Coastal characteristics and behaviour for eastern Nile Delta region, Egypt (Burullus- Port Said)

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The Egyptian government has implemented many measures to protect the eroded areas by constructing seawalls, jetties, groins, revetments, and detached breakwaters. Coastal zone characteristics are different from one site to another in their formation due to hydrodynamic forces resulted from waves, currents, tides and site characteristics. The study area extends from Al-Burullus outlet to Port Said city along the northern coast of the Nile Delta. The Nile Delta coast suffers from severe erosion problems. Erosion has caused huge damage to the coastal regions at Al-Burullus village, Baltim city, Ras El-Bar, and Port-Said. The Coastal Research Institute (CoRI) has developed a plan to study the coastal factors along the Egyptian coasts through an intensive field work program. Field work consists of hydrographic surveying, recording of sea level rises, wave characteristics and current velocity measurements. These surveying have been carried out and completely analyzed to study the changes of the beach characteristics as shoreline changes, bed slopes, submerged bars and the coastal sediment transport. Measurements indicate that seabed slope is steeper near the shore than at the off shore zones according to the decreasing of the bed grain size. Also, it was noticed that, there are two or three rows of submerged bars parallel to the shoreline. The majority are about 1.5 m high and located at distances vary from 50 to 200 m off the shoreline. Measurements also indicate that there is shoreline advance at zones of up drift of coastal structures. On the other hand, there is shoreline retreat and erosion at zones of down drift of the structures' lee side. This erosion took place due to the action of the littoral processes (wave and current actions). The present study recommends using sand nourishment in addition to constructing a system of groins with proper spacing and length in order to overcome erosion of the down drift sides of the structures.

يقوم معهد بحوث الشواطئ التابع للمركز القومى لبحوث المياه بتنفيذ برنامج بحثي مكثف يعتمد على قياس العوامل المؤثرة مثل الأمواج البحرية والتيارات الساحلية والمد والجذر وكذلك المسح البحري وذلك لتحديد أماكن النحر والترسيب وتوزيع الكثبان الرملية الساحلية وميول قاع البحر وتكوين الضهارى (ترسيبات متراكمة تحت سطح الماء) البحرية ومتوسط حجم حبيبات القاع على طول الساحل لمنطقة الدراسة. ويتناول البحث دراسة المنطقة الساحلية من بوغاز البرلس حتى بور سعيد وهذه المنطقة تعتبر الجزء الشرقي من دلتا نهر النيل وهى تتعرض للنحر منذ سنوات عديدة. وقد اتخذت عدة إجراءات لحماية تلك السواحل في منطقة البرلس ومصايف بلطيم ورأس البر وبور سعيد. وقد تم تحليل البيانات التى تم جمعها خلال عامى ٢٠٠١و٢٠٠٢ واوضحت النتائج وجود ترسيبات غرب اعمال الحماية فى كل من البرلس و بلطيم ورأس البر. كما لوحظ وجود نحر شرق تلك الاعمال وذلك لاعتراضها لحركة الرواسب فى الاتجاه السائدة من الغرب الى الشرق والتى نتجت من الامواج الساقطة فى الاتجاه السائد الشمالى الغربى بنسبة ٦٩% وبارتفاعات من ١-٢ متر وفترة زمنية من ٦-٧ ثانية والتى ادت الى تكوين تيارات ساحلية من الغرب الى الشرق بنسبة ٧٤% وسرعة متوسطة ٤٦سم/ث. وتقترح الدراسة حماية مناطق النحر الناتجة شرق اعمال الحماية بعمل تغذية صناعية من الرمال الخشنة مع نظام من الرؤوس البحرية القصيرة.

Keywords: Nile Delta coast, Hydrodynamic, Shoreline, Coastal structures

1. Introduction

The study area is located on the eastern part of the Nile Delta coast, fig. 1. It extends from Al-Burullus outlet in the west to Port-Said in the east with a total length of about 140 km. The coastline of this area features a hump in the area of Baltim and a promontory in the area of Damietta, with a large concave shoreline in between. It is also characterized by five openings, namely: Al-Burullus outlet, Kitchener drain, Gamasa Drain, Damietta outlet and El-Gamil outlet for Al-Manzala Lake. In addition, Damietta harbor is located to the east of Gamasa drain as shown in fig. 1.

The Nile Delta coast has suffered from erosion problems since 1900, except in Al-Burullus area where erosion started 1000

years ago as mentioned by Orlova and Zenkovich [1]. Due to the erosion problem, the village of Burg El-Burullus has been relocated further in land, Ras El-Bar summer resort and some of its infra-structure has been destroyed. The eroded sediment has been transported towards the east, Manohar, M [2] and [3] causing the siltation at the outlets of Al-Burullus & Damietta outlets and causing the others to migrate eastwards (Kitchener and Gamasa drains outlets).

The Coastal Research Institute (CoRI), National Water Research Center (NWRC), Ministry of Water Resources and Irrigation (MWRI), has conducted an intensive field work program study. The program consists of surveying of the hydrographic profiles shown in Fig. 2, recording of sea level rise, wave characteristics, and current velocities.

The Egyptian government has implemented many measures to protect the eroded areas by constructing seawalls, jetties, groins, revetments, and detached breakwaters. All these types of structures were built to protect the eroded zone along the coast of the study area at Al- Burullus, Baltim resort and Ras El-Bar, fig. 3. Unfortunately, the negative effects (severe erosion) were observed on the lee coast of these structures. Accordingly, field measurements were carried out to study these problems. The measurements are naval profiles, grain size, waves, littoral currents, and tides. The measured field data were analyzed and represented.

