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SEDIMENT BUDGET AND EROSION ASSESSMENT OF THE HAIHAU COASTAL ZONE, NAMDINH PROVINCE, NORTHERN VIETNAM

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ABSTRACT

The Haihau district of Namdinh province, Northern Vietnam is well-known as the most intensive erosional shoreline of Vietnam. The velocity of erosion could reach 10-15 m/y. In the region, erosion occurs due to longshore sediment transport either to the south or to the north. However, the main reason is southeast ward longshore sediment transport. Based on the methods of CERC (U.S Army Coastal Engineering Research Center), volumes of southeast ward and northwest ward sediment transport rates are 400,715 m^3/y and 312,142 m^3/y, respectively. The net sediment transport rate is southeast ward with a volume of 88,569 m^3/y.

Keywords: Haihau coast, longshore transport rate, sediment budget, Vietnam, wave

Introduction

The Haihau district of Namdinh province which is situated on the south coast of the Red River delta. The study area is about 30 km from the south of the Red River (Balat) mouth (Fig. 1). The shoreline of the Haihau district is 30 km long, faces SE and represents a serious widespread erosion. The shoreline retreat in this region was 10-15 m/year in the past 50 years. The erosion could also reach 20-30 m/y in some years (Nhuan and Tien et al., 1996). The Haihau coast still remains evidences of erosion such as a pagoda built at the beginning of 20th century and located 1 km away from the former shoreline at that time. However it is now under water levels. In 1993, a resort building was built at a site 300 m landward from shoreline but it is under water levels in spring tides nowadays.

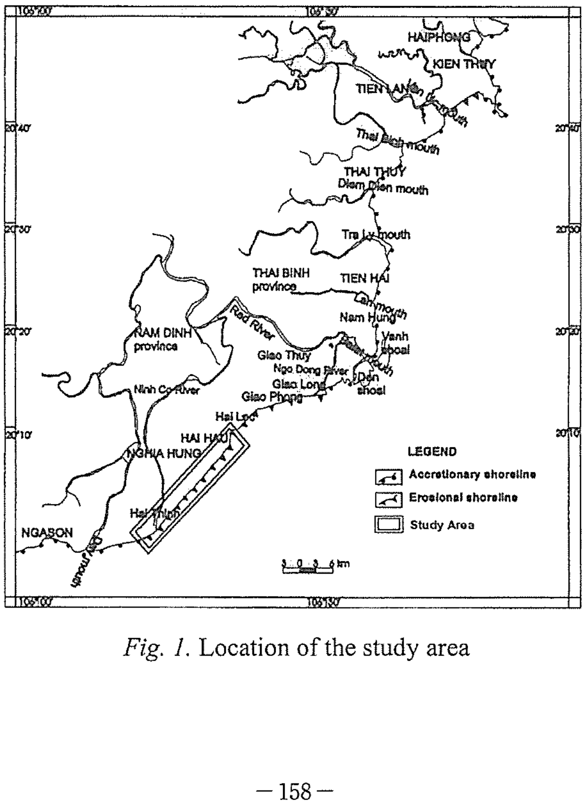

Fig. 1. Location of the study area

The Haihau coast used to be connected to the Red River by the Ngo Dong river. Nevertheless, the Ngo Dong river was dammed in 1955 (Vinh et al.,1996) and have interrupted sediment sources from the Red River. The tide is mixed with a diurnal dominance. The average tidal amplitude is 2-3m. Waves usually have a dominant direction from the east or northeast during the dry season (winter) and from east, southeast during the wet season (summer). The average and maximum wave heights are 0.7-1.3 m and 3.5-4.5m, respectively, but in severe storms wave heights can reach over 5 m (Nhuan and Tien et al., 1996). In order to prevent wave attacks the shoreline is being protected by dikes. In front of the dikes, the beach is gently slope with an average value of 1/350 (after topographical map scale 1: 50,000 published in 1991). The beach is constituted by fine sand with an average diameter of about 80 m (Vinh at al., 1996).

The coastal erosion causes the loss of land, demolishment of infrastructure and expansion of saline intrusions. Therefore the research on shoreline change of the Haihau district will contribute useful information for a rational land use and mitigation of hazards related to accretion and erosion.

Methods and materials

The erosion is assessed by calculation of sediment longshore transport rates. At the shoreline, sediments are parallely mobilised to the south due to north or east waves. At the same time, south waves will move sediments to the north. Therefore there are two possible directions of motion, north and south. The net longshore transport rate is calculated by a formula:

$$Q_{net} = Q_{south} - Q_{north} \qquad (1)$$

where Q_{south} and Q_{north} are the southern and northern longshore transport rates, respectively and Q_{net} is the net longshore transport rate..

