# THE REPORT ON ENVIRONMENTAL EFFECTS OF COAL FIRING POWER STATIONS AND INTEGRATED STEEL MILL IN THE REPUBLIC OF SINGAPORE

## VOLUME I – WATER QUALITY

FEBRUARY 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

# THE REPORT
# ON
# ENVIRONMENTAL EFFECTS
# OF COAL FIRING POWER STATIONS
# AND
# INTEGRATED STEEL MILL
# IN THE REPUBLIC OF SINGAPORE

## VOLUME I – WATER QUALITY



FEBRUARY 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

# PREFACE

In response to a request of the Government of the Republic of Singapore, the Government of Japan decided to conduct a water and air quality survey on the Environmental Effects of the planned Coal-Firing Power Stations and the Integrated Steel Mill and entrusted the survey to the Japan International Cooperation Agency (JICA).

The JICA sent to Singapore a water quality survey team consisting of ten experts headed by Mr. Yoichi Suzuki of the Industrial Pollution Control Association of Japan.

The team exchanged views with the officials concerned of the Government of Singapore and conducted a field survey in the Seraya and Tekong Areas.

After the team returned to Japan, data analyses and simulation were conducted and the present report has been prepared.

I hope that this report will serve for the environmental assessment study and the environmental protection measures in Singapore.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Singapore for their close cooperation extended to the team.

February, 1982

Keisuke Arita
President
Japan International Cooperation Agency

TABLE OF CONTENTS

# SUMMARY & RESULTS

## (I) Summary of Study

The Government of the Republic of Singapore has requested the Government of Japan to extend its technical assistance to conduct the study on the environmental effects of coal firing power stations and integrated steel mill which will be sited in the new industrial estates under the development plan of the Republic of Singapore.

In response to the request, the preliminary survey team has been dispatched to Singapore in December 1980 and the team entered into agreement on the scope of work including survey items, survey schedule and so on, as attached in the last part of this report.

Japanese survey team for water quality have stayed in Singapore for about 40 days during February 15th to March 26th of 1981 for the purpose of conducting various observations involved in this study.

The survey has been carried out for obtaining the basic data necessary for the simulation, and for obtaining the data related to the characteristics of the survey areas.

The survey has been conducted by establishing the survey points in the survey areas (Seraya Area and Tekong Area) for current survey, tide observation (relative data collected), meteorological observation (relative data collected), water temperature and salinity survey, water quality survey and collection of past survey data.

Following the field survey, the data analysis and simulation have been conducted during May to December 1981, and the report has been compiled.

Fig. (I)-1 shows the flow chart of the study. Table (I)-1 shows the specifications of the survey conducted, and Table (I)-2 shows the time schedule of field survey.

Fig. (I)-1 Environmental impact assessment

- WATER QUALITY -

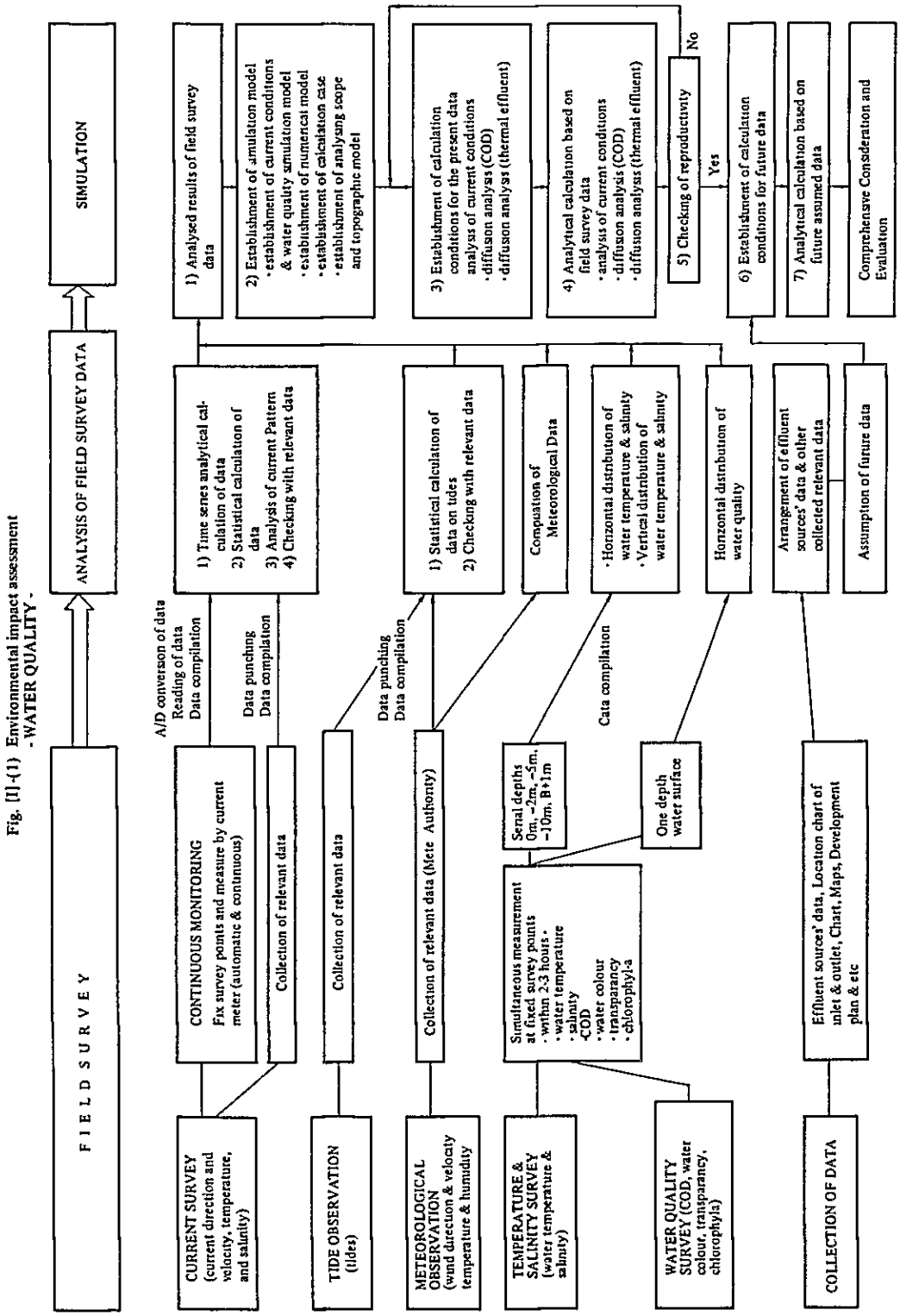


Table (I)-1 Specification of field survey

| Survey Item | Survey Point | Survey Layer | Survey Period | Survey Method |
|---|---|---|---|---|
| 1. Current Survey (current direction velocity, temperature, salinity) Field Survey | Seraya Area SC1 – SC6 | SC1 — –8m<br>SC2 — –8m<br>SC3 — –12m<br>SC4 — –5m<br>SC5 — –6m<br>SC6 — –6m | February 23rd to March 13th 1981 | Survey conducted by setting AANDERAA current meter at the survey points by sub-surface float system. Measuring interval of current meter was 5 minutes. |
| | Tekong Area TC1 – TC4 | TC1 — –7m<br>TC2 — –5m<br>TC3 — –5m<br>TC4 — –7m | February 26th to March 17th 1981 | |
| Collection of past survey data | Pulau Ayer Merbau Area St1 – St5 | –3m | August 7th to August 25th 1979 | Report on Boring and Survey for Petrochemical Complex at Pulau Ayer Merbau of Singapore for Petrochemical Corporation of Singapore – October 1979 – Survey conducted by setting CT-3 type current meter by surface float system and measured direction and velocity with interval of 30 minutes |
| | The Straits of Malacca and Singapore | –10m | July 10th to August 19th 1978<br>November 9th to December 20th 1978 | Report on the Joint Survey for Tide and Tidal Current of the Straits of Malacca and Singapore – Survey conducted by setting NC type current meter by surface float system and measured direction and velocity |
| 2. Tide Observation Collection of relative data | Slave One Jurong Wharf | | February 23rd to March 17th 1981 | Relative data supplied by PSA |
| | Victoria Dock Jurong Wharf | | March 1st to March 31st 1981 | Singapore Tides Table and Port Facilities issued by PSA |
| 3. Meteorological Observation Collection of relative data (wind direction, velocity, temperature & humidity) | Changi Air Base JTC Flatted Factory | | February 23rd to March 17th 1981 | Meteorological Service Singapore supplied the relative data. |
| 4. Water Temperature & Salinity Survey Field Survey | Seraya Area S1 – S49<br>Tekong Area T1 – T35 | 0, –2, –5, –10 & Bottom +1m | March 2nd 1981 –13.00 to 16.00 hour<br>March 5th 1981 –15 00 to 17.00 | Survey conducted for water temperature by hanging down electric thermometer, for salinity by salinometer after sampling sea water |
| 5. Water Quality survey (COD, transparency, water colour, & chlorophyll-a Field Survey | Seraya Area Representative points among S1 – S49<br>Tekong Area Representative points among T1 – T35 | –0.5m | - ditto - | For COD, analysed by permanganate method after sampling sea water by sampler. For transparency, SECCHI DISC used and water colour measured by standard colour of For cholophyll-a, measured by spectro-photo meter after sampling, filtering extracting and separating by centifugal force. |
| 6 Collection of Data | | | | Collected the relative data, including effluent sources' data, maps, charts and other information materials |

## Table (I)-2 Time schedule of field survey

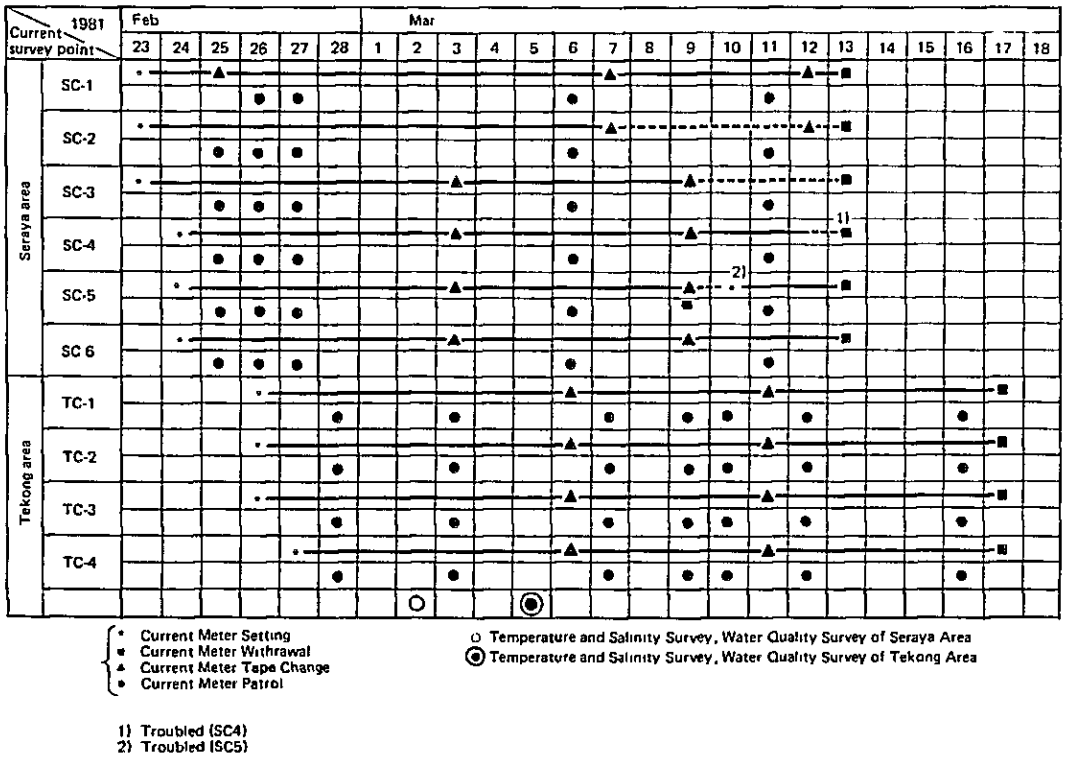


Table (I)-3 Specifications of simulation

| Item | | Present (1981) | | Future (1990) | |
|---|---|---|---|---|---|
| | | Seraya | Tekong | Seraya | Tekong |
| (a) Analysis of current conditions | | | | | |
| Tidal current | | o | o | o | o |
| Constant current | A | o | o | o | ◎ |
| Constant current | B | - | - | o | - |
| (b) Analysis of pollutant diffusion | | | | | |
| COD | A | o | o | o | ◎ |
| COD | B | - | - | o | - |
| (c) Analysis of thermal effluent diffusion | | | | | |
| | A | o | o | o | o |
| | B | - | - | o | - |

Remarks: Constant current A of Seraya is westward pattern and constant current B is eastward pattern.

◎ mark includes the case only for coal firing power station and the case of coal firing power station + integrated steel mill.

## (II) Summary of Results of Field Survey

### (II)-1 Current Survey

#### (II)-1-1 Summary of current survey

There are various flowing current generated by various reasons in the sea. This current survey has been conducted for (1) obtaining the data of these various currents and (2) obtaining the data related to the diffusion of pollutants caused by the various currents which are used as the basic data for simulation.

Fig. (II)-1 shows the current conditions and the diffusion pattern of trade effluent of the present and future. The current survey has been conducted for obtaining the data of the current conditions, water quality and other items of the present as shown in the left part of the figure, and those data obtained through the current survey have been used for simulation, as shown in the right part of the figure.

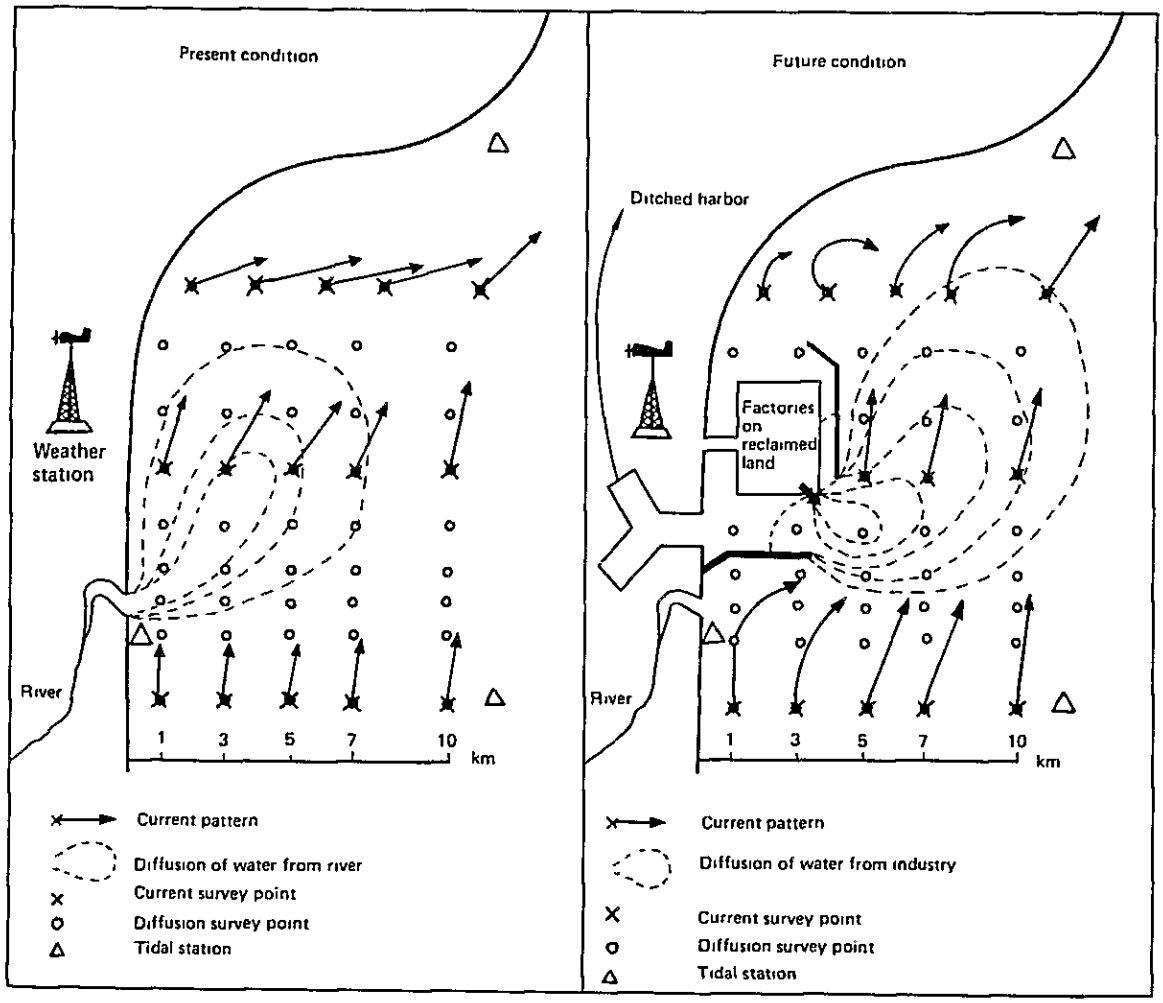



Fig. (II)-1 Current conditions and diffusion pattern of trade effluents

The current survey in this study includes (1) the field survey conducted at the survey areas (Seraya and Tekong) by current meters and (2) the collection of the relative data.

Table (II)-1 shows the outline of the current survey conducted at Seraya Area and Tekong Area.

Table (II)-1 Outline of current survey (field survey)

| | Survey point | Survey depth | Survey period | Survey method |
|---|---|---|---|---|
| Field survey | Seraya area SC1 - SC6 (refer to Fig. (II)-2)) | SC1 - -8 m<br>SC2 - -8 m<br>SC3 - -12 m<br>SC4 - -5 m<br>SC5 - -6 m<br>SC6 - -6 m | February 23rd to March 13th, 1981 | By mooring AANDERAA current meters, measured current direction, velocity, temperature, & salinity at 5 minutes interval. |
| | Tekong area TC1 - TC4 (refer to Fig. (II)-3)) | TC1 - -7 m<br>TC2 - -5 m<br>TC3 - -5 m<br>TC4 - -7 m | February 26th to March 17th, 1981 | - ditto - (Refer to Fig. (II)-4 for setting system of current meter) |

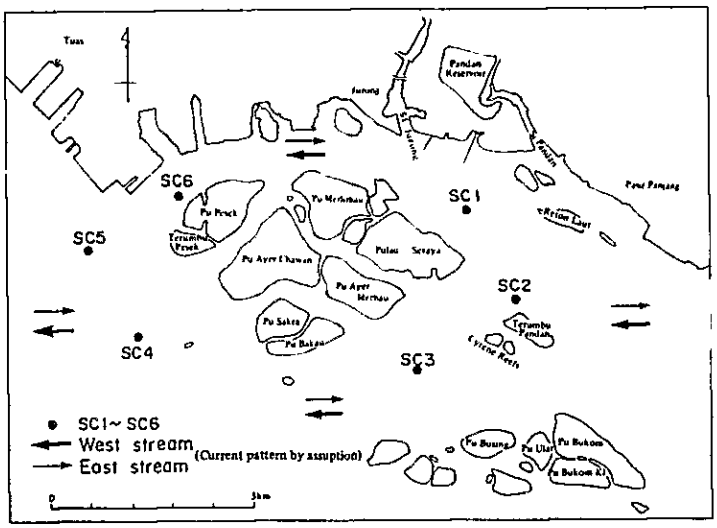



Fig. (II)-2 Survey points of pulau Seraya Area

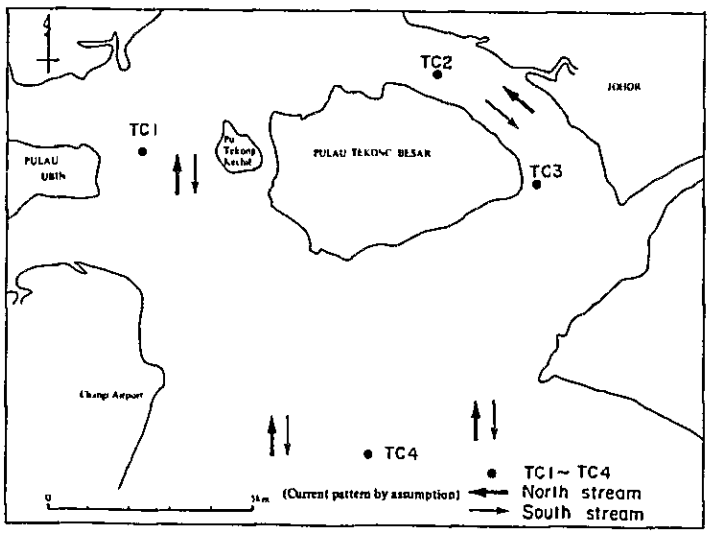



Fig. (II)-3 Survey points of Pulau Tekong Area

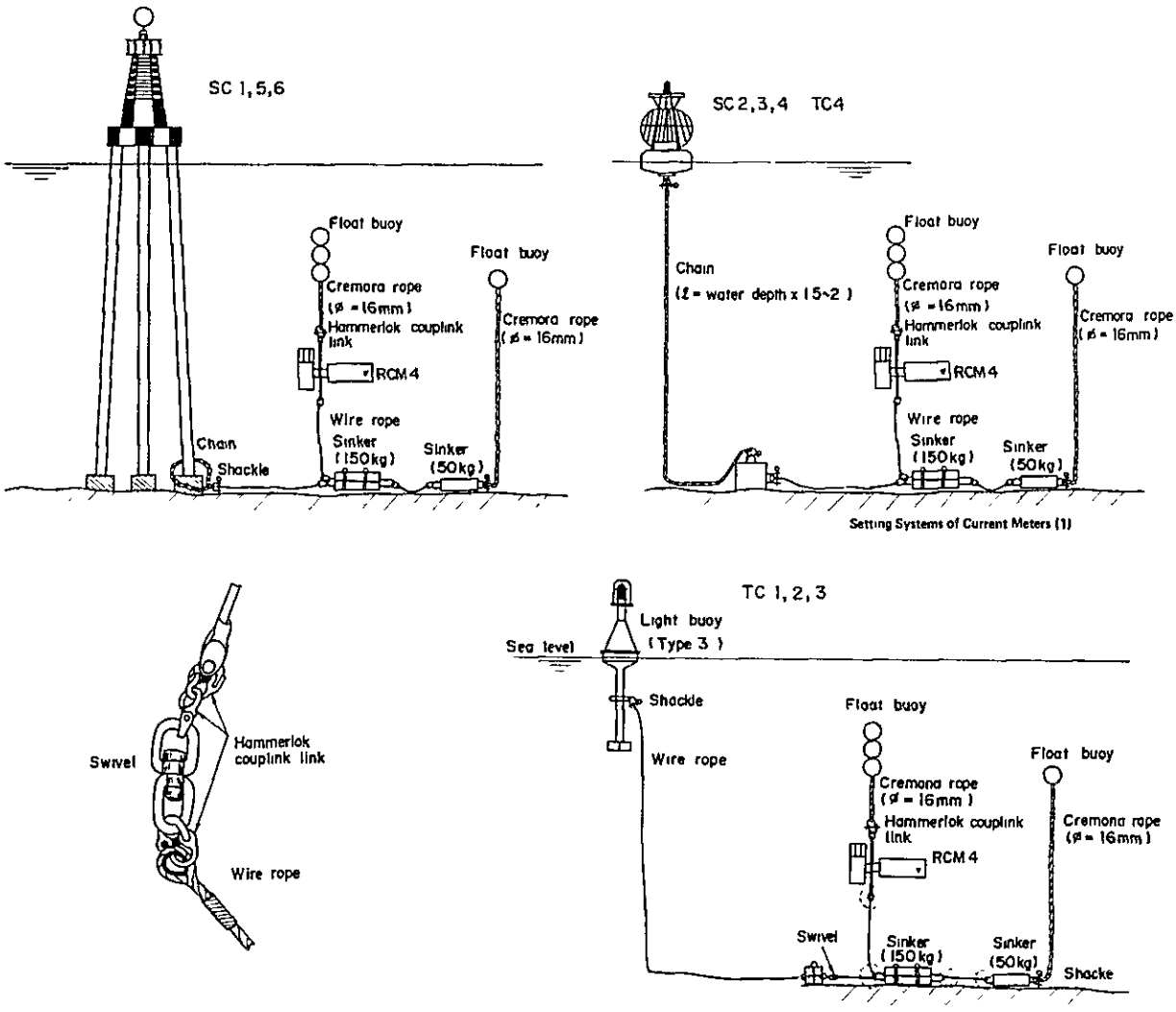



Fig. (II)-4 Mooring system of current meters at current survey

Table (II)-2 shows the outline of curent survey (collection of relative data).

Table (II)-2 Outline of current survey (collection of relative data)

| | Survey point | Survey depth | Survey period | Survey method |
|---|---|---|---|---|
| Collection of relative data | Pulau Ayer Merbau area St1 - St5 (refer to Fig. (II)-5)) | -3 m | August 7th to August 25th, 1978 | Tidal current observation data (current direction & velocity) measured by CT-3 type current meter |
| | The Straits of Malacca and Singapore (refer to Fig. (II)-6)) | -10 m | 1st survey July 10th to August 19th, 1978<br>2nd survey November 9th to December 20th, 1978 | Analysed results of tidal current observation data measured by NC type current meter |

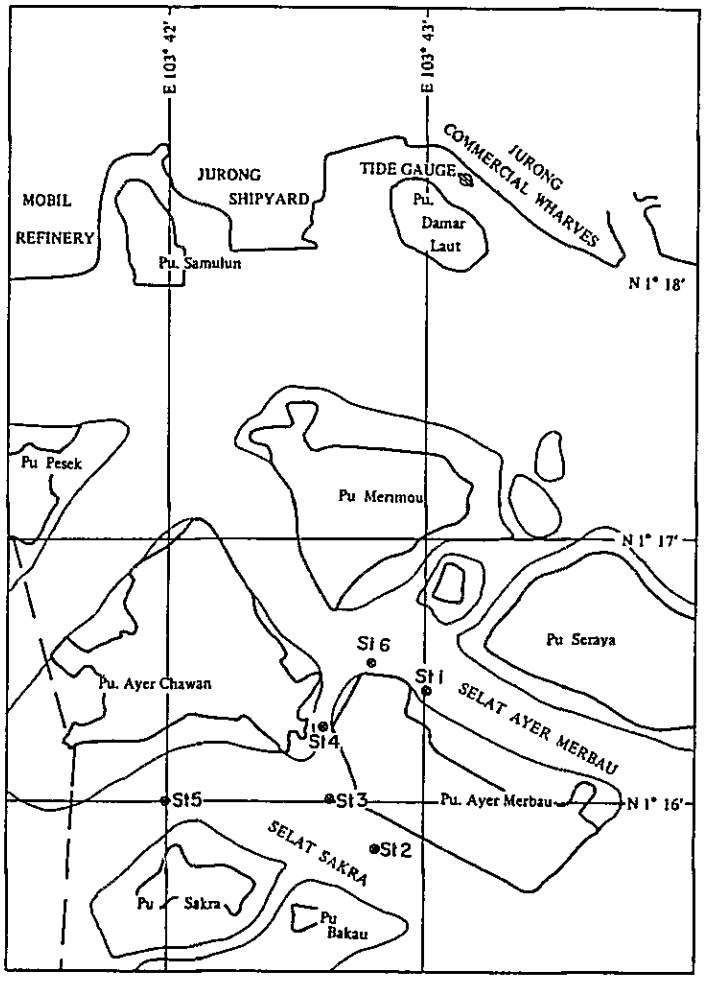



Fig. (II)-5 Survey points of Pulau Ayer Merbau Area

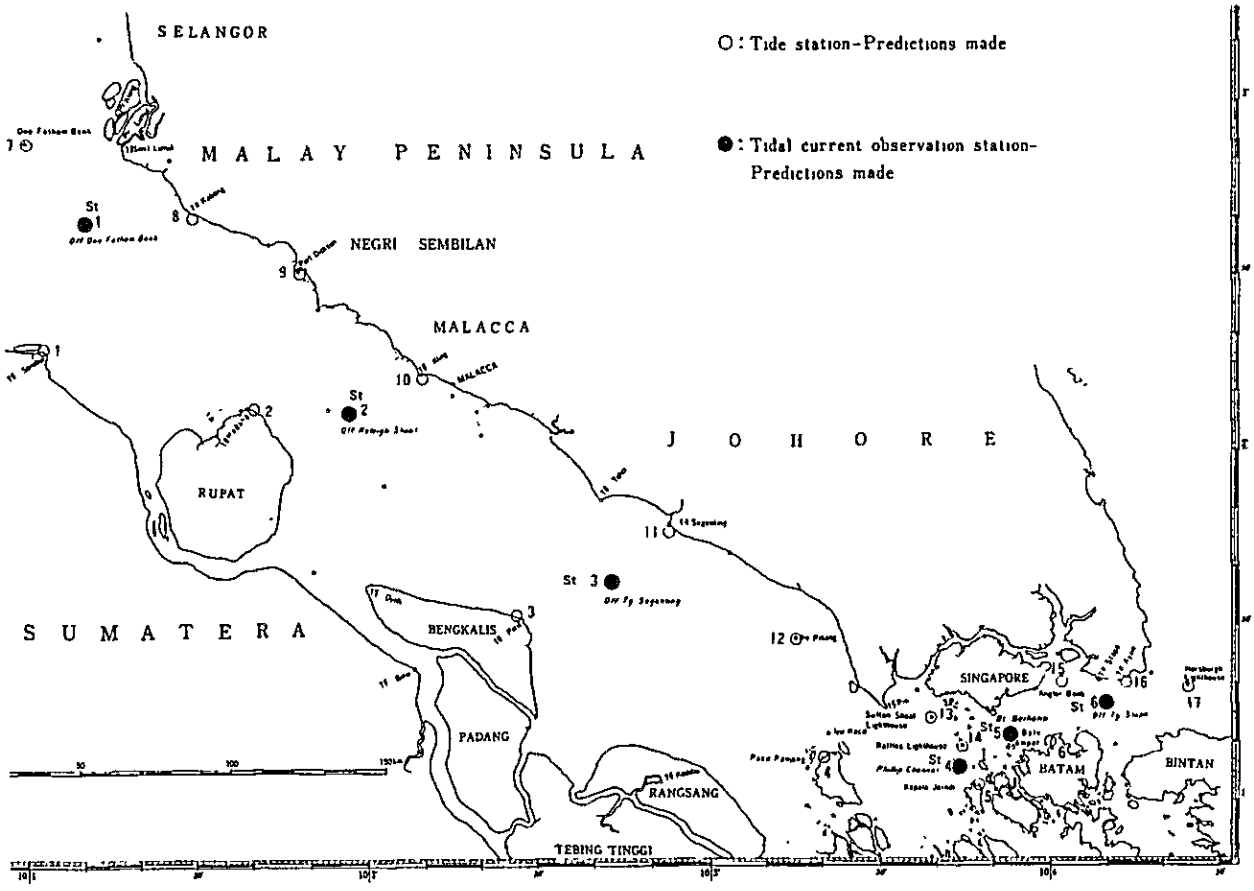



Fig. (II)-6 Survey point chart of current survey at the Straits of Malacca and Singapore

(II)-1-2 Results of survey

The results of analysis of the field survey data have clarified that in the survey areas surrounding Singapore, the tidal current generated by the tides (cyclic fluctuation of sea surface) were dominant.

The tidal current is fluctuating by the certain cycles of 1/4, 1/2, 1 and 15 days, and it can be observed at the survey points as the oscillating current which has the above cycle. (Refer to Fig. (II)-7.)

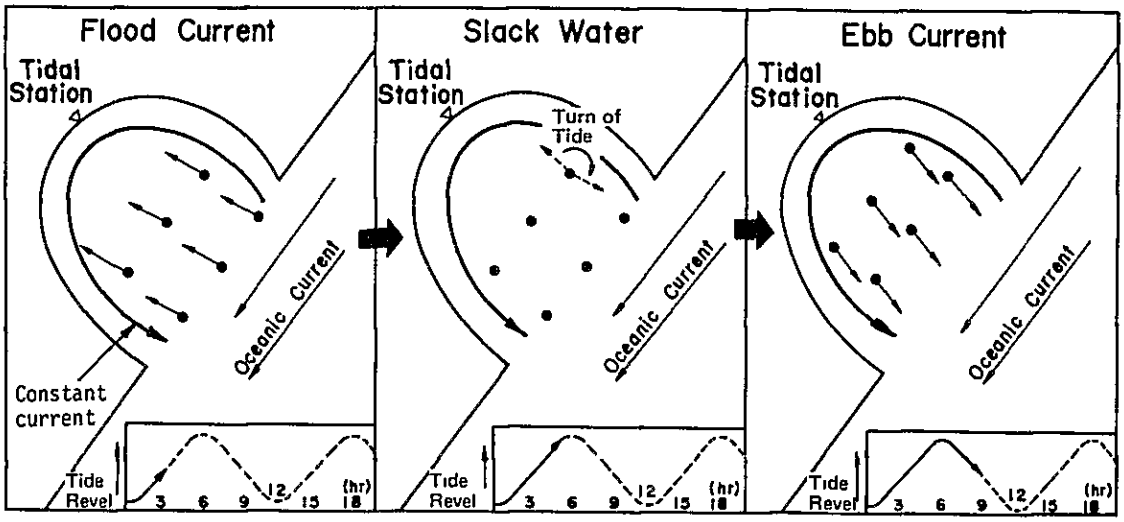



Fig. (II)-7 Model diagram of relation between Tidal and constant current

In Seraya Area, it was found that the diurnal tidal current was dominant which is fluctuating by the cycle of about 1 day.

