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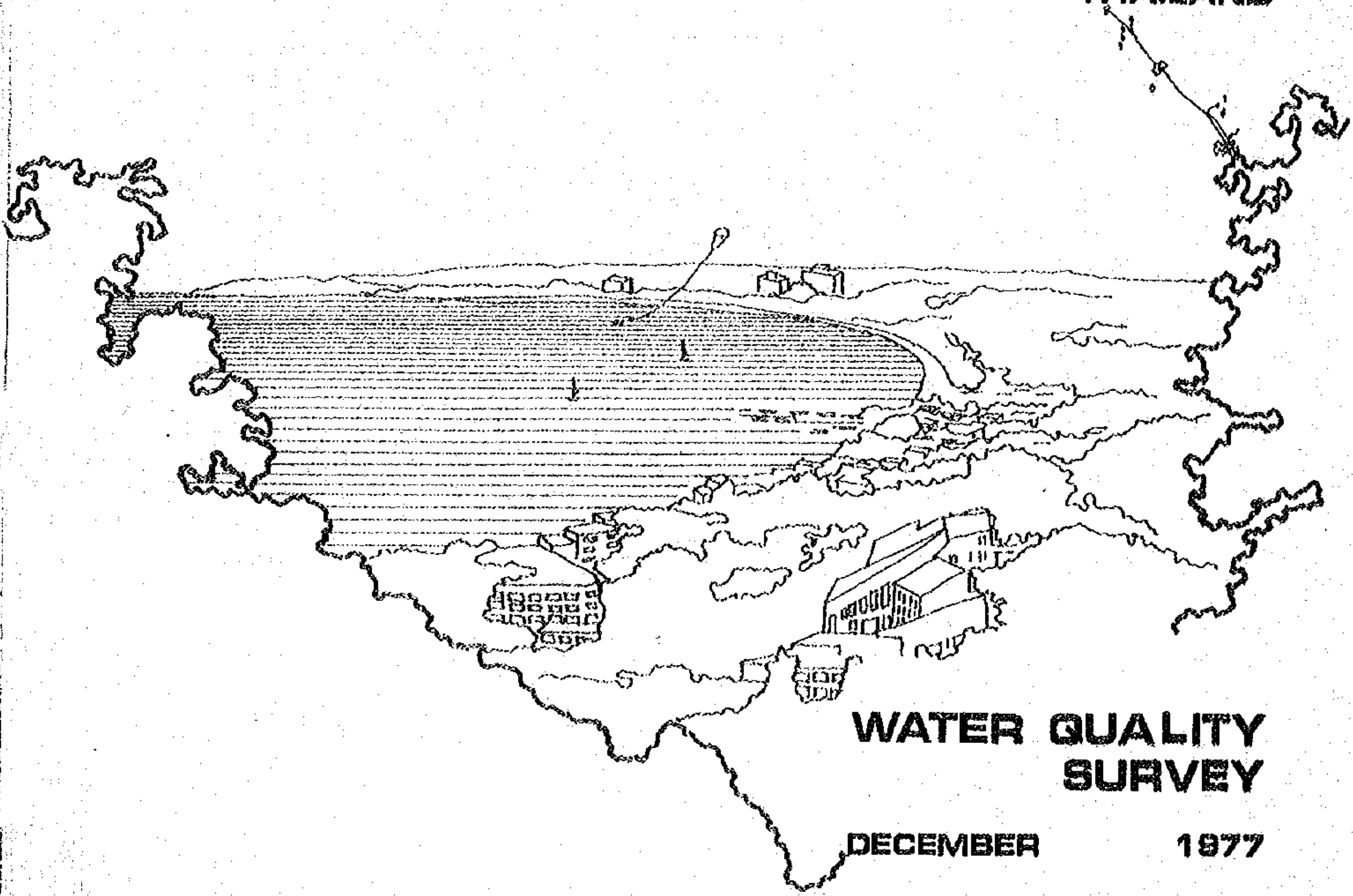
PATTAYA

TOURISM DEVELOPMENT

THAILAND



WATER QUALITY SURVEY

DECEMBER 1977

JAPAN INTERNATIONAL
COOPERATION AGENCY

TOURIST ORGANIZATION
OF THAILAND

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Chapter 2. SURVEY ON CURRENT

CHAPTER 1 OUTLINE

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1.1 Background

The sea water quality survey was made as a part of the masterplan study for the Pattaya Tourism Development Project by the Japan International Cooperation Agency.

Pattaya is now developing very rapidly as an ocean resort. However, in preparing the masterplan for Pattaya, the Japanese survey team had some doubts about the sea water quality which is the most important determining factor in the development of ocean resort, and the available data obtained from previous studies were insufficient to evaluate the present and future water quality. Consequently, the field survey of the water quality including sediment condition and current survey was decided to conduct in order to secure the basis on which the masterplan stands.

The survey was made at Pattaya from 10 Aug. to 8 Sept. 1977.

1.2 Purposes of Survey

The purposes of this survey are summarized as follows:

(1) to know the existing water quality level to determine the adequacy as an ocean resort.

(2) to decide what kinds of measures are required to maintain better sea water quality at the Pattaya resort area.

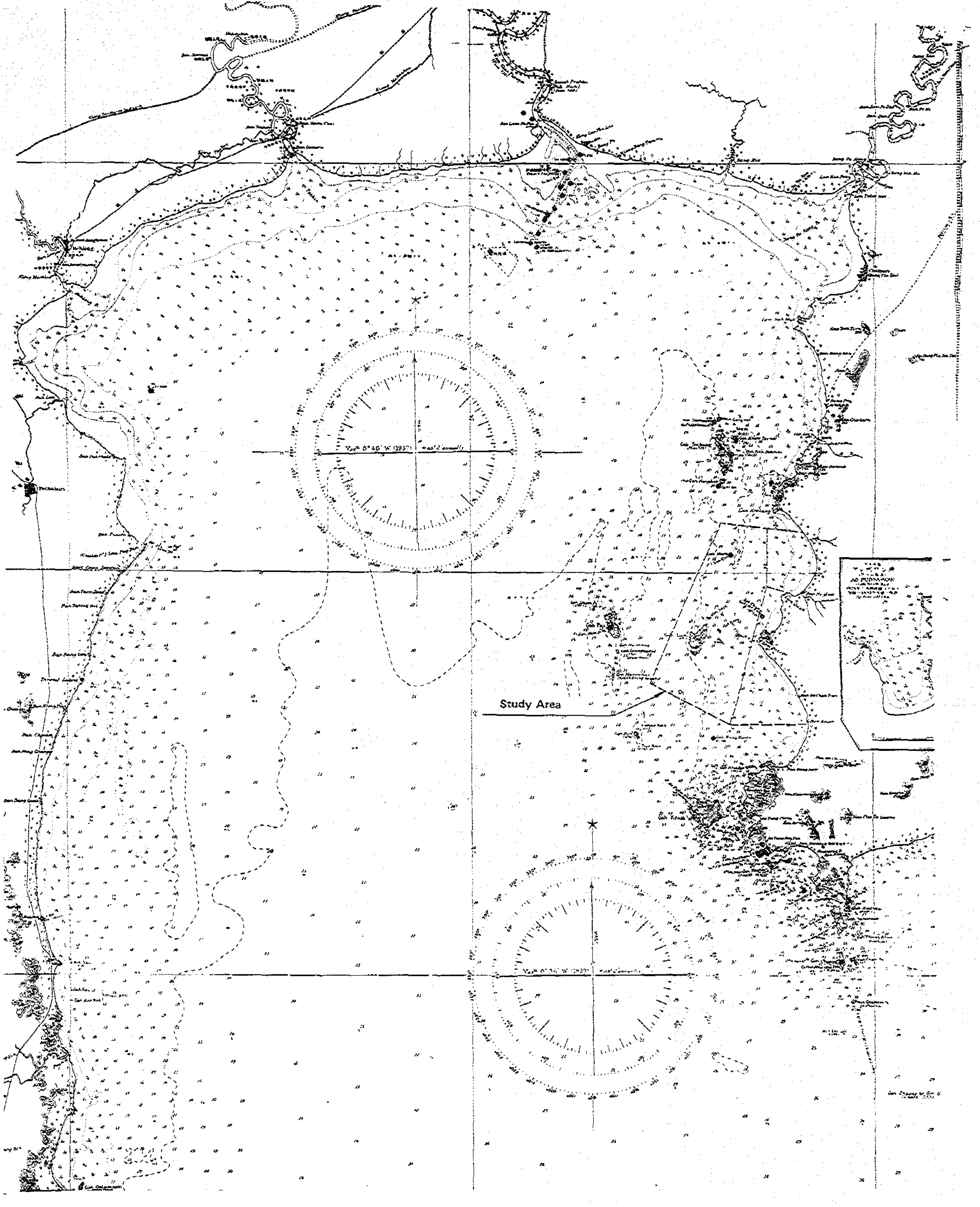
Following three survey items, water quality, sediments condition and current condition were surveyed to meet the objectives of the study.

1.3 The Study Area and Submarine Topography

The location of this study is the offshore area of Pattaya which is located at the east coast of the Upper Gulf of Thailand. Please refer to the location map on page 2 .

Although field surveys dealing with marine environment generally have to be conducted as widely as possible, the area limited in scope of this study is shown in Fig. 1.2. The study area was derived from the

Fig. 1-1 Location Map



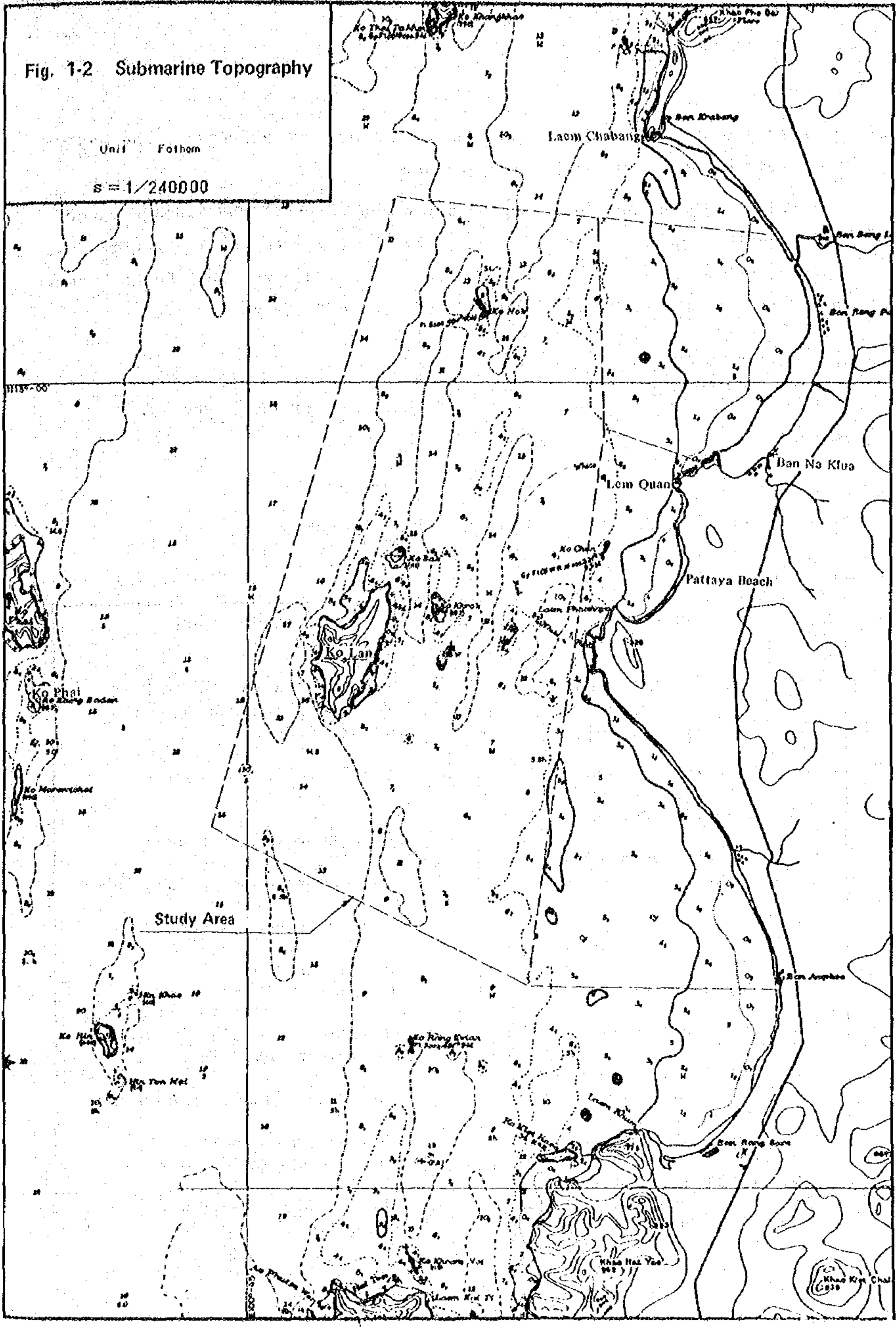


Fig. 1-2 Submarine Topography

primary aim of this survey which was to measure the effects of the waste water discharged into the Pattaya sea area.

Fig. 1.2 also provides the submarine topography. The average water depth in the Upper Gulf is relatively shallow (15 m to 20 m). Significantly, the deepest sea bottom which is 25 m to 30 m reaches the Ko Sichang sea area from the Outer Gulf through offshore of Pattaya.

1.4 Schedule of Survey

Table 1.1 reports the schedule of the field survey conducted at Pattaya.

Table 1.1 Schedule of field survey

1)

Date	Discription	Date	Discription
Aug.			
10.	Arrived at Bangkok.	17.	Preparation for Analytical room. Locate the Current meter at St. C.
11.	Meeting with TOT.		
12.	Move for Pattaya. Check instruments. Sight inspection of river.	18.	Sampling for Coliform Bacteria.
		19.	Check Analytical reagent.
13.	Check instruments. Sight inspection of sea area.	20.	Sea water sampling in Block-B.
		21.	Sea water analysis.
14.	Setting up Current meter at St. B, (continuous 15-day observation station).	22.	Sea water analysis. Current analysis.
15.	Setting up Current meter at St. A and C (continuous 25-hour observation stations). Check Current meter at St. B (every day check to 30 Aug.).	23.	Sea water sampling in Block-A. Sea water analysis.
		24.	Sea water sampling in Block-C.
		25.	Sea water analysis. Current analysis.
16.	Preparation for Analytical room. Recovery of Current meter at St. A (Current meter was lost at St. C).	26.	Water and sediment sampling in rivers. Sea water analysis. Current analysis.

Date	Discription
Aug.	
27.	Sea water sampling in Block-D. Sea and river water analysis.
28.	Sea water sampling in Block-D. Setting up Current meters at St. C and D (continuous 25-hour observation stations).
29.	Sampling for Coliform Bacteria. Sea water analysis. Resetting up Current meter at St. C. Recovery of Current meter at St. D. Setting up Current meter at St. E (continuous 25-hour observation station).
30.	Recovery Current meter at St. B, St. C and St. E. Setting up Current meter at St. F (continuous 25-hour observation station). Sea water analysis.
31.	Sea water analysis.
Sep.	
1.	Sediment sampling in Sea area. Sea water analysis.
2.	Check and packing instruments.
3.	Data adjustment. (Reporting)
4.	Reporting.
5.	Sample transportation. Reporting.
6.	A visit to AIT. Report bookbinding.
7.	A Report and meeting with TOT.
8.	Arrived at Tokyo.

CHAPTER 2 SURVEY ON CURRENT

CHAPTER 2 SURVEY ON CURRENT

2.1 Summary

2.1.1 Purpose of survey

The present survey is intended to gauge the distributions of the current in Pattaya sea waters. In this connection, the current survey was conducted in the Pattaya region to collect basic ocean parameters such as the water quality and the current distributions, which are the fundamental elements for an ocean resort.

2.1.2 Period and location of survey

Table 2.1 shows the collected data on the weather, wind direction, wind velocity and operational processes during the survey. The survey was conducted over the following period:

From 14 Aug. 1977 to 1 Sept., 1977.

Table 2.2 lists the locations of the observation stations, which are in turn presented on the map of Fig. 2.1.

Table 2.2 Locations of observation stations

Station No.	Latitude (N)	Longitude (E)
A	13° 02' 05"	100° 50' 16"
B	12° 57' 48"	100° 49' 56"
C	12° 51' 40"	100° 48' 52"
D	12° 52' 53"	100° 51' 26"
E	12° 56' 20"	100° 51' 52"
F	12° 59' 04"	100° 52' 52"

Table 2-1 Wind and Wave condition during survey period

Date	Discription	Weather	Wind direction	Wind force	Wave direction	Wave height (cm)
Aug.						
10	Arrived at Bangkok.					
11	Meeting with TOT.					
12	Move to Pattaya. Check instruments. Sight inspection of rivers.					
13	Check instrument. Sight inspection of sea area.					
14	Setting up Current meter at St. B (continuous 15-day observation station).	fine	SSW	1	SSW	30
15	Setting up Current meters at St. A and C (continuous 25-hours observation stations). Check Current meter at St. B (every day check to 30 Aug.)	fine	NW	1∿2	NW	50
16	Preparation for Analytical room. Recovery of Current meter at St. A. (Current meter was lost at St. C.)	fine	S	1∿2	SSW	50

Table 2-1 Wind and Wave condition during survey period (Cont.)

Date	Discription	Weather	Wind direction	Wind force	Wave direction	Wave height (cm)
Aug.						
17	Preparation for Analytical room. Locate the Current meter at St. C.	cloudy after fine	S	1	SW	50
18	Sampling for Coliform bacteria.	cloudy after fine	SW	1∿3	SW	40(AM) 70(PM)
19	Check water sampling in Block-B.	cloudy	SW	2	S	70
20	Sea water sampling in Block-B.	cloudy	SW	1∿2	S	50(AM) 120(PM)
21	Sea water analysis.	cloudy partialy fine	SW	2	S	70(AM) 100(PM)
22	Sea water analysis. Current analysis.	cloudy partialy fine	SW	1	SW	50
23	Sea water sampling in Block-A. Sea water analysis.	cloudy	SW	1∿2	SW	50
24	Sea water sampling in Block-C.	cloudy	WSW	1	WSW	30(AM) 40(PM)
25	Sea water analysis. Current analysis.	cloudy	SW	1	SW	30

Table 2-1 Wind and Wave condition during survey period (Cont.)

Date	Discription	Weather	Wind direction	Wind force	Wave direction	Wave height
26	Water and sediment Sampling in rivers. Sea water analysis. Current analysis.	cloudy	WSW	1	SW	30
27	Sea water sampling in Block-D. Sea and river water analysis.	fine	SW	1	SW	40
28	Sea water sampling in Block-D. Setting up Current meters at ST. C and D (continuous 25-hour ovservation stations).	fine	SW	1	SW.	40
29	Sampling for Coliform Bacteria. Sea water analysis Resetting up Current meter at St. D. Setting up Current meter at St. E.	cloudy after fine	SW	2∿1	SW(AM) WSW(PM)	50(AM) 30(PM)
30	Recovery of Current meters at ST. B, St. C and St. E. Setting up current meter at St. F. Sea water analysis.	cloudy after fine	SW	1	SW(AM) W(PM)	30(AM) 20(PM)
31	Sea water analysis. Recovery of Current meter at St. F.	fine	clean			

Table 2-1 Wind and Wave condition during survey period (Cont.)

Date	Discription	Weather	Wind direction	Wind force	Wave direction	Wave height
Sep.						
1	Sediment sampling in sea area. Sea water analysis.	fine	W	1	W	30
2	Check and packing instruments.					
3	Data adjustment.					
4	Reporting.					
5	Sample transportation. Reporting.					
6	A visit to AIT. Report bookbinding.					
7	A report and meeting with TOT.					
8	Arrived at Tokyo.					

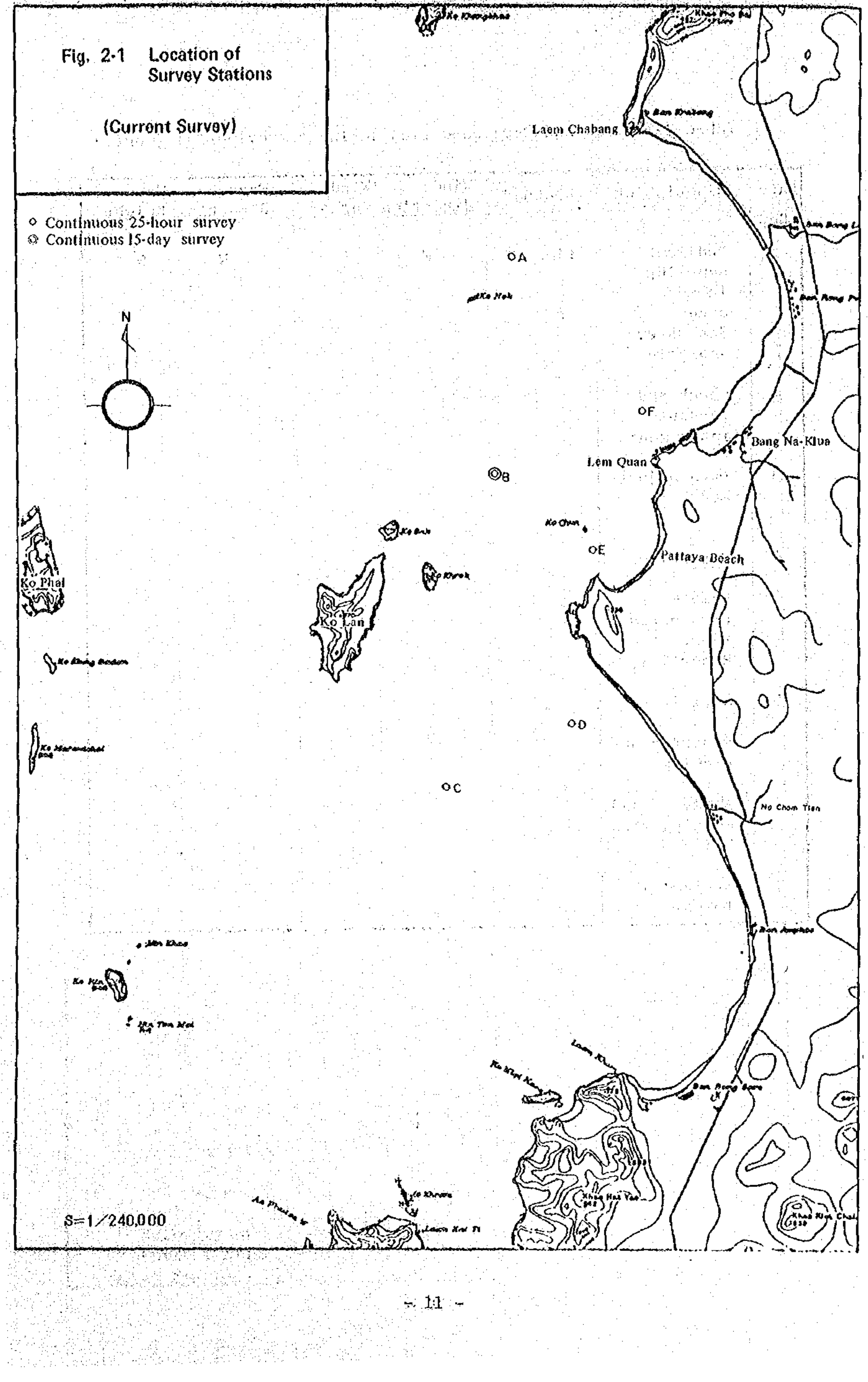


Fig. 2-1 Location of Survey Stations

(Current Survey)

2.1.3 Survey items

(1) Tide

The observation data of the tide during the corresponding period to our survey were obtained from the tide station at Ko Sichang and examined by the harmonic analysis.

(2) Continuous 15-day observation

When the constant coefficients by harmonic analysis are derived from tidal current data, we can obtain a lot of imformation about the characteristics thereof. But it is very difficult to conduct a continuous observation sufficient enough for harmonic analysis. Although there are some problems, data from a continuous 15-day or one month observation at 1 or 2 stations are usually used to obtain harmonic coefficients of main tide conponents while data from a continuous 25-hour observation are used at other stations. In this study, a continuous observation was conducted at the Station B for the period of 15 days from 14 Aug. to 30 Aug., 1977.

(3) Continuous 25-hour observation

Continuous 25-hour observations were conducted at Stations A, C, D, E and F from 15 to 16 Aug. and from 28 to 31 Aug., 1977, respectively.

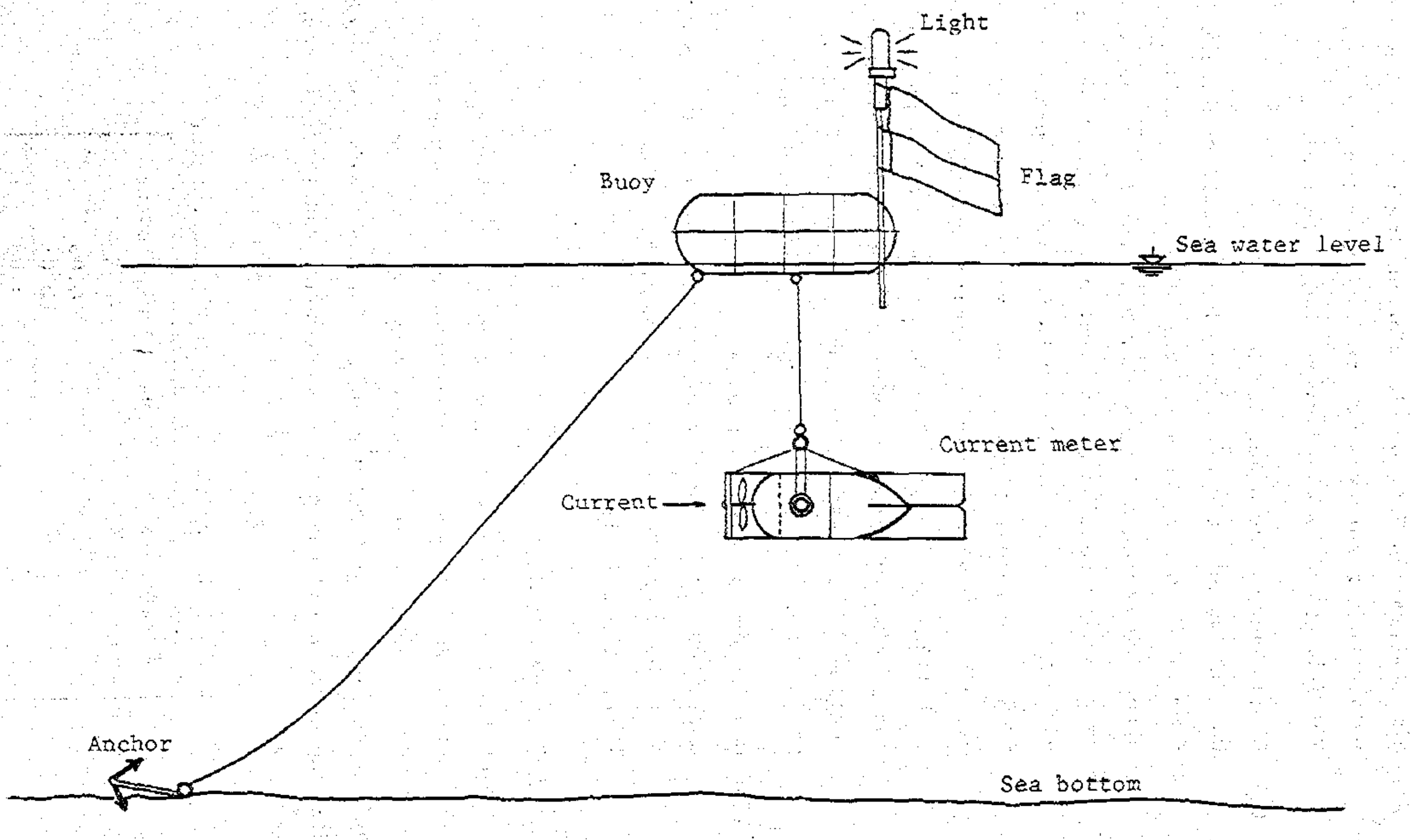
2.1.4 Method of survey

The observation was made in the so-called middle layer, and the measuring instruments were placed under water at depths shown in Table 2.3. After determining the location, a bouy was anchored at each station. An OC self-recording current meter hung on the buoy while continuously recording the current for the period of 25 hours and 15 days, respectively. (See Fig. 2.2)

Table 2.3 Current meter depth under water

Station No.	Depth under water
A	8.0m
B	10.0m
C	10.0m
D	5.0m
E	5.0m
F	4.0m

Fig. 2-2 Anchoring of OC Current Meter



2.2 Method of Analysis

2.2.1 Tide

The tide in each season as shown in Table 2.4 was obtained by the harmonic analysis of the tide data at Ko Sichang tide station during the current survey period.

Table 2.4 Tide in each season
(At Ko Sichang Vo = 1.910m)

Spring Tide					Neap Tide				
T	SPRING	SUMMER	AUTUMN	WINTER	T	SPRING	SUMMER	AUTUMN	WINTER
0	975	2.436	1.553	.319	0	2.510	2.872	1.539	1.404
1	1.312	2.510	1.719	.757	1	2.383	2.622	1.129	1.126
2	1.763	2.596	1.979	1.327	2	2.260	2.331	.803	.912
3	2.231	2.627	2.249	1.930	3	2.190	2.067	.620	.820
4	2.615	2.542	2.441	2.466	4	2.198	1.880	.616	.887
5	2.833	2.303	2.486	2.857	5	2.280	1.792	.788	1.118
6	2.845	1.910	2.356	3.063	6	2.404	1.795	1.099	1.480
7	2.661	1.406	2.067	3.086	7	2.521	1.858	1.488	1.916
8	2.336	.369	1.680	2.986	8	2.574	1.929	1.883	2.349
9	1.361	.395	1.289	2.779	9	2.520	1.959	2.215	2.704
10	1.633	.079	.989	2.592	10	2.338	1.912	2.448	2.923
11	1.436	-.010	.860	2.467	11	2.038	1.777	2.556	2.978
12	1.416	.155	.943	2.433	12	1.660	1.570	2.556	2.874
13	1.571	.552	1.227	2.480	13	1.264	1.334	2.493	2.647
14	1.351	1.115	1.651	2.564	14	.920	1.128	2.386	2.356
15	2.171	1.747	2.121	2.619	15	.691	1.008	2.310	2.067
16	2.437	2.341	2.532	2.576	16	.617	1.018	2.288	1.836
17	2.564	2.807	2.790	2.386	17	.711	1.174	2.325	1.700
18	2.508	3.087	2.842	2.034	18	.952	1.464	2.405	1.664
19	2.269	3.168	2.683	1.549	19	1.293	1.841	2.491	1.708
20	1.900	3.083	2.361	1.002	20	1.673	2.242	2.537	1.792
21	1.489	2.895	1.963	486	21	2.030	2.594	2.502	1.866
22	1.139	2.682	1.594	103	22	2.312	2.837	2.360	1.888
23	940	2.516	1.347	-.765	23	2.491	2.931	2.110	1.833
24	949	2.438	1.284	024	24	2.564	2.867	1.777	1.703

Table 2.5 Harnomic constant of tide

	M2	S2	K2	K1	O1	P1
V	530	220	060	690	427	230
K	134.7	189.6	189.6	162.5	121.2	162.5

2.2.2 Current

1) Method of data compliation

The data on the continuous 15-day observation were compiled in such a manner as to read the current direction and the current velocity value every 10 minutes, from which two vectors, namely, the north and east components were resolved.

The velocity component diagrams were drawn on the basis of these components plotted on time-basis, and then each diagram was resolved into the harmonic analysis, leading to the calculation of the harmonic constant (Table 2.6).

The current ellipse diagram for the spring tide and the tropic tide was drawn on the basis of the harmonic constant formed in connection with the high water time at Ko Sichang.

The data collected from the continuous 25-hour observation were sampled every 20 minutes and the velocity component diagram was drawn in the same manner as in the continuous 15-day observation.

In the resolution of the harmonic analysis per day, the velocity component V_t was calculated as follows:

$$V_t = V_o + V_1\cos(15°t-k_1) + V_2\cos(30°t-k_2) + V_4\cos(60t-k_4)$$

Letting V_o = constant current,

then, the harmonic analysis is given by,

$V_1\cos(15°t-k_1)$ = Diurnal tide

$V_2\cos(30°t-k_2)$ = Semidiurnal tide

$V_4\cos(60°t-k_4)$ = Quarterdiurnal tide.

In making up the data collected from the continuous 25-hour observation at Stations A, C, D, E and F, the revised calculation on the high water made using the harmonic constant obtained from the continuous 15-day observation at each station (Table 2.7).

These continuous observations for 15 days and for 25 hours were synthesized into the current diagram for the spring tide and the tropic tide, and into the constant current diagram. A computer was used in calculating these data.

Table 2-6 Harmonic Constants
(Continuous 15-day observation)

			M_2	S_2	K_2	N_2	K_1	O_1	P_1	Q_1	M_f	MS_f	Constant Current
Main Direction Component (8)	V	m/s	0.264	0.133	0.036	0.043	0.181	0.086	0.060	0.026	0.021	0.012	-0.015
	K	0	49	110	110	31	61	35	61	358	103	130	
Current Ellipse	D L	0	7	13	13	6	13	348	13	86	25	357	253
	V L	m/s	0.264	0.134	0.036	0.043	0.182	0.092	0.060	0.031	0.022	0.012	0.035
	K L	0	49	110	110	32	61	40	61	74	109	133	
	D S	0	97	103	103	96	103	78	103	176	115	87	
	V S	m/s	0.001	0.007	0.002	0.006	0.003	0.018	0.001	0.025	0.007	0.003	
	K S	0	139	20	20	302	331	310	331	164	199	43	

Table 2-7 Harmonic Constants
(Continuous 25-hour observation)

Station	Layer	Date		Axis	M_1			M_2			M_4			Constant Current	M_1/M_2
		Age of Sun	Declination		Direction	Speed	Time	Direction	Speed	Time	Direction	Speed	Time		
A	8.0M	1977. 8. 15		L	18	0.216	2.3	4	0.338	2.3	298	0.023	2.1	163	0.64
		d	N9° 18′	S	108	0.005	20.3	94	0.068	5.3	28	0.018	3.6	m/s	
		0.8	~N5°18′	S/L		0.02			0.18			0.39		0.038	
C	10.0M	1977. 8. 29		L	8	0.197	13.9	8	0.471	2.0	81	0.026	5.9	237	0.42
		d	S6° 1′	S	98	0.037	19.9	98	0.028	5.0	171	0.019	4.4		
		14.9	~S0°36′	S/L		0.19			0.06			0.73		0.025	
D	5.0M	1977. 8. 28		L	339	0.193	14.1	345	0.481	2.1	63	0.021	3.6	152	0.40
		d	S9° 26′	S	69	0.004	8.1	75	0.022	5.1	153	0.003	2.1		
		13.7	~S5°14′	S/L		0.02			0.05			0.16		0.052	
E	5.0M	1977. 8. 29		L	50	0.120	13.3	44	0.339	1.5	44	0.024	1.4	211	0.35
		d	S4° 40′	S	140	0.012	19.3	134	0.010	4.5	134	0.007	2.9		
		14.9	~S0°15′	S/L		0.10			0.03			0.30		0.037	
F	4.0M	1977. 8. 30		L	24	0.123	12.9	27	0.403	2.0	323	0.023	1.5	251	0.31
		d	S10°18′	S	114	0.015	6.9	117	0.017	5.0	53	0.008	0.0		
		15.7	~N3° 1′	S/L		0.13			0.04			0.32		0.039	

2) Spring tide

The main current direction as shown in the chart, moves nearly north (south) at the Stations A, B and C, north-northwest (south-southeast) at D, and northeast (southwest) at E and F, respectively.

When observing the current at the Station B, it was noticed that the north current starts around the low water time at Ko Sichang and reaches its strongest at the interim time between the low water and the high water, while the south current starts at the high water time at Ko Sichang, and its strongest at the interim time.

There is little difference among the stations in the continuing time of the tide as well as in the time difference of the tide. The only exception was at Station E whose tidal time shows approximately 30 to 40 minutes (M_2 component) earlier than that of the Station B under the influence of the topography. (See Table 2.8)

Table 2.8 Current at each station

Station	depth	principal direction	M2		M1		constant current	
			velocity ratio	range of lag	velocity ratio	range of lag	θ	V m/sec
A	8.0	4	0.942	+8	1.244	-8	163	0.038
B	10.0	8	1.000	0	1.000	0	253	0.035
C	10.0	8	1.167	-8	1.674	-56	237	0.025
D	5.0	345	1.327	-10	1.246	-72	152	0.052
E	5.0	44	0.841	-36	1.020	-92	211	0.037
F	4.0	27	0.949	+2	1.726	-68	251	0.039

However, the distributions of a current as known, vary under the influence of the moon at new, full and both quarters, as well as seasonal and astronomical conditions, respectively. The variations are indicated on the four seasons' current curve at the Station B. (See Fig. 2.3).

According to the curve, the current velocity of the spring tide is approx. 0.4m/sec. at its peak (the strongest), but it sometimes reaches approx. 0.6m/sec. at the new and full moons of the solstitial points in the summer and the winter when the diurnal tide components is prevalent.

3) Tropic tide

The current distributions of the tropic tide are almost the same as that of the spring tide.

The strongest south current velocity was observed at Station B and was approx. 0.366m/sec., and it took place two hours after the high water time at Ko Sichang.

The other current velocities at the time at each station were read as follows:

Station A: 0.395m/sec.
C: 0.442m/sec.
D: 0.530m/sec.
E: 0.301m/sec.
F: 0.387m/sec.

On the contrary, the strongest north current velocity was observed at the Station B and was approx. 0.344m/sec. and it took place two hours after the low water time at Ko Sichang.

The other current velocities at the time at each station were read as follows:

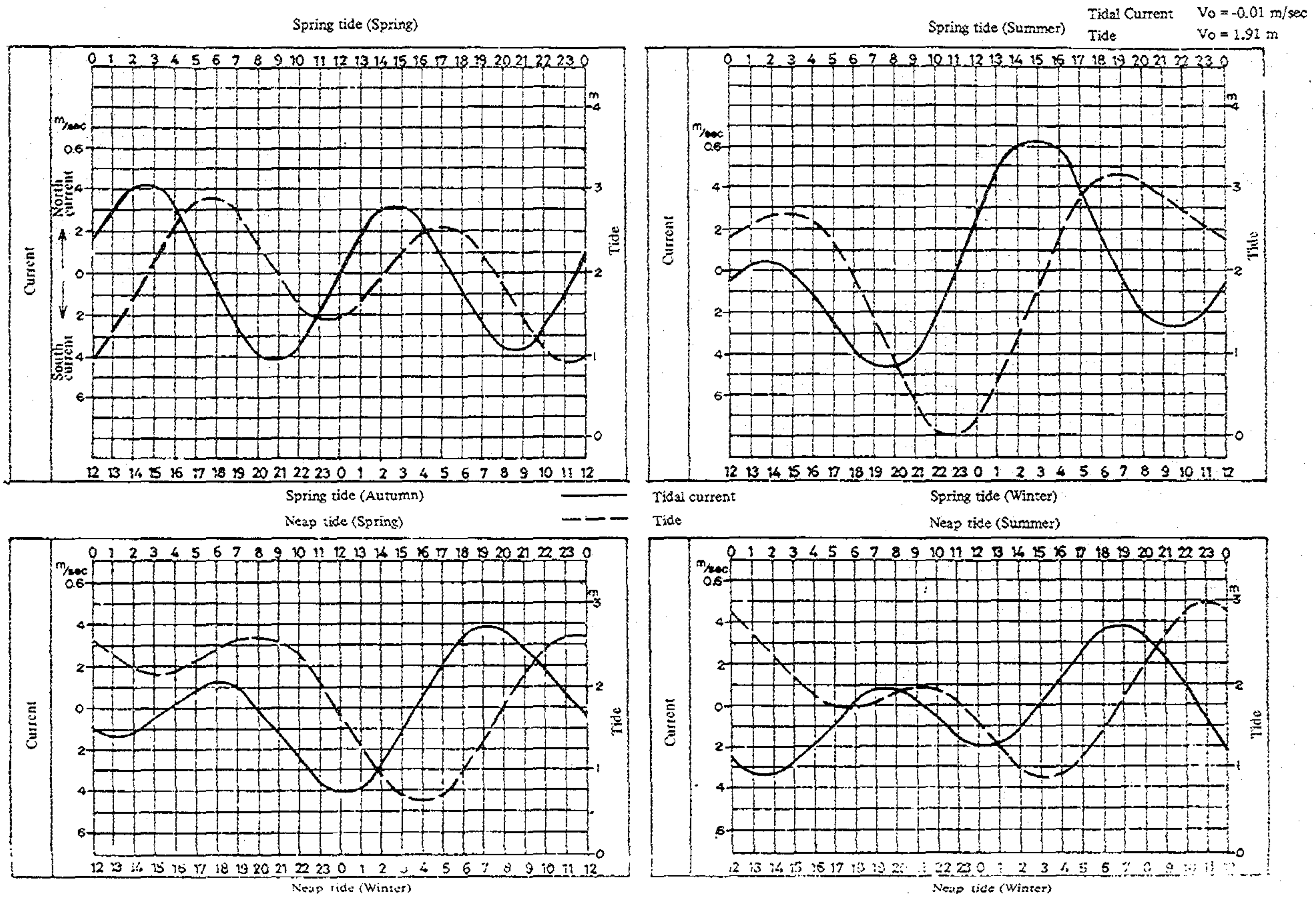
Station A: 0.326m/sec.
C: 0.409m/sec.
D: 0.428m/sec.
E: 0.230m/sec.
F: 0.329m/sec.

4) Periodical components

Fig. 2.4 reports an amplitude distribution of 24 components (amplitude distribution of time-period components) observed diurnally. This amplitude distribution shows that 12-hour and 24-hour components have a relatively high amplitude, clearly indicating that the current components form remarkably regular flows in this sea area.

Moreover, the diurnal changes in the amplitude of 4-, 6-, 8-, 12- and 24-hour components are shown in Fig. 2.5. As seen from Fig. 2.5, it has been found that the 4-, 6- and 8-hour components have a minute amplitude and exhibit irregular

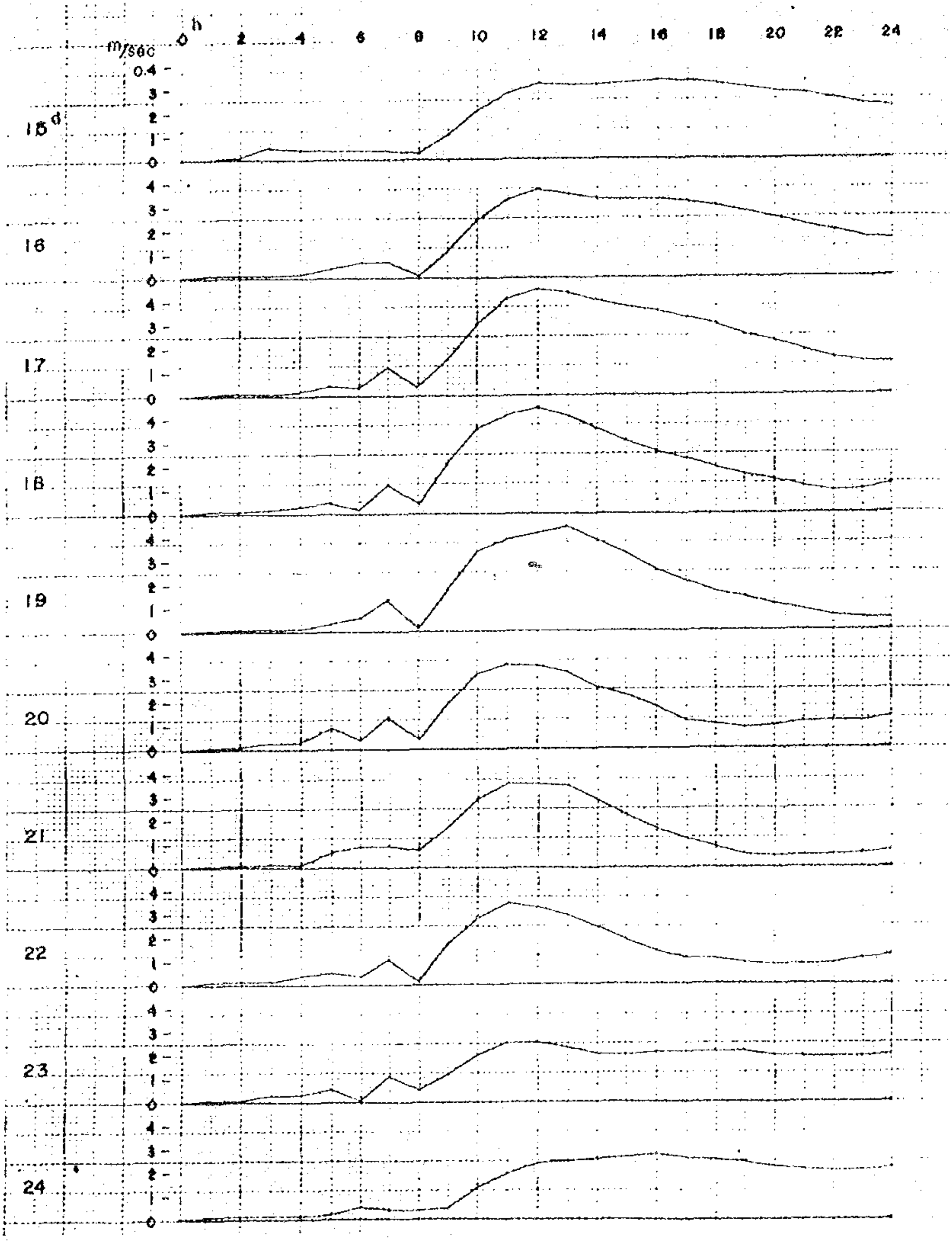
Fig. 2-3 Tide and Tidal Current



changes, while the 12- and 24-hour components show an ebb and flow under a certain relationship with the age of the moon and the lunar declination, respectively. Then, in order to analyze periodical components of longer period, the amplitude distribution of the respective time-periodical components determined by aggregating all 15 days' data has been presented in Fig. 2.6. As seen in Fig. 2.6, the peaks can be found in 12- and 13-hours components (M_2, S_2) and 23- ∿ 25-hour components (K_1, O_1, P_1). On the basis of these amplitude data, a contour line diagram has been drawn as shown in Fig. 2.7, with the period (time) taken on the ordinate and the date of observation on the abscissa and by entering the amplitude in the respective lattice points. As shown in Fig. 2.7, the amplitude of those components having a period of 8 hours or shorter exhibits an irregular ebb and flow and the 12- and 13-hour components present an ebb and flow corresponding to the change in the age of the moon, while those having a longer period have a mutual interaction, resulting in a contour line which runs in the longitudinal direction.

Fig. 2.8 shows the change in the amplitude of the diurnal component over periods ranging from 1 day to 15 days, representing an aspect of the correlation of flow which is associated with the time scale. According to Fig. 2.8, it can be seen that a significant correlation of flow does exist up to the period of 1 day, while in the second day and after it is extremely feeble.