Based on Q_{south}, Q_{north} and Q_{net} the situation of sediment balance can be elucidated. When absolute value of Q_{net} is small, the shoreline is stable. A positive Q_{net} indicates an erosional shoreline with dominant southward sediment movements while a negative Q_{net} is an evidence for an erosional shoreline with dominant northward sediment movements.

The Haihau district is a high wave energy coast (Duc et al., 2001) and sediments are mostly mobilised by waves. Sediment longshore transport rates are determined by energy flux method with a formula of CERC (Shoreline protection manual, 1978):

$$Q = a \times P_{ls} \quad (\text{yard}^3) \qquad (2)$$

where Q is longshore transport rate, "a" is an empirical coefficient, equal to 7500, and P_{ls} is the longshore energy flux factor entering the surf zone. P_{ls} is calculated by a formula as follows:

$$P_{ls} = 32.1 H_B^{5/2} \sin 2\alpha_{Bs} \; (\text{ft.lbs/sec/ft}) \quad (3)$$

where - α_{Bs} is the breaking wave angle (Fig. 2)
- H_B is breaking wave height (ft)

After Sanamura (1983), H_B is obtained from the formula:

$$H_B/H_o = (\tan\beta)^{0.2}(H_o/L_o)^{-0.25} \qquad (4)$$

β is the beach slope, H_o is deep water wave height and L_o is deep water wavelength ($L_o = gT^2/2\pi$, g is the acceleration of gravity = 9.82 m/s^2 and T is the period of waves).

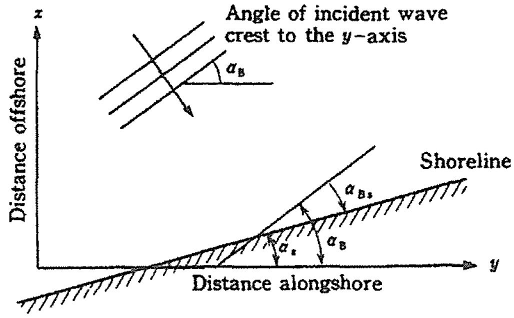

Fig. 2. Definition of breaking wave angle (α_{Bs})

Table 1: Frequency (%) of the wave height (1960 - 1994) in winter at Hondau station

Wave Height (m)	N	NE	E	SE	S	SW	W	NW	**Total**
α_{Bs} (degrees)	45	90	45	180	-45	-	-	-	
< 0.25	3.03	3.25	7.11	4.19	0.79	0	0	0	18.37
0.25-0.50	2.76	2.30	4.08	3.05	0.38	0.05	0.03	0.32	12.95
0.50-0.75	4.81	5.37	11.04	7.75	0.70	0.07	0.02	0.31	30.07
0.75-1.00	2.63	3.19	8.56	4.29	0.19	0.02	0.00	0.13	19.02
1.00-1.50	1.72	2.26	9.01	3.09	0.39	0.07	0.00	0.01	16.57
1.50-2.00	0.21	0.20	1.57	0.29	0.10	0.02	0.00	0.00	2.39
2.00-2.50	0.02	0.00	0.08	0.01	0.01	0.00	0.00	0.00	0.12
2.50-3.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Total	12.16	13.32	34.35	18.48	1.77	0.23	0.05	0.76	100.0

Table 2: Frequency (%) of the wave height (1960 - 1994) in summer at Hondau station

Wave Height (m)	N	NE	E	SE	S	SW	W	NW	**Total**
α_{Bs} (degrees)	45	90	45	180	-45	-	-	-	
< 0.25	1.69	1.69	4.17	6.37	5.42	1.93	0.10	0.85	22.22
0.25-0.50	1.24	0.86	1.52	3.49	1.41	0.33	0.28	0.63	9.77
0.50-0.75	2.06	1.94	4.92	8.66	4.47	1.43	0.33	0.75	24.56
0.75-1.00	1.06	1.22	3.44	4.23	3.24	1.01	0.11	0.25	14.56
1.00-1.50	1.24	1.29	3.54	4.79	6.69	2.72	0.10	0.13	20.53
1.50-2.00	0.23	0.51	0.77	1.28	2.53	0.96	0.06	0.04	6.39
2.00-2.50	0.08	0.09	0.24	0.26	0.48	0.18	0.01	0.01	1.34
2.50-3.00	0.01	0.02	0.09	0.10	0.05	0.02	0.00	0.01	0.28
3.00-4.00	0.00	0.00	0.06	0.07	0.05	0.04	0.00	0.01	0.23
4.00-5.00	0.00	0.00	0.00	0.03	0.01	0.02	0.00	0.00	0.06
5.00-6.00	0.00	0.00	0.01	0.02	0.03	0.01	0.00	0.00	0.06
Total	5.93	5.93	14.59	22.3	18.97	6.74	0.88	1.82	100.0

