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THE KINGDOM OF THAILAND

BANGKOK METROPOLITAN ADMINISTRATION

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

APPENDIX

MARCH, 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

SDS

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Appendix A DESCRIPTION OF MASTER PLAN AREA

The characteristics of the Master Plan Area gives a decisive influence on the planning of the flood protection and drainage system. Therefore, the general characteristics of the Area are explained in this Appendix.

1. Topography and Land Subsidence

The Master Plan Area (Fig. A.1) is located in part of the "central plain" which is an extensive and rather flat area formed by the sediments of the Chao Phraya River and its tributaries over a long period of time. The width of the lowland in the central plain ranges from 200 km in the southern part, to 150 km in the middle and 60 km in the north.

Pumping of groundwater carried out since the 1970s has changed topographic features. The recent land subsidence at critical areas has a maximum rate of 10 cm per year. A large part of the Eastern Bangkok Plain has already subsided and this area becomes a large lake during a flood period. Fig. A.2 shows the ground surface elevation in the eastern Bangkok Plain. Figs. A.3 to A.5 show the ground surface elevations and profiles respectively in the Master Plan Area, which are based on the recent survey conducted from June to July 1984 by the Study Team. The lowest parts of the Master Plan Area are Lat Phrao, Hua Mark, Bang Kapi and Phra Khanong. The ground elevations in these areas are less than 1.0 metre above MSL and the lowest is below MSL, while the highest water level of the Chao Phraya River exceeds 2.0 metres above MSL in the core area of Bangkok. It is noted that the shaded areas of Fig. A.3 were generally reclaimed with housing development and their ground surface elevations are higher by 50 to 100 cm than the adjacent virgin land.

In order to prevent further land subsidence, the MWWA, the largest consumer of groundwater made the plan to replace it with surface water. Future land subsidence rate based on the MWWA's plan is estimated by AIT, and the further details are described in Appendix D.

The amount of land subsidence between 1983 and 2000 is estimated as 1.0 metre in the whole Master Plan Area except of Bang Khen and Bang Sue area, northwestern part of the Master Plan Area where it is estimated as 0.7 m. These amount are used in planning the proposed flood protection and drainage facilities. Fig. A.6 is an estimated ground surface elevation in the Master Plan Area in 2000. Most of the Area will be below mean sea water level, which will make it difficult to have storm water runoff directly into the River by gravity flow.

2. Geology

In the Master Plan Area, the alluvial and marine deposits extend to an indeterminate depth of not less than 300 metres as shown in Fig. A.7. It is thought that almost all those deposits have been laid in the Quarternary and recent times and are formed by sands of alluvial origin. However, the upper 15 to 20 metres consists of clays, mainly of marine origin. The marine and alluvial deposits have formed an homogenuous and level plain.

The sub-surface deposits in the Bangkok area are as shown in Fig. A.8 and general characteristic of each layer is as follows:

(1) Weathered Clay-Top Layer

The uppermost layer of around 2 metres is a grey-brown clay and forms a weathered "dry crust" partially filled by various materials. The formation is made of normally consolidated or slightly over-consolidated clay.

(2) Soft Bangkok Clay

Very soft to medium dark grey silty clays, reaching depths generally between 10 and 20 metres, are formed rather recently and highly compressible.

(3) Stiff to Hard Clay

Stiff to hard clay and yellow-brown clay lies underneath the soft Bangkok clay. The depth of this formation is generally between 15 and 30 metres and thickness is 10 to 15 metres.

(4) Dense Sand Layers

Dense sand layers are light brown to greyish-brown fine to medium sand with some sandy clay.

Their formation is underneath the stiff to hard clay and generally the depths are from 20 to 40 metres. N-values of upper and lower layers range from 10 to 15 and 30 to 50 respectively. This layer is considered as a sintable foundation layer for structures.

3. Climate

3.1 Rainfall

Bangkok belongs to a savanna climate with low precipitation and distinct dryness in winter. It has three different seasons, the "Cold Season", which includes November, December and January; "Hot Season", extending from February through May, and the "Wet Season", covering the other five months of June through October. The relatively dry period extends from November through April with practically no rainfall in December and January.

Basically affecting the rainfall regime is the direction of the wind and its force and humidity in combination with the relief of the country; in other words, the nature of the rainfall is both orographic and cyclonic. In the dry season, lasting generally from November to May, the northeast tradewinds, also called the winter monsoon, reach Thailand, but since these winds come mainly from the continental land masses of Asia, they are dry and do not bring much rainfall. However, contrary to this rather simple picture, the rainy season is a complex phenomenon.

When, in spring, the sun proceeds northwards and heats the land masses, temperature and pressure differences between the land and the extended areas of water, the Bay of Bengal, the Gulf of Thailand and the Pacific Ocean, causes air movements from sea to land, which become so strong that the winter monsoon is forced back and is replaced by the summer monsoon blowing from the southwest from May to September.

Due to the variations of ground levels, the differences in temperature and pressure often cause developments of a very local character, forming high and low pressure areas and thus leading to cyclonic centres forming on the various seas.

Table A.1 Climatological Data for the period 1951 - 1980 in Bangkok

Subject	J	F	M	A	M	J	J	A	S	O	N	D	Annual Average
Temperature (°C.)													
Mean	25.6	27.2	28.6	29.6	29.1	28.6	28.1	27.8	27.6	27.5	26.6	25.5	27.7
Mean Max.	31.9	32.7	33.8	34.9	34.1	33.0	32.5	32.2	31.9	31.7	31.3	31.3	32.6
Mean Min.	20.6	22.8	24.6	25.7	25.4	25.1	24.8	24.7	24.4	24.3	22.8	20.7	23.8
Relative Humidity (%)													
Mean	73.0	76.0	77.0	77.0	79.0	79.0	80.0	81.0	84.0	83.0	79.0	74.0	78.0
Evaporation (mm.)													
Mean - Pan	185	169	195	170	140	141	130	119	100	125	153	182	1809
Cloudiness (0-8)													
Mean	4.7	5.2	5.4	5.6	6.6	6.8	6.9	7.0	7.2	6.5	5.3	4.7	6.0
Wind (Knots)													
Prevailing wind	NE	S	S	S	S	S	SW	W	W	NE	N	NE	-
Mean wind speed	3.6	5.1	5.8	5.7	4.6	4.8	4.5	4.6	3.8	3.3	3.5	3.4	-
Max. wind speed	31 NNE	37 N	48 ENE	56 E	42 W	43 S	SE 43	SW 45	WNW 44	SSW 40	NE 45	ENE 31	NNE 56 E
Rainfall (mm.)								W					
Mean	10.3	30.7	23.7	63.5	185.3	159.8	170.7	198.2	341.8	221.3	44.0	8.9	1458.2
Mean rainy days	1.7	3.0	3.3	6.2	15.6	16.7	18.3	20.6	21.3	16.7	5.5	1.4	130.3
Greatest in 24 hr.	39.3	73.0	52.8	133.5	124.2	167.3	108.8	97.8	153.7	123.2	81.2	32.0	167.3
Day/Year	31/61	11/64	24/73	22/51	15/66	13/79	30/55	26/71	23/68	5/60	2/69	8/72	13/79

Remark : 1 Evaporation 1937 - 1966

Between April and October, pre-monsoon storms, or small-scale cyclones, may form in the Bay of Bengal with the wind blowing in a northeast direction.

A similar storm centre, the typhoon, develops at about the same time in the Pacific Ocean, also moving north and south with the sun. The centre of the typhoon brings rain to Thailand in August, but the heaviest rain occurs in September when the typhoon passes through the country on a wide front.

The wet season is covered by the regular rainfall of the southwest monsoon which begins in the middle of May. Rainfall increases intensely in June to August and dies out in the middle of September, contributing tangibly to the water regime of the Kingdom with a fairly large precipitation every four five days. Fig. A.9 shows the direction of rain-bearing winds approaching Thailand during the year.

Due to flat relief, the annual rainfall in Bangkok is only about 1,400 mm. But it is interesting to note that, within Bangkok, there are considerable differences in the annual amounts of rainfall, and it appears that precipitation is higher on the eastern side of the Chao Phraya (Nonthaburi, Bangkok, Samut Prakan) than on the western side (Thonburi). Samut Prakan, closer to the sea, reports nearly 1,600 mm, whereas Nonthaburi, 40 km to the north, has only 1,300 mm.

Table A.1 shows that the heaviest rains are brought by the summer monsoon winds and reach a maximum in September.

3.2 Evaporation and Humidity

Evaporation has a definite negative correlation with rainfall. Measurements in Bangkok reported by AIT indicate the figures of 150 mm per month during the low rainfall season between December and April, dropping to about 120 mm per month in September.

The actual evapotranspiration figures vary with rainfall, temperature, soil moisture and other factors. According to the report of NEB in 1982, the highest, mean and lowest evapotranspiration figures are 113 mm/month, 81 mm/month and 39 mm/month respectively for the Lower Chao Phraya Basin. These are shown in Fig. A.10.

3.3 Temperature

The average annual temperature of Bangkok amounts to 27.7°C. But the average monthly figures range from 25.5°C in December to 29.6°C in April. Mean monthly maximum and minimum range from 31.3°C to 34.9°C, and from 20.6°C to 25.7°C respectively.

3.4 Wind Movements

Highest monthly mean wind speed is reported for March (5.8 knots). From that month it gradually decreases until December (3.4 knots). Expressed in the Beaufort Scale, mean monthly wind speeds never reach 3. An analysis of the annual wind speed distribution reveals the following percentages: calm 22 per cent, and 4 knots 27 per cent, 4-16 knots 49 per cent, and above 16 knots 2 per cent. The prevailing wind direction is either from the north or the south according to summer and winter monsoon.

4. The Chao Phraya River Basin

4.1 General

Thailand is located in the monsoonal region which has a distinct dry season and a flood season caused by monsoonal rains. The major part of streamflow comes from surface flow and subsurface flow in the wet season and from baseflow in the dry season. As shown in Fig. A.11 the Chao Phraya River Basin occupies most of the northern region and the central part of Thailand. The total drainage area of the Chao Phraya River Basin is 162,000 sq.km. The whole drainage area is generally divided into the Upper Chao Phraya River Basin and the Lower Chao Phraya River Basin. The outlet of the Upper Basin is located at Nakhon Sawan at which the Northern Rivers: Ping, Wans, Yom, and Nan emerge to become the Chao Phraya River. The drainage areas of the Upper and Lower Chao Phraya River Basins are 106,500 and 55,000 sq.km respectively.

