



**MANGROVE HABITAT DYNAMICS
AND SEA-LEVEL CHANGE**

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**Preliminary Study on the Submarine Sedimentation around Mangrove Habitats
In Malay Peninsula - Khlong Thom, Satun and Kemaman Areas -
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INTRODUCTION

Distribution and composition of submarine surface sediments, water depths and characteristics of sea surface waters were investigated in and around the mangrove habitats in three areas, Khlong Thom and Satun areas in South Thailand in December 1996 and August 1997 and Kemaman area in West Malaysia in December 1996 to summarize present submarine sedimentary processes in and around the habitats (Fig. 1). This report is mainly concerned with on-board observations of the surface sediments and the water depths in 1996 and 1997 and of the surface waters in 1997, and preliminary results from analyses of the sediments in the laboratory.

No systematic sedimentological studies have been made in these areas. Thus, sampling sites were selected uniformly within the areas for the purposes of the following scientific searchings; (1) recognition of submarine topographies, (2) spatial distribution of surface sediments, (3) spatial distribution of benthic micro-organisms and (4) characteristics of sea surface waters. Taking these scientific searchings into account sedimentary processes of water areas within these areas are illustrated and classified.

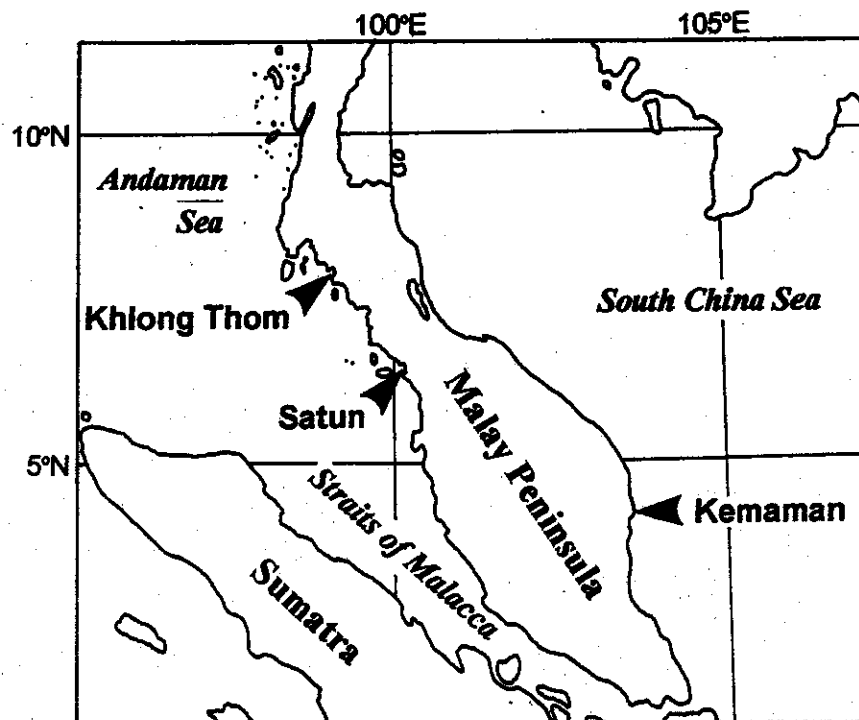


Fig. 1: Index map of the Khlong Thom, Satun and Kemaman areas in the southern part of the Malay Peninsula.

The sediment samples used for the present study were collected in December 1996 at the Khlong Thom, Satun and Kemaman areas, and August 1997 at Khlong Thom and Satun areas. Sampling devices were a Seki-type grab sampler in 1996 and a Tamura-type grab sampler in 1997. Salinity, temperature, hydrogen ion exponent (pH) and dissolved oxygen amount (DO) measurements for sea surface waters were conducted in the Khlong Thom and Satun areas in August 1997. The site survey was always carried out with a depth measurement by an about 20-metres-long nylon rope with an about 2 kg weight.

In the laboratory, smear slides were prepared and examined under the microscope for muddy sediments. For sandy sediments, the entire sample was heated over 24 hours at about 50 °C, and its dry weight was measured. Then, it was washed repeatedly to remove mud, and dried and weighed again to obtain proportional mud contents. Micro-organic remains such as ostracode and foraminifer specimens were picked up from the remains, and other coarse material was made into a thin section and examined under the microscope.

1. KHLONG THOM AREA

1-1. Topography

Figure 2 shows topographic features and distribution of the mangrove habitats of the Khlong Thom area in the western coast of the Malay Peninsula, South Thailand. The area can be divided morphologically into the head area in the east, the mouth area in the west by the Hang Island, and the area of the Straits of Malacca outside of the estuaries.

The head area where is on the east of the Hang Island is divided further into two narrow and long estuaries, the south Khlong Thom and north Khlong Phela Estuaries. These estuaries run together east of the Hang Island. Several islands, such as the Lu Du Island having NE-SW to E-W longitudinal axes are distributed in the junction of two estuaries. These islands seem to be composed mainly of sand banks. The mangrove habitats are widely distributed along the two narrow estuaries, on these islands in the junction and in the eastern coast of the Hang Island. On the other hand, the mouth area connected with the head area by a channel on the north of the Hang Island and a few narrow channels on the south is sheltered from the Straits of Malacca by several comparatively large islands such as the Si Bo Ya, To Lung, Nok Khem and Pu Islands having N-S to NNW-SSE longitudinal axes. These islands are composed mainly of the Jurassic - Cretaceous sedimentary rocks (Department of Mineral Resources, 1987). The mangrove habitats are distributed in the northern coast of the area, on the Nok Khem Island and in the eastern coast of the Si Bo Ya Island.

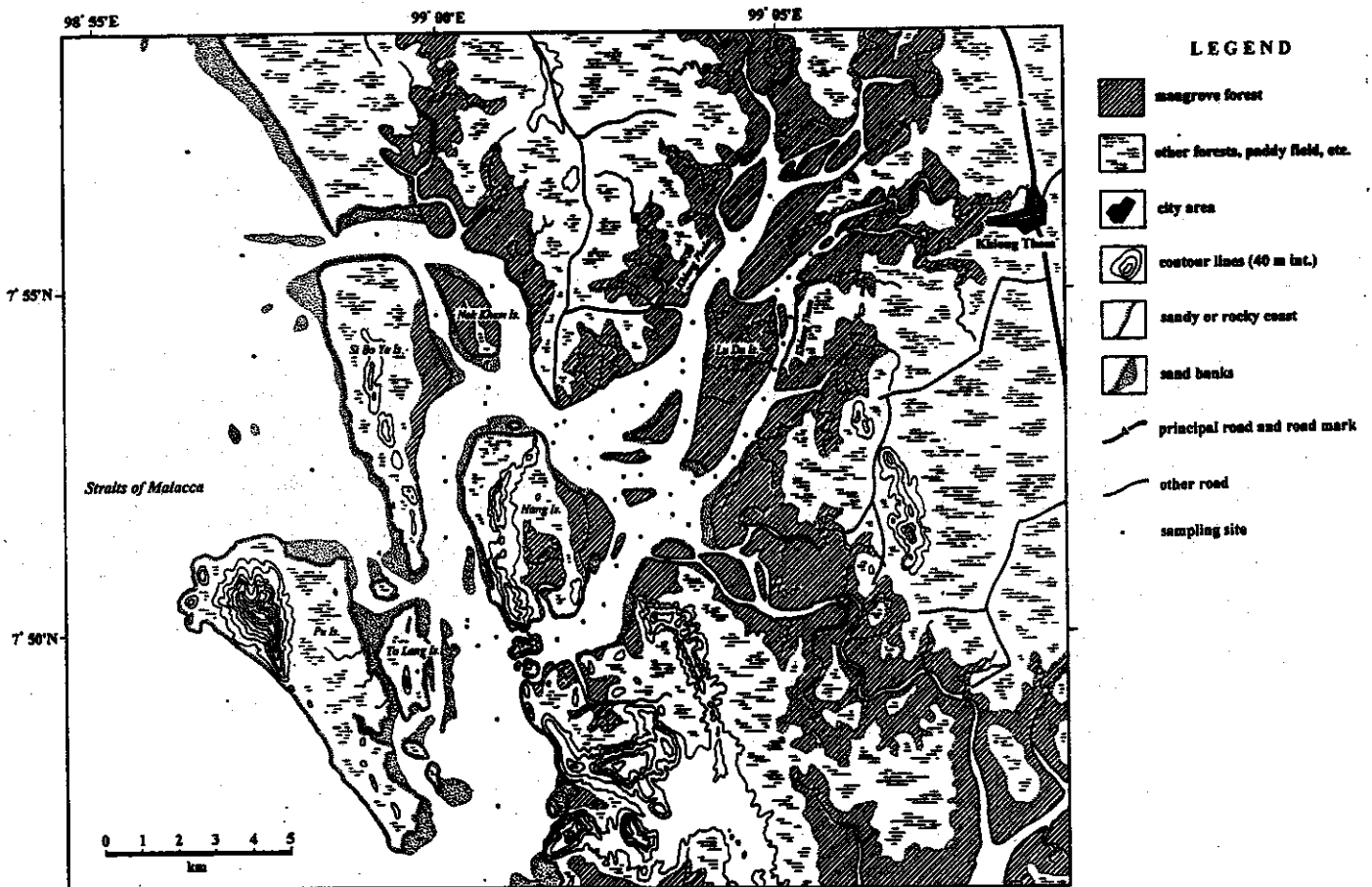


Fig. 2: Topographic features and distribution of mangrove habitats in the Khlong Thom area, South Thailand. Dots in the water area indicate survey sites in both 1996 and 1997.

Figures 3 and 4 show the survey sites in the Khlong Thom area in December 1996 and August 1997, respectively. The bottom sediment samplings in December 1996 were mainly carried out in the head area with some preliminary survey sites in the mouth area (Fig. 3), and the samplings in August 1997 were extended in the areas of the mouth and the Straits of Malacca (Fig. 4). Twenty-four and 32 samples were successfully obtained in these sites in 1996 and 1997, respectively, with exceptions of the sites 15 and 16 in 1996 where the water depths were deeper than the length of the rope at the sampling time (Tables 1 and 2).

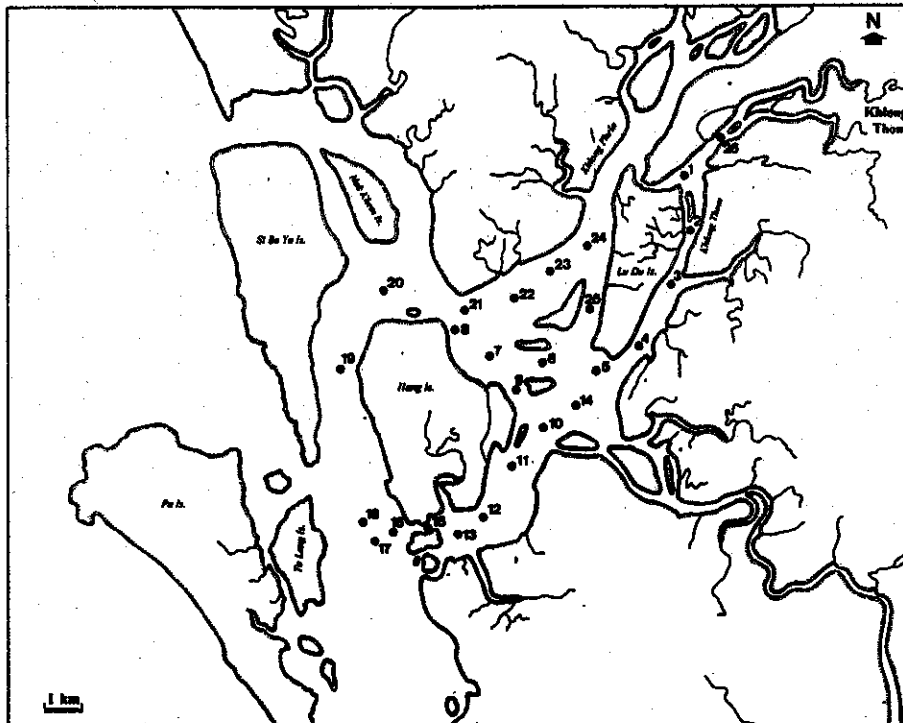


Fig. 3: Sediment sampling and water depth measurement sites in the Khlong Thom area in December 1996.

