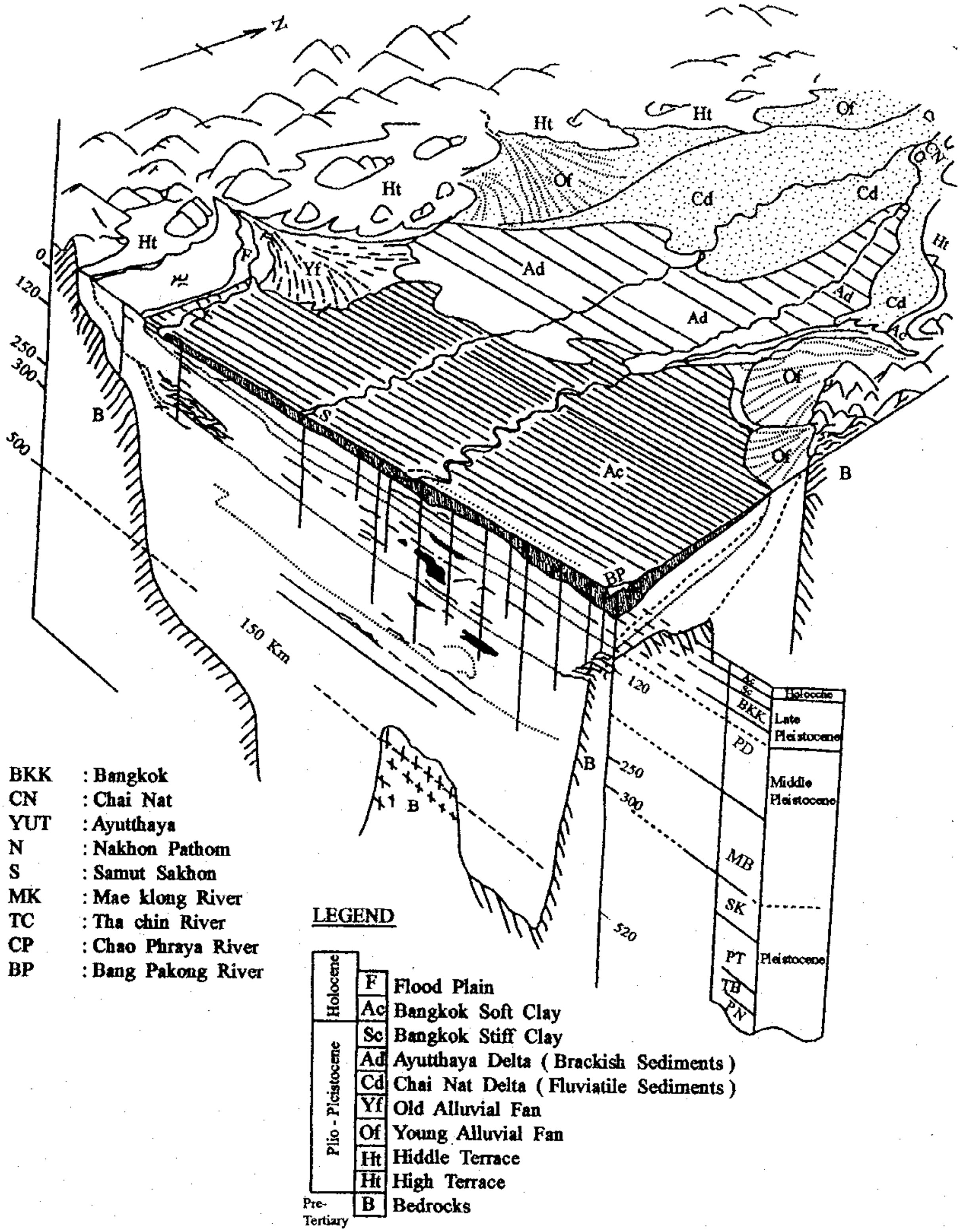
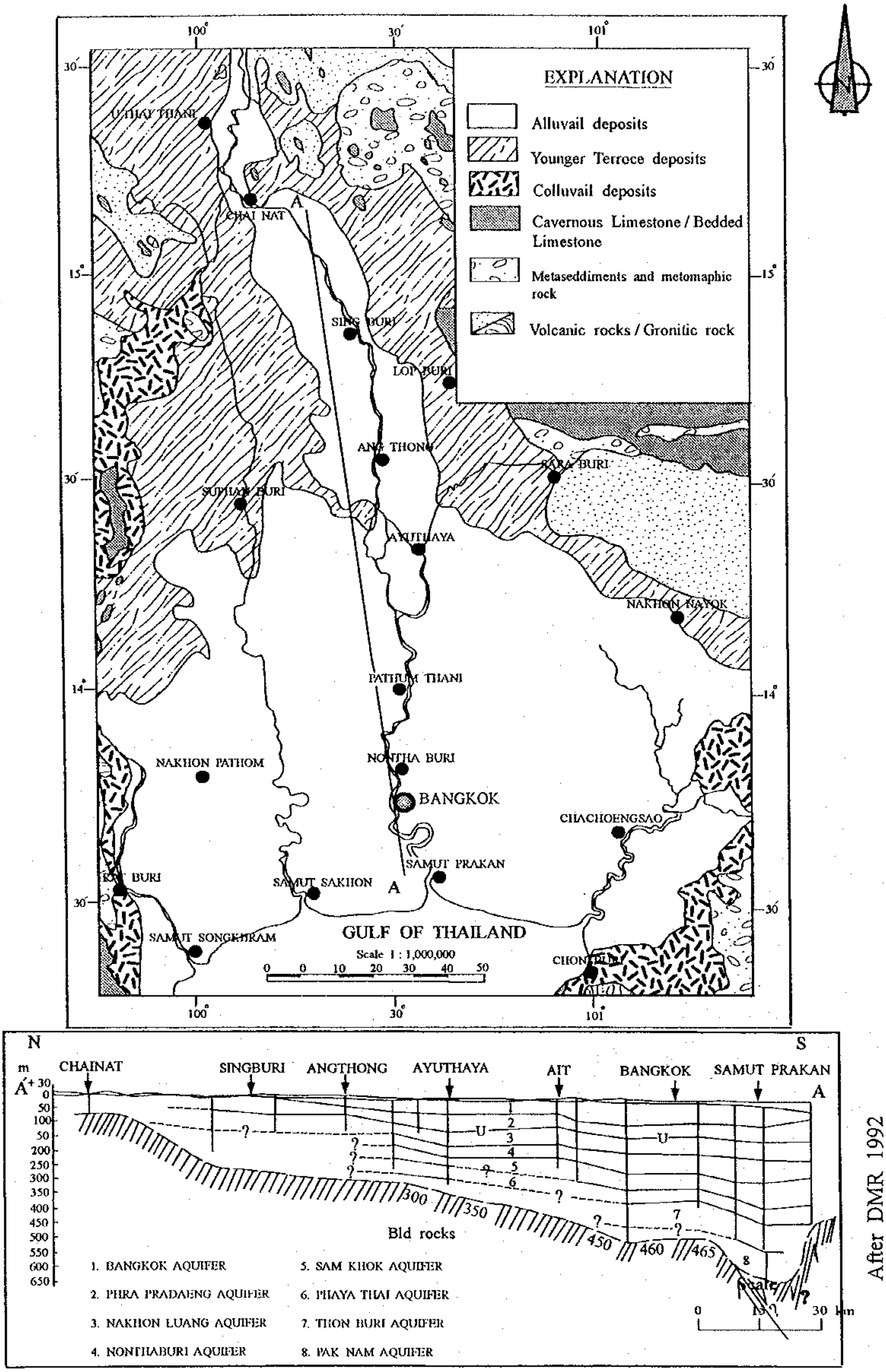


