NUMERICAL MODELLING FOR MORPHOLOGICAL CHANGES ALONG THE NILE DELTA COAST (EL-BANAIEEN AREA)

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ABSTRACT

Based on the wave climate for the Nile Delta coast, the wave-induced sediment transport causes changes in beach due to cross-shore as well as longshore sediment transport. Many factors affect the longshore drift rates, such as the wind and wave data, soil structures of the bed (D_{50}), shore profiles, existing sea structures, and the geological evolution and morphodynamics of the coast. The main factor affecting the littoral drift estimates is the wave climate information. This paper was done to clarify the main factors that underlie the observed morphological changes along this shore. We investigate the longshore and cross-shore sediment transport rates along the El-Banaeen coast using numerical mdeling.The model LITPROF of the LITPACK software of DHI is found to simulate well the beach morphological changes by adjustment of the calibration parameters. In addition, The LITDRIFT module of the LITPACK modeling has been used for computing the longshore and cross-shore sediment fluxes in the nearshore region. The hydrodynamic and beach profile data were measured in the morphology field and used for calibration and validation. The results show that the CERC equations give significantly high values, however LITDRIFT provides a reasonable comparison with Kamphuis formula values. Due to its consideration of both the bed slope and the amount of sediment to be obtained, the Kamphuis equation performs better than the longshore sediment transport (LST) estimate provided by the CERC formula.
Keywords: Nile Delta, Hydrodynamic, LITPROF, LITDRIFT, Morphology

1 INTRODUCTION

In the dynamic environment of the near-shore, sediment transport is extremely complex. Beach morphology changes because of wave-induced sediment transport. Both cross-shore and longshore sediment transport occur (Shahul, 2010). The shoreline position and sediment budget along Alexandria and the Nile delta coasts show that coastal regions can be split into several discrete sedimentation units known as "littoral cells (Frihy & Lotfy 1997). Each cell has a full cycle of littoral sedimentation and transportation, including sediment sources, sinks, and transport paths as shown in Fig. 1. It shows the wave rose and the dominant wave directions are north and northwest frequencies associated with significant northeast reversals. Wave rose (average wave direction-height distribution) measured at Abu Quir Bay (Frihy, 2003). In addition, it includes the main geomorphologic units and the five sub-cells positions identified by Frihy & Lotfy (1997): I= Abu Quir sub-cell; II= Rosetta sub-cell; III= Burullus sub-cell; VI= Damietta sub-cell; and V= Port Said sub-cell. Also, it shows values of rate of erosion and accretion (m/yr) (Frihy, 2003). The eroding headlands that deliver enormous volumes of sand to the coast act as the sources of sediment for each littoral sub-primary cell (Figure 1). The natural movement of sediment and wave-induced longshore currents are reflected in the pattern of erosion vs. accretion. The seasonal fluctuations in wave approach along the delta coast are what produce convergent and divergent current patterns. The eroded sand is carried along the coastline by waves and currents until it encounters local sinks like promontory saddles, embankments, and long breakwaters, which stop it and direct it downcoast (Frihy, 2003). It should be highlighted that the longshore currents' capacity to transport sand is heavily influenced by the radiation stress created by breaking waves. A direct measurement of the real longshore sediment transport (LST) along the southern Mediterranean coast has not yet been taken. Gradients in longshore sediment transport play a crucial role in the response of a shoreline due to waves and currents at or near the engineering structures. Accurate prediction of the total longshore sediment transport rate is the most commonly required quantities to many coastal engineering studies. Examples of practical engineering applications include the beach response in the vicinity of coastal structures, nourishment requirements, and sedimentation rates in navigation channels. Accurate estimates of the longshore sediment transport distribution also aid in understanding migration of sediments, natural or artificial, and the development of coastal morphologic features.

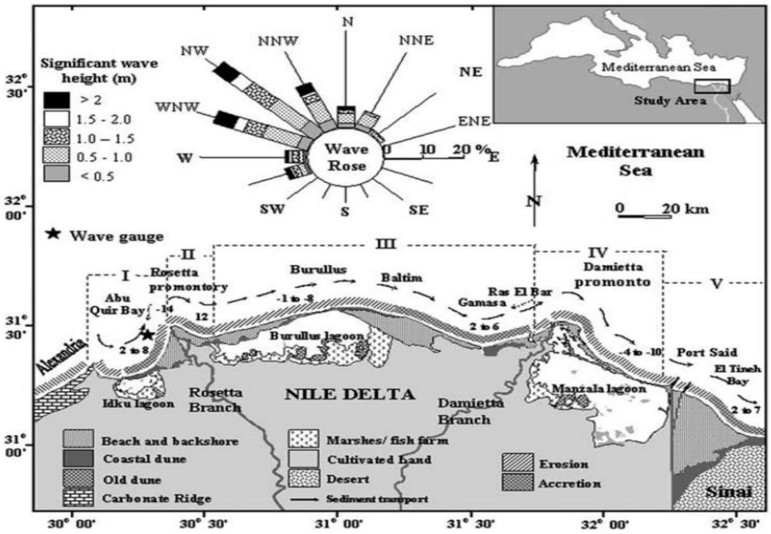


Figure 1. The net LST dominant flow direction on the Nile littoral cell Frihy (2003)

In addition, prediction of the cross-shore distribution of longshore sediment transport in the surf zone is necessary in designing and planning groins, jetties, and pipeline landfalls. In addition, it needed for the morphodynamical response of coastal areas to engineering works. Engineers need both the total longshore transport rate and the cross-shore distribution of the longshore transport rate for project planning and the development of predictive numerical simulation models.

The aim of the present study is to simulate the beach profile changes by using the LITPROF module in DHI's LITPACK package.The methodology of the present study, a large number of cases, is run through the model to reduce the variance between observed and computed values. the Longshore sediment transport rates (LSTR) is essential to the design the coastal structures and beach nourishment projects. So, the LITDRIFT module of the LITPACK modeling package, the CERC, and Kamphuis formulas are applied to estimate the longshore sediment transport (LST) for different wave conditions. This research contributes to an integrated study for near-shore wave transformation and preliminary evaluations for longshore drift quantities along the Nile Delta coast, near El-Burullus. The total longshore sediment transport rates and amounts are commonly required to be evaluated. They are essential in solving many coastal problems.