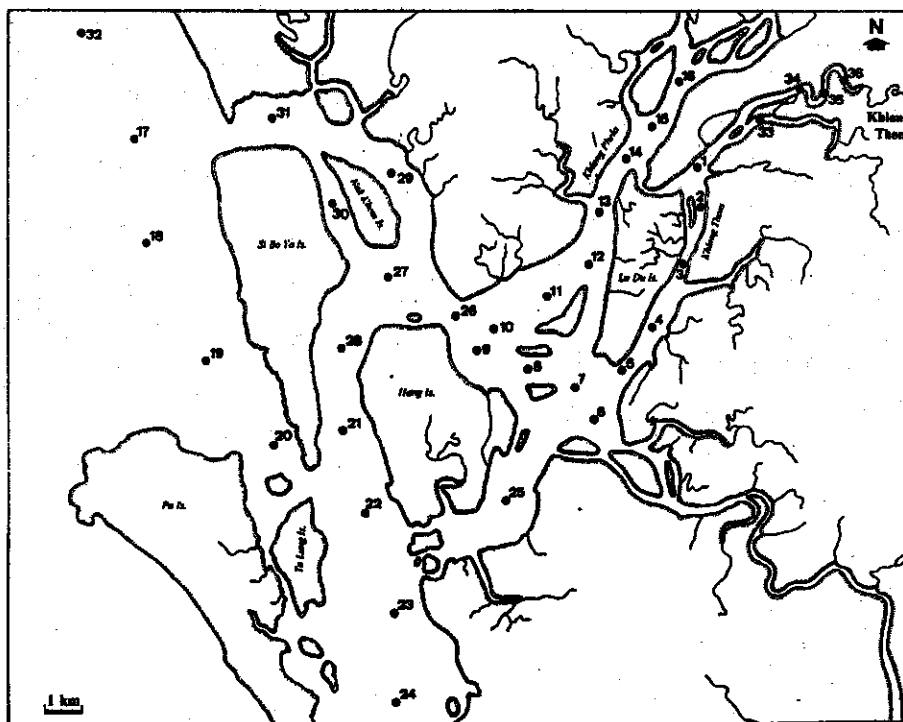


Fig. 4: Sediment sampling, and water depth and water characteristics measurement sites in the Khlong Thom area in August 1997.

Table 1: Results of sediment samplings in the Khlong Thom Area in December 1996.

| Site No. | Date (1996) | Time (hr) | Latitude (N) | Longitude (E) | Depth (m) | Sediment Type |
|----------|-------------|-----------|--------------|---------------|-----------|--|
| KT96-1 | 6 Dec. | 12:49 | 7° 54' 44" | 99° 05' 00" | 2.5 | granule gravelly mud with f. sand |
| KT96-2 | | 13:05 | 7° 54' 54" | 99° 04' 55" | 2.2 | plant debris rich gravelly f. sand |
| KT96-3 | | 13:15 | 7° 54' 19" | 99° 04' 44" | 3.2 | plant debris rich f. sand |
| KT96-4 | | 13:26 | 7° 52' 46" | 99° 04' 23" | 3.7 | plant debris rich f. sand |
| KT96-5 | | 13:36 | 7° 52' 21" | 99° 04' 01" | 1.0 | plant debris rich f. sand, stained in dark grey in lower part |
| KT96-6 | | 13:46 | - | - | 4.2 | plant debris rich gravelly f. sand |
| KT96-7 | | 13:56 | 7° 52' 24" | 99° 02' 21" | 3.8 | dark grey shelly f. sand |
| KT96-8 | | 14:08 | 7° 52' 47" | 99° 01' 47" | 14.8 | dark grey shelly f. sand |
| KT96-9 | | 14:26 | 7° 51' 51" | 99° 02' 38" | 1.4 | shell fragments and plant debris bearing f. sand |
| KT96-10 | | 14:41 | 7° 51' 20" | 99° 02' 51" | 3.5 | plant debris rich dark grey sandy mud |
| KT96-11 | | 14:49 | 7° 50' 53" | 99° 02' 30" | 3.6 | shell rich dark grey sandy mud |
| KT96-12 | | 14:58 | 7° 50' 15" | 99° 02' 13" | 8.2 | shell rich sandy mud with mud balls |
| KT96-13 | | 15:15 | 7° 50' 06" | 99° 01' 47" | 14.2 | shell fragments rich f.-m. sand |
| KT96-14 | 7 Dec. | 12:58 | 7° 51' 36" | 99° 03' 25" | 3.5 | shell rich f. sand |
| KT96-15 | | 13:15 | 7° 50' 01" | 99° 01' 19" | 20.0 | - |
| KT96-16 | | 13:22 | 7° 49' 58" | 99° 00' 53" | 20.0 | - |
| KT96-17 | | 13:25 | 7° 49' 54" | 99° 01' 40" | 14.0 | organic matter rich dark grey massive mud with reddish brown surface |
| KT96-18 | | 13:39 | 7° 50' 43" | 99° 00' 21" | 1.2 | shell rich f. sand |
| KT96-19 | | 13:53 | 7° 52' 35" | 99° 00' 18" | 3.6 | lateritic gravel bearing f. sand with shell fragments |
| KT96-20 | | 14:13 | 7° 53' 10" | 99° 00' 57" | 1.6 | shell bearing gravelly f. sand |
| KT96-21 | | 14:29 | 7° 53' 10" | 99° 02' 02" | 4.8 | lateritic gravel rich f. sand |
| KT96-22 | | 14:53 | 7° 53' 25" | 99° 02' 30" | 3.2 | gravelly muddy f. sand with shells and plant debris |
| KT96-23 | | 15:05 | 7° 53' 43" | 99° 03' 00" | 3.8 | shell fragments bearing gravelly f. sand |
| KT96-24 | | 15:28 | 7° 54' 13" | 99° 03' 46" | 8.5 | plant debris rich f. sand |
| KT96-25 | | 15:42 | 7° 53' 09" | 99° 03' 41" | 3.6 | plant debris rich dark grey sandy mud with a little shell fragments |
| KT96-26 | | 17:01 | 7° 55' 34" | 99° 05' 44" | 4.5 | plant debris rich reddish brown muddy sand |

Table 2: Results of sediment samplings in the Khlong Thom Area in August 1997.

| Site No. | Date (1997) | Time (hr) | Latitude (N) | Longitude (E) | Depth (m) | Sediment Type |
|----------|-------------|--------------|---------------|---------------|---|--|
| KT97-1 | 8 Aug. | 07:57 | 7° 55' 12.6" | 99° 05' 12.6" | 4.6 | plant debris rich pale brown muddy sand |
| KT97-2 | | 08:07 | 7° 54' 32.1" | 99° 05' 11.1" | 2.4 | plant debris and shell bearing f. sand |
| KT97-3 | | 08:14 | 7° 53' 59.8" | 99° 05' 02.4" | 4.7 | plant debris rich f. sand |
| KT97-4 | | 08:28 | 7° 53' 02.9" | 99° 04' 38.0" | 2.5 | shell fragments bearing f.-m. sand |
| KT97-5 | | 08:43 | 7° 52' 25.7" | 99° 04' 09.3" | 7.3 | gravel bearing f. sand with a small amount of shell |
| KT97-6 | | 09:00 | 7° 51' 21.2" | 99° 03' 47.8" | 4.0 | brownish grey sandy mud, brown layer in surface |
| KT97-7 | | 09:21 | 7° 52' 02.2" | 99° 03' 27.9" | 2.3 | plant debris rich muddy f. sand |
| KT97-8 | | 09:42 | 7° 52' 22.8" | 99° 02' 50.1" | 4.9 | shell and gravel bearing muddy f. sand |
| KT97-9 | | 09:57 | 7° 52' 30.2" | 99° 02' 20.3" | 1.1 | shell bearing f. sand |
| KT97-10 | | 10:08 | 7° 52' 49.3" | 99° 02' 38.4" | 1.8 | shell bearing f. sand |
| KT97-11 | | 10:22 | 7° 53' 23.1" | 99° 03' 09.1" | 5.8 | shell and gravel bearing f. sand |
| KT97-12 | | 10:34 | 7° 53' 48.1" | 99° 03' 37.8" | 8.0 | plant debris and shell bearing f.-m. sand |
| KT97-13 | | 10:46 | 7° 54' 30.1" | 99° 03' 53.5" | 8.9 | dark bluish grey mud, muddy f.-m. sand in surface |
| KT97-14 | | 11:00 | 7° 55' 15.5" | 99° 04' 15.8" | 13.0 | plant debris rich shell bearing f. sand |
| KT97-15 | | 11:11 | 7° 55' 45.2" | 99° 04' 44.1" | 9.0 | pebble-cobble gravel bearing f. sand |
| KT97-16 | | 11:22 | 7° 56' 26.5" | 99° 05' 09.8" | 9.0 | pebble-cobble gravel bearing f. sand |
| KT97-17 | 9 Aug. | 08:45 | 7° 55' 53.8" | 99° 57' 23.9" | 1.7 | shell and plant debris bearing olive grey f. sand |
| KT97-18 | | 10:06 | 7° 54' 34.5" | 99° 57' 40.0" | 2.8 | shell and plant debris bearing olive grey f. sand |
| KT97-19 | | 10:31 | 7° 52' 23.3" | 99° 58' 11.0" | 4.2 | calcareous rich olive grey f.-m. sand with mud balls |
| KT97-20 | | 10:50 | 7° 50' 52.6" | 99° 58' 13.4" | 1.2 | calcareous rich muddy olive grey f. sand |
| KT97-21 | | 11:15 | 7° 51' 14.3" | 99° 00' 04.9" | 9.0 | shell and laterite gravel bearing reddish brown f.-m. sand |
| KT97-22 | | 11:24 | 7° 50' 09.9" | 99° 00' 21.1" | 3.0 | shell fragment bearing olive grey f. sand |
| KT97-23 | | 11:44 | 7° 46' 42.2" | 99° 00' 34.9" | 9.2 | shell bearing muddy f.-m. sand with mud balls |
| KT97-24 | | 12:00 | 7° 47' 23.3" | 99° 00' 43.5" | 7.4 | gravel bearing muddy m. sand with mud balls |
| KT97-25 | | 12:32 | 7° 50' 30.1" | 99° 02' 20.4" | 6.4 | shell and plant debris rich dark olive grey muddy f. sand |
| KT97-26 | | 13:09 | 7° 52' 54.7" | 99° 02' 00.2" | 12.0 | shell bearing brown f.-m. sand |
| KT97-27 | | 13:30 | 7° 53' 32.6" | 99° 00' 58.8" | 10.5 | shell and fragments rich muddy f.-m. sand |
| KT97-28 | | 13:51 | 7° 52' 33.8" | 99° 00' 15.6" | 6.0 | gravel and shell bearing muddy f.-m. sand |
| KT97-29 | | 14:15 | 7° 54' 58.0" | 99° 01' 00.8" | 7.7 | laterite gravel and shell rich olive grey f. sand |
| KT97-30 | | 14:32 | 7° 55' 12.0" | 99° 59' 55.4" | 6.7 | shell and fragments bearing olive grey f. sand |
| KT97-31 | 14:54 | 7° 55' 48.7" | 99° 58' 50.8" | 11.7 | shelly olive grey f. sand | |
| KT97-32 | 15:14 | 7° 56' 47.1" | 99° 57' 46.7" | 4.0 | shell fragment bearing olive grey f. sand | |
| KT97-33 | 10 Aug. | 08:16 | 7° 55' 47.3" | 99° 55' 59.7" | 2.7 | plant debris rich brownish grey muddy sand |
| KT97-34 | | 08:50 | 7° 56' 15.5" | 99° 06' 41.4" | 2.5 | gravel bearing m.-c. sand |
| KT97-35 | | 09:07 | 7° 56' 13.1" | 99° 07' 01.2" | 2.4 | plant debris rich m.-vc. sand |
| KT97-36 | | 09:40 | 7° 56' 11.3" | 99° 07' 22.0" | 2.6 | laterite gravels with a small amount of f. sand |

Figure 5 shows the results of water depth measurements in the area in both 1996 and 1997. Water depths indicated in the figure are revised into the water depths in the lowest low tide period. The water depths of the head area are generally less than three metres with a few exceptions such as north, west and south of the Lu Du Island where the water depths are 10.3, 6.7 and 5.4 m, respectively. The water depths of the mouth and the Straits of Malacca areas are still shallow, generally less than four metres. The deepest parts of the Khlong Thom area are recognized in the south and north channels that connect the head area with the mouth area on the south and north of the Hang Island where the water depths are more than 18 m and 8.8 m, respectively.

