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Global Climate Change and Adaptation – A Sea-Level Rise Risk Assessment.

PROPOSAL NUMBER:
R030800032
REFERENCE NUMBER:
GLOBAL CLIMATE CHANGE

Prepared For:
The City of Cape Town
Environmental Resource Management Department

CITY OF CAPE TOWN | ISIXEKO SASEKAPA | STAD KAAPSTAD

THIS CITY WORKS FOR YOU

Phase two:
Final Report
Risk and impact identification
Report prepared by
Lucinda Fairhurst
May 2008

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The City of Cape Town have awarded LaquaR Consultants CC the contract for their Proposal Number: R03-404/06-07

Reference: Global Climate Change

Date: January – July 2008.

An extract from the Terms of Reference of the contract, relevant to this second Phase Two, now follows.

TERMS OF REFERENCE

Global Climate Change: Coastal Climate Change and Adaptation - A Sea-Level Rise Risk Assessment for the City of Cape Town

1. Background and Introduction:

The City of Cape Town administers approximately 307 km of coastline, arguably its single greatest economic and social asset. In October 2003 the City formally adopted a Coastal Zone Management Strategy with the intention of managing and safeguarding the coastal asset for current and future generations.

The City's coast provides a range of social and economic opportunities including recreational and amenity areas, sought after housing and development opportunities as well as core economic attributes. In addition, the City's coast is a dynamic ecological system that supports a wide range of species, ecological systems and ecological services.

Global climate change predictions suggest that amongst others, sea level rise and an increase in the intensity and frequency of storm events may have significant impact on coastlines across the globe. Cape Town with its extensive coastline may be particularly vulnerable to these predicted changes.

2. Motivation and Aim of Project

The aim of the Sea-Level Rise Risk Assessment Project is to:

- Model the predicted sea-level changes in a range of scenario's (time series, incremental climate change, shear events, and storm frequency and intensity).
- Model the form that those changes will take.
- Understand the associated impacts on existing coastal systems, infrastructure and property.
- Provide guidance and implications to future coastal development (to be included in the City's Coastal Development Guidelines).
- Identify high risk areas that are prone to high impact.
- Begin to understand and develop long-term mitigation measures.

The primary objective of this study is therefore:

To model and understand the ramifications of predicted sea-level rise and increased storm events for the City of Caped Town, thereby providing information that may be used for future planning, preparedness and risk mitigation.

3. Project Phases

The project will be undertaken in four distinct phases. Each phase of the project will provide specific outcomes and deliverables. Phase one has been completed and the report was submitted in March 2008. This report relates to phase two:

Phase Two: Risk and impact identification

- Review the nature of sea level rise impacts (coastal erosion, direct and indirect inundation of infrastructure, disruption of services, loss of habitat, etc) that might affect the coast of the City of Cape Town.

- Set up a series of consultative workshops with City officials, so as to gather a detailed assessment of the infrastructure and services provided by the City in the locations identified in the GIS model as being at maximum risk. These facilitated workshops will involve Departments responsible for all manner of City infrastructure and services, natural systems, commercial and residential property and policies for ensuring compliance. The Report from these Workshops with City officials will further provide details of the linkages between the impacts identified, and consolidated priorities.

INTRODUCTION TO PHASE TWO AND BACKGROUND TO THE MODEL

Introduction

As part of an ongoing climate change project commissioned by the City of Cape Town, LaquaR consultants CC facilitated six interactive workshops. This report combines the findings of the workshops held in various suburbs of Cape Town, South Africa during March and April 2008. The aim is to initiate identification and understanding of the risks and implications of sea level rise (including inundation and erosion as a result of storm surge) with a view to long term management and planning.

For preliminary identification purposes, the first two scenarios were used, namely: The present day very worst case scenario and the scenario at the end of the next decade to identify the most vulnerable coastal areas to inundation and erosion as a result of storm surge as the third scenario, the polar ice sheet melt scenario has no timeframe associated with it and includes permanent inundation.

Background to the model.

In summarising the report prepared by Prof Geoff Brundritt (submitted upon completion of phase one of this project in March 2008), the computer based GIS model demonstrates the coastal changes resulting from sea-level rise. Variables within the model are able to be changed to accommodate variations in predictions as well as illustrating the impacts of catastrophic and combined events. The model incorporates the City's aerial photography, survey data, contour maps and overlays of the infrastructure and services.

The nature of extreme sea level events along the coastline of the City of Cape Town were reviewed, through a re-interpretation of sea level records from the SA Navy Tidal Network stations at Simon’s Town and Cape Town. This information was used as the basis for the first Scenario: Present Day Very Worst Case Scenario.

Global projections of the influence of climate change on sea level, as given in studies such as the recent Assessment Reports of the Inter-Governmental Panel on Climate Change (IPCC) were reviewed. This provided estimates of the influence of climate change on local constituents of sea level in the vertical, as a series of projections on decadal and centennial scales, together with their range of uncertainties. This information was used as the basis for the second and third scenarios namely, Scenario at the End of the Next Decade and the Polar Ice Sheet Melt Scenario respectively.

There are three main contributing factors to the present day sea level:

Tides

The tides are completely predictable and affect the entire coastline in a uniform way.

The Weather Effect

Passing synoptic weather systems means that observed sea level can be higher than the predicted tide when the air pressure is low and when the wind piles the water up against the coast. However, their predictability is limited to little more than one week.

Wave set-up

Only affects surf zones so are not described in detail here.

Present Day Very Worst Case Scenario.

The purpose of this scenario is to summarise what is known about present day sea levels. It results from the simultaneous occurrence of an extreme tide and an extreme storm, an event with a nominal return period of 500 years. Such an event has not occurred along the Cape coast in recent years but it did occur along the KZN coast on 19/20 March 2007.

Using levels reported in historic analysis, three inundation levels were incorporated into the model and can clearly be seen in Figs. 1 and 2 below (the inundation levels are depicted in different colours for analytical purposes namely; blue, red and orange for LLD (Land Levelling Datum) +2m, LLD+4.5m and LLD+6.5m respectively).

<u>Note 1: The inundation levels discussed and depicted in this report and not considered permanent, but rather as levels of impact (with regard to scenarios 1 and 2).</u>

<u>Note 2: A key for all infrastructure illustrated in the figures are attached in the appendix:</u>

- LLD+2m in sheltered environments,
- LLD+4.5m above mean sea level in exposed environments, and
- LLD+6.5m above the mean sea level in very exposed environments.

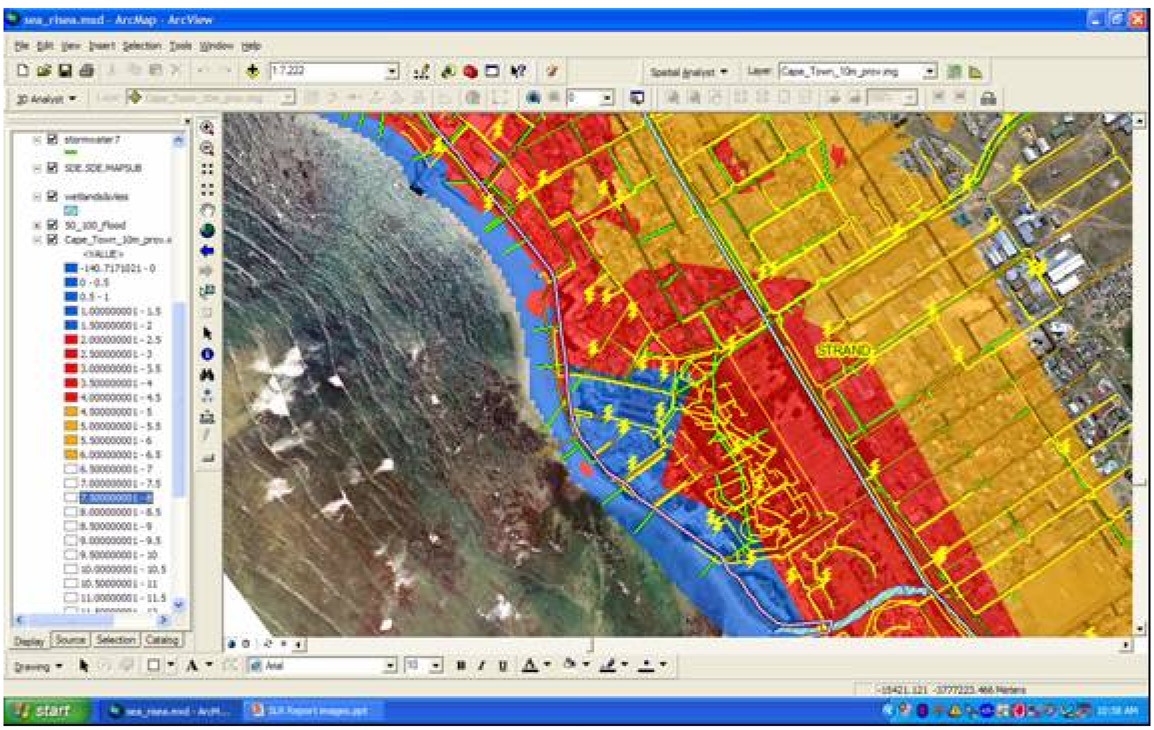

Fig. 1: A snap shot image (1:7,222) of the Strand area (a low-lying area without much protection), depicting the three inundation levels used in the GIS inundation model (scenarios 1 and 2) used to identify areas under threat to sea level rise.

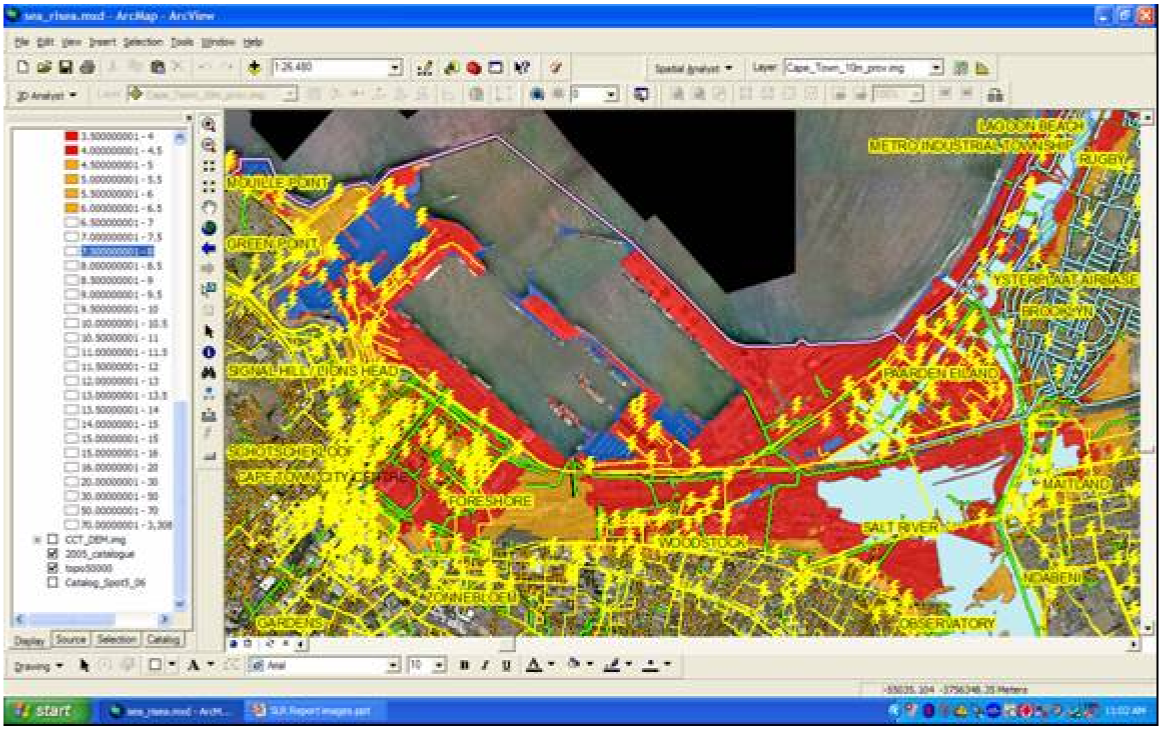

Fig. 2 A snap shot image (1:26,480) of Cape Town City centre, the docks and some of the surrounding suburbs depicting the three inundation levels used in the GIS inundation model (Scenarios 1 and 2) used to identify areas under threat to sea level rise.

It is worth noting however, that these levels can be considered conservative as higher levels have been measured in past storms. For example, from the September 2001 storm where a 17-metre wave was measured off Slangkop near Scarborough (Cape peninsula), and those measurements taken at the limit of the swash zones (that part of a beach over which the instantaneous shoreline moves back and forth as waves meet the shore) in places where greatest damage was caused along the KZN coast in March 2007.

Fig. 3: Sept 2001 – Three Anchor Bay	Fig. 4: March 2007 – Kwa Zulu Natal
	

The Scenario at the End of The Next Decade.

This scenario was created to estimate likely trends in the near future due to the increase in frequency and intensity of storms and sea level rise. Observations of sea level globally show a statistically significant sea level rise as part of human-induced climate change. At present, the rate of sea level rise is slow, but it does appear to be accelerating. This second scenario is intended to describe the situation along the coastline of the City of Cape Town, and to extrapolate from this situation so as to provide an estimate of the likely trends in the near future.

Unfortunately there are no consistent observations of sea level that have been made over a long enough time period (over several decades) available in South Africa nor Africa as a whole for analysis of sea level rise. However, at the end of the next decade, the sea level to be expected is not a great change from present day circumstances. Thus there is little threat of additional inundation. What is different however is how often any particular sea level can be expected. For example, the present day extreme sea level of LLD+163cm with an expected return period of 500 years should be compared with the sea level of LLD+165cm expected to occur with a return period of only thirty years at the end of the next decade. While the observed maximum sea level of LLD+150cm from 1960-1990 is expected to occur with a return period of just four years at the end of the next decade.