β was determined after the topographical map scale 1: 50,000 published in 1991 and it is 1/350. Wave characteristics in the region vary with time during the year. According to data of the Hondau monitoring station, in the winter (from December to March) the main wave direction is northeast offshore part and East and southeast near shore part (Tab. 1) The average wave height is 1.2 m in the offshore and 0.5-0.75 m in the near shore. The maximum height of wave is 6.6m in the offshore and 2.0 - 3.0 m in the near shore. In the summer (from June to September), the main directions of waves are south, southwest and east (40-

75%) offshore and 0.5-0.75 m in the nearshore (Tab. 2). The maximum height of wave is 7.9-8.0 m in the offshore and 5.0-6.0 m in the near shore (caused by a lot of storms and tropical cyclones). In transitional season (April - May and October- November), the wave directions and heights are differently varied (Tab. 3).

Table 3: Frequency (%) of the wave height (1960 - 1994) in transitional season at Hondau station

Wave Height (m)	N	NE	E	SE	S	SW	W	NW	**Total**
α_{Bs} (degrees)	45	90	45	180	-45	-	-	-	
< 0.25	0.72	1.41	6.94	7.24	2.78	0.33	0.02	0.06	19.50
0.25-0.50	0.70	0.96	4.60	4.04	0.81	0.03	0.04	0.08	11.27
0.50-0.75	0.82	2.05	10.30	10.16	2.44	0.26	0.01	0.09	26.17
0.75-1.00	0.66	1.42	6.33	6.02	1.82	0.19	0.01	0.05	16.50
1.00-1.50	0.62	1.22	6.29	7.47	4.40	0.68	0.01	0.01	20.70
1.50-2.00	0.11	0.08	0.97	1.93	1.72	0.21	0.00	0.00	5.04
2.00-2.50	0.05	0.07	0.13	0.21	0.26	0.00	0.00	0.00	0.71
2.50-3.00	0.00	0.01	0.00	0.05	0.01	0.00	0.00	0.00	0.28
Total	2.97	5.81	28.67	29.88	11.47	1.37	0.08	0.24	100.0

Results and discussions

The annual volume of sediment longshore transport rate of each wave range (average value of the range is used) in a season is calculated by the Eq. 1, 2, 3 and 4. Then the volume is multiplied to frequency of the range and divided by 3 (because each season has 4 months - one third of a year). The calculations are carried out with Microsoft Excel sheets as showed in table 4, 5 & 6.

In summer sediments are mostly transported by south waves. However northward and eastward waves make an opposite direction of sediment movement that reduces the annual northwest ward net longshore transport rate to 54,847 m^3/y (Tab. 7). In winter and transitional season northward an eastward waves are dominant in longshore sediment transport. The annual volumes of sediment moved southeast ward in winter, transitional season are 101,751 m^3/y and 162,497 m^3/y. The northwest ward longshore sediment rate is very small in winter (9,519 m^3/y) that makes a large different between southeast ward and northwest ward longshore sediment rate (92,232 m^3/y). Generally, the annual net longshore transport rate is southeast ward and equal to 88,569 m^3/y. The results of calculation also show that in all cases most sediment are removed by waves of heights from 1.0 to 1.5 m with percentages of 39.7 - 50.3% of the total.

Table 7. Volumes of long shore sediment transport due to waves

Wave direction / Season	**North**	**East**	**South**	**Sum**
Winter (m^3/y)	46,599	55,152	-9,159	92,232
Summer (m^3/y)	31,819	104,649	-191,315	-54,847
Transitional (m^3/y)	16,009	146,488	-111,312	51,184
Sum (m^3/y)	94,427	306,289	-312,146	88,569

The Ngo Dong river has dammed since 1955 and then the sediment supply in the Haihau coast has been interrupted. Therefore waves are the dominant factor in sediment mobilisation at the coast. The formula proposed by Shoreline Protection Manual was deduced from experimental tests with fine sands that seem to be as same as the seabed sediments of uniform fine sands at the Haihau coast. On the other hand the longterm dataset of wave monitoring provides reliable information about wave characteristics. These aspects make the above formula being reliable in use for this case.

Some disadvantages of using the formula can be also realised. Breaking wave angles ($_{Bs}$) are approximately because the dataset of wave monitoring only shows directions of waves without real angles in a specific co-ordinate. Some other factors such as tide, seadykes do not deal with the calculation.

After Vinh et al., 1996, the erosional intensity of the Haihau coast will reduce due to supplementary sediments from the Day and the Ninh Co rivers. Therefore the result of calculation seems to be a higher value for evaluating of erosion in the future.