An impression of the magnitude of the Chao Phraya River System can be obtained from the fact that the length of the Chao Phraya River from the source of the tributary Ping down to the Gulf of Thailand is roughly 1,000 km. The Ping itself has a length of 600 km, the Wang of 305 km, the Yom of 530 km and the Nan of 610 km. The Bhumibol Dam on the Ping River and the Sirikit Dam on the Nan River were built to store flood water, to generate hydro-electric power and to release water for irrigation, navigation, water supply and salinity control purposes. On the Wang River, the Kiu Lom Dam was constructed mainly for irrigation purposes. About 100 km downstream from Nakhon Sawan near Chai Nat Province, the Chao Phraya Dam was constructed to divert the river flow into the extensive irrigation schemes located downstream along both sides of the Chao Phraya River.

Downstream of Chai Nat Province, many effluent branches come off from the main river. Of these the Suphan, Noi and Lopburi are important ones. After giving off some minor effluents, the Chao Phraya River is greatly weakened when it reaches the city of Ayutthaya where it is joined by the fifth tributary on the east bank, the Pasak River. From here the river meanders as a single channel southward until it meets the Gulf of Thailand near Samut Prakan Province. The Suphan River does not join the Chao Phraya River but discharges into the sea near Samut Prakan Province, 35 km west of the Chao Phraya River Mouth. The lower stretch of the Chao Phraya River is affected by ocean tides. At Pa Mok near Ang Thong Province, located about 160 km from the river mouth, very slight fluctuation of water levels is noticeable during the period of low flow. Downstream from Bang Sai, the top width of the Chao Phraya River varies from 200 to 500 m. The overall gradient of the Chao Phraya River in this reach is roughly 5 to 6 cm per km. Bangkok, the Capital city of Thailand, is located both sides of the Chao Phraya River banks about 40 km from the river mouth. The elevation of the river banks neae Bangkok are approximatey 1.50 m above the Mean Sea Level. The gradient of the Chao Phraya River from Bangkok to the river mouth is very flat which is about 2 cm per km.

4.2 The Upper Chao Phraya River Basin

The Upper Chao Phraya River Basin is the major area which contributes to the flow of the Chao Phraya River. The Upper Basin covers the major part of the northern region of Thailand where the area is mountainous or hilly with wide sloping valleys running in the basin. The forests are evergreen and cover about 55 per cent of the whole drainage area of the Upper Chao Phraya River Basin.

About 85 per cent of the annual percipitation is caused by the southwest monsoon which extends from May through September while the northeast monsoon brings only a little rainfall from October to April. The annual average for the region is about 1,230 mm, the heaviest is along the Upper Nan River about 1,330 mm but the greater concentration being on the western side of the basin drained by the Ping River. The humidity and temperature of the Upper Chao Phraya River Basin have average value of 70 per cent and 24°C, respectively. Under these conditions, the average annual evapotranspiration is found to be equal to 900-1,000 mm. Floods usually occur in the lower reaches of the Ping, Wang, Yom and Nan Rivers and in the proximity of Nakhon Sawan. At present there are three major reservoirs and six governmental irrigation projects in the Upper Chao Phraya River Basin.

4.3 The Lower Chao Phraya River Basin

The Chao Phraya River Basin consists of the northern hilly areas and the Central Valley. In the Central Valley, an alluvial plain has been formed by th Chao Phraya River System. The upper plain in the Central Valley located north of Chai Nat is formed by the lower river valleys of the Ping, Yom and Nan Rivers. In the south of Chai Nat, the alluvial plain is called the Bangkok Plain and its greater part is the true delta of the Chao Phraya River. To the south the Chao Phraya Delta ends in the Gulf of Thailand. The overall gradient of the Chao Phraya Delta is very flat. At its apex near Chai Nat, approximately 200 km from the Gulf, the elevation is only 15 m above the Mean Sea Level. During flood stages, the delta area is completely inundated. The greater part of the Bangkok Plain is covered with a layer of so-called Bangkok Dark Heavy Clay approximately two metres thick. This soil, under the conditions of yearly flooding with water, is extremely well suited to rice production. More than half of Thailand's total rice production comes from the Bangkok Plain.

The mean annual rainfall over the Central Valley is about 1,340 mm. The mountainous region in the northern part of Thailand produces a rapid surface runoff resulting in high flow rates while the flat slope of the Bangkok Plain over the Central Valley of the Lower Chao Phraya River Basin retains the water for extended periods of time. Frequent flooding over the Bangkok Plain causes serious damage to crops and cities. In recent years, dikes have been constructed along both sides of the Chao Phraya River from Chai Nat to the vicinity of Bang Sai with an extension on the western side of the river down to Amphoe Pak Kret, Pathum Thani as shown in Fig. A.12. During flood periods, the Chao Phraya River throws out a portion of its discharge through the Lopburi River at Sing Buri Province and spreads over the flood plains in the vicinity of Lopburi City before returning to the Chao Phraya River at Ayutthaya. Flooding caused by the discharge from the Chao Phraya River also occurs in the vicinity of Ang Thong, Ayutthaya and Bang Sai.

The period of flooding in the flood plains of the Chao Phraya River from Chai Nat to Bang Sai generally extends from September to October. In the reach of the river from Bang Sai to the river mouth, flooding mainly extends from mid October to the beginning of December. Another factor which generates flooding in this region is the high tide condition in the Gulf of Thailand. The fresh water discharged toward the sea is substantially retarded causing a large volume of water to inundate the inland area, especially in the region of Bangkok City.

4.4 Main Klong

The Thai word klong, denoting a canal constructed for inland irrigation and or navigation, essentially means a natural tributary of distribution of a river. For the people in the delta, the klongs were the communication routes with the neighbourhood and the trading routes for the cargo boats laden with paddy. At the same time they provided water for domestic use in cooking, laundry, and bathing, and drinking water in the dry season. The klongs were also important for irrigating the ricelands. The klongs have been regrded as the means of distributing the floodwaters over the paddy fields to raise the rice crop.

Fig. A.12 shows the main klongs in the Lower Chao Phraya Plain.

Klong Sam Rong and Klong Saen Saep which connect the Chao Phraya river were dug for inland transportation. Klong Prem Prachakorn was dug to bypass the meanders of the Chao Phraya.

The other klongs such as Klong Phra Khanong (Prawet Burirom), Klong Sam Wa and Klong Hok Wa were built in the mid-nineteenth century, and provided necessary water for rice-growing.

Klong Sam Wa and Klong Hok Wa were included in the Rangsit canal system which comprosed a trunk canal, the Rangsit canal, and a lattice of several tens of canals. The Rangsit canal differed from the conventional canals in having lock gates at either end of the junction with the rivers, through which the water level could be controlled and the drainage and irrigation function increased.

In 1952 the Greater Chao Phraya Project was started for the irrigation and flood protection. The plan covered the whole of the Central Plain, most of which had already been fully developed as paddy field.

Originally, the Project had the following three objectives:

1) Supplementary irrigation to stabilize the production of wet-season paddy crop
2) to increase the yields of wet-season paddy and
3) to increase irrigated area by distributing the water of the Chao Phraya over as large an area as possible, and at the same time to mitigate flood damage in the high-water season by dispersing the flood-water.

The key structure in the system is a large barrage at Chainat.

Water conveyance to the young delta or Lower Central Plain on the east bank, which includes the Study Area, is achieved through the Chai Nat Pasak Canal via the Rama VI Dam.

The construction of the barrage was completed in 1957, and by 1962 the main part of the trunk and lateral canal system for conveyance and distribution of water had assumed its present form as shown in Fig. A.12.

Most of the central plain had already been fully developed as paddy field by the Greater Chao Phraya Project. In the area south of Ayutthaya, the irrigation is done by storage of water since gravity irrigation is difficult. The location of head works and regulating gates of navigation locks is shown in Fig. A.13. The water level has been controlled to be at about the same level as the land. The water level starts rising in August and lowers in November as shown in Fig. A.13.

In planning the Greater Chao Phraya Project, the net water requirement for a rice growing period of 180 days was estimated as 1,800 mm (10 mm per day), and the average effective rainfall for the same period was 1,050 mm. The difference of 750 mm is considered as the net irrigation water requirement. Allowing for losses in conveyance and distribution of about 800 mm, the estimated gross irrigation water required was calculated to be 1,550 mm (8.8 mm per day). In a survey of the water demand in the year 1968 in the northern region of the Greater Chao Phraya Project, it was reported that the approximate irrigation water supply was 950 plus/minus 270 mm for broadcast wet season rice.

5. Water Use

5.1 Water for Domestic, Industry and Commerce

Over 2 million cubic metres per day (CMD) water is consumed currently in BAngkok and its vicinity. The MWWA, established in 1967 supplies water of abut 1.75 million CMD for about 3 million people with a served area of 290 km^2 (Fig. A.14) in 1982. 1.3 million CMD is obtained from groundwater. Besides, groundwater is widely used in private sector because MWWA could not expand the water supply system to cope with the rapid expansion of urban development. The amount of groundwater in private sector reached 0.9 million CMD with number of wells of over 9,000. As a result, land subsidence has been taking place. It is found that the larger the use of groundwater, the higher the rate of land subsidence.

The MWWA, aiming at phasing out groundwater use both in MWWA and in the private sector, revised the master plan on water supply system of 1970 to cope with the future estimated population in 2000. According to the draft revised master plan, the Master Plan Area will be served with a MWWA water supply system in 2000. On the other hand almost all the eastern suburban Bangkok except the Master Plan Area, will not be covered with a water supply system by 2000.

5.2 Water Quality

1) Chao Phraya River

NEB monitered the water quality of the Chao Phraya River between 1978 and 1980, concerning the parameters of the components, such as temperature, Dissolved Oxygen (DO), Biocemical Oxygen Demand (BOD), Chlorine (Cl) and Nitrates (NO_3). According to the above survey, the present situation of water quality of the river is heavily polluted by industrial wastewater and domestic wastewater. Water pollution of the Chao Phraya River has been mainly caused by the development of industries along the river bank and concentration of population in the Bangkok Metropolis. The example of the variation of water quality (DO and BOD) along the River is shown in Fig. A.15.

2) Klongs

DDS started surveying the water quality of the klongs mainly in the Core Area in 1980. This activity is for sanitary conditions such as DO, BOD, CI, Hydrogen Sulfide (H_2S), Coliforms and Ammonium Nitrogen (NH_4^+-N). According to the Survey result, the surface water quality in the Core Area is very bad due to the discharge of sewers with domestic wastewater and industrial wastewater. Meanwhile, although the data is little, the rate of water pollution in the Master Plan Area is a little bit smaller than in the Core Area. The Study Team has collected the data of water quality for the klongs at the 11 water level gauge stations since September, 1983, in cooperation with DDS. Fig. A.16 to Fig. A.19 presents a graphical display of water pollution measured in 1983 by DDS and by the Study Team.

