DEFINING AN UNUSUAL LITTORAL REGIME TO OPTIMIZE DREDGING AT EAST LONDON

A K Theron[1] and J S Schoonees[1]

Abstract

Maintenance dredging at the Port of East London is a major annual expense. The aims of this investigation were to obtain relevant information on the sedimentary processes and to apply this information to reduce or optimize various facets of the required maintenance dredging. Information gleaned on various components of the sediment transport regime led to a holistic understanding of the sediment budget for the littoral sub cell at the port. The sedimentary regime is very interesting with a complex pattern of sediment movement around the harbour. In turn, this information could be applied practically in terms of: more efficient sandtraps, a new dump-site closer to the port, a spur which successfully protected the dolos armour units, and proposed extensions to the breakwater which potentially could significantly reduce maintenance dredging. Most of these applications have already led to significant savings on maintenance dredging costs for the port.

1. Introduction

Background

The Port of East London is situated on the south-eastern coast of South Africa on the Indian Ocean seaboard (Figure 1). It is one of the six largest ports in South Africa and maintenance dredging (ca. 600 000 m^3/annum) at this port also represents a major annual expense (ca. U$ 850 000). East London is exposed to fairly severe wave conditions (Figure 2) and is also renowned as the origin of the world renowned dolos breakwater armour unit. The port layout and local references are depicted in Figure 3.

Sedimentary regime

The sedimentary regime at East London is very interesting and quite unlike that of the other ports in South Africa. A major ocean current (the Agulhas) flows exceptionally close to the coastline in this area, thus significantly affecting nearshore sediment

---

[1] Research Engineers, CSIR, P O Box 320, Stellenbosch, 7599, South Africa
(fax: +27 21 888 2693, e-mail: atheron@csir.co.za)

movements. Of particular interest in this case, is that this strong deeper water current predominantly flows in the opposite direction of the longshore current in the surf zone (Figure 4). Furthermore, the Port of East London is the only riverine (the Buffalo River) harbour in South Africa; which all leads to a complex pattern of sediment movement around the harbour.

Aims

The aims of this investigation were to obtain relevant information on the sedimentary processes at East London and to apply this information to reduce or optimize various facets of the required maintenance dredging.

2. Environmental Data and Coastal Processes

General

The natural processes of sediment transport and deposition are the cause of sedimentation in ports, which necessitates routine maintenance dredging to maintain prescribed water depths. In order to reduce or optimize the required maintenance dredging at a specific port, it is therefore necessary to have a complete (as possible) understanding of the sedimentary processes at that port. To define the littoral regime at a specific site, certain environmental data and an understanding of the relevant coastal processes, are required (CSIR, 1994a, 1995, 1996).

Continental shelf sediment dynamics

The continental margin of the east coast of South Africa is characterised by an extremely narrow shelf. At East London the shelf is about 25 km wide and the shelf break is located at about the 100 m isobath. The south-westwardly (downcoast) flowing Agulhas Current reaches a peak surface velocity of over 2,5 m/s just beyond the shelf break off East London. The total downcoast sediment transport on the shelf along the East London coastline is estimated at about 24.10^6 m^3/annum.

In general it is possible to distinguish three more or less shore parallel physiographic seabed regimes, each reflecting specific wave and current characteristics (Martin and Flemming, 1986). The narrow nearshore zone is subjected to a high energy swell regime, and is covered by a thin wedge of sandy sediment. This wedge appears to have achieved dynamic equilibrium with the prevailing energy regime, and additional (terrigeneous) sediment is rapidly dispersed and fed into a sand stream, situated slightly further offshore on the broad continental shelf, where the Agulhas Current dominates sediment transport. Thus, the nearshore sediment wedge progrades seawards until it meets sufficient current strength for sand to be entrained. The sand is entrained and carried on the central shelf by the so-called "conveyor-belt process", driven by the Agulhas Current. This current-controlled part of the shelf can be further subdivided into two parallel zones: a broad central-shelf sand stream and a narrow outer-shelf gravel pavement. The current- scoured gravel pavement stretches along the outer margin of the shelf and probably extends onto the upper continental shelf slope. This lateral sequence clearly indicates a progressive increase in current velocity in the offshore direction - a phenomenon which is consistent with available current data.

The above description clearly indicates that vast amounts of sediment are transported along the shelf by the Agulhas Current. Furthermore, it appears that any excess sediment transported onto the current dominated zone of the shelf or deposited on the nearshore sediment wedge near the margin of the current dominated zone, would eventually be carried away by the south-westwardly flowing Agulhas current.

Tides

The mean spring tidal range at East London is 1,59 m, while the mean neap tidal range is 0,47 m.

