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THE EFFECTS OF BALTIM DETACHED BREAKWATERS ON THE GRAIN SIZE VARIATIONS AND LITTORAL SAND DRIFTS, EGYPT

BY

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ABSTRACT

Baltim sea resort is located on a very active dynamically convex shoreline some 120 km to the east of Alexandria. The beach resort area of Baltim is located on a very active shoreline which has experienced a net long-term shoreline retreat of about 4-5 m/year. An intensive protective structures consisting of a series of emerged detached breakwaters were built to reducecoastal erosion at this resort beach . The present investigation attempts to study the affects of Baltim detached breakwaters on the variation of grain size and littoral sand drifts. Coarser peak of mean grain size is observed at the 300 m distance of profile no.2 for the period 1992-1997. This peak could be related to Baltim detached breakwaters which were built between 1991 and 1998. Also, median diameter of sand behind the detached breakwater has decreased steadily with time and with seaward advance of the sand wedge into increasingly protected zones. The eastern down-coast of Baltim detached breakwater (no. 4) suffered from severe erosion. The total annual erosion drift rate at the down drift side of these bearwaters was estimated to be 2.68×10^6 m^3/year. This erosion normally resulted from the tombolo sand formations trapped behind the detached breakwaters, which have totally interrupted the longshore sand movement trending east. On the other hand, the annual accretion drift rates at upcoast of the detached break- water were found 1.92×10^6 & 1.96×10^6 m^3/year, respeotively.

INTRODUCTION

The central headland of Burullus was formed by the old "Sebennetic" branch 1,000 years ago (*ORLOVA & ZENKOVICH, 1974*). During the period from 1800 to 1900, Burg El Burullus village, east of Lake Burullus outlet, has already been moved to the south two or three times because of a continuous trend of shoreline retreat (*COASTAL PROTECTION STUDIES, 1978*).

The beach of Baltim is one of the primary public resorts fronting the central sector of the Nile Delta coast at about 11 km east of the Burullus outlet (Fig. 1).

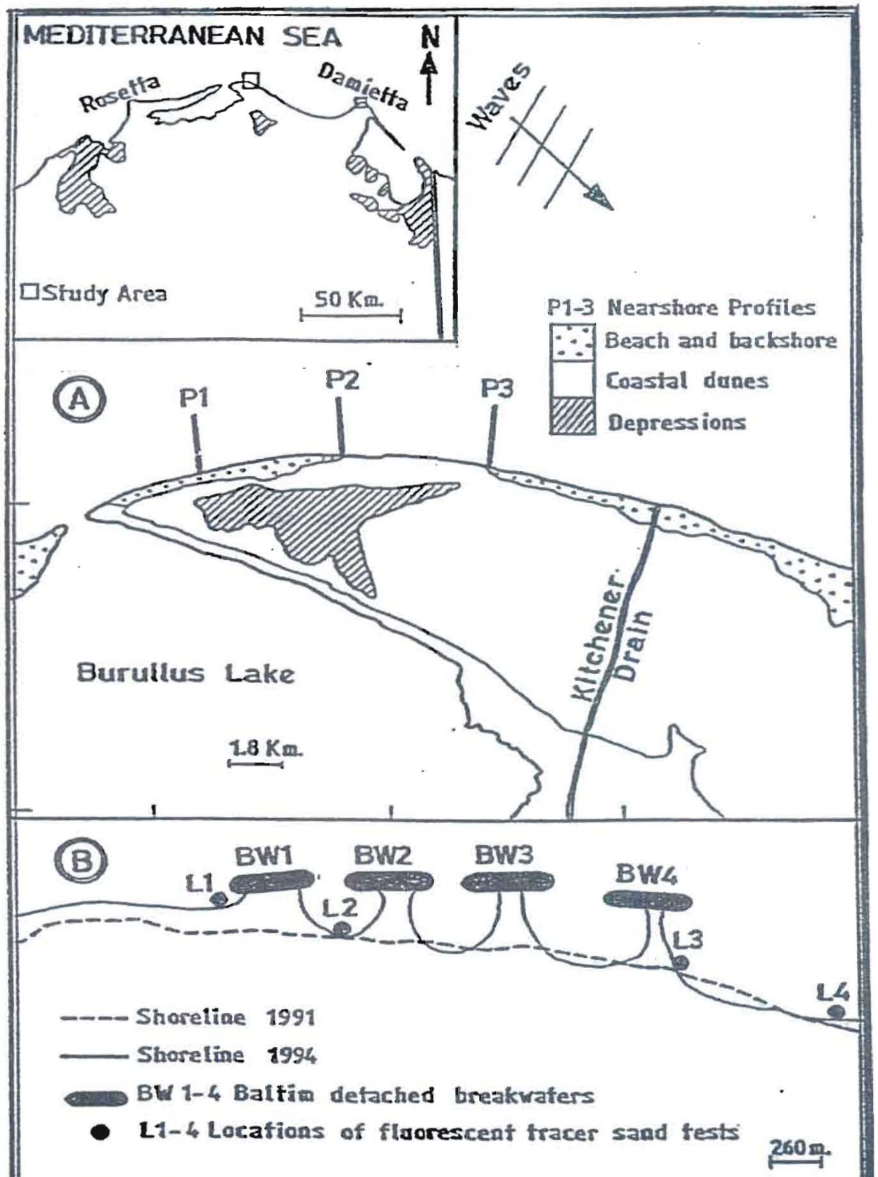

Fig. 1. Location map for the study area showing the nearshore profiles (A) and fluorescent tracer sand tests (B).

