ANALYSIS OF CHANGES IN THE RIVERBANKS OF MEKONG RIVER - VIETNAM BY USING MULTI-TEMPORAL REMOTE SENSING DATA

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ABSTRACT:

Riverbanks have eroded and accreted in a complex and dangerous way in Mekong Delta-Vietnam in recent years, especially in the two biggest rivers, Tien and Hau. Hong Ngu and Sa Dec District in Dong Thap Province, Tan Chau and Long Xuyen District in An Giang Province along Tien and Hau River have suffered from serious erosions with average speed from 5 to 30m per year which has taken away hundreds of hectares of farming land, houses and has damaged many schools, hospitals, offices and main roads (Quang Hai, 2008). This has caused a lot of difficulties for governmental planning, seriously affected the life of citizens and also the development of the local economy. Therefore, the study of the statistical data, change rates and the direction of the movement of riverbanks is necessary to predict the future changes in the riverbanks of Tien and Hau River which will happen in the future.

Consequently, the aim of this research is using remote sensing data which is known as an effective and fast technology to analyze the phenomenal hazard in the riverbanks. For this purpose, multi-temporal optical and radar satellite images (Landsat MSS, TM, ETM+, ASTER, and ERS-2) from 1989 to 2009 have been used. In addition to this topographical maps of the area were also used to provide the base map from 1966-1968 before the advent of remote sensing technique. The Digital Shoreline Analysis System (DSAS) software was applied for analyzing rate and predicting riverbank changes in next 5 and 10 years. The results for Sa Dec, Hong Ngu District are presented as hot spots showing the speed of erosion (reached to 50m per year) and were forecasted to erode from 100 to 520m in next 10 years.

Moreover according to Vietnam Southern Regional Hydro-meteorological Center news, Mekong Delta in year 2010 has suffered the lowest water level in 20 years because of the El-Niño phenomenon. Thus riverbanks of this area which will be changed more complicated should be detected instantly by remote sensing data. For that reason this research will continue updating riverbank information by using ALOS AVNIR and PRISM data acquired in 2010. The results are helpful in building more appropriate future planning strategies in order to protect the region and plan more effectively.

1. INTRODUCTION

Nowadays supervising and forecasting changes in riverbanks are important and necessary for managing and detecting environment in marine infrastructure. Hence in recent years, two largest rivers in Mekong Delta, Vietnam have eroded and accreted in complex and dangerous ways which have caused significant problems and difficulties for governmental planning, seriously affecting the lives of citizens and also the development of local economy. Especially, Hong Ngu and Sa Dec Districts in Dong Thap Province, Tan Chau and Long Xuyen Districts in An Giang Province along Tien and Hau Rivers have suffered from serious erosions with average speed from 5 to 30m per year which has taken away hundreds of hectares of farming land, houses and has damaged many schools, hospitals, offices and main roads (Quang Hai, 2008). Therefore, the study of the statistical data, change rates and the direction of the movement of riverbanks are necessary to predict the future of change of riverbanks of Tien and Hau River.

Consequently, the aims of this research are using remote sensing data which is known as an effective and fast technology to analyze the phenomenal hazard in the riverbanks. For this purpose, multi-temporal optical and radar satellite images (Landsat MSS, TM, ETM+, ASTER, and ERS-2) from 1989 to 2009 have been used. In addition to this topographical maps of the area were also used to provide the base map from 1966-1968 before the advent of remote sensing technique. The Digital Shoreline Analysis System (DSAS) software was applied to analyzing rate and predicting riverbank changes, while using weights were added to linear regression lines of the software for enhancing the relative of predicted changes with phenomenon in recent years. As the results, the hot spots such as Sa Dec, Hong Ngu District have the speed of erosion reached to 50m per year and have forecasted to be eroded from 100 to 520m in next 10 years.

