REPUBLIC OF INDONESIA
MINISTRY OF PUBLIC WORKS
DIRECTORATE GENERAL OF WATER RESOURCES DEVELOPMENT

MASTER PLAN STUDY
ON
LOWER ASAHAN RIVER BASIN DEVELOPMENT

INTERIM REPORT
(MAIN)

October 1985.

JAPAN INTERNATIONAL COOPERATION AGENCY

INTERIM REPORT

FOR

MASTER PLAN STUDY

ON

LOWER ASAHAN RIVER BASIN DEVELOPMENT

LIST OF REPORT

PREFACE

It is with great pleasure that I present this "Master Plan Study on the Lower Asahan River Basin Development (Interim Report)" to the Government of the Republic of Indonesia.

This study is composed of two parts, namely Part I on basic direction of the lower basin development and feasibility study on urgent flood control and Part II on development plan in the sector of agriculture.

This report embodies the result of Part I study which was carried out (in the Lower Asahan basin, Sumatra Island) from October 1984 to July 1985 by a Japanese study team commissioned by the Japan International Cooperation Agency following the request of the Government of the Republic of Indonesia to the Government of Japan.

The study team, headed by Mr. Makoto Tsuda of the Nippon Koei Co., Ltd., had a series of close discussion on the Project with officials concerned of the Government of Indonesia and conducted a wide scope of field survey and data analysis.

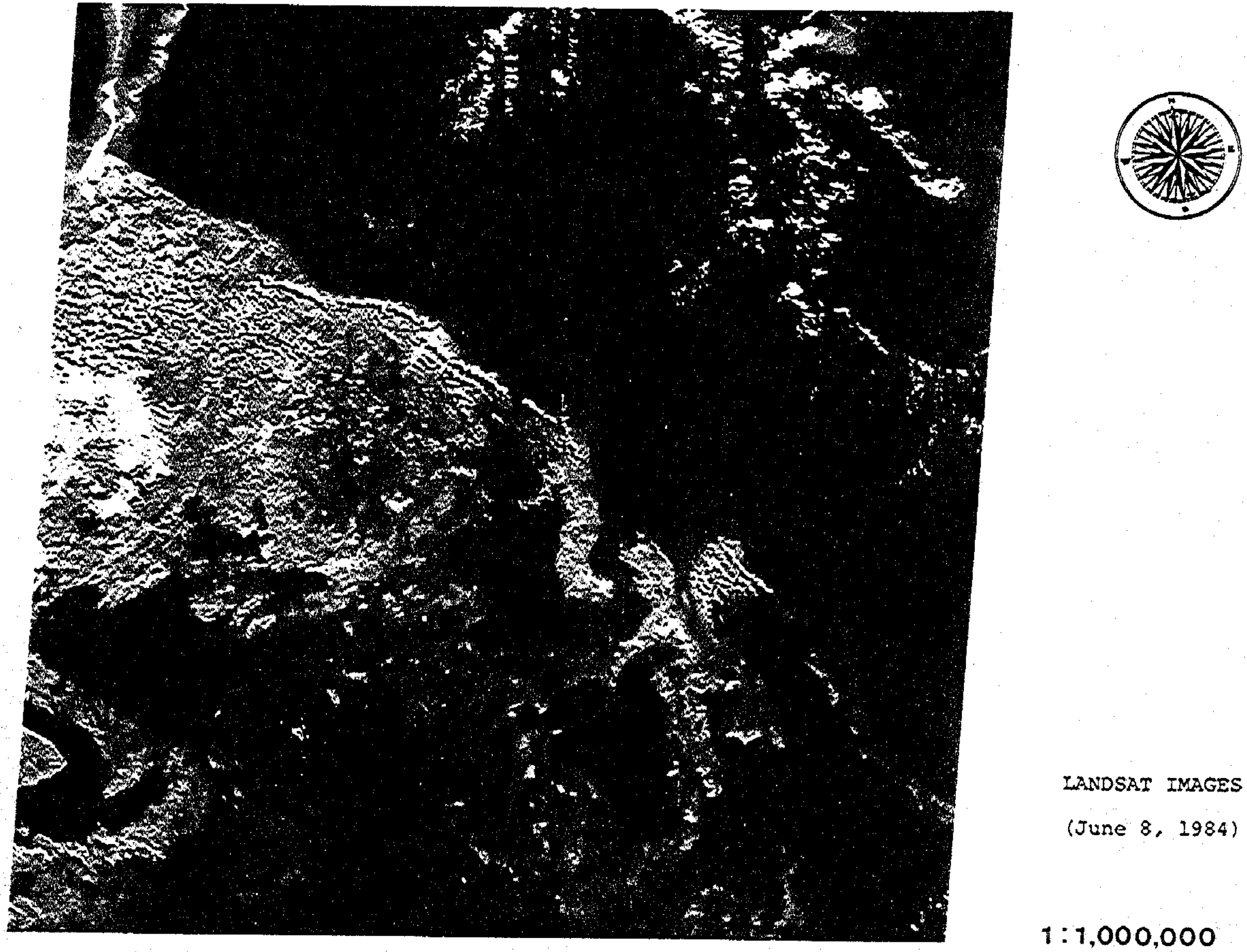
After the survey team returned to Japan, further studies were made and the present report has been formulated.

I hope that this report will be useful as a basic reference for the development of the Project.

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

October 1985

Keisuke Arita
President
Japan International
Cooperation Agency
Tokyo, Japan



LANDSAT IMAGES

(June 8, 1984)

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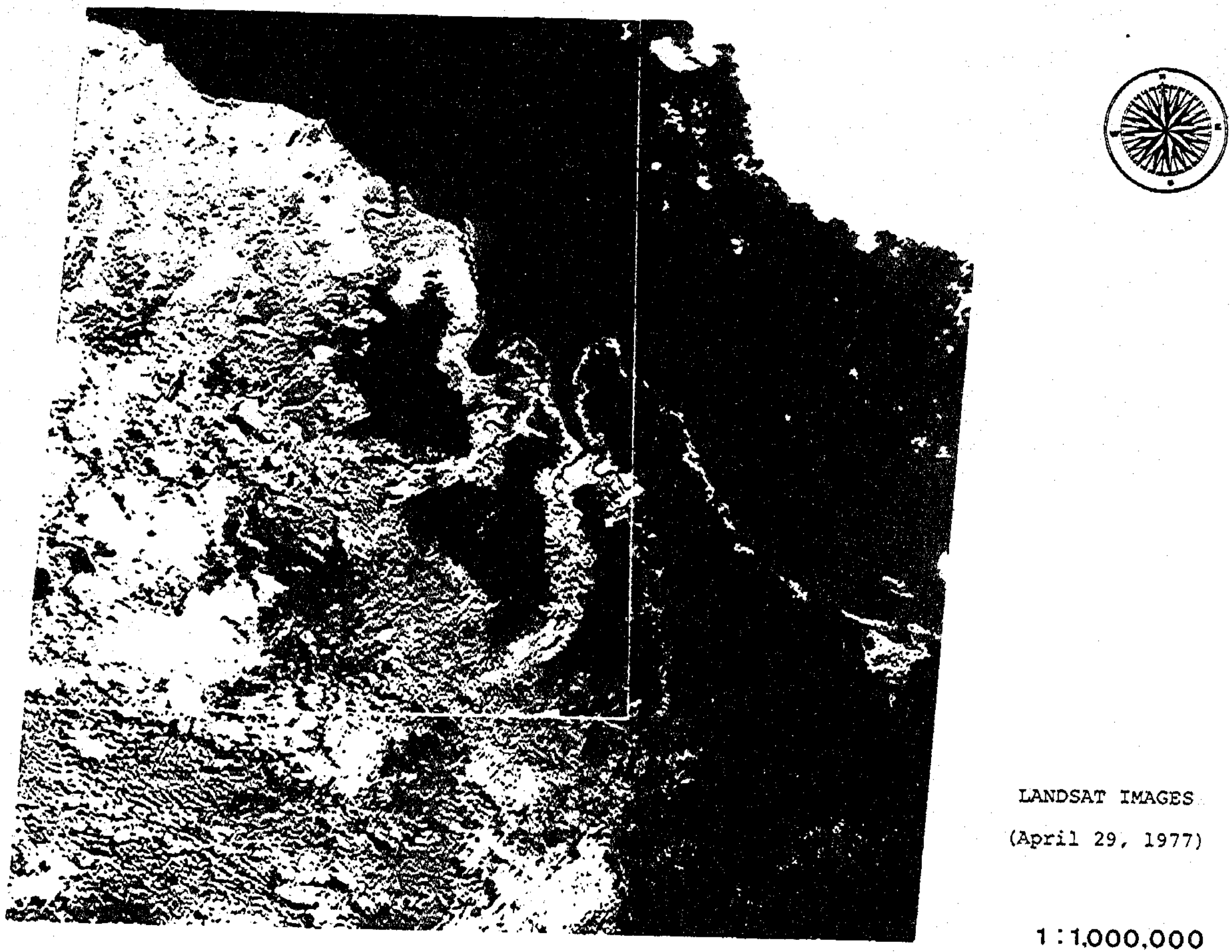