In Tekong Area, it was found that the semi-diurnal tidal current was dominant which is fluctuating by the cycle of about 1/2 day. Another current except the tidal current is the constant current. The constant current has the longer cycle period than the tidal current and it is defined as the constant current discriminating from the tidal current. (Refer to Fig. (II)-7)).

According to the data collected (Joint survey on tide and tidal current of the Straits of Malacca and Singapore), the characters of the constant current of the survey areas surrounding Singapore are as follows:

- As shown in the figure, the average sea level during May to September is higher in the side of the Straits of Malacca and so the current is flowing from the Straits of Malacca to the Straits of Singapore. It means the constant current in Singapore areas is the eastward (streaming towards east). On the other hand, during December to April, the opposite phenomena are generated, and the constant current comes westward. -

In this study, the survey period was from end-February to mid-March 1981 and so the constant current of westward has been observed. (Figs. (II)-8 and (II)-9)

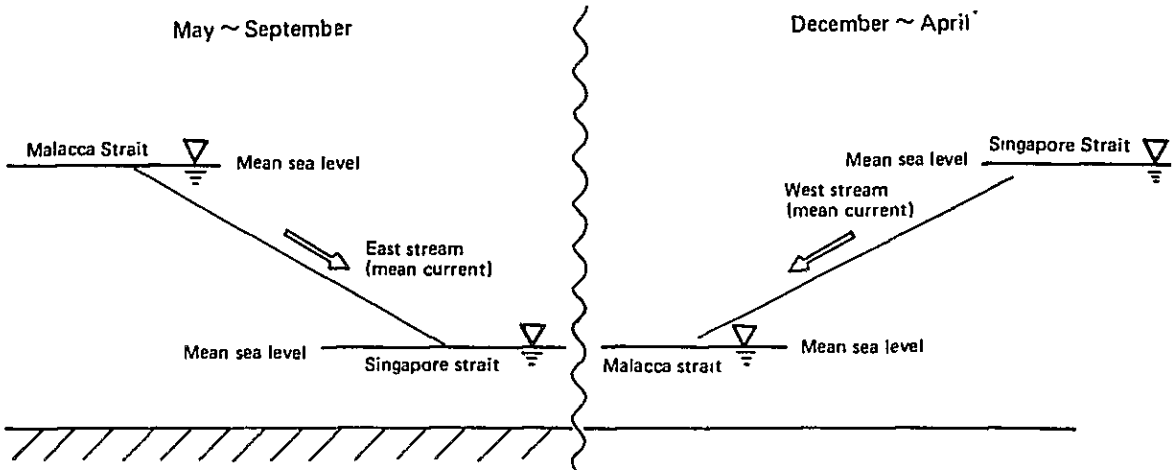
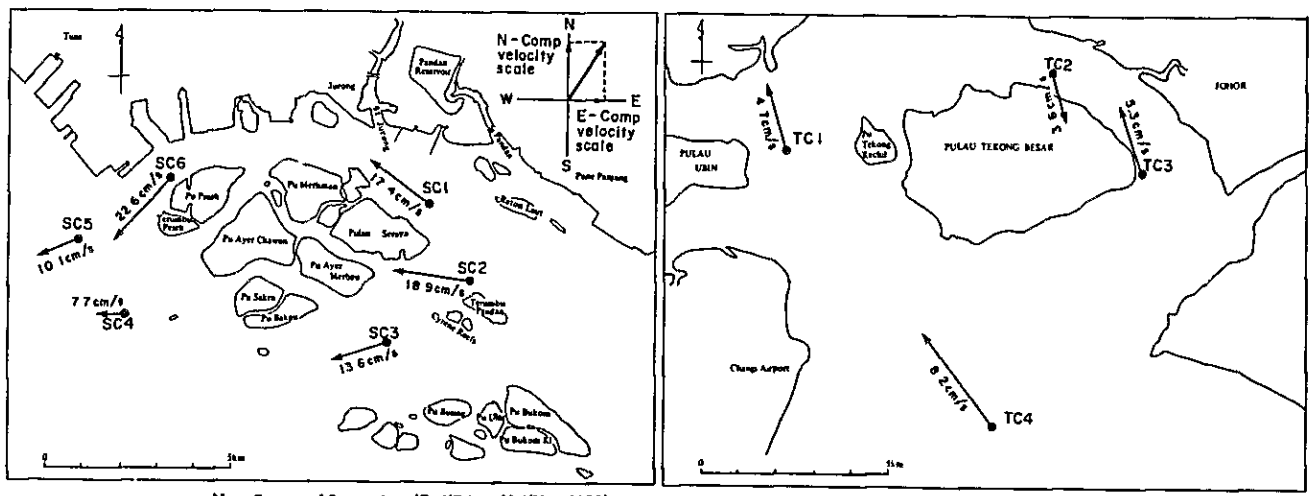



Fig. (II)-8 Comparison of mean sea level and mean current in the Straits of Malacca and Singapore




Mean Current of Seraya Area (End/Feb – Mid/Mar. 1981)

Mean Current of Tekong Area (End/Feb. – Mid/Mar. 1981)

Fig. (II)-9 Comparison of mean current in Seraya and Tekong Area

As previously described, the diurnal tidal current in Seraya Area and semi-diurnal tidal current in Tekong Area are found dominant. These can be confirmed by analysing the survey data by the process of harmonic analysis of the tidal current.

The harmonic analysis is to analyse the tidal current into various component current. In the process of such analysis, the dominant component current of the area is known which has the most magnificient current velocity value.

Tables (II)-3,4 show the tables of the dominant component current of the respective survey points.

Table (II)-3 Dominant component current of respective survey point

| Area | Survey point | The first dominant component current N-comp. (cm/sec) | The first dominant component current E-comp. (cm/sec) | The second dominant component current N-comp. (cm/sec) | The second dominant component current E-comp. (cm/sec) |
|---|---|---|---|---|---|
| Seraya Area | SC1 | $O_1$(19.21) | $O_1$(23.00) | $K_1$(19.07) | $K_1$(22.79) |
| | SC2 | $O_1$( 3.98) | $K_1$(40.26) | $K_1$( 3.18) | $O_1$(38.31) |
| | SC3 | $K_1$(10.54) | $O_1$(36.15) | $O_1$(10.31) | $K_1$(35.77) |
| | SC4 | $M_2$( 7.94) | $O_1$(26.21) | $S_2$( 2.92) | $K_1$(22.98) |
| | SC5 | $K_1$( 7.74) | $O_1$(23.95) | $O_1$( 5.18) | $K_1$(22.71) |
| | SC6 | $O_1$(33.71) | $O_1$(35.61) | $K_1$(33.15) | $K_1$(33.34) |
| Tekong Area | TC1 | $M_2$(28.07) | $M_2$(13.63) | $S_2$(11.32) | $S_2$( 3.41) |
| | TC2 | $M_2$(15.77) | $M_2$(40.48) | $M_4$( 4.36) | $S_2$(16.27) |
| | TC3 | $M_2$(43.55) | $M_2$( 2.39) | $S_2$(18.01) | $S_2$( 1.31) |
| | TC4 | $M_2$(29.24) | $M_2$(30.99) | $S_2$(11.88) | $K_1$(15.60) |

Table (II)-4 List of dominant component current of respective survey points at Pulau Ayer Merbau

| Survey point | The first dominant component current N-comp. (cm/sec) | The first dominant component current E-comp. (cm/sec) | The second dominant component current N-comp. (cm/sec) | The second dominant component current E-comp. (cm/sec) |
|---|---|---|---|---|
| St 1 | $O_1$(10.35) | $M_2$( 2.56) | $K_1$( 8.13) | $O_1$( 2.05) |
| St 2 | $O_1$(14.11) | $O_1$( 8.36) | $K_1$(12.95) | $K_1$( 7.57) |
| St 3 | $K_1$(14.15) | $K_1$(26.16) | $O_1$(13.28) | $O_1$(24.80) |
| St 4 | $K_1$(21.58) | $K_1$(33.70) | $O_1$(18.54) | $O_1$(29.49) |
| St 5 | $K_1$(23.87) | $K_1$(47.03) | $O_1$(21.39) | $O_1$(46.79) |

The component current enumerated in the above table are $K_1$ is luni-solar diurnal tidal current (cycle of 23.98 hours), $O_1$ is lunar diurnal tidal current (cycle of 25.82 hours), $M_2$ is lunar semi-diurnal tidal current (cycle of 12.42 hours) and $S_2$ is solar semi-diurnal tidal current.

$K_1$ and $O_1$ are the current which have the fluctuating cycle of about 1 day, and $M_2$ and $S_2$ are the current which have the fluctuating cycle of about 1/2 day.

From the table, in Seraya Area and Pulau Ayer Merbau Area, $K_1$ and $O_1$ are found dominant, and in Tekong Area, $M_2$ and $S_2$ are found dominant.

Figs. (II)-10 and (II)-11 show the representative current patterns of two survey areas. The figures show the time fluctuation of one cycle for the current conditions of dominant component current and constant current of two survey areas.

In Seraya Area, it can be observed that the diurnal tidal current of East/West direction is oscillating, and in Tekong Area, the semi-diurnal tidal current of South/North direction is oscillating.

Figs. (II)-12 and (II)-13 show the horizontal distribution of the current ellipse which express the current fluctuation of the dominant component current.

From the figures, it can be observed that the oscillating current of East/West direction in Seraya Area and of South/North direction in Tekong Area are dominant. Also from the shapes of current ellipse being almost straight, the appearance time of East/West current in Seraya Area and of South/North current in Tekong are found longer although the time for turn of tide is short.

Figs. (II)-14 and (II)-15 show the time series curves of current direction and velocity of two survey areas. The figures have illustrated the data of current direction and velocity measured by current meters in time series for the total period of the survey.

From the figures, the followings are observed:

(1) The current direction and velocity are fluctuating by certain cycle,
(2) the current is oscillating (direction turns by $180^{\circ}$),
(3) the time for turn of tides is short,
(4) the appearance time for the current of East/West direction in Seraya and for the current of South/North direction in Tekong are longer.

Fig. (II)-10 Current pattern of Seraya Area

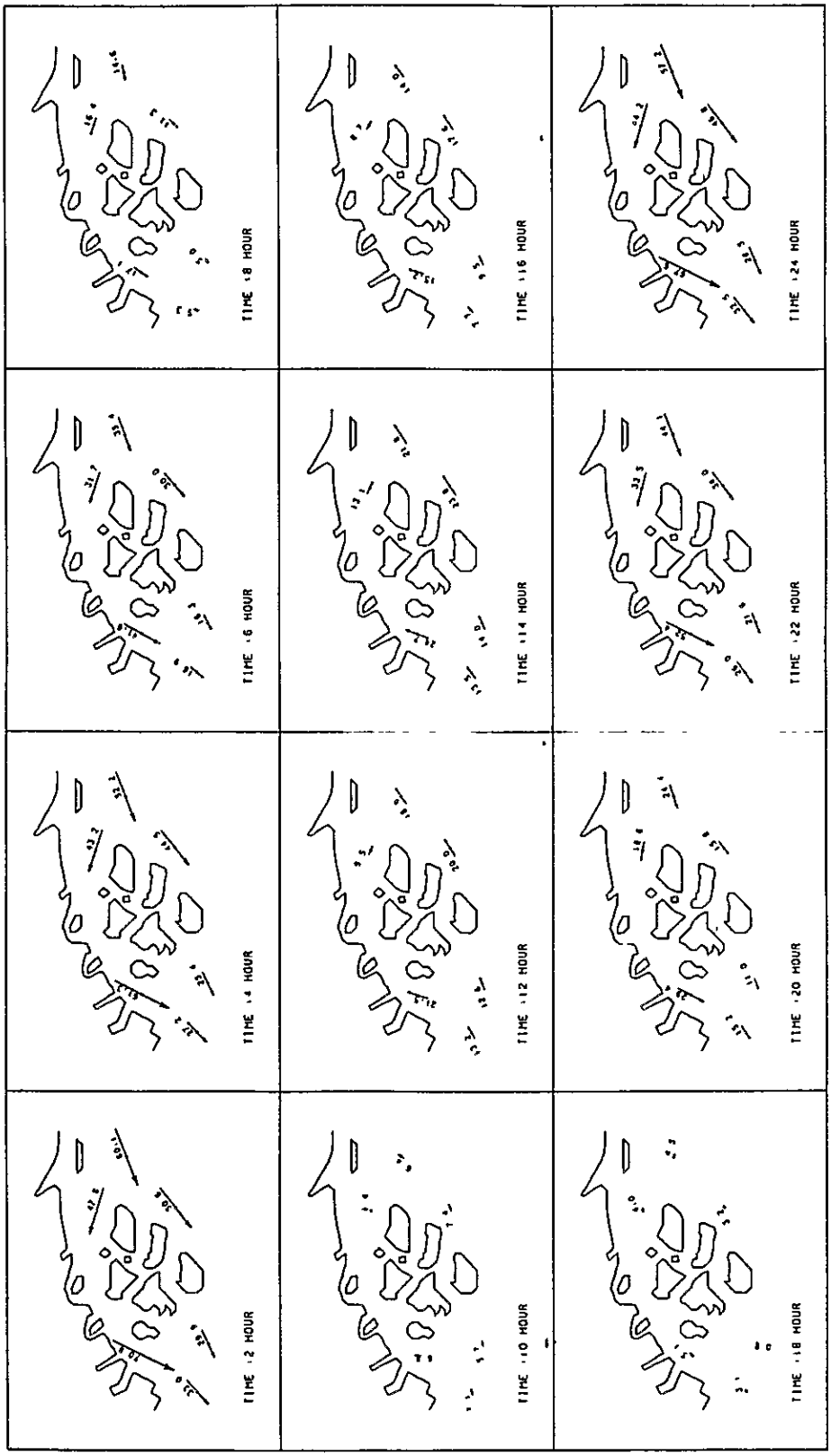


Fig. (II)-11 Current pattern of Tekong Area

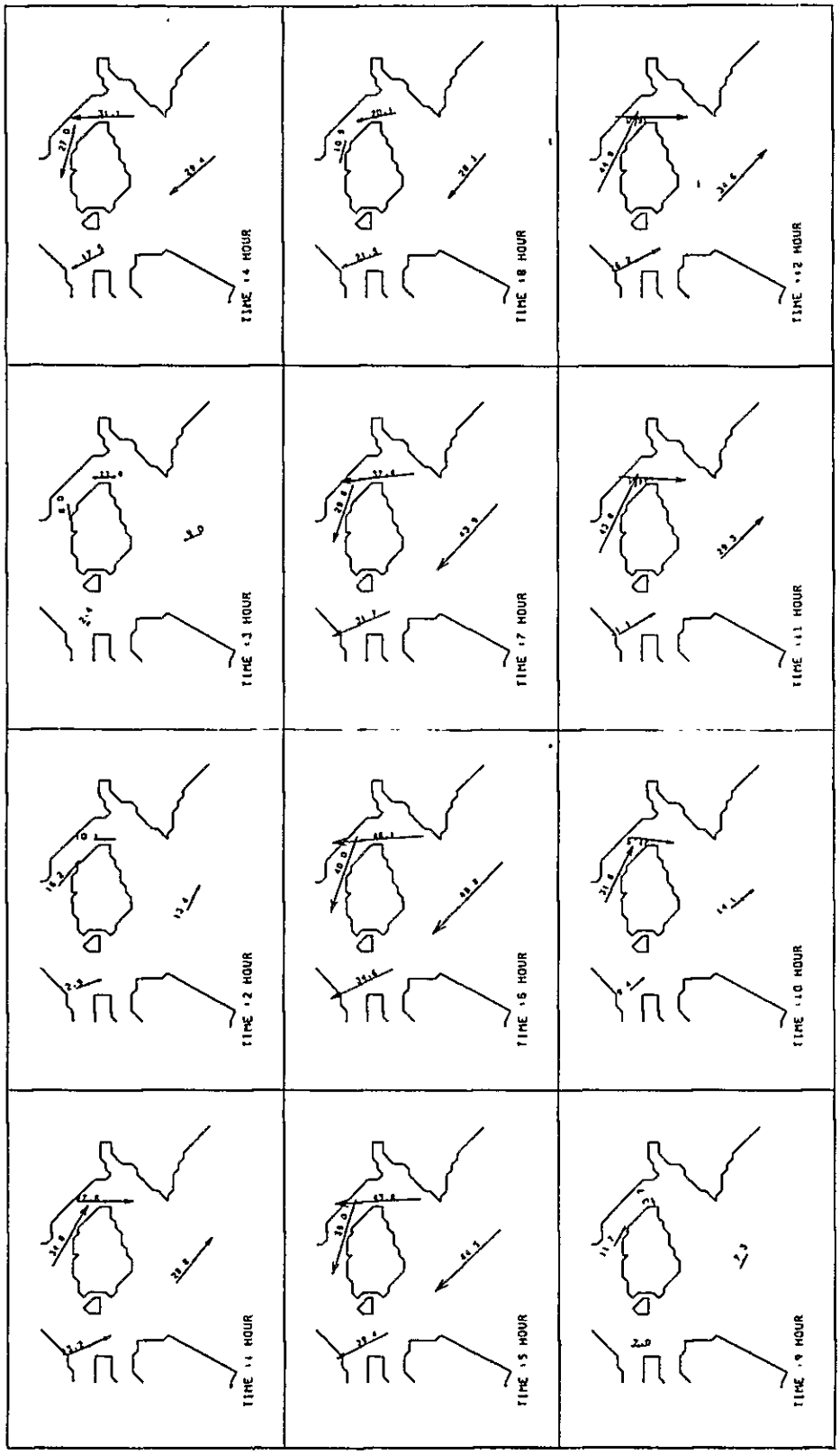


Fig. (II)-12 Horizontal distribution of current ellipse of dominant component current (Seraya Area)

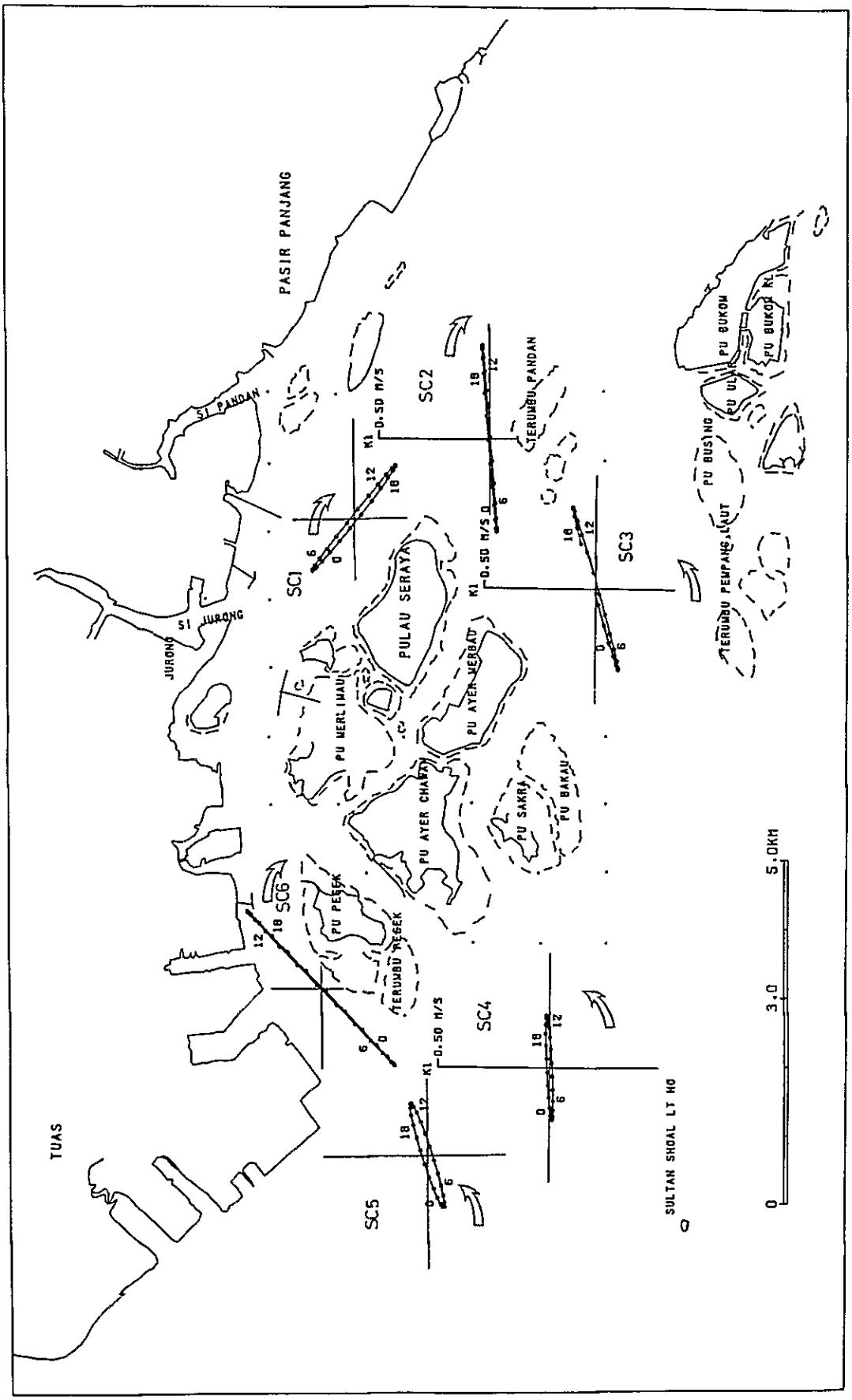


Fig. (II)-13 Horizontal distribution of current ellipse of dominant component current (Tekong Area)

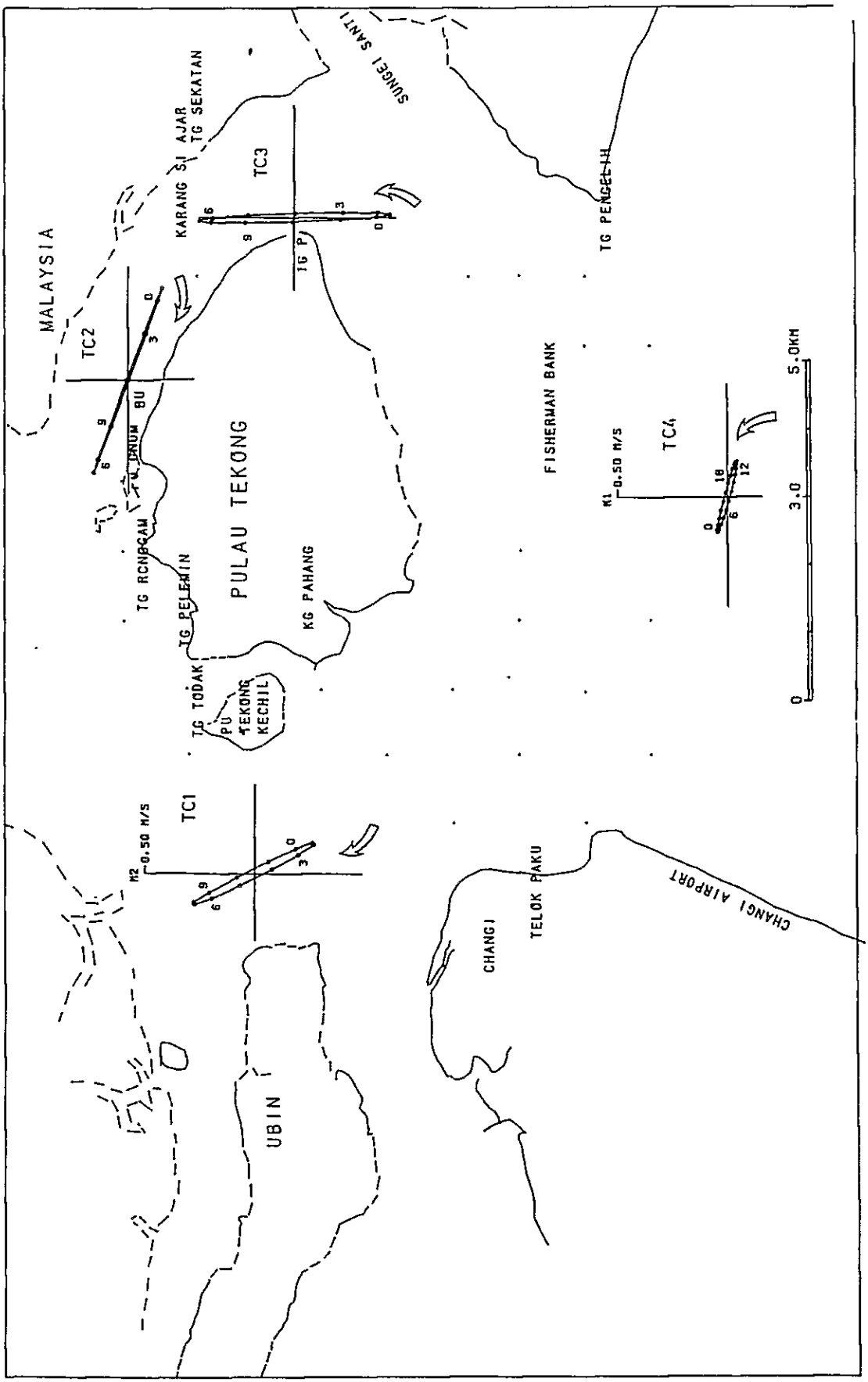
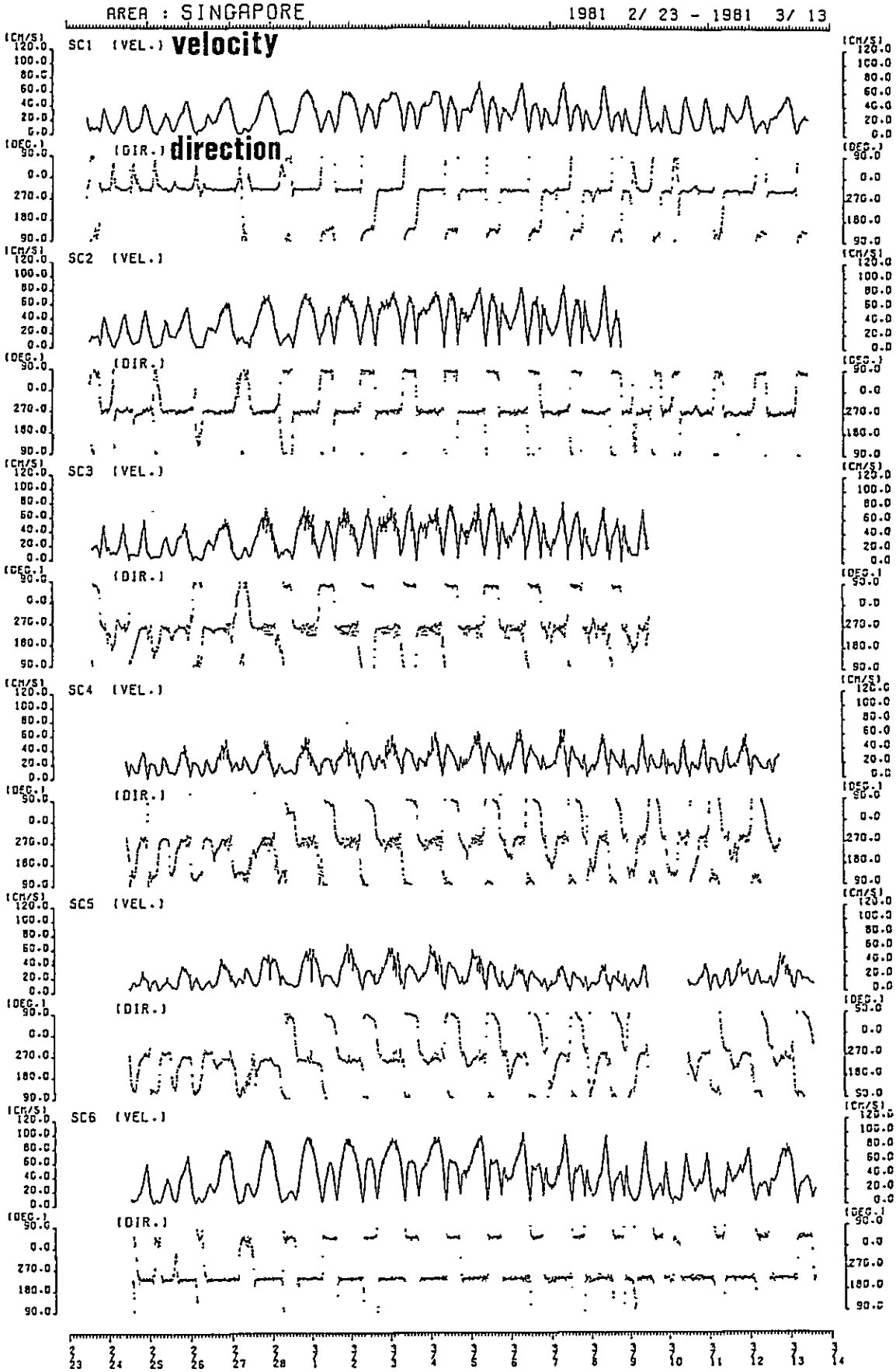


Fig. (II)-14 Time series of current direction and velocity curve (Seraya Area)



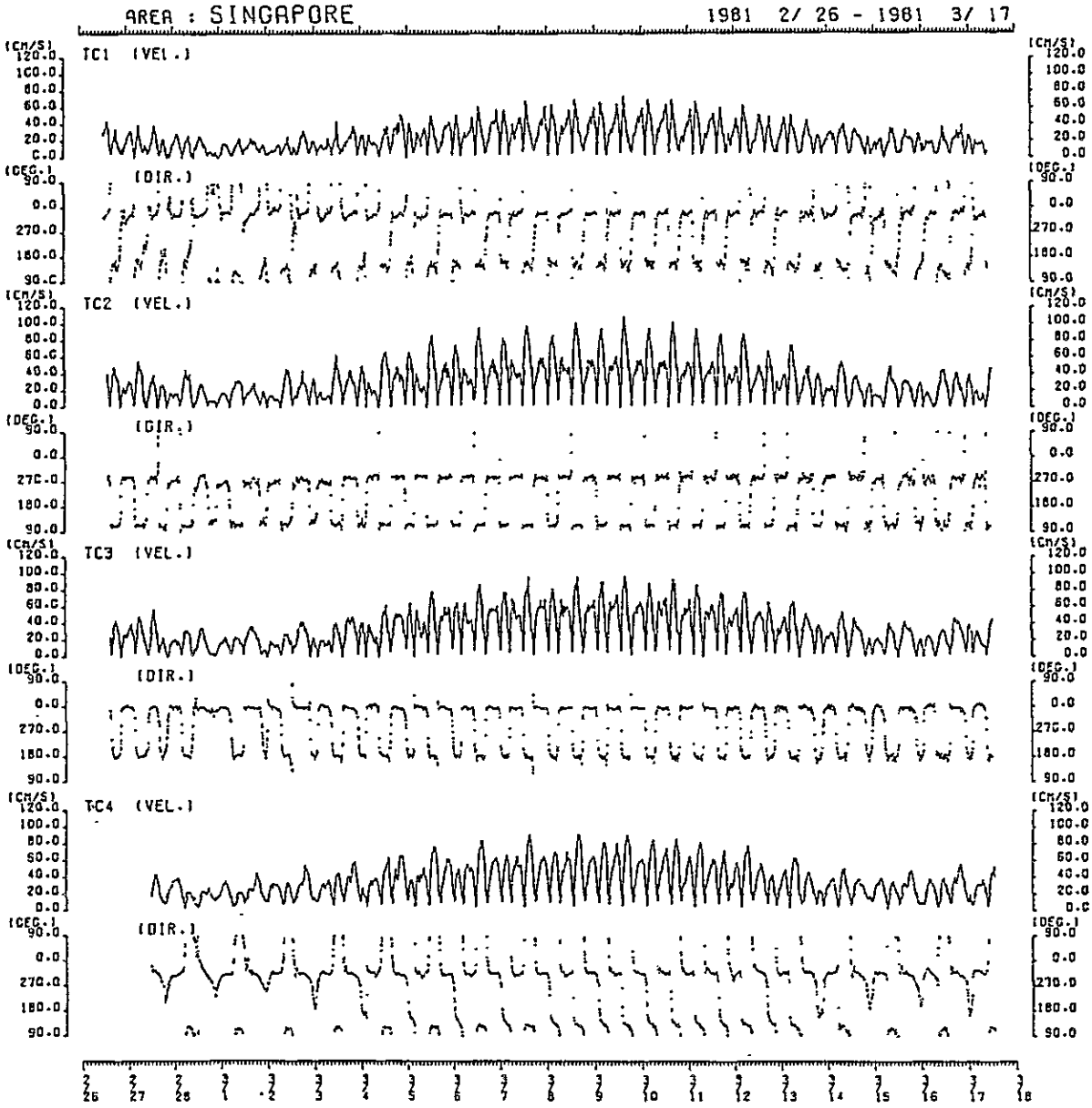



Fig. (II)-15 Time series of current direction and velocity curve (Tekong Area)

(II)-2 Tide Observation

(II)-2-1 Summary of tide observation

The data on the tides are necessary for establishing the open boundary conditions of simlulation.

