FINAL REPORT

THE STUDY ON THE DEVELOPMENT OF RAJANG PORT IN MALAYSIA

VOLUME I INTRODUCTION AND PRESENT SITUATION

FEBRUARY 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

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THE STUDY ON THE DEVELOPMENT OF RAJANG PORT

IN MALAYSIA

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J I C A

Japan International Cooperation Agency

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1. INTRODUCTION

1.1 Background of the Study

Rajang Port is defined as port facilities under control of the RPA (Rajang Port Authority) at Sibu, Sarikei, Bintangor, Sungei Merah and Tanjung Manis area on the Rajang River and its branches in the Rajang Delta, and is located in the State of Sarawak, Malaysia. Rajang Port plays an important role in the timber trade in the State of Sarawak. Rajang Port handled 5.2 million tons of cargo in total in 1989, 78% of which is timber and exported from the Tanjung Manis anchorage.

Recently, exports of timber, oil handling and imports of grains, daily necessities, etc., have rapidly grown at Rajang Port as the economy in the Rajang Valley has expanded. Moreover, progress in modernization of transportation such as containerization of general cargoes can be found also at the port. The port faces, however, deterioration of the facilities and shortage of capacity at Sibu and other wharves.

Since timber export constitutes one of the major bases to the Sarawak's economic growth, it is important to develop regions in Sarawak by establishment of a timber industry as one of leading industries. The state government plans to develop industrial areas for sawmills, plywood mills, etc., and to export more value-added products as well as to attract other industries. This plan also requires port development for timber products and so forth.

Merit Pila coal mine, which is located near Kapit and has the largest deposit in Malaysia, has produced coal since 1988. Export of this coal from Rajang Port started in 1989.

Sarawak Electricity Supply Corporation (SESCO) is preparing a plan for three coal thermal power plants one of which would be established in Sibu area by using coal from Merit Pila mine, another plant in Kuching area would be partly supplied from Merit Pila mine.

As further coal development is likely to be conducted, more coal exports and construction of power plants can be expected. Then coal terminal would be required as transfer point from river barges to ocean-going ships and coal supply deposit to the plants.

1.2 Objectives of the Study

The objectives of the Study are:

(1) To formulate a master plan for Rajang Port for the period up to the year 2010.

(2) To determine the technical, economic and financial feasibility of a short-term plan for the port within the framework of the master plan. The short-term plan shall be prepared for the period up to the year 1997.

1.3 Scope of the Study

In order to achieve the objectives mentioned above, the Study shall cover the following items:

(1) Review and Field Survey

1) To collect and review available information and reports relevant to the Study,
2) To conduct field surveys for evaluating the present conditions of the port.

(2) Observation of Natural Conditions
Field surveys for the following conditions will be carried out:

1) Meteorological conditions
2) Hydrographical conditions
3) Topographical conditions
4) Geological conditions

(3) Master Plan

1) To delineate the hinterland of the Port and estimate the economic potential of the hinterland.
2) To forecast port traffic up to the year 2010.

3) To establish the main goals and policy for the development of the Port.

4) To make recommendations on improvement of port facilities and cargo handling equipment.

5) To select the most appropriate site for the development of the port.

6) To formulate a phased development plan for the port.

7) To formulate a basic layout plan of land and water area utilization in the vicinity of the Port.

8) To formulate a basic layout plan of major port facilities and relevant infrastructure.

9) To make a rough cost estimation for the plan mentioned in the previous clause (8).

10) To make recommendations on management and operating systems for the port.

(4) Feasibility Study on Short-Term Plan.

On the basis of the above master plan, a short-term plan on the selected site will be formulated for the target year, and a feasibility study on it will be conducted.

1) To forecast the port traffic in detail up to the target year.
2) To formulate a detailed facilities improvement plan, including navigational aids and cargo handling systems.
3) To prepare a preliminary design.
4) To prepare an implementation programme.
5) To estimate capital and maintenance costs.
6) To conduct a preliminary environmental impact assessment.
7) To conduct an economic and financial analysis.
8) To make recommendations on management and operating systems.

1.4 Study Schedule

The Study is being carried out according to the flow chart shown in **Figure-1.4.1.1.** And, the each study item is being conducted on the schedule shown in **Figure-1.4.1.2.**

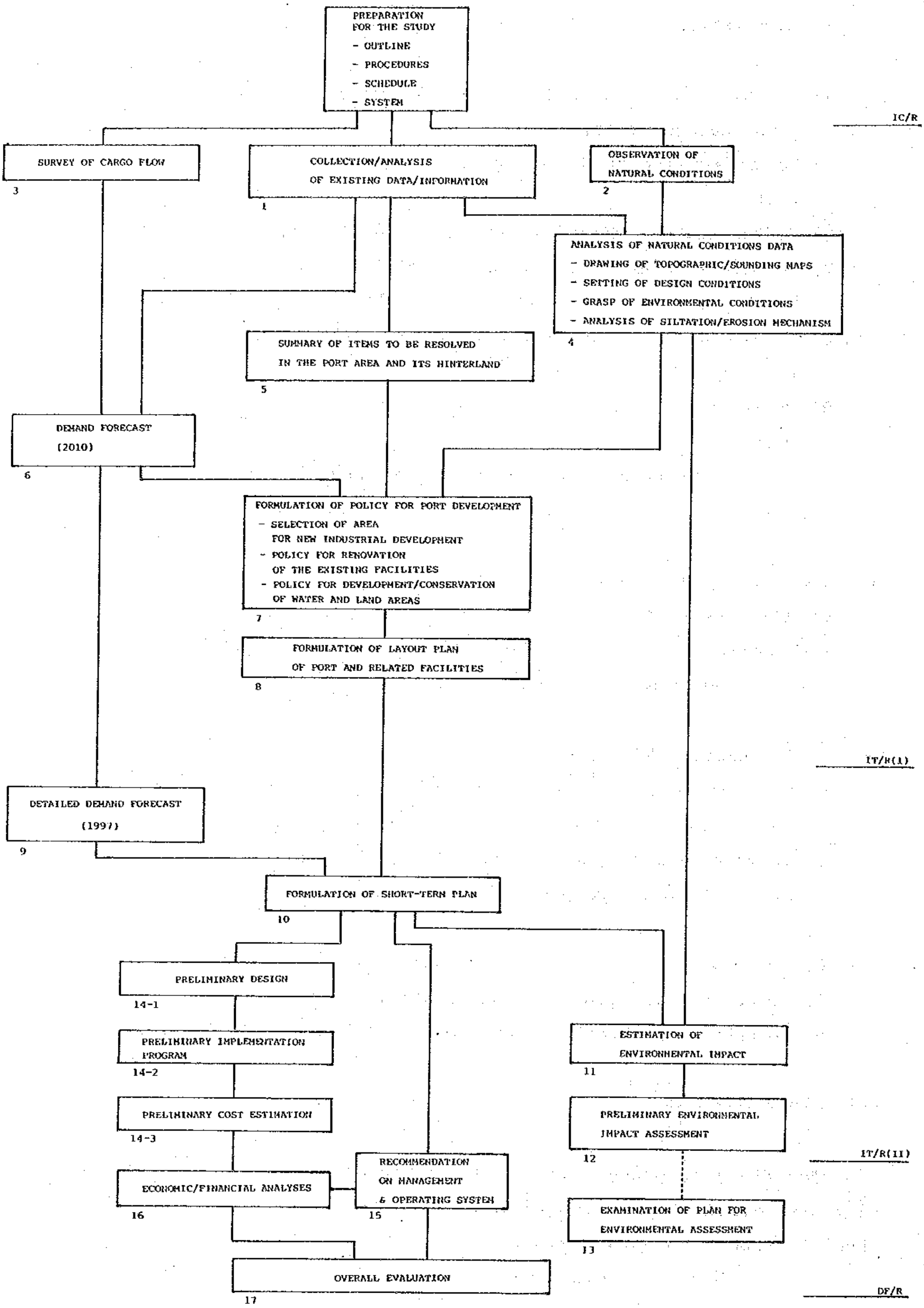
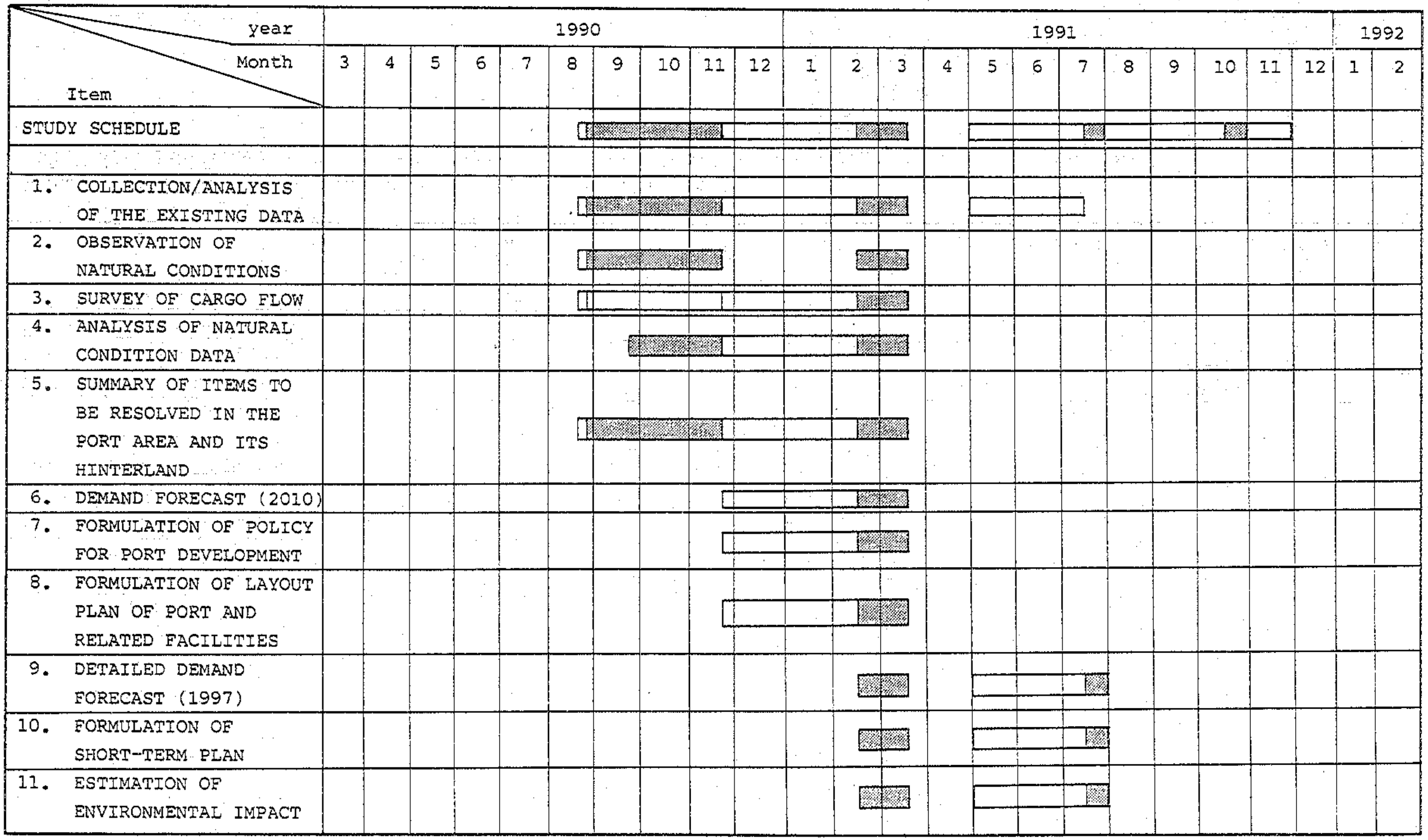
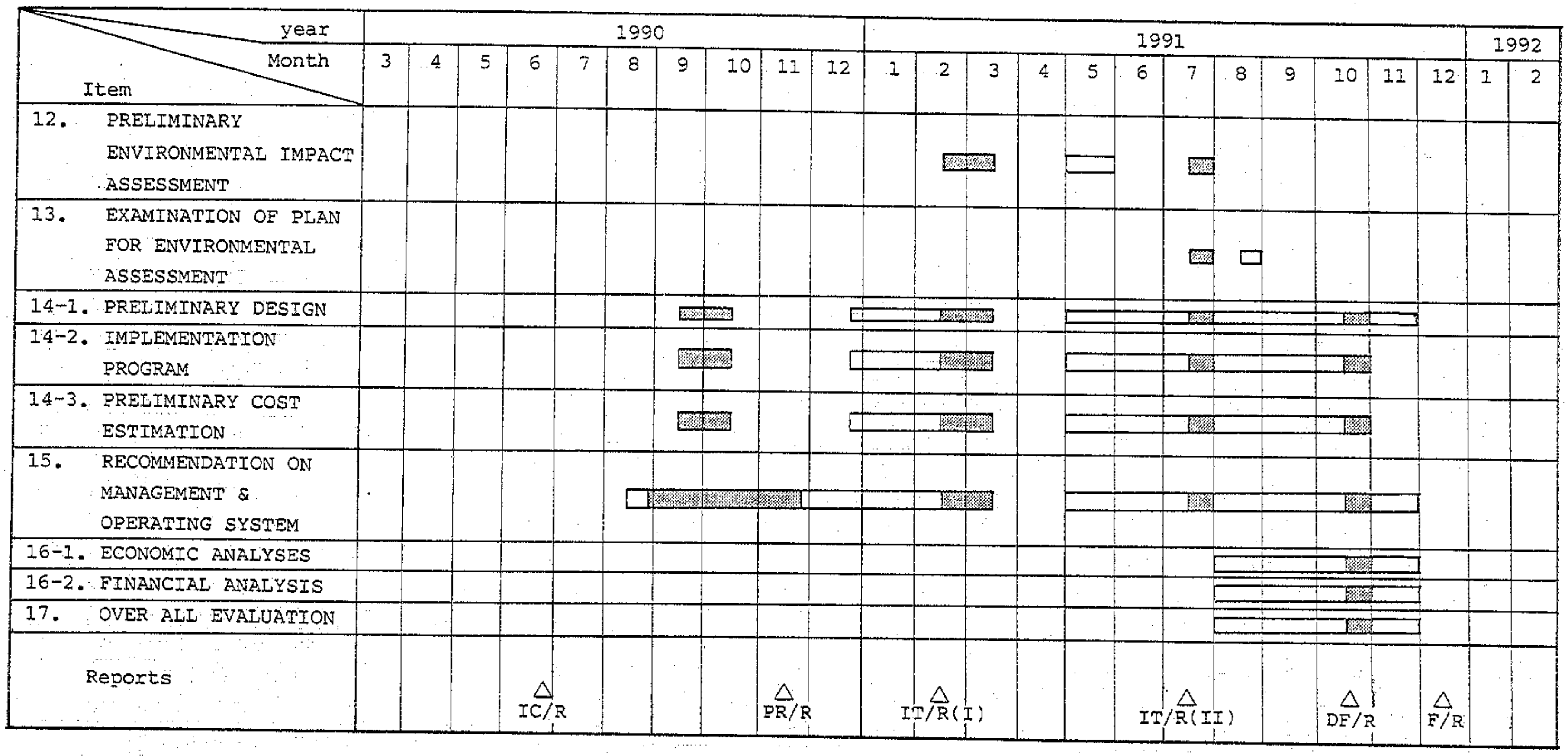


Figure-1.4.1.1 Working Procedure of the Study

Figure-1.4.1.2 Work Schedule





Legend : [shaded bar] Work in Malaysia [open bar] Work in Japan

IC/R: Inception Report PR/R: Progress Report IT/R: Interim Report DF/R: Draft Final Report F/R: Final Report

1.5 Organization of the Study Team

The Study Team consists of eleven experts. Their names and responsibilities are listed below.

Name	Responsibility
Ikuo MITSUHASHI	Leader
Hiroshi HORIKAWA	Port Planning/Acting Leader
Shoji KATUDA	Coastal Area Development Planning
Takahisa AOYAMA	Demand Forecast/Economic Analysis
Izumi ABE	Management and Operation/Financial Analysis
Yutaka YOSHIMORI	Preliminary Port Environment Study
Nobuaki KOJIMA	Navigational Aids Planning
Nobuya FURUHASHI	Natural Conditions (Meteorology and Oceanography)
Masahiro YOKOGAWA	Natural Conditions (Soil and Topography)
Yasuo KANESATO	Facility Design
Takeaki HOSHINO	Construction Method/Cost Estimation

1.6 Profile of the port

1.6.1 Malaysia

Malaysia consists of eleven states in the Peninsular of Malaysia and two states in Borneo. Its total area is 330,434km^2 (Peninsular Malaysia: 131,587km^2; Eastern Malaysia: 198,847km^2), four-fifths of which is covered with tropical timber forests or swampy lands. Malaysia has 16.9 million people and the GNP per capita was US$1,858 in 1988.

The transportation network is composed of 39,800 km of roads, 1,780 km of railways, 19 airports, including 5 international airports, and federal ports such as Penang, Kelang, Kuantanu, Johor and Bintulu, and major state ports such as Kuching, Kota Kinabalu, Rajang, etc. **(Figure-1.6.1.1)** Water transportation plays an extremely important role in cargo trading in Malaysia because Peninsular Malaysia and Eastern Malaysia are divided by sea and because the main export commodities are bulky primary products.

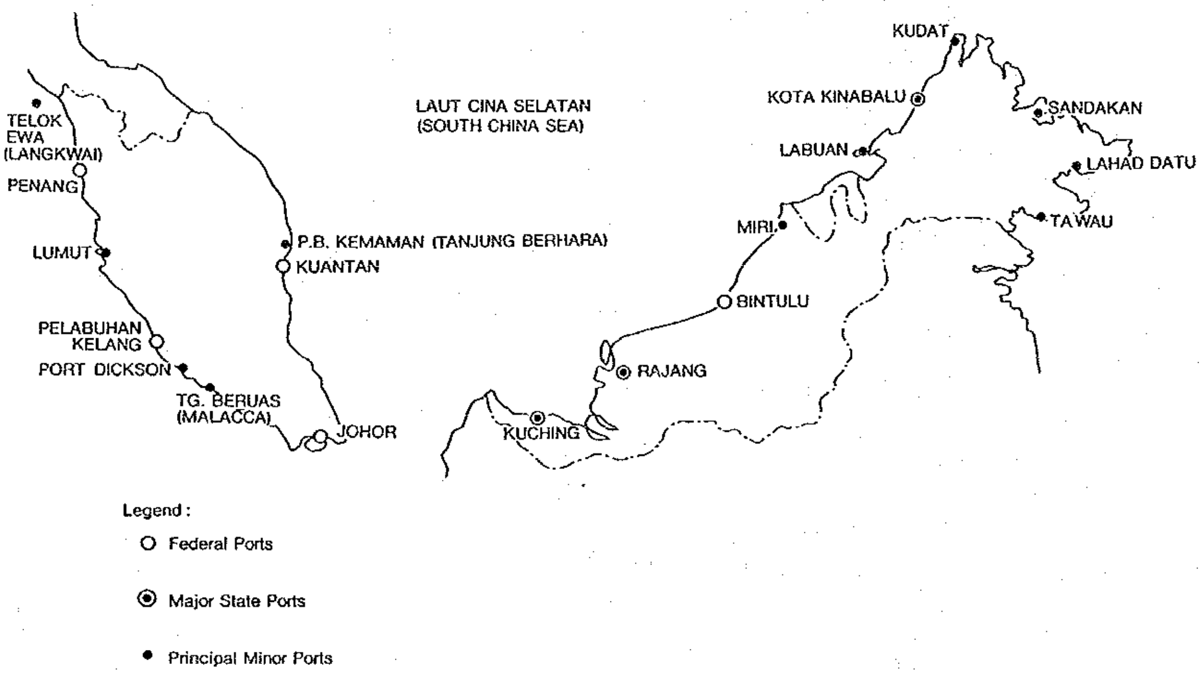


Figure-1.6.1.1 Ports in Malaysia

1.6.2 Sarawak

The State of Sarawak, where the Rajang Port is located, occupies the southwestern part of Eastern Malaysia and has an area of 124,449km^2, which accounts for 63% of the area of Eastern Malaysia. Although the inland area is mountainous, large plains extend along the shoreline and rivers. The whole area is covered with tropical timber forests or swampy land forests which block inland surface transportation. So, the Rajang and Lupar rivers in the southern area and the Baram river in the northern area and so on are used as transportation routes.

The population of Sarawak is about 1,593,000 in 1988 and the density is only 13 persons per km^2.

The main current industries of Sarawak are timber logging/processing, production of crude oil and liquefied natural gas, and agricultural products such as pepper, rubber, palm oil, etc. Log production in Sarawak began on a full scale in the 1970s and has rapidly grown. The production in 1990 reached to 18 million m^3, exceeding the production in Sabah. Export of timber logs and products from Sarawak in 1988 exceeded Rg. 2,100 million, and has the second-biggest share next to oil and gas of Sarawak's export products.

Sarawak State is moving vigorously forward economic growth mainly as a result of industrial development in five industries, that is, timber processing industry, petrochemical industry, agriculture, tourism industry and electronic industry. These industries require mass transportation modes to supply materials, export finished products and transport tourists; in other words, the development depends upon transportation to a great extent.

Although Sarawak State has made great efforts to develop a transportation infrastructure, roads are still not adequate due to natural conditions such as widely spreading forests, swampy land and many rivers. Sarawak State has proposed plans for improvement of the existing arterial road connecting Kuching, Sri Aman, Sibu, Bintulu, Miri and other major towns and construction of bridges on the road. However, it is expected to take a long time to implement the plans due to length of the roads and difficulty in construction caused by natural conditions. Moreover, development in air transportation is also ongoing such as the new Sibu international airport development. However, while air transportation is efficient for haulage of electronic products, it is not suitable as a mass transportation mode. On the other hand, Sarawak State has four major ports, Kuching, Rajang, Bintulu and Miri Ports, and an inland waterway network that connects these respective ports. Urban areas in Sarawak were originally developed using these waterways and water transportation is still the best mode for mass and economical transportation. Consequently, water transportation is extremely important and its development is needed to encourage industrial development.

1.6.3 Rajang Port

Rajang Port is located in the lower part of Rajang River, which is the longest river in Malaysia. Rajang Port is defined as port facilities under control of the RPA (Rajang Port Authority) at Sibu, Sarikei, Bintangor, sungei Merah and Tg. Manis area. Rajang Port can accommodate .ocean-going vessels and play a role as a gateway for not only major towns in the Lower Rajang River area such as Sibu, Sarikei and Bintangor, but also the other major towns in the Rajang River region, Belaga, Kapit, Song, Kanowit, Daro, Mukah, etc. Rajang River region and its adjoining areas, which comprise the central area of Sarawak, are rich in timber and coal resources and suitable for agricultural activities.

Rajang Port, defined as port facilities under control of the RPA at Sibu (the second -biggest city in Sarawak), Sarikei, Bintangor and Sungei Merah and an anchorage area at Tg. Manis, is located on the lower part of the Rajang River, which is the longest river in Malaysia.

Rajang Port has two main routes; the Rajang Route and the Paloh Route (**Figure-1.6.3.1**). By using the Rajang Route, vessels can sail up to Tg. Manis anchorage (26km from the river mouth), Sarikei (50km from the river month) and Bintangor (70km from the river month). Beyond Tg. Manis, only small ships can sail due to the shallow depth and dangerous corners. On the other hand, by using the Paloh Route, large vessels can travel 82km upriver to Sibu.

