CHAPTER 339

ASHDOD PORT'S EFFECT ON THE SHORELINE, SEABED AND SEDIMENT

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Abstract

During its 35 years of existence, Ashdod Port, Israel, caused changes to its physical environment. Analysis of aerial photographs and bathymetric surveys show that the port served as a sediment trap, blocking the natural northward sediment transport. Between 1958, prior to the port construction, and 1992 the beach to the south of the port underwent accretion which increased in magnitude from zero, at a distance of 2.5 km south of the port, to more than 100 m near the main breakwater. On the northern side of the port the shoreline was stable during that period. It was found that the beach north of the port did not suffer erosion because the sand of that beach was mined for building purposes prior to the port's construction. When the port was built, it was already a rocky beach.

Comparison between bathymetric surveys, which were carried out in the vicinity of the port, at various periods since prior to its construction until 1995, show that the port has trapped some 4.5 million m^3 of sediments on its southern side. Of these, about 2.2 million m^3 were deposited during the period of 1985-1995. It is estimated that more than half of this volume was deposited in 1992 during three very severe storms. On the basis of the depositional pattern in the vicinity of the port, and assumptions related to the net longshore sediment transport, it is estimated that more than half of the sediment volume bypasses the port northward.

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Introduction

Ashdod Port is located on the Mediterranean coast of Israel some 30 km south of Tel-Aviv. It was built between 1961 and 1964 on a straight sandy beach backed by sand dunes. About 200 m south of the main breakwater of the port Lakhish River discharges into the sea. The length of the existing main breakwater is 2,200 m and that of the lee breakwater is 900 m. The head of the main breakwater is at a water depth of 15 m, and the entrance of the port was 13 m deep when it was built. The port penetrates seaward from the shore to a distance of about 1,000 m.

Since the beginning of its operation in 1964, the volume of traffic in this port has continuously increased. Presently (1996), it handles some 13.7 million tons of cargo a year, but projections are for 15.4 million in the year 2000 and 16.6 million tons a year in 2010. It is therefore planned to expand the port by extending its main breakwater by 1,150 m to a water depth of about 21 m (Figure 1).

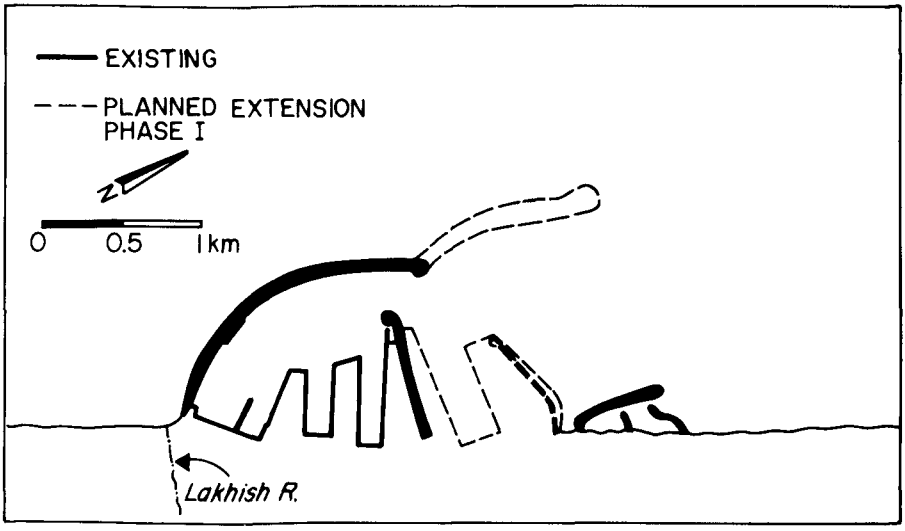

Figure 1. General plan for the planned expansion of Ashdod Port, phase I.