Conclusions

The dataset of longterm monitoring of waves, beach relief, seabed sediment and sediment sources of the Haihau coast permit a reliable using of the formula proposed by CERC. In winter and transitional seasons net longshore transport rate is southeast ward and an opposite direction (northwest ward) is presented in summer. However the Haihau coast has been eroded due to southeast ward sediment movements that caused by waves. The annual net longshore transport rate is about 88,569 m^3/y.

Acknowledgements

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Table. 4: Volumes of sediment transports of different directions in winter (T - wave periods, f - frequency of wave heights)

Sediment transport in Winter (from December to March) the North direction

Slope	Ho (m)	T (s)	f (%)	Lo (m)	Ho/Lo	H_B/Ho	**H_B (m)**	α_{Bs} (degrees)	H_B (ft)	Pls (ft.lbs/s/ft)	Q (yard^3/y)	Q (m^3/y)	Qreal (m3/y)	**Q (winter)**	Percent
0.00286	0.125	4.00	3.03	25.01	0.005	1.165	**0.15**	45.00	0.48	4.9	3.70E+04	2.83E+04	856	**285**	0.6
0.00286	0.375	4.00	2.76	25.01	0.015	0.886	**0.33**	45.00	1.09	38.7	2.90E+05	2.22E+05	6118	**2039**	4.4
0.00286	0.625	4.00	4.81	25.01	0.025	0.779	**0.49**	45.00	1.60	100.7	7.55E+05	5.78E+05	27783	**9261**	19.9
0.00286	0.875	4.00	2.63	25.01	0.035	0.716	**0.63**	45.00	2.06	189.3	1.42E+06	1.09E+06	28548	**9516**	20.4
0.00286	1.250	6.00	1.72	56.26	0.022	0.803	**1.00**	45.00	3.29	613.3	4.60E+06	3.52E+06	60494	**20165**	43.3
0.00286	1.750	6.00	0.21	56.26	0.031	0.738	**1.29**	45.00	4.24	1152.6	8.64E+06	6.61E+06	13880	**4627**	9.9
0.00286	2.250	6.00	0.02	56.26	0.040	0.693	**1.56**	45.00	5.12	1846.4	1.38E+07	1.06E+07	2118	**706**	1.5
0.00286	2.750	6.00	0.00	56.26	0.049	0.659	**1.81**	45.00	5.95	2689.8	2.02E+07	1.54E+07	0	**0**	0.0
0.00286	3.500	8.00	0.00	100.03	0.035	0.716	**2.51**	45.00	8.23	6057.3	4.54E+07	3.47E+07	0	**0**	0.0
0.00286	4.500	8.00	0.00	100.03	0.045	0.673	**3.03**	45.00	9.93	9703.4	7.28E+07	5.56E+07	0	**0**	0.0
0.00286	5.500	8.00	0.00	100.03	0.055	0.640	**3.52**	45.00	11.55	14136.2	1.06E+08	8.11E+07	0	**0**	0.0
												SUM =	139796	**46599**	

Sediment transport in Winter (from December to March) the East direction

Slope	Ho (m)	T (s)	f (%)	Lo (m)	Ho/Lo	H_B/Ho	**H_B (m)**	α_{Bs} (degrees)	H_B (ft)	Pls (ft.lbs/s/ft)	Q (yard^3/y)	Q (m^3/y)	Qreal (m^3/y)	**Q (winter)**	Percent
0.00286	0.125	4.00	7.11	25.01	0.005	1.165	**0.15**	45.00	0.48	4.9	3.70E+04	2.83E+04	2009	**670**	1.2
0.00286	0.375	4.00	2.30	25.01	0.015	0.886	**0.33**	45.00	1.09	38.7	2.90E+05	2.22E+05	5098	**1699**	3.1
0.00286	0.625	4.00	5.37	25.01	0.025	0.779	**0.49**	45.00	1.60	100.7	7.55E+05	5.78E+05	31018	**10339**	18.7
0.00286	0.875	4.00	3.19	25.01	0.035	0.716	**0.63**	45.00	2.06	189.3	1.42E+06	1.09E+06	34627	**11542**	20.9
0.00286	1.250	6.00	2.26	56.26	0.022	0.803	**1.00**	45.00	3.29	613.3	4.60E+06	3.52E+06	79486	**26495**	48.0
0.00286	1.750	6.00	0.20	56.26	0.031	0.738	**1.29**	45.00	4.24	1152.6	8.64E+06	6.61E+06	13219	**4406**	8.0
0.00286	2.250	6.00	0.00	56.26	0.040	0.693	**1.56**	45.00	5.12	1846.4	1.38E+07	1.06E+07	0	**0**	0.0
0.00286	2.750	6.00	0.00	56.26	0.049	0.659	**1.81**	45.00	5.95	2689.8	2.02E+07	1.54E+07	0	**0**	0.0
0.00286	3.500	8.00	0.00	100.03	0.035	0.716	**2.51**	45.00	8.23	6057.3	4.54E+07	3.47E+07	0	**0**	0.0
0.00286	4.500	8.00	0.00	100.03	0.045	0.673	**3.03**	45.00	9.93	9703.4	7.28E+07	5.56E+07	0	**0**	0.0
0.00286	5.500	8.00	0.00	100.03	0.055	0.640	**3.52**	45.00	11.55	14136.2	1.06E+08	8.11E+07	0	**0**	0.0
												SUM =	165456	**55152**	