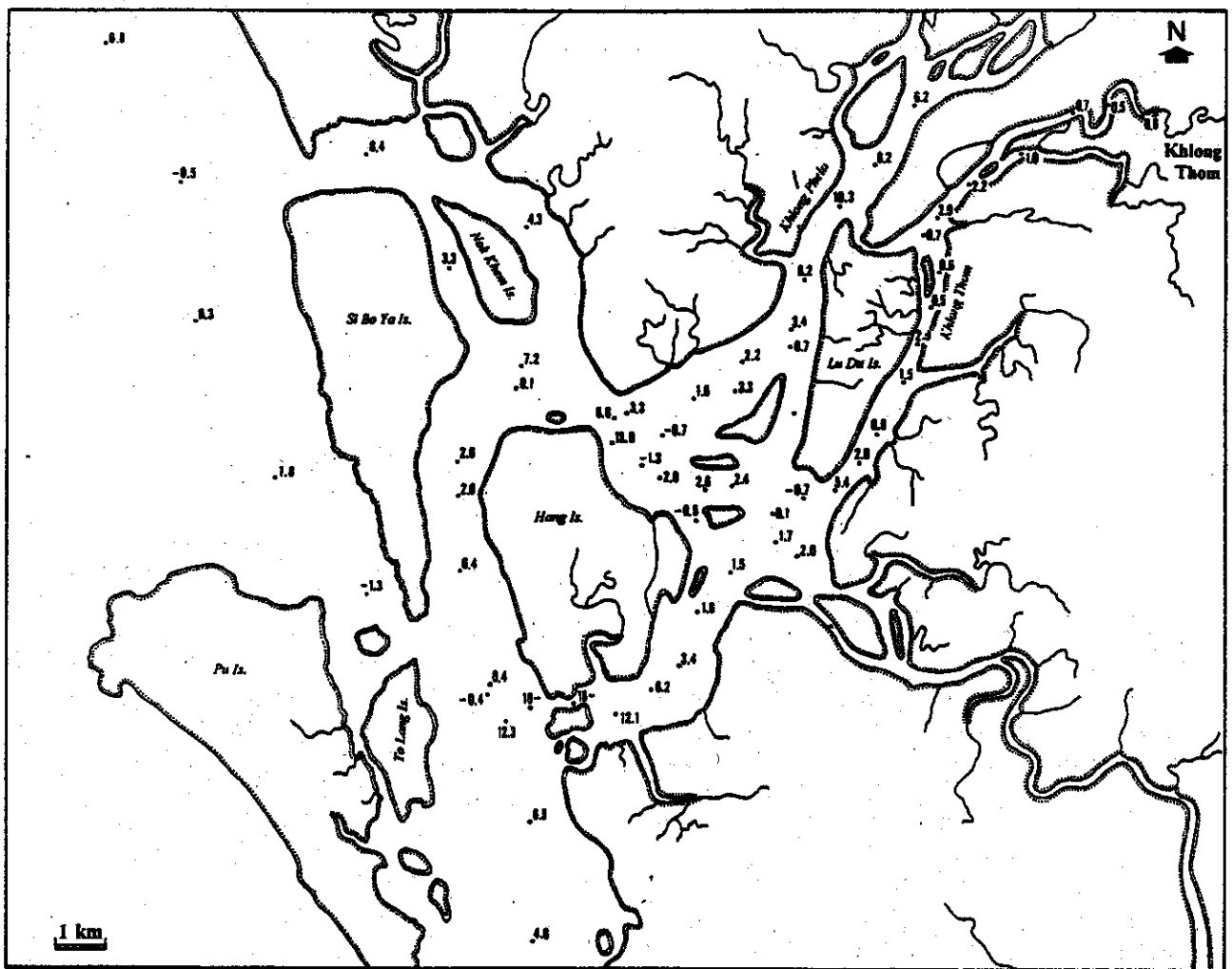


Fig. 5: Results of water depth measurements in the Khlong Thom area in both December 1996 and August 1997. Water depths (m) are revised into them during the lowest low tide.

1-2. Sediments

In the head area of the Khlong Thom area, the surface sediments in the narrow estuaries, the Khlong Thom and Khlong Phela Estuaries, are composed mainly of plant debris bearing fine-grained sand and yellowish brown coloured mud, and molluscan shell fragments and/or gravel bearing fine-grained sand in the junction area. Sand is composed mainly of fine-grained quartz and lithic fragments. Mud consists chiefly of clay minerals with a small amount of diatom tests. Gravels are composed mainly of lateritic lithic fragments. On the other hand, the surface sediments in the areas of the mouth and the Straits of Malacca consist mainly of molluscan shell and shell fragments bearing olive grey fine-grained sand. Sand and mud show similar compositions with the sediments of the head area.

Figure 6 illustrates the spatial distribution of mud contents of the surface sediments in the Khlong Thom area in December 1996. The mud contents in whole area are generally less than 25 % in weight, but there are some exceptions such as the sites 17 and 26 where the mud contents are 85 and 34 % in weight.

Remains of micro-organisms such as ostracodes and benthic foraminifers are frequently recognized in the surface sediments obtained in the junction area within the head area, and in both mouth and the Straits of Malacca areas (Fig. 7).

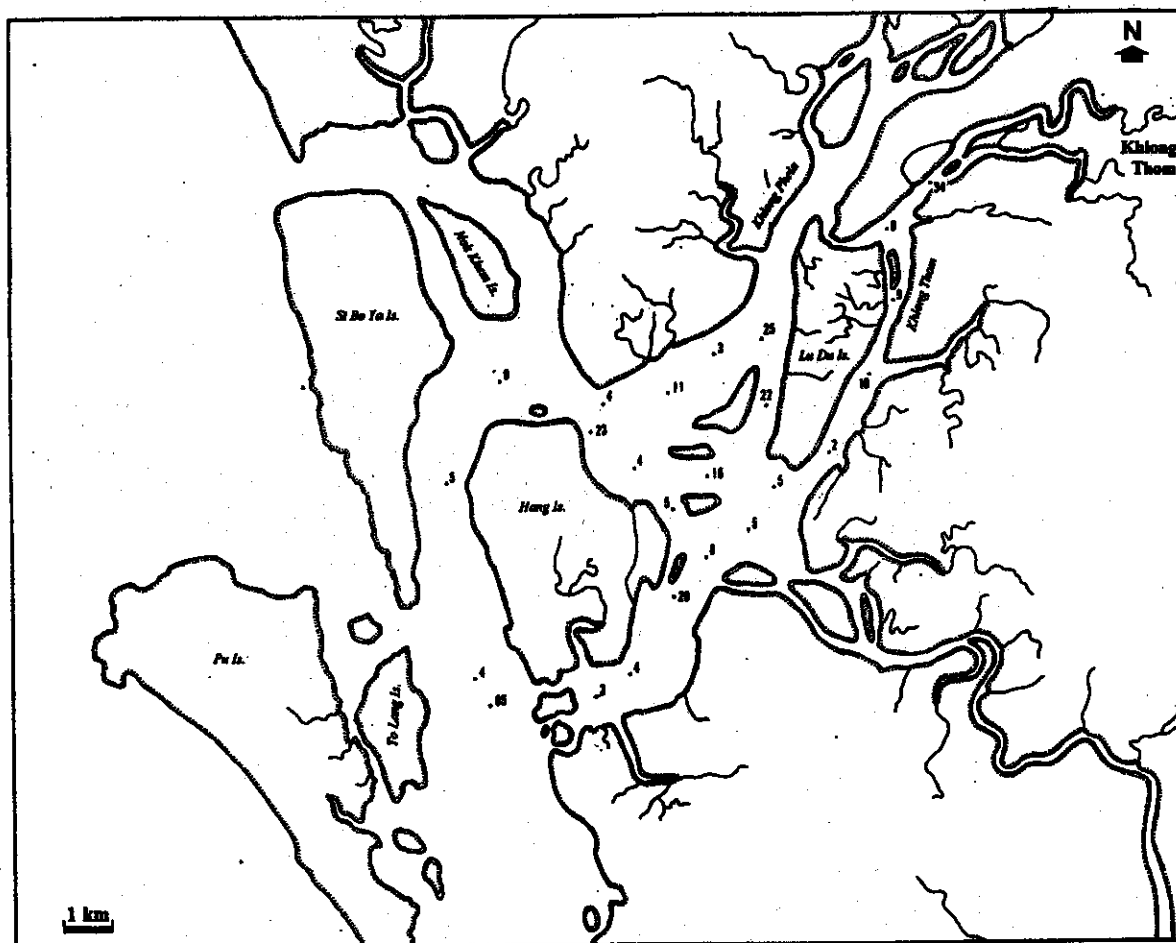


Fig. 6: Mud contents of the bottom sediments in weight percent of the Khlong Thom area in December 1996.