2. STUDY AREA

The Mekong River is one of the greatest rivers in the world. The Mekong River originated from Tibetan plateau, flowing 4500 km through China, Myanmar, Laos, Thai, Cambodia and Vietnam to East Sea of Vietnam. At Phnom Penh (Cambodia), it splits into two branches: Hau River (also called the Bassac River) and Tien River. The water flow of the Mekong River begins to rise at the end of May and reaches its highest point around September. When comparing with Hau River, the Tien

River has a more complicated shape and changes especially in the section of Dong Thap Province. Therefore the present study has been carried out in Tien River.

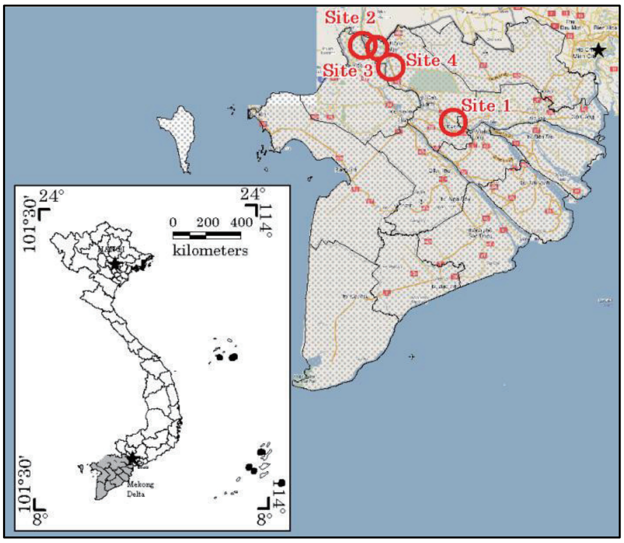

Figure 1. Study area

The Tien River with the length 240-250km and the width about 0.33-2.1km runs from Dong Thap Province, split into several branches at Vinh Long and empties it in to the sea at five points, namely: Ham Luong, Co Chien, Cua Dai, Cua Tien and Ba Lai (Fig.1). In this river, the phenomenon of erosion and accretion of riverbanks have been complicated especially in three sites which were marked namely No.1, 2, 3 located in SaDec, Hong Ngu Districts and Chau Ma Cape, respectively.

3. METHODOLOGY

The flowchart of steps followed in this study is presented in Fig.2.

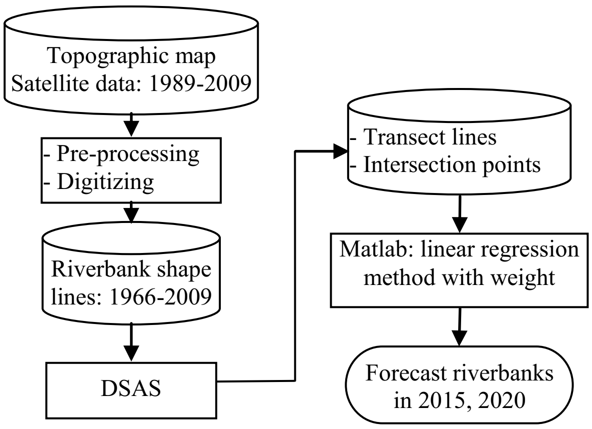

Figure 2. Flowchart of processing

The satellite data collected was pre-processed by geo-reference step and then digitized riverbanks of Tien River. The digitized vector lines were input in DSAS module running in ArcGIS environment. Through DSAS module, the transect lines and intersection point coordinate between transect lines and riverbank lines. Then these coordinates were input in Matlab program to a run linear regression method to forecast what will happen between the years 2015 and 2020.

3.1 Data source

The satellite data used in this paper were acquired by satellite Landsat, SPOT, Radarsat from the period time 1989 to 2009. Besides this, a topographic map was also used as base map. It has scale 1/50.000 printed by the National Geographic Directorate, Vietnam in 1966 with Transverse Mercator projection, Indian Datum 1960, Zone 48.

3.2 Pre-processing

Topographic map was as a base map for geo-referencing every satellite data with the root mean square error 0.6 pixels. All the data sources were re-sampled into 30m resolution.