The beach is loacted on a very active coastline consisting of a sandy arcuate coastline, which has experienced a net long-term background retreat of about 4-5 m/year (*TETRA – TECH, 1984*). Annual shoreline fluctuations due to moving cusps, however, have been documented to be on the order of about 100m, and a number of houses have been lost to the sea. The erosion in this area harmfully affected some important resort beaches which preferably need to be nourished by artificial sand. A small scale nourishment activity has been carried out at Baltim in 1984/1989 as an emergency protection and recreation scheme prior to the final large scale project. The desert sand has been supplied using trucks from a quarry at the contact between the western limit of the Nile Delta and the desert, of about 280 km from Baltim beach. In order to protect and widen the Baltim beach, an offshore breakwaters in conjunction with sand nourishment have been designed by *TETRA-TECH, 1984*. *BADR* (1996) studied the evolutionary changes along Burullus outlet during the period from 1909 to 1994. *EL-ASKARY & BADR* (1996) studied the foreshore sediments of the Nile Delta promontories (Rosetta, Burullus and Damietta).

EL-KOLFAT (1999) studied the protection of Baltim beach by means of detached breakwaters. *FRIHY* (1999) studied the impact analysis and mitigation measures of Baltim breakwaters. An intensive erosion control project was initiated to combat beach erosion in this area consisting of a series of emerged detached breakwaters to reduce coastal erosion at Baltim resort beach. The construction of the first phase of Baltim detached breakwaters started in July 1991 and was finished in June 1993. This phase consists of four segments from west to east with length 250m, 250, 350 and 250m respectively (Fig. 1). The segments are separated by gaps with widths 320m, 320 and 404m, respectively. The distance of breakwaters from the original shoreline is 220m. The water depth at location of the detached breakwaters is 2.75m.

Unfortunately, unexpected local erosion was observed just downcoast in the vicinity of the lately (recently) formed breakwater No. 4. Therefore, the construction of second phase of Baltim detached breakwaters is an extension to first phase. This phase consists of three rubble-mound segments which was finished in December 1998, and three detached breakwaters (third phase) expected to be built to cover about 5km distance alongshore. As a result of the construction of these breakwaters from the land, the formation of tombolo has been substantially accelerated. For each breakwater, an earth rocky groin was made as a temporal walkway to facilitate access of constructing equipment and materials to the offshore site. Severe errosion is to be expected in the coming years as a result of the formation of the tombolo.

The present study aims to:

- Determining to what extent sand was moving alongshore in the upward, downward and between two structures.
- Study the grain size variations along the study area.
- Compare the mean grain size between 1989 (Pre-Baltim detached breakwaters) and 1994 (post-building Baltim detached breakwaters).

MATERIALS AND METHODS

The bathymetric survey of the coastline were carried out down to 6m depths in the form of three cross-sections from 6km east Burullus outlet to 16km eastwards (Fig. 1A), measured along a baseline close to the shore. A samples were taken every 100m from the baseline was collected. These profiles extend seaward for about 1km or less depending on the nature of the nearshore topography. Annual data of hydrographic survey and sediment samples are available for the years between 1989 and 1997. Grain size analysis for samples were carried out by the conventional sieving method using a vibrating shaker. About 100gm split of each sample was screened for 20 minutes using one-phi class interval (0, 1, 2, 3, 4 and 5 phi). Grain size parameters proposed by *FOLK & WARD* (1957) were obtained by using computer programme.

Fluorescent sand grains used in the present study have the same grain size distribution, specific gravity and shape features as the natural Baltim beach sands. They are readily distinguishable from the mass of sediment and are convenient to count. Four field experiments were performed in August 1994 during similar sea state and storm conditions (Fig. 1B). At each sampling site, a grid of 48 samples was collected from eight nearshore profiles distributed along 150m distance and extending seaward for 50m. In each experiment 21 kg of tracer sands were released at 10 and 20m distance. The field and laboratory techniques were applied according to *INGLE* (1966). Generally, two release points were located and 21 kg of tracer sands were released during each test. Tracer sands were usually released at the up-drift side of the sampling stations distributed in a rectangular grid system. In the laboratory, each sample was examined under short-wave ultra violet light and the number of tracer grains was tabulated and then plotted at their respective stations and isopleths were constructed resulting in contoured patterns of tarcer dispersion with time.

RESULTS

I. *Hydrographic features and sediment characteristics*

On the basis of erosion and accretion in underwater nearshore profiles, Baltim coast is found to be in a state of dynamic instability. The nearshore profiles are highly variable with time where the erosion zone of one year may become an accretion zone in the coming year and vice versa (Fig. 2). The hydrographic profiles have generally two slopes, one in the breaker zone (from beach to 3 m depth) has steep and the other beyond the breaker zone (up to 6m depth).

Table (1) illustates the data and Figure (3) shows the mean grain size along the shore for the period 1989 - 1997. A significant pattern of sediment distribution was observed at the 300m distance of profile No.2 for the period 1992-1997. The mean grain size for each year creates a peak. This peak may be related to Baltim detached breakwaters which were built from 1991 to 1998.

Table (1): Mean grain size in phi units along coastal profile sediments for the period of 1989 to 1997.