The increasing concern in Israel, as in the rest of the world, regarding the effect of coastal construction on the marine environment, led the authorities in Israel to impose preparation of environmental impact statements (EIS) for each major coastal structure. As part of the requests of the EIS for the expansion of Ashdod port, a numerical sedimentological model had to be carried out. This model should predict the effect of the port's expansion on the environment, and in particular on the nearby bathymetry, coastline and sediments. The present study was carried out in order to gather available information on the sedimentological development resulting from the

construction of the existing Ashdod Port, and to evaluate the effect of its breakwaters on the sedimentological balance in the area and the stability, in terms of erosion or accretion, of the seabed and of the shoreline. The results of this study should be used to calibrate and verify the above mentioned model.

Previous studies on the effect of Ashdod Port on the sedimentological processes in its vicinity were carried out by Kran (1980) who analyzed bathymetric profiles which were surveyed between 1964 and 1971 in the vicinity of the breakwaters. Computations of changes in the volume of sediment in the vicinity of the port between 1959 and 1975 were made by Finkelstein (1980) and between 1959 and 1985 by Vajda et al. (1988). Rosen (1985) assessed the longshore sediment transport rate at Ashdod on the basis of wave energy flux calculation.

Three data bases were used for this study:

(a)Aerial photographs, taken since prior to the construction of the port until the present. They enabled to detect shoreline erosion and accretion caused by the port,

(b)Bottom charts and profiles which were prepared before and after the port was built. These were used in order to evaluate changes in the seabed which were caused by the port.

(c)Wave climate resulting from wave observations and measurements carried out near the port since 1957. These were used to evaluate the natural rate of sediment transport in the area, and in particular the longshore transport.

Methodology

Analysis of Aerial Photographs

The changes in shoreline position which resulted from the construction of the port were measured by comparing aerial photographs, which have been taken on different dates since prior to the port construction until 1992. To avoid errors resulting from seasonal changes in the shoreline, only photographs taken during the autumn season were used. This season was selected because the sea is calm and the beach face is steep at that period. Therefore, horizontal change in the waterline due to sea level fluctuations, is rather limited. Also, wave records showed that during the photography sortie and the days preceding it, wave height was less than 1 m. Eight aerial photographic sorties from the years 1958, 1964, 1971, 1976, 1980, 1983, 1988 and 1992 were selected for this study.

The analysis of aerial photographs was that adopted by Shoshany and Degani (1992). The analog format of the photographs was transformed into a digital one using a digital scanner. Prominent objects in the photographs were used to relate photographs from different dates into a uniform geographic system.

The line which separates the wet part of the beach from the dry one was selected to represent the shoreline because it is clear and sharp on the photograph. Also, this line does not fluctuate momentarily as the water line does. This line was further

accentuated by enhancing the brightness contrast. The 1988 sortie was selected as a reference sortie, because it contained a large number of common reference points which were seen on photographs from preceding and succeeding sorties. These reference points were used to rectify the aerial photographs and remove distortions from them. Once this was done, the shoreline was digitized for each sortie. It is estimated that the error involved in determination of the shoreline position is less than 10 m.

Bathymetric Analysis

Bathymetric surveys in the vicinity of the port, which were conducted in 1957, 1959, 1970, 1975, 1980, 1983, 1985 and 1995, were used for this study. The surveying methods which were employed in these surveys changed during this period. Until the early 1970's, navigation was carried out by sextant readings from the boat to reference points on the beach, and depth was measured using a Kelvin Hughes surveying echo sounder. After 1972 navigation was carried out by an electronic system, Decca Trisponder, and later by Miniranger. Data processing, interpolation of boat position and depth reading, and collation of these data, were carried out manually until the beginning of the 1980's and gradually changed to computer processing in the early 1980's. The survey of 1995 was carried out using a differential GPS system for navigation and a digital Odom echosounder. The collation of depth and position was carried out on board the surveying boat, using the OCEANOGRAPHER navigation and mapping computer software system, developed and written for such purposes by the third author. The charts were digitized and an interpolated grid of depth points for each survey was prepared. Each grid was subtracted from its predecessor, and depth differential maps which show the magnitude and spatial distribution of deposition or erosion on the seabed were prepared.