Fig. 2-4 Amplitude Distribution of Time-period Components



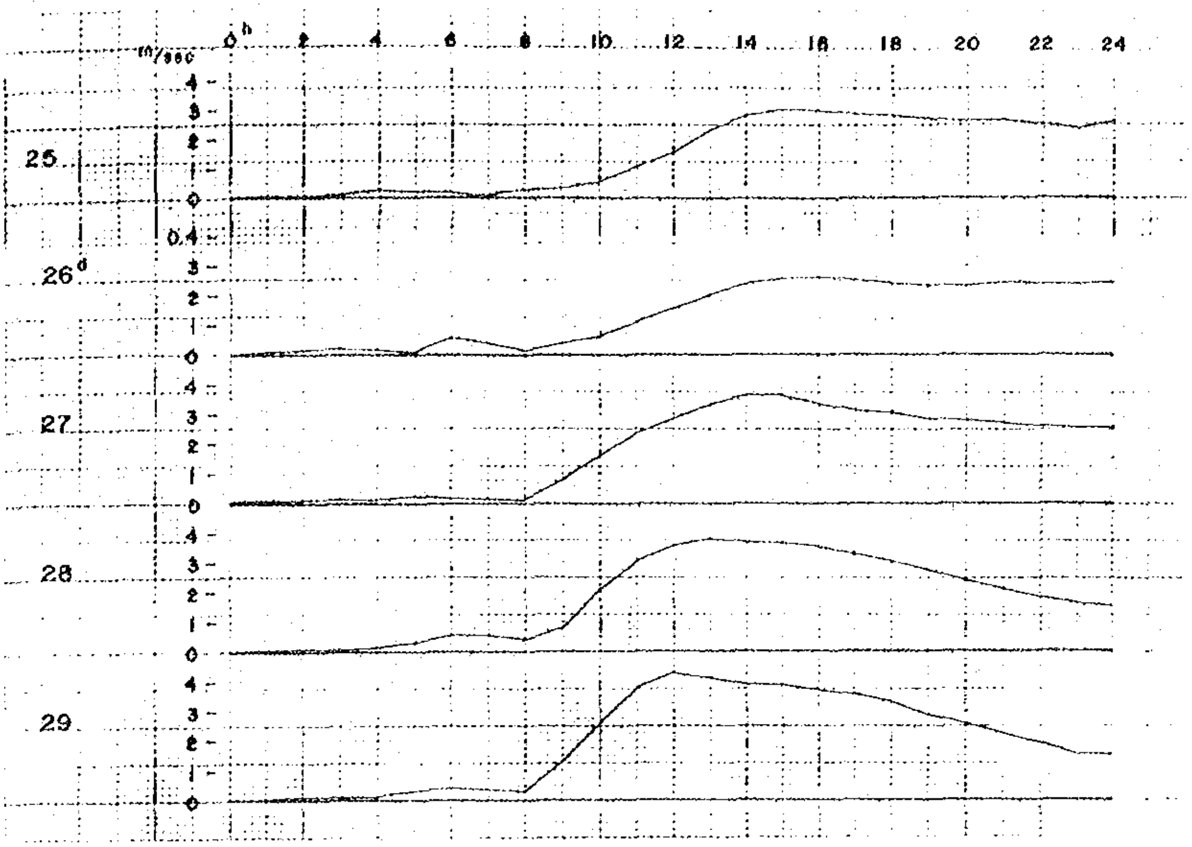

m/sec
0^h
2
4
6
8
10
12
14
16
18
20
22
24
25
26^d
27
28
29
0
1
2
3
4
0.4

Fig. 2-5 Diurnal Changes in the Amplitude

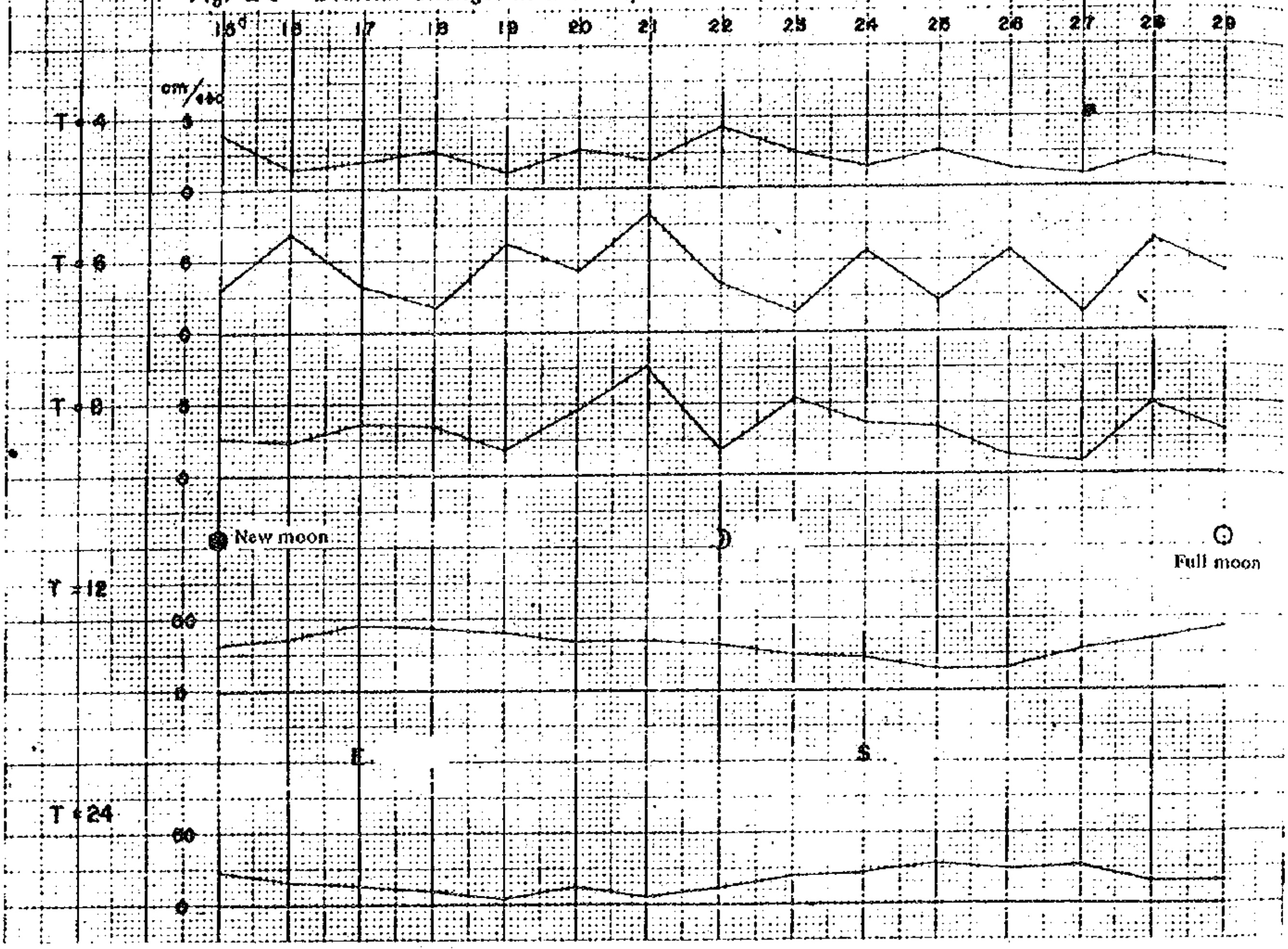


Fig. 2-6 Distribution of Total Amplitude

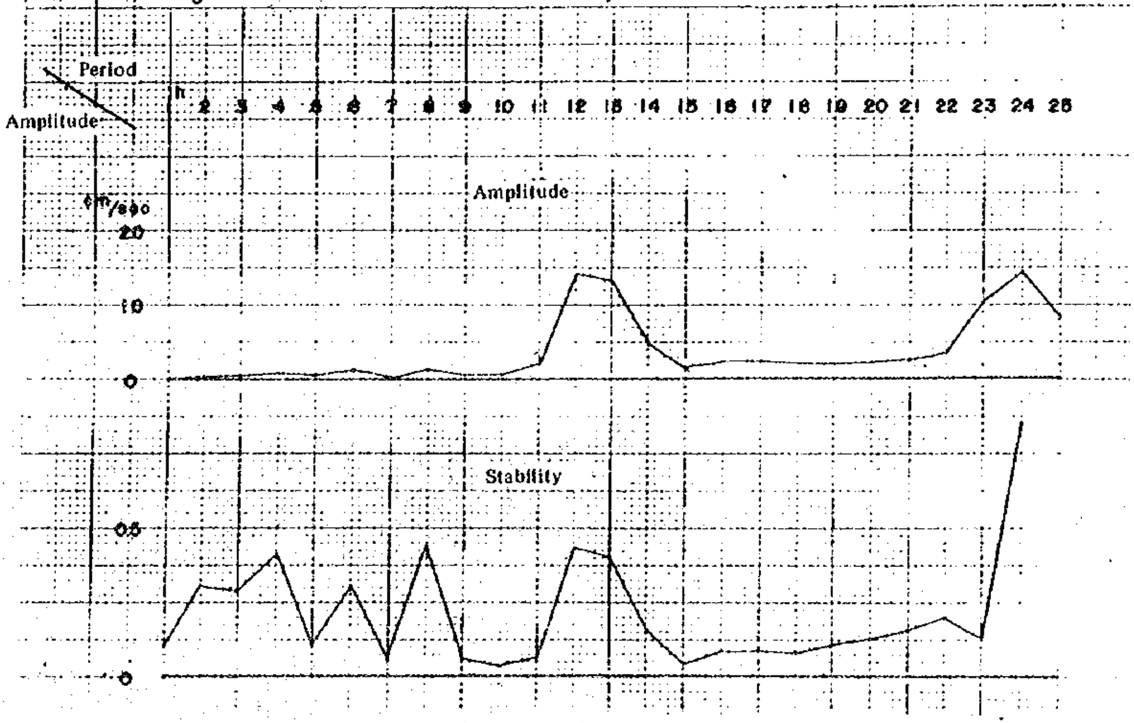


Fig. 2-7 Amplitude Contour

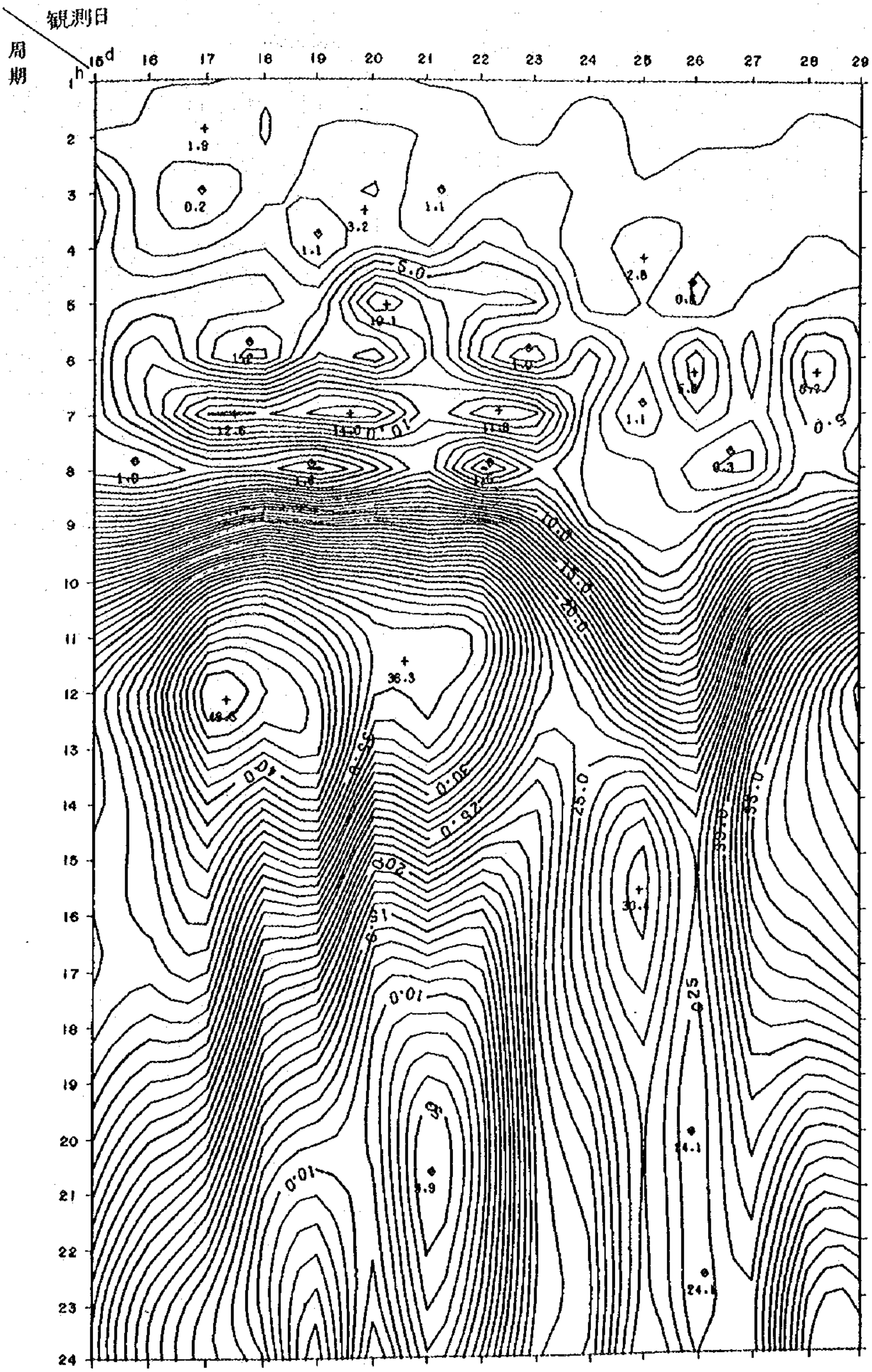
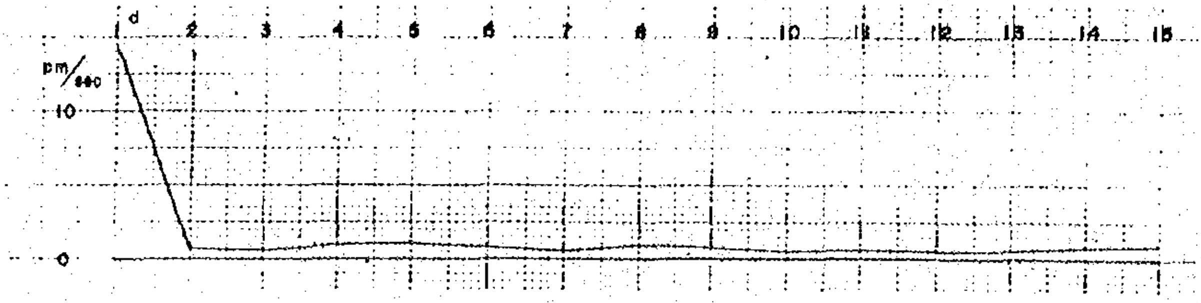


Fig. 2-8 Amplitude of Diurnal Component



2.2.3 Constant current component

A constant current is the flow influenced by the weather, oceanographic condition, the land water, the topography, etc. Simply it is generally the constant flow, though some slight change may be seen by daily observation.

The constant current in this sea area is weak over the entire area, and it can be readily understood from the fact that even the strongest value observed at the Station D during the observation was comparatively weak, i.e. 0.05m/sec.

On the whole, the current components to the south (as weak as 0.03 ∿ 0.05m/sec.) are slightly recognized at each station.

These constant currents have a tendency to flow parallel along the shore in the offshore as well as the sea coast.

It can be assumed that the distributions of the constant current have the similar trend in both the offshore and the sea coast.

What is most noticeable was the fact that the current from Laem-Chabang largely curves toward the west at or around Na Klua and passes through the offshore (north side) of Ko Lan island.

The direction and the velocity of the constant current at each station are as follows:

Station A:	163°N	0.038m/sec.
B:	253°N,	0.035m/sec.
C:	237°N,	0.025m/sec.
D:	152°N,	0.052m/sec.
E:	211°N,	0.037m/sec.
F:	251°N,	0.039m/sec.

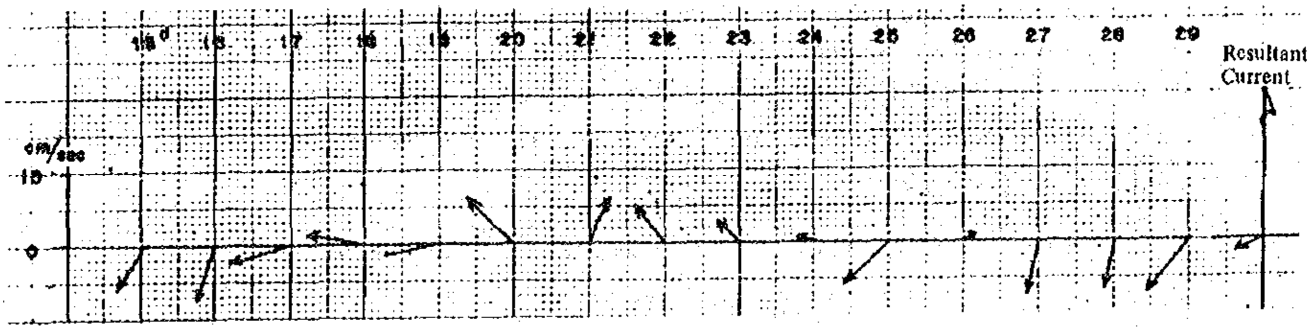
(See constant current diagram)

The constant current shows the trend as seen above, but it also changes itself day by day.

Fig. 2.9 shows the daily constant current diagram drawn on the basis of the mean value of the daily current for 24 hours, namely, from the zero o'clock of a day to the zero o'clock of the next day. From this diagram, it is found that the constant current indicates a considerable daily change, which is rather irregular.

It may be, therefore, proper to consider the idea that the constant current component indicated here is entirely the one obtained from the present observation somehow showing one of the patterns.

Fig. 2-9 Daily Constant Current



2.2.4 Diffusion coefficient

A turbulent diffusion coefficient can be derived from an auto-correlation function which, in turn, can be obtained from a statistical analysis of current observations (continuous 15-day observations at Station B). Futhermore, an analysis of the resultant turbulent diffusion coefficient will give a power spectrum, in which various periodical components can be seen.

The observations comprise time series data measured at a constant time interval. Since setting the reading interval to 10 minutes result in 144 intervals a day, about 2,200 observations can be obtained over a 15 day period. If the current direction (Θ°) and the flow velocity (Vm/sec.) of the observations are presumably decomposed into a main current direction component (M-Comp.) and a normal current direction component (X-Comp.), respectively, the values V_M and V_X of these two components can be expressed as follows:

$$V_M = V \cos(\Theta - \Theta_o), \quad V_X = V \sin(\Theta - \Theta_o),$$

where Θ_o is a main current direction, the value of which obtained from the main current component in the current harmonic analysis.

By substituting V_M and V_X by the respective deviations V' from their mean values over the entire observation period:

$$V_i'(t) = V_i\ (t) = \overline{V}_i \qquad \overline{V}_i = \frac{1}{N}\sum_{i=0}^{N-1} V_i(t),$$

where i representing component velocities.

Therefore, $\sum_{i=0}^{n-1} V_i'(t) = 0$.

The following analytical calculations have been performed on the basis of this $V_i'(t)$.

(1) Autocorrelation function

The coorelation between the observation $V'(t)$ at time t and the value $V'(t + \tau)$ at time $t + \tau$ which is τ after the time t can be expressed as follows:

$$C(\tau) = \overline{V'(t) \times V'(t + \tau)}.$$

In this equation, if $\tau = 0$, $C(0) = \overline{V'}^2$.

The normalized value $R(\tau)$ of the autocorrelation function $C(\tau)$ can be expressed as follows:

$$R(\tau) = \frac{C(\tau)}{C(0)} = \frac{\overline{V'(t) \times V'(t + \tau)}}{\overline{V'^2}}$$

The $R(\tau)$ shows a correlation in the observations having a time difference τ.

Assuming that the number of data are N, mean data value is $\overline{V}$ and the observations are $V'(t)$, the following formula can be obtained:

$$C(0) = \overline{V'^2} = \frac{1}{N} \sum_{t=0}^{N-1} V'(t).$$

Assuming that $\tau = \nu\Delta t$ ($\nu = 1, 2, 3, \ldots, m$), the value of the correlation $C(\tau)$ can be obtained as follows:

$$C(\nu\Delta t) = \frac{1}{N-\nu} \sum_{K=0}^{N-1-\nu} V'(K) \times V'(K + \nu)$$

In this survey, the analytical calculation has been performed on the assumption of $\Delta t = 10$ min. and $m = 200$.

The autocorrelation functions obtained herein are shown in Figs. 10 and 11. In these diagrams, "RAW DATA" shows the results of the analysis of observed $V'(K)$ while "Cut 60 Comp" is associated with the results of the analysis of observations from which 6 hours components were eliminated.

The resultant "Raw Data" in the autocorrelation curves showing a simple harmonic motion indicates that the flows at this station are dominated by tidal current components. In other words, the correlative peaks appearing at the curve

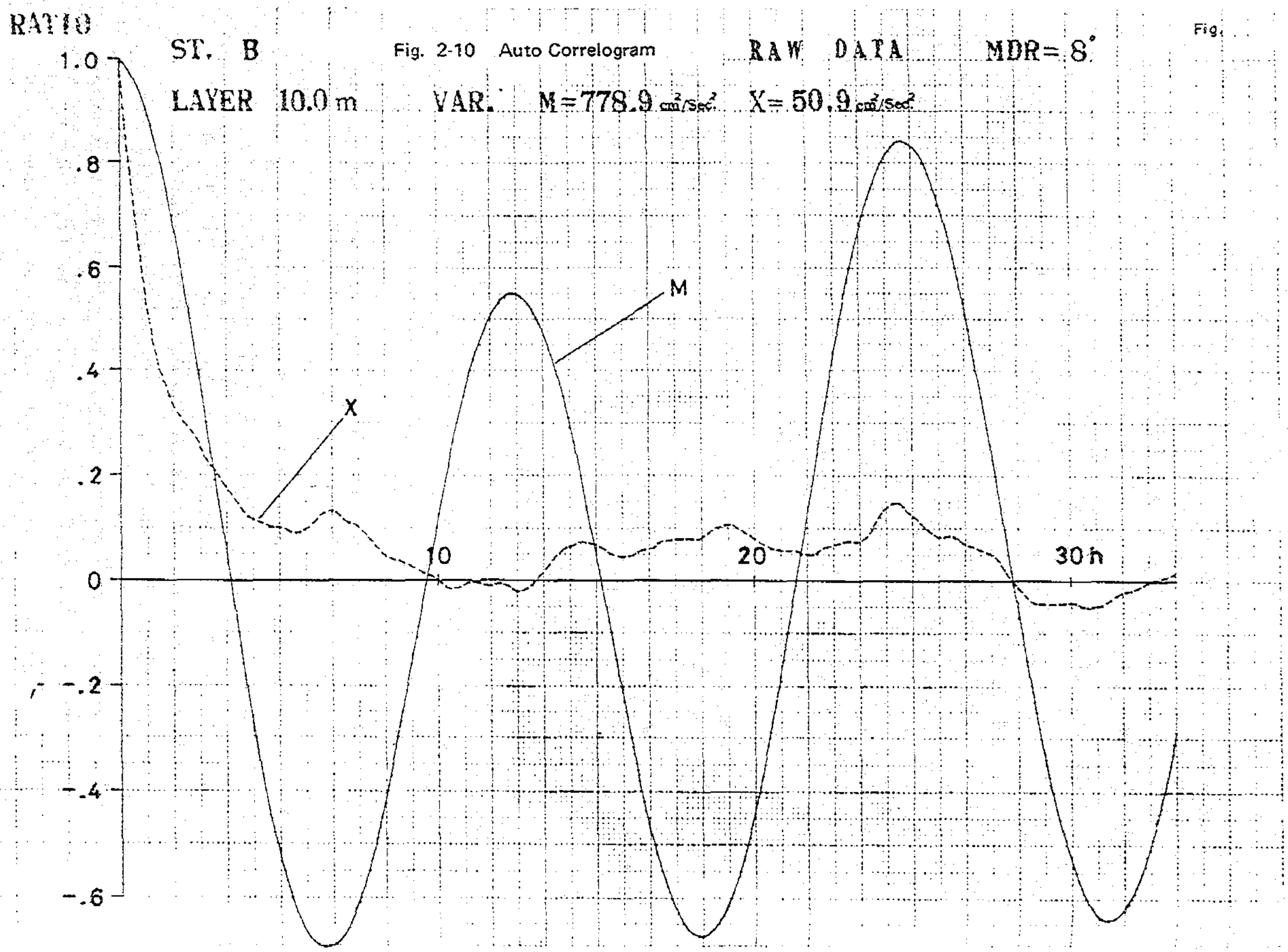


Fig. 2-10 Auto Correlogram

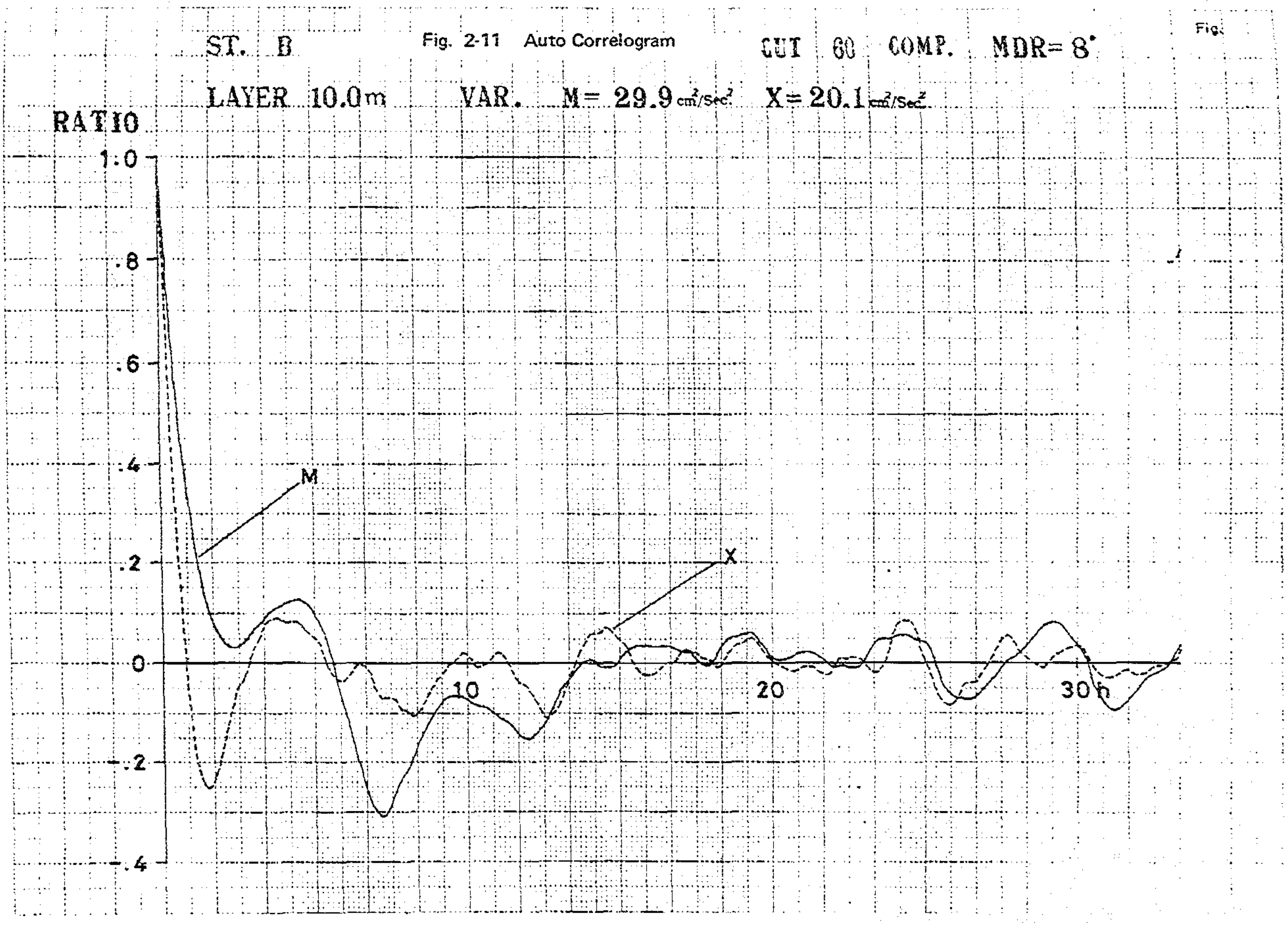


Fig. 2-11 Auto Correlogram

values 12.3h and 24.7h represent an existence of a semi-diurnal and diurnal components of the tidal current, respectively.

Similarly, the correlation curve of "Cut to Comp." shows that the correlation disappears rapidly in a shorter time. Therefore, it has been found that the flows in this sea area are dominated by long period components having a period longer than 6 hours, with an extremely minute value of short period components remaining after the elimination of those longer period components.

(2) Diffusion coefficient

G. I. Taylor calculated a diffusion coefficient from the following equation which was obtained from an autocorrelation function for flows at places the current goes to (Lagrange type flow):

$$K = \overline{V_L}^2 \int_0^\infty R_L(\tau)d\tau$$

where V_L and R_L are observations of Lagrange's fluctuation velocity and the autocorrelation function, respectively.

However, it is difficult to practically observe the Lagrange's fluctuation velocity and in considering the diffusion phenomena in coastal sea area, the value of the autocorrelation function of Euler type flow (time series data at a fixed point) is similar to that of the langrange type flow. The diffusion coefficient can be determined in terms of Euler's value by giving β on the assumption that $R_L(\eta) = R_E(\tau)$ and $\eta = \beta\tau$. Generally, the diffusion coefficient K is calculated from the following equation by letting $\beta = 1$:

$$K = \overline{V}^2 \times \{\sum_{K=0}^{h} C(K)/C(0)\} \times \Delta t$$

where h is a value of k giving $C(K) = 0$. However, the periodical components presumably contributing to the diffusion are those having a period shorter than several hours. Therefore, in order to determine the diffusion coefficient, it is necessary to eliminate longer period components such as tidal current components before calculating the autocorrelation function $R(\tau)$.

In this calculations, by taking 15 days (360 hours) as one unit of period, different 60 periodical components ranging from 1 to 60 periods were subjected to a Fourier analysis and the resultant sythesized values were eliminated from the observations.

Calculated results of the diffusion coefficient are given in Table 2.9. As the main current direction, a value (8°) was adopted, which was obtained as a weighted average of flow velocity amplitudes in the direction of the transeverse axis of the ellipse of main 6 current components (M_2, S_2, K_2, K_1, O_1, P_1) obtained from the current analysis, while a value (98°) resulting from the addition of 90° to the value of the main current direction was adopted for the normal direction.

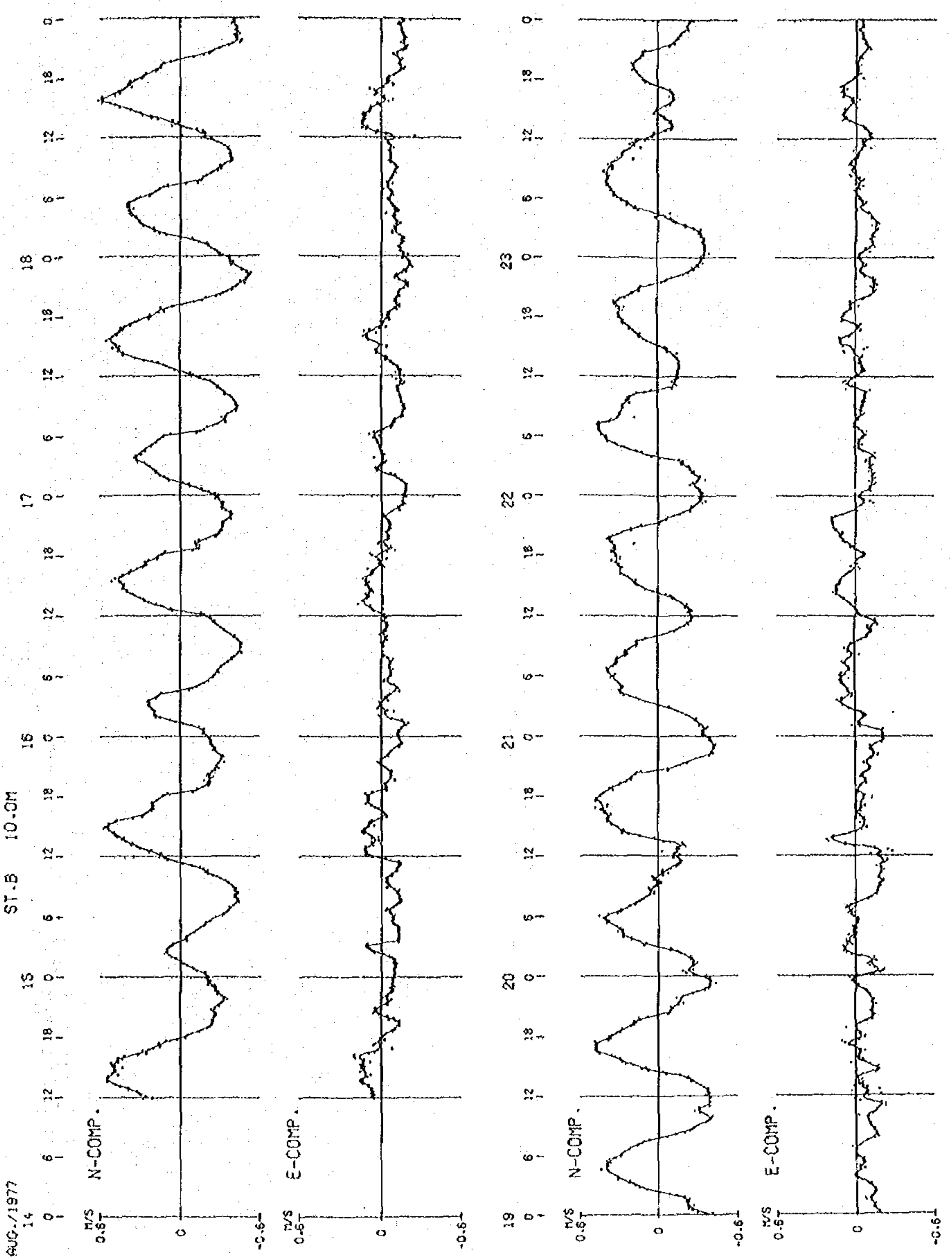
Table 2.9 Diffusion coefficient

St.	Layer	Data number	Main-Comp		X-Comp	
			Variance cm^2/sec^2	K cm^2/sec	Variance cm^2/sec^2	K cm^2/sec
B	10m	2286	29.9	1.188×10^5	20.1	3.150×10^4

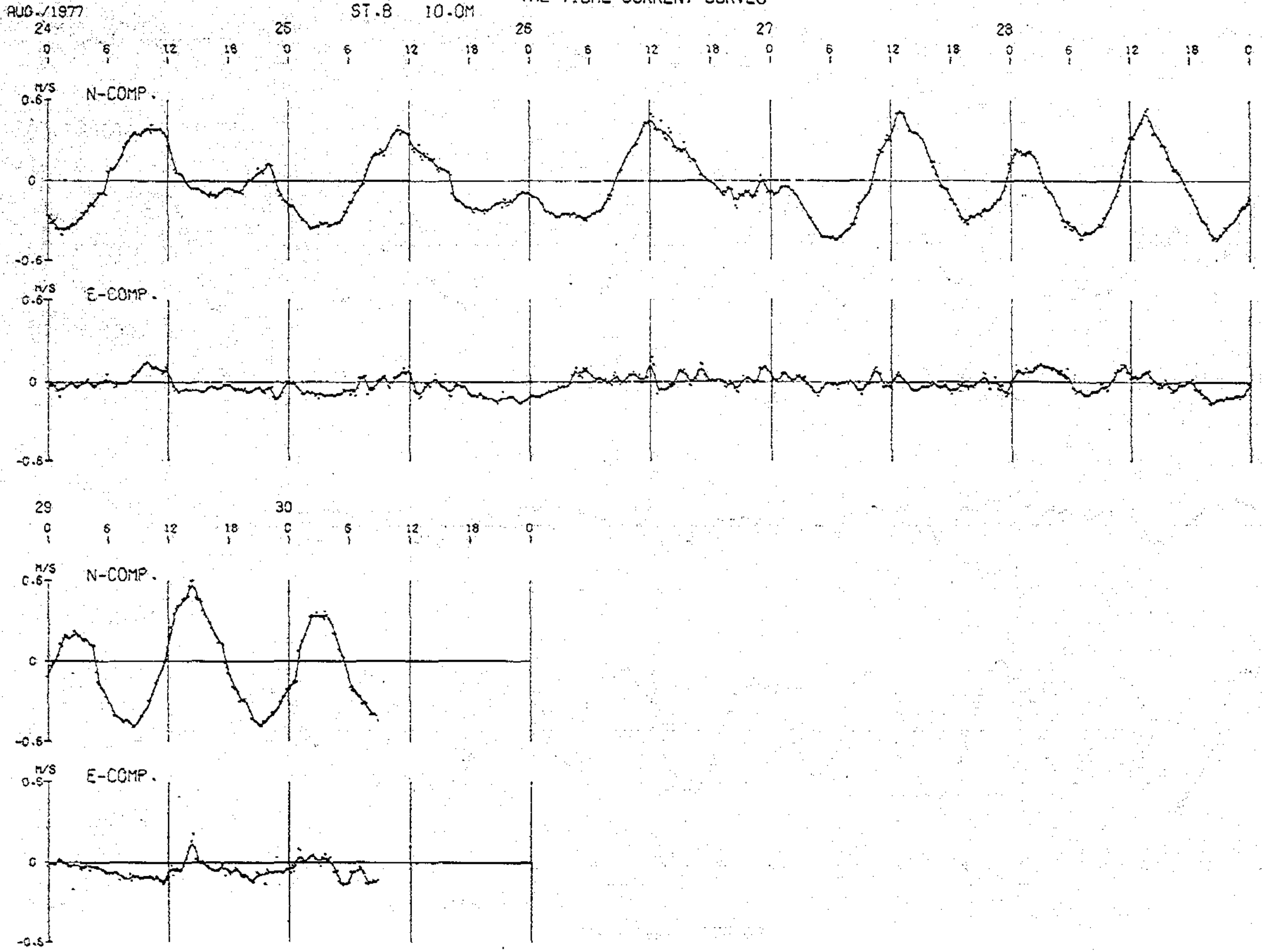
2-3 Attachment

2-3-1 Current component

THE TIDAL CURRENT CURVES

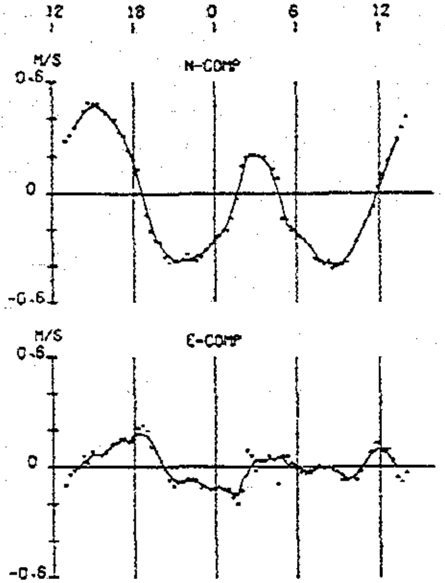


THE TIDAL CURRENT CURVES

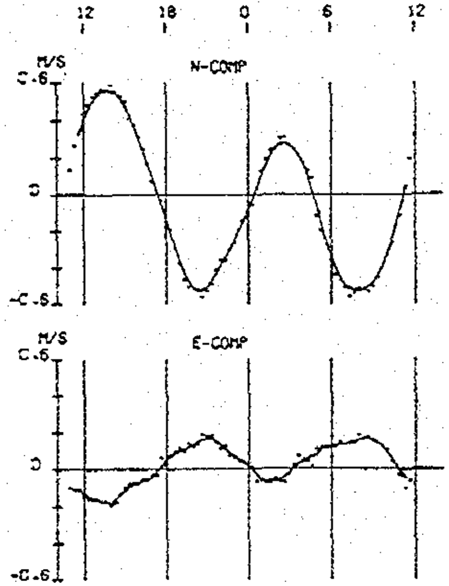


THE TIDAL CURRENT CURVES

15/AUG./1977 ST.A 8.0M



28/AUG./1977 ST.D 5.0M



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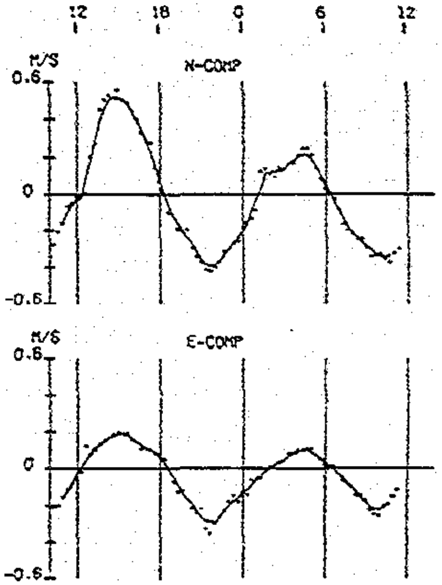
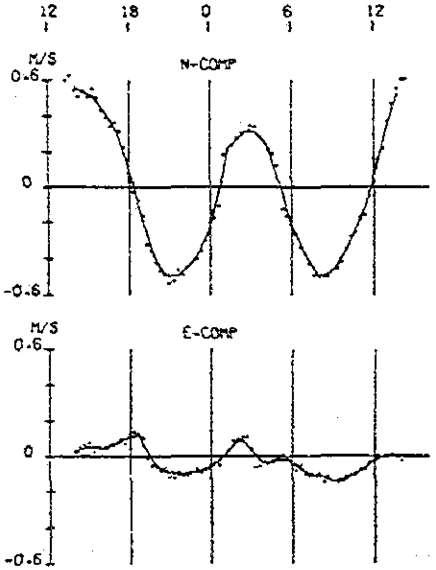


29/AUG./1977 ST.C 10.0M



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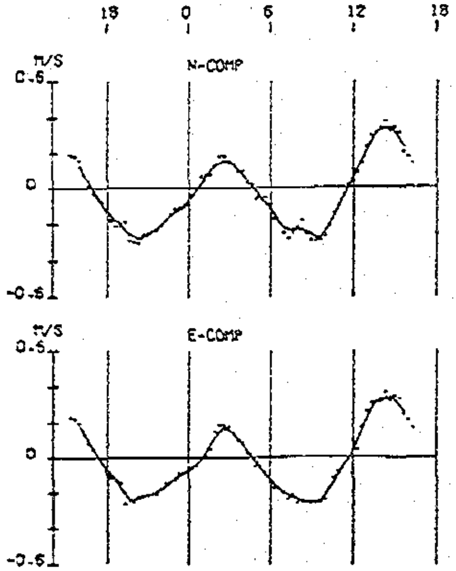
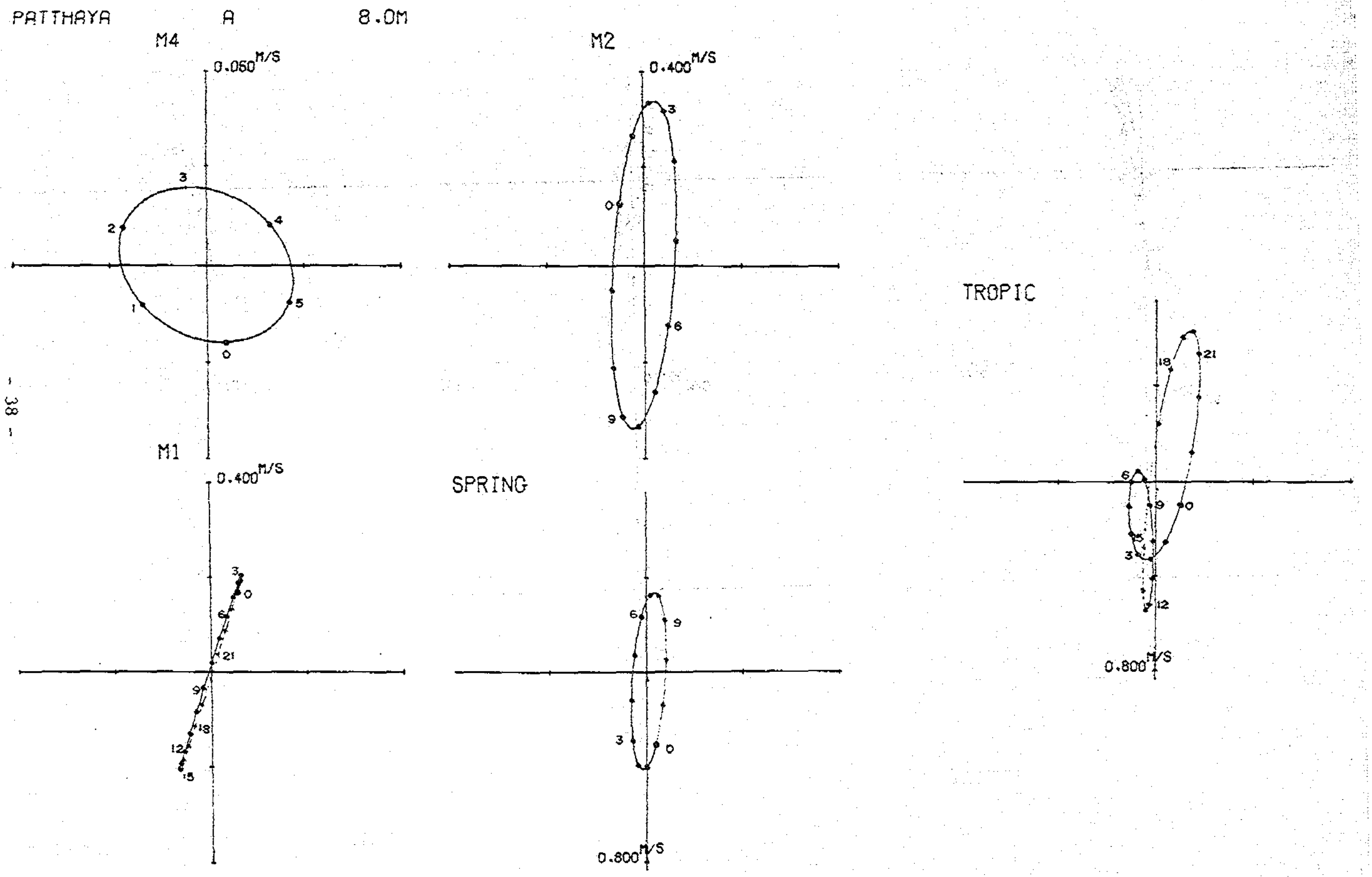
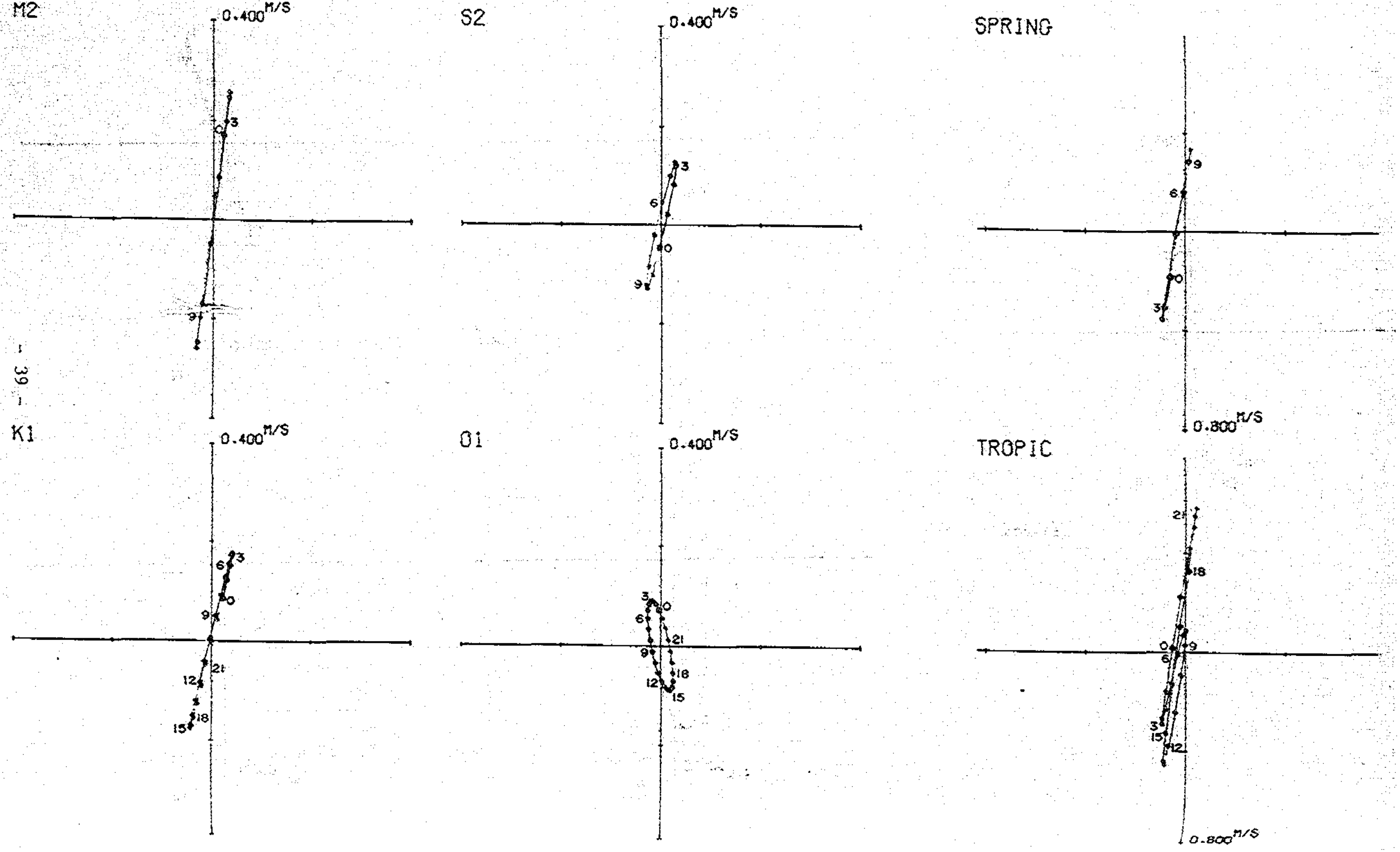


