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# Estimation of Coastal Stability Due to Coastal Structures

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**Abstract:** The coastal structures are unavoidable for various industrial operations. These are changing hydrodynamics of the marine and its adjacent areas; and are directly influencing environmental conditions of the marine environment. The sedimentation on shorelines is strongly under influence of the new structures. The methodology, which is introduced in the paper, is a comparative study of situation of sediments before and after constructing the coastal installations. It is a guiding tool for planners to find the influences of the new structures in the marine area.

**Keywords:** Coastal Stability, Erosion of Sediments on Coastal Shores, Deposition of Sediments on Coastal Shores, Marine Sediment Model

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## 1. Introduction

This paper addresses concerns about the potential effects of a new coastal structure on coastal stability of the adjacent marine area. There are always environmental concerns about the impact of the new coastal structures on coastal areas. The monitoring agencies always consider the ecological consequences of accelerated shallowing resulting from alterations in sediment transport dynamics following the construction of the new coastal structure. The ESIA reports are always wondering the effects of coastal structures which will be constructed in marine areas. It is expected that the new structure affects hydrodynamics of the coast and it may cause of change of coastal line due to erosion and sedimentation. It is necessary to analyze effects of the coastal structure on present hydrodynamics and forecast the potential changes of coastal line using suitable hydrodynamic simulation model. Countermeasures against the impacts should be provided in accordance with the simulation results taking into consideration of environmental protection.

Geo-morphological changes focuses on observations of coastal sedimentation and the need to determine the potential changes in sediment transport, after the new coastal structure is built. The hypothesis of limited long-shore transport is consistent with the minimal sand build up at the existing coastal structure. The potential impacts due to the new coastal structure are:

- changes in wave patterns;
- changes in currents;
- changes in sediment transport;
- changes in coastal orientation; and
- secondary impacts on coastal dunes.

As a result, the building party committed to carrying out a study to further investigate the effects of the new coastal structure development on the existing hydrodynamic conditions, alongshore littoral transport rates, and offshore (sub-littoral) sediment transport patterns. The paper is addressed herein in the following:

Determining the potential effects of the solid-core coastal structure on the area's coastal stability and focusing on potential changes to the erosional/depositional condition of the shoreline.

This process entails field study and wave refraction modeling. An area, Figure 1 and 2, with metrological, wave conditions and sea bottom topography (bathymetry) are selected.

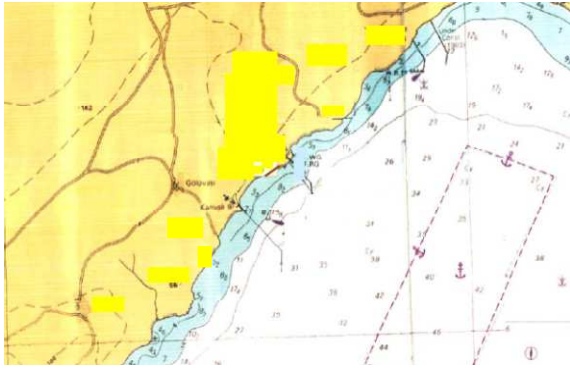


Figure 1. Location of the new coastal structure at marine area, [1].



Figure 2. A typical coastal structure, a jetty, [1].

## 2. Potential Changes in Sediment Transport

A 1D (one-dimensional) vertically averaged wave refraction and sediment transport model; SEDTRANS; [1], was used to analyse changes in sedimentary transport associated with the new coastal structure. The model, among other factors, provides offshore wave height and wavelength, inshore wave heights, directions and frequencies at a series of points along the coastline. Alongshore transport rates are established and compared before and after coastal structure construction, and to determine probable changes in sediment transport and coastal erosion / deposition with respect to the shoreline types present.

### 2.1. Wind Conditions

Winds generate the waves that affect the shoreline. The wind rose for the marine area south of the marine area is presented in Figure 3. Table 1 presents a summary of wind direction by percentage.

Table 1. Annual Wind Direction – Percentage, [1].

N	NNE	NE	ENE	E	ESE	SE	SSE
14	16	1	2	1	5	1	6
S	SSW	SW	WSW	W	WNW	NW	NNW
2	20	3	7	2	3	2	10

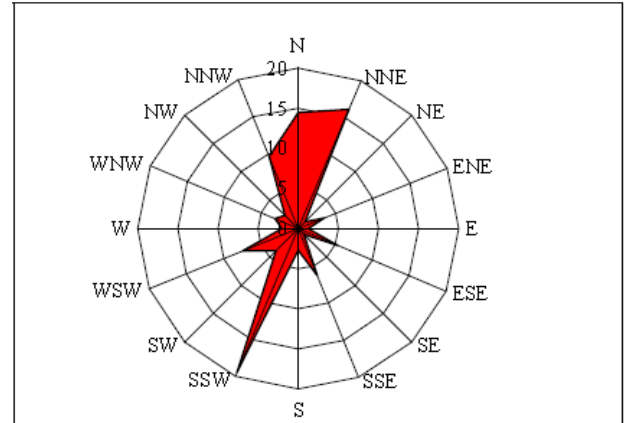


Figure 3. Annual wind rose of the marine area, [1].