Wave Data and Computation of Longshore Sediment Transport

Wave data have been collected from Ashdod Port region since 1957. Some of the data (1957-1975) were based on visual observations, some (1978-1992) on a combination of instrumental measurement (wave height and frequency) and visual observation (wave direction), and for three years, 1992-1995, wave height, frequency and direction were instrumentally measured. In view of the low reliability of the wave directions of the old wave data, the final computation of the longshore sediment transport rate, was based on the April 1992 - March 1995 wave data, gathered off Ashdod with a Datawell Wavec buoy at 3 hour intervals. These data were used as an input in computer programs using the formulas of longshore sediment transport known as the CERC (USArmy CERC-1984), Komar (Komar-1977), LCHF (Migniot et Manoujan-1983) and Bijker (Bijker-1972) formulae. The longshore sediment transport was computed for each sedimentological year, namely years starting in April on one year and ending in March of the following year, to comply with the sedimentological seasonal wave regime in this region.

To account for the longshore sediment transport taking place beyond the surf zone, the joint contribution of wave stirring and geostrophic current transport, current data statistics gathered by Israel Oceanographic & Limnological Reearch off Ashkelon, in 27 m water depth, were used in combination with the Bijker formula.

Results

Shoreline Position

Examination of the position of the shoreline south and north of the port, as derived from the aerial photographs analysis, reveals two phenomena. First, the distance between the positions of the shorelines of 1958, prior to the construction of the port, and 1964, when it was almost completed, is very small and falls within the resolution magnitude of the analysis. The second, is the change with time in the shoreline position south of the port versus those north of it. South of the port, a distinct accretion of the shore with time is noticed, whereas north of the port, the shoreline position is relatively stable with the exception of the sector in the immediate vicinity of the lee breakwater.

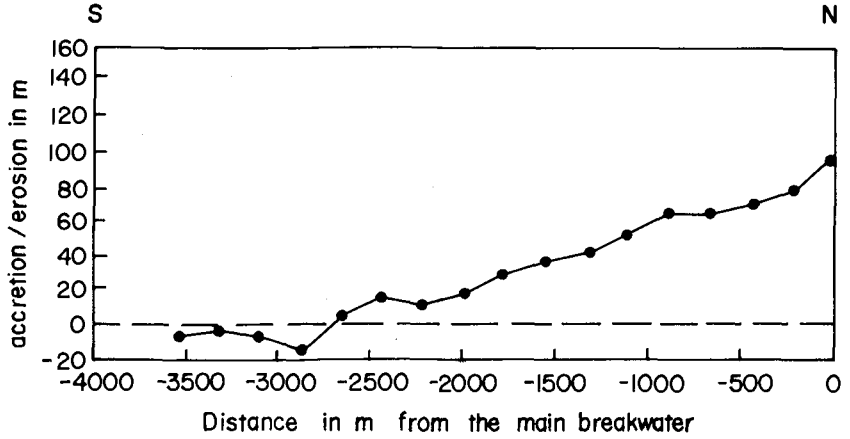

Figure 2. Difference in m between the mean position of the shoreline in 1958-1964 and that of 1983-1992 south of Ashdod Port.

Figures 2 and 3 were prepared with the purpose of showing the general trend in the development of the coastline, south and north of the port. It shows the distance between the mean position of the shoreline in the years 1958 and 1964 and that of the years 1983-1992. Figure 2 shows that during the study period the shoreline has advanced westward gradually from zero at 2,500 m south of the main (southern) breakwater to about 100 m near it. North of the port, Figure 3 shows that accretion has occurred very close to the lee (northern) breakwater, to a distance of about 300 m

north of it, but from there on northward, the position of the shoreline was rather stable during the study period.