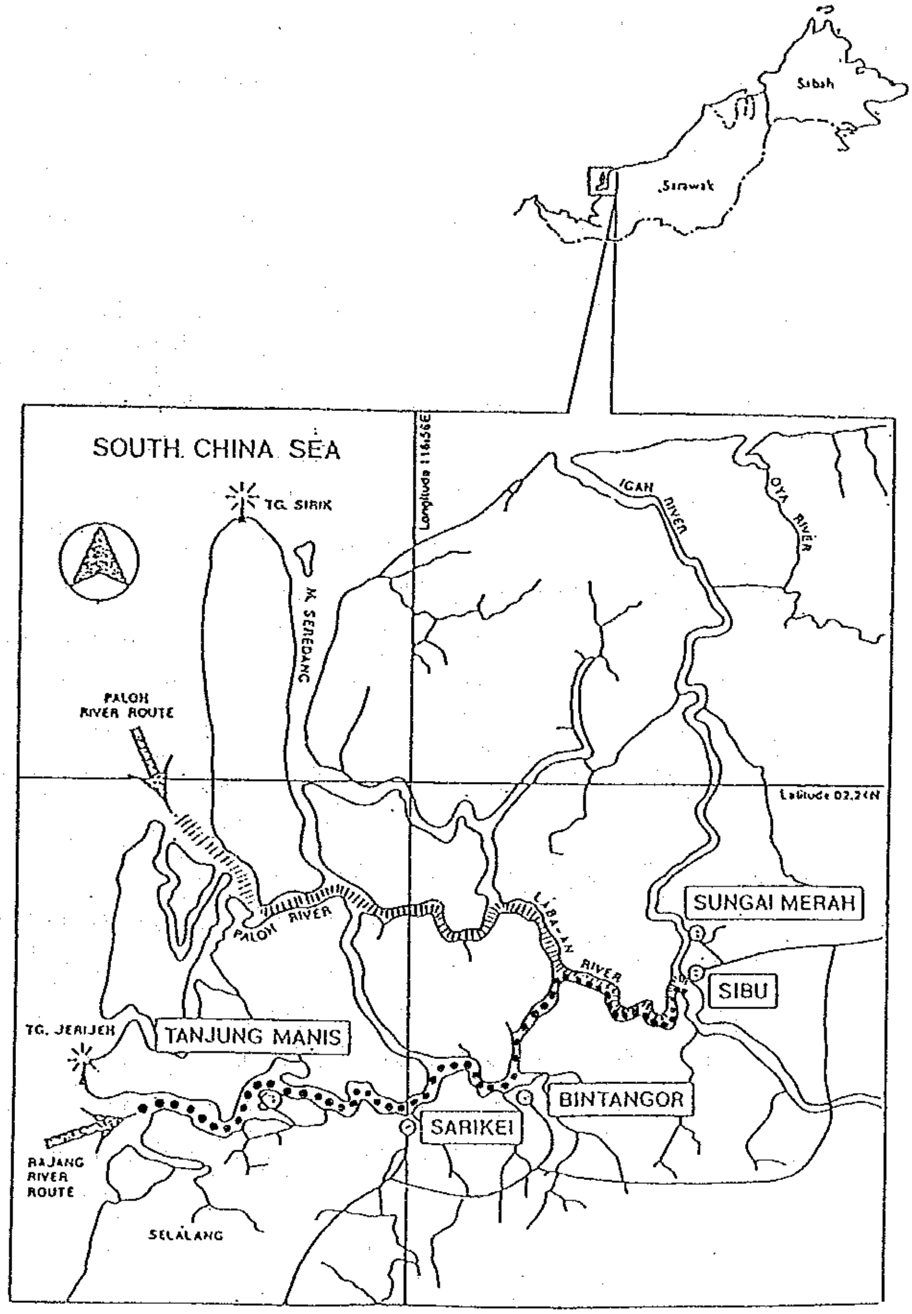


Figure-1.6.3.1 Location of Rajang Port and Navigation Routes

The Rajang River, the Paloh River and the many river branches make up a waterway network in the Rajang Delta, enabling effective water transportation routes which support the base of society and economy in the region.

The cargo volume handled at Rajang Port in 1989 was 5.2 million tons (export: 4.4 million tons, import: 0.8 million tons) and accounted for 6% of the total cargo volume in all ports in Malaysia. Logs and timber products accounted for 79% of the total cargo volume and 93% of the export cargo volume. Other main cargoes are oil products (240,000 tons), grains (6,1000 tons) and fertilizers (3,300 tons). Containers have been handled since 1982 at Sibu and the volume handled has rapidly grown (1989/1984: 257% growth, 12,125 TEUs in 1989). This rapid growth has caused a shortage of handling space for containers at Sibu.

The number of ships which called at Rajang Port in 1989 was 1,959 vessels, amounting to 6.6 million GRT in total (the average GRT is 3,363). 1,134 ships and 490 ships called at Tg. Manis anchorage and Sibu, respectively.

The main port facilities at Rajang Port are 444m-long and -8.5m-deep wharf at Sibu, one -7.6m-deep wharf at Sarikei, and one -4.6m-deep wharf each at Bintangor and Sungei Merah. There is only an anchorage at Tanjung Manis. The vital economic activities in the Rajang River region are generating more and more port cargoes such as export of timber products, agricultural products and mineral resources, import of oil products, which require proper terminals including container handling facilities for more rational and productive transportation. Thus, Rajang Port needs to be improved and meet these trend as a transportation center of the region.

1.7 Locational Conditions and Hinterland

The Rajang River, on which Rajang Port is located, originates in the Iran Mountains and flows into the South China Sea. The four wharves and deep anchorage of Rajang Port are located in the Rajang Delta, surounded with flat, low and mangrove-covered swampy land (**Figure-1.7.1.1**).

Rajang Port is located in the Rajang Delta and plays an essential role as a cargo and passenger terminal for the middle area of the state of Sarawak. This transportation system and an arterial road that runs the southern area of the Rajang Delta from Kuching to Miri (via Sibu) determines the hinterland (**Figure-1.7.1.2**). The hinterland of the port can be established as seen in **Figure-1.7.1.3**, which includes Sibu, Sarikei and Kapit Divisions and part of Sri Aman Division from the geographical conditions and road condition as follows:

- the Lupar River valley areas of Sri Aman Division, Sri Aman and Lubok Antu Districts, are included in the hinterland of Kuching Port because of their closer proximity to Kuching Port than to Sarikei Wharf
- in contrast, the Betong and Saratok Districts in Sri Aman Division belong to the hinterland of Rajang Port for the similar reason (moreover, agricultural products from these two districts are currently exported through Sarikei Wharf)
- Sibu, Sarikei and Kapit Divisions are strongly connected with Rajang Port through inland waterways of Rajang River and its branches
- Kapit and Belaga Districts seem closer to Bintulu Port than to Rajang Port on a map, but there are no adequate roads due to a mountainous topography between Bintulu and these two districts
- there is a relatively good road between Sibu and Bintulu and a portion of seaborne cargoes (palm oil) from Mukah district are currently shipped out from Bintulu Port, but Mukah Town can be accessed from Sibu easier than from Bintulu by road or rivers, so other cargoes are expected to be transported through Rajang Port

The population of this hinterland was about 0.5 million in 1980 and 0.6 million in 1990. The growth rate is almost stable and the population is expected to reach 0.9 million in 2010.

The main urban areas except Sibu, the most populous and activate city, are located south of the Rajang River. Sibu and the other main towns - Sarikei, Bintangor, Kapit, Kanowit, Saratok, Betong, etc - and villages are connected with waterways through the Rajang River system and an inadequate road system.

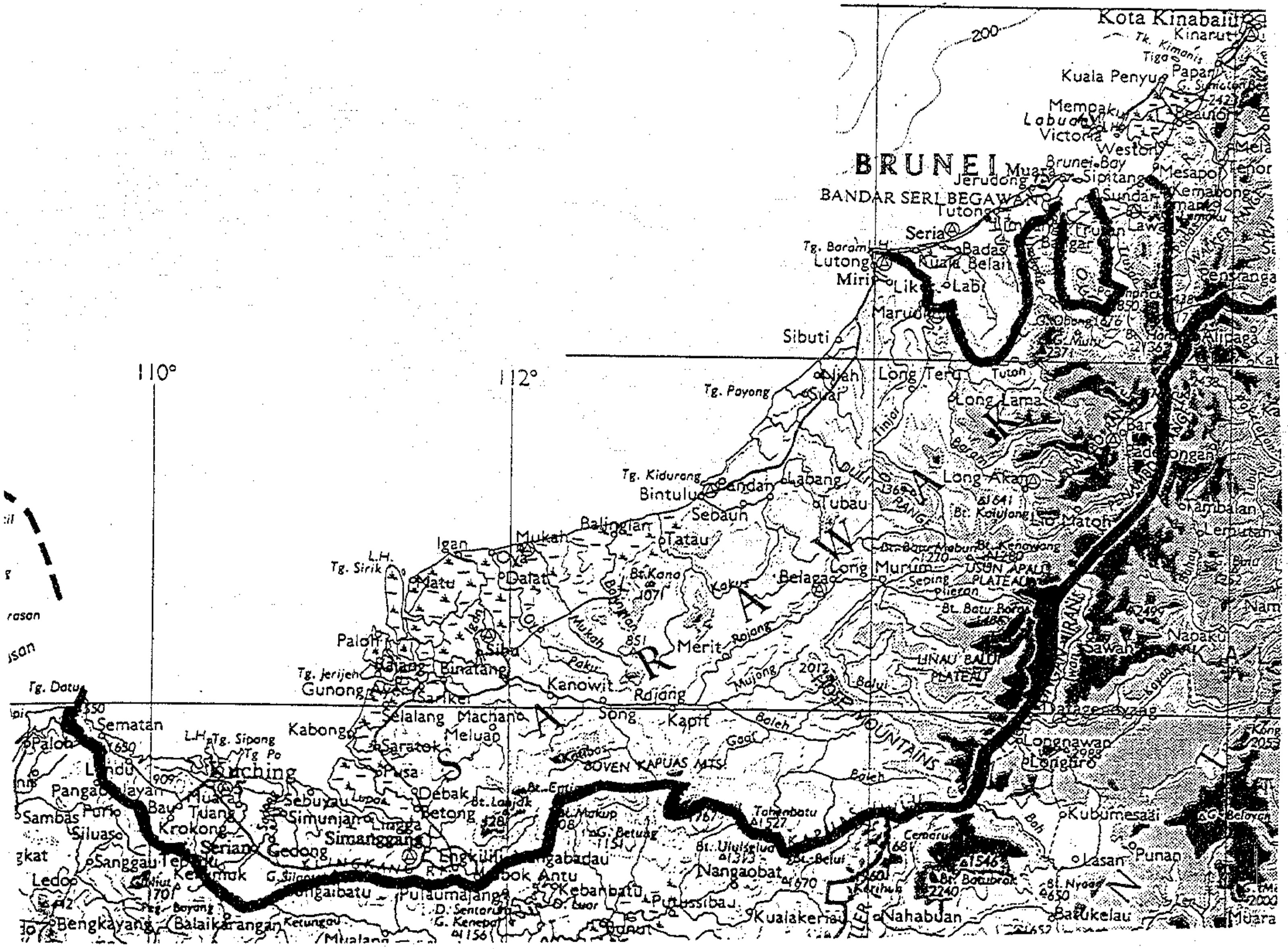


Figure-1.7.1.1 Topography of the Rajang River Region

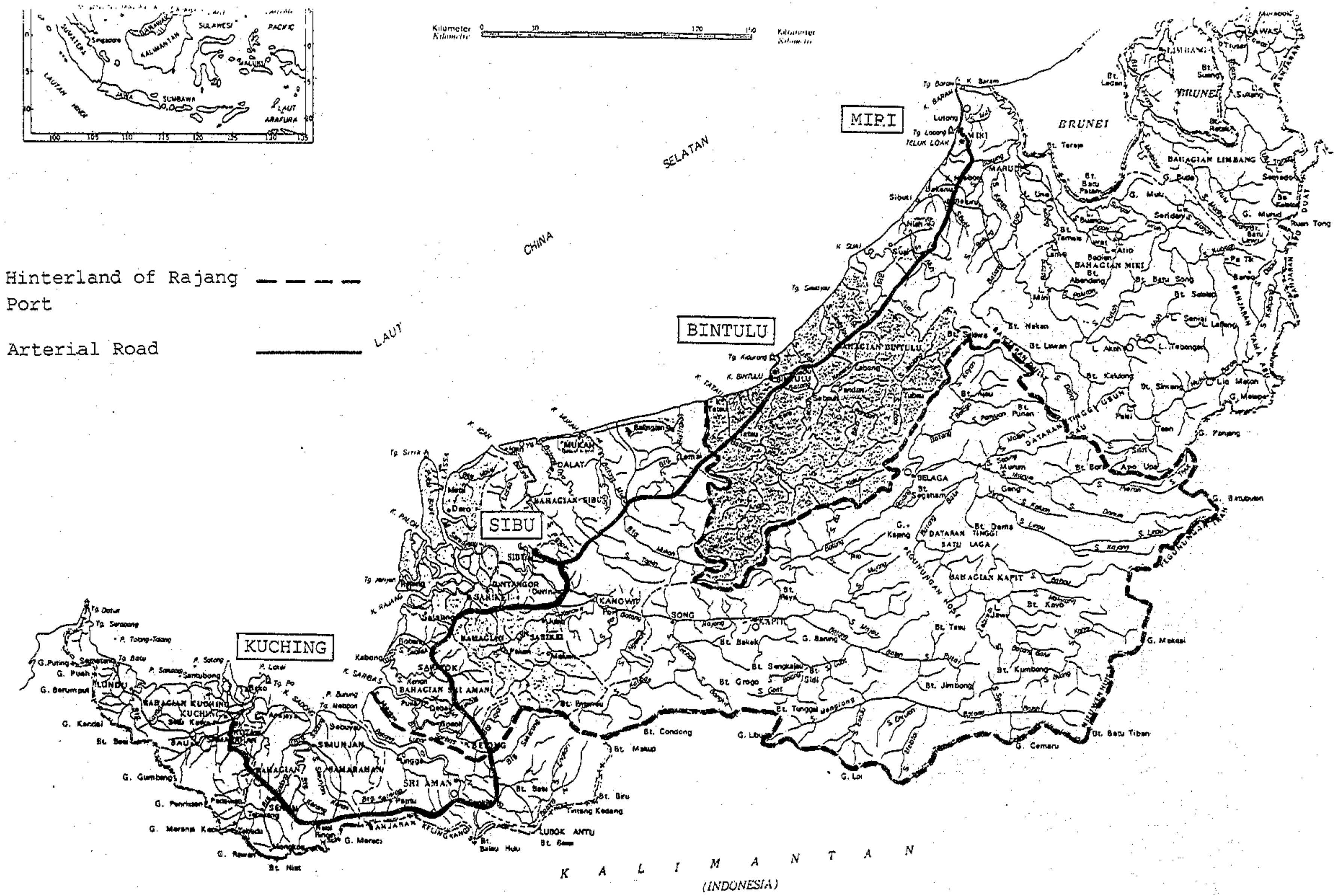


Figure-1.7.1.2 The Hinterland, Road System and Urban Areas

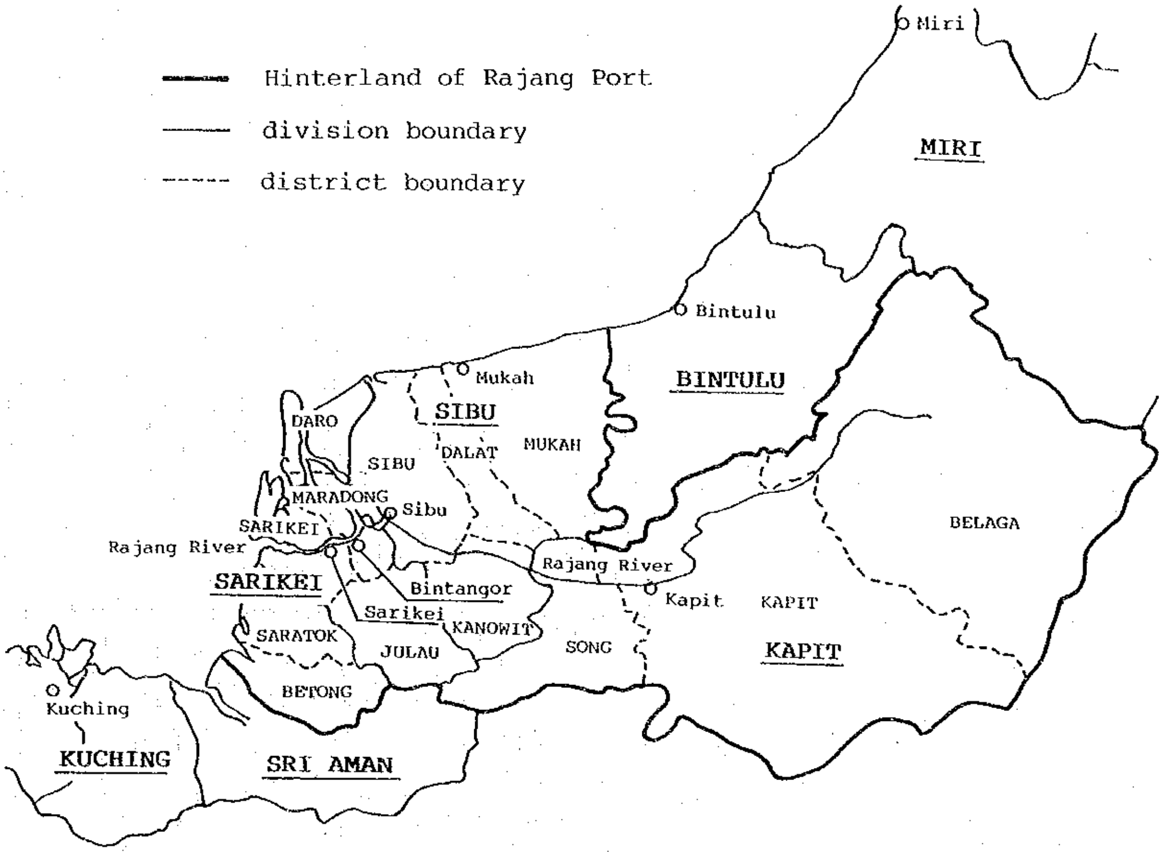


Figure-1.7.1.3 Districts in the Hinterland of Rajang Port

2. Natural Conditions

2.1 Topography and Bathymetry

2.1.1 General

(1) Survey instruments

The Topographic and Bathymetric surveys were conducted during the first field survey period from Sep. to Nov. in 1990. All survey instruments were supplied in Malaysia through local consultants. The survey instruments are listed in **Table-2.1.1.1.**

Table-2.1.1.1 List of Survey Instruments

Name of Instrument	Model	Quantity
GPS(Global Positioning System)	L-XII	3
EDM(Electric Distance Meter)	GTS-3	4
Data Roger	LZ-64	4
Total Station	AGA-412	3
Transit(Theodolite)	T-2	3
Level	NAKO	3
Echo Sounder	DE719C	1
Stereo Plotter	AG-1	1
Data Collector	FC-2	1
Computer	XT	1
Portable Computer	T1600	1
Automatic Tide Gauge		1
Survey Ship	50HP	1

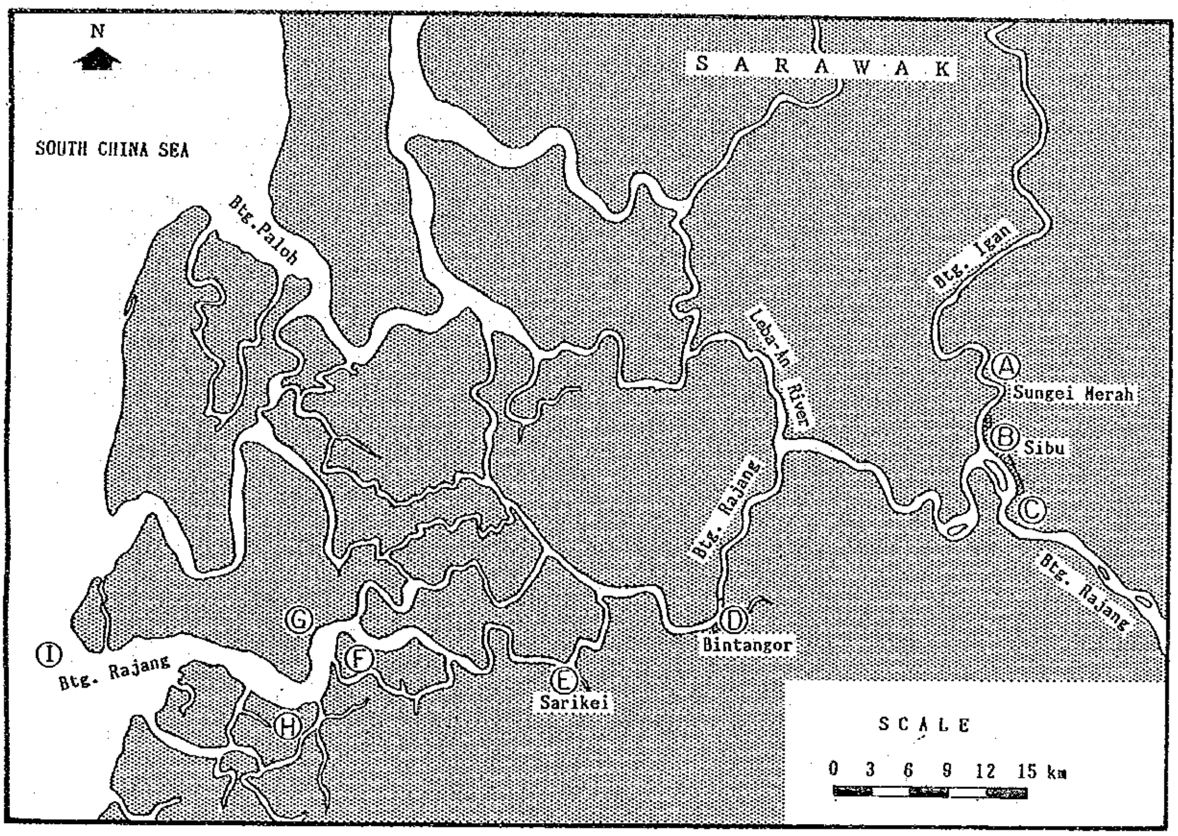
(2) Local consultants

In order to carry out the topographic and bathymetric survey works, the following local consultants collaborated with the JICA study team.

Jurukur Perintis, K.L.	: Primary Topographic Survey works and Bathymetric survey works
United Survey Consultant, Kuching	: Subcontractor of Topographic Survey works

(3) Survey area

The locations of the topographic and bathymetric survey area are as shown in the following figure and table.



No.	Location	Topography (Land leveling)	Bathymetry (Sounding)	Remarks
A	Sungai Merah	O	O	
B	Sibu Center	O	O	
C	Sibu South(Tg.Kumper)	O	O	
D	Bintangor	O	O	
E	Sarikei	O	O	
F	Tanjung Manis	O	O	Alternative-A site
G	Tanjung Sebubal		O	Alternative-B site
H	Opposite side of Tg.Sebubal	O	O	Alternative-C site
I	River Estuary		O	

[Note] The Topographic survey at G area was conducted in 1990 by STIDC.

Figure-2.1.1.1 Locations of the Topographic and Bathymetric Survey Area

(4) Miscellaneous

The coordination of the existing topographic maps by Land & Survey Department at the scale of 1:50,000 is controlled by the national grids which cover whole land of East Malaysia, and is indicated with the interval of one km. The other coordination of the Chart Map is controlled by the Latitude & Longitude of the global grids. Both coordinations are connected with the basic points having an authorized height.

2.1.2 Sibu area

(1) Sibu Center

Lower Rajang River runs from eastward to westward. The river at the city center of Sibu meanders suddenly as shown in **Figure-2.1.2.1.** The water depth along the outer circumference of the river (right side) is deeper than the inner. Therefore, the waterfront of this deeper side is fully utilized for the port facilities. The inner side of the semi-circle (left side) is relatively shallow, and sand-bar/sand-bank are developing.

The waterfront between the RPA wharf at Sibu Center and the Oil Jetty at Sg. Merah along the right bank of Igan River is used for local houses on the water, jetties of timber factories and public and private basins.