2 CASE STUDY (ELBANAEEN BEACH)

In the eastern part of the Burullus outlet is Borg El-Burullus city which its coast was suffering from severe erosion especially at down-drift breakwater as shown in Fig. 2. ElBanaeen area is located at 311074.23 m E, 3497261.48 m N, down drift El-Burullus fishing port. There are coastal structures like groin and its length is 150m, and two detached breakwaters with spacing 850 m from the first groin, spacing of the breakwater 1273m. the length of breakwaters 315 and 270 m respectively. The offshore distance of breakwater is 350m. ElBanaeen project constructed in 2008 to protect city from severe erosion and increase investment in the area. Unfortunately, like many other deltas, the Nile delta's coastal zone is undergoing extensive changes caused by both natural and anthropogenic influences. Natural factors affecting the Nile delta coast changes include sediment supply, coastal processes, tectonic activities, and climatic and sea level fluctuations (Stanley and Warne 1993). In the absence of sediment supply to the coast, coastal processes are mainly waves, and currents act together with the SLR to induce beach changes (UNDP/UNESCO 1978). The down-drift breakwaters suffer from severe erosion, so the littoral drift along the Nile Delta must study intensively to try to find the optimal solution for reducing or stopping the shoreline movement problem. According to Fig. 2, the length of the eroded area is 3.50 km with 200m width . To combat the erosion, the coastline needs to reinforce through building with nature. There are many alternatives can be applied in this area. For instance, a dune beach expansion is good option. This solution combines safety, nature development and recreation. In addition, this solution can protect the area from sea level rise phenomena. Another Option is Sand-Engine. It uses natural dynamics to distribute a huge sand nourishment along the coast, combating erosion and improving flooding safety. In addition, it increases recreational space along the coast and provides opportunities for the ecosystem (Mohamed, 2022).

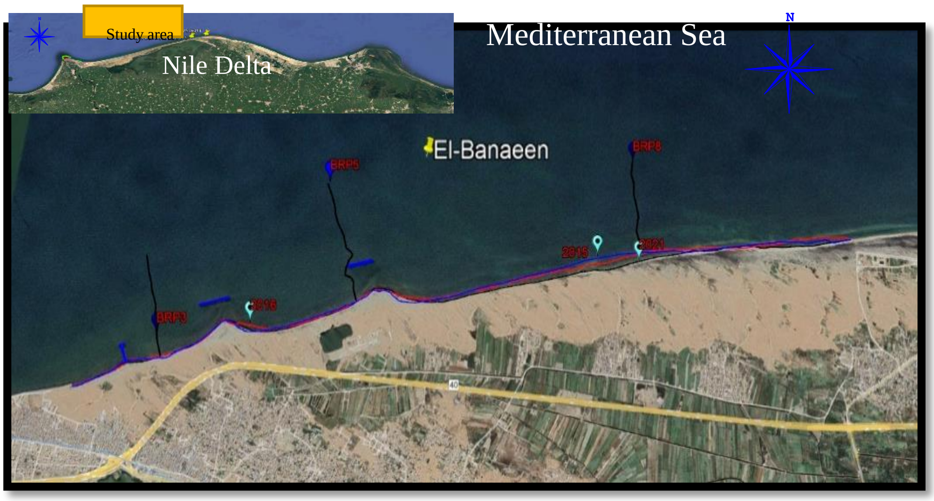
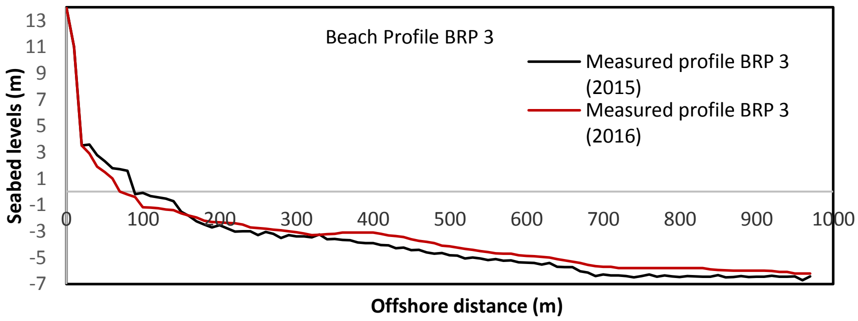
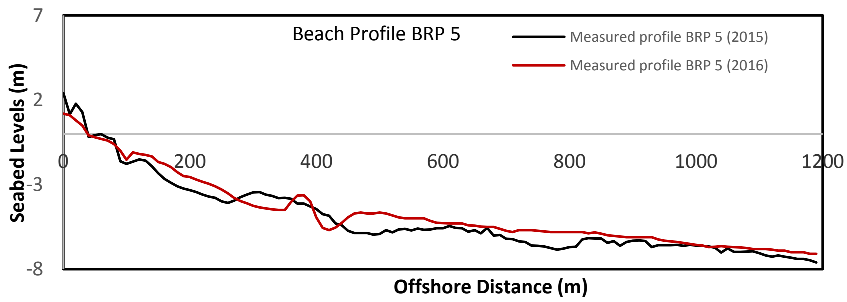


Figure 2. The shoreline changes at ElBanaeen beach in three years 2015, 2016 and 2021.(Google earth)

Beach-nearshore profiles were surveyed between 2015 and 2016 along the 7.0 km long study area. Fig. 2 shows that the survey data were collected along 10 profile lines, spaced between 500 and 1320 m intervals, and up to ~1.0 km offshore, corresponding to the - 6.0 meter water depth contour. Fig. 3 shows some examples of the beach profiles measured along the El-Baneen coast at various sites.