In summary, the situation could become more serious and the impacts and vulnerabilities of the first scenario can be used to illustrate what might be expected as the norm at the end of the next decade, when extreme spring and autumn storms coincide with spring tides.

Scenario Three: The Polar Ice Sheet Melt Scenario

This scenario incorporates the melting of the Greenland and West Antarctica Ice sheets and their contributions to Sea Level Rise whilst depicting areas that will become permanently inundated as a result. Complete elimination of the Greenland Ice Sheet is thought to eventually lead to a contribution of 7 meters and thus permanent inundation (Fig. 5). Whilst reports suggest polar Ice sheet melting to result in a rise in sea level of LLD+12m (Stern Review, 2007) (Fig.6) and as it continues, it will lead to the permanent inundation resulting in permanent loss of industrial areas, residential areas and disruption of the transport networks. The IPCC has withdrawn any upper bound estimate to its forecasts of sea level rise over the 21st century. So it is worth noting, that there is much uncertainty about the timing of these events occurring and it must be borne in mind that this scenario is fundamentally different from the previous two scenarios. In this scenario, the focus is on the mean sea level as global mean sea level is expected to rise as a result of land-ice and/or ice sheets melting resulting in water displacement. Tidal and weather system movements are not included in the illustrations presented here but can be added at a later date.

<u>Note: In concurrence with present global opinions, this scenario is not a prediction as there it is not currently possible to indicate the time frames or rate of the ice sheets melting!</u>

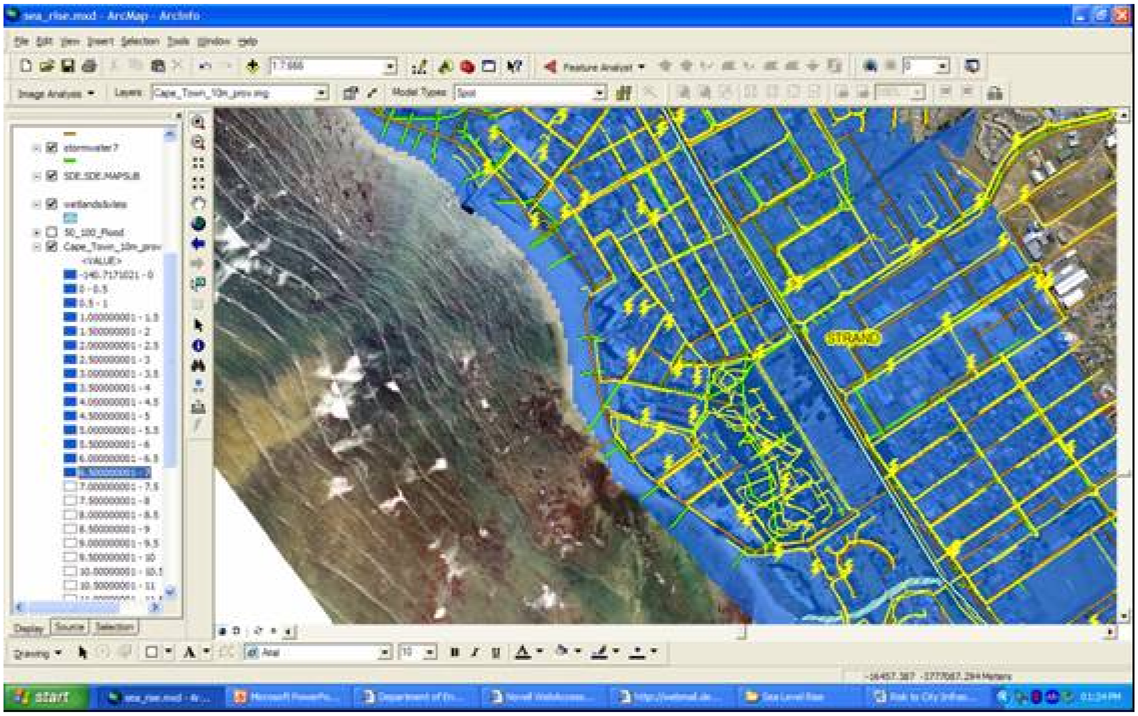

Fig. 5 A snap shot image (1:7,666) of the Strand (a low-lying area without much protection), the permanent inundation level predicted as a result of the Greenland ice sheet melting (a 7m rise in mean sea level).

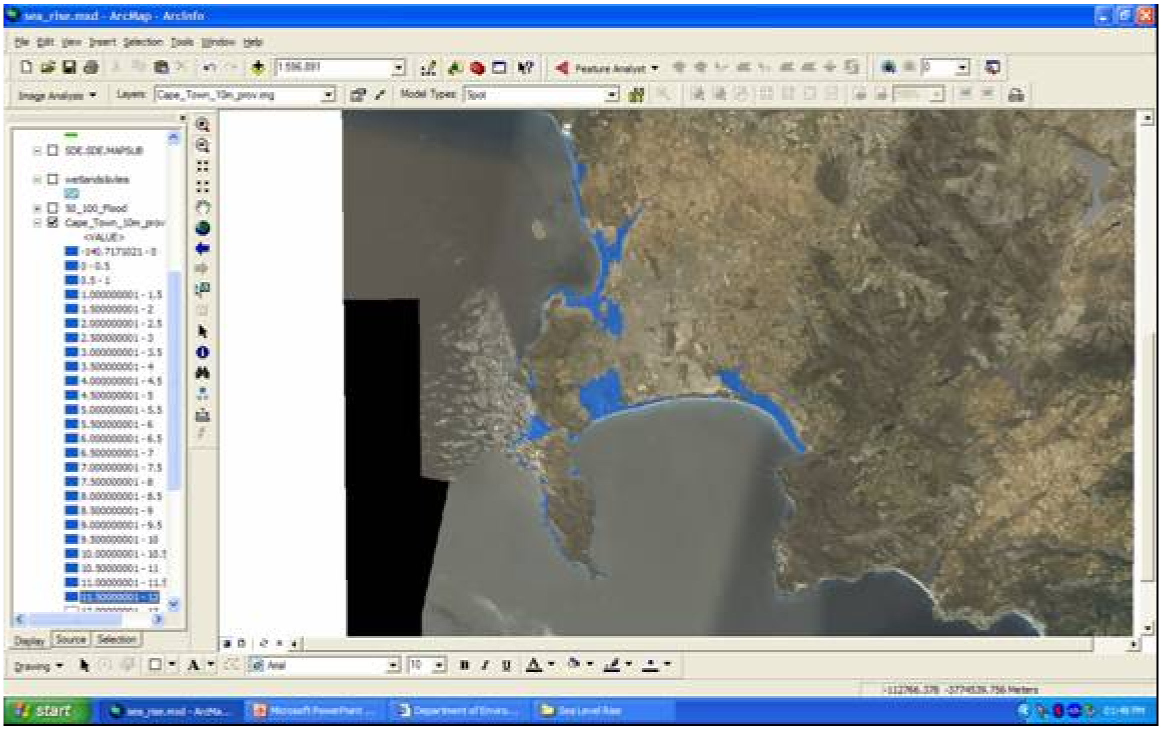

Fig. 6: A snap shot image (1:596,891) of the entire Cape Town coastline and the permanent inundation to be expected as a result of a 12m rise in mean sea level (illustrated in blue).

Summary and use of GIS inundation model as tool during phase two.

The model ties the baselines together: wave action over and above sea level rise. Scenarios 1 and 2 include storm events. If storms intensity and frequency increases in conjunction with sea level rise, the situation will be worsened. An increased frequency in storms would suggest that beaches and dunes will not have time to recover (beaches and sand dunes are considered as natural barriers from wave action, they are dynamic systems that are dependant upon a supply of sand and winds, the building and replenishment of them requires time for the sand particles to return and settle at the areas from which they have been removed through errosion). The model does not take this weakening into account.

The theory behind the scenarios one and two (2, 4.5 and 6.5m inundation heights) is taken from the erosion line on storm surge studies.

The mechanisms behind the ice sheets melting are not fully understood so it is not known when this will happen. There is currently not enough information, but precautionary measures should be taken as levels of permanent inundation are to be expected.

INTERACTIVE RISK ASSESEMENT WORKSHOPS

Objectives of the Workshops:

- Introduce and illustrate the current capabilities of the GIS inundation model.
- Raise awareness of sea level rise resulting from global climate change.
- Develop an understanding of potential sea level rise impacts on the present infrastructure and amenities offered by the City of Cape Town.
- Identify and agree on areas of particular threat to damage and to extract information about infrastructure present in certain areas that may not have been accounted for in the current model.
- Begin the process of gathering up-to-date information and potential developments occurring in areas under threat.
- Identify improvements that can be made to the model.

The agendas for each of the workshops held were the same so only the agenda from the first workshop is attached, together with lists of all participants.

Workshop Format

The focus of each of the workshops was to bring together various city officials representing a range of City line functions, technical departments and coastal areas in order to start identifying and understanding what the risks and implications that sea level rise may have on key infrastructure, amenities and future developments.

Each workshop began with a short verbal introduction to the 'Climate Change Project' orchestrated, originated and funded by the City of Cape Town. This was followed by a short presentation to introduce the GIS inundation model, whilst visually demonstrating its current capabilities and expected effects on the City's coastline using the three scenario's created and outlined during the first phase of this project (report submitted March 2008) namely;

- Present Day Very Worst Case Scenario
- Scenario at the End of the Next Decade
- Polar Ice Sheet Melt Scenario

with the aim of identifying current City infrastructure (such as roads, stormwater systems, Wastewater works, harbours and amenities) that will be at risk under the various climate scenarios.

In order to contend with the long coastline and the various infrastructure and services that fall under the jurisdiction of the City of Cape Town, six workshops were held. Four workshops where area based (*) and two were held to look at the city wide problems around infrastructure and disaster and risk management:

- Risk to City Infrastructure (Transport, Electricity, Stormwater and Sewerage),
- Disaster Risk management.
- Silwerstroom Strand to Milnerton *,
- Cape Town Port to Llandudno *,
- Hout Bay to Strandfontein *,
- Monwabisi to Gordons Bay *,

Significant risks identified during the workshops

Natural protection

- Sand dune barriers - There is some natural protection around Cape Towns coastline offered by sand dunes however, it has been pointed out that some of these dune systems are not working as they should and reconstruction of the dunes takes time which are thought to cause problems as the frequency and intensity of storms increases in the future. Due to the way that the city has been developed, many of the dune systems have been cut off from replenishment which has resulted in them not working as well as they should and thus reducing the protection that they once offered to the City's coastal infrastructure. There is also pressure from the community in some places such as the Dolphin Beach front (Big Bay) to remove them for aesthetic reasons.

- Offshore reefs, rocky ledges and Islands – These offer protection to the coast by dissipating and thus reducing the energy within waves approaching the shore.

Impacts on infrastructure

The entire coastline that falls under the jurisdiction of the City of Cape Town was examined at a ratio of 1:4000 using the GIS reconstruction model in order to initiate the identification of threatened areas. The second part of each of the workshops was a visual presentation of snapshot images taken of these areas considered to be under threat. Significant risks identified using the GIS inundation model and the workshop participants have been combined and are discussed below.

Cape Town's coastline is extremely diverse and sea level rise will have different effects along the different sections of the coastline. This is dependant upon environmental conditions such as sediment type, coastal platform and the bathymetric of the ocean floor adjacent to the coast. For example, the high cliffs of the Cape Peninsula are far less vulnerable than many of Cape Town's sandy shored Atlantic coast suburbs. Soft erodible coastlines backed by flat and low lying coastal plains are obviously the most vulnerable to relative sea level rise. These types of environments are generally estuaries and tidal inlets. Areas that have been highlighted with the use of the inundation model and workshop participants are tabulated below with a general overview of the relevant infrastructure and a brief description of the environment (Tables I, II, III and IV).

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Table I: Areas and infrastructure identified as being under threat between Silwerstroom Strand and Milnerton.

Coastal Zone	**Areas with threatened infrastructure**	**Infrastructure effected**	**General comments**
Silwerstroom Strand to Milnerton	Van Riebeeckstrand, Melkbosstrand, Bloubergstrand, Milnerton, Table View, Woodbridge Island, The Metro Industrial Township, Paarden Island, Brooklyn, Rugby, Salt River, Maitland, City Docks, Big Bay.	Electrical cables and substations, stormwater pipes, sewerage pipes, Main water pipes, Roads and Property, Potsdam Waste water works, Caltex Oil Refinery.	The land in this coastal zone has a very shallow gradient and many low lying areas. Thus, vulnerability to inundation reaches quite far inland. There is some protection offered by sand dunes. The soft sandy sections within this section of the coastline have historically shown a high degree of mobility and are currently being eroded. These dunes will be under even greater threat of errosion taking place (once inundation from the sea does occur) from both the seaward side and the landward side and so will not withstand frequent storm events. Therefore, areas currently considered as semi exposed will soon become very exposed. There are various infrastructures present under the Sout and Diep River flood lines. The Milnerton Lagoon and the Rietvlei wetland systems are open to the sea. Overall effect of the Peninsula and Robben Island reduces deep water wave heights of most swells (predominant south-westerly swell). The coastal areas would be very exposed in the event of westerly and north-westerly storms. Raised groundwater tables may lead to water logging problems. Heavy rainfall or river flooding would exacerbate problems. An extensive study on the impact on Woodbridge Island and the immediate surrounding areas has been conduced and reported for Woodbridge Island by Hughes (1992).

Table II: Areas and infrastructure identified as being under threat between Cape Town Port and Llandudno.