Year	Distance (m)		0	100	200	300	400	500	600	700	800	900
1989	P6	Depth	-2.4	0.5	2.4	3.3	3.1	3.8	4.4	5.2	5.7	
		Mz	2.29	0.97	1.99	2.01	2.82	2.82	2.83	2.59	2.61	
	P11	Depth	-1.7	0.6	2.4	3.0	3.4	4.4	4.8	5.4		
		Mz	1.95	1.32	1.42	2.71	2.73	2.96	2.96	2.95		
	P16	Depth	-0.1	-1.4	1.0	2.5	2.7	3.2	3.7	4.7	5.4	6.1
		Mz	2.07	2.09	2.39	2.09	2.82	2.64	2.71	2.81	1.09	1.51
1990	P6	Depth	0.8	1.8	2.6	4.2	5.2	6.0				
		Mz	1.28	2.34	2.27	2.69	2.68	2.76				
	P11	Depth	-2.5	1.8	2.8	2.4	3.8	4.1	4.4	4.8	5.2	5.8
		Mz	2.37	2.29	2.46	3.12	3.11	2.81	3.08	3.16	3.07	3.13
	P16	Depth	-1.2	2.4	1.3	2.8	3.2	4.2	4.2	4.7	5.3	
		Mz	2.55	0.55	1.97	3.10	3.06	3.14	3.02	3.18	3.11	
1991	P6	Depth	1.2	1.6	3.6	4.6	4.6	4.7	5.6	5.1	5.9	
		Mz	2.78	3.1	1.30	1.15	1.36	3.06	3.07	1.61	1.68	
	P11	Depth	0.9	1.9	3.2	3.9	4.7	5.1	5.6	6.0		
		Mz	2.35	3.08	3.12	2.99	3.17	3.21	3.26	3.25		
	P16	Depth	-1.4	2.4	4.0	4.4	6.2					
		Mz	0.80	2.36	3.09	2.82	2.21					
1992	P6	Depth	-0.3	1.0	2.8	3.5	4.6	5.2	5.8			
		Mz	2.60	2.23	2.30	2.97	2.93	2.34	0.41			
	P11	Depth	-2.5	-0.2	0.9	2.3	4.1	3.7	4.3	4.9	6.0	
		Mz	1.85	1.84	2.51	1.47	2.84	2.87	2.77	2.87	2.83	
	P16	Depth	-0.5	1.0	3.0	4.0	4.0	4.9	5.3	6.0		
		Mz	1.99	1.95	2.50	2.60	2.90	2.95	2.70	2.85		
1993	P6	Depth	-0.7	1.6	2.8	4.0	4.5	4.9	5.4	5.9		
		Mz	1.99	2.09	2.83	2.94	3.00	2.96	3.09	2.96		
	P11	Depth		-0.8	0.4	0.7	3.0	3.6	4.4	4.9	5.4	5.8
		Mz		2.06	1.56	1.50	2.92	2.91	2.93	2.95	2.87	3.10
	P16	Depth	-1.3	-1.0	1.6	3.5	3.8	4.0	4.1	5.5	5.9	
		Mz	1.73	2.04	2.23	2.25	3.20	3.03	3.11	3.27	3.04	
1994	P6	Depth	2.3	1.5	3.2	3.8	4.8	5.5	6.0			
		Mz	2.17	2.51	3.09	3.02	2.83	3.00	3.13			
	P11	Depth	-2.4	0.5	1.8	2.6	2.1	3.8	4.5	5.7	6.3	
		Mz	2.03	2.79	2.88	2.46	2.45	2.84	3.02	2.79	3.00	
	P16	Depth	-1.8	-2.7	-3.2	3.9	4.6	5.7	6.9			
		Mz	2.07	1.10	2.92	2.84	2.84	3.38	3.05			
1995	P6	Depth	-0.8	0.9	3.7	4.1	4.7	5.1	5.5	6.1		
		Mz	1.73	3.06	2.72	3.23	3.25	3.81	3.56	3.10		
	P11	Depth	-3.0	-2.1	0.9	0.9	1.8	3.5	4.1	5.0	5.5	6.0
		Mz	1.89	2.04	2.77	2.04	2.86	3.05	2.87	2.95	2.99	2.98
	P16	Depth	-1.1	0.7	2.4	3.2	3.8	4.6	5.0	5.6	6.2	
		Mz	1.35	2.04	2.80	2.45	3.36	3.12	3.33	3.10	0.86	
1996	P6	Depth	-2.0	1.3	3.3	3.9	4.3	4.9	5.5	6.0		
		Mz	3.06	2.95	2.95	3.19	2.84	2.56	2.48	2.84		
	P11	Depth	-1.6	-0.7	0.4	2.7	3.5	4.2	4.8	5.6	6.0	
		Mz	1.79	3.19	1.84	2.84	2.88	3.06	3.06	3.33	3.33	
	P16	Depth	-1.4	1.4	2.2	4.2	4.8	5.5	5.6	6.1		
		Mz	2.65	1.89	1.95	3.06	3.06	2.95	3.06	3.33		
1997	P6	Depth	0.2	0.9	2.6	4.0	3.7	4.5	4.9	5.5	5.9	
		Mz	2.33	2.74	2.84	3.06	3.06	3.06	2.95	2.95	3.19	
	P11	Depth	-1.6	-1.7	2.0	2.0	2.5	4.5	4.5	5.0	5.4	5.8
		Mz	2.26	1.74	3.06	1.59	3.06	2.95	2.84	2.95	3.06	3.06
	P16	Depth	-0.5	1.5	2.5	2.9	3.5	4.3	5.0	5.4	5.8	
		Mz	2.13	2.48	2.95	2.74	3.06	2.95	2.95	3.06	3.19	