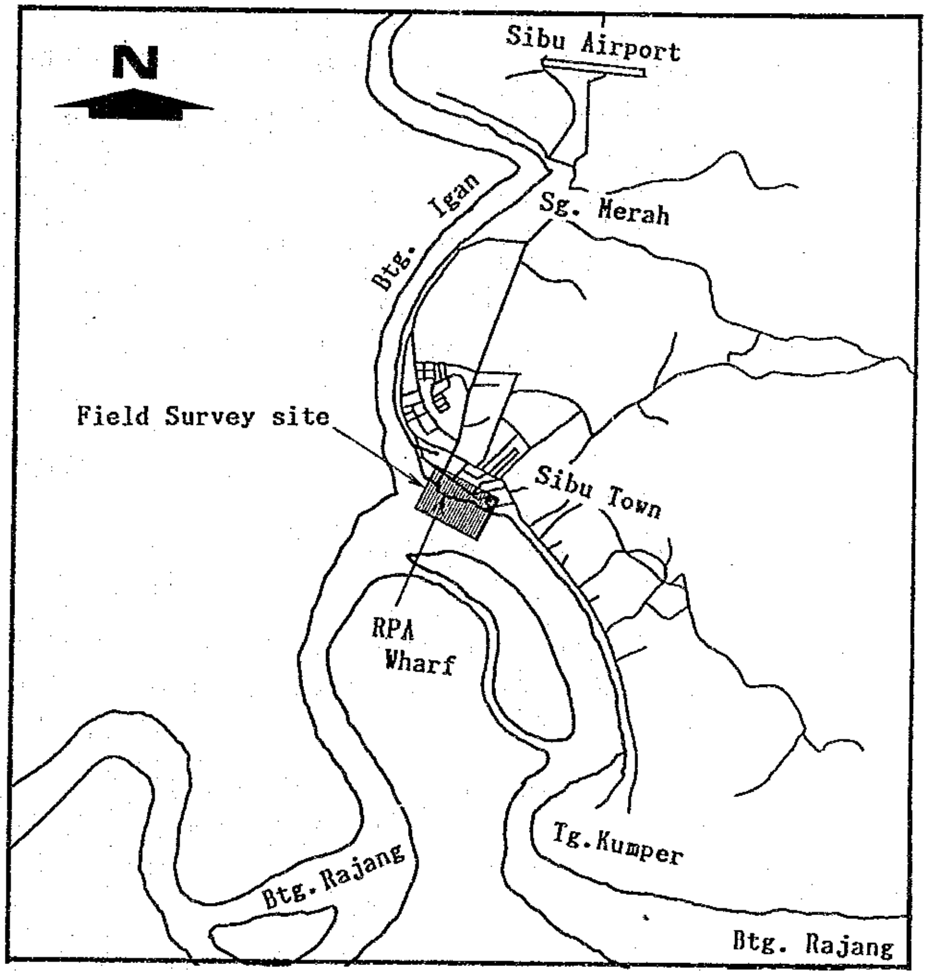


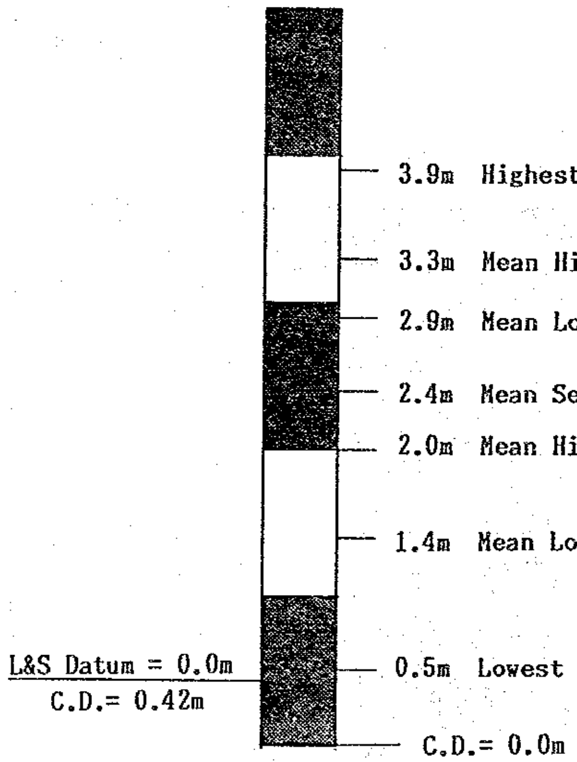
Figure-2.1.2.1 Location of Field Survey at Sibu Center

The waterway at the crossing point of Rajang River and Igan River is considerable narrow.

To obtain the up-dated topographical & bathymetrical map, the survey works by the study team were carried out at Sibu wharf and the vicinity.

The topographical and bathymetrical map is shown in **Figure-2.1.2.3.**

Figure-2.1.2.2 shows the tidal levels at Sibu RPA wharf. The levels are quoted from TIDE TABLES 1990 published by Hydrographic Department.



[Note] The Datum level by Land & Survey Department (L&S Datum) is 0.42 m higher than the Sarawak Chart Datum (C.D.) at Sibu.

Figure-2.1.2.2 Tidal Levels at Sibu RPA Wharf

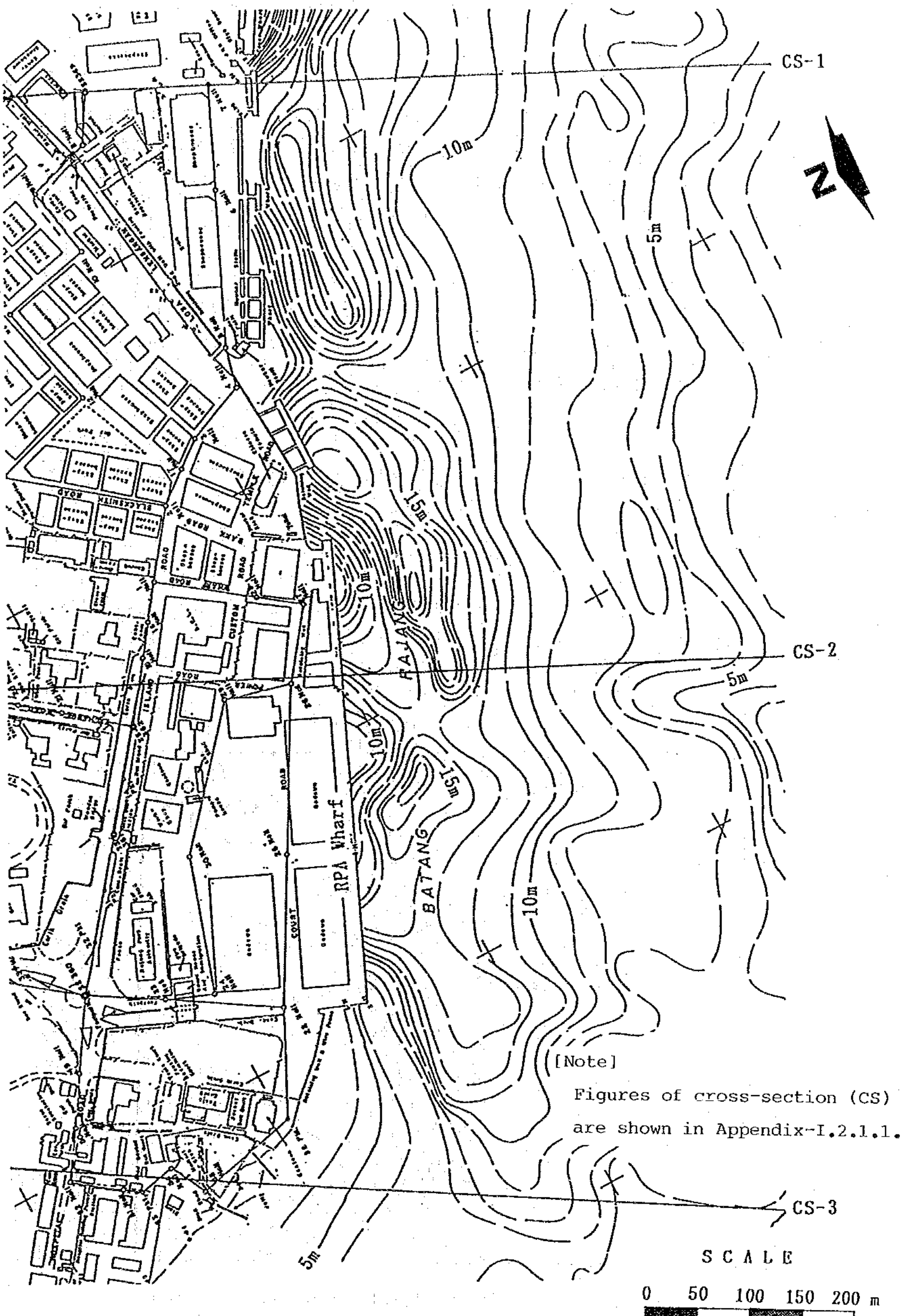


Figure-2.1.2.3 Topographical and Bathymetrical Map of Sibu Center(by JICA)

(2) Sg. Merah

In order to select a site for a new oil jetty at Sg. Merah, land leveling and sounding works were carried out at the waterfront of the right bank of Igan River located 0.8 to 1.8 km downstream of the existing oil jetty.

A road runs parallel to Igan River behind the surveyed area, and three reclaimed lands for sawmills are dotted. Trees grow on the river bank and the behind is cultivated as paddy field. But in some parts there remain natural bushes of swampy forest.

The cross-sectional gradient of the river bottom from the bank is rather steep. The average distance to contour line of C.D. -5.0m water depth is approximately 28m.

The tidal level data of Sibu Center is applicable to this area.
The location of the survey by JICA is shown in the following figure.
The topographical and bathymetrical map is shown in **Figure-2.1.2.5.**

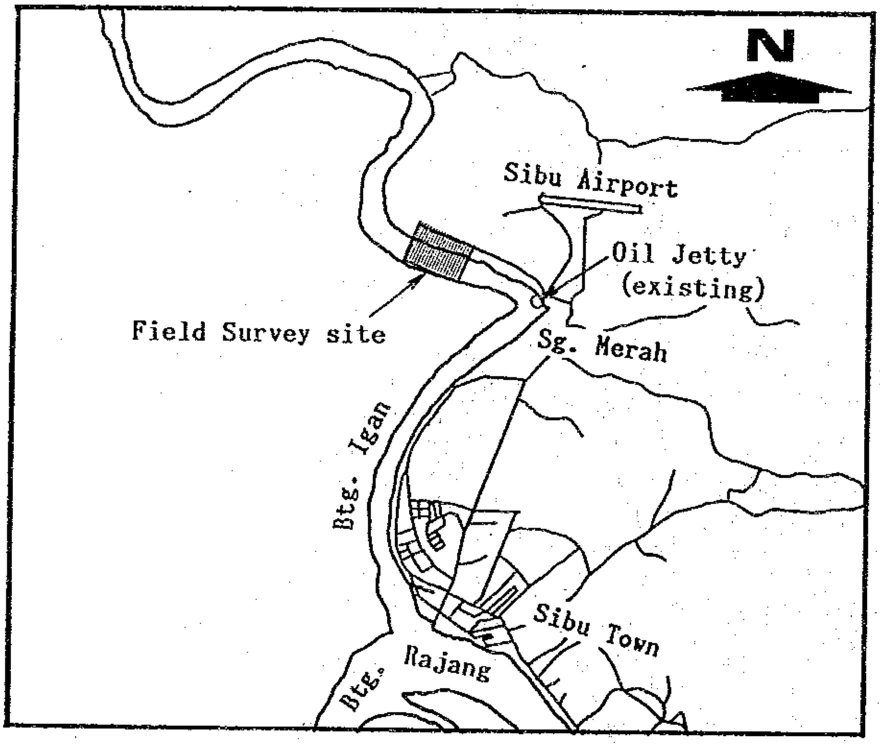
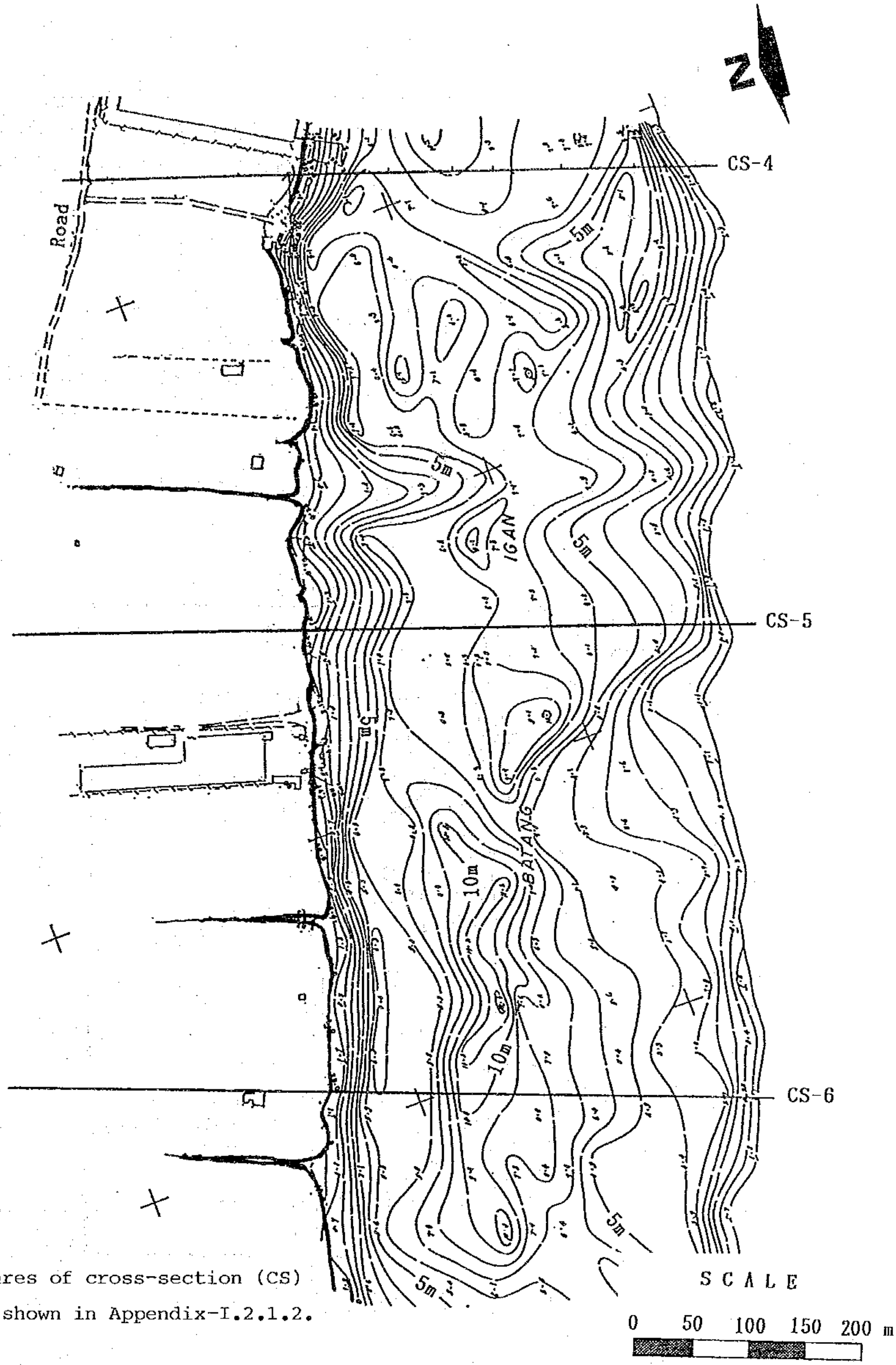


Figure-2.1.2.4 Location of Field Survey at Sg. Merah



[Note]

Figures of cross-section (CS) are shown in Appendix-I.2.1.2.

Figure-2.1.2.5 Topographical and Bathymetrical Map of Sg. Merah (by JICA)

(3) Sibu South (Tg. Kumper)

The survey was carried out in the area between a power transmission pylon at Tg. Kumper and ferry terminal at the Upper Lanang industrial estate for an alternative site for new supplementary terminal of Sibu Center.

Some part of this area is used at present for paddy, farmer's houses, fruit gardens, etc. and remainder is bushes.

The cross-sectional gradient of the rive bottom from the bank is gentle. Horizontal length to the depth of C.D. -5.0m and -7.5m from the bank are about 110m and 250m respectively. The tidal level data is same as that of Sibu Center. The location map of this survey and the survey result are shown in **Figure-2.1.2.6** and **Figure-2.1.2.7.**

Three cross-sections of the river are shown in **Appendix-I.2.1.3.**

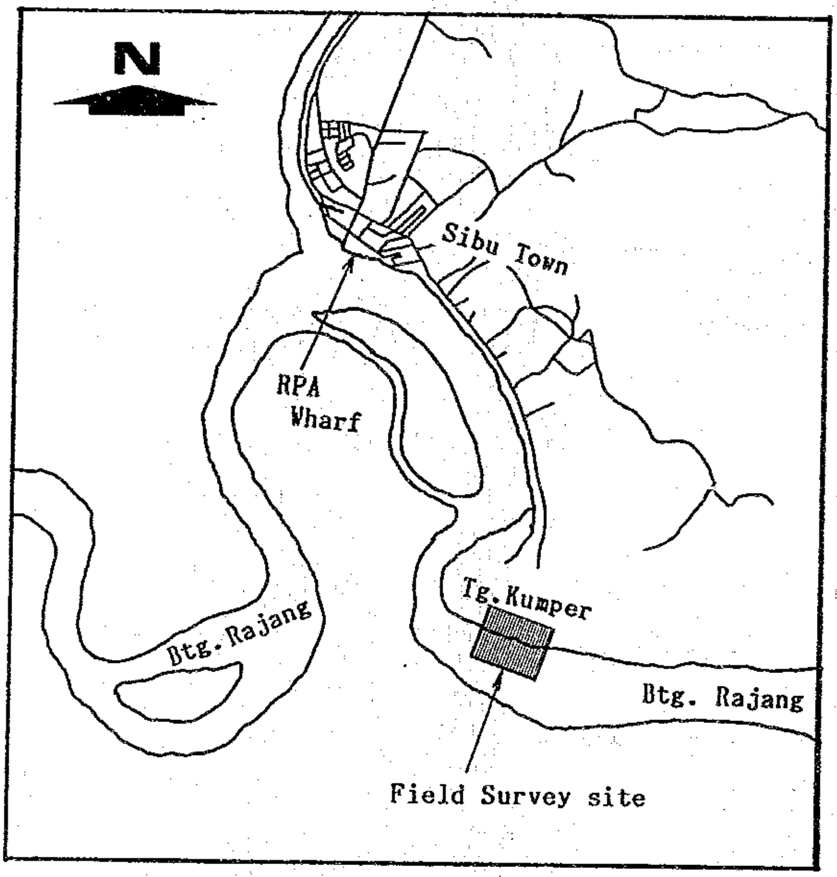


Figure-2.1.2.6 Location of Field Survey at Sibu South (Tg. Kumper)

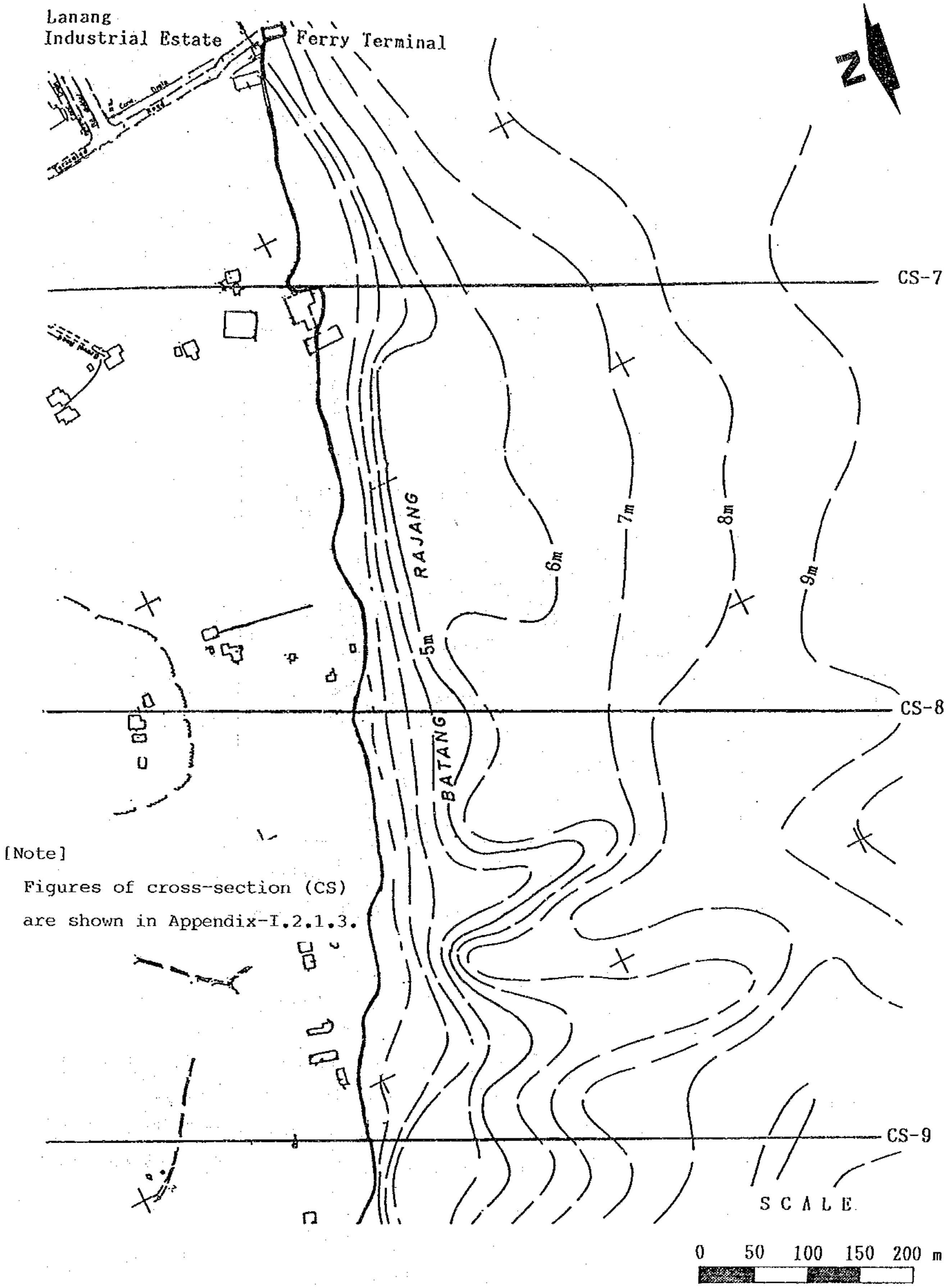


Figure-2.1.2.7 Topographical and Bathymetrical Map of Sibu South (Tg. Kumper) (by JICA)

2.1.3. Bintangor

Bintangor town is located at about middle point between the junction of Leba-An River and Rajang River (See **Figure-2.1.1.1**) and Sarikei town.

Bintangor town is extended along the left bank of Rajang River and also located between two tributaries named Bintang River and Maradong River as shown in the following figure.

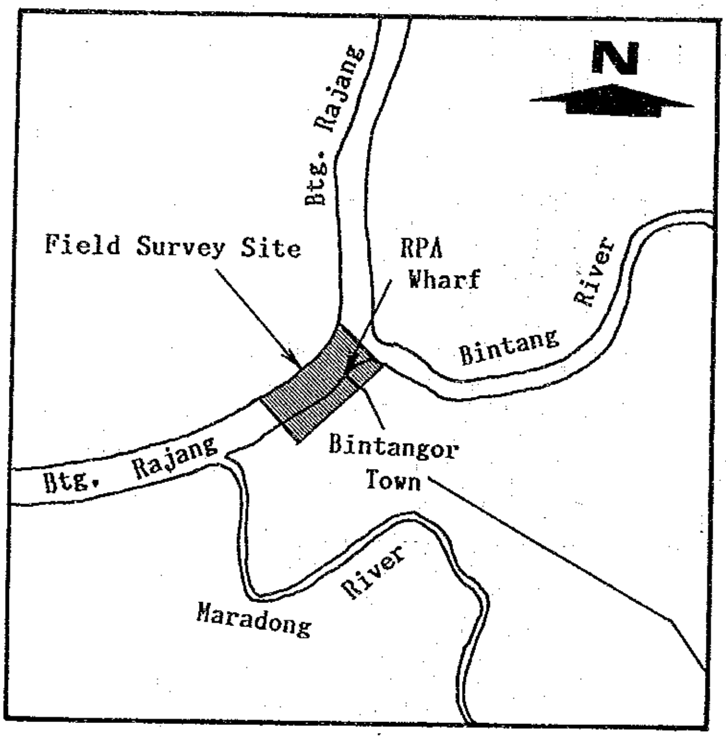


Figure-2.1.3.1 Location of Field Survey at Bintangor

The surroundings of Bintangor are covered with the forest, but some areas are cultivated for plantations of pepper and fruits, etc..

Regarding the water depth at the existing Bintangor wharf, the deep water track of C.D. -10.0m runs on the comparatively wide waterway.

Cross-sectional slope of the river bottom from the river bank or the retaining walls is rather steep and its gradient is one by four to one by seven.

The tidal levels at Sarikei area can be applied to that of Bintangor. **Figure-2.1.3.2** shows the tidal levels at Sarikei area. The levels are quoted from TIDE TABLES 1990 published by Hydrographic Department.