After JICA / DMR , 1995

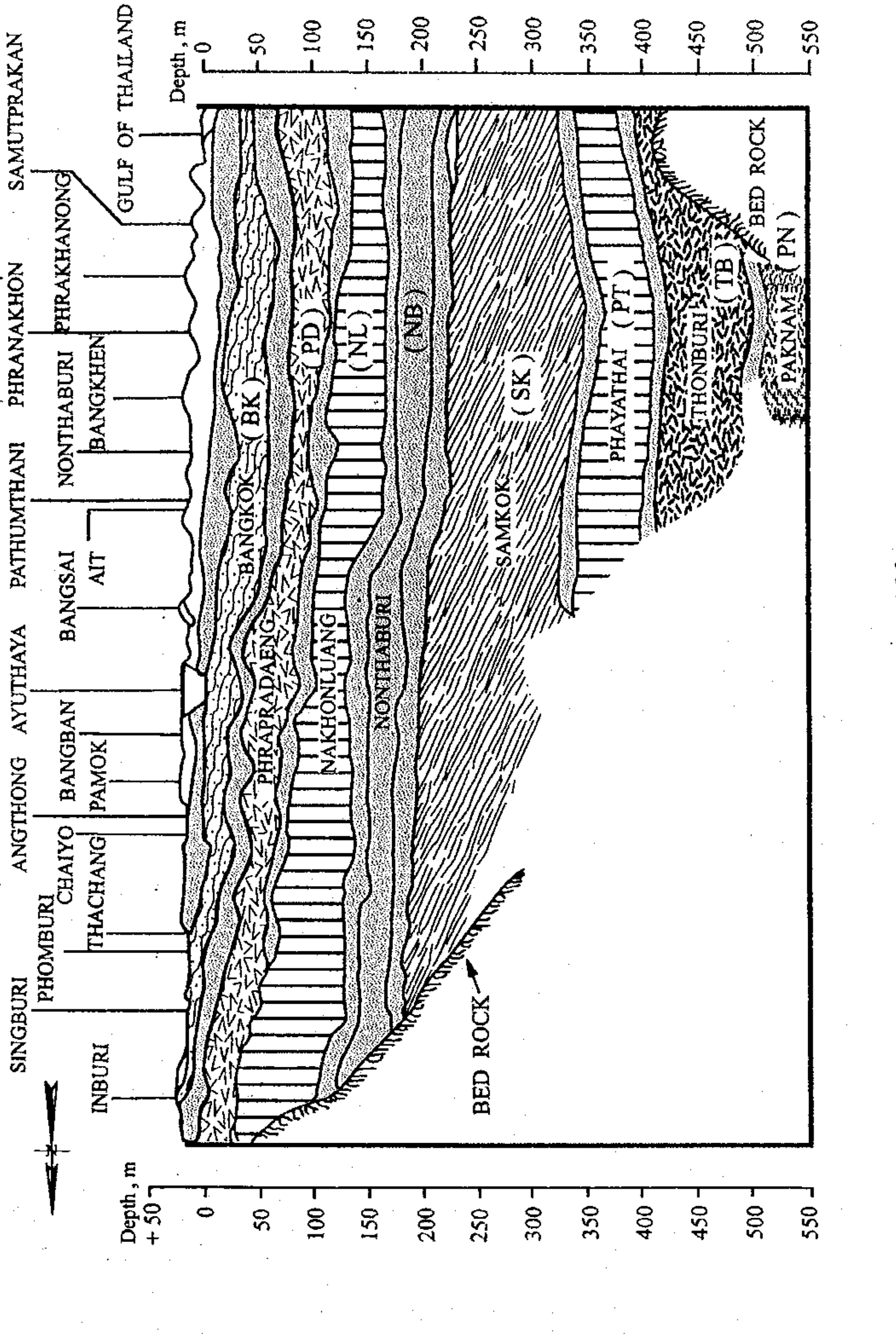
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN

CTI ENGINEERING CO., LTD AND INA CORPORATION

Fig.1.3.1
SCHEMATIC DLAGRAM OF THE LOWER CENTRAL PLAIN

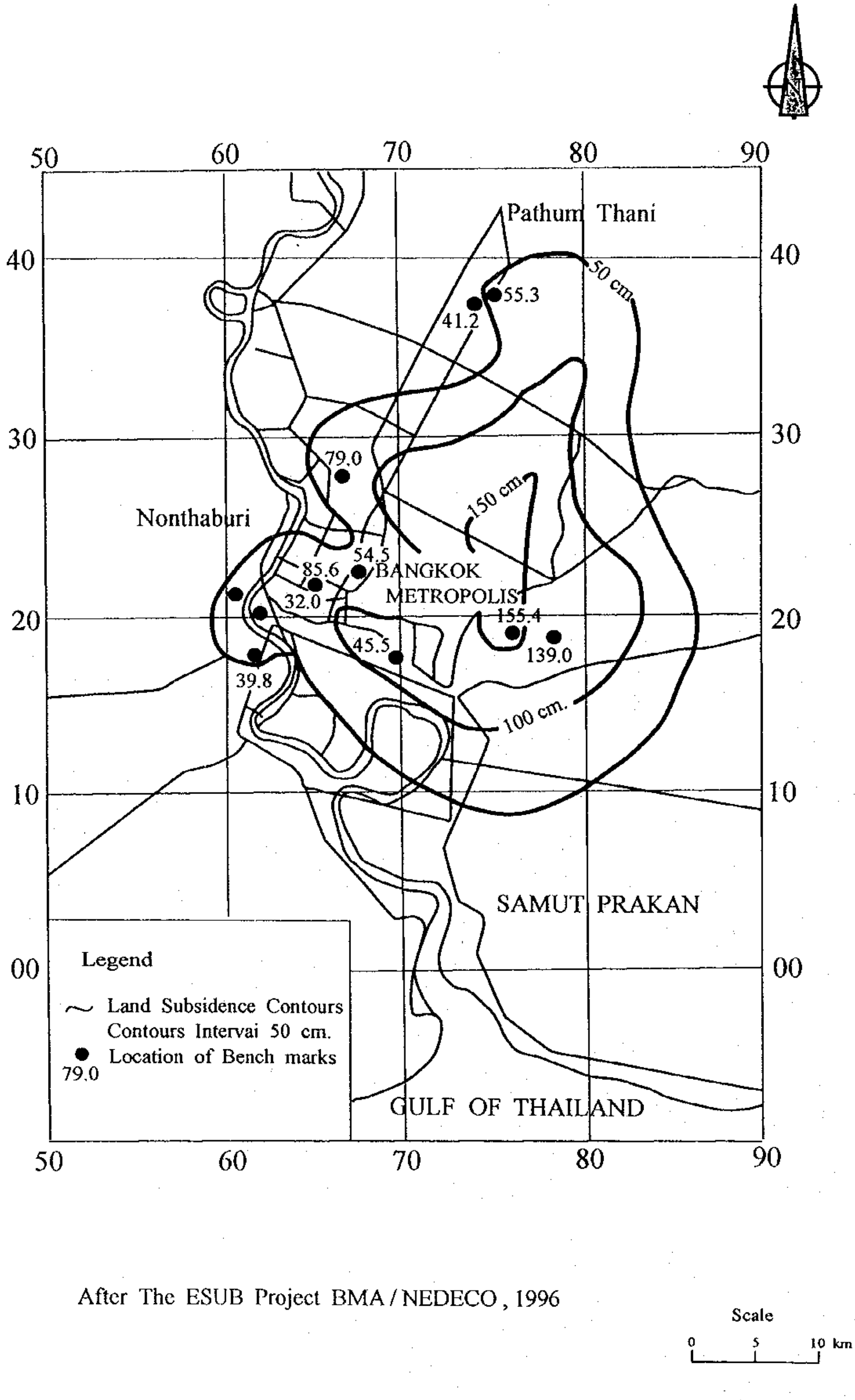


STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig. 1.3.2 HYDROGEOLOGIC MAP OF THE LOWER CENTRAL PLAIN AND N-S PROFILE OF THE STRATA
CTI ENGINEERING CO., LTD AND INA CORPORATION	



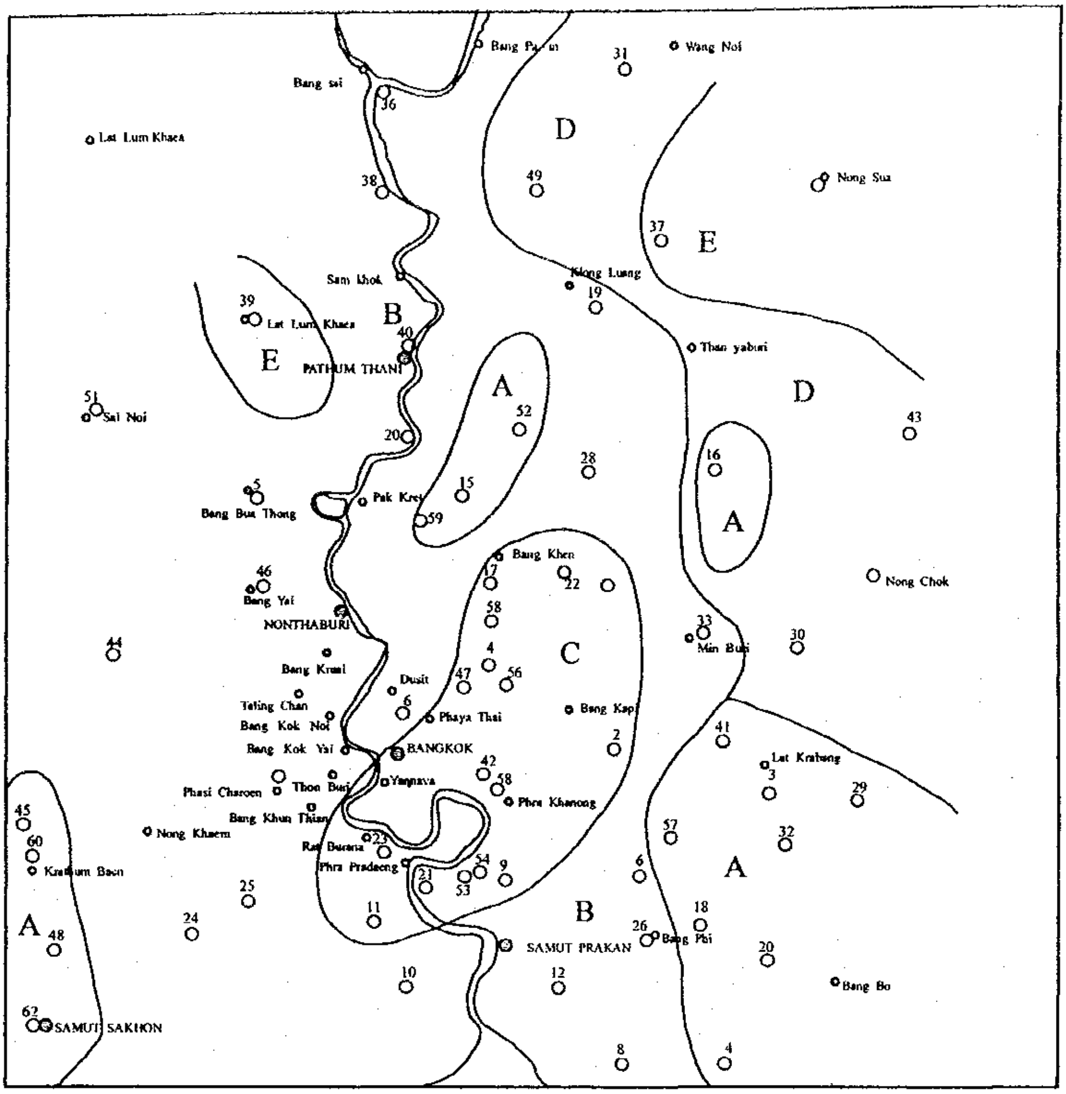
After Balasubrmaian et al, 1989

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig. 1.3.3 SUBSOIL LAYERING SYSTEM OF THE ENTIRE CHAO PHRAYA PLAIN
CTI ENGINEERING CO., LTD AND INA CORPORATION	