6. Economy

6.1 National Level

Thailand has enjoyed high economic growth during the past two decades. The national income has increased by approximately eight percent per year, and the real GDP has quadrupled and GDP per capita has more than doubled. (GDP per capita in 1980 = US$670)

The most striking feature of Thailand's growth pattern over the past two decades has been the sustained growth of the agricultural sector. Agricultural output, the highest single sources of income (25% of total income in 1981), has expanded at a rather high rate of five per cent per annum. Thailand has enjoyed not only agricultural self-sufficiency but also the position of a continuous net food exporter. Most of the growth of agricultural production can be explained by the expansion of land under cultivation along with relatively stable average yields. In most areas, it has been easier or more economical to increase cultivated land rather than to increase the production rate of existing cultivated land.

Recent growth rate in the industrial sector, approximately 11% per annum, has been sustained by the private sector. The government has been providing infrastructural support and exerting relatively limited control over private industry. A free enterprise environment has allowed development to take place at a rapid rate coping with the needs and resources available. The share of manufacturing in GDP reached 21% in 1981. The industrialization process initiated during the 1960s was geared toward import substitution. Export expansion became very important source of industrial growth toward the end of 1970's accounting for about one third of industrial sector growth.

The rapid economic change have also affected social and environmental conditions, and increased urban congestion leading to deterioration in culture, social value, mental well being, and the safety of lives and property. Furthermore, it is also widely accepted that past development effort and economic progress has only benefited certain parts of the country, and a large number of people are still living in absolute poverty. It is estimated that there are 10 million people in rural areas who are in this category. On the other hand, recent world economic changes, particularly under the high energy price, international financial crisis, high inflation rate, and stagnant economic growth, have greatly affected Thailand's economy which is heavily dependent on international trade, particularly as an importer of energy, and capital.

In order to overcome these distortions and difficulties, the government of Thailand created a new national economic discipline, the Fifth National Development Plan 1982-1986. It has the following main characteristics.

1) The adjustment of economic structure rather than economic growth.
2) Equity in national economic and social development effort
3) Poverty alleviation for people in backward rural areas.
4) More closer coordination between economic and social development effort and national security management
5) The implementation of the Plan into the operational private sector.

The Plan, drafted by National Economic and Social Development Board, has its main focus on economic development of provincial areas for in the past, the trend was to mobilize national resources to the capital area, Bangkok.

6.2 Municipal Level

The economic activities of Greater Bangkok Area is significant for the entire economy of the Kingdom. Because of the highly centralized nature of Thailand's bureaucracy and also with the geographical advantage, all the major central government facilities, industrial firms, trading houses, multi-national corporations and international organizations are located in the Bangkok Area. These establishments are supported with a seaport, airport, other transportation facilities, and also with various commercial and service activities, resulting in a high concentration of people and their economic activities in the city. The population in the Greater Bangkok (Nonthaburi, Thon Buri, Samut Prakarn & Phra Nakhon) shares 10% of total population and 50% of total urban population in the Kingdom in 1970. Although the area comprises only 0.6% of the country, 30% of GDP is generated in the city.

The major manufacturing industrials are food processing, textiles, printing, metal works, repair shops and chemicals. More than half of the manufacturing enterprises are in Bangkok. Out of 2,000 establishments in Greater Bangkok, about 20% are located in Thon Buri and Samut Prakarn respectively. (Industrial census 1970).

The employment and income structure reflect the characteristics of the city. Within the economic active population in Bangkok, 17% are employed in the industrial sector, 29% in agriculture and 54% are engaged in commerce, transportation, communication and other general services. The wage and salary earners comprise 47%, while the figure is 12% in the entire country, and the share of unpaid family workers are 27% while that of the country is 50%.

The production workers that reside in Bangkok are 29% of the national total, and 51% of the highly qualified technical, managerial and clerical personnel are working in Bangkok. These figures support the rest of the country.

The difference in income level induces an inflow of migrants from the outer area, which brings a rapid growth of urban population estimated to be 5% per year in 1979. Various problems due to rapid urbanization are evident in inadequate infrastructures such as transportation facilities, water supply, sewage, waste disposal, drainage and other public facilities. The phenomenon of flooding deteriorates the condition further, brings about another burden for the Municipality as the infrastructure is essential for Bangkok to function as the capital of Thailand.

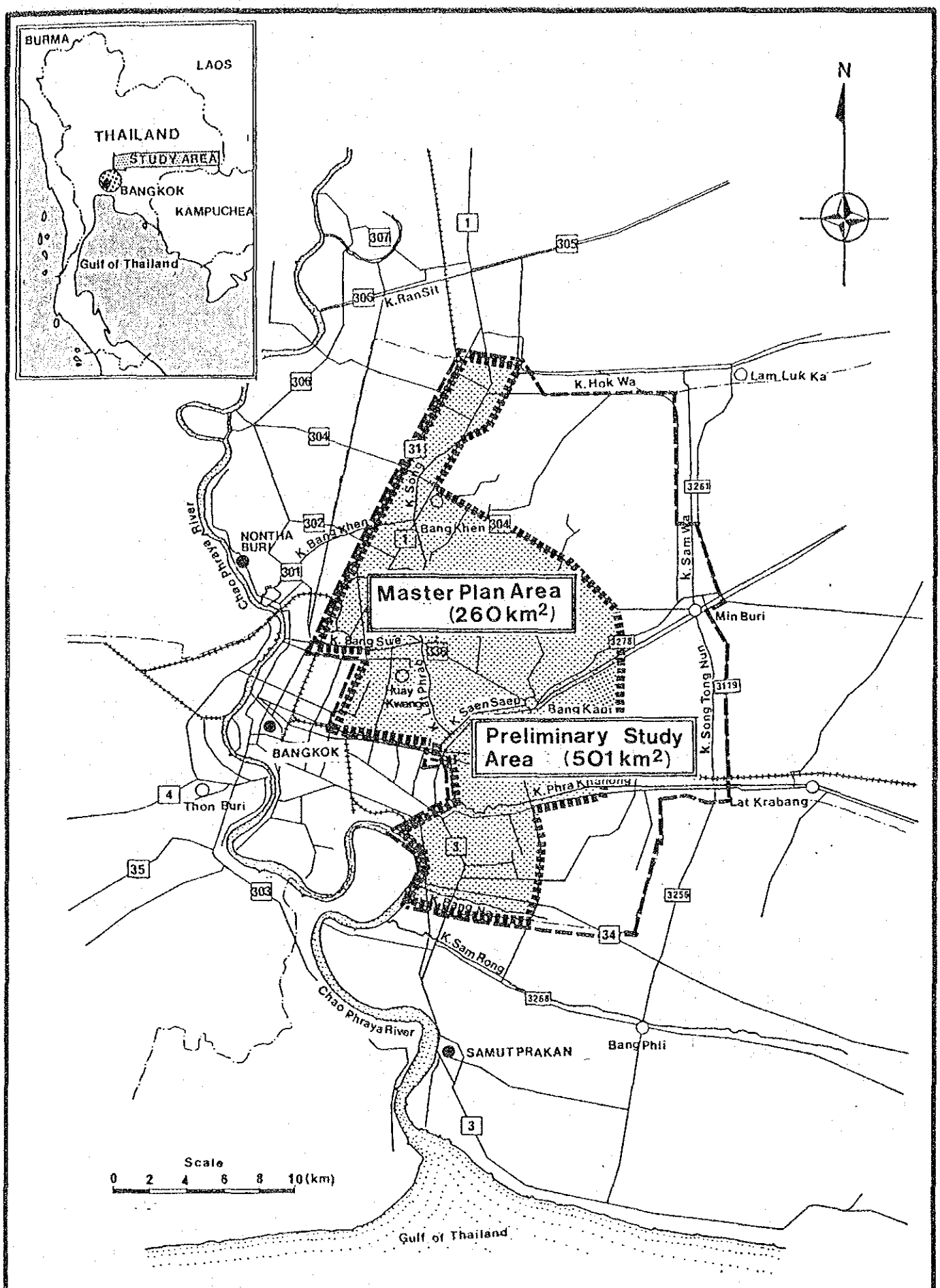
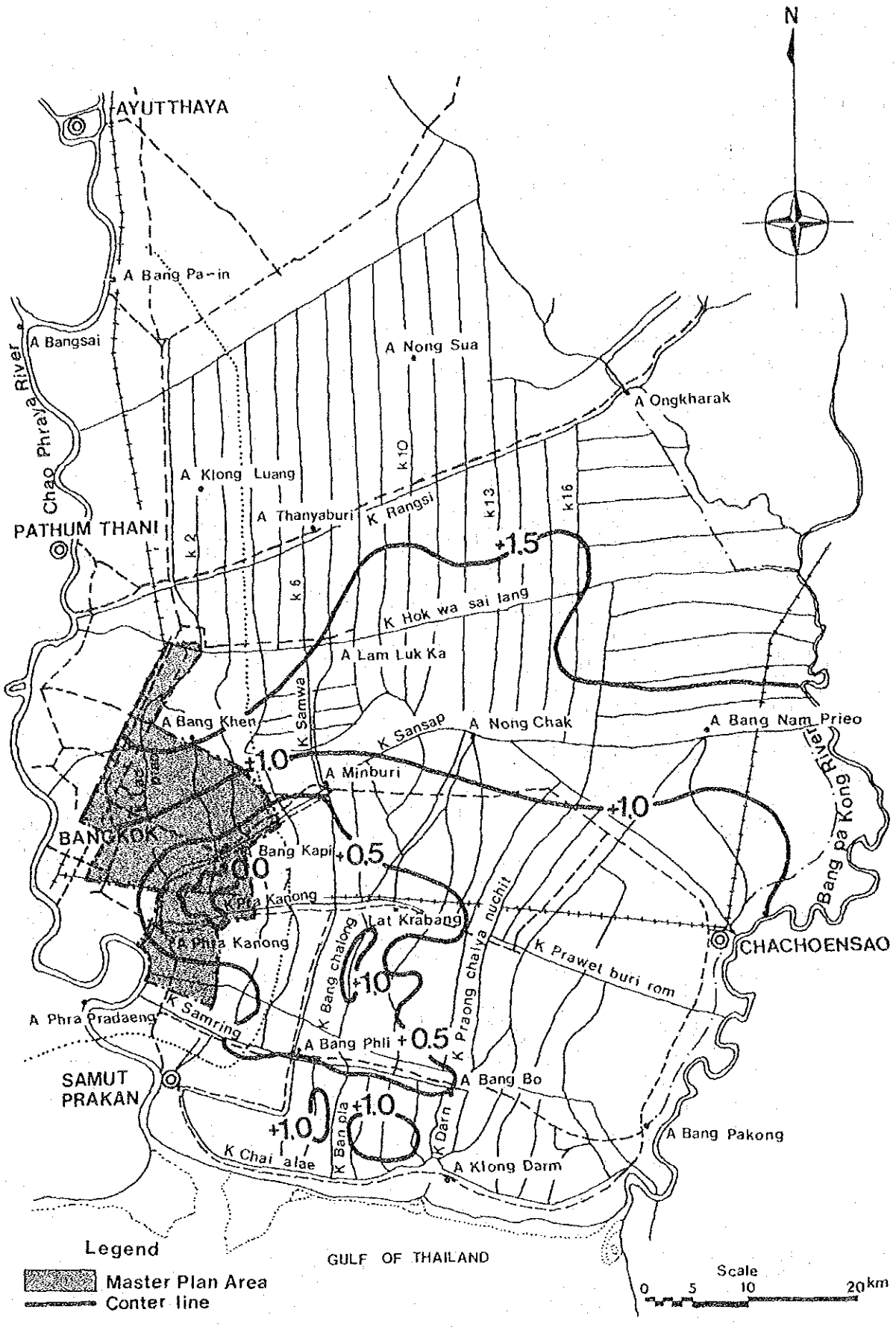