The survey result by JICA is shown in **Figure-2.1.3.3.**

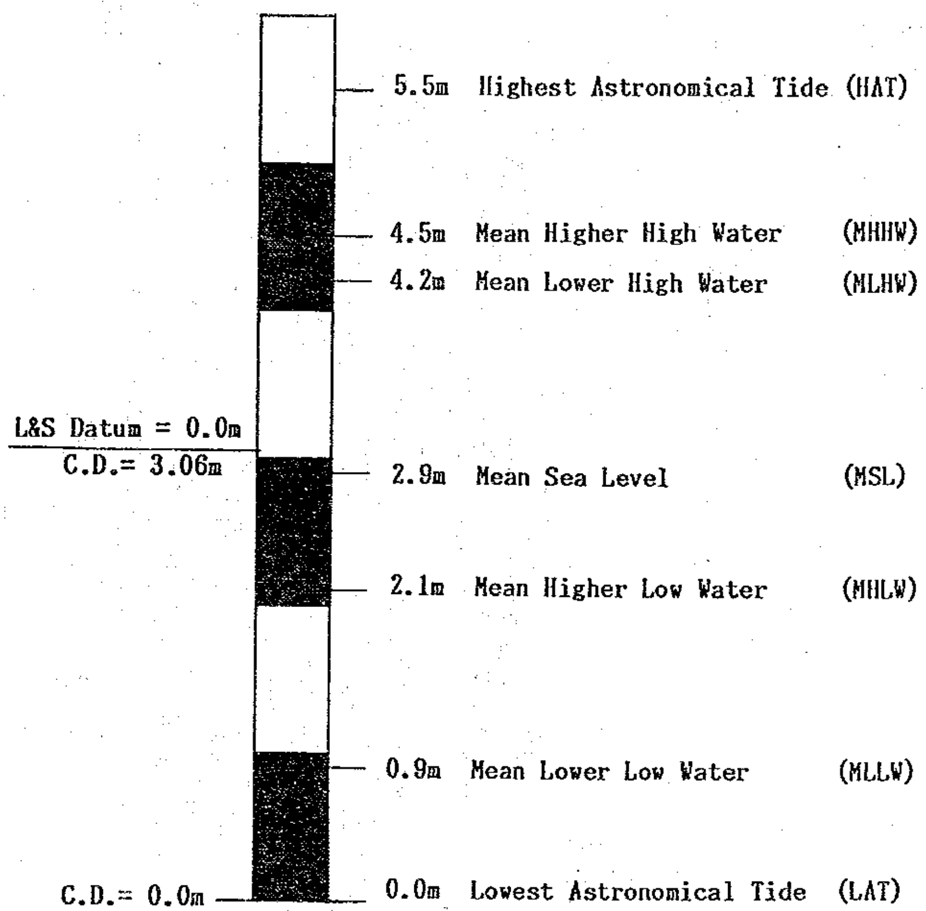


Figure-2.1.3.2 Tidal Levels at Sarikei Area

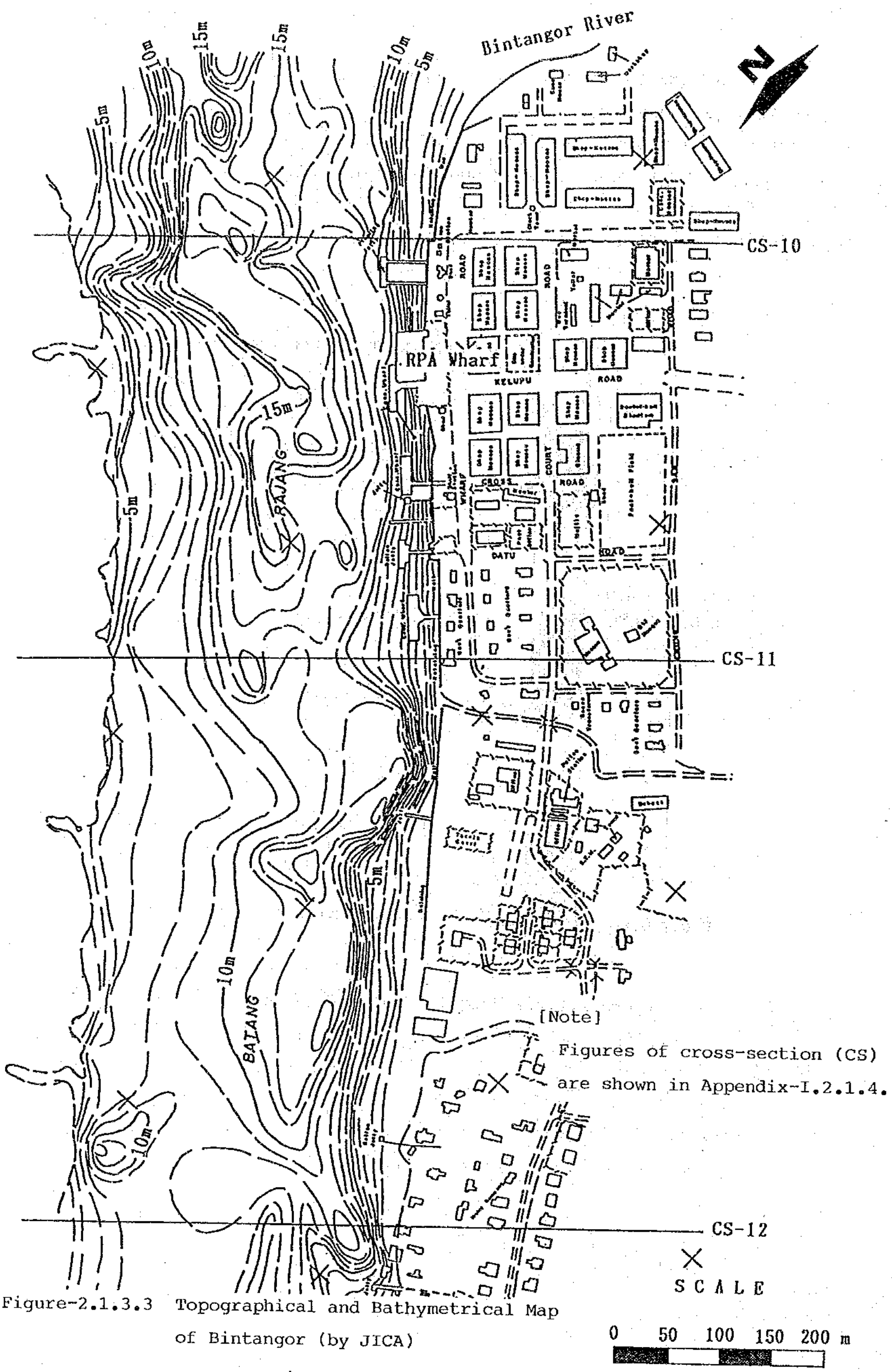


Figure-2.1.3.3 Topographical and Bathymetrical Map of Bintangor (by JICA)

2.1.4 Sarikei

Sarikei town is located between Nyelong River and Sarikei River along the left bank of Rajang River.

The stream of Rajang River turns from south to west at the junction with Nyelong River as shown in the following figure.

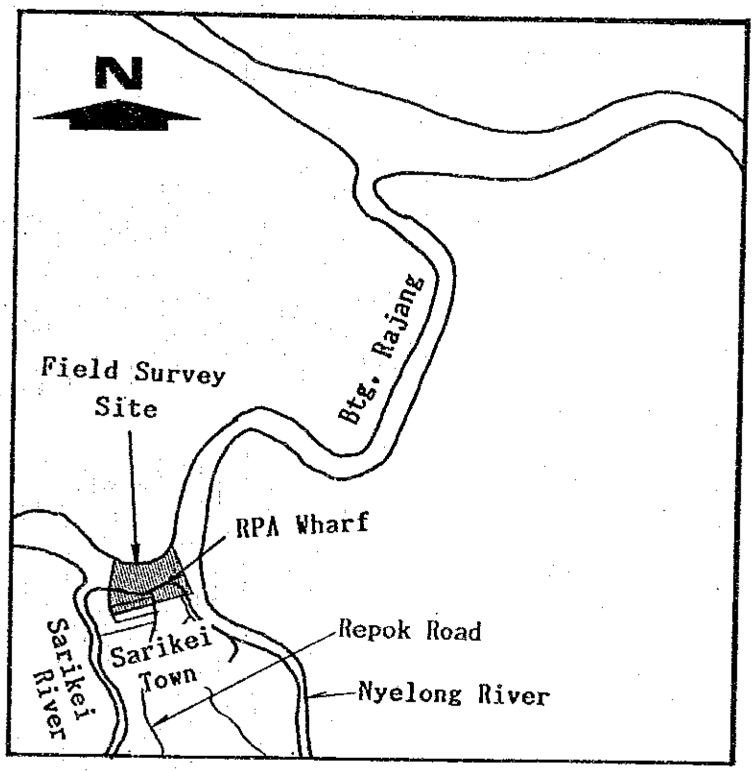
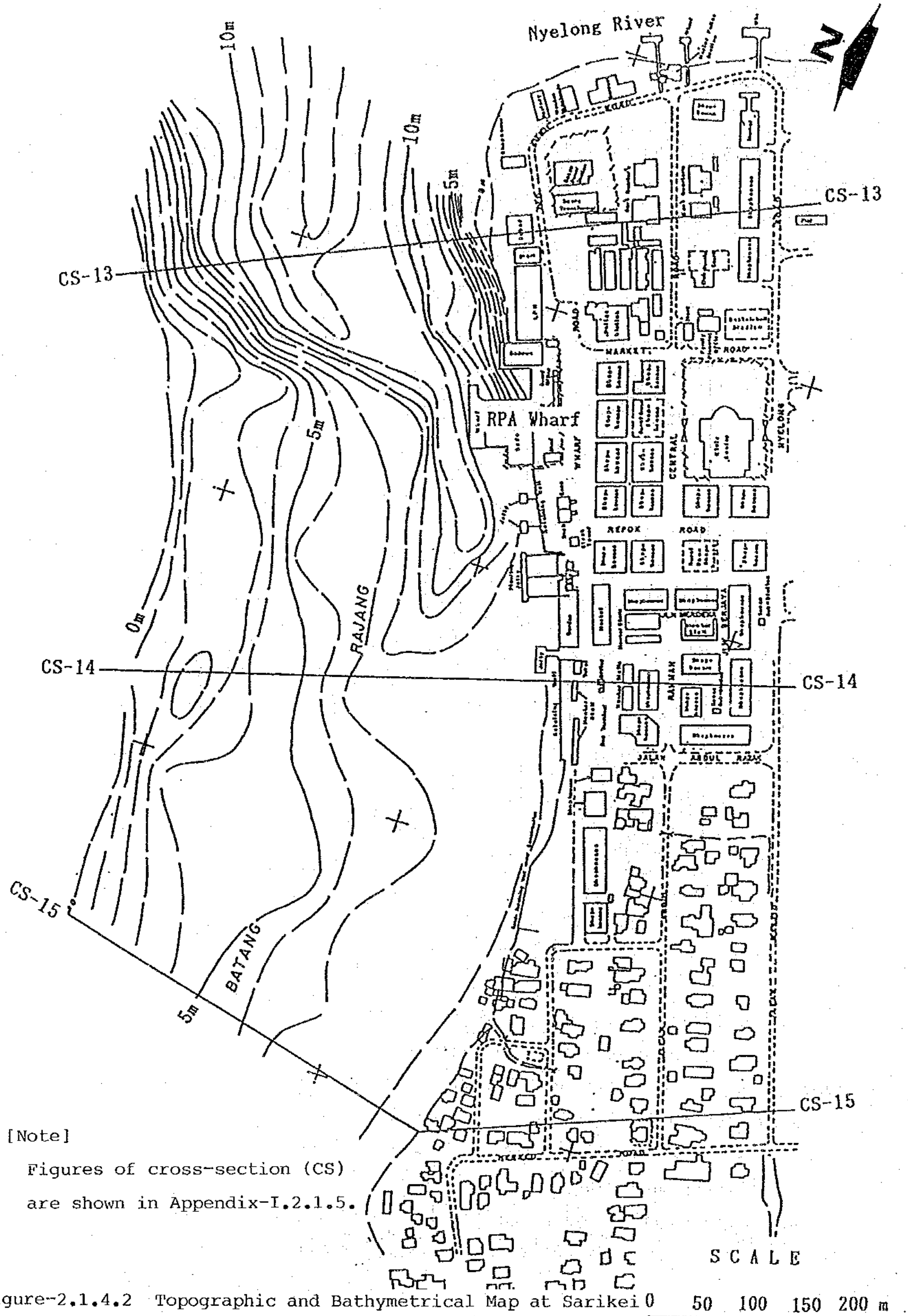


Figure-2.1.4.1 Location of Field Survey at Sarikei

The bank around RPA wharf, where the deep water track is closest to the left bank, is protected by the retaining walls. The cross-sectional slope of the river bottom at the west part of the town keeps the gradient of one by four to one by five. The land adjacent to Sarikei town is swampy forest and the hinterland along a paved road named Repok Road is well cultivated for plantation.

The topographic and bathymetric survey were conducted at the waterfront of Sarikei town as shown in **Figure-2.1.4.2.**

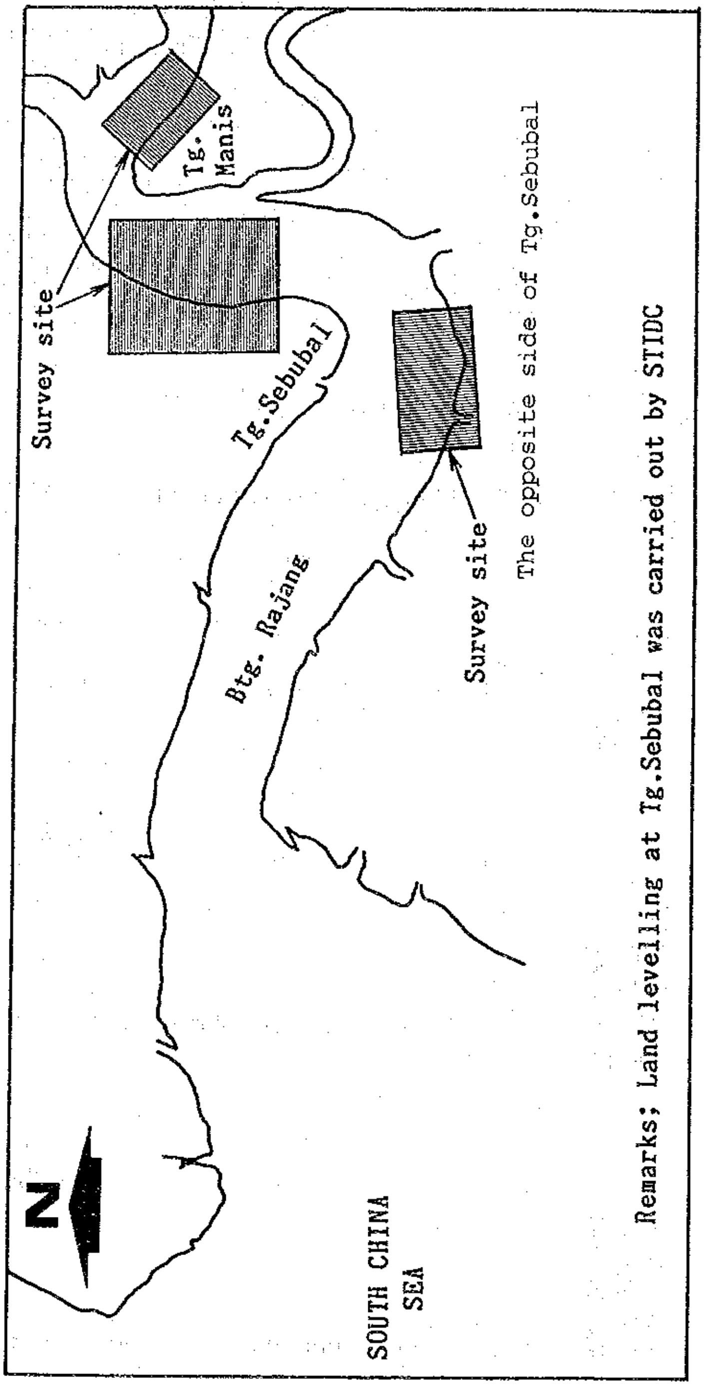


[Note]
Figures of cross-section (CS) are shown in Appendix-I.2.1.5.

Figure-2.1.4.2 Topographic and Bathymetrical Map at Sarikei (by JICA)

2.1.5 The Tanjung Manis area

The Tanjung Manis area consists of Tanjung Manis, Tanjung Sebubal and the opposite side of Tg. Sebubal as shown in the following figure.



Remarks; Land levelling at Tg.Sebubal was carried out by STIDC

Figure-2.1.5.1 Location of Field Survey at the Tg. Manis Area

(1) Tanjung Manis

Tanjung Manis is located at about 30km upstream from the estuary.

The width of the river is about 1.2km at Tanjung Manis. The south bank has been developed by a private timber industry company while the north bank is covered with swampy forest. The ground elevation at the front line of the south bank varies between +2.0m at lower parts and +2.5m at higher parts above Land and Survey Datum. The difference between Land and Survey Datum and Chart Datum at Tg. Manis is 3.29m. Therefore, the ground elevation is given as C.D. +5.3m at lower parts and C.D. +5.8m at higher parts.

Figure-2.1.5.2 shows the tidal levels at Tg. Manis (Gunong Ayer). The levels are quoted from TIDE TABLE 1990 published by Hydrographic Department.

The survey result by JICA is shown in **Figure-2.1.5.3.**

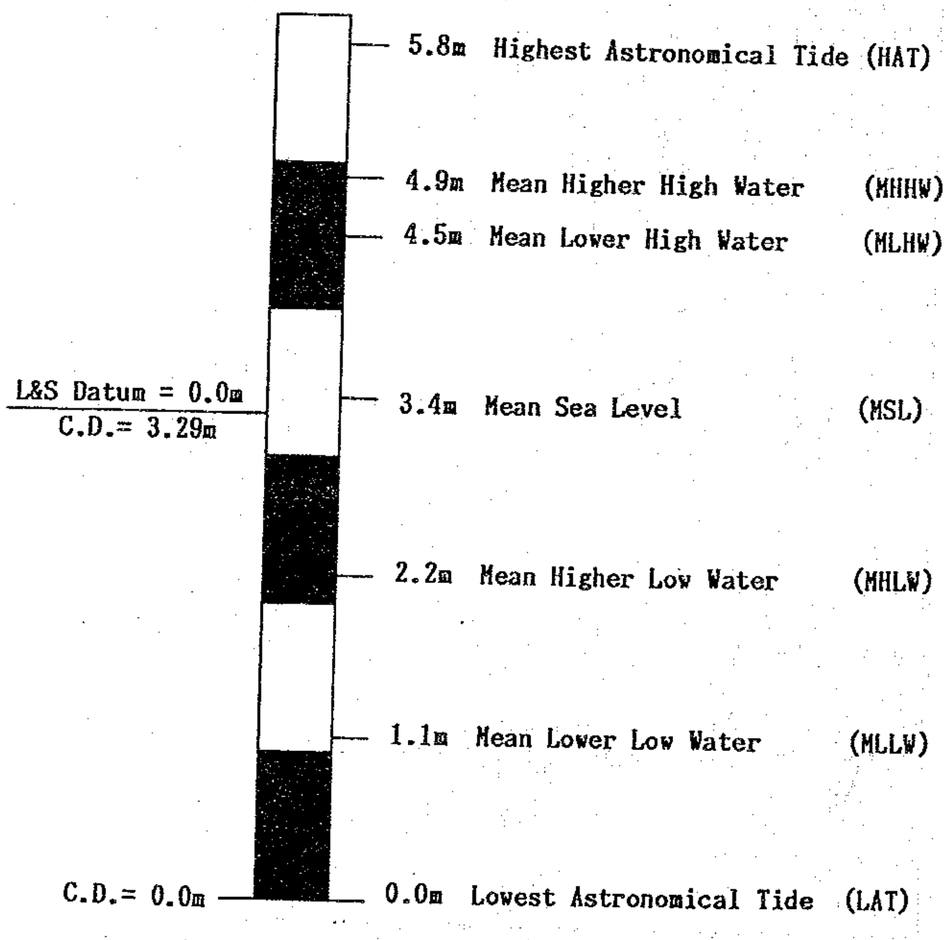
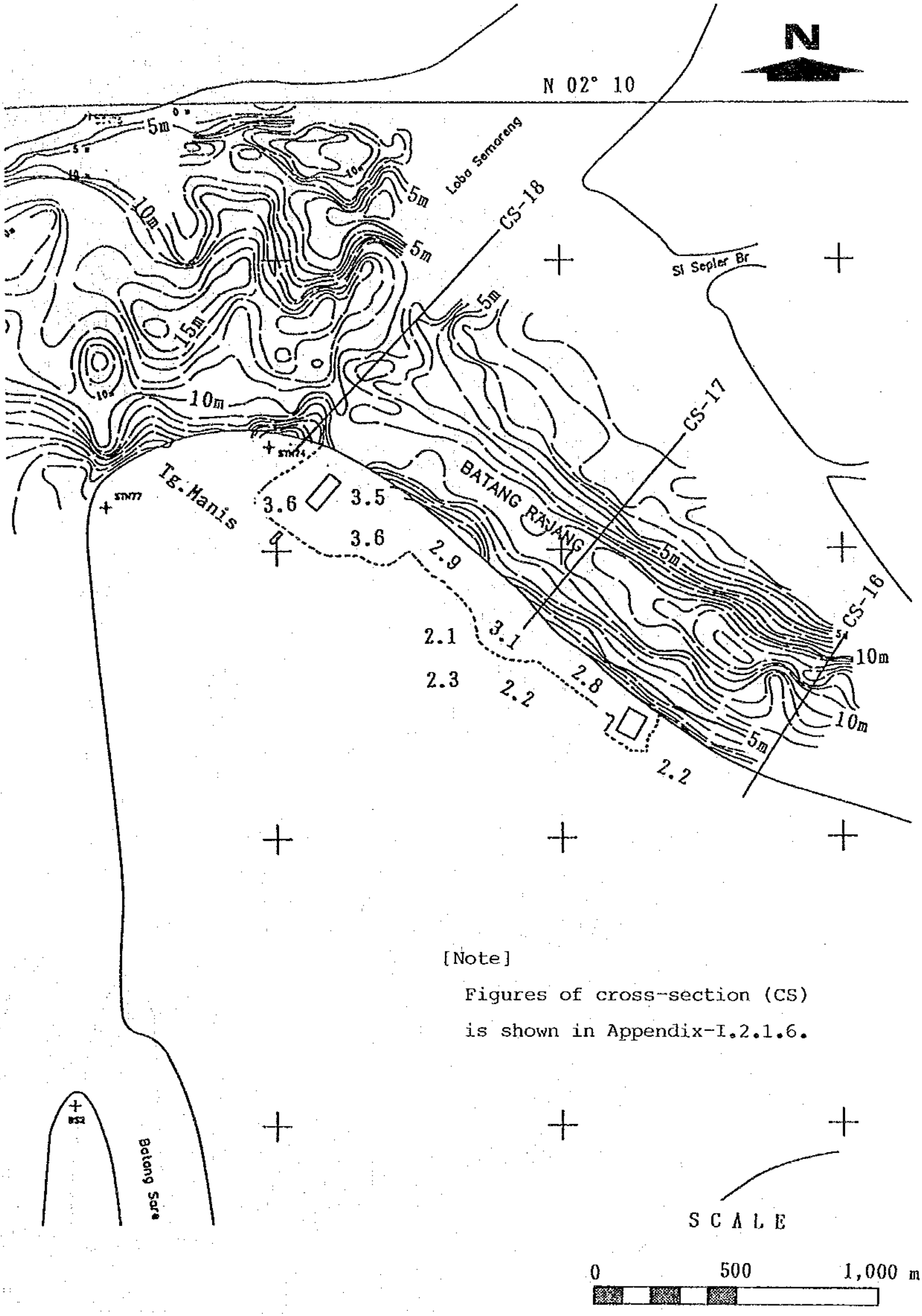


Figure-2.1.5.2 Tidal Levels at Tg. Manis



[Note]

Figures of cross-section (CS) is shown in Appendix-I.2.1.6.

