Combined marine storm and Saros spring high tide erosion events along the KwaZulu-Natal coast in March 2007

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A STORM SWELL, COINCIDING WITH A SAROS spring high tide, struck the KwaZulu-Natal coast on 19–20 March 2007. At its peak, the storm produced swells of ~8.5 m, caused significant coastal erosion and unprecedented damage to coastal property, estimated at more than one billion rand. Property damage resulted from unwise urban planning during the coastal building boom of the last two decades. Local exacerbating factors included construction too close to the high water mark, adverse coastal profile, and coastal modification. The town of Ballito, north of Durban, presented all these aspects and was the worst-hit area. The storm also destabilized the coast, consequently chronic coastal erosion will continue until a new equilibrium is achieved.

Introduction

In this article we give a preliminary overview of the erosion experienced by the KwaZulu-Natal coast during the storm of 19–20 March 2007. Its effects spread from Port St Johns, in the Eastern Cape province, to Maputo in Mozambique, but KwaZulu-Natal (KZN) received the brunt of the storm. Roads were damaged at Margate, Uvongo, St Michael's-on-Sea, Port Shepstone, Umkomaas, Durban, Umdloti, Ballito and Zinkwazi. The South Coast railway-line experienced severe damage at Mtwalume and Sezela (Fig. 1). Private property along the coast was also damaged. The provisional repair bill exceeds one billion rand.

Antecedent conditions

The oceanographic conditions prior to 19 March had been somewhat unusual for KwaZulu-Natal, with sea swells as high as 2–3 m. The beaches were consequently depleted of sand. The sustained high swells were partly due to tropical cyclones Dora and Gamede. Remnants of swell generated by Cyclone Dora were combined with swell produced by a well-developed cold front to the south of the South African east coast. This resulted in swells as high as 2–3 m (personal observation) in the Durban area on 11–13 February. Cyclone Favio followed, but did not affect the KZN coast.

Cyclone Gamede moved westward towards Madagascar on 26 February, turned south on the 28th, and then stalled in the South Indian Ocean from 1–6 March. Although downgraded from a cyclone to an extra-tropical depression by this stage, this storm produced winds capable of forming sizeable swell. The fact that the weather system had moved southwards beyond the shadow of Madagascar meant that this easterly swell reached the KwaZulu-Natal coast unimpeded from 1–5 March. The swell was 2–4 m (personal observation) in amplitude and, on breaking, was transformed into plunging breakers that pounded the coast. Durban's lower beachfront experienced some flooding and erosion, especially when these swells coincided with spring high tides on 3–4 March. Durban beachfront shops sandbagged their entrances to resist the tide. Erosion damage was also experienced at Margate, St Michael's-on-Sea and Ballito.

The storm of 19–20 March

The storm started as a frontal low, which passed south along the South African east coast on 17 March. It intensified and rapidly developed into a cut-off low southeast of East London on 18 March[1] (Fig. A in supplementary material online), reaching a maximum intensity some 700 km southeast of Durban early on 19 March,[2] where it remained almost stationary until 20 March. This intense low had a central pressure of less than 996 mb, which supported strong pressure gradients that generated and sustained strong winds off the east coast from the morning of 18 March through to the morning of the following day. Offshore winds of 40 knots (20.6 m/s) from the south were recorded east of East London; there were also winds of 45 knots (23.2 m/s) off the KZN coast, from the southwest, on the morning of 19 March.