Sediment transport in Winter (from December to March) the South direction

Slope	Ho (m)	T (s)	f (%)	Lo (m)	Ho/Lo	H_B/Ho	**H_B (m)**	α_{Bs} (degrees)	H_B (ft)	Pls (ft.lbs/s/ft)	Q (yard^3/y)	Q (m^3/y)	Qreal (m3/y)	**Q (winter)**	Percent
0.00286	0.125	4.00	0.79	25.01	0.005	1.165	**0.15**	-45.00	0.48	-4.9	-3.70E+04	-2.83E+04	-223	**-74**	0.8
0.00286	0.375	4.00	0.38	25.01	0.015	0.886	**0.33**	-45.00	1.09	-38.7	-2.90E+05	-2.22E+05	-842	**-281**	2.9
0.00286	0.625	4.00	0.70	25.01	0.025	0.779	**0.49**	-45.00	1.60	-100.7	-7.55E+05	-5.78E+05	-4043	**-1348**	14.2
0.00286	0.875	4.00	0.19	25.01	0.035	0.716	**0.63**	-45.00	2.06	-189.3	-1.42E+06	-1.09E+06	-2062	**-687**	7.2
0.00286	1.250	6.00	0.39	56.26	0.022	0.803	**1.00**	-45.00	3.29	-613.3	-4.60E+06	-3.52E+06	-13717	**-4572**	48.0
0.00286	1.750	6.00	0.10	56.26	0.031	0.738	**1.29**	-45.00	4.24	-1152.6	-8.64E+06	-6.61E+06	-6610	**-2203**	23.1
0.00286	2.250	6.00	0.01	56.26	0.040	0.693	**1.56**	-45.00	5.12	-1846.4	-1.38E+07	-1.06E+07	-1059	**-353**	3.7
0.00286	2.750	6.00	0.00	56.26	0.049	0.659	**1.81**	-45.00	5.95	-2689.8	-2.02E+07	-1.54E+07	0	**0**	0.0
0.00286	3.500	8.00	0.00	100.03	0.035	0.716	**2.51**	-45.00	8.23	-6057.3	-4.54E+07	-3.47E+07	0	**0**	0.0
0.00286	4.500	8.00	0.00	100.03	0.045	0.673	**3.03**	-45.00	9.93	-9703.4	-7.28E+07	-5.56E+07	0	**0**	0.0
0.00286	5.500	8.00	0.00	100.03	0.055	0.640	**3.52**	-45.00	11.55	-14136.2	-1.06E+08	-8.11E+07	0	**0**	0.0
												SUM =	-28556	**-9519**	

Table. 5: Volumes of sediment transports of different directions in summer (T - wave periods, f - frequency of wave heights)

