.4 illustrates the situation on the ground. The river flow will again be attenuated.

6.3 The lower Sand River

At the point where the quartzite ridge ends, the river turns east-north-eastward and enters the currently active lower eastern end of the Oyster Bay dunefield (Fig 6.5). The gradient is steeper, about 1:70. During dry periods, moving dunes can completely block the river course, as documented in the Geomorphology Addendum Report (Illenberger, 2010b). When a wet period ensues, the river will dam up against the dunes until the dune is overtopped or ruptured by piping and liquefaction. A flash-flood will result, forming a sandy floodplain on which eroded plants and loose vegetation are strewn, as is the typical appearance of the Sand River in this area after high rainfall events (Figure 4.6). The river will erode dunes that are in its way (Figure 4.7), entraining much sand that is carried downstream until where the Sand River debouches into the Kromme River estuary, where the sand is deposited to form the Sand River delta.

Figure 6.1 The lowermost end of the Sand River farmland catchment. Flow is slow through the wetland vegetation

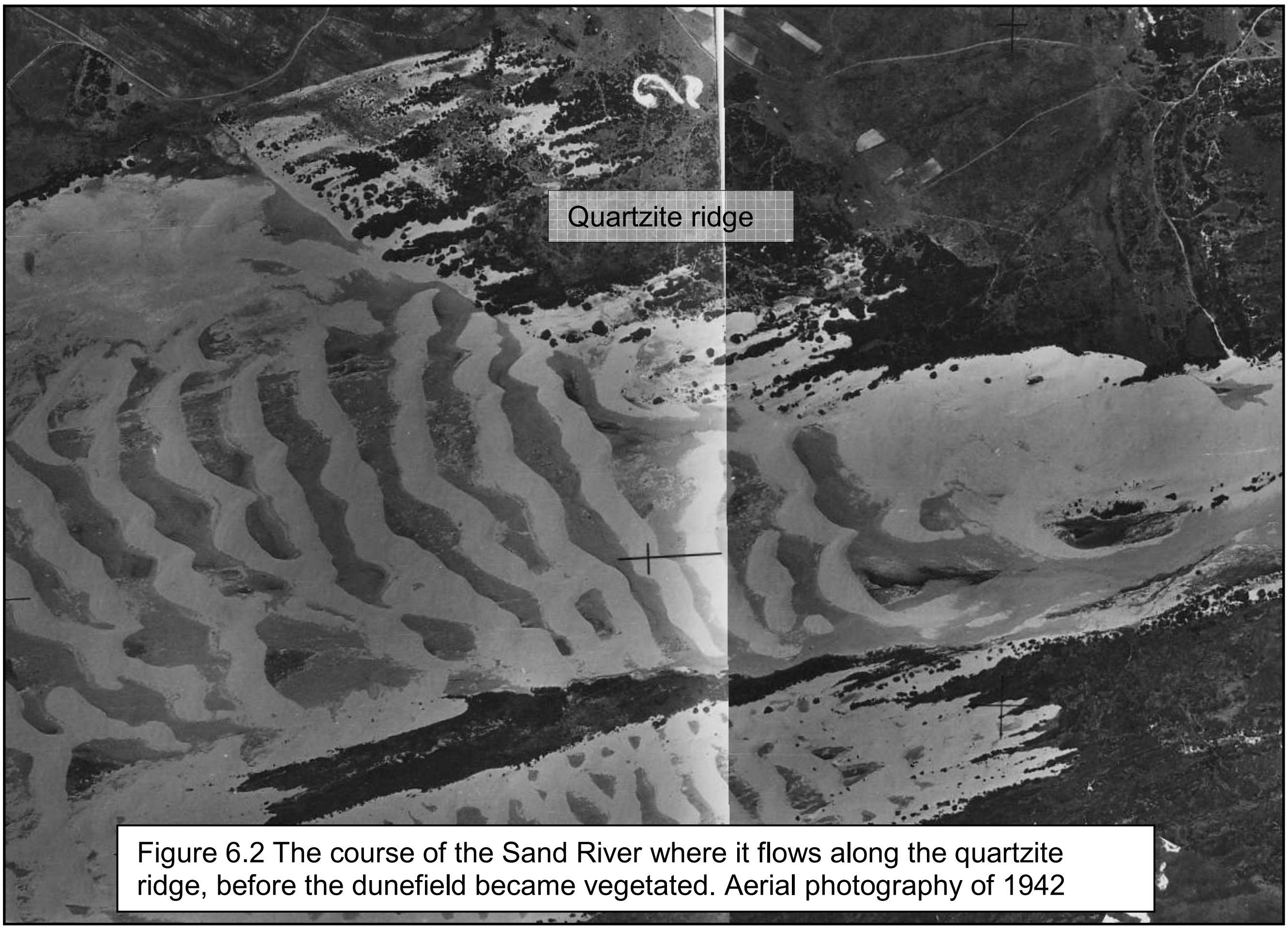


Figure 6.2 The course of the Sand River where it flows along the quartzite ridge, before the dunefield became vegetated. Aerial photography of 1942