After The ESUB Project BMA / NEDECO, 1996

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig. 2.1.1 LAND SUBSIDENCE IN BANGKOK AREA AND VICINITY 1933 - 1986
CTI ENGINEERING CO., LTD AND INA CORPORATION	



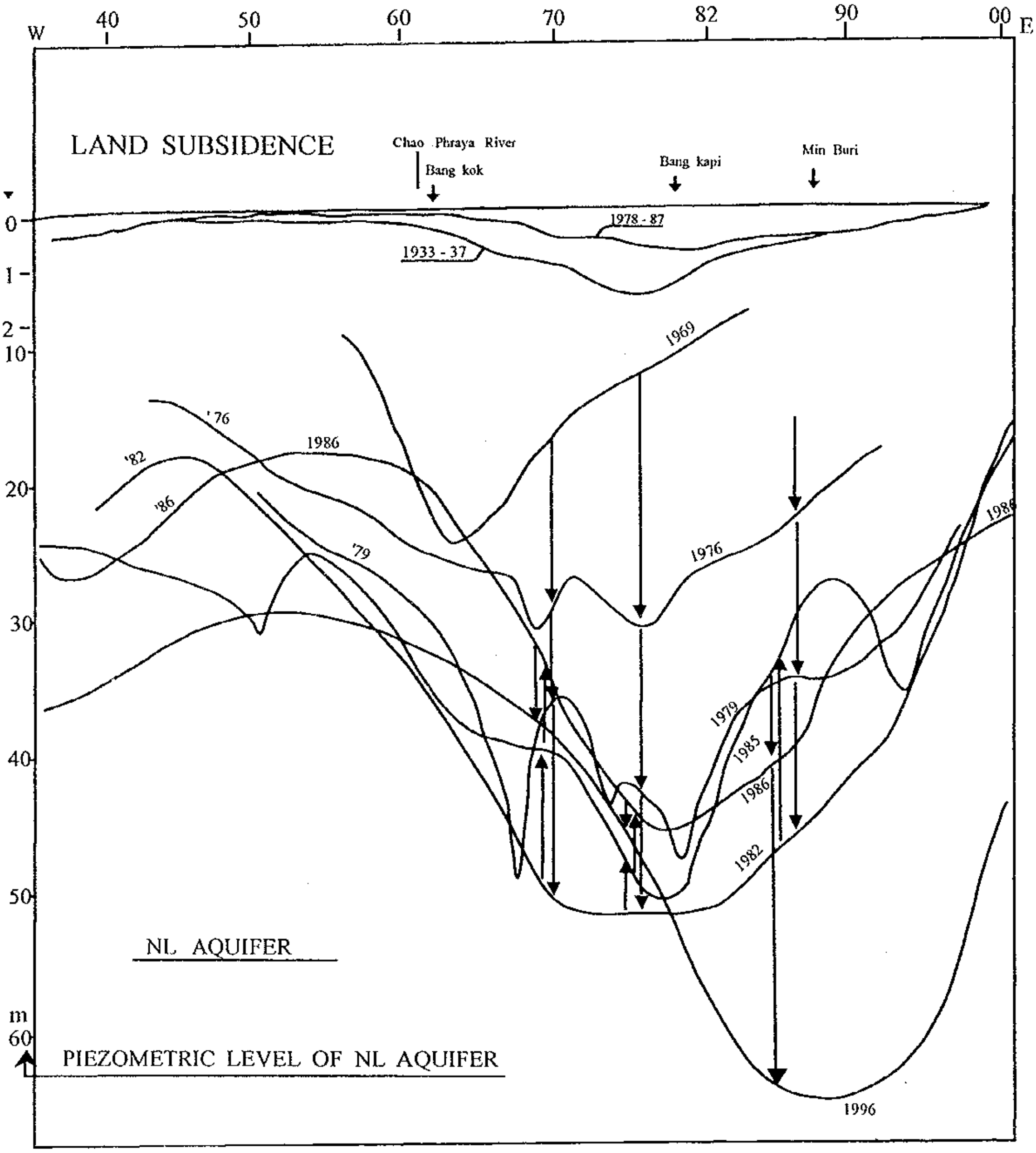
LEGEND :

A	TYPE A : WATER LEVEL IS RAPIDLY DECLING
B	TYPE B : WATER LEVEL IS RAPIDLY DECLINING WITH A. SHORT PERIOD OF RECOVERY BETWEEN 1984 AND 1987
C	TYPE C : WATER LEVEL IS SLOWLY DECLINING
D	TYPE D : WATER LEVEL IS SLOWLY DECLINING
E	TYPE E : WATER LEVEL IS STABLE OR NOT CHANGING
● ○	DMR OBSERVATION WELLS

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN

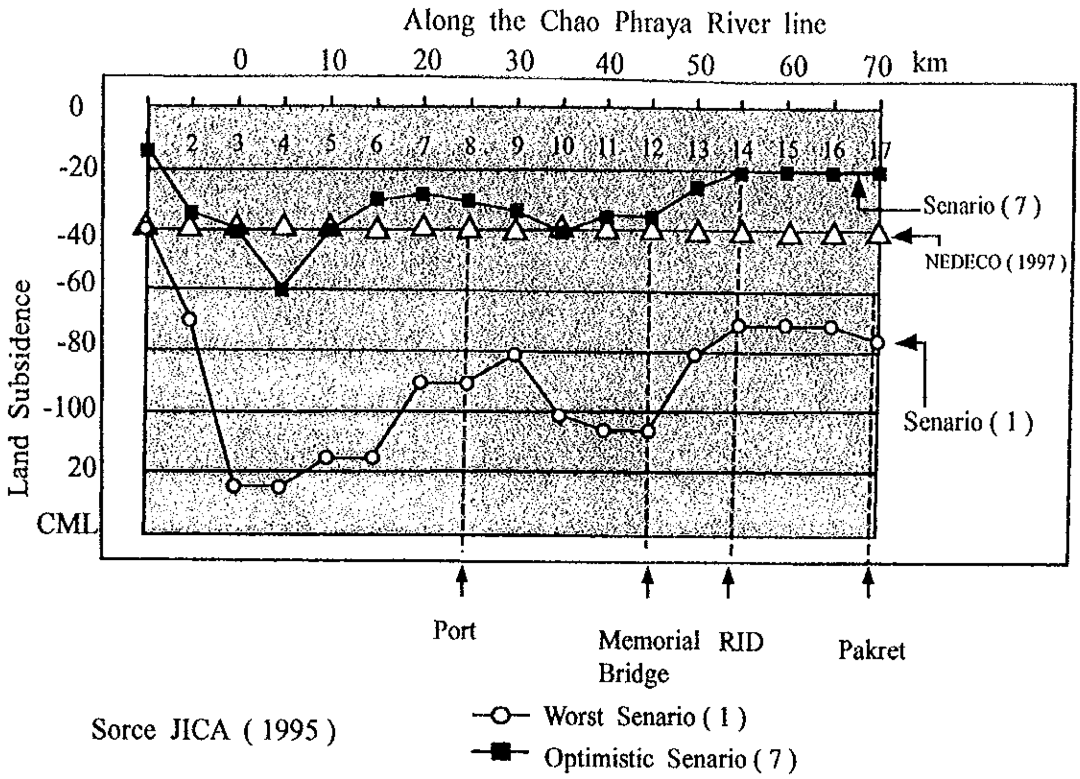
CTI ENGINEERING CO., LTD AND INA CORPORATION

Fig. 2.3.1
AREAL DISTRIBUTION OF FIVE TYPES OF PATTERNS OF GROUNDWATER LEVEL CHANGES

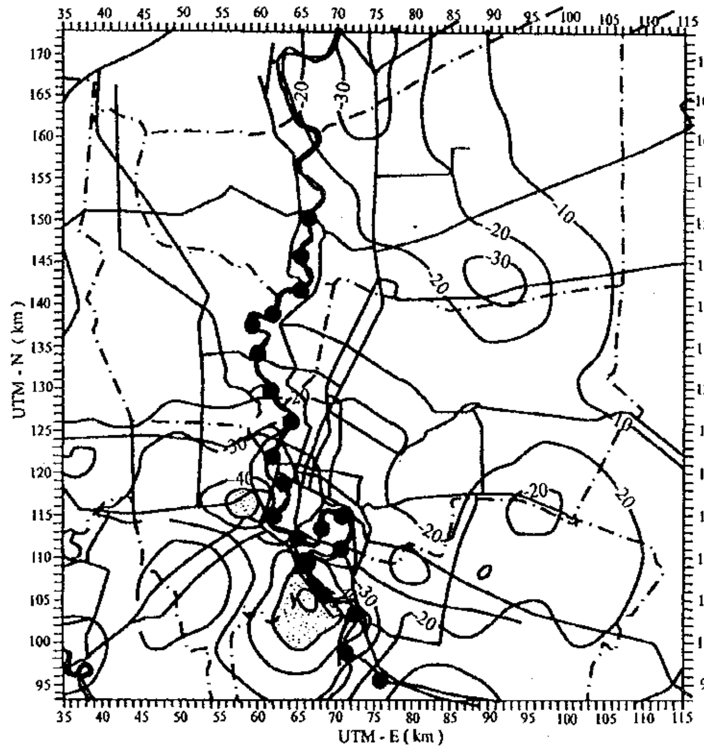


Modified JICA / DMR (1995)