Sediment transport in Summer (from June to September) the North direction

Slope	Ho (m)	T (s)	f (%)	Lo (m)	Ho/Lo	H_B/Ho	**H_B (m)**	α_{Bs} (degrees)	H_B (ft)	Pls (ft.lbs/s/ft)	Q (yard^3/y)	Q (m^3/y)	Qreal (m3/y)	**Q (summer)**	Percent
0.00286	0.125	4.00	1.69	25.01	0.005	1.165	**0.15**	45.00	0.48	4.9	3.70E+04	2.83E+04	477	**159**	0.5
0.00286	0.375	4.00	1.24	25.01	0.015	0.886	**0.33**	45.00	1.09	38.7	2.90E+05	2.22E+05	2748	**916**	2.9
0.00286	0.625	4.00	2.06	25.01	0.025	0.779	**0.49**	45.00	1.60	100.7	7.55E+05	5.78E+05	11899	**3966**	12.5
0.00286	0.875	4.00	1.06	25.01	0.035	0.716	**0.63**	45.00	2.06	189.3	1.42E+06	1.09E+06	11506	**3835**	12.1
0.00286	1.250	6.00	1.24	56.26	0.022	0.803	**1.00**	45.00	3.29	613.3	4.60E+06	3.52E+06	43612	**14537**	45.7
0.00286	1.750	6.00	0.23	56.26	0.031	0.738	**1.29**	45.00	4.24	1152.6	8.64E+06	6.61E+06	15202	**5067**	15.9
0.00286	2.250	6.00	0.08	56.26	0.040	0.693	**1.56**	45.00	5.12	1846.4	1.38E+07	1.06E+07	8470	**2823**	8.9
0.00286	2.750	6.00	0.01	56.26	0.049	0.659	**1.81**	45.00	5.95	2689.8	2.02E+07	1.54E+07	1542	**514**	1.6
0.00286	3.500	8.00	0.00	100.03	0.035	0.716	**2.51**	45.00	8.23	6057.3	4.54E+07	3.47E+07	0	**0**	0.0
0.00286	4.500	8.00	0.00	100.03	0.045	0.673	**3.03**	45.00	9.93	9703.4	7.28E+07	5.56E+07	0	**0**	0.0
0.00286	5.500	8.00	0.00	100.03	0.055	0.640	**3.52**	45.00	11.55	14136.2	1.06E+08	8.11E+07	0	**0**	0.0
												SUM =	95457	**31819**	

Sediment transport in Summer (from June to September) the East direction

Slope	Ho (m)	T (s)	f (%)	Lo (m)	Ho/Lo	H_B/Ho	**H_B (m)**	α_{Bs} (degrees)	H_B (ft)	Pls (ft.lbs/s/ft)	Q (yard^3/y)	Q (m^3/y)	Qreal (m^3/y)	**Q (summer)**	Percent
0.00286	0.125	4.00	4.17	25.01	0.005	1.165	**0.15**	45.00	0.48	4.9	3.70E+04	2.83E+04	1178	**393**	0.4
0.00286	0.375	4.00	1.52	25.01	0.015	0.886	**0.33**	45.00	1.09	38.7	2.90E+05	2.22E+05	3369	**1123**	1.1
0.00286	0.625	4.00	4.92	25.01	0.025	0.779	**0.49**	45.00	1.60	100.7	7.55E+05	5.78E+05	28418	**9473**	9.1
0.00286	0.875	4.00	3.44	25.01	0.035	0.716	**0.63**	45.00	2.06	189.3	1.42E+06	1.09E+06	37341	**12447**	11.9
0.00286	1.250	6.00	3.54	56.26	0.022	0.803	**1.00**	45.00	3.29	613.3	4.60E+06	3.52E+06	124504	**41501**	39.7
0.00286	1.750	6.00	0.77	56.26	0.031	0.738	**1.29**	45.00	4.24	1152.6	8.64E+06	6.61E+06	50893	**16964**	16.2
0.00286	2.250	6.00	0.24	56.26	0.040	0.693	**1.56**	45.00	5.12	1846.4	1.38E+07	1.06E+07	25411	**8470**	8.1
0.00286	2.750	6.00	0.09	56.26	0.049	0.659	**1.81**	45.00	5.95	2689.8	2.02E+07	1.54E+07	13882	**4627**	4.4
0.00286	3.500	8.00	0.06	100.03	0.035	0.716	**2.51**	45.00	8.23	6057.3	4.54E+07	3.47E+07	20841	**6947**	6.6
0.00286	4.500	8.00	0.00	100.03	0.045	0.673	**3.03**	45.00	9.93	9703.4	7.28E+07	5.56E+07	0	**0**	0.0
0.00286	5.500	8.00	0.01	100.03	0.055	0.640	**3.52**	45.00	11.55	14136.2	1.06E+08	8.11E+07	8106	**2702**	2.6
												SUM =	313946	**104649**	