Wind

The south-westerly wind is the dominant wind throughout the year, while strong north-easterlies may occur in all seasons. These directions are approximately parallel to the coast. The average recorded wind speed is about 4,5 m/s.

Waves

In this study, the incident wave climate was determined from deepsea VOS (Voluntary Observing Ships) data and nearshore Waverider recordings. The median significant wave height is 1,6 m and the 1% exceedance wave height is 3,4m. The median peak wave period is 11,2 s. The most common deepsea wave direction is south to south-west. To obtain more information on the nearshore wave climate, wave refraction modelling was also carried out. An example is shown in Figure 5, for a deep-water wave height of 3 m and a peak wave period of 13,5 s with a southerly deepsea wave direction. The weighted mean surf zone width along the seaward half of the main breakwater is about 150 m.

Currents

Currents were measured by means of Endeco and Aanderaa current profilers, drogue tracking, drifter buoys and dye tracking. Figure 6 shows information on some of the deeper water current measurements as well as the current patterns derived from this information. Thus, it was found (for example) that the offshore currents flow in a south-westerly direction for about two-thirds of the time and in the opposite (north-easterly) direction for about one quarter of the time.

Currents were also simulated by means of the Delft 3D mathematical model (WL|Delft Hydraulics, 1996). Figure 7 shows an example for the most common situation which is a south-westerly current of 0,3 m/s.

Surf zone (wave induced) currents were measured along the beach to the south-west of the port. These measurements were conducted by means of dye tracking tests (in conjunction with drogue measurements). The associated wave conditions were derived from Waverider recordings, while the waves directions were hindcasted.

Sediment

Sediment samples were collected over a wide area around the port. The sediment characteristics were determined by analysing samples in a settling tube. The average median grain size is about 0,2 mm.

Aerial photographs

Analysis of aerial photographs provided additional information on nearshore wave directions, current patterns and shoreline changes. South of the harbour, the direction of the incident waves is such that in virtually all instances a current generally flowing towards the harbour would be generated near the shore. The wave attack on the seaward side of the main breakwater would mostly not generate very significant currents parallel to the breakwater. At the beach directly north of the port, no significant wave generated longshore currents are indicated. Past port developments initially caused the shorelines on both sides of the port to prograde significantly. More recently, the shoreline appears to have stabilised with smaller variations occurring.

Bathymetric surveys and dredging data

Analysis of subsequent bathymetric surveys proved to be a valuable tool in studying the changes in bottom topography, erosion and deposition areas and determining volume changes. Bottom topography changes, together with the dredging data, in terms of sediment volumes dredged over time in specific areas, provided an important part of the overall picture. Information on the dredging records for the main sandtrap is shown in Figure 8, while the annual dredging volumes for the other port areas are shown in Figure 9. The total volume of sediment dredged annually at the port, is about 600 000 m^3 to 650 000 m^3 on average.

3. Sediment transport regime/budget

3.1 Transport through/around main breakwater

A separate study was conducted to determine specifically the rate of sand deposition on the inside of the main breakwater and from where this sand originates. This basically entailed determining the volume of sand moved *through* the breakwater and the volume moved to the inside of the breakwater from *around* its head. A wide variety of different means were employed to determine this: long-term dredging records, repeated surveys of a specially dredged "test-pit", suspended sediment samples, a newly developed suction sampler, an electronic current profiler, drogue and dye tracking, drifter buoys and a theoretical determination of the suspended versus bedload ratio. Interesting comparisons of the results could thus be made. The results of a side-scan sonar survey of the area was also interpreted with regard to the study, as this information provided interesting circumstantial "evidence" completing a part of the sediment transport "puzzle". Thus, it was concluded that 60 000 - 80 000 m^3/annum of sediment moved through the breakwater, while 20 000 - 50 000 m^3/annum moved around the head of the main breakwater (The breakwater has since been made more impermeable and as such, the rate of sediment movement through the breakwater has been reduced.).

3.2 Longshore Transport

The longshore transport along the beach to the south-west of the main breakwater (300 000 - 500 000 m^3/annum) was estimated by means of the modified Kamphuis method (Schoonees and Theron, 1996). The directional distribution of the longshore sediment transport was determined from the nearshore wave climate.

3.3 Transport in deeper water

The sediment transport in deeper water due to the combined effects of currents and waves was also estimated (by means of the Van Rijn (1989) method). Thus, the sediment carrying capacity of the currents was assessed, leading to estimates of the sediment transports at the dump-site and in the "bar" area (Figure 9). The strong deepwater current (the Agulhas) predominantly flows in the opposite direction of the longshore current in the surf zone.