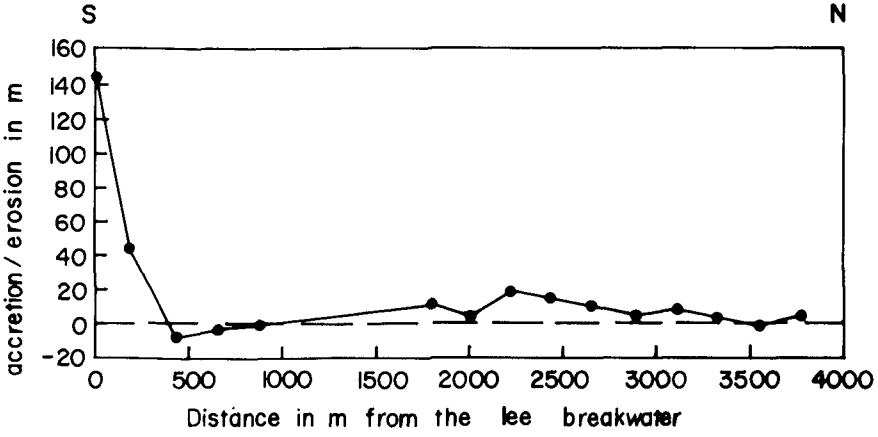

Figure 3. Difference in m between the mean position of the shoreline in 1958-1964 and that of 1983-1992 north of Ashdod Port.

Bathymetric Changes

Examination of the depth differential maps which resulted from the analysis of the bathymetric charts shows that the first impact of the port on the seabed was a severe erosion, up to 2.5 m, north of the port and deposition of up to 3.0 m next to the lee breakwater. With some fluctuations in magnitude, these effects remained throughout the history of the port.

Another phenomenon, which also started following the port's construction, is the increase of deposition near the beach south of the port as well as near the head of the main breakwater. Deposition increased both in thickness as well as in space with time. In 1975, sediment was "creeping" along the main breakwater reaching about a third of its length. In 1980, the depositional area south of the main breakwater increased, and the accumulation at the head of the breakwater increased in thickness. In 1983, deposition followed the same pattern but increased in thickness. Between 1983 and 1985, minor changes occurred in the sea bottom, but between 1985 and 1995, an impressive deposition took place along the southern part of the main breakwater and south of it, parallel to the beach, at a distance of between 700 and 1,000 m. The thickness of this deposition is mostly up to 2.0 m but in restricted areas up to 3.0 m. 4.5 million m^3 of sediment have accumulated in the studied area south of the main

breakwater between 1957 and 1995. Of these, 2.3 million m^3 between 1957 and 1985, and 2.2 million m^3 between 1985 and 1995.

Assessment of Wave Climate and Longshore Sediment Transport

Figures 4-6 show the average yearly marginal distributions of the deep water wave characteristics off Ashdod during sedimentological years 1993-1995 (04/1992 -03/95) using data bases of 3 hours data, noon daily data and maximum daily data. Figure 4 shows the marginal distribution of deep water characteristic wave heights, Figure 5 shows the marginal distribution of peak wave periods, and Figure 6 shows the marginal distribution of deep water wave directions for the mentioned period.

Figures 7 and 8 provide the average yearly marginal distributions of the general current characteristics off Ashkelon (15 Km south of Ashdod Port) which were measured in 1992-1993 (Rosen, 1993). The current was measured at a water depth of 27 m, 10 m below the sea surface. Figure 7 shows the marginal distribution of hourly averaged current speeds, and the marginal distribution of hourly averaged current directions is presented in Figure 8.

On the basis of these data and the various formulas mentioned before estimates of the longshore transport were obtained. As can be seen in Figure 9, there are differences of up to four times among the various formulas. The evaluation using the CERC formulae of the net transport is about 3 times larger (720,000 m^3/year) than that of Bijker formula (230,000 m^3/year) without accounting for the presence of currents