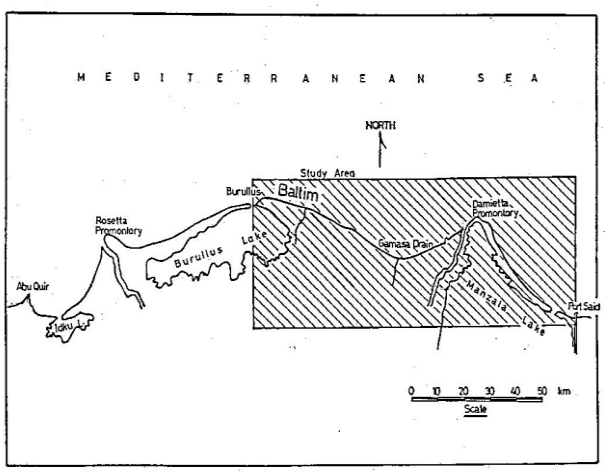

Fig. 1. The study area.

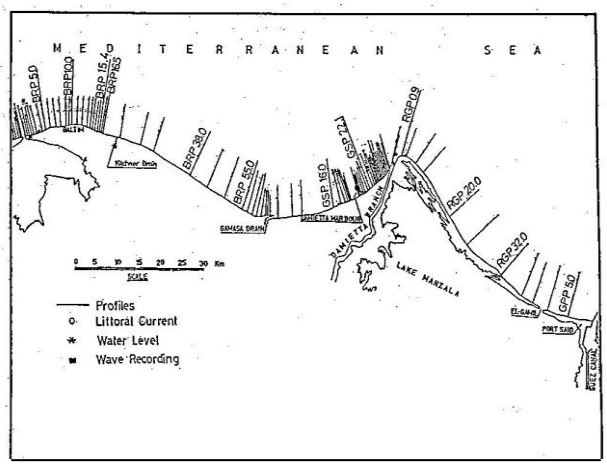

Fig. 2. Location of hydrographic profiles and hydrodynamic activeties.

2. Objectives of the study

a- Identify the problem of coastal erosion of the eastern Nile Delta coast.
b- Evaluate the driving forces controlling the severe erosion along the study area, and mitigation measures to help in solving
c- Propose mitigation measures and structures to cope with erosion

3. Description of protection works along the study area

3.1. Protection works along the study area

3.1.1. Burullus seawall

Al Burullus seawall was built in 1984 with a width of 5m and level of + 2.5m, (amsl). Geotxtile polyester membrane was spread at a level of –3.5 ms on the bed. Fragments of basalt were filled above it, and 1m^3 concrete blocks were placed randomly against the seawall in order to disperse the action of waves.

The seawall was extended at each end by a flexible, protective mound of bazalt fragments 2.5m above MSL, with a crest width of about 10 m. The front slope of the mound is 1: 4. The extensions were from the western end to the eastern jetty and from the eastern end for a distance at about 900 m, as shown in fig. 3. Beynd that, sand dunes extend along the east wards.

3.1.2. Burullus outlet jetties

The jetty on the western side of Al Burullus outlet was constructed around 1971. It extends about 120m into to sea. Another jetty was constructed in 1982 lies on the eastern side of the Outlet at a distance of about 280m from the western one. Due to the eastern jetty, the sediments deposited upstream of it caused the partial shoaling of Al Burullus outlet. CoRI 1985 studied the water movement, the currents, and the changes of the outlet cross sections, and designed an equilibrium cross section. Also, it is recommended to construct of a new jetty in the middle of the outlet and extending the western one. As a result, the width of the outlet decreased to 88 m in 1990 after El-Kolfat [4], as shown in fig. 3.

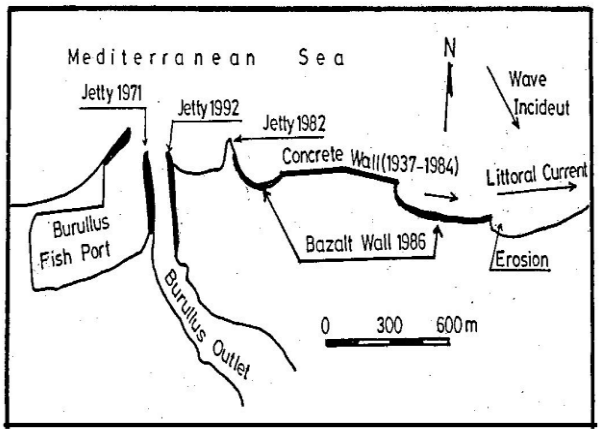

Fig. 3. Burullus protection work outlet jetties and Burullus fish port, still under construction.

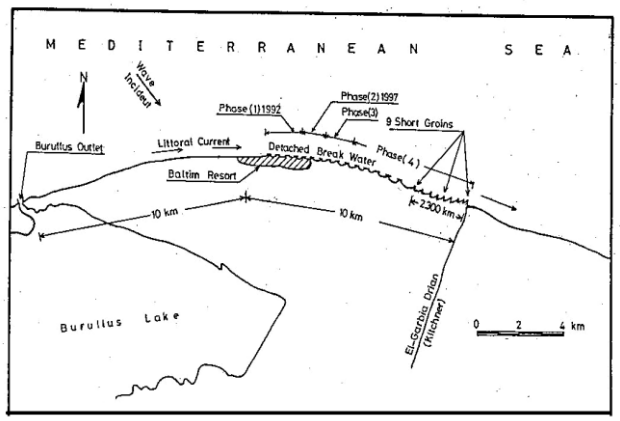

Fig. 4. Baltim sea resort protection works phase (3) and (4) still under construction.