The primary wind conditions that generate waves, which are used as input to SEDTRANS, are provided in Table 2. Winds from the SW to the NE come off the land and winds from ENE and E have a short fetch and are not common.

Table 2. Wind conditions in SEDTRANS model.

Direction	% Frequency	Total Sec/Year	Comment
SE	6	1892160	Includes SE, ESE
SSE	8	2522880	Includes SSE, S
SSW	23	7253280	Includes SSW, SW
Total	37	11668320	

### 2.2. Wave Climate

The probability distribution for waves based on wind conditions and fetch is considered as sample data, [2], and then probabilistic wave heights, periods and directions are developed. The principal wave components, which are used in the sediment transport model, are identified and presented in Table 3.

Table 3. Wave Frequency analysis and values used in SEDTRANS model.

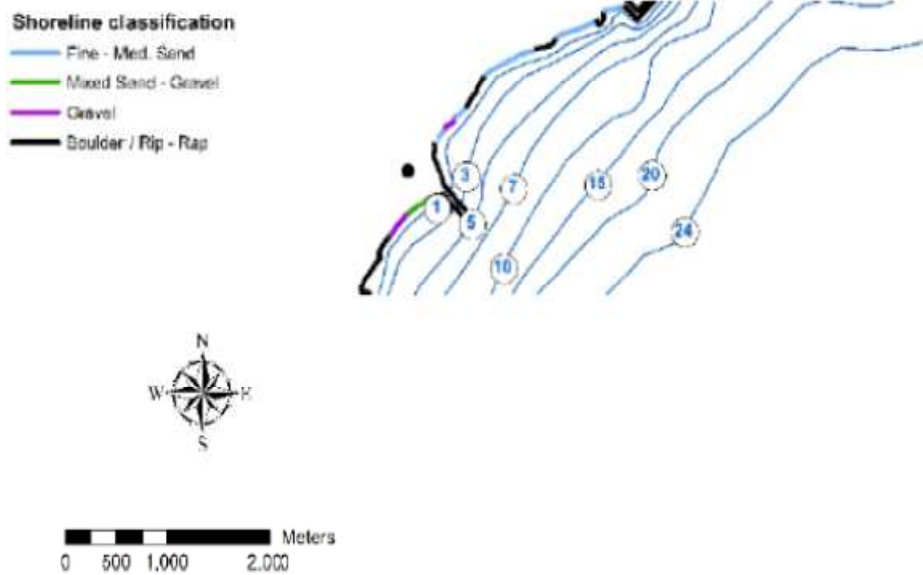
Frequency	Total sec(Table 2)	H <sub>0</sub> (m)	T (sec)
Wind Direction: SE			
84.39%	1596715	0.50	2.67
13.18%	249314	1.00	3.77
2.44%	46104	2.00	5.34
0.0014%	27	4.00	7.55
100.00%	1892160		
Wind Direction: SSE			
86.42%	2180312	0.50	2.67
11.73%	296056	1.00	3.77
1.84%	46499	2.00	5.34
0.0005%	13	4.00	7.55
100.00%	2522880		
Wind Direction: SSW			
53.02%	3846017	0.50	2.67
24.92%	1807758	1.00	3.77
21.03%	1525064	2.00	5.34
1.0263%	74440	4.00	7.55
100.00%	7253280		

### 2.3. Shoreline Types, Grain Size and Bathymetry

Shorelines in the area were categorized during recent field surveys. The primary shorelines with the estimated average grain size and porosity of each category are listed in Table 4.

**Table 4.** Sediment types with  $K$  and grain size parameters used in SEDTRANS.

Shoreline Type	K	Grain Size ( $d_0$ ) (mm)
Fine-Medium Sand	.039	0.25
Mixed Sand and Gravel	0.03	2.0
Gravel	0.01	20
Boulder / Riprap	0	1000



**Figure 4.** Bathymetry and shoreline types in the marine area, [1].

### 2.4. The SEDTRANS Model

The SEDTRANS model has features of, [2-15]:

**Refraction:** Refraction is the bending of waves because of varying water depths on the water bottom, bathymetry. The part of a wave in shallow water moves slower than the part of a wave in deeper water. So, when the depth under a wave crest varies along the wave crest, the wave bends, according to Snell's Law. An example of refraction is when waves approach a straight shoreline at an angle.

**Diffraction:** Diffraction usually happens when waves encounter an obstacle, such as a breakwater, marine structure or an island. The turning of the waves into the sheltered region results the changes in wave heights in the waves and waves spread out. A parameterization technique was developed for diffraction in the SEDTRANS.

Transport rate or erosion and deposition,  $Q_I$ , from CEM 1998, [2], is;

$$Q_I = K \left[ \frac{\rho \sqrt{g}}{16 \kappa^{1/2} (\rho_s - \rho) (1 - n)} \right] H_b^{5/2} \sin(2 \alpha_b) \quad (1)$$

where ;

Bathymetry was digitized from a nautical chart. In the area of the new coastal structure, bathymetry was also updated. A map of shoreline types and bathymetry is presented in Figure 4.