LANDSAT IMAGES

(April 29, 1977)

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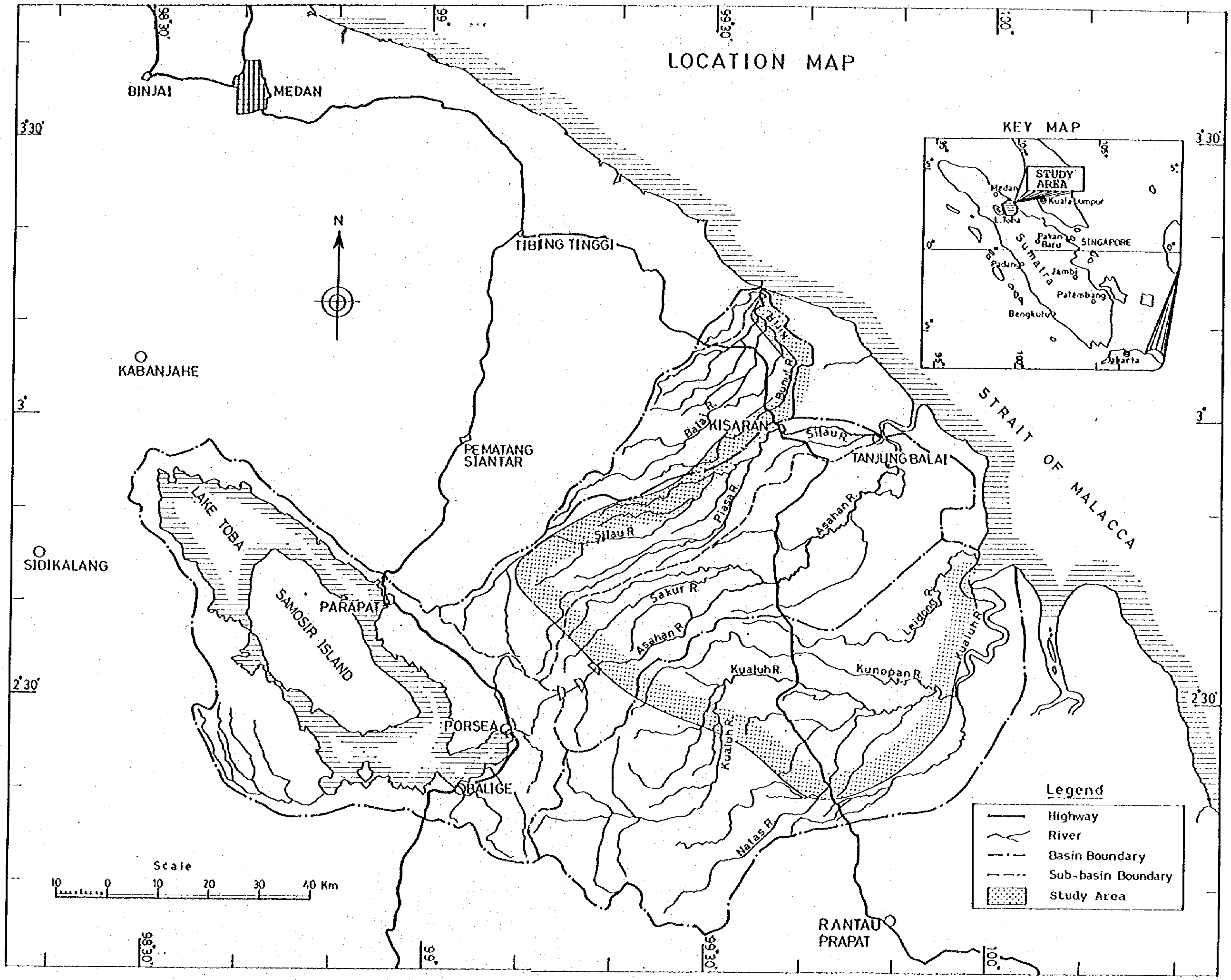

LOCATION MAP
KEY MAP
STUDY AREA
Medan
Kuala Lumpur
L.Toba
Pakan Baru
SINGAPORE
Padang
Sumatra
Jambi
Palembang
Bengkulu
Jakarta
BINJAI
MEDAN
TIBING TINGGI
KABANJAHE
PEMATANG SIANTAR
KISARAN
TANJUNG BALAI
STRAIT OF MALACCA
LAKE TOBA
SAMOSIR ISLAND
SIDIKALANG
PARAPAT
PORSEA
BALIGE
RANTAU PRAPAT
Silau R.
Balai R.
Bunut R.
Piasa R.
Asahan R.
Sakur R.
Leidong R.
Kualuh R.
Kunopan R.
Natas R.
Scale
10 0 10 20 30 40 Km
Legend
Highway
River
Basin Boundary
Sub-basin Boundary
Study Area
3°30'
3°
2°30'
98°30'
99°
99°30'
100°

SUMMARY

1. This study titled as "Master Plan Study on Lower Asahan River Basin Development" aims to establish a Master Plan for land and water resources development in the study area of about 6,000 km^2 extending along the lower reaches of the Asahan, Silau, Bunut and Kualuh rivers. The Master Plan shall envisage the development program up to the year 2005 A.D. from a viewpoint of long-range policies as raising the productivity, increasing employment opportunities, promoting transmigration and improving the living standard in the study area.

2. The program for whole survey and study works was divided into two stages from the viewpoint of efficient and orderly execution, namely Part I and Part II. Part I works aimed to carry out the required surveys and studies mainly for the folowing five objectives:

i) to find the basic direction of land and water resources development based on the socio-economic and natural conditions given in the study area
ii) to establish a master plan for flood control
iii) to make a feasibility study on an urgent flood control project
iv) to make a study and recommendations on water regulation of Lake Toba
v) to report a survey and study program required for Part II works

In continuation to Part I works, Part II works will be carried out mainly for establishment of the agricultural development master plan well coincided with the flood control master plan.

This Interim Report describes all the results of studies for the Part I works.

3. The objective study area lies in Kabupaten Asahan and Labuhan Batu, North Sumatra Province, about 160 km south-east of Medan, capital of the Province. Being blessed with rich water and land resources under the tropical monsoons the study area has been developed mainly with large estates of rubber, oil palm and coconut since long ago. With a population increase, now reaching about 800,000 persons, area of paddy field gradually increased to the present level of about 77,000 ha with supplemental upland field of about 15,000 ha for cropping. However the study area is also suffered from frequent floods due to heavy tropical shower causing considerable damages on crops as well as on social and private properties. In spite of much effort of the Indonesian Government to construct earth dikes in recent years, still the flood carrying capacity of major rivers is far less than the flood peak discharges resulting in frequent distruction of those dikes. Hence, this Master Plan Study for flood control is urgently necessitated.

4. The socio-economic survey and land use survey revealed that the study area has been already developed into excellent land use patterns leaving almost no wasted land except swampy lands. Considerably large size estates of rubber, oil palm and coconut occupy about 32% of the study area and contribute fairly high income, but those estates can not absorb so many labor families. On the contrary very small holding size of paddy field per family, say only about 0.8 ha on an average, makes difficult to support the ever-increasing farming population due to low unit yield of crops. The low yield is mainly attributable to the insufficient irrigation development. Hence, the raising of land productivity of cultivated lands is deemed most urgent need to mitigate the population pressure and increase the per-capita income. The present paddy production in the study area is not sufficient even to the local demand.

The above facts imply the urgent need to establish a flood control master plan and an agricultural development master plan. Especially the urgent flood control measures shall be realized in the most heavily damaged area.