Coastal Zone	**Areas with threatened infrastructure**	**Infrastructure effected**	**General comments**
Cape Town Port to Llandudno	Woodstock, Foreshore	Electrical cables and substations, stormwater pipes, sewerage pipes, Main water pipes, Roads and Property, Electricity line and substations.	The land in this coastal zone varies significantly in a topographical sense. The oceanic bathymetric and depth enables large swells to be held in the surrounding water and so are capable of big wave action. There is not much by means of protection from the sea. Soft sandy sections of the coastline are already noticeably eroding (an example of where this has been noticed is Llandudno). The main areas that are considered to be under threat are the low lying areas inland of the city harbour. Sea Point is considered to be particularly vulnerable as it is reclaimed land that has not been stabilised. Camps Bay and Clifton are areas of particular importance to the tourism industry so there is concern over the errosion of the beaches. New developments and high-raised properties in many of the coastal areas have car parking areas that are below sea level.
	Mouille Point/ Three Anchor Bay	Sewerage pipes, Stormwater pipes	
	Sea Point	Sea wall - reclaimed land.	
	Bantry Bay, Camps Bay, Clifton, Bakoven, Llandudno.	Stormwater pipes, sewerage pipes, Main water pipes, Roads and Property.	

Table III: Areas and infrastructure identified as being under threat between Hout Bay and Standfontein.

Coastal Zone	Areas with threatened infrastructure	Infrastructure effected	General comments
Hout Bay to Standfontein	Hout Bay, Kommetjie	Electrical cables and substations, stormwater pipes, sewerage pipes, Main water pipes, Roads and Property, Electricity line and substations, Harbour	This coastal area is relatively unprotected although Hout bay itself may be a little more protected than the other areas that fall into this section. There is little information about the effects of storm damage in these areas. Development along these shores is higher up than the inundation levels incorporated into the current model. The areas that would appear to be most vulnerable and potentially have the most infrastructures under threat are Hout Bay and Kommetjie. However, Hout Bay is fairly shallow and so is not capable of holding a big swell but, further investigation into the effects of big storms on the Harbour and coastal developments is necessary. There are a number of developments that are currently present which are below the flood line of the Hout Bay River. Kommetjie is low lying land with a shallow gradient and is an area that has been proposed for densification.
	Soetwater	Main road, Campsite	
	Sandkop, Witsand	Main road, Old landfill site	
	Misty Cliffs	Private property	
	Scarborough	Electrical cables and substations, stormwater pipes, sewerage pipes, Main water pipes, Roads and Property, Electricity lines	

Table III: Continued….

Coastal Zone	**Areas with threatened infrastructure**	**Infrastructure effected**	**General comments**
Hout Bay to Standfontein	Koelbaai	Main road	The effects of sea level rise on the False Bay coastline have been studied in detail (Hughes, 1992). The Western seaboard is mostly hard substrate and rocky with a few sandy bays and pocket beached such as Glencairn and Fish Hoek. Most of the development on the rocky shores is higher up than the inundation levels incorporated in the model. In the past, the coastal railway line has undergone direct wave attack in places. The areas that are indicated to be most under threat of sea level rise by the GIS inundation model are the low-lying towns on the northern shore. There is little protection in these areas and the main road that runs along the coast get over-washed during extremely high tides. The western seaboard is relatively sheltered from the southerly swells and prevailing south-easterly summer winds. The wastewater treatment works are also indicated as being under threat (see below for more information).
	Millers Point	Sewerage pipes	
	Rocklands/Murdock Valley	Sewerage pipes, Private property.	
	Simons Town, Fish Hoek, Clovelly, Kalk Bay, Saint James, Glencairn, Muizenberg, Zeekoevlei, Cape Flats	Electrical cables and substations, stormwater pipes, sewerage pipes, Main water pipes, Roads and Property, Electricity line and substations, Kalk Bay Harbour, Cape Flats Wastewater Treatment works.	
	Strandfontein	Stormwater pipes and outlets	

Table IV: Areas and infrastructure identified as being under threat between Monwabisi and Gordons Bay.

<table>
<tr><th>Coastal Zone</th><th>Areas with threatened infrastructure</th><th>Infrastructure effected</th><th>General comments</th></tr>
<tr><td rowspan="4">Monwabisi to Gordons Bay</td><td>Monwabisi</td><td>Stormwater and sewerage pipe outlets, sewerage pump station. Amenities at resorts</td><td rowspan="4">The development along the northern shore in this coastal section is on very low lying land and so is indicated as being under major threat by the GIS inundation model (scenarios 1 and 2). The east seaboard has limited developments on rocky shores. The presence of wide rocky ledges offshore in the Strand-Gordons Bay area is thought to reduce wave impacts due to waves breaking far offshore. Gordons bay is currently protected by a seawall which may offer some protection to storm surge impacts, this is dependant upon maintenance. The Strand and Gordons Bay areas are very low-lying and the effects of inundation are indicated as spreading very far inland. Much development in this area under the floodline of the rivers in these areas.</td></tr>
<tr><td>Maccassar</td><td>Waste water treatment works, stormwater and sewerage pipes, some private property</td></tr>
<tr><td>Strand</td><td rowspan="2">Electrical cables and substations, stormwater pipes, sewerage pipes, Main water pipes, Roads and Property, Electricity line and substations, sewerage pump stations, Harbours. Amenities at resorts.</td></tr>
<tr><td>Gordons Bay</td></tr>
</table>

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Planning and development

Present concerns

- There is much pressure for development along the coast.
- There is re-development occurring (perhaps in a 5 year cycle) all the time. However, places that were thought to be safe historically may not be in the future and should be identified.
- It would be impossible to change the entire potentially affected infrastructure that is already present as it would not be financially viable.
- Cape Town City currently has no long term development plan.
- The current building regulations (NEMA) only require an Environmental Impact Assessment for building within 100m from the high water mark however; the model has proven this to be ineffective in some areas.
- In the future, the ability of the structures that are currently there to protect may be reduced (both natural and manmade i.e. sand dunes and seawalls) and so the areas that are currently considered protected or sheltered may become more exposed.
- Risk of flooding to private and commercial properties.

Future plans

- Densification or high density nodal development rather than strip development is currently being proposed for certain areas that are already developed in order to protect/conserve natural areas and recreational spots. This may pose problems in the areas that have been highlighted by the GIS inundation model (scenarios 1 and 2) as the effects on an area of high density would be severe. It is worth noting however, that smaller areas may be able to be self sustaining and so if one area is affected, the knock-on effect on neighbouring areas may be reduced.

There are a number of areas that are considered 'at risk', where future development is proposed. Some of these areas and the proposed development issues raised during the workshops are presented below in Table V. Please note that these areas are not presented in any particular order.

Table V: Areas with planned development considered 'at risk' to sea level rise impacts.

Areas identified for future development	Description and Information provided
Hout Bay Harbour	Water front houses are being proposed and leases are already being procured for suture development.
Hout Bay River mouth	There is a proposal for the development of a hotel near the river mouth. The area where the development is proposed is very low lying land and will be under the river floodline and under threat from expected sea level rise.
Western side of the Lourens River (AECI site).	Development is planned in this area which is very close to the river and sea. The land is low-lying land and has been highlighted as under threat by the GIS inundation model (scenarios 1 and 2).
Muizenberg.	There are applications to build on the seaward side of the railway line.
Pipelines from the harbour to the Caltex oil refinery	Caltex has proposed creating a third pipeline to the refinery. Although we were informed that this pipeline can filled with seawater in the case of a storm event.

Recommendations

- The City of Cape Town has a rapidly expanding population and demand for housing, much of which is centred around the coast. This pressure and demand, coupled with lack of foresight, may result in the degradation of future coastal developments. The City's coastline must be regarded as an enormous asset in terms of its aesthetic, recreational, economic and protective value. Planning decisions on this level must therefore be of the utmost importance to any future developments. In order for the natural protection that is currently offered by beaches and dune barriers to continue, there is a great need to protect what is currently remaining by restricting coastal development that is directly on the coast and perhaps restrict development to well behind areas of potential risk.

- There is a need to manage existing infrastructure and start informing future planning, especially development along the coast, by looking at long-term models.

- Soft erodible coastal areas are expected to retreat with the rising sea levels and increase in frequency and intensity of storms. Although the retreat of the coastline is not expected to happen at a constant rate, it must be allowed ‘room’ to retreat. This could be achieved with the use of natural undeveloped buffer zones in front of developments. Where there is no room and the profile has been fixed by a structure, the characteristics of the shore will change and the presence of the structures protection may result in its own increased vulnerability. Avoid further development in low lying areas specifically those areas that are below the 50 year floodline.

Impacts on Services

There are a number of concerns about the services provided by the City of Cape Town. Much of the infrastructure relating to the services was installed to cope with the development pressures and population of the time. However, in a relatively short period of time, much development and expansion of Cape Town has occurred and it has not been possible to adapt the infrastructure and services provided by the city in order to accommodate these pressures. Therefore, there is an immense amount of pressure on the existing infrastructure. An example can be seen in the stormwater systems where the pipes have limited capacity. Pressure has increased as a result of the development in two ways: the amount of surface runoff has increased with the developments (as less ground surface are a is able to absorb the water) and the need for storm water systems (newly developed areas have simply had their storm water systems attached to the old existing ones).

Transport

Present Concerns

- Storms have impacted upon transport systems in the past in low lying area such as the main road in Fish Hoek which has experienced flooding. There has also been disruption of the public rail transport in this area.

- The coastal railway system is expected to become increasingly effected by increasing sea levels.

- Traffic congestion has been problematic in the past in areas where the transport systems such as roads have been affected by flooding etc.

- Failure of coastal defences that are currently not maintained will lead to the disruption of services such as public transport. If there are consistent failures of the public transport system, more of the population may be encouraged to increase use in private transport which with further add to the congestion on the roads.

- Some roads can be raised incrementally, but bridges cannot, as it is too expensive. If a bridge is to be raised, the duration of its life span with regard to the next 100 years must be taken into consideration.

- Many of the road systems that fall under the jurisdiction of the City of Cape Town are old. Bridges and roads have 'life spans'. Roads are currently thought to have between 50 - 100 years. Flooding events increase errosion and can reduce the expected life span of these types of infrastructure.

- The Cape Town Harbour has been highlighted as an area of concern by the GIS inundation model (scenarios 1 and 2). The expected increase in frequency and intensity of storms may therefore impact upon sea transport. The increase in frequency and intensity of storms may also impact on berthing, loading and storage facilities for oil and gas.

Future Plans

- A rapid bus system is proposed to run from Table View to Cape Town City Centre using the old Paarden Eiland railway line.

- Just below Phillipi, there are plans for a new road. The profile of this area would suggest that there is protection but the land is reclaimed and so should be considered extremely vulnerable.

- There are plans for a dedicated public transport road, maybe even a railway line, next to Table Bay Boulevard.

- Reconstruction of Table Bay Boulevard is planned, which will raise the road level by 300mm, but with the model predictions of a few meters, this may prove to be futile.

- Rail services are planned up the West coast running along the coast line. They will be affected by sea level rise.

Recommendations

- Improve land drainage and stormwater systems and perhaps put pumps systems in place where roads and rail are essential for the continuity in Cape Town.

- Survey the coast to identify locations that could be more vulnerable to damage due to age and condition of roads and rail (i.e. produce a risk matrix for these infrastructure).

- Consider moving major roads and railway lines closer inland to avoid risk of coastal errosion.

- Prepare plans and equipment to handle storm events more effectively (i.e. sand bags that are already in use in the Fish Hoek area).

- No building in flood plains.

- Introduce coastal defences that can serve to protect important infrastructure.

Stormwater systems

Present Concerns

- There are a number of stormwater drains that are currently being flooded during storm and flooding events, resulting from sand/silt blockage, some of the areas that were raised during the workshops are stated below:

  - Strand
  - Fish Hoek
  - Noordhoek
  - Sea Point

- Sewerage infrastructure is normally associated with that of stormwater. It was stated during the workshops that the infrastructure further inland suffers the most physical damage as a result of heavy rains and flooding events.

- Silt deposits in the stormwater infrastructure often exacerbate blockage. During flooding events, some of the pipes burst under the increased pressure (from the increased water levels as a result of the storm and the pipes getting clogged up with silt) and often the water is forced up to the surface contributing to further flood damage.

- Pipes are quite small; they have been joined to sewerage pipes to keep the flow going. This is the case for a number of areas in the Cape as they were designed for them to work together.

- Local industry also puts rubbish down the drains.

- The amount of pressure is increasing on the systems as a direct result of development as well as runoff from infrastructure built.

- Camps Bay has a storm water pipe above the sand on the beach and infrastructure on a beach is undesirable.

- The impact on large infrastructure such as main culverts and river systems in terms of monetary value was raised. There is a myriad of small infrastructure, but it is the large ones which are important.

- Already have problems with the stormwater systems in Strand during storms.

Future plans

In general, stormwater systems are now being kept away from beach areas, as it causes problems.

Recommendations

- Increase drain and pipe size where possible.
- Increase maintenance of drainage ditches and pipes.
- Extension and separation of stormwater drainage into separate systems to cope with increased flows.
- Ensure that future development plans incorporate the capacity of the stormwater drainage systems for future planning and development to ensure that living and working locations do not exceed the systems capacity limits.

General comments

- The impacts of floods inland are thought to be of a greater concern than damaged infrastructure in the coastal areas and should be investigated.
- The amount of runoff increases with the increased amount of infrastructure built.
- Ground water levels will increase with sea level rise. In low lying areas, when a rain event occurs, stormwater will back up as there are shallow gradients in the Cape flats.

Contacts for information

Barry Wood - 021 400 1204, barry.wood@capetown.gov.za - for information that is regularly updated.

Paul Rhode – head of planning for bulk water – 021 487 2487, Paul.Rhode@capetown.gov.za - ask about report by CSIR (hydraulic model for water flow).

Malville Swanson – 021 360 1193, Mel.swanson@capetown.gov.za

Freshwater

Present Concerns

- There is an increase in demand for potable water with the increase in the Cape Town human population this has raised concerns about the availability of the resource.