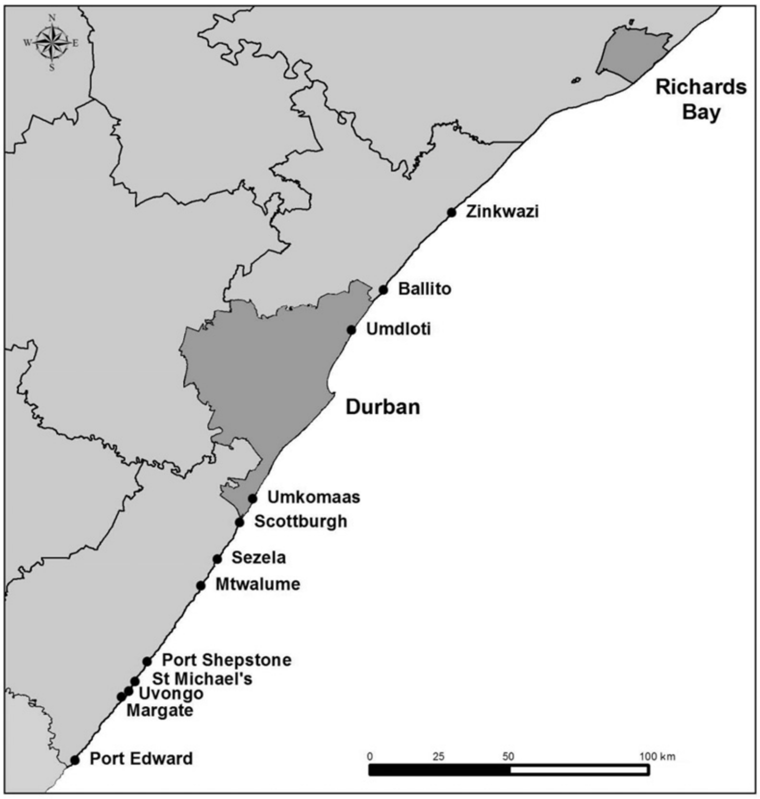

Fig. 1. Location map showing the various damage locations (drawn by Riaan Botes, Geodynamic Systems).

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A maximum gust of 19.5 m/s was recorded at Durban on the 18th, the maximum 5-minute average wind speed was 13.9 m/s, and average wind speed for the day was 10.7 m/s.[3] At Richards Bay, wind speeds averaged 10.7 m/s on 18 March, with 5-minute average speeds peaking at 14.2 m/s.[4]

Wind speed and duration, combined with sufficient fetch distance (~450 km), generated large swells off the KZN coast. The CSIR's wave-rider buoy, located at the 30-m depth isobath some 2 km off Richards Bay, measured a significant wave height of 8.5 m, with a period of 16 seconds, at the peak of the storm at 05:00 on 19 March. Peak wave height reportedly attained 14 m (M. Rossouw, CSIR, pers. comm.).

The peak in swell coincided roughly with the peak high tide, measured at 03:56 in Durban. Added to this, the SE–SSE direction of the swell, with a period of 16 seconds, meant that it approached parallel to the coastline, orientated approximately NNE–SSW, resulting in minimal refraction and dissipation of energy and exposing the coast to the maximum force of the swell. Large swells continued to pound the eastern seaboard until the evening of 20 March, by which time the significant swell height had declined to less than 3 m, with a period of 12 to 14 seconds (M. Rossouw, pers. comm.).

The storm swell struck during the peak equinoctial spring high tide of a Saros (18.03-year) tidal cycle. This was predicted to be 2.24 m (on the 19th) and 2.28 m (on the 20th) relative to Chart Datum (CD),[5] compared to the average tidal range of 1.8 m above mean sea level.[6] Consequently, water reached areas that are seldom inundated by the sea. Such areas are not in equilibrium with marine processes and are readily eroded. The landward edge of the swash zone was surveyed at +8 m CD in the Durban area. In parts of Ballito and Salt Rock, particularly high swash levels were recorded (8 m CD) at locations with a southerly aspect adjacent to headlands.

Coastal erosion

Storm swells erode sediment, lowering the beach profile,[7] and this process led to coastal erosion. Property was damaged in heavily urbanized coastal areas, especially where development was close to the high water mark (HWM) (Fig. 2). The erosion line for this storm is located between the 4- and 5-m contours above mean sea level (between 4.9 and 5.9 m CD).

Nearshore and beach sands were washed away and transported beyond the surf zone, to be deposited in longshore bars on the inner shelf, the outer boundary of which is placed at –30 m.[8] An unknown amount of sand will have been transferred out to the mid-shelf and possibly to the outer shelf, well beyond the influence of fair weather wave action to return it to the beach. Sediment deposited within the longshore bars will gradually be reworked shoreward.

The eThekwini (Durban) coastline lost an estimated 3.5 million cubic metres (5.2 million tons) of sand as a result of storm erosion. During the storm, the HWM retreated by 10–30 m in a few hours at Ballito (Fig. 3). Umkomaas, where the HWM retreated by 10 m, and Umdloti (16 m) also experienced severe marine erosion. The March storm has destabilised the coast, and chronic erosion continues. This will persist until a new equilibrium is reached.

Fig. 2. Beach erosion at Ballito. Note the failed gabions of a previous sea-defence structure. The dune sand on which the structure stands has been undercut, exposing the infrastructure.

Impacts

The extent of coastal erosion was dependent on five factors:

Proximity to the high water mark. Some urban development was too close to the HWM.