3.3 Extracting the riverbanks

Riverbanks were extracted from topographic maps and satellite images by digitizing. From the topographic map, it was digitized follow the rivers shown in the map.
For the satellite data, the composite images RGB by band 542 were used to enhance the objects and distinguish clearly between soil, vegetated land, mud clay soil and water and to be easily digitized. The files of riverbanks digitized were in shape format.

3.4 Forecasting for riverbanks

The Digital Shoreline Analysis System (DSAS) is a computer software that computes rate-of-change statistics from multiple historic shoreline positions residing in a GIS and computing rates of change. First the baseline was defined as the buffer of the riverbank in 2009. Second DSAS generates transects that are cast perpendicular to the baseline at a user-specified spacing alongshore. Then the intersection points between transects and multi-temporal riverbank lines were created to input into the linear regression equation to predict the riverbank change in the future, based on the equation 1:

$$y = ax + b \tag{1}$$

Where,
y: regressed position
a: rate change
x: date
b: constant

However, in order to enhance the prediction which relative more with recent year than farer year, the weight which can be calculated in equation 2 was added to the linear regression. This weight was created by the authors and run in Matlab. Furthermore this weight was supposed to be more accuracy than weight which is done in DSAS.

$$w_i = \frac{1}{S_w \times (t_{pred} - t_i)^2} \tag{2}$$

Where, $S_w = \sum_{i=1}^{n} \frac{1}{(t_{pred} - t_i)^2}$

w_i: weight
t_{pred}: predict years (in 2015 or 2020)
t_i: historical years

Because every site was detected by different serial-temporal period, thus weights which were calculated base on the equation 2 were shown table 1, 2, 3, 4 for site 1, 2, 3 and 4.

Table 1. Weight for Site 1

Date	Weight 2015	Weight 2020
1989 Jan. 16	0.02	0.04
1996 Feb. 21	0.04	0.06
2001 Sep. 06	0.07	0.10
2003 Apr. 05	0.10	0.12
2005 Jan. 20	0.13	0.16
2007 Jan. 26	0.21	0.21
2009 Jun. 24	0.43	0.31

Table 2. Weight for Site 2

Date	Weight 2015	Weight 2020
1966	0.01	0.01
1989 Nov 15	0.02	0.03
1991 Nov. 29	0.03	0.04
1995 Mar. 13	0.04	0.05
1999 Feb. 20	0.05	0.07
2001 Jul. 11	0.07	0.09
2003 Feb. 07	0.09	0.11
2004 Apr. 22	0.11	0.13
2007 Feb. 02	0.21	0.19
2009 Jan. 30	0.37	0.27

Table 3. Weight for Site 3

Date	Weight 2015	Weight 2020
1995 Mar. 13	0.04	0.06
1996 Feb. 20	0.05	0.08
2001 Jul. 11	0.08	0.10
2003 Feb. 07	0.10	0.12
2004 Apr. 22	0.12	0.14
2007 Feb. 02	0.22	0.21
2009 Jan. 30	0.39	0.29

Table 4. Weight for Site 4

Date	Weight 2015	Weight 2020
1989 Nov 15	0.02	0.03
1991 Nov. 29	0.02	0.04
2001 Jul. 11	0.06	0.09
2003 Feb. 07	0.08	0.10
2004 Apr. 22	0.09	0.12
2007 Feb. 02	0.18	0.17
2008 Feb. 13	0.23	0.21
2009 Jan. 30	0.32	0.24

4. RESULTS

Along riverbanks of Tien River, there are two phenomenal as erosion and accretion happening. Erosion is the main phenomenal happened in all the Tien River such as in site 1, 2, 3, 4 where happening strongly in Sa Dec (Site 1) (Fig.3) and in upstream of Thuong Phuoc Cape (Site 2) (Fig.4) with rate of 50m, 33m per year, respectively. The remainders have rate 15 to 17 m per year (Fig.5 and Fig.6). The accretion phenomenal has happened in downstream of Thuong Phuoc Cape (Site 2) (Fig.4) has rate 17-20m per year.