- With a rise in sea level, it is expected that saline intrusion will increase in coastal areas thus affecting freshwater resources.

- Concerns were expressed about a decrease in the quality of freshwater due to sewerage intrusions in the event of stormwater drainage failure and flooding.

- Sea level rise will compromise aquifers, such as the Cape Flats aquifer, which is earmarked be used as a future source of water. It is planned to recharge this aquifer with treated wastewater.

- The aquifer under Khayelitsha is relatively safe from sea level rise, but the water table will rise, increasing damp areas, which is a concern for housing in Khayelitsha. The aquifer sits on a saline wedge from the sea. Sea level rise will push it back, and push the water table up. The dynamic nature of the water table is illustrated through its response to the tides.

Recommendations

- Freshwater resource management for example quantifying freshwater resources and monitoring and maintaining freshwater quality.

- A sea water barrier is needed to prevent the Cape Flats aquifer from being compromised. If flooding occurs, the result could be that sewerage could be pumped into the aquifer.

Contacts for information

Christiaan van Lill – 021 970 3023 – tiaan.van_lill@capetown.gov.za - at Bellville could perhaps have information on water and sanitation

Jeanette Kane – 021 400 5083 – jeanette.kane@capetown.gov.za - about water catchment as there is new flood management in the Silvermine River.

Martin Thompson – 021 710 8128 – martin.thompson@capetown.gov.za - about water catchment in Muizenberg

Sewerage/ Waste water

Present Concerns

- Many wastewater plants are close to rivers in order to discharge thus leaving them vulnerable in the event of flooding in the localised area.

- To date, flooding events in the long terms (i.e. the increase in frequency) have not been considered with regards to its impact on infrastructure.

- The newer ponds are lined but the older ones are not, this can be checked by overlaying the 1999 photography with those captured in 2005.

- Current technologies used are outdated.

- There are many sewerage lines and pump stations located along the coastal edge in low-lying areas. Some of theses are already out of service a result of being impacted upon by the sea.

- Sewerage lines cannot be redesigned without considerable cost.

- Already have problems with sewerage during storms in the strand area.

- There is an agreement on the necessity of these infrastructures (pipes and pump stations) being setback from the coast, but it is contrary to development demands i.e. as most of these systems work with the use of gravity.

- Sewerage seepage with incorrect management could lead to problems such as: odour and pest control and contamination of fresh potable water.

- Landfill sites that become inundated could also lead to those problems highlighted above whilst also increasing the risk of pollution (i.e. if a landfill site is not capped and is then flooded, the waste within the landfill may disperse).

Cape flats Wastewater treatment works

- The ponds are quite high when taking into account the height of the walls but may get sea water rising from below.

- Water from ponds has leeched into Zeekoevlei.

- Catchment pipe at Cape flats Wastewater works already leaks into Zeekoevlei.

Potsdam Wastewater Treatment works

- Currently undergoing an Environmental impact Assessment with a view to expansion however, the ponds have been highlighted as an area for concern by the model.

Pump stations

- Many pump stations are close to the coast.

- Small pump station costs in the region of R350, 000 to replace or build from scratch (note that this does not include the connecting pipes etc.).

- Major pump station at the Lourens River mouth.

- There is a small pump station on the Strand beach which is below the high water mark.

Future plans

- Potsdam Waste water treatment plant is being extended, because the wastewater treatment capacity has to keep pace with the development in Blouberg.

- There currently a tender that is going to go out to make a cut off pipe at the Cape flats Wastewater Treatment works to prevent leeching into Zeekoevlei.

- Sewerage works by Maccassar are currently planning to extend to zandvlei. Massive pump station to be built.

- There are plans to rebuild the pump station currently situated on the Strand beach; this has already been highlighted as being under threat.

- There currently is pressure for sewerage pipe route along Soetwater for Misty Cliffs and Scarborough which currently use septic tanks. The road that is proposed to be used is shown to be inundated by the GIS model.

Recommendations

- If wastewater plants had to be moved to safer areas the cost would be considerable, but considerations should be made for future development particularly in relation to the increased pressure on existing infrastructure.

- Gravity and water flow - need to explore different ways for disposing of services (i.e. waste etc).

- Can’t move Potsdam - retrofitting, new technologies that lessens our dependency on main services when threatened

- Septic tanks although concern was raised about the effects of the water table getting higher and their potential to poison ground water.

- A survey is needed to check which of the waste water ponds are lined.

- Wastewater treatment has to keep pace with development.

- Alternative technologies for waste disposal should be further investigated.

Information of output rates

- Melkbos and Potsdam present are outputs 39megs. There is currently a need for 47megs it is estimated that an output of 110megs will be needed in 50 years time.

- Milnerton (old works) detention pans - used to take 14 days but the modern infrastructure allows a quicker ‘turn around time’ - 1 hour.

Contacts for information

Brian Thomson – 021 710 8014 – brian.thomson@capetown.gov.za - for information on pump stations. Perhaps also help with costing

Rodney Bishop – 021 487 2454 – Rodney.bishop@capetown.gov.za - supply details of where all sewage pumps are situated.

Kevin Samson – 021 487 2606 – Kevin.samson@capetown.gov.za - head of treatment works at Strand (can be contacted regarding plans to extend Maccassar)

Tertius De Jager – 021 360 1192 or 084 246 2465 – tertius.d_jager@capetown.gov.za

Charl Möller – 021 850 4318 – charl.moller@capetown.gov.za information between Monwabisi and Kogel Bay.

Hans Degenaar – 021 850 4482 – hans.degenaar@capetown.gov.za - for the engineering report on future capacity.

Electricity

Present issues

- Koeberg nuclear plant.
    - Cooling system relies on seawater.
    - Outflow.
- Present disruption of energy supplies will be further exacerbated.
- There are numerous substations for electrical distribution in the Strand and Milnerton areas.
- Power loss from damage to overhead cables.

Future Plans

- Plans to develop Koeberg further southward to incorporate a new pebble bed reactor and northward to incorporate nuclear expansion.

Recommendations for the future

- Monitoring of certain beaches began 3 years ago to see the impact of storms on sand etc.

- Alternative energy resources such as solar water heaters.

- Use of renewable energy to reduce reliance on non-renewable. However, this would still require cables and substations so the issue of their location in relation to being under treat to sea level rise would remain.

- All overhead cables to be moved underground. Although this solution would be very costly.

- Apply the model to a synoptic chart to get 4/5 day warnings.

Contacts for information

Roadwell Mpongo for information on electrical substations email address: roadwell.mpongo@capetown.gov.za

Jonathan Traut – 021 918 7087 – jonathan.trout@capetown.gov.za

Jan Von Willigh – 021 840 2576 – jan.von_willigh@capetown.gov.za - (Monwabisi - kogel baai)

Amenities

The sea walls in place now are for amenities, not protection against sea level rise. The impacts upon the coastal amenities provided by the City of Cape Town, if not maintained and protected, could result in a loss of recreational potential.

Future Plans

- Council has a resorts policy for upgrading of resorts, but maybe those under threat should not be upgraded. Need to liaise with them.

General concerns

- Underground services cannot be changed or relocated without great expense. Therefore, a fuller understanding of the impacts of climate change upon current and future infrastructure is required.

- Who is responsible for sea walls? If a wall supports roads, roads deal with it; if it is for flooding, stormwater deals with it. It can even come under amenities. Roads and Stormwater look after the Sea Point Promenade at present.

Contacts for information

Rafik Khan - Rafik.khan@capetown.gov.za - 021 845 5565 (Information of the numbers of people using the resorts between Monwabisi and Kogel Bay).

Disaster/Risk Management

- There must be a long-term plan for disaster management and implementation.
- There is a need to ensure that the decisions taken do not expose the community to adverse risks – create an order of priorities for example, in some areas, certain roads would be high on the list and in certain situations, one or two of the lanes can be open
- Access to hospitals.
- Currently storm damage is rated fourth out of twenty, this changes seasonally!
- Current warnings are on a large scale and do not pin point precise areas that require management.
- There is a need to develop and put in place an early warning weather system that would provide warnings in greater detail than those that are currently available. The proposed system should have the ability to pinpoint the precise areas that are under threat of being impacted upon by events such as those of storms.

Responsibility issues

Points raised regarding the responsibilities of the council

- If government passes building development plans are they responsible?
- According to the coastal bill, if the structural damage is incurred as a result of natural forces, the council is not liable for resulting costs.

- If the city council allows development in areas that have already been highlighted as being under threat, the City may be held liable.

- Who is responsible for awareness?

- How do we communicate these issues to the public without creating panic?

- Who is responsible in general:

    - National government?
    - Insurance?
    - Provincial government?
    - Building companies?

Cross-cutting issues and general points of concern.

- There is a lack of synergy between various departments. An issue raised during the workshops highlighted this using solid waste as an example. It is currently cleared away and moved, however, in some areas it is thought that the waste ends up being reintroduced to the system (i.e. the water catchment area) thus further exacerbating the situation of ‘clogging up’ of ‘build-up’ within infrastructural systems such as stormwater and sewerage.

- A number of the beaches are being eroded away so the water is able to come in closer. One example can be seen on north side of Llandudno where there used to be sand. This sand has already been eroded away to exposing the rock underneath thus providing evidence that beaches are slowly eroding away.

- Loss of sandy beaches will impact on tourism.

- Alien clearing resulting in increased water flood levels during flooding events. Some of these plants are very effective at absorbing water before it got into the ground water.

- Concern was raised about the people in poor areas. There will be an impact on the City from a social perspective. Khayelitsha will be devastated in a flood.

- Tourism - If an event happens before the tourist season and restaurants, accommodation and beaches are impacted upon, how will this affect the economy? Changes of our landscape may affect tourism.

- Docks can be maintained but are currently thought to be too shallow at present.

- How will communications be effected?

- Increasing insurance costs.

- Reclaimed land.

There are a number of areas where land has been reclaimed which falls under the jurisdiction of the City of Cape Town. Some of these areas are therefore considered particularly vulnerable. Some reclaimed land will be able to endure storms of a particular intensity better than others. This is entirely dependant upon how they have been handled some examples of the methods used and points of concern can be seen below:

Stabilised land.

Paarden Eiland has been stabilised however, the land level is extremely low and thus under threat of inundation (Figs 7 and 8). The question was raised regarding future financial and resource investment. However, there is a lot of economic pressure as it is an industrial hub.

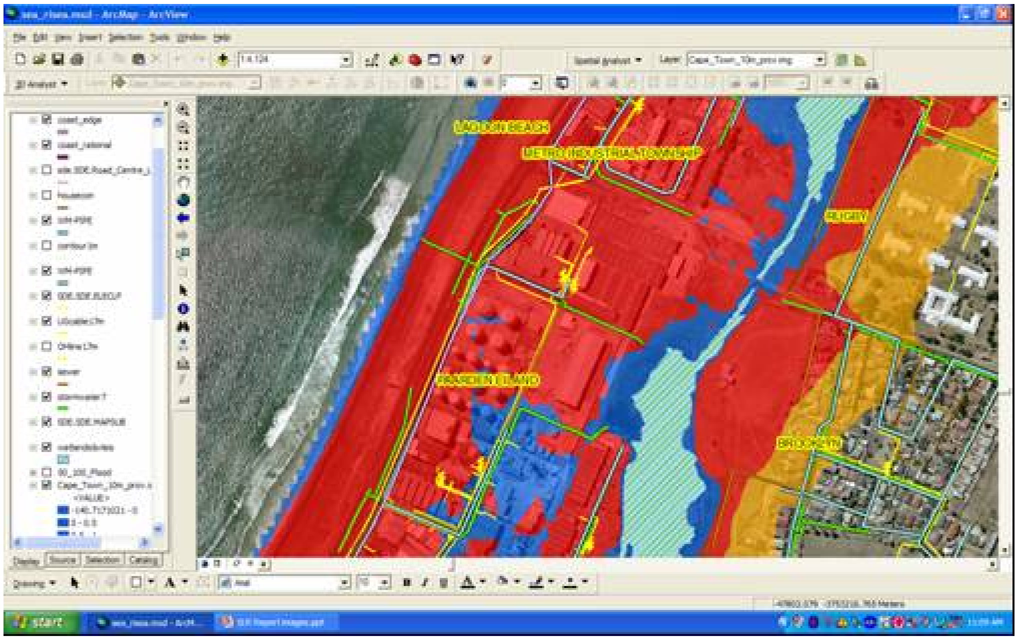

Fig. 7: A snap shot image (1:4,124) of the Paarden Eiland and metro industrial township areas (a low-lying area without much protection), depicting the three inundation levels used in the GIS inundation model (scenarios 1 and 2) to identify areas under threat to sea level rise.