Fig. A.1 MASTER PLAN AREA

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

JICA 2528B.E 1985A.D



(Source : AIT)

Fig. A.2 GROUND ELEVATION IN THE EASTERN BANGKOK PLAIN

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

JICA 2528B.E 1985A.D

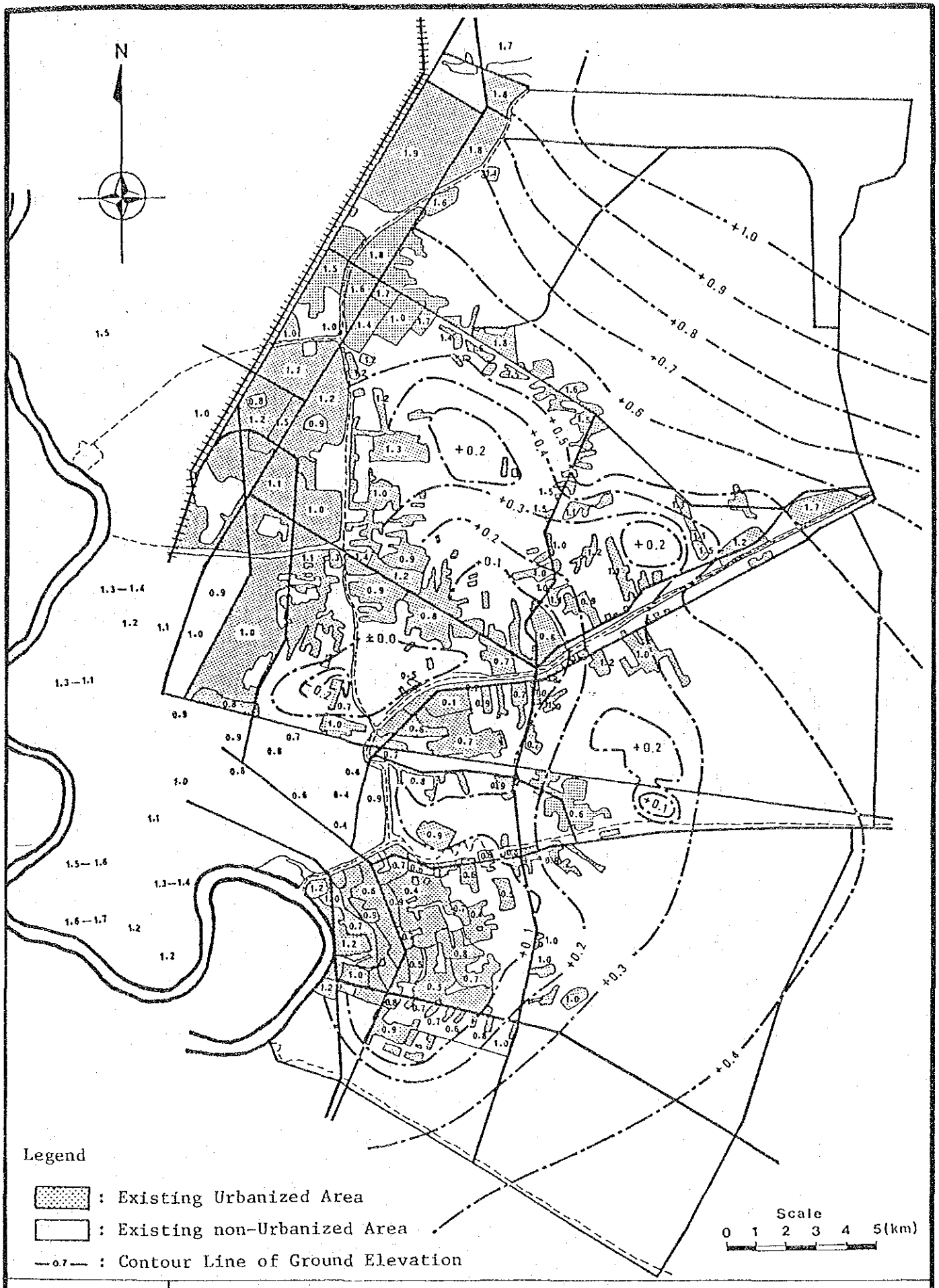
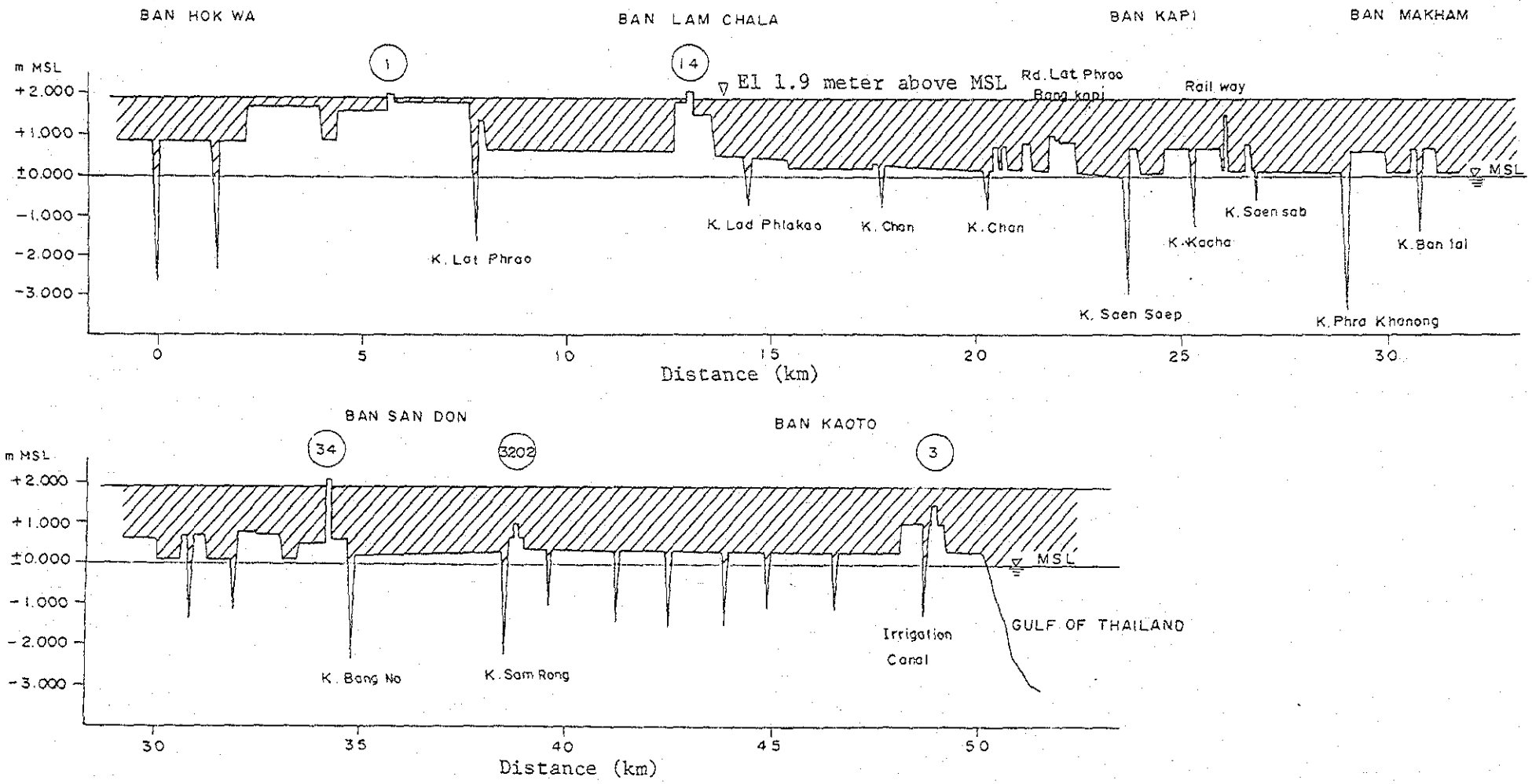