Coastal profile. Most of the KZN coast is relatively steep, which mitigated the damage. Ballito has one of the lowest coastal profiles in the province (between 0 and 15 m a.m.s.l.), however, and was the worst affected. At the town, and also in parts of Uvongo and of Scottburgh, the

Fig. 3. A multi-storey building in Ballito, which was partially undercut by the storm.

erosion line cut through urban development and maximized the damage. Elsewhere this storm erosion line was located on the beach.

Coastal shape. Property adjacent to the deepest parts of embayments was hard hit. These zones are typically areas of natural erosion and so storm damage was to be expected. Many built structures that failed were located adjacent to, or upon rocky, headlands and within bays encompassed by rock shelves. Wave energy was focused in these areas, especially where overwash was not allowed to dissipate naturally. The coast at Ballito juts out into the ocean and may therefore have been more directly exposed to the southeasterly swells.

Coastal type. Sandy and rocky coastal sections generally withstood the storm's onslaught and so damage to adjacent property was minimal. In contrast, mixed coastlines (of rock and sand), such as much of the Ballito strand, were severely impacted, with associated property damage. Much of the breaking wave energy was dissipated downwards as scouring. If a rock shelf is present, at a level higher than the potential scour depth, the wave energy is reflected back, forced forward and coastal erosion is enhanced.

Naturally vegetated coastlines are in dynamic equilibrium with the sea and were able to absorb the storm energy. Minor erosion occurred in the green belts but the combination of coastal dune sand input and natural vegetation groundcover inhibited erosion, which was repaired fairly quickly. In many cases the vegetated dunes were undercut and the beach profile steepened, but the dunes themselves were able to absorb the wave energy.

The impact arising from the removal or alteration of psamoseral vegetation is also to be noted. The loss of frontal dune vegetation is to be expected in the face of such a severe storm.[9] What was notable, however, was that where vegetation comprising primarily species such as *Chrysanthemoides monilifera* were present, the dune rapidly reverted to a more stable gradient. Where lawn or exotic vegetation was in place, dunes adopted a steep and unstable gradient following the storm.[10]

Coastal modification. Well-constructed seawalls stood in many instances. However, hydraulic roughness at their margins and crest (when they were overtopped by the sea) led to standing-wave erosion behind the walls. In extreme cases, this left the seawall standing while the sediment behind was removed. At other points, scour pits were excavated at the down-current end of standing seawalls. In some cases, waterloffel walls withstood the onslaught, while older seawalls crumbled.

Property damage was accentuated in places where land had been reclaimed from the sea. In some instances, especially at Ballito, this was exacerbated where reclaimed land was built up. High banks failed when their toes were undercut by erosion. Coastal dune erosion had been noted in Ballito (at Salmon Bay) some six months earlier. The local authority relocated sand from the beach to bolster the dune to protect infrastructure. On 19–20 March, the most severe damage to built structures was near the area from which beach sand had been removed for this purpose.

Storm severity

The spectacular damage to property that took place on 19–20 March was a consequence of the building boom of the last twenty years. If such a storm had struck prior to this urban expansion, there would have been considerably less damage to property. The unprecedented destruction is due mainly to buildings having been erected in the wrong place.

Whereas the latest storm produced swells of about 8.5 m on 19 March, the swell generated by Cyclone Imboa (in February1984) was about 9 m in the Richards Bay area (M. Rossouw, CSIR, pers. comm.). Another storm, in April 1984, was reputed to have caused 8-m swells.[11] Wave heights of 8–10 m and with periods of 11–17 seconds have also been recorded during mid-winter storms in the Natal Bight.[12] The March 2007 storm swell was therefore unusual, but not unique. Large magnitude coastal storms were not experienced during the nineties, however,[13,14] or early in this century (personal observation). March of this year was the first time that the many new urban coastal developments were put to the test of withstanding a severe storm.

The outer wall of the Thompsons Bay tidal pool (2.5 km north of Ballito, built in 1962) was destroyed in the latest storm. This implies a minimum recurrence interval of 45 years. Furthermore, an archaeological midden, which ceased functioning in the 1920s (L. van Schalkweg, pers. comm.) was scoured open in Ballito. This suggests that such a storm has not hit this coast in some eighty years.

Lessons learned

- The storm swells associated with Cyclone Gamede were a precursor to the March storm event and predisposed the east coast to a second onslaught from the sea.
- Natural coastlines can absorb the impact of storms relatively well. Areas with an intact Admiralty Reserve (a natural green belt) were relatively unaffected.
- Low-profile coasts, such as at Ballito, experienced severe damage.
- Property constructed on mixed (sand and rock) coastlines suffered the greatest damage.
- Some buildings, roads and railways have been constructed too close to the high water mark.
- A rigid building-ban, building setback line and buffer zone should be selectively established along the coast and rigorously enforced.
- Along many urbanized coasts, the coastal dune cordons have been destroyed and cannot rebuild the deflated beaches after severe storm events.
- The damage to be expected from coastal storms will be costly if future building construction is unchecked.
- The effect of coastal headlands and other promontories should be taken into account in urban planning.