2-3-2 Current ellipse


PATTHAYA
A
8.0M
M4
0.060 M/S
M2
0.400 M/S
M1
0.400 M/S
SPRING
0.800 M/S
TROPIC
0.800 M/S
0
1
2
3
4
5
6
9
12
15
18
21

PATTHAYA B 10.0M



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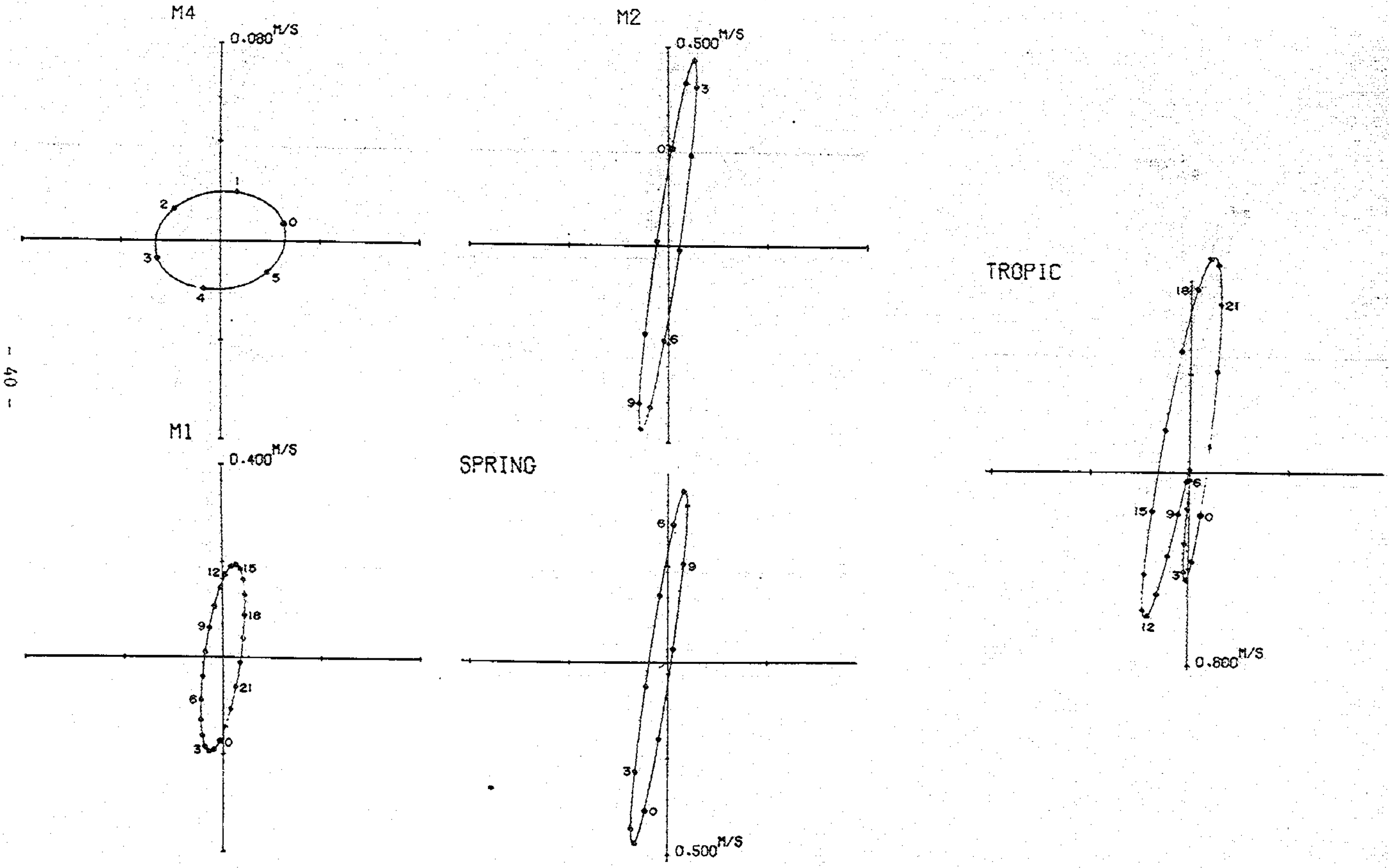
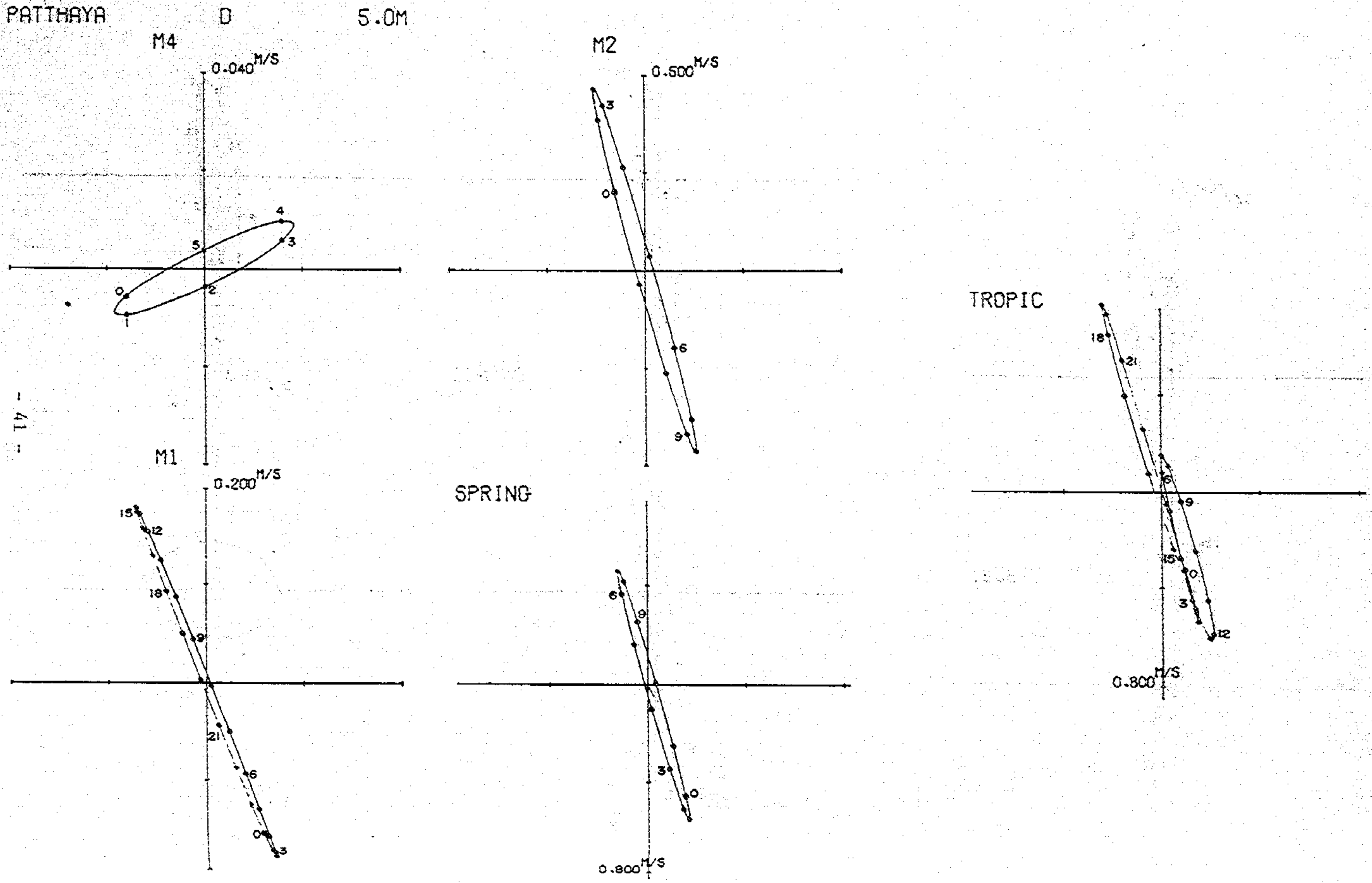
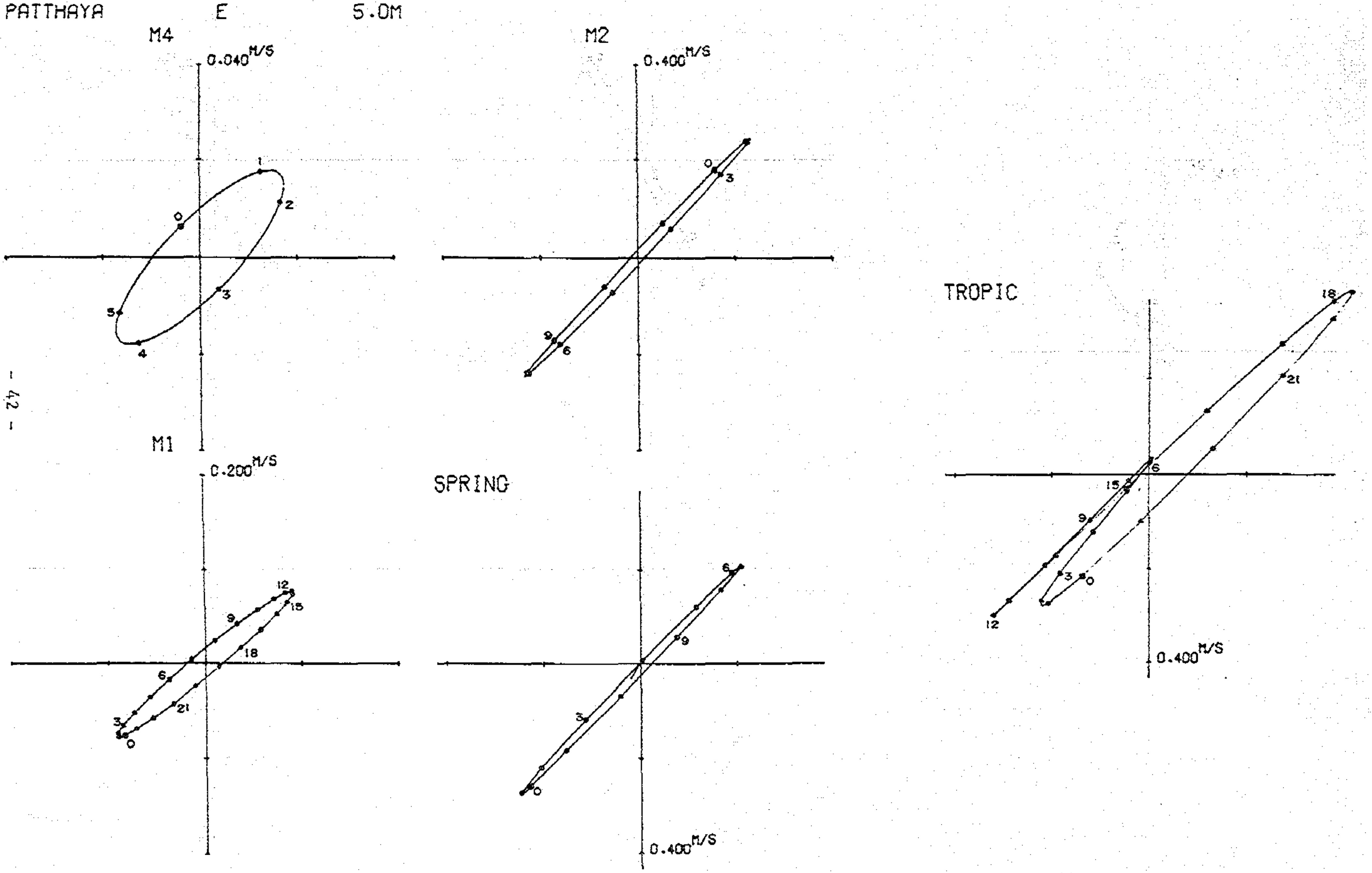



PATTHAYA
D
5.0M
M4
0.040 M/S
0
1
2
3
4
5
M2
0.500 M/S
0
3
6
9
M1
0.200 M/S
0
3
6
9
12
15
18
21
SPRING
0.800 M/S
0
3
6
9
TROPIC
0.800 M/S
0
3
6
9
12
15
18
21


PATTHAYA
E
5.0M
M4
0.040 M/S
0
1
2
3
4
5
M2
0.400 M/S
0
3
6
9
TROPIC
0
3
6
9
12
15
18
21
0.400 M/S
M1
0.200 M/S
0
3
6
9
12
15
18
21
SPRING
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3
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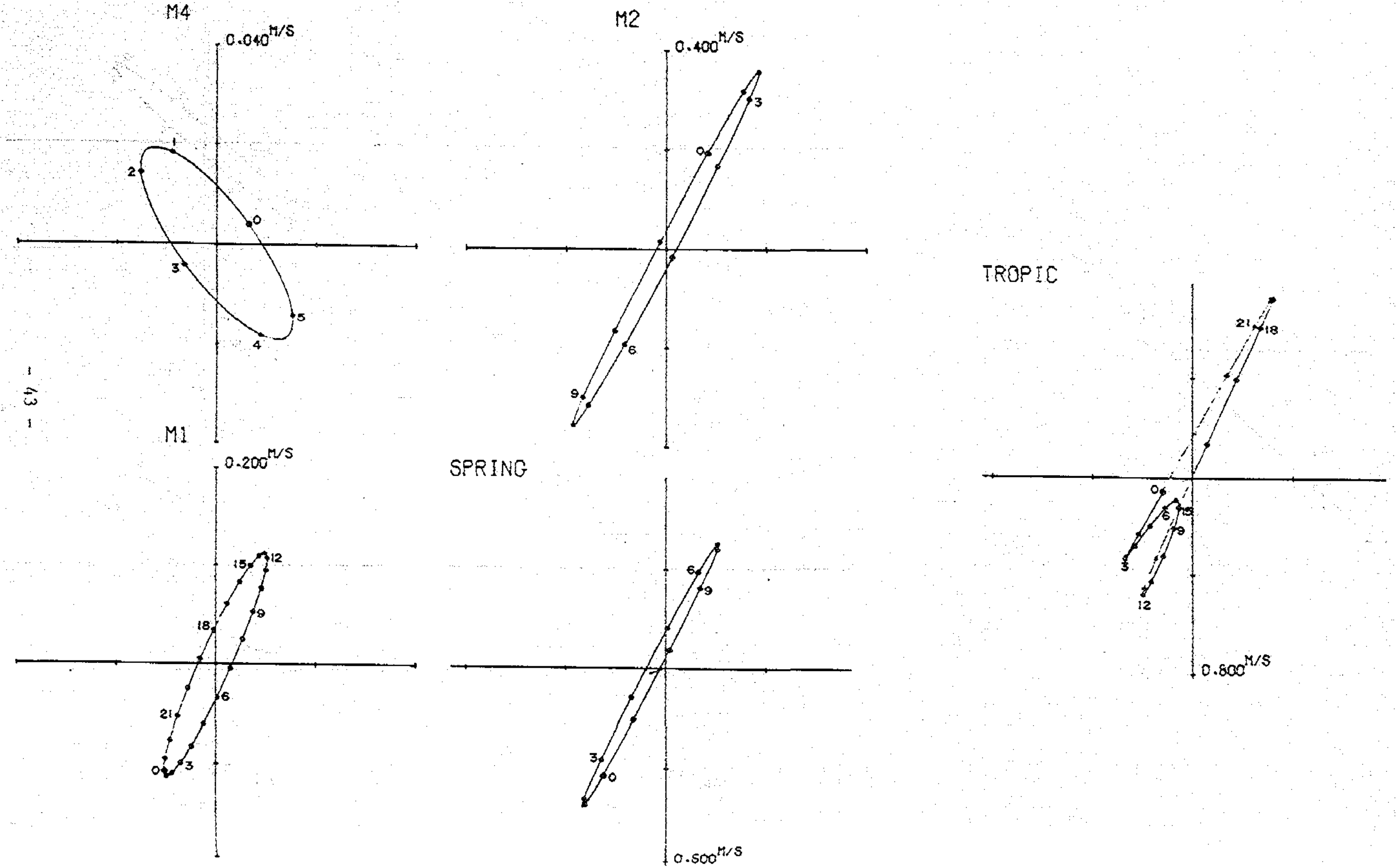
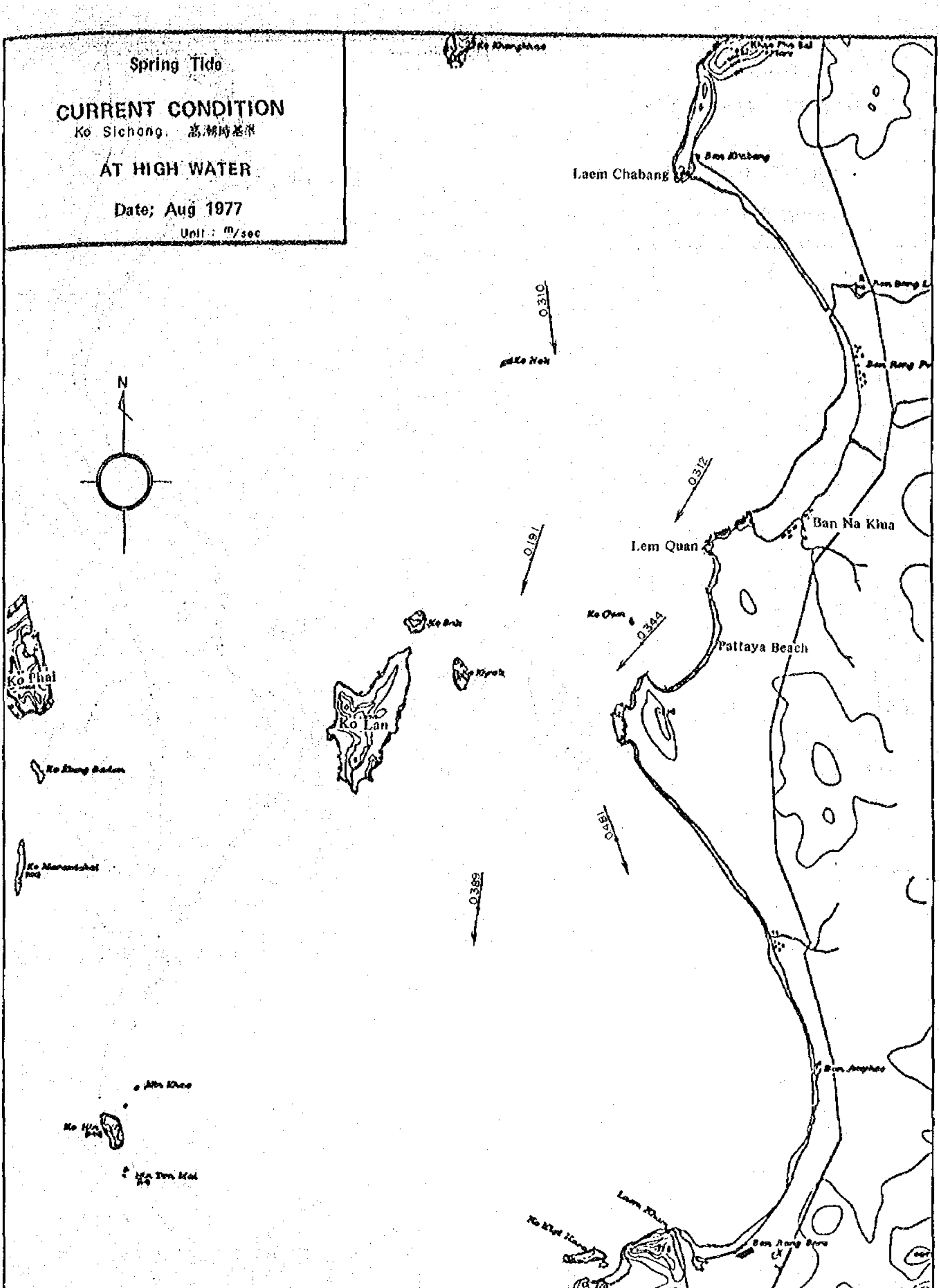
9
0.400 M/S

PATTHAYA F 4.0M



2-3-3 Current diagram at spring tide



Spring Tide

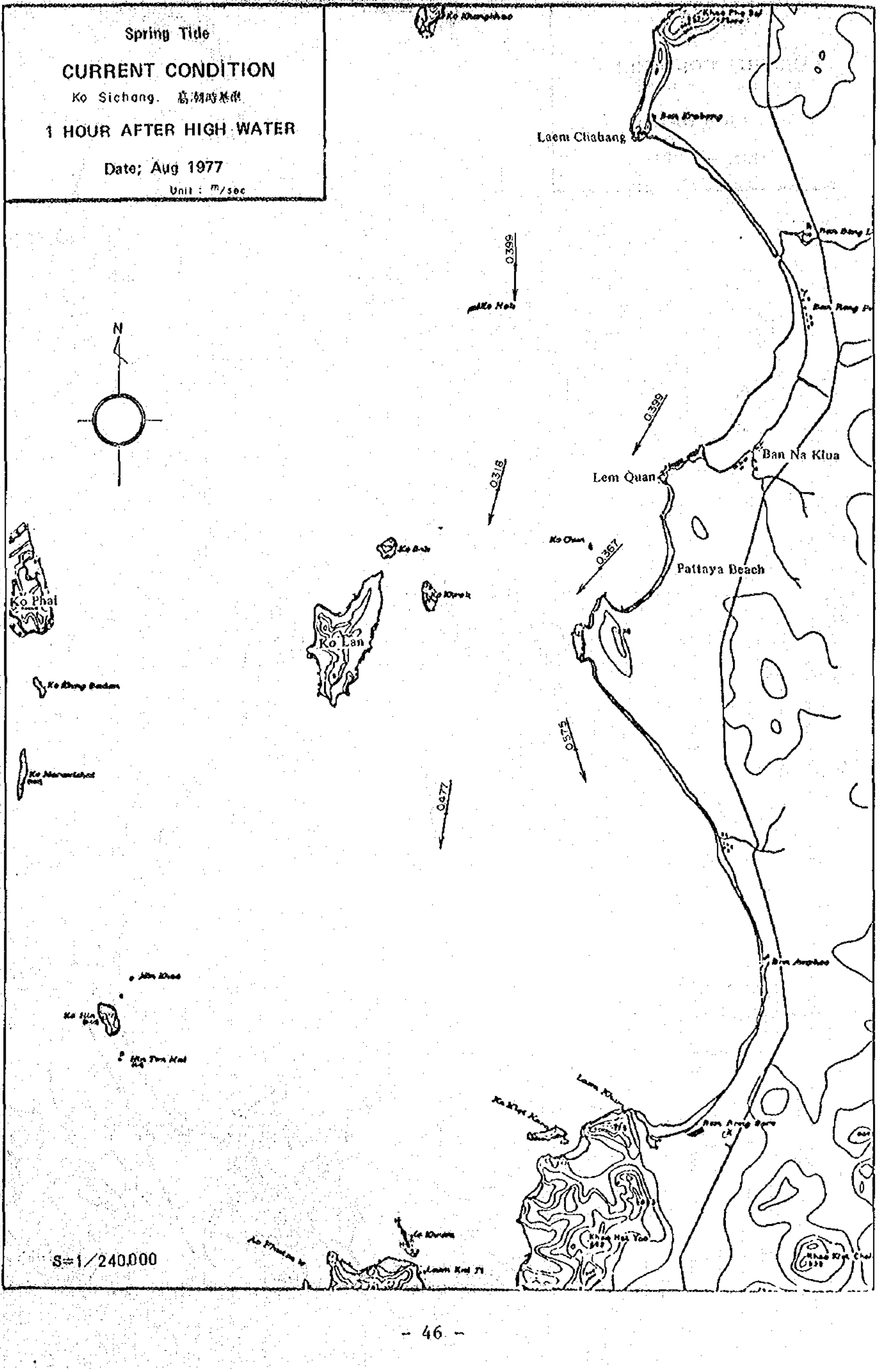
CURRENT CONDITION

Ko Sichong. 高潮時基準

AT HIGH WATER

Date; Aug 1977

Unit : m/sec



Spring Tide

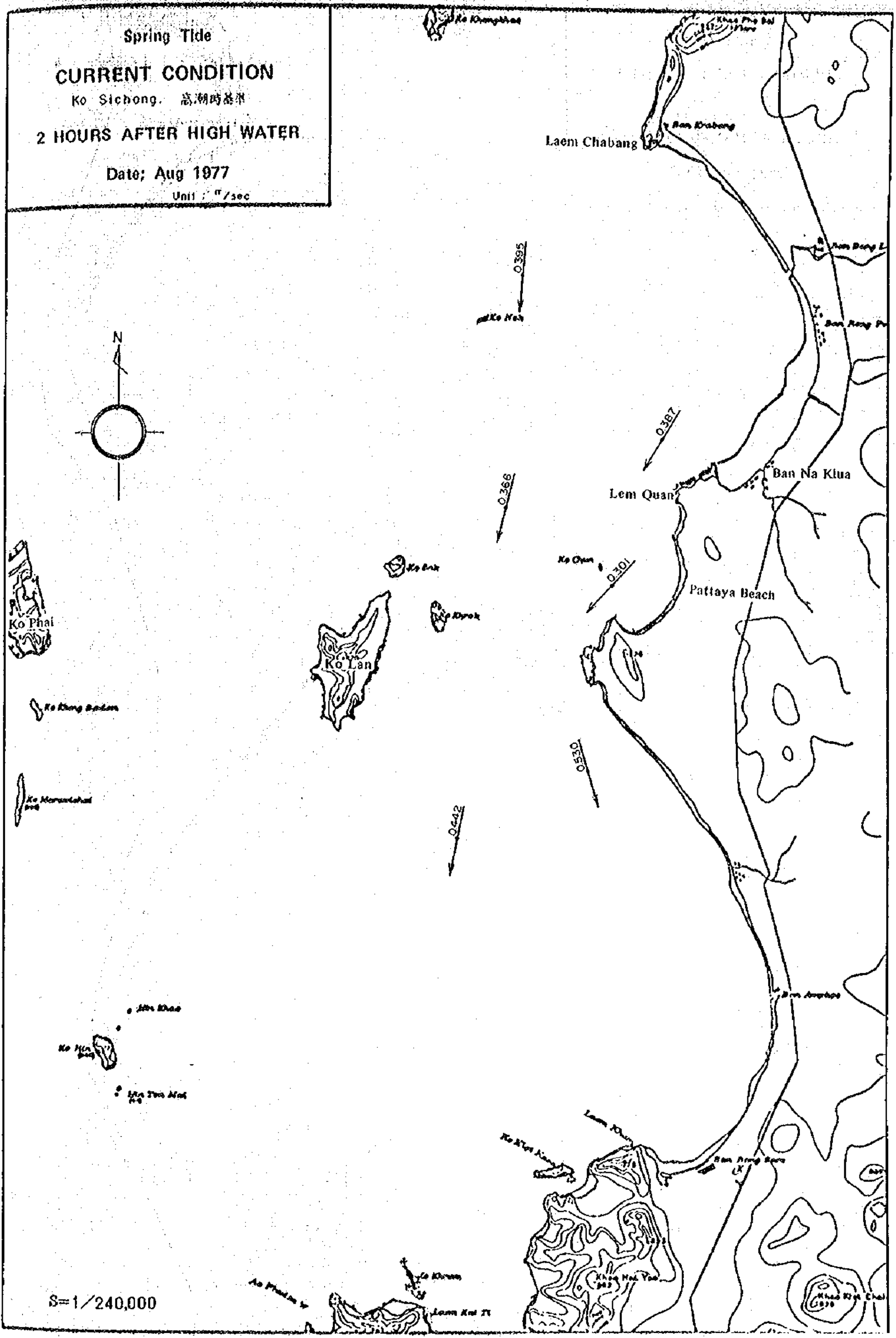
CURRENT CONDITION

Ko Sichang. 高潮時基準

1 HOUR AFTER HIGH WATER

Date; Aug 1977

Unit : m/sec



Spring Tide

CURRENT CONDITION

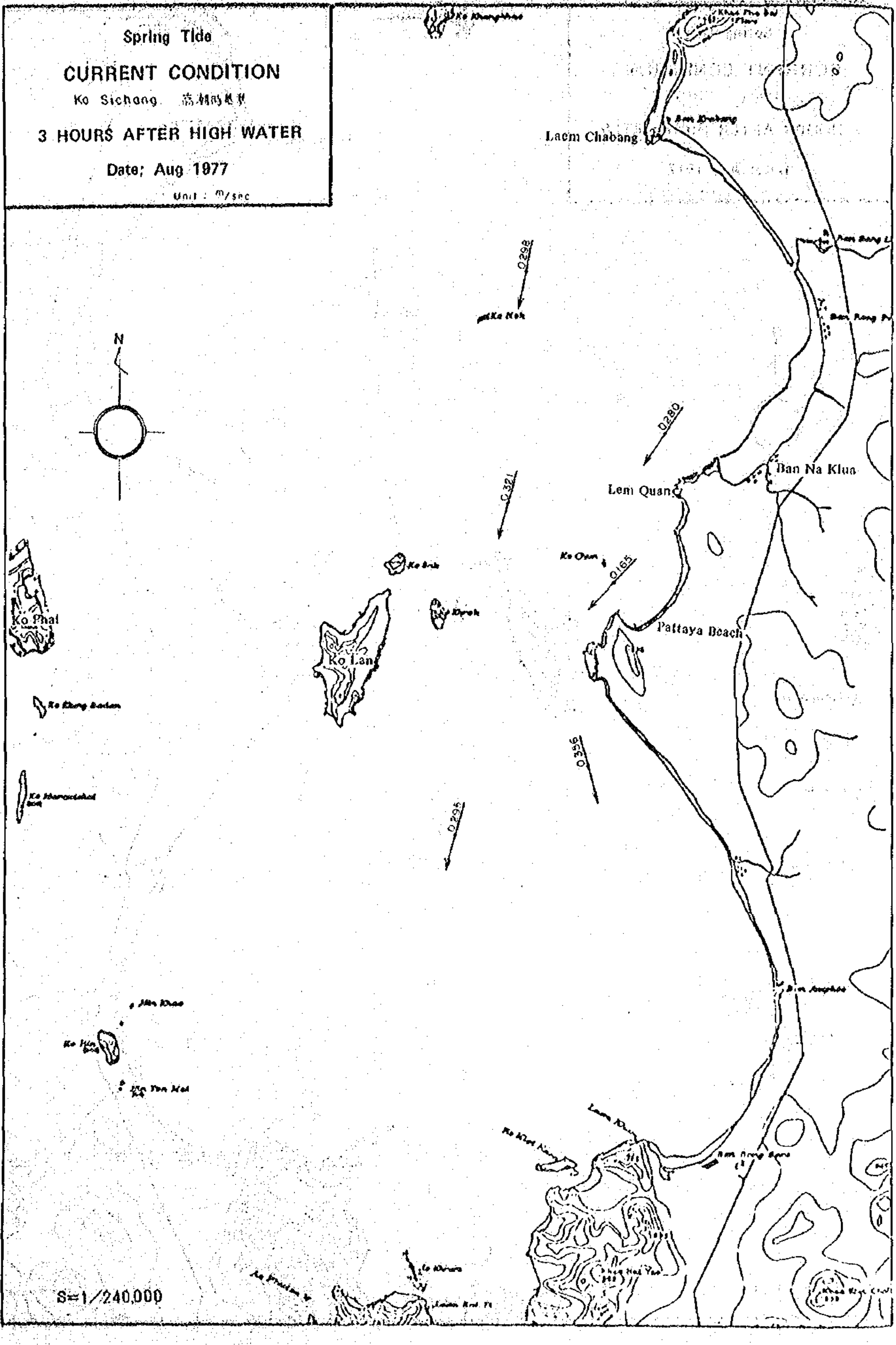
Ko Sichong. 高潮時基準

2 HOURS AFTER HIGH WATER

Date; Aug 1977

Unit : m/sec

S=1/240,000



Spring Tide

CURRENT CONDITION

Ko Sichang 高潮時基準

3 HOURS AFTER HIGH WATER

Date; Aug 1977

Unit : m/sec

Spring Tide

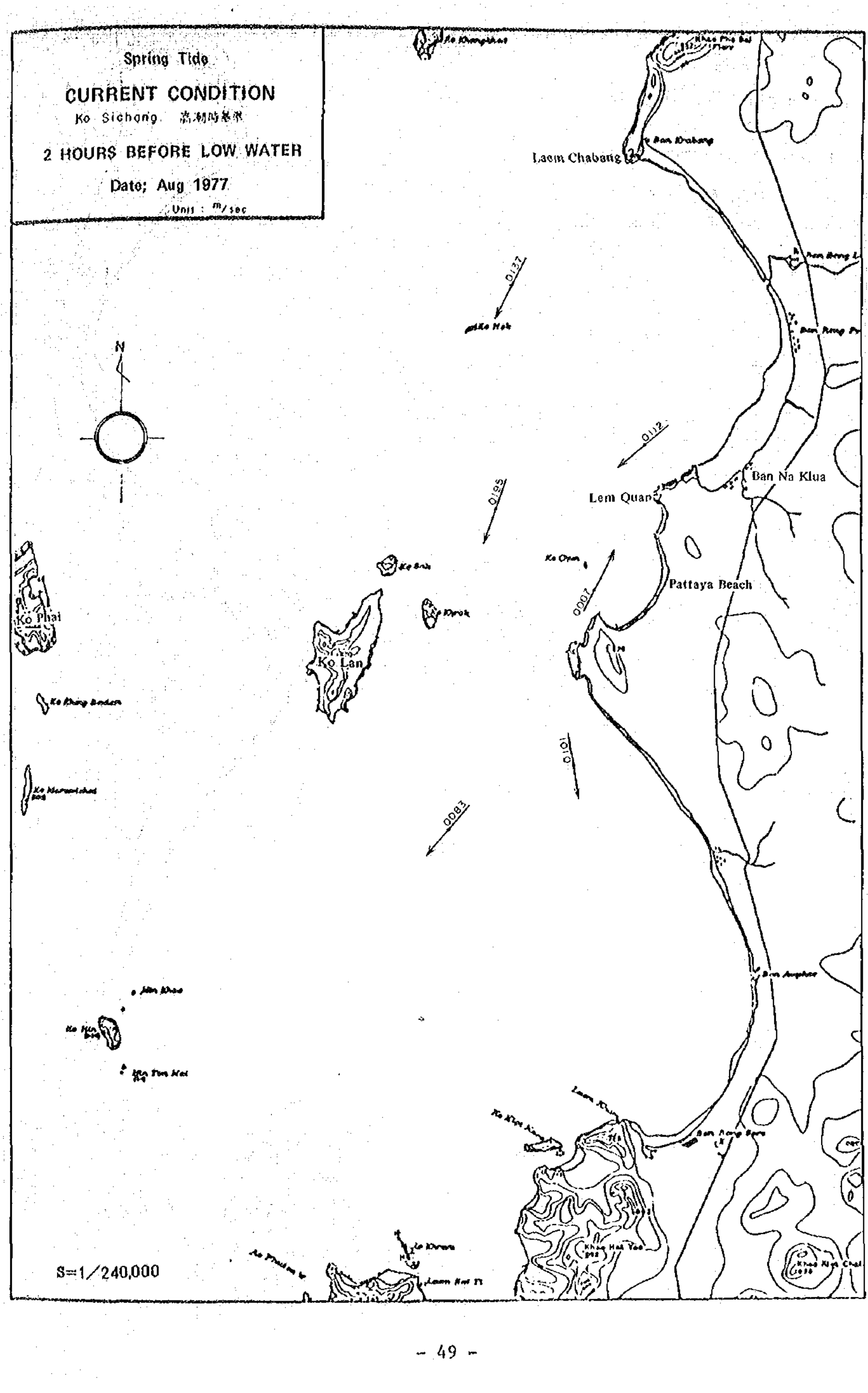
CURRENT CONDITION

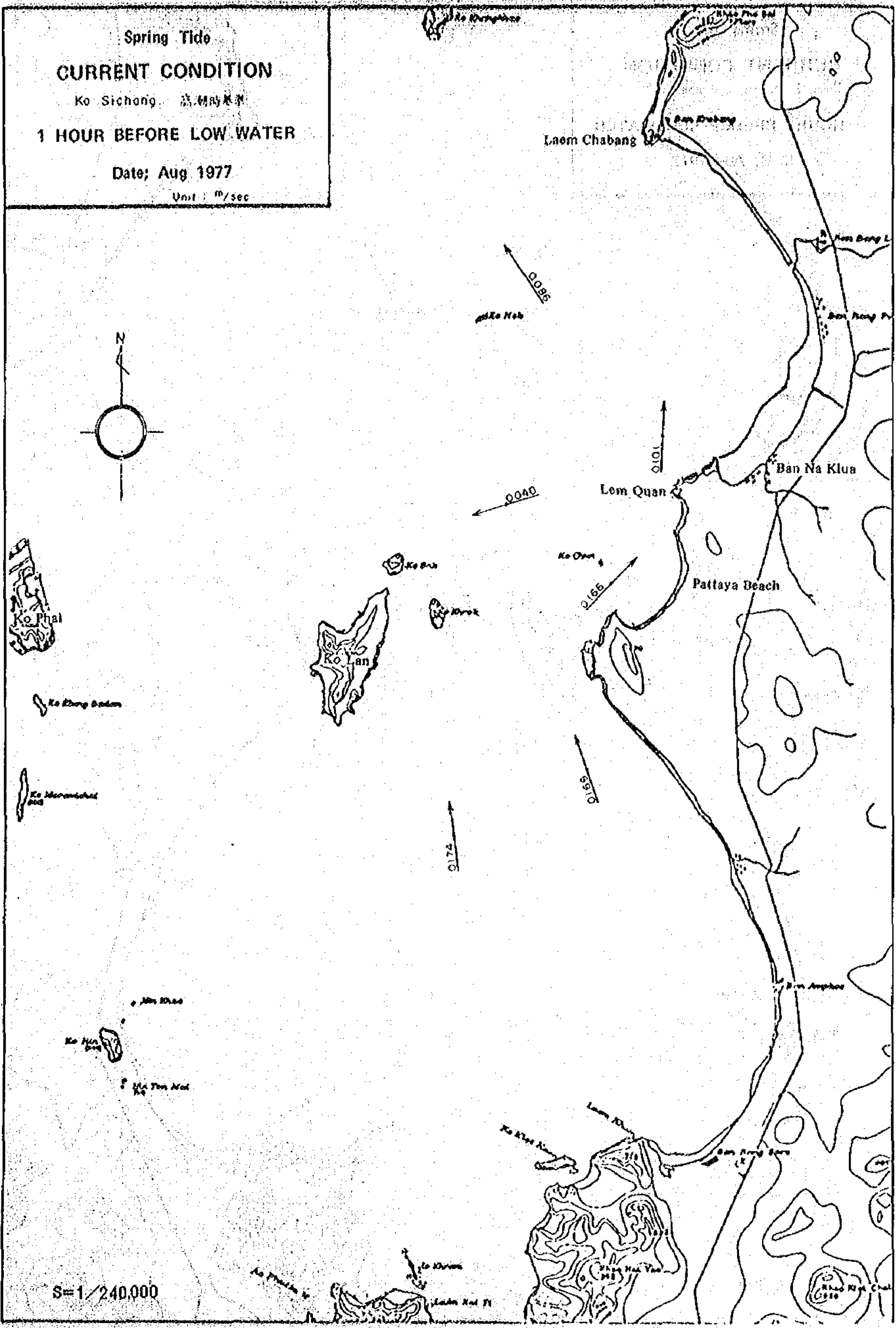
Ko Sichang 高潮時基準

2 HOURS BEFORE LOW WATER

Date; Aug 1977

Unit : m/sec





Spring Tide

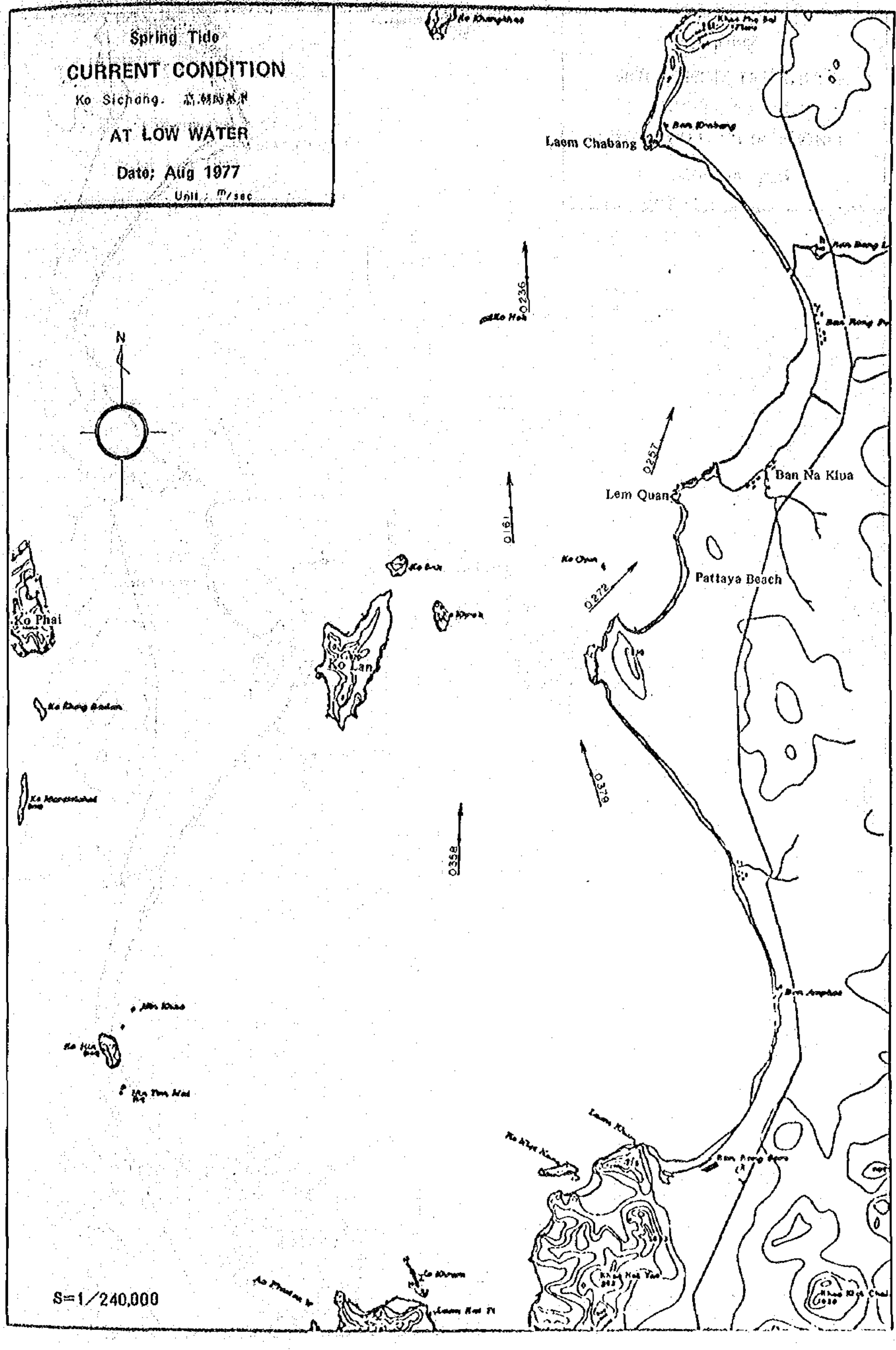
CURRENT CONDITION

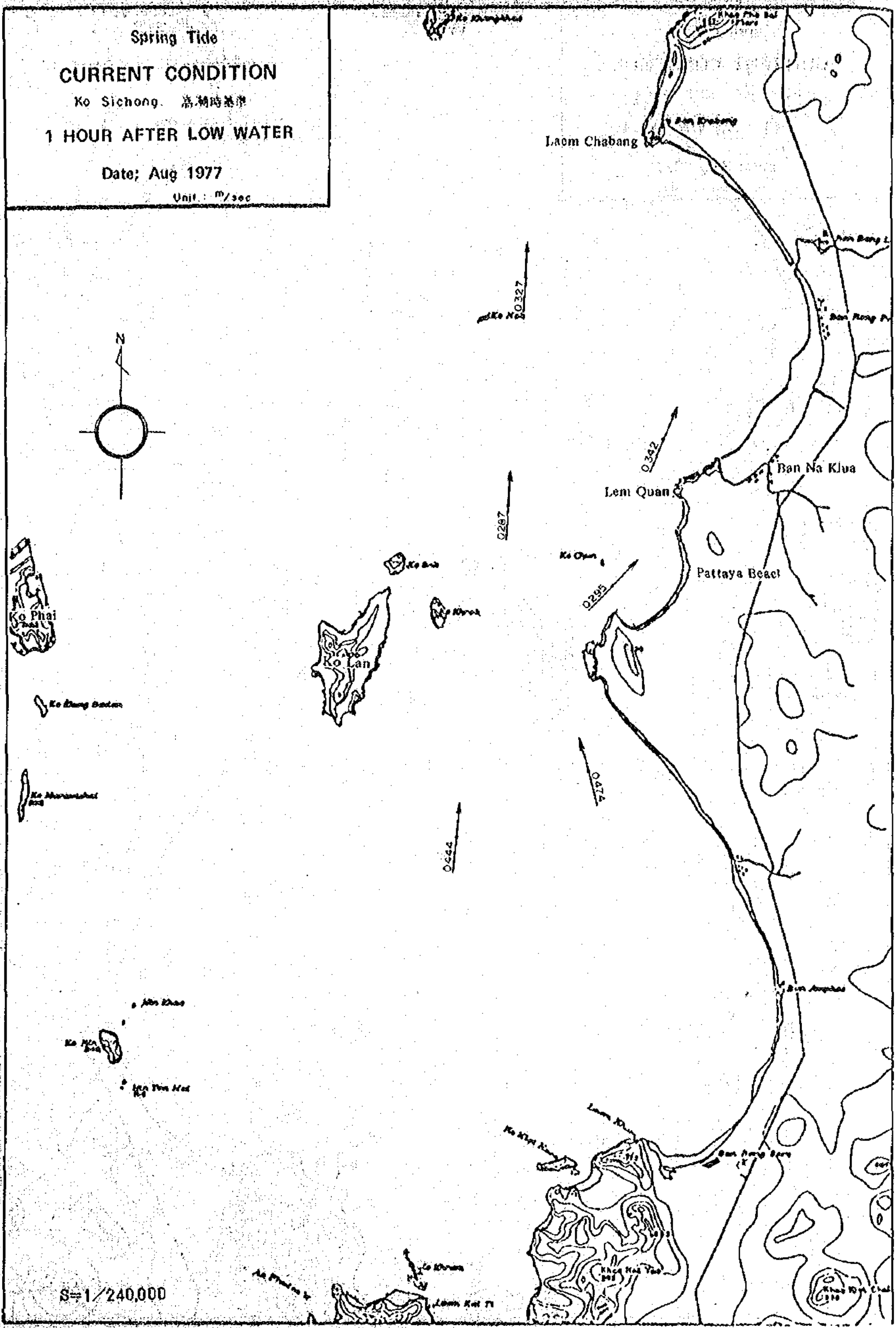
Ko Sichong 高潮時基準

1 HOUR BEFORE LOW WATER

Date; Aug 1977

Unit : m/sec


Spring Tide
CURRENT CONDITION
Ko Sichang. [illegible]
AT LOW WATER
Date; Aug 1977
Unit : m/sec