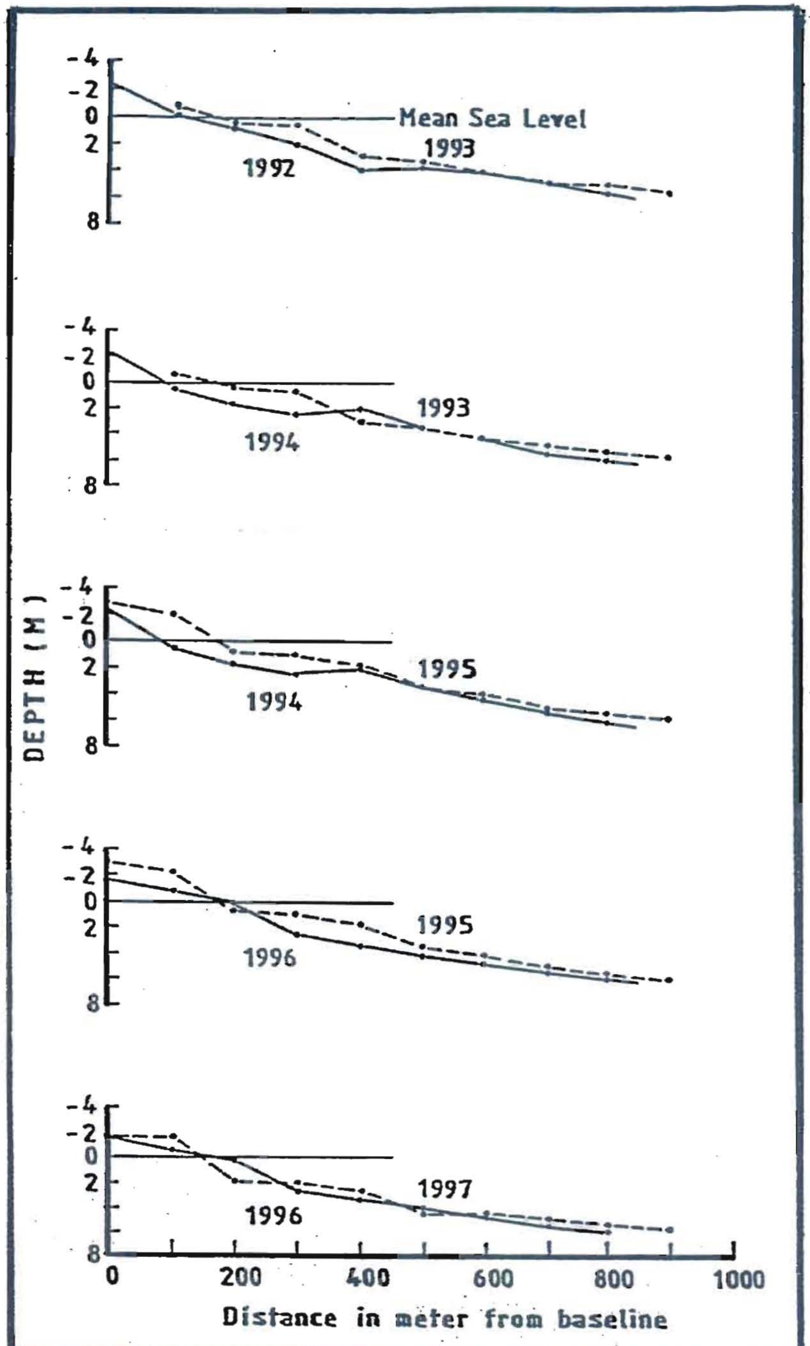

Fig. 2: Accretion and erosion of profile no. 2 during 1992- 1997.