In this study, data observed by PSA have been collected and analysed. Also the analysed results conducted in the Joint Survey on Tide and Tidal Current of the Straits of Malacca and Singapore have been collected and referred to the results of analysis conducted in this study.

Fig. (II)-16 shows the location chart of the tide observatories.

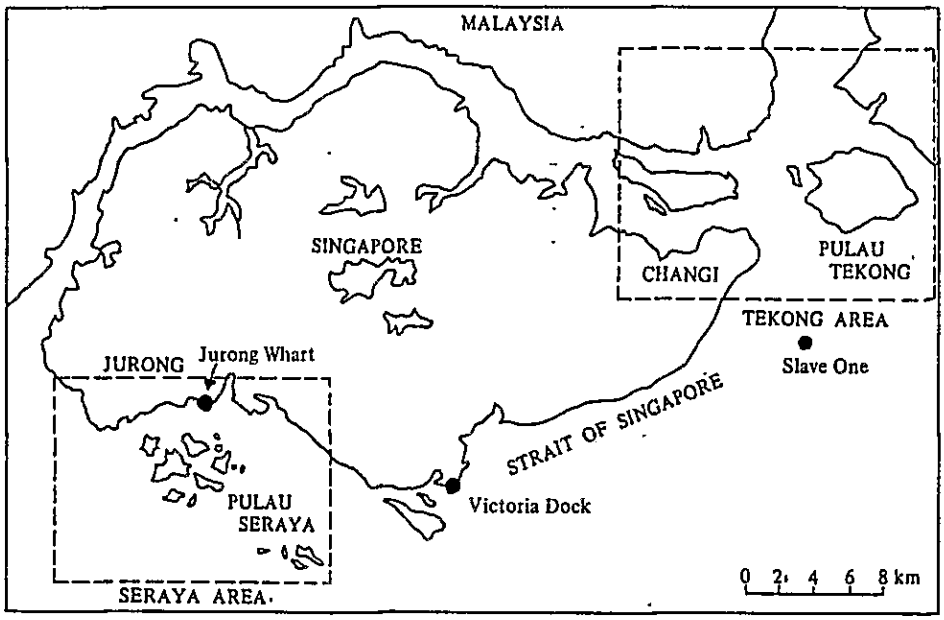



Fig. (II)-16 Location chart of tide observatory

The tide is the fluctuation of seal level generated by the movement of sun and moon, as shown in Fig. (II)-17.

As the tide is closely connected with the movement of astronomic bodies, it fluctuates by the certain cycle. The tidal range is also fluctuating.

The characteristics of the tide of the survey areas are obtained by harmonic analysis of the observation data.

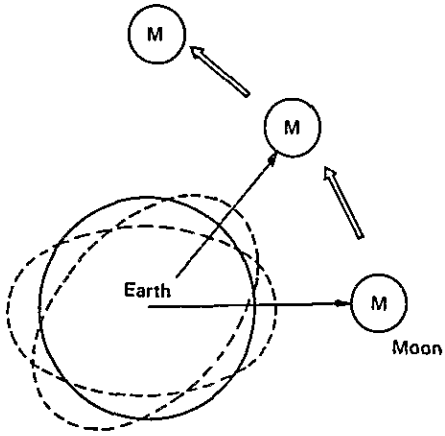



Fig. (II)-17 The earth surface change by tidal force

(II)-2-2 Results of survey

Fig. (II)-18 is the diagram which shows the tide fluctuation at Jurong Wharf and Slave One.

From the figure, the sea level is found fluctuating by the cycle of about 1/2 day. Also the diurnal inequality can be observed.

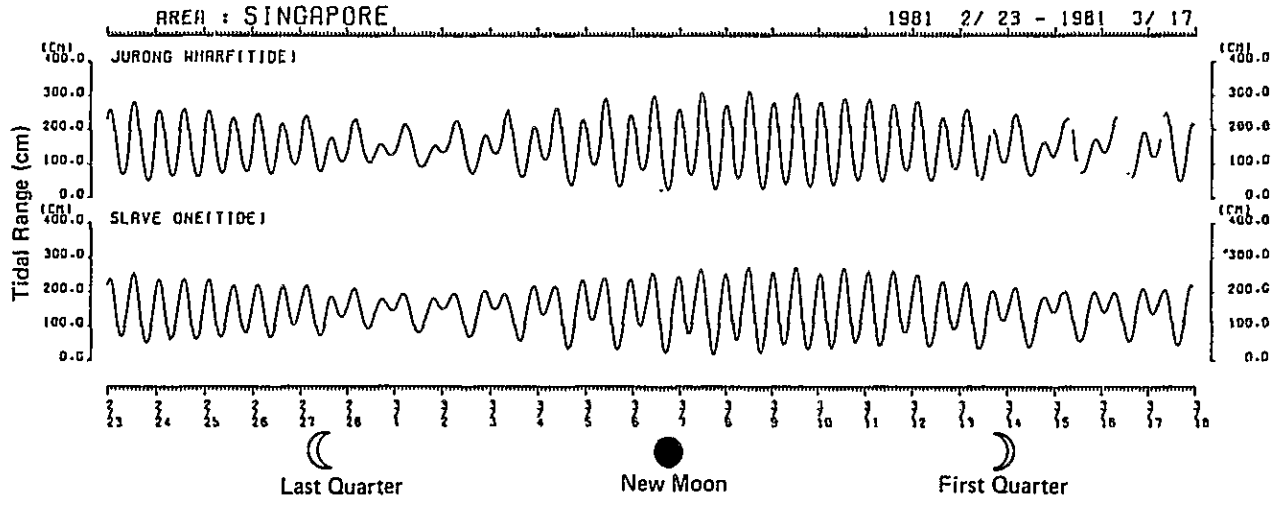



Fig. (II)-18 Tide curve of the survey period

The results of harmonic analysis of tide have clarified that both in Seraya and Tekong Area, $M_2$ component tide is dominant which is fluctuating by the cycle of about 1/2 day (lunar semi-diurnal tide-cycle of 12.42 hours).

From the above, the tide of two areas are fluctuating by the cycle of about 1/2 day.

Also the flow of tidal wave is found propagating from Tekong side (Slave One) to Seraya side (Jurong Wharf) which is the flows propagating from the east to the west. The time difference (about 40 km distance between Slave One and Jurong Wharf) is aobut 20 to 36 minutes in semi-diurnal tide of $M_2$ and $S_2$, and 164 to 188 minutes in diurnal tide of $K_1$ and $O_1$.

(II)-3 Meteorological Observation

Meteorological observation data are necessary as one of the basic data for simulation of thermal effluent diffusion.

In this study, the observation data have been collected from Meteorological Service Singapore measured at Changi Air Base and JTC Flatted Factory.

The collected data have been arranged for the use of simulation processes.

(II)-4 Water Temperature and Salinity Survey

(II)-4-1 Summary of survey

Water temperature and salinity survey data are necessary as the data for diffusion calculation in the process of simulation. The survey has been conducted during 13:00 to 16:00 of the 2nd March 1981 in Seraya Area, and during 15:00 to 17:00 of the 5th March 1981 in Tekong Area.

Fig. (II)-19 shows the survey points of two areas.

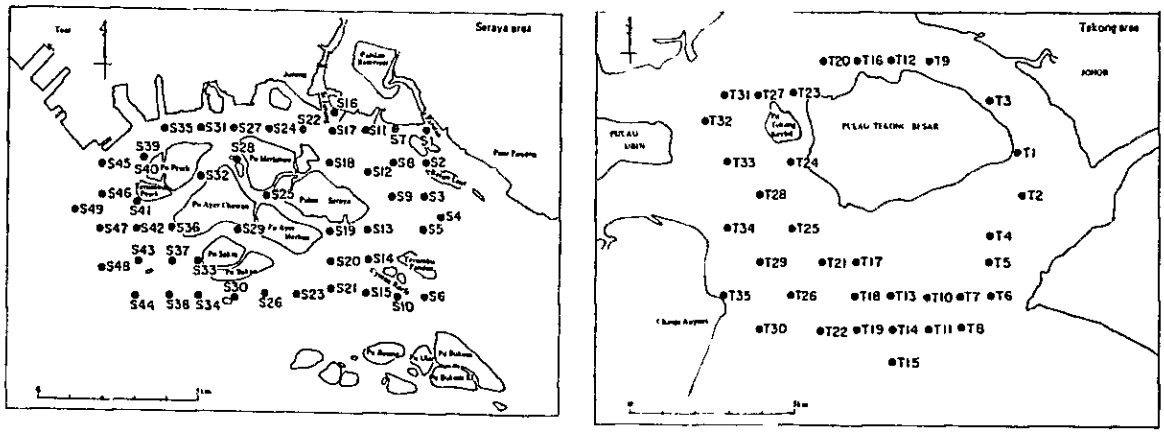



Fig. (II)-19 Survey point of water temperature and salinity survey

(II)-4-2 Results of survey

Tables (II)-5,6 show the results of the survey. Fig. (II)-20 shows the horizontal distribution of water temperature and salinity.

From the tables and figure, the followings are confirmed:

— Seraya Area

At all the points and depths, the water temperature is within the range of 27.9 to 29.8°C, and the salinity is within the range of 30.87 to 32.91%. No big difference in distribution is found.

— Tekong Area

At all the points and depths, the water temperature is within the range of 28.2 to 28.9°C, and the salinity is within the range of 30.58 to 32.39%. The salinity shows slightly lower values than that of Seraya Area.

Table (II)-5 Results of water temperature and salinity survey (Mar.2, 1981) in Seraya Area

| Layer | Temperature (°C) | | | | | Salinity (‰) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | | Max. | x | σ | Min. | | Max. | x | σ |
| -0.5 m | 28.1 | ~ | 29.8 | 28.4 | 0.30 | 30.87 | ~ | 32.91 | 32.78 | 0.28 |
| -2 m | 28.0 | ~ | 28.9 | 28.3 | 0.19 | 31.81 | ~ | 32.88 | 32.74 | 0.23 |
| -5 m | 27.9 | ~ | 28.5 | 28.1 | 0.10 | 32.73 | ~ | 32.88 | 32.83 | 0.04 |
| -10 m | 27.9 | ~ | 28.3 | 28.1 | 0.09 | 32.73 | ~ | 32.89 | 32.83 | 0.04 |
| B+1 m | 27.9 | ~ | 28.3 | 28.1 | 0.09 | 32.68 | ~ | 32.90 | 32.81 | 0.09 |

Table (II)-6 Results of water temperature and salinity survey (Mar.5, 1981) in Tekong Area

| Layer | Temperature (°C) | | | | | Salinity (‰) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | | Max. | x | σ | Min. | | Max. | x | σ |
| -0.5 m | 28.2 | ~ | 28.9 | 28.5 | 0.14 | 30.64 | ~ | 32.38 | 31.43 | 0.50 |
| -2 m | 28.2 | ~ | 28.9 | 28.5 | 0.14 | 30.59 | ~ | 31.93 | 31.16 | 0.47 |
| -5 m | 28.2 | ~ | 28.7 | 28.4 | 0.13 | 30.58 | ~ | 31.95 | 31.20 | 0.46 |
| -10 m | 28.2 | ~ | 28.5 | 28.4 | 0.09 | 30.60 | ~ | 31.99 | 31.34 | 0.49 |
| B+1 m | 28.2 | ~ | 28.9 | 28.4 | 0.15 | 30.59 | ~ | 32.39 | 31.51 | 0.60 |

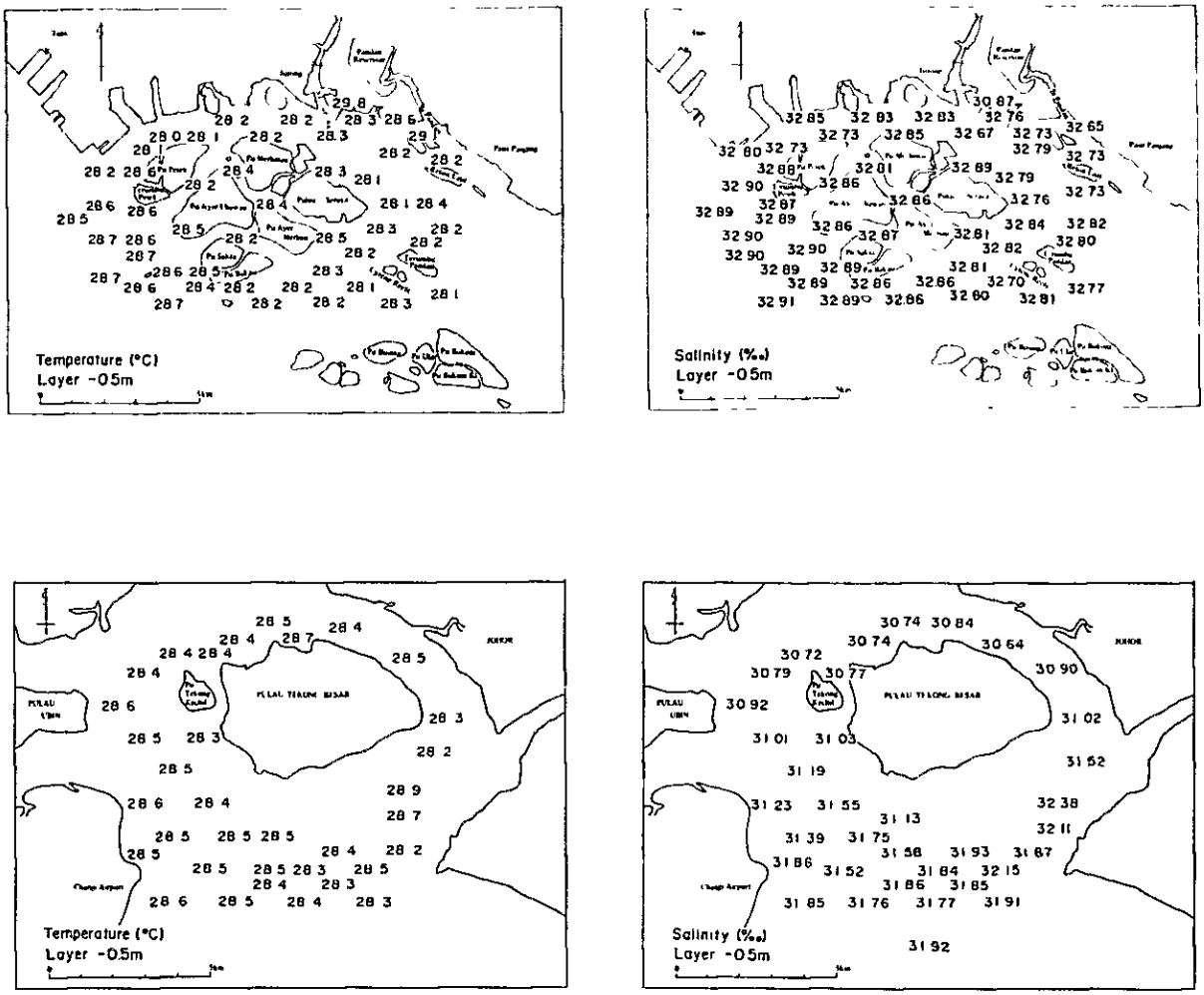



Fig. (II)-20 Horizontal distribution of water temperature and salinity in Seraya Area and Tekong Area

(II)-5 Water Quality Survey

(II)-5-1 Summary of Survey

Water quality survey data are necessary for establishing the water quality model and for determining the open boundary concentration in the process of simulation.

The survey has been conducted simultaneously with the survey for water temperature and salinity.

The survey items are COD, water colour, transparency and Chrolophill-a.

The survey points have been selected from the points for the water temperature and salinity survey as the representative points. (However, the survey for water colour and transparency has been conducted at all the points.)

Fig (II)-21 shows the locations of the survey points for COD and Chrolophill-a.

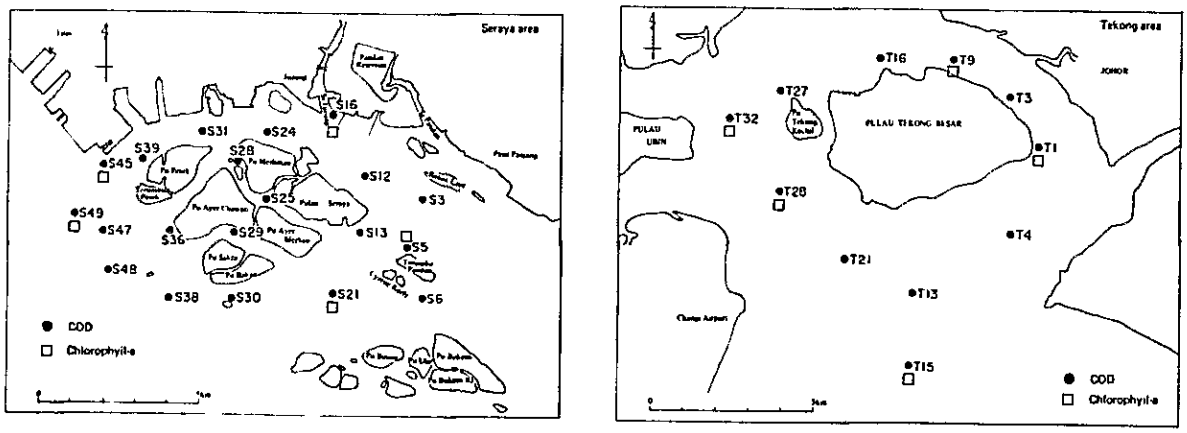



Fig. (II)-21 Survey point for Water quality (COD & Chrolophyll-a)

(II)-5-2 Results of survey

Table (II)-7 shows the results of survey. Figs. (II)-22,23 show the horizontal distribution of water quality in two areas.

Table (II)-7 Results of Survey

| Item | Seraya Area | | | | Tekong Area | | | |
|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | $\overline{X}$ | $\sigma$ | Min. | Max. | $\overline{X}$ | $\sigma$ |
| COD (ppm) | 0.1 | 3.9 | 0.3 | 0.2 | 0.7 | 2.5 | 1.5 | 0.6 |
| Transparency (m) | 0.9 | 8.2 | 3.9 | 2.0 | 0.5 | 2.5 | 1.3 | 0.4 |
| Water color | 7 | 12 | - | - | 11 | 15 | - | - |
| Chlorophill-a ( g/l) | 1.0 | 2.6 | - | - | 3.4 | 9.7 | - | |

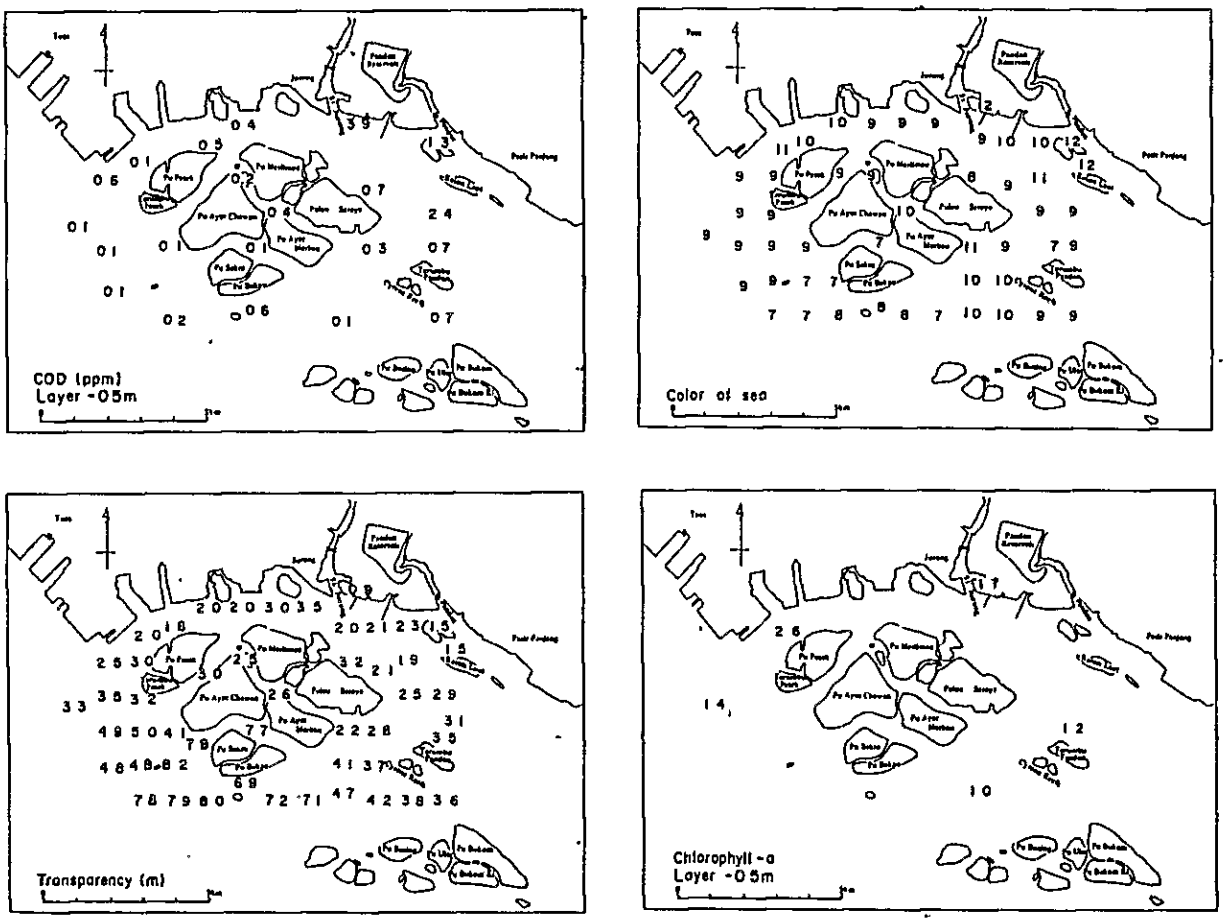



Fig. (II)-22 Horizontal distribution of water quality in Seraya Area

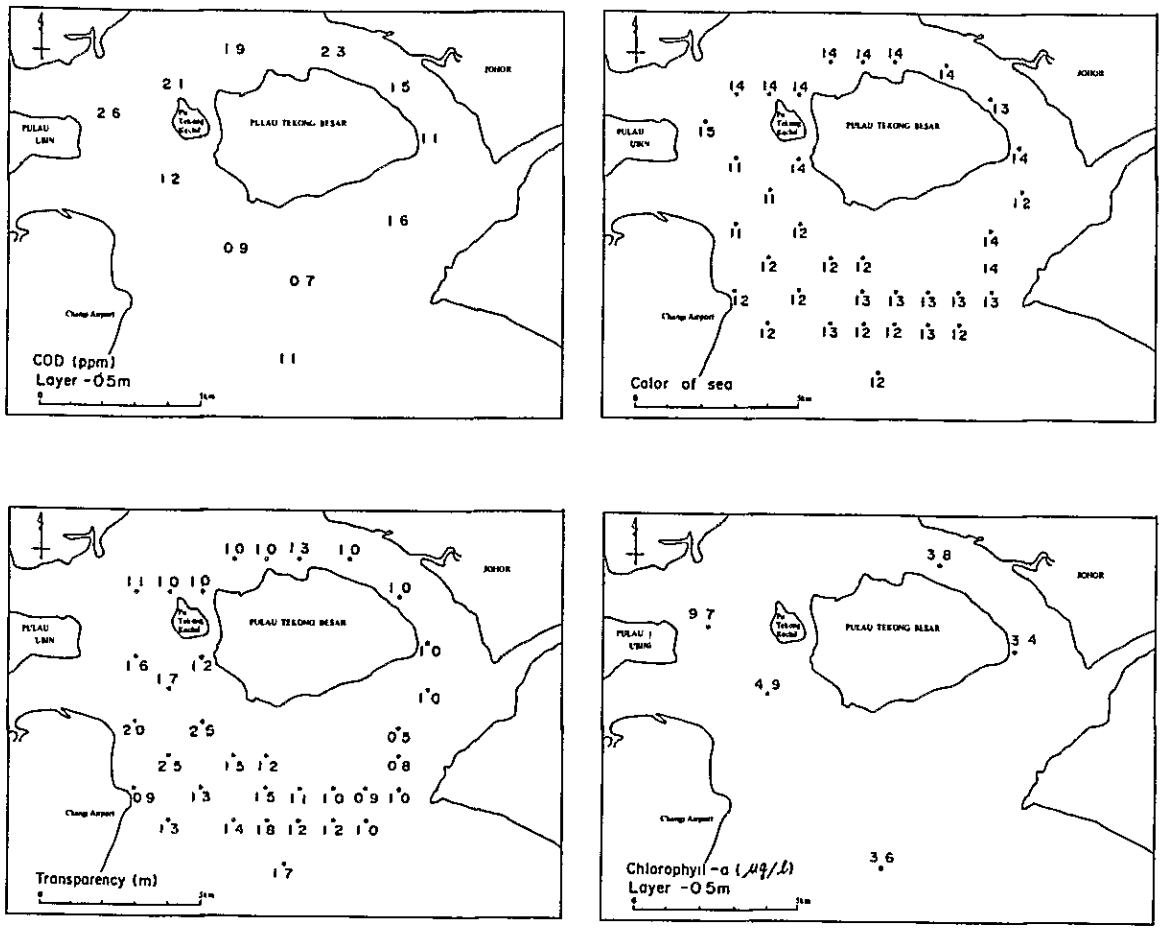



Fig. (II)-23 Horizontal distribution of water quality in Tekong Area

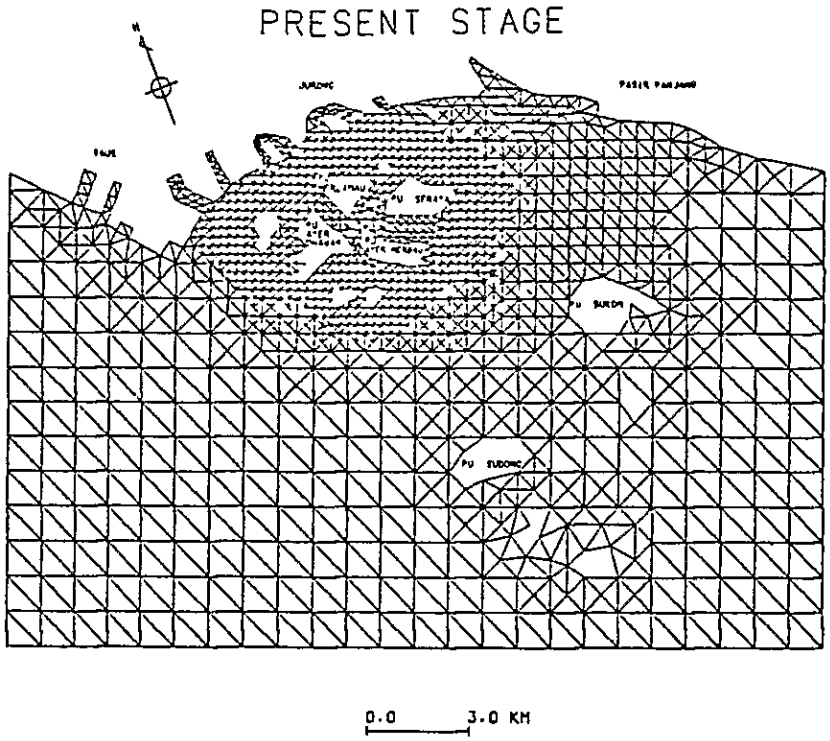
## (III) Summary of the Results of Simulation

### (III)-1 Seraya Area

#### (III)-1-1 Analysed results of current conditions

Fig. (III)-1 shows Finite Element Mesh, used for calculation.

Fig. (III)-2 shows the present and future current conditions at the time of EBB tide and Flood tide respectively.



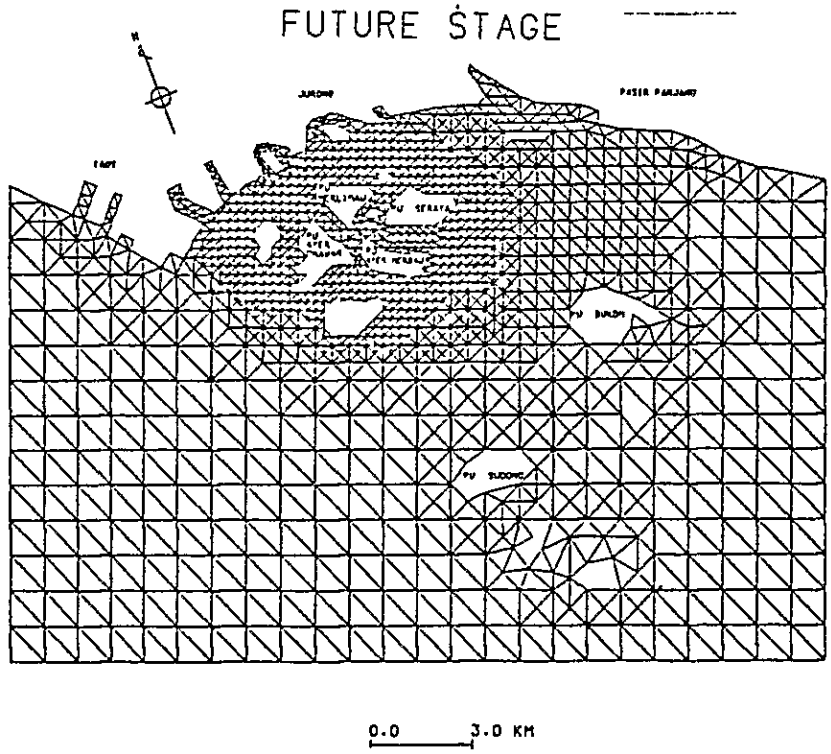
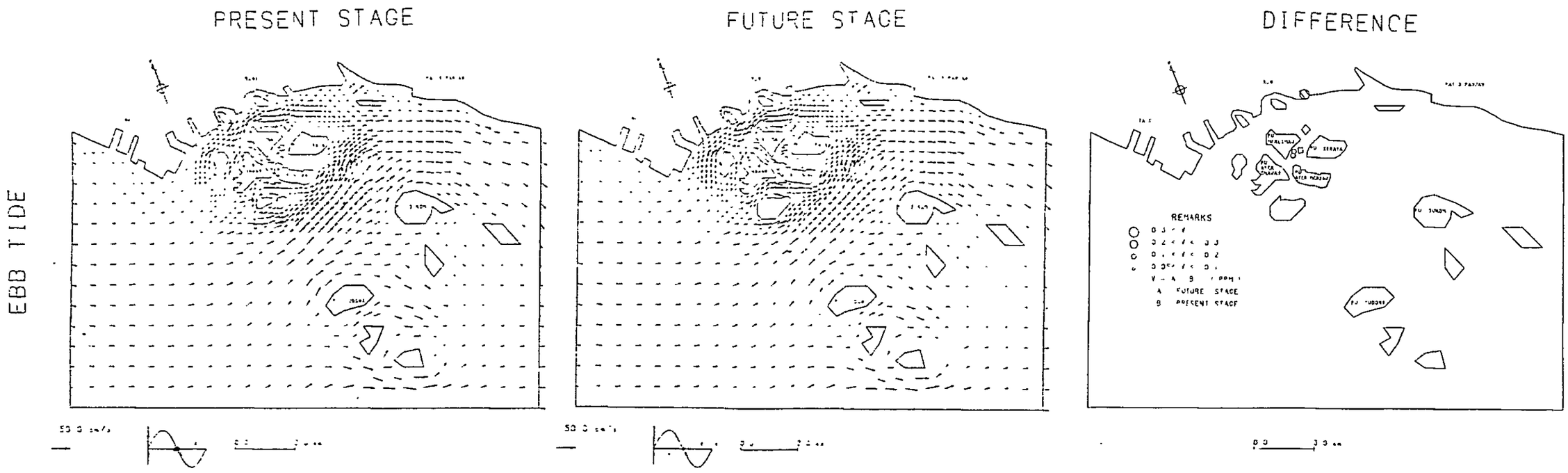




Fig. (III)-1 Finite element mesh

Fig. (III)-2 shows the present and future current conditions at the time of EBB tide and Flood tide respectively.