Spring Tide

CURRENT CONDITION

Ko Sichong. 高潮時基準

1 HOUR AFTER LOW WATER

Date; Aug 1977

Unit.: m/sec

Spring Tide

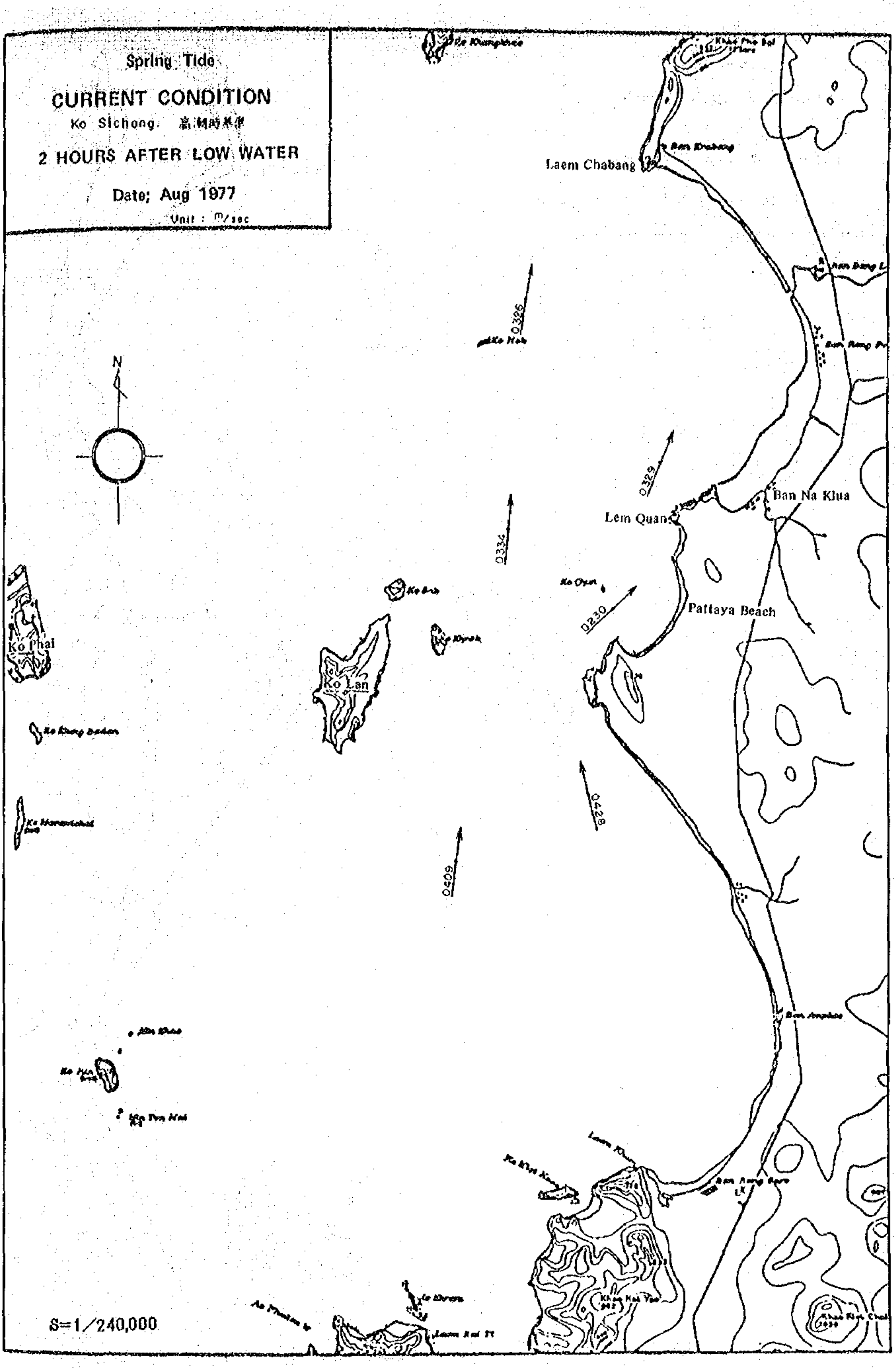
CURRENT CONDITION

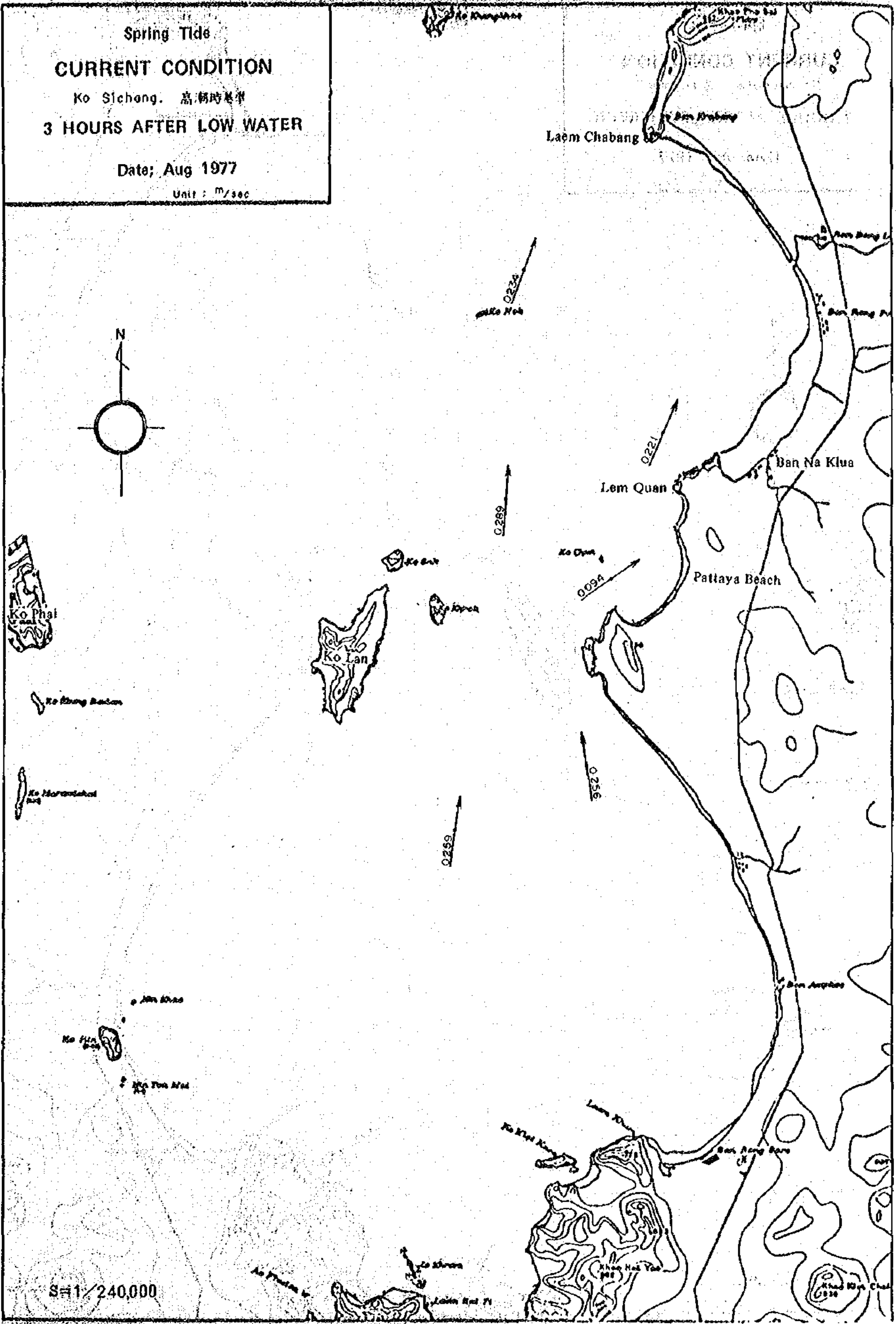
Ko Sichong. 高潮時基準

2 HOURS AFTER LOW WATER

Date; Aug 1977

Unit : m/sec





Spring Tide

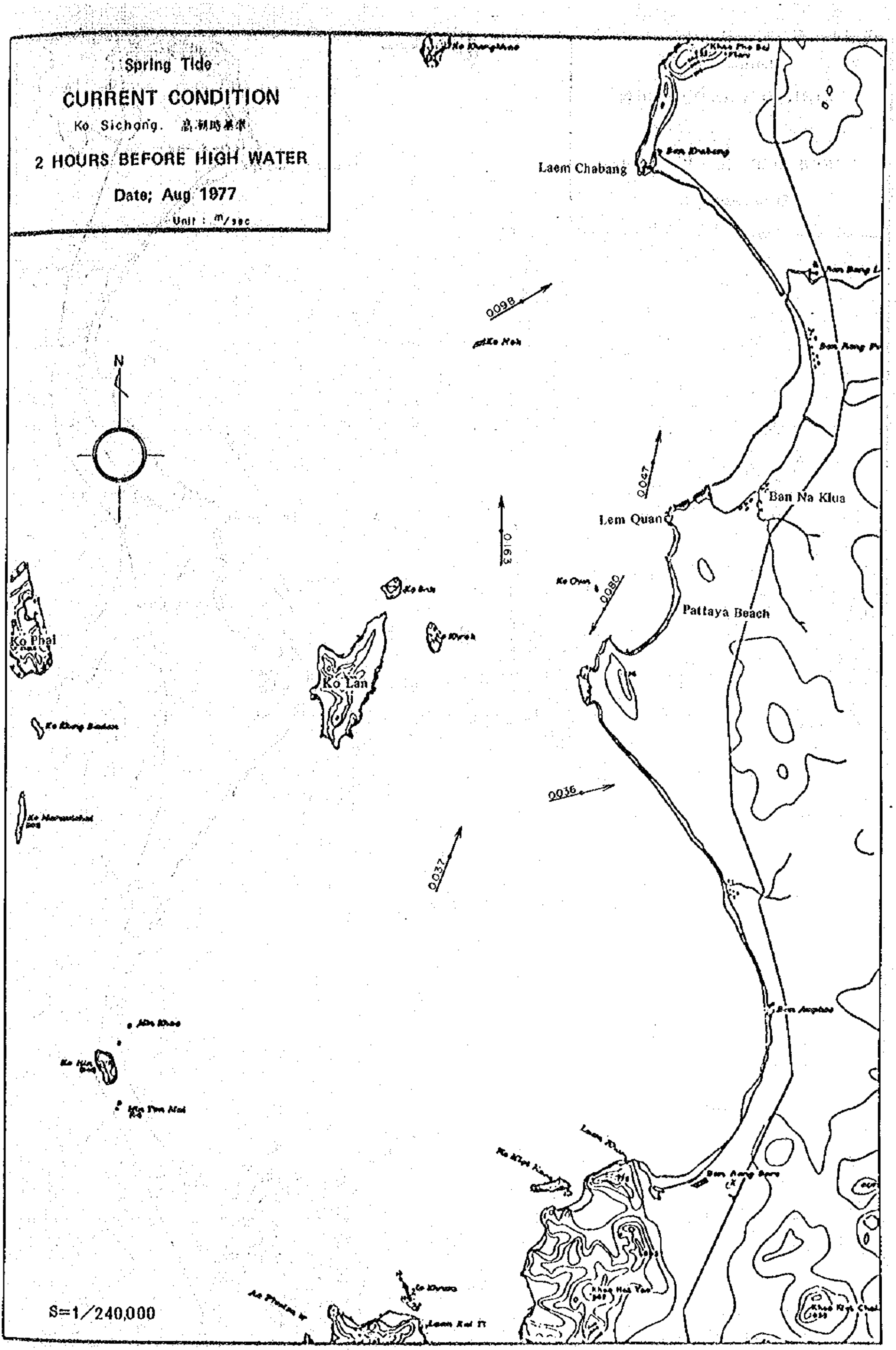
CURRENT CONDITION

Ko Sichong. 高潮時基準

3 HOURS AFTER LOW WATER

Date; Aug 1977

Unit : m/sec



Spring Tide

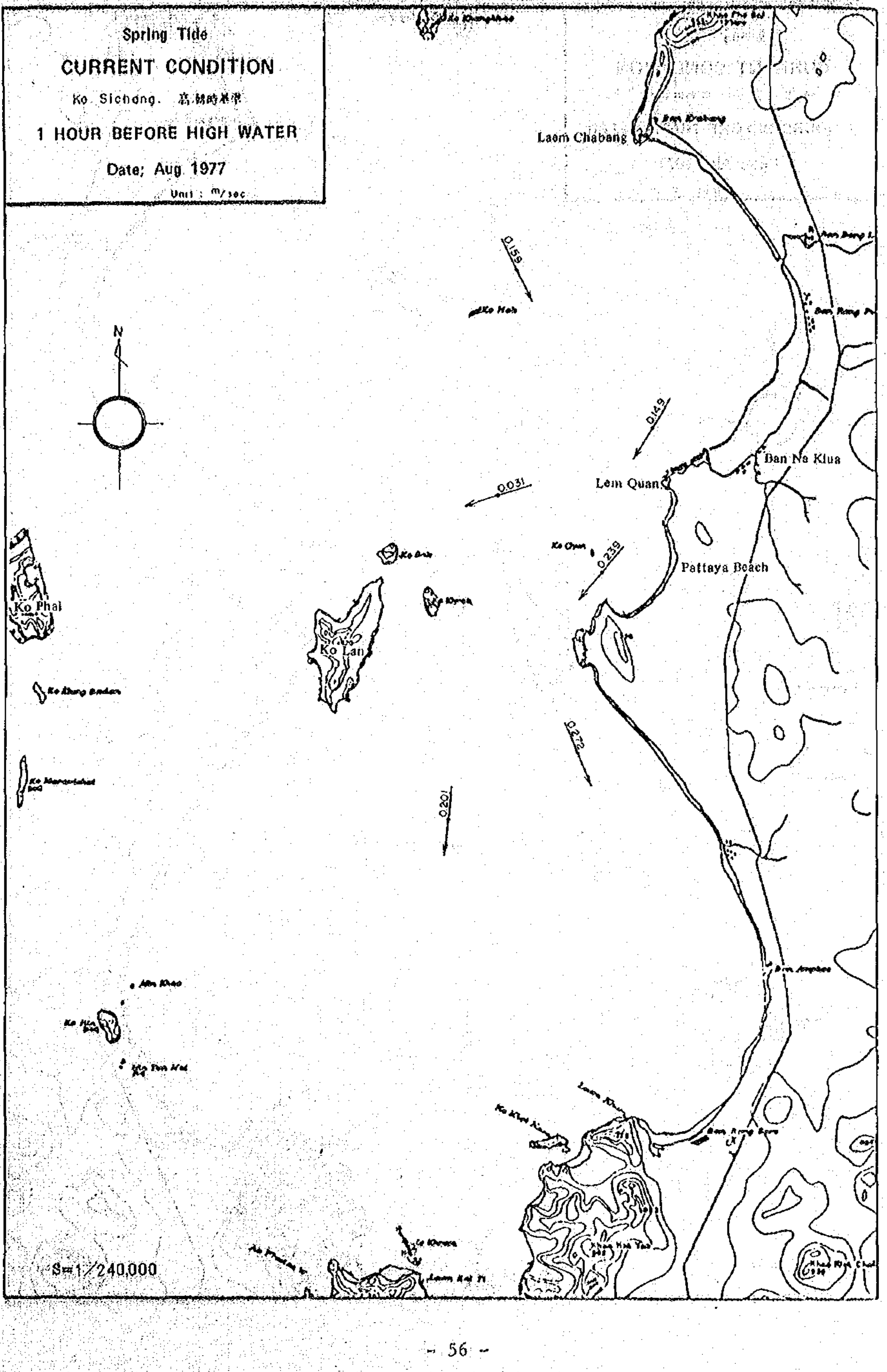
CURRENT CONDITION

Ko Sichong. 高潮時基準

2 HOURS BEFORE HIGH WATER

Date; Aug 1977

Unit : m/sec



Spring Tide

CURRENT CONDITION

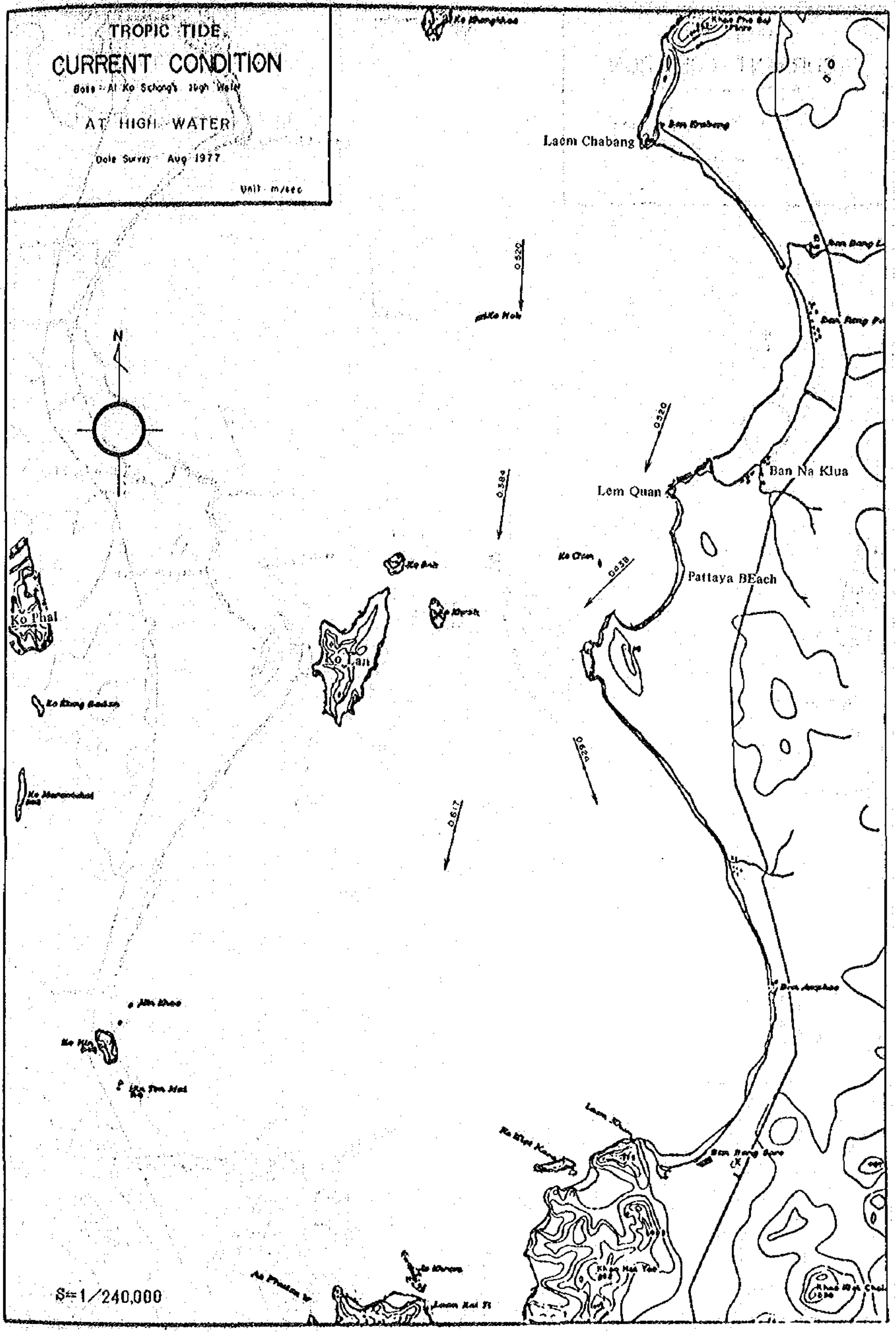
Ko Sichong. 高潮時基準

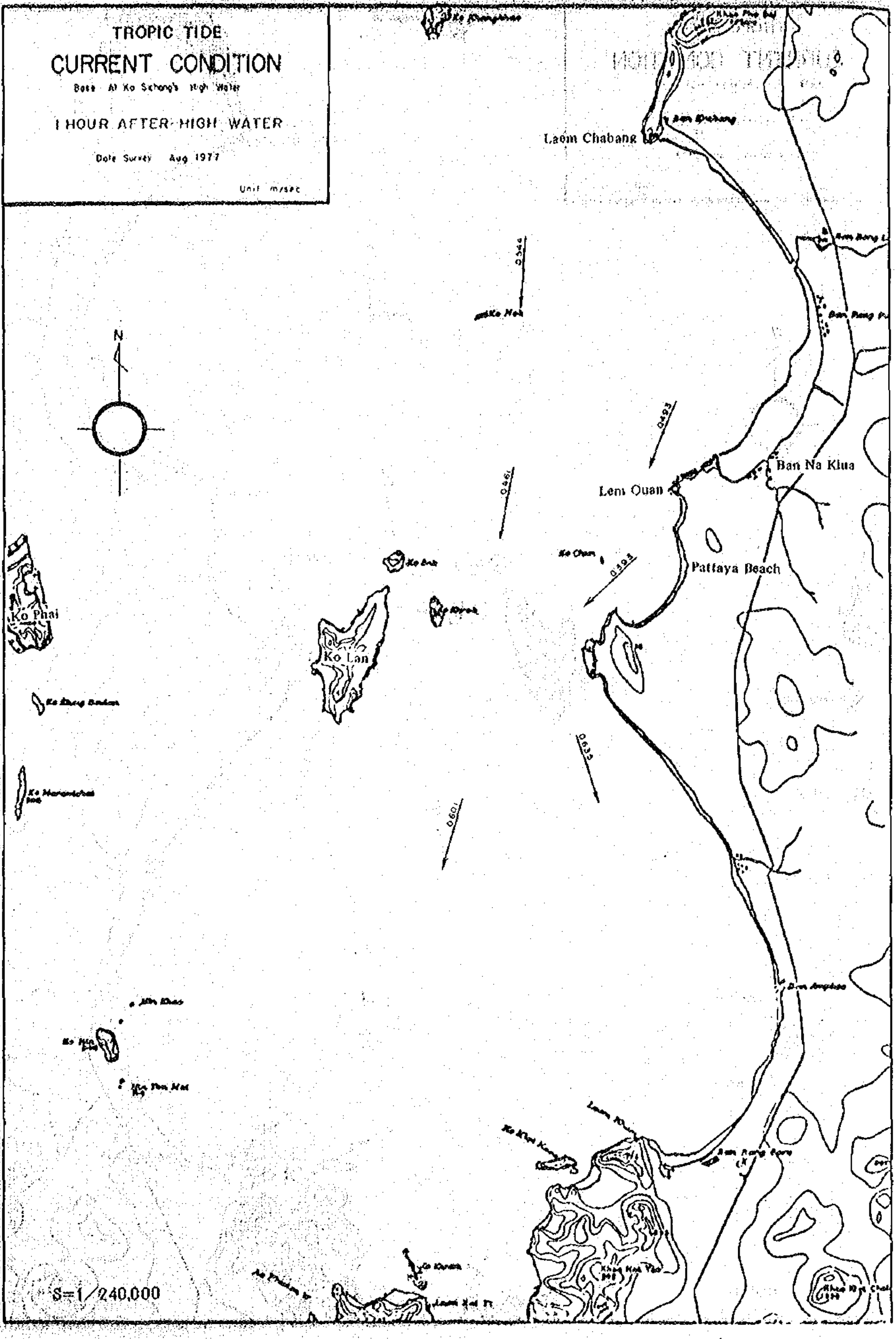
1 HOUR BEFORE HIGH WATER

Date; Aug 1977

Unit : m/sec

2-3-4 Current diagram at tropic tide


TROPIC TIDE
CURRENT CONDITION
Date : At Ko Sichang's High Water
AT HIGH WATER
Date Survey : Aug 1977
Unit : m/sec
N
Laem Chabang
Ban Krabang
Ko Khangkhao
Ko Nok
0.520
0.320
Lem Quan
Ban Na Klua
0.384
Ko Sak
Ko Lan
Ko Krok
Ko Rin
0.438
Pattaya BEach
Ko Phai
0.624
0.617
S=1/240,000



TROPIC TIDE

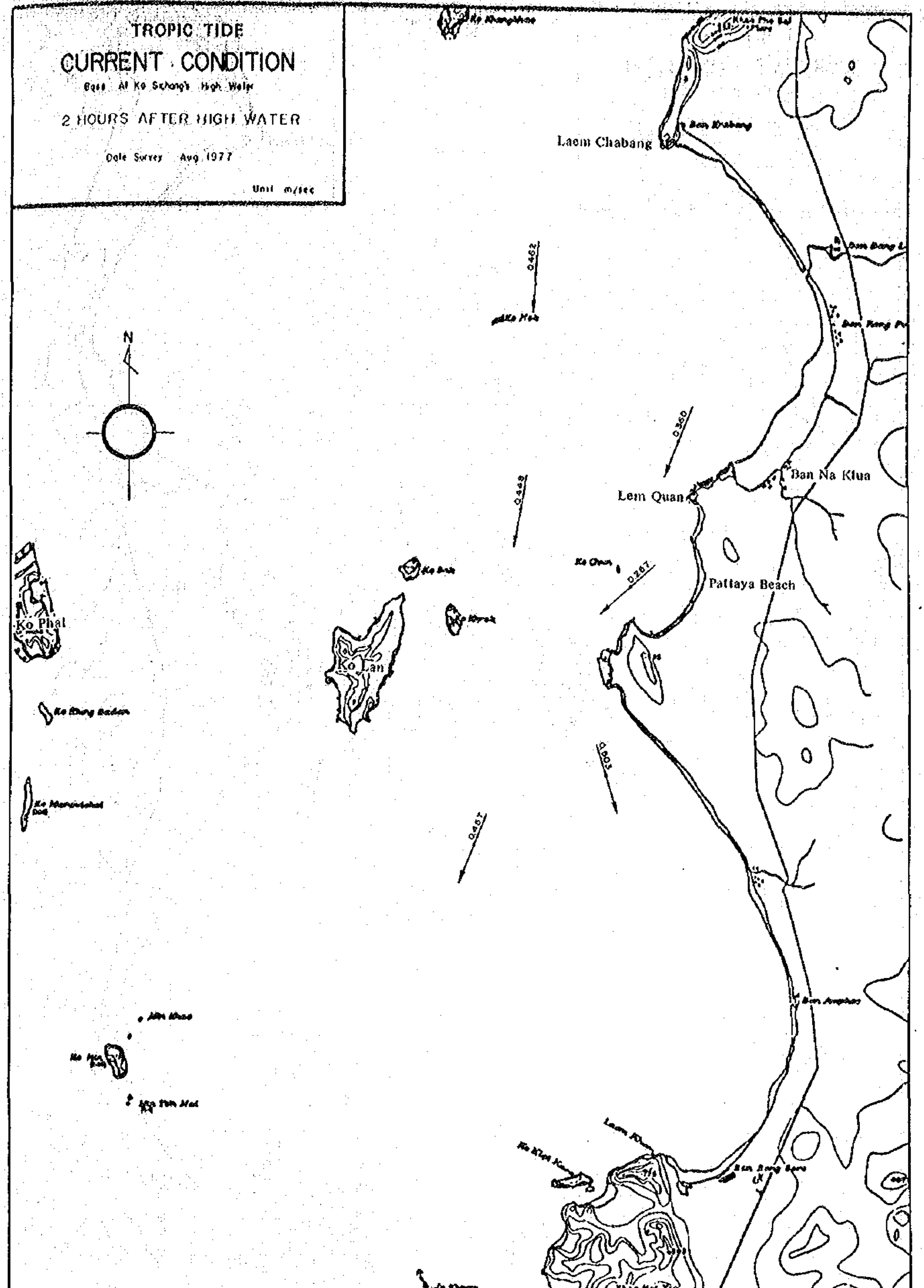
CURRENT CONDITION

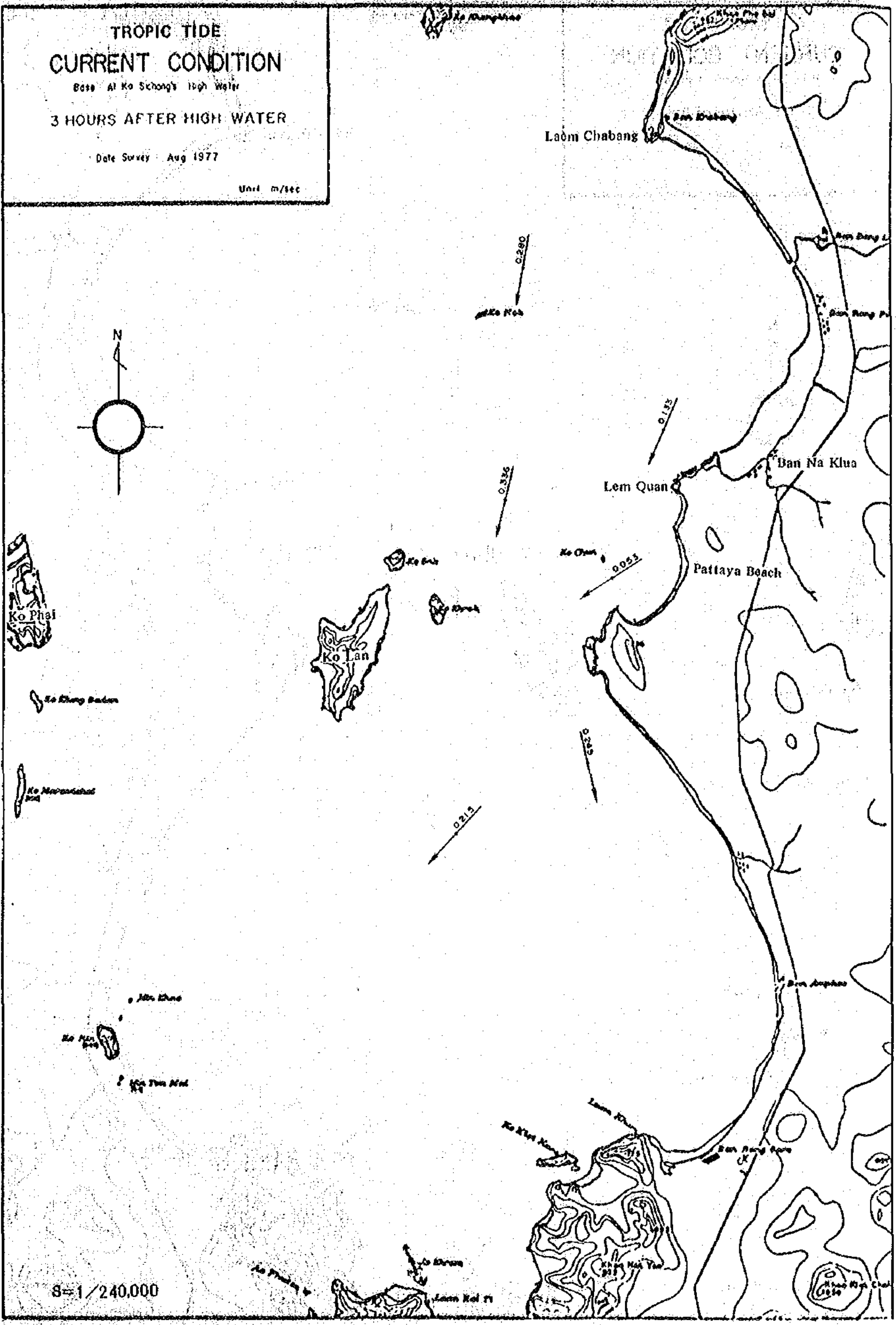
Base At Ko Sichang's High Water

1 HOUR AFTER HIGH WATER

Date Survey Aug 1977

Unit m/sec


TROPIC TIDE
CURRENT CONDITION
Base At Ko Sichang's High Water
2 HOURS AFTER HIGH WATER
Dale Survey Aug 1977
Unit m/sec
N
Laem Chabang
0.462
0.360
Lem Quan
Ban Na Klua
0.448
0.267
Pattaya Beach
Ko Phai
Ko Lan
0.503
0.457
S=1/240,000

TROPIC TIDE
CURRENT CONDITION
Base At Ko Sichang's High Water
3 HOURS AFTER HIGH WATER
Date Survey Aug 1977
Unit m/sec
N
Laem Chabang
Lem Quan
Ban Na Klua
Pattaya Beach
Ko Phai
Ko Lan
Ko Nok
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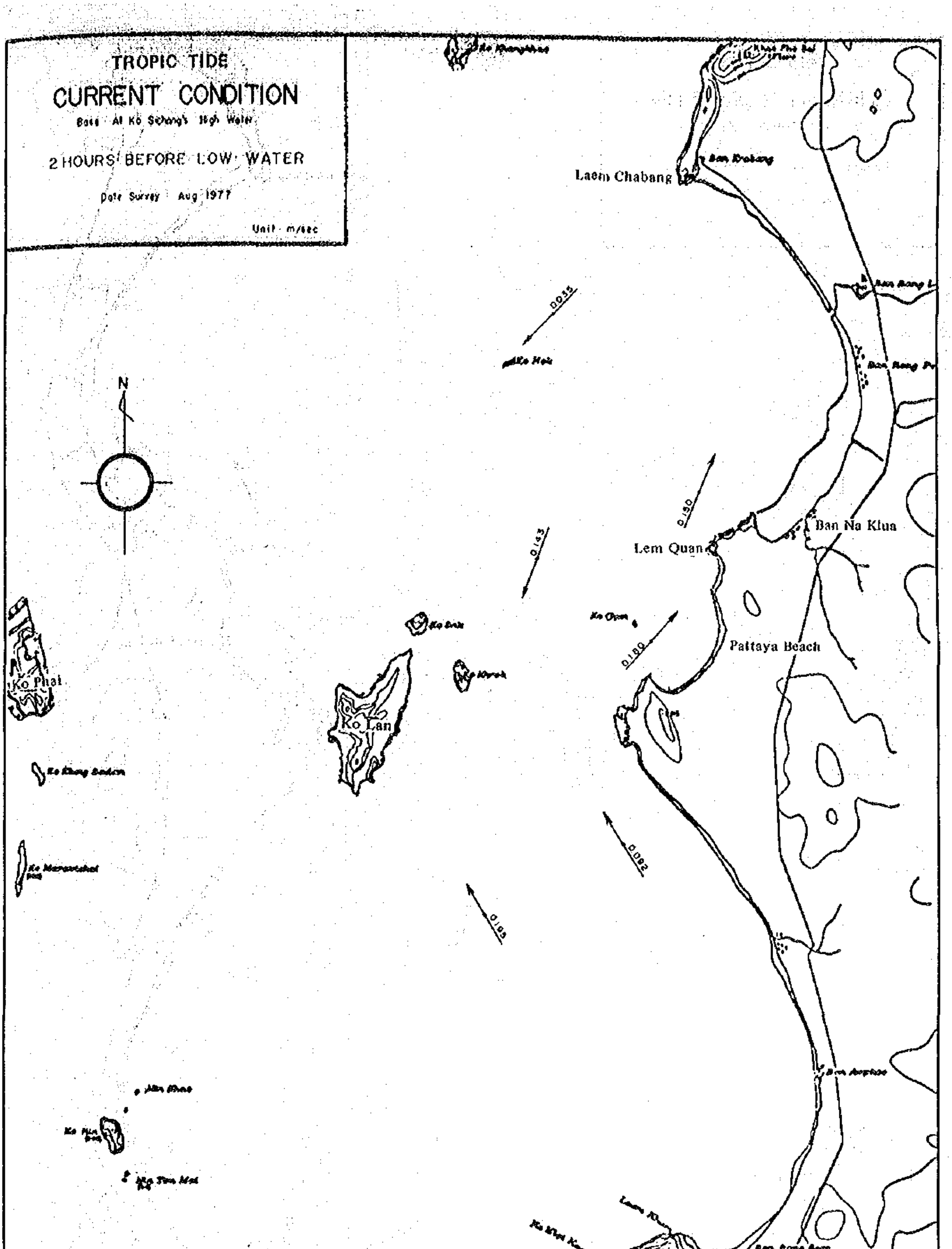
0.133
0.336
0.053
0.245
0.215
S=1/240,000


TROPIC TIDE

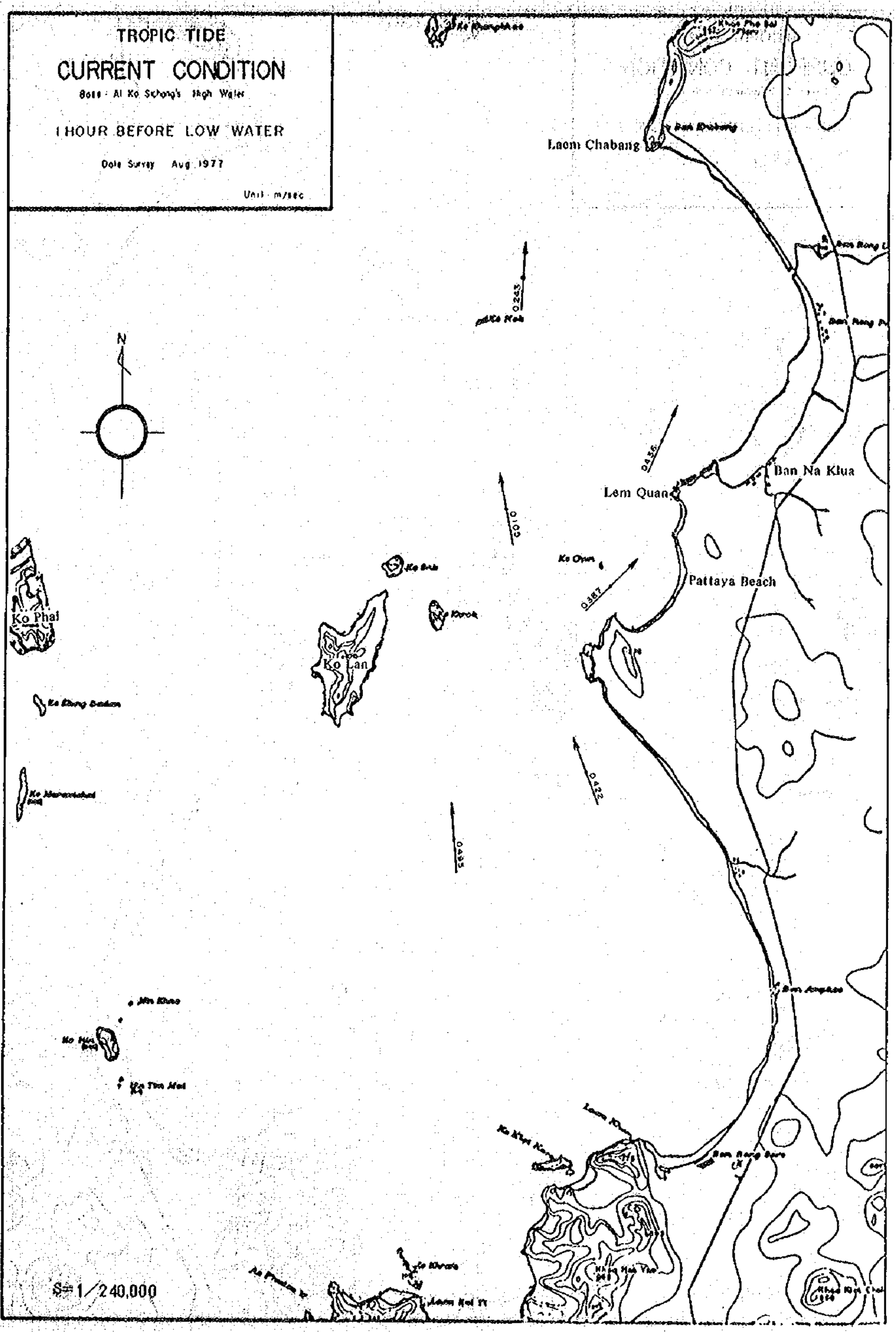
CURRENT CONDITION

Base At Ko Sichang's High Water

2 HOURS BEFORE LOW WATER

Date Survey Aug 1977

Unit m/sec



TROPIC TIDE

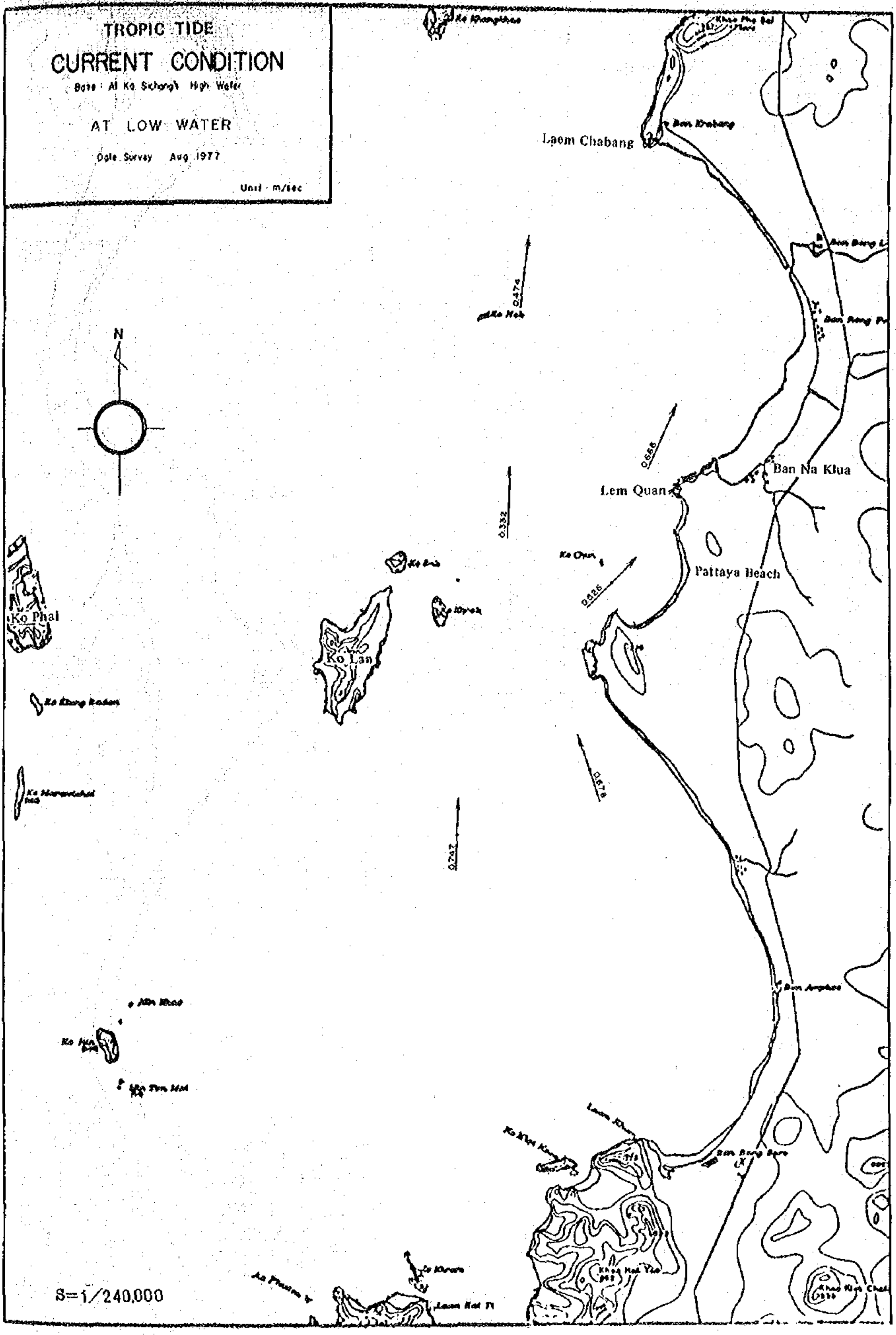
CURRENT CONDITION

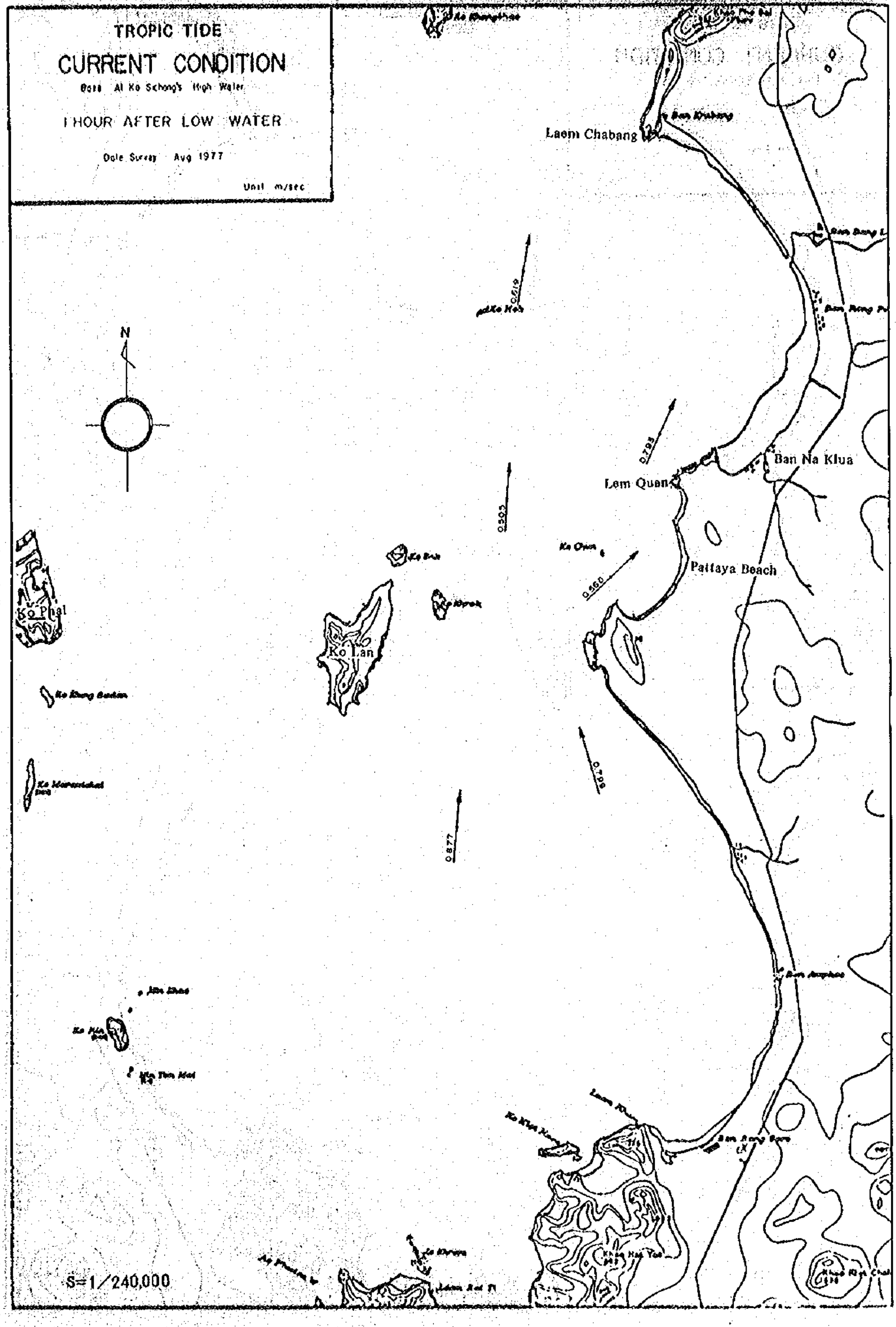
Base : At Ko Sichang's High Water

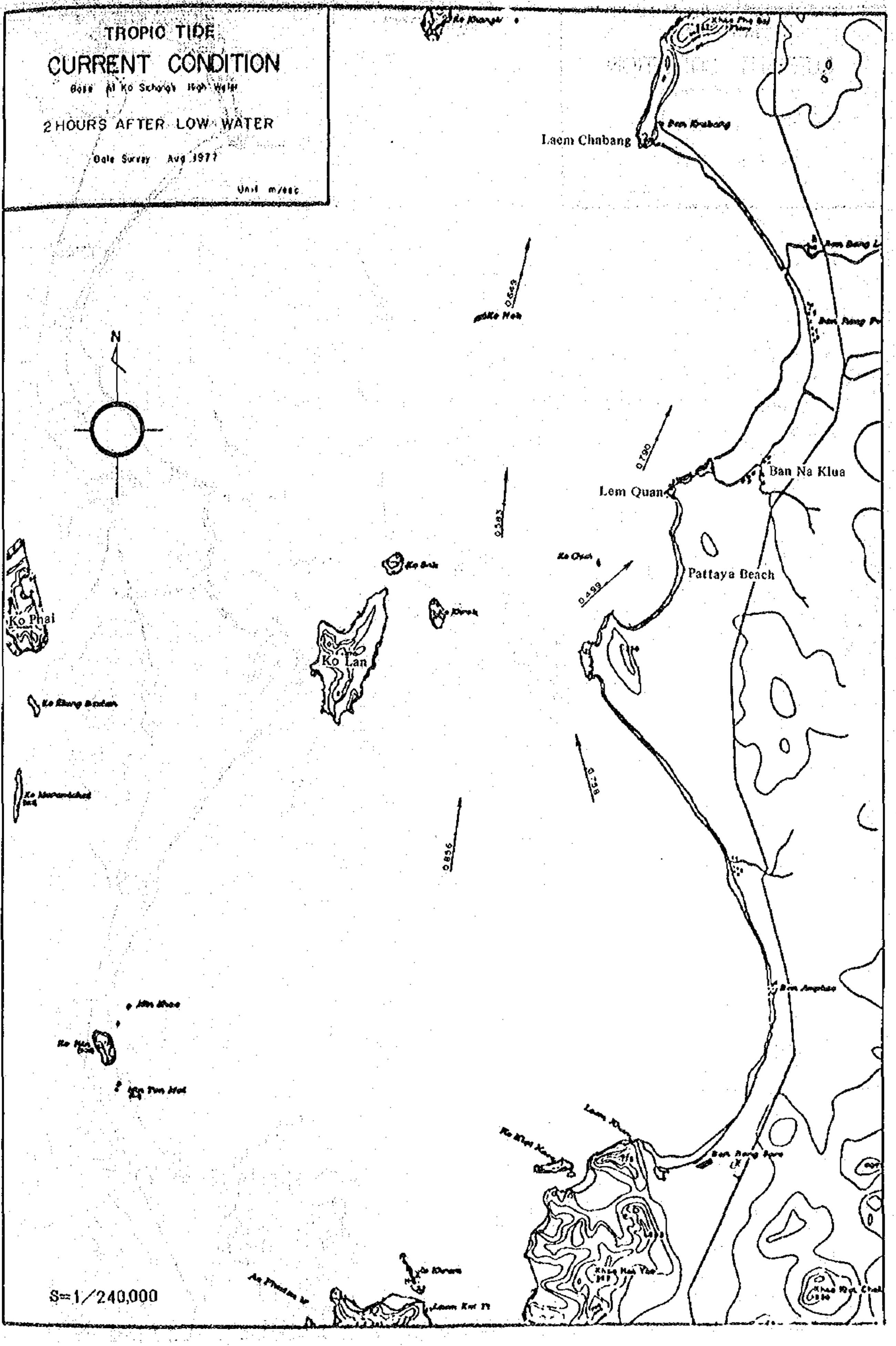
1 HOUR BEFORE LOW WATER

Date Survey Aug 1977

Unit : m/sec


TROPIC TIDE
CURRENT CONDITION
Base : At Ko Sichang's High Water
AT LOW WATER
Date Survey Aug 1977
Unit : m/sec
N
S=1/240,000
0.474
0.666
0.332
0.625
0.678
0.747
Laem Chabang
Ban Krabang
Lem Quan
Ban Na Klua
Pattaya Beach
Ko Lan
Ko Phai