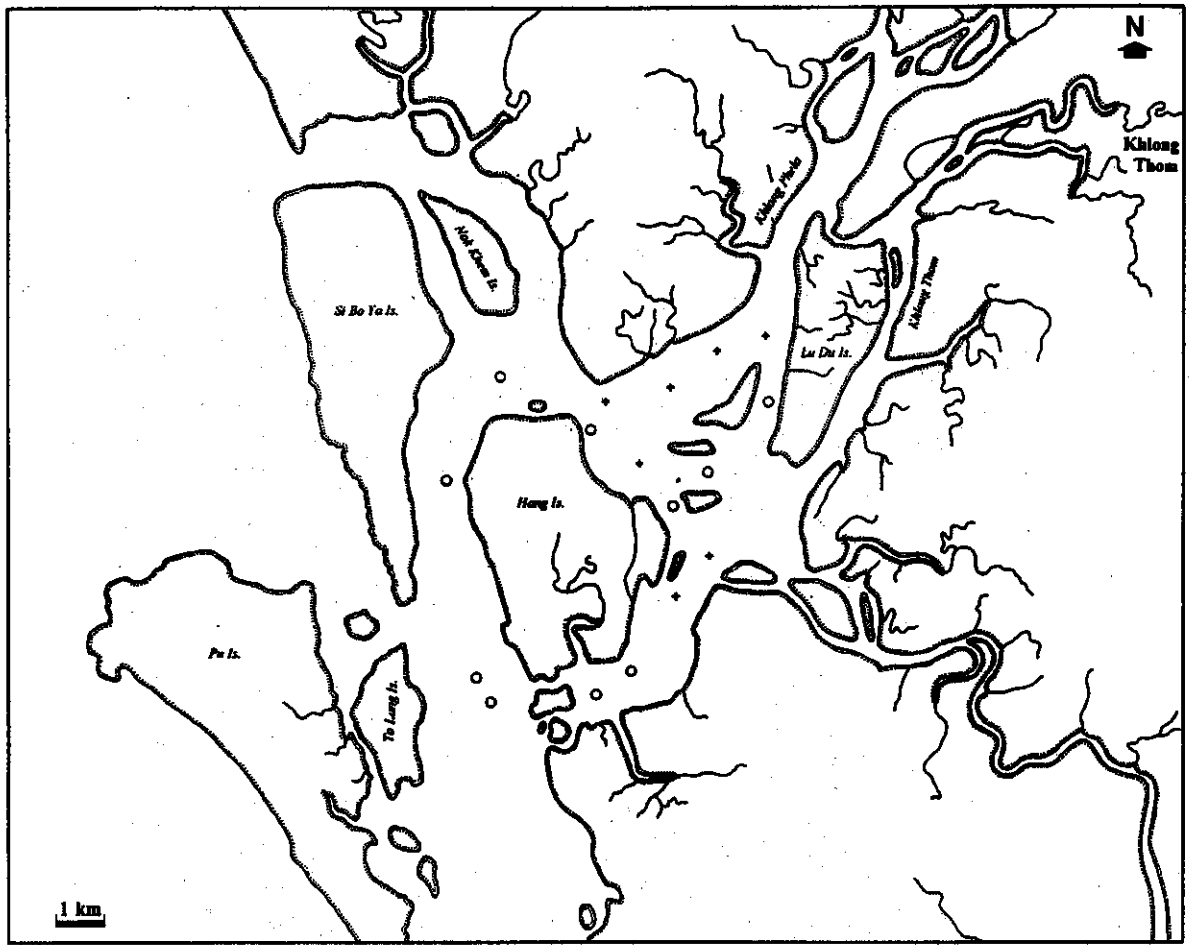


Fig. 7: Occurrence of ostracode tests from the bottom sediments in the Khlong Thom area in December 1996 (O: dominant, +: frequent).

1-3. Salinity of Surface Waters

Figure 8 shows spatial distribution of salinity of the surface water during a low tide period in the Khlong Thom area in August 1997. The salinity is more than 25 ‰ in the mouth and the Straits of Malacca areas, between 20 and 25 ‰ in the junction area within the head area, and less than 20 ‰ in the head area. It shows a marked decrease in the Khlong Thom Estuary from 20.5 ‰ near the junction area to 1.7 ‰ near the town of Khlong Thom.

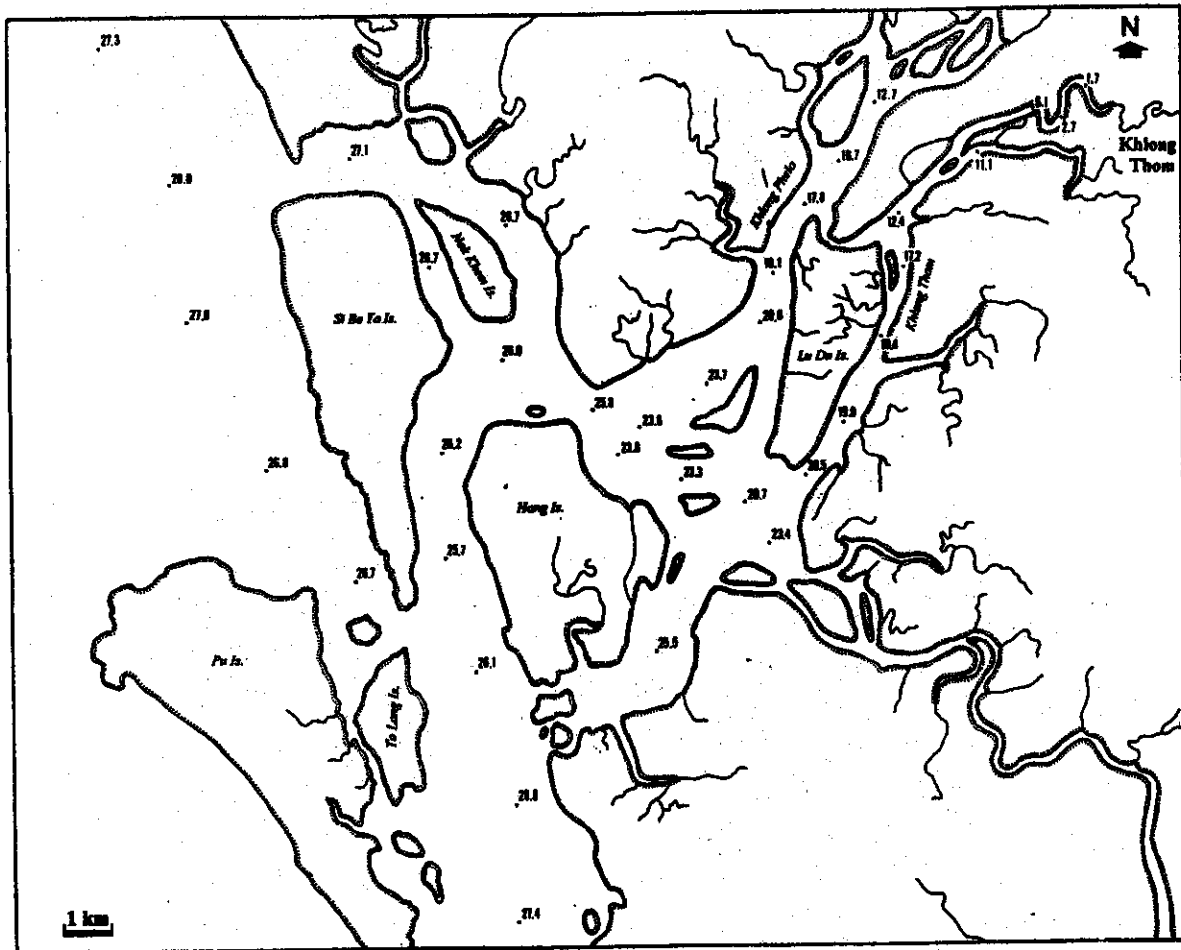


Fig. 8: Results of salinity measurements of the surface water (‰) during a low tide period in the Khlong Thom area in August 1997.

1-4. Temperature of Surface Waters

Figure 9 shows spatial distribution of surface water temperatures in the Khlong Thom area in August 1997. They are constant between 28 and 31 °C in whole area. No morphologically controlled inclination is recognized.

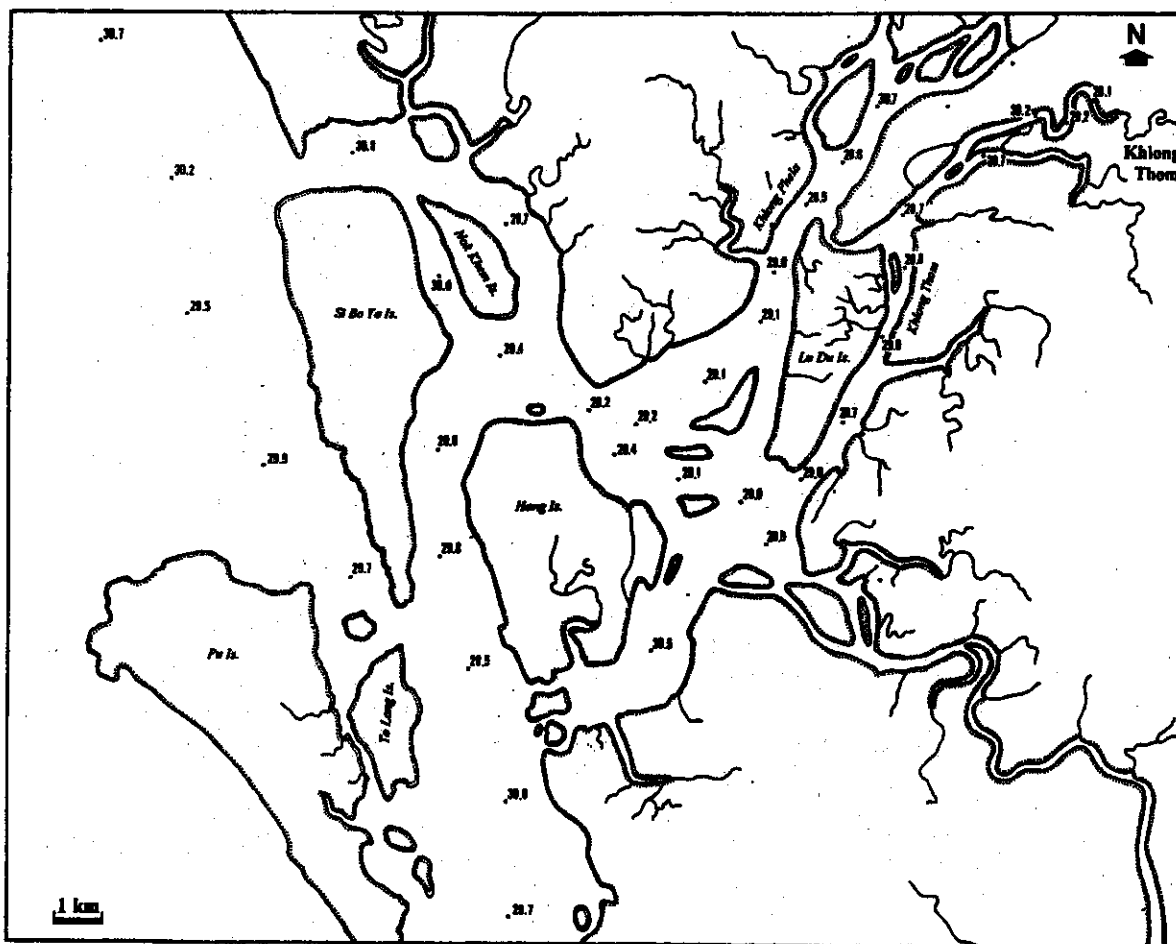


Fig. 9: Results of the surface water temperature measurements (°C) during a low tide period in the Khlong Thom area in August 1997.

1-5. Hydrogen Ion Exponent (pH) of Surface Waters

Figure 10 shows spatial distribution of hydrogen ion exponents (pH) of the surface waters in the Khlong Thom area in August 1997. The pH values are more than 8.1 in the areas of the mouth and the Straits of Malacca, between 8.3 and 7.6 in the junction area within the head area, and generally less than 7.7 in the areas of the Khlong Thom and Khlong Phela Estuaries.