3.1.3. Baltim detached breakwaters

A system of four phases of detached breakwaters has been implemented since 1992 to protect the Baltim sea resort covering about 7-8 Km of coastline, El- Kolfat [5]. These protection works started at a distance of about 10 km from the Burullus outlet up to a distance of 2.3km before the mouth of the Kitchner Drain. The first three phases have been executed and the fourth phase was begun in May 2003 as was mentioned by El-Kolfat [6]. The number of segments in the whole system is fifteen detached breakwaters. The down drift area on the eastern side of the fourth phase is now protected by a gravel revetment and 9 short groins as shown in fig. 4.

3.1.4. Ras El-Bar detached breakwaters and Damietta harbor breakwaters

Eight detached breakwaters 200m in length with 200m between them were constructed in 400 m from the original shoreline to protect the Ras El-Bar sea resort. The project was constructed during the period from 1986 to 2000. This protected area is located in the down drift side of the entrance to the Damietta Harbor Breakwaters as shown in fig. 5.

3.1.5. Damietta jetties and the eastern seawall

The mouth of Nile Branch at Damietta was protected by construction of two jetties on the banks of the mouth. The eastern side of the Damietta mouth was protected by the construction at a 5Km seawall along the coast towards the east as shown in fig. 5.

3.1.6. El-Gamail jetties and port-said detached breakwaters

Six segments of detached breakwaters were constructed in 1997 on the eastern side of the El-Gamail outlet to protect the beaches from erosion and to create sandy beach in the area. The El-Gamail outlet opening was protected by two Jetties on the each sides of the opening as shown in fig. 6.

4. Field data program

The field work program included the surveying of the hydrographic profiles, wave

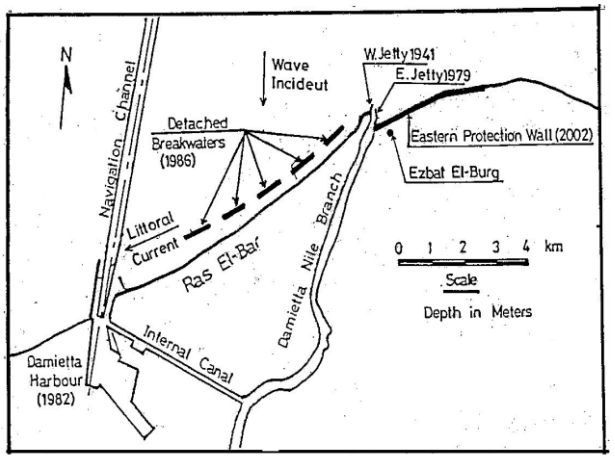

Fig. 5. Damietta harbour, ras El-Bar detached breakwater outlet jetties and Damietta eastern sea wall.

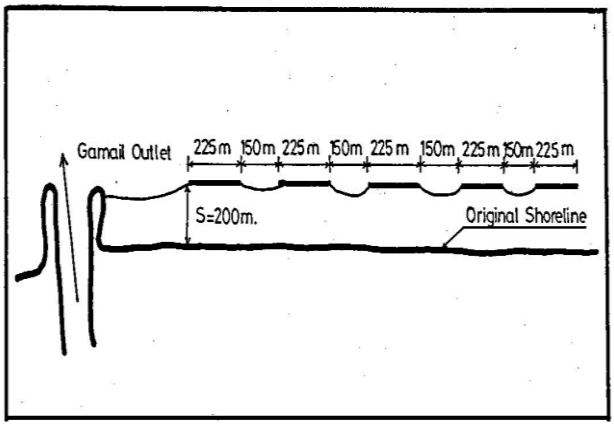

Fig. 6. El-Gamail jetties and Port Said detached breakwaters (1997).

characteristics and current velocities, as well as recording of sea level rises. These measurements have been carried out and analyzed to study the changes of the beach characteristics, shoreline changes, bed slopes, submerged bars and the volumetric of sediment changes. Al Between the Burullus outlet and Port Said there are 97 profiles. These profiles were connected to each other by a baseline. This baseline has fixed points as reference points for measurements. It is parallel to the shoreline.

4.1. Wave recording

Wave characteristics are recorded; wave height, period, direction, and number of waves breaking. The wave recording was carried out using an S4 device, for more details Inter-Ocean [7]. Wave data is analyzed and calculated during the period from July 2001 to March 2002.

4.2. Current measurements

Littoral currents and their directions were measured at seven stations; four (stations) on the eastern side of Burullus outlet and three (stations) on the western side. Also, the littoral currents were measured at four stations on the western side of the Damietta mouth. The measurements were taken using submerged type of floats. The time (T) of the certain distance (L) was determined by using stopwatch. Then the velocity V = L/T m/sec.

4.3. Water level records

Changes in sea level were measured using an automatic gauge called "horizontal seba water level recorder" this gauge was installed at the Burullus outlet near the open sea. It records the water levels continually on a graph. The recorders are related to the datum of zero level of the Egyptian Survey Authority (the mean sea level). Water level records were carried out during the period from 2001 to 2002.