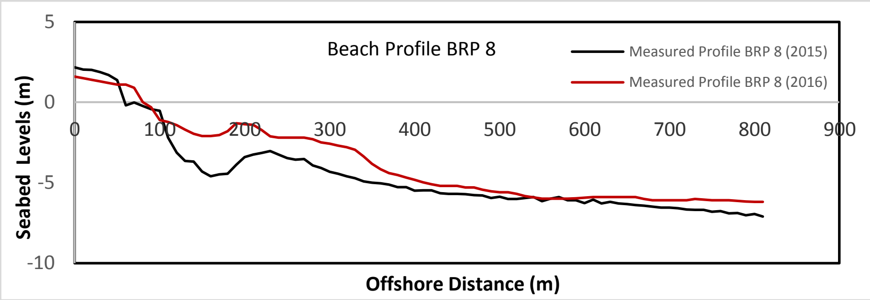


Figure 3. Measured beach profiles along El-Banaeen coast

3 LITPROF MODULE OF LITPACK

3.1 Hydrodynamic Module

3.1.1 Wave transformation and breaking

Waves in the surf zone are the primary process for moving sediment, and the wave-induced longshore current is the main mechanism for transport of this sediment. For this research, longshore sediment transport generated by wave-driven currents is considered, although wind, tide, and other forcing mechanisms also may drive currents that will move sediment alongshore. Almost all longshore sediment transport occurs in the surf zone because of the great intensity of turbulence generated by breaking and broken waves. The breaker zone is characterized by waves, which have shoaled from offshore, becoming unstable, and dissipating their energy through breaking. Turbulence from breaking waves contributes greatly to mobilizing sand, which any current can transport.

Using the model LITPROF in DHI's LITPACK package, the cross-shore profile variations based on a timeseries of wave incidents were described. LITPROF is a tool for estimating on-offshore transport rates as well as a tool for investigating the mechanics of cross-shore sediment transport. This model's deterministic description of the sediment transport considers the effects of oblique wave attack and the interaction of motion with currents in either direction on the time-varying hydrodynamic forces, the turbulence, the mean flow characteristics, and the resulting sediment transport. The model can be applied on complex coastal profiles with longshore bars. The model assumes that longshore gradients in hydrodynamic and sediment conditions are insignificant, and the onshore bathymetry is approximately parallel to the coast. At the offshore boundaries, the root-mean-square wave height (h_{rms}), mean wave period (T_m), and mean wave direction (θ_m) are used to identify time-varying wave conditions.The model calculates vertical variations of turbulence, shear stress and mean flow for which the effects of asymmetry of the wave orbital motion, mass flux in progressive waves, surface rollers and the wave setup are considered. The wave transformation over the profile takes into account the important phenomena in the nearshore zone such as shoaling, refraction, energy loss due to bed friction, and wave breaking (Danish Hydraulic Institute (DHI), 2014).
The cross-shore change of wave height is computed in LITPROF from the wave energy equation, which is:

$$\frac{d}{dx}\left(E_f \cos\alpha\right) = D_{br} + D_{bf} \quad (1)$$

Where: E_f =wave energy flux, α= the wave incidence angle, x=the cross-shore direction, D_{br} = energy dissipation due to wave breaking, and D_{bf} = energy dissipation due to bottom friction.
The wave energy flux is calculated using linear wave theory:

$$E_f = \frac{1}{16}\rho_w g H_{rms}^2 c \left(1 + \frac{2kd}{\sinh(2kd)}\right) \quad (2)$$

Where, ρ_w = water density, H_{rms} = root mean square wave height, c = wave celerity, k= wave number, and d= water depth.

In the surf region, energy is generated from the organized wave motion and changed into turbulence through the development and decay of surface rollers. Surface rollers are crucial for cross-shore morphodynamics because they produce turbulence and net mass-flux.

In the LITPROF model, the roller surface description of Dally and Brown (1995) is used. Oblique incident waves result in the following roller surface description:

$$\frac{d}{dx}(E_f \cos\alpha) + \frac{d}{dx}\left(0.5\rho_r c^2 \frac{A}{T}\cos\alpha\right) = \rho_r g \beta_d \frac{A}{T} \quad (3)$$

Where: ρ_r = density of roller including air bubbles, A=Surface roller area, and β_d=empirical constant.

3.2.1 Longshore current

A shear radiation stress, Sxy, caused by the approaching waves is acting parallel to the coast. A longshore current is produced by a change in radiation stress, -Sxy/x, along a normal to the coast. The flow resistance from the bed and from wave-generated turbulence resist the current, and eddies created by waves and circulation currents smooth out the velocity distribution along the coast profile. The equation defining balance between the following forces can be used to determine the littoral current:

(i) Radiation stress,
(ii) Flow resistance,
(iii) Transfer of momentum.

For waves approaching the coast at an angle, the longshore currents are calculated from the wave induced radiation stress gradients.

$$-\frac{\overline{\partial S_{xy}}}{\partial x} = \tau_b - \frac{\delta}{\delta x}\left(\rho E D \frac{\delta v}{\delta x}\right) \quad (4)$$

Where, S_{xy}= the shear radiation stress which drives the longshore current, τ_b = bed shear stress, E = cross-shore momentum exchange factor, and V = longshore current velocity.

In the present model, the longshore momentum flux S_{xy} consists of a contribution of the wave motion and from the surface rollers:

$$\frac{dS_{xy}}{dx} = \frac{d}{dx}\left(\frac{1}{c}E_f \sin\alpha\right) + \frac{1}{T}\frac{d}{dx}(\rho_r A c \sin\alpha \cos\alpha) \quad (5)$$

It can be demonstrated that the shear radiation stress is constant while the energy flux is constant despite the low energy dissipation outside of the breaker zone.

3.3.1 Cross-shore sediment transport and morphological Module

An intra-wave hydrodynamic model that describes the time evolution of the bed boundary layer is used to compute sediment transport. The continuity equation provides a description of the change in bed level:

$$\frac{\delta z_b}{\delta t} = -\frac{1}{(1-n)}\frac{\delta q_{s,x}}{\delta x} \quad (6)$$

Where z_b = bed level, n = porosity of the bed material, and $q_{s,x}$ = cross-shore transport rate. The LITPROF module uses the forward in time-central in space (FTCS) method to solve the continuity equation. The model is composed of several modules as shown in Fig. 4. The wave and current profiles across the coastal zone are calculated in the first module. The cross-shore sediment transport rate is calculated in the second module. To calculate the changes in the cross-shore profile, one uses the solution of the bottom sediment continuity equation.