TROPIC TIDE
CURRENT CONDITION
Base At Ko Sichang's High Water
I HOUR AFTER LOW WATER
Date Survey Aug 1977
Unit m/sec
N
Laem Chabang
Ban Na Klua
Lem Quan
Pattaya Beach
Ko Phai
Ko Lan
0.619
0.793
0.503
0.560
0.798
0.877
S=1/240,000


TROPIC TIDE

CURRENT CONDITION

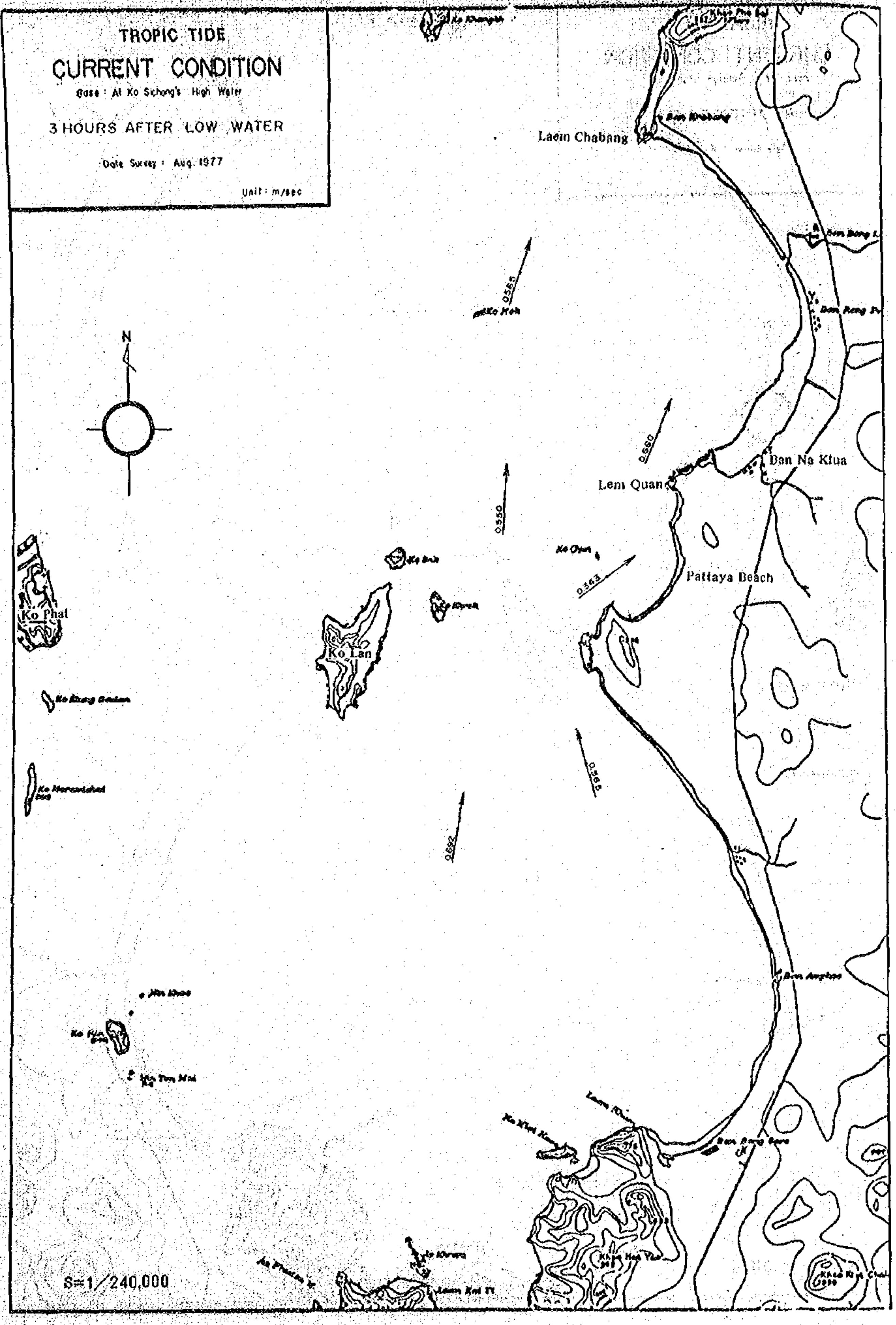
Base At Ko Sichang High Water

2 HOURS AFTER LOW WATER

Date Survey Aug 1977

Unit m/sec

S=1/240,000



TROPIC TIDE

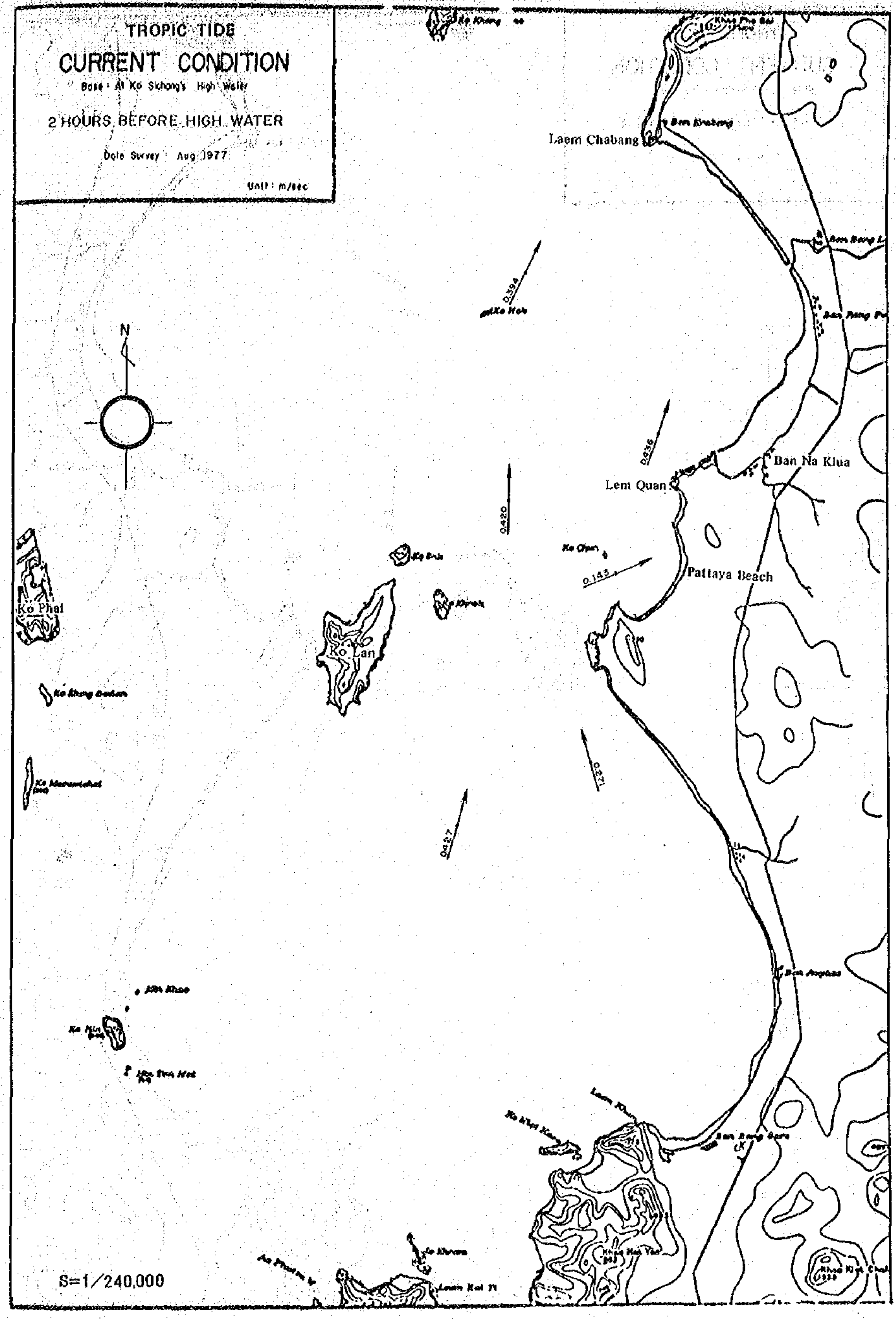
CURRENT CONDITION

Base : At Ko Sichong's High Water

3 HOURS AFTER LOW WATER

Date Survey : Aug. 1977

Unit : m/sec



TROPIC TIDE

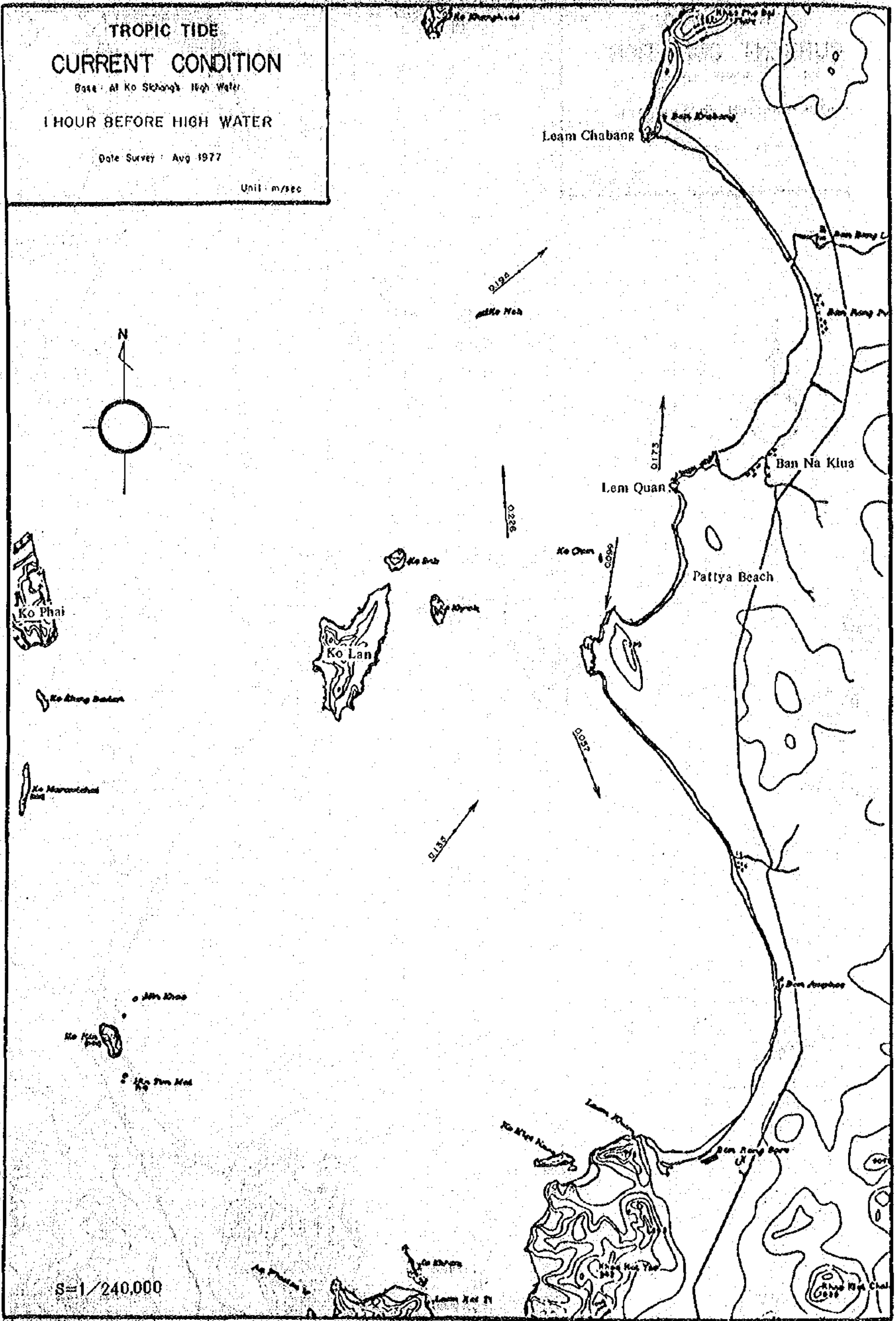
CURRENT CONDITION

Base : At Ko Sichang's High Water

2 HOURS BEFORE HIGH WATER

Date Survey : Aug 1977

Unit : m/sec



TROPIC TIDE

CURRENT CONDITION

Base : At Ko Sichang's High Water

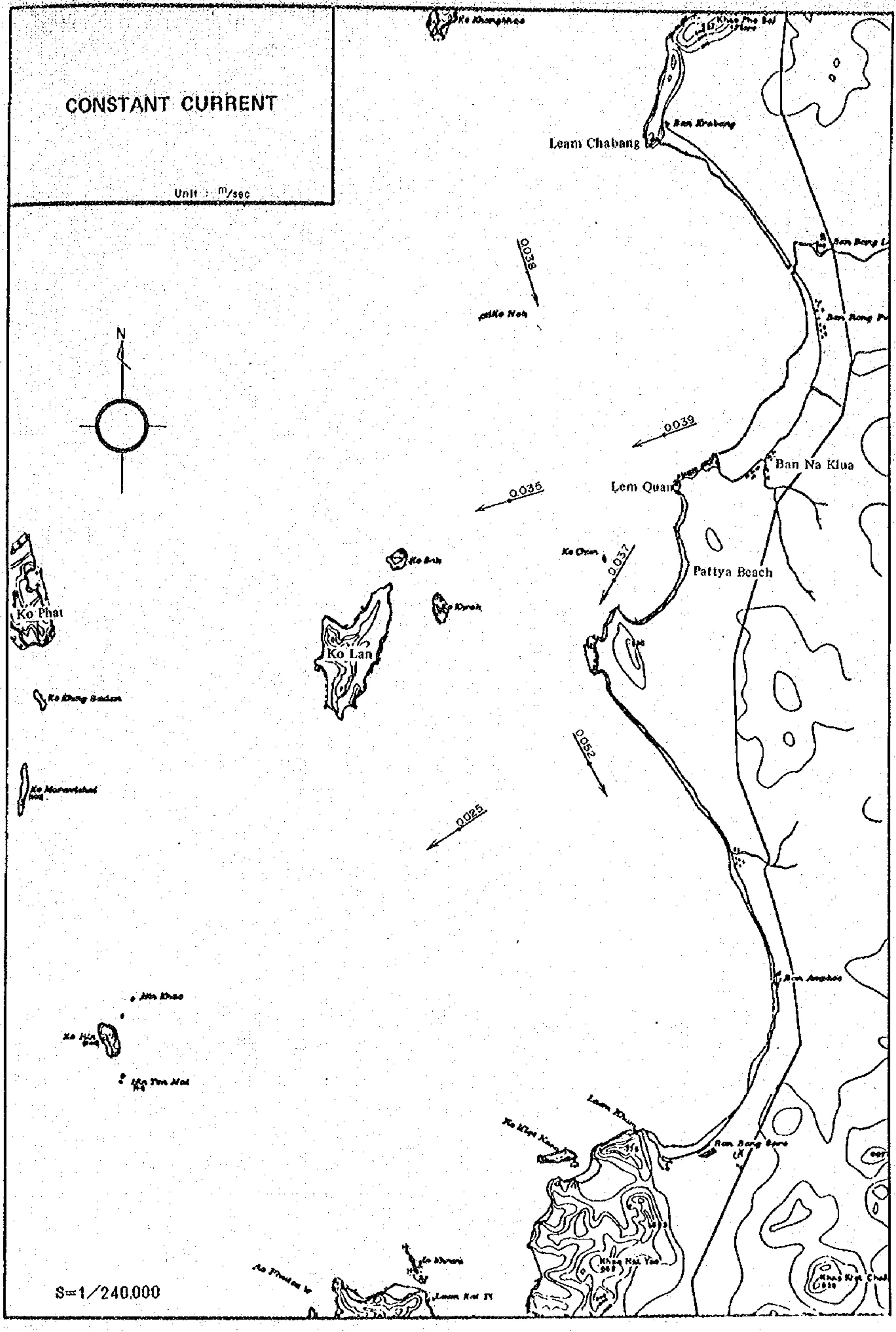
1 HOUR BEFORE HIGH WATER

Date Survey : Aug 1977

Unit : m/sec

2-3-5 Constant current diagram

CONSTANT CURRENT



CHAPTER 3 SURVEY ON WATER AND BOTTOM SEDIMENT

CHAPTER 3 SURVEY ON WATER AND SEDIMENT

3.1 Outline of Survey

3.1.1 Purpose of survey

The major purpose of this study is to grasp the present water quality of Pattaya coastal waters and to know how the discharge of waste water from the Tapioca factory and residential areas affects the quality of sea water.

3.1.2 Location of survey

Fig. 3.1 shows survey station for water quality. The sea area was been conveniently divided into 4 blocks which are representatives of the local characteristics.

Block A represents the northern shore waters including the Na Klua river mouth; Block B is Pattaya beach waters; Block C is the southern sea area of the Na Chom Tien river mouth; Block D consists of the offshore sea area of Block A, B and C.

Locations of survey stations within each block were chosen in order to evaluated the average water quality of each block and the effect of pollutants from the land.

As regard the River Na Klua and the River Na Chom Tien, they were surveyed at the river mouthes and the upper part of rivers.

Sediment were also surveyed for the same underlining purpose as described above.

Water quality test on coliform bacteria was conducted at the other survey stations because of the difference in survey objectives; this case conducted with a view of the sanitary aspect for a swimming beach. Fig. 3.2 shows survey stations for coliform bacteria test.

Fig. 3-1 Location of Survey for Water and Sediment Sampling

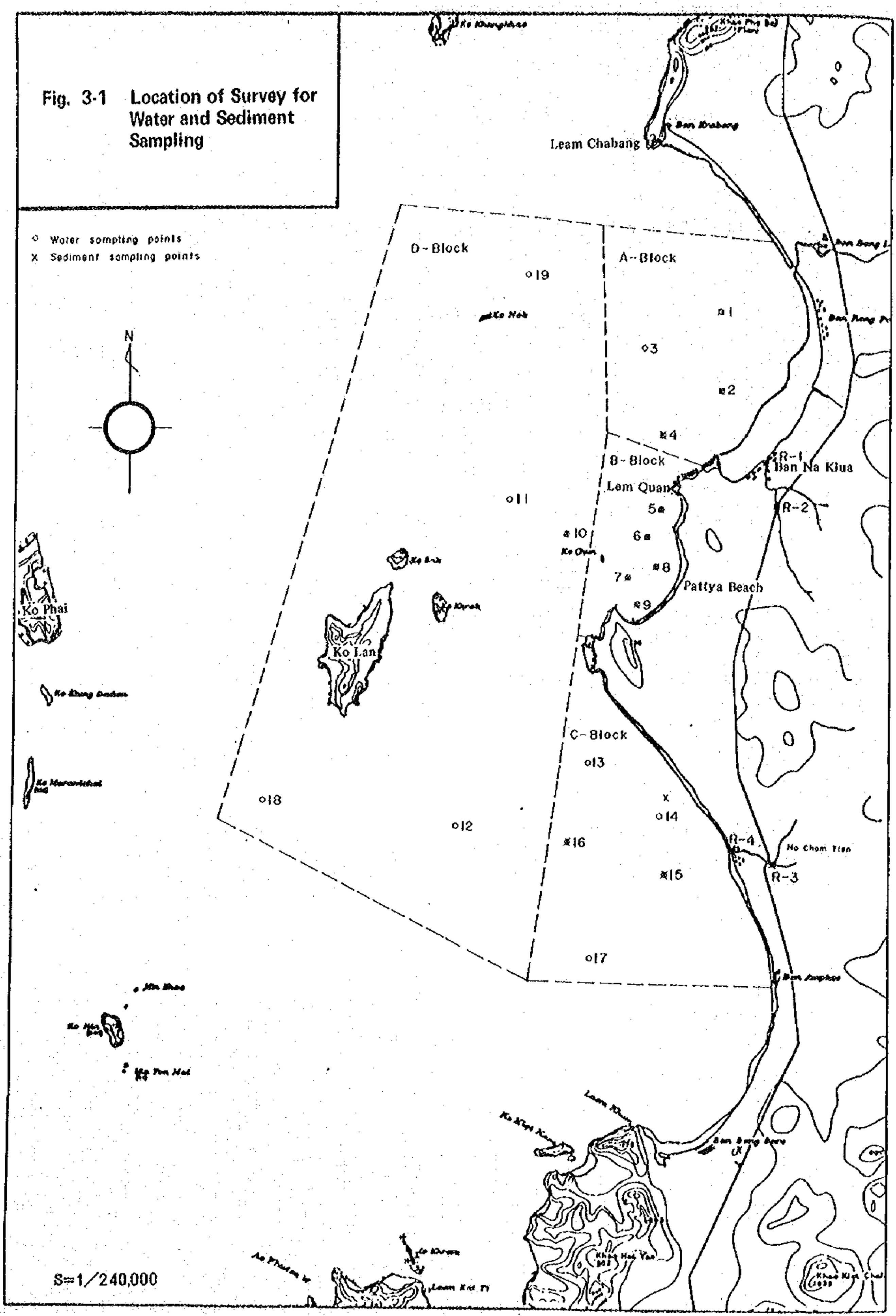


Fig. 3-2 Location of Survey for Coliform Bacteria Sampling

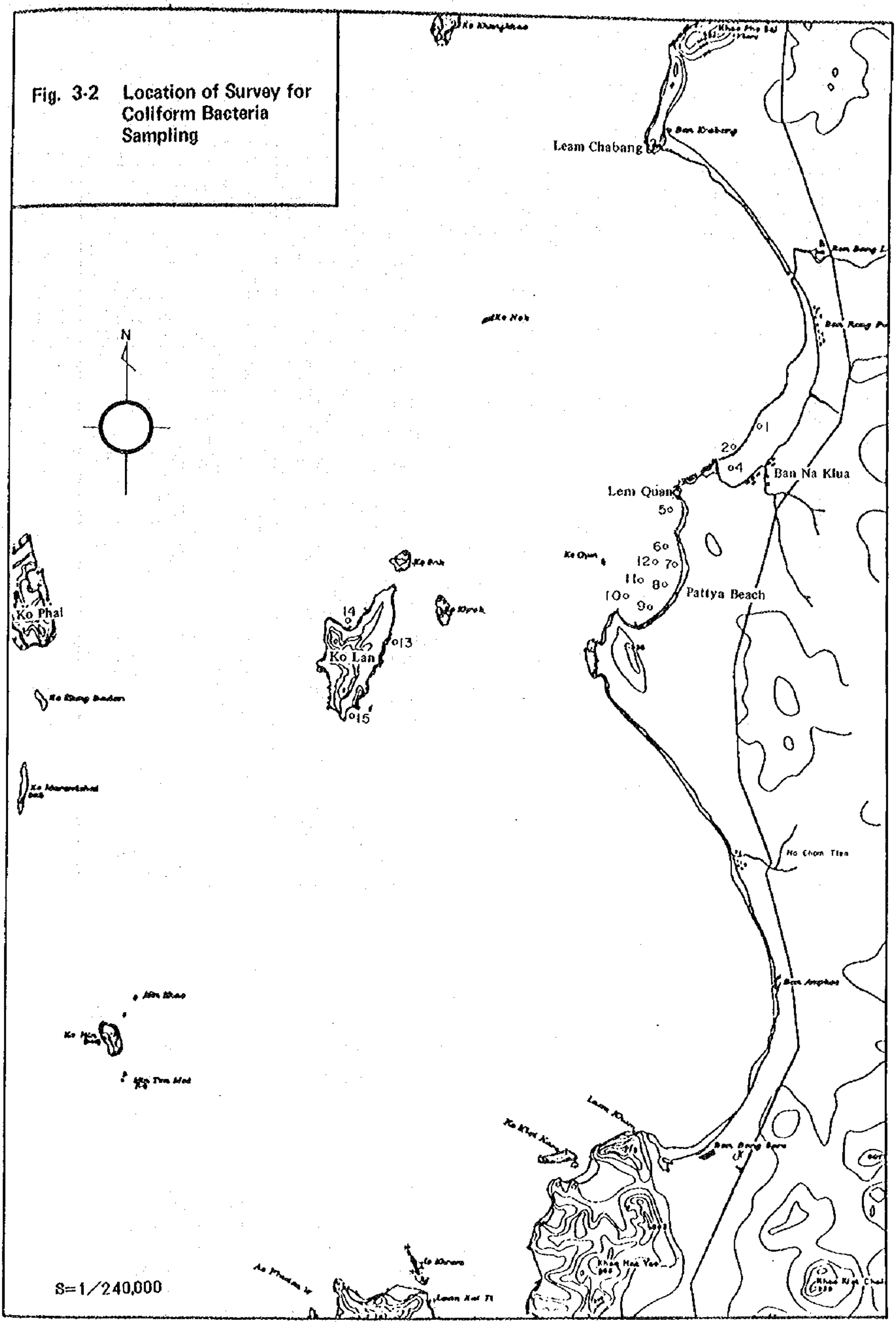


Table 3-1 Location of Sea Water Sampling Stations

Block	Station	Latitude	Longitude	Remark
A	* St. 1	13° 01' 24"	100° 54' 00"	
	* 2	12° 59' 52"	100° 54' 00"	
	3	13° 00' 44"	100° 52' 28"	
	* 4	12° 59' 04"	100° 54' 52"	St. F (Current Survey)
B	* 5	12° 57' 36"	100° 52' 48"	
	* 6	12° 57' 08"	100° 52' 32"	
	* 7	12° 56' 22"	100° 52' 08"	
	* 8	12° 56' 32"	100° 52' 43"	St. B (Current Survey)
	* 9	12° 55' 52"	100° 52' 24"	St. C (Current Survey)
D	* 10	12° 57' 11"	100° 51' 00"	St. D (Current Survey)
	11	12° 57' 48"	100° 49' 56"	
	12	12° 51' 40"	100° 48' 52"	
C	13	12° 52' 53"	100° 51' 26"	
	* 14	12° 51' 52"	100° 52' 50"	
	* 15	12° 50' 46"	100° 52' 58"	
	* 16	12° 51' 22"	100° 51' 04"	
	17	12° 49' 12"	100° 51' 32"	
D	18	12° 52' 04"	100° 45' 09"	
	19	13° 02' 05"	100° 50' 16"	St. A (Current Survey)

* Sediment Sampling Station

3.1.3 Survey items

According to the purpose of the survey, survey items were decided in order to grasp the present water quality and the effect thereon of waste water discharged from the Tapioca factory and residential area.

Survey items

a) Sea water quality

1) Air temperature 2) Water temperature
3) Transparency 4) pH 5) DO
6) SS 7) Cℓ 8) COD 9) Total-N
10) Organic-N 11) NO_3-N 12) NO_2-N
13) NH_4-N 14) Total-P 15) Organic-P
16) PO_4-P 17) TOC 18) CN-Ratio
19) n-Hexane Extracts 20) Colliform Bacteria

(n-Hexane Extracts only were measured from St. 5 to St. 9)

b) River water quality

All items listed above except for n-Hexane Extracts and coliform bacteria test were measured in two rivers.

c) Survey items on sediment

1) Ignition Loss 2) COD 3) Total-S
4) TOC 5) Grain Size

3.1.4 Survey method

1) Sampling methods

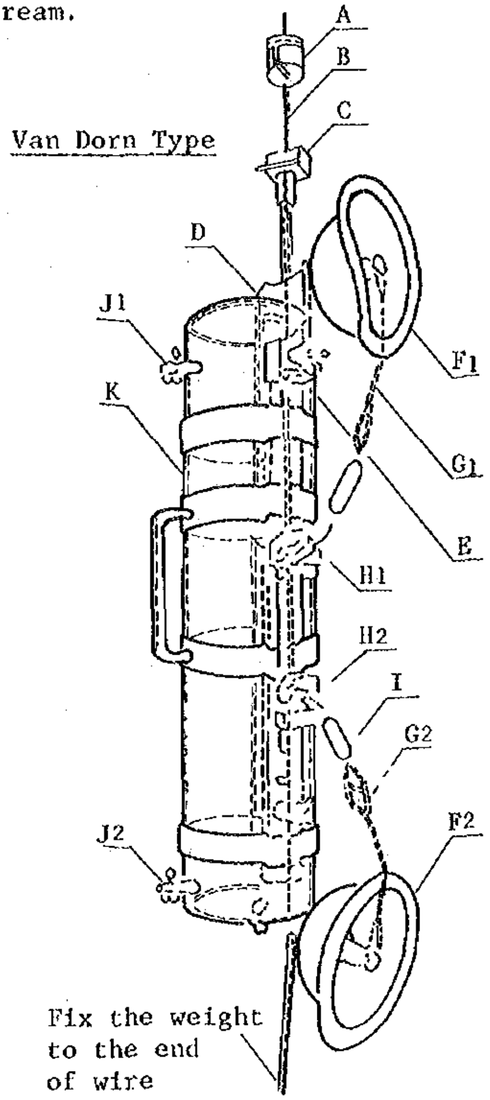
a) Water Sampling

Sea water was collected by the use of the Van Dorn sampler at three different water depths (i.e. surface, middle (about 5m) and bottom layer (about 10m)) at the same station.

Concerning the river survey, surface water was collected at the central axis of the stream.

Fig. 3-3 Van Dorn Type Water Sampler

F_1 , F_2 = Rubber stopper
G_1 , G_2 = Wire for rubber stopper
H_1 , H_2 = Wire clasp for rubber stopper
I = Wire fixing device
J_1 , J_2 = Rubber tube of pinch cock for discharge
K = Transparent cylinder
A = Messenger
B = Wire (or rope)
C = Messenger receiver
D = Rubber string
E = Wire clamp

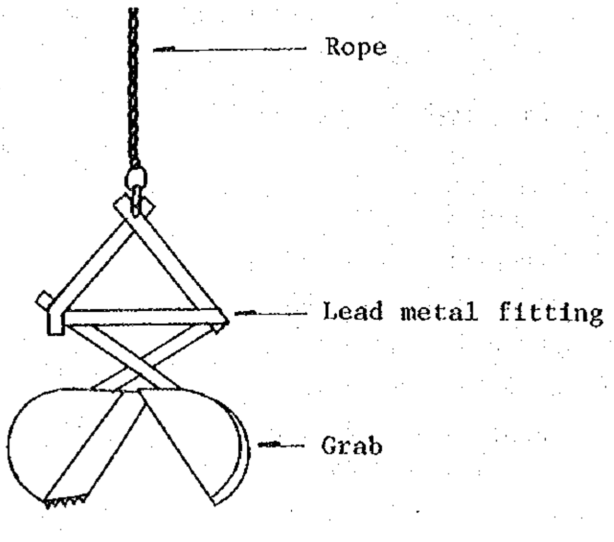


Water samples were put in polyethylene bottles and then stored in the ice box until chemical analysis started. Atmospheric and water temperature were measured on board at the survey station.

b) Sediment sampling method

The bottom samples were collected with the Koken Type Grab Sampler. Samples were prepared as a mixture of sediments collected separately three times at the same station. Different kinds of materials such as sand and mud, colour and smell were observed on board at the same time. Samples were frozen in order not to change the quality and then transported to Japan where they were analysed in the laboratory.

Fig. 3-4 Koken Type Grab Sampler



c) Sampling layer and time

In the sea area, water samples were collected from the survey stations both at the time of low tide and high tide from the water depth of 0m, 5m and 10m (and only from the water depth of 5m at St. 12, 18 and 19). Water sampling depth at each station is shown in Table 3.2.

Table 3-2 Sampling Time and layer

Station	Sampling time	Sampling layer	Sample Number
St. 1	High Tide	0	St. 1.H
	Low Tide	0	St. 1.L
St. 2	High Tide	0	St. 2.H
	Low Tide	0	St. 2.L
St. 3	High Tide	0	St. 3.H.0
		5	St. 3.H.5
	Low Tide	0	St. 3.L.0
		5	St. 3.L.5
St. 4	High Tide	0	St. 4.H.0
		5	St. 4.H.5
	Low Tide	0	St. 4.L.0
		5	St. 4.L.5
St. 5	High Tide	0	St. 5.L.5
	Low Tide	0	St. 5.L
St. 6	High Tide	0	St. 6.H
	Low Tide	0	St. 6.L
St. 7	High Tide	0	St. 7.H
	Low Tide	0	St. 7.L
St. 8	High Tide	0	St. 8.H
	Low Tide	0	St. 8.L
St. 9	High Tide	0	St. 9.H
	Low Tide	0	St. 9.L
St.10	High Tide	0	St.10.H.0
		5	St.10.H.5
		10	St.10.H.10
	Low Tide	0	St.10.L.0
		5	St.10.L.5
		10	St.10.L.10
St.11	High Tide	0	St.11.H.0
		5	St.11.H.5
		10	St.11.H.10
	Low Tide	0	St.11.L.0
		5	St.11.L.5
		10	St.11.L.10
St.12	–	5	St.12

(to be cont'd)

Station	Sampling time	Sampling layer	Sample Number
St.13	High Tide	0 5	St.13.H.0 St.13.H.5
	Low Tide	0 5	St.13.L.0 St.13.L.5
St.14	High Tide	0 5	St.14.H.0 St.14.H.5
	Low Tide	0 5	St.14.L.0 St.14.L.5
St.15	High Tide	0 5	St.15.H.0 St.15.H.5
	Low Tide	0 5	St.15.L.0 St.15.L.5
St.16	High Tide	0 5	St.16.H.0 St.16.H.5
	Low Tide	0 5	St.16.L.0 St.16.L.5
St.17	High Tide	0 5	St.17.H.0 St.17.H.5
	Low Tide	0 5	St.17.L.0 St.17.L.5
St.18	-	5	St.18
St.19	-	5	St.19
St.R-1*	High Tide	0	St.R-1.H
	Low Tide	0	St.R-1.L
St.R-2*	-	0	St.R-2.L
St.R-3*	-	0	St.R-3.L
St.R-4*	High Tide	0	St.R-4.H
	Low Tide	0	St.R-4.L

* River Water

2) Analytical method

Table 3.3 shows the analytical method of water quality and Table 3.4 shows the method of sediments condition analysis. Most of chemical analysis were carried out in the land laboratory in Pattaya, while other chemical parameters were analyzed in Japan.

Following items were analyzed in Pattaya

1) Air temperature 2) Water temperature
3) Transparency 4) DO 5) pH
6) COD 7) NO_3-N 8) NO_2-N 9) NH_4-N
10) PO_4-P

(Coliform bacteria analysis was conducted by A.I.T)

Samples for n-Hexane Extracts, SS and CN ratio analysis were properly pretreated to send to Japan.

Table 3-3 Analytical Methods for Water Quality

Item	Analytical Method
Air Temperature	Alcoholic Thermometer
Water Temperature	Mercury Thermometer
Transparency	P. Secchi desk at Sea, Transmittance meter at river
DO	Modified Winkler's Sodium Azide Method
pH	Glass Electrode Method
COD	Pottassium Permanganate Method
Chlorinity	Salinometer Method (Convert Salinity into Chlorinity by M. Knudsen equation)
SS	Glass Fiber Filter Method
NH_4-N	Indophenol Blue Method
NO_2-N	Azo Dye Formation Method
NO_3-N	Azo Dye Formation Method with Cd-Cu Reduction Column
Total-N	The Sum of NH_4-N, NO_2-N, NO_3-N and Organic-N
PO_4-P	Ascorbic Acid Method
Total-P	Ascorbic Acid Method after Wet Digestion
n-Hexane Extract	Solvent Extract Method
TOC	Combution Infrared Method
CN-Ratio	CN corder

Table 3-4 Analytical Methods for Sediment

Item	Analytical Method
Ignition Loss	Weight Loss at 900°C
COD	Pattassium Permanganate Method
TOC	Wet Digestion Method
Total-Sulfide	Steam Distillution Method
Grain Size	Standard Sieve and Hydrometer

3.2 Results of Survey

All of the data obtained here are compiled in the final section as an attachment, the results are summarized as follows.

3.2.1 Results of water quality survey

* Water Temperature

Water temperature, having been reflected by high daytime temperature, remained substantially high at more than 29°C at all of the stations except these located at the upper rivers. Furthermore, no temperature variation was observed during high tide, low tide or vertically.

* Transparency

Transparency was generally low throughout the study area, especially in the coastal area of Pattaya beach (Block B) and offshore of the Na Klua river mouth where the value was less than 5m. The offshore area (Block D) shows the transparency of around 13m.

* pH

The value of pH in the sea water was in the range of 8.47 showing no extraordinary level, the same hold true for the pH value in the river water. Stations 7 through 9 of Block B, Pattaya Beach coastal area, had a relatively high value, which was over 8.40.

* Cℓ

The distributions of Cℓ contents are shown in Figures 3.5 and 3.6. Cℓ contents in the sea area are relatively small between 15‰ ∿ 17.5‰. Especially smaller values were observed in Block A and B. From this fact it may be deduced that the sea water movement is weak in these Blocks by the topographic characteristics.

The observations were made both at the time of low tide and high tide, and almost same results were obtained.

In the river area, the sea water reaches more than 2 km above the river mouth because of the weak river flow.

* DO

DO contents in the sea water is affected by water temperature and the Cℓ content. The higher the temperature and Cℓ content, the lower the oxygen saturation rate. Oxygen content in this sea area was slightly lower than that in the Japanese coastal area because of the lower oxygen saturation rate.

Figs. 3.7 and 3.8 show the distribution of the oxygen saturation rate. High oxygen saturation rate can be seen in all of the sea stations except the river mouth area.

The Na Klua river had no oxygen at the time of low tide both at the river mouth as well as at the upper river. It is no biological production under such an anaerobic conditions.

* COD

COD value in the sea area was low excluding the coastal area of the Pattaya Beach (Block B), whose COD value was quite high, especially at the time of high water having shown 2 ppm (which was more than the standard level in the Japanese swimming beaches). Figs. 3.9 and 3.10 shows COD distribution of the sea area. As regard the river water, very high COD value especially at St. R.2.L with 91.8 ppm, R.1.L and R.3.L with over 10 ppm was evident indicating that the river water was quite polluted by organic pollutants.