4.4. Surface samples of sea bed

Samples from the bottom of the sea were collected along the measured profiles using a Grab sampler. Mechanical and wet analyses for 10 samples were made for each profile. The mean grain size of the surface bottom samples during the period from 2001 to 2002 were calculated using the formula of Folk and Ward [8].

5. Data analyses and results

5.1. Analysis of wave data

A statistical analysis of the wave heights and directions observed by S4 devices was conducted. Wave parameters were calculated from data collected and presented by the wave rose in fig. 7 during the period from July 2001

to March 2002. Data examined in this study indicates that the height of the waves prevailing during spring and summer rarely exceeded 1-1.5 m for waves blown from the WNW. Winter waves were much higher than summer waves fluctuating between stormy and calm intervals blowing from the N, NNW, NW and W sectors. Accordingly, the predominant wave directions (NNW, NW and WNW, totaling 69%) are responsible for the generation of longshore currents towards the east. 29% represents waves from the N, NNE and NE sectors, which generate a reverse longshore current towards the west, during March and April. The remaining insignificant frequency (2%) represents the calm conditions. The average wave height and period are 0.5m and 6.35 sec, respectively.

5.2. Longshore current

The longshore current velocities and their directions were taken during the years 2000 and 2001 and the results of the analyses are as follows.

On the Eastern side of the Burullus outlet, the predominant current direction is towards the East except in May 2000, Dec. 2000, and March 2001 where the current reveres its direction from east to west.

The average current velocity towards the East and West are 46.3cm/sec and 43cm/sec, respectively. The percentages of the current occurrence towards the East and towards West are 73.67% and 20.83%, respectively.

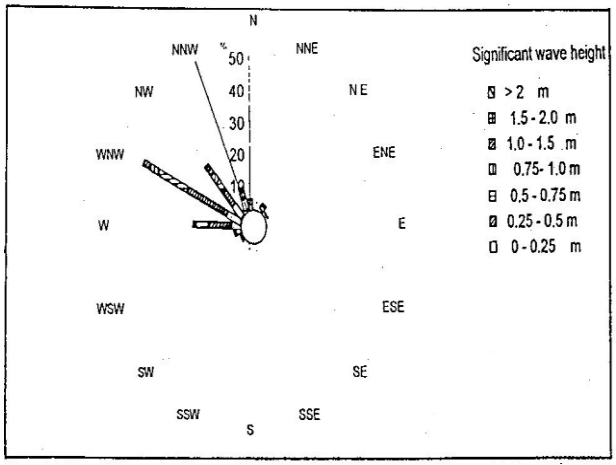

Fig. 7. Wave rose on the western side of Damietta harbour during the period from July 2001 to Marsh 2002.

On the Western side of the Damietta Mouth (Ras El Bar peninsula), the direction of the longshore current has no predominant direction, rather it fluctuates monthly.

The average current velocity towards both the East and West is 30cm/sec. The maximum current velocities towards the East and West are 42cm/sec and 44cm/sec respectively. The percentages of the current occurrence towards the East and towards West are 18 % and 46.5 %, respectively. These results agree with that analysis for longshore current at Burullus coast was carried out for the period from 1980 to 1989 by Fanos A.M. and Khafagy A.A. [9].

5.3. Sea level rises

The extents of water level variations during the study period were measured using the "horizontal seba water level recorder". The record sheets indicate the water level variation with time for every hour during the period from January 2001 to December 2002. The calculations were carried out in order to get the different water levels as shown in (table 2.) and in figs. 8 and 9 for El Burullus and Ras El-Bar during 2002. The calculated levels are important in designing the coastal structures and in correcting the profile depths. The maximum water level recorded is 73 cm above zero of Egyptian survey authority.

5.4. Hydrographic profiles

A survey of the hydrographic profiles was carried out and thoroughly analyzed to study the changes in the beach characteristics, shoreline, bed slopes, and submerged bars, as well as the volumetric changes. The following subsections give the details of the analysis and results.

The data of profiles is corrected and related to zero survey level of Egyptian survey authority datum. The corrected data of depths and distances are represented in figs. 10 and 11, which show the spatial distribution of some selected samples of profiles to represent the different zones along the coasts. Figs. 10-a and 10-b indicate that there is erosion at the eastern side of the eastern protection works of Burullus village in front of Banayeen Village

Table 1
Longshore current on eastern burullus outlet and western damietta mouth

Zone	Currents towards east (cm/sec)			Currents towards west (cm/sec)			% age Rough sea	% age Calm sea
	Max. Vel.	Av. Vel.	% of Occ.	Max. Vel.	Av. Vel.	% of Occ.		
Eastern burullus outlet	71	46.33	73.67	67	43	20.83	-----	5.5
Western damietta mouth	42	30	18	44	30	46.5	29.5	6

According beaufort scale, rough sea and calm sea are defined by wave height <0.5m and >2.5m respectively.

Table 2
Tidal parameters during period from 2001 to 2002. (cm).

Location	HHWL	LLWL	MHWL	MLWL	MWL
El burullus	54	2	47.23	28.68	38.13
Ras el-Bar	77	-17	37	15	26

Where:
All levels are related to Egyptian survey authority datum.
HHWL is the high high water level. LLWL is the low low water level.
MHWL is the main high high water level. MLWL is the main low low water level.
MWL is the main water level.