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 2.3.2 WEST - EAST PROFILE OF THE PIEZOMETRIC LEVEL ALONG 1,520,000 LINE
CTI ENGINEERING CO., LTD AND INA CORPORATION	



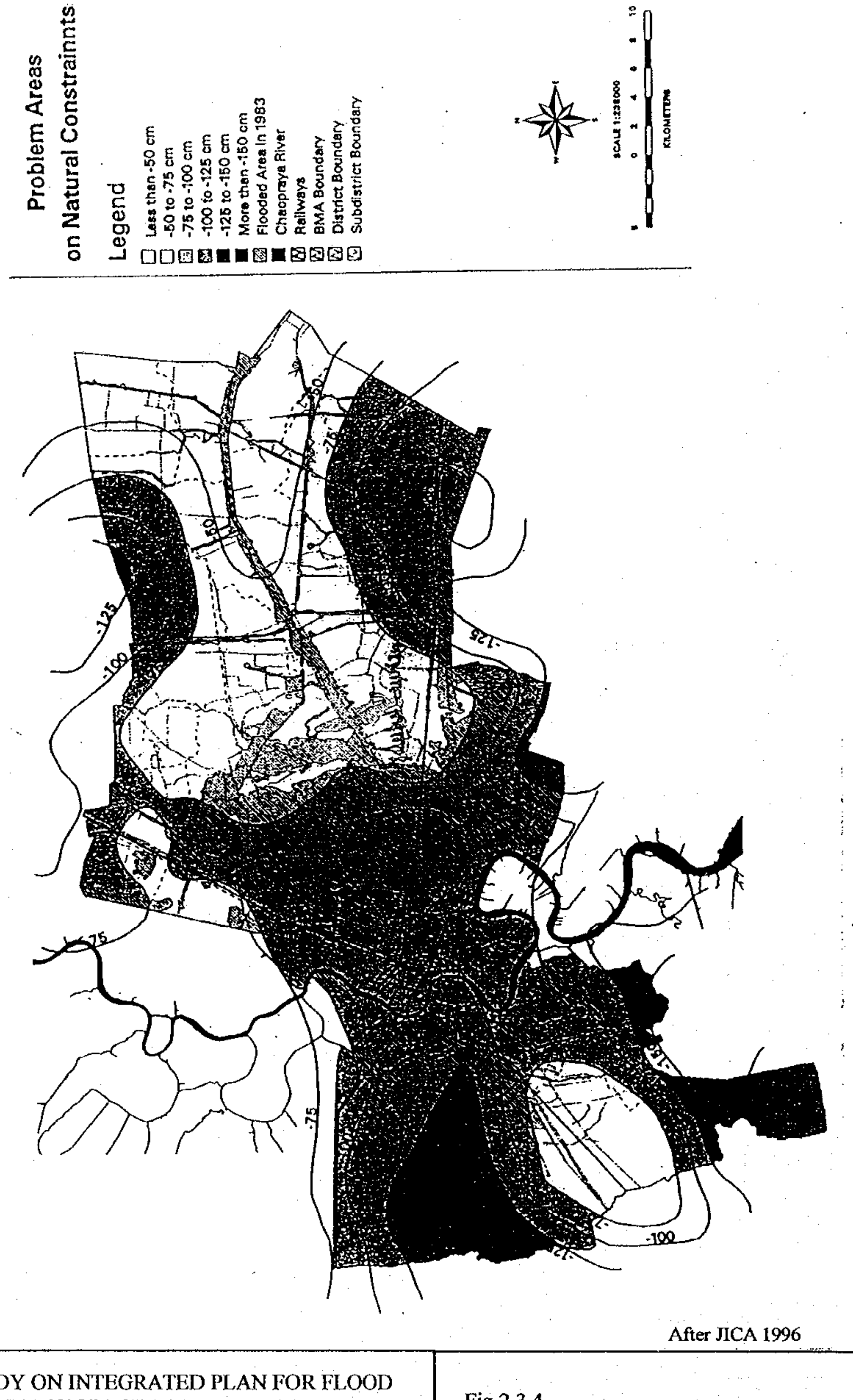
Sorce JICA (1995)



SIMULATED LAND SUBSIDENCE (cm)
FROM 1993 TO 2017 (25 years)
BY FUTURE SCENARIO 7

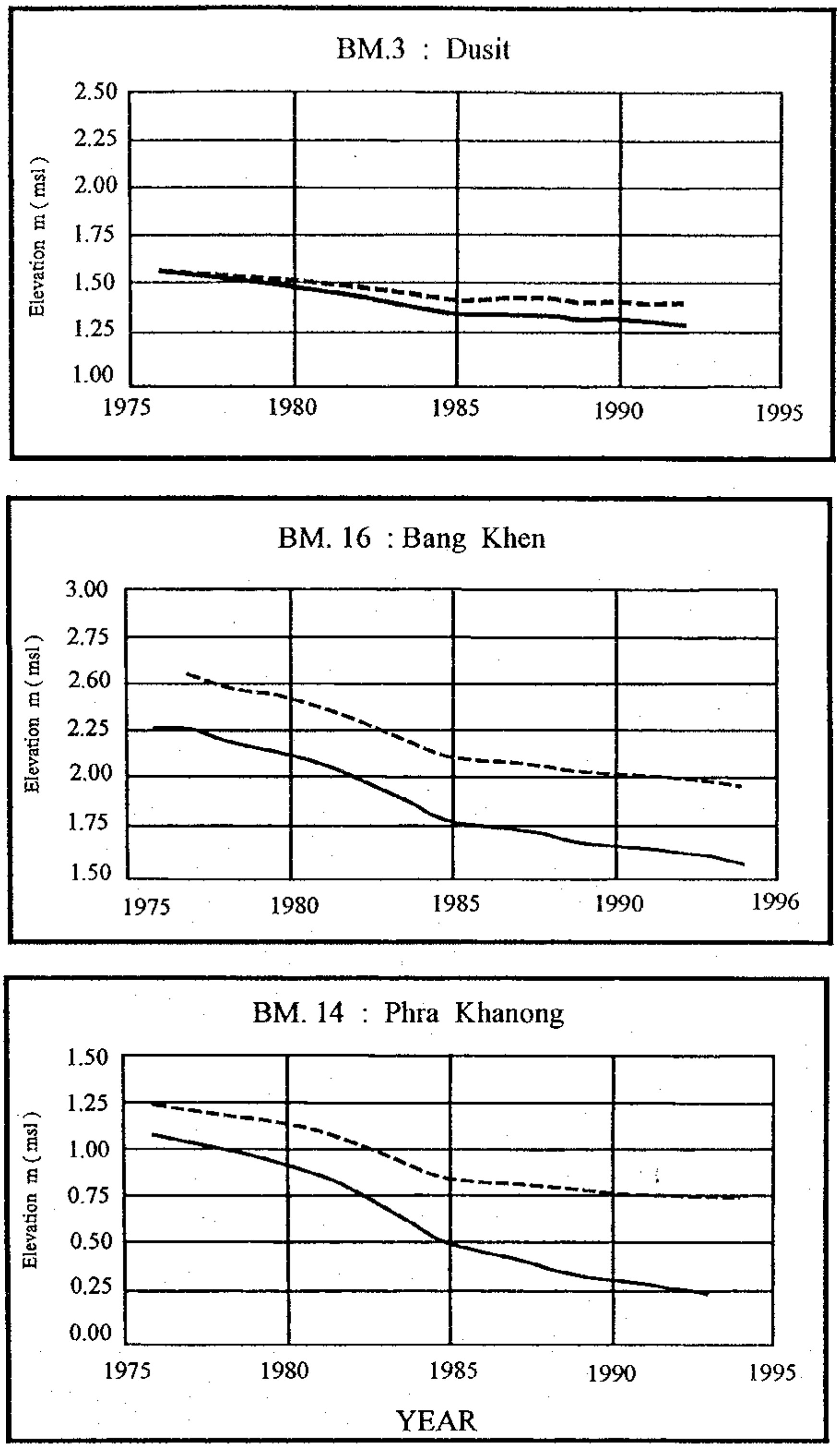
After JICA (1995)

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 2.3.3 LAND SUBSIDENCE IN 2017 (ESTIMATED IN 1995 , JICA)
CTI ENGINEERING CO., LTD AND INA CORPORATION	



After JICA 1996

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig.2.3.4 MAP OF NATURAL CONSTRAINTS
CTI ENGINEERING CO., LTD AND INA CORPORATION	