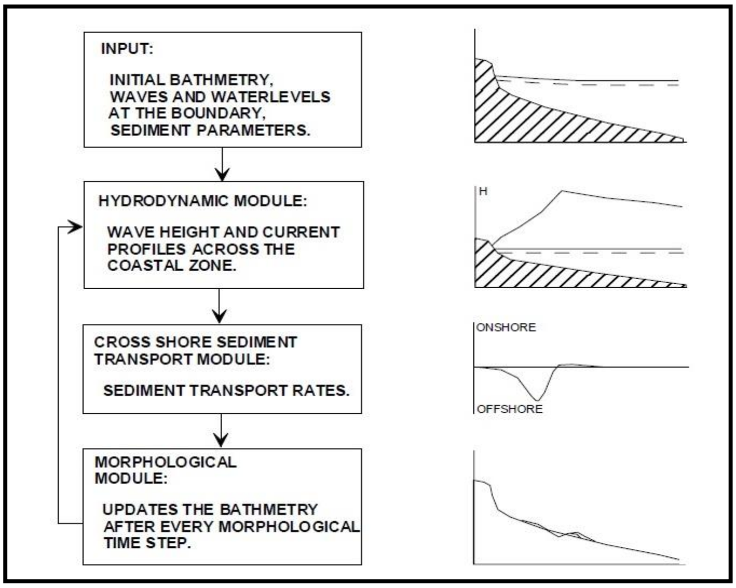


Figure 4. The structure of the model

3.2 Estimation of littoral drift

Total longshore sediment transport (LST) rate is one of the most commonly necessary amount in coastal engineering. It is required for problems like the infilling of dredged channels, distribution of beach fills and placed dredged material, and the morphodynamic response of coastal areas to engineering works. Additionally, the assessment of the impact on the shoreline, which is frequently caused by gradients in the LST rate, is essential to the design of shoreline structures and beach nourishment projects. The formulas for estimating the LST rate that are used the most frequently are discussed first in the following section.

The Danish Hydraulic Institute's (DHI) LITDRIFT module of the LITPACK modelling package, the CERC and Kamphuis formulas are used to calculate longshore sediment transport (LST). The most effective method for calculating the LST should be chosen based on the relevance and resilience concept for the coast. In addition, the dependence of several factors, such as the breaking wave height, wave period, nearshore slope, sediment grain size, etc., which have a significant impact on sediment transport.

3.2.1. CERC formula

The CERC equation (USACE, 1984), which is based on field data, is the most commonly used formula for the total LST rate in coastal engineering practice. It is based on the principle that the volume of sand in transport, Qlst is proportional to the longshore wave power per unit length of the beach and given by,

$$Q_{lst} = \frac{\rho K \sqrt{g/\gamma_b}}{16(\rho_s - \rho_w)(1-n)} H_{s,b}^{2.5} \sin(2\theta_b) \quad (7)$$

Where Q_{lst} is the longshore transport rate in volume per unit time, ρ_w is the water density taken as 1025 kg/m^3 for seawater, ρ_s is the grain density taken as 2650 kg/m^3 for sand, K is an empirical coefficient, g is the gravity acceleration, n is the porosity (≅0.4), $H_{s,b}$ is the significant wave height at breaking, γ_b is the breaker index (=H_b /d_b), generally taken as 0.78, and θ_b is the wave angle at breaking line. The shore protection manual suggests using the value K= 0.39, which was calculated from Komar and Inman's (1970) original field experiment employing tracers (USACE, 1984). The 46 most reliable field measurements out of the 240 total field measurements analysed again by Schoonees and Theron (1993, 1996) yielded a K value of about 0.2.

3.2.2. Kamphuis formula

Kamphuis (1991) developed a relationship for estimating LST rates based primarily on physical model experiments. The formula which Kamphuis (2002) found to be applicable to both field and laboratory data is,

$$Q_{vol} = 6.4 * 10^6 H_{s,b}^2 T_p^{1.5} m_b^{0.75} D_{50}^{-0.25} \sin(2\theta_b)^{0.6} \quad (8)$$

Where where Q_{vol} is the total immersed volume in m^3/year, $H_{s,b}$ is the significant wave height at breaking, θ_b is the wave angle at breaking line, T_p is peak wave period, m_b is the beach slope near the breaking, i.e., the slope over one or two wavelengths seaward of the breaker line, and D_{50} is the median grain size. The Kamphuis formula takes into account all the important parameters for the mobilization and transport of sediment like the wave period and beach slope.This is particularly important for El- Baneen coast.

3.2.3. LITDRIFT module of LITPACK

The LITDRIFT module is part of the LITPACK modelling package and is used to calculate littoral drift and longshore current in coastal areas. Using a single profile, the LITDRIFT module simulates the cross-shore distribution of wave height, setup, longshore current, and littoral drift (DHI, 2014). The cross-shore distribution of the longshore current and the wave setup are obtained by solving the longshore and cross-shore momentum balance equations. Wave decaying resulting from breaking is modelled using either a Battjes and Janssen (1978) model or an empirical wave decay formula. The longshore current velocity profile is calculated using Eq. (9) presented below, which defines the shore-parallel momentum balance.

$$\tau_b - \frac{d}{dy}\left(\rho_w E d \, {du}/{dy}\right) = -\left(\frac{ds_{xy}}{dy}\right) + \tau_w + \tau_{cur} \quad (9)$$

Where τ_b is the bed shear stress due to the longshore current, ρ_w is the water density, E is the momentum exchange coefficient, d is the water depth, u is the longshore current velocity, y is the shore normal coordinate, S_{xy} is the shear component of the radiation stress, τ_w and τ_{cur} are the driving forces due to wind and current, respectively.

The LITDRIFT determines the net/gross littoral transport over a specific design time. Important components are included, such as the relationships between the water level, the profile, and the incident sea waves. The input data provided for evaluating the physical conditions of the transport of sediment includes the cross-shore profile, hydrodynamic information, which also includes information on water level, wave, current, and wind data. The output of the LITDRIFT module provides a comprehensive predictive description of the cross-shore distribution of the longshore sediment transport for an arbitrary bathymetry for both regular and irregular sea states.