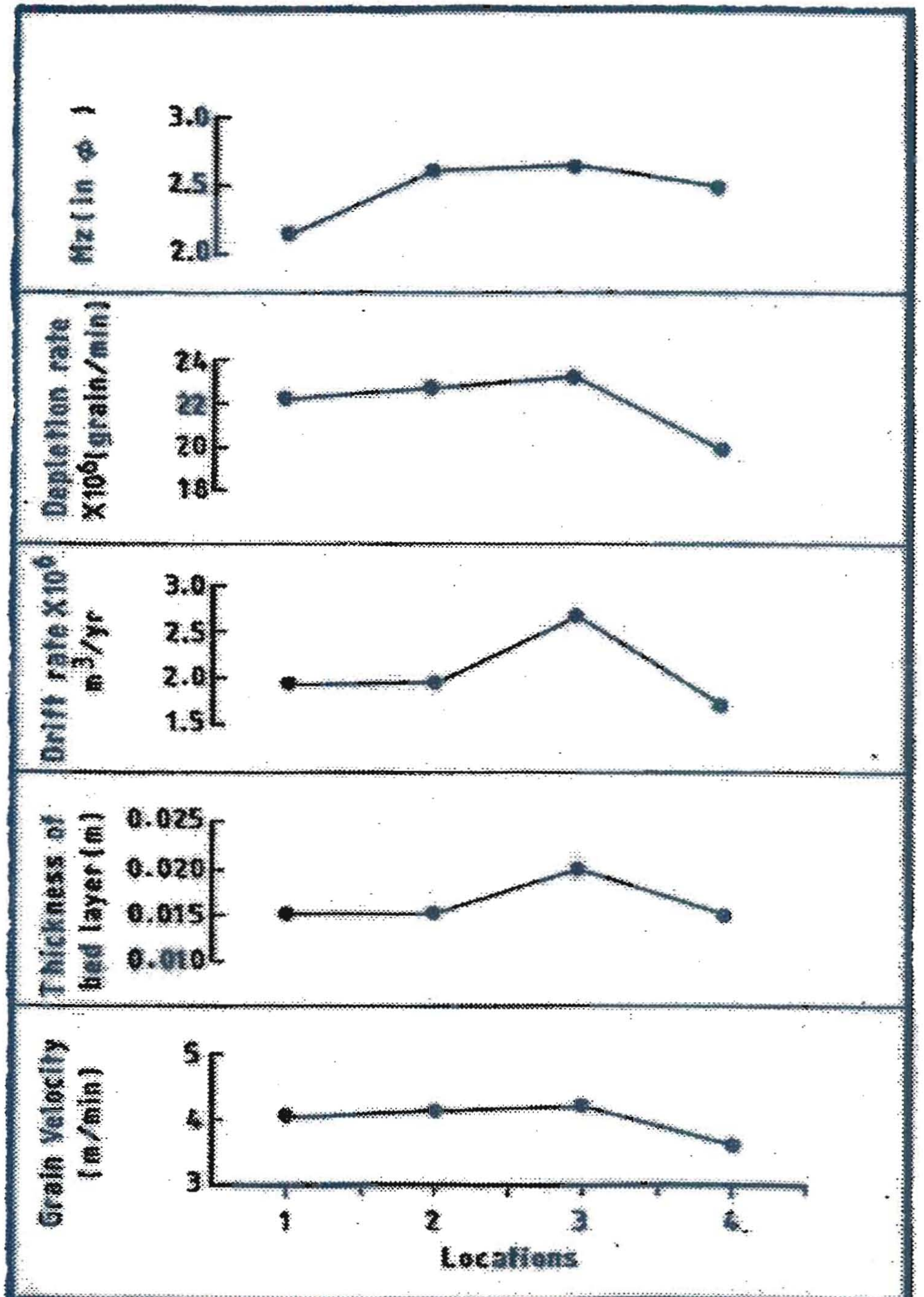

Fig. 3: Mean grain size off 300 m distance sediments along the study area.

The peak is considered to be more coarser than the other neighbouring sample points (Fig. 3). *EL-FISHAWI* (1992) mentioned that the coarser peaks of mean grain size were observed at locations 16,20 and 22 km east of the Burullus outlet from 1976 to 1988. These peaks occur in each position for a certain period of years and then tend to move eastwards. With the end of peak movement at location 22 km, it tends to move westwards to occupy the original site at the location 16 km.

Accretion of sand behind the breakwater is thus a lag concentration as previously pointed out by *HANDIN & LUDWICK* (1950). As accretion continues the shoreline moves seaward into areas of decreasing wave energy, causing a decrease in the median diameter of sand transport past the structure. This action is strikingly illustrated by the change in median diameter of sand behind the breakwater with time. Average median diameter of the pre-Baltim deatched breakwater beaches (1989) was 2.0 ϕ (0.25 mm), while average median diameter behind the detached breakwaters in 1994 at the time of the tracer tests was 2.48 ϕ (0.18 mm), Table 2.

Table (2): Comparison between mean grain size in both 1989 and 1994.

Location	Date	Mz, ϕ	Mz, mm
Loc.1	1/9/1989	1.95	0.258
	2/8/1994	2.15	0.225
Loc.2	1/9/1989	1.97	0.255
	3/8/1994	2.60	0.165
Loc. 3	2/9/1989	2.04	0.243
	3/8/1994	2.65	0.159
Loc. 4	2/9/1989	2.06	0.239
	2/8/1994	2.50	0.177
Average (1989)		2.01	0.249
Average (1994)		2.48	0.182

Thus, median diameter of sand behind the detached breakwater has decreased steadily with time and with seaward advance of the sand wedge into increasingly protected zones. This is in agreement with INGLE (1966).

Hydrodynamic forces affecting the study area

The hydrodynamic forces affecting the beach and nearshore zone are the wave heights, littoral current velocity and direction and sea level variation, while those affecting the processes that shape the coastal dune and backshore zone are the wind direction and velocity. This primary agents cause transportation and deposition of the coastal sediments and therefore change in the coastal processes.

Waves

This are the primary force operating on the beach and depend upon the winds that generate them in the open sea. Wave action along the coast is seasonal in nature and during the Winter season there are generally about 13 storms which cause severe erosion to the coast. The analysis of wave data during 1993 and 1994 shows that the average wave height was found to be 1.5 m. Also, it was observed that the maximum percentages of wave heights occurrences ranged between 1.4 to 1.6 m. The predominant direction of the waves is NNW, but during the Winter season waves approach the coast from the N, NNE and NE. The Summer season is characterized by NNW and NW swells.

Sea level variation :

Sea level variation influences to some limited extent the sediment movement along the Nile Delta shore by shifting the level of attack of wave action and by govering the flows in estuaries, lakes and drain outlets.

Recorded daily high and low water at Burullus outlet was analysed for the year 1994. The following gives the average sea level characteristics :

mean water level (20cm), mean high water level (22cm), mean low water level (18cm), highest high water level (75cm) and lowest low water level (-22cm). The tides along the Nile Delta coast are semi-diurnal in nature with two high and two low waters in a tidal day with comparatively little diurnal inequality.

Littoral current :

The breaking of waves at an angle with the beach causes the generation of a littoral current that flows along the shore. This current plays an important part in the longshore movement of beach materials, which is fundamental for erosion and accretion. The measurments of littoral current where carried out at the same locations and the same time of fluorescent tracer tests. Measurements were made by float and a stop watch to observe the time taken by the float traversing a know distance of 20m. The velocity and direction of the littoral current illustrated in (Table 3).