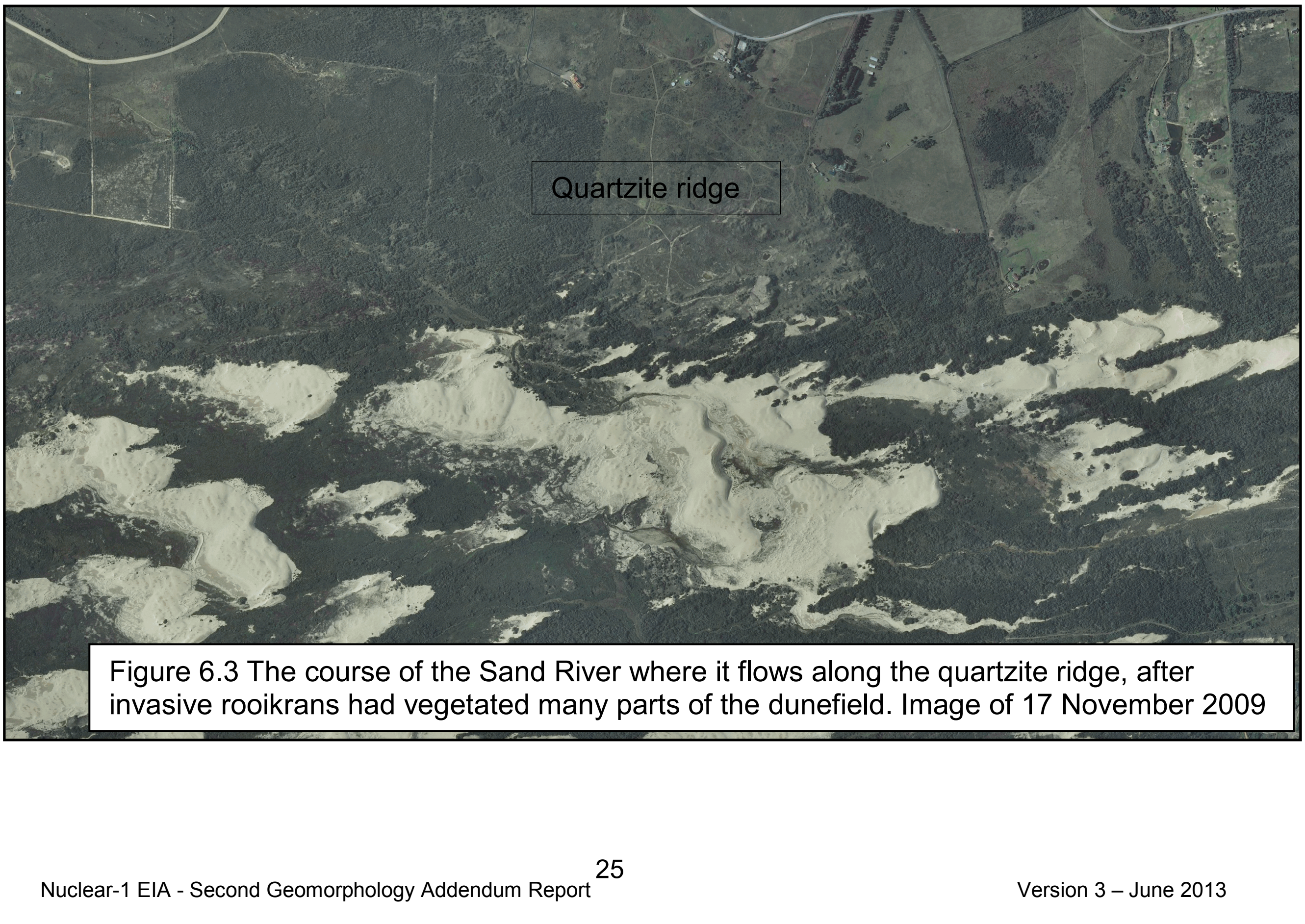


Figure 6.3 The course of the Sand River where it flows along the quartzite ridge, after invasive rooikrans had vegetated many parts of the dunefield. Image of 17 November 2009

Figure 6.4 The Sand River at the point where the quartzite ridge ends, choked with wetland vegetation

Figure 6.5 The Sand River where it turns east-north-eastward and enters the currently active Oyster Bay dunefield

Figure 6.6. The lower Sand River after a high rainfall event (the flood of 3 August 2006). It has a wide sandy floodplain on which eroded plants and loose vegetation are strewn. The river has eroded into the dune in the background. Photographed 19 August 2006.

Figure 6.7. The Sand River after a high rainfall event (the flood of 3 August 2006), eroding a dune and entraining much sand. Photographed 19 August 2006.

6.4 The catchment area of the Sand River

The original catchment of the Sand River was 13.5 km², of which 9 km² was farmland and 4.5 km² was dunefield - the main Oyster Bay dunefield.

The breaching of the southern tongue added 1.9 km² to the catchment of the Sand River. The wetland drainage diverted by the cutoff canal (Fig 6.8) has a catchment of 2.3 km², which was also added to the Sand River catchment when the southern tongue was breached. The catchment portions are summarised in Table 6.1.

Table 6.1. Current Sand River catchment	Area (km²)	percentage
Total catchment of the Sand River	17.5	100
Farmland	9	51
Original eastern sector of Oyster Bay dunefield	4.5	25
Southern tongue	1.9	11
Wetlands added by cutoff canal	2.3	13