4 DATA AND METHODOLOGY

4.1 The main field data for study area

The work will consist of the main tasks such as collecting required data, setting up the model, calibrating and validating the model, running the study case, and finally showing the results. The first task is collecting required data; the field data are bathymetric data (profile cross-sections), sediment data, wave data should be collected. The second step is setting up the model and preparing the cross-shore profiles. If the longshore sediment transport has to be calculated, the sediment characteristics must be defined along the cross-shore profile. The most important parameter is the mean grain diameter d_{50} and the fall velocity of sediment. The friction is defined as the local bed roughness across the profile. The wave data are the wave height, wave angle and wave period at specific depth. Some parameters must be set for a description of the wave breaking.

Because waves from the NW, NNW, and WNW are moving towards the shoreline, the study area's main longshore current flows from west to east (62–65%). However, due to easterly winds, particularly in March and April, the wave component from the N, NE, and NNE sectors causes a reversed longshore current towards the west (24–29%). The majority of the delta coast experiences waves that frequently break at oblique angles, creating strong easterly currents that move at speeds of 40 to 60 cm/sec (FANOS, 1986). Statistical analysis of the waves recorded in Abu Quir Bay, at 18.5 m depth between 1985 and 1990 and in front of Damietta harbor, at depth 12 m between 1997-2010 as shown in Table 1.

Table 1. Wave characteristics along the Nile Delta coast (Iskander, 2013)

Wave Condition	**Location**	**Abu Quir Bay**	**Damietta Harbor**
	Duration	1985-1990	1997-2010
	Measured Depth	18.5 m	12.0 m
Average Condition	Hs	1.91 m	1.02 m
	Tp	6.0 sec.	6.3 sec.
	Direction	NW	NW
Maximum Condition	Hs	5.44 m	4.47 m
	Tp	12.8 sec.	5.6 sec.
	Direction	WNW	NW
Winter Condition	Hs	1.24-3.18 m	0.5-2.16 m
	Tp	4.5-7.8 sec.	4.4-8.3 sec.
	Direction	NW	NW
Summer condition	Hs	1.15-2.12 m	0.43-1.12 m
	Tp	4.9-6.8 sec.	4.5-7.3 sec.

Fig. 5 summarizes the wave climate along the Nile Delta coast. The figure shows the dominant wave direction and the most frequent ranges of significant wave heights. Most of the waves arrive from the North and West quadrants.

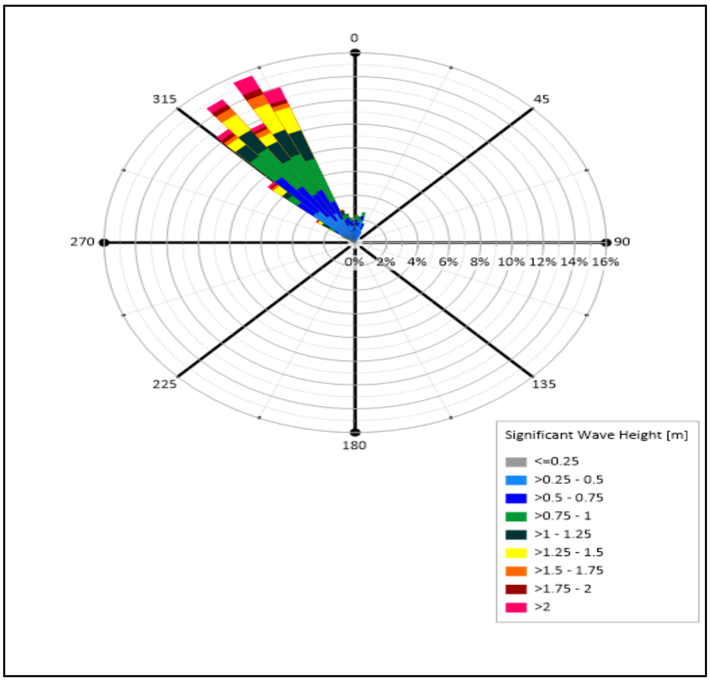


Figure 5. Significant Wave height (H_s) in function of wave direction along the Nile Delta coast

Seabed samples at the study area were collected and analyzed. Most of seabed material is sand. The beach sands of the Nile Delta are mostly fine-grained sand (0.13-0.25 mm) with some local medium sand (0.25-0.5 mm). Based on a small number of sediment samples, a constant bed roughness parameter and the median grain size of the sand (D_{50} = 0.14 mm) at ElBanaieen area, are assumed. The fall velocity of the particle is equal 0.0015m/sec.

5 RESULTS AND DISCUSSIONS

4.1. Model calibration and validation

Numerical models should always be improved to fit the study area data, and any modifications are decided on during the calibration process. The models' calibration factors must be adjusted as part of the calibration process. In the present study, a large number of cases have been run through the model to reduce the variance between observed and computed values.

The principal tuning parameters used for the calibration of the LITPROF simulation model for a particular area are the scale parameter and the maximum angle of the bed slope. The scale parameter is a calibration parameter that represents the cross-shore momentum exchange. The maximum angle of the bed slope, 30°; the scale parameter, 3; the γ_1 and γ_2 (wave breaking factors), respectively, 0.88 and 0.6; and the roller coefficient factor, β_r = 0.15; these are the final values for the tuning parameters in the present study. The model is calibrated by comparing the predicted outcomes with those observed at various tuning parameters as shown in Fig. 6. It compares the measured profile with the calculated profiles for two different SP values (3 and 4.5). As the scale parameter value decreases, the profile gets closer to the measured value. The model performs best when the wave breaking parameters, the other calibration parameter, are also modified (γ_1 is 0.88 and γ_2 is 0.6). In this scenario, the computed profile closely matches the measured one. Fig. 7 shows a plot of the predicted elevations versus the observed at various points along the profile (BRP 3). It can be seen that the observed values are relatively similar to those expected with a correlation coefficient of 0.995. As a result, the model in its present situation can be used to predict changes in beach morphology.