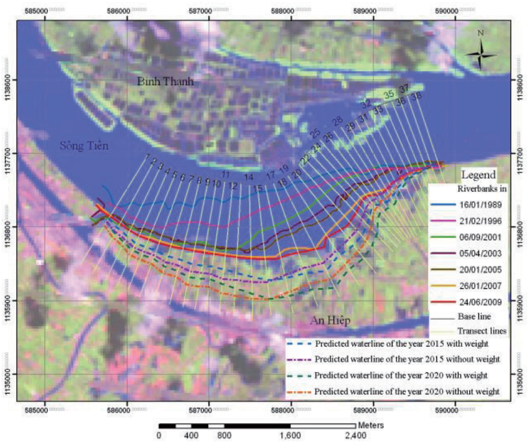

Figure 3 Sa Dec District (Site No.1)

In Fig.3 at Sa Dec District, there are 38 transects create with the distance 100m. Riverbanks of Tien River in Sa Dec District have eroded seriously. Especially in the curved riverbanks in Tan Quy Dong, Tan Quy Tay, An Hiep commune of Sa Dec Province, 850m was eroded in southerly in width from 1989 to 2009. Forecasting for riverbanks of Tien River in 2015 and 2020 was shown in Appendix 1. According to appendix 1, in 2015 and 2020 the eroded width will be 137m and 254 in average which some place will be over 200m and 400m, respectively such as transect 14 to 22.

Thuong Phuoc Cape (Fig.4) was divided into two side as left side and right side. At left side area defined as transects from 1 to 39, the riverbanks of Tien River are predicted to be eroded with maximum width of 184m in 2015 and 330m in 2020 (transect 34 in Figure 5) (Appendix 2), while at the right side (transect from 40 to 68) to be accreted to 108m in 2015 and 171m in 2020 (transect 50 in Figure 5) (Appendix 3).

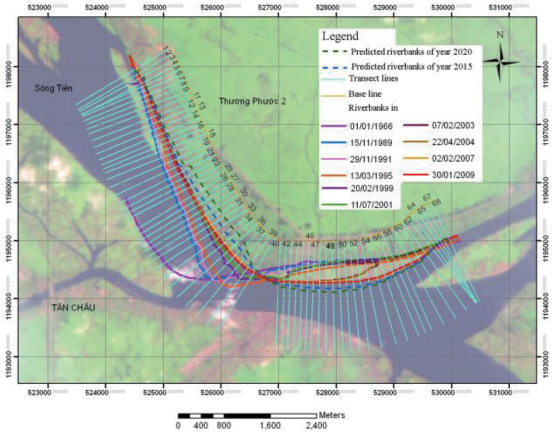

Figure 4 Thuong Phuoc Cape of Hong Ngu District (Site No. 2)

Besides Long Khanh A islet (Fig.5) was divided into two parts as upper side and lower side to analysis. In both side, the erosion phenomenon has happening which made land surface become reducing. The heaviest erosion area is at the cape of islet with the rate 17m per year. From year 1966 to 2009, the riverbanks of upper side have eroded regularly and is predicted to go into mainland 169m in 2015 and 254m in 2020 (Appendix 4) while the rate of lower side is lower. However in recent year from 2007 to 2009, the riverbank of lower side has erosion rate increasing and is supposed to be lost reach to 91m in 2015 and 170m in 2020 (Appendix 5).

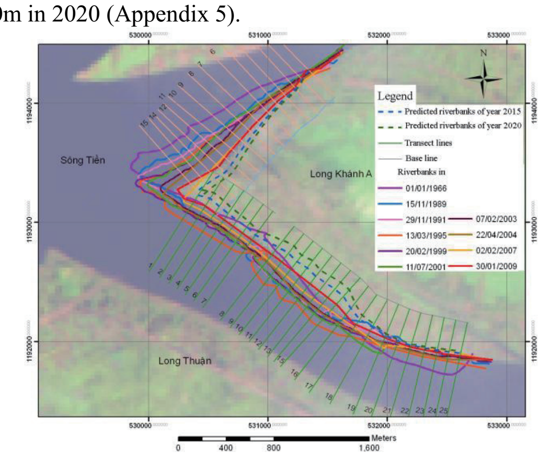

Figure 5. Cape of Long Khanh A islet (Site No. 3)

In Chau Ma cape (Site 4) (Fig. 7) located in Hong Ngu District, Dong Thap Province which has also erosion phenomenal as the other site in both left and right riverbanks with rate up to 20m per year. Therefore they were predicted to be eroded 100m in 2015 and 200m in 2020 (Appendix 6 and 7).