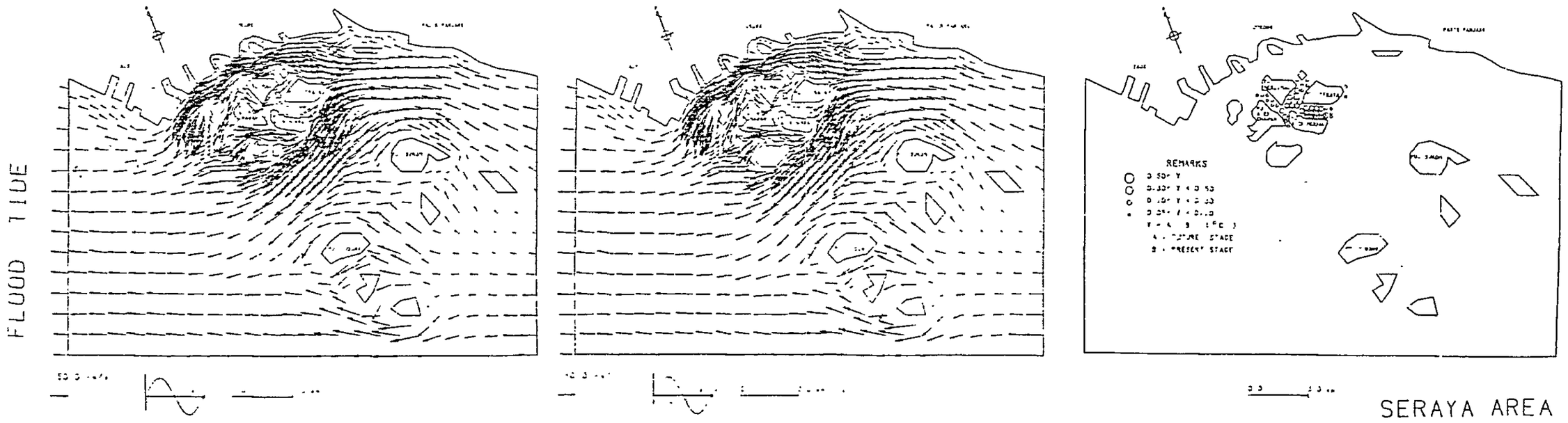



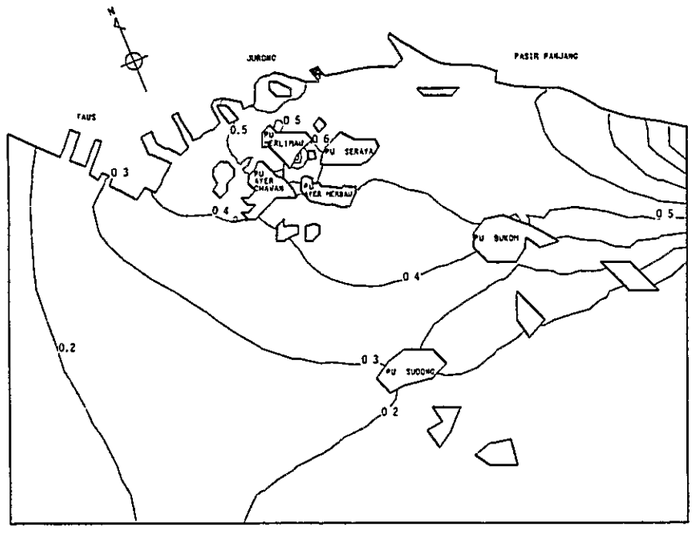

Fig. (III)-2 Current conditions of the present and future in Seraya Area

PRESENT STAGE

FUTURE STAGE

DIFFERENCE

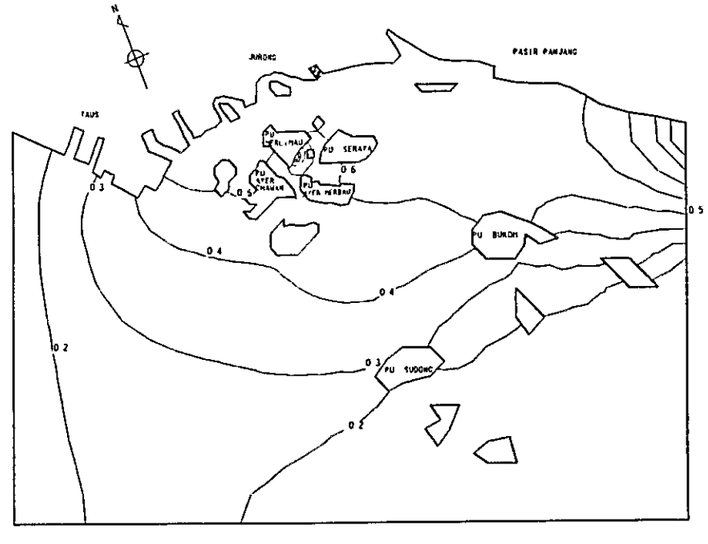
COD




UNIT : ppm

0 0 3 0 KM

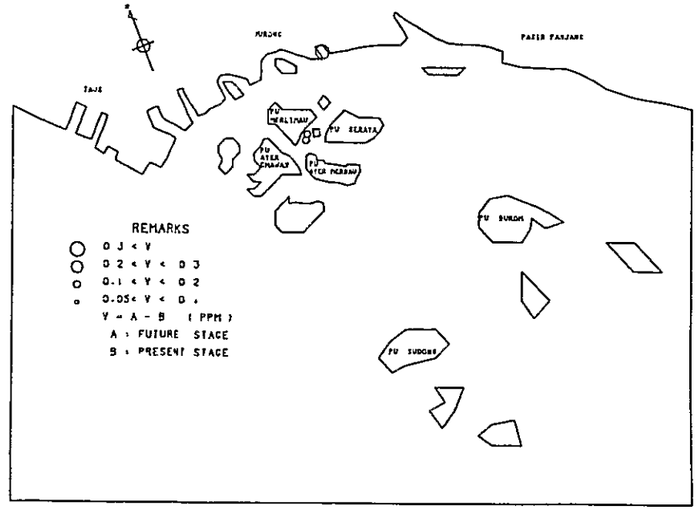
1 : 125000




UNIT : ppm

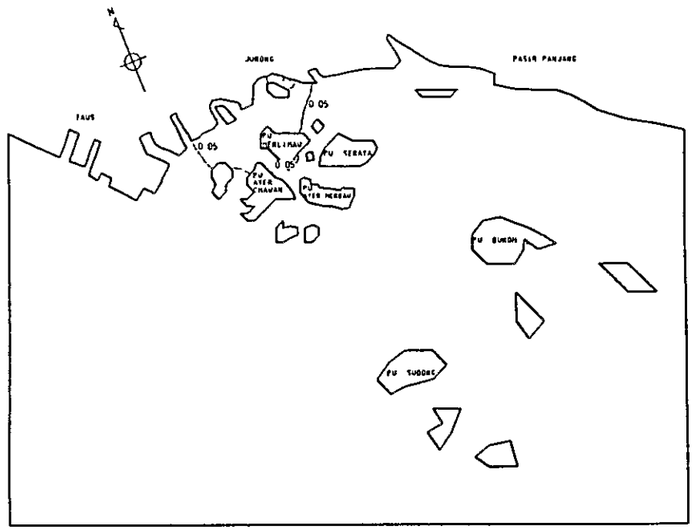
0 0 3 0 KM

1 : 125000




0 0 3 0 km

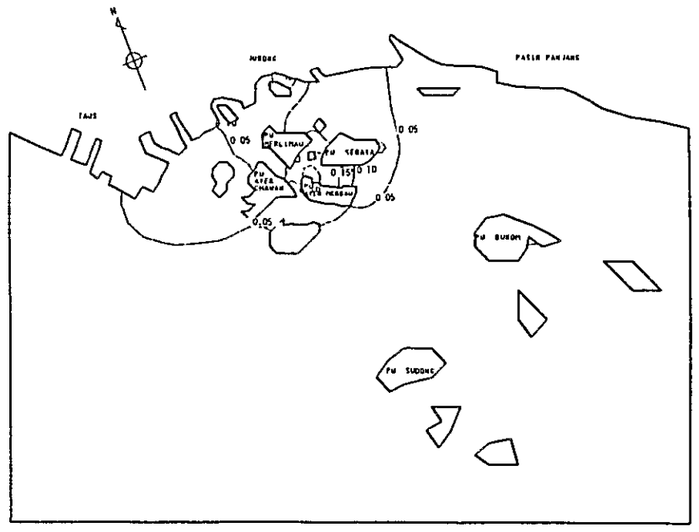
TEMP




UNIT : °c

0 0 3 0 KM

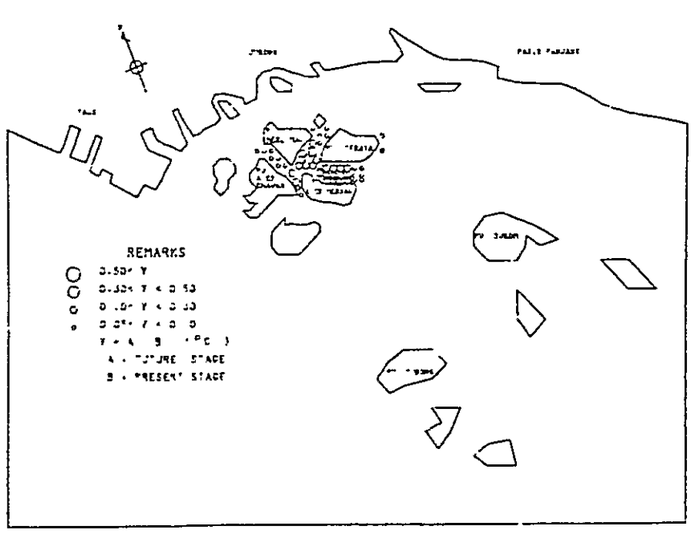
1 : 125000




UNIT : °c

0 0 3 0 KM

1 : 125000




SERAYA AREA

Fig. (III)-3 Water quality of the present and future in Seraya Area

From the figures, the increase in the current velocity of maximum 6 cm/sec. is observed in the sea area of 2 km x 1 km surrounded by Pulau Sakra, Pulau Bakau, Pulau Chawan and Pulau Merbau, when the present and future current conditions are compared. In other sea areas, no change can be observed in the current conditions.

(III)-1-2 Analysed results of COD and thermal effluent diffusion

Fig. (III)-3 shows the present and future water quality based on the calculation results of COD and thermal effluent diffusion.

From the figure, the increase in the future COD concentration exceeding 1 ppm is found only at the mouth of Pandan river. The average value of COD concentration at the representative survey points is 0.654 ppm for the present and 0.85 ppm for the future. The increase of COD loads comes 0.2 ppm.

The results of diffusion calculation of thermal effluent indicate the additional increase of water temperature is 0.1$^{o}$C in the maximum is found at the sea area of 1 km x 1 km surrounded by Pulau Merlimau, Pulau Merbau and Pulau Seraya. In other sea areas, no particular changes are found.

(III)-2 Tekong Area

(III)-2-1 Analysed results of current conditions

Fig. (III)-4 shows the finite element mesh used for calculation.

Fig. (III)-4 Finite element mesh Tekong Area

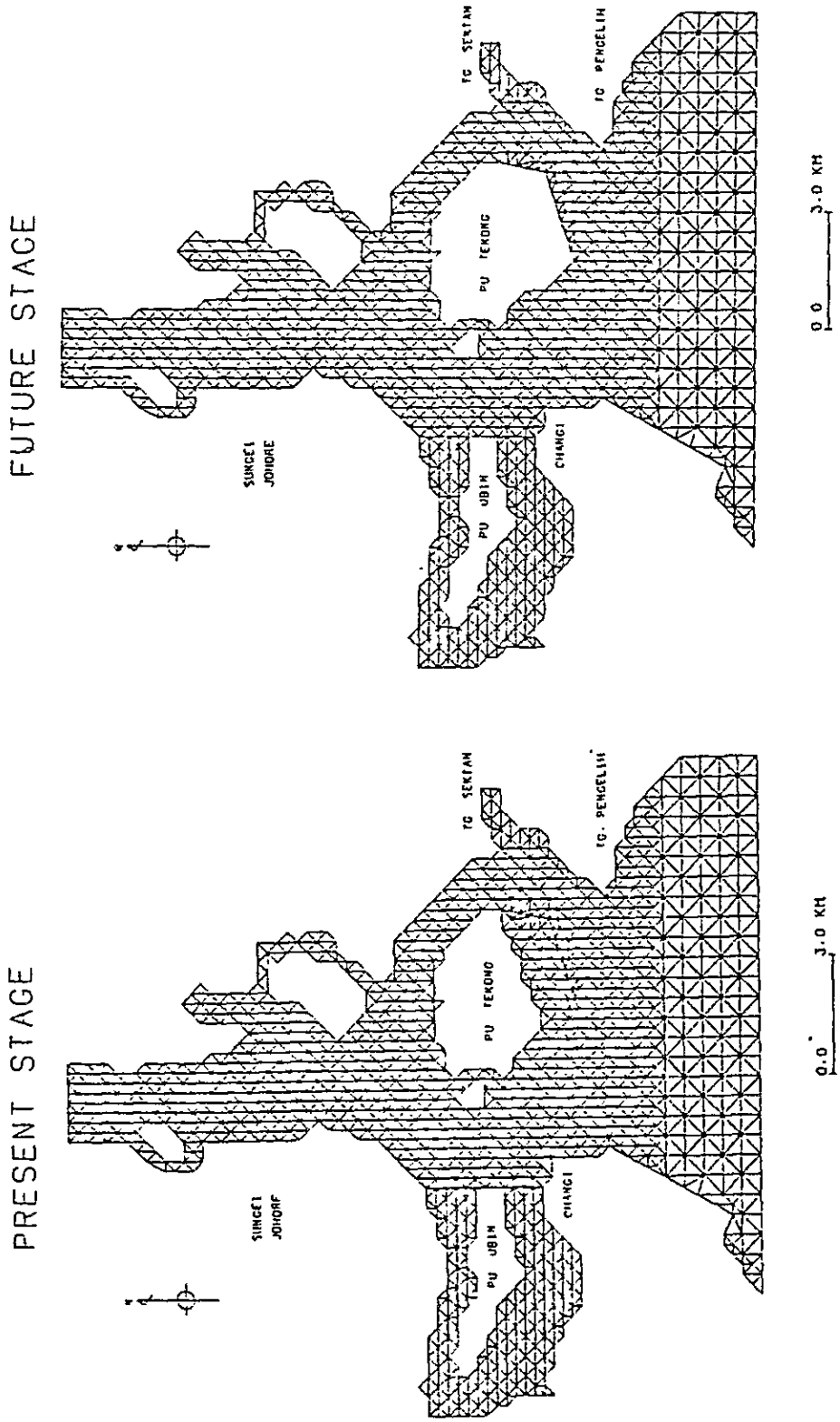


Fig. (III)-5 shows the present and future current conditons at the time of EBB tide and Flood tide respectively.

From the figures, the increase in the current velocity of maximum 8 cm/sec. is observed in the waterway of 1 km x 1 km located between the reclaimed site of Pulau Tekong and Tg. Pengelish at the EBB tide, when compared the velocity of the present and future.

The increase of current velocity at the Flood tide is observed maximum 6 cm/sec. in the waterway of 2 km x 3 km located between the reclaimed site of Pulau Tekong and Tg. Pengelish.

In the southern area of the reclaimed site of Tekong of 2 km x 2 km, the decrease of the current velocity is observed for maximum 6 cm/sec. In the east/south sea area of Changi of 3 km x 3 km, the increase of the current velocity is observed for maximum 4 cm/sec.

(III)-2-2 Analysed results of COD and thermal effluent diffusion

Fig. (III)-6 shows the present and future water quality based on the calculation results of COD and thermal effluent diffusion.

From the figure, the increase of future COD concentration is observed only for 0.03 ppm at the area near the effluent exit.

At present, there is no discharge of thermal effluent in this area, and so the calculation for the present has not been conducted.

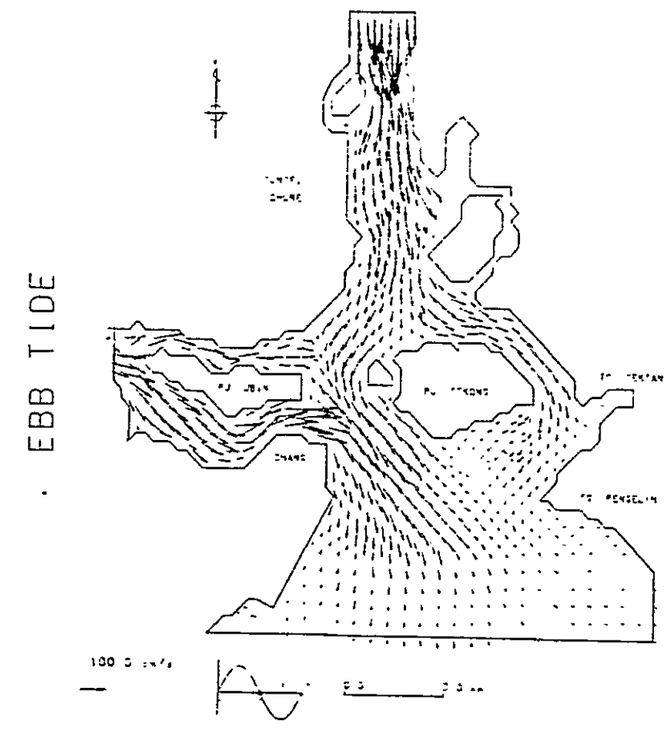
The increase of water temperature in future is exprected to be maximum 0.5$^{o}$C. In the waterway of 3 km x 3 km located between the reclaimed site of Pulau Tekong and Tg. Pengelish, the increase of water temperature of 0.1$^{o}$C is observed particularly at the exit area.

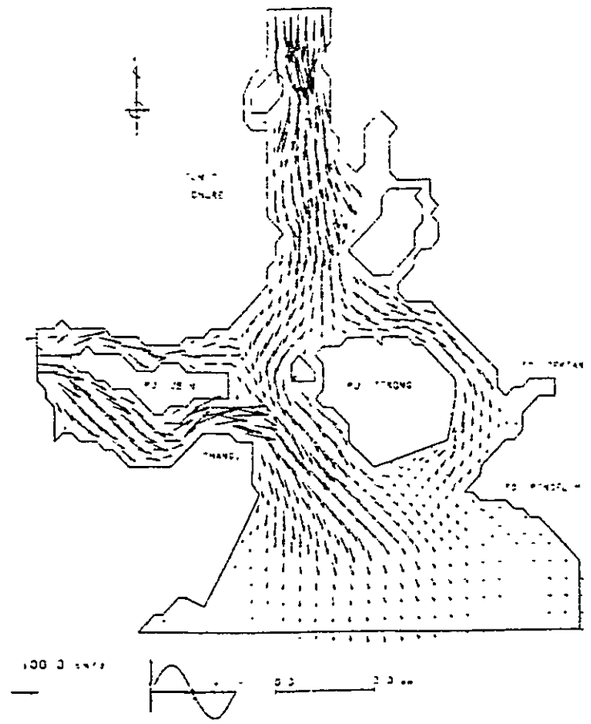
PRESENT STAGE

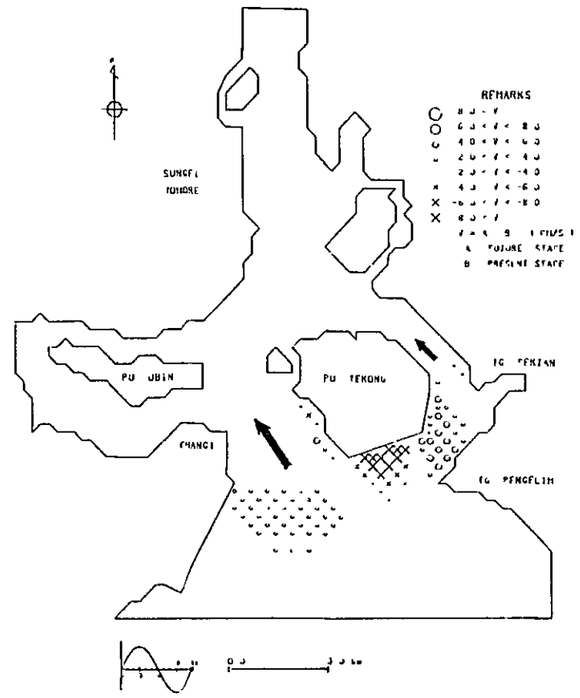
FUTURE STAGE

DIFFERENCE

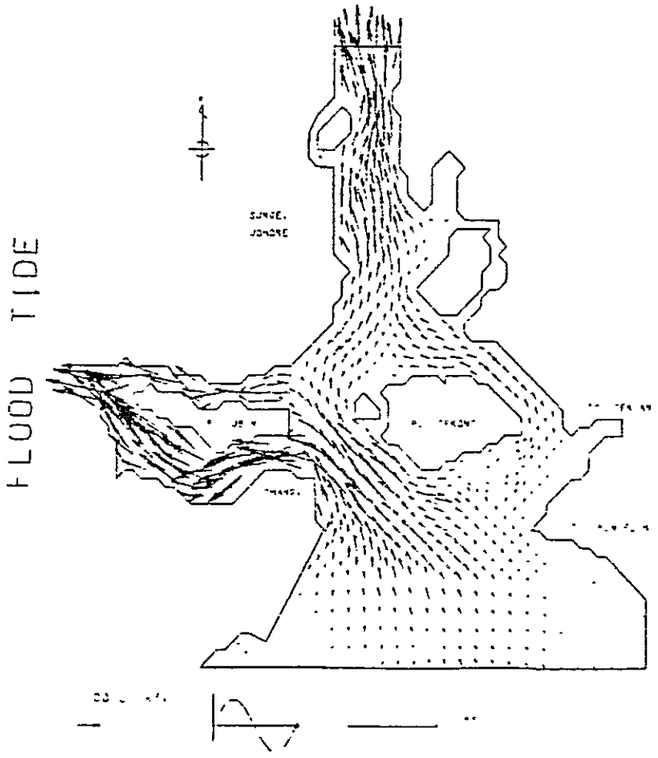
EBB TIDE

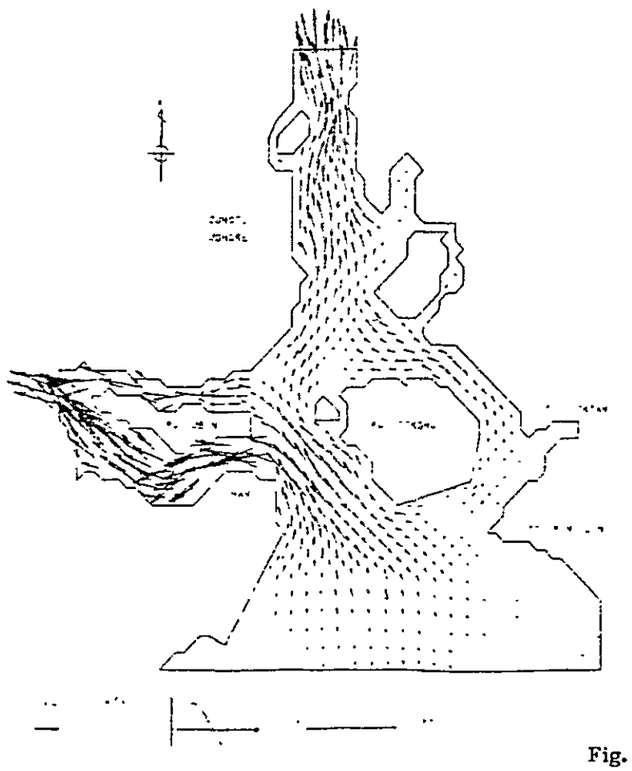







FLOOD TIDE





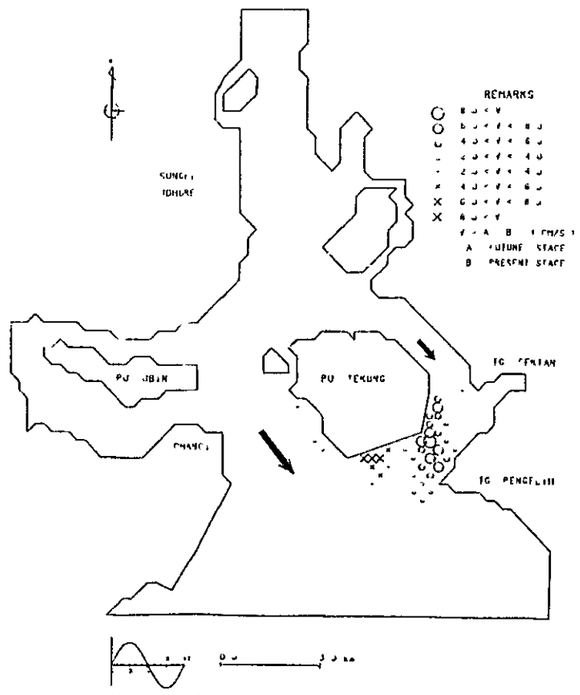


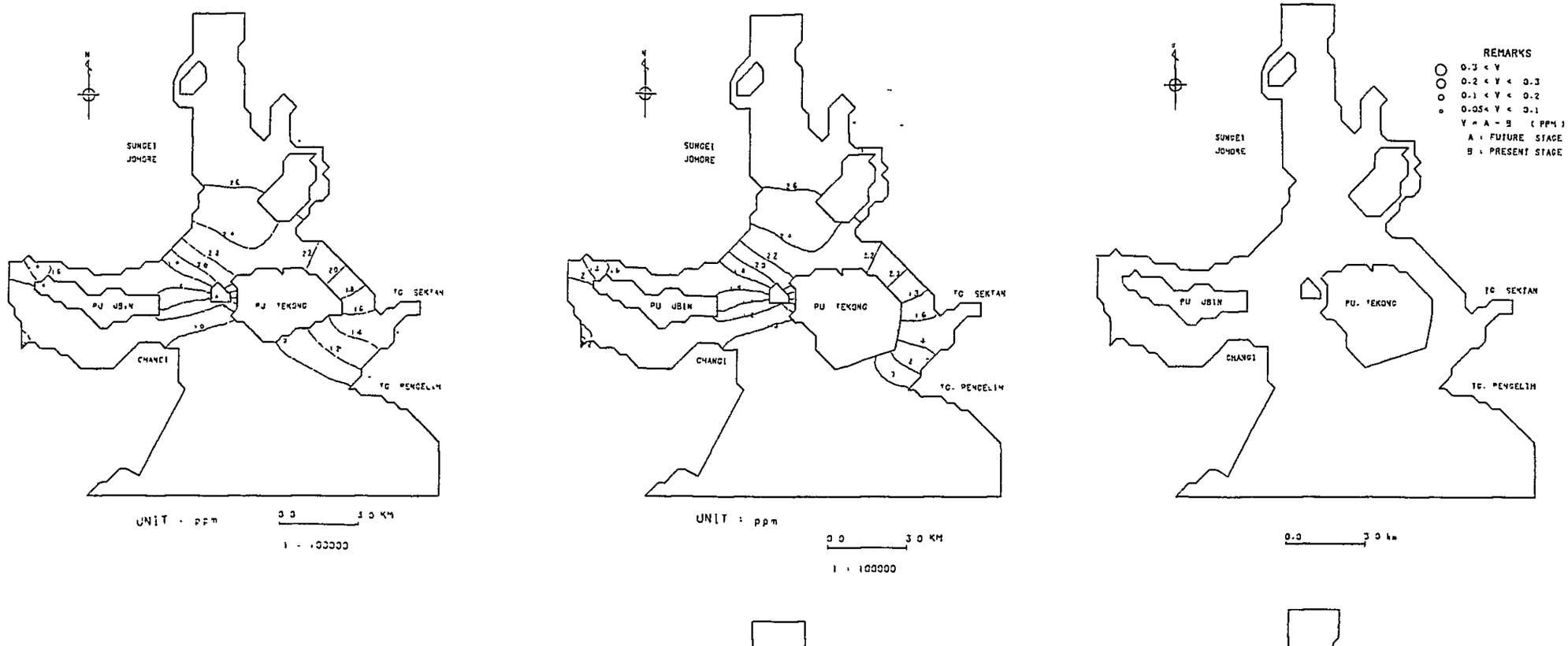

Fig. (III)-5 Current conditions of the present and future in Tekong Area

PRESENT STACE

FUTURE STAGE

DIFFERENCE

COD




TEMP

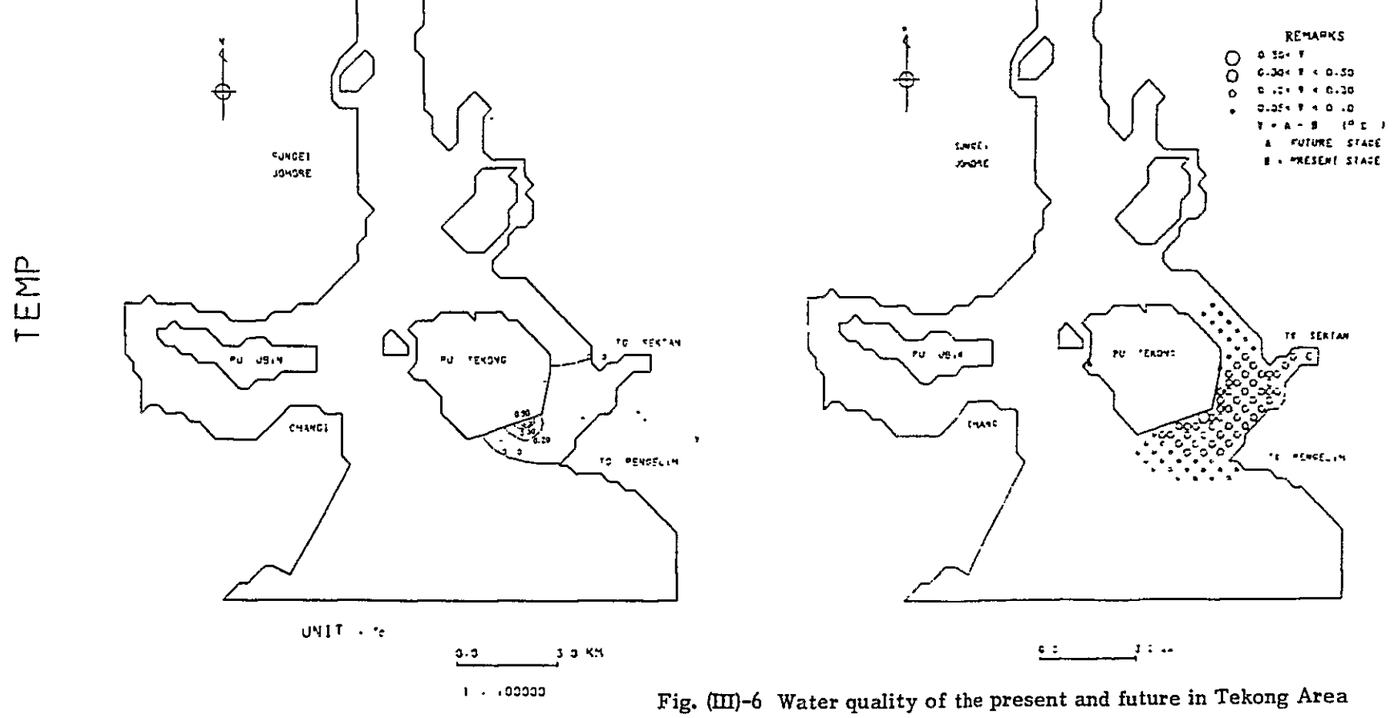



Fig. (III)-6 Water quality of the present and future in Tekong Area

# PART I INTRODUCTION

## CHAPTER 1 BACKGROUND AND OUTLINE OF THE STUDY

### I-1 Background of the Study

The Government of the Republic of Singapore has requested the Government of Japan to extend its technical cooperatijon to the study on the environmental effects of the development plan proposed by Jurong Town Corporation (hereinafter referred to as "JTC") at the official meeting held in August 1979 in Singapore between the Government of the Republic of Singapore and Annual Consultation Mission of the Government of Japan on technical cooperation for Singapore.

In response to the above request, the Government of Japan has decided to conduct a preliminary survey on the study of environmental effects of coal firing power stations and the integrated steel mill which will be developed by the Government of the Republic of Singapore, and Japan International Cooperation Agency (hereinafter referred to as "JICA") has been commissioned to conduct the preliminary survey.

JICA has sent a premilinary survey team of 7 persons, headed by Mr. I. Kikushima, deputy director, Environmental Protection Guidance Division, Industrial Location & Environmental Protection Bureau, Ministry of International Trade and Industry (MITI) to Singapore for 13 days during the 8th to the 20th of December 1980. The preliminary survey team has made the necessary surveys and has had the meetings with JTC who has been designated as the counterpart of Singapore side to discuss on the feasibility of the study, including the specifications of the study and the relative conditions.

And the Scope of Work and the Minutes of Meetings have been prepared and signed between JTC and JICA, including the following subjects mutually agreed.

(1) Time schedule of the study on environmental effects
(2) Specifications of the field survey
(3) Specifications of the simulation
(4) The contribution of the Government of the Republic of Singapore

Based on the Scope of Work and the Minutes of Meetings, JICA has conducted the field survey and simulation for the water quality during February to December 1981.