5. The flood control master plan covering four major rivers, Bunut, Silau, Asahan and Kualuh rivers, is presented in this Interim Report. Among alternative plans, the most economical flood control solution was recommended, which mainly consists of earth dikes along those rivers except Asahan river where the combination of earth embankment and natural retarding basin is recommended. The Master Plan aims to protect the lands along rivers from 30-year probable flood.

6. Flood damage survey clarified that most vast and frequent damages have been occurred along the Asahan river downstream reaches lower than Pulau Raja and Silau river lower than Kisaran. Therefore the feasibility study was directed to those rivers. The economical comparison studies revealed that the recommendable scale of urgent flood control plan shall be 10-year probable flood. Feasibility study on the urgent flood control plan clarified that the internal rate of return derived from this project is 12.4% with the total construction cost of 36,484 million Rupiahs.

The geotechnical surveys proved no serious difficulty on the construction of earth embankment as for the foundation and soil materials except careful drying operation of soils before embankment.

7. Water resources survey revealed that abundant fresh water is available in this area from both surface and ground water, while only less than two percent of surface flow is being used at present. Chemical analysis of waters in Lake Toba, Asahan, Silau, Bunut and Kualuh rivers proved good quality for any use without recognizable contamination or pollution. However any future large scale industrial development which might cause water pollution shall be avoided or thoroughly checked not to worsen the water quality.

It was observed that severe irrigation water shortage exists in lower reaches along the Bunut river, especially in dry season, hence a possible diversion plan from Silau river is worthy to study its possibility and economy in Part II study works.

The saline water intrusion near estuary of Asahan river was surveyed. The result proved no bad effect on fresh water utilization since only 6 km from the estuary has the saline water in the bottom even at the spring tide with almost lowest river discharge. The same survey on Kualuh river is recommended in Part II study as explained in the Discussion Note.

8. The sedimentation survey and study revealed not so serious problem existing at present although random cutting of trees in scattered patches is observed, which shall be controled by other administrative means. The river bed between Tanjung Balai and the estuary is gradually silted in a long run of years. But the port function of Tanjung Balai has been shifted by development of inland transportation and port Belawan. It was observed a little rising of river bed of Silau river but not so serious to require urgent dredging at present. However, future long monitoring may be required to see what changes will happen after the urgent flood control facilities are to be completed.

9. Environmental survey proved no serious problem existing at present except improvement of social health. The existence of special malaria mosquitoes, called as Anopheles Sundaicus, which lay their eggs into semi-saline water of 5,000 to 20,000 ppm of salt, suggests negative answer for semi-saline water fish pond development or deep dredging of river bed to allow them further multiplication of those mosquitoes. The flood control and agricultural development will not cause any environmental harms but rather improve living conditions by easy domestic water supply, increase of transportation amenity, etc.

10. The analysis and studies on water regulation of Lake Toba revealed a possible solution to satisfy the requirements from both the flood control and efficient water utilization. The recommendable method suggested to set up the seasonal water level control and discharge control together with improved operation of the existing regulating dam. According to one model (Case V) as explained in detail in this Interim Report, the 100-year probable flood can be regulated less than

300 m3/sec discharge from the regulating dam below the restricted flood high water level of EL 905.50m on one hand and the minimum discharge from the dam even in driest season can be kept at 80 m3/sec even when the water level reaches near the restricted low water level of EL 902.40m.

Even if such water regulation is applied on the past actual inflow into Lake Toba (43 years' records), out of total average inflow of 101 m3/sec, 95.6 m3/sec can be utilized for power generation which can assure the production of aluminium of about 95% of 225,000 t/year at full capacity.

11. In addition to the above study, a further study was made for mitigating the downstream flood tentatively since the present river channel has very low flood carrying capacity until the urgent flood control facilities along the Asahan downstream reaches are to be completed. It suggests that it is possible to restrict the maximum discharge from the regulating dam at 200 m3/sec all through the flood period under the highest flood water level of EL 905.47m, 3 cm lower than the restricted flood water level. Hence it may be recommendable to take such measures until the completion of the flood control facilities in the downstream reaches of the Asahan river.

12. Even the flood discharge from the regulating dam is to be reduced less than before, still the flood derived from the remaining catchment area between the regulating dam and Pulau Raja is considerably big. Therefore it is recommended that a flood forecasting and warning system will be provided in the remaining catchment area.

It may be composed of four robot rain gages and four robot river water level gages, a control office at Kisaran and a wireless connection between the control office and Medan DPU office.

13. In connection with the above flood control studies it was found that the Asahan No. 3 Power Development Project under planning will have very high intake dam with considerably large storage capacity.

The intake dam, according to the Feasibility Report, will have five meters draw-down to regulate the discharge required for power generation. About 12 million m3 of effective storage capacity is there with this draw-down. If this storage capacity is utilized also for flood control against the flood inflow from the remaining catchment area of 214 km2 after the regulating dam, the peak flood discharge from the remaining area of 407 m3/sec in case of 30-year probability can be cut down to only 100 m3/sec. It will reduce the peak flood of 1,355 m3/sec at Pulau Raja into 1,048 m3/sec less than the designed flood carrying capacity of the urgent flood control plan. So that it is strongly recommended to plan the Asahan No. 3 Intake Dam to have a flood control function. The electric energy loss thus caused by flood control operation is estimated to be less than one percent of the annual energy output expected.

14. The detailed scope of works, time schedule and survey programs required for Part II work are described in this Interim Report. Early and smooth execution of this Part II work is recommended.

INTERIM REPORT
FOR
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ON
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TABLES

FIGURES

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TERMINOLOGY

Administrative districts

Prop.	= Propinsi	Province
Kab.	= Kabupaten	Regency
Kec.	= Kecamatan	Subdistrict
Kodya	= Kotamadya	City
Kel.	= Kelurahan	Village (urban area)
Ds.	= Desa	Village (rural area)
Kp.	= Kampung	Village (rural area)
Tj.	= Tanjung	

Institutions

Balai Kota		City Office
BAPPEDA	= Badan Perencanaan dan Pembangunan Daerah	Regional Planning and Development Agency
Bina Marga		Roads and Bridges
Cipta Karya		Building Construction and Water Supply
DGWRD		Directorate General of Water Resources Development
DPMA	= Direktorat Penyelidikan Masalah Air	Directorate of Hydraulic Engineering
DPUP	= Dinas Pekerjaan Umum Propinsi	Provincial Public Works
DPU	= Departement Pekerjaan Umum	Ministry of Public Works
JICA		Japan International Cooperation Agency
PLN	= Perusahaan Listrik Negara	State Electricity Corporation
ITB	= Institut Teknologi Bandung	Bandung Institute of Technology

TERMINOLOGY

RISPA		Research Institute of Sumatra Planter's Association
P3SA	= Proyek Perancangan Pengembangan Sumber Sumber Air	Water Resources Development Planning Division
PMG	= Pusat Meterologi dan Geofisika	Institute of Meteorology and Geophysics
INALUM	= P.T. Indonesia Asahan Aluminium	Indonesia Asahan Aluminium Company

Natural Objects

Bt.	= Batang	river
S,Sei	= Sungai	river
A.	= Aek	river
Banjir Kanal		flood way or diversion channel
G.	= Gunung	mountain
Sawah		paddy field or rice field
Ladang		dry paddy field

UNITS AND CONVERSION FACTORS

1) Length

mm = millimeter

cm = centimeter

m = meter

km = kilometer

2) Area

ha = hectare = 10^4 sq.m

sq.km = square kilometer = 10^6 sq.m

3) Volume

l, ltr = liter = 1,000 cu.cm

cu.m = cubic meter

mcm = million cubic meter

4) Weight

mg = milligramme

g = gramme

kg = kilogramme

t, ton = metric ton = 1,000 kg

qwt = kwintal = quintal = 100 kg

5) Time

s, sec = second

min = minute

h, hr = hour

d = day

yr = year

6) Currency

US$ = United States Dollar

Rp = Indonesian Rupiah

¥ = Japanese Yen

US$ 1 = Rp 1,100 = Y 250

7) Others

MSL = mean sea level

kWh = kilowatt hour

MWh = megawatt hour

1,000 kWh

mho = micromhos(conductance)

% = per cent

ppm = parts per million

Hp = horse power

°C = degree centigrade

°D = degree of hardness

10^3 = thousand

10^6 = million

10^9 = billion

8) Derived measures

m/s = meter per second

m^3/s,cms = cubic meter per second

t/ha = ton per hectare

kwh/yr= kilowatt hour per year

CHAPTER I INTRODUCTION

1.1 Purpose of the Report

This Interim Report for Master Plan Study on Lower Asahan River Basin Development Project was prepared in accordance with the Scope of Works agreed on July 27, 1984 between the Japan International Cooperation Agency (JICA) and the Directorate General of Water Resources Development (DGWRD) Ministry of Public Works, the Government of the Republic of Indonesia.