Coefficients of correlation having the value over 80% in almost transect of site 1 to 4 means these are strongly related to the historical phenomenon. However some values under 30% mean the phenomenal is local and not regular such as in of transects 32 to 38 of left side riverbanks of Thuong Phuoc Cape and 2 to 6 of right side riverbanks of Chau Ma cape. Specially, in the transect 47 to 64 (Appendix 3), the coefficient of correlations are very low nearly 0. It is caused by nonlinear change in this area as there is not much change before year 2001 but accretion a lot from riverbanks in 2003 to 2009.

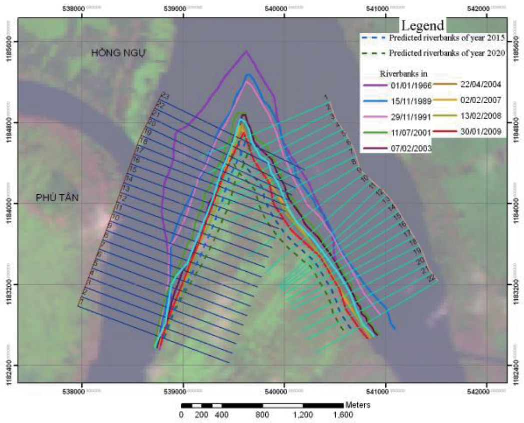

Figure 6 Cape of Chau Ma islet (Site No. 4)

5. CONCLUSION

Basing on the DSAS with enhancing of time weight of linear regression can forecast more accuracy the riverbanks change in the future.

Multi-temporal optical and radar satellite images (Landsat MSS, TM, ETM+, ASTER, and ERS-2) from 1989 to 2009 have been used. As the results, Tien riverbanks in Sa Dec District are predicted to be eroded the highest rate as 50m per year and until 2015 and 2020. The other riverbanks such as Cape of Thuong Phuoc left side, Cape of Long Khanh A islet and Cape of Chau Ma islet were predicted to be eroded up to 100m in 2015 and 200m in 2020. Beside the erosion is the main phenomenal in Tien River, accretion has also happened in Cape of Thuong Phuoc right side of Tien riverbanks (Site No. 2) with the rate about 17 - 20m per year and predicted to be accreted 108m in 2015 and 171m in 2020.

Moreover according to Vietnam Southern Regional Hydro-meteorological Center news, Mekong Delta in year 2010 has suffered the lowest water level in 20 years because of the El-Niño phenomenon. Thus riverbanks of this area which will be changed more complicated should be detected instantly by remote sensing data. For that reason this research will continue updating riverbank information by using ALOS AVNIR and PRISM data acquired in 2010. The results are helpful in building more appropriate future planning strategies in order to protect the region and plan more effectively.

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APPENDIX

Appendix 1 Sa Dec

Transects	Forecasting in 2015		Forecasting in 2020	
	Coefficient of Correlation	Change (m)	Coefficient of Correlation	Change (m)
(1)	*(2)*	*(3)*	*(4)*	*(5)*
1	0.56	-28	0.62	-67
2	0.87	-65	0.89	-133
3	0.91	-79	0.93	-160
4	0.92	-101	0.94	-201
5	0.91	-101	0.91	-204
6	0.91	-100	0.92	-203
7	0.92	-127	0.94	-258
8	0.94	-142	0.96	-283
9	0.94	-165	0.96	-331
10	0.95	-162	0.96	-326
11	0.94	-156	0.95	-314
12	0.93	-172	0.94	-349
13	0.95	-191	0.96	-380
14	0.97	-220	0.98	-431
15	0.99	-256	0.99	-486
16	0.99	-259	0.99	-481
17	0.97	-261	0.97	-479
18	0.93	-295	0.94	-527
19	0.97	-261	0.97	-476
20	0.94	-245	0.95	-444
21	0.94	-223	0.95	-406