3.4 Fluvial transport

Riverine sediment inputs were calculated from sediment production charts and the sediment trapping efficiency of dams in the river. The mean annual runoff of the Buffalo River is estimated to be about 41.10^6 m^3, with a sediment load of about 80 000 m^3/annum. However, the dams trap more than 90% of the sediment; thus, the sand transported into the port is estimated to be less than 10 000 m^3/annum.

3.5 Sediment balance/budget

Analysis and interpretation of all of the above lead to a relatively complicated sediment balance for the littoral sub cell at the Port of East London, as depicted in Figure 10 (CSIR, 1994a, 1995, 1996).

4. Applications

Having obtained a holistic understanding of sediment transport patterns, this enabled the use of this information to optimize maintenance dredging activities in the area (CSIR, 1994a, 1994b, 1995, 1996).

4.1 Sandtraps

The location and layout of a number of new sandtraps were determined so as to intercept the main sources of sediment deposition in the harbour and entrance channel. The old, newly dredged and proposed sandtraps are depicted in Figure 11. The optimum dimensions of these sandtraps were also determined in terms of theoretical sand trapping efficiency and practical aspects of the dredging.

4.2 Dump site

Based mainly on the current patterns and the carrying capacity of the offshore currents, the location of a new (closer) dredge-material dump site was determined, as depicted in the Figure 12. The risk of sediment moving back to the port is acceptably low and the much shorter dumping cycle represents a significant cost saving.

4.3 Spur

The location and layout of a spur on the main breakwater was determined conceptually. The main purpose of this spur is to traps stones, rocks and debris which damage the armour units and secondarily, to reduce sediment transport towards the harbour. This spur was built (Figure 13) and functioned well in trapping rocks, etc, (but, as expected, was too small to significantly affect sediment transport).

4.4 Current deflecting structure

The practical and economical feasibility of reducing the amount of sediment transported towards the port by means of a "current deflecting" structure attached to the main breakwater was investigated conceptually. This investigation included limited hydrodynamic modelling of various alternative extensions to the main breakwater (eg. Figure 14). Such a structure could possibly significantly reduce the annual amount of maintenance dredging required with potential substantial direct cost savings. As an example, the estimated cost/benefit ratio of a 200 m extension to the main breakwater is shown in Figure 15. An additional major benefit of such as structure could be significant savings in maintenance costs of the present main breakwater. (More detailed investigations are being proposed at present.)

5. Final Conclusion

Information gleaned on various components of the sediment transport regime led to a holistic understanding of the sediment balance/budget. In turn, this information could be applied practically in terms of: more efficient sandtraps, and new dump-site closer to the port, a spur which successfully protected the dolos armour units, and proposed extensions to the breakwater which potentially could significantly reduce maintenance dredging. Most of these applications have already led to significant savings on maintenance dredging costs for the port.

References

CSIR (1994a). Oos-Londenhawe: Sedimentasie, sandvangput en storting. *CSIR Report* EMAS-C 94020, Stellenbosch.

CSIR (1994b). Oos-Londenhawe: Beplanning en invloed van golfbreker-uisteeksel. *CSIR Report* EMAS-C 94046, Stellenbosch.

CSIR (1995). Port of East London: Sedimentation on the inside of the southern breakwater. *CSIR Report* EMAS-C 95034, Stellenbosch.

CSIR (1996). Reduction of dredging costs by limiting sediment transport towards the Port of East London: Feasibility Study. *CSIR Report* EMAS-C 96018, Stellenbosch.

Martin A K and Flemming B W (1986). The Holocene shelf sediment wedge off the south and east coast of South Africa. Knight R J and McLean J R (Eds), Shelf Sands and Sandstones. *Canadian Society of Petroleum Geologists*, Memoir II, p 27-44.

Schoonees J S and Theron A K (1996). Improvement of the most accurate longshore transport formula. *25 Intern. Conf. on Coastal Eng.*, Orlando, Florida. ASCE, Volume 3, Chapter 282, page 3652 - 3665.

Van Rijn L C (1989). Sediment transport by currents and waves - Handbook. *Delft Hydraulics, Report* H461, Volume 2, page 10.15 - 10.21.

WL|Delft Hydraulics (1996). Delft3D-FLOW version 0.1, User Manual release 2.48, WL|Delft hydraulic, the Netherlands.

Acknowledgement

The above investigations were conducted by the CSIR under contract to Portnet who paid for the work. The CSIR gratefully acknowledge the help and assistance given by Mr Vonk Claassens (The Port Engineer) and his staff in conducting these investigations.