This Interim Report is prepared to report all the results of surveys and studies made for the Part I works which aims i) to find the basic direction of land and water resources development, ii) to establish a flood control master plan, iii) to make a feasibility study on an urgent flood control project selected from the master plan, iv) to make studies and recommendations on water regulation of Lake Toba, and v) to recommend a detailed survey and study program required for Part II works which mainly aims at establishment of master plan for agricultural dvelopment.

1.2 Progress of the Study

The surveys and studies for the Part I works were commenced from October 1984 and almost all the field works were completed by the end of July 1985. Since then the remaining analyses and studies were carried out in Japan and completed by the end of September 1985. Thus this Interim Report was compiled by the middle of October, 1985.

During the suvey period until the end of July 1985 the JICA Study Team submitted the following four reports to DGWRD.

1.	Inception Report	December 5, 1984
2.	Progress Report I	January 29, 1985
3.	Progress Report II	March 23, 1985
4.	Discussion Note	July 26, 1985

Official meetings between both parties including the Advisory Committee of the Japanese Government and Indonesian Authorities concerned were held every time to discuss the above reports and the views and comments were confirmed by both parties in the Minutes of Meeting respectively.

All the comments from DGWRD made through an official letter dated August 19, 1985 were answered in this Interim Report.

1.3 Personnel Assigned

The JICA organized and sent a study team consisting of 15 specialists headed by Mr. M. TSUDA, Team Leader and Mr. H. ONO, Deputy Team Leader to carry out the required works in their respective field. In addition JICA assigned six members of Advisory Committee headed by Dr. K. NAKAZAWA, Director of JICA to advise the Study Team and inspect the results of study.

The members of the Advisory Committee attended all the official meetings with DGWRD and exchanged their views each other for successful execution of the study works.

The DGWRD assigned Indonesian counterpart personnel to achieve transfer of knowledge as deep as possible. The twelve persons were selected from a consulting firm in Bandung from the end of December 1984. They have worked together with JICA team members in the same field.

The lists showing all the above members assigned are shown in Tables 1.1 and 1.2 with their itinerary as shown in Fig. 1.1.

1.4 Transfer of Knowledge

The above 12 counterpart personnel were trained through on-the-job training system mainly about the followihg works.

a) Actual field surveys including ground reconnaissance, sampling of materials, required field tests at the spot, collection of data from various organizations, interview survey with local people, etc.

b) Analyses on the data collected including statistical analysis, engineering analyses by calculations or graphical analyses, hydrological analyses, hydraulic calculations, probability analyses, land use mapping, etc.

   Especially for flood control planning the use of electronic computers was trained regarding the calculations of flood patterns, flood carrying capacity of river channels, probable flood analyses by storage function method, etc.

c) Engineering judgement on the results of surveys, tests and analyses was transferred in the fields of hydrology, hydraulics, soil property related to the structural design, socio-economy, land use, etc.

However the period of training was limited less than five months due to short time of field works and the delay of assignment. Although short in time most of those trainings were very fruitful for the counterparts as the knowledge was transferred through actual jobs immediately understandable at the respective spot.

CHAPTER II BACKGROUND AND OBJECTIVE OF THE STUDY

2.1 Background of the Study

The study area is located in the central part of North Sumatra Province facing to the Strait of Malacca and blessed with rich water and land resources implying the high development potential. Especially Lake Toba, the origin of the Asahan river, offers favorable stable water source through its vast regulating capacity by its large surface area of 1,100 km^2. Owing to its high surface elevation of El 905 m, the outflow of about 100 m^3/s of annual average discharge is now being utilized for hydropower generation at Siguragura and Tangga power stations (603 MW in total) to supply the power to the aluminium smelter with annual production capacity of 225,000 tons at Kuala Tanjung.

Owing to the rich rainfall, this study area is also suffered from frequent floods due to insufficient flood control facilities. Major rivers running in the study area are Bunut in the north, Silau and Asahan in the centre and Kualuh river in the south. The annual rainfall more than 4,500 mm precipitates on the slope of mountain divide from which those rivers originate except the Asahan main stream. The rainfall gradually decreases toward the coast of the Strait of Malacca as little as 1,300 mm. However the heavy rainfall in the mountains causes rapid flood flow often inundating the plain along the lower reaches of the rivers. Due to such flooding and insufficient infra-facilities, the study area has been constrained to the low socio-economic development stage compared with Medan and its vicinities.

The above circumstances imply the strong need of raising the land productivity by means of development of water resources. The ever-increasing population pressure, not only by the natural increase but also due to transmigration, urges the needs to increase job opportunities and to secure the stable living conditions as well.

2.2 Objective of the Study

The objective of the Study is, therefore, to conduct a master plan study for water and land resources development in the Lower Asahan River Basin, covering the period up to 2005 A.D. from the viewpoint of long-range policies as raising the productivity, increasing employment opportunities, promoting transmigration and bettering the living conditions in this region.

The actual program for the whole survey and study works was divided into two stages from the viewpoint of efficient and orderly execution, namely Part I and Part II. Part I works aimed to carry out the required surveys and studies mainly for the following five objectives:

i) to find the basic direction of land and water resources development based on the socio-economic and natual conditions given in the project area

ii) to establish a master plan for flood control

iii) to make a feasibility study on an urgent flood control project

iv) to make a study and recommendations on water regulation of Lake Toba

v) to report a survey and study program required for Part II works

In continuation to the Part I works, the Part II works will be carried out mainly for establishment of the agricultural development master plan well coincided with the flood control master plan.

This Interim Report describes all the results of studies for the Part I works.

2.3 Study Area

The study area covers the lower Asahan basin (about 6,000 km^2) including Bunut river and a part of Kualuh river basin as the objective area for the master plan. The upper basin of the Asahan river including Lake Toba is considered in its plan as the external conditions in relation with the downstream flood problems and optimum utilization of water resources.

Administratively the objective study area lies in Kabupaten Asahan and Labuhan Batu, North Sumatra Province, about 160 km south-east of Medan, capital of the Province. Being blessed with rich water and land resources under the tropical monsoons the study area has been developed mainly with large estates of rubber, oil palm and coconut since long ago. With a population increase, now reaching about 800,000 persons, area of paddy field gradually increased to the present level of about 77,000 ha with supplemental upland field of about 15,000 ha for cropping. However the study area is also suffered from frequent floods due to heavy tropical shower causing considerable damages on crops as well as on social and private properties. In spite of much effort of the Indonesian Government to construct earth dikes in recent years, still the flood carrying capacity of major rivers is far less than the flood peak discharges resulting in frequent distruction of those dikes. Hence, this Master Plan Study for flood control is urgently necessitated.

No big scale industries exist in the study area due to poor electricity supply condition and non-existence of underground mineral resources except coal reserve in extreme southern hills. The major towns, such as Kisaran, Tanjung Balai, etc. have been electrified with isolated diesel generators, although a transmission line connecting Kisaran with Medan Network is under construction at present.

3.1 Topography

The study area lies in the central part of North Sumatra Province facing the Strait of Malacca running in the direction from northwest to southeast. The topography of the study area is broadly divided into four zones almost in parallel to the coast line, namely i) steep mountain area ranging from EL 1,500 m to approximately EL 100 m in elevation mostly covered by natural and secondary forests, ii) low undulating hills or terrace extending between elevations of about 100 m and 15 m, iii) wide and flat alluvial plain lower than EL 15 m including lower swampy area, and iv) coastal sand dune or coastal sand bar in width of 2 or 3 km along the coast line having the maximum elevtions of 10 to 14 m.

Four major rivers dissecting this study area rise in the steep mountain area and flow down generally in northeast direction with remarkable meanders in the lowermost alluvial plain lower than 10 m in elevation.