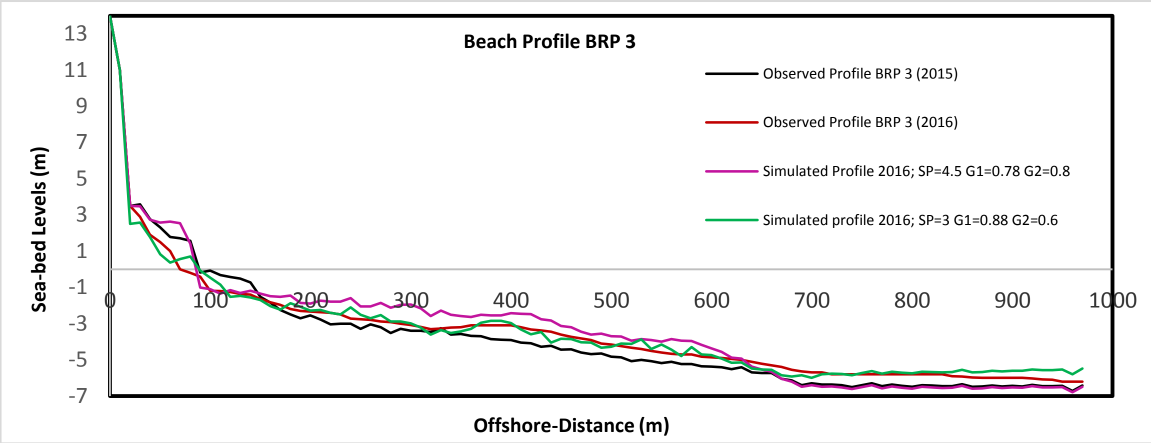


Figure 6. Comparison of simulated profiles with the measured profiles

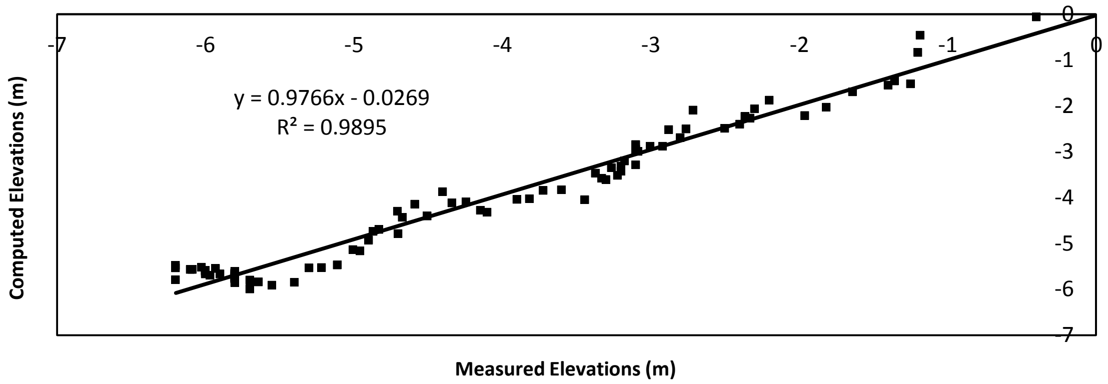


Figure 7. Comparing observed bed-levels to calculated beach elevation

The longshore current (LSC) and Longshore sediment transport rate (LSTR) across the three different profiles for two years 2015 & 2016 are computed by the LITDRIFT module is presented in Table 2 & 3. Four different wave condition (Average, Maximum, Summer, and Winter) are selected for the present study.

Beach profile BRP3 after the groin, the current velocity is near 1 m/sec except in the maximum condition the velocity above 1 m/sec. The longshore sediment transport rates across the profile also range between 0.42 to 0.25 m3/sec for 2015. In year 2016, the current velocities near 0.65 m/sec. and the littor drift rates decreased and ranges from 0.18 to 0.15 m3/sec. Beach profile BRP5 near the second detached breakwater, the longshore current velocity increases and ranges from 1.2 to 1 m/sec. So, the littoral drift rates across the profile rises and ranges between 0.45 to 0.3 m^3/sec and settled behind the deatched breackwater for year 2015. In 2016, the current velocities and the littor drift rates are still the same for 2015. The current velocities range from (0.45 - 0.2m/sec), and the littor drifts dramatically decreased and range from 0.07-0.03 m3/sec for beach profile BRP8 for year 2015. The values of current velocities and longshore sediment transport rates increased compared to year 2015.

Table2. Current velocities and longshore sediment transport across the three different profiles for 2015

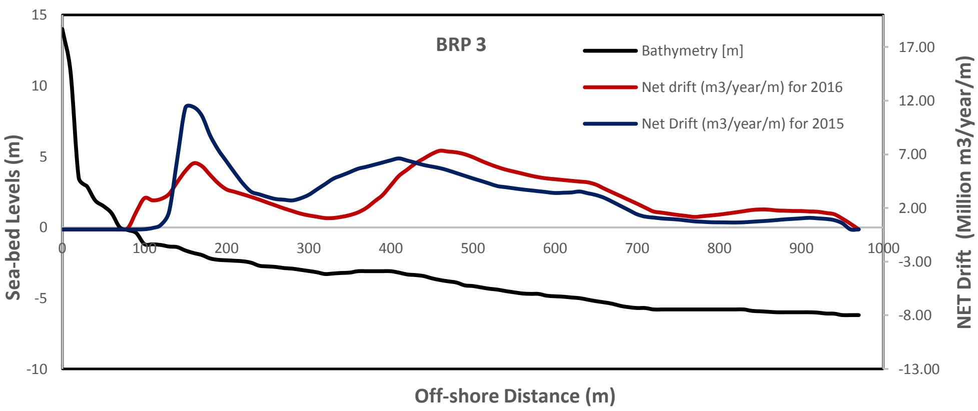
Wave condition	BRP3	BRP5	BRP8
Average	V= 0.965 m/sec. Qbx+Qsx=0.358 m^3/sec.	1.09525 m/sec. 0.445 m^3/sec.	0.208 m/sec. 0.0447 m^3/sec.
Maximum	1.135 m/sec. 0.423 m^3/sec.	1.285 m/sec. 0.316 m^3/sec.	0.343 m/sec. 0.027 m^3/sec.