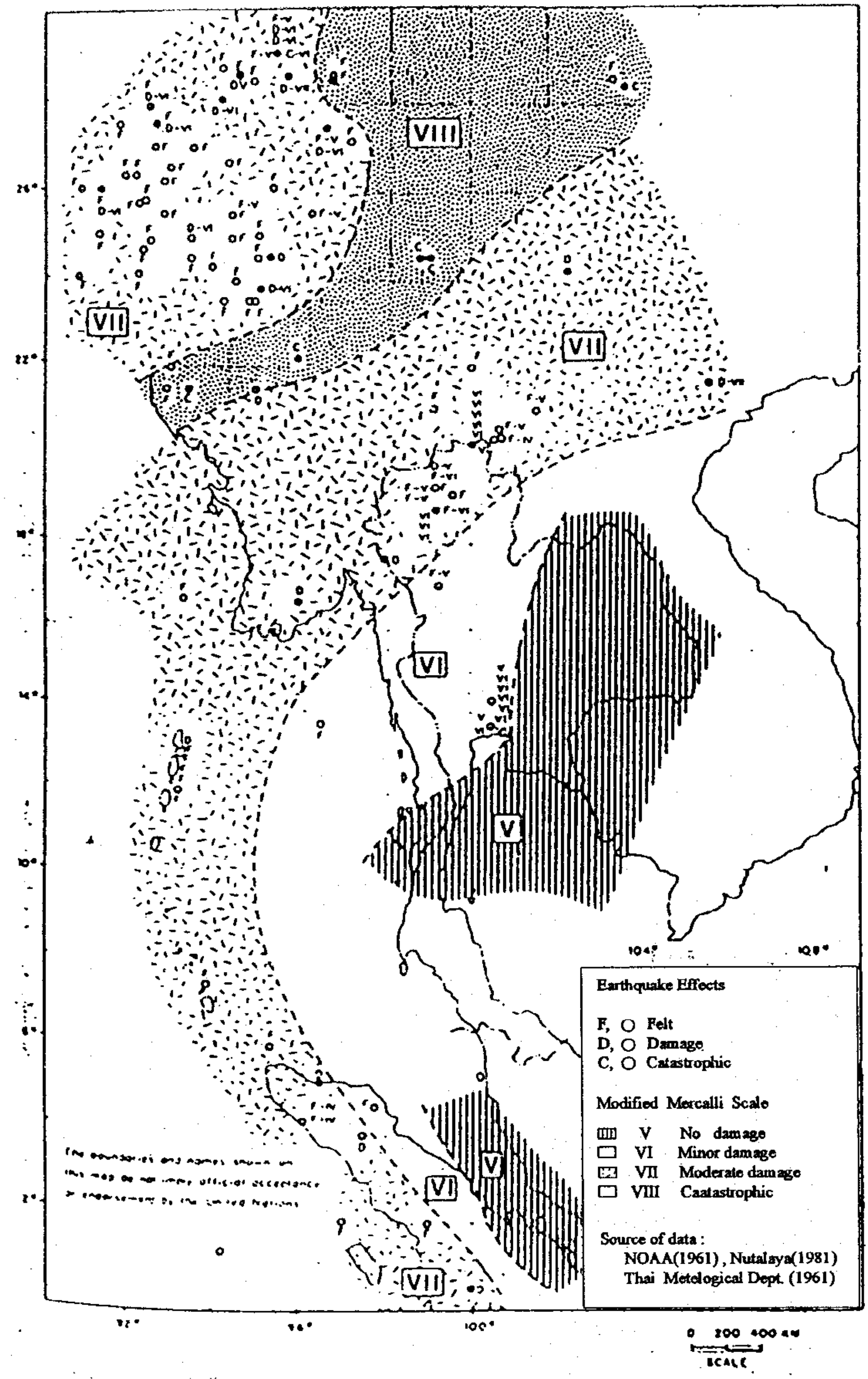


——— Surface Station

- - - - - Deep Station (22m. - MSL approx.)

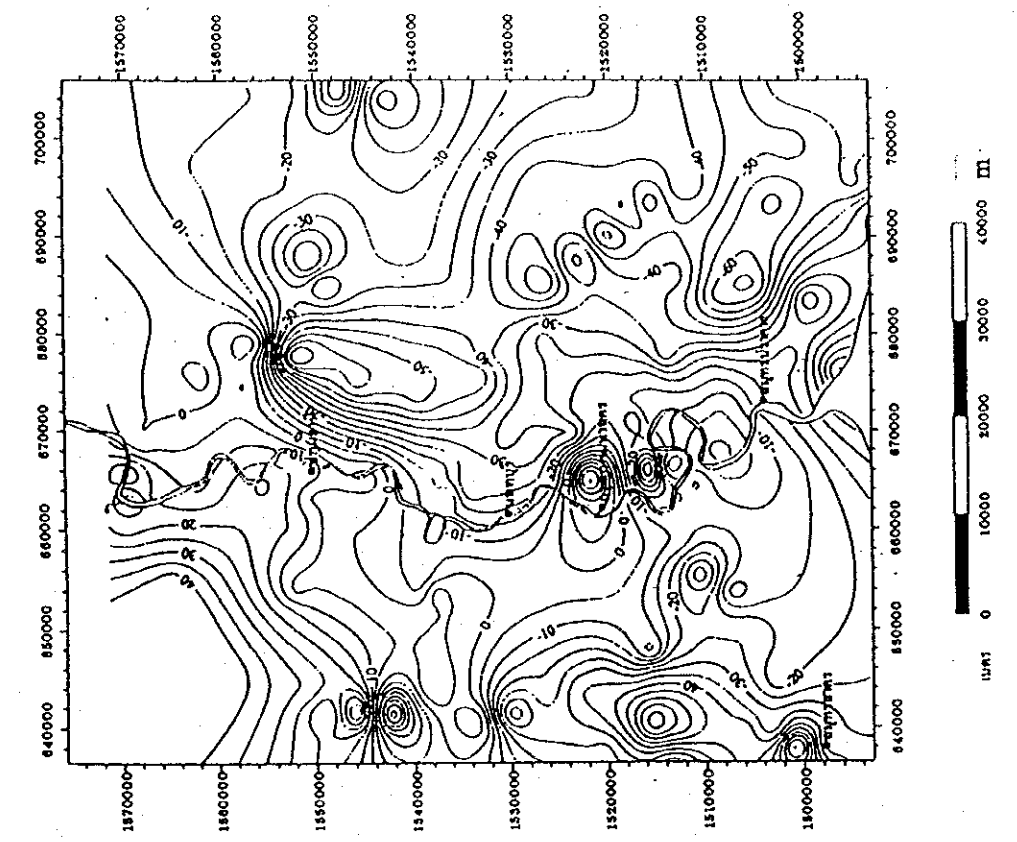
Source : RTSD , BMA / NEDECO - SPAN - WDC (1996)

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 2.3.5 FLOOD PROTECTION AND DRAINAGE SYSTEMS IN EASTERN SUB - URBAN BANGKOK
CTI ENGINEERING CO., LTD AND INA CORPORATION	

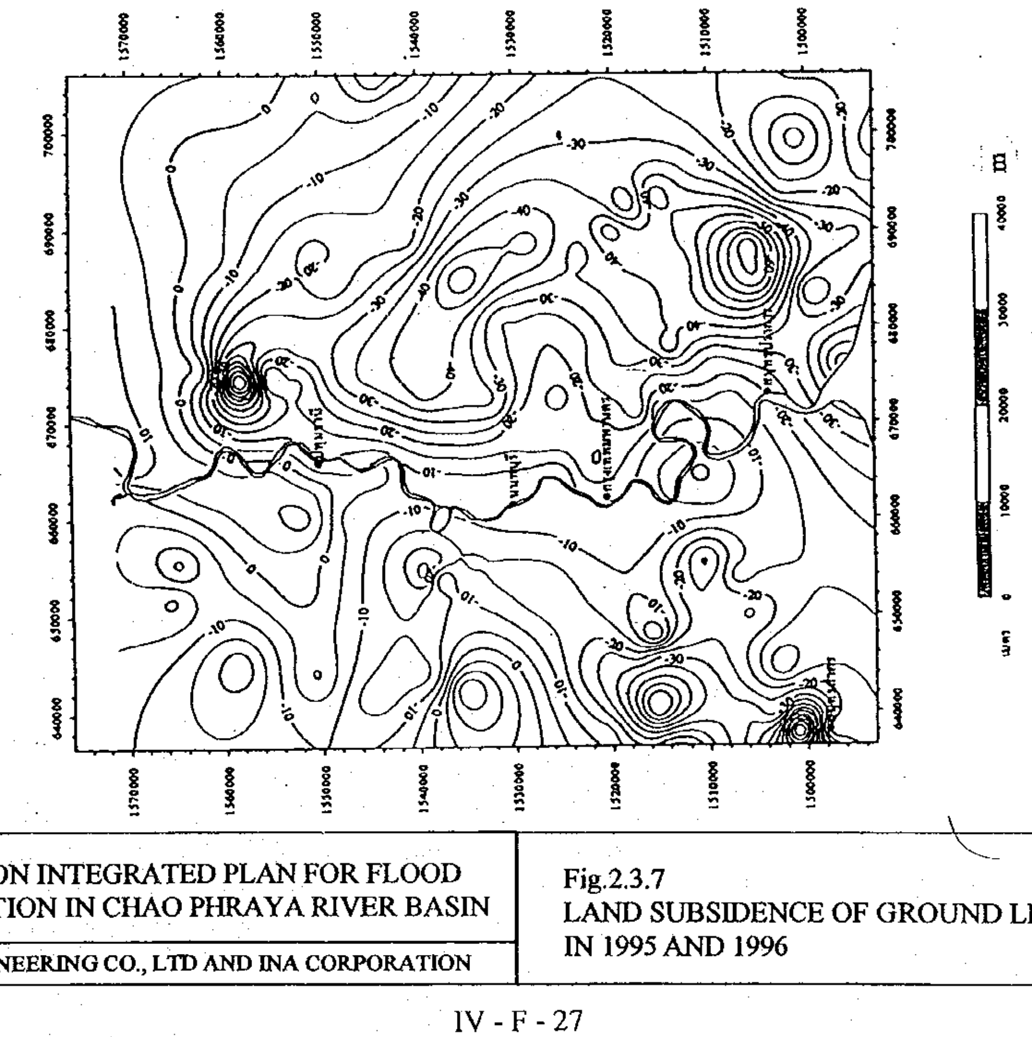


STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig.2.3.6 SUBSIDENCE AND FLOOD PROTECTION IN EASTERN SUB-URBAN BANGKOK
CTI ENGINEERING CO., LTD AND INA CORPORATION	