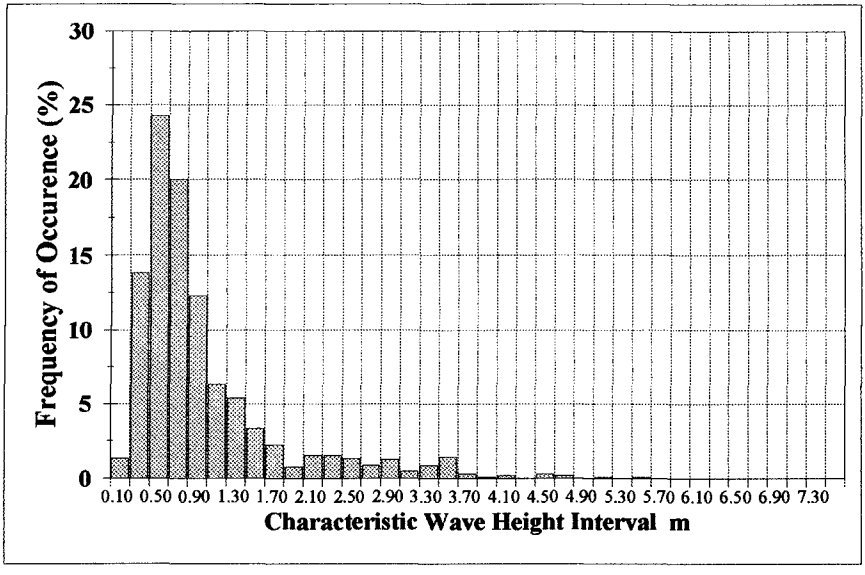

Figure 4. Yearly deep water distribution of characteristic wave height (04/92-03/95).

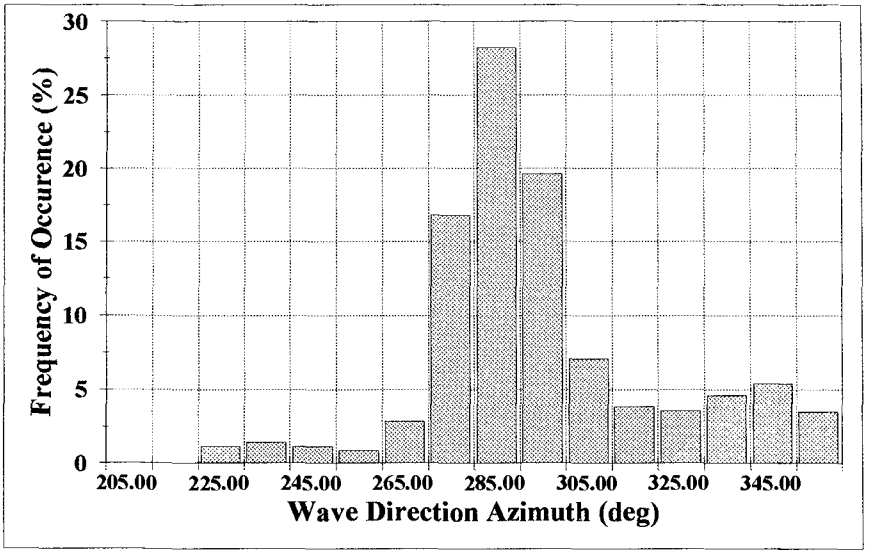

Figure 5. Yearly deep water distribution of peak wave periods (04/92-03/95).

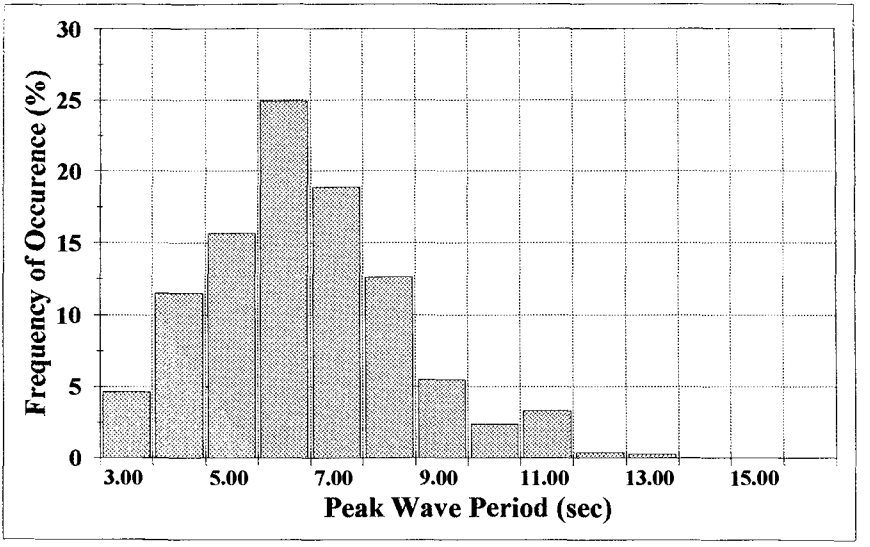

Figure 6. Yearly deep water distribution of wave directions (04/92-03/95).