Sediment transport in Summer (from June to September) the South direction

Slope	Ho (m)	T (s)	f (%)	Lo (m)	Ho/Lo	H_B/Ho	**H_B (m)**	α_{Bs} (degrees)	H_B (ft)	Pls (ft.lbs/s/ft)	Q (yard^3/y)	Q (m^3/y)	Qreal (m3/y)	**Q (summer)**	Percent
0.00286	0.125	4.00	5.42	25.01	0.005	1.165	**0.15**	-45.00	0.48	-4.9	-3.70E+04	-2.83E+04	-1531	**-510**	0.3
0.00286	0.375	4.00	1.41	25.01	0.015	0.886	**0.33**	-45.00	1.09	-38.7	-2.90E+05	-2.22E+05	-3125	**-1042**	0.5
0.00286	0.625	4.00	4.47	25.01	0.025	0.779	**0.49**	-45.00	1.60	-100.7	-7.55E+05	-5.78E+05	-25819	**-8606**	4.5
0.00286	0.875	4.00	3.24	25.01	0.035	0.716	**0.63**	-45.00	2.06	-189.3	-1.42E+06	-1.09E+06	-35170	**-11723**	6.1
0.00286	1.250	6.00	6.69	56.26	0.022	0.803	**1.00**	-45.00	3.29	-613.3	-4.60E+06	-3.52E+06	-235292	**-78431**	41.0
0.00286	1.750	6.00	2.53	56.26	0.031	0.738	**1.29**	-45.00	4.24	-1152.6	-8.64E+06	-6.61E+06	-167221	**-55740**	29.1
0.00286	2.250	6.00	0.48	56.26	0.040	0.693	**1.56**	-45.00	5.12	-1846.4	-1.38E+07	-1.06E+07	-50823	**-16941**	8.9
0.00286	2.750	6.00	0.05	56.26.	0.049	0.659	**1.81**	-45.00	5.95	-2689.8	-2.02E+07	-1.54E+07	-7712	**-2571**	1.3
0.00286	3.500	8.00	0.05	100.03	0.035	0.716	**2.51**	-45.00	8.23	-6057.3	-4.54E+07	-3.47E+07	-17368	**-5789**	3.0
0.00286	4.500	8.00	0.01	100.03	0.045	0.673	**3.03**	-45.00	9.93	-9703.4	-7.28E+07	-5.56E+07	-5564	**-1855**	1.0
0.00286	5.500	8.00	0.03	100.03	0.055	0.640	**3.52**	-45.00	11.55	-14136.2	-1.06E+08	-8.11E+07	-24319	**-8106**	4.2
												SUM =	-573945	**-191315**	

Table. 6: Volumes of sediment transports of different directions in transitional seasons (T - wave periods, f - frequency of wave heights)

Sediment transport in Transitional season (April-May and October-November) the North direction

Slope	Ho (m)	T (s)	f (%)	Lo (m)	Ho/Lo	H_B/Ho	**H_B (m)**	α_{Bs} (degrees)	H_B (ft)	Pls (ft.lbs/s/ft)	Q ($yard^3$/y)	Q (m^3/y)	Qreal (m3/y)	**Q (transition)**	Percent
0.00286	0.125	4.00	0.72	25.01	0.005	1.165	**0.15**	45.00	0.48	4.9	3.70E+04	2.83E+04	203	**68**	0.4
0.00286	0.375	4.00	0.70	25.01	0.015	0.886	**0.33**	45.00	1.09	38.7	2.90E+05	2.22E+05	1552	**517**	3.2
0.00286	0.625	4.00	0.82	25.01	0.025	0.779	**0.49**	45.00	1.60	100.7	7.55E+05	5.78E+05	4736	**1579**	9.9
0.00286	0.875	4.00	0.66	25.01	0.035	0.716	**0.63**	45.00	2.06	189.3	1.42E+06	1.09E+06	7164	**2388**	14.9
0.00286	1.250	6.00	0.62	56.26	0.022	0.803	**1.00**	45.00	3.29	613.3	4.60E+06	3.52E+06	21806	**7269**	45.4
0.00286	1.750	6.00	0.11	56.26	0.031	0.738	**1.29**	45.00	4.24	1152.6	8.64E+06	6.61E+06	7270	**2423**	15.1
0.00286	2.250	6.00	0.05	56.26	0.040	0.693	**1.56**	45.00	5.12	1846.4	1.38E+07	1.06E+07	5294	**1765**	11.0
0.00286	2.750	6.00	0.00	56.26	0.049	0.659	**1.81**	45.00	5.95	2689.8	2.02E+07	1.54E+07	0	**0**	0.0
0.00286	3.500	8.00	0.00	100.03	0.035	0.716	**2.51**	45.00	8.23	6057.3	4.54E+07	3.47E+07	0	**0**	0.0
0.00286	4.500	8.00	0.00	100.03	0.045	0.673	**3.03**	45.00	9.93	9703.4	7.28E+07	5.56E+07	0	**0**	0.0
0.00286	5.500	8.00	0.00	100.03	0.055	0.640	**3.52**	45.00	11.55	14136.2	1.06E+08	8.11E+07	0	**0**	0.0
												SUM =	48026	**16009**	

Sediment transport in Transitional season (April-May and October-November) the East direction