22	0.91	-205	0.93	-367
23	0.92	-183	0.93	-327
24	0.91	-160	0.92	-284
25	0.90	-147	0.91	-260
26	0.87	-141	0.89	-247
27	0.61	-123	0.70	-207
28	0.58	-122	0.68	-205
29	0.57	-125	0.66	-206
30	0.65	-109	0.72	-181
31	0.50	-84	0.63	-136
32	0.00	-61	0.45	-94
33	0.05	-37	0.45	-57
34	0.00	-30	0.35	-44
35	0.20	-24	0.37	-35
36	0.24	-18	0.30	-27
37	0.00	-9	0.02	-10
38	0.13	-8	0.14	-10
Average		-137		-254

Appendix 2 Thuong Phuoc 2 left side

(1)	(2)	(3)	(4)	(5)
1	0.00	7	0.00	11
2	0.31	-10	0.52	-24
3	0.34	-36	0.34	-62
4	0.79	-22	0.81	-42
5	0.65	-15	0.69	-34
6	0.52	-9	0.55	-22
7	0.70	-16	0.74	-35
8	0.68	-24	0.75	-51
9	0.63	-26	0.70	-57
10	0.70	-34	0.77	-71
11	0.68	-32	0.75	-66
12	0.68	-33	0.75	-69
13	0.69	-34	0.76	-71
14	0.68	-38	0.75	-80
15	0.70	-41	0.76	-85
16	0.72	-47	0.78	-97
17	0.77	-50	0.82	-103
18	0.78	-56	0.83	-115
19	0.79	-58	0.84	-118
20	0.80	-61	0.85	-122
21	0.83	-110	0.89	-226
22	0.83	-113	0.89	-230
23	0.83	-115	0.89	-235
24	0.84	-119	0.90	-241
25	0.87	-128	0.92	-255
26	0.88	-131	0.92	-259
27	0.89	-135	0.93	-265
28	0.90	-139	0.94	-272

29	0.92	-143	0.95	-276
30	0.94	-150	0.97	-284
31	0.95	-155	0.97	-293
32	0.96	-164	0.98	-304
33	0.96	-170	0.98	-310
34	0.96	-184	0.96	-330
35	0.90	-181	0.89	-320
36	0.78	-171	0.76	-294
37	0.27	-128	0.31	-211
38	0.00	-79	0.00	-122
39	0.00	-40	0.00	-56
Average		-82		-156

Appendix 3 Thuong Phuoc right side

(1)	(2)	(3)	(4)	(5)
40	0.87	53	0.87	98
41	0.91	57	0.90	103
42	0.76	73	0.76	126
43	0.64	78	0.66	129
44	0.62	89	0.66	147
45	0.57	95	0.62	156
46	0.39	101	0.49	165
47	0.00	100	0.35	161
48	0.00	102	0.22	163
49	0.00	105	0.09	166
50	0.00	**108**	0.00	**171**
51	0.00	101	0.00	146
52	0.00	102	0.00	146
53	0.00	99	0.00	139
54	0.00	89	0.00	122
55	0.00	82	0.00	110
56	0.00	74	0.00	96
57	0.00	61	0.00	77
58	0.00	57	0.00	75
59	0.00	49	0.00	64
60	0.00	40	0.00	51
61	0.00	32	0.00	40
62	0.00	17	0.00	20
63	0.00	4	0.00	**2**
64	0.00	**3**	0.00	8
65	0.50	-8	0.51	-15
66	0.64	-12	0.64	-21
67	0.71	-13	0.72	-23
68	0.70	-16	0.73	-27
Average		**59**		**89**