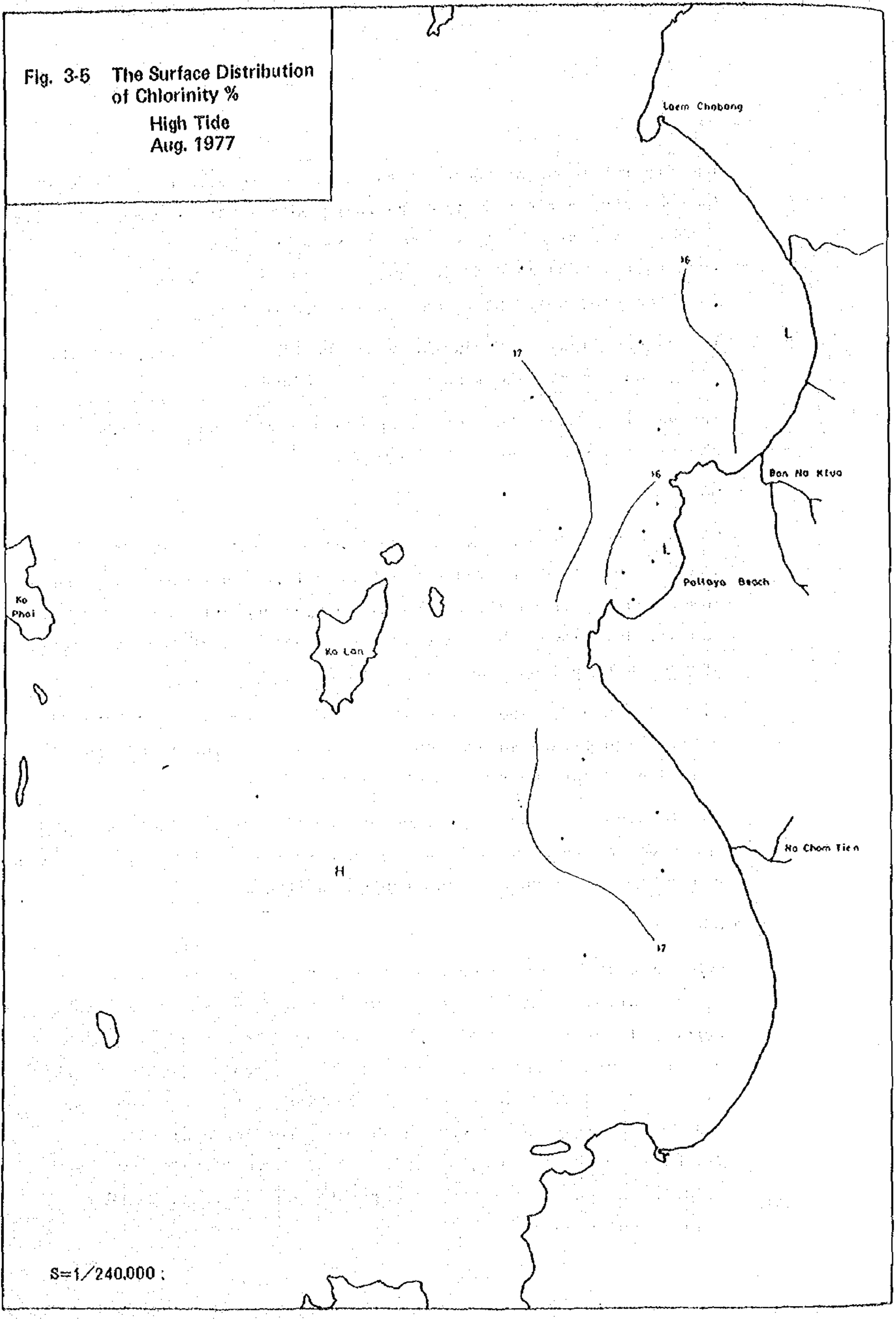


Fig. 3-5 The Surface Distribution of Chlorinity %
High Tide
Aug. 1977

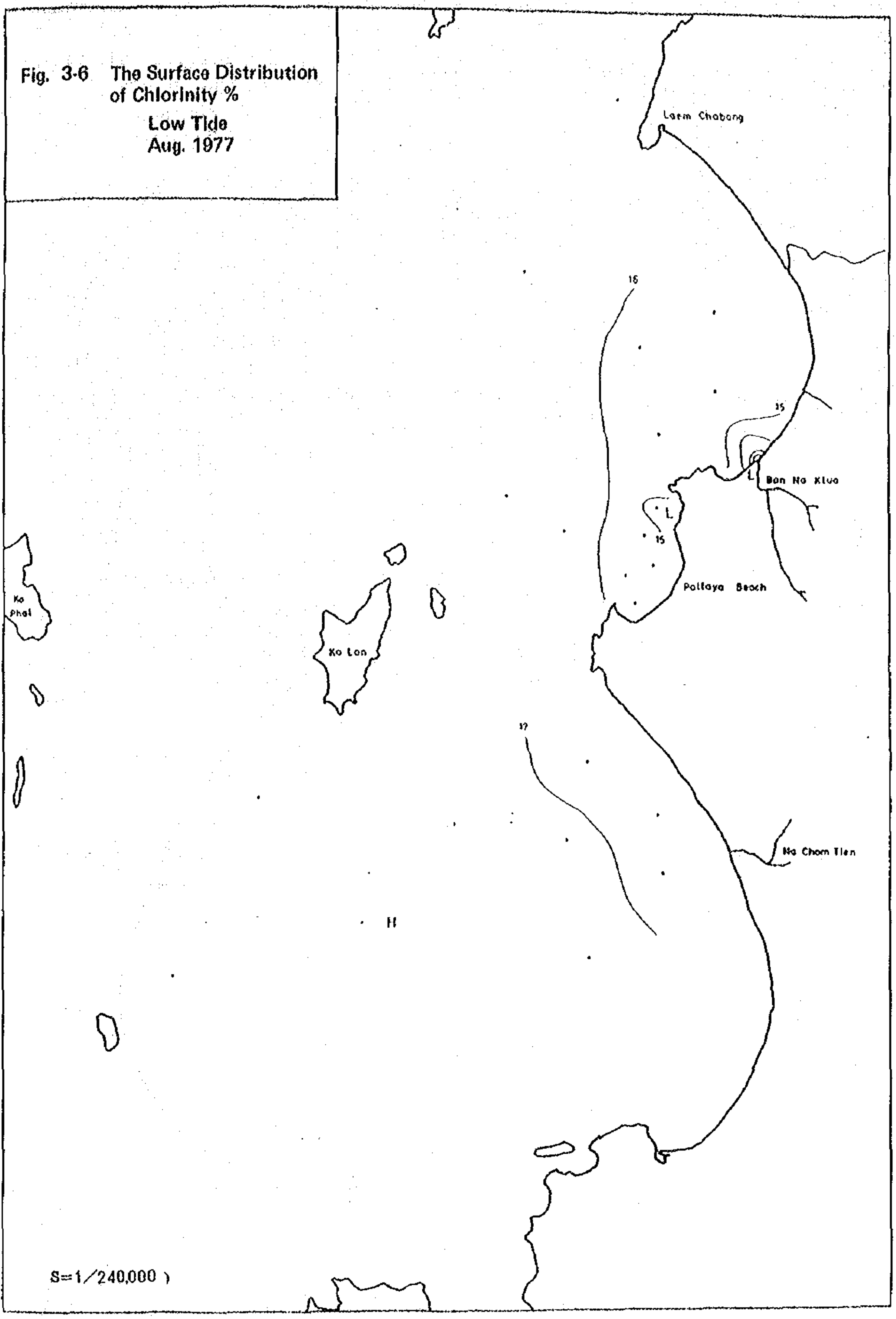


Fig. 3-6 The Surface Distribution of Chlorinity %
Low Tide
Aug. 1977

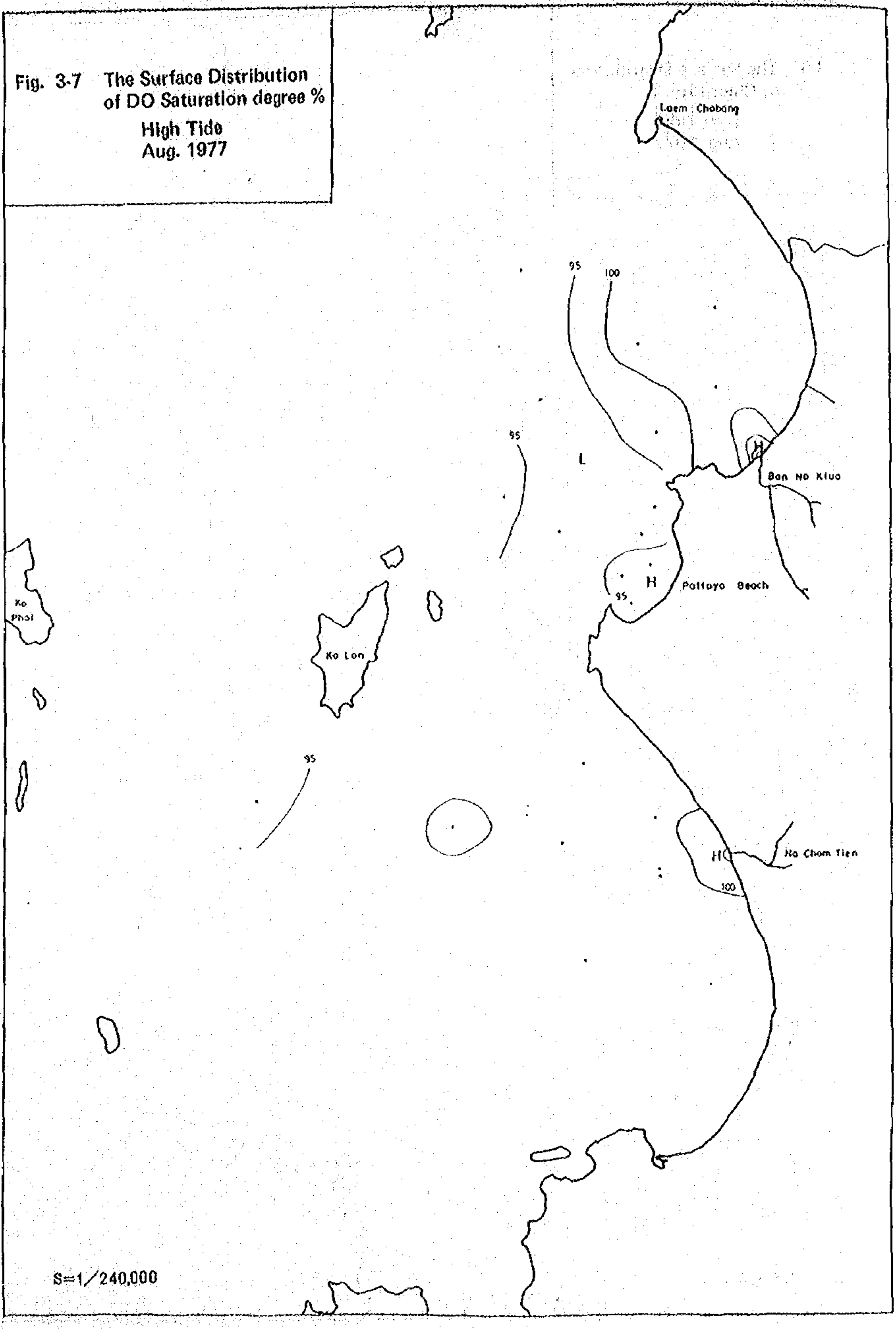


Fig. 3-7 The Surface Distribution of DO Saturation degree %

High Tide

Aug. 1977

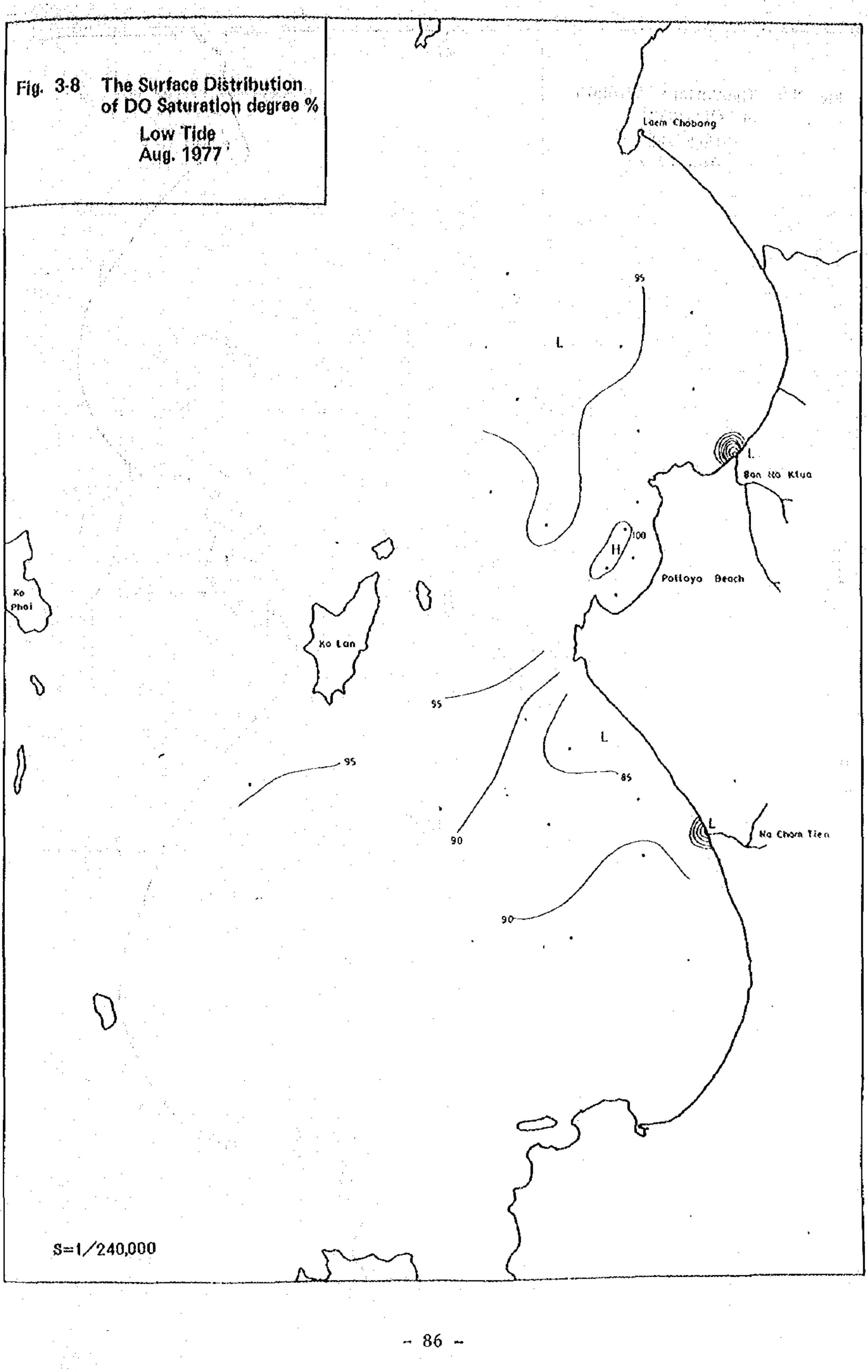


Fig. 3-8 The Surface Distribution of DO Saturation degree %

Low Tide

Aug. 1977

Fig. 3-9 The Surface Distribution of COD (PPm)
High Tide
Aug. 1977

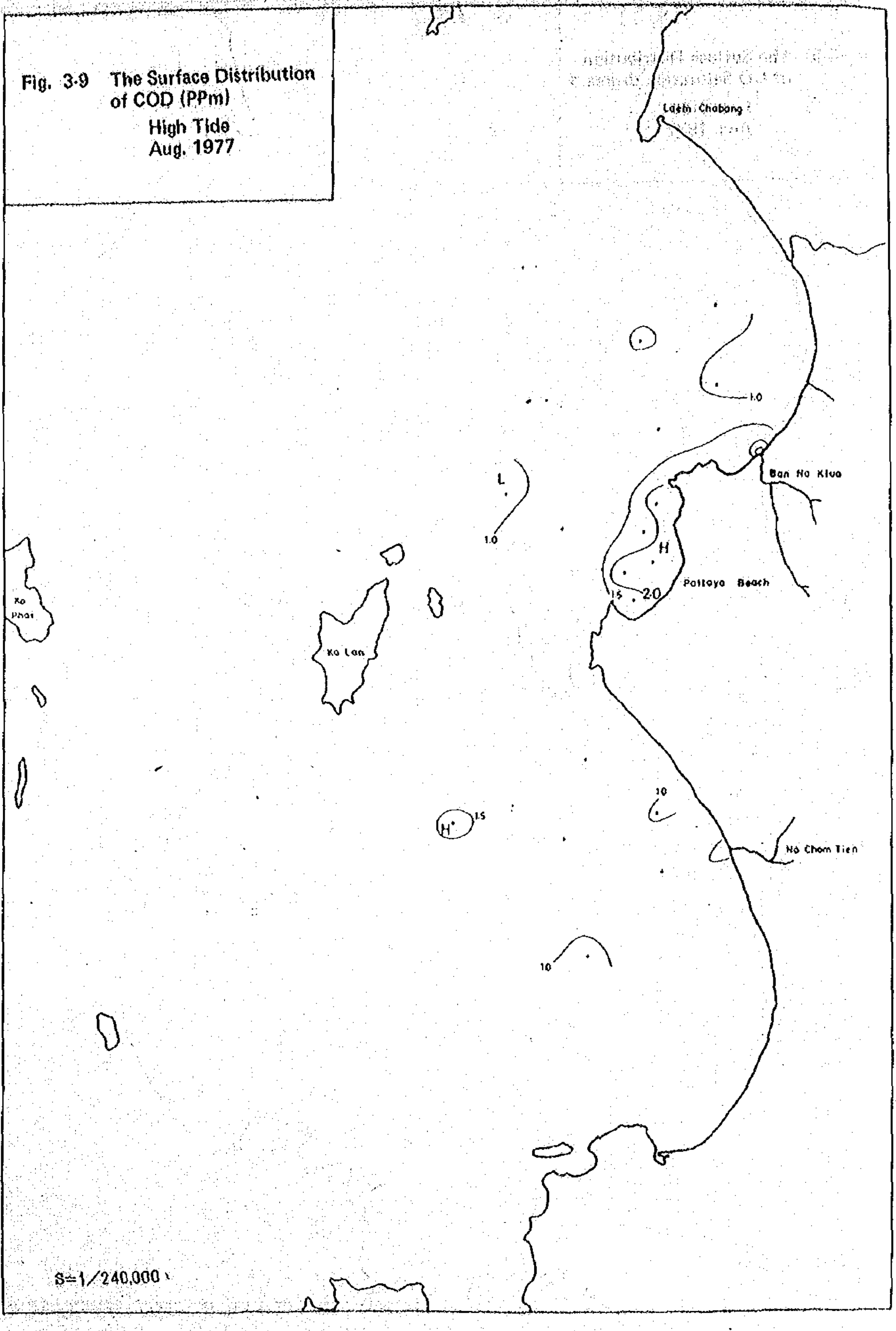
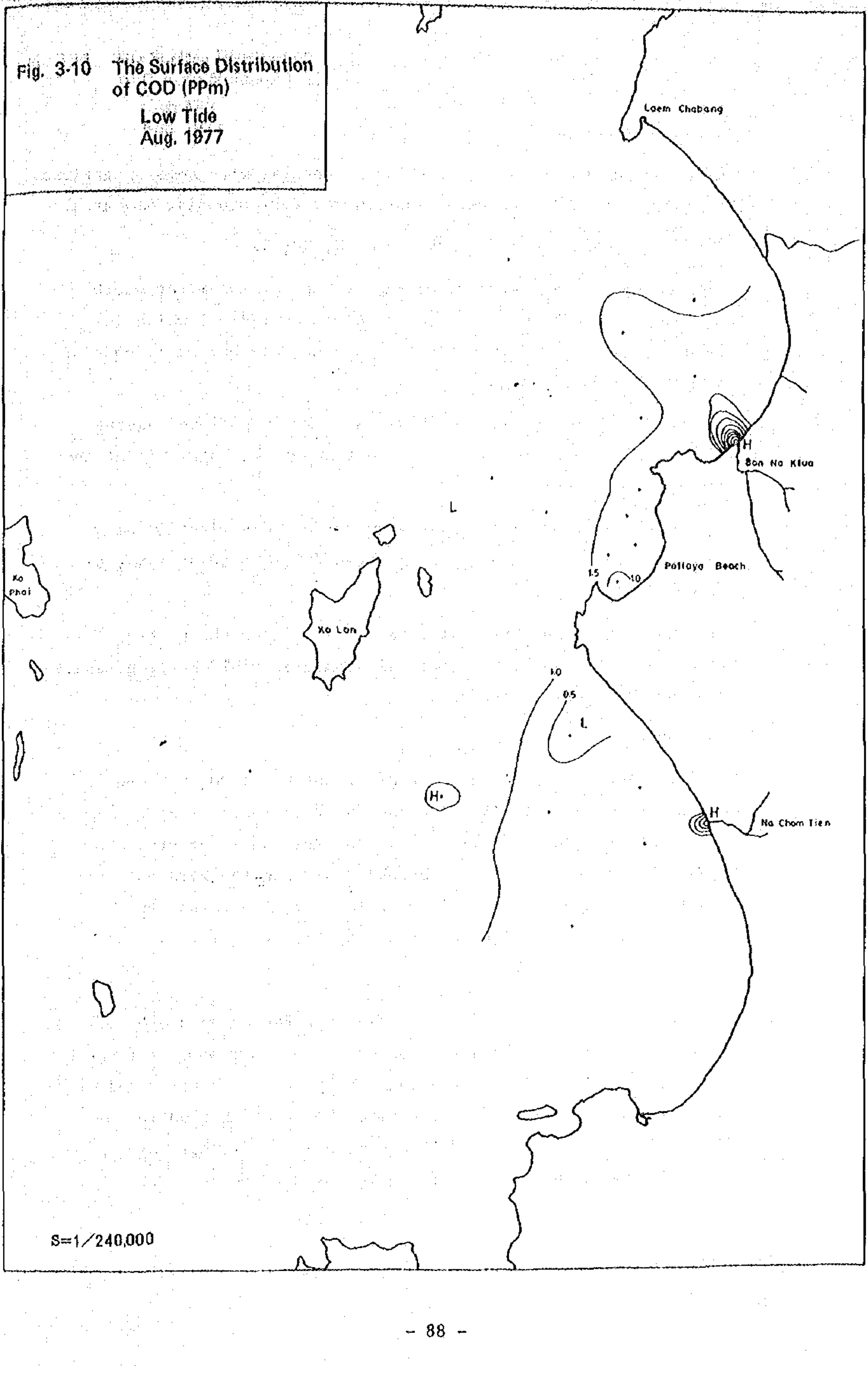


Fig. 3-10 The Surface Distribution of COD (PPm)
Low Tide
Aug. 1977



* Suspended Substance

Suspended Substance content was low in general with some exceptions. The load of SS was considered less in the corresponding sea area.

* Nitrogen Compound (Org.-N, NO_3-N, NO_2-N, NH_4-N)

Total Nitrogen Value was found high at the Na Klua river mouth and low at the other area. But the Ammonia-N(NH_4-N) which is extraordinary high in comparison with other sea waters is consist of more than 80% of Total-N.

We observed that the River Na Klua was heavily polluted having 700 μg at Total-N/ℓ at the mouth and 1,200 μg at Total-N/ℓ at the upper part of river.

Figs. 3.11, 3.12 and 3.13, 3.14 show surface distribution of Organic Nitrogen and Inorganic Nitrogen (NO_3-N + NO_2-N + NH_4-N) respectively.

This shows that Inorganic Nitrogen content along the Pattaya Beach was high, indicating that this sea area could be progressively undertaking eutrophication.

* Phosphorous

Fig. 3.15 and Fig. 3.16 show the distribution of PO_4-P content on the sea surface at high tide and low tide respectively. PO_4-P contents are generally low except for the river area and Pattaya Beach area (Block-B) thereby depicting the same pattern as Nitrogen compound. It will be well to remember that the Organic phosphate is also low except for the river area.

* TOC

TOC content is generally about 0.1 mg/ℓ in the ocean and 5 mg/ℓ in an inlet area. Our observation this time came across a relatively high value as a whole with the range between 3 mg/ℓ through 10 mg/ℓ in the sea area. Figs. 3.17 and 3.18 show the distribution of TOC. The Pattaya beach area (Block B) and the offshore area (Block D) had higher values than other area's stations.

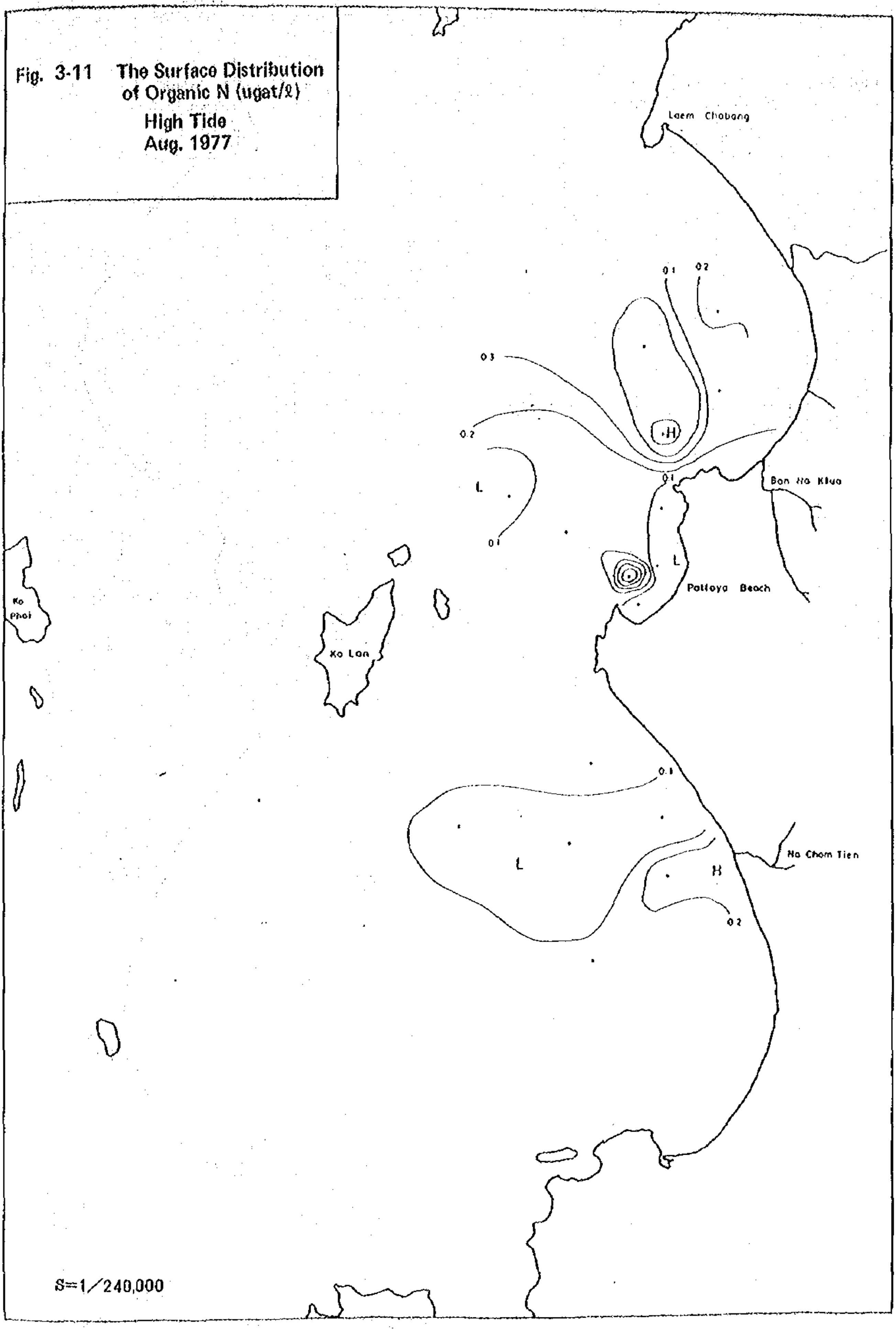
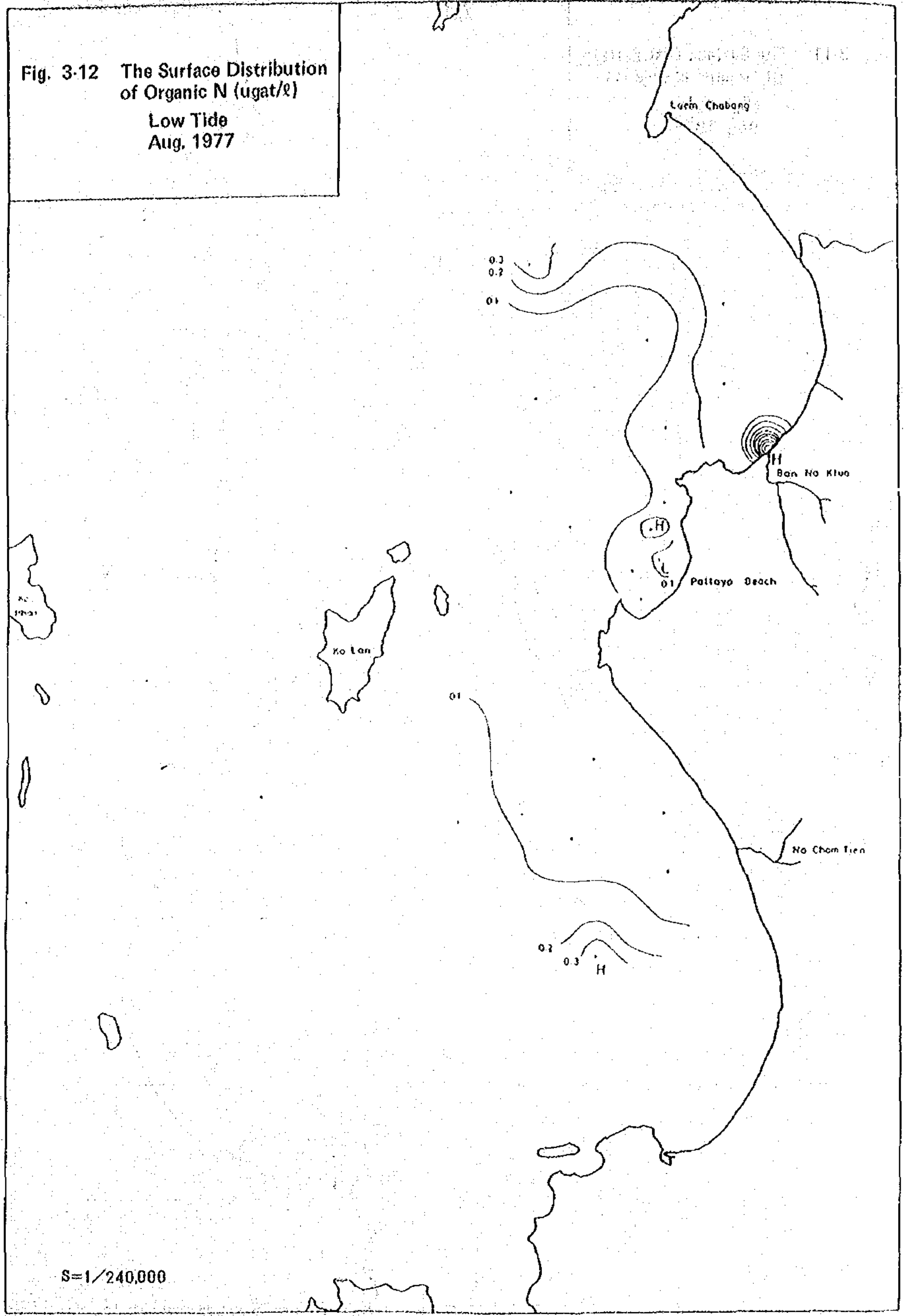


Fig. 3-11 The Surface Distribution of Organic N (ugat/ℓ) High Tide Aug. 1977

Fig. 3·12 The Surface Distribution of Organic N (ugat/ℓ)
Low Tide
Aug. 1977



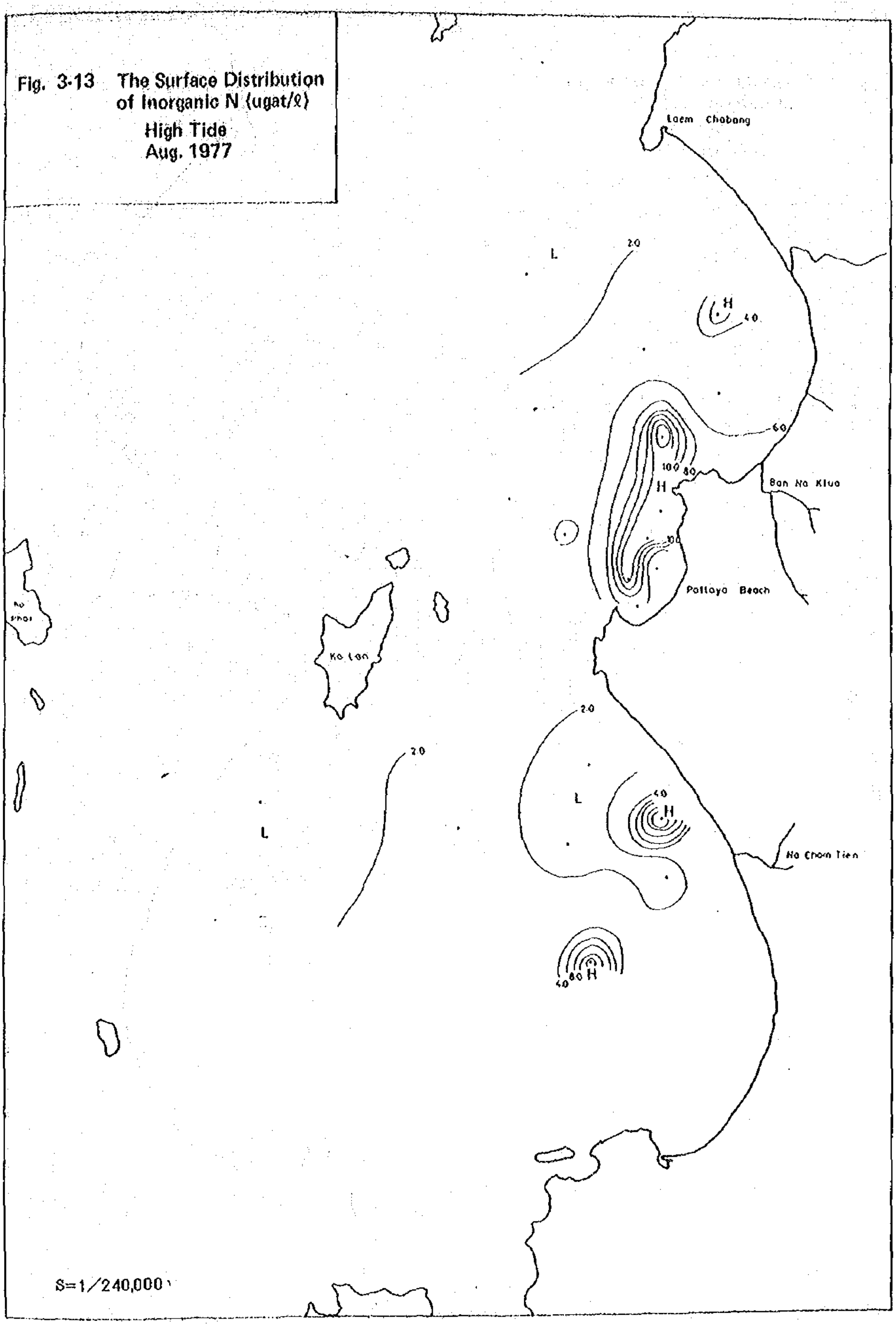
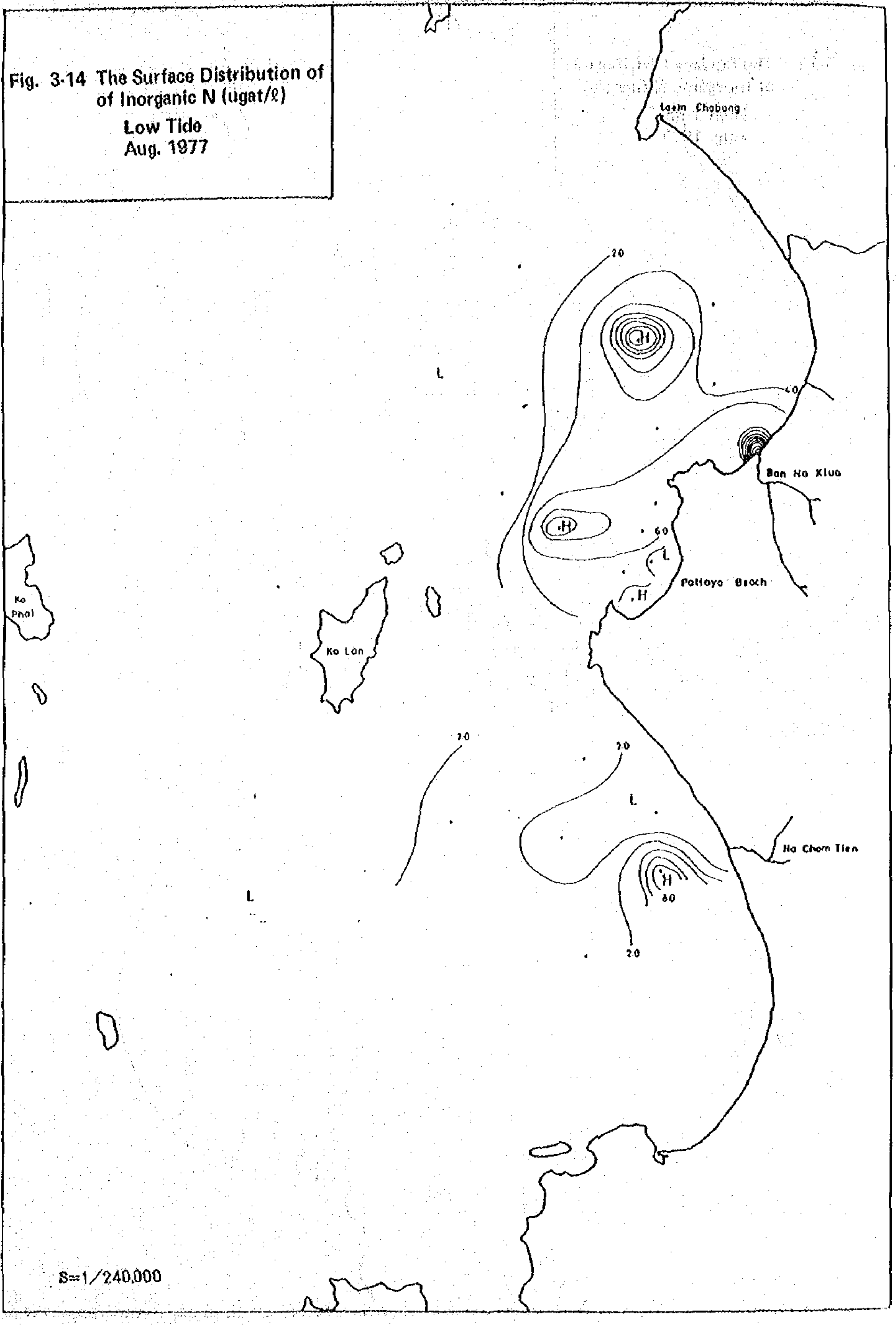


Fig. 3-13 The Surface Distribution of Inorganic N (ugat/ℓ)
High Tide
Aug. 1977

Fig. 3-14 The Surface Distribution of of Inorganic N (ugat/ℓ)
Low Tide
Aug. 1977



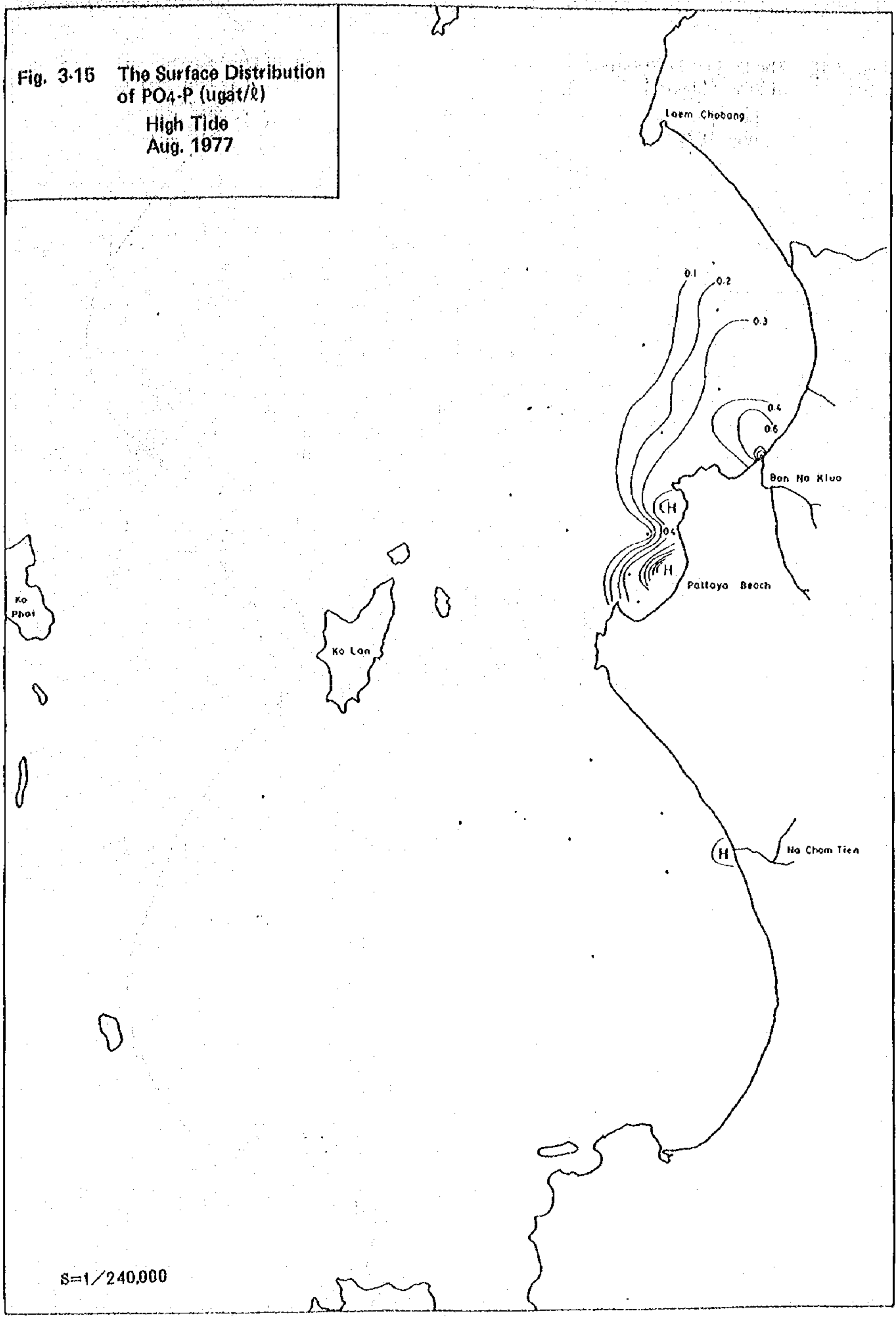
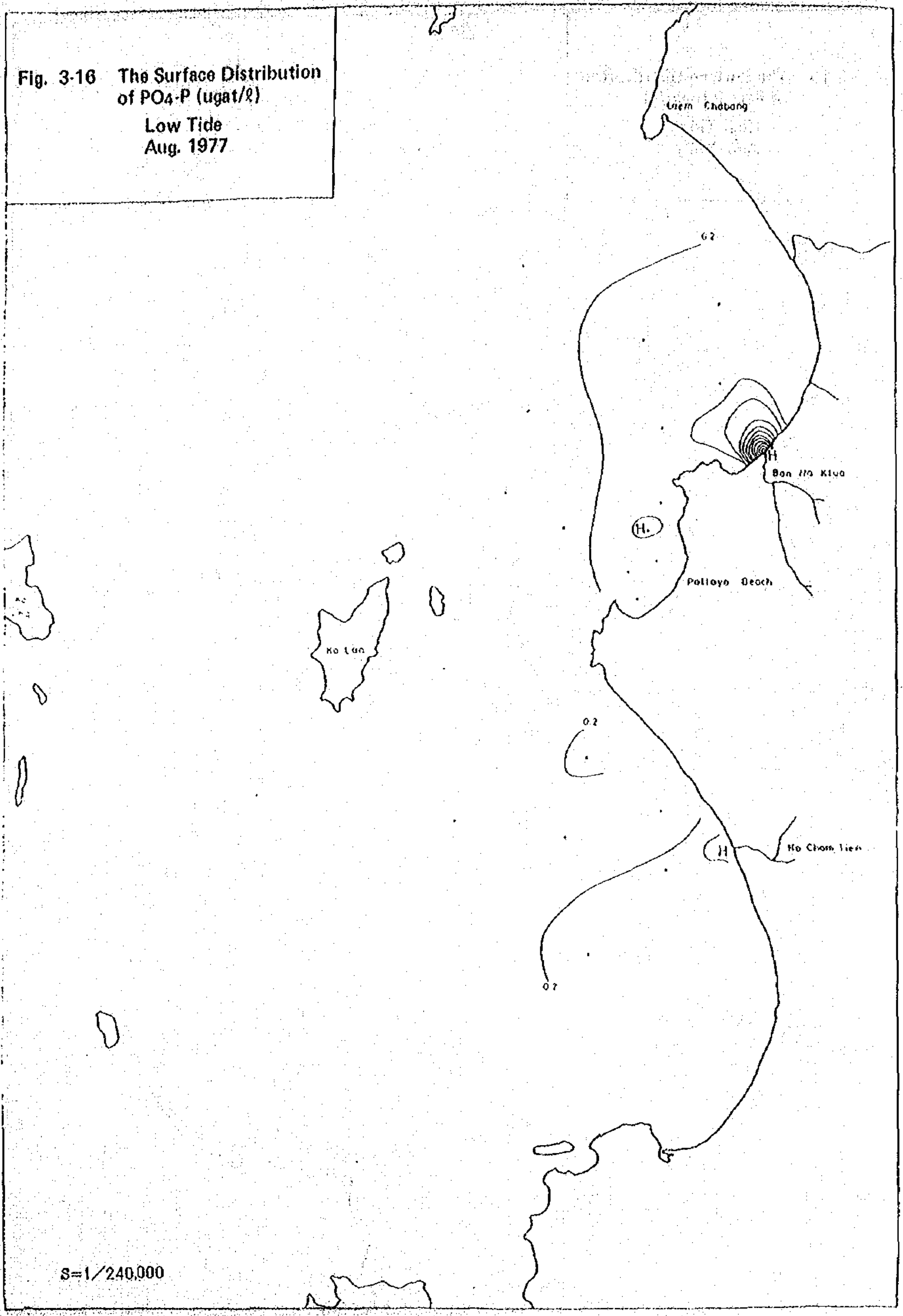


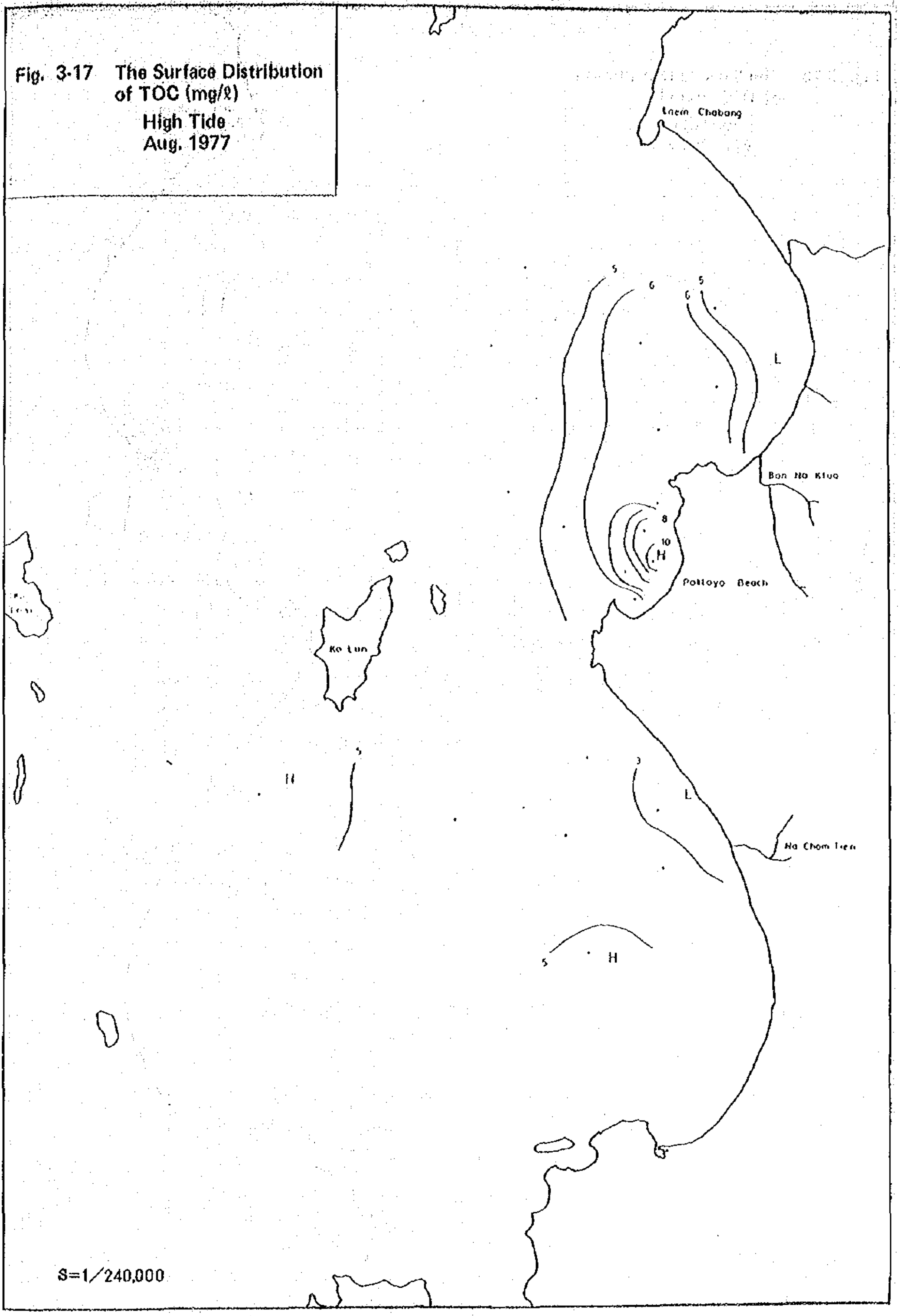
Fig. 3-15 The Surface Distribution of PO_4-P (ugat/ℓ)
High Tide
Aug. 1977

Fig. 3-16 The Surface Distribution of PO_4-P (ugat/ℓ)
Low Tide
Aug. 1977



S=1/240,000

Fig. 3-17 The Surface Distribution of TOC (mg/ℓ)
High Tide
Aug. 1977



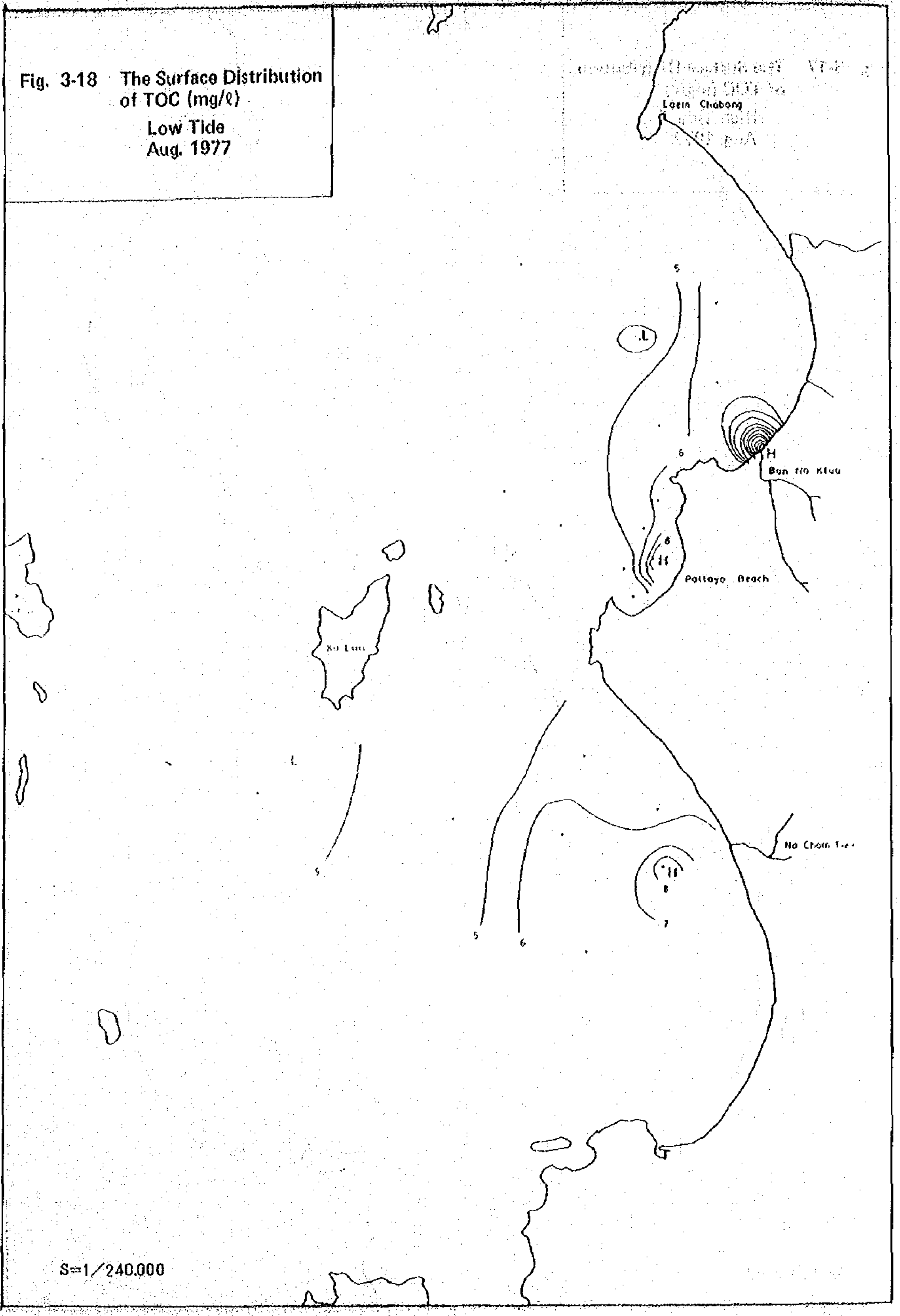


Fig. 3-18 The Surface Distribution of TOC (mg/ℓ)
Low Tide
Aug. 1977

* CN-Ratio

CN-Ratio is a useful indicator to presume the source of suspended substance, which is the ratio of Organic Nitrogen and Organic Carbon. The CN Ratio observed in this study varied drastically, but the tendency was for a lower rate along the coast. R.1.L and R.2.L of Na Klua river had extremely low values, both of which were less than 10.