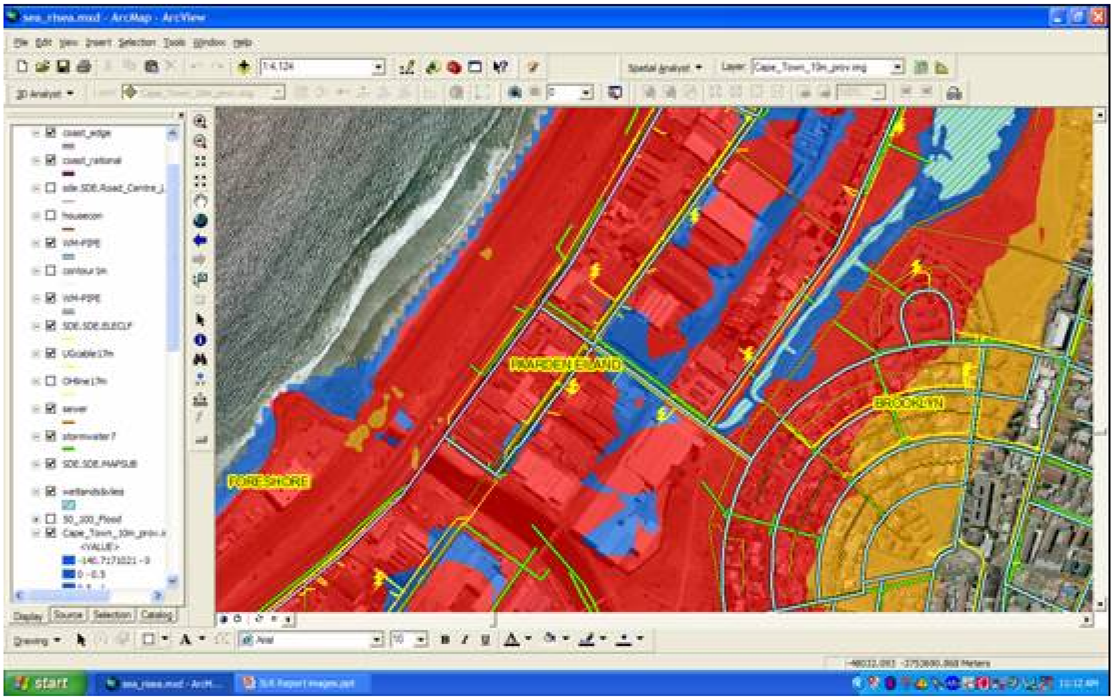

Fig. 8: A snap shot image (1:4,124) of the Paarden Eiland area (a low-lying area without much protection), depicting the three inundation levels used in the GIS inundation model (scenarios 1 and 2) to identify areas under threat to sea level rise.

<u>Land that has not been stabilised</u>

Sea point promenade (an old land fill site)

Although according to the model (Fig. 9), the area would not appear to be under much threat and thus considered at low risk, the land has not been stabilised so the only protection is the sea wall. The seawall is not maintained on a regular basis. The only maintenance that does occur is fixing breaks therefore rendering the area as being considered to be at high risk.

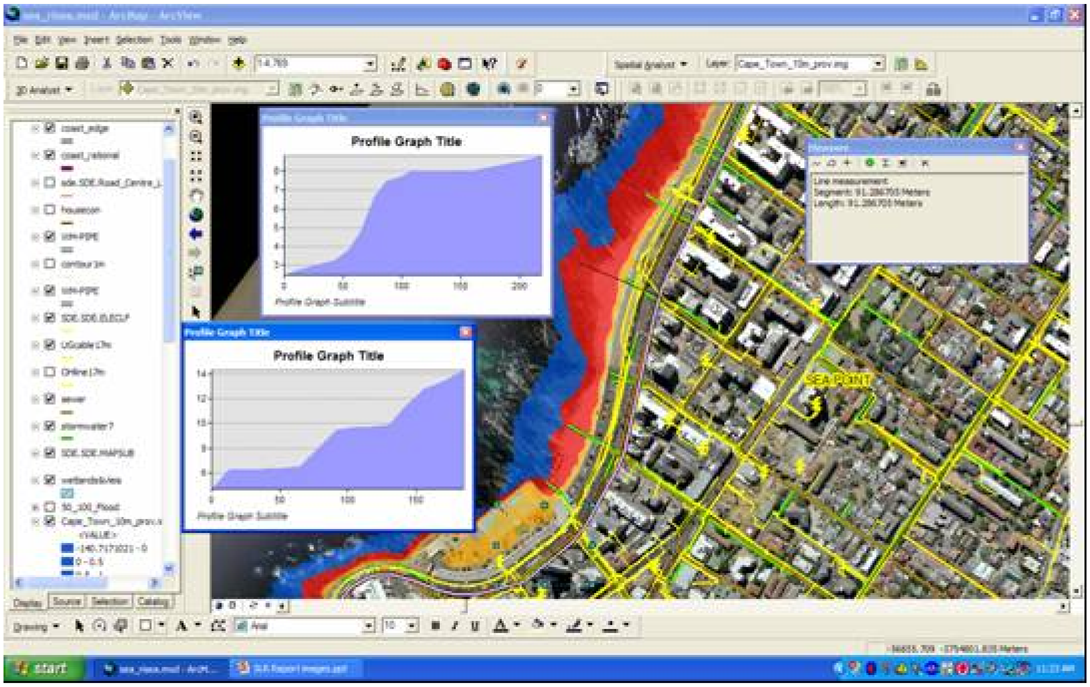

Fig. 9: A snap shot image (1:4,769) of the Sea Point depicting the three inundation levels used in the GIS inundation model (scenarios 1 and 2) to identify areas under threat to sea level rise.

Sea Point is able to hold large swells due the offshore bathymetry and topographical gradient which gives rise to another concern. If the wall breaks during an extreme storm event, the wave action and resulting errosion could lead to the developed land behind the wall being eroded very quickly with serious ramifications.

<u>Landfill sites</u>

Witsand beach was a landfill site for Ocean View and Kommetjie for around 30 years. The site was closed in the early 80's but is not lined or capped. Efforts were made to cover the site with the utilisation of fences that were placed on the top to assist in the ‘build-up’ of moving sand. The dune is currently moving in a north westerly direction and already becomes exposed in the winter when the freshwater comes from the landside resulting in an accumulation of water in the wetland area at the back. The refuse that is currently stored there is mostly plastics. When the wetlands break through, the refuse will spread out.

STORMS

Background Information

The storm that hit Durban in March 2007 started as a frontal low which intensified and rapidly became a cut-off low. It caused unprecedented damage to coastal property and major coastal errosion (Smith *et. al.*, 2007). These ‘cut-off low’ weather systems usually occur during spring and autumn. Cape Town has not been exposed to the magnitude of damage as seen in Durban, but the model looks at the implications of a big storm on a higher base (sea level).

There is concern over whether the frequency and intensity of storms will increase. Currently, there are two schools of thought. The first of which being that of the IPCC, which does not speculate as it takes hard evidence from the past and extrapolates into the future and does not show an increase in frequency and intensity. The other school of thought is that IPCC estimations are far too conservative considering climate change as a runaway system. Theron (2007) stated that damaging storms are thought to become more frequent and increase in intensity in the future.

Some infrastructure present in coastal areas is currently protected by sand dunes. However, after big storms the dunes will be weakened. Hard and very soft (sandy) beaches are generally protected, but it is the pocket beaches that experience the most damage. Storms that occur a few weeks after rain events when the land is water saturated will become problematic i.e. Disa River and Zeekoevlei, among others.

Previous Storm events and issues discussed during the workshops.

1974 (September)

- Flooding, spring high and rain. Build-up lasted for a week as the water could not get out - catchment management issue.

1978

- Boats ended up on the beach (has been referred to as a tidal wave)

1984 (May)

- Storm surge and wave set-up was estimated to be 1.2m (Jury et al. 1986).
- It was not the biggest storm recorded here.
- Waves reached extreme heights at Bikini beach.
- Earlier in the 80’s the Cape experienced big wave events, weakening the coast before this particular storm, which is why it did so much damage.
- Erosion caused on Woodbridge Island was 34m.

2001 (September)

- Did not occur during a spring tide.
- Waves came over the sea point promenade - they were jet skiing on Camps Bay main road - 17m waves at Scarborough. Below are some images of the storm (Figs 10, and 11 a and b).

Fig. 10: Photograph of waves impacting the shore line at Three Anchor Bay during the September 2001 storm of the Cape Coast.


(a)


(b)

(Argus 6 September 2001)

Fig. 11 a & b: Photographs of a ship that ran aground off Scarborough during the September 2001 the crew were airlifted off the ship by helicopter (a).

General point

Reclaimed land, in particular, has been the worst effected in the past.

Combining sea level rise and flooding events

The storm events discussed above are often associated with flooding events resulting from storms and their associated rainfall inland thus increasing the vulnerability of development and infrastructure in low-lying areas around river mouths and below floodplains. It should be noted that if the occurrence of flooding coming from inland often occurs at around the same time as a coastal storm event. In these cases, the water will not be able to drain away as quickly as might be expected and thus exacerbate the situation. An example of this is illustrated in Figs 12 and 13. By alternating between the two images, it is clear that development has been allowed to occur below the river flood line in the past.

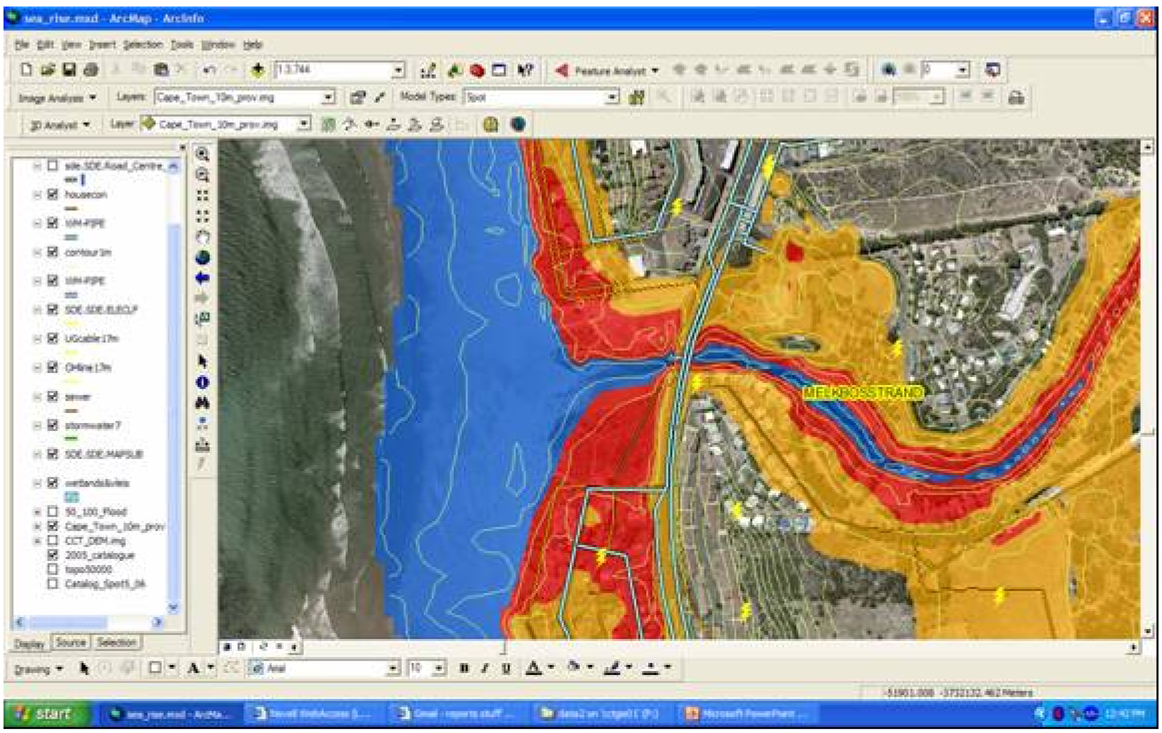

Fig. 12: A snap shot of Melkbosstrand (1:3,744) and the low-lying areas around the Sout River with the three inundation levels used in the GIS inundation model (scenarios 1 and 2) overlaid, highlighting the areas considered under threat to sea level rise.

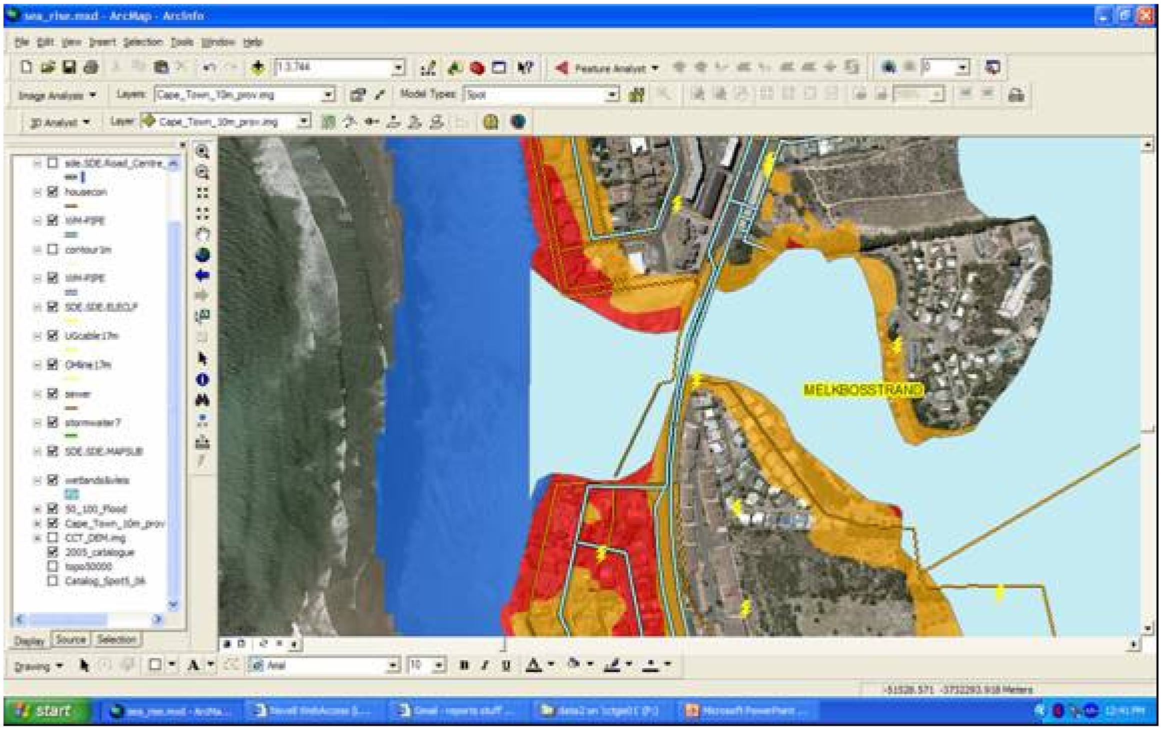

Fig. 12: A snap shot of Melkbosstrand (1:3,744) and the low-lying areas around the Sout River with the three inundation levels used in the GIS inundation model (scenarios 1 and 2) and the 100 year flood line overlaid, highlighting the areas considered under threat to sea level rise.