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Supplementary material to:

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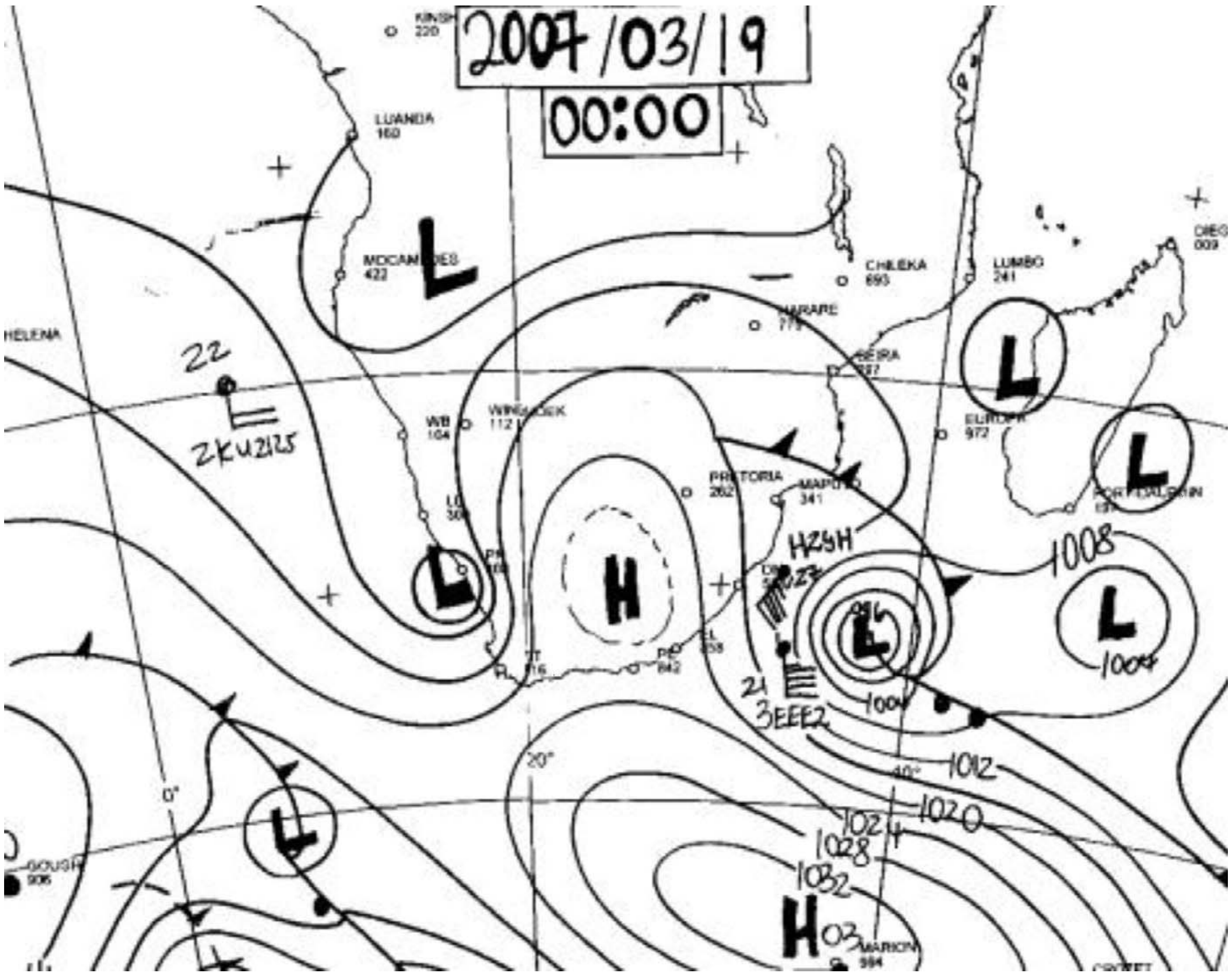

Fig. A. Synoptic chart showing the position of the storm, southeast of South Africa, that generated the swell which struck the KwaZulu-Natal coast on 19 and 20 March (courtesy of WeatherSA[1]).