Figure-2.1.5.3 Topographic and Bathymetrical Map at Tg. Mains (by JICA)

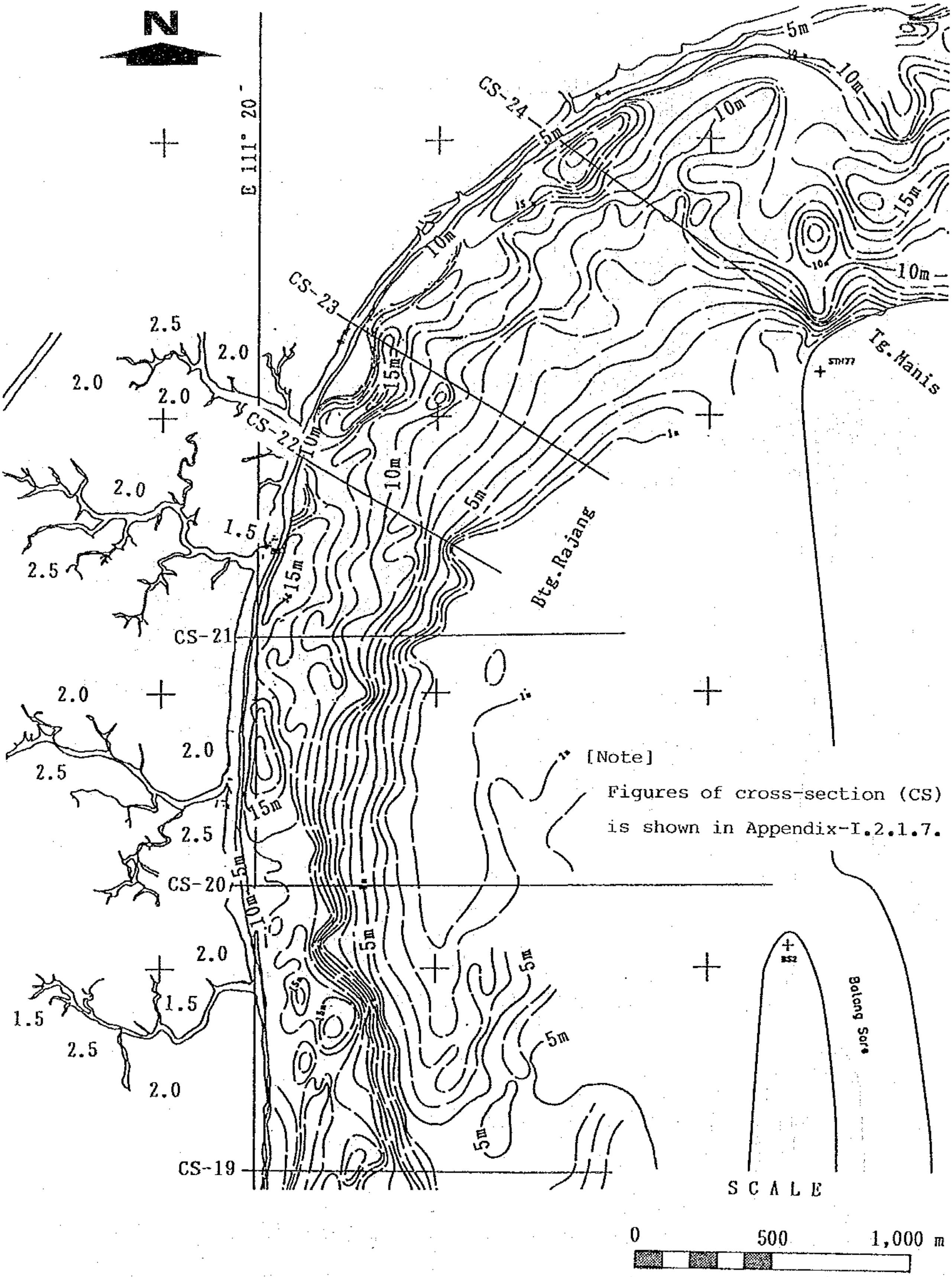
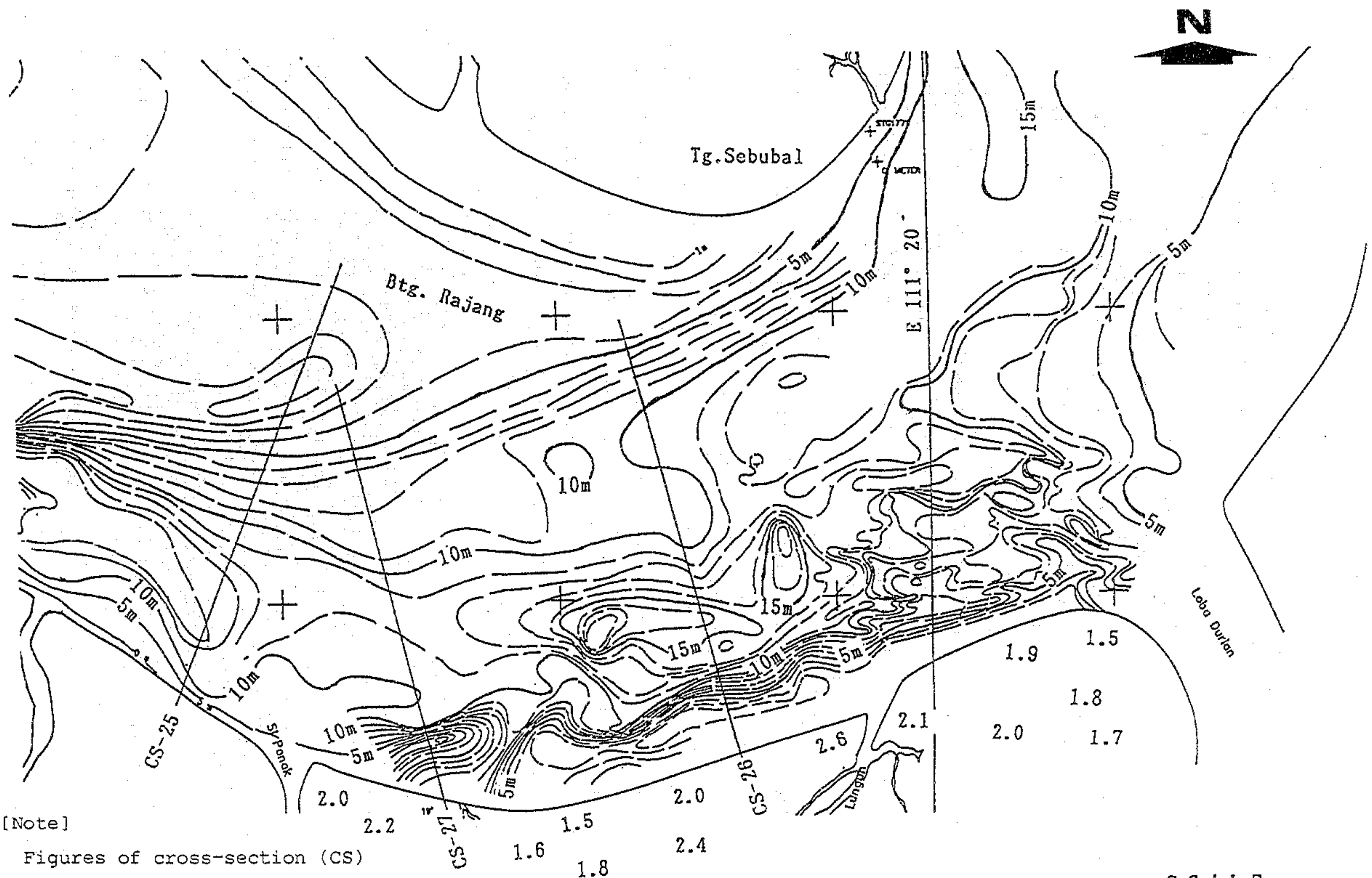


Figure-2.1.5.4 Topographic and Bathymetrical Map at Tg. Sebubal (by JICA)



[Note]
Figures of cross-section (CS)
is shown in Appendix-I.2.1.8.

SCALE
0 500 1,000 m

Figure-2.1.5.5 Topographic and Bathymetrical Map at the opposite side of Tg. Sebubal (by JICA)

(2) Tanjung Sebubal

Tanjung Sebubal is located at about 26km upstream from the estuary. The width of the rive is about 1.7km at Tanjung Sebubal and both sides of the river are covered with mangrove forest. The ground elevation at this site is almost same level as that at Tg. Manis.

The topographic and bathymetric map is shown in **Figure-2.1.5.4.**

(3) The opposite side of Tanjung Sebubal

This area is located at about 20km upstream from the estuary. Width of the river is about 2.0km in front of this area and both sides of the river are covered with mangrove forest. The ground elevation at this site is about +5.3m above C.D. at Tg. Manis.

The topographic and bathymetric map is shown in **Figure-2.1.5.5.**

(4) Tanjung Sebubal to the river mouth

The sounding works from Tg. Sebubal to the river mouth were carried out by Marine Department in 1985. The river bed of this area can be said to be comparatively stable. The bank and the cross-sectional slopes of the both river sides are also stable because the river flows straightly, not meandering.

(5) Erosion and sedimentation

1) Outlook on erosion

The erosion is gradually progressing in the surrounding area of Tg. Manis although the mangrove and other various species of trees and bushes protect the river bank from erosion to some extent. The sedimentation will also occur simultaneously.

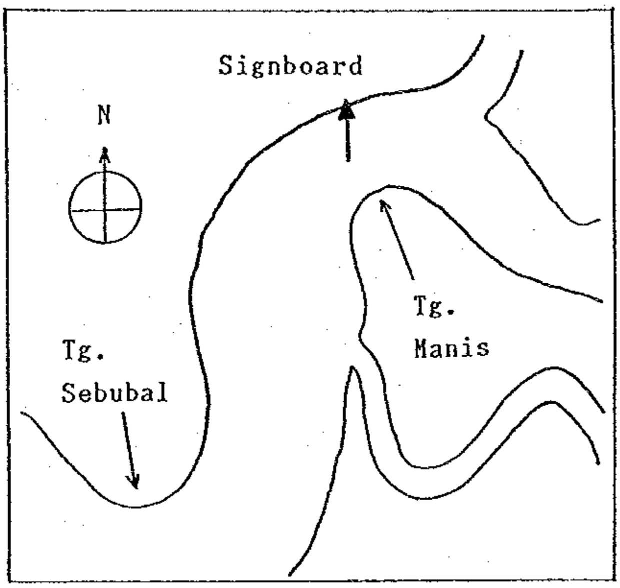
This is inferred from the following observation during the first field survey in October, 1990 ;-

- Many fallen trees are uprooted and lying down or drifting around the bank.

A signboard installed on the bank for ship navigation has slightly inclined at the opposite side of Tg. Manis. (See Photo-2.1.5.1)

No topographical data is available for proving the change of shore line, but according to unofficial information by Marine department of Sarikei, the extent of erosion would be about 20 feet for 3 years around surface level of the river bank.

Location map of Signboard



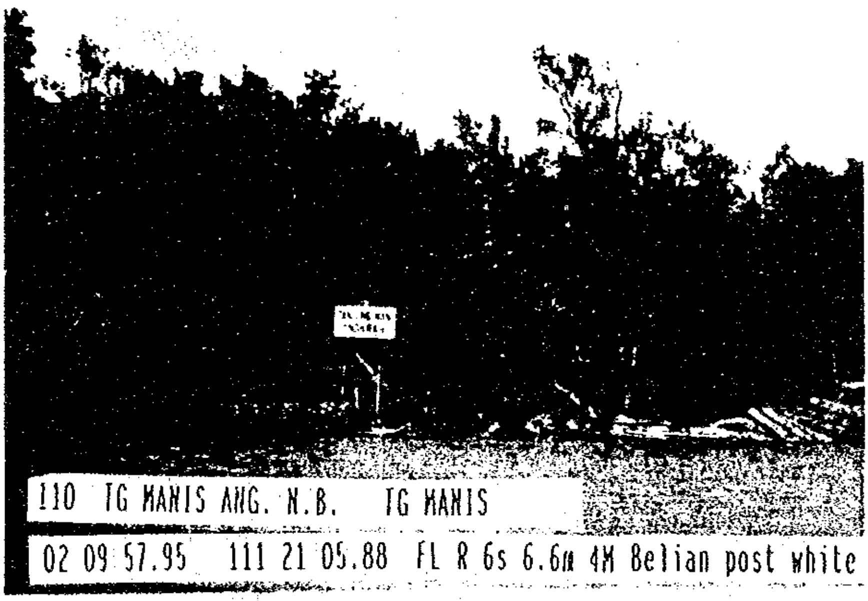


Photo-2.1.5.1 A navigative signboard on a slightly inclines

2) Erosion/Sedimentation on the proposed development sites

As stated in 3.1.3(3) of Volume-II, two sites were proposed as the alternative location for the new development in Tg. Manis area - Site B at Tg. Sebubal East (the west opposite shore of Tg. Manis), and Site C at the opposite side of Tg. Sebubal.

In order to examine the ground surface change of shore line and river bed on the sites, the results of the sounding carried out in 1990 by the study team were compared with the sounding map by Marine Department, Sarawak (Tg. Manis to Tg. Sebubal in 1979 and Tg. Sebubal to Kuala Rajang in 1985).

The changes and analysis on erosion and sedimentation are explained in **Appendix-I.2.1.9.** Stated herebelow is outline of the changes around Tg. Manis area.

The area is diveded into the following 6 zones as shown in **Figure-2.1.5.6.**

Zone-1 : River mouth and surroundings of Sg. Semareng
(Sedimentation area)

Zone-2 : Intermediate area between Zone-1 and Zone-3
(Stable area)

Zone-3 : Northern part of Tg. Sebubal East
(Erosion area)

Zone-4 : Southern part of Tg. Sebubal East
(Stable area)

Zone-5 : River mouth of Sg. Limut and surroundings
(Sedimentation area)

Zone-6 : Opposite side of Tg. Sebubal
(Erosion area)

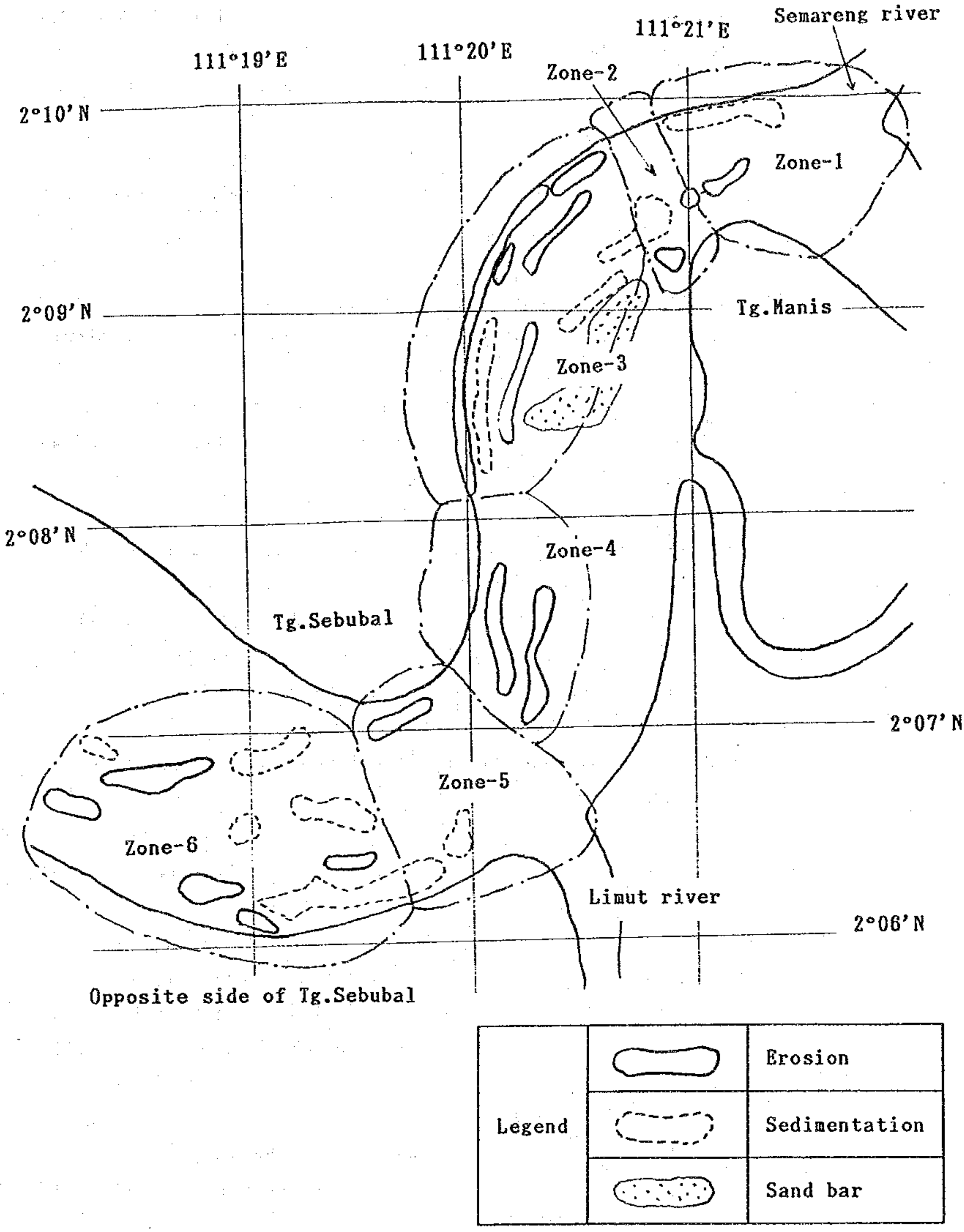


Figure-2.1.5.6 Ground surface change of shoreline and river bed around Tg. Manis area

a) Zone-1 : A big volume of sedimentation is observed along the northern shoreline eastward from 111°21' E. The sedimentation is considered to be due to seasonal and/or yearly works of Semareng stream at its mouth.

On the other hand, great deal of erosion is observed at about 250 meters offshore from the said sedimentation area.

b) Zone-2 : The shoreline and river bed in the zone seems to be rather stable because the area is intermediate between sedimentation and erosion.

c) Zone-3 : This is extremely eroded area. The erosion is observed along the entire shore of the zone. In some area the shoreline has been eroded by more than 5 meters in these 11 years.

In the southern part of the zone, however, sedimentation also take place southward from 2°09'N.

d) Zone-4 : The zone is in a similar situation as in Zone-2. The erosionis, however, rather dominant than sedimentation.

e) Zone-5 : The zone is in a similar situation as in Zone-1 due to its location at the mouth of Limut river.

f) Zone-6 : The zone is in a similar situation as in Zone-3.

3) Conclusion

Naturally the erosion is caused by the current and wave of the river water colliding against the bank, which will be strengthened by the occasional water flood of monsoon and the strong waves of wind and ship navigation.

It will take long time years to carry out the investigation to indicate the main cause and accurate extent of the erosion, because the erosion is clearly the work of the water in a passage of time.

Generally a meandering river has erosive parts and sedimentary parts along its flow. The Rajang River is the typical one as shown in **Figure-2.1.1.1.** When the river meanders, the main stream collides against the outer bank. Deep water area and the erosion area, therefore, observed along the outer side. The opposit side (inner side) of the river is shallow, which results in sedimentation.

At Sibu Center, the slope of the river bank is actually protected against the similar erosion. (See **Figure-2.1.2.5** in **Volume III**).

It is, therefore, recommended that proper measures of protection shall be considered also at Tg. Manis when the facilities are constructed.

2.1.6 Estuary

No sounding work had been performed since 1975 outside the Rajang river estuary before the study team in 1990.

The study team carried out sounding in a rectangular area with vertices of 1 (N2°10'40"-E111°4'05"), 2 (N2°8'20"-E111°8'55"), 3 (N2°6'50"-E111°8'10") and 4(N2°9'15"-E111°3'40") as shown in **Figure-2.1.6.1.**

The navigation channel is established in the valley between the wide spread shallow sand bars, Wong Sands and Bohari Bank, as shown in **Figure-2.1.6.1.**

Comparing the results of the surveys in 1975 and 1990 at the study area, it is observed that the most shallowest point has been deepened by about 0.5m and sifted to south-west-southward by about 700m.

(See **Figure-2.1.6.2** to **Figure-2.1.6.3**)

It is confirmed by the study that the water depth at the navigation channel and the estuary has become slightly deeper than before.

Generally speaking, in the estuary areas, the volume of soil transported from the river is kept in equilibrium with the volume of soil that moves offshore due to river flush, wave action littoral current, etc., from the long-term perspective. Therefore, we can say that the water depth of the estuary tends to remain constant unless it is artificially manipulated.

To confirm this tendency, we carried out a sounding survey in the estuary area. Comparing the result with that of a previous survey conducted in 1979, it was found that the water depth at the estuary increased slightly over 10 years. Moreover, we cannot identify the phenomena or development projects which would facilitate siltation in the estuary area. Consequently, we believe that the present water depth at the estuary will be maintained in the future.

The result of our bathumetric survey conducted in the end of the dry season also shows that the main channel appears to be sufficiently deep even during the dry season. During periods of heavy rainfall, the estuary may become broader by flush of river current.

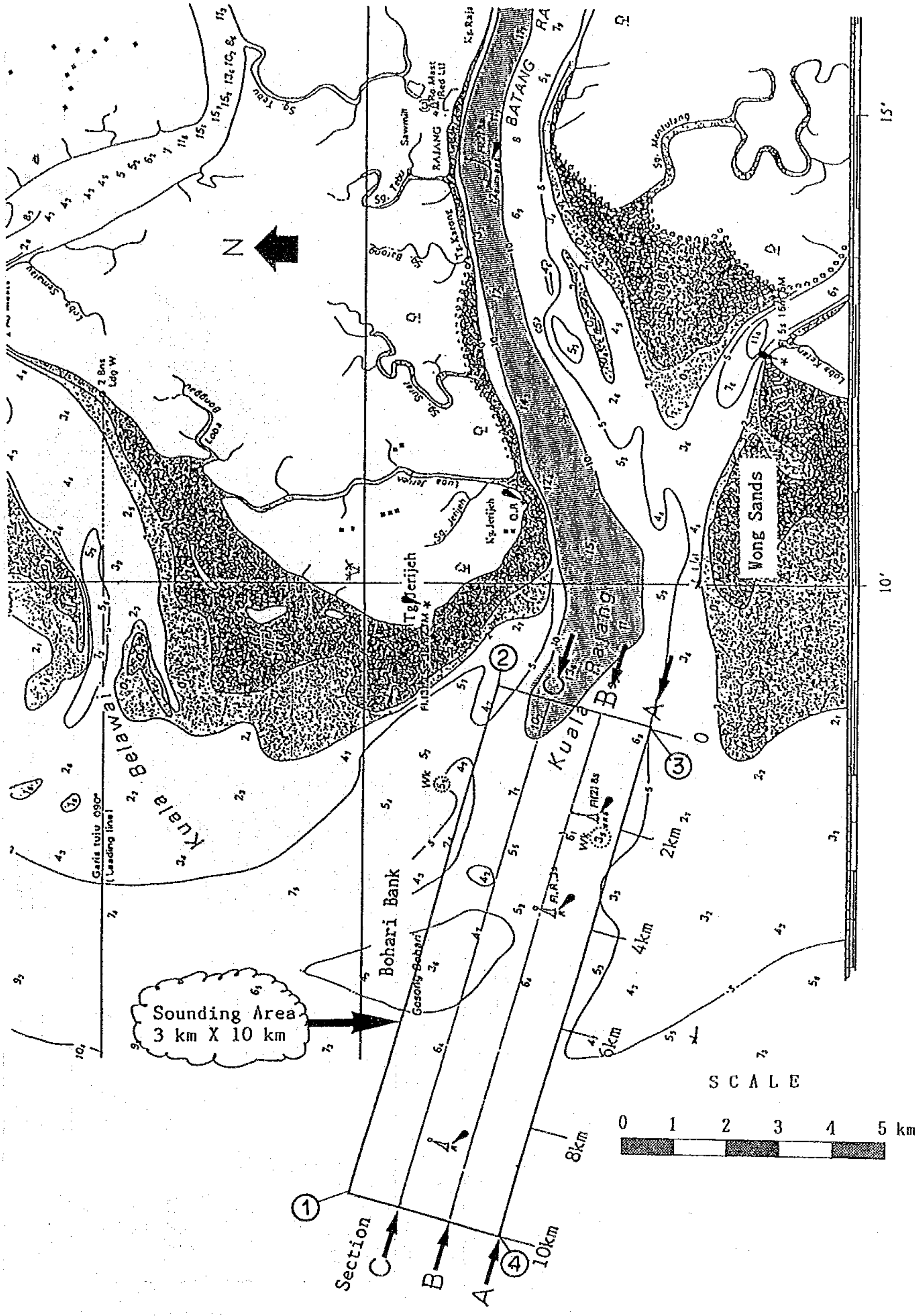


Figure-2.1.6.1 Sounding Area of the Estuary

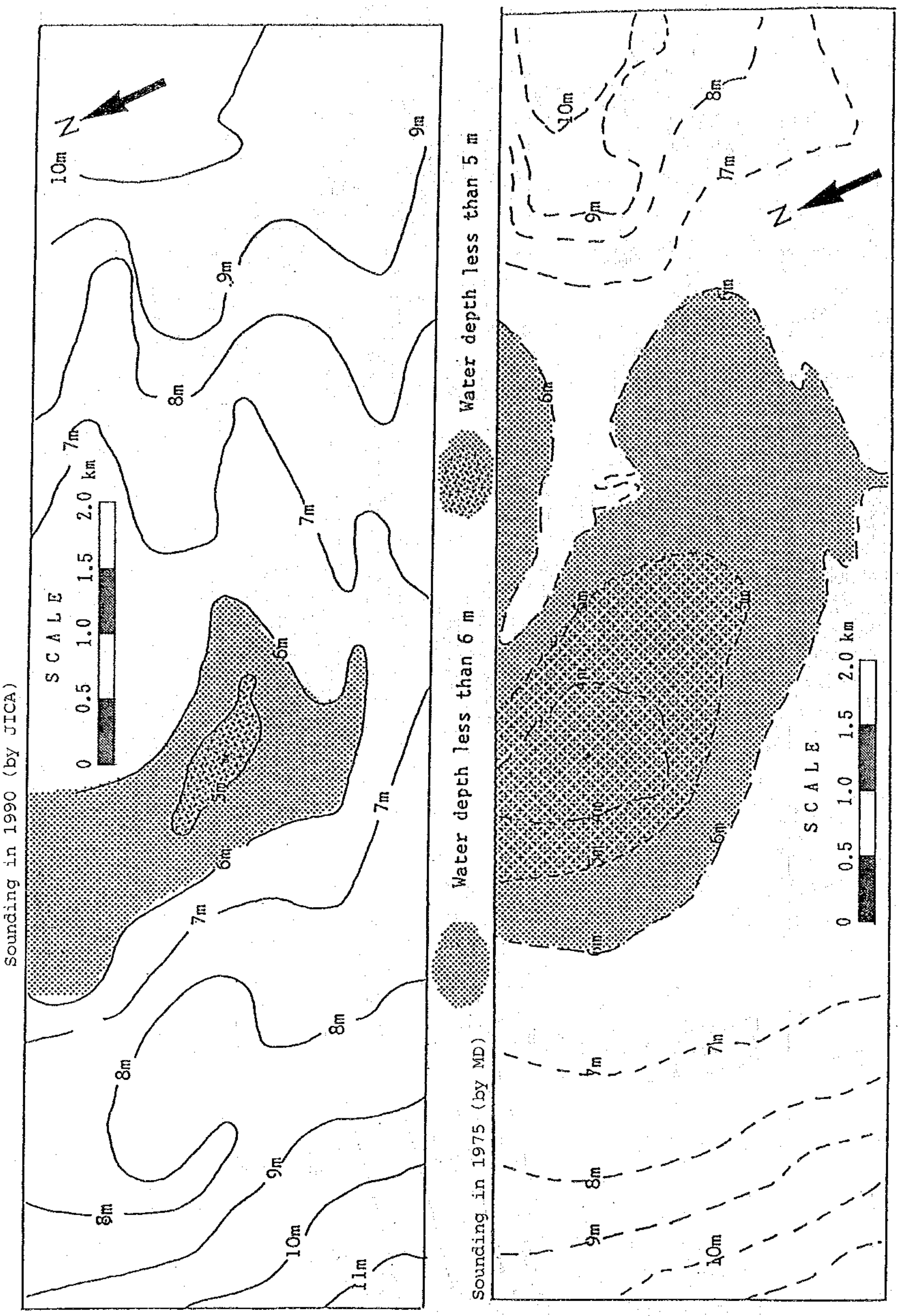


Figure-2.1.6.2 Comparison of bottom change at the Estuary

-------- contour of sounding in 1975 (by MD) ——— contour of sounding in 1990 (by JICA)