Winter	0.950 m/sec. 0.298 m^3/sec.	1.03 m/sec. 0.439 m^3/sec.	0.319 m/sec. 0.071 m^3/sec.
Summer	0.912 m/sec. 0.256 m^3/sec.	1.01 m/sec. 0.401 m^3/sec.	0.462 m/sec. 0.0359 m^3/sec.

Table3. Current velocities and longshore sediment transport across the three different profiles for 2016

Wave condition	BRP3	BRP5	BRP8
Average	V= 0.665 m/sec. Qbx+sx=0.179 m^3/sec.	1.09525 m/sec. 0.445 m^3/sec.	0.746 m/sec. 0.226 m^3/sec.
Maximum	1.135 m/sec. 0.423 m^3/sec.	1.253 m/sec. 0.354 m^3/sec.	0.893 m/sec. 0.346 m^3/sec.
Winter	0.637 m/sec. 0.183 m^3/sec.	1.01 m/sec. 0.439 m^3/sec.	0.311 m/sec. 0.062 m^3/sec.
Summer	0.612 m/sec. 0.158 m^3/sec.	1.01 m/sec. 0.401 m^3/sec.	0.458 m/sec. 0.032 m^3/sec.

In Figure 8, results from the numerical module (LITDRIFT) are shown. The volumes of sediment transported across the beach profile are shown, indicating that most of the sediment transport occurs in the near shore zone between -4 m and the still water level for the three profiles (BRP3, BRP5, BRP8). In addition, near the shore and off-shore locations , the net littoral drift is approximately zero; the rates change in the nearshore zone depending on the bathymetry. In addition, LITDRIFT module results showed that the net littroral drift rate across the three profiles is more than $20x10^6$ m^3/year from the seashore to a depth of 6 m. Iskander (2020) stated that the majority of the migration of coastal sediment is in an easterly direction. Due to waves and currents, the Nile Delta area has the highest longshore sand transport rates per year ($1x10^6$ m^3/year). Off Bardawil Lake, it drops to around half ($0.5x10^6$ m^3/year). Figure 9 shows that the rate of erosion along the Nile Delta is approximately $20x10^6$ m^3/year from the seashore to a depth of 6 m.



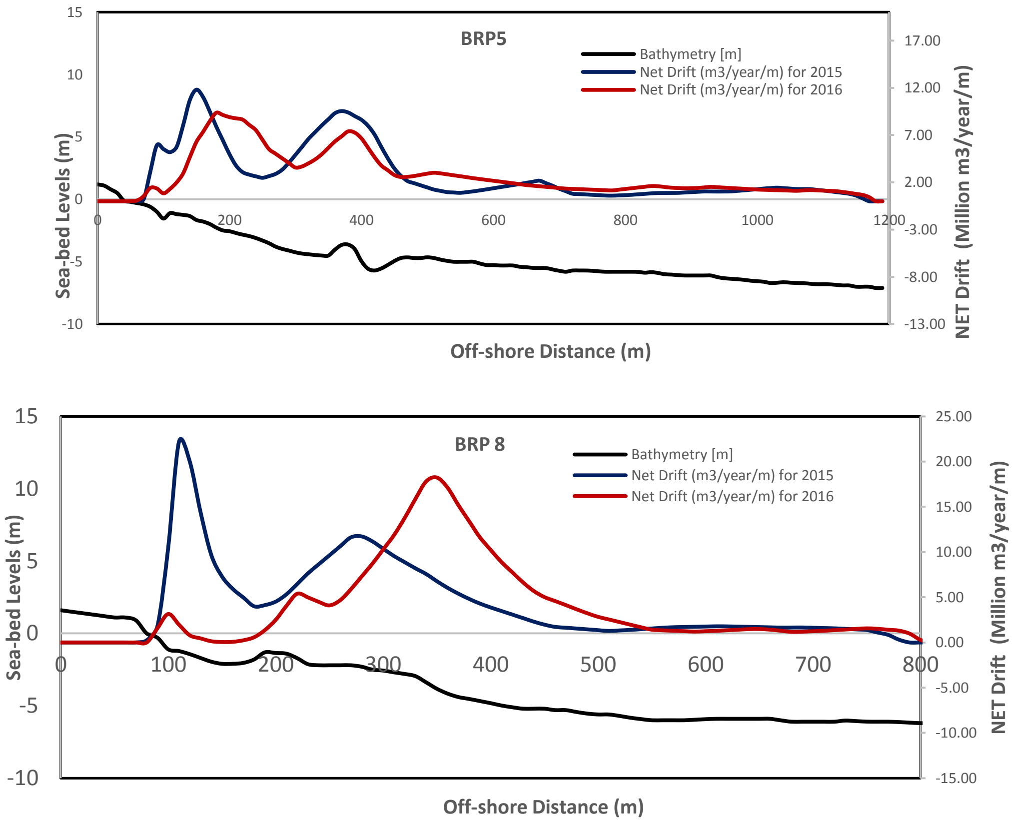


Figure 8. LITDRIFT results of the net littoral drift in function of the bathymetry for El- Banaeen area

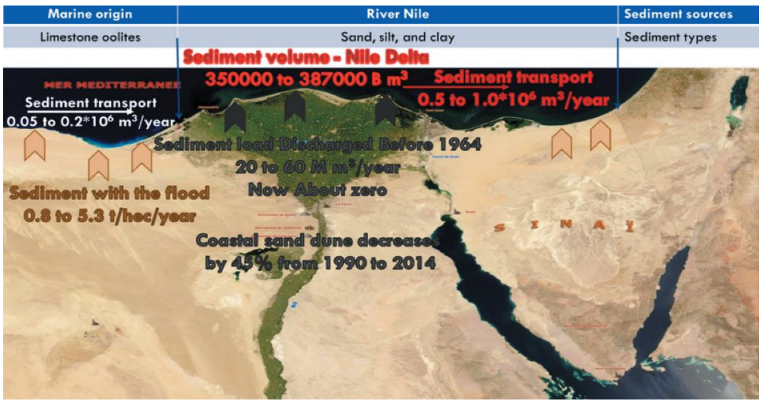


Figure 9. Sediment types and sediment sources along the Northern Egyptian Coast (Iskander, 2021)

The results computed by using the LITDRIFT shows reasonably good comparison with values of the Kamphuis formula, While the CERC formulae gives significantly high values as shown in Fig. 10. In comparison to the Kamphuis method, which depends on an empirical formula, the values obtained through numerical model analyses using LITDRIFT are more accurate because the model output is based on simulation of the site-specific field processes and the effects of coastal processes have been taken into account. The LST estimation using the Kamphuis equation yields better results than that of the CERC because the Kamphuis equation has taken the sediment gain size and bed slope into account.