Land subsidence of groud level with in 1m depth
(Land subsidence in mm.for duration 1995 for 1996)



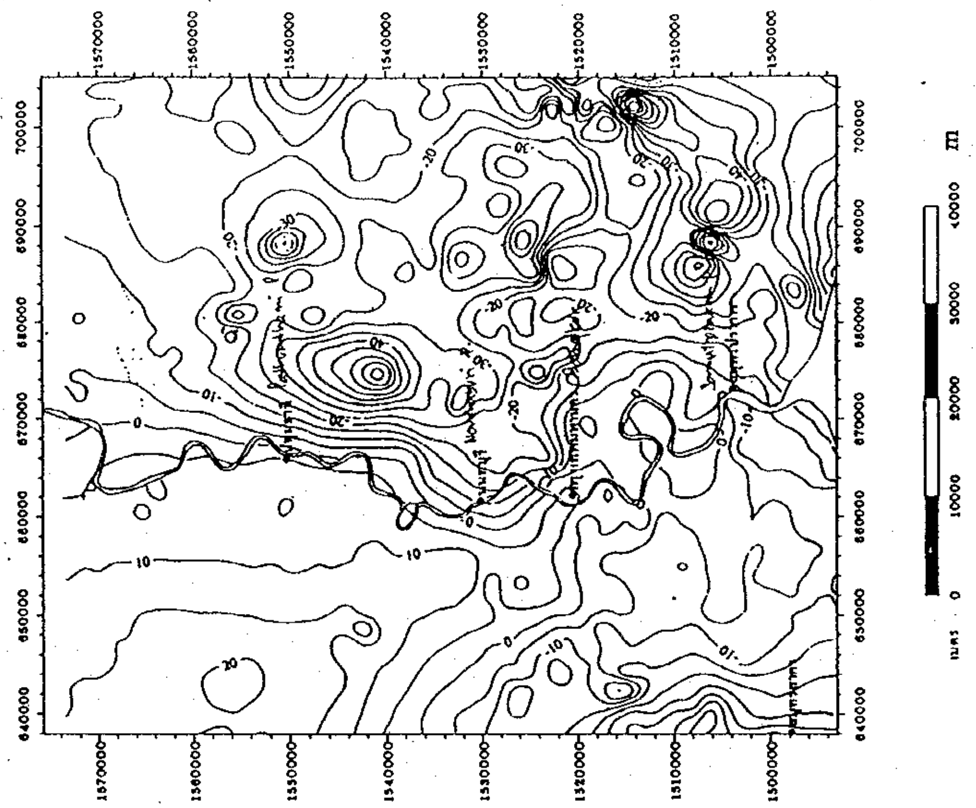
Land subsidence of groud level with in 1m depth
(Land subsidence in mm.for duration 1994 for 1995)



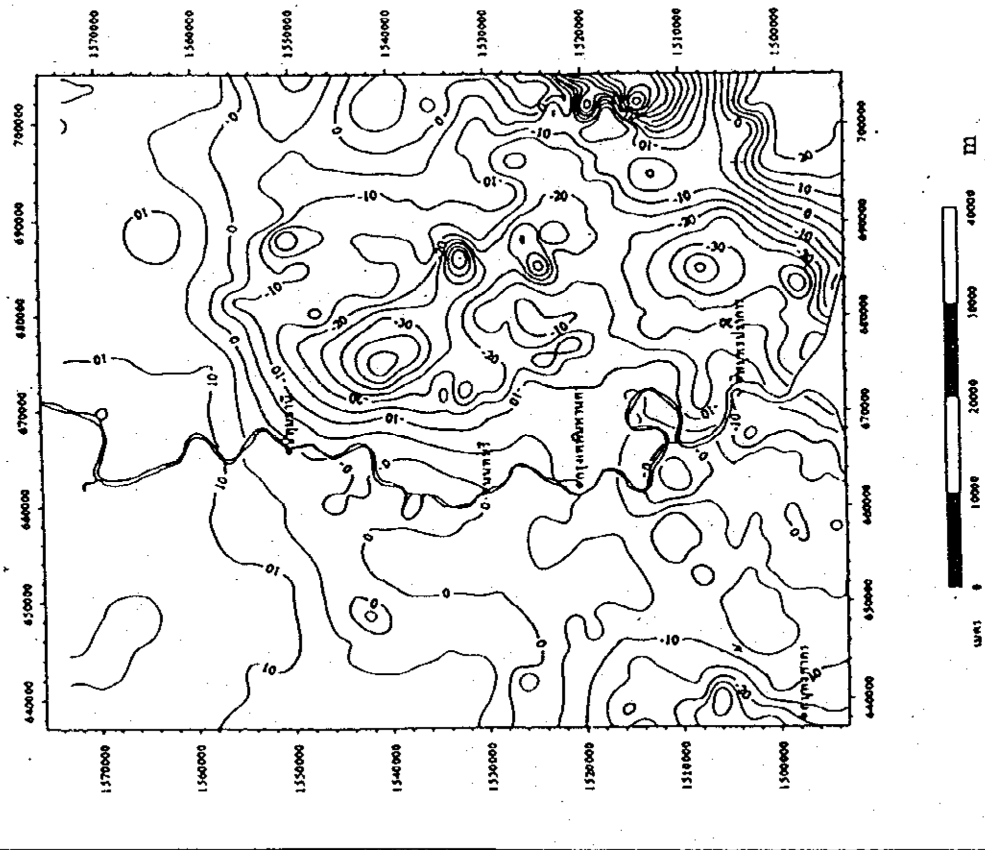
After G&D/DMR (1995,1996)

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig.2.3.7 LAND SUBSIDENCE OF GROUND LEVEL IN 1995 AND 1996
CTI ENGINEERING CO., LTD AND INA CORPORATION	

Map showing land subsidence of ground in sand level
(showing land subsidence in mm. for duration of near 1995-1996)



Map showing land subsidence of ground in sand level
(showing land subsidence in mm. for duration of near 1994-1995)



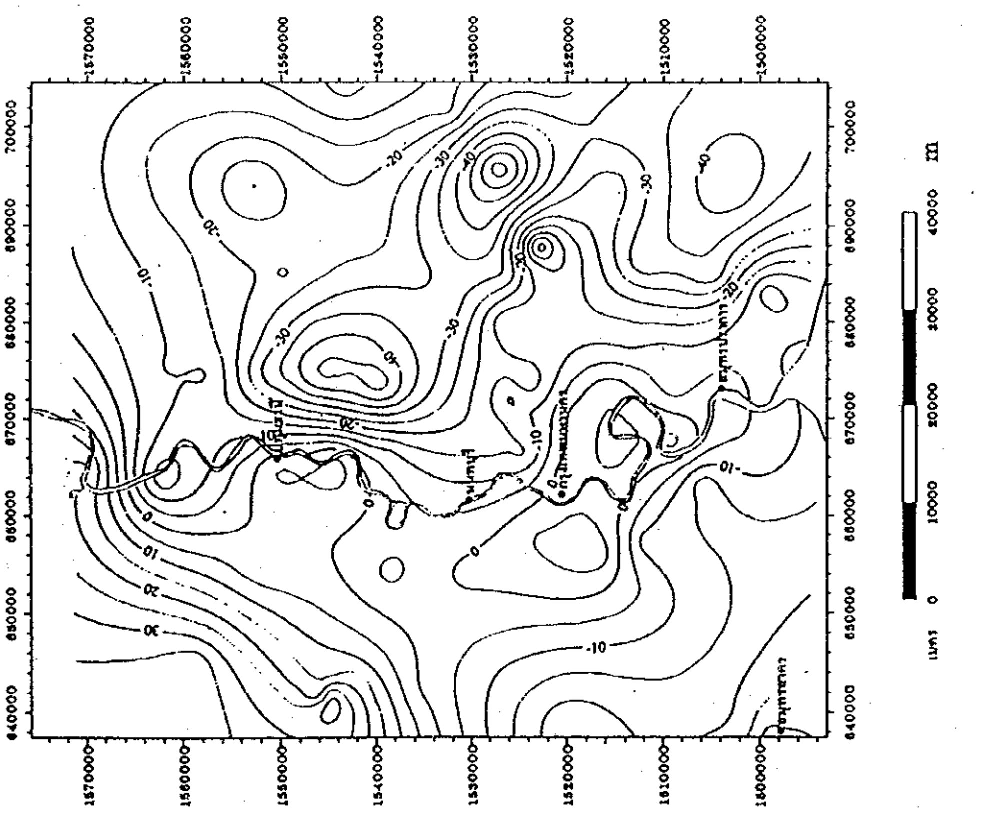
After G&D/DMR (1995,1996)