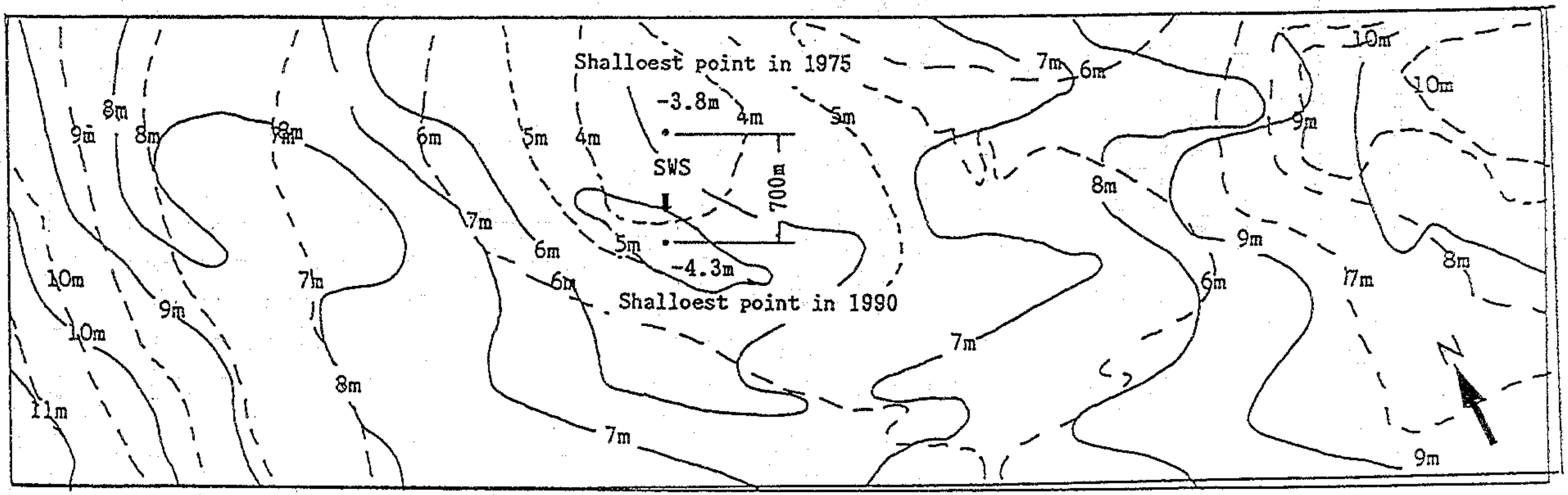


Figure-2.1.6.3 Comparison of counter in 1975 and 1990 Scale 0 0.5 1.0 1.5 2.0 km

2.2 Meteorology

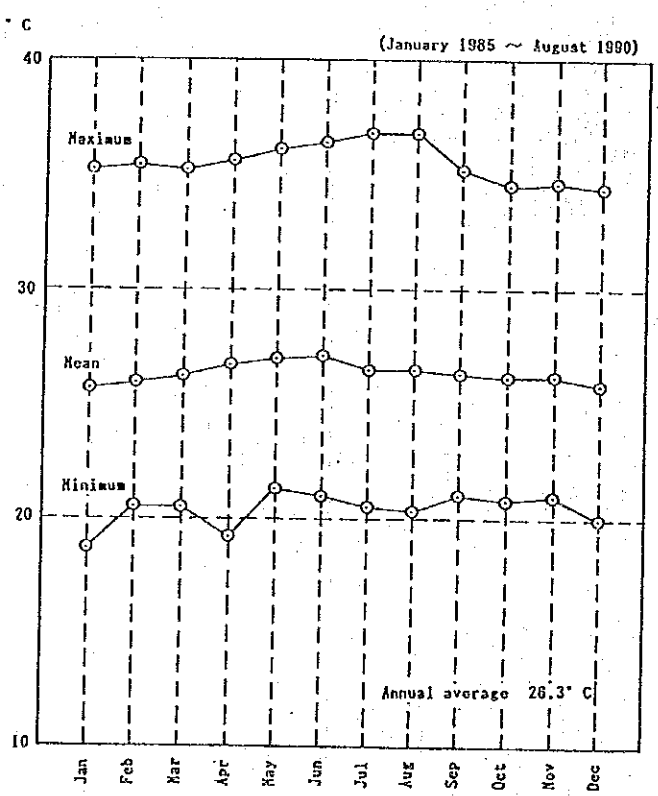
2.2.1 General

The Rajang Delta has a tropical climate - hot and humid with heavy rainfall. Temperature ranges from 20 to 36 degrees celsius all the year round with humidity of usually over 65 percent. Average precipitation is as much as 4,000 mm a year. Two monsoons affect weather; North-east monsoon (November - March) usually brings heavy rainfall while south-west monsoon (May - September) is generally drier.

Figure-2.2.2.1 - Figure-2.2.5.3 show weather data obtained by the meteorological observatory at Sibu Airport.

2.2.2 Temperature

Air temperature is high throughout the year as shown in **Figure-2.2.2.1.** The figure shows that the monthly mean temperatures are between 25.7 and 27.1 degrees celsius. The highest temperature during the 1985-1990 period was recorded at 36.8 degrees celsius and the lowest one was 18.7 degrees celsius.

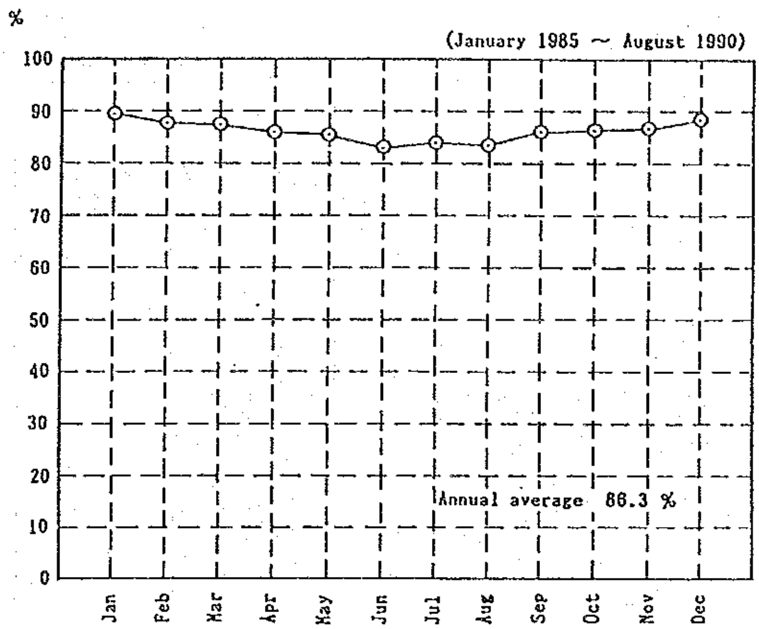


source ; Sibu Airport Observatory

Figure-2.2.2.1 Monthly Temperature

2.2.3 Humidity

Humidity is fairly high throughout the year and the average annual relative humidity is 86.3 percent. Monthly variation of the mean relative humidity is shown in **Figure-2.2.3.1.** The mean relative humidity at 2 pm. recorded during the 1979-1989 period was between 65 and 71 percent.



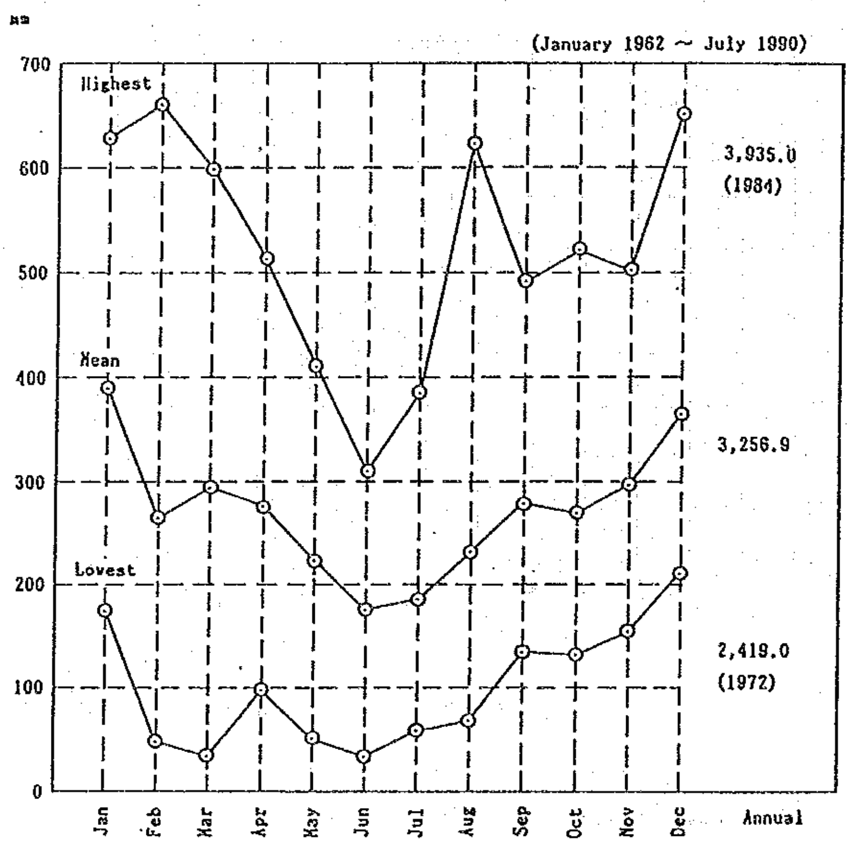
source ; Sibu Airport Observatory

Figure-2.2.3.1 Monthly Mean Relative Humidity

2.2.4 Precipitation

The average annual precipitation is approximately 3,200 mm. The monthly total rainfall is shown in **Figure-2.2.4.1.** The highest monthly rainfall recorded during the 1979-1989 period was 659mm and maximum rainfall in a day was 209.6mm.

An average total number of rainy days a year was 231 days.



source ; Sibu Airport Observatory

Figure-2.2.4.1 Monthly Total Rainfall

2.2.5 Wind

The wind in Sarawak is weak throughout the year. Strong wind of more than 10m/sec blows rarely, and calm condition (wind speed less than or equal to 0.2m/sec) prevails by 25-45% per day (24 hours) on an average 10 years. **Figure-2.2.5.1** shows the annual wind roses at main cities in Sarawak.

Overall characteristics of wind depends on the monsoon. In the north-east monsoon season, north and northeast wind is prevailing, and wind from south-east to west prevails in the south-west monsoon season. **Table-2.2.5.1** show seasonal wind frequency by wind speed and direction at Sibu Airport. The monthly maximum and mean surface winds at Sibu Airport are shown in **Figure-2.2.5.2** and **2.2.5.3.**

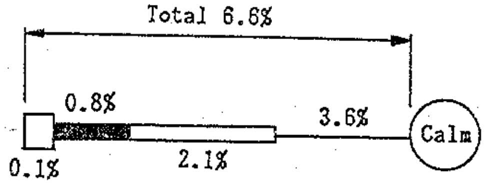
The maximum gust speed of 30m/sec was recorded in 190 degrees direction (SSW) in August, 1967.

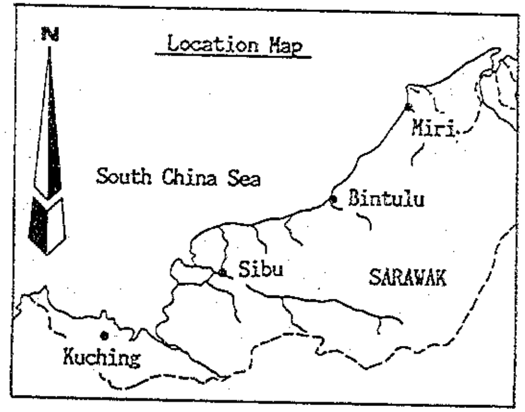
For designing marine facilities, it is necessary to adjust wind speed from inland figure (at Sibu Airport) to coastal figures.

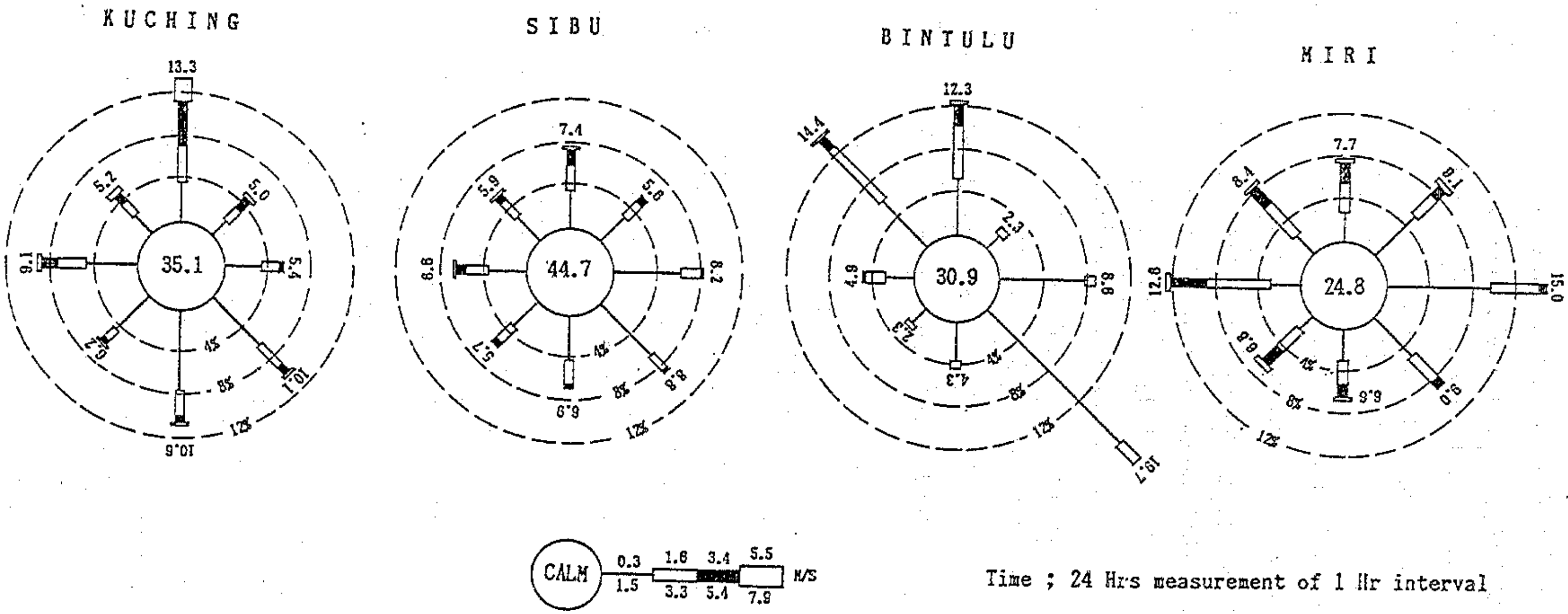
Explanation of Wind Rose Diagram

Example ; Location-Sibu, Wind direction-West

Wind speed (m/sec)	Percentage (%) frequencies of time
0.3 ~ 1.5	3.6
1.6 ~ 3.3	2.1
3.4 ~ 5.4	0.8
5.5 ~ 7.9	0.1







Time ; 24 Hrs measurement of 1 Hr interval

Figure-2.2.5.1 Annual Wind Rose (1968-1987)

SOURCE : Climatological Division
Malaysian Meteorological Service

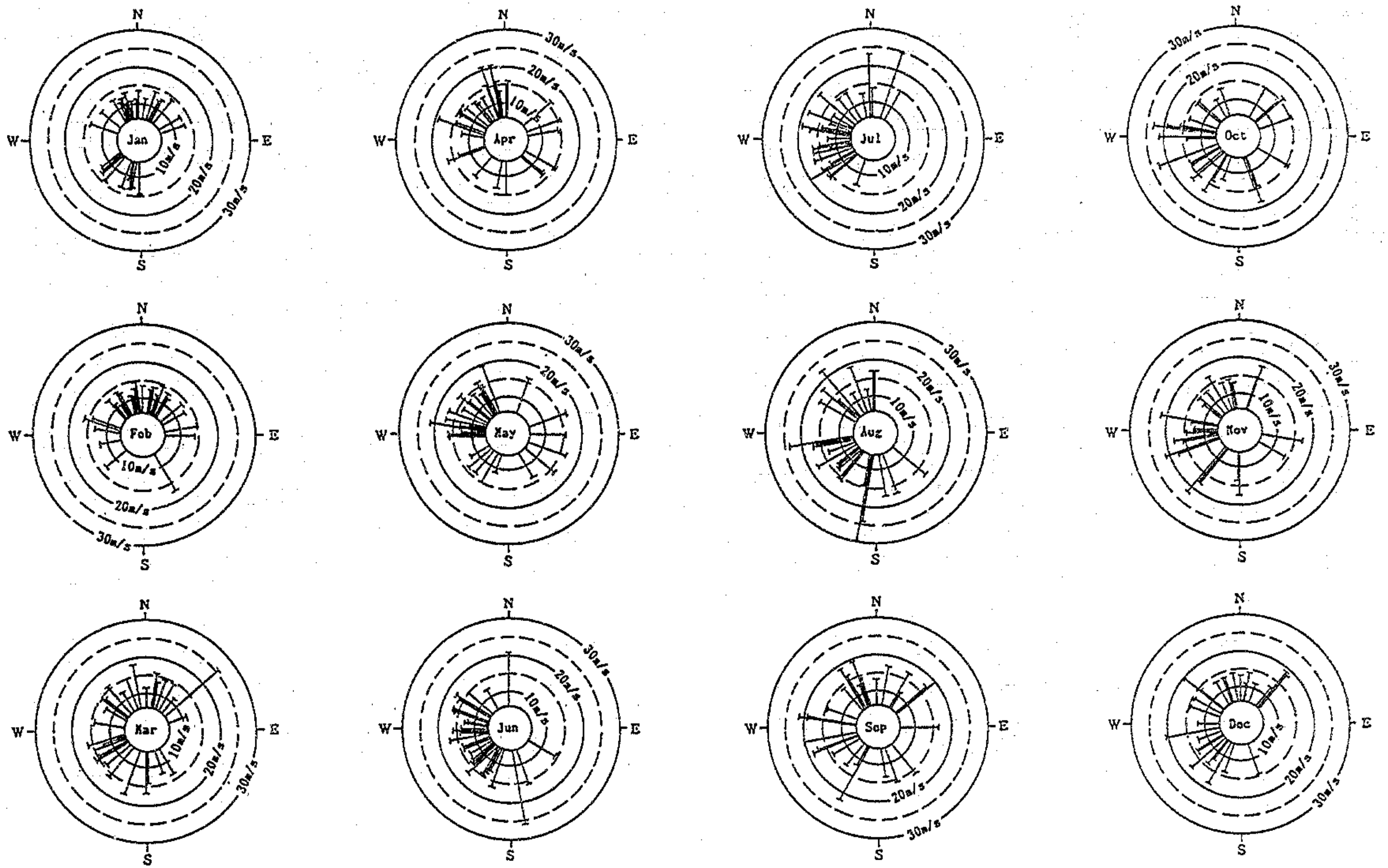


Figure-2.2.5.2 Monthly Maximum Surface Wind at Sibu Airport (1964-1990)

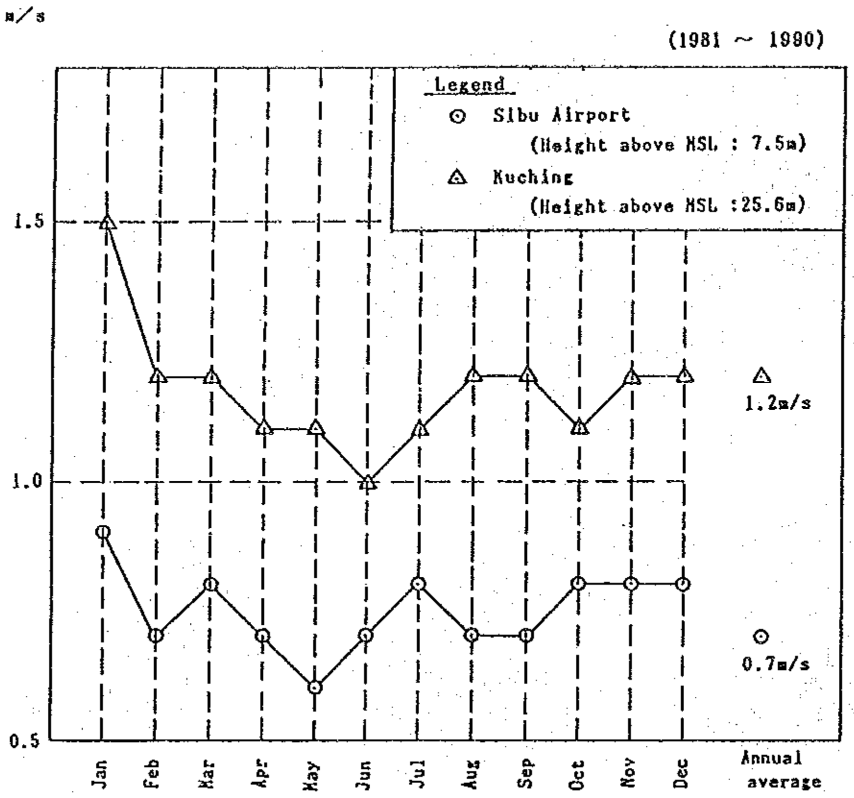


Figure-2.2.5.3 Monthly Mean Surface Wind Speed

Table-2.2.5.1(1) Frequencies of Wind Direction and Speed

Station : Sibu Period : 1968—1987 Time : 24 Hours

APRIL unit ; %

Speed (m/s)	Direction									
	N	N E	E	S E	S	S W	W	N W	CALM	TOTAL
≦ 0.2	-	-	-	-	-	-	-	-	46.9	46.9
0.3~1.5	3.1	2.9	7.7	7.3	3.9	2.7	3.3	2.8	-	33.7
1.6~3.3	2.1	1.4	1.9	1.7	1.4	1.2	2.4	1.9	-	14.0
3.4~5.4	0.9	0.5	0.3	0.2	0.2	0.3	0.9	1.4	-	4.7
5.5~7.9	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.2	-	0.4
≧ 8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
Total	6.2	4.8	9.9	9.2	5.5	4.3	6.6	6.3	46.9	100

MAY—SEPTEMBER (South-west monsoon) unit ; %

Speed (m/s)	Direction									
	N	N E	E	S E	S	S W	W	N W	CALM	TOTAL
≦ 0.2	-	-	-	-	-	-	-	-	45.0	45.0
0.3~1.5	2.3	2.2	6.8	8.2	5.0	3.9	3.7	2.9	-	35.0
1.6~3.3	1.0	0.8	2.0	2.8	3.1	2.4	2.2	1.6	-	15.9
3.4~5.4	0.3	0.2	0.3	0.4	0.6	0.5	0.8	0.7	-	3.8
5.5~7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	-	0.2
≧ 8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
Total	3.6	3.2	9.1	11.4	8.7	6.8	6.8	5.3	45.0	100

OCTOBER unit ; %

Speed (m/s)	Direction									
	N	N E	E	S E	S	S W	W	N W	CALM	TOTAL
≦ 0.2	-	-	-	-	-	-	-	-	42.8	42.8
0.3~1.5	2.7	2.1	6.5	8.2	5.0	3.9	4.3	2.8	-	35.5
1.6~3.3	1.5	0.9	1.8	1.9	2.6	2.6	2.7	2.1	-	16.1
3.4~5.4	0.6	0.1	0.2	0.2	0.6	0.8	1.4	0.9	-	4.8
5.5~7.9	0.1	0.0	0.0	0.0	0.1	0.1	0.2	0.2	-	0.7
≧ 8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
Total	4.9	3.1	8.5	10.3	8.3	7.4	8.6	6.0	42.8	100

source ; Sibu Airport Observatory

Table-2.2.5.1(2) Frequencies of Wind Direction and Speed

Station : Sibu Period : 1968—1987 Time : 24 Hours

NOVEMBER—MARCH (North-east monsoon) unit ; %

Speed (m/s)	Direction									
	N	N E	E	S E	S	S W	W	N W	CALM	TOTAL
≦ 0.2	-	-	-	-	-	-	-	-	44.4	44.4
0.3~1.5	4.8	3.9	5.7	5.1	3.6	2.7	3.3	3.1	-	32.2
1.6~3.3	3.7	2.7	1.5	1.0	1.3	1.4	1.9	2.1	-	15.6
3.4~5.4	2.6	1.1	0.2	0.1	0.3	0.4	0.9	1.2	-	6.8
5.5~7.9	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.1	-	0.6
≧ 8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
Total	11.4	7.8	7.4	6.2	5.2	4.5	6.2	6.5	44.4	100

ANNUAL unit ; %

Speed (m/s)	Direction									
	N	N E	E	S E	S	S W	W	N W	CALM	TOTAL
≦ 0.2	-	-	-	-	-	-	-	-	44.7	44.7
0.3~1.5	3.5	3.1	6.2	6.7	4.3	3.3	3.6	3.0	-	33.7
1.6~3.3	2.3	1.8	1.8	1.9	2.2	1.9	2.1	1.9	-	15.9
3.4~5.4	1.5	0.7	0.2	0.2	0.4	0.5	0.8	0.9	-	5.2
5.5~7.9	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	-	0.3
≧ 8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
Total	7.4	5.6	8.2	8.8	6.9	5.7	6.6	5.9	44.7	100

source ; Sibu Airport Observatory

2.2.6 Visibility

No visibility record is available for this area. Visibility is usually very good unless it showers.