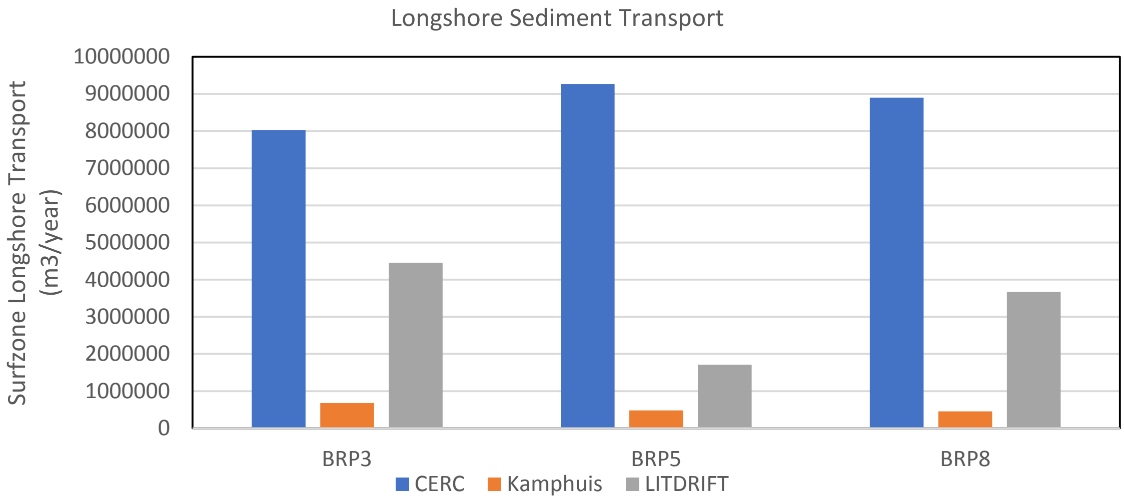


Figure 10. Longshorev sediment transport in the surf zone at El- Banaeen coastline computed using Kamphuis formula, CERC formula and LITDRIFT module of LITPACK

CONCLUSIONS

El-Baneen area suffers from erosion downdrift due the negative impact of the coastal measures. The erosion happens due the longshore transport. It is very difficult to measure (L.S.T). In the present research, the LITPROF simulations, which were calibrated with field data, generated results with a high degree of accuracy. The numerical modelling study further supports the high beach erosion and offshore accretion. The model's successful operation indicates that it may be used to predict coastal conditions in other coastal areas after it has been validated. In addition, according to the results of the LITDRIFT module, the net littroral drift rate over the three profiles is greater than $20x10^6$ m^3/year from the shoreline to a depth of 6 m. According to field measurements, the majority of coastal sediment migration is in an easterly direction. The Nile Delta region has the highest longshore sand transport rates annually ($lx10^6$ m^3/year) because to waves and currents. So, the results from calculations using the LITDRIFT show comparably good results to those obtained using the Kamphuis formula, whereas the CERC formulae produce exteremly higher results. Because the model output is based on simulation of the natural processes and their effects have been taken into account, the obtained values from LITDRIFT module are more accurate than the results obtained using the Kamphuis method, which depends on an empirical formula. Due to the inclusion of the sediment gain size and bed slope in the Kamphuis equation, the LST estimation using this equation produces better results than that using the CERC.

ABBREVIATIONS

LITPROF Profile development module
LITPACK Littoral Processes and Coastline Kinetics
DHI Danish Hydraulic Institute
LITDRIFT Longshore Current and Littoral Drift
LST Longshore sediment transport
LSTR Longshore sediment transport rate
SLR Sea level rise
FTCS Forward in time-central in space
SP Scale parameter
LSC The longshore current

SYMBOLS

α the wave incidence angle (°)
x the cross-shore direction (m)
D_{br} the energy dissipation due to wave breaking (W/m^2)
D_{bf} the energy dissipation due to bottom friction (W/m^2)
H_{rms} the root mean square wave height (m)
c the wave celerity (m/sec.)
k the wave number (m^{-1})
ρ_r the density of roller including air bubbles
A the surface roller area (m^2)
β_d the empirical constant (-)
S_{xy} the shear radiation stress which drives the longshore current (N/m^2)
E_f the wave energy flux
τ_b the bed shear stress ((N/m^2)
E the cross-shore momentum exchange factor (-)
V the longshore current velocity (m/sec.)
z_b the bed level (m)
n the porosity of the bed material (-)
$q_{s,x}$ the cross-shore transport rate (m^3/sec.)
Q_{lst} the longshore transport rate in volume per unit time (m^3/year)
ρ_w the water density taken as 1025 kg/m^3 for seawater
ρ_s the grain density taken as 2650 kg/m^3 for sand
K an empirical coefficient (-)
g the gravity acceleration (m/sec.2)
$H_{s,b}$ the significant wave height at breaking (m)
γ_b the breaker index (=Hb /db), generally taken as 0.78 (-)
θ_b the wave angle at breaking line (°)
Q_{vol} the total immersed volume (m^3/year)
T_p the peak wave period (sec.)
m_b the beach slope near the breaking (-)
D_{50} the median grain size (mm)
d is the water depth (m)
u the longshore current velocity (m/sec.)
y the shore normal coordinate (-)
τ_w & τ_{cur} are the driving forces due to wind and current
γ_1 & γ_2 wave breaking factors (-)
β_r the roller coefficient factor (-)
$Q_{bx}+Q_{sx}$ the longshore sediment transport (m^3/sec)

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