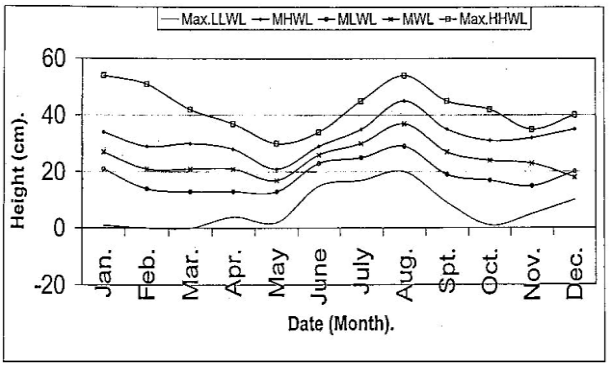

Fig. 8. Burullus sea level during year 2002.

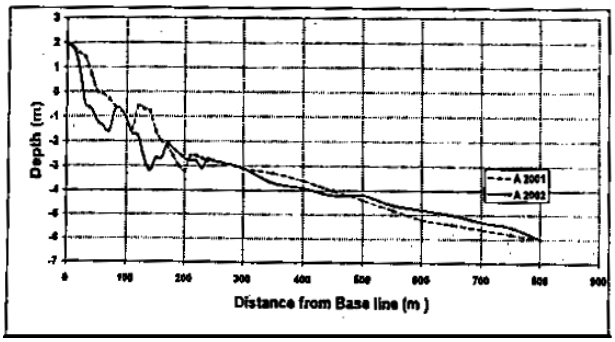

Fig. 10-a. Erosion at the down drift zone of burullus protections, BRP 5.0.

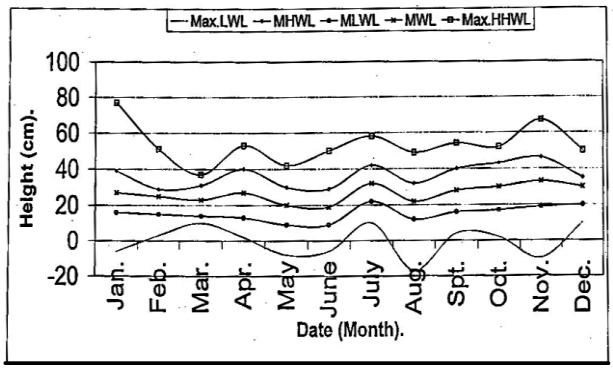

Fig. 9. Res El-Bar sea level during year 2002.

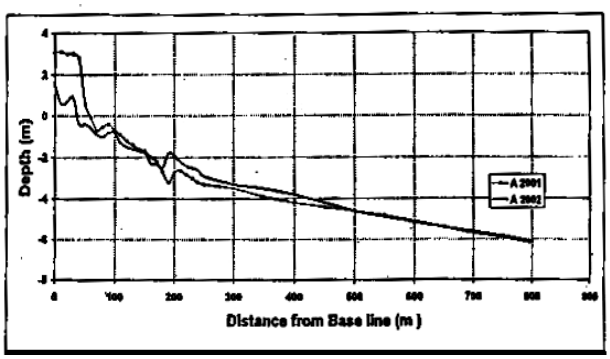

Fig. 10-b. Erosion at the down drift zone of Baltim detached breakwaters, BRP 16.5.

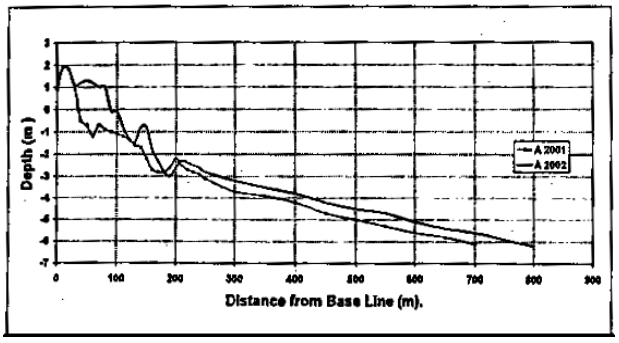

Fig. 11-a. Accretion behind Baltim detached breakwaters, BRP 15.4.

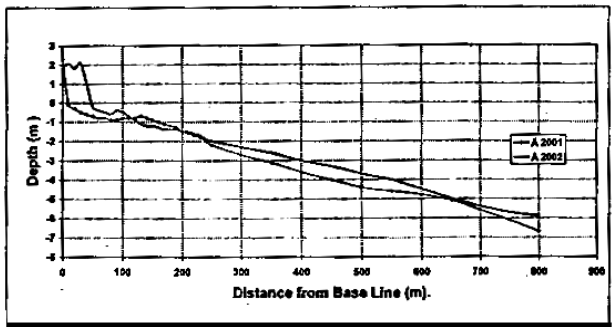

Fig. 11-a. Accretion on eastern side of Dameitta harbour breakwaters, GSP 22.1.

and at the down drift of the detached breakwater phase (3). Phase (3) of Baltim detached breakwaters were planned to protect the eroded zone at the down drift of the phase (2), The working started in this phase since May 1997 for one year and stopped till 2002. Also, figs. 11-a and 11-b indicate that there are accretion zones in the shadow area behind the detached breakwaters in the Baltim sea resort and on the eastern side of the Damietta harbour breakwaters. In general in the coastal area between the kitchner drain and Damietta, the profiles are dynamically stable, keeping their forms at maximum steepness, and altering between erosion and accretion.