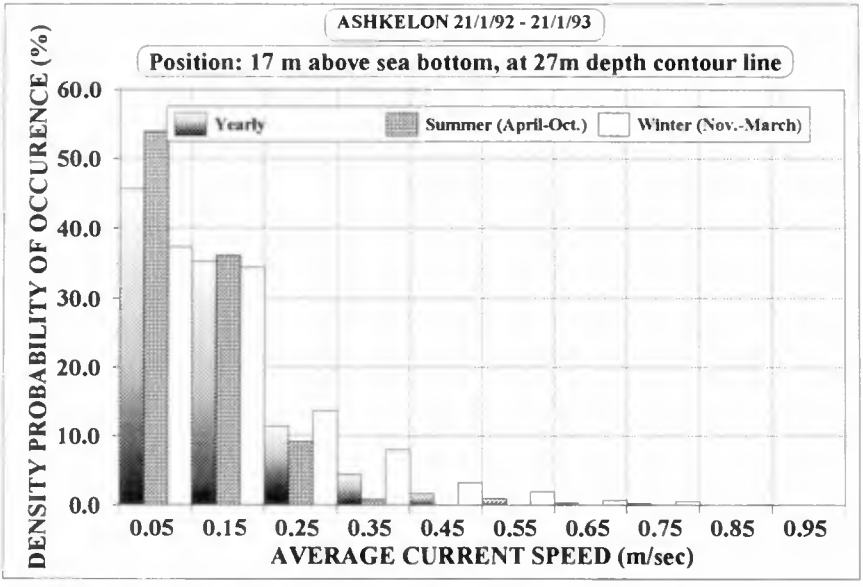

Figure 7. Current speed distribution offshore Ashkelon.

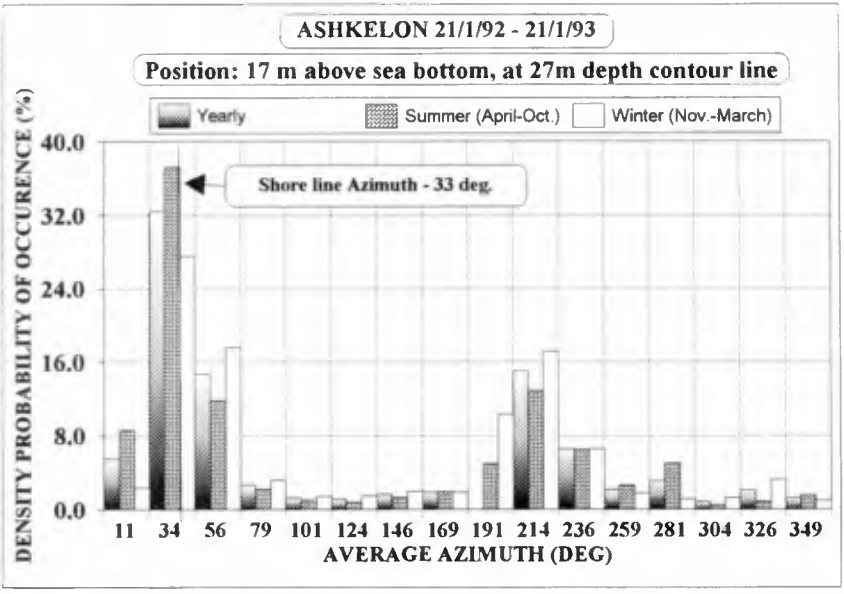

Figure 8. Current direction distribution offshore Ashkelon.

beyond the surf zone. The LCHF provides a value which is about 0.75 of the Bijker formula without currents beyond the surf zone. The comparison between the estimate of the transport with and without accounting for the currents beyond the surf zone is also presented in the same Figure. As one may see, the transport assessment including currents beyond the surf zone on the basis of the current statistics given in Figures 6 and 7 leads to volumes comparable to those of the CERC formula. In Figure 10 the yearly average longshore sediment transport distribution across the shore at Ashdod, based on the period 04/92-03/95, is presented.