* n-Hexan Extracts

n-Hexan Extracts were determined only in Block B which is the nearshore area of Pattaya beach. All the stations excluding St.7.L showed no n-Hexan Extract.

* Coliform bacteria

Coliform bacteria tests were conducted twice on Thursday and Monday to become aware of the difference between weekday use and weekend use. The first test surveyed on Thursday showed low values in all stations. But we had a slightly higher value at the time of the second test, St. 2 and St. 9 in particular recorded more than 1,000 MPN/100 mℓ.

3.2.2 Results of sediment condition survey

* Ignition Loss

The value of Ignition loss is generally used as an indicator to determine the organic matter contents of sediments. The results of this survey show low values at most of survey stations. But St. 4, St. 10 and St. 16 had more than 10% which is considered to be relatively rich in organic matter.

* TOC

TOC contents had the tendency to increase toward the offshore area from the nearshore as shown in Fig. 3.19. St. 10 and St. 16 had higher values than other stations.

* COD

Fig. 3.20 shows the distribution of COD. COD values are low as a whole and tend to increase toward the offshore area from the nearshore area.

Fig. 3-19 The Sediment Distribution of TOC (mg/g)
Aug. 1977

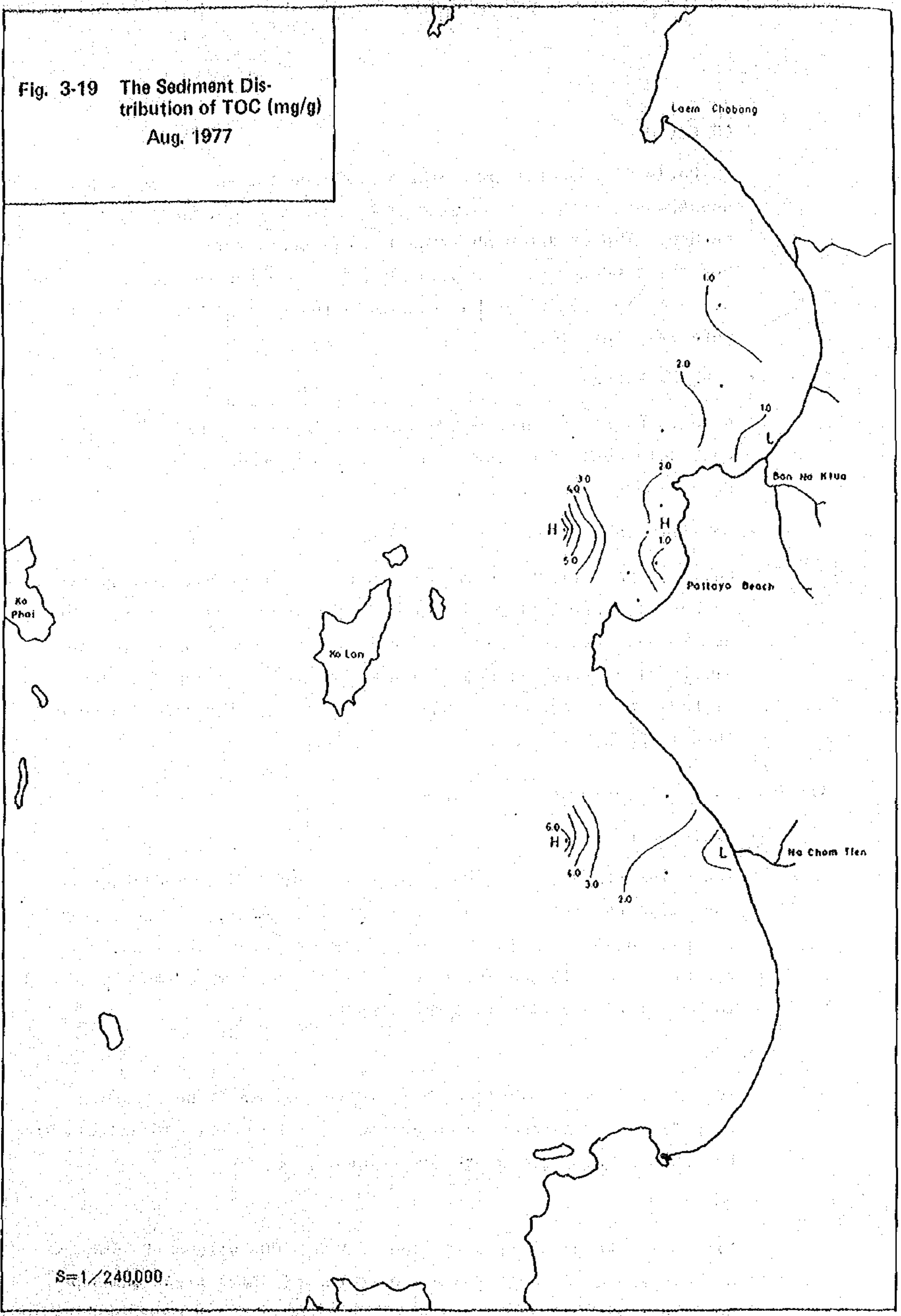
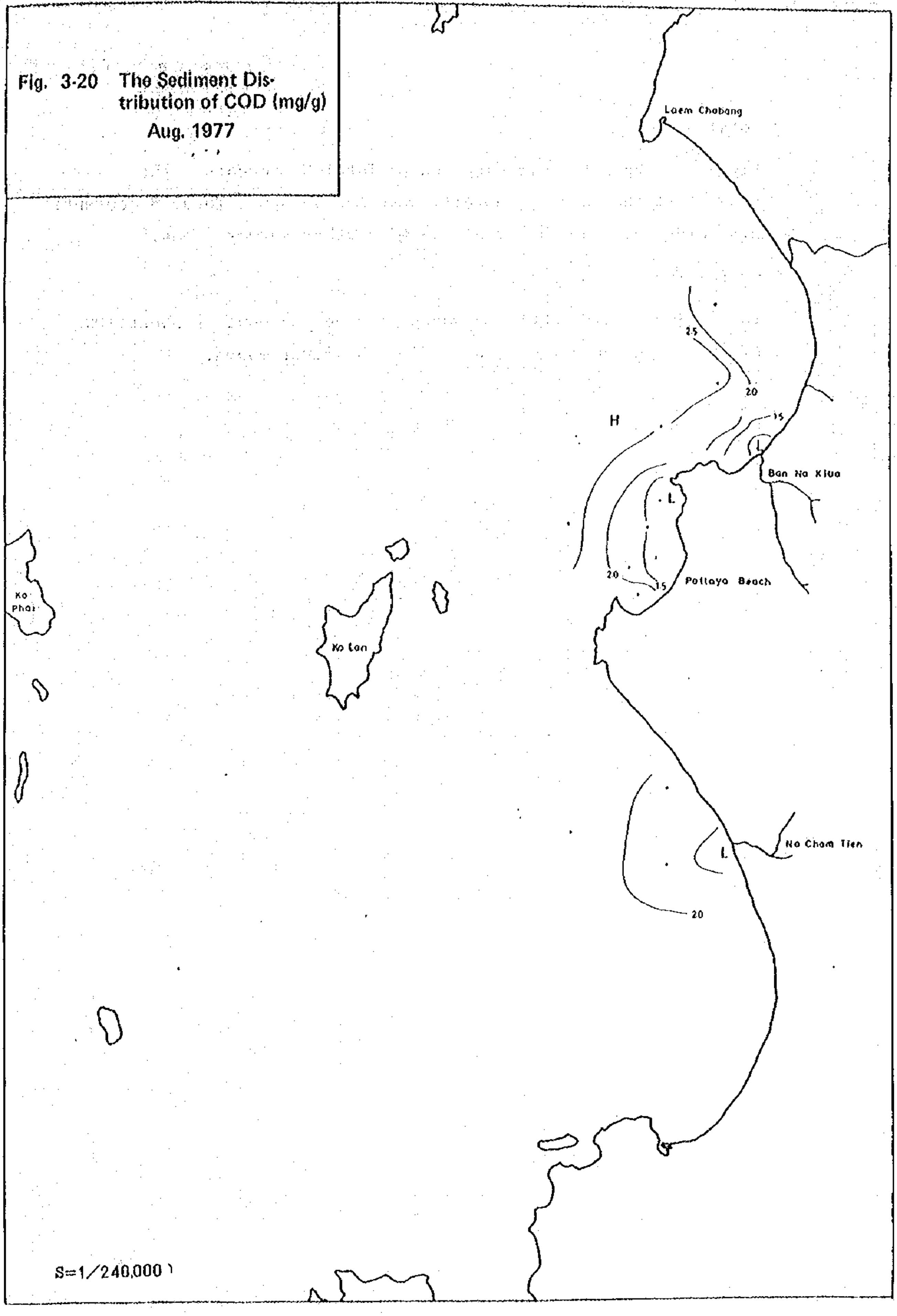


Fig. 3-20 The Sediment Distribution of COD (mg/g) Aug. 1977



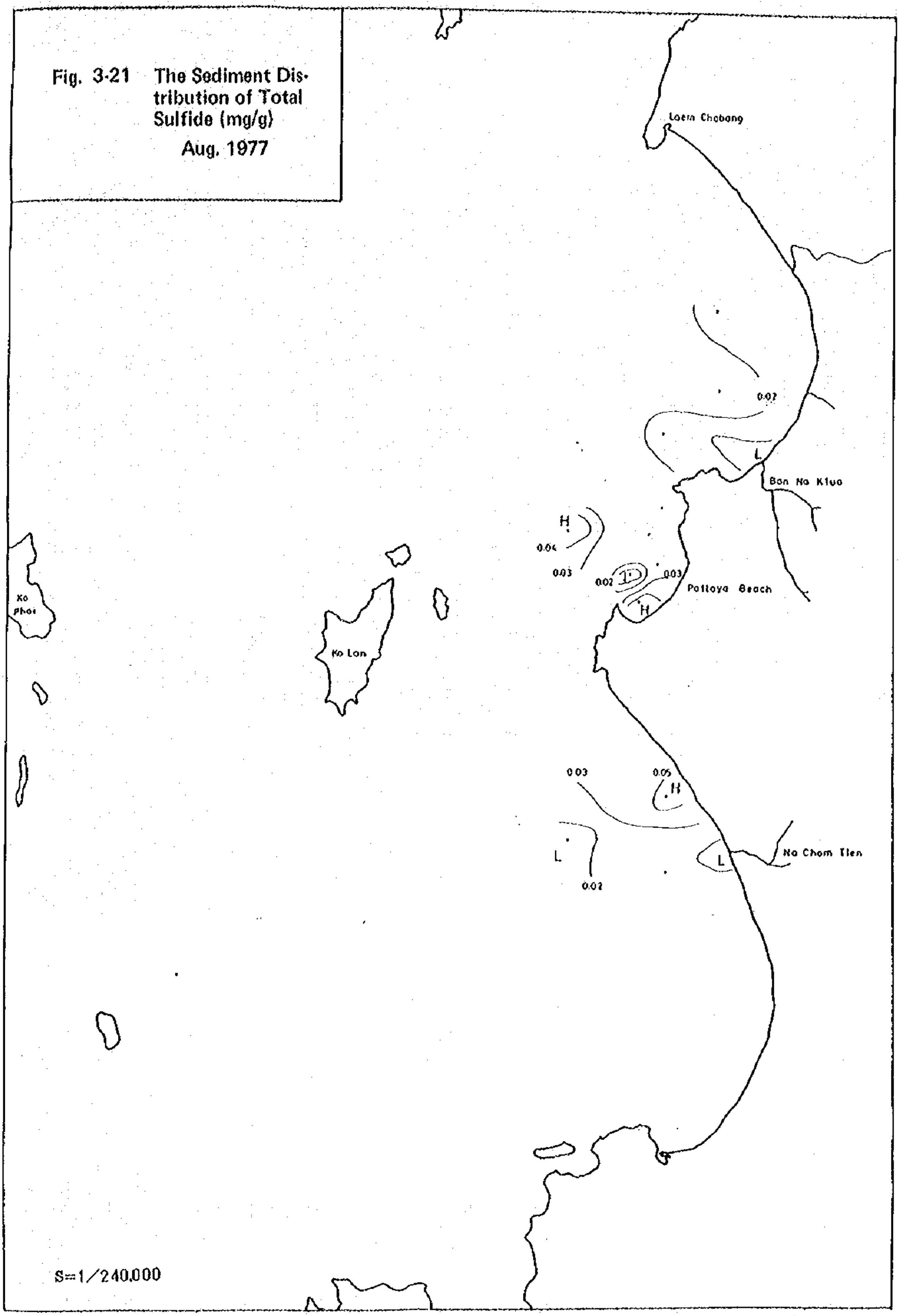
* Total-S

Fig. 3.21 shows the distribution of Total-S contents. The results of the survey generally gave low values. Total-S contents are relatively low in comparison with other survey items.

* Grain size

The sediments are mostly composed of sand and contain about 10% of fine silt and colloid, excluding the river mouth.

Fig. 3-21 The Sediment Distribution of Total Sulfide (mg/g)
Aug. 1977



3-3 Attachment

3-3-1 Analytical data for water quality survey

THE RESULTS OF WATER QUALITY SURVEY

1) Sea Water

Items / Sample No.	Date	Time	Tide	Air Temperature (℃)	Depth (m)	Transparency (m)	Water Temperature (℃)	pH	Cℓ (‰)	DO (ppm)	DO Saturation Degree (%)	COD (ppm)	SS (ppm)	Total-N (μgat/ℓ)	Organic-N (μgat/ℓ)	NO$_3$-N (μgat/ℓ)	NO$_2$-N (μgat/ℓ)	NH$_4$-N (μgat/ℓ)	Total-P (μgat/ℓ)	Organic-P (μgat/ℓ)	PO$_4$-P (μgat/ℓ)	TOC (mg/ℓ)	CN ratio (C/N)	n-Hexane Extract (ppm)
St. 1 .H	8.23	12:57	High	28.0	8.20	3.0	30.1	8.35	15.7.	4.77	101.6	1.03	5	6.8	0.11	〈0.05	〈0.05	6.69	1.18	0.89	0.29	4	270	—
1 .L		07:05	Low	27.0	6.05	3.0	29.2	8.37	15.2	6.63	96.6	1.46	4	3.8	0.29	〈0.05	〈0.05	3.51	0.98	0.63	0.30	6	490	
St. 2 .H	8.23	13:25	High	27.2	6.60	2.7	30.0	8.37	16.0	6.88	102.8	0.97	5	3.6	0.23	0.08	〈0.05	3.29	0.94	0.58	0.36	6	520	—
2 .L		07:25	Low	27.0	5.30	1.9	29.6	8.28	15.7	6.51	96.2	1.54	8	3.6	0.25	〈0.05	〈0.05	3.35	1.26	0.89	0.37	6	520	
St. 3 .H. 0	8.23	12:37	High	27.5	10.30	6.0	30.0	8.36	16.2	6.86	102.6	0.99	5	3.2	0.49	〈0.05	〈0.05	2.71	0.76	0.71	〈0.05	6	580	—
3 .H. 5							30.1	8.32	16.5	6.24	94.0	0.85	5	2.8	0.32	0.45	0.11	1.92	0.94	0.55	0.39	5	690	
3 .L. 0		06:50	Low	27.0	8.80	4.0	29.2	8.33	15.7	6.32	92.6	1.86	4	18	0.03	0.13	〈0.05	18.0	0.90	0.53	0.37	2	99	
3 .L. 5							29.1	8.33	15.8	6.63	97.1	1.54	4	4.8	0.10	〈0.05	〈0.05	4.70	0.98	0.54	0.44	6	390	
St. 4 .H. 0	8.23	12:10	High	28.0	11.00	5.0	29.4	8.30	16.6	6.46	96.0	1.05	5	16	0.55	0.05	〈0.05	15.4	0.62	0.33	0.29	6	120	—
4 .H. 5							30.0	8.32	16.5	6.26	94.0	1.40	6	4.7	0.18	0.13	〈0.05	4.38	0.66	0.61	〈0.05	6	400	
4 .L. 0		06:25	Low	27.0	7.90	4.5	29.4	8.34	15.9	6.59	97.1	1.31	4	4.5	0.15	0.05	〈0.05	4.30	0.76	0.44	0.32	5	430	
4 .L. 5							29.2	8.32	16.2	6.28	92.5	1.40	4	9.1	0.06	0.23	0.13	8.68	0.83	0.33	0.50	4	210	
St. 5 .H	8.20	08:12	High	27.5	6.30	4.0	29.1	8.33	15.1	6.26	90.9	2.16	2	14	0.07	0.23	〈0.05	13.7	2.63	2.00	0.63	6	130	〈 1
5 .L		13:25	Low	28.0	5.10	3.5	29.6	8.39	14.9	6.65	97.4	1.68	2	6.4	0.10	0.08	〈0.05	6.21	0.83	0.44	0.39	6	290	〈 1
St. 6 .H	8.20	08:45	High	27.5	7.00	5.0	29.1	8.32	15.1	6.42	93.2	1.80	2	14	0.10	0.20	〈0.05	13.7	0.83	0.78	〈0.05	9	130	〈 1
6 .L		13:38	Low	28.0	5.90	4.0	29.6	8.36	15.0	6.84	100.3	1.56	2	8.0	0.27	0.08	〈0.05	7.65	0.90	0.37	0.54	5	240	〈 1
St. 7 .H	8.20	08:55	High	27.5	6.70	5.5	29.8	8.44	15.1	6.67	98.2	2.18	2	14	0.61	〈0.05	〈0.05	13.4	1.04	0.57	0.47	7	140	〈 1
7 .L		13:49	Low	27.6	5.90	4.5	29.8	8.47	15.0	6.86	100.8	1.56	2	5.5	0.19	0.05	〈0.05	5.26	1.08	0.65	0.43	4	340	1
St. 8 .H	8.20	07:50	High	27.5	4.60	4.6	29.0	8.41	15.1	6.21	90.2	2.18	2	5.8	0.06	〈0.05	〈0.05	5.74	1.01	—	1.60	10	330	〈 1
8 .L		13:10	Low	28.0	3.90	3.5	29.7	8.42	15.1	6.65	97.8	1.74	3	2.9	0.05	〈0.05	〈0.05	2.88	1.04	0.55	0.49	8	640	〈 1
St. 9 .H	8.20	07:38	High	27.5	4.80	4.7	29.7	8.40	15.0	6.46	94.8	1.76	2	6.7	0.03	0.10	〈0.05	6.57	0.98	0.51	0.47	5	270	〈 1
9 .L		13:01	Low	29.7	4.00	3.5	29.7	8.40	15.2	6.59	96.9	1.40	2	7.5	0.17	〈0.05	〈0.05	7.33	1.01	0.60	0.41	4	250	〈 1
St.10.H. 0	8.27	14:40	High	27.1	17.30	7.0	30.3	8.32	17.3	6.19	94.4	1.21	2	1.9	0.18	〈0.05	〈0.05	1.72	0.55	0.50	〈0.05	5	1000	—
10.H. 5							30.4	8.22	16.2	6.03	90.9	1.80	2	7.7	0.31	0.08	〈0.05	7.33	0.62	0.57	〈0.05	5	250	
10.H.10							29.9	8.21	17.5	5.55	84.3	1.07	3	0.21	0.12	〈0.05	0.09	〈0.05	0.66	0.51	〈0.05	5	9200	
10.L. 0		08:37	Low	29.0	15.30	10.0	30.1	8.24	16.6	6.19	93.2	1.15	2	12	0.03	0.20	〈0.05	11.8	0.44	0.39	〈0.05	4	150	
10.L. 5							30.0	8.32	17.1	6.09	92.1	1.33	1	13	0.05	0.05	〈0.05	12.9	0.69	0.64	〈0.05	4	140	
10.L.10							29.9	8.28	17.4	4.97	75.3	1.37	2	12	0.48	0.50	0.32	10.7	1.04	0.86	0.18	4	150	
St.11.H. 0	8.27	15:10	High	27.0	21.20	8.5	30.1	8.32	17.0	6.32	95.6	0.91	1	3.0	0.03	〈0.05	〈0.05	2.97	0.55	0.50	〈0.05	4	620	—
11.H. 5							30.2	8.24	17.2	6.11	93.0	1.66	2	10	〈0.02	0.08	〈0.05	10.0	0.76	0.71	〈0.05	6	180	
11.H.10							29.9	8.22	17.5	5.74	87.1	0.91	3	1.9	0.34	0.61	〈0.05	0.97	0.83	0.78	〈0.05	5	4700	—
11.L. 0		09:10	Low	27.3	18.75	13.0	30.0	8.32	16.6	6.38	96.0	1.09	1	1.4	0.09	〈0.05	〈0.05	1.31	0.83	0.78	〈0.05	4	1300	
11.L. 5							29.8	8.22	16.6	6.19	92.7	1.68	1	0.52	0.27	〈0.05	〈0.05	0.25	0.76	0.71	〈0.05	2	3400	—
11.L.10							29.9	8.22	17.5	5.57	84.5	1.09	2	3.4	0.14	0.68	0.19	2.39	1.01	0.96	〈0.05	8	630	
St.12	8.28	11:05	Low	27.0	17.00	9.0	30.0	8.27	17.4	6.13	93.1	1.70	4	2.4	0.09	0.05	〈0.05	2.23	0.48	0.43	〈0.05	4	770	—
St.13.H. 0	8.24	12:41	High	28.0	10.50	8.0	30.0	8.34	17.0	6.44	97.4	1.13	14	1.3	0.14	〈0.05	〈0.05	1.13	0.34	0.29	〈0.05	4	1400	—
13.H. 5							30.0	8.38	17.0	6.36	96.1	1.05	5	2.7	0.17	〈0.05	〈0.05	2.50	0.37	0.32	〈0.05	4	690	
13.L. 0		06:02	Low	27.0	8.85	5.0	29.4	8.29	16.9	5.67	84.6	0.40	10	2.4	0.03	0.78	0.06	1.53	0.48	0.08	0.40	5	800	
13.L. 5							30.0	8.28	17.2	5.47	82.7	0.40	4	5.7	0.08	0.61	〈0.05	5.01	0.55	0.35	0.20	7	340	
St.14.H. 0	8.24	14:27	High	27.8	10.40	7.0	30.0	8.37	16.6	6.63	99.7	0.99	4	15	〈0.02	〈0.05	〈0.05	15.3	0.62	0.57	〈0.05	3	120	—
14.H. 5							29.8	8.39	16.8	6.48	97.5	1.52	4	9.5	0.05	〈0.05	〈0.05	9.40	0.76	0.61	〈0.05	5	200	
14.L. 0		07:28	Low	27.0	9.65	7.5	29.6	8.32	16.6	5.98	89.3	0.79	4	1.2	0.02	〈0.05	〈0.05	1.19	0.55	0.50	〈0.05	5	1600	
14.L. 5							29.7	8.32	16.2	5.82	86.5	0.87	3	2.2	0.30	0.25	0.11	1.63	0.66	0.61	〈0.05	7	880	
St.15.H. 0	8.24	14:05	High	27.8	9.60	7.0	30.0	8.33	16.7	6.50	97.9	1.13	5	2.0	0.22	〈0.05	〈0.05	1.73	0.55	0.50	〈0.05	4	930	—
15.H. 5							29.8	8.38	16.9	6.50	97.7	1.39	3	1.4	0.47	〈0.05	〈0.05	0.88	0.62	0.57	〈0.05	5	1600	
15.L. 0		07:10	Low	27.0	9.35	7.0	29.6	8.33	16.9	6.05	90.7	0.73	4	10	〈0.02	0.18	〈0.05	9.88	0.69	0.38	0.31	8	180	
15.L. 5							29.7	8.33	16.9	5.90	88.5	0.61	3	2.3	0.05	0.33	〈0.05	1.89	0.73	0.35	0.38	4	810	
St.16.H. 0	8.24	13:10	High	27.8	10.10	8.0	30.0	8.39	16.9	6.59	99.4	1.33	2	1.2	0.05	〈0.05	〈0.05	1.13	0.55	0.50	〈0.05	4	2000	—
16.H. 5							29.9	8.39	17.0	6.57	99.1	0.85	2	11	〈0.02	〈0.05	〈0.05	11.0	0.69	0.64	〈0.05	5	180	
16.L. 0		06:27	Low	27.0	5.60	–〉5.6	29.7	8.34	17.1	5.92	89.0	0.85	3	1.2	0.01	0.28	〈0.05	0.88	0.55	0.50	〈0.05	6	1500	
16.L. 5							29.8	8.25	17.1	5.85	88.3	0.57	2	5.1	0.02	0.51	〈0.05	4.54	0.62	0.57	〈0.05	5	380	
St.17.H. 0	8.24	13:32	High	27.5	12.10	7.0	29.9	8.38	17.2	6.44	97.4	0.89	3	13	0.05	〈0.05	〈0.05	12.9	0.59	0.54	〈0.05	5	150	—
17.H. 5							29.7	8.38	17.3	6.26	94.4	1.39	4	4.0	0.19	〈0.05	〈0.05	3.76	0.69	0.64	〈0.05	5	480	
17.L. 0		06:50	Low	27.0	12.70	8.0	29.7	8.36	17.0	6.05	91.0	0.77	2	2.6	0.31	0.18	〈0.05	2.08	0.98	0.58	0.40	6	710	
17.L. 5							29.8	8.35	17.0	6.05	91.2	1.01	4	1.7	0.40	〈0.05	〈0.05	1.25	0.76	0.71	〈0.05	4	1100	
St.18	8.28	12:00	Low	28.7	23.50	12.5	29.9	8.31	17.4	6.28	95.3	1.33	3	0.94	0.08	〈0.05	〈0.05	0.81	0.34	0.29	〈0.05	5	2000	—
St.19	8.28	10:00	Low	27.2	16.20	13.0	29.9	8.22	16.4	6.26	93.7	1.07	〈 1	0.88	0.33	〈0.05	〈0.05	0.50	0.40	0.35	〈0.05	4	2100	—

2) River Water

Items / Sample No.	Date	Time	Tide	Air Temperature (℃)	Transparency (cm)	Water Temperature (℃)	pH	Cℓ (‰)	DO (ppm)	DO Saturation (%)	COD (ppm)	SS (ppm)	Total-N (μgat/ℓ)	Organic-N (μgat/ℓ)	NO$_3$-N (μgat/ℓ)	NO$_2$-N (μgat/ℓ)	NH$_4$-N (μgat/ℓ)	Total-P (μgat/ℓ)	Organic-P (μgat/ℓ)	PO$_4$-P (μgat/ℓ)	TOC (mg/ℓ)	CN-ratio (C/N)
St. R. 1. H.	8.26	14:30	High	30.0	〉30	33.0	8.39	15.9	7.90	125.1	2.59	15	4.5	0.15	1.42	0.43	2.50	1.68	0.86	0.82	4	410
R. 1. L.		07:20	Low	26.0	10.0	28.3	7.54	12.6	〈0.01	—	16.8	37	710	2.3	1.66	1.05	705	54	3.00	51	31	9.6
St. R. 2. L.	8.26	07:43	Low	26.0	1.5	27.8	6.85	0.4	〈0.01	—	91.8	592	1200	4.3	9.68	〈0.05	1186	286	1.33	153	78	8.3
St. R. 3. L.	8.26	08:10	Low	27.0	13.5	28.2	7.34	10.9	4.86	66.3	15.4	34	39	0.43	4.21	0.96	33.5	5.43	2.18	3.25	30	92
St. R. 4. H.	8.26	15:00	High	28.5	〉30	31.4	8.41	16.5	6.86	105.8	1.98	8	2.6	0.20	1.61	〈0.05	0.78	1.12	0.97	0.15	3	690
R. 4. L.	8.27	07:30	Low	26.7	〉30	29.7	7.81	16.8	4.53	67.9	3.31	13	1.4	〈0.02	1.36	〈0.05	0.05	1.58	0.90	0.68	6	1400

The Results of Coliform Bacteria Survey

Items / Sample No.	Depth (m)	Water Temperature (°C)		Coliform Bacteria (MPN/100mℓ)	
		First Time	Second Time	First Time	Second Time
St. 1	1.1	30.7	30.8	2	33
2	1.4	30.5	31.0	5	1,600
3	-	-	-	-	-
4	0.9	30.8	31.0	170	540
5	3.6	30.8	30.7	< 2	46
6	3.2	30.8	30.2	< 2	49
7	1.0	30.2	30.2	22	33
8	0.9	30.9	30.4	14	540
9	0.9	30.4	30.3	< 2	> 2,400
10	4.7	30.6	30.3	< 2	49
11	4.0	30.4	30.2	< 2	9
12	4.2	30.3	30.2	< 2	33
13	2.9	30.3	30.0	280	33
14	3.0	30.7	30.1	2	11
15	3.5	30.4	30.0	2	2

Sampling Date : First Time 18th Aug.
Second Time 29th Aug.

3-3-2 Analytical data for sediment survey

Analytical Data for Sediment Survey

1) Sea

Items / Sample No.	Ignission loss (%)	Total-Sulfide (mg/g)	TOC (mg/g)	COD (mg/g)
St. 1	4.6	0.03	0.5	1.5
St. 2	5.3	0.04	1.5	2.6
St. 4	10.6	0.02	2.9	2.5
St. 5	5.7	0.04	1.9	0.2
St. 6	4.3	0.04	2.0	1.5
St. 7	6.6	0.02	2.5	1.9
St. 8	2.9	0.04	0.9	1.1
St. 9	5.6	0.06	2.3	2.0
St.10	24.5	0.06	7.2	2.6
St.14	3.9	0.05	2.2	1.9
St.15	5.0	0.03	1.8	1.5
St.16	18.5	0.02	6.7	2.5

2) River

Items / Sample No.	Ignission loss (%)	Total-Sulfide (mg/g)	TOC (mg/g)	COD (mg/g)
St.R.1	0.7	0.01	0.7	0.6
St.R.2	3.1	0.08	5.8	3.0
St.R.3	2.7	0.06	2.5	2.2
St.R.4	1.1	0.02	0.3	0.5

Relationship between Grain Size and Weight Percent of Smaller Grain Size

Sample : No St. − 1 m ~ m) Specific Gravity 2.541

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %							100	77.9	55.2	42.4	31.9	25.5
Hydrometer	Grain Size mm	0.052	0.037	0.023	0.013	0.009	0.006	0.003	0.001				
	Weight %	18.4	16.6	11.7	8.8	8.8	8.8	7.2	7.2				

Sample : No St. − 2 m ~ m) Specific Gravity 2.534

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %							100	84.1	65.8	53.6	41.6	26.7
Hydrometer	Grain Size mm	0.050	0.035	0.022	0.013	0.0093	0.0066	0.0030	0.0013				
	Weight %	21.3	19.3	17.3	13.3	11.3	11.3	10.7	8.6				

Sample : No St. − 4 m ~ m) Specific Gravity 2.547

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %							100	83.1	68.8	46.8	37.7	33.8
Hydrometer	Grain Size mm	0.051	0.037	0.023	0.013	0.0095	0.0067	0.0033	0.0013				
	Weight %	26.8	23.6	20.2	18.3	16.1	15.1	13.6	9.5				

Sample : No St. − 5 m ~ m) Specific Gravity 2.513

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %					100	98.8	83.9	66.5	55.3	41.6	30.4	21.2
Hydrometer	Grain Size mm	0.052	0.036	0.023	0.013	0.0097	0.0069	0.0033	0.0013				
	Weight %	19.7	18.7	13.6	11.5	10.5	9.4	9.2	7.8				

Sample : No St. − 6 m ~ m Specific Gravity 2.549

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %						100	98.8	83.0	59.9	46.5	35.5	29.4
Hydrometer	Grain Size mm	0.051	0.037	0.023	0.013	0.0099	0.0069	0.0035	0.0014				
	Weight %	22.2	18.2	12.2	10.2	10.2	10.2	8.6	7.6				

Sample : No St. − 7 m ~ m Specific Gravity 2.561

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %							100	97.6	95.2	92.8	70.2	24.0
Hydrometer	Grain Size mm	0.052	0.037	0.023	0.013	0.0097	0.0069	0.0034	0.0014				
	Weight %	15.7	13.8	9.9	9.9	7.9	7.9	7.4	7.4				

Sample : No St. − 8 m ~ m Specific Gravity 2.555

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %							100	68.5	42.1	26.9	17.8	11.7
Hydrometer	Grain Size mm	0.053	0.037	0.023	0.013	0.0098	0.0069	0.0034	0.0014				
	Weight %	8.4	7.6	7.6	5.1	5.1	5.1	5.4	5.4				

Sample : No St. − 9 m ~ m Specific Gravity 2.556

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %							100	95.4	92.0	88.6	79.5	47.5
Hydrometer	Grain Size mm	0.050	0.035	0.022	0.013	0.0094	0.0067	0.0033	0.0013				
	Weight %	22.6	17.9	17.0	12.3	11.4	10.4	9.9	8.0				

Sample : No St. − 10 (m ~ m) Specific Gravity 2.554

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %						100	87.5	69.4	59.7	55.5	45.8	41.6
Hydrometer	Grain Size mm	0.049	0.036	0.022	0.013	0.0092	0.0065	0.0033	0.0013				
	Weight %	31.5	28.0	25.7	23.5	21.3	20.3	13.2	7.5				

Sample : No St. − 14 m ~ m Specific Gravity 2.545

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %							100	78.0	61.2	48.6	28.7	20.3
Hydrometer	Grain Size mm	0.050	0.036	0.022	0.013	0.0094	0.0066	0.0033	0.0013				
	Weight %	16.0	13.4	11.7	9.9	9.9	9.1	6.5	6.5				

Sample : No St. − 15 (m ~ m) Specific Gravity 2.598

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %							100	88.1	70.3	56.5	36.7	24.8
Hydrometer	Grain Size mm	0.051	0.036	0.023	0.013	0.0095	0.0067	0.0033	0.0013				
	Weight %	15.2	12.5	10.9	10.1	9.3	9.3	7.7	7.7				

Sample : No St. − 16 (m ~ m) Specific Gravity 2.465

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %							100	80.0	66.2	57.4	39.9	32.4
Hydrometer	Grain Size mm	0.050	0.036	0.023	0.013	0.0096	0.0068	0.0034	0.0014				
	Weight %	25.2	21.0	16.8	15.7	14.7	12.6	11.5	9.2				

Sample : No St. − R − 1 m ~ m Specific Gravity 2.593

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %					100	99.4	75.0	31.1	11.6	4.9	1.2	0
Hydrometer	Grain Size mm												
	Weight %												

Sample : No St. − R − 2 m ~ m Specific Gravity 2.495

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %						100	92.6	69.3	62.4	42.9	33.4	27.1
Hydrometer	Grain Size mm	0.049	0.034	0.022	0.013	0.0092	0.0065	0.0032	0.0013				
	Weight %	24.6	22.9	22.0	20.2	18.5	18.5	17.6	14.9				

Sample : No St. − R − 3 m ~ m Specific Gravity 2.411

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %						100	94.2	87.2	77.9	61.5	35.8	24.0
Hydrometer	Grain Size mm	0.053	0.037	0.023	0.013	0.0097	0.0069	0.0034	0.0014				
	Weight %	22.8	21.9	20.9	19.9	18.9	18.9	17.9	15.9				

Sample : No St. − R − 4 m ~ m Specific Gravity 2.591

Sieve	Grain Size mm	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight %					100	99.9	97.9	71.6	10.0	2.0	0.2	0.1
Hydrometer	Grain Size mm												
	Weight %												

CHAPTER 4 FINDINGS OF SURVEY

CHAPTER 4 FINDINGS OF SURVEY

4.1 Current

The characteristics of tidal currents will be studied on the basis of the harmonic constants obtained from the continuous 15-day observation and the continuous 25-hour observation.

Generally, the type of the tidal current is classified as follows.

$\frac{K_1 + O_1}{M_2 + S_2} < 0.5$: : Semidiurnal type

$0.5 < \frac{K_1 + O_1}{M_2 \quad S_2} < 1.5$: Mixed type

$1.5 < \frac{K_1 + O_1}{M_2 \quad S_2}$: Diurnal type

Table 4.1 shows the coefficients which were obtained at each survey station by calculating the equation explained above.

Table 4.1

Station	St.A	St.B	St.C	St.D	St.E	St.F
$\frac{K_1+O_1}{M_2+S_2}(=\frac{M_1}{M_2})$	0.64	0.67	0.42	0.40	0.35	0.31

The following equation has been used for the data of the continuous 25-hour observation;

$$\frac{K_1+O_1}{M_2+S_2} = \frac{M_1}{M_2}$$

From the above-mentioned table 4.1, it is obvious that station A and B have a mixed type, while the other four stations C, D, E and F have a semidiurnal type. This shows that the offshore of Pattaya beach is the area at which the regular tidal current from the outer sea encounters the mixed type tidal current influenced by the topographic condition. In other words, the study area is considered to be divided into two sea areas such as South of Pattaya and North of Pattaya. This pattern is clearly shown by the current diagram. The average current directions at the time of the flood tide, the ebb tide and the turn of tidal current are shown in Fig. 4.1, 4.2, 4.3 and 4.4. At the time of the change in current direction toward the ebb tide from the flood tide, the flow near Laem Khlong located at the north end of Pattaya beach tends to join the strong main current which flows in the west sea water area of Ko Lan.

On the other hand, at the time of change in the current direction toward the flood tide from the ebb tide, the flow in South of Pattaya changes the current direction in advance, and then the flow near Laem Khlong has the tendency of going down to the south along Pattaya beach.

This is also recognised from the constant current diagram which shows the constant current toward Ko Lan from Laem Khlong.

Therefore, the clockwise current in the Upper Gulf heads for the middle of the Gulf at the offshore of Laem Khlong and then flows out toward the outer Gulf.

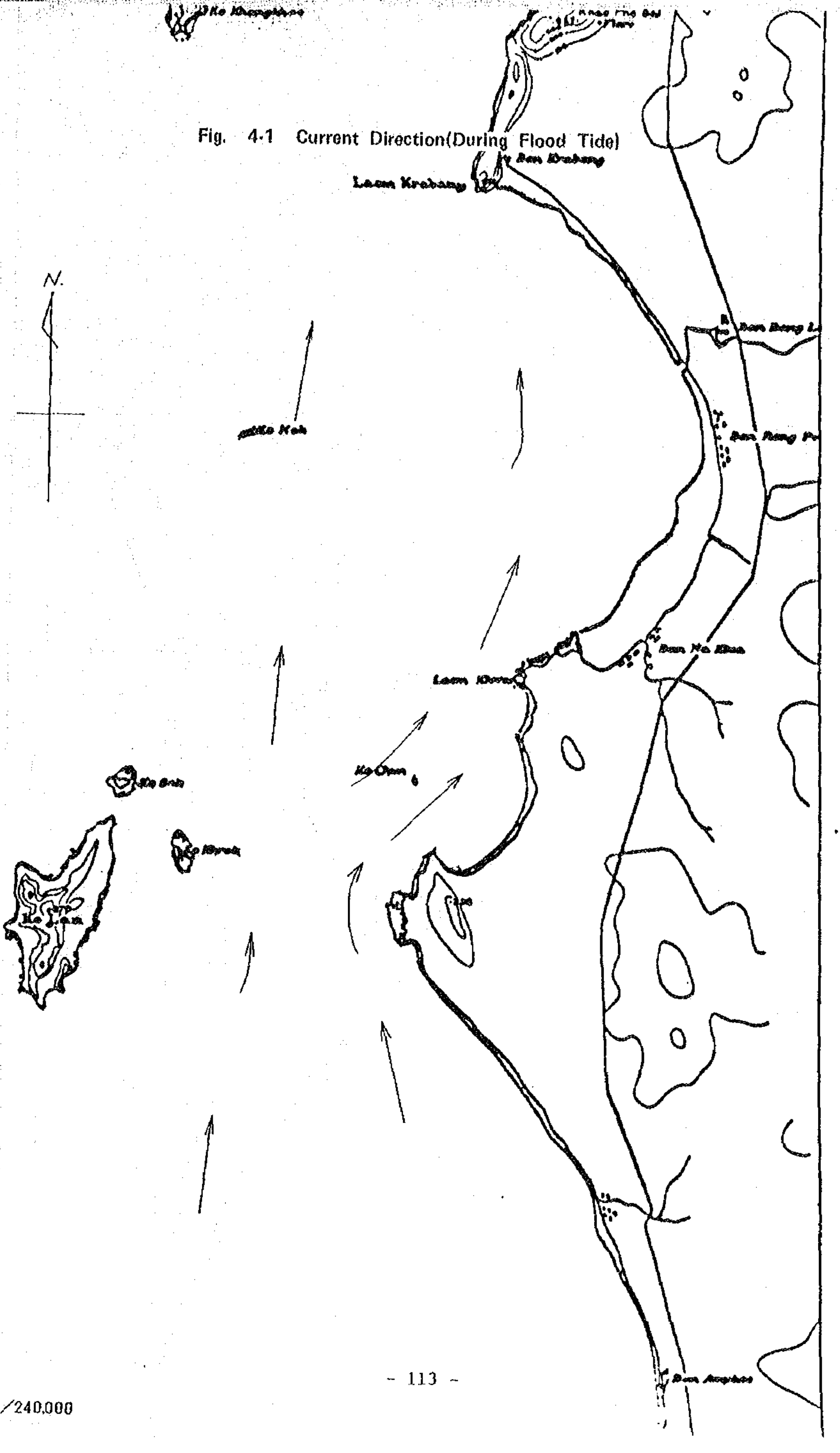


Fig. 4-1 Current Direction(During Flood Tide)

S=1/240,000

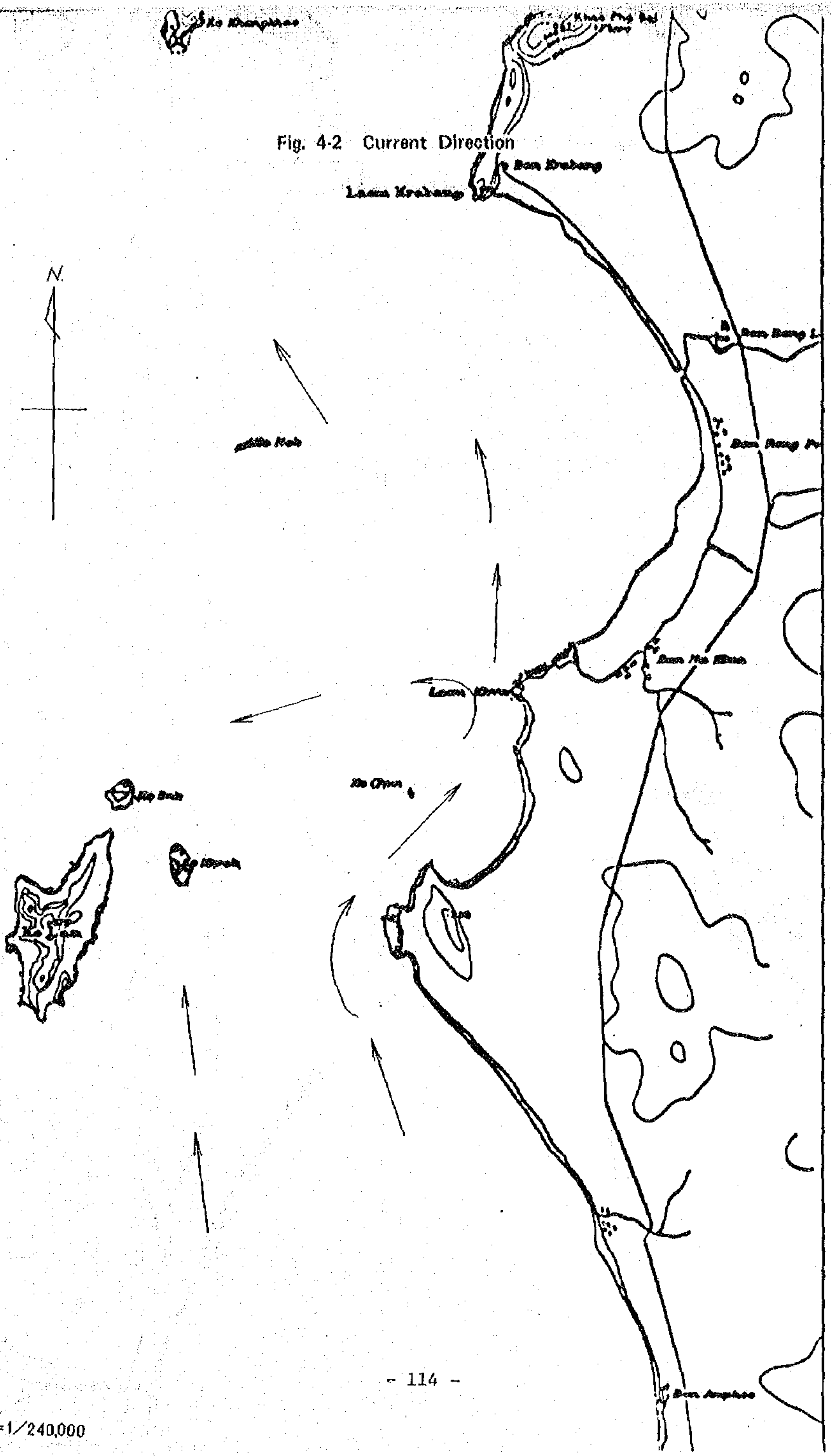
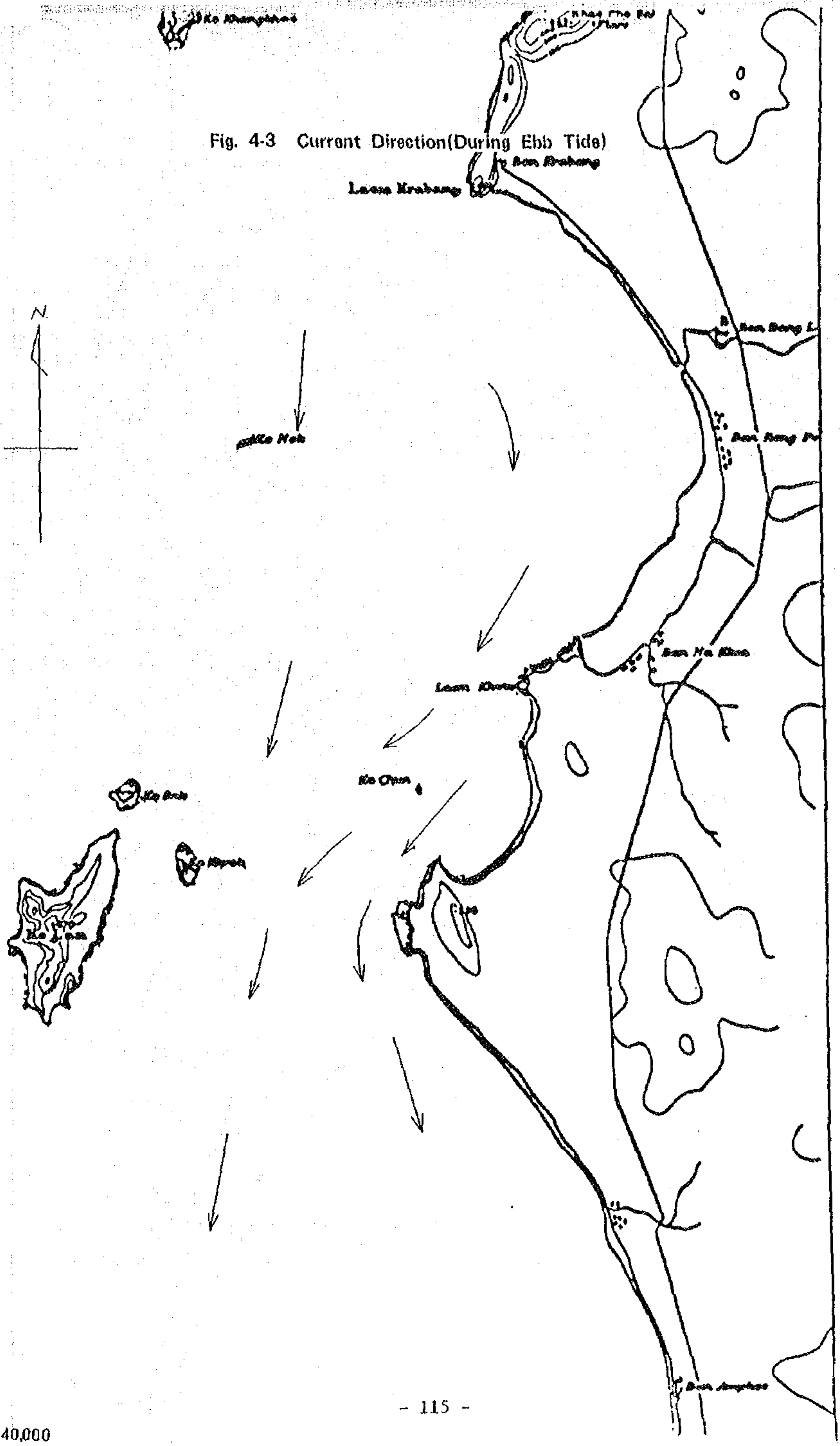


Fig. 4-2 Current Direction

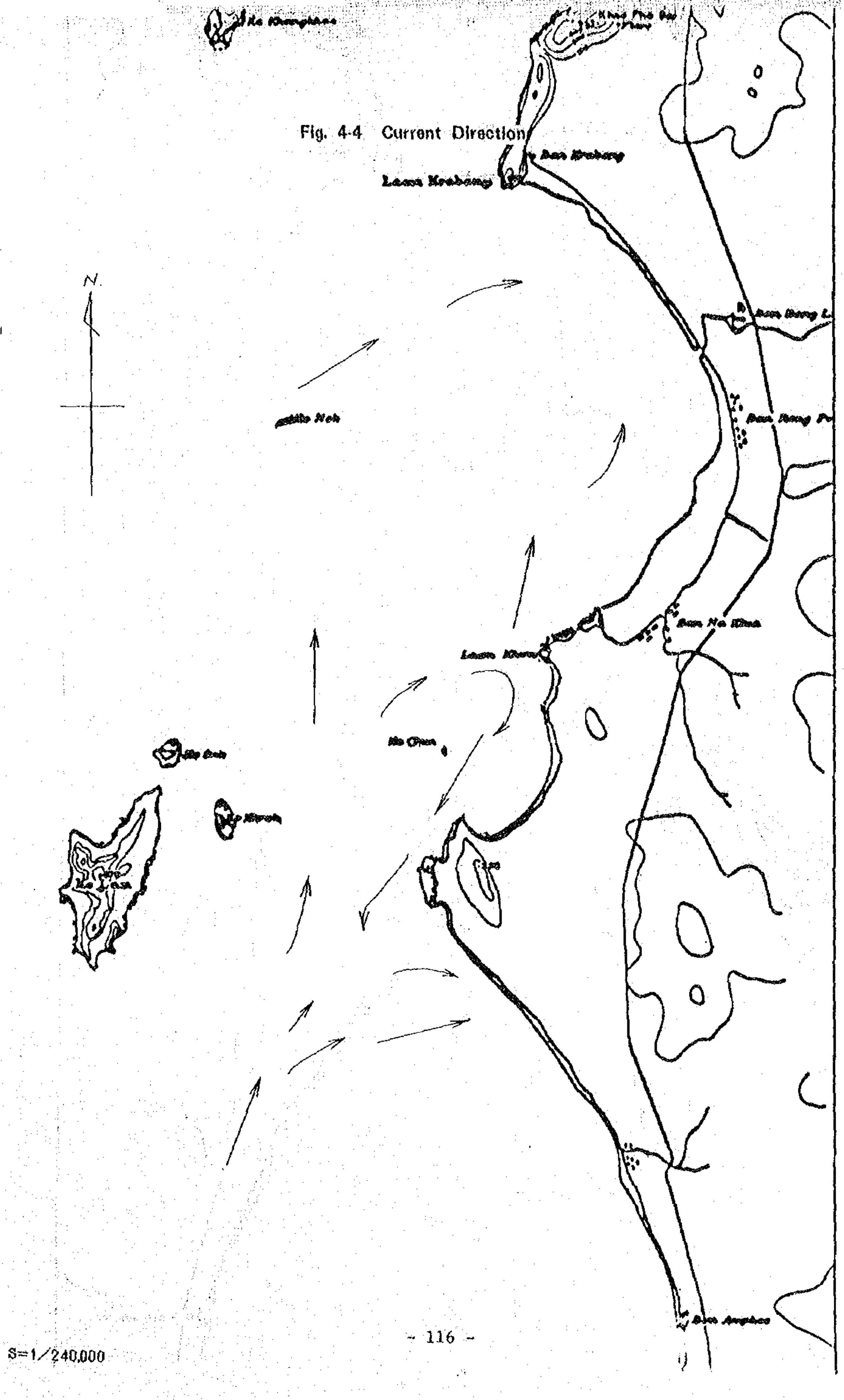
S=1/240,000

Fig. 4-3 Current Direction(During Ebb Tide)



S=1/240,000

Fig. 4-4 Current Direction



S=1/240,000

4.2 Water and Sediment

The water quality of Pattaya is polluted to some extent, although it is not a critical condition from the view point as an ocean resort. The pollution problem has resulted from not only the waste water discharged directly into the Pattaya sea but also the polluted sea water of the Upper Gulf.