### I-1-2 Objective of the study

The objectives of the study are to conduct the field survey on the water quality of the sea areas of the proposed sites of the coal firing power stations and integrated steel mill which will be developed by the Government of Singapore, and based on the data obtained throught the field survey and also the collected data related to the present and future effluent sources, to conduct simulation of COD and water temperature which will predict the environmental impact of the coal firing power stations and integrated steel mill under operation in 1990.

## CHAPTER 2 OUTLINE OF THE STUDY

### I-2-1 Survey areas

The survey areas are the following 2 areas of the proposed sites of the coal firing power stations and integrated steel mill and those locations are shown in Fig. I-1.

(1) Pulau Seraya Area (proposed site of coal firing power station)
(2) Pulau Tekong Area (proposed site of coal firing power station and integrated steel mill)

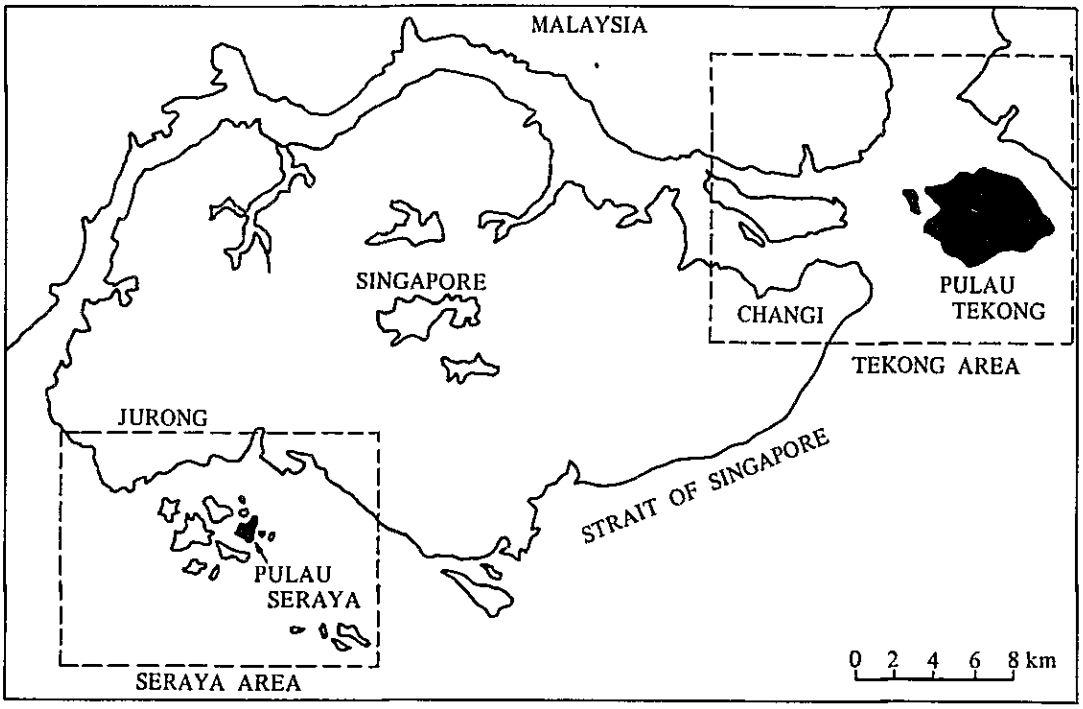



Fig. I-1 Survey area of this study

I-2-2 Survey schedule

The survey schedule is as follows:

(a) Field survey during February 15th 1981 to March 26 1981
(b) Collection of data and simulation during April 1981 to Octorber 1981

I-2-3 Survey items and survey methods

I-2-3-1 Field survey

In order to survey the present current conditons of the survey area and to obtain the basic data necessary for the simulation of future conditons, the following field survey has been conducted. The survey has been carried out under the close cooperation of JTC, Port of Singapore Authority (hereinafter referred to as "PSA") and National University of Singapore (hereinafter referred to as "NUS").

1) Current survey

The continuous and automatic monitoring on current direction, current velocity and water temperature has been conducted for 15 days by AANDERRA Current Meters as follows:

At surrounding area of Pulau Seraya -- 6 points (one depth)
At surrounding area of Pulau Tekong -- 4 points (one depth)

2) Survey on water temperature and salinity

The survey on horizontal and vertical distribution (average 5 depths) of water temperature and salinity has been conducted as follows:

At surrounding area of Pulau Seraya -- 49 points (survey on salinity conducted at 28 points only for surface layer)
At surrounding area of Pulau Tekong -- 35 points (survey on salinity conducted at 24 points only for surface layer)

3) Survey on water quality

(a) COD (Par-Manganate Method)

At surrounding area of Pulau Seraya -- 21 points (surface layer)
At surrounding area of Pulau Tekong -- 11 points (surface layer)

In addition to the above, the chemical analysis for COD by Dichromate Method has been conducted and the analysis of Chrolophyll-a has been carried out at 5 points of the above two sea areas respectively.

(b) Transparency and water colour

At surrounding area of Pulau Seraya -- 49 points
At surrounding area of Pulau Tekong -- 35 points

4) Collection of past survey data

The data of the tide and meteorological conditions of Singapore has been collected through JTC and the report on the joint survey of the tide and the tidal current of the Straits of Malacca and Singapore from Maritime Safety Agency, Japanese Government.

I-2-3-2 Analysis of field survey data

The data obtained through the field survey together with the collected data of the past survey have been brought back to Japan and the following analysis have been conducted.

(1) Statistical analysis of current direction and velocity fluctuation
(2) Analysis of current pattern
(3) Statistical analysis of tides
(4) Arrangement of meteorological data
(5) Horizontal and vertical distribution of water temperature and salinity
(6) Vertical distribution of COD

I-2-3-3 Collection of effluent sources' data and future assessment

The effluent sources' data which will be used as input data of the simulation have been collected and supplied by JTC based on the questionnaire prepared by Japanese side.

The effluent data related to the coal firing power stations and integrated steel mill under planning have been discussed and fixed between Singapore and Japanese sides as mentioned in the Minutes of Meetings. Further, the data related to other emission sources have been supplied by JTC and those have been used by Japanese side for assumption of future effluent conditons with the estimated developing plan of the Republic of Singapore which supplied by Singapore side.

### I-2-3-4 Simulation

Establishing the calculation parameter based on the above basic data and effluent data, the following simulation have been conducted.

(1) Current conditions (present and future)
(2) COD (present and future)
(3) Thermal effluent (present and future)

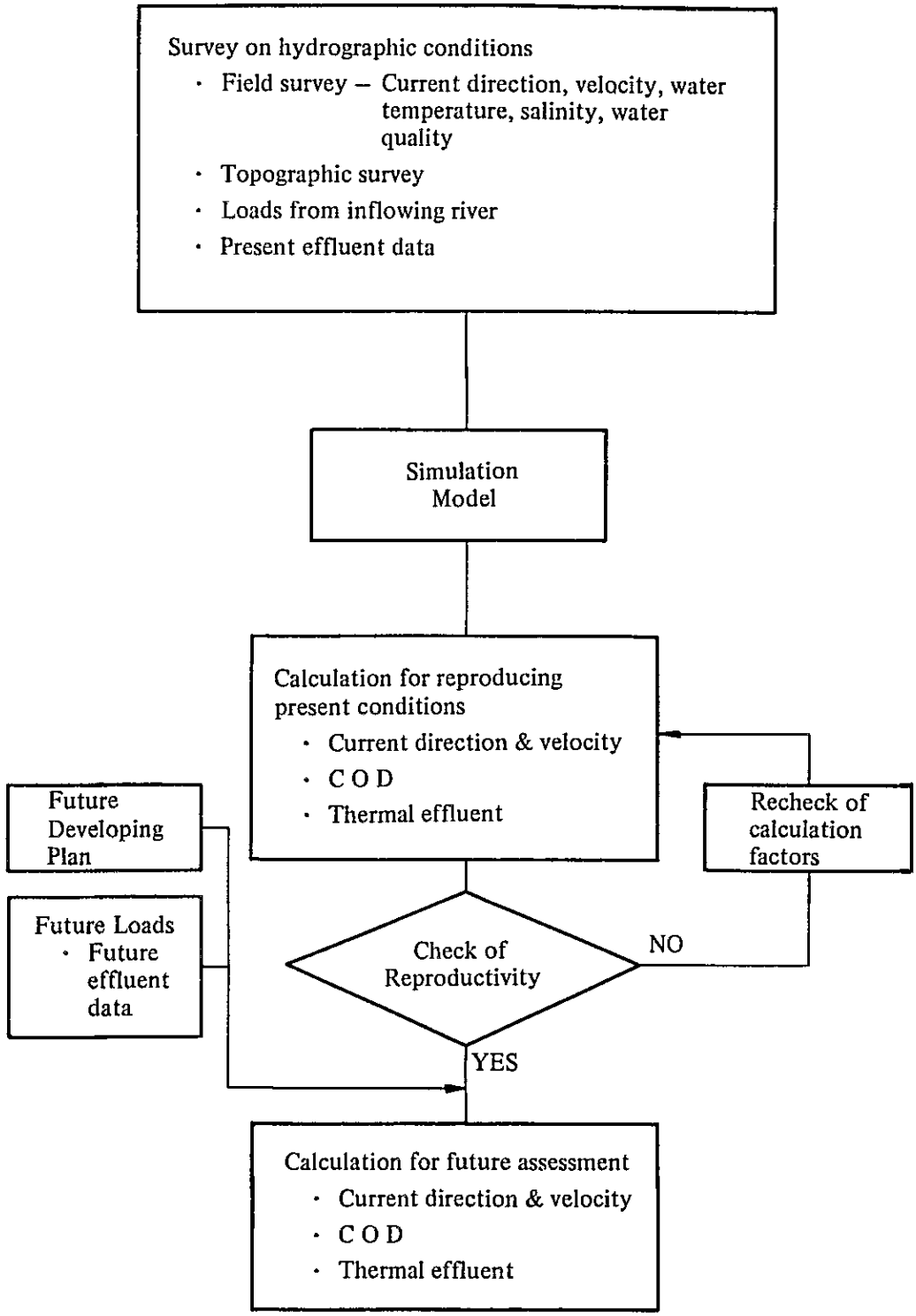



Fig. I-2 Processes of simulation

I-2-4 Formation of survey team

Table I-1 shows the formation of survey team.

Table I-1 Formation of survey team

| | | |
|---|---|---|
| Yoichi Suzuki | Team leader | 15th Feb. - 26th Mar. 1981 |
| Kihachi Inagaki | Coordinator & Industrial Location | 15th Feb. - 1st Mar. 1981<br>12th Mar. - 25th Mar. 1981 |
| Shoji Ohmori | Industrial Location | 18th Feb. - 25th Feb. 1981 |
| Shoji Arisawa | Technical Survey | 15th Feb. - 26th Mar. 1981 |
| Shusei Iwata | Technical Survey | 15th Feb. - 26th Mar. 1981 |
| Norio Kawada | Technical Survey | 15th Feb. - 26th Mar. 1981 |
| Isoharu Kon | Technical Survey | 15th Feb. - 11th Mar. 1981 |
| Tsutomu Kasahara | Technical Survey | 15th Feb. - 8th Mar. 1981 |
| Nobuhiro Tamura | Technical Survey | 15th Feb. - 8th Mar. 1981 |
| Shingo Itonaga | Technical Survey | 15th Feb. - 11th Mar. 1981 |

* The members of the team belong to Industrial Pollution Control Association of Japan (IPCAJ).

## CHAPTER 3 PROCESSES OF ENVIRONMENTAL ASSESSMENT

The processes of environmental assessment are described in this chapter.

For reference, the flowchart of "environmental assessment for industrial pollution" which have been conducted under the guidance of Ministry of International Trade and Industry (MITI) in Japan. (Fig. I-3-1-(1)) The processes of the above study are classified into (1) preparation for the project, (2) field survey, (3) assessment and (4) compilation of the report.

In the study conducted in Singapore, the same processes have been taken.

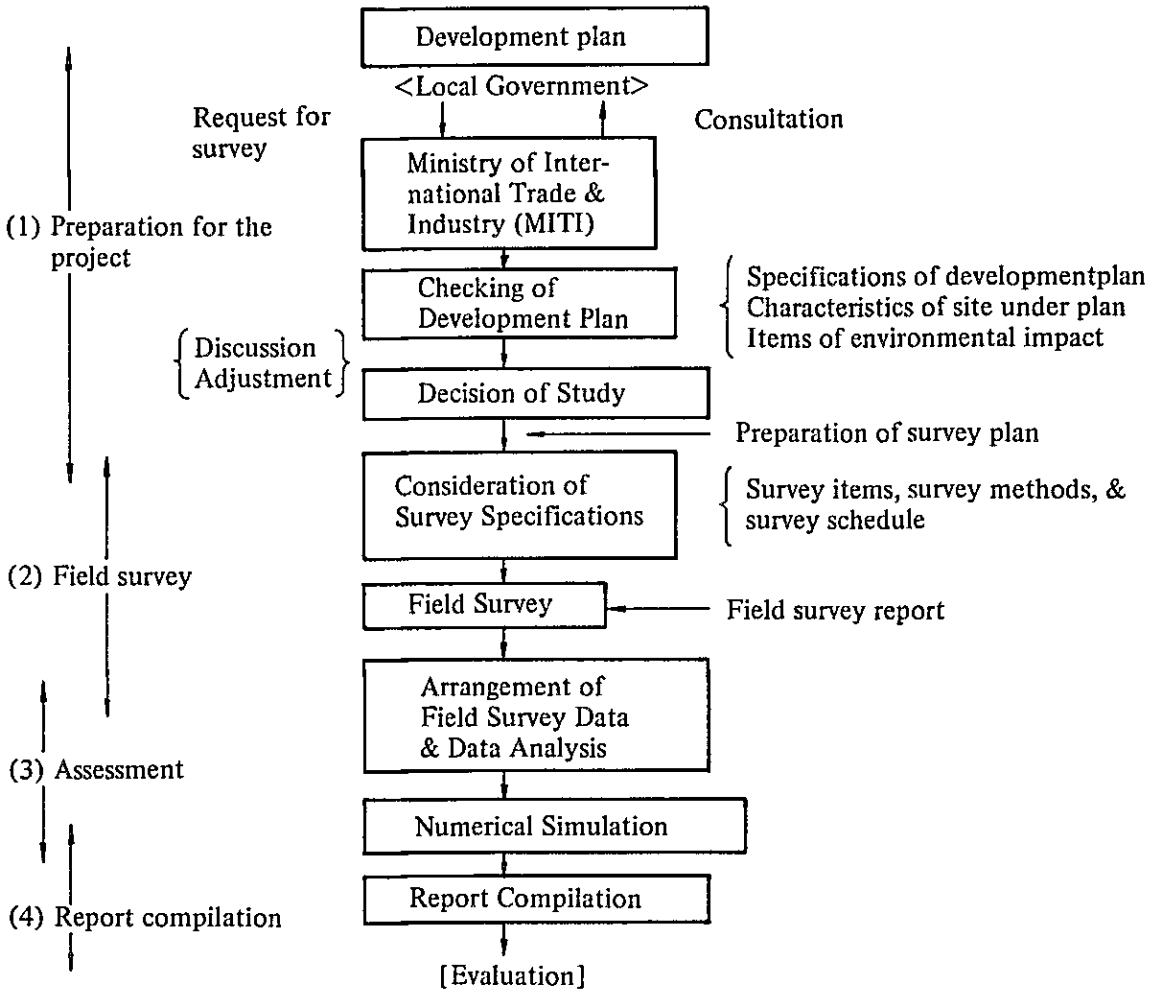



Fig. I-3-1-(1) Flowchart of environmental assessment for industrial pollution

## I-3-1 Processes of preparation for project

At the first stage, the development plan submitted with the request to conduct the environmental assessment is studied and the items of environmental impact are extracted which will be expected in the course of development.

In the case of the environmental study conducted in Singapore, the above preparation works have been carried out by the preliminary survey team and the following specifications have been agreed with Singapore side, as shown in Table I-3-1-(1).

Table I-3-1-(1) Development plan and environmental impact items

| Development plan | Environmental impact items | Field survey items | Items for simulation |
|---|---|---|---|
| Coal firing power stations (Seraya & Tekong) | Thermal effluent<br>Trade effluent reclamation | Current direction & velocity, temperature salinity, COD & etc. | COD water temperature |
| Integrated steel mill (Tekong) | Trade effluent reclamation | Current direction & velocity, temperature salinity, COD & etc. | COD |

After the above process, the preparation for the field survey, simulation and comprehensive plan of the study are conducted.

## I-3-2 Processes of field survey

The field survey is carried out according to the processes as shown in Fig. I-3-2-(1)

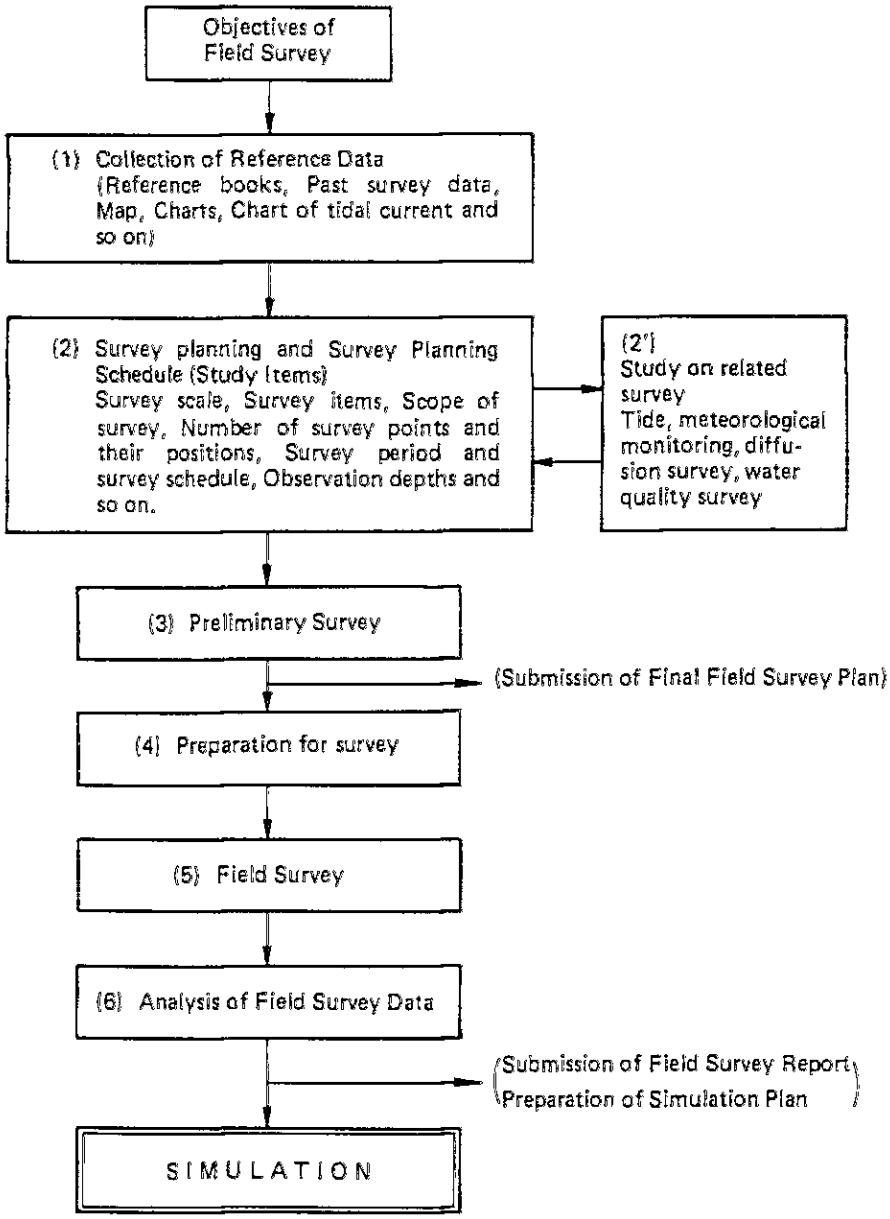



Fig. I-3-2-(1) Flowchart of field survey

## I-3-2-1 Collection of relative data

Prior to the field survey, the collection of relative data is conducted which is very important as one of the preparation processes. The instructive data are the maps, charts, tidal tables, tidal current charts, and other reference books. Referring to these data, the survey plan is designed.

I-3-2-2 Survey plan

The checking items for the survey plan are (1) scope of survey, (2) survey items, (3) survey areas and so on.

These items have to be determiend very clearly and also consideration has to be given to the meteorological conditions, current conditions, availability of survey boats and local staffs, possibility to have the cooperation of Authorities concerned, necessary expenses involved in the survey and so on.

1) Scope of Survey

In some cases of environmental assessment in Japan, the tide observation, meteorological observation, diffusion survey, water quality survey, biological survey, river survey, and sea bottom survey besides the current survey are conducted. In case of Singapore study, some of the survey have been exempted and some have been substituted by the data collected which based on the past survey conducted by the reliable organizations.

2) Survey items

The items for the current survey are current direction, velocity, water temperature and salinity.

The conventionl current meters are capable to measure only current direction and velocity, but by the development of sensors, the current meters of the present are capable to measure the water temperature and salinity as well as the current direction and velocity. In this study, new type current meters (AANDERAA Curret Meter) have been used.

Besides the above 4 items, the survey is usually conducted for the depth, bottom topography and bottom quality when these data are not obtainable. As for the diffusion survey, the horizontal and vertical distribution of water temperature and salinity are observed. For water quality, COD and other items are taken up.

3) Survey areas and survey point

The survey areas are determined by the characteristics of the current conditions of the sea areas and also consideration is given to the predicting scope in the process of simulation.

Besides the above, the number of current meters, survey boats available and the current conditions of the sea areas are considered for determination of survey areas and survey point. The examples are shown in Fig. I-3-2-(2).

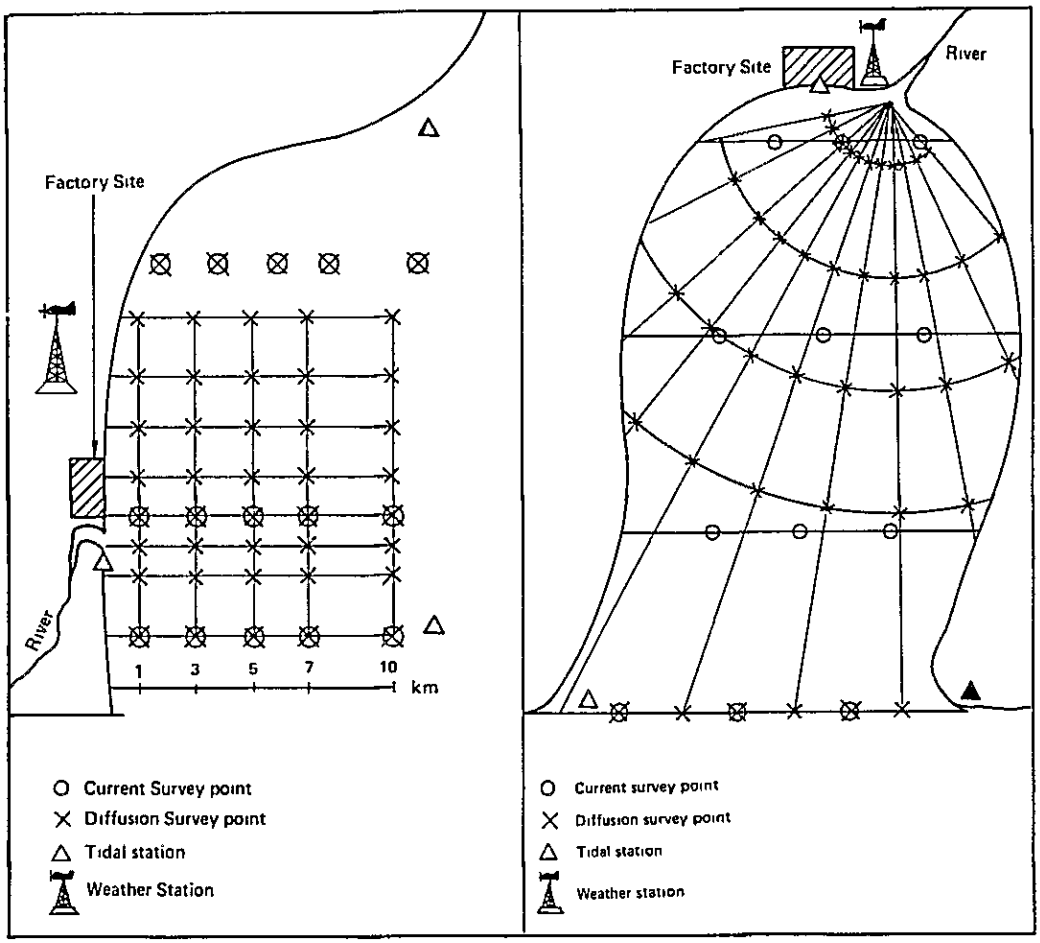



Fig. I-3-2-(2) Examples for determination of survey areas and survey points

4) Survey schedule

The survey schedule is determind by the objectives of the survey but the current conditions of the survey areas are the important factors for the same. This is due to the fact that the diffusion behaviour of effluent is only be possible to estimate by the flucutation behaviour of the current.

For example, the survey is necessary to be conducted for more than 15 days at the sea area where 1/2 or 1 day cycle tide is dominant. This is because that the tide has the clear cycle of 1/4, 1/2, and 15 days.

For the survey at the area where the longer cycle tide is dominant, the survey is carried out for 30, 45 or 60 days.

5) Survey depths

The survey depths are determied by the type of current meter and current conditions of the survey area. When the observation is conducted for one depth, the current meter is usually set at the depth of -5 m from the surface. For the serial depths, the curret meter is set at -5 m, -10 m, B+5 m, and or B+2 m. The number of depths and their positions are determined by the objectives of the survey and the current conditions.

The example of depths are shown in Fig. I-3-2-(3).

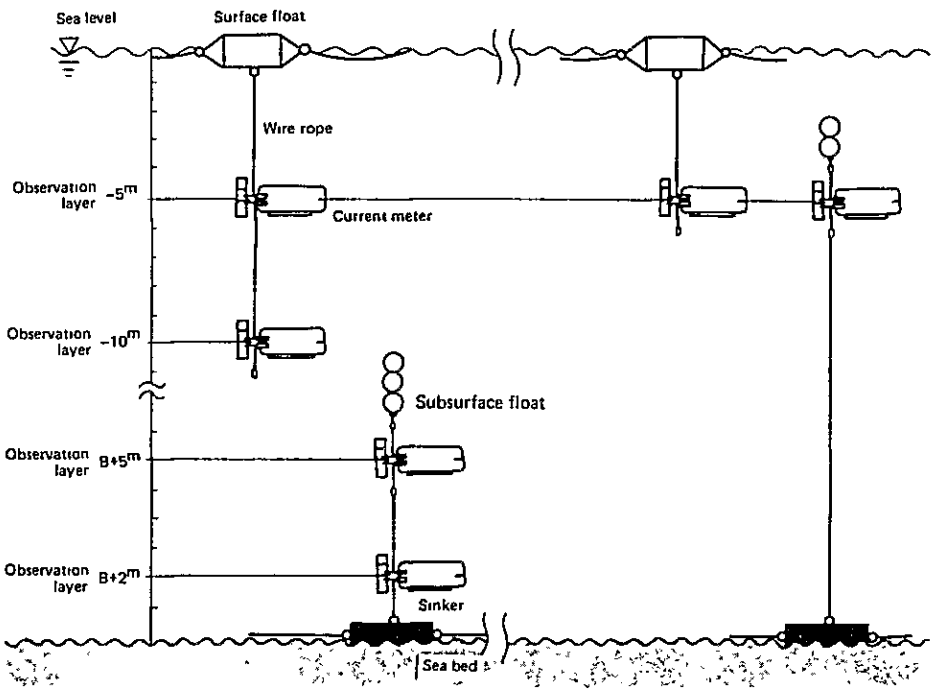



Fig. I-3-2-(3) An example of observation depths at current survey

For water temperature and salinity survey (diffusion survey) and water quality survey, the serial observation is usually conducted. For example, at 0 m, -0.5 m, -1 m, -2 m — (every 1 m) — -10 m, -20 m, — (every 10 m) — and +1 m from the bottom. The distance between depths is rather denser than other observation.

Fig. I-3-2-(4) shows an example of observation depths for water temperature and salinity survey, and water quality survey.

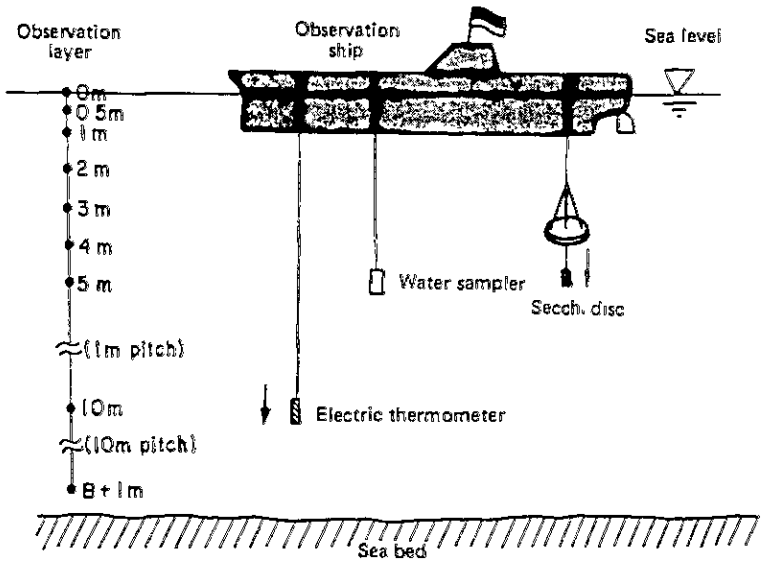



Fig. I-3-2-(4) Example of observation depths for diffusion survey and water quality survey

I-3-2-3 Compilation of survey plan

After considering the above 5 items and factors, the total survey plan is compiled together with other necessary factors. An example of the survey plan is shown in Table I-3-2-(2).

Table I-3-2-(2) An example of survey plan

1) Survey objective:

2) Survey area: (show the charts of survey areas and survey points)

3) Survey schedule: (for example) February 24th to Mrach 13th 1981. (attach time schedule and survey boat list)

4) Survey methods:

| Survey item | Survey area Survey point | Survey depth | Survey schedule | Survey method |
|---|---|---|---|---|
| Current survey Current direction, velocity, temperature, salinity | SC 1 - SC 6 | B+8 m | Feb. 24 - Mar. 13 1981 | Measurement by AANDERAA current meter at 10 min. interval. Subsurface floating system |
| Diffusion survey Water temperature and salinity | S1 - S30 | 0, -1, -2 —— -10, B+1 m | March 2, 1981 09:00-12:00 | Temperature by electric thermometer, salinity by salinometer after sampling by KITAHARA sampling bottle |
| Water quality survey COD & others | S1 - S30 | 0, -5, B+1 m | | After sampling, chemical analysis by JIS method |
| Collection of relative data | | | | Collection of relative and available data |

I-3-2-4 Preliminary survey

After the survey plan is prepared and checked, the preliminary survey is conducted at the survey site.

The survey items are inspection of the survey areas, arrangement of survey boats and local staffs, arrangement of godown for the observation instruments & materials, and other necessary items.

Except the above, the contact with the marine authority is necessary in most cases, as the observation points are fixed up on the navigation routes of the ships and steamers. In case of need, the application documents are to be submitted to the authority concerned.

I-3-2-5 Preparation works

The adjustment, packing and transportation of the observation instruments are usually carried out from about one month prior to the field survey.

At the survey site, the transported instruments and other materials are to be unpacked and adjusted. Also these instruments and materials are to be loaded on the survey boats.

I-3-2-6 Field survey

In the study conducted in Singapore, the field survey has been carried out for (1) current survey, (2) diffusion survey, and (3) water quality survey.

The current survey is carried out by mooring the current meters at the survey points.

The mooring systems of the current meters are employed according to the current conditions of the survey areas and the capacities of the current meters.

Fig. I-3-2-(5) shows the examples of mooring systems employed in Japan, and the upper figure shows the mooring system of the current meter, which is usually called as "Surface System".

The light buoys of the both side are connected with the anchors of sea bed, and the current meter is moored with the surface float located between the light buoys as shown in the figure.

The advantages of this system are (1) easy in mooring works and (2) also easy to collect the data from the current meters.

So this system is mostly employed in the current survey conducted in Japan.

The lower part figure shows the mooring system of the current meter which is called as "Sub-surface buoy system".

The light buoys of the both side are connected with the anchors of sea bed, and these are also connected with the anchor located between two anchors. The current meter is moored with the center anchor with sub-surface float, as shown in the figure.

The advantages of this system are (1) to avoid the influence of the waves and (2) to avoid the accident which may be caused by the ships' navigation, as the current meter is moored under the surface. However, it is disadvantageous under this system that the divers have to be employed for mooring works and collecting data.