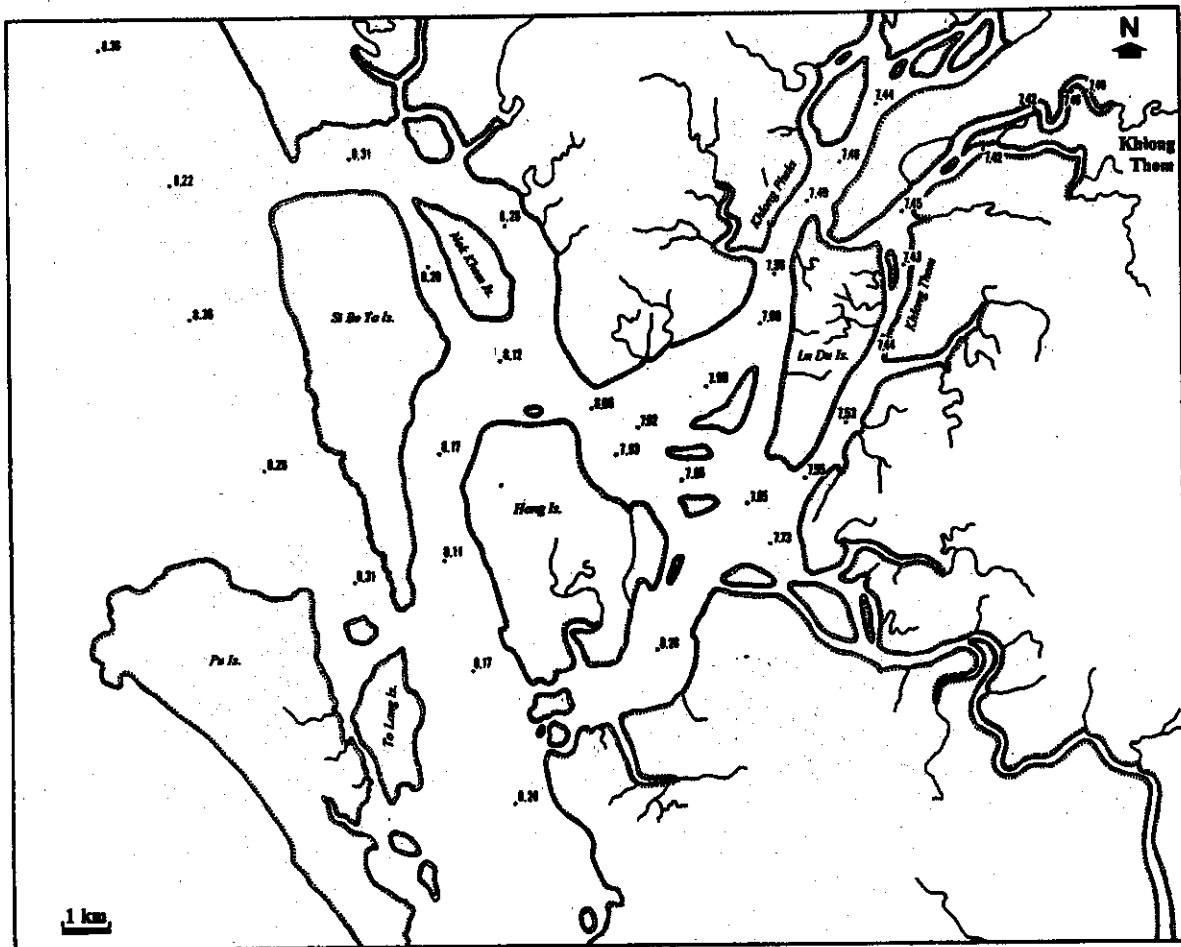


Fig. 10: Results of hydrogen ion exponents (pH) measurement of the surface water during a low tide period in the Khlong Thom area in August 1997.

1-6. Dissolved Oxygen Amount (DO) of Surface Waters

Figure 11 shows spatial distribution of dissolved oxygen amount (DO) of the surface waters in the Khlong Thom area in August 1997. The DO are around 6 ppm in the area of the Straits of Malacca, between 4.5 and 5.7 ppm in the mouth area with an exception of the site 24 where it is 2.83 ppm, between 4.0 and 4.5 ppm in the junction area within the head area, and less than 4.0 ppm in the areas of the Khlong Thom and Khlong Phela Estuaries with an exception of the site 13 where the value is 4.49 ppm.

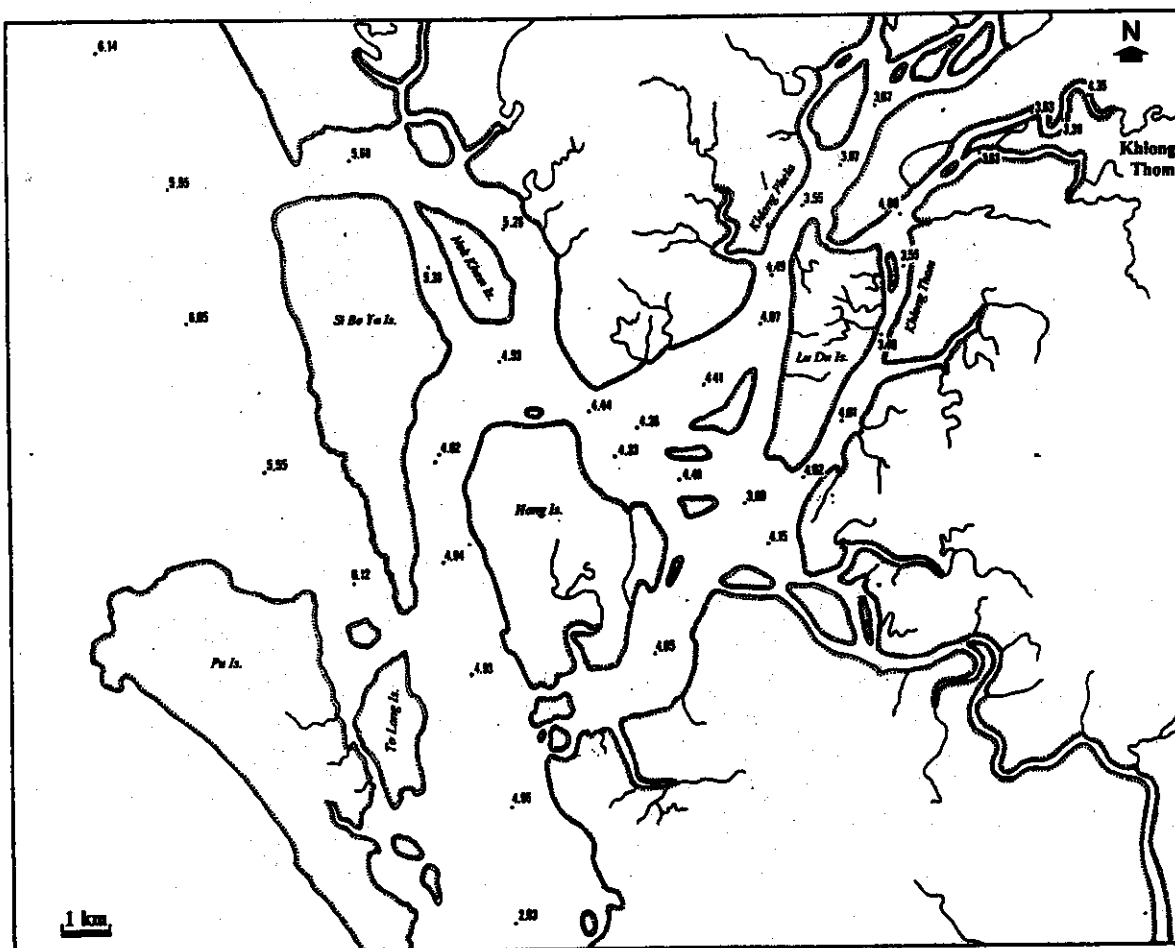


Fig. 11: Results of dissolved oxygen amount (DO) measurement of the surface water (ppm) during a low tide period in the Khlong Thom area in August 1997.

2. SATUN AREA

2-1. Topography

Figure 12 shows topographic features of the Satun area in the western coast of the Malay Peninsula, South Thailand. The area can be divided into the Tam Ma Lung Bay area, the Khlong Ta Chin Estuary extending northeastwards from the bay, and the area of the Straits of Malacca where some small islands are situated.

The Tam Ma Lung Bay opens south-southwestwards to the Strait of Malacca. The bay, about 3 km in width and 6 km in depth, has a western straight and an eastern curved coastal lines. Several low hills are situated on the southeastern coast of the bay. The long and narrow Khlong Ta Chin Estuary starts east-northeastwards from the northeastern part of the Tam Ma Lung Bay. It turns north-northwestwards at about 4 km from the bay where is on the west of a mountain chain composing of limestones, shales and sandstones of the Ordovician Thung Song Group (Department of Mineral Resources, 1987). The estuary extends about 8 km north-northwestwards between the mountain chain and a long and narrow hill that consists same strata as the mountain chain. The width of the estuary is about few hundreds metres in the south but it decreases to about 100 m in the northernmost. The islands, such as the Yao, Khamin and Karap Islands, situating south of the bay in the Straits of Malacca are composed mainly of the Ordovician sedimentary rocks such as limestones, shales and sandstones of the Thung Song Group (Department of Mineral Resources, 1987). The mangrove habitats are widely distributed around the Tam Ma Lung Bay, the Khlong Ta Chin Estuary, and the eastern coast of the Straits of Malacca.

Figures 13 and 14 show the survey sites in the Satun area in December 1996 and August 1997, respectively. The bottom sediment samplings in December 1996 were mainly carried out in the Tam Ma Lung Bay and the southern part of the Khlong Ta Chin Estuary areas (Fig. 13), and the sediment samplings in August 1997 were carried out chiefly in the northern part of the estuary and the Straits of Malacca areas (Fig. 14). Twenty six and 27 sediment samples were successfully obtained in these sites in 1996 and 1997, respectively (Tables 3 and 4).

Figure 15 shows the results of the water depth measurements in the Satun area in both December 1996 and August 1997. Water depths indicated in the figure were revised into the depths during the lowest low tide periods in the area. The water depths of the Tam Ma Lung Bay area are less than 1 m in the western and central part of the bay, but they are more than 5 m along the eastern coastal and northernmost bay head areas. The water depths of the Khlong Ta Chin Estuary are generally greater than the bay, around 4 m in the southern part and 10.5 m in a site of the northern part. On the other hand, they in the area of the Straits of Malacca are generally shallow less than 2 m.

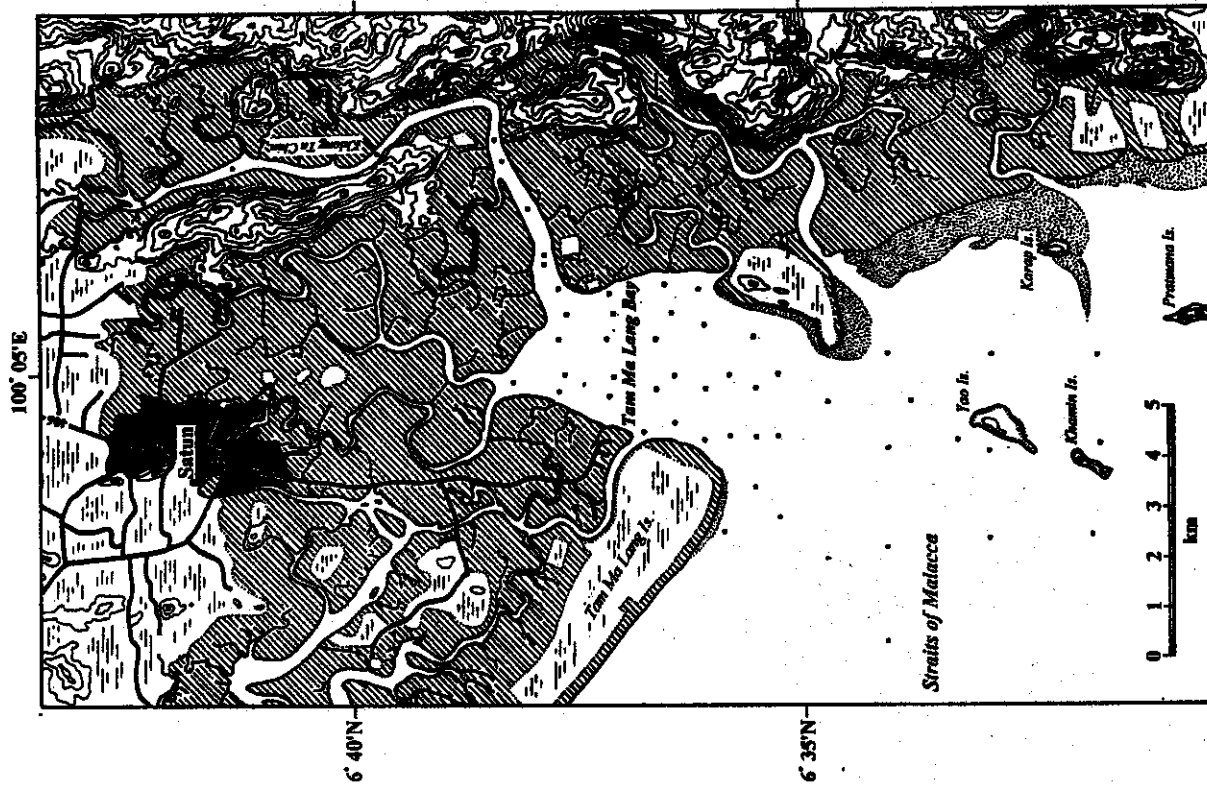


Fig. 12: Topographic features and distribution of mangrove habitats in the Satun area, South Thailand (Legend is same as Fig. 2).