Table. 3: Result of tracer tests at Baltim coast.

Location	Date	Depletion rate × 10^6 (grain/min)	Grain velocity (m/min)	Thickness of mobile layer (m)	Drift rate × 10^3 m^3/day	× 10^3 m^3/month	× 10^6 m^3/year	Littoral current Velocity (cm/sec)	Dir
Loc.1	2/8/1994	22.21	4.05	0.015	5.2	157.5	1.92	62	E
Loc.2	3/8/1994	22.77	4.15	0.015	5.4	161.4	1.96	80	E
Loc.3	3/8/1994	23.25	4.23	0.020	7.3	219.3	2.68	75	E
Loc. 4	2/8/1994	19.95	3.63	0.015	4.7	141.1	1.72	70	E
Average			4.02				71.75		

Winds :

Winds are mainly the result of horizontal differences in pressure. The direction and strength of wind play an active role in controlling the process and form of sand accumulation. Daily measurements of winds were carried out by the station of Egyptian Meteorological Authority at Baltim. The obtained data include measurements made in 1990. The total wind rose diagram shows that 1-3, 4-6, 7-10 and 11-16 knots are mainly from NNW. During Summer season, the winds are mostly blowing from the NNW quadrangle. In Winter season the wind blows more often from SSW. Then, in February-April it blows fro NNW and N.

Sediment movement and dispersion

The technique of the present study depends on the rate with which fluorescent sand tracer grains left the respective sample grids. Field and laboratory techniques were made according to INGLE(1966). By using the approximate number of tracer grains released during the field test and the number of tracer grains remaining within the sample grid at any elapsed time (Fig. 4), the number of tracer grains leaving the sample grid can be determined then, the average depletion rate, i.e. the number of tracer grains leaving the sample grid per minute, can be estimated.

Thus, it is indicated to compute the sediment drift according to the following four equations of INGLE (1966) :

$$t_{50} = \tfrac{1}{2}\, G/D_e \quad (1)$$

$$U_g = I/t_{50} \quad (2)$$

$$V = K.W.B. \quad (3)$$

$$Q_i = V.U_g.\, 1440 \quad (4)$$

where t_{50} = time for one half the total tracer grains to leave the sample grid (in minutes).
G = total number of tracer grains released.
D_e = average equilibrium depletion rate (grains/minute)
U_g = average grain velocity (meter/minute)
I = distance of tracer travel (m)
V = unit volume of sand movement (m)
K = constant beach length of 1 m
W= width of the foreshore-inshore zone (m)
B = depth of the mobile layer (m)
Q_i= rate of drift (m^3/day)

Fluorescent tracer experiments are conducted under a wide variety of foreshore/inshore conditions. Littoral direction of tracer movement at each of the tested beaches reflected the relationships of seasonal variation in direction of littoral current and waves approach along Baltim coast. Generally, waves arriving from NW cause dominantly eastward littoral drift. It must be emphasized that the grain size velocity calculated according to INGLE (1966) presumably represents an estimate of the velocity of all travelling sand grains.