Fig. A.3 GROUND ELEVATION IN THE MASTER PLAN AREA AS OF 1984

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

JICA 2528B.E 1985A.D

NORTH-SOUTH SECTION



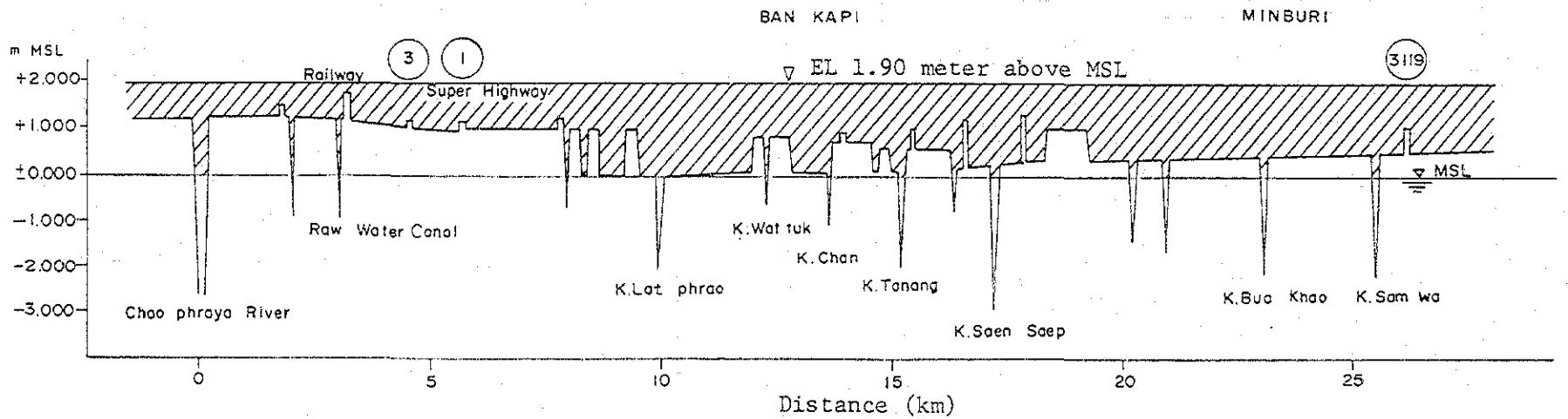
Same Note as Fig. 2.4, 2.5 of Preliminaly Report

Fig. A.4 NORTH-SOUTH PROFILE OF THE MASTER PLAN AREA IN 1987

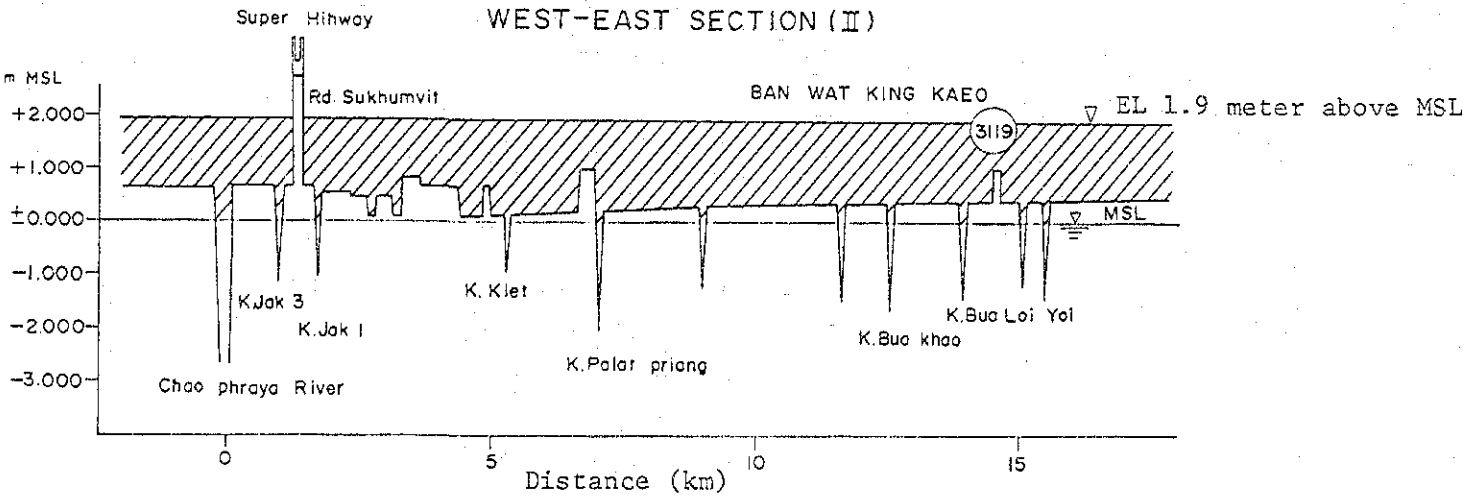
MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

JICA 25288R.E 1985A.D

WEST-EAST SECTION (I)



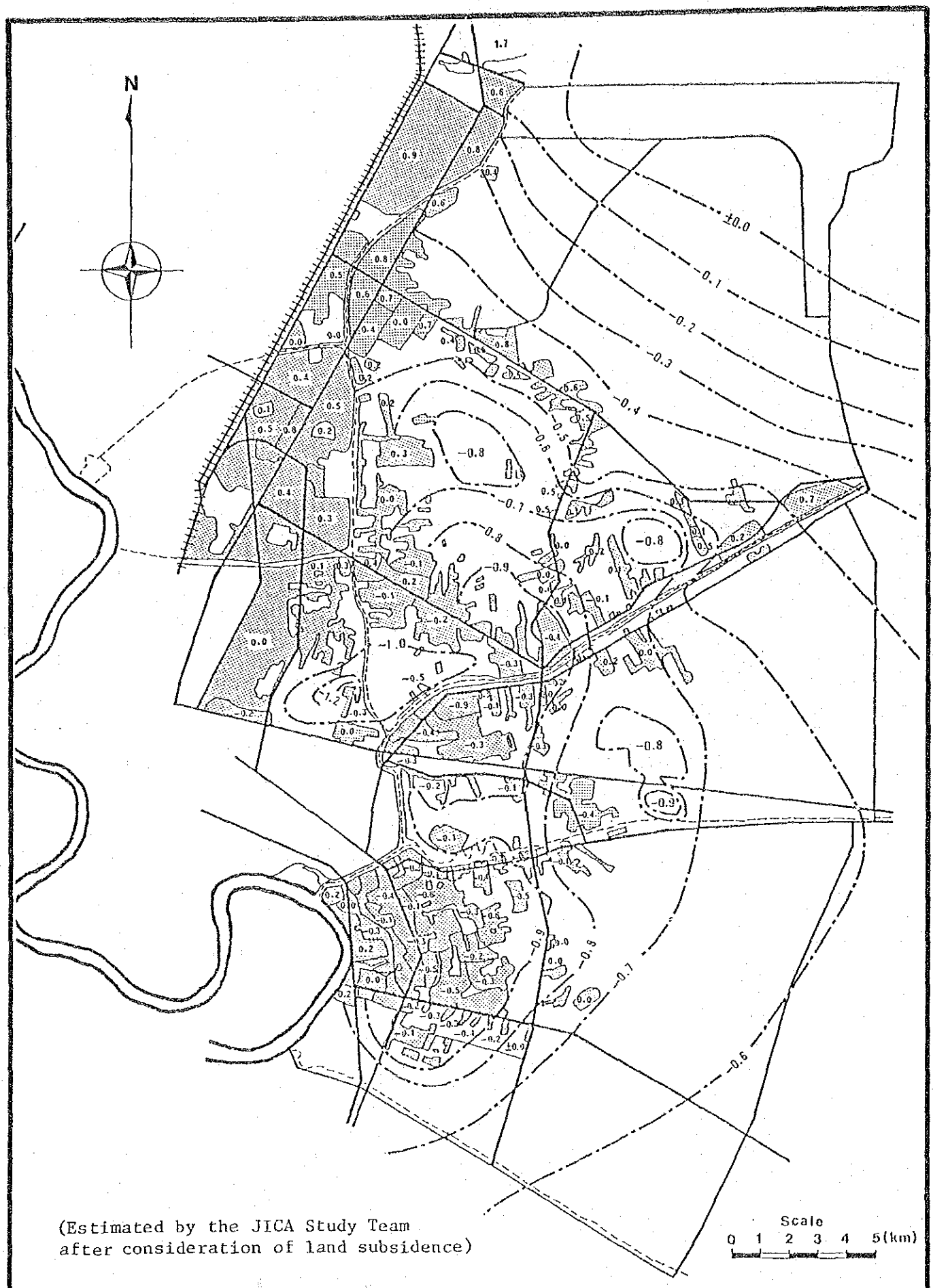
WEST-EAST SECTION (II)



Same Note as Fig. A.4

Fig. A.5	FAST-WEST PROFILE OF THE MASTER PLAN AREA IN 1984

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

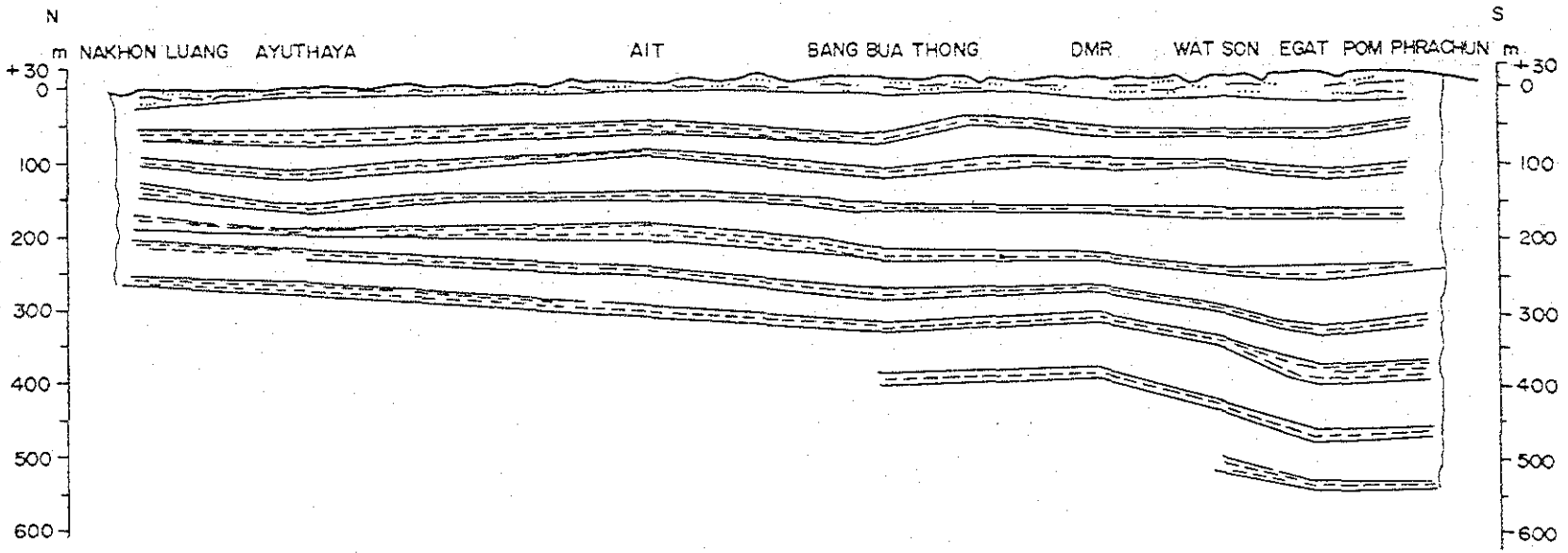


(Estimated by the JICA Study Team
after consideration of land subsidence)

Fig. A.6 GROUND ELEVATION IN MASTER PLAN AREA IN 2000

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

JICA 2528B.E 1985A.D



EXPLANATION

Clay : Bangkok clay, soft on top, stiff at bottom

Clay (confining bed) : Consists predominantly of stiff clay, with sandy clay or fine sand layers or lenses.