5.4.1. Coastal sand dunes

Different types of sand dunes have been developed directly on the shore along coast from Bourg El Burullus to Gamasa drain and extending about 0.3-1.5 km inland. The height of these dunes ranges from 4 to 20m above sea level, gradually decreasing from the Burullus outlet towards the east as shown in fig. 12. The map was modified by El- Banna M. M. [10]. The sand dunes are an important coastal protective formation. They are considered the first line of defense against erosion. They prevent the movement of storm waves and tides into the land area behind the beach. There is some cultivated land between dunes, where the palm tree and other trees are growing.

5.4.2. Shoreline change

The shoreline changes during the period from Nov. 2001 to Nov.2002 are shown for different zones along the study area in table 3. Fig. 13 shows that there is shoreline advancing in the zones of the updrift of the detached breakwaters in the Baltim sea resort in the area behind the detached breakwater in the Baltim sea resort on the eastern side of Damietta Harbor. In addition, there is shoreline retreating at the zones of the down drift of Burullus seawall and at the down drift of the structures in Baltim beach.

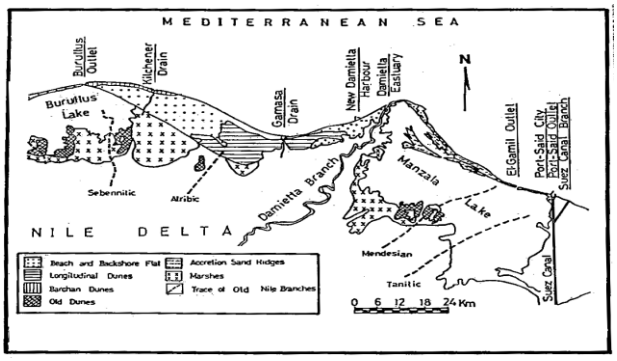

Fig. 12. General map of sand dunes along study area and its features (1).

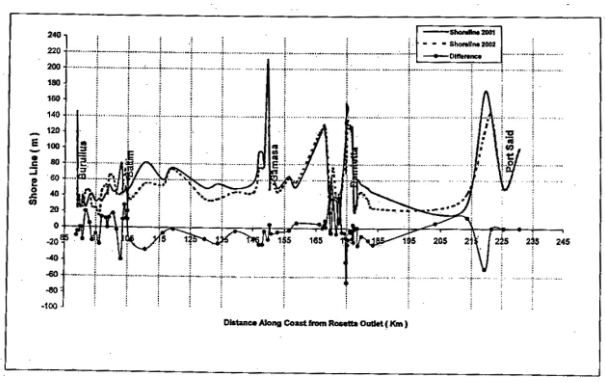

Fig. 13. Shore line changes along study area.

Table. 3
Shoreline changes during period between 2001 and 2002 (m)

X* (km)	Y** (m)		Difference (m)	X* (km)	Y** (m)		Difference (m)
	2001	2002			2001	2002	
88.8	145	135	-10	167.1	125	125	0
89.1	30	25	-5	167.6	126	130	4
89.6	40	35	-5	167.9	118	127	9
90	25	25	0	168	118	125	7
90.4	25	25	0	168.1	117	125	8
90.8	40	25	-15	168.2	115	116	1
91.7	25	45	20	169.4	13	53	40
93	40	45	5	169.5	13	32	19
93.8	41	25	-16	169.6	58	55	-3
95	32	24	-8	169.7	40	34	-6
96.1	35	15	-20	170	65	59	-6
96.9	32	45	13	170.6	39	75	36
98.2	42	43	11	171.6	41	34	-7
98.7	42	42	0	172.5	5	43	38
99.2	53	65	12	173.4	54	49	-5
100.5	45	62	17	174.4	98	92	-6
101.6	45	42	-3	174.7	112	70	-42
103	81	42	-39	174.9	157	90	-45
103.6	43	53	10	175.1	155	135	-20
104.1	45	73	28	175.4	150	136	-14
104.5	51	62	11	174.6	132	120	-12
105	35	55	20	175.9	130	127	-3
105.2	35	75	40	176.1	130	125	-5
105	45	55	10	176.4	125	122	-3
105.9	51	35	-16	176.7	128	115	-13
110.6	82	55	-27	176.9	75	79	4
116.1	60	53	-7	177.1	51	34	-17
119.4	75	73	-2	177.2	22	23	1
129.5	50	36	-14	177.3	30	28	-2
133.7	55	36	-19	178	29	29	0
139.3	49	45	-4	178.2	29	29	0
145.3	58	43	-13	178.4	60	39	-21
146.9	95	75	-20	179.6	55	45	-10
148	95	75	-20	181.8	50	35	-15
148.6	82	78	-4	183.4	45	25	-20
149.8	212	198	-14	203.3	18	24	6
150.3	50	54	4	213.6	31	44	13
150.8	72	65	-7	219.2	170	120	-40
152.8	50	45	-5	221.5	143	143	0
156.4	65	62	-3	225.6	50	50	0
158.8	52	58	6	230.6	100	100	0
166.1	115	120	5				

X* = distance along coast from rosetta outlet, in (km).
Y** = distance of shoreline from the baseline, in (m).

5.4.3. Sea bed slope variation

Seabed slopes along the study area ranging between depths of (0.0) and (-6 m) are calculated and represented in table 4 and in figs. 14. It is clear that the slopes are steeper at shallow depths than at deeper ones. Also, the seabed slope is decreasing towards the East direction. This decreasing because the distributions of mean grain size decrease towards offshore and towards the East as shown in fig. 15. Fig. 15 indicates that the mean grain size onshore is 0.25 mm and 0.1 in offshore at Dameitta zone and the mean grain size onshore is 0.35 mm and 0.15 in offshore at Burullus zone. As result, the profile slopes between the kitchener drain and Damietta are flatter than the profile slopes on the western side.