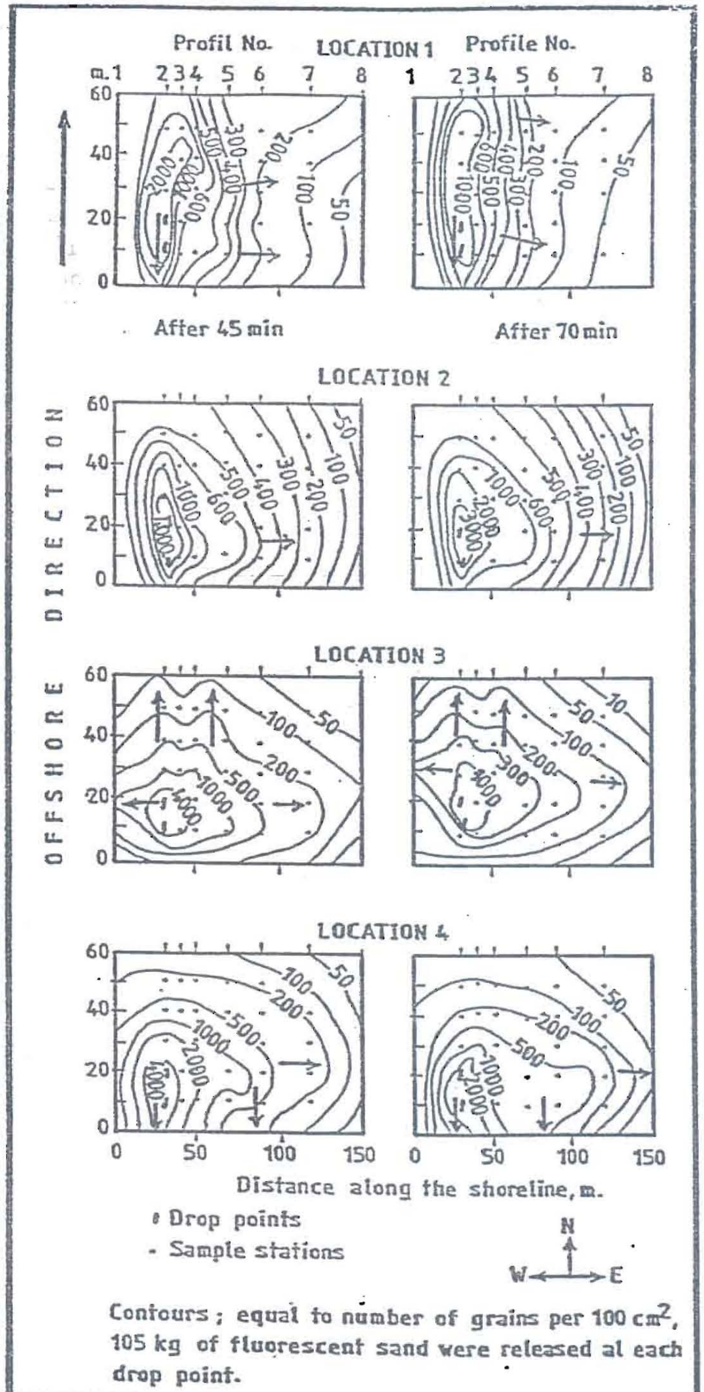

Fig. 4: Dispersion of fluorescent sand across foreshore-inshore area affected by littoral current.

Sand movement around Baltim detached breakwaters

Coastal engineering problems have provided a major impetus for research inside the dynamics of nearshore sediment transport. Modern sediment tracing techniques offer the most significant tool yet devised to accomplish this task in the field. During this investigation, sand movement was traced in upward, downward and between two structures (Fig. 1). The fluorescent sand experiments are useful tools to estimate the sediment discharge, drift rate and direction. Variation in longshore current direction and velocity, presence of natural or artificial barriers are the main factors which play an effective role in determination of magnitude and direction of sediment dispersion in the studied area.

The calculated average grain velocity was found to be in the range of 3.63 – 4.23 m/min. The mean grain velocity for all tests was about 4.02 m/min (6.7 cm/sec). Thus, the mean grain velocity on all the tested beaches was approximately 1/11 of the mean littoral current velocity (71.75 cm/sec), Table 3. The relatively low values of average grain velocities indicate that the bulk sand load travel along the beach has a slow rate. These values also suggest that most of the sand grains travel in traction manner or within the mobile layer rather than in suspension manner (INGLE, 1966). The present study indicates that grain velocity is effective in the resultant drift rate (Fig. 5). To a lesser degree the thickness of the mobile layer is also effective. The effect of mean grain size on the drift rate is a matter of controversy. WATSON (1970) stated that the rate of transport increased with the increase of grain size diameter within the sand size range, while YASSO (1976) indicated an inverse relationship. A monotonically increase of speed of transport with decreasing mean grain size was observed by DUANE & JAMES (1980). The present study shows that the grain size diameter is not significant in estimating the sediment transport rate.

Interpretation of fluorescent tracer maps

The examination of fluorescent tracer maps revealed that longshore current plays an important role in the sediment dispersion. The longshore current and sediment pattern were created by the low angle of breaker incidence which was too small to cause a strong unidirectional current. Table (4) illustrates a percentage of occurrence and drift rates for each direction of sediment movement along Baltim coast. The four examined locations within the studied area will be discussed individually to detect the different directions of sediment transport. Figure (4) shows a dispersion of sediment transport pattern along Baltim coast.

Location 1 :

Patterns of fluorescent sand dispersion indicated that a significant percentage of tracer grains were transported eastward (66.67%) under all weather conditions. So, the easterly longshore transport is responsible for the largest amount of sand movement along the beach. A considerable portion of the sediments showed a distinct tendency to move landward (33.33%). The annual drift rate in this location was found to be 1.92×10^6 m^3/year. The detached breakwater No.1 plays an effective role in obstructing eastward drift. Therefore, the most prominent portion of sediments moving to east (66.67%) and estimated to be 1.28 × 10^6 m^3/year is responsible for the accretion processes at this location (Table 4 and Figure 4). The landward drift (33.33% ; 0.64 × 10^6 m^3/year) is also effective in encouraging beach accretion.

Location 2 :

The fluorescent test was performed between two detached breakwaters (nos 1 & 2). The pattern of movement indicated that the most prominent trend of a large percentage of fluorescent grains was their tendency to move eastward (50% ; 0.98 × 10^6 m^3/year) and landward (50%; 0.98 × 10^6 m^3/year). The annual drift rate was estimated to be 1.96 × 10^6 m^3/year. It is also observed that accretion is predominant at this location. Following construction of the first two detached breakwaters (Nos. 1 & 2), they have produced accretion and rapid formation of tombolos with large contact widths. As a result of the formation of the tombolo, extensive development of the entire beach frontage has rapidly increased before completing the other breakwaters.

Location 3 :

Fluorescent tracer test was performed downward of detached breakwater No. 4. As shown from Table (4) and Figure (4), the greatest tracer dispersal occurred at the offshore (50%). Such offshore transport emphasized the ineffectiveness of littoral current to generate strong unidirectional of flow (EL-FISHAWI, et al., 1991) .The relatively higher values of the average annual offshore drift rate (1.34× 10^6 m^3/year) than that of both the eastward (0.67× 10^6 m^3/year) and westward (0.67× 10^6 m^3/year), indicate that the offshore sediment movement is the main responsible for the observed erosion at the downdrift. Therefore, the eastern side of the detached breakwaters (No.4) suffered from severe erosion. The total annual erosion drift rate is found to be 2.68 × 10^6 m^3/year. This erosion normally resulted from the tombolo sand formation trapped behind the first and second detached breakwaters, which have totally interrupted the longshore sand movement trending east. The sudden erosion observed in this local area has not previously occurred at a higher rate than occurred previously.