According to Marine Department Sarikei, visibility in the Tanjung Manis area is as follows;

- Almost clear all the time
- Visibility of 2 to 3 miles occurs at the worst condition

Dense fog is occasionally observed over the river surface in the next early morning of a very hot day.

2.3 Soil Analysis

2.3.1 General

The geology of the lower Rajang valley and the adjacent areas of over 25,000 square km down stream of Rajang River from Kapit, is mainly composed of sedimentary rocks. These rocks range in age between Upper Cretaceous and Alluvial era, and also include a few Tertiary intrusive and extrusive igneous rocks.

The study area is located in the Rajang Delta, which has flat, low-lying and mainly swampy topography. The area consists of a thick sequence of geosynclinal sedimentary rocks of Upper Cretaceous to Upper Eocene age, comprising mildly or dynamically metamorphosed argillaceous rocks, sand stone and rare conglomerate. The extensive coastal plains are built of unconsolidated quaternary sediments.

The subsurface soil features in the study area vary in each locations. but are generally shown in the following figure.

Surface layer:	Very soft to soft silt with peat, woody organics, some trace of sand
Second layer:	Soft to stiff sandy clayey silt with some traces gravel, or silty sand
Third layer:	Clayey silty sand with gravel, or very dense/firm silt
Fourth layer:	Weathered sandstone, mudstone or shale

Figure-2.3.1.1 Typical subsurface soil strata in the Rajang delta

The study team collected the existing boring data on the related sites.

Additional borings and laboratory tests were carried out by the study team as follows;

* List of boring machines and test machines:

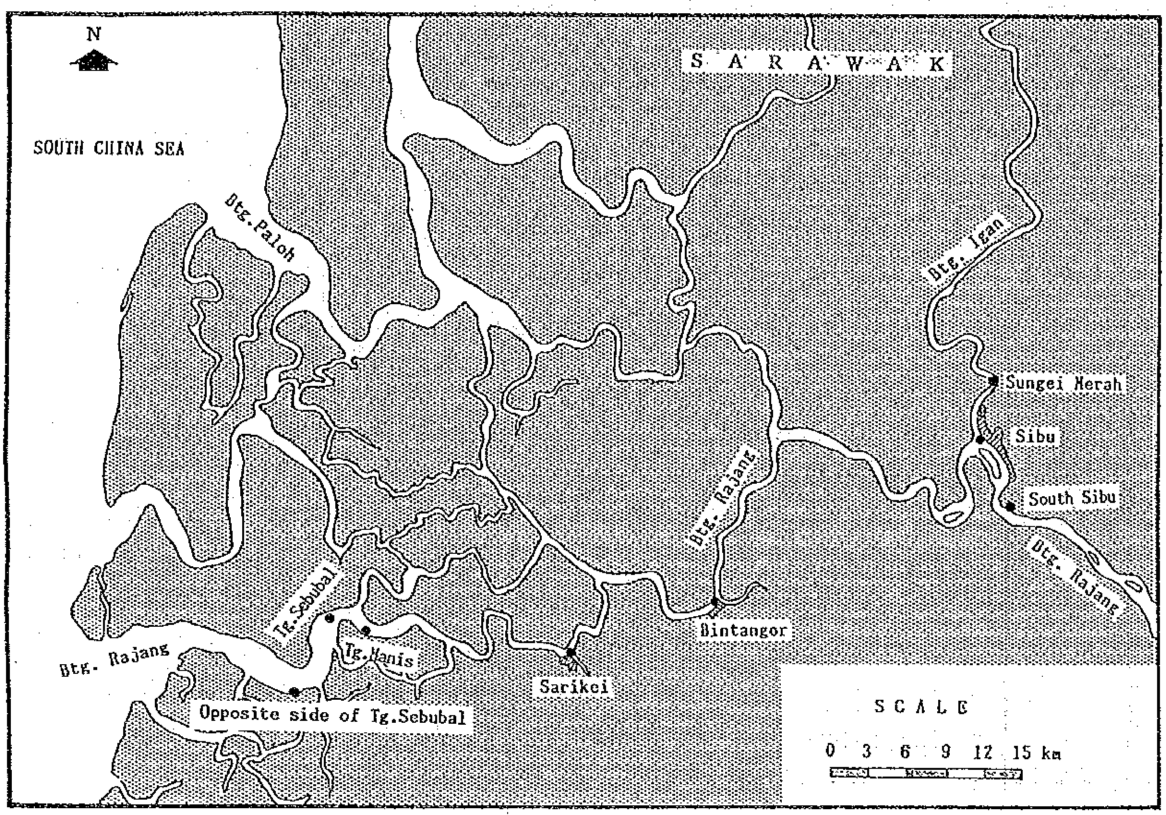
Table-2.3.1.1 List of Boring Machines and Test Machines

Item	Name of Machine/ Equipment/Apparatus	Description	Quantity	Procured by	Remarks
Boring	Boring Machine	YSO-1	1 set	local	with accessories
	Boring Machine	YMB-2	1 set	local	with accessories
	Boring Pontoon	200 t	1 set	local	with frame
Laboratory test	Specific gravity		1 set	local	
	Grain-size analysis		1 set	local	
	Moisture content		1 set	local	
	Unit density		1 set	local	
	Liquid limit		1 set	local	
	Plastic limit		1 set	local	
	Unconfined compression		1 set	local	
	Consolidation		1 set	local	

* Period of operation: 8 Oct. 1990 to 10 Nov. 1990

* Carried out by: Geotechnique East Malaysia Sdn. Bhd.

* Location of boring: as shown in Figure-1.3.1.2.



Name of Place	Number of Boring			Remarks (Borehole No.)
	Land	River	Total	
Sungai Merah	1	-	1	BH No.12
Sibu Center	1	-	1	BH No.13
South Sibu (Tg.Kumper)	1	-	1	BH No.14
Bintangor	-	1	1	BH No.11
Sarikei	-	1	1	BH No.10
Tanjung Manis	1	1	2	BH No.8 & 9
Tanjung Sebubal	1	2	3	BH No.5, 6 & 7
Opposite side of Tg. Sebubal	1	3	4	BH No.1, 2, 3 & 4
Total	6	8	14	

Figure-2.3.1.2 Location of Soil Boring

2.3.2 Sibu Area

Three borings for soil investigation were carried out by the team in this area.

The boring points at Sibu Center, Sungai Merah and Tg. Kumper (Sibu South) are shown in the following map.

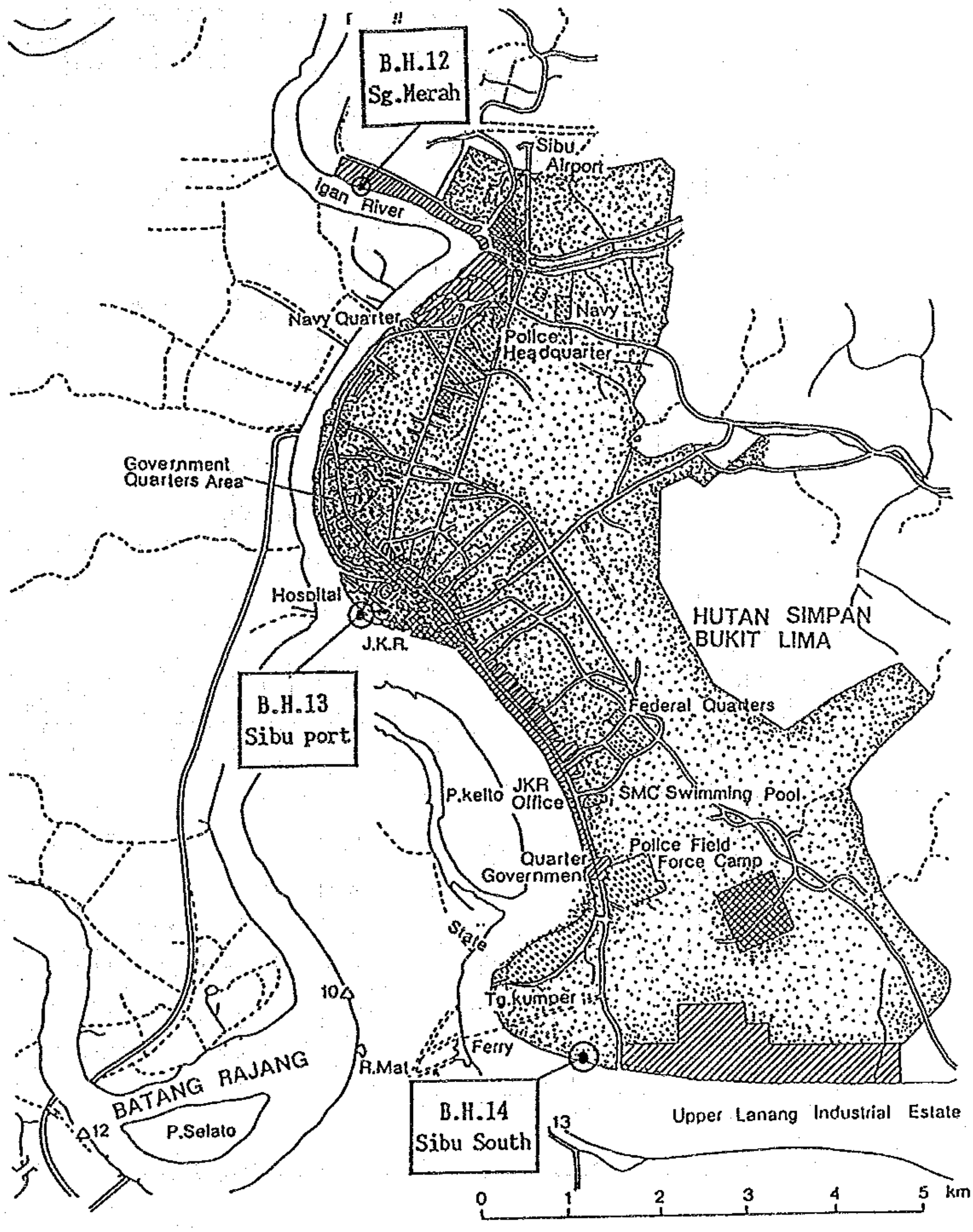


Figure-2.3.2.1 Map of Boring Points at Sibu Area

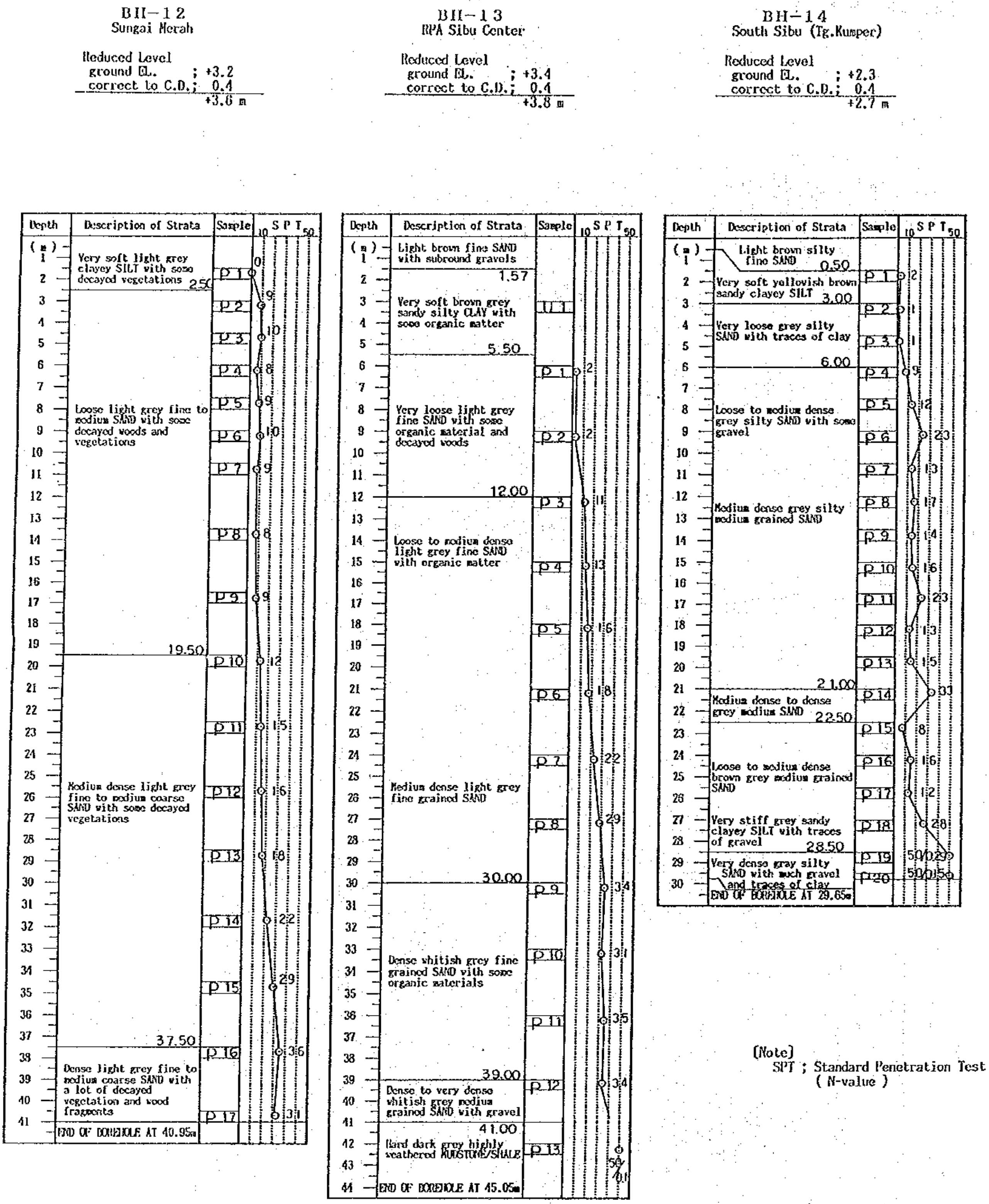


Figure-2.3.2.2 Soil Strata at Sibu Area (by JICA)

Each strata of 3 boring points are similar, and subsurface soil consists of sandy soil with vegitation and/or decayed woods (fragment) from surface to the rock formation. (See **Figure-2.3.2.2**)

The laboratory test results are shown in the Appendix.

(1) Sungai Merah

At Sg. Merah, the boring could not reach to a rock layer in spite of the drilling length of 41m (C.D.-37.4m). The figures of strata show only sand up to the end of the bore hole except the top layer silt with thickness of 2.5 m. This sandy strata is divided into two parts; the upper layer consists of loosed sand with thickness of 17m and the lower layer medium dense sand with thickness of more than 20m.

(2) Sibu Center

The soil strata at Sibu Center is similar to that of Sg. Merah. The only difference is that level of the rock formation of weathered mudstone/shale appears at C.D. -37m.

A lot of soil data in and around Sibu Center are available. The soil investigation carried out by RPA shows the similar results to ours. These result shows that the level of the sandstone/shale formations is about C.D. -30 to -38m or below, and above the rock layer, consists of loose to dense sand and/or soft to stiff clayey silt.

(3) Sibu South

The soil strata at Sibu South (Tg. Kumper) is also similar to those in Sibu area. A very dense sand layer like rock formations appears at C.D. -26m. The strata above the sand layer, from the ground (C.D.+3m) to C.D. -26m consist of very loose to medium dense sand having the N-values of 1 to 33.

(4) River bottom sediment

The river bottom sediment at Sibu area consists of clayey silt having the thickness of about 2-4 meters.

2.3.3 Bintangor

One boring was carried out by the team at the left bank of the river as shown in **Figure-2.3.3.1**.

The rock formation of the sandstone/siltstone appears in the shallow depth of C.D. -10m. Above the rock layer, there is very soft grey silty clay layer with thickness of 13m. (See **Figure-2.3.3.2**)

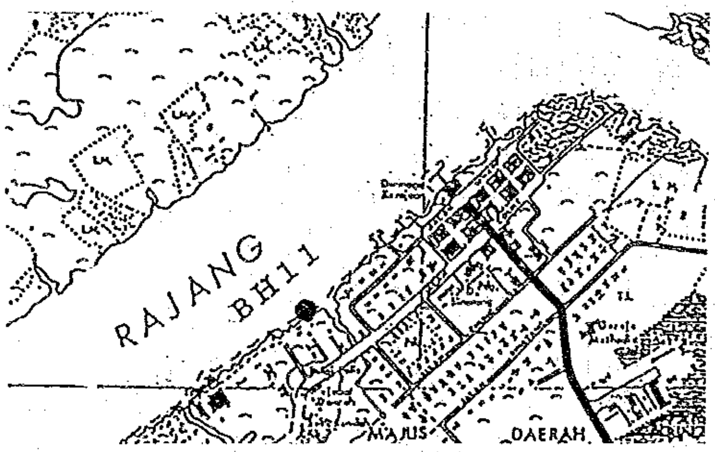


Figure-2.3.3.1 Location map of Boring at Bintangor

2.3.4 Sarikei

One boring was also carried out by the team in the left bank of the river as shown in **Figure-2.3.4.1**.

The strata of this area are similar to those of Bintangor. The hard rock formations appear in C.D. -14m. The results of 17 borings carried out by RPA are similar to ours.

The rock formation level is C.D. -11 to -15m and the layer above the rock is very soft to stiff silty clay and/or clayey silt. (See **Figure-2.3.4.2**)

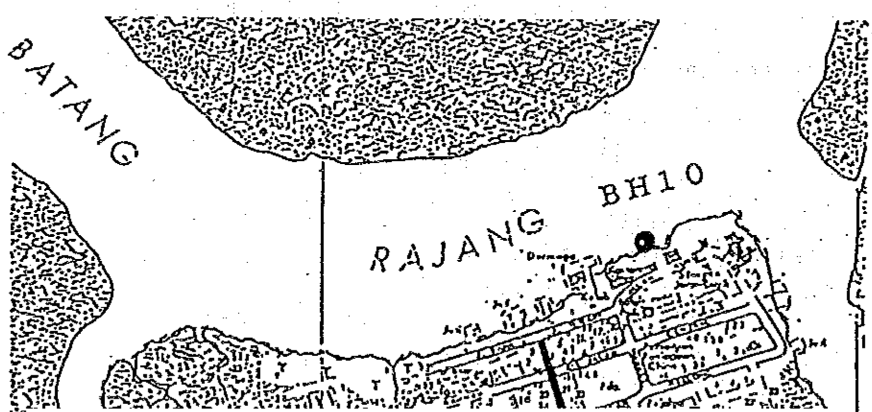


Figure-2.3.4.1 Location map of Boring at Sarikei

BH11

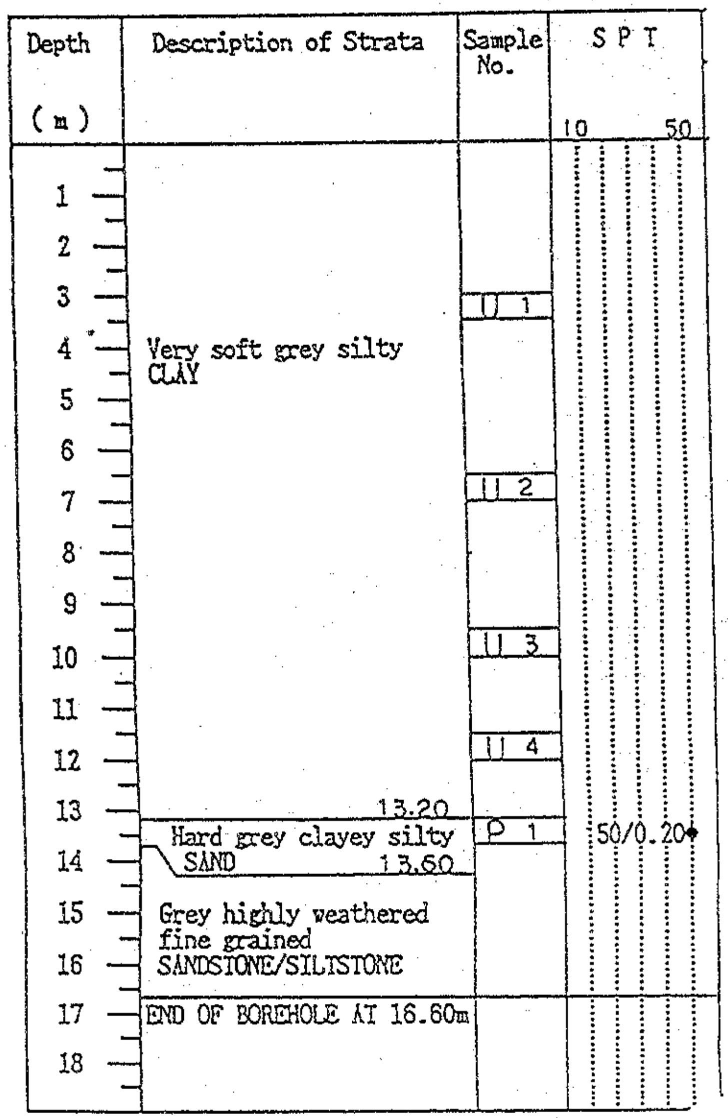


Figure-2.3.3.2 Results of Soil Investigation at Bintangor

(by JICA)

[Note]
SPT ; Standard Penetration Test
(N-value)

BH10

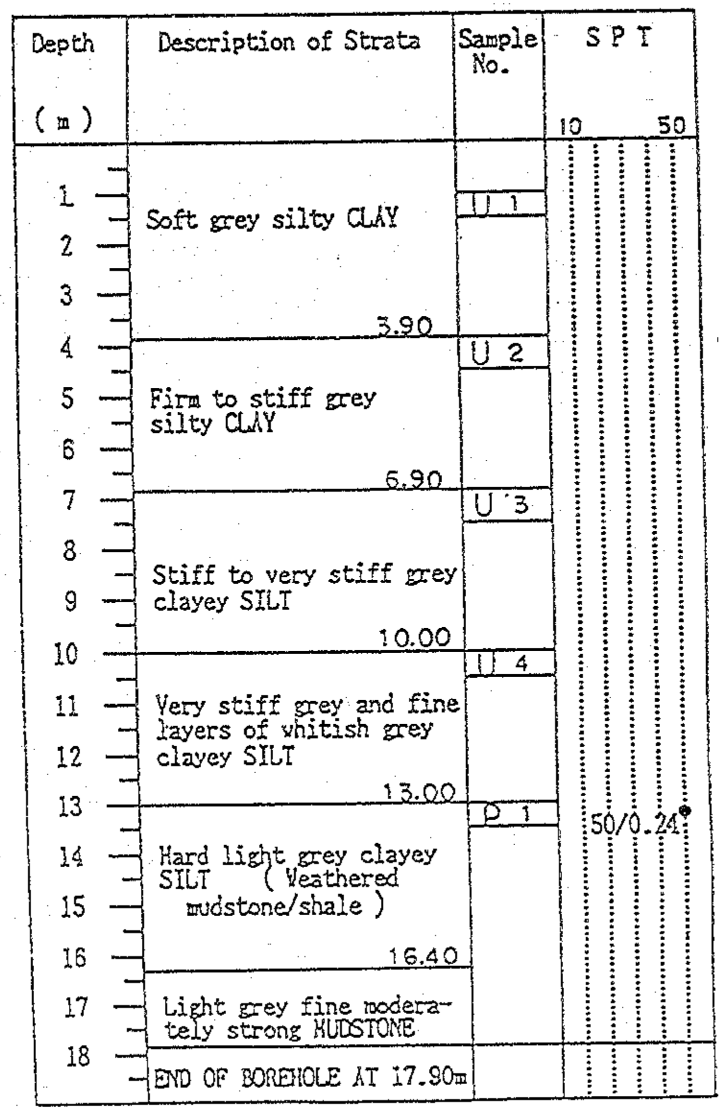


Figure-2.3.4.2 Results of Soil Investigation at Sarikei

(by JICA)

2.3.5 **The Tg. Manis area**

The Tg. Manis area covers Tg. Manis, Tg. Sebubal and the opposite side of Tg. Sebubal.