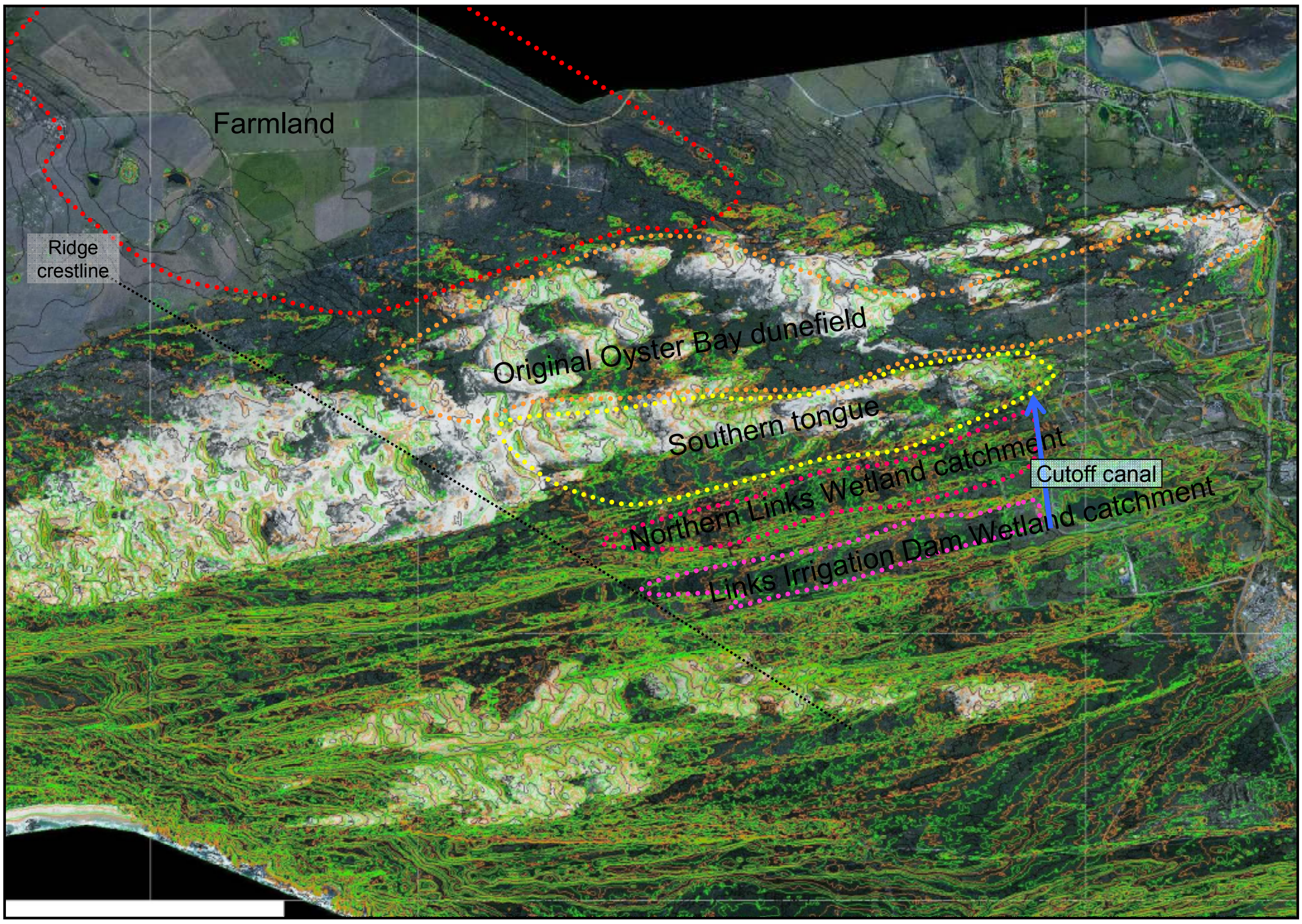


Figure 6.8 Components of the current Sand River catchment. Base image 24 March 2011.

6.5 Conclusions

The flash-floods that the Sand River experiences do not originate in the farmland catchment, as the river gradient is low and the valley bottom is mostly wetland. Rather, the flash-floods are caused by moving dunes that block the river channel within the dunefield during dry periods. When the river flows again, water would pond against the dunes until the interdune pond overflows and breaches, causing a flash-flood.

It often happens that there is not one big flood, but a number of smaller rain events. The landscape becomes progressively more saturated with water, so that there is less and less absorption capacity, and the proportion of runoff increases accordingly. A rainfall event of 100 mm or so at the end of such a wet season can generate a flood with high peak flow that can cause significant damage. This happened in 2011 and 2012 (see Chapters 7 & 8).

The Sand River erodes dunes as it makes its way through the dunefield, entraining much sand. Large volumes of sand as well as plant debris are carried down the Sand River during floods. This is a normal fluvial process, not a debris flow. The sand is ultimately deposited in the Sand River delta in the Kromme River estuary. This has been happening for hundreds of years.

Dunefields can create unique catchments of varying size, which can have sudden increases in size as dunefields move. Human intervention can also increase the size of a catchment significantly, e.g. the cutoff canal along the western (upstream) border of the St. Francis Links Golf Course diverted runoff into the southern tongue, which has now become a part of the Sand River catchment.

7 THE 2011 FLOODS

In 2011 there was not one big flood, but a number of smaller rain events. At Cape St. Francis weather station, 60 mm fell on 18 March, 87 mm on 8 May, 63 mm on 8/9 June, 76 mm on 24/25/26 June, 123 mm on 2/3/4 July, and 43 mm on 24 July. The landscape became progressively saturated with water, so that there was less and less absorption capacity, and the volume of runoff increased accordingly. The largest event was 2/3/4 July.

7.1 The breaching of the southern tongue of the Oyster Bay dunefield

Figure 7.1 illustrates the situation at the southern tongue of the Oyster Bay dunefield soon after the November 2007 flood. There is evidence of strong flow in channels that weaved their way through dunes. Large volumes of water accumulated in inter-dune ponds. The pond in the nose of the southern tongue was very large; it was close to breaching. Another 50-100 mm of rain might have breached it.

In July 2011, a large volume of water again accumulated in the nose of the southern tongue. Flow was augmented by water from the cutoff canal. The sequence of events is described in Figures 7.2, 7.3 and 7.4. It culminated in the artificial breaching of the southern tongue, as illustrated in Figure 7.5. The Sand River culvert was washed away in the ensuing flash-flood, and the Sand River delta in the Kromme River estuary gained about 80 000 m³ of sediment (see Chapter 9). Figure 7.6 is an aerial view of the situation on 9 July 2011, after the breach of the southern tongue.

It could be speculated whether the southern tongue would have breached naturally without the addition of the runoff from the cutoff canal. Considering the situation in 2007 where the southern tongue was close to breaching, and the fact that in 2011 water continued to flow out of it for weeks after the artificial breaching, it is possible that it would have breached naturally. Also, the biggest rainfall event in 2011 was 123 mm on 2/3/4 July. However, human interventions definitely played a significant part in the events in 2011.

7.2 Conclusions

The water that is released when an interdune pond breaches will generate a flash-flood that can be very big. It is a catastrophic event. Large amounts of sediment and plants may be transported by the high energy peak water flow.

Figure 7.1 The southern tongue of the Oyster Bay dunefield soon after the November 2007 flood. Photographs from Silberbauer (2009)