The light buoys are arranged so as to light on and off by the fixed time interval for sending the notice to the ships and steamers nagivating in the night. Sometimes, the radar-reflectors are installed to the light buoys.

In the study conducted in Singapore, the sub-surface buoy system has been employed, taking all the conditions, and the recommendation of PSA into consideration.

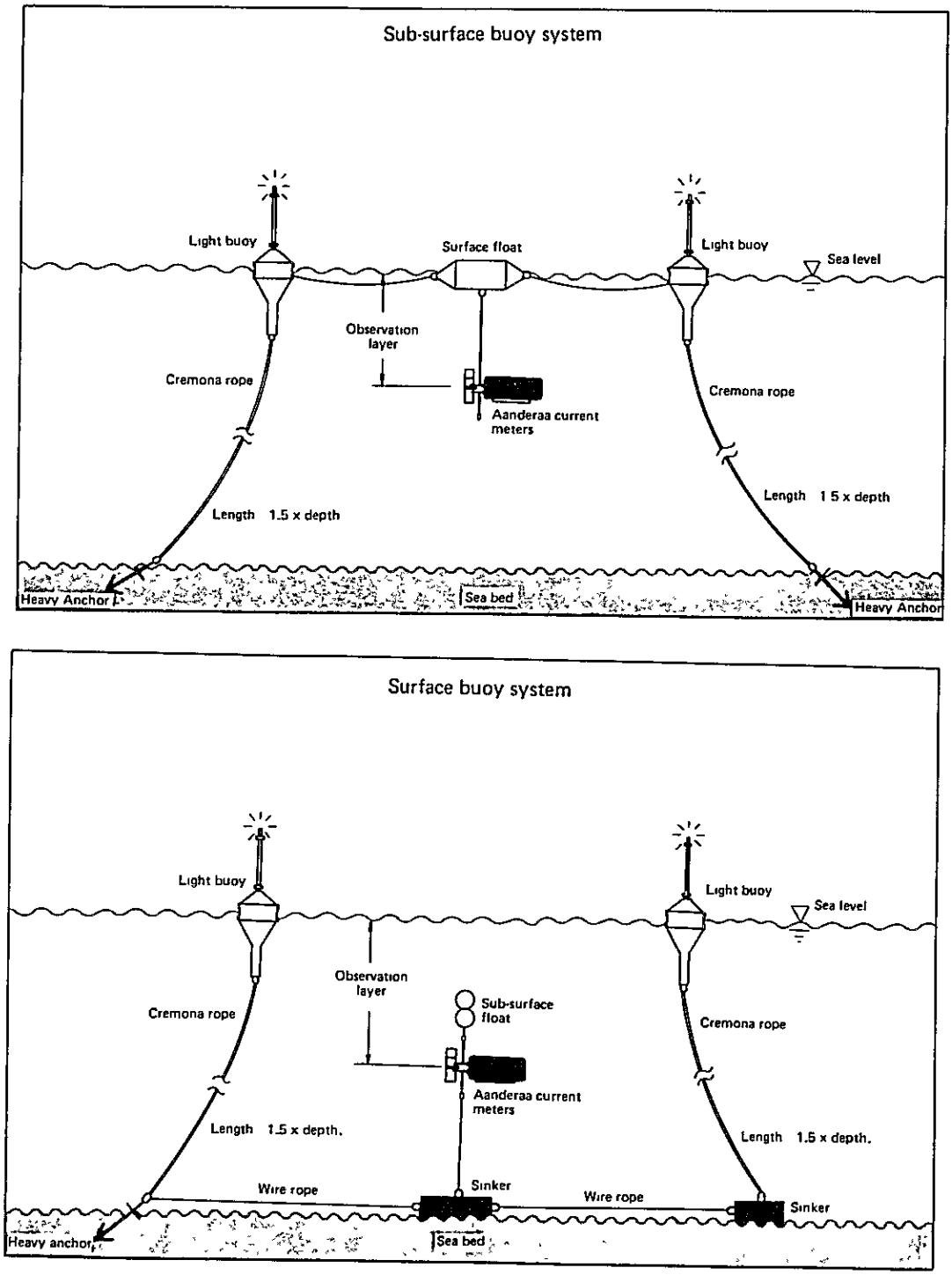



Fig. I-3-2-(5) Mooring system of current meter

The diffusion survey and water quality survey are carried out after completing the mooring of current meters at the survey points. This is due to the fact that the current conditions of the survey areas are obtained from the data measured by the current meters.

These two surveys are carried out by stopping the survey boats at the survey points, as shown in Fig. II-3-2-(4).

At the survey points, the measurement of depth, transparency, water colour, wind direction, wind velocity, atmospheric temperature and water temperature are conducted. Also for the measurement of salinity, COD and other items, the sampling of sea water is conducted. The chemical analysis of sampled water is sually carried out on the land, and so the samples are contained in Poly-ethylene or glass bottles soon after the sampling and kept cooled by ice blocks.

### I-3-2-7 Data analysis

The data obtained by the above surveys are collected and analysed into various figures and tables which are complied as the report of the field survey with the comments.

The detailed description on data analysis will be developed in the following parts of this report.

## I-3-3 Summary of simulation

For the large scale industrial development plan, the environmental impact by such plan should be estimated. The environmental impact assessment is conducted for predicting the physical change (changes of current conditions by reclamation & etc.) and chemical change (changes of water quality by trade effluent & etc.), and also predicting other environmental impacts which may be caused by the industrial development, and finally for evaluating the development plan which include the recommendation for the control measures.

Simulation is one of the most important processes together with the field survey in the total works involved in the environmental impact assessment.

There are two main methods of simulation for water quality at present which are (1) the method by hydraulic model and (2) the method by numerical simulation.

The hydraulic model method is the conventional method which constructs minimized models of the coastal topography, the sea bottom topography and so on for reproducing the sea area of the actual site in the laboratory building. After reproducing the site area, the experiments are carried out by tide generater for the changes of current conditions, by spreading the chemical dyes for the changes of diffusion and water quality, and so on.

By the rapid improvement and development of computers, the method by numerical simulation has been introduced and come to the common method, which make calculations under various equations. The advantages of the method by numerical simulation are (1) more accurate in the calculation results, (2) easy to change the input conditions, and so on.

For the calculation methods for numerical simulation, there are two main ways which are most commonly employed. There are (1) Finite Element Method and (2) Differential Method.

The finite element method is a kind of numerical analysis of the differential equation which has been used in various fields.

In the differential method, the calculation area is in most cases divided into the fixed scale grid, but in the finite element method, the elements can be divided into arbitrary shapes and scales. By this, the reproduction of complexed topography is possible in more accurate way.

In this study, the numerical simulation method and finite element method have been employed.

Fig. I-3-3-(1) shows the processes of simulation and Table I-3-3-(1) shows an example of simulation plan.

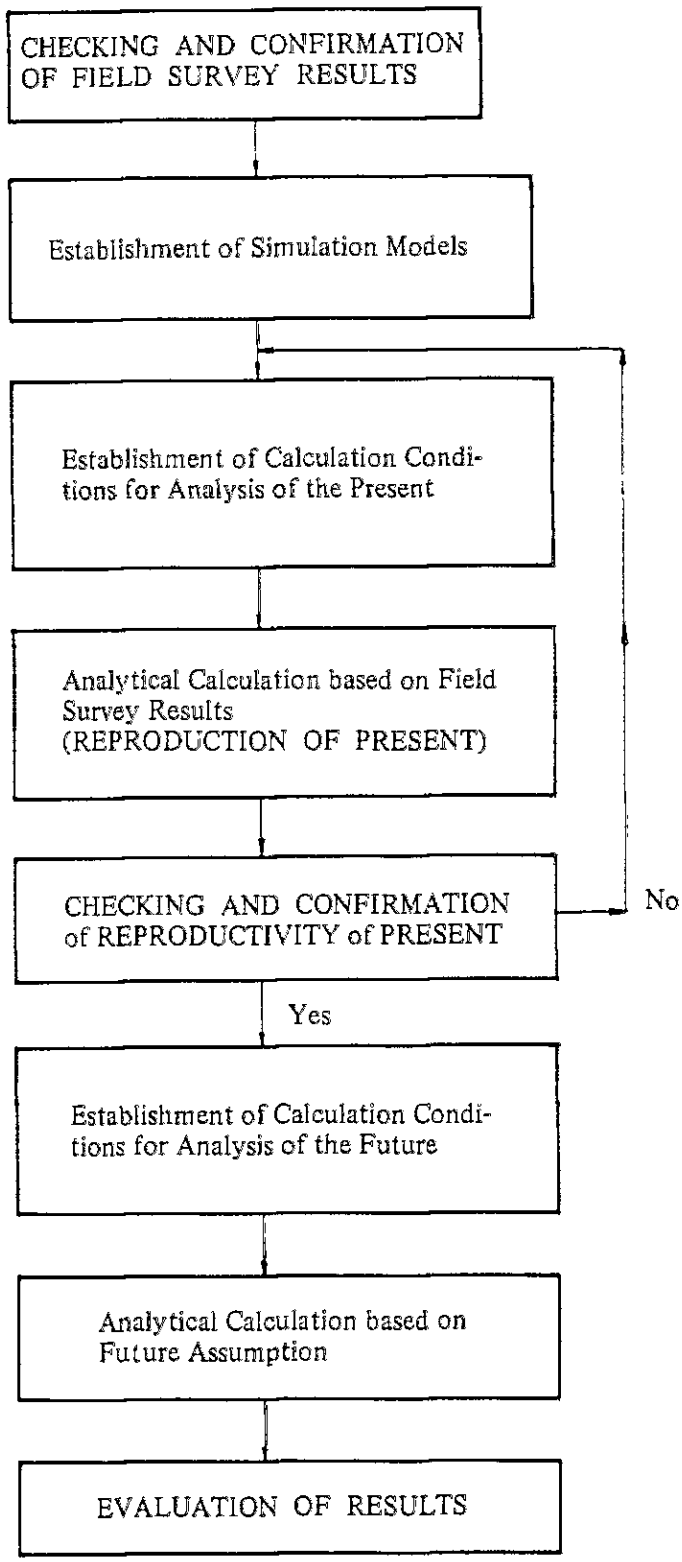



Fig. I-3-3-(1) Flowchart of simulation process

Table I-3-3-(1) An example of simulation plan

(1) Objective of study

(2) Survey area

(3) Survey items and survey process

(4) Analysing area and element division

(5) Calculation case

(6) Calculation method

# PART II FIELD SURVEY

## CHAPTER 1 CURRENT SURVEY

### II-1 Outline of Current Survey

#### II-1-1 Current survey

The current survey has been conducted for the purpose to investigate the present current conditions of survey areas (sea areas surrounding Pulau Seraya and Pulau Tekong) and the data obtained through the survey are the basic data which will be used in the process of simulation.

The current survey is defined as to obtain the continuously measured data of current direction, velocity, temperature and salinity by mooring the current meters at many survey points and to analyse these collected data for the purpose of investigating the current conditions of the survey areas.

The purpose of investigating the current conditions is to obtain the basic data which will be used for the assessment of effluents diffusion when such effluents are discharged from the plants and factories in the future. Fig. II-1-1 shows the current conditions and diffusion pattern of effluents.

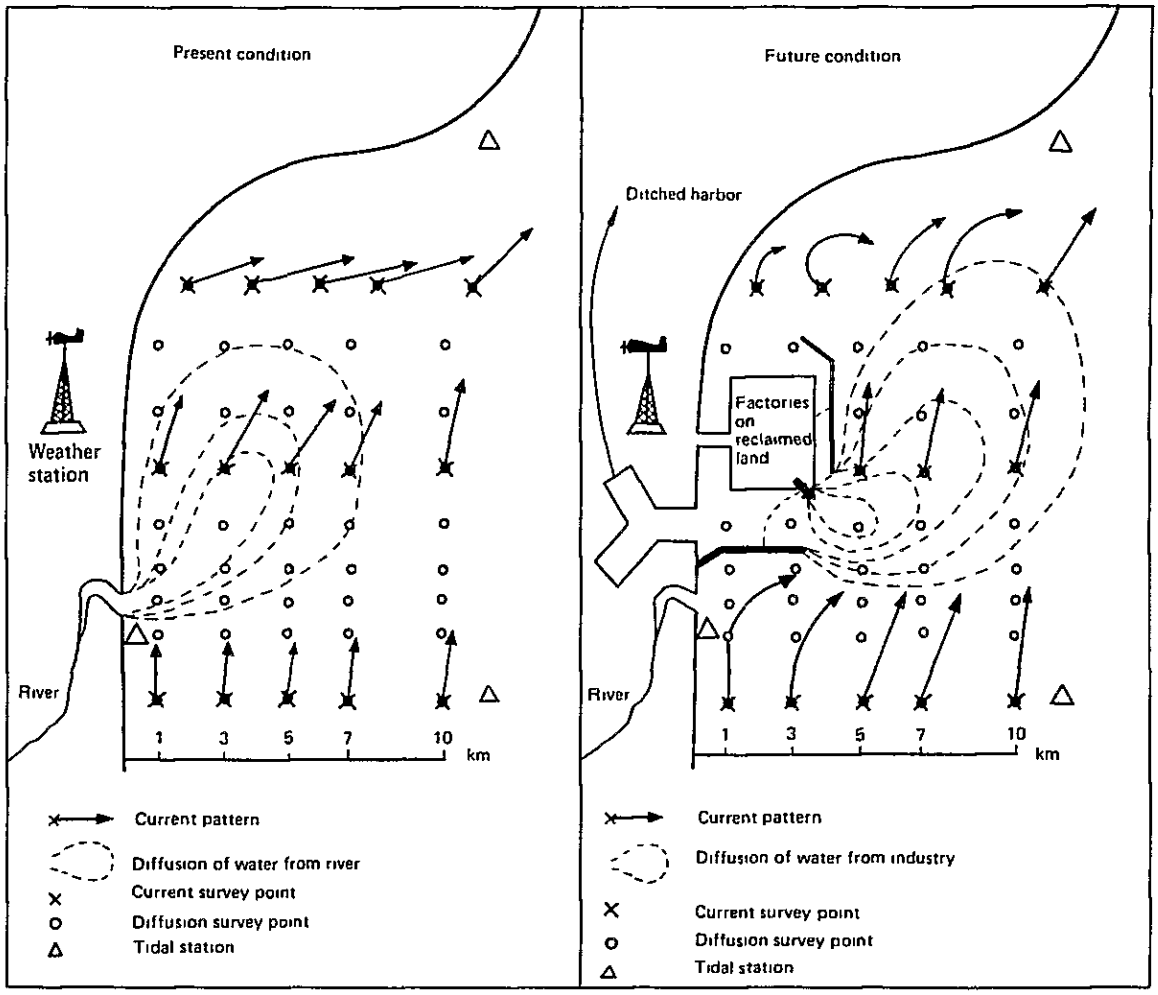



Fig. II-1-1 Current conditions and diffusion pattern of effluents

In the left side of the figure the current conditons obtained through the field observation and diffusion pattern of river water are shown.

The long term current survey is conducted at the survey points which designed so as to cover the total survey areas and is investigated the present current conditions pattern.

On the other hand, the diffusion survey (such as temperature and salinity distribution) is conducted to estimate the diffusion coefficient from fresh water distribution because the salinity is good indicator for fresh water diffusion in the sea. The diffusion coefficient represents the difference power and its unit is $cm^2/sec$.

The tide observation, meteorological monitoring and water quality survey are also conducted simultaneously.

In the right side of the figure, the current conditions pattern of the case which the topographic changes have caused by the reclamation, construction of harbours and factories, and diffusion pattern of trade effluents are shown. These respective patterns of the future are obtained by reproducing the present conditions based on the data of the field survey and putting the future variation factors together into large capacity computers. The processes to reporduce and assess the present and future current conditions and diffusion conditions of trade effluents are defined as simulation calculation.

The simulaton methods of air and water quality have been based on the wind tunnel experiments and hydraulic model experiments (physical model) but by the development of large capacity computers, the method based on the numerical simulation (numerical model) has now been the most popular and standardized. Fig. II-1-2 shows the figure of reproduced current conditions in the process of simulation.

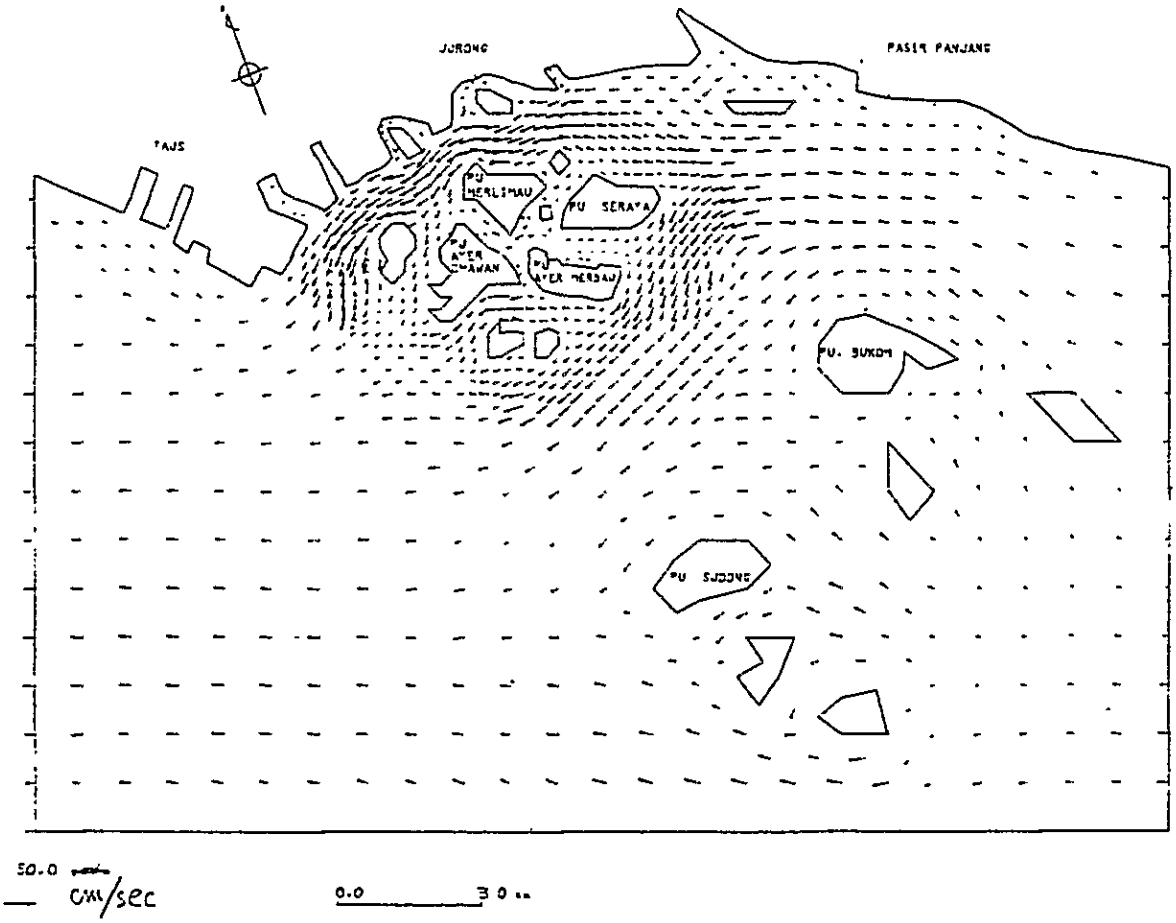



Fig. II-1-2 Reproduced current conditions in the process of simulation

This figure shows a part of current conditions of Pulau Seraya Area reproduced by the large capacity computers based on the data of current survey conducted at Pulau Seraya Area.

As described in the above, the process of simulation is to reproduce the present current condition based on the data obtained through the current survey and then to predict the change of the future current conditions, putting the variation factors such as the topographic changes which might be caused by reclamation and so on of under development plans.

Further, after prediction of current conditions, the diffusion conditions of the present and future trade effluents are calculated and the total situation of contamination is evaluated.

The verification process is the most important item of works in simulation. From this, the current survey is the most important item of works in the field survey.

II-1-2 Outline of current survey in this study

Table II-1-1 shows the outline of current study conducted in this study. The field works and collection of reference data are main items.

The field works, as shown in the upper part of the table, have been conducted in two sea areas, Seraya and Tekong. The survey has been carried out by mooring the current meters at the surve points continuously for the duration of about 20 days during end February to mid March 1981.

The number of survey points have fixed, 6 at Seraya and 4 at Tekong. The survey depth was one.

The main measuring instruments have been transported from Japan to the Republic of Singapore by surface. Soon after the cargoes arrived in Singapore, the preparation works have been taken over and under the cooperatrion of JTC, unpacking and adjustment of the instruments have carried out in the JTC godown. Throughout the study, including various surveys, all the works have been carried out under the full cooperation and assistance of JTC. PSA has also assisted the survey team in providing the survey vessel, PESEK, and her crews, and other necessary information and data related to this study.

With regard to the collection of reference data, the current survey data of Pulau Merubau and the survey data of the Straits of Singapore and Malacca were obtained.

The above mentioned field data and past survey data have been arranged and analysed by the large capacity computers which produced the results of the field survey as described later.

Table II-1-1 Outline of current survey in this study

| | Survey items | Survey points & survey depths | Date | Remarks |
|---|---|---|---|---|
| Field survey (Seraya) | Current direction, velocity, temperature, salinity | SC1 -8 m<br>SC2 -8 m<br>SC3 -12 m<br>SC4 -5 m<br>SC5 -6 m<br>SC6 -6 m | Feb. 23 to Mar. 13, 1981 | AANDERAA current meter employed |
| Field survey (Tekong) | Current direction, velocity, temperature, salinity | TC1 -7 m<br>TC2 -5 m<br>TC3 -5 m<br>TC4 -7 m | Feb. 26 to Mar. 17, 1981 | AANDERAA current meter employed |
| Collection of past data (Pulau Ayer Merbau Area) | Current direction & velocity | St1 -3 m<br>St2 -3 m<br>St3 -3 m<br>St4 -3 m<br>St5 -3 m | Aug. 7 to Aug. 25, 1979 | Report on boring and survey for petrochemical complex at Pulau Ayer Merbau of Singapore for petrochemical corporation of Singapore - October 1979 - |
| (The Straits of Malacca and Singapore) | Current direction, velocity, and tide | Fixed points continuous observation 1-6 -10 m<br><br>Serial depths observation 1-4 & 6 -2.5 m, -5 m, -10 m, -15 m, -20 m, -25 m, -30 m, -35 m --- | First survey Jul. 10 to Aug. 19, 1978<br><br>Second survey Nov. 9 to Dec. 20, 1978<br><br>1 or 2 days in the above period | Report on the joint survey for tide & tidal current of the Straits of Mallacca and Singapore |

## II-1-3 Current conditions

The current conditions mean the current velocity pattern in the sea. Like as many rivers are flowing on the land, the sea has various scales of current patterns. These current patterns can be observed visbly when the wooden chips are floatig and running on the surface of the sea.

The behaviour of the current is expressed by the current velocity. There are two methods of current measurement, (1) the method which trace the marker or buoy moving with current (Lagrange method) and (2) the method which use the current meter at fixed point (Eyler method).

Except these two mothods, there is the dynamical calculation method which indirectly calculate the current obtaining the density distribution from the temperature and salinity based on assumption of ocean current, like KUROSHIO.

(1) Lagrangian method is to obtain the current condition tracing the markers at proper time intervals from the survey boat.

Usually the float buoy set with the drag plate under the sea surface is drifted in the sea, and measures the buoy position tracing by the survey boat in many cases, but the new system has been developed to trace the float buoy by radiometry from the land, putting the radio emitter to the buoy.

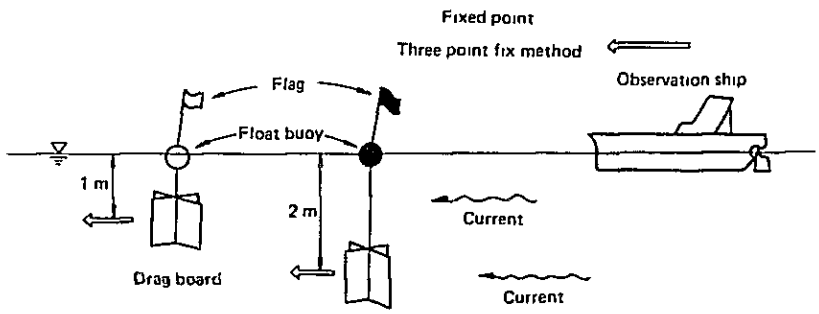



Fig. II-1-3 Lagrange method of current measurement

(2) Eylerian method is employed in most of the surveys. So various kinds of current meters have been developed. The current meters which are mainly used in the survey conducted in Japan are shown in Table II-1-2. These current meters are used properly according to the objectives of the survey.

For example, 3) and 4) type current meters are used for long term measurement like the survey conducted in the Republic of Singapore in this particular study. For survey on the ocean current condition, 5) G,E.K. type current meter is used.

Table II-1-2 Current meters mainly used for survey in Japan

| | Name of current meter | Sensor |
|---|---|---|
| 1) | Electromagnetic current meter | Potentiometric electrode |
| 2) | Ultra sonic current meter | Ultra sonic tranducer |
| 3) | Ono's current meter | Impeller (velocity) vane (direction) |
| 4) | AANDERAA current meter | Rotar (velocity) vane (direction) temperature sensor, salinity sensor |
| 5) | G. E. K. | Geomagnetic electro-kinetograph |

The measurement by the above current meters are carried out by mooring the current meters at monitoring points except the case of 5). The mooring systems of these current meters have been designed according to the oceanic conditions.

There are various currents in the sea originated by various factors as shown in Fig. II-1-4. The typical currents of the ocean are ocean current and tidal current. The ocean current is generally something like big river running through the ocean and it flows in constant manner but regionally the yearly, seasonally or some kind of low frequency fluctuation is found. So it is difficult to evaluate the current conditions.

The tidal current is the current caused by the transportation of sea water together with the tide movements and it fluctuates the current regularly. So by analysing the data obtained through the observation at survey points, the current conditions are able to evaluate by the tidal current.

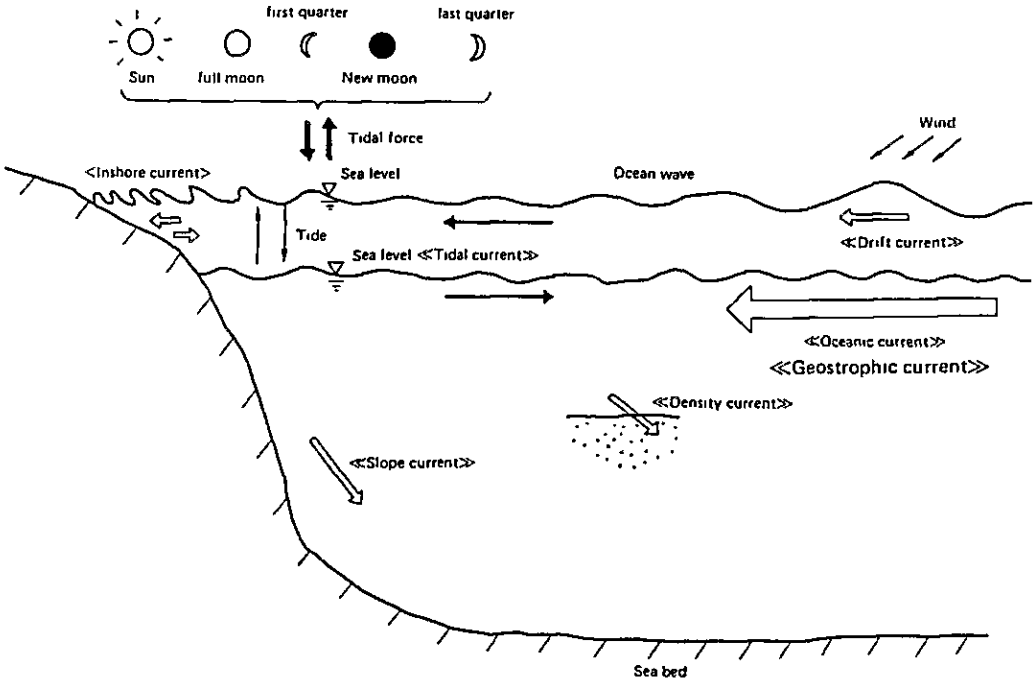



Fig. II-1-4 The model figure of sea water flows

The tidal current is the oscillating current caused by tidal variations.

The tide, although the detailed descriptions are made in later chapter, show the regular fluctuation caused by tidal force of the sun and moon.

Fig. II-1-5 shows the distribution of tidal force observed on the surface of the earth.

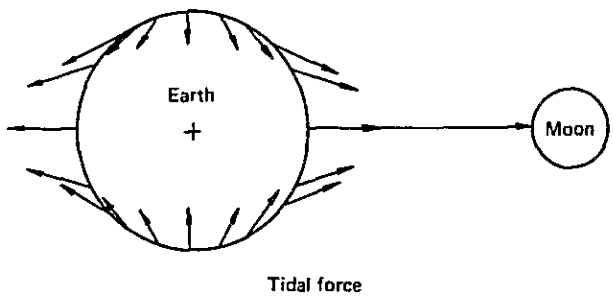



Fig. II-1-5 Distribution of tidal force of the earth surface

The fluctuation of the tidal current can be observed from the coast or the port. Within the certain time period (about 24 hours and 50 minutes), the high water and low water can be clearly recognized twice a day respectively.

Also there is a case that the high and low water are caused only once in a day. These are classified as the former is the semi-diurnal tide and the latter is the diurnal tide.

The scale of the sea level variation which is called as tidal range is changed by the moon age. Such variation is large at the top of new moon and full moon, and it is called as spring tide. At the top of the first quarter and the last quarter, the variation is small and it is called as neap tide. This is shown in Fig. II-1-6.

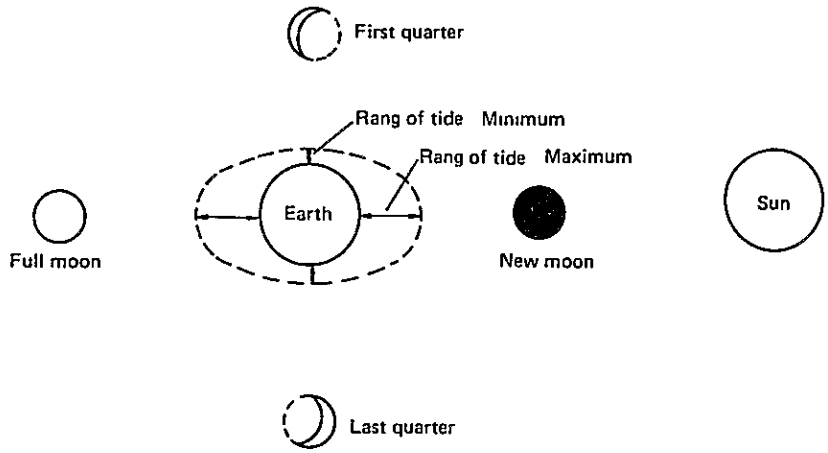



Fig. II-1-6 Relation between moon age and tidal current

The tidal current is the horizontal flow of the current which is caused by the variation of the tide. So the tidal current and the tide are closely related. However, it does not mean that the tidal current and the tide are fluctuating in the same behaviors. There are regional differences between them.

The tidal current is slow in the midst of the ocean where the ocean current is dominant, and is fast at the strait and at the mouth of gulf.

The typical example of the tidal current variation can be observed particularly from the point of the straits, the narrow cannal and or the mouth of the gulf.

Fig. II-1-7 is the coordinates which show the variation of the current direction and velocity by vector. This figure is the tidal current hodograph.

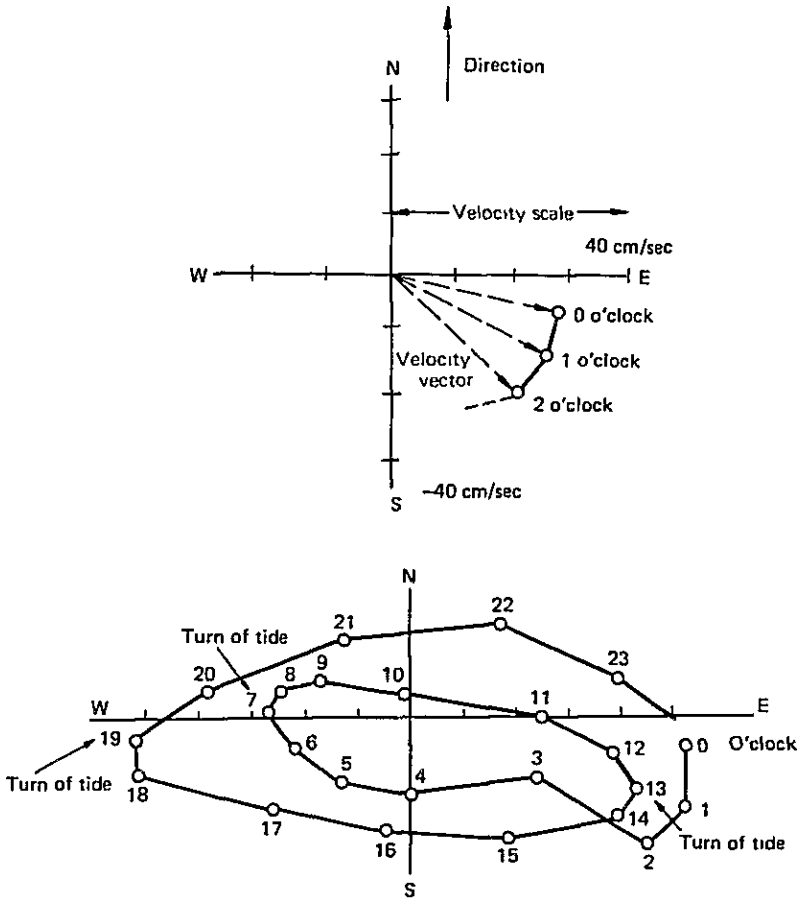



Fig. II-1-7 Tidal current hodograph

In this figure, the curve is tide at the top of velocity vector of each hour and the number represents the time.