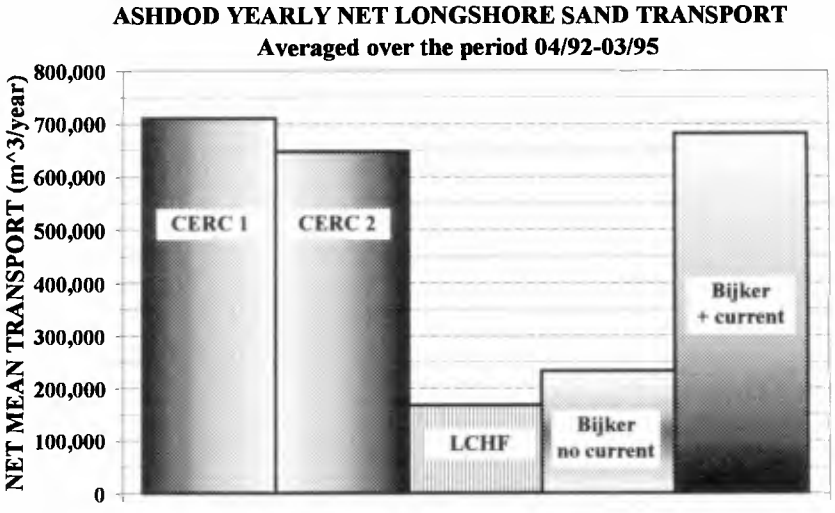

Figure 9. Comparison among methods of evaluation using the 3 hours data set.

Considering the fact that the assessment using currents was based by one year of currents data, during a harsher weather than in the following two years, the average longshore net transport was assessed on a weighted average between assessment with currents and assessment without currents. Thus, an yearly net longshore transport of 350,000 m^3 to the North was assessed as the most probable rate for a normal year.

Discussion

Shoreline Changes

The results of the shoreline analysis clearly indicate that the net sediment transport in the area of Ashdod Port is northward. Under these conditions, one would expect erosion to occur north of Ashdod Port, but no such erosion of the shoreline is noticed from the analysis of the aerial photographs. The reason for this is the sand mining activity which was very intensive on this beach until 1964. This can be seen in Figure 11, which is an aerial photograph taken in 1958, prior to the port construction. The

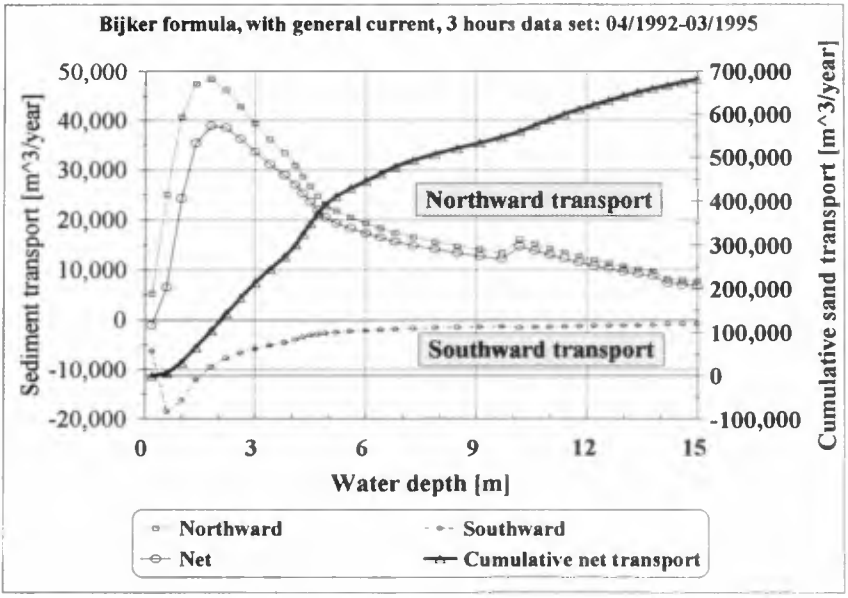

Figure 10. Yearly cross-shore sand transport profile at Ashdod (with currents).

scars of the sand mining are clearly seen on this picture, as well as on aerial photographs taken from the coast both north and south of this point. More than 5 million m^3 of sand were mined between 1949 and 1963 from the beaches stretching along some 30-40 km of the Ashdod coastline (Zifzif Committee, 1964).