5.4.4. Submerged coastal bar

The Coastal bars are submerged dunes formed parallel to the shoreline, usually predominant in the breaker zone and offshore zone between water depths 3 m and 5m. They may be formed into two or three parallel rows at different depths.

The bar characteristics are calculated and represented in table 4 and in fig. 16 which indicates that the bar height did not exceed 1.5 m. The majority of bars may be formed at a distance of between 50 and 200 m from the shoreline.

It was noticed that the bars formed in the accreted area have heights of 0.5- 1.5 m and are steeper than those formed in the eroded area.

The bars formed in the eroded area are smaller and flatter. Also, it was noticed that there storm bars have been formed in the western zone of Damietta at a distance of between 360 and 600m from the shoreline.

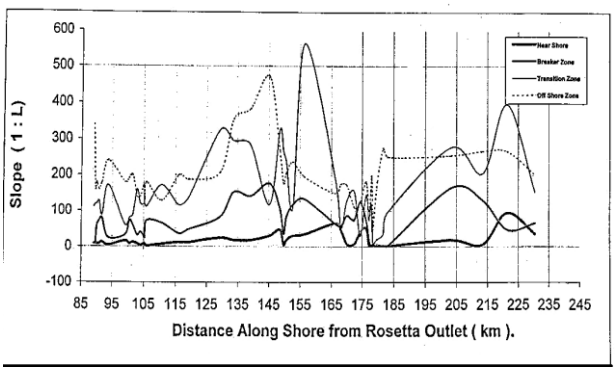

Fig. 14. Bed slope variations along study area, 2002.

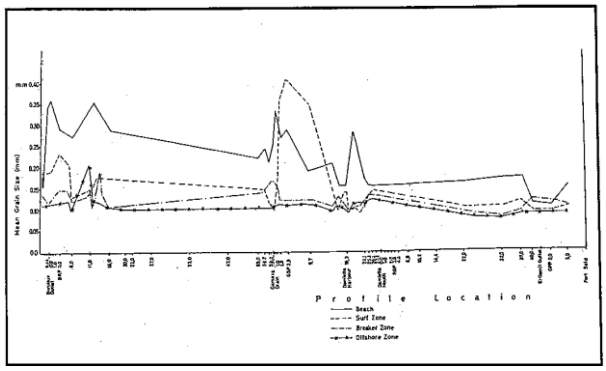

Fig. 15. Distribution of average mean grain size (mm) for the study area.

5.4.5. Volumetric changes along study area

The volumetric changes were calculated during the period from Nov. 2001 to Nov. 2002 by means of computer programs, for more details about the used computer program, Iskander [11]. Fig. 17 shows the variations in the volumetric erosion and accretion along the study area for different depths (> 0), (0-2m), (2-4m) and (4-6m) water levels.

5.5. Analysis of sea bed samples

The beach and surface bottom samples collected were subjected to complete grain size analysis during May 2000.

1. Mechanical sieve analysis for sediment coarser than 0.063mm.
2. Pipette Tube analysis for sediment finer than 0.063mm.

Mean grain size in mm (D_{50}) was determined along the study area and is represented in fig. 15. This figure indicates that the seabed in the study area in the zone in front of the Baltim sea resort is composed of coarser sand than the neighboring zone, this is matching with the results of Frihy, et-al. [12].

The accumulation of coarse sand at this zone is related to the detached breakwaters, which deduce the reversing rip currents. Rip currents wash and disperse the finer sediment in this zone. So, this zone is distinguished by coarse sand.

Table. 4
Sea bed slopes and heights of coastal bars along study area, 2002.