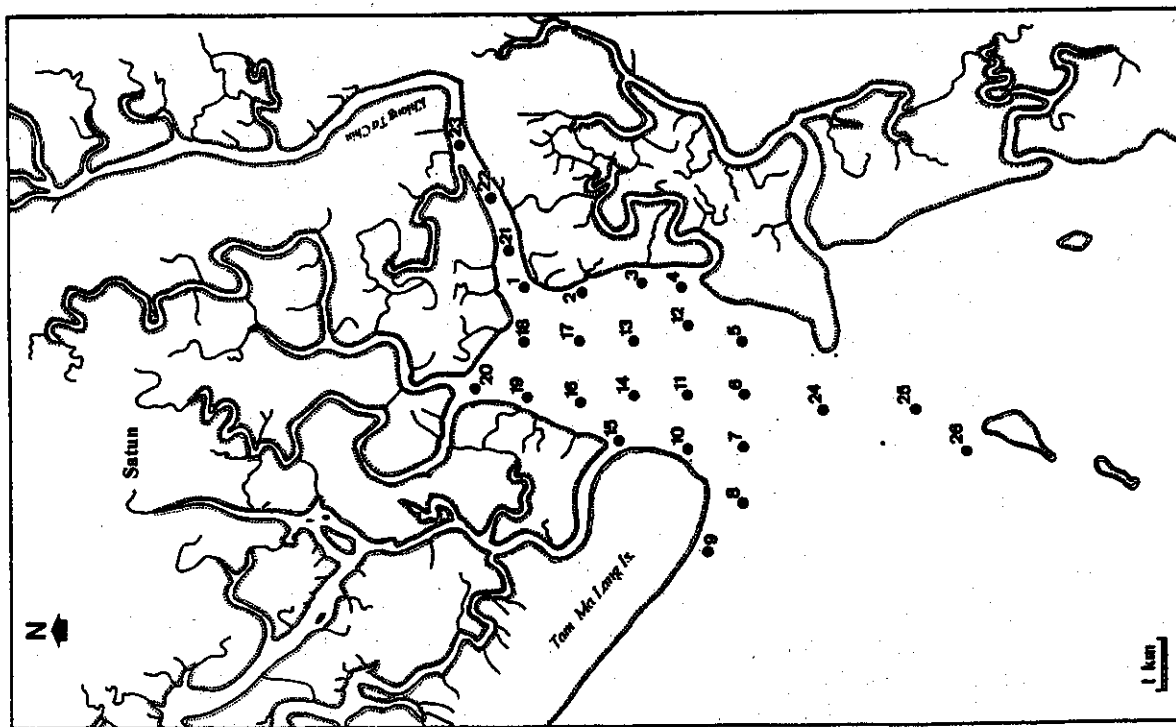


Fig. 13: Sediment sampling and water depth measurement sites in the Satun area in December 1996.

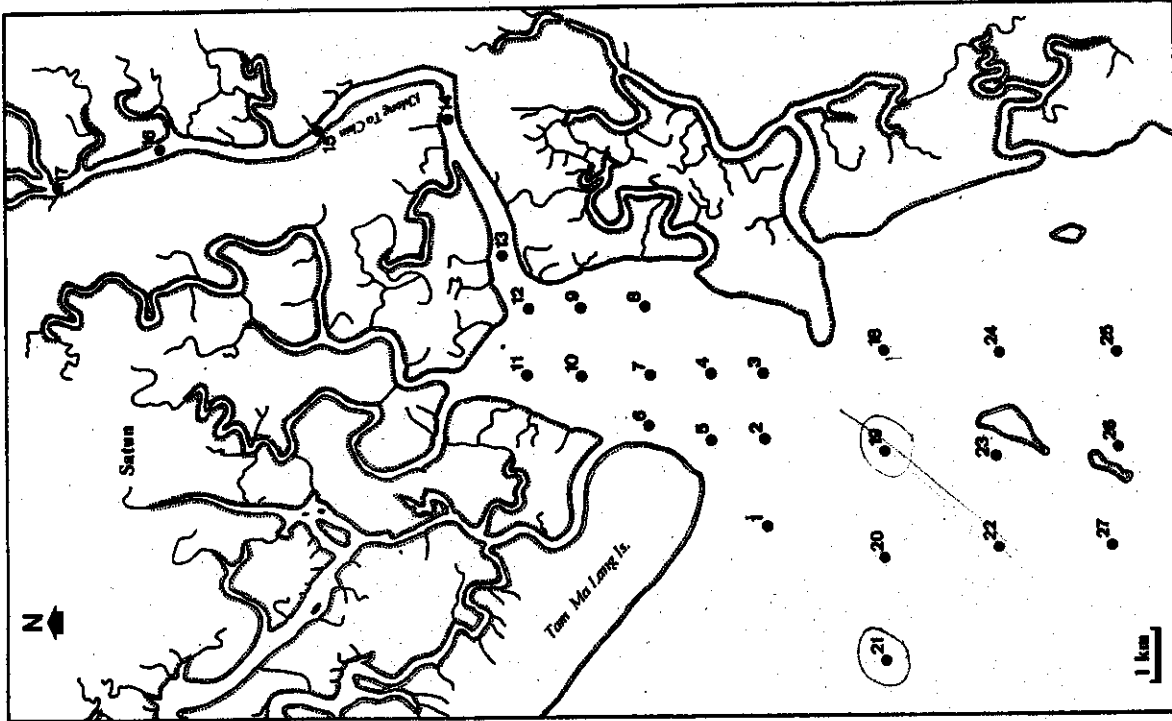


Fig. 14: Sediment sampling, and water depth and water quality measurement sites in the Satun area in August 1997.

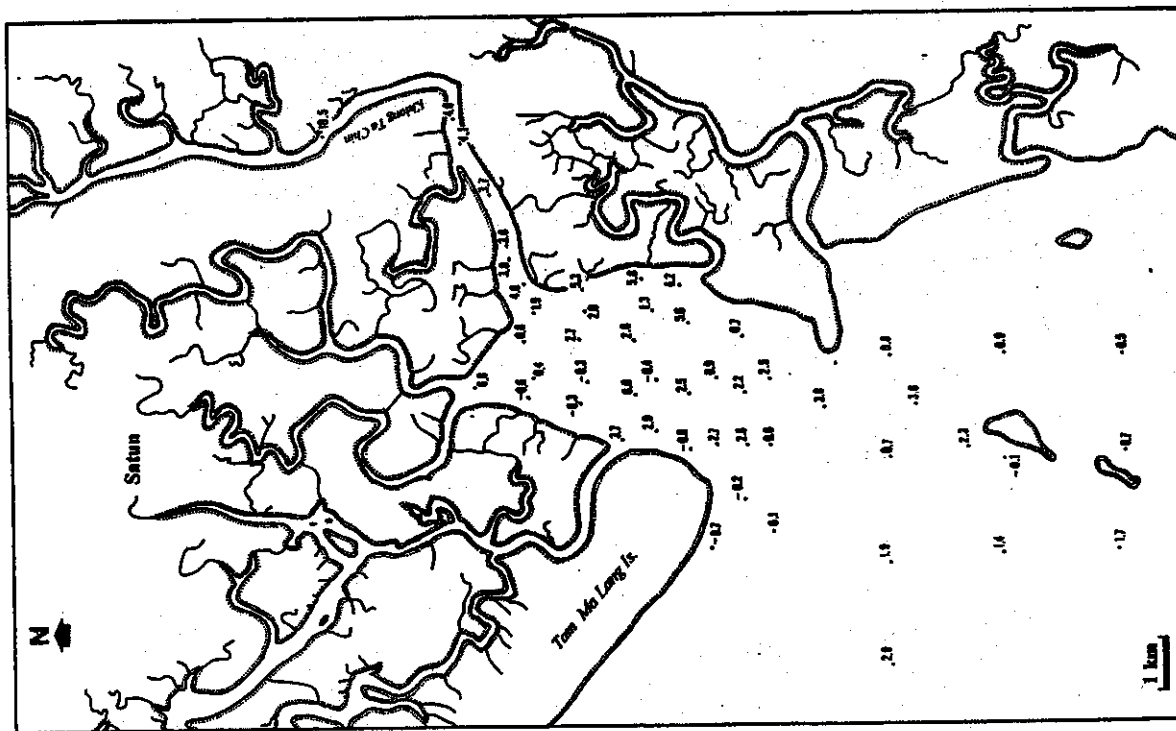


Fig. 15: Results of water depth measurements in the Satun area in both December 1996 and August 1997. Water depths (m) are revised into them during the lowest low tide.

Table 3: Results of sediment samplings in the Satun Area in December 1996.

| Site No. | Date (1996) | Time HR | Latitude (N) | Longitude (E) | Depth (m) | Sediment Type |
|----------|-------------|---------|--------------|---------------|-----------|--|
| ST96-1 | 30 Nov. | 13:05 | - | - | 7.0 | shell bearing muddy c.-vc. sand |
| ST96-2 | " | 13:15 | - | - | 7.5 | plant bearing grey muddy c.-vc. sand |
| ST96-3 | " | 13:30 | - | - | 8.0 | bluish grey massive mud |
| ST96-4 | " | 13:37 | - | - | 6.5 | shell and plant debris bearing bluish grey massive mud |
| ST96-5 | " | 13:49 | - | - | 3.0 | shell fragments and plant debris bearing bluish grey massive mud |
| ST96-6 | " | 14:00 | - | - | 4.5 | shell and plant debris rich bluish grey mud |
| ST96-7 | " | 14:10 | - | - | 5.0 | fragmented plant debris rich bluish grey mud |
| ST96-8 | " | 14:22 | - | - | 2.0 | plant debris rich, shell bearing dark bluish grey mud |
| ST96-9 | " | 14:26 | - | - | 1.5 | plant debris rich, shell bearing dark bluish grey mud |
| ST96-10 | " | 14:55 | - | - | 1.2 | plant debris rich dark bluish grey mud |
| ST96-11 | " | 15:05 | - | - | 4.5 | plant debris rich dark bluish grey - bluish grey mud |
| ST96-12 | " | 15:15 | - | - | 7.5 | shell rich bluish grey mud with large plant debris |
| ST96-13 | " | 15:24 | - | - | 4.6 | shell and plant debris bearing bluish grey mud |
| ST96-14 | " | 15:35 | - | - | 2.5 | shell fragments bearing bluish grey mud |
| ST96-15 | " | 15:45 | - | - | 5.5 | bluish grey massive mud covered by a thin c. sand layer |
| ST96-16 | " | 15:51 | - | - | 1.5 | bluish grey mud covered by a brownish mud layer |
| ST96-17 | " | 16:01 | - | - | 4.5 | plant debris rich, shell bearing bluish grey mud |
| ST96-18 | " | 16:12 | - | - | 2.5 | plant debris rich, shell bearing bluish grey mud |
| ST96-19 | " | 16:29 | - | - | 1.0 | plant debris rich bluish grey mud |
| ST96-20 | " | 16:21 | - | - | 8.5 | plant debris rich bluish grey mud |
| ST96-21 | 1 Dec. | 10:00 | - | - | 5.0 | plant debris and shell bearing bluish grey muddy c. sand |
| ST96-22 | " | 10:10 | - | - | 5.0 | plant debris and shell bearing bluish grey muddy c. sand |
| ST96-23 | " | 10:25 | - | - | 5.5 | plant debris bearing bluish grey mud with reddish brown surface |
| ST96-24 | 2 Dec. | 09:55 | 6° 29'48" | 100° 04'51" | 5.0 | shell and plant debris rich dark blue massive mud |
| ST96-25 | " | 10:10 | 6° 28'46" | 100° 04'51" | 4.8 | shell rich, plant debris bearing bluish grey massive mud |
| ST96-26 | " | 10:20 | - | - | 3.5 | bluish grey massive mud with fine organic matter |