The low hilly area, having a good natural drainage with many small streams, is mostly utilized for rubber and oil palm estates with dotted small paddy fields. Since long ago the national railway and the main highway have been constructed on this hills or along the foothills utilizing the good drainage conditions. Therefore, most of the major towns and villages are developed along this zone too. Also many small hamlets are mainly developed on or along the natural levees stretched on the both banks of main and branch streams. Numerous secondary roads branch off from the highway in both directions to mountain area and coast area.

The wide alluvial plain is classified into two areas, namely comparatively higher area than EL 4 m and the lower swampy area. The higher alluvial area has been mostly developed into estates of rubber, oil palm and coconut and considerably large size paddy fields. The easy topography to take irrigation water made this alluvial plain suitable for irrigated farming. The silty soils having less infiltration and rich humus are well suited for submerged paddy cropping. But the high groundwater table and less drainable condition prvailing in this alluvial area make the flood damages larger when inundated.

The lowermost alluvial plain lower than EL 4 m forms wide swampy area, especially between Asahan and Kualuh rivers and the right bank of the Kualuh. The Landsat false color composite image clearly shows the boundaries of those swampy areas and the vegetation cover. The ground reconnaissance with this Landsat photograph made clear that most of the swamps are covered by bushes and shrubs but some areas covered by thick swampy forests with high trees more than 10 m. The water in those swamps is obstructed their drainage way to the sea by the high coastal sand dunes, being obliged to drain into the lowest reaches of the main streams of Asahan and Kualuh through small streams. The drainage capacity is so small resulting in water logging and stagnation in long duration. The bogging swamps in deeper areas do not accept human access, but the fringes of those swamps were gradually developed into paddy fields or coconut plantation recently by planned settlement or random settlement under the heavy population pressure.

The coastal sand dunes are mostly utilized for coconut plantation, small patches of paddy fields and upland fields. The coast margin affected by high tide is mostly occupied by mangrove.

3.2 Climate

The study area lies in the tropical monsoon zone between 2 and 3 degrees in North Latitude and 99 and 100 degrees in East Longitude.

Annual average temperature on low alluvial plain along the coast is approximately 26°C with very little seasonal variation. Absolute maximum temperature is around 33°C and the minimum is around 21°C. All those temperatures around Lake Toba at the elevation of EL 910 m are about 6°C lower than those values at the coast plain.

Annual rainfall depth differs almost in parallel with the coast line up to the mountain divide to the catchment area of Lake Toba. The mountain ridge around at an elevation of 1,500 m above M.S.L. has about 4,500 mm annual rainfall, while it decreases with elevation toward the coast where only 1,500 mm average annual rainfall is observed.

The catchment area of Lake Toba is about 3,700 km^2 surrounded by mountain ranges of about 1,500 m and has an average annual rainfall of approximately 1,820 mm. It is observed that southern area has a little higher rainfall ranging from 2,000 to 2,200 mm, while the northern area has less rainfall ranging from 1,400 to 1,600 mm.

Monthly distribution of rainfall is different by the location from east to west. North Sumatra has a narrow width of about 200 km between the Strait of Malacca and the Indian Ocean, hence the monthly rainfall distribution pattern at a certain place is much affected by its location because of prevailing monsoons from both seas. In the main rainy season from October to December the north-east monsoon is predominant in this region. The onset of the rainy season begins from the coast along the Strait of Malacca and gradually moves into the inland area with one or one and a half month time lag.

While the secondary rainy season covering March through May is caused by south-west monsoon from the Indian Ocean. Therefore the secondary rainy season begins from the coast of Indian Ocean and proceeds to inland with about one month time lag.

The above fact is clearly analyzed by comparison of the monthly rainfall records at Medan, Pematang Siantar, Parapat and Sibolga. The monthly rainfall records at those places are shown in Table 3.1 for 22 years from 1920 to 1941. The average monthly rainfalls are converted into the share ratios against the annual average rainfall and those monthly ratios are graphically shown on Fig. 3.1. From this Figure the following characteristics of the rainfall distribution are clearly observed:

1) The maximum rainfall peaks at Medan and Pematang Siantar occur in October, while those at Parapat and Sibolga occur in November.

2) On the contrary, the secondary rainfall peaks at Sibolga and Parapat occur in April, one month earlier than those at Pematang Siantar and Medan.

3) The influence of the secondary rainy season, caused by the south-west monsoon from the Indian Ocean is very little at Medan, especially in February. The influence on Pematang Siantar is also moderate.

4) The period between the both peak months at Medan and Pematang Siantar is therefore only five months. It naturally makes not so heavy shortage of rainfall during this transit period. On the contrary, the period between the both peak rainfall months at Parapat and Sibolga is seven months, two months longer than that of Medan and Pematang Siantar. At Parapat, therefore, considerably less rainfall months happen in June and July.

The above characteristics of rainfall depth and seasonal distribution naturally affect on the seasonal runoff of rivers and also inflow into Lake Toba. So that the discharge analysis was carefully carried out by checking with the monthly rainfalls observed at nearby observatories.

Relative humidity is fairly high through a year. Monthly variation ranges between 83 and 92 percent resulting in annual average of around 88 percent.

Records of wind, sunshine and evaporation are so few that clear seasonal tendency can hardly be analyzed. But general tendency is observed as follows:

1) Wind velocity is generally very small through a year except sudden instant gales occurred a few times a year. Annual average wind velocity is a little less than 0.3 m/sec.

2) Sunshine hours in the main and secondary rainy seasons are very short as the number of rainy days reaches more than 15 days per month. Considerably long sunshine hours were recorded in June, July, August and September.

3) Evaporation records are available only at two places but the observation has incomplete with many lacking days. It was however estimated from those records that the annual average evaporation may be around 1,300 mm in the study area. This fairly small evaporation may be justified by the facts of considerably high humidity, large number of rainy days (normally 190 to 220 days a year), weak wind velocity and not so high air temperature. Trial estimations suggested that the annual average evaporation from the surface of Lake Toba may be around 930 mm per annum ranging from 1 mm/day to 7 mm/day at the maximum.

As the climatic conditions of coastal area and highlands around Lake Toba, climatic record at Sei Dadap near Kisaran and Balige is shown in Table 3.2.

3.3 Hydrology

3.3.1 Rainfall

There are about 80 rainfall gaging stations in the study area mostly established by PMG, RISPA, and DPU as shown in Fig. 3.2. The periods of available records at those stations are shown in Figs. 3.3 and 3.4. Some of daily rainfall records have been already lost even though monthly records at the same period is still available.

In order to know the aerial distribution of annual rainfall, an areawise isohyetal map of annual mean rainfall depths covering the study area was prepared as shown in Fig. 3.5. It shows the general trend in the study area that rainfall depth increases gradually from coastal area of about 1,500 mm towards mountainous area near the Tangga dam of about 4,000 mm. It decreases in reverse to 1,500 mm through 2,000 mm around Lake Toba. Although it is recognized that the maximum value is recorded at the eastern side of mountain outside Lake Toba, range of the heavy rainfall is still uncertain because of thin observation net-work compared with that in the lower area. Aerial distribution of annual rainfall seems to be the same as that of heavy rainfall during flood times. Monthly rainfall patterns of eight stations are also shown in Fig. 3.6.

Probable one day rainfall were calculated by the Gumbel method on the basis of the estimated one day maximum basin rainfall every year, which is shown in Table 3.3, with regard to upper reaches of Pulau Raja, Kisaran, Tanjung Balai, Teluk Binjai and Tanjung Tiram stations. The results are shown in Table 3.4 and Fig. 3.7. The maximum two day rainfall is also shown in Table 3.3 and Fig. 3.7 for reference.

3.3.2 Stream flow

There are water level gaging stations along the Asahan, Silau and Kualuh rivers, and also at Lake Toba. Their locations are shown in Fig. 3.8. At present 9 gaging stations are being operated by both DPU and INALUM on an hourly-basis except Kisaran station where thrice-daily staff gage readings at every 7:A.M., 12:A.M. and 5:P.M. are executed. Availability of water level records is shown in Fig. 3.9.