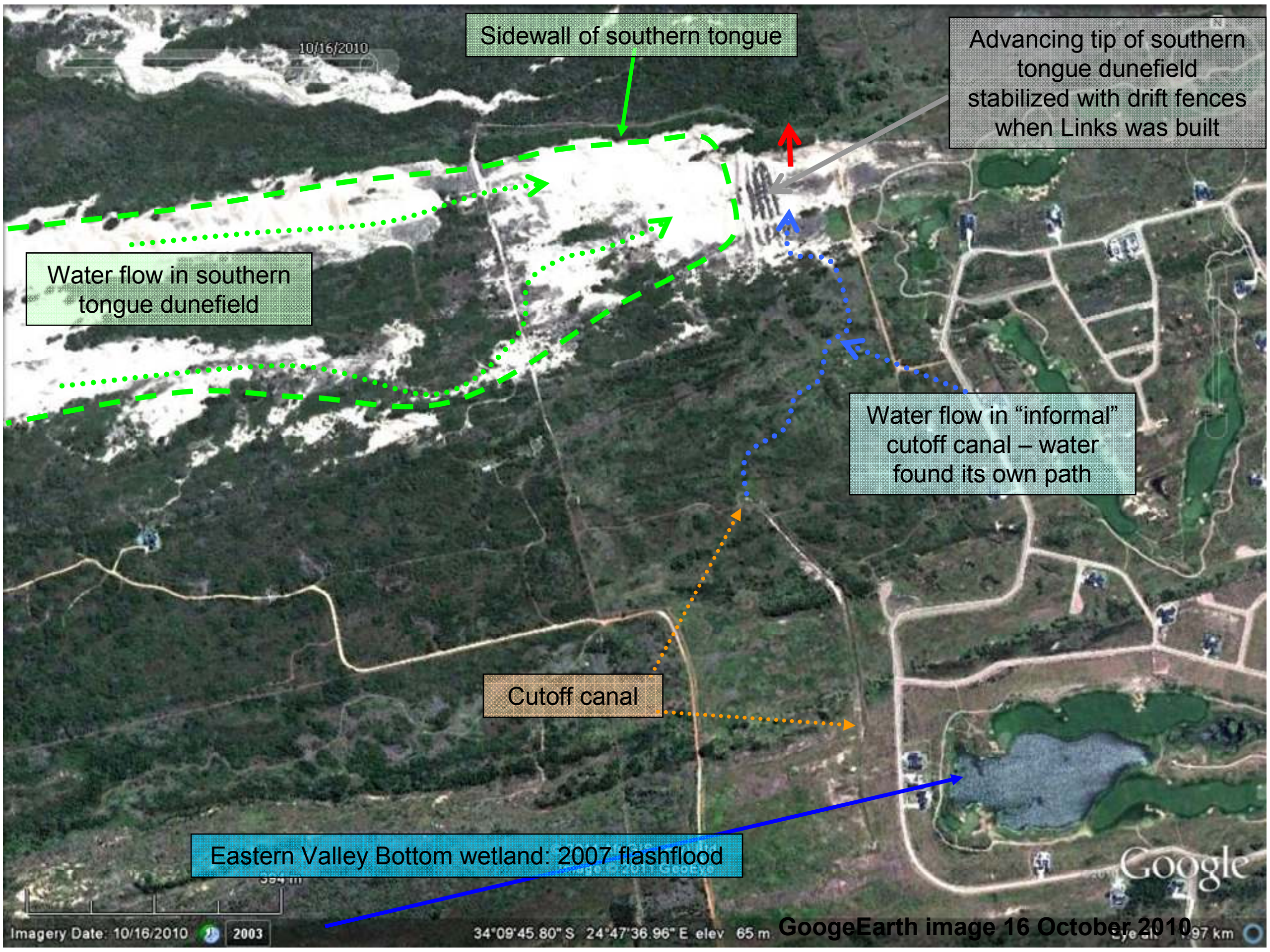
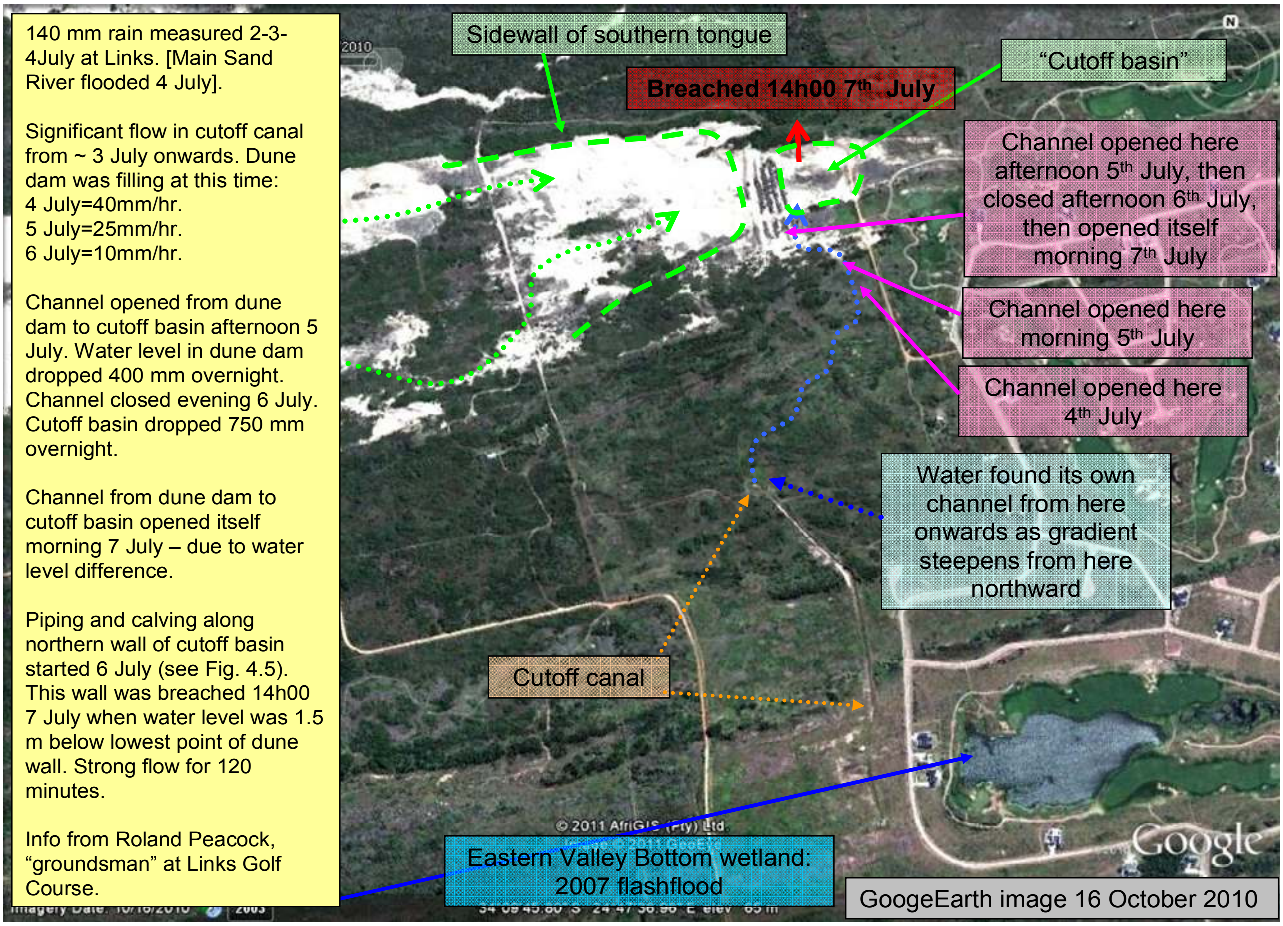


Figure 7.2 Features of the southern tongue of the Oyster Bay dunefield, July 2011


140 mm rain measured 2-3-4July at Links. [Main Sand River flooded 4 July].

Significant flow in cutoff canal from ~ 3 July onwards. Dune dam was filling at this time:
4 July=40mm/hr.
5 July=25mm/hr.
6 July=10mm/hr.