Table 4: Results of sediment samplings in the Satun Area in August 1997.

| Site No. | Date (1997) | Time HR | Latitude (N) | Longitude (E) | Depth (m) | Sediment Type |
|----------|-------------|---------|--------------|---------------|-----------|--|
| ST97-1 | 14 Aug. | 09:25 | 6° 30'32.0" | 100° 03'20.6" | 2.0 | plant debris and shell bearing bluish grey mud, brown layer in surface |
| ST97-2 | " | 09:42 | 6° 29'59.0" | 100° 04'10.8" | 2.5 | plant debris rich bluish grey mud with a small amount of shell |
| ST97-3 | " | 10:00 | 6° 29'42.5" | 100° 04'59.2" | 4.4 | shell rich bluish grey sandy mud, brown layer in surface |
| ST97-4 | " | 10:16 | 6° 30'39.8" | 100° 06'18.5" | 2.7 | plant debris rich bluish grey sandy mud, brown layer in surface |
| ST97-5 | " | 10:37 | 6° 30'41.7" | 100° 04'18.4" | 4.5 | plant debris rich bluish grey mud, brown layer in surface |
| ST97-6 | " | 10:53 | 6° 31'22.1" | 100° 04'29.0" | 4.6 | plant debris bearing brownish grey mud |
| ST97-7 | " | 11:07 | 6° 31'22.4" | 100° 05'00.4" | 1.3 | plant debris and shell bearing olive grey mud, brown layer in surface |
| ST97-8 | " | 11:17 | 6° 31'23.0" | 100° 05'41.0" | 3.0 | molluscan shell rich olive grey sandy mud |
| ST97-9 | " | 11:32 | 6° 31'59.9" | 100° 05'38.1" | 3.6 | plant debris and shell rich olive grey sandy mud |
| ST97-10 | " | 11:46 | 6° 31'59.4" | 100° 05'00.2" | 1.3 | plant debris and shell bearing olive grey soupy mud |
| ST97-11 | " | 12:12 | 6° 32'32.2" | 100° 05'02.6" | 1.1 | olive grey mud with vc. quartz sand |
| ST97-12 | " | 12:30 | 6° 32'38.5" | 100° 05'34.5" | 3.4 | molluscan shell rich olive grey sandy mud |
| ST97-13 | " | 12:40 | 6° 32'49.2" | 100° 06'24.2" | 6.3 | plant debris, vc. quartz sand and shell bearing olive grey sandy mud |
| ST97-14 | " | 12:56 | 6° 33'15.9" | 100° 07'32.2" | 6.0 | olive grey mud, brown layer in surface |
| ST97-15 | " | 13:17 | 6° 34'36.5" | 100° 07'28.4" | 11.9 | slightly muddy c.-vc. quartz sand |
| ST97-16 | " | 13:34 | 6° 36'00.6" | 100° 07'20.2" | ? | plant debris rich muddy c.-vc. quartz sand |
| ST97-17 | " | 13:50 | 6° 37'13.3" | 100° 08'53.6" | ? | plant debris rich muddy c.-vc. quartz sand |
| ST97-18 | 15 Aug. | 09:04 | 6° 28'59.7" | 100° 05'02.8" | 3.2 | plant debris and shell rich muddy f. sand |
| ST97-19 | " | 09:17 | 6° 28'59.0" | 100° 03'59.7" | 3.0 | oyster shell fragments with a small amount of f. sand |
| ST97-20 | " | 09:36 | 6° 29'06.6" | 100° 02'59.4" | 4.2 | shell fragments bearing bluish grey sandy mud |
| ST97-21 | " | 09:49 | 6° 29'00.6" | 100° 02'00.0" | 4.2 | shell rich bluish grey sandy mud |
| ST97-22 | " | 10:36 | 6° 27'57.8" | 100° 02'52.8" | 3.5 | oyster shell fragments rich f. sand |
| ST97-23 | " | 10:48 | 6° 28'08.3" | 100° 04'01.9" | 1.9 | shelly f. sand |
| ST97-24 | " | 11:02 | 6° 27'58.7" | 100° 05'00.2" | 2.8 | shelly bluish grey mud |
| ST97-25 | " | 11:14 | 6° 27'00.4" | 100° 05'03.0" | 2.4 | shell and plant debris bearing bluish grey mud |
| ST97-26 | " | 11:26 | 6° 26'56.9" | 100° 04'17.9" | 2.5 | shell fragments bearing black f. sand |
| ST97-27 | " | 11:45 | 6° 27'01.0" | 100° 03'00.1" | 3.5 | molluscan shells with a small amount of f. sand |

2-2. Distribution of Surface Sediments

Plant debris bearing bluish grey homogeneous mud is the dominated surface sediments in the Tam Ma Lung Bay area. Molluscan shell and shell fragments are commonly contained in the sediments from the eastern part of the bay, and they are particularly rich in the site 12 of 1996. Sand consists mainly of fine- to very fine-grained quartz. The surface sediments in the Klong Ta Chin area are composed mainly of muddy coarse to very coarse grained quartz sand. They in the area of the Straits of Malacca consist of bluish grey sandy mud and muddy sand with plant debris, molluscan shell and shell fragments.

Figure 16 illustrates the spatial distribution of mud contents of the surface sediments in the Satun area in December 1996. The mud contents in the western and central part of the bay are generally more than 90 %. There are some exceptions but the mud contents in the eastern part and the areas of the estuary and the Straits of Malacca are markedly lower than the bay area.

Remains of micro-organisms such as ostracodes and benthic foraminifers are frequently recognized in the surface sediments obtained in the bay mouth and the Straits of Malacca areas in 1996 (Fig. 17)



Fig. 16: Mud contents of the bottom sediments in weight percent of the Satun area in December 1996.



Fig. 17: Occurrence of ostracode tests from the bottom sediments in the Satun area in December 1996 (O: dominant, +: frequent).

2-3. Salinity of Surface Waters

Figure 18 shows spatial distribution of surface water salinity in the Satun area in August 1997. The salinity is more than 25 ‰ in the area of the Straits of Malacca, between 23 and 26 ‰ in the Tam Ma Lung Bay area, and between 19 and 22 ‰ in the Khlong Ta Chin Estuary area where the salinity shows a gradual decrease from 21.8 ‰ near the bay to 19.1 ‰ at the northern end of the estuary.

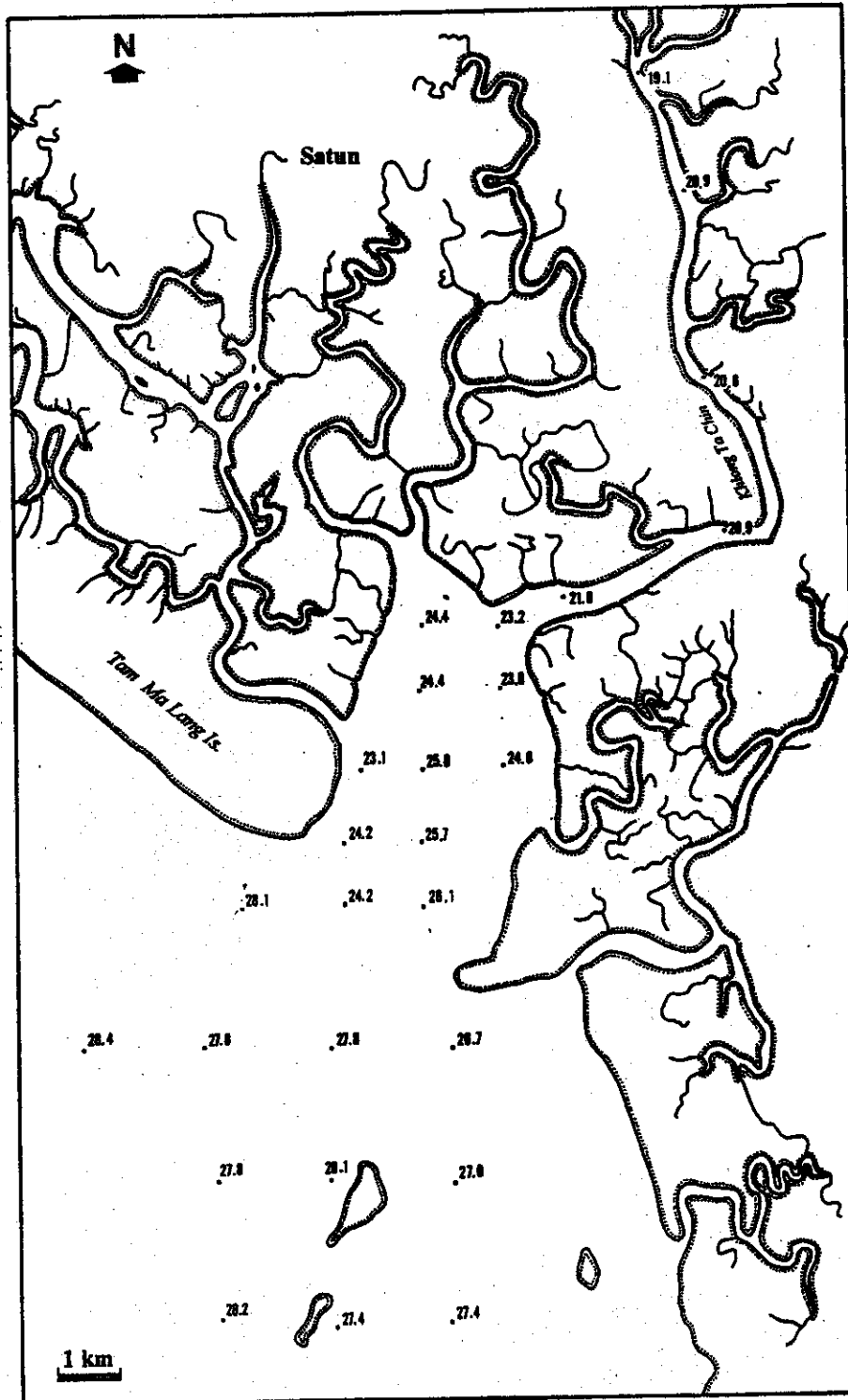


Fig. 18: Results of salinity measurements of the surface water (‰) during a low tide period in the Satun area in August 1997.

2-4. Temperature of Surface Waters

Figure 19 shows spatial distribution of surface water temperatures in the Satun area in August 1997. The surface water temperatures are constant between 30 and 32 °C in whole area. No marked morphologically controlled inclination is recognized.