$\rho_s$  = the mass density of the sediment grains ( $\rho_s=2650\text{kg/m}^3$ );

$\rho$  = the mass density of water ( $\rho=1025 \text{ kg/m}^3$ );

$n$  = in place sediment porosity ( $n \approx 0.4$ );

$K$  = dimensionless coefficient (see Table 4);

$\kappa$  = the breaker index ( $= 0.72 + 5.6 S$ );

$S$  = the bottom slope;

$\alpha_b$  = the breaker angle relative to the shoreline;

$H_b$  = breaking wave height;

$$H_b = H_I^{4/5} \left( \frac{c_{gl} \cos \alpha_I}{\sqrt{g} / \kappa \cos \alpha_b} \right)^{2/5} \quad (2)$$

$c_{gl}$  = the deep water wave celerity ( $= g T / 2\pi$ );

$T$  = the wave period;

$\alpha_I$  = the deep water wave direction; and

$H_I$  = deep water wave height.

SEDTRAN calculates shore-reaching angle, transport with given conditions.

## 3. Results

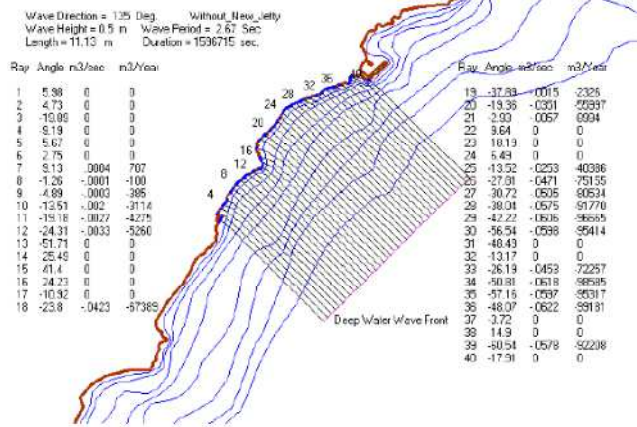
### 3.1. SE Wave Conditions (Before and After Jetty)

A jetty, which new installation on the shore line, is constructed in the shore area, for these conditions, the

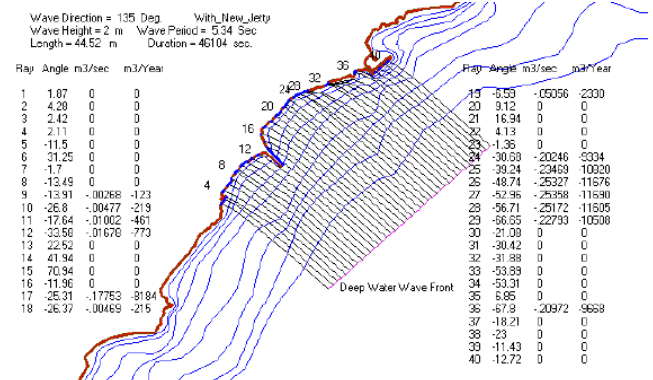
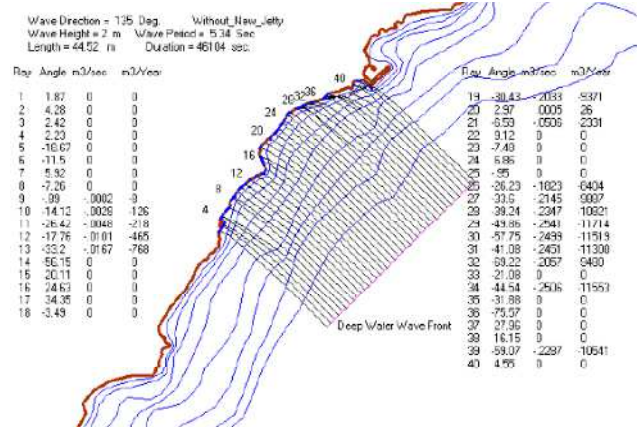
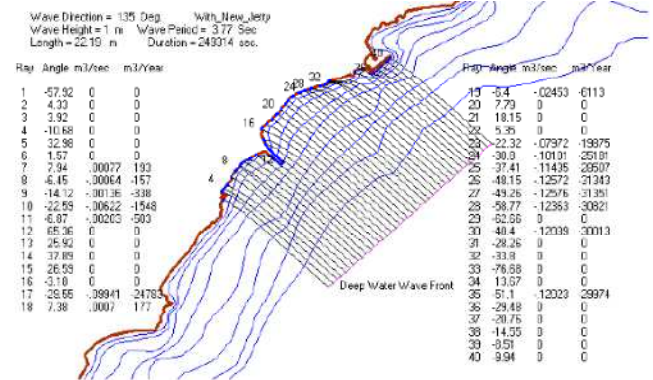
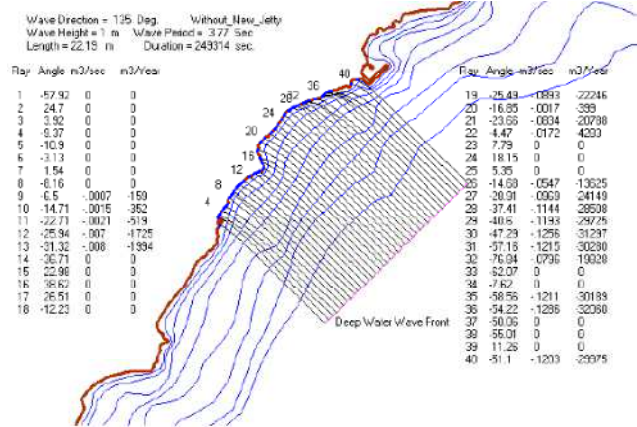
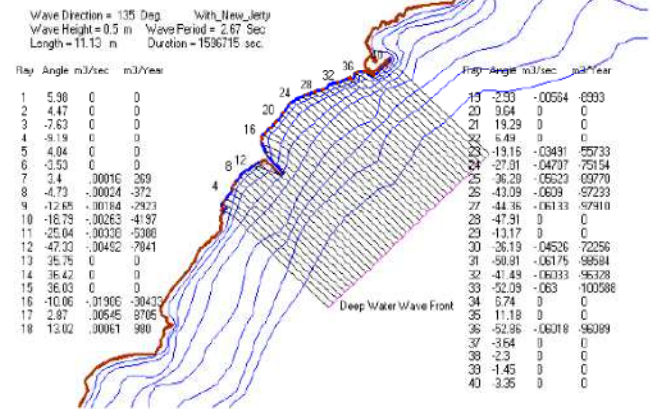
transport rates and wave rays before and after jetty placement are shown in Table 5.