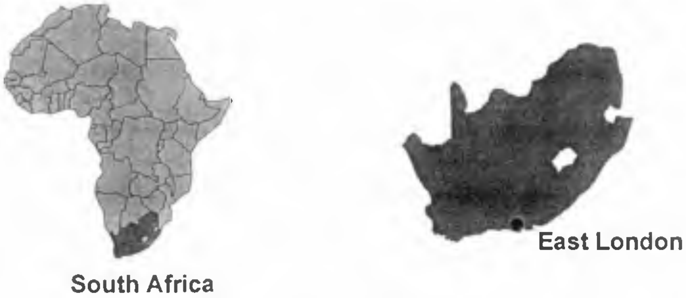

Figure 1: Site

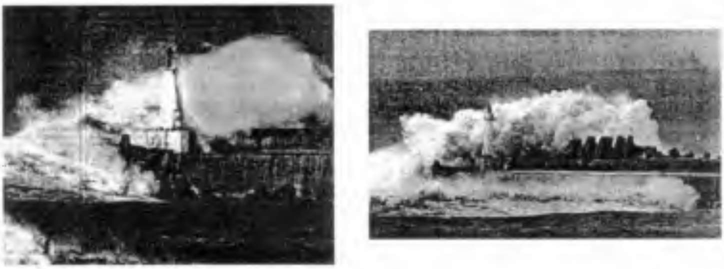

Figure 2: East London - Birthplace of the dolos

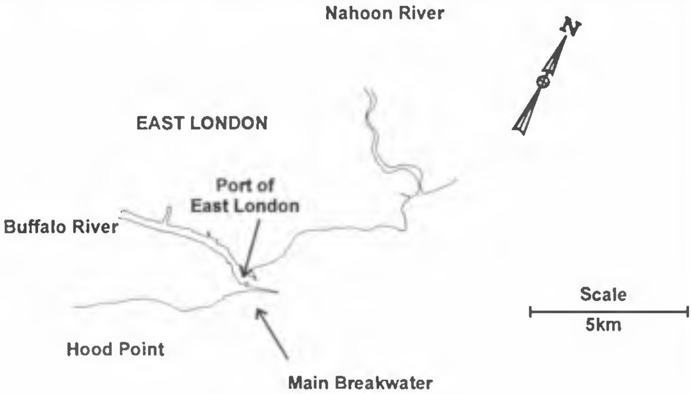

Figure 3: Location map

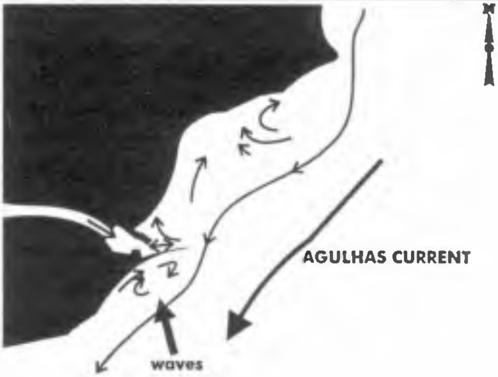

Figure 4: Complex current regime

T_p = 13,5s
H_o = 3m
θ = southerly

Figure 5: Wave refraction and bathymetry

MEASURING STATIONS

Current pattern	v (cm/s)	%
	46	64
	31	24
	12	8
	11	4

Figure 6: Current measurements

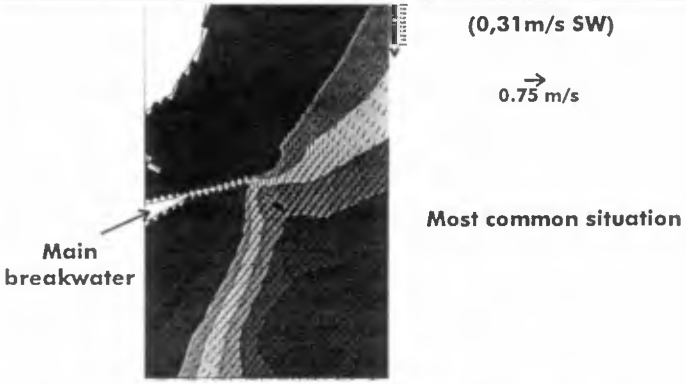

Figure 7: Current simulation