Sand and gravel (aquifer) : consists of sand and gravel of various sizes and colours moderately to well sorted, subangular to rounded. The aquifers are commonly interbedded with clay layers and lenses.

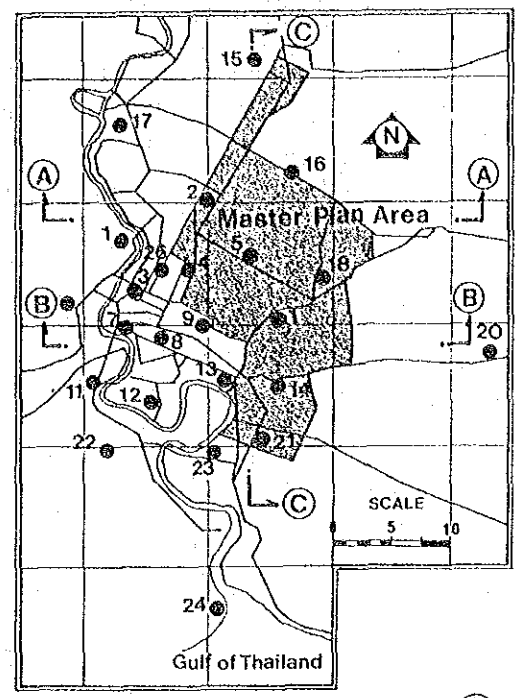
Scale
Horizontal : 1:400,000
Vertical : as indicated

Source : Investigation of Land Subsidence, AIT

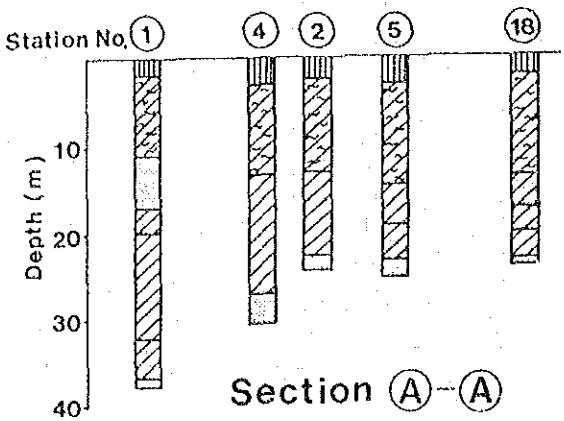
Fig. A.7 NORTH-SOUTH GEOLOGIC PROFILE OF THE LOWER CHAO PHRAYA BASIN

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

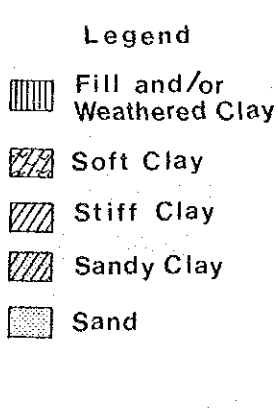
JICA 2528B.E. 1985A.D

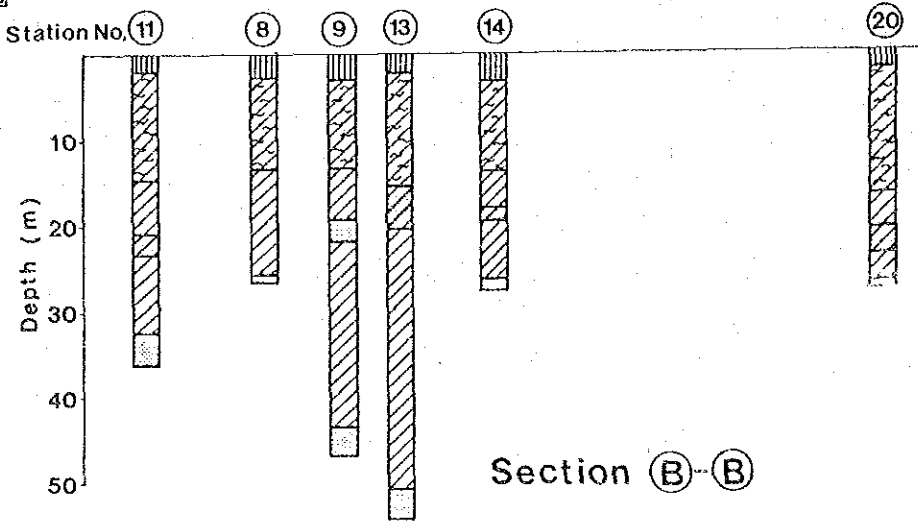


Key Map

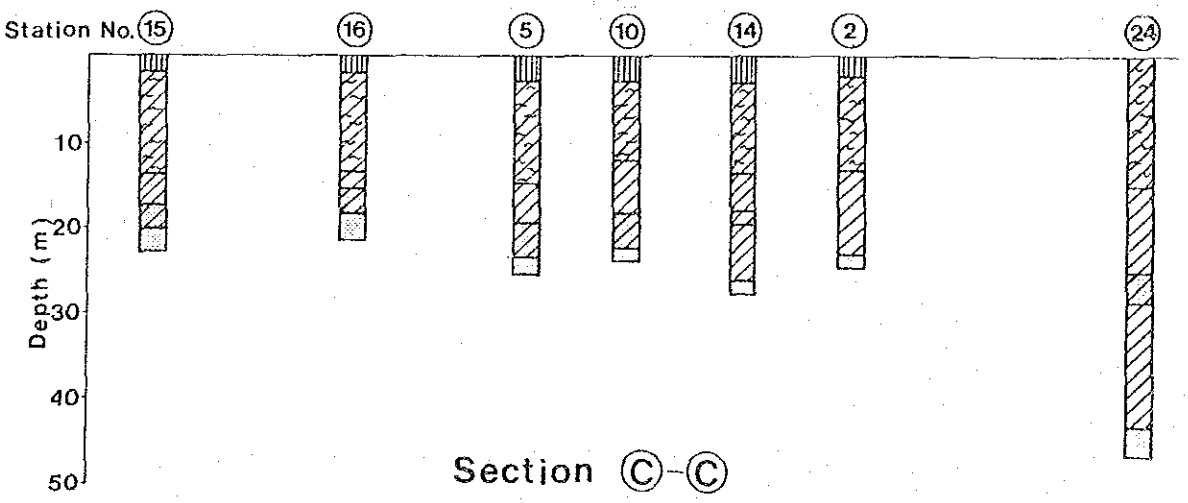


Section Ⓐ-Ⓐ





Section Ⓑ-Ⓑ



Section Ⓒ-Ⓒ

Source : A I T

Fig. A.8 SUB-SURFACE GEOLOGIC PROFILE IN MASTER PLAN AREA

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

JICA 2528B.E 1985A.D

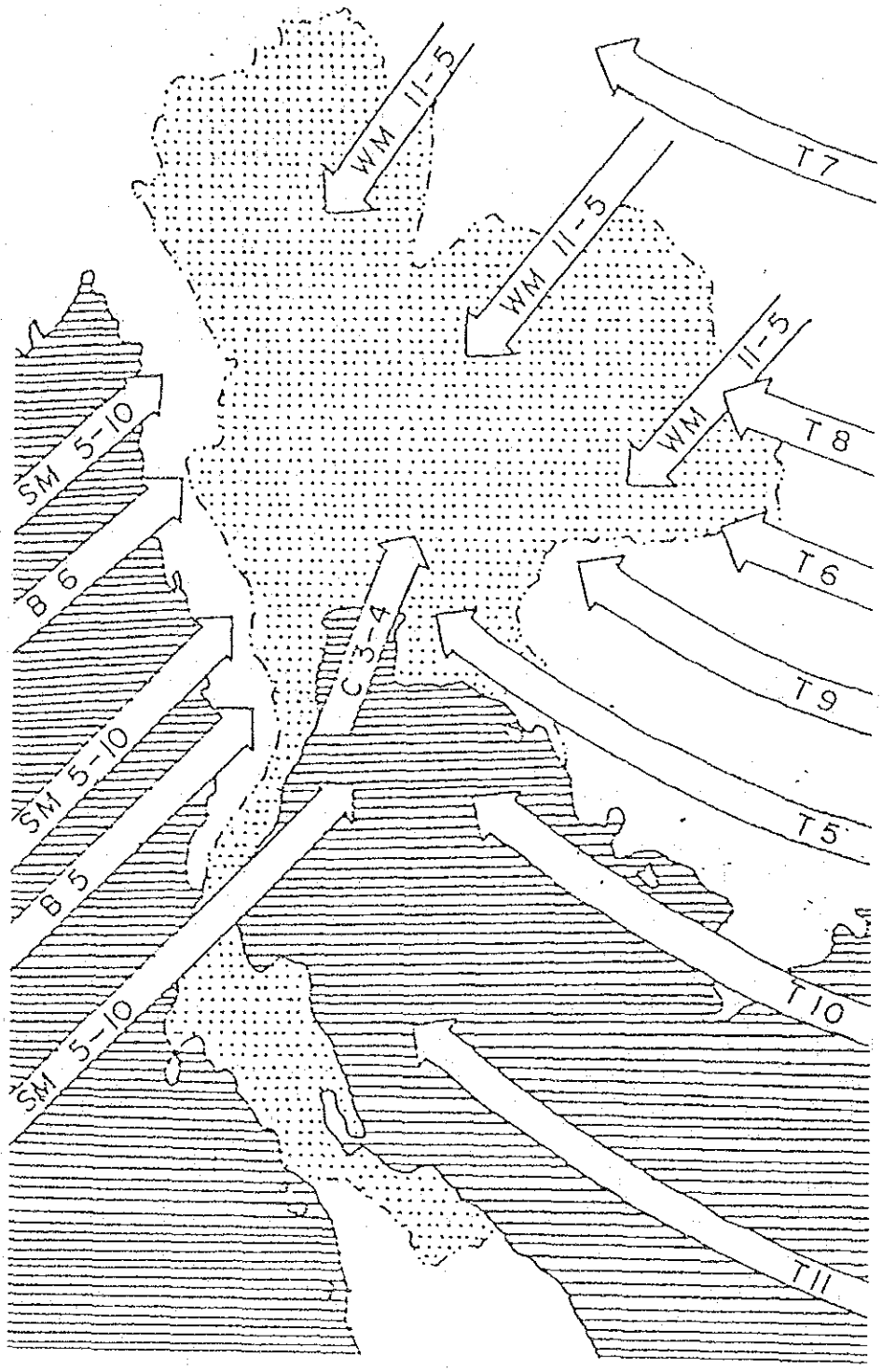
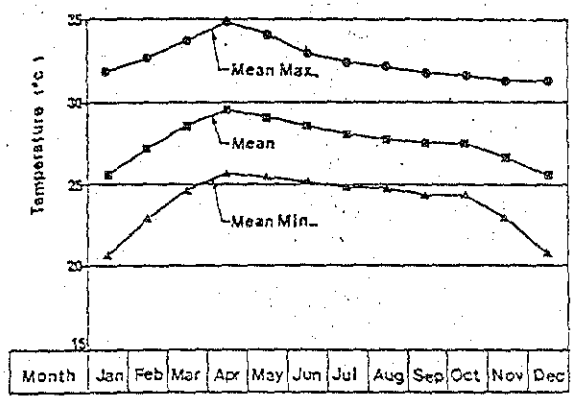