Collection of water level records at Pulau Raja, Kisaran and Pulo Dogom stations of the Asahan, Silau and Kualuh river basins were completed by the end of 1984. In addition discharge measurement was carried out by the Study Team at Pulau Raja from the end of January through the beginning of February 1985 to supplement the high water range of the discharge rating curve. The results are shown below:

Date	Water Level (Gauge height) (m)	Discharge (cms)
Jan. 31 '85	2.73	202
Feb. 1 '85	2.58	230
Feb. 1 '85	2.52	212
Feb. 2 '85	2.28	201
Feb. 2 '85	2.20	171

Discharge rating curves at the stations were revised by use of both the measurement records and hydraulic calculations based on the river cross sections surveyed by DPU. The cross-sections of the said three stations during discharge measurements since 1980 were compared to check the changes as shown in Fig. 3.10. It revealed that they have not experienced so much changes. Therefore, the discharge rating curves shown in Fig. 3.11 were used for conversion of daily water levels into daily stream flows. The monthly mean discharges at those stations are shown in Table 3.5 and Fig. 3.12. Usually high water flow is observed in September through January or February, and also in May or June. In August in general, the discharge decreases to the minimum, being about a half of that in May or June.

Monthly mean dishcarge at Pulau Raja from residual area excluding upstream catchment area of Lake Toba was also estimated as shown in Table 3.6, which was supplemented by the correlation between discharges of the Silau river at Kisaran and the residual area as shown in Fig. 3.13.

According to this analysis the annual average discharge after 1979 at Pulau Raja (4,608 km^2) is approximately 150 m^3/sec (4.7 billion m^3 per year), out of which 90 m^3/sec (60%) flows from Lake Toba and 60 m^3/sec (40%) flows from the remaining catchment area of 812 km^2.

The specific discharges per 100 km^2 of catchment area for Asahan, Silau and Kualuh rivers are shown below:

River	Station	Catchment (km²)	Annual Mean Discharge (m^3/sec)	Specific Discharge (m /sec/$100km^2$)
Asahan	Pulau Raja	4,608	151.8	3.29
	Regulating Dam	3,796	94.0	2.48
	Remaining area	812	57.8	7.12
Silau	Kisaran	1,050	61.2	5.83
Kualuh	Pulo Dogom	1,116	61.4	5.50

The lowest specific discharge from the catchment area of Lake Toba is mainly attributable to the considerably less rainfall and the high evaporation loss from the Lake surface. The very high specific discharge for the remaining area of Asahan river is mostly due to heavy rainfall in the mountain area. Silau and Kualuh rivers have comparatively moderate rainfall in the upstream reaches.

3.3.3 Tide

Records of tide level at Kuala Tanjung and Bagan Asahan, which are located in 3^o-22'N and 99^o-28'E, and 3^o-01'N and 99^o-52'E facing to the Strait of Malacca respectively, were collected. The records demonstrate regular two cycles a day. They were arranged in Table 3.7 and Fig. 3.14 being summarized below:

(El.m)

Section	HHL	MHHL	MSL	MLLL	LLL
Kuala Tanjung	1.64	0.85	0.0	-0.86	-1.87
Bagan Asahan	2.25	1.17	0.0	-1.16	-1.75

where, HHL : Higher High Level
MHHL : Mean Higher High Level
MSL : Mean Sea Level
MLLL : Mean Lower Low Level
LLL : Lower Low Level

3.4 Geology

The geological formation of the study area concurs to the four topographical zones. The schematic topography and geology are shown in Fig. 3.15 and the general stratigraphy is as follows:

General Stratigraphy of Study Area

Geological Age	Stratigraphy	Composition
Quarternary	Sand Dune or Bar Alluvial Plain Deposit Alluvial Terrace Deposit Tuff Volcanic Rocks	Sand, silt Sand, silt, clay, organic soil Sand, silt White tuff, laterite Lava, ignimbrite, Volcanic breccia etc.
Tertiary	Sandstone and Shale	Sandstone, shale, Conglomerate
Pre-Tertiary (Paleozoic)	Pre-Tertiary Rocks	Sandstone, shale Quartzite, Mylonite

Those rocks and deposits are generally developed in parallel to the coastal line, well coinciding with the topographic characteristics.

Basement rocks exposed in the mountain area are composed of acidic volcanic rocks, which are pyroclastic rocks derived from volcanic eruptions in early Quarternary, such as rhyolites or liparitic pyroclastic product, so-called ignimbrite or welded tuff. Those rocks are generally very hard, if not weathered, offering good foundations for any heavy structures.

The ignimbrite is overlain by several layers of tuff sand, consolidated tuff and top overburden consisting of loamy lateritic soils.

Pre-tertiary sedimentary rocks intercalated coal bed are overlain in the vicinity of the village Perlaoian located upstream about 25 km from the crossing of highway and Kualuh river.

The low hilly area is widely covered by thick laterite ranging from 5 to 10 m underlain by soft white tuff which probably belongs to Quarternary and is characterized by the presence of pumice fragments. This formation is also derived from the Toba volcanic eruptions and partially interbedded with thin sand and gravel layers dipping slightly northeastward.

The lower ends of the hilly area at the elevation of 10 to 15 m have terrace deposits mainly composed of sand and silt forming belts, projected low ridges and isolated islands. This formation seems coastal terrace deposits formed in early Alluvial period.

Alluvial plain deposit (I) mostly consists of fine silty to clayey soils interbedded by thin sandy soil layers and organic soil layers. Those were transported from the hinterland composed of acidic volcanic rocks, tuff and laterite. Even now the sedimentation is progressing continuously.

Alluvial plain deposit (II) in the vast swampy areas between the lower Asahan river and Kualuh river is made of fine silty to clayey soils and organic soil.

The coastal sand dunes or sand bars are mostly composed of coarse to fine sand of volcanic native glass or hard quartz particles originated from ignimbrite.

All the above geological and geomorphological observations are compiled in the general geological map of the study area (Fig. 3.16) and specific geological map of the lower Asahan river (Fig. 3.17).

3.5 Land Use

3.5.1 Present Land Use

The results of land use survey covering 6,600 km^2 were compiled in two maps on a scale of 1/200,000, one the Present Land Use Map and another Existing Paddy Field and Potential Land for Future Agricultural Development. The reduced copies of the maps are attached to this reports as Figs. 3.18 and 3.19.

The whole land area was classified into ten (10) categories of land use as shown below:

	Land Use Category	Area (ha)	Percentage (%)
1.	Settlement land	9,079	1.4
2.	Paddy field	90,832	13.7
3.	Upland cultivated land	15,442	2.4
4.	Coconut estate	43,230	6.5
5.	Rubber estate	107,607	16.3
6.	Oil palm estate	58,398	8.9
7.	Upland forest	158,440	23.9
8.	Bushes (Swampy)	48,592	7.3
9.	Swamp (Mostly forest)	125,851	19.0
10.	Others	4,100	0.6
	Total	661,571	100.0

The upland forest includes both the natural forest and secondary forest. The secondary forest consists of rubber trees, oil palm, clove trees, coffee, etc. but those trees are planted mixed with natural forest trees, so that detailed demarcation is almost impossible. Anyway it shall be noticed that such cash crops are planted in the upland forest on a small scale private basis.

The paddy field occupies only about 14% of the total land area and mostly lies in low lands. Upland cultivated lands are planted with cassava, maize, various kinds of pulses and legumes and vegetables.

The three major estate crops, namely, rubber, oil palm and coconut, occupy about 32% of the whole area, rubber estate still occupies 16.3% but the area is gradually decreasing and mostly changed into oil palm estate due to economic reason. The coconut estate also gradually is being shifted to paddy field.

The swamp forest and bushes occupy about 26% of the whole area. The difficult access and living conditions reject human settlement by their bogging ground and frequent floods. However the recent high population pressure is obliging local people to intrude into the fringes of those swamps.

3.5.2 Adaptability of Present Land Use

In this study area it was identified to utilize the lands in a good coincidence of topography. In other words, the general land use in the study area is well adapted to the natural given conditions. The land use characteristics were easily confirmed by overlapping the geological map and the land use map as identified below:

a) Rubber estates amounting to 107,600 ha are developed in two major areas, one on hilly area along the Silau river and another on hilly area along the Kualuh river. Those areas have a good drainage topographically and also geologically as being underlain by tuff sand layer. The terrace deposits mainly composed of sand and silt at the lower end of hilly areas are also utilized.

b) Oil palm estates amounting to 58,400 ha mainly concentrate on the hilly area along the Asahan river.

c) Coconut estates mostly extend on the sand dune belt along the coast of Malacca Strait utilizing high chlorine content in water.

d) Most of paddy fields are developed on the alluvial plain along the streams or the fringe of swampy areas, utilizing the high water holding capacity of silty or clayey soils and easy topography to take water from streams.

e) The highway and railway have been constructed on the hilly area or the foothills where good drainage and solid foundation are secured. The lateral or secondary roads were developed along the natural levees along many streams. Major towns and villages have developed along those highway and lateral roads.

f) Upland fields scatter on hilly area mostly not irrigated due to higher elevation than stream flows.