Appendix 4 Long Khanh A right side

(1)	(2)	(3)	(4)	(5)
1	0.89	-66	0.90	-118
2	0.96	-75	0.96	-136

3	0.97	-69	0.97	-126
4	0.97	-63	0.97	-117
5	0.98	-61	0.98	-114
6	0.98	-60	0.98	-120
7	0.95	-50	0.95	-91
8	0.98	-80	0.98	-150
9	0.98	-91	0.98	**-170**
10	0.93	-81	0.94	-147
11	0.95	-92	0.96	-169
12	0.88	-81	0.90	-145
13	0.90	-87	0.92	-156
14	0.93	**-93**	0.94	-168
15	0.94	-92	0.95	-167
16	0.97	-70	0.97	-128
17	0.92	-51	0.92	-92
18	0.58	-36	0.62	-64
19	0.12	-18	0.30	-33
20	0.66	**-13**	0.69	**-24**
21	0.60	-13	0.60	-24
22	0.48	-17	0.48	-30
23	0.41	-19	0.41	-32
24	0.47	-23	0.49	-40
25	0.56	-22	0.57	-39
Average		**-57**		**-104**

Appendix 5 Long Khanh A left side

(1)	(2)	(3)	(4)	(5)
1	0.36	0	0.38	3
2	0.59	**-15**	0.64	**-22**
3	0.82	-16	0.86	-26
4	0.82	-22	0.86	-36
5	0.88	-24	0.90	-40
6	0.85	-29	0.89	-47
7	0.80	-35	0.87	-56
8	0.70	-45	0.81	-71
9	0.70	-54	0.81	-86
10	0.70	-65	0.81	-105
11	0.68	-74	0.80	-121
12	0.44	-72	0.68	-116
13	0.69	-75	0.80	-122
14	0.73	-83	0.81	-132
15	0.71	**-98**	0.77	**-153**
Average		**-47**		**-75**

Appendix 6 Cape of Chau Ma islet right side

(1)	(2)	(3)	(4)	(5)
1	0.00	**-13**	0.33	**-22**
2	0.00	-16	0.00	-22
3	0.00	-20	0.00	-29
4	0.00	-21	0.00	-30
5	0.00	-30	0.00	-44
6	0.00	-37	0.00	-57
7	0.00	-44	0.42	-71
8	0.66	-50	0.70	-87
9	0.82	-58	0.81	-106
10	0.88	-64	0.87	-120
11	0.95	-66	0.94	-126
12	0.98	-73	0.97	-137
13	0.98	-77	0.98	-146
14	0.99	-78	0.99	-147
15	0.99	**-81**	0.99	**-152**
16	0.98	-77	0.99	-147
17	0.98	-72	0.99	-140
18	0.98	-67	0.99	-133
19	0.98	-68	0.99	-135
20	0.98	-69	0.99	-138
21	0.98	-68	0.99	-135
22	1.00	-61	1.00	-123
23	1.00	-53	1.00	-108
Average		**-55**		**-102**

Appendix 7 Cape of Chau Ma islet left side

(1)	(2)	(3)	(4)	(5)
1	0.95	-78	0.96	-163
2	0.98	**-102**	0.99	**-200**
3	0.98	-102	0.98	-195
4	0.97	-92	0.97	-175
5	0.98	-82	0.98	-160
6	0.98	-80	0.98	-154
7	0.98	-74	0.99	-146
8	0.97	-74	0.98	-148
9	0.98	-71	0.98	-144
10	0.99	-75	0.99	-150
11	0.99	-73	0.99	-143
12	0.99	-70	0.99	-136
13	0.98	-67	0.98	-130
14	0.98	-66	0.98	-127
15	0.98	-66	0.97	-127
16	0.97	-67	0.97	-128
17	0.98	-67	0.98	-129
18	0.98	-68	0.98	-131
19	0.98	**-64**	0.98	**-126**
20	0.98	-65	0.99	-131
21	0.99	-67	0.99	-137
22	0.98	-68	0.99	-142
Average		**-74**		**-146**