**Table 5.** Wave refraction and sediment transport rates for 0.5 m, 1.0 m, 2.0 m and 4.0 m SE waves, [1].

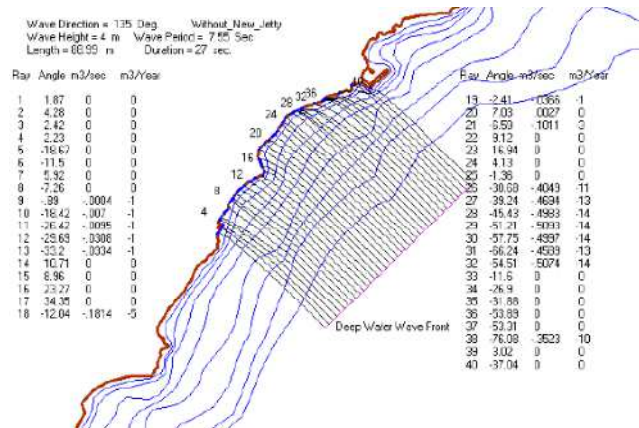
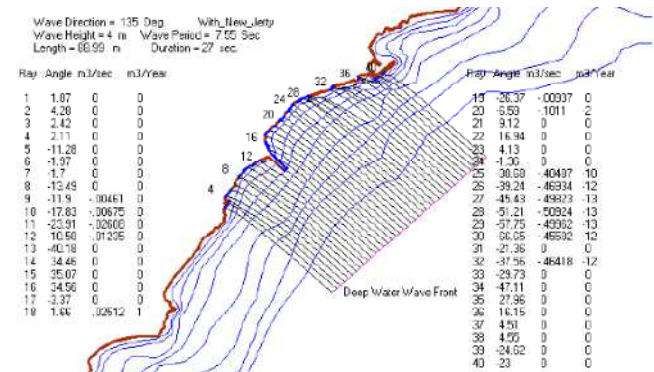
#### Before Jetty