X[1] (km)	Bed slope[2] during 2002				Heights of coastal bars 2002 (m)		
	Near shore zone[3]	Breaker zone[4]	Transition zone[5]	Off shore zone[6]	Inner off shore bar (m)	Breaker zone bar (m)	Outer off shore bar (m)
89.1	0.125	0.125	0.008929	0.002941	0.7	0.4	0.6
89.6	0.125	0.083333	0.008333	0.00625	0.88	0.64	.....
90	0.125	0.017857	0.008333	0.005556	0.9	0.7	0.5
90.8	0.125	0.013889	0.007813	0.00625	0.54	0.63	.....
91.7	0.0833	0.0125	0.011364	0.005556	0.8	0.5	.....
93.7	0.25	0.041667	0.005814	0.004167	1.5	1.1	.....
99.1	0.0625	0.03125	0.016667	0.005556	0.54	0.63	.....
100.5	0.125	0.013889	0.0125	0.005208	0.72	.....	.....
101.6	0.0833	0.016667	0.011364	0.005	0.64	0.72	.....
103	0.125	0.03125	0.00625	0.007143	0.54	0.9	.....
104	0.25	0.025	0.008333	0.007143	0.45	0.45	.....
105.1	0.125	0.035714	0.008333	0.005814	1.18	0.9	.....
105.3	0.125	0.041667	0.007143	0.007576	0.45	0.54	.....
105.9	0.5	0.013889	0.008929	0.005556	0.56	0.78	.....
110.6	0.1429	0.015385	0.005814	0.007752	0.9	.....	.....
116.1	0.0833	0.027778	0.008621	0.005	0.63	.....	.....
119.4	0.0833	0.020833	0.007143	0.005319	0.64	0.72	.....
129.4	0.0417	0.012048	0.003077	0.004831	.....	.....	.....
133.7	0.0556	0.006536	0.00339	0.002825	0.61	.....	.....
139.2	0.0556	0.007042	0.003534	0.002611	0.33	.....	.....
145.2	0.0333	0.00565	0.008475	0.002119	0.66	.....	.....
148.6	0.0213	0.009259	0.003077	0.003759	0.6	.....	.....
149.8	0.1667	0.028571	0.003759	0.00565	.....	0.44	.....
150.7	0.0556	0.012048	0.004237	0.004831	0.44	.....	.....
152.8	0.0333	0.008475	0.008929	0.004237	0.67	.....	.....
156.4	0.0294	0.007463	0.001776	0.005102	0.56	.....	.....
166.1	0.0154	0.015385	0.005	0.006667	0.44	0.44	.....
168.1	0.0217	0.017857	0.018868	0.005714	.....	.....	.....
170	0.1429	0.011628	0.007752	0.005814	0.67	.....	.....
172.5	0.125	0.013333	0.006494	0.009091	0.33	.....	.....
174.4	0.025	0.008	0.033333	0.008	0.89	.....	.....
176.3	0.0192	0.013699	0.006849	0.005525	0.44	0.56	.....
177.2	0.25	0.052632	0.013514	0.01	0.56	0.33	.....
177.8	0.5	0.25	0.007937	0.006289	.....	0.57	.....
178.1	0.5	0.25	0.013514	0.005102	.....	0.57	0.29
179.6	0.25	0.5	0.052632	0.005988	.....	.....	0.42
181.7	0.5	0.5	0.028571	0.003636	.....	0.83	.....
183.4	0.5	0.25	0.01	0.004	.....	0.67	.....
203.3	0.0556	0.006061	0.00361	0.003937	0.33	0.28	.....
213.5	0.1667	0.007692	0.004878	0.003759	0.3	0.33	.....
221.4	0.0105	0.021277	0.002532	0.003759	.....	.....	.....
230.5	0.0286	0.015385	0.006536	0.004975	0.7	0.25	.....

X[1] = distance along coast from rosetta outlet, in (km).
Slope[2] = vertical height (m)/ horizontal length (m)
Near shore zone[3] is the zone between shoreline and the zone of wave breaking.
Breaker zone[4] is the zone of wave breaking.
Transition zone[5] is the zone between the zone of wave breaking and the zone of deep water.
Off shore zone[6] is the zone of deep water.

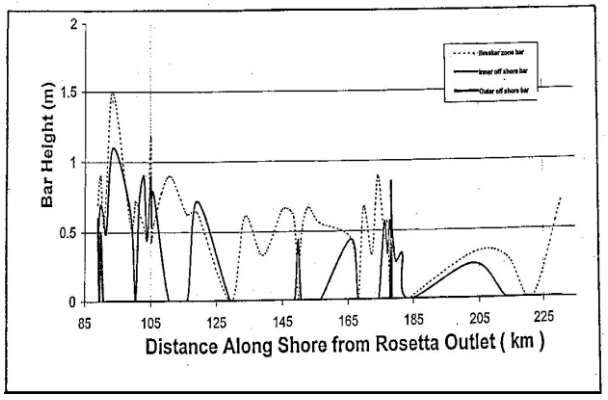

Fig. 16. Bar height distributions along the study area, 2002.

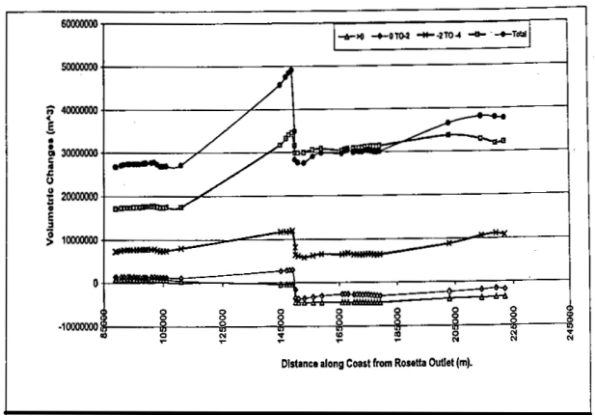

Fig. 17. Volumetric changes along study area during year 2002.

6. Summary and conclusions

Field data collected during the period between Nov. 2001 and Nov. 2002 have been analyzed and indicated that, there is severe erosion at the down drift zones of the following coastal structures; the Al Burullus seawall, at Baltim detached breakwaters. These erosions took place in the eastern side of these structures due to the hydrodynamic forces of the predominant wave direction of NW and WNW (69 %) with wave height and wave period (1-2) m and 6.35 sec respectively. The long shore velocities; at Burullus coast, the predominant current (46.3 cm/sec, 73.67%) and (43 cm/sec, 20.83%) towards the East and West respectively. On western Damietta coast, the average long shore velocity towards both the East and West is 30cm/sec., with percentages of occurrence towards the East and West are 18 % and 46.5 %, respectively.

On the other hand, the accretions took place mostly at the up drift zone of the coastal structures at Baltim Detached Breakwaters and Damietta breakwaters Harbor. The accretions are formed due to blocking the long shore sediment transport in the up drift side of the construction. It is recommended to construct a system of groins with proper spacing in order to overcome the erosion of the down drift sides of the structures. Also, beach nourishment is needed in order to prevent erosion of adjacent shorelines of the above protection structures.

Continues monitoring is recommended to measure the effectiveness of the proposed protection measure.

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