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN

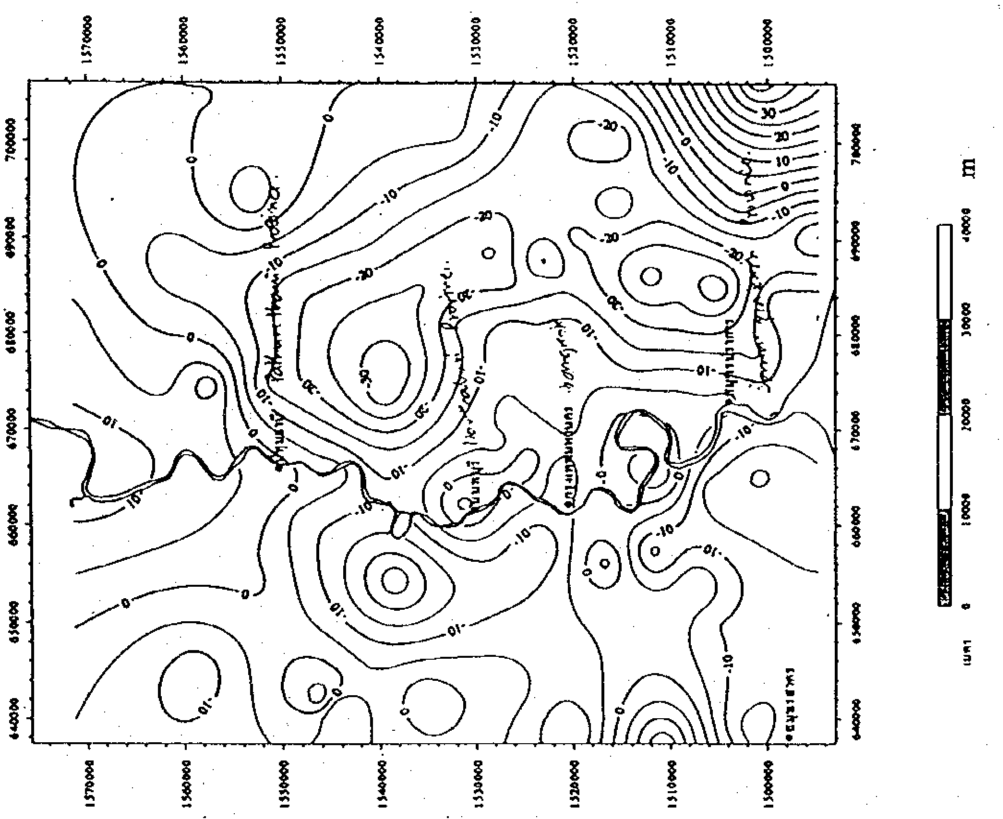
CTI ENGINEERING CO., LTD AND INA CORPORATION

Fig.2.3.8
LAND SUBSIDENCE OF GROUND IN BK. LEVEL IN 1995 AND 1996

Map showing land subsidence of ground in aquifer level
(showing land subsidence in mm. for duration of near 1995-1996)

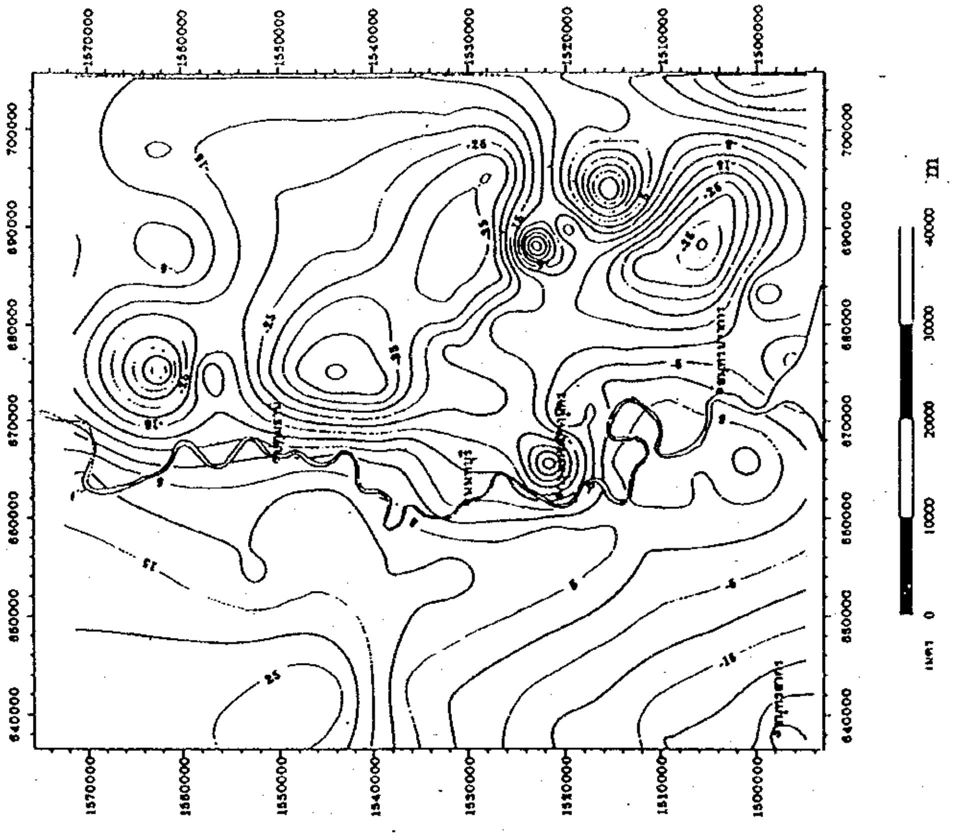


Map showing land subsidence of ground in aquifer level
(showing land subsidence in mm. for duration of near 1994-1995)

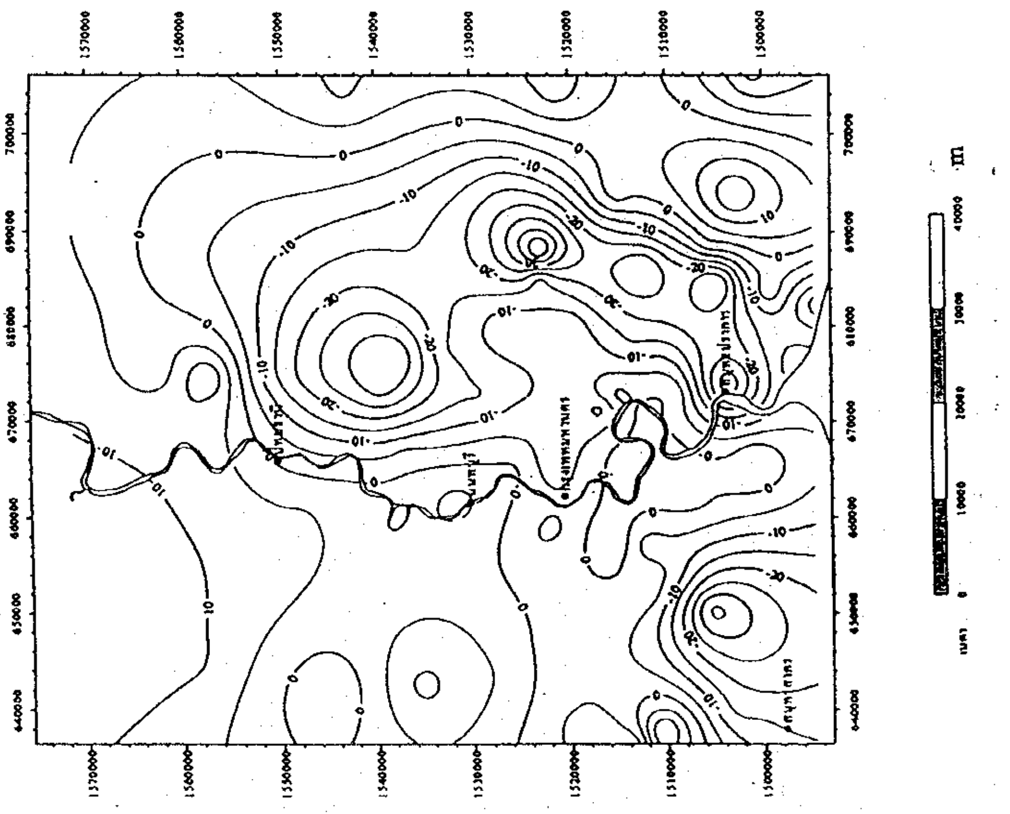


After G&D/DMR (1995,1996)

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig.2.3.9 LAND SUBSIDENCE OF GROUND IN AQUIFER. LEVEL OF PD IN 1995 AND 1996
CTI ENGINEERING CO., LTD AND INA CORPORATION	



Map showing land subsidence of ground in aquifer level of Nakhon Luang
(showing land subsidence in mm. for duration of near 1995-1996)