From Fig. II-1-7, the variation of the tidal current of about one day can be recognized. During 0 hour to 7:00 hour, the current velocity fluctuates and the direction changes to the opposite side, west. Again the current starts changing to the original direction, east. The status of 7:00 hour is called as turn of tidal current. At 13:00 hour, the direction returns back again to the original way, east, of 0 hour. This is the second turn of tidal current. After that, the current changes to westward and repeats the same turns. 19:00 hour is the third turn of tide and at 24:00 (0 hour) again it returns to the original direction, east. From the above, the regular current variation pattern can be seen.

The current of 4 times turn of tide is a half day period tidal current and the current of 2 times turn of tide is one day period tidal current. Fig. II-1-8 shows the model figure of the relation between tide and tidal current.

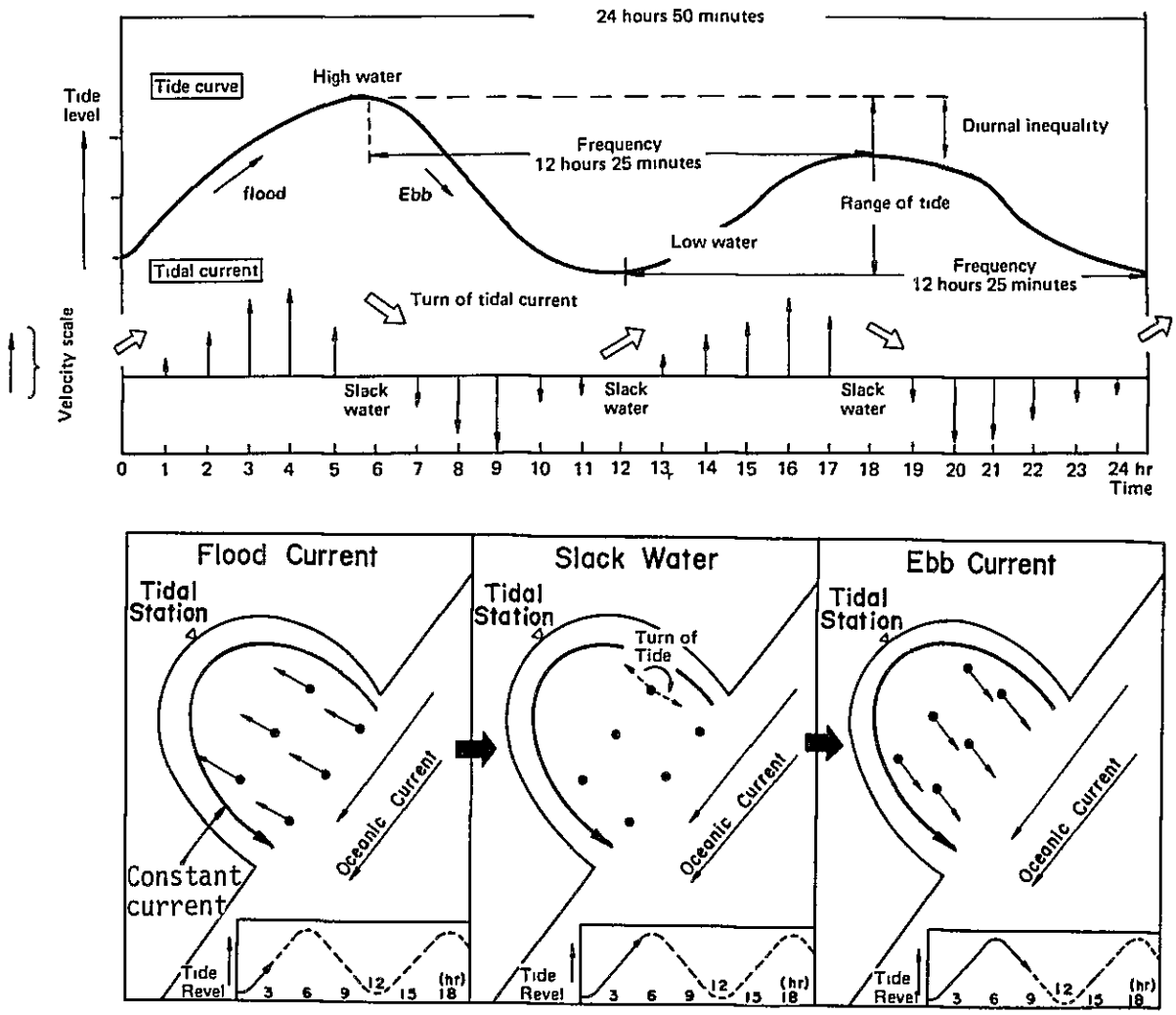



Fig. II-1-8 Model figure of relation between tide and tidal current

After the process of variation of one tidal cycle, the level of sea surface return back to the original position and so the sea water should, in principle, return back to the original position, too. But at the actual sea areas, it does not return back due to the influences of topography, the constructions like mole, rotation of the earth, inflows from the big river and so on.

These variation components are called as constant current. And by the constant current, the sea water in the gulfs and the straits are propagated gradually to the outside ocean. The constant current is obtained by averaging the total data obtained through the observation duration.

The long term behaviour of the sea water movement is determined by the constant current existing in the site. Even magnitude of the constant current is small in order, from the standpoint of long term scale, the constant current is the important factor to determine the difffusion behaviour in the sea. So from the above, th constant current is one of the important items to be analysed together with the tide and tidal current, particularly when the current survey is conducted at the sea area where the tidal current is dominant.

In the simulation, reproduction of this constant current is important. In this study conducted in the Republic of Singapore, the current survey has been conducted for the period of 15 days as the survey areas are found the tidal current being dominant from the past data.

## II-1-2 Specifications of Field Survey

### II-1-2-1 Survey items and observation points

1) Survey items of field survey

The specifications of the items conducted in this current survey are shown in Table II-1-2-(1).

These items have been measured simultaneously by Aanderaa current meter. This current meter is the rotar type self-recording current meter produced by Aanderaa Instruments Ltd., of Norway, and mostly used in the current survey conducted in Japan. The handling is easy and the long term continuous measurement is also possible. Measured data is automatically recorded in the magnetic tape installed in the pressure house and so after the observation, data arrangement is carried out speedily by connecting with the large capacity computer.

This current meter has the advantage that it can also measure the water temperature and salinity besides the current direction and velocity. For further details, refer to the later paragraph II-1-2-4.

In Japan, the impeller type self-recording current meter, ONO System Current Meter, is also employed in the current survey.

Table II-1-2-(1) Survey items of the current survey

| Measurement Item | Range | Sampling Intervals | Sensor Type |
|---|---|---|---|
| Current direction | 0 to 360°C | 5 minutes (mean data) | Magnetic compass |
| Velocity | 2.5 to 250 cm/sec | 5 minutes (moment data) | Rotor and Electric counter |
| Temperature | 10.08 to 36.04°C | 5 minutes (moment data) | Thermistor |
| Conductivity | 0 to 70 mmho/cm | 5 minutes (moment data) | Inductive cell |

With regard to the above tabled survey items, the followings are remarked:

i) The current velocity shows 5 minutes mean value.

ii) The current direction, temperature and salinity are shown by the instantaneous values of every 5 minuts.

2) Location of observation

The selection works of the location of observation which are usually considered prior to the field survey is one of the most important works. The items to be considered and the reference materials are shown in Table II-1-2-(2).

Table II-1-2-(2) Items and reference for location selection

| | Items | Names of reference |
|---|---|---|
| 1) | Coastal topography | Chart and map |
| 2) | Depth | Chart |
| 3) | Sea bottom topography | Chart and bathymetric chart |
| 4) | Marine bottom sediments | Chart and bottom sediments chart |
| 5) | Harbour limit and location | Chart and reference materials on port |
| 6) | Locations of light buoys | Chart and reference materials on port |
| 7) | Anchorages and navigation routes | Chart and reference materials on port |
| 8) | Location of rivers | Map |
| 9) | Scope of fishery right | Fishery chart |
| 10) | Location of existing factories | Map and factories sites map |
| 11) | Reclamation plan (future) | Reclamation plan map |
| 12) | Factories construction plan | Factories construction plan map |
| 13) | Current conditions of survey area | Tidal current chart |

Among the items enumerated in the above table, 1) to 8) are usually able to investigate with the charts, maps and other reference materials which are also rather easy to obtain prior to the field survey, but with regard to 9) to 13), the reference materials are sometimes difficult to obtain. In most cases, the preliminary survey team are sent to the survey site for the confirmaton of these items under the cooperation and assistance of the local authorities concerned.

In this study conducted in Republic of Singapore, these items have been carefully checked and investigated and the survey items have been determined.

The field survey have been conducted in two areas, Pulau Seraya and Pulau Tekong. Fig. II-1-2-(1) shows the survey areas which are extending around two islands.

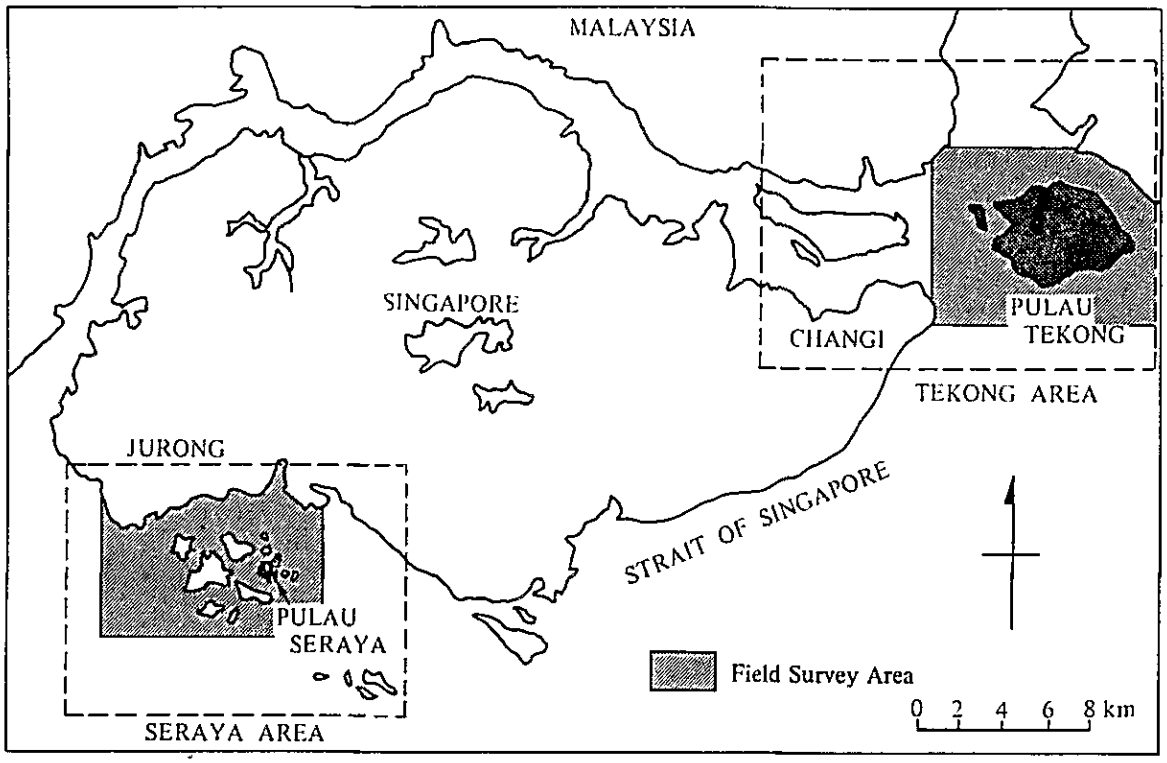



Fig. II-1-2-(1) Field survey areas

— Pulau Seraya area

Pulau Seraya area is located in front of Jurong industrial area which is extending in the south/west part of the Republic of Singapore. Seraya survey area include Pulau Seraya, Pulau Merlimau, Pulau Ayer Merbau, Pulau Ayer Chawan, Pulau Sakra, Pulau Pesek and other small islands. Further to the east/south of Pulau Seraya area, there exist Pulau Bukon, Pulau Semakau, Pulau Sebarok, Pulau Sudong, Pulau Pawai, Pulau Semany and other small islands.

Fig. II-1-2-(2) shows the survey points of Pulau Seraya area, and Table II-1-2-(3) shows the latitude and longitude of the survey points. Fig. II-1-2-(3) shows depth curve chart of the area.

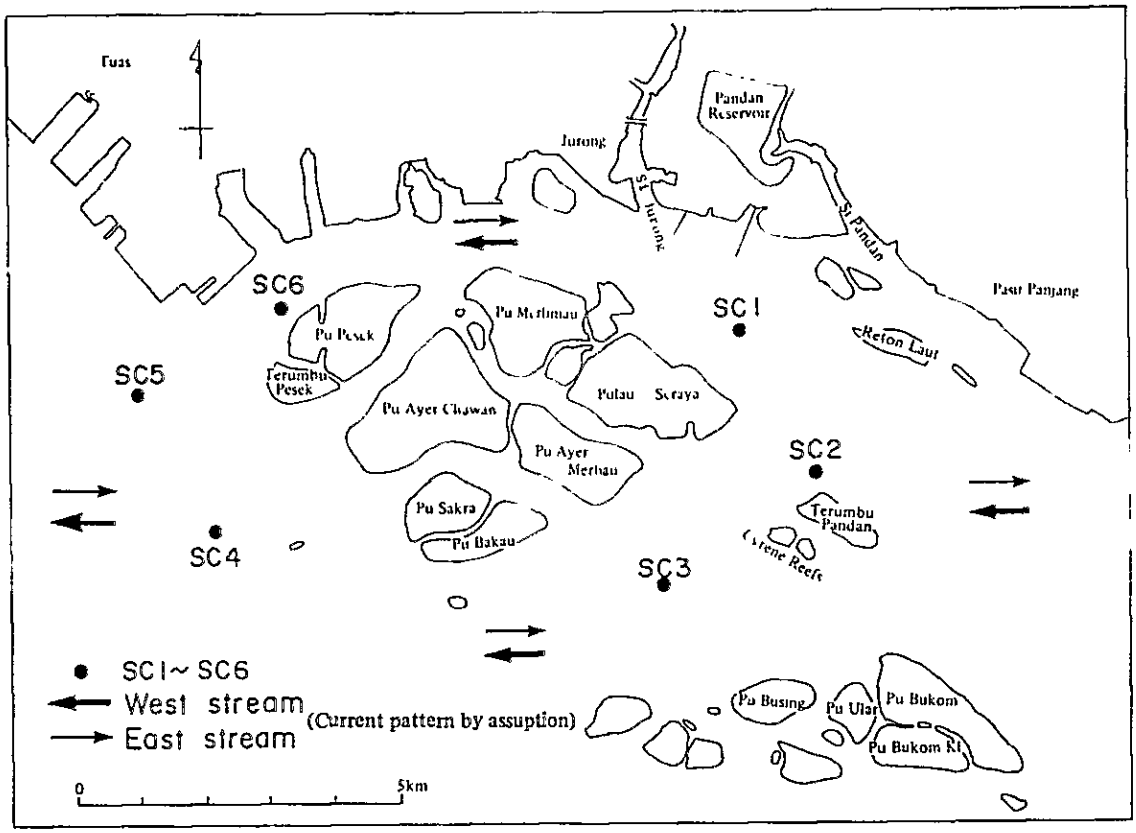



Fig. II-1-2-(2) Survey points of Pulau Seraya Area

Table II-1-2-(3) Location of observation of Pulau Seraya Area

| Station Number | Name of Buoy and Beacon | Position | | Depth (m) | Observation Layer (m) |
|---|---|---|---|---|---|
| | | Lat. N | Long. E | | |
| SC1 | Pusing Beacon | 01° 17' 01" | 103° 44' 31" | 14 | 11 |
| SC2 | North Cyrone Buoy | 01° 15' 53" | 103° 45' 09" | 23 | 15 |
| SC3 | Sawa Buoy | 01° 15' 05" | 103° 43' 57" | 20 | 12 |
| SC4 | Essoy No. 1 Buoy | 01° 15' 26" | 103° 40' 12" | 16 | 8 |
| SC5 | Triton Beacon | 01° 16' 27" | 103° 39' 33" | 13 | 8 |
| SC6 | Pesek Beacon | 01° 17' 18" | 103° 40' 51" | 15 | 10 |
| | | | | (average 16.8m) | |

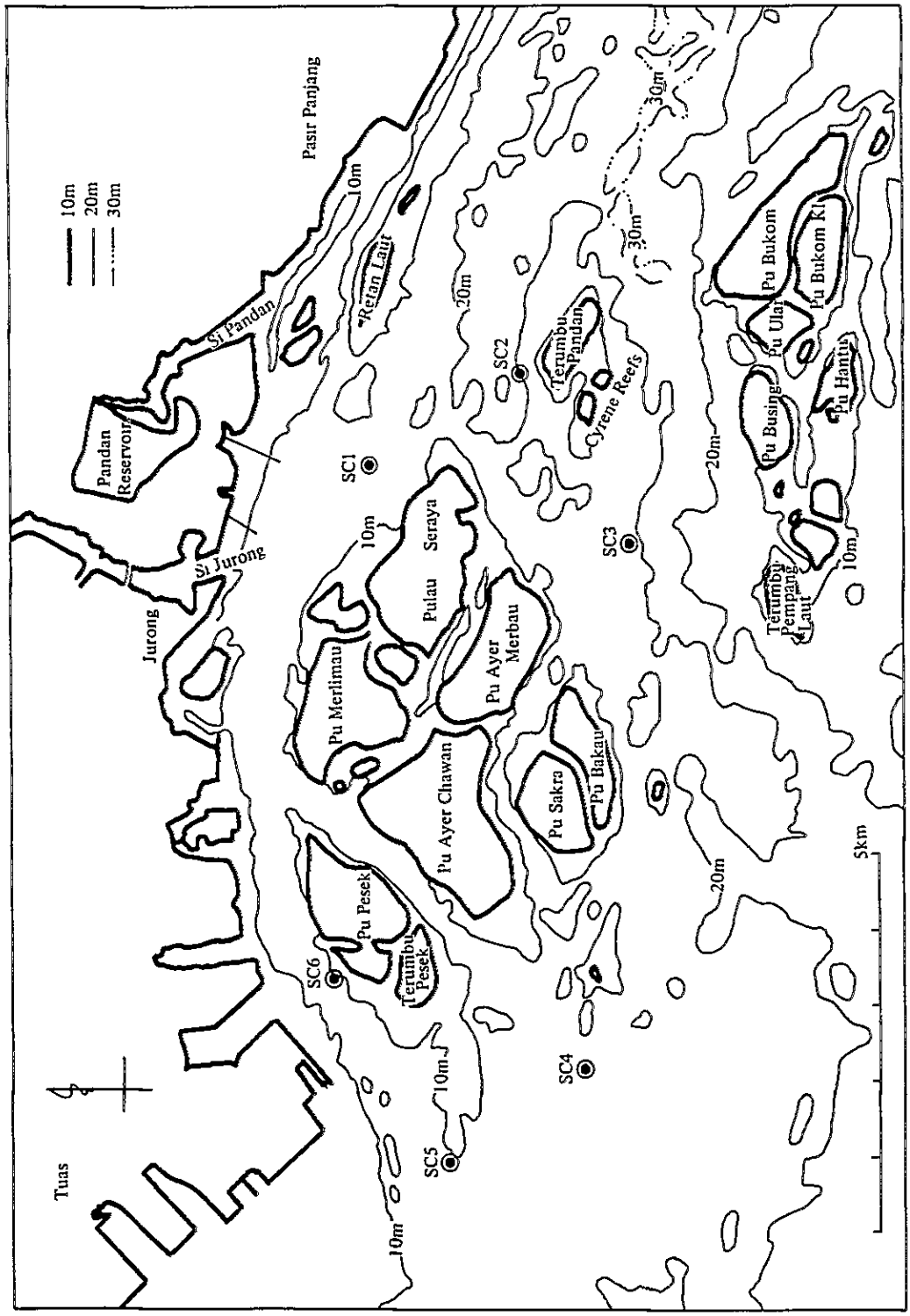


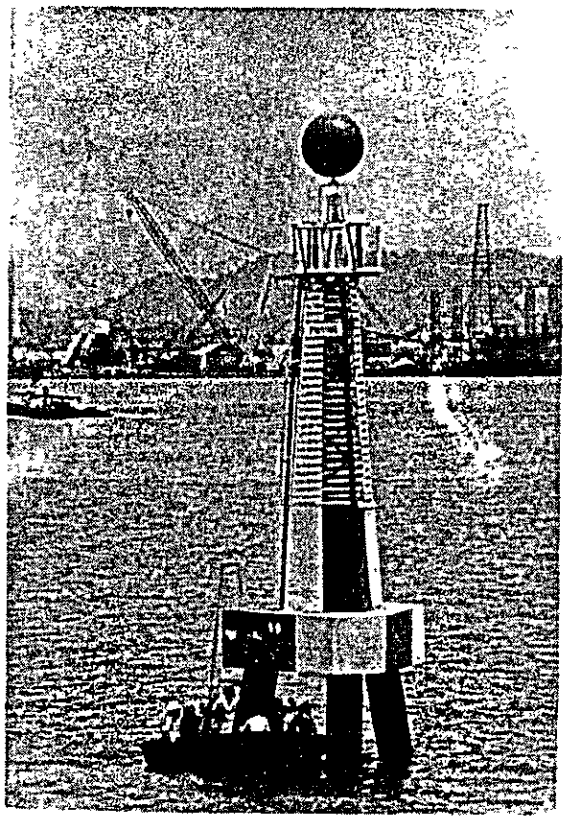

Fig. II-1-2-(3) Bottom topography chart of Pulau Seraya Area

As shown in Fig. II-1-2-(2), the survey points are observed surrounding Pulau Seraya and othe islands (hereinafter referred to as "Seraya Area" due to the assumption that there will be the eastward and westward currents).

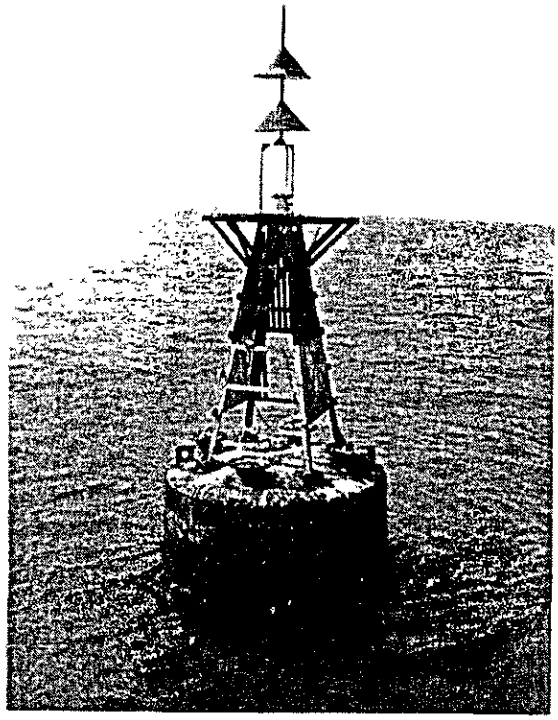
Fig. II-1-2-(2) shows the assumed current patterns by vector. Regarding to the depth distribution of the survey area, the east side of Pulau Seraya is deeper. The deepest is located between Seraya Area and Pulau Bukom. The isobath of -20 m is extending from east to west which is making waterway. Therefore the depth of SC2 and SC3 are the deepest among 6 survey points as these two are located in this area. For reference, the average depth of 6 survey points is 16.8 m but SC2 and SC3 are both -20 m.

At the survey points as shown in Table II-1-2-(3), the existing light buoys and beacon towers were utilized for mooring the current meters. The consideration has been given to the current meters not being obstacled by the navigation of ships and steamers. Fig. II-1-2-(4) shows the pictures of light buoys and beacon towers which represent the survey point, SC1 to SC6.

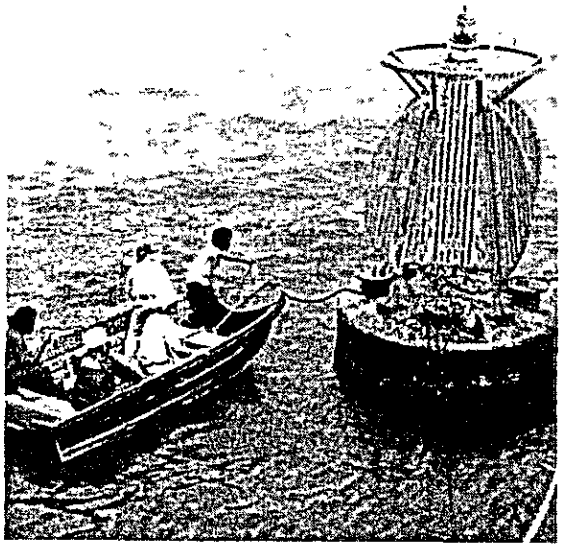
SC1



SC2



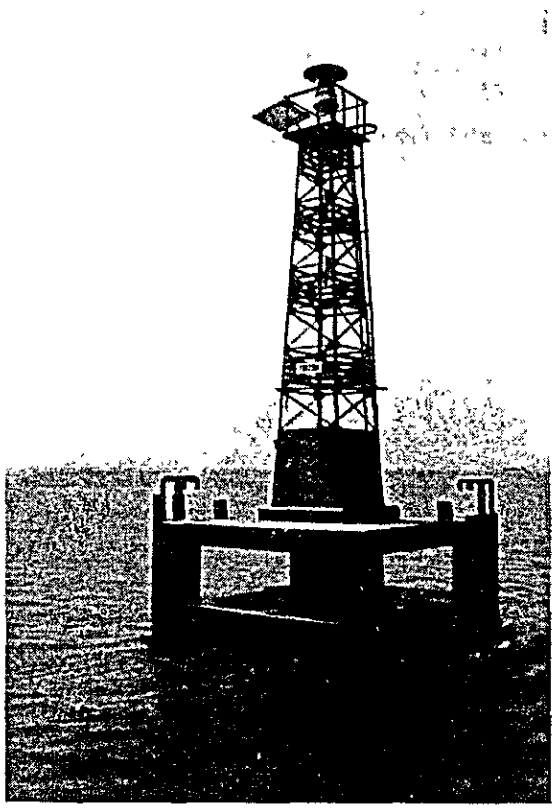
SC3



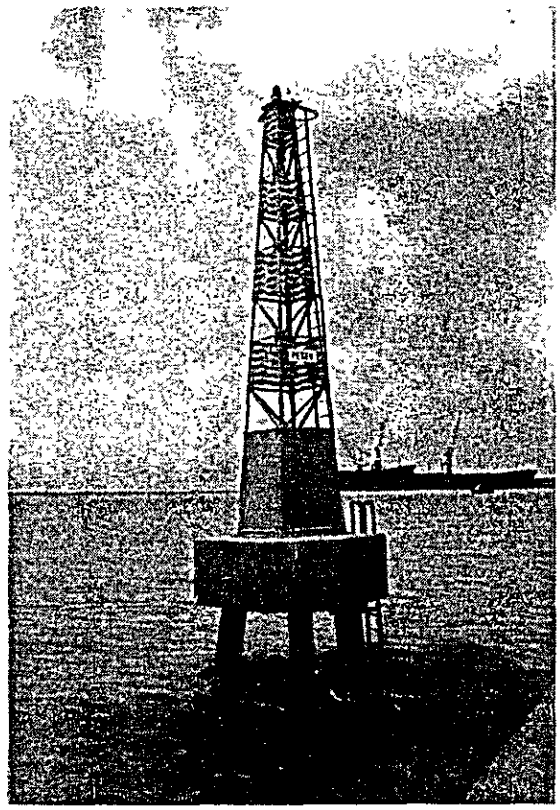
SC4

Fig. II-1-2-(4) Suvey points of Pulau Seraya Area (1)

SC5



SC6



Light buoy for SC1 ~ SC6

Fig. II-1-2-(4) Suvey points of Pulau Seraya Area (2)

— Pulau Tekong Area

Pulau Tekong Area is located at the north/east side of the Republic of Singapore and faced to the east outlet of the Straits of Johor. The area consists of Pulau Tekong, Pulau Tekong Kechil and other small islands. The east side of Pulau Tekong area is Malaysia over the Straits of Johor.

In Pulau Tekong area, 4 survey points were determined. Fig. II-1-2-(5) shows the location of 4 survey points and Table II-1-2-(4) shows those latitude and longitude. Fig. II-1-2-(6) shows the bottom topography chart of the area.