#### After Jetty



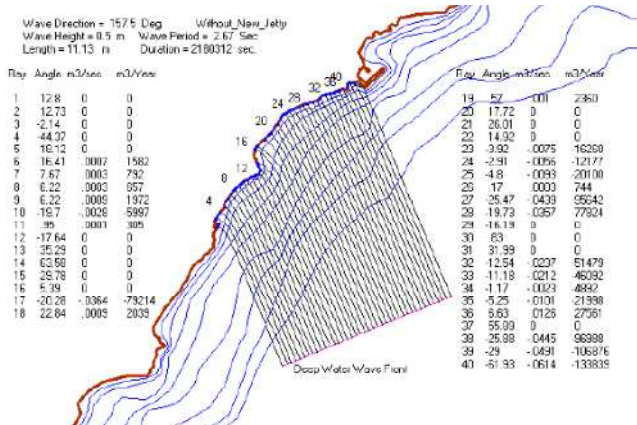
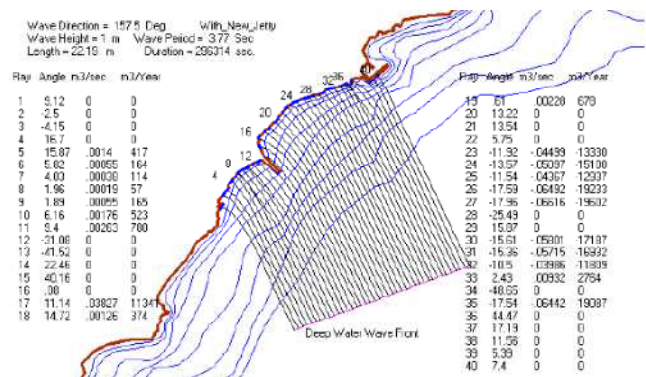
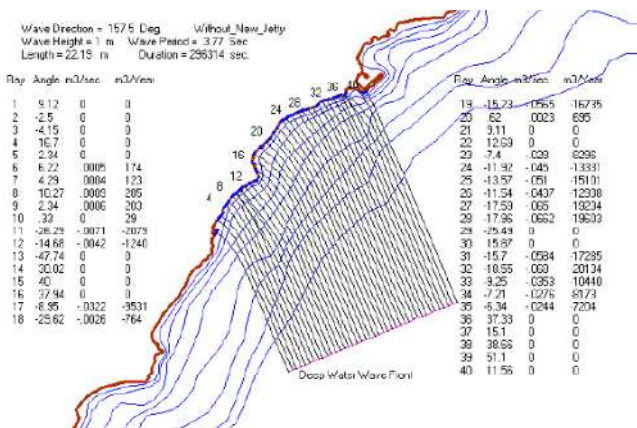
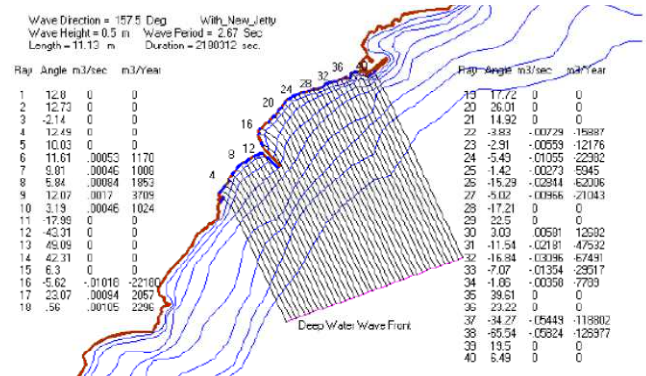


**Before Jetty****After Jetty****3.2. SSE Wave Conditions (Before and After Jetty)**

before and after jetty placement are shown in Table 6.

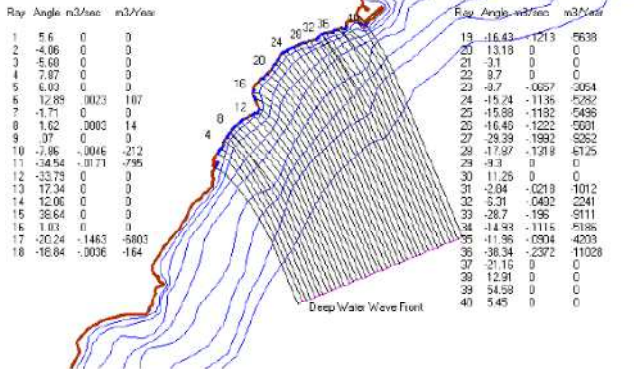
For these conditions, the transport rates and wave rays

**Table 6.** Wave refraction and sediment transport rates for 0.5 m, 1.0 m, 2.0 m and 4.0 m SSE waves, [1].

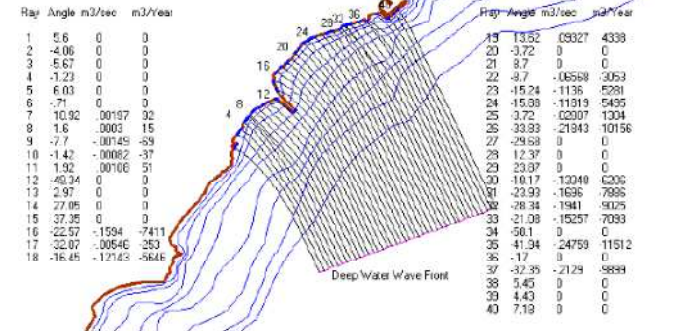
**Before Jetty****After Jetty**

**Before Jetty**

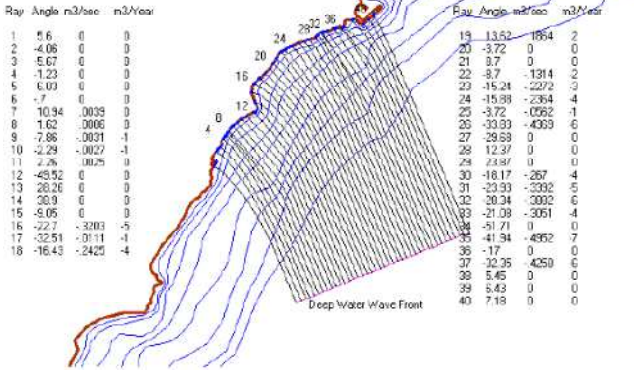
Wave Direction = 157.5 Deg Without New Jetty  
Wave Height = 2 m Wave Period = 5.34 Sec  
Length = 44.52 m Duration = 46499 sec.