Slope	Ho (m)	T (s)	f (%)	Lo (m)	Ho/Lo	H_B/Ho	**H_B (m)**	α_{Bs} (degrees)	H_B (ft)	Pls (ft.lbs/s/ft)	Q ($yard^3$/y)	Q (m^3/y)	Qreal (m^3/y)	**Q (transition)**	Percent
0.00286	0.125	4.00	6.94	25.01	0.005	1.165	**0.15**	45.00	0.48	4.9	3.70E+04	2.83E+04	1961	**654**	0.4
0.00286	0.375	4.00	4.60	25.01	0.015	0.886	**0.33**	45.00	1.09	38.7	2.90E+05	2.22E+05	10196	**3399**	2.3
0.00286	0.625	4.00	10.30	25.01	0.025	0.779	**0.49**	45.00	1.60	100.7	7.55E+05	5.78E+05	59494	**19831**	13.5
0.00286	0.875	4.00	6.33	25.01	0.035	0.716	**0.63**	45.00	2.06	189.3	1.42E+06	1.09E+06	68711	**22904**	15.6
0.00286	1.250	6.00	6.29	56.26	0.022	0.803	**1.00**	45.00	3.29	613.3	4.60E+06	3.52E+06	221224	**73741**	50.3
0.00286	1.750	6.00	0.97	56.26	0.031	0.738	**1.29**	45.00	4.24	1152.6	8.64E+06	6.61E+06	64112	**21371**	14.6
0.00286	2.250	6.00	0.13	56.26	0.040	0.693	**1.56**	45.00	5.12	1846.4	1.38E+07	1.06E+07	13764	**4588**	3.1
0.00286	2.750	6.00	0.00	56.26	0.049	0.659	**1.81**	45.00	5.95	2689.8	2.02E+07	1.54E+07	0	**0**	0.0
0.00286	3.500	8.00	0.00	100.03	0.035	0.716	**2.51**	45.00	8.23	6057.3	4.54E+07	3.47E+07	0	**0**	0.0
0.00286	4.500	8.00	0.00	100.03	0.045	0.673	**3.03**	45.00	9.93	9703.4	7.28E+07	5.56E+07	0	**0**	0.0
0.00286	5.500	8.00	0.00	100.03	0.055	0.640	**3.52**	45.00	11.55	14136.2	1.06E+08	8.11E+07	0	**0**	0.0
												SUM =	439463	**146488**	

Sediment transport in Transitional season (April-May and October-November) the South direction

Slope	Ho (m)	T (s)	f (%)	Lo (m)	Ho/Lo	H_B/Ho	**H_B (m)**	α_{Bs} (degrees)	H_B (ft)	Pls (ft.lbs/s/ft)	Q ($yard^3$/y)	Q (m^3/y)	Qreal (m3/y)	**Q (transition)**	Percent
0.00286	0.125	4.00	2.78	25.01	0.005	1.165	**0.15**	-45.00	0.48	-4.9	-3.70E+04	-2.83E+04	-785	**-262**	0.2
0.00286	0.375	4.00	0.81	25.01	0.015	0.886	**0.33**	-45.00	1.09	-38.7	-2.90E+05	-2.22E+05	-1795	**-598**	0.5
0.00286	0.625	4.00	2.44	25.01	0.025	0.779	**0.49**	-45.00	1.60	-100.7	-7.55E+05	-5.78E+05	-14094	**-4698**	4.2
0.00286	0.875	4.00	1.82	25.01	0.035	0.716	**0.63**	-45.00	2.06	-189.3	-1.42E+06	-1.09E+06	-19756	**-6585**	5.9
0.00286	1.250	6.00	4.40	56.26	0.022	0.803	**1.00**	-45.00	3.29	-613.3	-4.60E+06	-3.52E+06	-154751	**-51584**	46.3
0.00286	1.750	6.00	1.72	56.26	0.031	0.738	**1.29**	-45.00	4.24	-1152.6	-8.64E+06	-6.61E+06	-113684	**-37895**	34.0
0.00286	2.250	6.00	0.26	56.26	0.040	0.693	**1.56**	-45.00	5.12	-1846.4	-1.38E+07	-1.06E+07	-27529	**-9176**	8.2
0.00286	2.750	6.00	0.01	56.26	0.049	0.659	**1.81**	-45.00	5.95	-2689.8	-2.02E+07	-1.54E+07	-1542	**-514**	0.5
0.00286	3.500	8.00	0.00	100.03	0.035	0.716	**2.51**	-45.00	8.23	-6057.3	-4.54E+07	-3.47E+07	0	**0**	0.0
0.00286	4.500	8.00	0.00	100.03	0.045	0.673	**3.03**	-45.00	9.93	-9703.4	-7.28E+07	-5.56E+07	0	**0**	0.0
0.00286	5.500	8.00	0.00	100.03	0.055	0.640	**3.52**	-45.00	11.55	-14136.2	-1.06E+08	-8.11E+07	0	**0**	0.0
												SUM =	-333937	**-111312**	