Location 4 :

Fluorescent sand map (Fig. 4) showed that the most prominent trend of a large percentage of tracer grains was their tendency to move landward (66.67% ; 1.15 × 10^6 m^3/year). A lesser portion moved eastward (33.33% ; 0.57 × 10^6 m^3/year). It is interesting to observe that the accretion phenomenon was found to be predominate. The annual accretion rate estimated to be 1.72 × 10^6 m^3/year. A number of studies have indicated that accretion of sand behind the breakwater is due to the reduction in competence of longshore currents and breaker action resulting from the diffraction of waves by the breakwater (GRANT SHEPARD, 1940; HANDIN & LUDWICK, 1950).

Table 4: Percentage of occurrence and drift rates (x 10^6 m^3 /year) for each direction of sediment movement along Baltim coast.

Location	To E		To W		Offshore		Land ward		Total annual Drift rate
	%	Drift rate	%	Drift rate	%	Drift rate	%	Drift rate	
Loc. 1	66.67	1.28	-	-	-	-	33.33	0.64	1.92
Loc. 2	50.00	0.98	-	-	-	-	50.00	0.98	1.96
Loc.3	25.00	0.67	25.00	0.67	50.00	1.34	-	-	2.68
Loc. 4	33.33	0.57	-	-	-	-	66.67	1.15	1.72

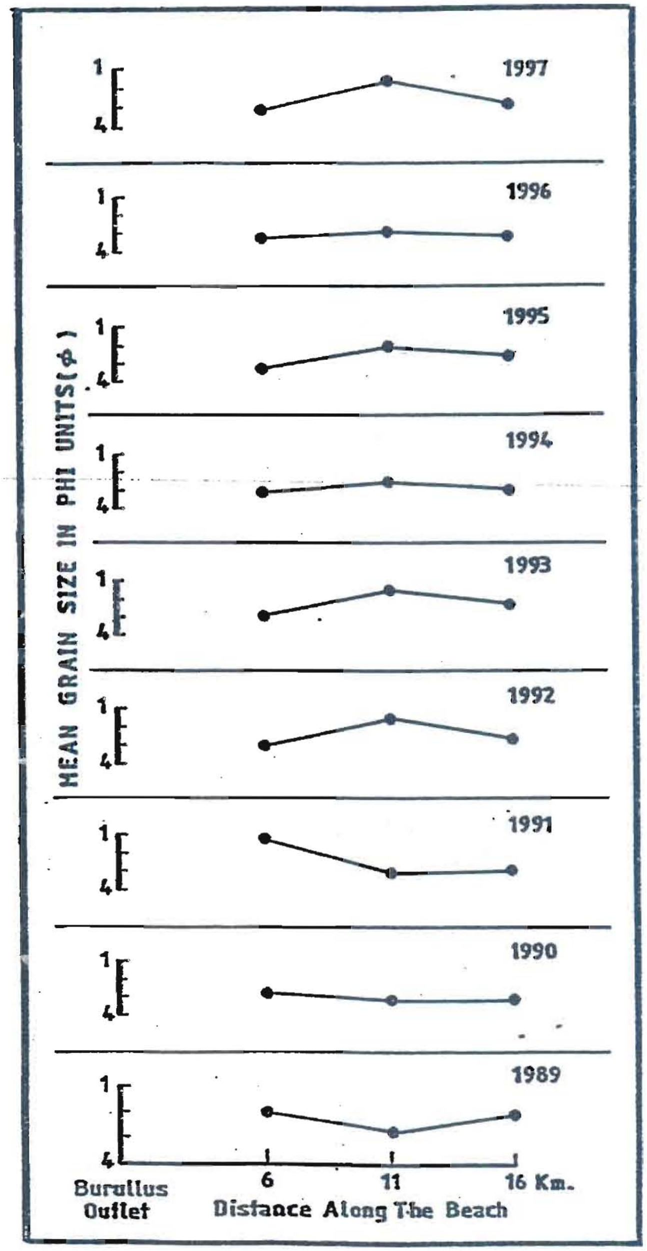

Fig. 5: Resultant grain velocity, thickness of mobile layer, drift and depletion rates and mean grain size at Baltim coast.

CONCLUSIONS

The study of grain size variation and sediment drift rates at Baltim detached breakwaters, leads to the following conclusions :

1) The nearshore profiles are variable with time where the erosion zone of one year may become an accretion zone in the coming year and vice versa.
2) The sediments at the 300m distance of profile no. 2 have coarser peak than that of profiles 1 & 3 for the period 1992-1997. This peak could be related to Baltim detached breakwaters which were built from 1991 to 1998.
3) Median diameter of sand behind the detached breakwater has decreased steadily with time and with seaward advance of the sand wedge into increasingly protected zones.
4) Relatievly high rates of sediment drift are obtained by increasing of grain velocity and mobile layer thickness.
5) The eastern side of Baltim detached breakwaters (no. 4) suffered from severe erosion. The total annual erosion drift rate was estimated to be 2.68×10^6 m^3/year. This erosion normally resulted from the tombolo sand formations trapped behind the first and second detached breakwaters which have totally interrupted the longshore sand movement trending east. On the other hand, the total annual accretion drift rates at first and second fluorescent tracer tests were found 1.92×10^6 m^3/year & 1.96×10^6 m^3/year, respectively.

As a suggested temporal remedy of this problem is to remove part of the tombolo to allow sand to bypass normally alongshore and so nourishing the erodede areas in the downcoast.

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