**After Jetty**

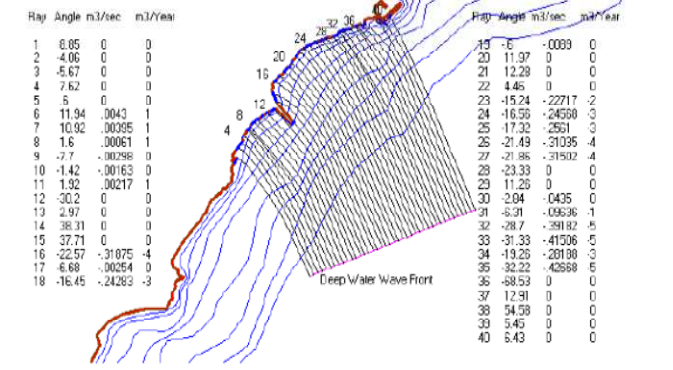
Wave Direction = 157.5 Deg With New Jetty  
Wave Height = 2 m Wave Period = 5.34 Sec  
Length = 44.52 m Duration = 46499 sec.



Wave Direction = 157.5 Deg Without New Jetty  
Wave Height = 4 m Wave Period = 7.55 Sec  
Length = 68.95 m Duration = 13 sec.



Wave Direction = 157.5 Deg With New Jetty  
Wave Height = 4 m Wave Period = 7.55 Sec  
Length = 68.95 m Duration = 13 sec.

**3.3. SSW Wave Conditions (Before and After Jetty)**

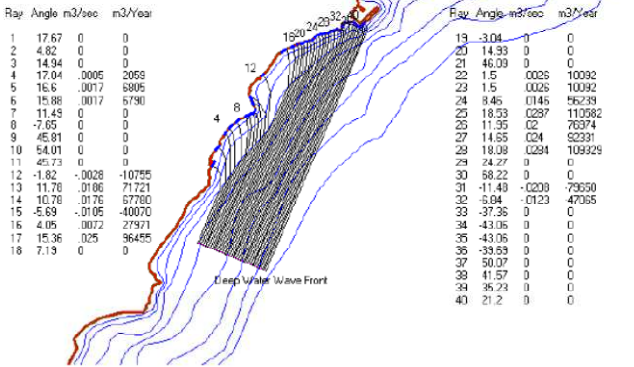
For these conditions, the transport rates and wave rays

before and after jetty placement are shown in Tables 7 and 8.

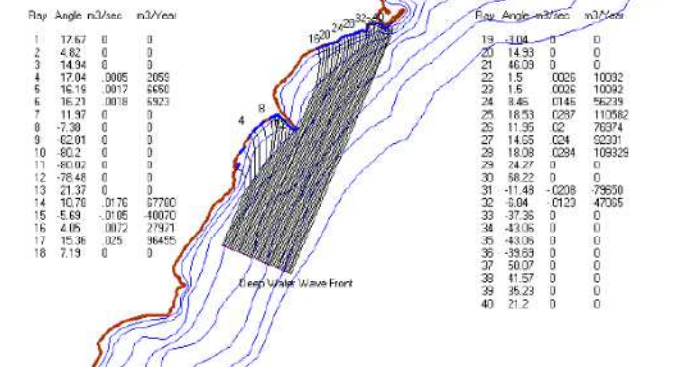
Table 7. Wave refraction and sediment transport rates for 0.5 m, 1.0 m, 2.0 m and 4.0 m SSW waves, [1].

**Before Jetty**

Wave Direction = 202.5 Deg Without New Jetty  
Wave Height = 0.5 m Wave Period = 2.67 Sec  
Length = 11.13 m Duration = 3846017 sec.

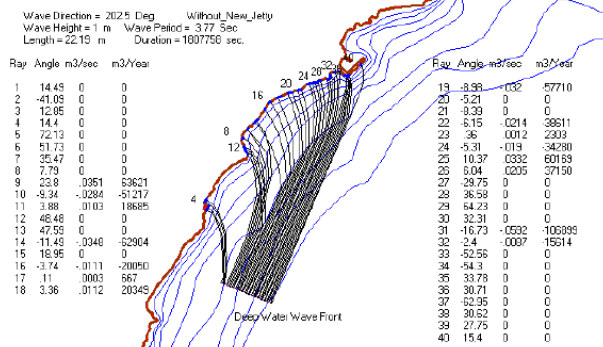
**After Jetty**

Wave Direction = 202.5 Deg With New Jetty  
Wave Height = 0.5 m Wave Period = 2.67 Sec  
Length = 11.13 m Duration = 3846017 sec.