The study team carried out nine (9) borings in this area as shown in **Figure-2.3.5.1**.

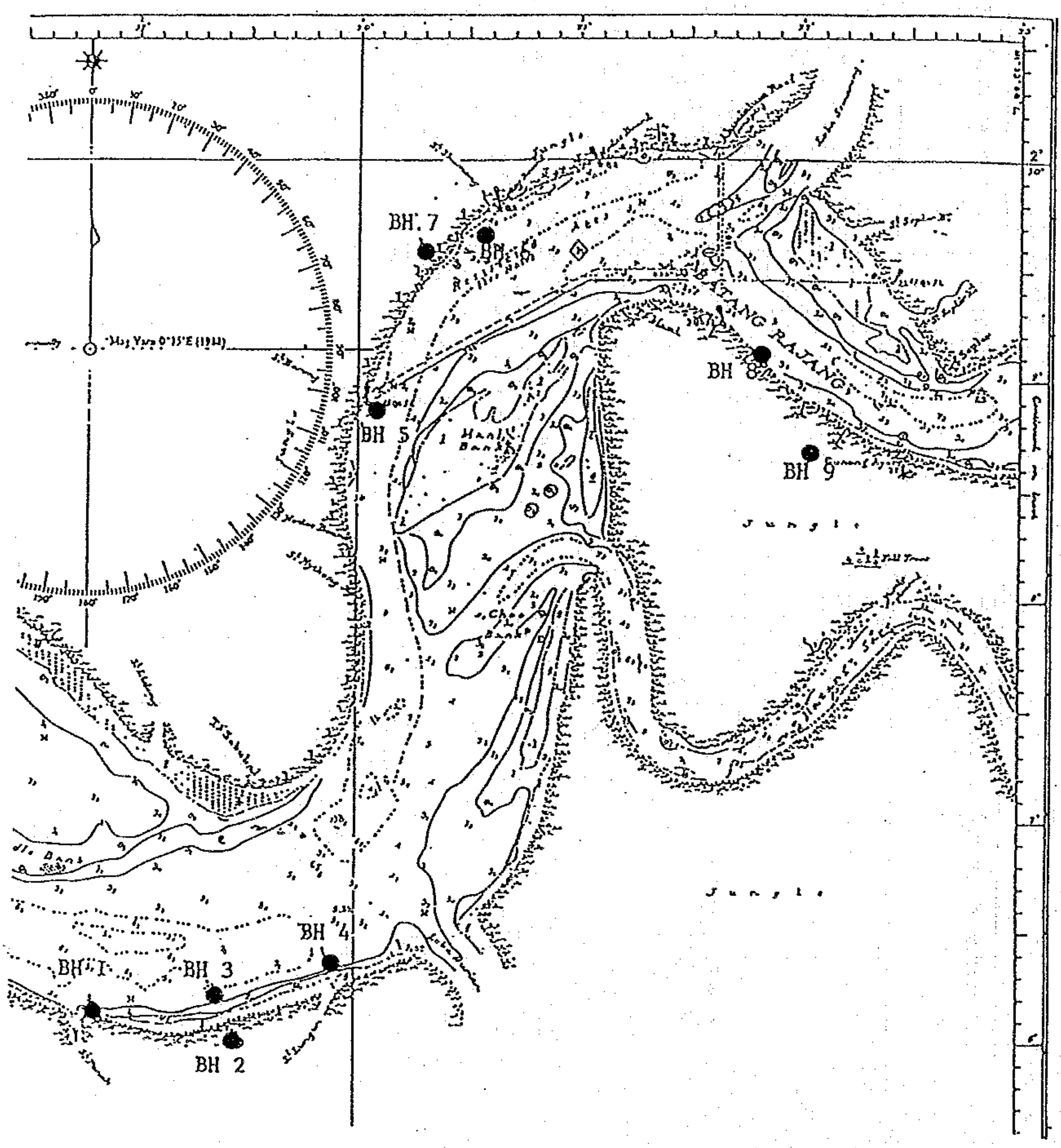


Figure-2.3.5.1 Location Maps of Borings at the Tg. Manis Area

Each soil strata of three areas are similar, but the level of the rock formation is different a little at each location. The rock layer at Tg. Manis appears at the level of about C.D.-15m, which is shallowest in the area. At Gunong Ayer (east of Tg. Manis) where the custom office stands, the weathered rock formation is exposed to the air.

The rock formation of other two locations appears at the level of about C.D. -20m. The rocks consist of the weathered sandstone with shale, mudstone and siltstone. The strata above these rocks consist of very soft to stiff silt with sand & clay.

The subsurface soil profiles of these areas are shown in **Figure-2.3.5.2** to **Figure-2.3.5.4**.

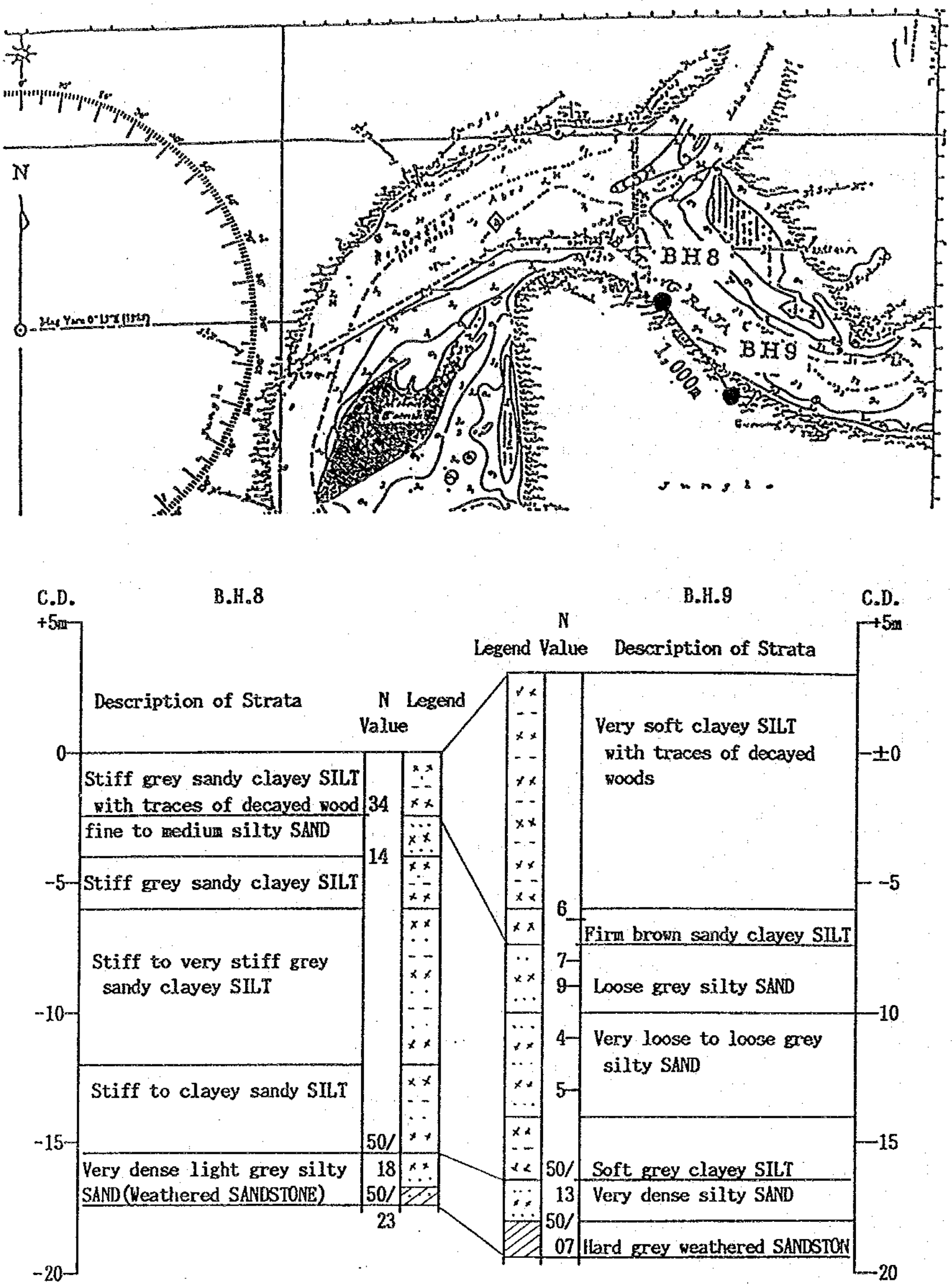


Figure-2.3.5.2 Subsurface Soil Profile at Tg. Manis (by JICA)

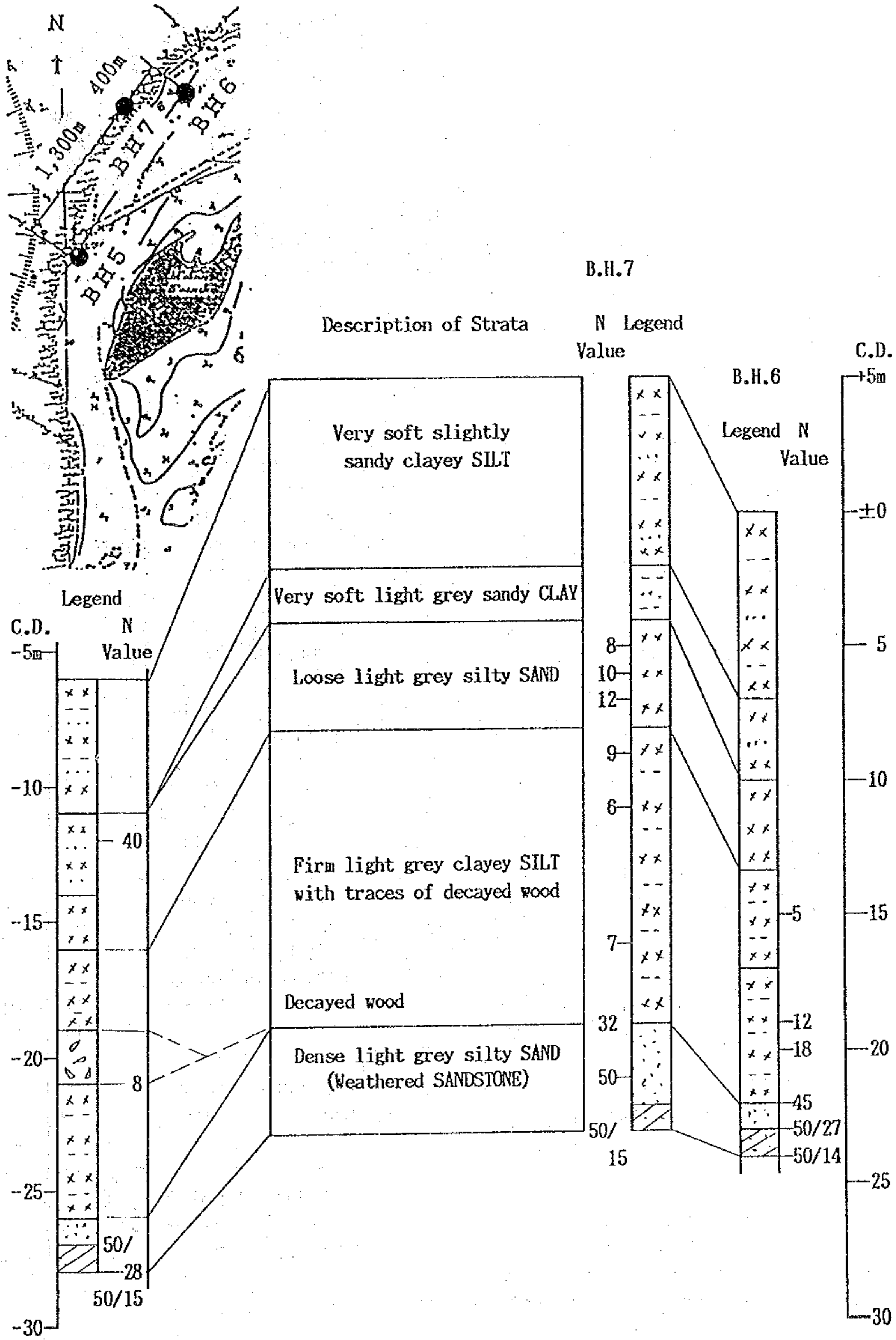


Figure-2.3.5.3 Subsurface Soil Profile at Tg. Sebubal (by JICA)

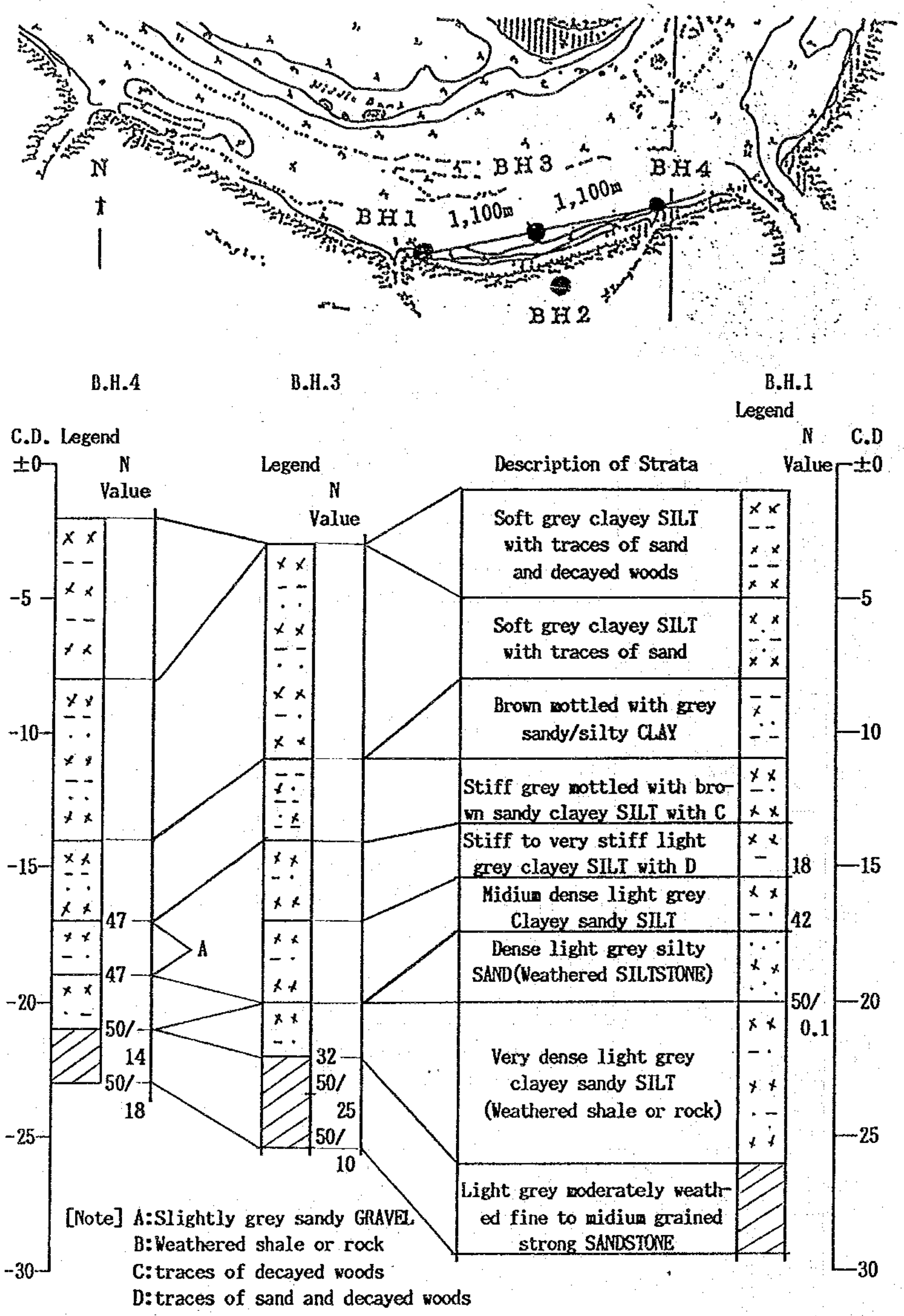


Figure-2.3.5.4 Subsurface Soil Profile at the opposite side of Tg. Sebubal (by JICA)

In order to study the suitability of river bed sediment as the construction material, sampling tests were carried out in the Tg. Manis area as shown in **Figure-2.3.5.5.**

The results of the grain size analysis are shown in **Talbe-2.3.5.1.** In addition judging from the results of boring carried out by STIDC, almost all of the soil (sand) at the sand bars (west of Tg. Manis and south of Tg. Sebubal) can be used as reclaiming material.

Table-2.3.5.1 Grain Size Analysis of the River Bottom Sediments (by JICA)

Location	Grain Size Distribution (%)				Classification of Soil		
	Gravel	Sand	Silt	Clay	D=50 Size(mm)	Classification	Suitability *①
South Tg.Manis (Section A)							
a	4	45	34	17	0.055	Silt	×
b	0	91	0	9	0.15	Fine Sand	○
c	0	93	0	7	0.15	Fine Sand	○
d	0	99	0	1	0.32	Medium Sand	○
e	0	98	0	2	0.23	Medium Sand	○
f	0	16	56	28	0.012	Silt	×
g	0	14	62	24	0.009	Silt	×
h	29	25	29	17	0.08	Fine Sand	△
Tg. Sebubal (Section B)							
a	3	80	0	17	0.23	Medium Sand	○
b	3	70	16	11	0.20	Fine Sand	△
c	0	97	0	3	0.33	Medium Sand	○
d	0	100	0	0	0.28	Medium Sand	○
e	0	99	0	1	0.30	Medium Sand	○
f	2	66	18	14	0.17	Fine Sand	△
g	0	93	0	7	0.25	Medium Sand	○
h	2	91	0	7	0.25	Medium Sand	○
Tg. Manis (Section C)							
a	2	50	33	15	0.065	Fine Sand	△
b	0	40	40	20	0.03	Silt	×
c	3	18	56	23	0.012	Silt	×
d	2	23	52	23	0.02	Silt	×

*① : Suitability of soil for land reclamation
○ Suitable △ Applicable × Unsuitable

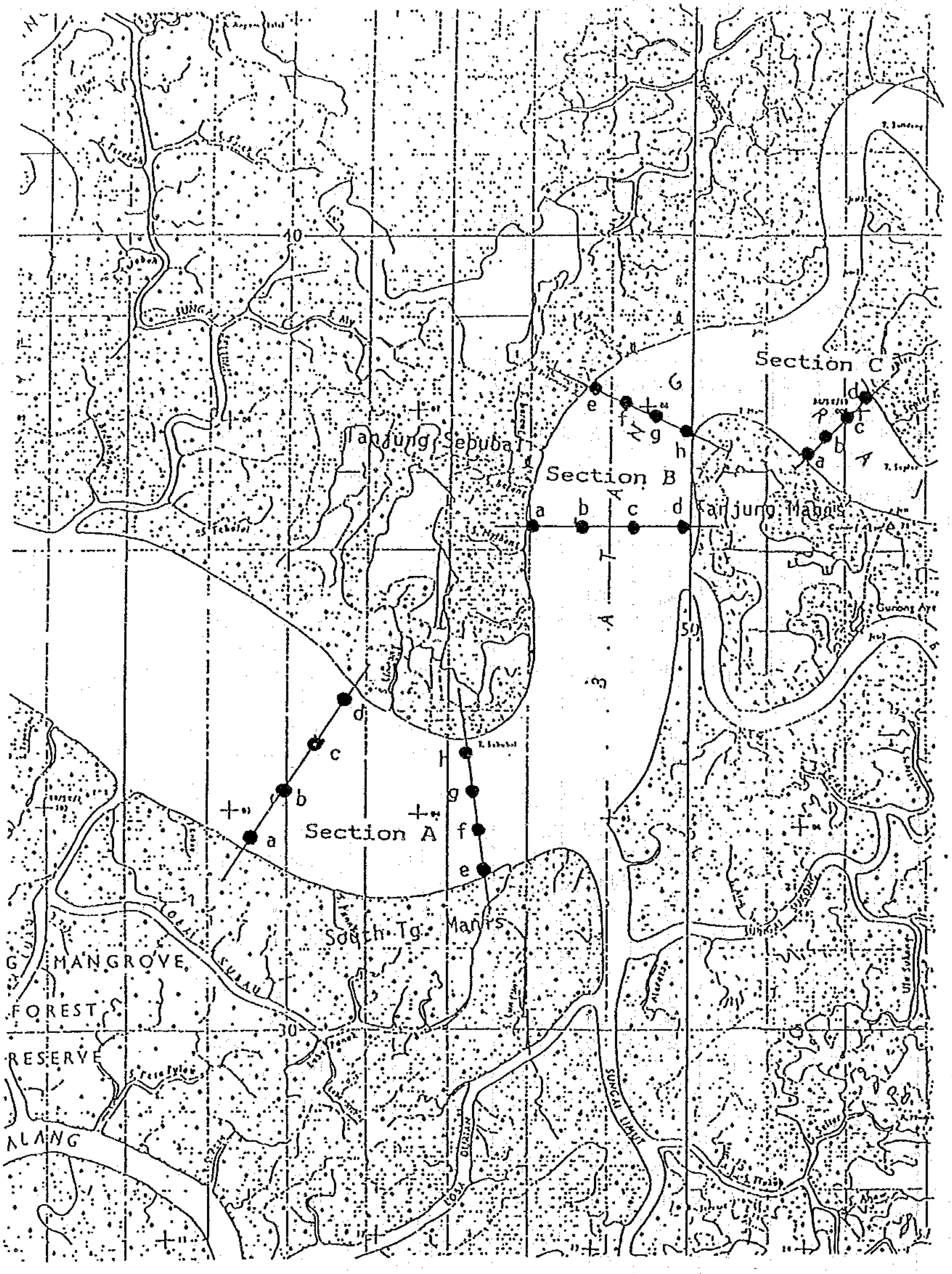


Figure-2.3.5.5 Location of Bottom Sediments Sampling at the Tg. Manis Area