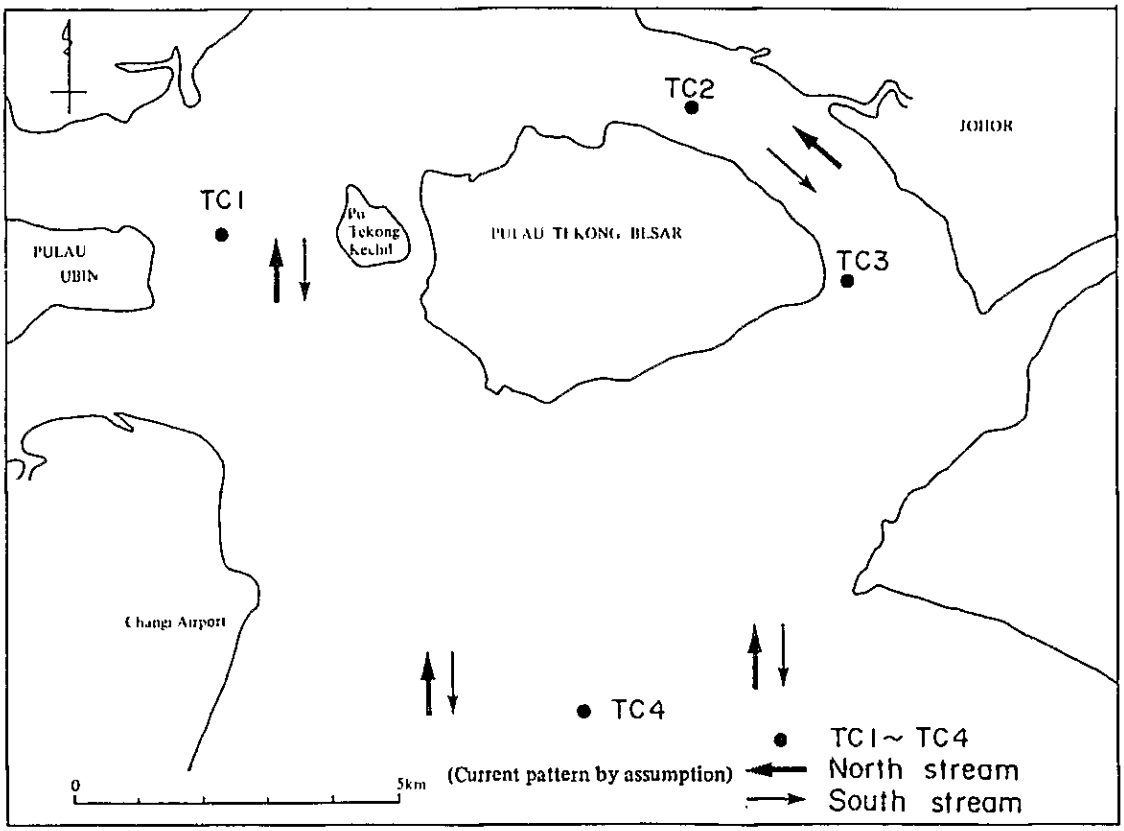



Fig. II-1-2-(5) Survey points of Pulau Tekong Area

Table II-1-2-(4) Locations of observation of Pulau Tekong Area

| Station Number | Name of Buoy and Beacon | Position | | Depth (m) | Observation Layer (m) |
|---|---|---|---|---|---|
| | | Lat. N | Long. E | | |
| TC1 | | 01° 25′ 00″ | 104° 00′ 08″ | 26 | 16 |
| TC2 | | 01° 26′ 03″ | 104° 04′ 03″ | 12 | 7 |
| TC3 | | 01° 24′ 39″ | 104° 05′ 20″ | 12 | 7 |
| TC4 | Angler Buoy | 01° 21′ 06″ | 104° 03′ 07″ | 16 | 8 |
| | | | | (average 16.5m) | |

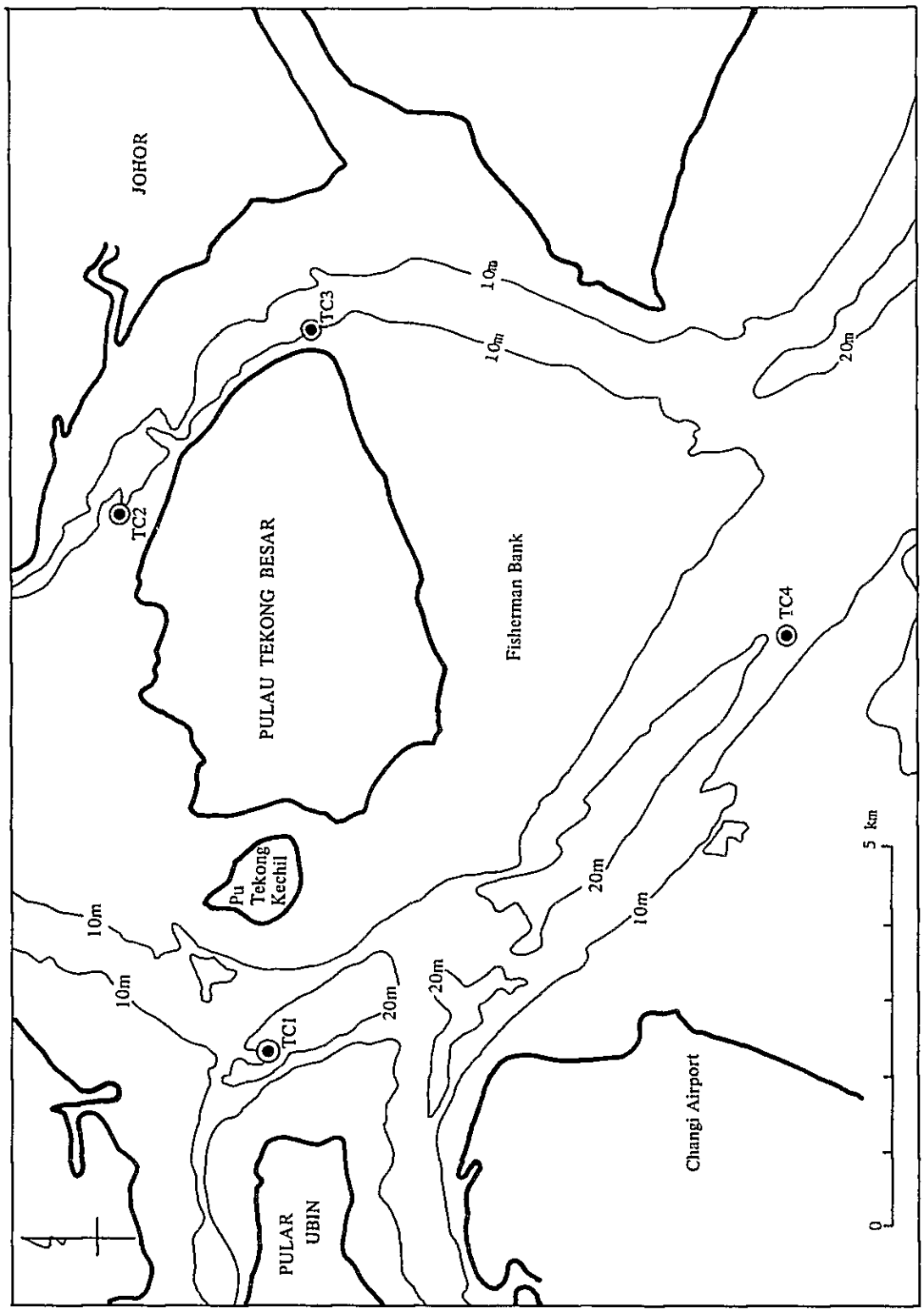



Fig. II-1-2-(6) Bottom topography chart of Pulau Tekong Area

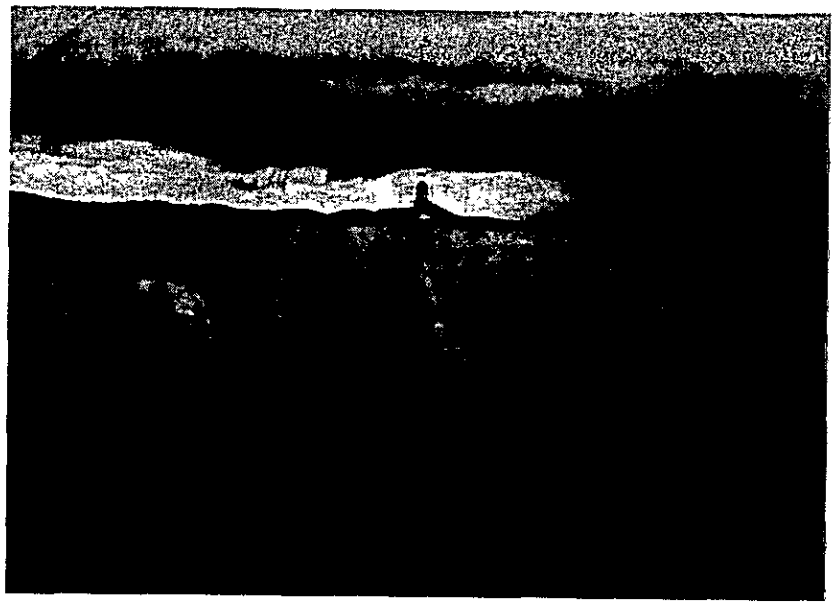
As shown in Fig. II-1-2-(5), the survey points were observed surrounding Pulau Tekong, due to the assumption that the current conditions of the area is dominated by the north/south ward current around Pulau Tekong. The assumed current pattern is shown in Fig. II-1-2-(6) expressed by vector.

With regard to the bottom topographgy, fisherman bank area, south side of Pulau Tekong, is very shallow, which is less than 1 m, and the sea area between Pulau Ubin, Changi and Pulau Tekong is deep. Therefore the depth of TC1 which is located in this are is the deepest among 4 survey points. For reference, the averaged depth of 4 survey points is 16.5 m although TC1 is 26 m.

Among 4 survey points, (TC1 to TC4), light buoys have been brought from Japan for setting at TC1 to TC3 as there were no existing light buoys or beacon towers at these points. At TC4, the existing buoy was utilized.

Fig. II-1-2-(7) shows the pictures of light buoys for TC1 to TC3 and a existing light buoy for TC4.

Zeni-Light buoy for TC1 ~ TC3



Light buoy for TC4

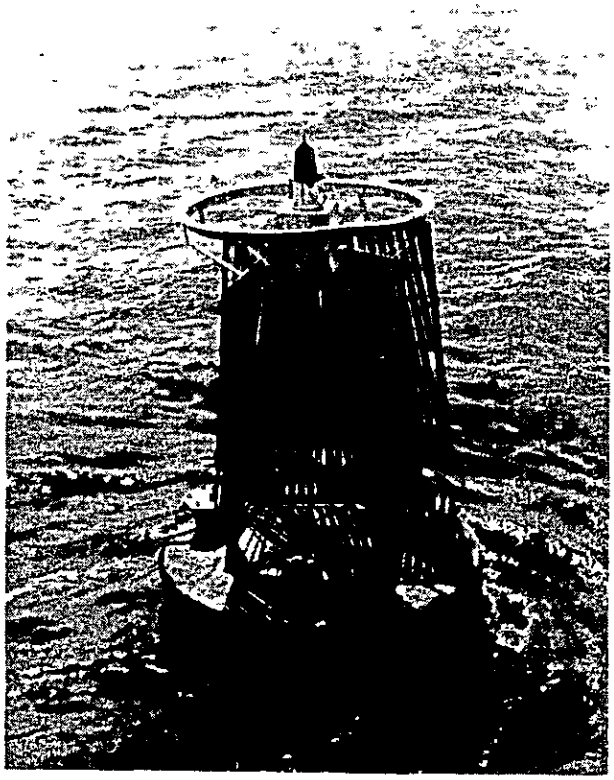


Fig. II-1-2-(7) Light buoy for TC1 ~ TC3 and light buoy for TC4

II-1-2-2 Daily progress of survey

1) Total time schedule

Table II-1-2-(5) shows the total time schedule of the survey which includes the survey for temperature, salinity and water quality. The total survey schedule is as under.

| | | |
|---|---|---|
| 1981 | February 15th | Survey team arrived in Singapore |
| | Febraury 15th - February 22nd | Preparation works |
| | February 23rd - Febraury 27th | Mooring of current meters |
| | February 28th - March 12th | Patrol on current meters survey on temperature, salinity and water quality |
| | March 13th | Withdrawal of current meters at Pulau Seraya Area |
| | March 17th | Withdrawal of current meters at Pulau Tekong Area |
| | March 18th - March 25th | Collection and arrangement of data and others |
| | March 26th | Departure of survey team |

The field survey has been conducted under the close cooperation of Jurong Town Corporation as well as Port of Singapore Authority (PSA) who provided the survey team with the vessel "PESEK" which was so powerful and helpful in mooring and withdarwal of the current meters.

All the activities related to the field survey has been progressed according to the schedule prepared under the close consultation between the survey team and JTC. The schedules are shown in Table II-1-2-(6) and Table II-1-2-(7).

Table II-1-2-(5) Singapore environmental study, field survey

Schedule for Water Quality

| | |
|---|---|
| Feb. 15th (Sun) fine & shower | Japanese survey team (9 persons) arrive in Singapore |
| Feb. 16th (Mon) fine | Meeting with JTC officers and briefing on survey plan |
| Feb. 17th (Tue) fine & shower | Inspection tour of survey areas |
| Feb. 18th (Wed) fine | Official visit to PSA<br>Unpacking of the instruments<br>Meeting with divers<br>Meeting with JTC officers |
| Feb. 19th (Thu) fine | Arrangement and adjustment of instruments<br>Official visit of National University of Singapore (NUS)<br>Official visit to EDB (Economic Development Board)<br>Meeting with JTC officers |
| Feb. 20th (Fri) fine | Preparation work for setting current meters<br>Transferred analytical instruements to NUS |
| Feb. 21st (Sat) fine | Preparation work for settig current meters<br>Adjustment of analytical instruments |
| Feb. 22nd (Sun) fine | Rest day |
| Feb. 23rd (Mon) fine | Loadig the instruments and materials on Pesek<br>Mooring current meters at Seraya Area (SC1, SC2 and SC3) |
| Feb. 24th (Tue) fine | Mooring current meters at Seraya Area (SC4, SC5, and SC6) |
| Feb. 25th (Wed) fine & shower | Patrol at Seraya Area and tape-change at SC1, arrangement of collected tape, preparation for chemical analysis |
| Feb. 26th (Thu) fine & shower | Mooring current meters at Tekong area (TC1, TC2 and TC3)<br>Patrol at Seraya Area |
| Feb. 27th (Fri) rain | Mooring current meter at Tekong area (TC4)<br>Patrol at Seraya Area<br>Preparation for chemical analysis |
| Feb. 28th (Sat) fine | Patrol at Tekong Area<br>Meeting with JTC officers<br>Preparation for water quality survey |
| Mar. 1st (Sun) fine | Rest day |
| Mar. 2nd (mon) fine | Water quality survey at Seraya Area |
| Mar. 3rd (Tue) fine | Tape change at Seraya Area (SC3, 4, 5, 6)<br>Patrol at Tekong Area |
| Mar. 4th (Wed) rain | Water quaity survey at Tekong area suspended because of rain<br>Chemical analysis<br>Data arrangement for the collected data |

| | |
|---|---|
| Mar. 5th (Thu) fine | Water quality survey at Tekong area |
| Mar. 6th (Fri) fine | Patrol at Seraya Area<br>Tape change at Tekong Area (TC1, 2, 3, 4)<br>Chemical analysis |
| Mar. 7th (Sat) fine | Tape change at Seraya Area (SC1 and 2)<br>Patrol at Tekong Area<br>Collected data arrangement<br>Chemical analysis |
| Mar. 8th (Sun) fine | 2 members departed |
| Mar. 9th (Mon) fine | Tape change at Seraya Area (SC3, 4, 5, 5, 6)<br>At SC5 float-buoy found lost, and current meter collected<br>Patrol at Tekong Area<br>Chemical analysis |
| Mar. 10th (Tue) fine | Remooring current meter at Seraya Area (SC5)<br>Patrol at Tekong area<br>Collected data arrangement<br>Transport analytical instruments from NUS to JTC |
| Mar. 11th (Wed) fine | 2 member departed<br>Patrol at Seraya Area<br>Tape change at Tekong Area (TC1, 2, 3, 4) |
| Mar. 12th (Thu) fine | Tape change at Seraya Area (ST1, 2)<br>Patrol at Tekong Area |
| Mar. 13th (Fri) fine | Withdrawal of current meters at Seraya Area (SC1 to 6) |
| Mar. 14th (Sat) fine | Collected data arrangement |
| Mar. 15th (Sun) fine | Reset day |
| Mar. 16th (Mon) fine | Patrol at Tekong Area<br>Collected data arrangement<br>Meeting with JTC officers |
| Mar. 17th (Tue) fine | Withdrawal of current meters at Tekong Area (TC1 to 4) |
| Mar. 18th (Wed) fine | Unloading the instruments and materials from Pesek.<br>Collected data arrangement<br>Delivery 3 Zenilight Buoy to JTC |
| Mar. 19th (Thu) fine | Packing instruments for transportation to Japan |
| Mar. 20th (Fri) fine | Delivery of cargoes to shipping agent |
| Mar. 21st (Sat) fine & shower | Technical visits to U1 Pandon Waste Incineration Plant and Sewage Treatment Plant |
| Mar. 22nd (Sun) fine & shower | Rest day |
| Mar. 23rd (Mon) fine | Technical visit to Jurong Power Station<br>Official visit to NUS |
| Mar. 24th (Tue) fine | Meeting at JTC for reporting the outline of survey<br>Official visit to PSA and reported outline of survey |
| Mar. 25th (Wed) fine | Meetig with JTC |
| Mar. 26th (Thu) fine | Departure of survey team |

Table II-1-2-6-(1) Time schedule

ENVIRONMENTAL STUDY

TENTATIVE SCHEDULE

| | | |
|---|---|---|
| **Sunday, 15 Feb 81** | | |
| 6:55 pm | : | Arrival at Paya Lebar Airport by JL 715 |
| **Monday, 16 Feb 81** | | |
| 9:00 am | : | JTC coach to pick up team from Hotel for Jurong Town Hall |
| 9:30 am - 12:00 pm | : | Meeting with JTC officers |
| 12:00 pm - 2:00 pm | : | Lunch |
| 2:15 pm - 5:00 pm | : | Inspection of SIU facilities<br>Checking equipment at Town Hall<br>JTC coach to send team back to Hotel |
| **Tuesday, 17 Feb 81** | | |
| 8:30 am | : | Contractor's coach to pick up team from Hotel |
| 9:00 am - 12:00 pm | : | Inspection of 6 monitoring points around Pulau Seraya by boat |
| 2:00 pm - 5:00 pm | : | Inspection of 4 monitoring points around Pulau Tekong by boat<br>Coach to send team back to Hotel |
| **Wednesday, 18 Feb 81** | | |
| 8:30 am | : | Contractor's coach to pick up team from Hotel |
| 9:00 am - 10:30 am | : | Meeting with PSA officers |
| 11:00 am - 12:00 pm | : | Adjustment and preparation of equipment |
| 2:00 pm - 5:00 pm | : | Job briefing for all involved, including divers<br>Adjustment and preparation of equipment<br>Coach to send team back to Hotel |
| **Thursday, 19 Feb 81** | | |
| 8:30 am | : | Coach to pick up team from Hotel |
| 9:00 am - 12:00 pm | : | i) Meeting with JTC officers<br>ii) Preparation of equipment |
| 2:30 pm - 5:00 pm | : | Meeting with EDB officers<br>Preparation of equipment<br>Coach to send team back to Hotel |
| **Friday, 20 Feb 81** | | |
| 8:30 am | : | Coach to pick up team from Hotel |
| 9:00 am - 12:00 pm | : | Meeting with JTC officers<br>Preparation of additional minutes of meeting<br>Preparation of equipment |
| 2:00 pm - 5:00 pm | : | Preparation of equipment<br>Coach to send them back to Hotel |
| **Saturday, 21 Feb 81** | | |
| 8:30 am | : | Coach to pick up team from Hotel |
| | : | Meeting with JTC officers<br>Preparation of additional minutes of meeting |
| 9:00 am - 1:00 pm | : | Adjustment of equipment<br>Coach to send team back to Hotel |

Table II-1-2-6-(2) Time schedule

ENVIRONMENTAL STUDY

TENTATIVE SCHEDULE (WEEK 2)

| | | |
|---|---|---|
| **Monday, 23 Feb 81** | | |
| 8:00 am | : | Term Contractor to provide 1 no 3T crane and 2 nos 3T lorries at Town Hall |
| | | Contractor's launch to be at Jurong Town Pier |
| | | Contractor's coach to pick up Team from Hotel |
| | | Contractor's labourers to report at Town Hall |
| | | Divers to report to Town Hall with equipment |
| 8:30 am - 9:30 am | : | Loading equipment onto lorries |
| 9:00 am | : | PSA's buoy tender 'Pesek' to arrive at Jurong Marine Base (JMB) |
| 9:45 am - 11:00 am | : | Loading equipment onto 'PESEK' at JMB |
| 11:30 am - 3:00 pm | : | Setting up equipment at 3 points around Pulau Seraya |
| 3:00 am - 5:00 pm | : | Reserved |
| | | Patrol around Pulau Seraya |
| | | Coach to send team back to Hotel |
| **Tuesday, 24 Feb 81** | | |
| 8:00 am | : | Contractor's coach to pick team up from Hotel |
| | | Contractor's labourers to be at Jurong Town Pier |
| | | PSA's 'Pesek' to be at Jurong Town Pier |
| | | Contractor's launch to be at Jurong Town Pier |
| 8:30 am | : | Depart Jurong Town Pier for Pulau Seraya area |
| 9:00 am - 12:30 pm | : | Setting up equipment around Pulau Seraya area |
| 2:00 am - 5:00 pm | : | Reserved |
| | | Patrol around Pulau Seraya |
| | | Coach to send team back to Hotel |
| **Wednesday, 25 Feb 81** | | |
| 8:00 am | : | Contractor's coach to pick up team from Hotel |
| | | Divers to report at Jurong Town Pier |
| | | PSA's 'Pesek' to be at Jurong Town Pier |
| | | Contractor's launch to be at Jurong Town Pier |
| | | Contractor's labourers to be at Jurong Town Pier |
| 8:30 am | : | Leave Jurong Town Pier for Pulau Seraya area |
| 9:00 am - 12:30 pm | : | Reserved for setting up equipment around Pulau Seraya area |
| 2:00 pm - 5:00 pm | : | Reserved |
| | | Patrol around Pulau Seraya |
| | | Coach to send team back to Hotel |
| **Thursday, 26 Feb 81** | | |
| 8:00 am | : | Contractor's coach to pick up team from Hotel |
| | | Divers to report at Jurong Town Pier |
| | | Contractor's launch to be at Jurong Town pier |
| | | Contractor's labourers to be at Jurong Town Pier |
| | | PSA's 'Pesek' to go for refuelling and proceed to station at Pulau Tekong |
| 8:30 am | : | Leave Jurong Town Pier for Pulau Seraya area |
| 9:00 am - 5:00 pm | : | Patrol around Pulau Seraya area |
| | | Coach to send team back to Hotel |

Friday, 27 Feb 81

| | | |
|---|---|---|
| 8:00 am | | : Coach to pick up team from Hotel<br>Contractor's laboureres to be at Hotel<br>Divers to report at Changi Point Pier<br>PSA's 'Pesek' to be at Changi Point<br>Contractor's launch to be at Jurong Town Pier and Changi Point Pier |
| 9:00 am - | 5:00 pm | : Group 1 : Depart Changi Point Pier<br>Group 2 : Depart Jurong Town Pier<br>Group 3 : NUS |
| 9:00 am - | 5:00 pm | : Setting equipment around Pulau Tekong area<br>Patrol around Pulau Seraya area<br>Coach to send team back to Hotel |

Saturday, 28 Feb 81

| | | |
|---|---|---|
| 8:00 am | | : Coach to pick up team from Hotel<br>Contractor's labourers to be at Hotel<br>Divers to report at Changi Point Pier<br>PSA's 'Pesek' to be at Change Point Pier<br>Contractor's launch to be at Changi Point Pier and Jurong Town Pier |
| 9:00 am - | 1:00 pm | : Group 1 : Depart Changi Point Pier<br>Group 2 : Depart Jurong Town Pier<br>Group 3 : NUS |
| 1:00 pm - | 3:00 pm | : Setting equipment around Pulau Tekong area<br>Patrol around Pulau Seraya area<br>Coach to send team back to Hotel |

Table II-1-2-(7) Tentative time schedule, personnel, transport, equipment requirements
Environmental Study - Water Quality, 1981

## TENTATIVE TIME SCHEDULE, PERSONNEL, TRANSPORT, EQUIPMENT REQUIREMENTS
## ENVIRONMENTAL STUDY — WATER QUALITY, 1981

| 1981/Date | Description | Personnel | | | | Transport | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Engr | Tech Off | Diver | Labourer | Motor Coach | Land Rover | Buoy Tender | Boat W/Crane | Motor Launch | |
| Sun 15 Feb. | Arrival in Singapore | | | | | 1 | 1 | | | | Paya Lebar Air port. |
| Mon 16 Feb | Meeting with JTC officers<br>Checking equipment at Town Hall | | | | | 1 | | | | | |
| Tue 17 Feb | Survey tour of 10 monitoring points<br>Checking equipment at Town Hall<br>Meeting with various authorities | 2 | 1 | | 5 | 1 | 1 | | | 2 (TP) (CC) | |
| Wed 18 Feb | Adjustment of equipment<br>Briefing on job schedules | 2 | 1 | 2 | 5 | 1 | | | | | |
| Thurs 19 Feb | Adjustment and preparation of equipment | 1 | 1 | | 5 | 1 | | | | | |
| Fri 20 Feb | Adjustment and preparation of equipment | 1 | 1 | | 5 | 1 | | | | | |
| Sat 21 Feb | Adjustment and preparation of equipment | 1 | 1 | | 5 | 1 | | | | | |
| Sun 22 Feb | Rest Day | | | | | | | | | | |

Notes:
- JTC
- PSA
- Term Contractor
- PSA/Hire
- Hire/Quotation
- TP: Town Pier
- CC: Changi Creek

1. Motor coach to pick up Japanese Team from Hotel in the morning and send Team back to Hotel in the evening.
2. Launch and sea transport to be at location indicated at appointed time in the morning.

| 1981/Date | Description | Personnel | | | | Transport | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Engr | Tech Off | Diver | Labourer | Motor Coach | Land Rover | Buoy Tender | Boat W/Crane | Motor Launch | |
| Mon 23 Feb | Setting equipment at 3 points around Pulau Seraya | 1 | 1 | 2 | 5 | 1 | 1 | 1 (TP) | | 1 (TP) | |
| Tue 24 Feb | Setting equipment at 3 points around Pulau Seraya | 1 | 1 | 2 | 5 | 1 | 1 | 1 (TP) | | 1 (TP) | |
| Wed 25 Feb | Reserved for setting and patrol around Pulau Seraya | | | 2 | 5 | 1 | | 1 (TP) | | 1 (TP) | |
| Thurs 26 Feb | Loading equipment for transportation to Changi Point | | | 2 | 5 | | 1 | | | | *See detail |
| | Patrol around Pulau Seraya | | | | | 1 | | | | 1 (TP) | |
| Fri 27 Feb | Setting equipment at 2 points around Pulau Tekong | 1 | 1 | 2 | 5 | 1 | | 1 (CC) | | | |
| | Patrol around Pulau Seraya | | | | | | 1 | | | 1 (TP) | |
| Sat 28 Feb | Setting equipment at 2 points Pulau Tekong | 1 | 1 | 2 | 5 | 1 | | 1 (CC) | | | |
| | Patrol around Pulau Seraya | | | | | | 1 | | | 1 (TP) | |
| Sun 1 Mar | Rest Day | | | | | | | | | | |
| Mon 2 Mar | Measurement and sampling at Pulau Seraya | 1 | 1 | 2 | 5 | | 1 | | | 5 (TP) | |
| | Patrol around Pulau Tekong | | | | | | | | | 1 (CC) | |

2) Time schedule of current survey and collection of data

Table II-1-2-(8) shows the time schedule of current survey. The main works involved in the current survey are (1) mooring of the current meters, (2) patrol, (3) collection of recorded data from the currrent meters and (4) withdrawal of the current meters.

These works have been carried out according to the time schedule mentioned in Table II-1-2-(8).

Table II-1-2-(9) shows the specifications of collected data. During the period of current survey, two accidents have occurred at SC4 and SC5 although these accidents are of minor but the data lack for short period could not be avoided.

The accident at SC4 was caused by missing 3 sub-surface buoys due to the unidentified reason and the current meter was lying on the sea bed since evening time of the 12th March, one day before the withdrawal. So the data recorded before the accident was found more than enough in terms of quality and length.

The accident at SC5 was caused by missing 2 sub-surface buoys among 3 as shown in Fig. II-1-(8) due to the unidentified reason and the current meter has inclined at forty-five degrees since the 9th March, and on the next day the 10th March, the current meter has been remoored in proper manner. The data lack for about one day was cuased but the necessary data have been collected satisfactory enough in terms of quality and quantity.

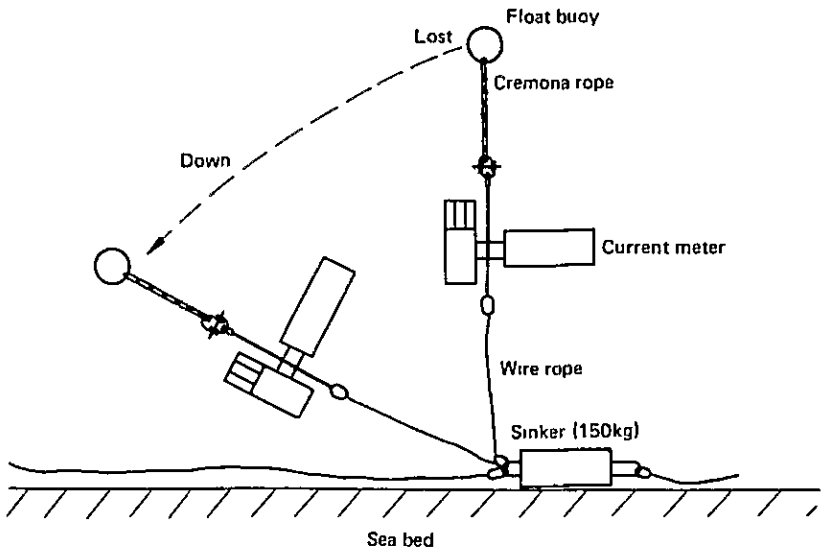



Fig. II-1-8 Accident at SC5

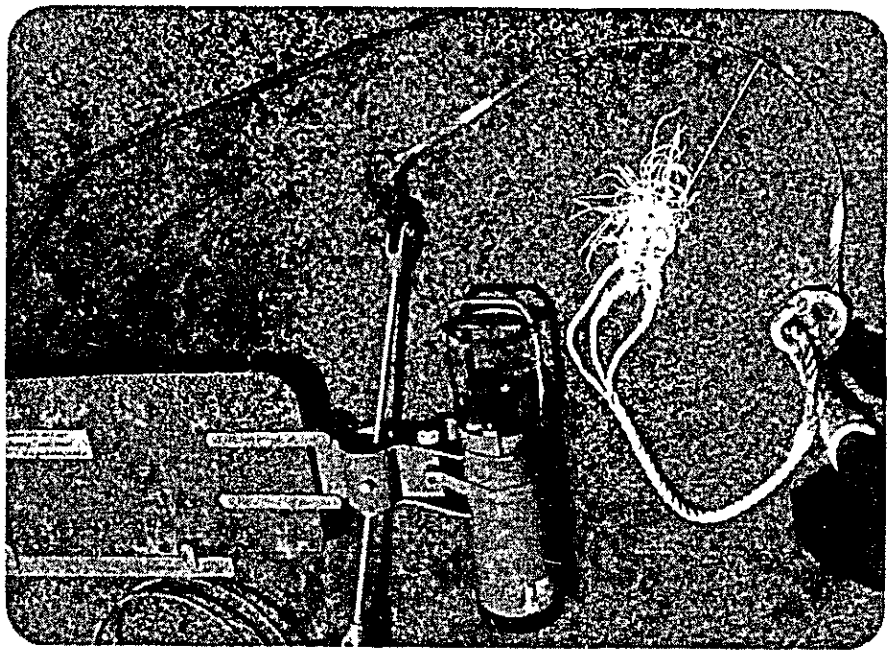


Fig. II-1-2-(9) Accident at SC4

Table II-1-2-(8) Time schedule of current survey

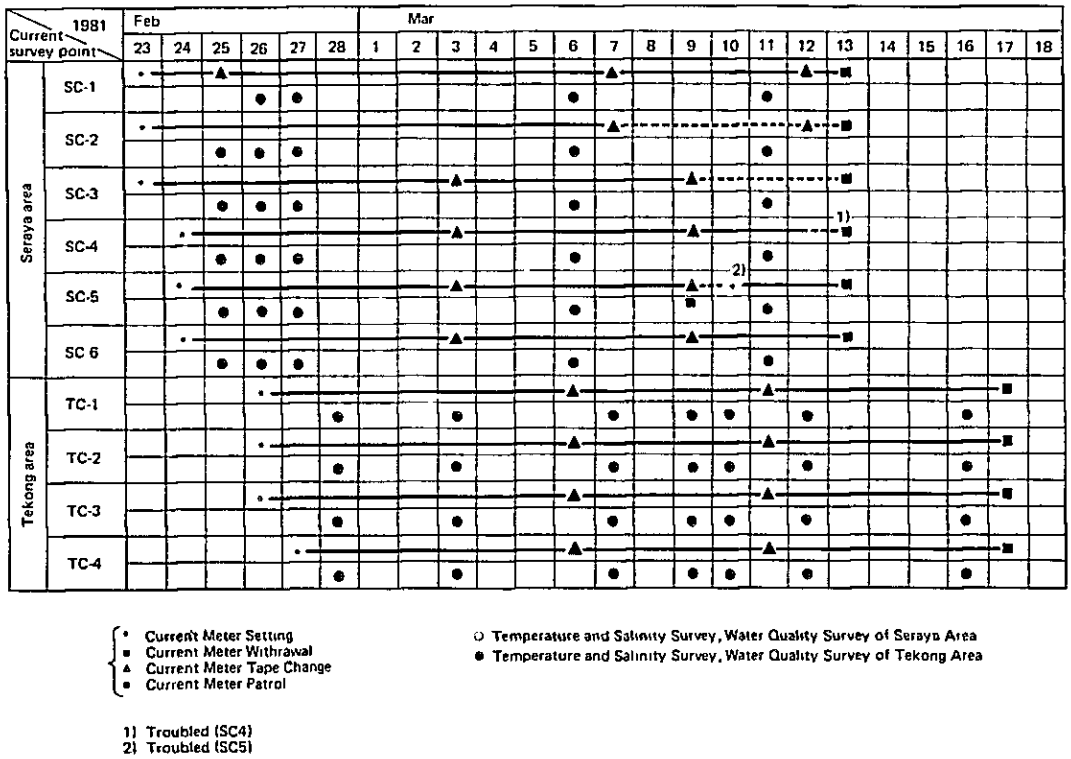



Table II-1-2-(9) Data collection of current survey

| Station | From To | Remarks |
|---|---|---|
| SC1 | Feb. 23. 12:30 to Mar. 13. 10:35 | No Trouble |
| SC2 | Feb. 23. 14:15 to Mar. 13. 11:35 | Velocity Trouble Mar. 8. 19:30 to Mar. 13. 11:35 |
| SC3 | Feb. 23. 15:35 to Mar. 13. 12:20 | All Trouble Mar. 9. 13:10 to Mar. 13. 12:20 |
| SC4 | Feb. 24. 11:35 to Mar. 13. 13:50 | Velocity Trouble Mar. 12. 18:25 to Mar. 13. 13:50 |
| SC5 | Feb. 24. 12:35 to Mar. 13. 13:40 | All Trouble Mar. 9. 11:30 to Mar. 10. 11:20 |
| SC6 | Feb. 24. 13:20 to Mar. 13. 14:25 | No Trouble |
| TC1 | Feb. 26. 11:50 to Mar. 17. 09:55 | No Trouble |
| TC2 | Feb. 26. 13:30 to Mar. 17. 11:35 | No Trouble |
| TC3 | Feb. 26. 14:45 to Mar. 17. 12:00 | No Trouble |
| TC4 | Feb. 26. 15:00 to Mar. 17. 13:00 | No Trouble |