## Before Jetty



## After Jetty

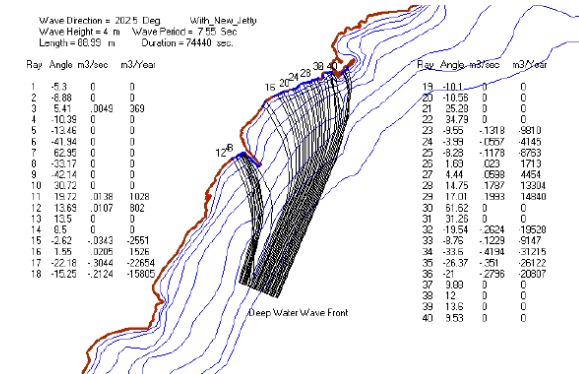
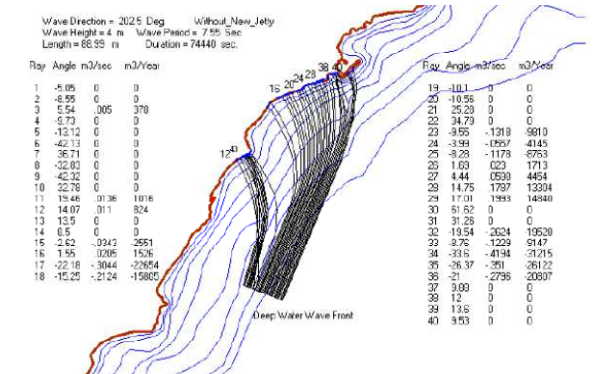
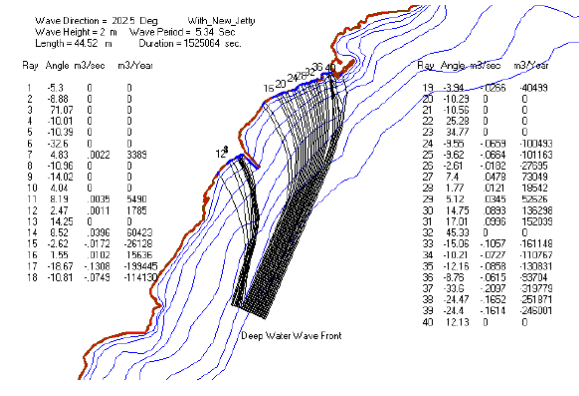
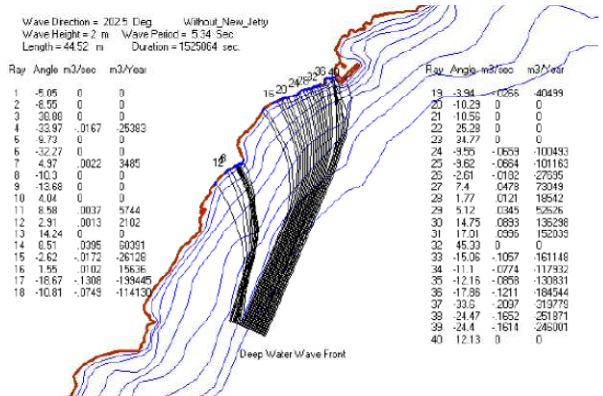
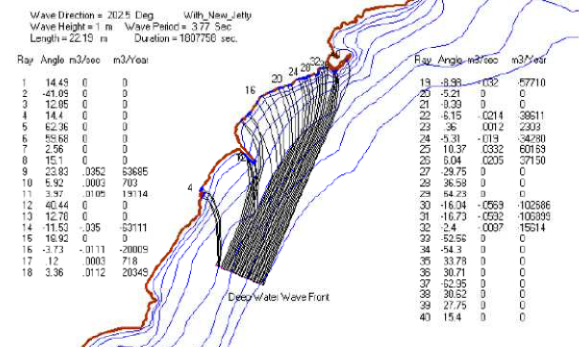
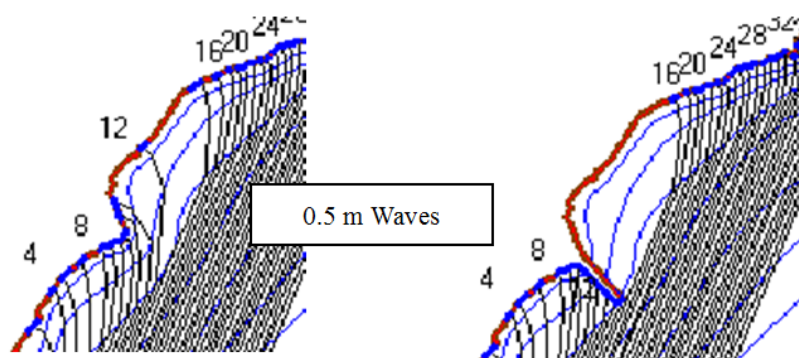
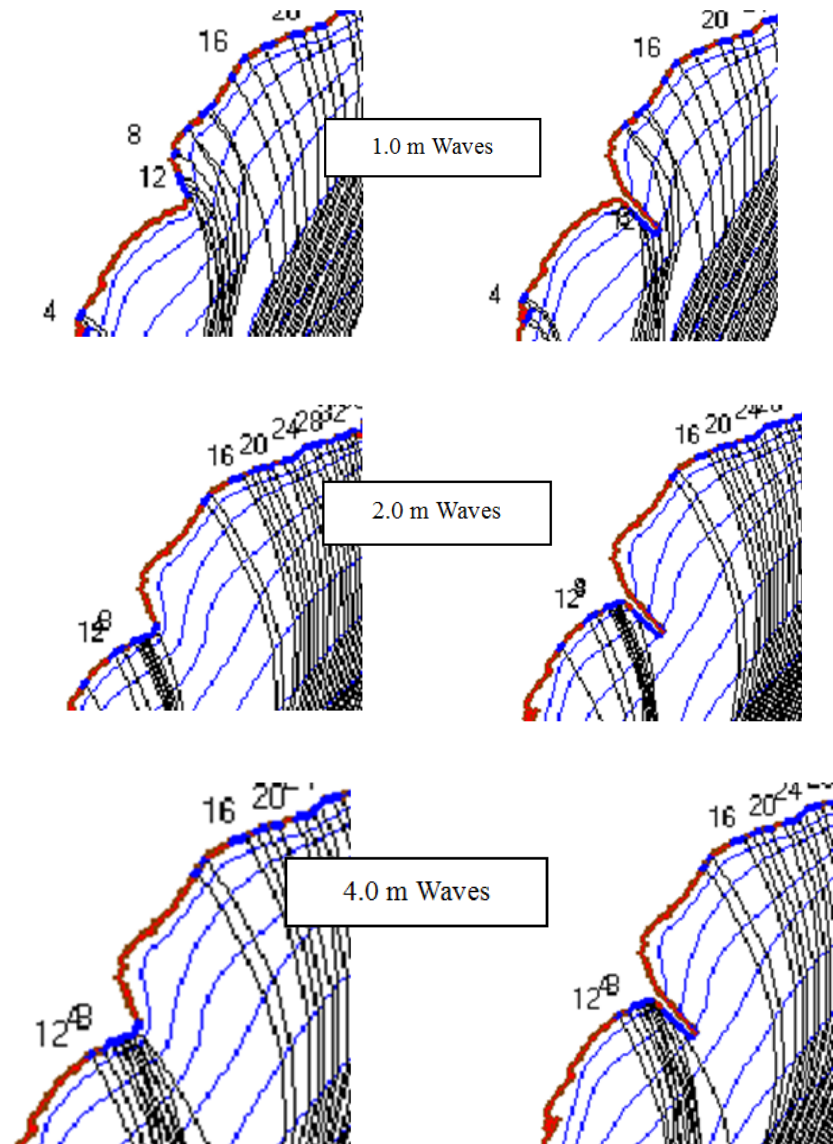