All the above land use patterns are well characterized by excellent utilization of the given natural conditions, such as topography, drainability, soils, etc. with the wisdom accumulated in long history. It suggests no necessity to change the present land use patterns except improvement to higher land productivity, some crop diversification by future economic trend and demand and national or social requirement.

3.5.3 Desirable Future Development

As identified above, almost no wasted lands exist in the study area due to ever-increasing population pressure. Or in other words there is no more physical land space to accommodate the increasing population. It is therefore prerequisite to raise the land productivity of the present cultivated land intensively. The development of swampy areas shall be examined in depth as for their soil conditions and economy.

The upland forest of about 24% shall be reserved as it is for the land and water conservation as well as necessary supply sources of cattle feed and fire wood for local inhabitants.

Three major recent changes of land use were observed by comparison of land use maps of 1974 and the latest one prepared this time as shown below:

(1) Rubber estates with old trees were changed into oil palm estates due to low international market price of rubber.

(2) Paddy field is gradually extended into coconut estates or swamp areas due to shortage of rice supply in this area.

(3) The fringe areas surrounding swamps are changed into estates or paddy field by random settlement of individuals.

From a view point of economy it seems that the agricultural development, particularly the irrigation development on the existing cultivated land, has the highest priority to raise the land productivity as well as to achieve self-sufficiency of rice in this area.

3.6 Socio-Economy

(Refer to APPENDIX C for details)

3.6.1 Present Socio-Economic Conditions

The objective areas for the master plan study covers about 6,000 km^2 including 13 Kecamatans in Kabupaten Asahan, 3-Kecamatans in Kabupaten Labuhan Batu and Kotamaja Kisaran and Tanjung Balai.

Population in this study area is 798,900 in 1983 increasing with annual growth rate of 1.2%.

Traditionally this area has been developed by plantations of rubber, coconut and oil palm since long ago. So that those estates still occupy about two-thirds areas in the whole arable lands, leaving one-third for cultivated lands. About 65% of the population is engaged in the agricultural sector.

The share of agricultural sector in the Gross Regional Domestic Product (GRDP) in the study area also occupies a majority of about 64% in 1980.

The per capita incomes in 1981 for Kab. Asahan, Labuhan Batu and Kotamaja Kisaran and Tanjung Balai were approximately Rp. 331,000, Rp. 314,000 and Rp. 372,000 respectively at the current prices. Those amounts are higher than Rp. 283,000 of North Sumatra Province, but lower than Rp. 386,000 of Kotamaja Medan. The average figures seem at a comparatively high level due to higher incomes derived from the estate crop production.

However the average land holding size of the farmers in this area is as small as 0.8 ha per family. In addition the average unit yield of paddy is also as low as 2.9 ton per ha. Those farmers have far lower incomes than the above average.

Out of total labor force of about 419,000 in the study area, 212,900 are those farmers accounting for 51% of total labor force. Thus numerous low income level farmers can hardly purchase enough fertilizers, chemicals, improved seeds, buffaloes, etc. required for their paddy production.

The irrigated land occupies only about 20% of the total paddy field of about 74,000 ha net. The existing irrigation facilities are not so complete to keep high efficiency and even distribution of water. Due to those incomplete facilities the annual paddy production is not stable, for example, at a severe drought in 1981 the paddy production in this area reduced to about a half of normal production. Those cultivated lands normally extending along the rivers and streams are frequently suffered from floods too.

Social infrastructures, such as transportation, communication, power and water supply, etc. are comparatively developed in major cities of Kisaran and Tanjung Balai. But the secondary networks have not well developed yet, leaving fairly wide gap between urban and rural areas.

It is recognized in recent years that some younger generation leaves this region to other towns and districts to find jobs.

3.6.2 Basic Direction of Socio-Economic Development

Natural conditions of this region are good on the whole and there are no major constraints for the regional development except frequent damages caused by floods.

As the land use study clarified, all the lands were well utilized under heavy population pressure except swampy areas. Although those wide swamps are worthy to examine their future development potential and its economy, it is easily understood that much investment will be required and creation of benefit will take far longer time. It is therefore recommendable to raise the land productivity of the existing cultivated lands at first.

Among many measures to raise land productivity of cultivated lands, the first priority shall be given to prevent frequent inundation by floods. This implies the urgent need of flood control of major rivers, particularly Asahan and Silau rivers in consideration of the extent of damages.

The second priority shall be given to the rehabilitation and improvement of the existing irrigation and drainage facilities because of early generation of benefit with smaller investment.

The improvement of irrigation facilities shall be carried out even small irrigation projects along small streams.

The third priority will be given to extension of irrigated lands by enlargement of existing facilities or additional facilities and also extension of farm land by swampy land development.

Since the above development will require considerable length of time, probably exceeding the target year of 2005 A.D. of master plan, it is essential that practical realization of project development should be formulated through careful study of project evaluation and priority sequence of project development.

3.7 River Conditions

3.7.1 General

The area four major rivers in the study area, namely Bunut, Silau, Asahan and Kualuh from the north to south.

The Bunut river is a southernmost thributary of Kiri river originating in low hills of about 300 m in elevation. It has 621 km^2 of catchment with its 59 km length. It flows northeastward in parallel with the Silau river up to near Kisaran, after which it flows northward through rubber and oil palm estates and paddy fields. Finally it joins with Kiri river about 15 km upstream from the estuary where small port of Tanjung Tiram lies at the coast. The width of river channel at the highway bridge is only 15 m. It gradually widens to the middle reaches but only 20 to 25 m, while it becomes about 40 to 50 m along Kiri river. In the downstream reaches, the both banks have been developed into paddy fields, some areas of which are under irrigation. But this area often suffers from shortage of water due to little discharge of the river. Flood peak discharge is also not so big, but sometimes it causes inundation over paddy field.

In recent years about 14 km long low dikes were constructed on both banks and not so much flood damages happen now.

The Silau river, large tributary of the Asahan river, has a catchment area of 1,180 km^2 with a total length of about 100 km.

The river originates on the eastern slopes of Mt. Parparean and flows northeastward along steep and narrow valleys. At Samba Huta, it joins the Ambalutu river. Downstream from the confluence, the topography changes from hill to plain and the land has been developed by estates of rubber, coconut and oil palm. Afterwards, the river flows eastward and joins the Piasa river at Jati Sari. From Jati Sari to Kisaran, the river flows northward with meandering on the plain. The river slope becomes gentler gradually toward downstream from 1/800 to 1/1,500. In the downstream reaches from Kisaran, the river flows eastward and finally joins to the Asahan river at Tanjung Balai. In this stretch, there are some irrigation intakes and drainage sluices. The land on the both banks of the river has been developed for paddy field. The continuous dike has been built on both the banks to protect the land from floodings in a total length of 28 km.

The Asahan river has a catchment area of 6,863 km^2 including Lake Toba catchment of 3,796 km^2, with 152 km length. The Asahan river originates from Lake Toba. The lake has vast natural regulating capacity by its wide water surface area of 1,100 km^2. The water level of the lake is being controlled at bout EL 905 m by Regulating dam located at 14 km downstream from the outlet of Lake Toba.

The Asahan river flows down northeastward on steep slopes of mountain along deep and narrow gorges up to Bandar Pulau, about 65 km from Lake Toba through Siguragura and Tangga dams for hydropower generation. Downstream from Bandar Pulau, the river flows eastward and the river slope decreases gradually and the surrounding topography changes from hill to plain. The land on both the banks of the river has been developed by rubber and oil palm estates. At a point about 3 km upstream from highway bridge at Pulau Raja, the river joins the Sakur river.

Downstream from Pulau Raja, the river flows northeastward with meandering on the alluvial plain. The river slope decreases gradually toward downstream, being 1/4,000 and 1/13,000 respectively in the vicinity of Pulau Raja and Tanjung Balai. The dike of about 11 km in length is built on the right bank to protect the area of Padang Mahondang. In the downstream reaches from Pulau Raja, the swamp area extends widely to the right bank and partly to the left bank.