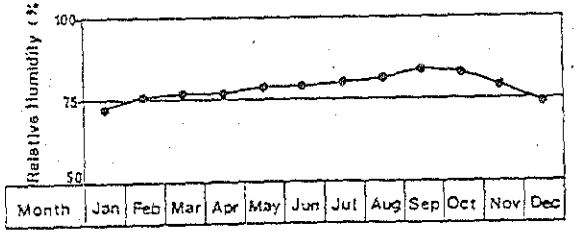
Fig. A.9	WIND INFLUENCING THE CLIMATES OF THAILAND

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

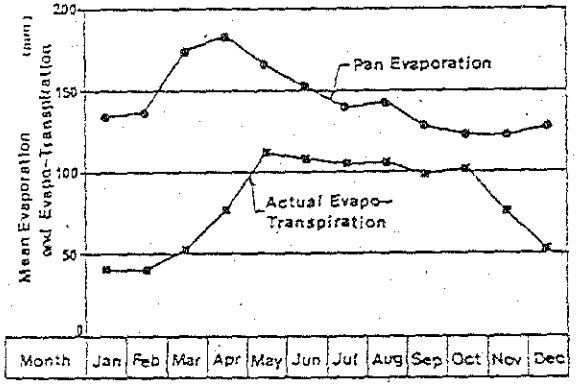
JICA 2528B.E 1985A.D



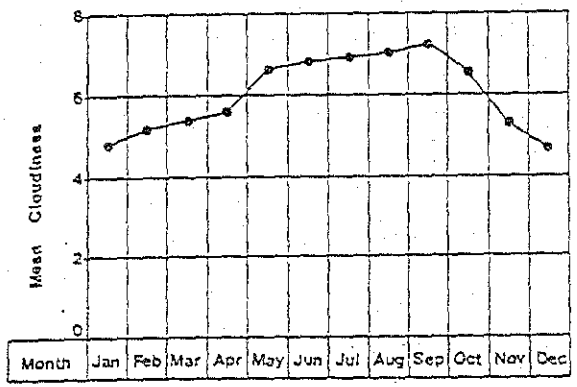
Temperature



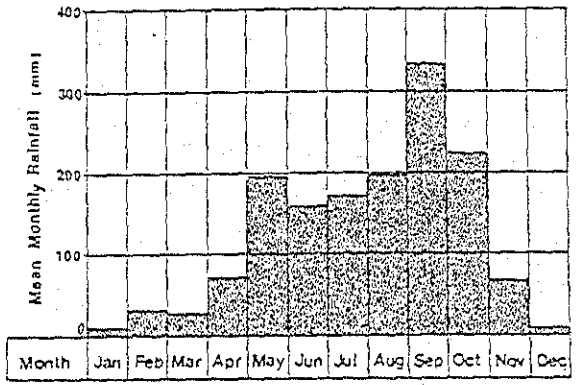
Humidity



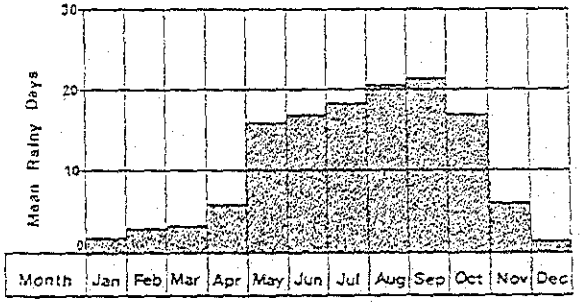
Evaporation and Evapotranspiration



Cloudines



Monthly Rainfall



Rainy Days

Note

1. Source

Evaporation: AIT, Rainfall and Evaporation Analysis of Thailand, 1980 12.

Evapotranspiration : NEB, Groundwater Resources in Bangkok Area Development and Management Study, 1982

Others: Meteorological Department

2. Period

Evaporation: 17 years

Evapotranspiration : 1956 - 1974

Rainfall and Rainy Days: 1951 - 1982

Others: 1951 - 1980

Fig. A.10 CLIMATOLOGICAL DATA IN BANGKOK

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

JICA 2528 B.E. 1985 A.D.

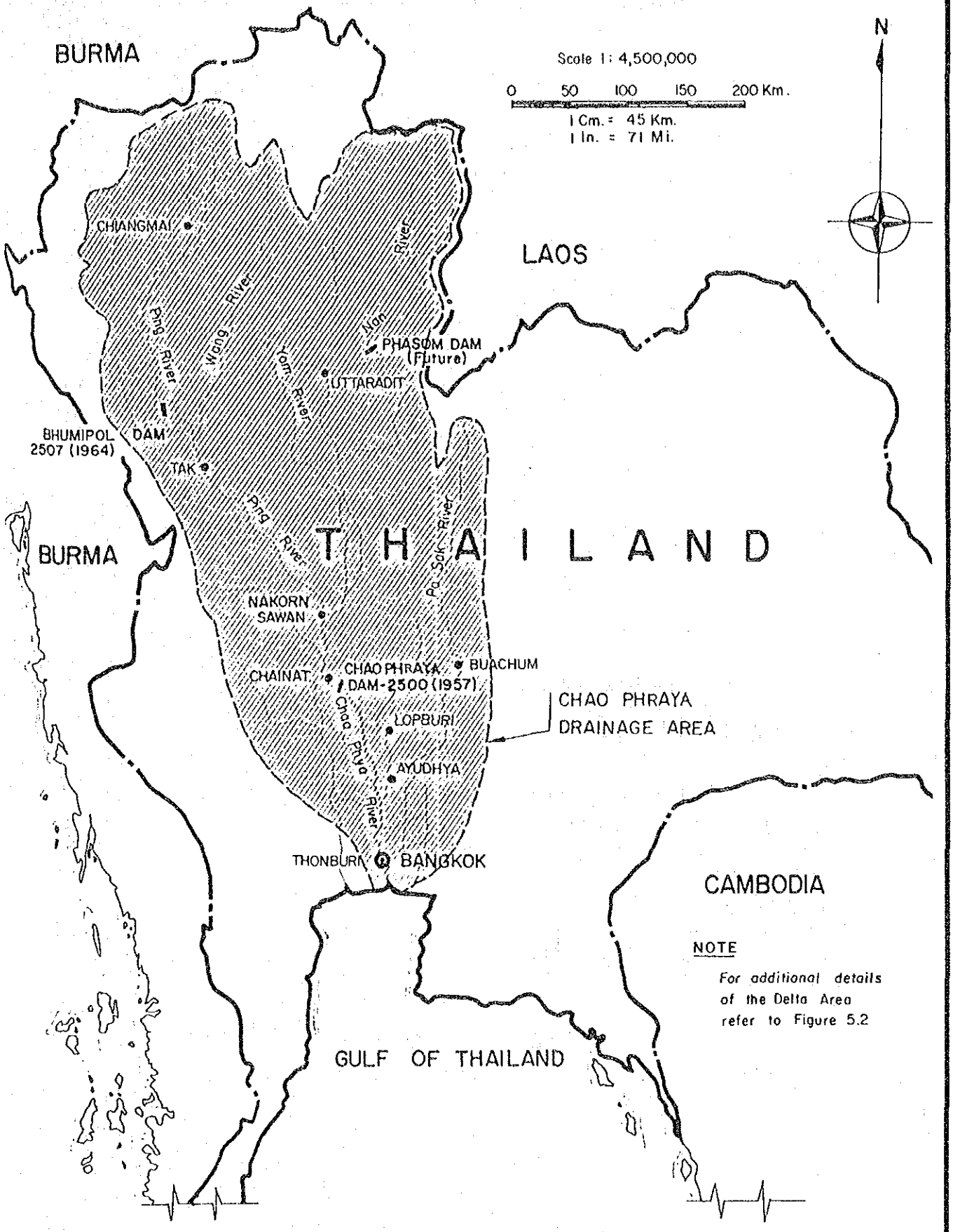
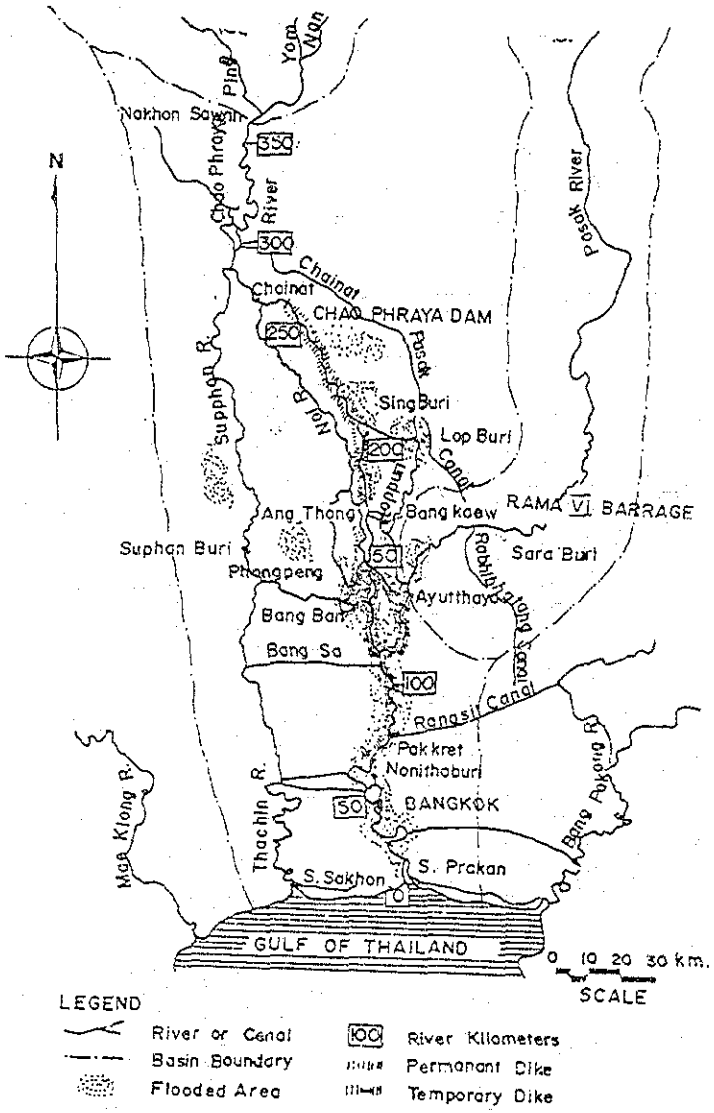