Table 8. Detailed view around new jetty SSW waves, [1].

## Before Jetty

## After Jetty





**Table 9.** Analyse of annual sediment transport at three locations; before and after jetty; [1].

Waves		South of New Jetty				North of New Jetty				East of Jetty			
Height	Dir	#	BEFORE	AFTER	#	#	BEFORE	AFTER	#	#	BEFORE	AFTER	#
0.5	135.0	12	-5260	-7841	12	18	-67389	-30433	16	39	-92208	-96089	36
1		13	-1994	-503	11	19	-22246	-24783	17	40	-29975	-29974	35
2		13	-768	-773	12	19	-9371	-8184	17	39	-10541	-9668	36
4		13	-1	no strike	12	18	-5	1	19	38	-10	no strike	
Subtotal			-8023	-9117			-99011	-63399			-132734	-135731	
0.5	157.5	11	305	1024	10	17	-79214	-22180	16	40	-133839	-126977	38
1		12	-1240	780	11	17	-9531	11341	17	35	-7204	-19087	35
2		11	-795	51	11	17	-6803	-7411	16	36	-11028	-9899	37
4		10	-1	no strike	10	16	-5	-4	16	37	-6	-5	35
Subtotal			-1731	1855			-95553	-18254			-152077	-155968	
0.5	202.5	6	6790	6923	6	12	-10755	no strike		32	-47065	-47065	32
1			no strike	no strike	11	9	63621	63685	9	32	-15614	-15614	32
2		7	3485	1785	12	14	60391	no strike		39	-246001	-246001	39
4		12	824	802	12	15	-2551	no strike		36	-20807	-20807	36
Subtotal			11291	9510			110706	63685			-329487	-329487	
Total			1537	2248			-83858	-17968			-614298	-621186	

‘+’ = transport to right of wave ray, ‘-’ = transport to left of wave ray.

‘#’ = wave ray number from refraction diagram.



## 4. Discussion of Results

It is seen that there are no changes in wave rays before and after jetty placement for waves coming from the SSE and SE because of the alignment of the jetty with the approaching waves. SSW waves show some shadowing due to the jetty, which is evident under the 0.5 m and 1.0 m waves, however there is also a natural shadowing to the north due to the natural refraction of SSW waves due to bathymetry, as shown under 2.0 m and 4.0 m wave conditions (Tables 7 and 8).

An analyse of the annual sediment transport rates at three locations, south of the jetty, north of the jetty, and surrounding are presented in Table 9. Results of this analysis indicate:

- No net change east of the jetty,
- No net change south of the jetty.
- Several changes north of the jetty:
  - Less transport southward with waves from SE and SSE.
  - Less northward transport with SSW waves due to shadow zone.
  - Less annual transport to the south.

In detail analysis, these conclusions are not altered significantly by analyzing the shoreline with the jetty and surrounding by using the SEDTRANS model. In other words, there are no significant expected changes in annual sedimentary transport along shorelines adjacent to the new jetty, see Table 9. The transport north of the jetty has decreased because this area is being sheltered by the jetty. However, annual sedimentary transport has not been changed, and the shorelines are expected to remain stable with the jetty and surrounding.

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