Channel opened from dune dam to cutoff basin afternoon 5 July. Water level in dune dam dropped 400 mm overnight. Channel closed evening 6 July. Cutoff basin dropped 750 mm overnight.

Channel from dune dam to cutoff basin opened itself morning 7 July – due to water level difference.

Piping and calving along northern wall of cutoff basin started 6 July (see Fig. 4.5). This wall was breached 14h00 7 July when water level was 1.5 m below lowest point of dune wall. Strong flow for 120 minutes.

Info from Roland Peacock, “groundsman” at Links Golf Course.

Figure 7.3 Events culminating in the breach of the southern tongue of the Oyster Bay dunefield, 7 July 2011

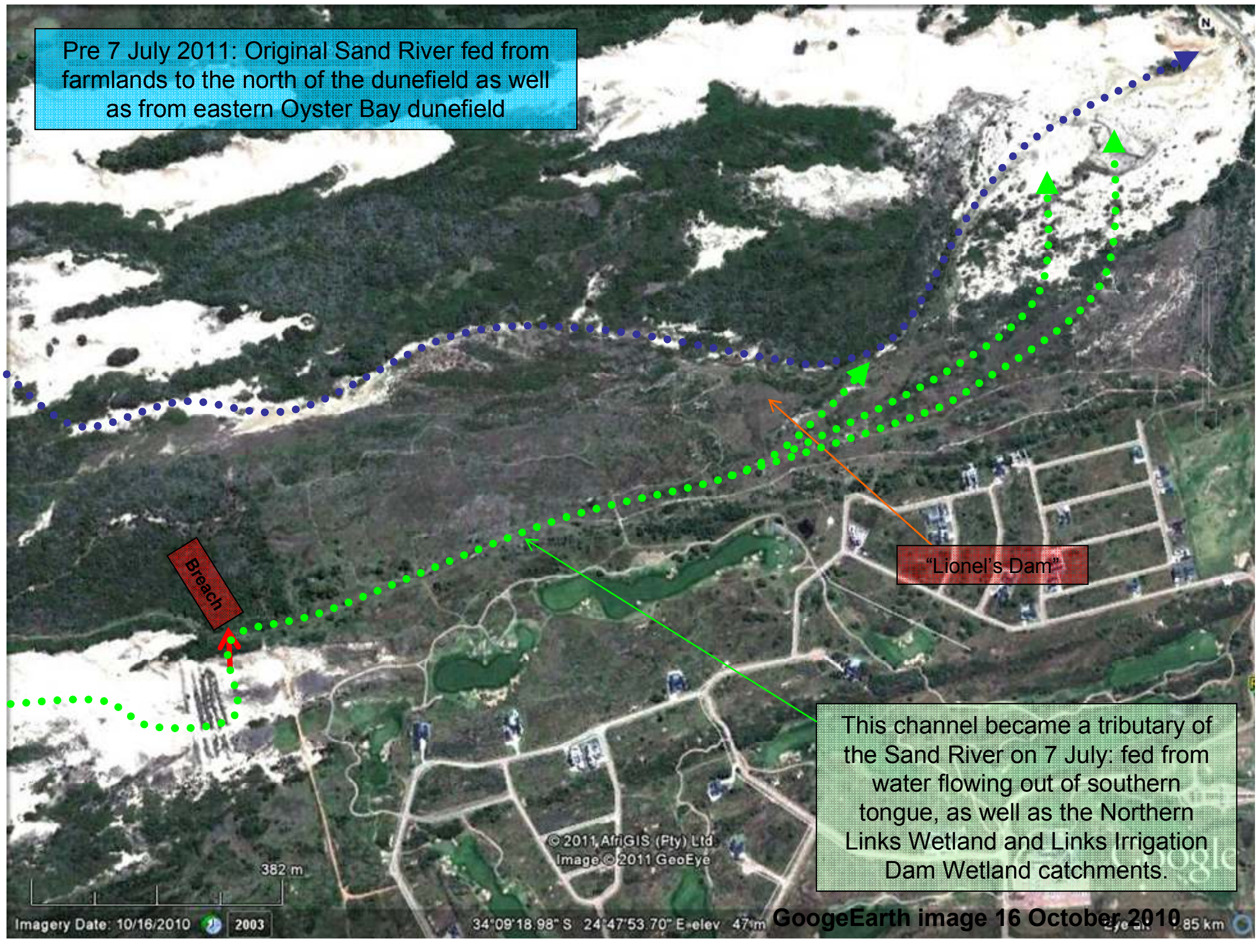


Figure 7.4 Flow paths during the flashflood after the breaching of the southern tongue of the Oyster Bay dunefield on 7 July 2011