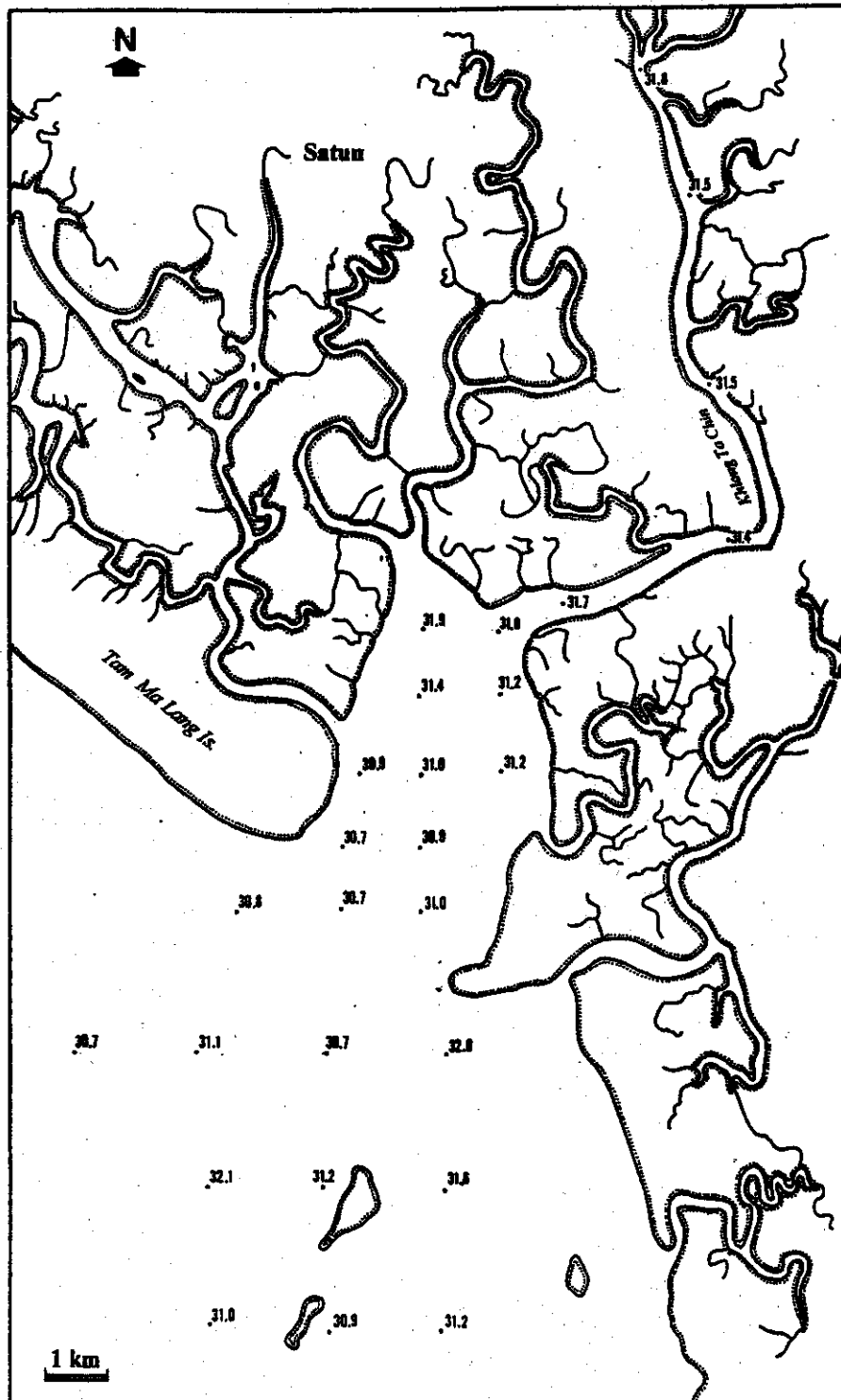


Fig. 19: Results of the surface water temperature measurements (°C) during a low tide period in the Satun area in August 1997.

2-5. Hydrogen Ion Exponent (pH) of Surface Waters

Figure 20 shows spatial distribution of hydrogen ion exponents (pH) of the surface waters in the Satun area in August 1997. The pH values are more than 8.2 in the area of the Straits of Malacca, between 7.8 and 8.2 in the Tam Ma Lung Bay area, and less than 8.0 in the areas of the Khlong Ta Chin Estuary. A gradual decrease from 8.13 near the bay to 7.61 in the northernmost end of the estuary is recognizable.

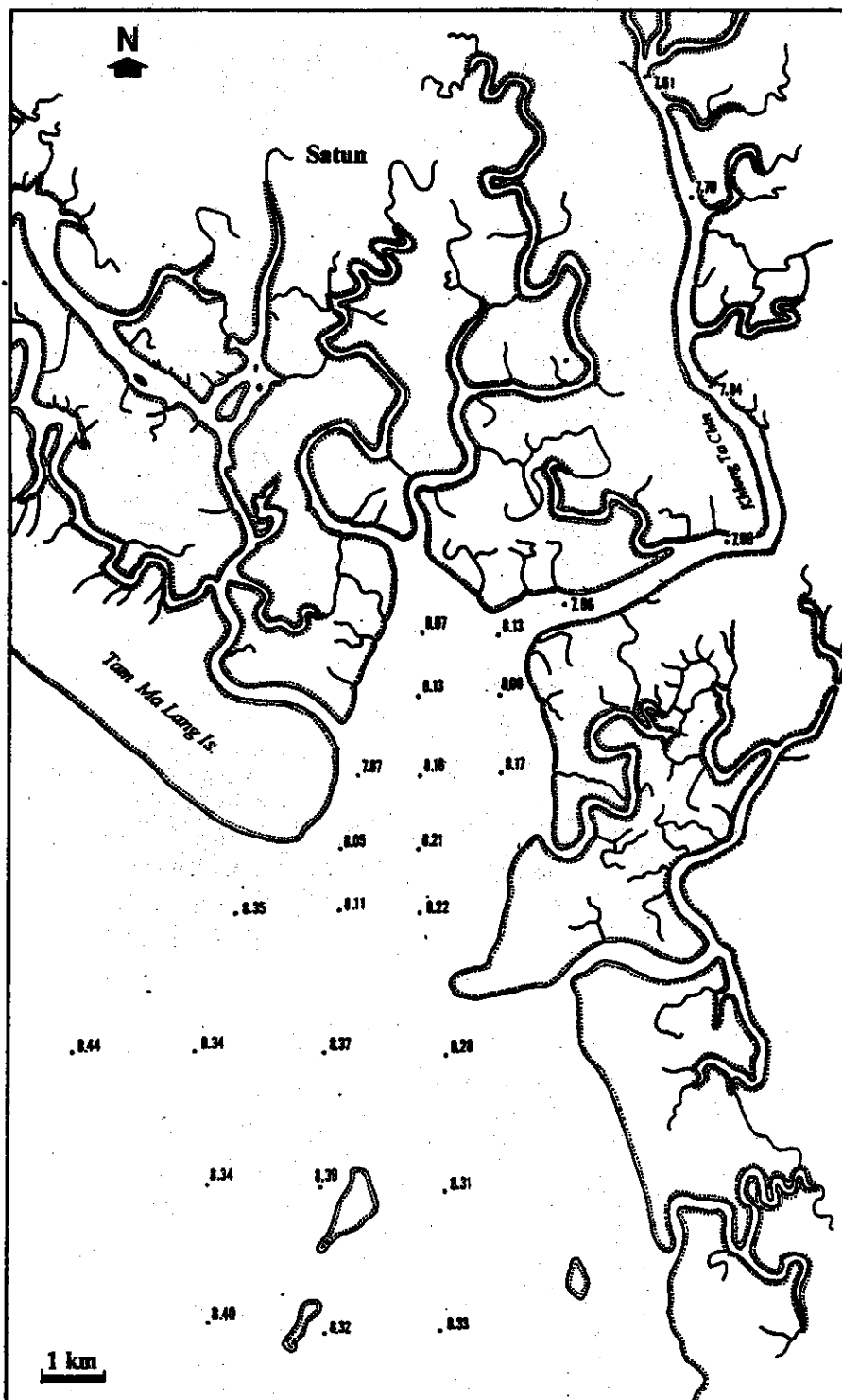


Fig. 20: Results of hydrogen ion exponents (pH) measurement of the surface water during a low tide period in the Satun area in August 1997.

2-6. Dissolved Oxygen Amount (DO) of Surface Waters

Figure 21 shows spatial distribution of dissolved oxygen amount (DO) of the surface waters in the Satun Area in August 1997. The DO in the area of the Straits of Malacca are markedly low between 3.1 and 3.6 ppm. On the other hand, they in the Satun Bay area are comparatively high between 4.7 and 6.8 ppm. They are between 5.6 and 6.3 ppm in the area of the Khlong Ta Chin Estuary.

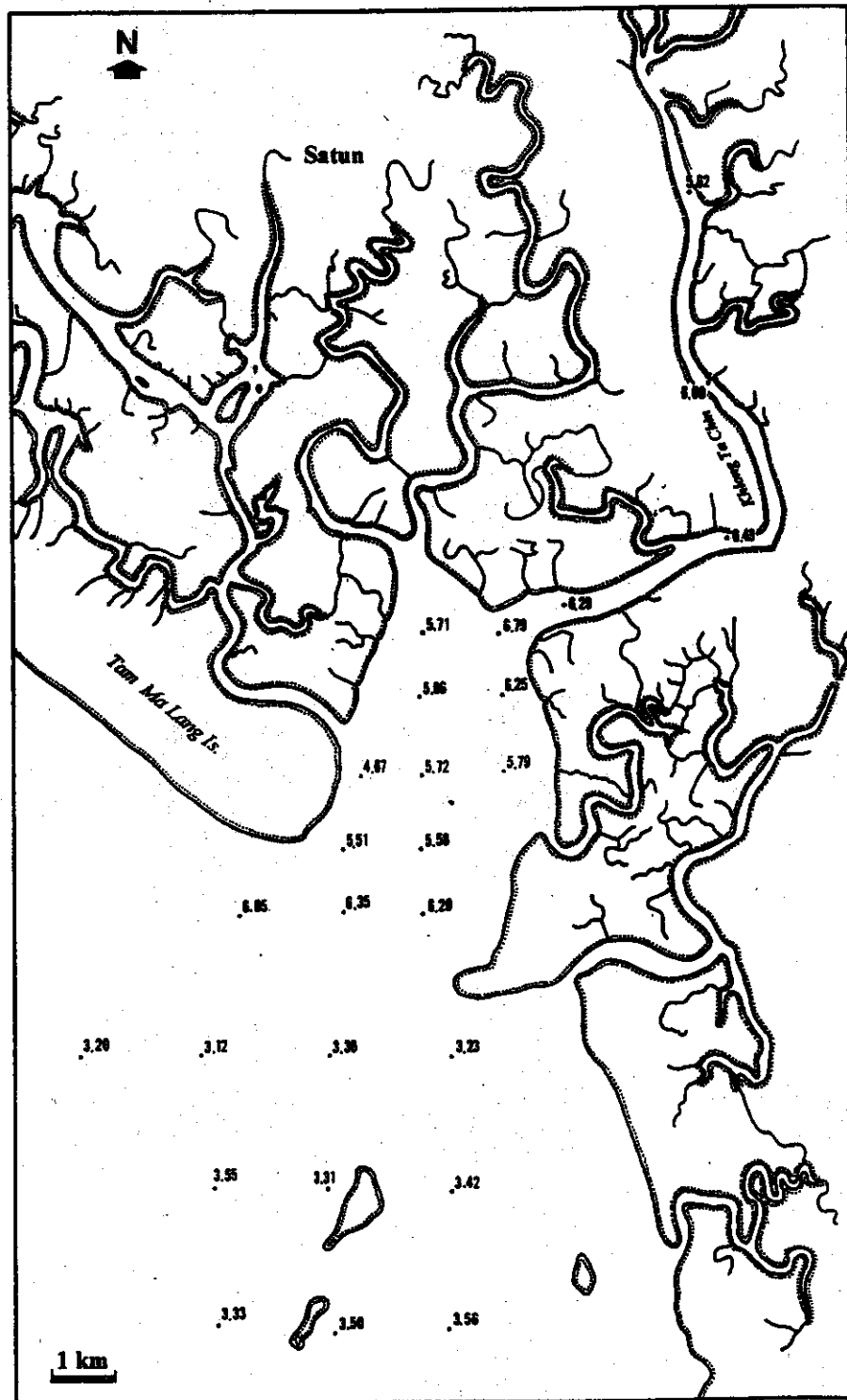


Fig. 21: Results of dissolved oxygen amount (DO) measurement of the surface water (ppm) during a low tide period in the Satun area in August 1997.