As regard the pollution problem in the Upper Gulf of Thailand, AIT and Dr. Ludwig calculated the average BOD value in the Upper Gulf on the basis of the flushing time and the total load of pollutants. The result was about 2 ppm in BOD value. While, about 1 ppm COD value was observed in the offshore area in our water quality survey. Although the correlation between BOD and COD values is uncertain, these results show comparatively good condition in the Gulf of Thailand.

The waste water discharged from the tapioca factories and the residential area is the main source of pollutants. Since most of the tapioca factories were not in full operation, they gave no serious influence on the sea water quality. But the results of the survey show high TOC content in comparison with COD value and low SS content, pointing out that most of them were in the form which is hard to decompose; such as colloid or dessolved materials. These organic matters presumably resulted from tapioca factories and were distributed widely because of very slow sedimentation rate.

The river Na Klua and Na Chom Tien are severely polluted. Especially in the case of the river Na Klua which had almost no dissolved oxygen as well as other indicators proving that the level of pollutant contents was extraordinarily high.

According to Figs. 4.5 ∿ 4.12 which show the correlation between pollutants and chlorinity therefore the existence of a mixture of sea water and fresh water, the inflow of pollutants into the sea is easily recognized. However, the influence on the sea water quality was not of a significant nature because of the small quantity of the river water discharged during the survey period. Pollutants moved into the sea primarily by tidal fluctuation.

NA KLUA· A- BLOCK

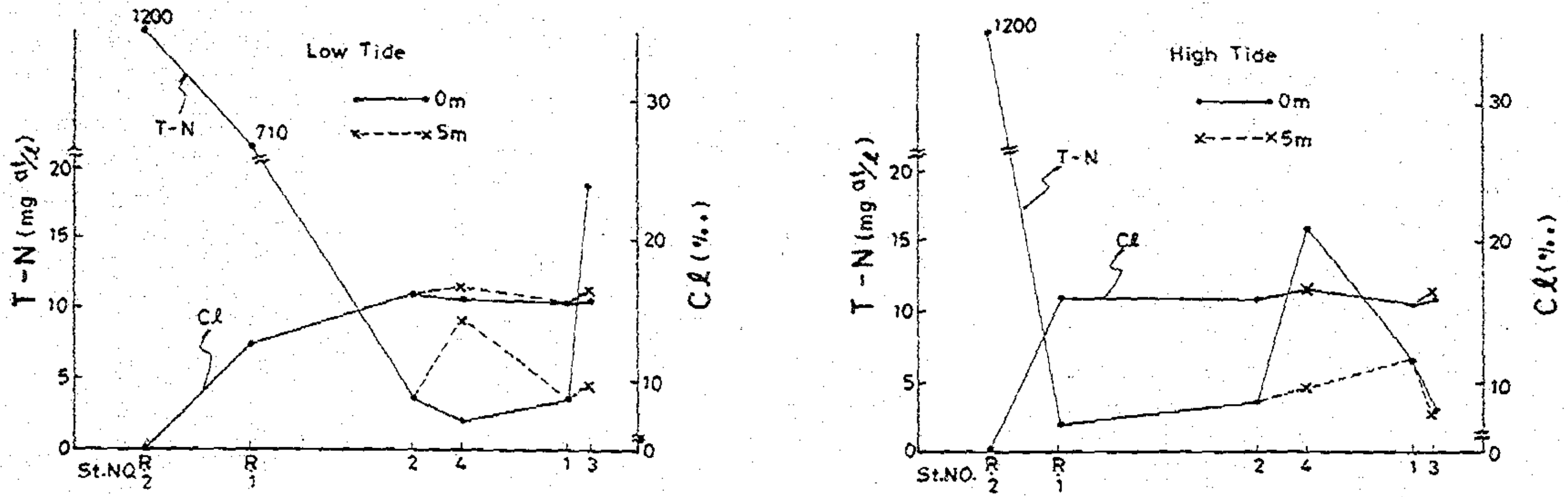


Fig. 4-5 Relations between T-N and Chlorinity (Cℓ)

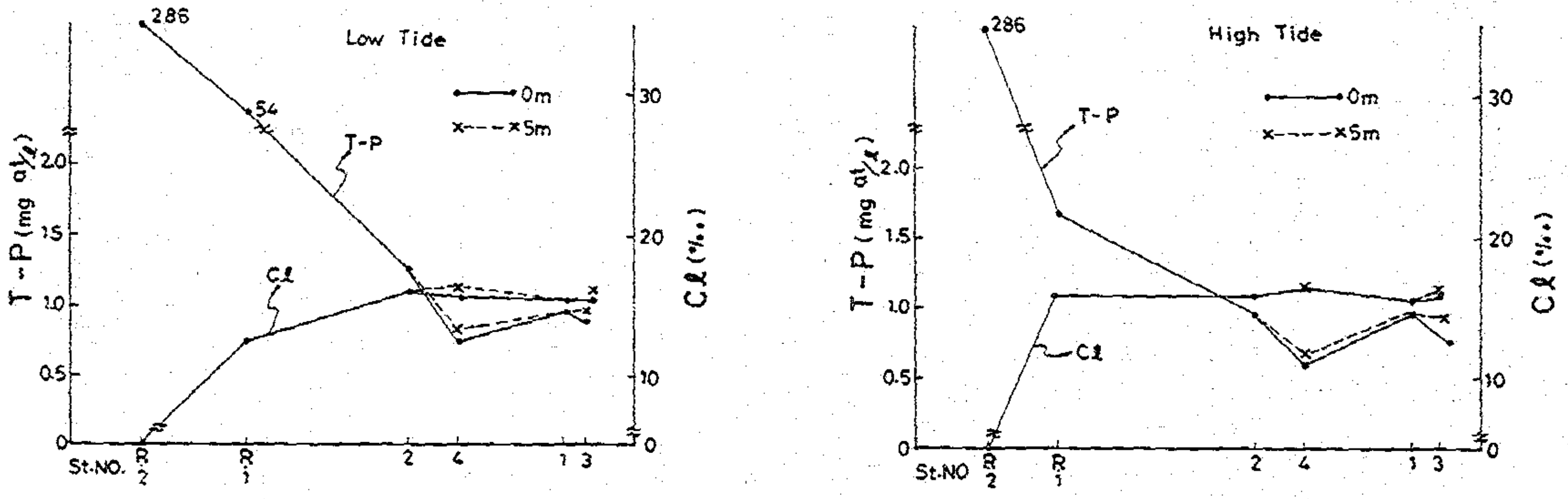


Fig. 4-6 Relations between T-P and Chlorinity (Cℓ)

NA KLUA A-BLOCK

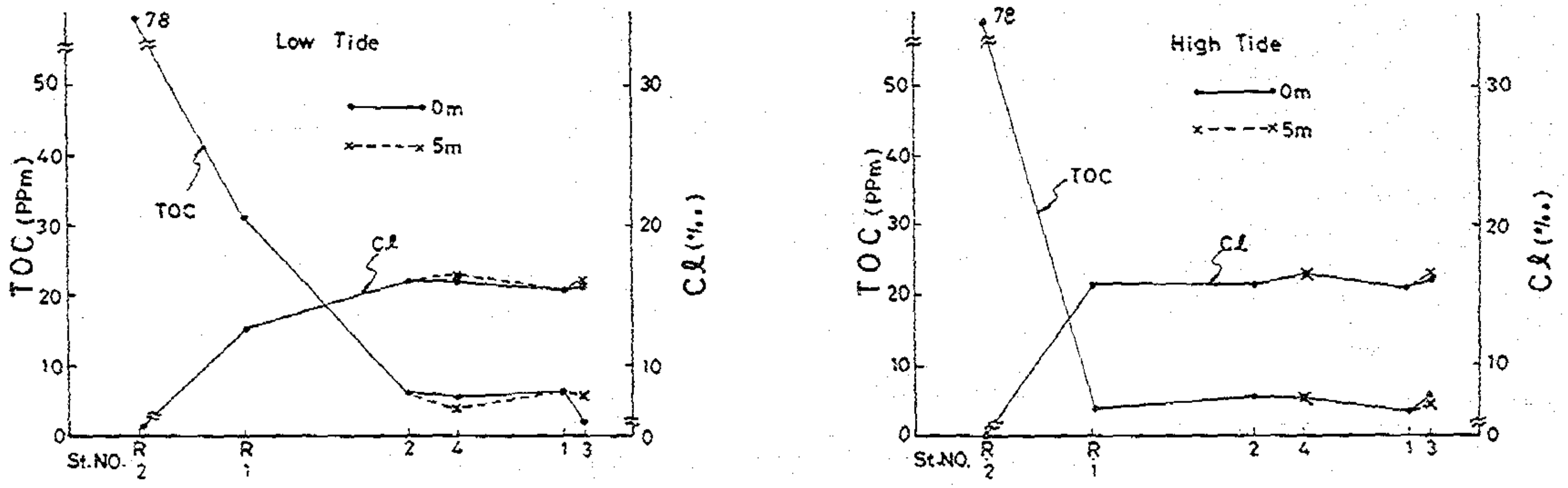


Fig. 4-7 Relations between TOC and Chlorinity (Cℓ)

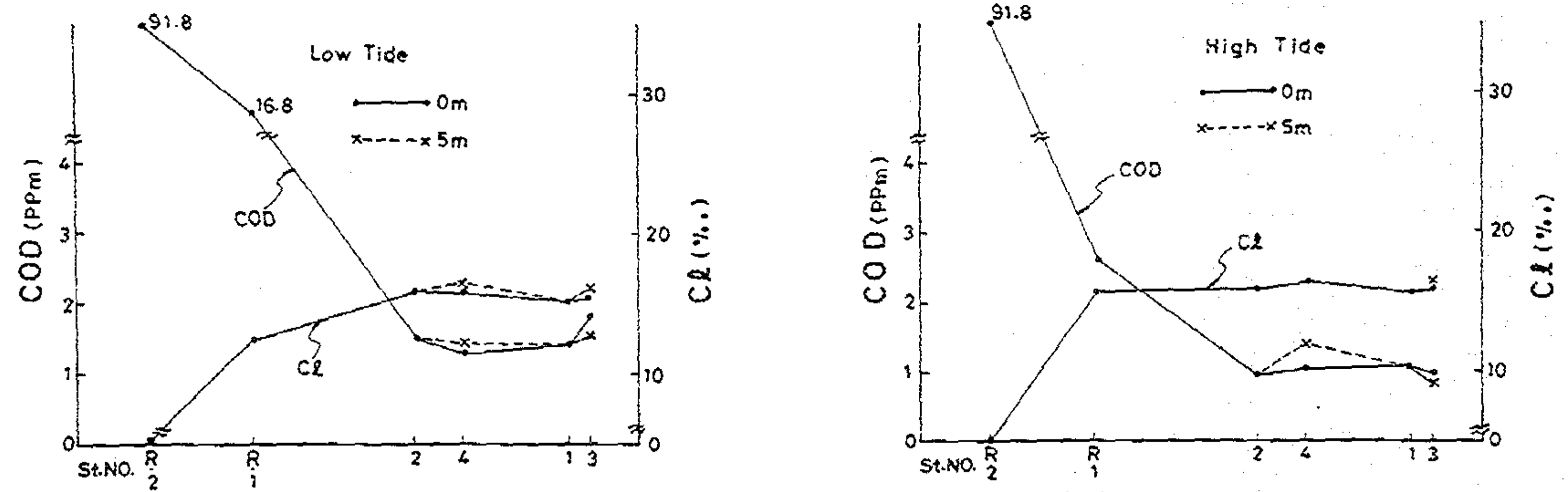


Fig. 4-8 Relations between COD and Chlorinity (Cℓ)

NA CHOM TIEM - C-BLOCK

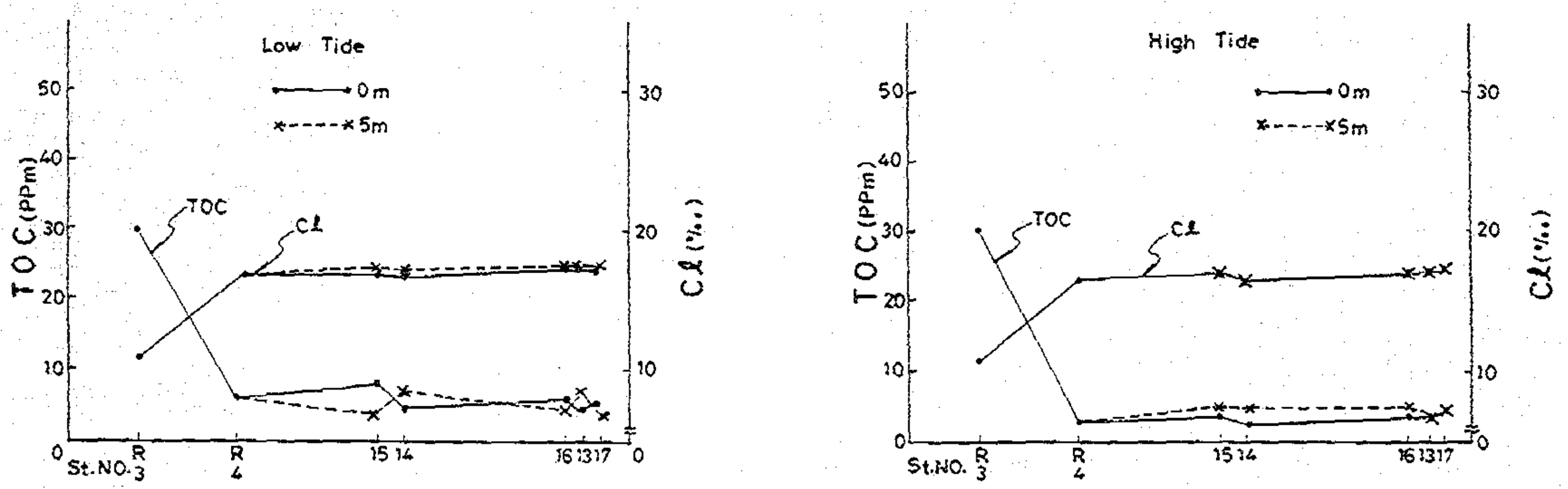


Fig. 4-9 Relation between TOC and Chlorinity (Cℓ)

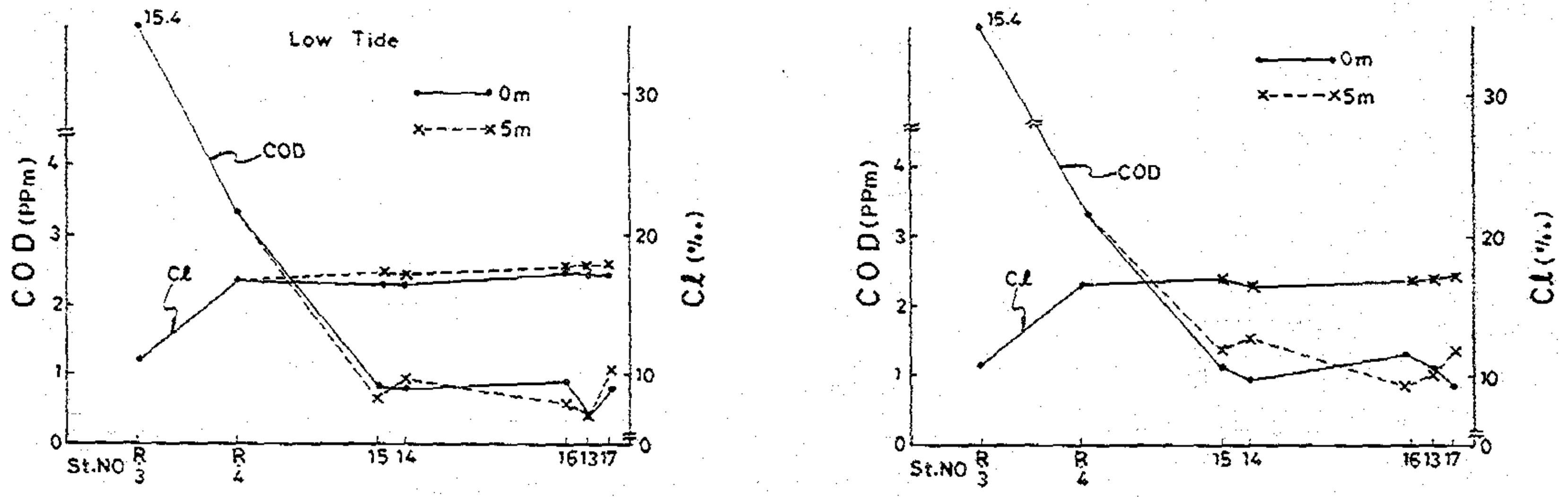


Fig. 4-10 Relations between COD and Chlorinity (Cℓ)

NA CHON TIEM C-BLOCK

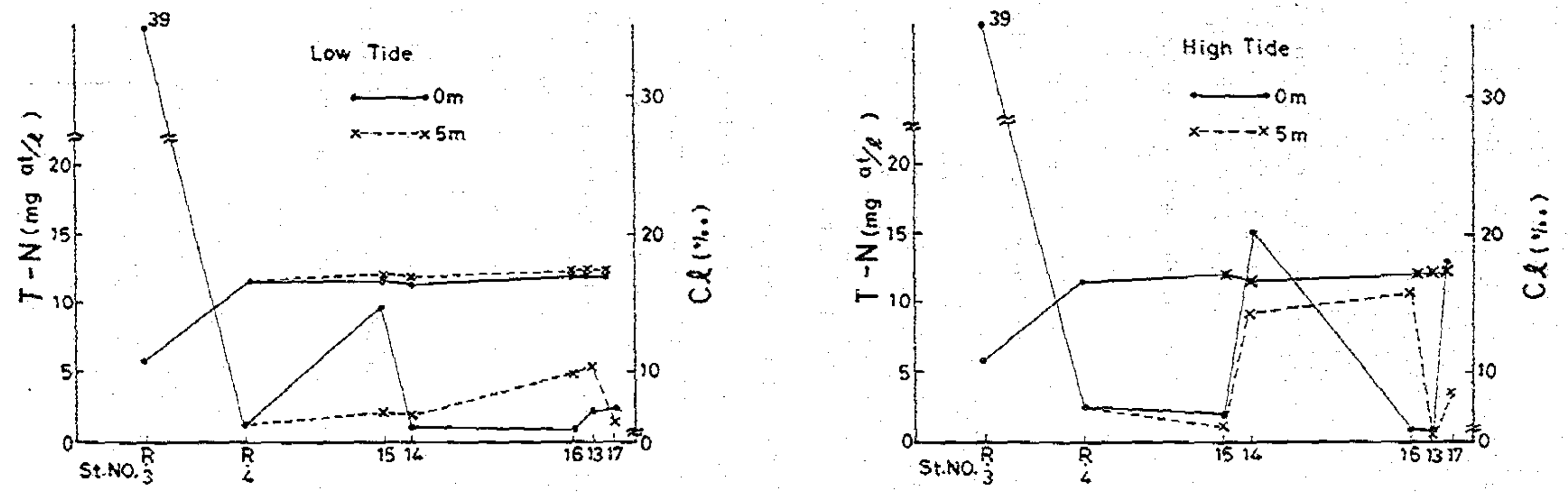


Fig. 4-11 Relations between T-N and Chlorinity (Cℓ)

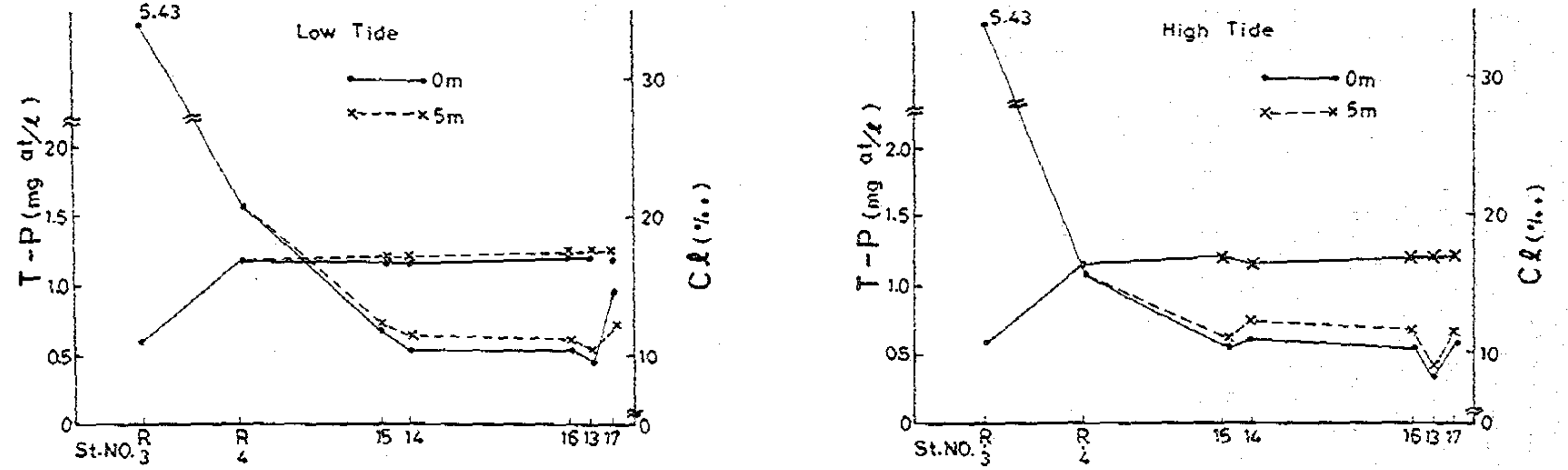


Fig. 4-12 Relations between T-P and Chlorinity (Cℓ)

Relatively good conditions were recognized in the survey of sediment. Sediment are mainly composed of sand with fine silt and colloid. Most of the colloid presumably resulted from the discharged waste water from the tapioca factories. The sea sediments had slightly higher contents of pollutents than the river sediment. The reasons of which are deducted as follows:

(1) The waste water discharged from the tapioca factories contains very fine suspended substance which is hard to resolve. As the sedimentation rate is very slow, there was less accumulation in the river and most of fine suspended substance were conveyed into the sea.

(2) Pollutants discharged into the northern part of the Upper Gulf were transported to the Pattaya sea by the clockwise constant current and were gradually deposited.

The reason that the condition of sediment was relatively clean is due perhaps to the fact that the regenerative capacity of the sea water is sufficient enough to check the pollutants.

On the other hand, the most important aspect of the sea water quality survey is to evaluate the present water quality level. It is only through this survey that the question whether or not the present water quality level is favorable for an ocean resort area, can be answered. The Japanese water quality standard for beach resorts are set up in 5 items such as pH, COD, DO, Coliform Bacteria and n-Hexan Extracts as shown in Table 4.2. This standard will be used to discuss the water quality level with regard to COD, Coliform Bacteria and n-Hexan Extracts. pH and DO can not be discussed on the same basis because of differences in water temperature and characteristics of the sea water between the Japanese sea and the Gulf of Thailand.

Table 4.2 Japanese sea water quality standard for beach resort

pH	7.8 ∿ 8.3
COD	Less than 2 PPM
DO	More than 7.5 PPM
Coliform Bacteria	Less than 1,000 MON/100 mℓ
n-Hexane Extract (Oil)	undetect

The survey area was roughly divided into 4 Blocks to analyze the local characteristics. The water quality characteristics of each Block are summarized as follows in comparison with the Japanese standard.

In Block A, only one survey station had more than 1,000 MPN of Coliform Bacteria and COD contents were less than 2 ppm at all survey stations. Moreover, the periodical surveys conducted by NEB show more than 1,000 MPN of Coliform Bacteria in some points. Although high level of pollutants was observed around the river mouth of the Na Klua, Block A shows favorable sea water conditions as a whole.

In Block B, some survey stations registered excessive values of COD, Coliform and n-Hexan Extracts in comparison with the Japanese standard. The NEB's survey also indicated excessive Coliform Bacteria along the Pattaya shoreline. Cafeful attention will be required to keep the water quality of Pattaya beach in good condition.

The water quality in Block C was relatively better than the Japanese standard. Only the river mouth of Na Chom Tien had the COD value of 3 PPM.

In Block D which includes Ko Lan, the water quality survey shows satisfactory results.

4-3 Environmental Characteristics

From the foregoing descriptions in Paras. 4-1 and 4-2, the environmental characteristics of Pataya coastal zone can be summarized as follows:

4.3.1 Existing characteristics

As to the state of the current, the effect of the clockwise constant flow at the Upper Gulf can be found also in the Pattaya coastal zone, producing a constant southward flow. However, since the velocity of the constant flow is weak, it can be safely said that this coastal zone has a relatively high sensibility in terms of the state of the current. The characteristics of the current at the offshore area of Na Klua River differ from those at the south thereof. That is to say, a remarkably varying mode of diurnal tide is found at the offshore area of Na Klua River, as compared with a relatively regular semi-diurnal tide found at the south.

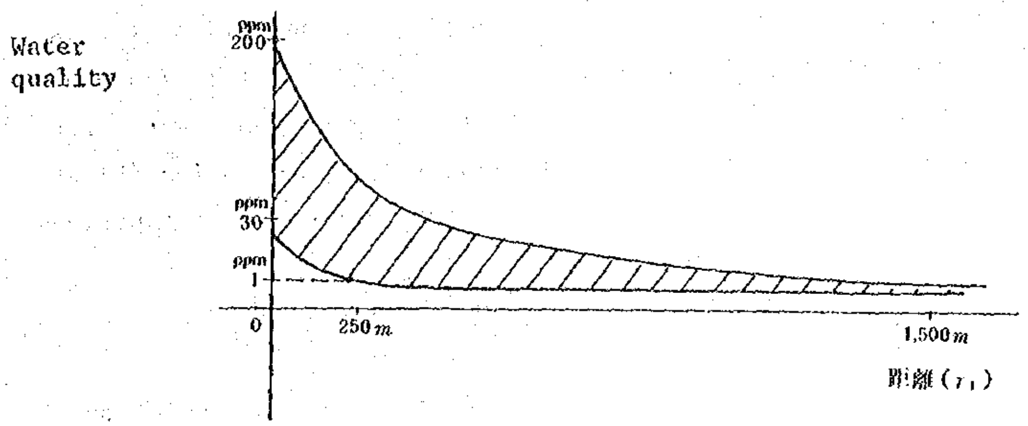
Concerning the water quality, it can be concluded that the water at the Upper Gulf is not contaminated so severely, on the basis of the results of analysis of water sampled at the offshore points which can be regarded as representing the quality of basic water at the Upper Gulf.

The Pattaya coastal zone is being subjected to an increasingly larger effect of domestic waste water and that of the waste water discharged form tapioca factories. However, in this coastal zone, since the quality of the sediment has not deteriorated so seriously from the direct inflow of the domestic waste water, it is suggested that this sea area has a relatively high sea water self-purification.

4.3.2 Environmental characteristics in the future

Assuming that the Pattaya coastal zone has a waste water load of 41,800 tons/day (the quantity based on the sewage plan in the Master Plan) in 1996, about 20 years from now, in addition with an assumed waste water quality of 200 ppm under conditions without treatment facilities, the distance (radius) to a point where approx. 1 ppm improvement in the water quality can be achieved can be determined as 1,500 m in accordance with the Joseph-Sendner's equation. However, assuming that waste water is discharged after treatment through treatment facilities to achieve the water quality of 30 ppm, the water quality improvement range corresponding to 1 ppm of improvement can be determined as approx. 250m by the same equation.

Water quality estimate based on Joseph Sendoner's equation



Therefore, with a remarkable increase in the quantity of waste water in the future, the water quality in the Pattaya Beach coastal zone will tend to deteriorate if no treatment facility is provided, consequently aggravating the conditions for the subsistence of the beach resort.

However, since the diffusion coefficient cannot be taken account of in the Joseph-Sendner's equation, study on the affected range through the use of a diffusion coefficient based on the observations obtained in this sea area resulted in finding that the distance needed for achieving a 0.5 ppm improvement on the present level under conditions without treatment facilities is only 150 m. In waste water after being subjected to a treatment, there can be hardly any contribution of the distance to the 0.5 ppm improvement in the water quality. Table 4.3 shows a relationship between the distance and the concentration of waste water determined by Iwai's equation on the basis of the quantity of waste water in the future. Additionally, as seen from the relationship between the radius and the waste water concentration according to the Joseph-Sendner's formula given in Table 4.4, the distance is reduced to as small as about 500 m after the completion of treatment facilities.

Therefore, apart from the effect of the pollution that will be transferred from the Upper Gulf, it is expected that the Pattaya coastal zone can main tain a clean water quality after the waste water treatment facilities have started their operation.

Several equations are known for determining the dilution and diffusion of waste water in a sea area, including the Joseph-Sendner's equation in which the diffusion coefficient (K) is proportional to the distance (r). By applying this Joseph-Sendner's equation to a continuous source of waste water and considering the transferrable term, the concentration (S) at the distance (r) from the waste water source can b e expressed in the following equation.

$$S = (S_0 - S_1)\ [1 - \exp.\{-\frac{Q}{\pi dp}(\frac{1}{\gamma} - \frac{1}{\gamma_1})\}\ ] + S_1$$

Also, in a sea area having a steady flow (u), the solution of the distribution of two-dimensional horizontal diffusion where waste water flows out continuously from one point in the sea area can be expressed as follows:

$$S = \frac{q\ \exp.(xu/2Kx)}{2\pi d\sqrt{Kx \cdot Ky}} K_0(\frac{u}{2})\sqrt{\frac{1}{Kx}(\frac{x^2}{Kx} + \frac{y^2}{Ky})}$$

where K (y) is a second class transformation of Bessel function. Here, assuming that $K_X = K_y = K$ and $y = 0$;

$$S = \frac{q}{2\pi dK} \exp.(\frac{xu}{2K}) K_0(\frac{xu}{2K})$$

With variables of a large value, Bessel function can be approximately expressed as $K_0(y) = \frac{\sqrt{\pi}}{2y} \cdot \exp.(-y)$, the solution can be as follows:

$$S = \frac{q}{2d\sqrt{\pi Kux}}$$

Table 4.3 (Iwai's equation)

（但し $d = 2.0m$、$K = 11.88 cm^2/S$、$U = 0.38 cm/S$）

Year	1976	1981	1986		1991		1996	
Quantity	7,900	18,100	21,600		33,700		41,800	
Concentration Distance X	200	200	200	30	200	30	200	30
50	0.17	0.39	0.47	0.07	0.73	0.11	0.91	0.14
100	0.12	0.26	0.33	0.05	0.52	0.08	0.64	0.10
150	0.10	0.23	0.27	0.04	0.42	0.06	0.52	0.08
200	0.09	0.20	0.23	0.04	0.37	0.05	0.45	0.07
250	0.08	0.18	0.21	0.03	0.33	0.05	0.41	0.06
300	0.07	0.16	0.19	0.03	0.30	0.04	0.37	0.06
350	0.06	0.15	0.18	0.03	0.28	0.04	0.34	0.05
400	0.06	0.14	0.17	0.02	0.26	0.04	0.32	0.05
450	0.06	0.13	0.16	0.02	0.24	0.04	0.30	0.05
500	0.05	0.12	0.15	0.02	0.23	0.03	0.29	0.04
550	0.05	0.12	0.14	0.02	0.22	0.03	0.27	0.04
600	0.05	0.11	0.14	0.02	0.21	0.03	0.26	0.04
650	0.05	0.11	0.13	0.02	0.20	0.03	0.25	0.04
700	0.05	0.10	0.13	0.02	0.20	0.03	0.24	0.04
750	0.04	0.10	0.12	0.02	0.19	0.03	0.23	0.04
800	0.04	0.10	0.12	0.02	0.18	0.03	0.23	0.03
850	0.04	0.10	0.11	0.02	0.18	0.03	0.22	0.03
900	0.04	0.09	0.11	0.02	0.17	0.03	0.21	0.03
950	0.04	0.09	0.11	0.02	0.17	0.03	0.21	0.03
1000	0.04	0.09	0.10	0.02	0.16	0.02	0.20	0.03
1050	0.04	0.09	0.10	0.02	0.16	0.02	0.20	0.03
1100	0.04	0.08	0.10	0.01	0.16	0.02	0.19	0.03
1150	0.04	0.08	0.10	0.01	0.15	0.02	0.19	0.03
1200	0.03	0.08	0.10	0.01	0.15	0.02	0.18	0.03
1250	0.03	0.08	0.09	0.01	0.15	0.02	0.18	0.03
1300	0.03	0.08	0.09	0.01	0.14	0.02	0.18	0.03
1350	0.03	0.08	0.09	0.01	0.14	0.02	0.17	0.03
1400	0.03	0.07	0.09	0.01	0.14	0.02	0.17	0.03
1450	0.03	0.07	0.09	0.01	0.14	0.02	0.17	0.03
1500	0.03	0.07	0.09	0.01	0.13	0.02	0.17	0.02
1550	0.03	0.07	0.09	0.01	0.13	0.02	0.16	0.02
1600	0.03	0.07	0.08	0.01	0.13	0.02	0.16	0.02
1650	0.03	0.07	0.08	0.01	0.13	0.02	0.16	0.02
1700	0.03	0.07	0.08	0.01	0.13	0.02	0.16	0.02
1750	0.03	0.07	0.08	0.01	0.12	0.02	0.15	0.02
1800	0.03	0.07	0.08	0.01	0.12	0.02	0.15	0.02
1850	0.03	0.06	0.08	0.01	0.12	0.02	0.15	0.02
1900	0.03	0.06	0.08	0.01	0.12	0.02	0.15	0.02
1950	0.03	0.06	0.07	0.01	0.12	0.02	0.15	0.02
2000	0.03	0.06	0.07	0.01	0.12	0.02	0.14	0.02

Table 4.4 (Joseph Sendoner's equation)

（但し $d=2.0m$、$P=0.01cm/S$、$S_1=0$、$\gamma_1=\infty$）

Year	1976	1981	1986		1991		1996	
Quantity	7,900	18,100	21,600		33,700		41,800	
Concentration Distance x	200	200	200	30	200	30	200	30
50	5.74	12.90	15.30	2.29	23.35	3.50	28.55	4.28
100	2.89	6.56	7.80	1.17	12.04	1.81	14.82	2.22
150	1.93	4.40	5.24	0.79	8.11	1.22	10.01	1.50
200	1.45	3.31	3.94	0.59	6.11	0.92	7.55	1.13
250	1.16	2.65	3.16	0.47	4.91	0.74	6.07	0.91
300	0.97	2.21	2.64	0.40	4.10	0.61	5.07	0.76
350	0.83	1.90	2.26	0.34	3.52	0.53	4.35	0.65
400	0.73	1.66	1.98	0.30	3.08	0.46	3.81	0.57
450	0.65	1.48	1.76	0.26	2.74	0.41	3.39	0.51
500	0.58	1.33	1.59	0.24	2.47	0.37	3.06	0.46
550	0.53	1.21	1.44	0.22	2.24	0.34	2.78	0.42
600	0.48	1.11	1.32	0.20	2.06	0.31	2.55	0.38
650	0.45	1.02	1.22	0.18	1.90	0.29	2.36	0.35
700	0.42	0.95	1.13	0.17	1.77	0.26	2.19	0.33
750	0.39	0.89	1.06	0.16	1.65	0.25	2.04	0.31
800	0.36	0.83	0.99	0.15	1.55	0.23	1.92	0.29
850	0.34	0.78	0.93	0.14	1.46	0.22	1.80	0.27
900	0.32	0.74	0.88	0.13	1.37	0.21	1.70	0.26
950	0.31	0.70	0.84	0.13	1.30	0.20	1.61	0.24
1000	0.29	0.67	0.79	0.12	1.24	0.19	1.53	0.23
1050	0.28	0.63	0.76	0.11	1.18	0.18	1.46	0.22
1100	0.26	0.61	0.72	0.11	1.13	0.17	1.40	0.21
1150	0.25	0.58	0.69	0.10	1.08	0.16	1.33	0.20
1200	0.24	0.55	0.66	0.10	1.03	0.15	1.28	0.19
1250	0.23	0.53	0.64	0.10	0.99	0.15	1.23	0.18
1300	0.22	0.51	0.61	0.09	0.95	0.14	1.18	0.18
1350	0.22	0.49	0.59	0.09	0.92	0.14	1.14	0.17
1400	0.21	0.48	0.57	0.09	0.88	0.13	1.10	0.16
1450	0.20	0.46	0.55	0.08	0.85	0.13	1.06	0.16
1500	0.19	0.44	0.53	0.08	0.83	0.12	1.02	0.15
1550	0.19	0.43	0.51	0.08	0.80	0.12	0.99	0.15
1600	0.18	0.42	0.50	0.07	0.77	0.12	0.96	0.14
1650	0.18	0.40	0.48	0.07	0.75	0.11	0.93	0.14
1700	0.17	0.39	0.47	0.07	0.73	0.11	0.90	0.14
1750	0.17	0.38	0.45	0.07	0.71	0.11	0.88	0.13
1800	0.16	0.37	0.44	0.07	0.69	0.10	0.85	0.13
1850	0.16	0.36	0.43	0.06	0.67	0.10	0.83	0.12
1900	0.15	0.35	0.42	0.06	0.65	0.10	0.81	0.12
1950	0.15	0.34	0.41	0.06	0.64	0.10	0.79	0.12
2000	0.16	0.33	0.40	0.06	0.62	0.09	0.77	0.12

CHAPTER 5 CONCLUSION

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The findings, which were obtained through our survey on tidal current, water quality, and sediment condition as aforementioned, can be summarized as follows:

5.1 Tidal Current

According to the survey results, it is clear that the tidal current in the Pattaya beach area is influenced by the fluctuation of tide. The current usually flows north at the time of the flood tide and into the opposite direction at the ebb tide. The maximum current speed measured at the time of spring tide is about 0.4 m/sec and almost the same value is obtained at each survey station.

As to the constant current, though some variations in its speed and direction were observed during the survey period, it normally flows southward. Even though such a low velocity of the current as 3-4 cm/sec is registered at Station B, prevailing direction of the current is the south; the current flows south into the central area of the Gulf of Thailand passing the north side of Ko Lan island. Judging from the time difference of the tides (M2) in the Upper Gulf area, it is understood that the tidal current in the Upper Gulf moves clockwise as a whole. Since this movement has an inclination to concentrate on the deep-sea area off Pattaya, we assume that the constant current in the Pattaya area is also influenced by such a large scale tidal-current circulation.

Diffusion coefficient obtained from the current speed survey at Station B was relatively large for a coastal area. Comparing the velocity of the current registered at other stations with the velocity at Station B, we can infer that the diffusion coefficient at those stations will be almost the same in value as the one at Station B.

5.2 Water Quality and Sediment Condition

The water in the Pattaya sea area is rather clean on the whole. There exist, however, several problematical points that should not be neglected to maintain the area as a beach resort. Especially, contamination of the Na Klua River and Pattaya beach (shown in parameters such as COD, coliform and n-Hexane extracts) gives us a warning. Pollution in the Pattaya beach area is mainly caused by the domestic sewage directly flowing into the beach area. In our survey, we found that the water of this area contained considerable amount of nutrient salt (N,P.) with the value of 0.5 - 0.6 μgat/l at PO_4. Incidentally, one of the survey stations marked the value exceeding 1.0 μgat/l. In N-compound examinations, we also found that the contents of the inorganic nitrogens (NO_2-N, NO_3-N and NH_4-N) were slightly higher than desirable and we suspected that the eutrophication might be in progress.

One of the vital requirements for a beach resort is, needless to say, to have clear, lucid water around. In Pattaya beach, however, the lucidity of water can not necessarily be said satisfactory, for presently the lucidity in Block A and B is 5m.

From the conclusion mentioned above, we recommend precaution be exercised over the following points for the conservation of the marine environment in the Pattaya area.

i) The extent of pollution in the Gulf of Thailand as a whole is not so advanced yet as to be worried about seriously. However, since most of the pollution sources are located north of the Upper Gulf such as the Chao Phuraya River, which runs through Bangkok, the polluted water from this area flows into the Gulf and is picked up by the current moving clockwise going down south. This situation needs close watching hereafter. Further, constant attention should be paid to the rubbish and the waste water to come out of various development projects taking place on the north of Pattaya.

ii) The problem more directly related to the subject area is the pollution of the Na Klua River and of the Pattaya offshore area. As regards the Na Klua River, major sources of pollutants are the domestic sewage and the waste water from Tapioca factories. The main flow from the Na Klua River goes toward Ko Lan island and part of this flow runs south along the coast toward Pattaya beach. The situation being such, steps to improve water quality in the subject area are desired to be taken urgently.

Contamination in the Pattaya offshore area is mainly caused by the direct inflow of the domestic sewage. This problem will mostly be solved with the completion of the sewerage work, details of which are being studied in the Pattaya Tourism Development project. During our survey, n-Hexane was detected in the water off Pattaya. This extract is considered to have come from the waste abandoned from tourist ships. Such abandonment, therefore, needs strictly be regulated.

Because the velocity of the current in the Pattaya area is high and the diffusion coefficient is large as aforestated, it is naturally assumed that the polluted water in this area is spread fast and diluted with ease. In case the inflow of the waste water from the north of the Upper Gulf is controlled, the sewerage in the Pattaya area is completed, and the waste water from tapioca factories is properly regulated, good water quality essential to a beach resort will be guaranteed for this area.

Reviewing the whole results of our water-quality survey, we can conclude that the water quality in the subject area adequately satisfies the standard values required in Japan, and so the values can be utilized as a reference in controlling the water quality and in maintaining good marine environment in Thailand.