At Tanjung Balai, the Asahan river joins the Silau river and finally empties into the Strait of Malacca. Downstream from Tanjung Balai the river widens gradually toward the sea, being 200 m and 1,500 m respectively in the vicinity of Tanjung Balai and the river-mouth.

The Kualuh river has a catchment area of 3,820 km^2 of wide area with its total length of 165 km. The Kualuh river originates on the northeastern slopes of Mt. Sihabuhabu and flows northeastward along steep and narrow valleys. Near Pulodogom, the river joins the Harimau river. Downstream from Pulodogom, the river flows eastward and the surrounding topography changes from hill to plain. The river slope decreases gradually toward downstream. At Kileng Sandala, the river joins the Natas river. In the stretch between Pulodogom and the confluence of the Natas river, estates of rubber and oil palm and paddy field extend to the both banks of the river. To protect the paddy field, the dike has been built on the left bank in the downstream reaches of highway bridge. Afterwards, the river flows with meandering on the alluvial plain and joins the Kanopan river at Teluk Binjai and the Kuo river at Kuala Bangka. The swamp area extends widely to the right bank downstream from the confluence of the Natas river and the left bank downstream from the confluence of the Kanopan river. Afterwards, the Kualuh river flows northward and finally empties into the Strait of Malacca at Tanjung Leidong. Downstream from the confluence of the Kuo river, the Kualuh river widens gradually toward the sea, being 200 m and 4,000 m respectively in the vicinity of Kualuh Bangka and the estuary.

General features of those rivers are illustrated in Fig. 3.20.

3.7.2 Existing Flood Control Facilities

In the study area, the river dikes of 86 km in total length have been constructed in the middle and lower reaches. The dike length for each river is as follows:

River	Dike length (km)		
	Mainstream	Tributary	Total
Bunut river	14	-	14
Silau river	28	-	28
Asahan river	11	4	15
Kualuh river	22	7	29
Total	75	11	86

The location of those existing dikes is shown in Fig. 3.21. Almost all the dikes were constructed in the form of the cross-section with crown width of 2 - 3.5 m, side slope of 1:1 - 1:2 and height of 1 - 4 m as illustrated in Fig. 3.22. River improvement and rehabilitation works during 1982 to 1984 are listed in Table 3.8.

Any other flood control facilities such as diversion channel, artificial retarding basin, etc., are not found in the study area.

The related structures of the river such as bridge, drainage outlet, irrigation intake exist along the river courses. The location and dimension of bridges are listed in Table 3.9 and the profile of major bridges are shown in Figs. 3.23 to 3.25. The dimension of drainage outlets, irrigation intakes are shown in Table 3.10.

3.7.3 Discharge Capacity of Existing Channels

The discharge capacity of the existing river channel was estimated based on water level calculation by the non-uniform flow method in the stretch from the river-mouth to Pulau Raja for the Asahan river and from Tanjung Balai to the confluence of the Piasa river for the Silau river. In the calculation, the values of Manning's roughness coefficient shown in Table 3.11 were adopted in this study considering the existing channel conditions.

The estimated discharge capacities are shown in Table 3.12 and Fig. 3.26. From the figure, the following facts are recognized.

(1) Bunut river

a) The channel upstream from highway bridge at Bunut has comparatively high discharge capacity of 80 cms.

b) Downstream from the bridge, the capacity decreases to 50 cms near the confluence with the Beluru river.

c) Downstream from the confluence with Silau Tua river, the capacities increase toward the river-mouth of the Kiri river from 100 to 500 cms.

(2) Asahan river

a) The channel upstream from highway bridge at Pulau Raja has comparatively high discharge capacity of 1,300 cms.

b) Downstream from the bridge, the discharge capacities decrease gradually toward downstream. Near the confluence of the Nantalu river, the capacity decreases to extremely low value of 200 cms.

c) Downstream from the confluence of the Lebah river, the capacities increase toward the river-mouth from 200 to 3,500 cms.

(3) Silau river

a) The channel upstream from Kisaran has comparatively high discharge capacity of 800 cms.

b) In the vicinity of Kisaran, the capacity is 700 cms. Downstream from Kisaran, the capacity decreases from 600 to only 150 cms.

(4) Kualuh river

a) The channel upstream from highway bridge at Gunting Saga has comparatively high discharge capacity of 1,100 cms.

b) Downstream from the bridge, the capacities decrease gradually toward downstream. Near the confluence with the Pamengke river, the capacity decreases to low of 200 cms.

c) Downstream from the confluence, the capacities increase toward the river-mouth from 350 to 1,500 cms.

d) The discharge capacities of the downstream reaches of the Kanopan river are from 50 to 100 cms.

3.8 Flood Discharge

3.8.1 Recorded Major Floods

Water level data of the lower Asahan, Silau and Kualuh rivers at Palau Raja, Kisaran and Pulo Dogom are available from 1977, 1973 and 1979 respectively. There is no record of the Bunut river. Gaging stations at Palau Raja and Pulo Dogom are automatic, but at Kisaran staff gage reading at 7 o'clock in the morning, 12 o'clock noon and 5 o'clock in the evening. Since then there are some apprehensions that the flood peak of the Silau river be not recorded. The annual maximum flood peak of each river is shown in Table 3.13.

It is recognized that the flood in January 1984 was the most remarkable in the lower Asahan and in the Kualuh rivers, and in the Silau river the biggest flood occurred in December 1973. Big floods occur usually in September through January and also in May in this area.

It should be noticed that the runoff in the lower Asahan river has been influenced by the artificial control of outflow from Lake Toba since February 1981.

The Asahan and Silau river basins might be suffered from most severe damage by the flood in December 1973 according to the verbal information from the site. The peak discharge of that flood was roughly estimated to be 800 m^3/s on the basis of discontinuous hydrograph at Kisaran. It was confirmed from the fact that the basin rainfall of Pulau Raja and Kisaran on Dec. 1, 1973 was ranked in the first since 1963.

3.8.2 Flood Discharge Analysis of Asahan and Silau Rivers

(1) Flood Runoff in Asahan and Silau River Basins

The Asahan and Silau river basins were divided into sub-basins as shown in Fig. 3.27. The flood simulation model to analyze flood runoff mechanism of the Asahan and Silau river should simulate hydraulic behavior in the basin for the various flow conditions. It incorporates river basin components such as sub-basins, channels, dams and retarding basins as shown in Fig. 3.28. The storage function method was applied to calculate flood runoff from each sub-basin and channel. All the coefficients were calculated from the typical past floods in May 1975, September/October 1977, May 1982 and January 1984. After establishing the model, a check was made by comparison of the calculated hydrographs with the actually recorded ones as shown in Fig. 3.29, which shows a good coincidence. So that this selected storage function model was applied to estimate the probable flood peak discharges from the probable maximum daily rainfalls.

(2) Flood Overlapping

Major floods in the past of which daily discharge was bigger than 170 m^3/s for the residual area of Pulau Raja and also 200 m^3/s for Kisaran were picked up in due consideration of discharge capacity of the existing channel. Seasonal frequency of flood is shown in Fig. 3.30. The following flood characteristics were recognized from the frequency analysis:

a) Flood is often appeared during September through January and also in May,
b) Bigger floods occur in September through January.

Flood of Sept./Oct. 1977 is recognized as a typical flood.

From the rainfall records since 1963 when the most of rainfall gaging stations started their operations, it is recognized that the residual area received much rainfall during three months from October to December in 1963 and 1969 as shown in Fig. 3.31. In that season the Regulating dam might have to spill out surplus water in considerable length of time.

The flood outflow from the Regulating dam of Lake Toba is 400 m^3/sec at the maximum under the present operation rule. The hydraulic study showed that the flood reaching time from the dam to Pulau Raja and that of the remaining catchment area to Pulau Raja are nearly same. So that there is almost no possibility to avoid the overlapping of both floods. Therefore the probable flood peak discharge at Pulau Raja is estimated by adding 400 m^3/sec to the flood peak discharge from the remaining catchment area, except for case of 2-year probability when only 315 m^3/sec will be discharged from the dam.

(3) Probable Floods Estimated for Asahan and Silau

The results of calculations are summarized below, the details of which can be referred to APPENDIX G.

River	Site	Return Period (Year)						
		2	5	10	15	30	50	100
Asahan	Pulau Raja	625	826	1,001	1,106	1,355	1,523	1,839
Silau	Kisaran	449	457	565	670	911	1,055	1,300