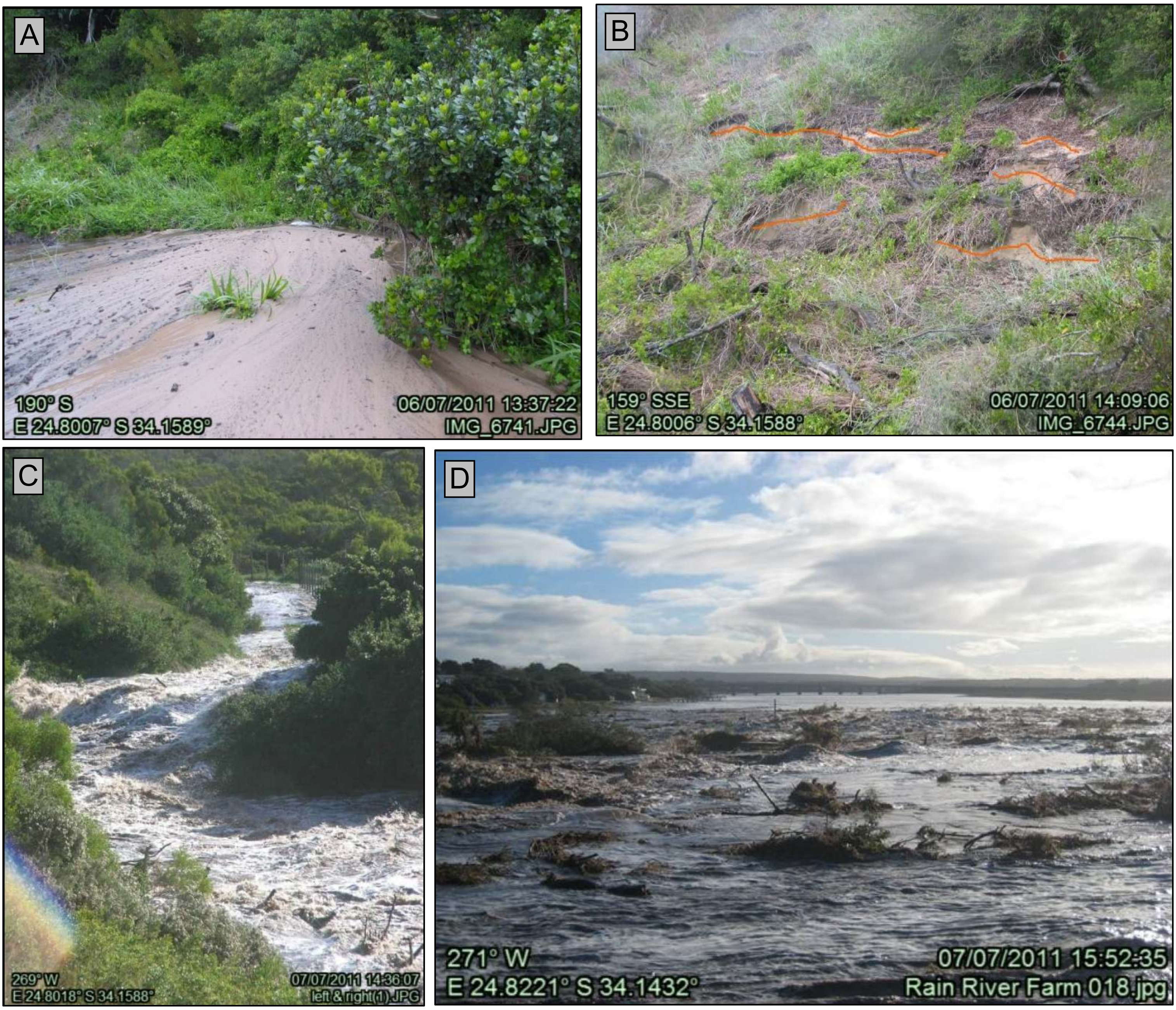


Figure 7.5 Events culminating in the breach of the southern tongue of the Oyster Bay dunefield, 7 July 2011. A: "piping" (water flowing through the base of the sidewall of the southern tongue, depositing sandy material). B: slumping along the sidewall of the southern tongue. C: the torrent of water released by the breach. D: sand and debris deposited on the Sand River delta in the Kromme estuary. Photographs from Silberbauer (2011a).

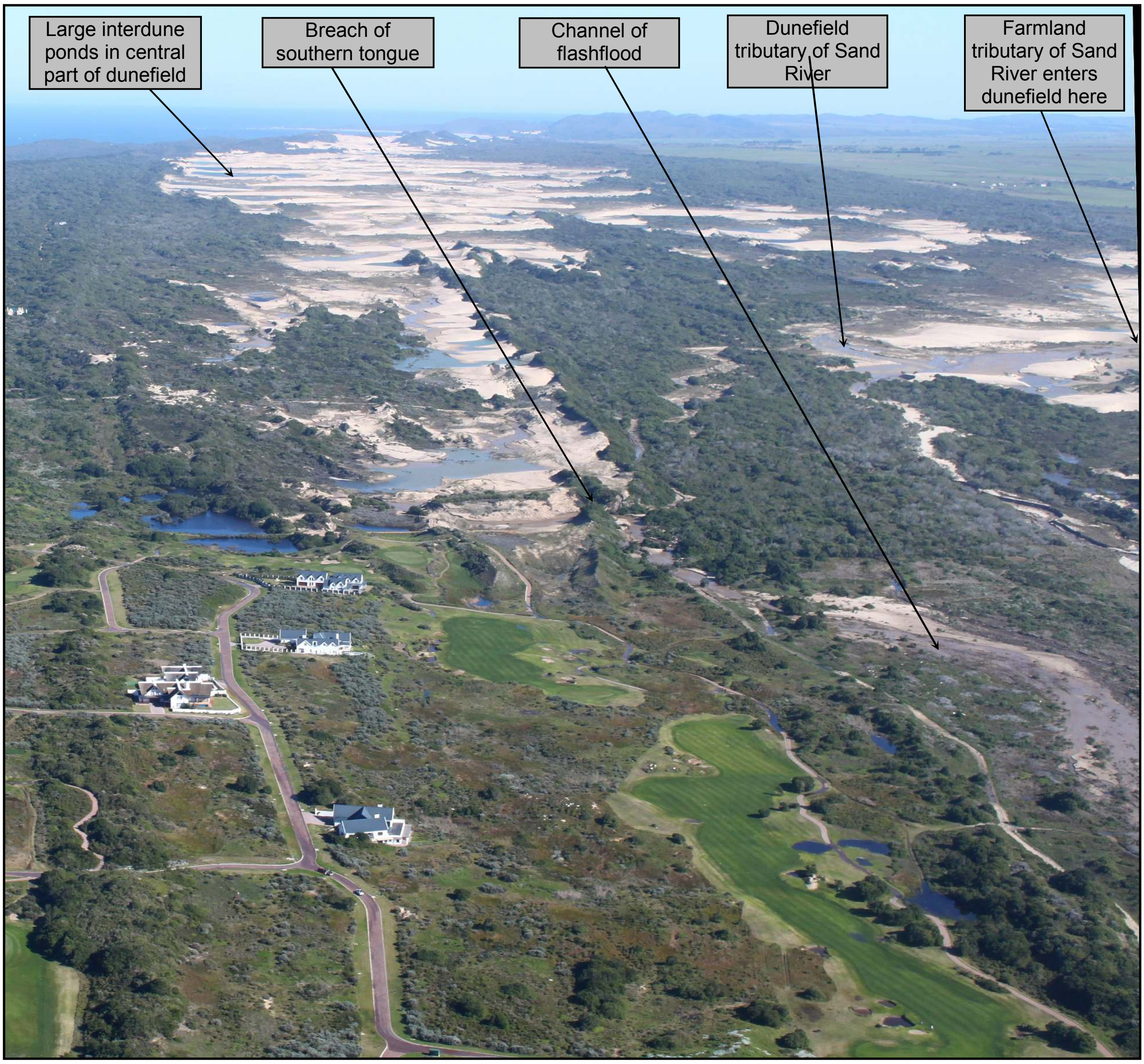


Figure 7.6 The situation on 9 July 2011, after the breach of the southern tongue. Photo courtesy of Don McGillivray, Africoast Engineers

8 THE 2012 FLOODS

In 2012, similar to 2011, there was not one big rainfall event, but a number of smaller events. At Cape St. Francis weather station the rainfall records are as follows: 98 mm on 8/9 June, 69 mm on 13/14/15 June, 46 mm on 6/7/8 August, 40 mm on 11/12 August and 113 mm on 17-20 October. The landscape again became progressively saturated with water, so that there was less and less absorption capacity, and the proportion of runoff increased accordingly. The largest rainfall event was 17-20 October.