Effects of directional storms: Case study

The coastline that falls under the jurisdiction of the City of Cape Town is not uniform in shelf bathymetry, its substrate (with hard/rocky and soft sections that are particularly vulnerable to errosion) and positioning (some areas are bays that are protected from the direction of certain weather and swell conditions). With this in mind, it is imperative that swell direction, size and weather are taken into account whilst assessing the impact of storm damage to coastal infrastructure and development in certain areas.

To illustrate the potential of the GIS inundation model as a tool for management purposes relating to future sea level rise and storm events, the area known as Woodbridge Island on the west coast, and some areas to the north, have been selected and are discussed below. It is worth noting that a number of detailed studies such as those reported by

Hughes and Brundrit (1991) and Hughes (1992) have been carried out on the south coast, False Bay area.

Table Bay: Woodbridge Island

This area is located approximately 5 km north of Cape Town (Fig. 13). This part of the coastline is exposed to westerly and north-westerly storms as the Peninsula and Robben Island act as barriers and generally reduce deep water wave heights. There are however instances when swells from a wider distribution reach the area by diffraction and refraction around the Peninsula. The main features are the Diep River's ephemeral estuary (generally closed in the summer by a low berm) and the fact that the area is backed by a tidal inlet (Milnerton Lagoon) and wetland system (Rietvlei).

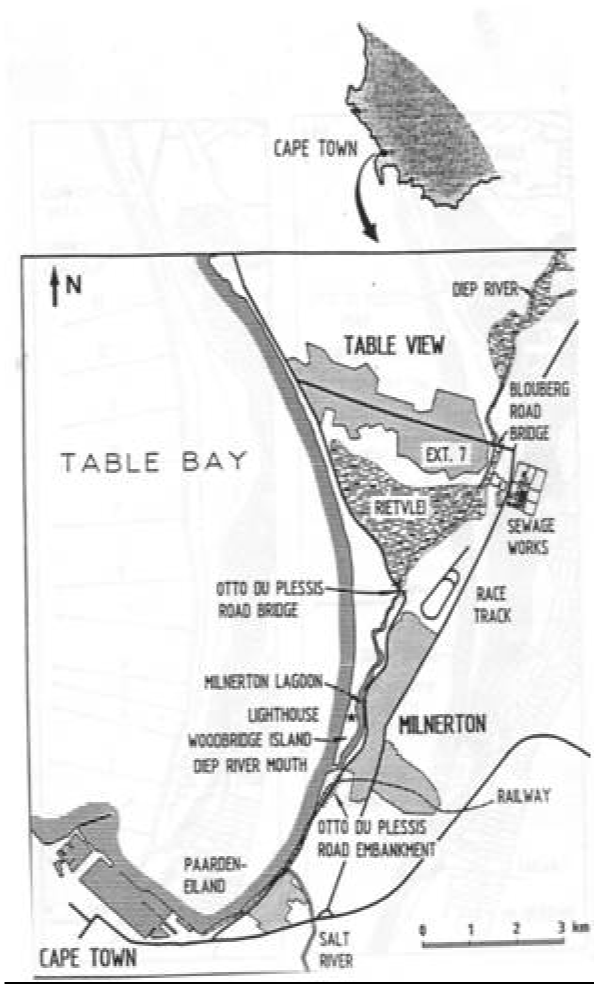

Fig. 13: Location of study area, Woodbridge Island (after Hughes et al. 1992).

Woodbridge Island itself is an intensely developed residential area situated on a portion of the spit on the seaward side of the Diep River near its mouth. There is much development and infrastructure close to the waterline with a minimal buffer zone. Due to property development on Woodbridge Island a number of predictive models for storm errosion are documented (CSIR, 1986 and Hughes et al. 1991 cited by Hughes, 1992) which present the maximum coastal errosion for a 1 in 50 year storm as being 25m. However, the calculations assume that the dune barriers have no breaks and the errosion to Woodbridge Island caused by the storm in May 1984 (approximate 1 in 40-50 year storm) was 34m suggesting this value to be an underestimation in certain areas.

This particular part of the coast is low-lying and has been highlighted by the GIS inundation model as being under threat. The three inundations levels are illustrated in blue, red and orange for LLD+2.5m, LLD+4.5m and LLD+6.5m respectively (Fig. 14). The shoreface is soft and erodible and has in the past shown a high degree of mobility. A sand dune barrier, which is reasonably vegetated, and consists of some blow-out features, offers slight protection from the north. With dune heights of +/- 5 m, it can be seen from the profile that these are not very wide, thus offering particularly limited protection (Fig. 14).

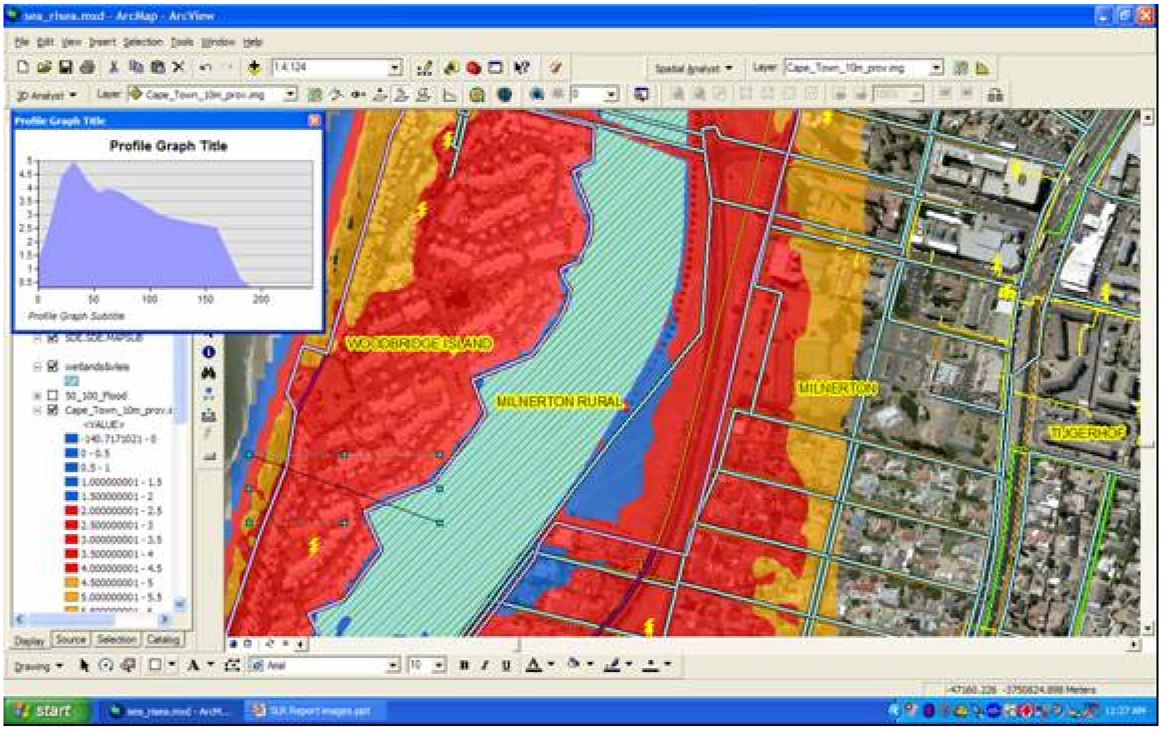

Fig. 14: A snap shot of Woodbridge Island (1:4,124), with the three inundation levels used in the GIS inundation model (scenarios 1 and 2). The profile produced from the transect line shown indicates the height and width of the dune which is currently offering protection from the sea.

The area circled in Fig.15 indicates a particularly low-lying and vulnerable section of the dune barrier where intrusion of seawater is capable of breaking through (between LLD+2m and LLD+4.5m) and effectively shortening distance from the open sea. If such an event were to occur, errosion would therefore be able to take place from the landward side of the residential areas as well as the seaward side whilst also exposing the Milnerton coastline to direct wave action.

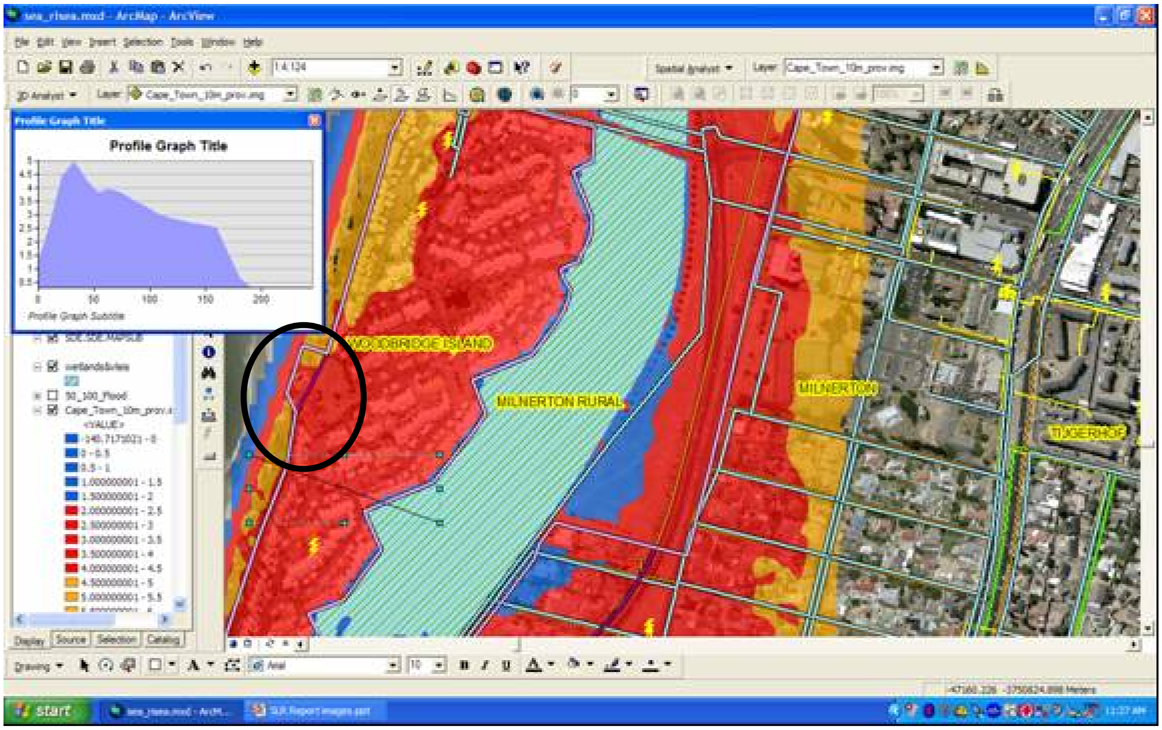

Fig. 15: A snap shot of Woodbridge Island (1:4,124), with the three inundation levels used in the GIS inundation model (scenarios 1 and 2). The circle on the image indicates a particularly vulnerable part of the dune barrier.

If the worst case scenario (as illustrated in the figures above) of a storm surge and wave set-up were to occur producing an elevation in sea level up to 6.5m elevation above LLD, Woodbridge Island and those parts of Milnerton adjacent to the shoreline would be completely flooded and seriously damaged as a result of errosion. A surge of this magnitude would certainly penetrate into the lagoon and the vlei. A combination of such an event and heavy rainfall or river flooding would further exacerbate the problem (Fig. 16) as there would be no place for the water to dissipate.

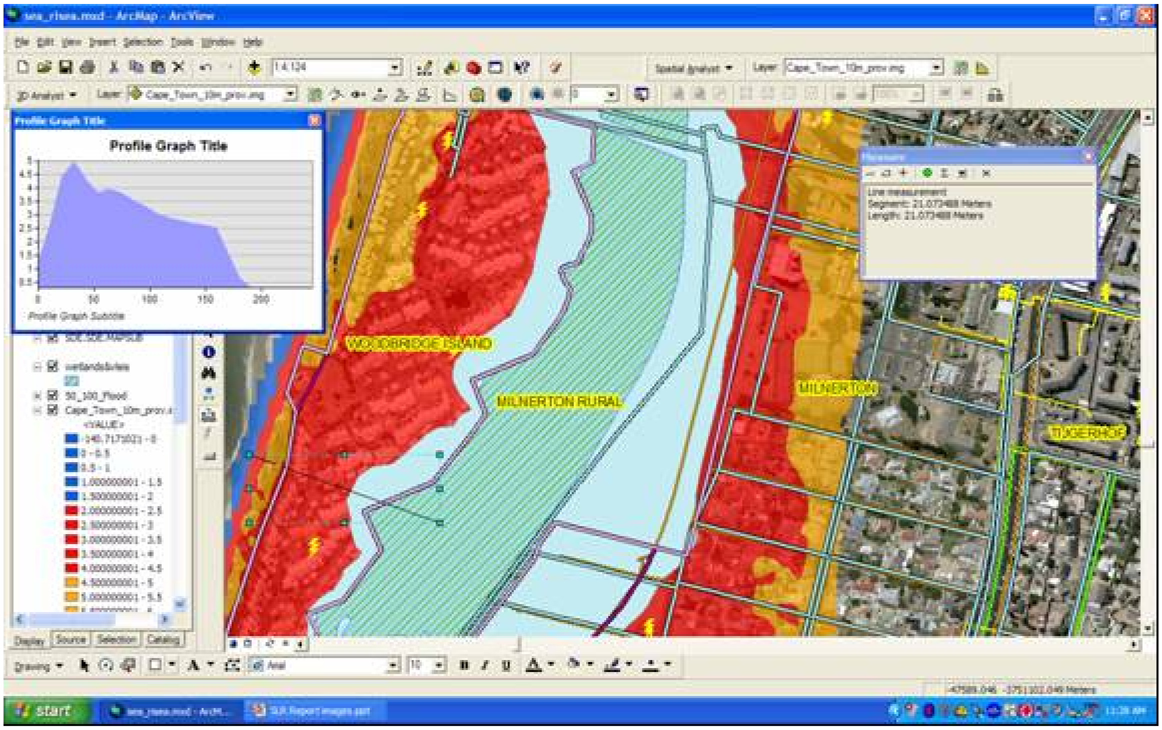

Fig. 16: A snap shot of Woodbridge Island (1:4,124), with the three inundation levels used in the GIS inundation model (scenarios 1 and 2). The Diep River 100 year flood line is illustrated in pale blue.