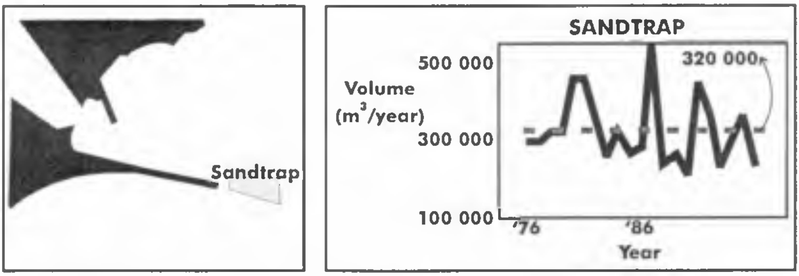

Figure 8: Sandtrap dredging records

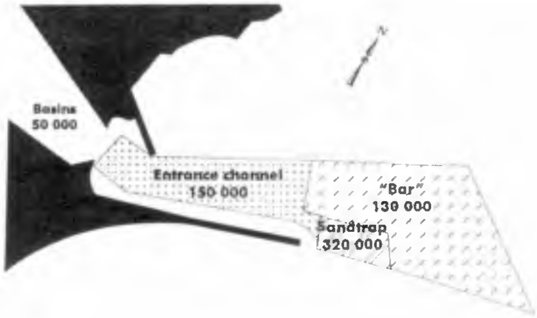

Figure 9: Annual dredging volumes (in m³/a)

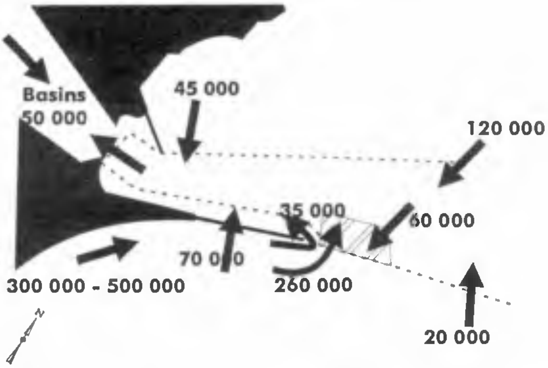

Figure 10: Sediment budget (m^3/year)

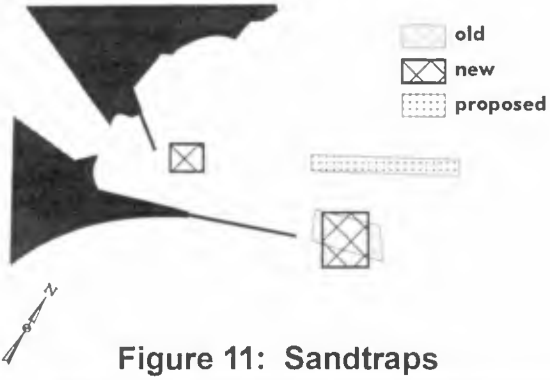

Figure 11: Sandtraps

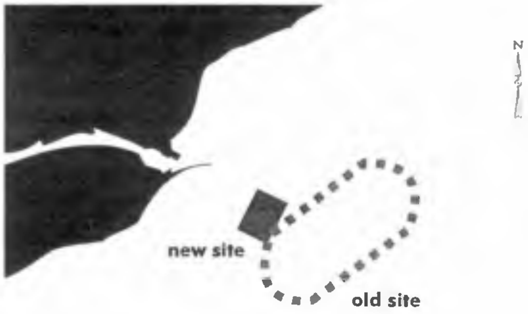

Figure 12: Dump sites

Figure 13: Rock Spur

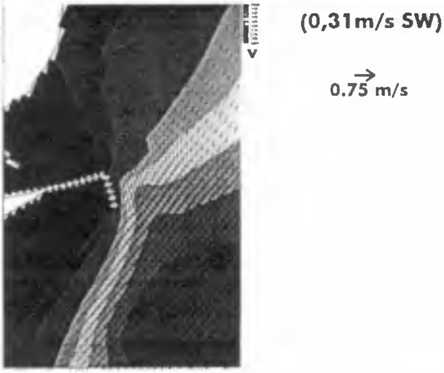

Figure 14: Currents around 300m extension

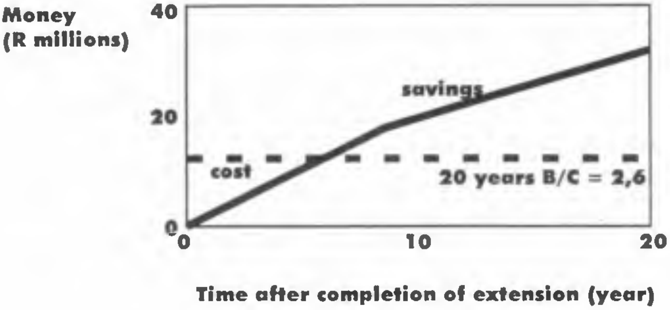

Figure 15: Cost/benefit of a 200m extension