8.1 The Santareme event of 15 September 2012

The Santareme event of 15 September 2012 provides a dramatic example of the flash-flood that can result when an interdune pond breaches (Figures 8.1 & 8.2). The flood resulted from the rupture of an interdune pond in the Santareme dunefield. The dunefield had been artificially stabilised, preserving the transverse dune topography that dams surface runoff.

8.2 Destruction of Sand River culvert on 22 October 2012

The final rainfall event of 2012 was the largest event for that year: 113 mm on 17-20 October. It resulted in a flood that washed away the temporary Sand River culvert that had been built in August 2011 (Figure 8.3).

The culvert constructed in August 2011 consisted of seven pipes. It appears these pipes became blocked, so the road surface was overtopped and washed away. The culvert that was built after the October 2012 flood consists of seven pipes and a box culvert (Fig. 8.4). The seven pipes are not at the same level on the upstream side, so some of these pipes could potentially be blocked (Fig. 8.5). The inclusion of the box culvert will hopefully make this temporary culvert better able to handle future floods.

8.3 Conclusions

Flash-floods definitely pose a threat to humans, houses and infrastructure in that they can occur without warning and cause substantial damage.

Persons who observed the build-up of water in the Santareme dunefield realied the potentially dangerous situation and made the authorities aware of this. The damage that resulted when the interdune pond breached could have been avoided if the authorities had heeded the warnings. The installation of siphon pipes to safely drain an interdune pond upstream of the one that had breached on 15 September 2012 (Fig. 8.2) illustrates an easy way to alleviate the problem.

Interdune ponds should be monitored during periods of high rainfall, to see if dangerous situations are developing. Aerial surveys from a small aircraft are an efficient way to do this.

The temporary Sand River culvert needs to be replaced urgently with a suitably designed permanent structure.

Figure 8.1 The flash-flood that flowed through Santareme on 15 September 2012. The photograph was taken in Tom Brown Boulevard; source of photograph: St Francis Chronicle. The flood resulted from the rupture of an interdune pond in the Santareme dunefield. The dunefield has been artificially stabilized, preserving the transverse dune topography that dams surface runoff.

Figure 8.2 Above: An interdune pond in the Santareme dunefield “upstream” of the pond that ruptured on 15 September 2012. Left: three pipes were installed as siphons to drain the pond gradually, so as to avoid a further flashflood.

Figure 8.3 The dying moments of the Sand River culvert on 22 October 2012

Figure 8.4 The temporary culvert over the Sand River built in October 2012

Figure 8.5 The seven pipes on the upstream side of the 2012 culvert. The pipes are not at the same level, so some of these pipes could potentially be blocked.

9 SAND RIVER DELTA IN THE KROM ESTUARY

Appendix E illustrates the history of the Sand River delta in the Kromme River estuary. From this one can deduce:

- The Kromme estuary is typically sand-choked. The sand is derived from the Sand River and from tidal currents that carry sand into the estuary from the sea, to create deposits near the mouth called flood-tidal deltas.
- Tidal currents slowly redistribute sand over years to form sand bodies of various shapes (depending on whether the flood or ebb tides are forming them). These sand bodies extend from the mouth to 2 km upstream of the R330 bridge. See for example the images from 1961, 1969, 1971, 1999, 27 June 2003, 6 March 2006, 16 October 2010 and 7 November 2011 in Appendix E. There is very little variation in the outline of the sand bodies over the years.
- Wholesale flushing of the estuary has not happened since 1942. Illenberger & Burkinshaw (2007) conjectured it needs at least a 1:100 year flood to do this, maybe even a 1:500 year flood. This is unlike other estuaries like the Gamtoos and Sundays estuaries that are flushed completely every 10-20 years.
- An even bigger flood would now be needed to completely flush the Kromme River estuary because the two dams on the river have a combined capacity that is about 3 times the mean annual runoff. The dams act like detention ponds (in civil engineering parlance) that attenuate floods: if the dams are empty before a flood, they first have to be filled before floodwaters will reach the Kromme estuary.
- Smaller floods do carry sediment out of the Kromme estuary; such floods have occurred a number of times since 1942. These floods reshape and shift downstream the Sand River delta and flood-tidal deltas. See for example the 1971 and October 2006 photographs in Appendix E.
- Tidal currents redistribute sediment to restore an “equilibrium” channel cross-section large enough the carry the volume of water moved in and out by each tide. This has happened after every Sand River flood event to date.
- The Sand River delta has never blocked the Kromme estuary completely, and it is not likely to do so.

9.1 Volumes of sand deposited in the Kromme Estuary

Volumes of sand that the Sand River deposits in the Kromme Estuary have never been precisely determined. CSIR (1984, 1988 & 1991) estimated that about 10 000 m^3 have been deposited per flood event for the past 50 years or so. Watermeyer et al. (1993) estimated that the Sand River could deposit between 5 000 and 20 000 m^3 per flood event in the Kromme River estuary.

Elkington (2012) gives results from a topographic survey that was conducted immediately after the flood event of 7 July 2011. The volume of sand was estimated to be in the region of 60 000 m^3.

Frank Silberbauer (pers. comm. 2012) conducted some surveys after the 7 July 2011 flood event and investigated images of various dates. From this he estimated that this event added 80 000 m^3 of sand to the delta.

10 SUPPOSED DEBRIS FLOWS REVISITED

Frank Silberbauer (pers. comm. 2012 and Silberbauer, 2011b) demonstrated that the supposed debris flow deposits identified by Prof. Ellery and his colleagues (Ellery & Elkington, 2011; Elkington, 2012) are actually bulldozer deposits made when a berm was built to protect a dam ("Lionel's Dam") from the Sand River (Figure 10.1).

Figure 10.1 Locality of the supposed debris deposit (black arrow) and Lionel's Dam. GPS co-ordinates of the deposit from Ellery & Elkington (2011). Image 7 November 2011.