It is worth noting that the residents of Woodbridge Island are aware of this problem as have been replenishing, re-vegetating and maintaining the protective dunes themselves. The main problems in this area are in-fact the dunes that are further north (Fig.17) as no action has been taken to stabilize, maintain or replenish the dunes. Therefore, it is highly probable that the thin barriers offered is breached or broken, it will most definitely leave the land behind (i.e. Milnerton) extremely vulnerable and open to the full force of storm events and direct wave action.

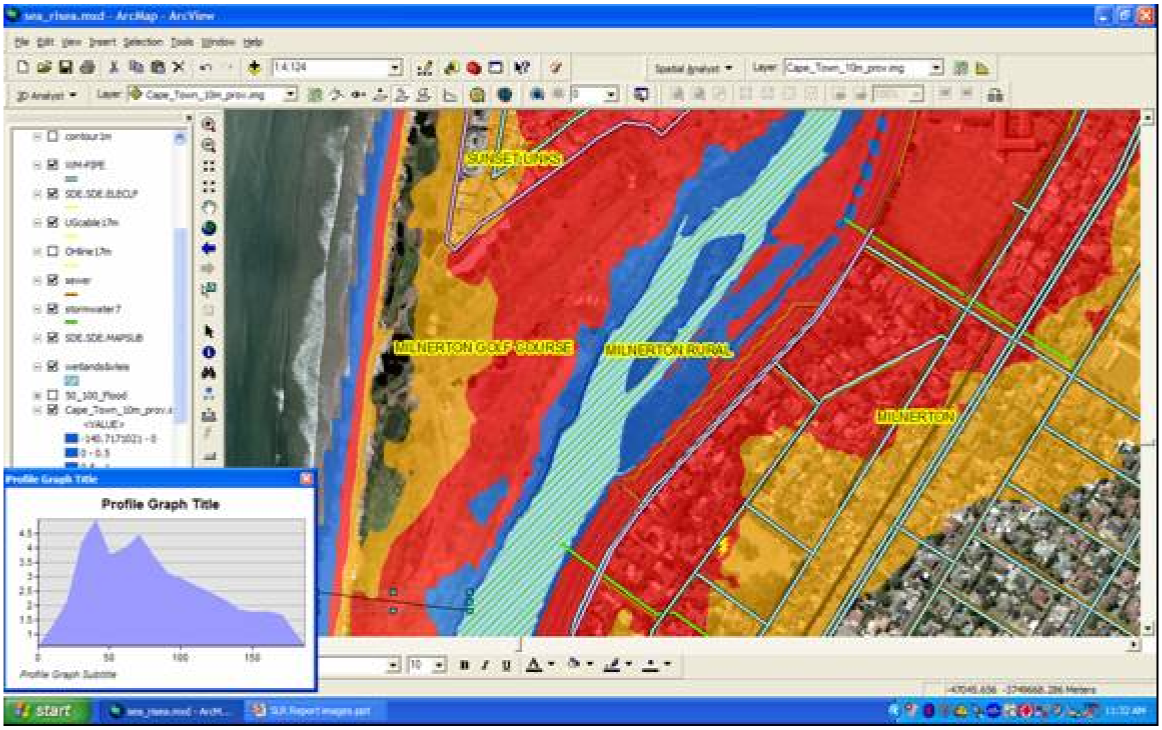

Fig. 17: A snap shot of the area directly to the north of Woodbridge Island (1:4,124), with the three inundation levels used in the GIS inundation model (scenarios 1 and 2) with a profile of the dune illustrating the little protection it offers.

Aside from the visible residential properties, roads and electrical sub stations in figs 14-17 above, infrastructures such as main water, sewerage and stormwater pipes would most definitely be affected. With these infrastructural concerns in mind, one should also be aware of the impact of such an occurrence on the Potsdam Wastewater works which is positioned to the east of Rietvlei (Fig. 18 and 19). The model has illustrated the ponds to be under threat when the rise in sea level is between LLD+5m and LLD+6.5m, however, this situation would most certainly be further exacerbated as a result of a small rise in groundwater levels and/or a flooding event when all three bodies of water would become connected (Fig 20).

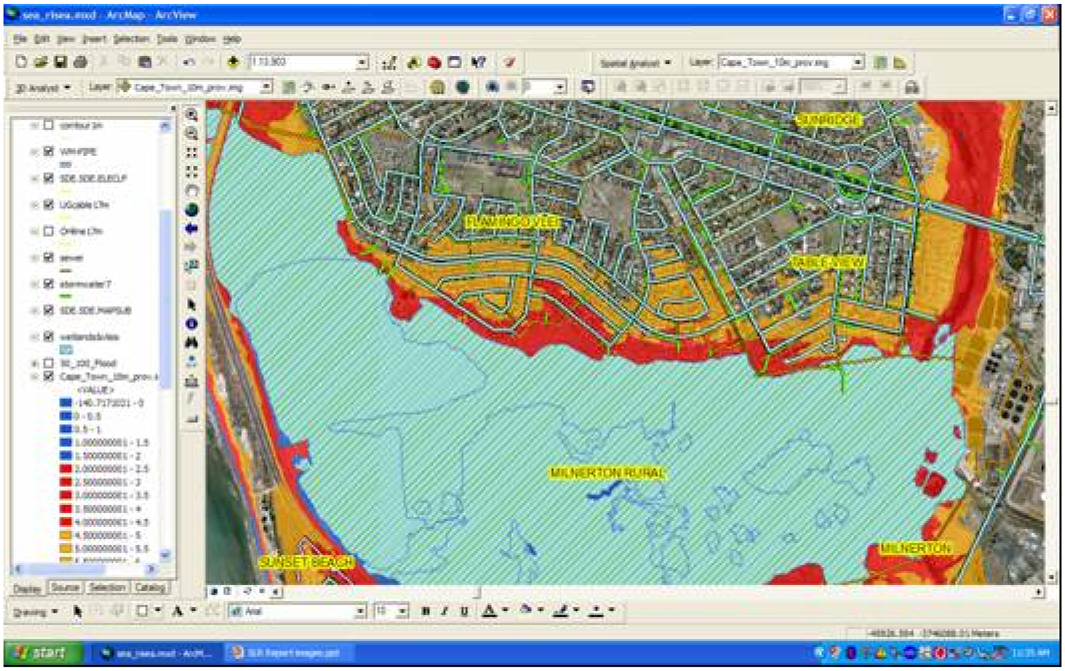

Fig. 18: A snap shot of the Rietvlei area and the Potsdam Wastewater works (1:13,903), with the three inundation levels used in the GIS inundation model (scenarios 1 and 2).

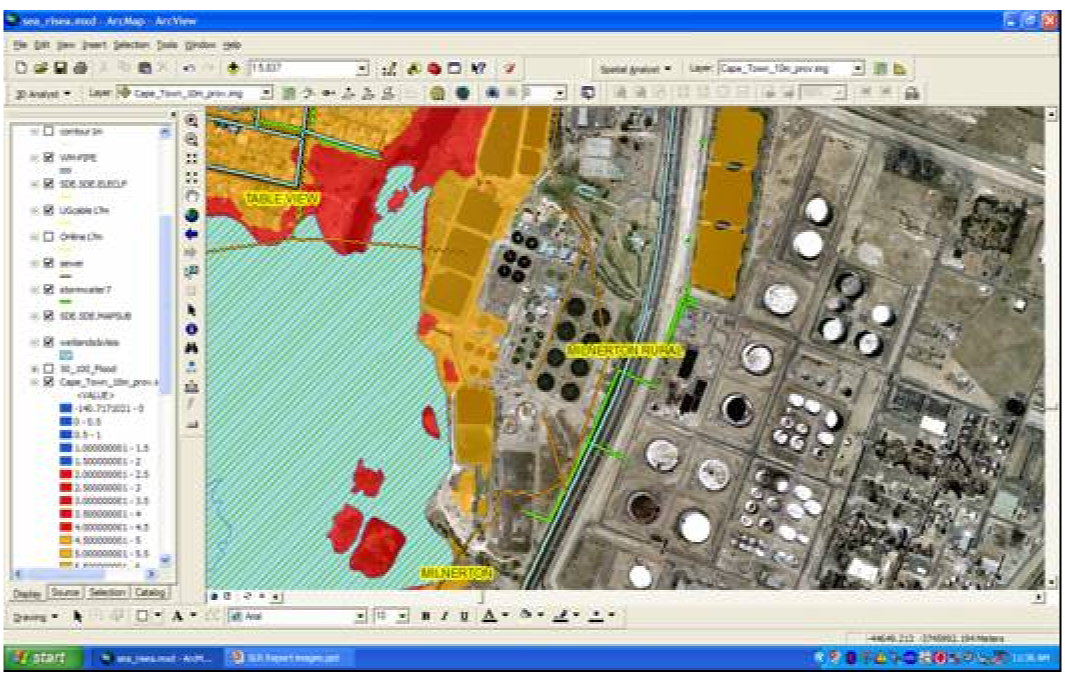

Fig. 19: A snap shot of the Potsdam Wastewater works (1:5,837), with the three inundation levels used in the GIS inundation model (scenarios 1 and 2).

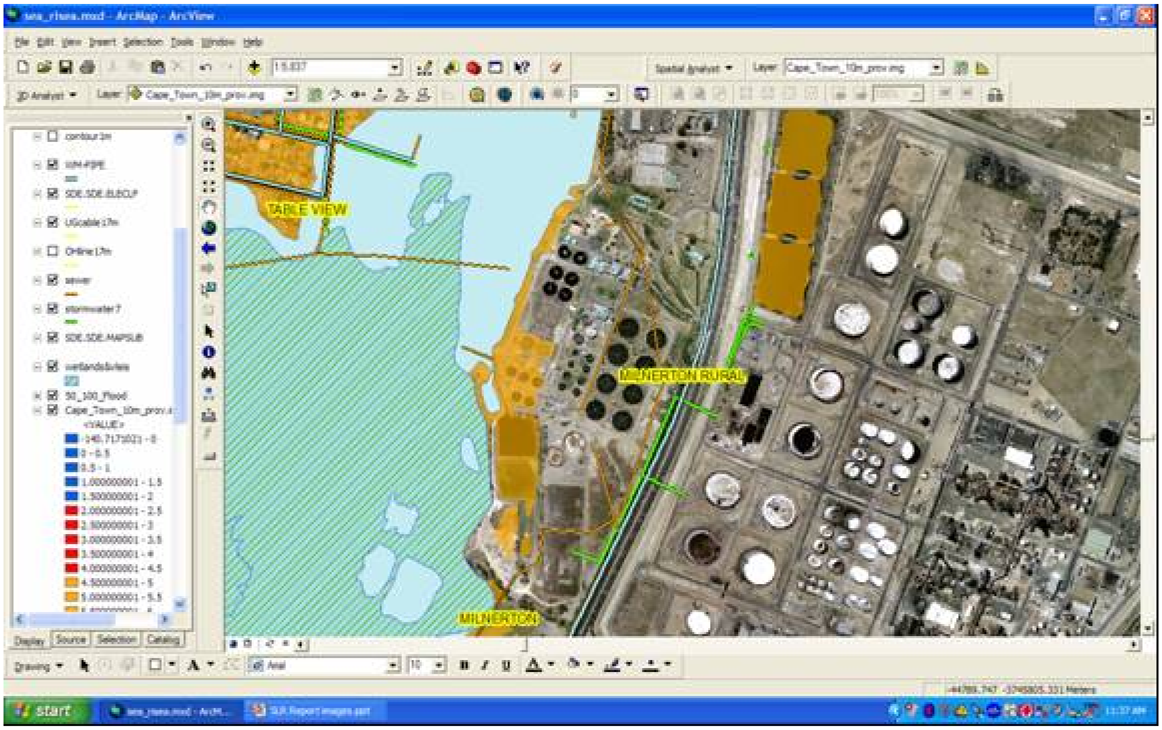

Fig. 20: A snap shot of the Potsdam Wastewater works (1:5,837), with the three inundation levels used in the GIS inundation model (scenarios 1 and 2) and the flooding of the Diep River.

It is therefore worth noting here that at present there are gaps in the data available for the various infrastructures provided by the City. A concerted effort should be made to rectify this in order to improve the effectiveness of the model as a tool for future management and estimating the potential costs to the city.

Long term effects and permanent inundation.

In the long term, accelerating sea level rise and the threat of permanent inundation resulting from the melting of polar ice sheets (Figs 5 and 6) must be taken into account for future planning. Although there is no timeframe associated with this occurrence that can be put forward at this time, there is a great need for further investigation and monitoring changes over time to advance the accuracy of sea level rise predictions.

FUTURE OF THIS PROJECT/THE WAY FORWARD.

Potential hazards have been recognised thus far through the use of the GIS inundation model produced during phase one of this project and the interactive workshops held. However, further studies are required before the determination of a final management plan. The main infrastructure and services provided by the City are built have been built to service a permanent urban infrastructure. As the sea level rises, these infrastructure may have to evolve in order to cope with the new conditions. It is clear from the studies and works that have been carried out so far, that each region has unique assets and vulnerabilities and the impacts upon these is an underdeveloped area of research.