Figure 11. Aerial photograph taken in 1958 showing the scars of beach mining along the Ashdod shoreline.

This mining must have left the coast either devoid of loose sand, or close to it. The sand trapped south of the port after its construction "healed" these scars and widened the beach. However, north of the port, the beach was already rocky before the port construction, lacking sand to be removed by erosion, and this is why the position of the shoreline remained stable. The rocky beach extends today to some 3.5 km north of the port, and from there on northward, sand becomes gradually more ubiquitous on the beach.

Bathymetric Changes

The most striking finding of the analysis of the sea bottom changes is the massive accumulation of sediment, more than 2 million m^3, which took place between 1985 and 1995. This raises a few questions: Was this accumulation a gradual one or an episodic event? What caused this rapid accumulation? Where did the sediment come from?

It was found that a bathymetric survey which was carried out in 1991 offshore Ashdod city, overlapped a small part of our study area in the south. Depth differential maps for the period 1985-1991 and 1991-1995 clearly showed that sediment accumulation which occurred in that area was greater in the period of 1991-1995 by many times than in 1985-1991. This indicates that the massive accumulation of sediment seen in the depth differential map for the period 1985-1995 occurred sometime between 1991 and 1995. The most prominent event that occurred in the period of 1991-1995 is a series of very severe storms which occurred in December 1991, February 1992 and December 1992. In one of them, February 1992, the deep water characteristic wave height was 7.2 m and in the others more than 5 m. Computation of longshore sediment transport rate using a simulated storm with waves of this magnitude resulted in a net transport of up to 400,000 m^3 per storm. The storms of 1991-1992 are therefore responsible for the large deposition of sediment which was detected in the 1985-1995 depth differential map.

There was, however, another source of sediment input into the area. The Lakhish River, which discharges into the sea just south of Ashdod Port, has flooded during the storms, particulary during that of February 1992. According to Hydrological Survey of Israel, the water flow of this river in 1992 was the largest ever to be recorded. Figure 12, which is an aerial photograph taken 10 days after the flood, shows an extensive shoal in front of the river mouth which was formed, at least partly, by the sediment brought by the river to this area.

Sediment Bypass of Ashdod Port

The issue of sediment bypass of Ashdod Port is an important one because it implies to what degree the port acts as an obstacle to the natural transport of sand to the northern beaches of Israel. However, the evidence for such a bypass is only an indirect one. The depth differential map for the period of the port's existence clearly

Figure 12. Aerial photograph taken on 14 February 1992, 10 days after the flooding of Lakhish River, showing the shoal which was formed in front of the river's mouth.

shows that the pattern of accumulation of sediment south of the port, follows the contour of the main breakwater, surrounds it, and there are areas north of the port in which sediment accumulation is already noticed. According to reports of the Ports and Railways Authority the entrance channel to ashdod Port is undergoing siltation. As it is unlikely that this siltation results from an on-offshore transport at this depth, it is another confirmation to the sediment bypass of the port.

It is difficult to provide the rate of sediment bypass because there is no direct way to measure it and we do not have quantitative information for all the parameters which control it. Nevertheless, an attempt was made to come up with an estimate which is based on assumptions and estimates. For the 10 year period between 1985 and 1995 some 3.5 million m^3 entered into the area as a result of the normal net yearly longshore sediment transport (350,000 m^3/yr x 10 years). In addition, the storms of 1992 yielded some 0.9 million m^3 (400,000 m^3/Feb.92 storm + 2 x 250,000 m^3 for the other 2 storms). It is estimated that Lakhish River contributed 0.25 million m^3 during the flood of 1992. All these add up to about 4.6 million m^3 that were input into the area south of Ashdod Port during that period of time. At that time 2.2 million m^3 of sediment were trapped in the area south of the port implying that 2.45 million m^3, i.e. more than 50% of the sediment managed to bypass the port during that decade.

Acknowledgments

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