11 IS THE SAND RIVER UNIQUE?

The Sand River carries a very high sediment load that is pure sand. Rivers like this do occur in nature in other parts of the world. Figure 11.1 illustrates a dunefield and river in New Zealand. It seems that such systems can take "physical punishment".

Figure 11.1 The Te Paki River that flows through the dunefield adjacent to Ninety Mile Beach, New Zealand.

12 CONCLUSIONS AND RECOMMENDATIONS

12.1 Dune morphodynamics in the Cape St. Francis Headland-bypass dunefield

The headland-bypass dunefields at Cape St. Francis have been cut off from their source beaches due to human activities. If there is no human intervention to counter this (other than continuing to stabilize the dune ridge along Oyster Bay beach), the dunefields will slowly be stabilized over the next 1000 years or so by natural re-vegetation processes and the continuing spread of invasive alien vegetation.

If the dune ridge along the Oyster Bay Village shoreline were allowed to become mobile and over-run the village, the feeder zone of the dunefield would revert to its natural state and eventually start feeding sand into the dunefield. However, if this dune ridge is managed and not allowed to remobilize, the sand supply to the dunefield will remain cut off. This is the more likely scenario.

If invasive alien species like rooikrans are cleared, natural re-vegetation will be slower, advancing dunefields will move faster as the vegetation is easier to overcome, and the loss of mobile dunes due to encroachment by alien vegetation will stop. The dunefields will revert to their natural mobility.

It is predicted that if invasive alien species are kept in check, the eastern margins of dunefields will continue to advance at their historic rates, i.e. the leading tongues of dunefields will move eastward at rates of 10 to 30 m/yr. The trailing ends of dunefields will continue to be vegetated at about 5 m/yr. These rates will not change significantly with time.

The localities and nature of wetlands in the dune areas have changed very much over the life of the dunefields, corresponding to their dynamic nature. Large active dune areas has been lost due to human impacts and the numbers of inter-dune wetlands have correspondingly reduced.

12.2 Assessment of access routes IR-1 and IR-2 across mobile dunes

The impacts are restricted to issues related to mobile dunes. Both routes cross the trailing (western) ends of patches of mobile dunefields, where dune movement is slowing down. The mobile dunes are moving along valleys that would be filled to build the roads. As such the only viable option would be to stabilize the patches of mobile dunes to the west (upwind) of the proposed routes. The main consequence of this would be to lose a small area of mobile dunes. The environmental impact will be low.

As a mitigatory offset, Eskom could undertake to restore mobile dunes in the bulk of the Oyster Bay dunefield, which they currently own, by removing alien vegetation. An area much larger than what would be stabilized would thus be re-mobilized.

12.3 Assessment of access routes IR-1 and IR-2 across vegetated parabolic dunes and linear dune ridges

This portion of the access road entails crossing the vegetated dunes with a road that would need cut and fill to create a road with a smooth gradient. Terraforce or similar blocks must be used to stabilise the sides of the cut and fill, as rehabilitation by vegetating the slopes will be difficult and slow. There will thus be little effect on the stability of the dunes, apart from the risk of slumping during the construction phase. The environmental impact will be low.

12.4 The catchment and flow of the Sand River

The flash-floods that the Sand River experiences do not originate in the farmland catchment, as the river gradient is low and the valley bottom is mostly wetland. Rather, the flash-floods are caused by moving dunes that block the river channel within the dunefield during dry periods. When the river flows again, water ponds against the dunes until the inter-dune ponds overflow and breach, causing a flash-flood.

It often happens that there is not one big rainfall event, but a number of smaller events. The landscape becomes progressively saturated with water, so that there is less and less absorption capacity, and the proportion of runoff increases accordingly. A rainfall event of 100 mm or so at the end of a wet season can generate a flood with high peak flow that can cause significant damage. This is what caused the floods of 2011 and 2012.

The Sand River erodes dunes as it makes its way through the dunefield, entraining much sand. Large volumes of sand and plant debris are carried down the Sand River during floods. This is a normal fluvial process, not a debris flow. The sand is ultimately deposited in the Sand River delta in the Kromme estuary. This has been happening for hundreds of years.

Dunefields can create unique catchments of varying sizes and these catchments can suddenly increase in size as dunefields move. Human intervention can also increase the size of a catchment significantly, e.g. the cutoff canal along the western (upstream) border of the Links Golf Course diverts runoff into the southern tongue of the Oyster Bay dunefield, which has now become a part of the Sand River catchment.

12.5 The 2011 floods and the breaching of the southern tongue of the Oyster Bay dunefield

In 2011 there was not one big flood, but a number of smaller rain events. The landscape became progressively more saturated with water, so that there was less and less absorption capacity, and the volume of runoff increased accordingly. The largest event was 123 mm on 2/3/4 July. After this rain, a large volume of water accumulated in the nose of the southern tongue and flow was augmented by water from the cutoff canal. The southern tongue was artificially breached on 7 July. The Sand River culvert was washed away in the ensuing flash-flood, and the Sand River delta in the Kromme estuary gained about 80 000 m^3 of sediment.

The water that is released when an interdune pond breaches will generate a flash-flood that can be very big, resulting in a catastrophic event. Large amounts of sediment and plants may be transported by the high energy peak water flow.

12.6 The 2012 floods

In 2012, similar to 2011, there was not one big flood, but a number of smaller rain events. The landscape again became progressively more saturated with water, so that there was less and less absorption capacity, and the volume of runoff increased accordingly.

The Santareme event of 15 September 2012 provides a dramatic example of a flash-flood that can result when an interdune pond breaches. The dunefield had been artificially stabilized, preserving the transverse dune topography that dams surface runoff. The flood resulted from the rupture of one of these ponds.

The final rainfall event of 2012 was the largest event for that year: 113 mm on 17-20 October. It resulted in a flood that washed away the temporary Sand River culvert that had been built in August 2011.

12.7 Sand River delta in the Kromme Estuary

The Kromme estuary is typically sand-choked. The sand is derived from the Sand River and from tidal currents that carry sand into the estuary from the sea. The Sand River delta has never blocked the Kromme estuary completely, and it is not likely to do so.

12.8 Debris flows and debris flow deposits

The supposed debris flow deposit is a bulldozer deposit.

12.9 Recommendations

Alien vegetation across the whole dunefield areas needs to be mapped to confirm and refine projected scenarios for future dunefield dynamics.

Interdune ponds should be monitored during periods of high rainfall, to see if dangerous situations are developing. Aerial surveys from a small aircraft are an efficient way to do this.

The temporary Sand River culvert should be urgently replaced with a suitably designed permanent structure.

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