The main points that can be drawn to date are as follows:

- The impacts of groundwater flooding and salt water intrusion may be reduced by proper management where sufficient freshwater flow in aquifers is available.
- Highly developed open and low-lying coasts are generally vulnerable to increased erosion and storm damage.
- Strip and ribbon development close to the shoreline is to be avoided wherever possible. As vulnerability of these areas increase with the length of the developed area and reduces manageability in cases for disaster and risk management.
- Increased errosion of soft areas i.e. beaches and sand dunes will result in the loss of beaches and the increased vulnerability of the infrastructure adjacent to them.
- Developed tidal inlets in open coasts are exceedingly vulnerable to storm flooding.
- Changes in water-tables (i.e. elevation resulting from sea level rise and salt water intrusion) have the potential to cause serious engineering problems in developing and built up areas.

- The model has great potential in becoming a very useful tool to influence forward planning and an early warning system for disaster risk management purposes.

Phases 3 and 4.

Having identified the areas that are mostly likely to be under threat of being impacted upon, the third phase of this project will start quantifying the risks associated with sea level rise. This will investigate the manner of the risks in association with their probability and who will be affected (i.e. private property, public infrastructure and tourism revenue). A descriptive analysis of the biophysical impacts, implications and induced risk will be carried out in order to identify the social, environmental and economic vulnerabilities. This phase is expected to be completed by the end of May 2008.

Phase four of this project will investigate a risk management approach with regards to adaptation whilst acknowledging the increase in uncertainty that comes with climate change by increasing caution with the use of buffer zones etc. It will review the options for cost and efficacy across infrastructural, biological and socio-institutional methodologies with a view to integration with the City of Cape Town and its approach to flood management in order to enable proactive planning, operations and maintenance, disaster planning and communicating the risks.

Issues raised during the workshops to be incorporated in phases 3 and 4 of the current project.

- Must factor into these phases the lifetimes of the infrastructure.
- Could get data and methodology of financial implications from insurance companies
- Offer choices to the city in many cases the natural buffer zones are not that effective any more i.e. dune paths that have been cut off by development.

Adaptation and Mitigation Recommendations

- Bash and rebuild - at what cost?
- Sea walls could be used as a basis for roads, protecting the roads and all infrastructures behind them. However, walls add a false sense of security and if the wall is breached the damage will be amplified! A coastal engineering department is needed (Suggested in relation to responsibilities of sea wall maintenance)
- We cannot engineer against nature!
- Hard structures as a solution are not possible in the next 10-20 years. It is unlikely that anything will be done in the short term.
- Rather prevent further development. Balance this need for combating sea level rise with other needs.
- A natural barrier that could be used is marim grass. It grows in sand dunes, traps sand and builds the dune out towards the sea. It needs maintenance. Hard structures, as an alternative, are very costly.
- Hard/breakwater structures – these are more expensive than managing dunes.

- Dolices work at dissipating energy but they are not aesthetically pleasing. However, they can be used in areas where there is high elevation to protect infrastructure.

SUMMARY AND PROPOSITIONS FOR THE FUTURE AND FURTHER EXPANSION OF THE CURRENT PROJECT

From the GIS inundation model, the interactive workshops held, and the case study reported above, the problematic areas of the City of Cape Towns coastline that are most likely to be impacted by sea level rise have been identified. It is, at this time, difficult to make predictions within a specific time frame. Nevertheless, predictions can be firmed up in the next decade. As the years go by, more information will be gained. The rate of sea level rise (doubling over the last 10 years) could stay the same, or double again, compounding the problem.

Disaster risk management plans in the past have generally been to wait until the situation occurs and then deal with the situation at hand. However, in the event of such storms and inundation taking place, it is abundantly obvious that disruptions, in the magnitudes highlighted during this investigation, of integral infrastructures such as electricity, waste water and roads will leave Cape Town immobile. It is therefore imperative that protective measures are required to be put in place.

There are numerous ‘protective’ measures that can be used for the coastline. However, their effectiveness in relation to ‘lifespan’ and cost are dependant upon various aspects such as the morphology, location (in terms of prevailing swell, wave and wind size and direction) and their socio-economic importance. There are also other aspects that should be taken into consideration, such as structures that have been introduced in the past may have been proven to be effective in reducing the direct impact of wave damage in the local vicinity but may have a ‘knock-on’ effect in other neighbouring sections of the coast i.e. increasing sand errosion from a popular tourist beach. There must be a balance between decisions made on financial grounds vs. whole costs (e.g. environment, sustainability etc –these require more weight). For these reasons, further research and studies are required.

- There is a need to engage with outside authorities, for example airports and ports and the Table Mountain National Park in order to incorporate their infrastructures and any changes that may have been made into the model.

- At present, the process time for adaptation and mitigation processes is too long. It will be very costly to change all existing infrastructure and protect it all. Therefore, the areas that can be considered as being under threat should be highlighted and made known for future planning and development such as housing developments and sewerage as once expensive infrastructure has been instilled, it will not be possible to move it and thus have to be protected.

- Combined schemes with utilities and government departments, working closer together.

- An in-depth survey should be carried out to understand exactly what impact sea level rise may have on different sections of the city. Options of protective measures should then be investigated properly before deciding upon the one to invest in i.e. Baden Powell Drive - mobility may not be affected but on the other hand Sea Point promenade may have a much greater impact.

- There is a need for baseline observations:

    - **Sea level**

        - To improve present estimates and verify the increase in the rate of sea level rise and frequency and intensity of storms.

        - To identify changes in size, speed and direction associated with swell, wind and storms.

        - In addition to measurements of trends, extreme events must be seen to be of great importance as it is only through the study of storm levels at a given location can future extreme levels be modelled and thus predict.

        - Link changes in temperature with sea level rise.

    - **Coastal erosion/sediment transportation**

        - Surveys of the whole coast should be carried out over a long-term basis to monitor changes.

        - Monitoring programs of beaches and near shore profiles including beach nourishment and maintenance rates.

    - **Storm damage**

        - Damage should be reported with estimates of water levels and erosion rate.

    - **Flooding and heavy rains**

        - Increase rain gauge monitoring.

    - **Potential impact assessments**

        - Identify areas that may have inadequate freshwater supplies.

        - Coastal management – possibly reducing access to vegetated, protective dune barriers.

Although it is currently speculated that if private property is continuously damaged, in the long run, insurance companies are likely to be the driving force for future development. There are certain steps that the City needs to address within its own departments:

- Need to get a long term perspective in legislation.

- Tax incentives (and other forms of incentives) to ‘do the right thing’.

General issues raised relating to sea level rise and actions that should be initiated by the Cape Town City Council

- Areas proposed for high densification should be looked at in more detail using the model to ensure these are not areas that are under threat i.e. Kommetjie.

- Plans should be put in place for how to manage disasters in existing areas that are highlighted. We have to know how to deal with existing areas, e.g. densification in Sea Point.

- Coastal development guidelines should be setback from the coast although it is contrary to development demands. Infrastructure should not be left un-maintained and until it ‘breaks’. Options of solutions should be identified as soon as possible.

- Information from this project and model should be included in structural codes, e.g. with the building of bridges, etc.

- Need to focus of areas which are 'needed to be saved' for example Paarden Island where there is much economic pressure.

- Survey areas that of proposed investment as in the long term, it is entirely possible that these areas will be permanently inundated anyway.

The GIS inundation Model

Model Improvements

- There is currently little known about sea-level rise and chaos of storm, intensity of storm increase? Don't know drivers and must model to find out.

- Include water table rise in the wetland areas.

- Include Bathymetric information in order to aid information about wave setup and energy dissipation i.e. those areas that can hold a big swell (Clifton and Sea point) and those that cannot (False Bay shallower and far less of a gradient) and mapping of offshore reefs and rocky ledges that may provide some protection.

- Robin Island - how much protection does this offer and from storms. Surveys should be conducted in order to include this information in the model.

Infrastructural information to be included

- Include a layer with current road names etc.

- Information on stormwater systems is updated on a regular basis this should be included in the model.

- Include information from the bulk water department - CSIR hydraulic model for water flow.

- The registered servitude should be addressed and infrastructure that is currently available should be included i.e. the Caltex pipeline that currently runs from the harbour to the oil refinery.

- Include a layer that illustrates the areas which are currently proposed for nodal development.

- Gather up-to-date data on the infrastructure and include this in the model as currently the information presently in the model has some fairly significant gaps.

Services

- Include information about where the storm water and sewerage pipes have been joined to ensure flow as these may be considered to be weak.

- Use the model to identify waste water ponds that could become inundated as a result of rising sea level. Perhaps this could be achieved by comparing images taken in 1999 and 2005. Those that were not present in the earlier images are not lined.

- Add directional flow for sewerage, stormwater and water mains.

- Map all reclaimed land sites and indicate which have been stabilized and which have not.

- Include information on the size of the pump stations for electricity, sewerage, stormwater and water mains.

Using the model as an early warning system.

During the workshops, the use of the model as a management tool was highlighted time and time again. With certain improvements, the model could also be used as an early warning system which could be used to pinpoint specific locations of the City's coastline under threat under the expected conditions. An early warning system that takes into account the swell direction and size to dictate disaster management response in certain areas and thus prevent similar situations to that of the flooding in Sedgefield in December 2007. In this situation, the national parks authority was slow in acting upon opening the river mouth. If warnings could be issued in advance and the authorities made aware of the potential implications in advance, they would be better equipped to mitigate more effectively.

Recommendations by Prof. Geoff Brundritt towards this end are stated below:

NOTE: There is different information available in advance to any particular event.

- Six months in advance,
    - For each month, a list of danger days for extreme sea levels, and the times of danger on those days
    - Some months will have no danger days
    - South African Navy Hydrographic Office www.sanho.co.za
    - Contact: Ruth Farre, Tidal Superintendent 0217872911 or 0824265950
- Six days in advance,
    - Extreme storm weather forecast for the City of Cape Town coastline
    - Wind and waves
    - South African Weather Service www.weathersa.co.za
- Danger Days,
    - A Danger Day is when storm sea level might rise above the level of the Highest Astronomical Tide
    - Time and duration of danger for each danger day of the month
    - *In-house calculation. Percentage probability of sea level exceeding the danger level on each danger day, and for the month as a whole*
- Danger Days Example (Extracted from www.sanho.co.za)

HAT=2.09

6 April 03h10 1.97 = HAT-12cm

7 April 03h50 2.00 = HAT-9cm

8 April 04h32 1.96 = HAT-15cm

6 May 03h31 1.94 = HAT-15cm

All durations less than 1 hour

- Probability of sea level exceeding Highest Astronomical Tide
    - April 2008

6 April	7%
7 April	14%
8 April	6%

      Combined April probability 24%
    - May 2008

6 May	3%

      Combined May probability 3%

Calculated from probability that storm will be big enough for total sea level to exceed HAT. On 6 April, need weather effect to add +12cm, which will only occur 7.2% of time. Detail follows.

Cumulative Normal Distribution of Weather Effect at Simon's Bay with Mean=0 and St Dev=8.22cm

High tide below HAT by	Probability of NOT reaching HAT	Probability of exceedance
0 cm	0.500	0.500
1 cm	0.548	0.452
2	0.596	0.404
3	0.642	0.358
4	0.687	0.313
5	0.728	0.272
6	0.767	0.233
7	0.803	0.197
8	0.835	0.165
9	0.863	0.137
10	0.888	0.112
11	0.910	0.090
12	0.928	0.072
13	0.943	0.057
14	0.956	0.044
15	0.966	0.034
16	0.974	0.026
17	0.980	0.020
18	0.986	0.014
19	0.990	0.010

Calculation Detail

- If high tide on the day is HAT – z, then a weather effect exceeding z will result in a total sea level exceeding HAT. This probability can be read off from the exceedance in the Normal Distribution tables.

- If there are several danger days in the month, the probability Ptotal of every danger day being safe in that month is the product of the individual probabilities of the weather effect NOT reaching the required level on that day. The probability of a least one day going over that limit is then equal to 1-Ptotal.

Six day wind and wave forecast

- Outsource: Get special forecast from South African Weather Service Maritime Weather Office at Cape Town International Airport: Contact Johan Stander 021 934 3296

- In-house: Use NOAA Wavewatch III http://polar.ncep.gov/waves/viewer.shtml? Atlantic: Significant wave height / Wind speed and direction.

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Jury, M. R., Shillington, F. A., Prestige, G. and Maxwell, C. D. (1986) - Meteorological and Oceanographic Aspects of a Winter Storm of the South Western Cape Province, South Africa. *S. Afr. J. Science* 82, 315-319.

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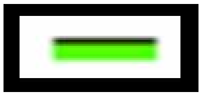
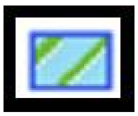
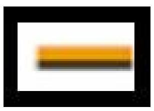
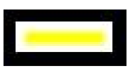
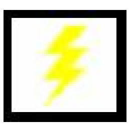
APPENDIX

Key for infrastructure illustrated in GIS snap shots:

	Stormwater pipes
	Wetlands and Vleis
	Sewerage pipes
	Main water pipes
	Electricity
	Electrical pump stations

AGENDA

Climate Change: Sea Level Rise – Risk to City Workshop (Silwerstroomstrand to Milnerton Coastal strip).

18 March 2008

Blaauwberg Conservation Management Centre, Eerstesteen Resort, Blaauwberg, Cape Town.

09:30 Welcome and Introduction to the workshop (Gregg Oelofse)
Presentation of GIS climate change sea level rise model (Lucinda Fairhurst)

10:30 TEA / COFFEE

10:45 Discussion and presentation of snap shot images taken from Silwerstroomstrand to Milnerton.

11:00 Identification of specific areas of concern with critical infrastructure

11:15 Identification of vulnerable communities with restricted capacity for relocation

11:30 Identifying and filling in gaps

11:45 Conclusions and closing

12:00 CLOSE OF WORKSHOP

WORKSHOP PARTICIPANTS

DATE: 10th March 2008

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DATE: 18th March 2008

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