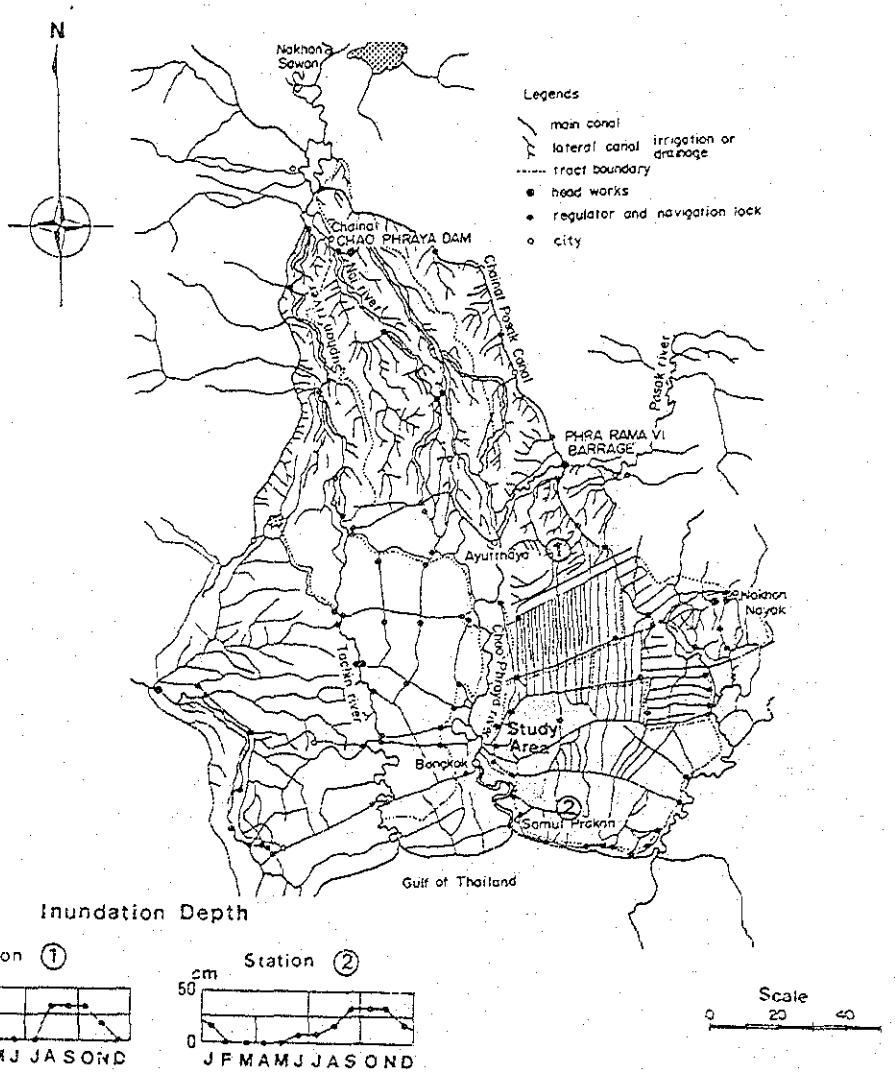
Fig. A.11 CHAO PHRAYA RIVER BASIN

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

JICA 2528B.E 1985A.D



Map of Inundation of Chao Phraya and Its Diking System

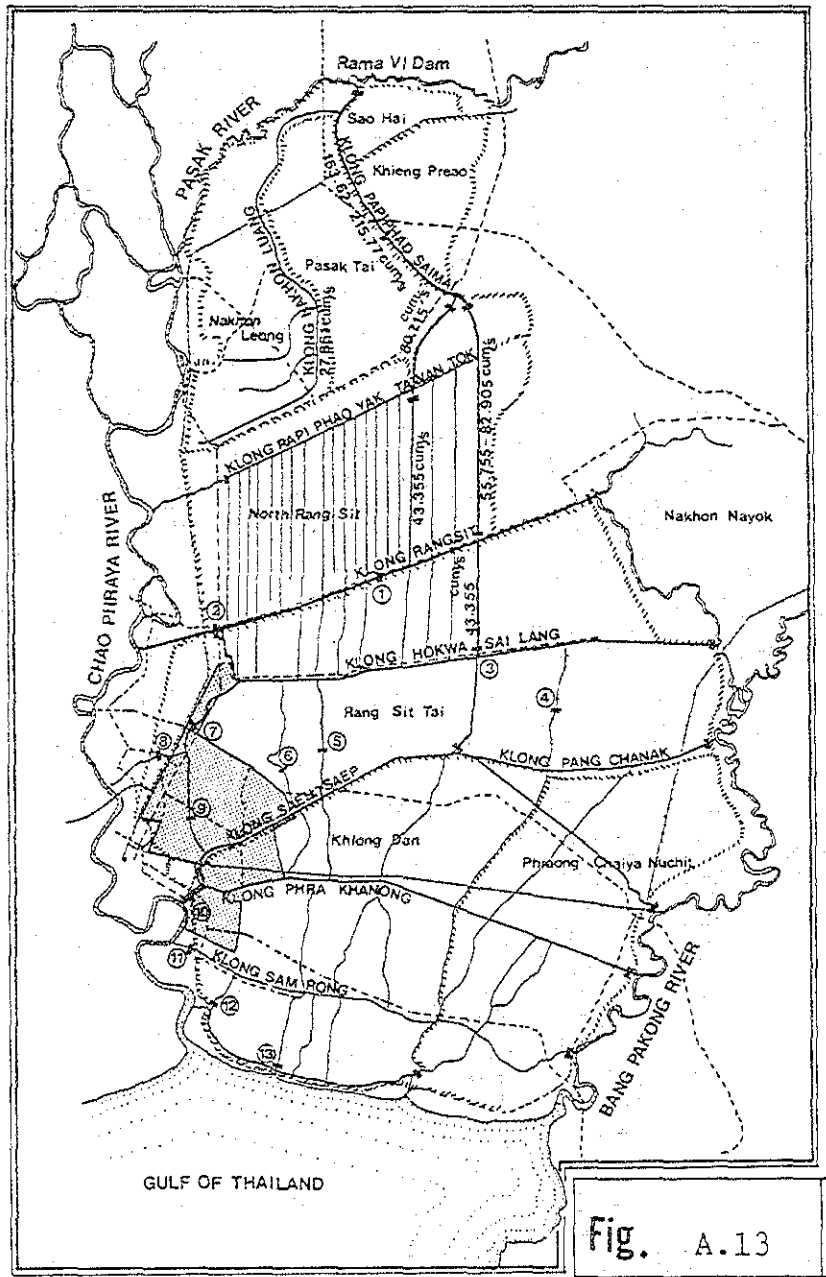


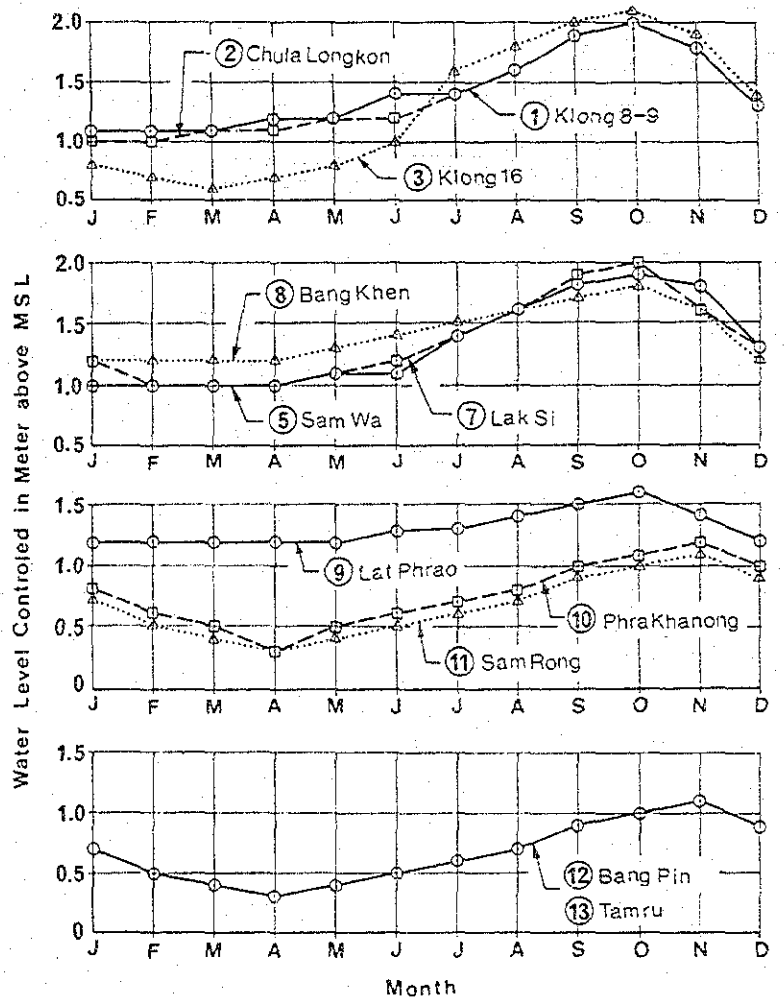
(Source: RID)

Irrigation Canal Network for the Greater Chao Phraya Project

Fig. A.12	EXISTING DIKE & IRRIGATION CANAL IN CHAO PHRAYA BASIN

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK





[Source : RID]

Fig. A.13 IRRIGATION SYSTEM AT AND NEAR THE MASTER PLAN AREA AND WATER LEVELS AT CONTROL GATES

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

JICA 2528 B.E. 1985 A.D