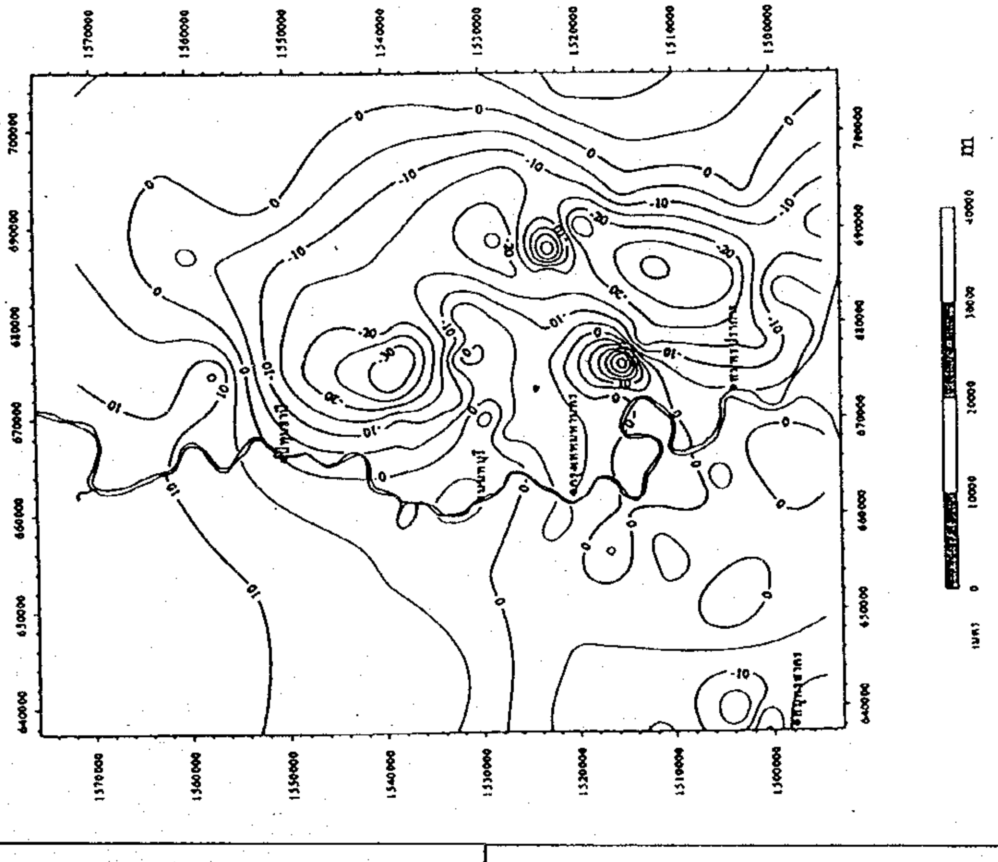


Map showing land subsidence of ground in aquifer level of Nakhon Luang
(showing land subsidence in mm. for duration of near 1994-1995)

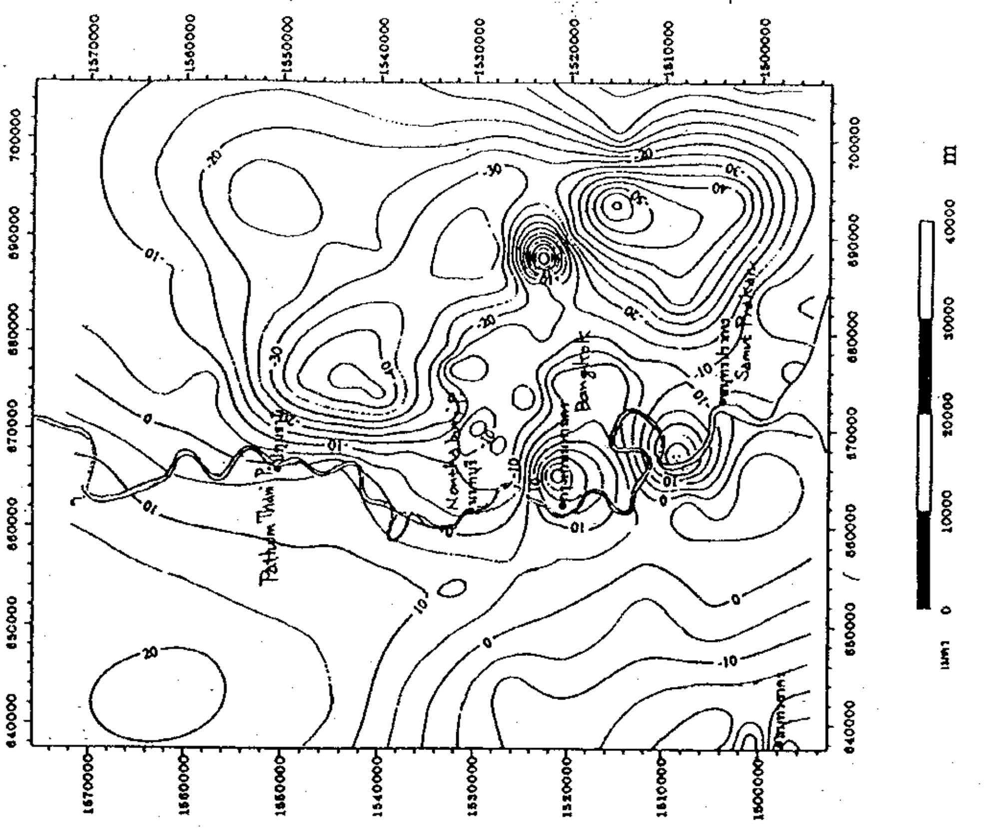
After G&D/DMR (1995,1996)

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig.2.3.10 LAND SUBSIDENCE OF GROUND IN AQUIFER LEVEL OF NL IN 1995 AND 1996
CTI ENGINEERING CO., LTD AND INA CORPORATION	

Map showing land subsidence of ground in aquifer level of Nonthaburi
(showing land subsidence in mm. for duration of near 1994-1995)

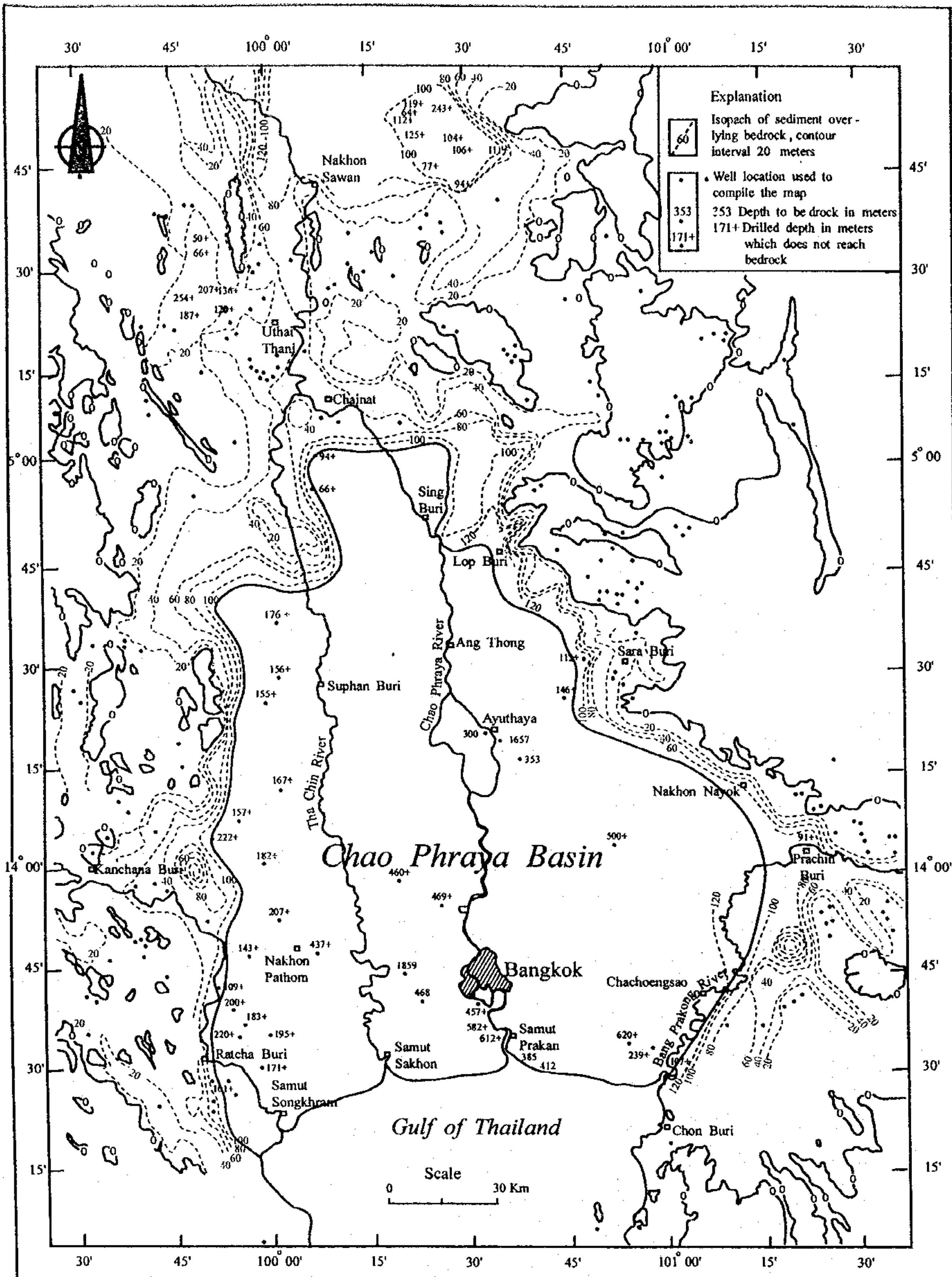


Map showing land subsidence of ground in aquifer level of Nonthaburi
(showing land subsidence in mm. for duration of near 1995-1996)

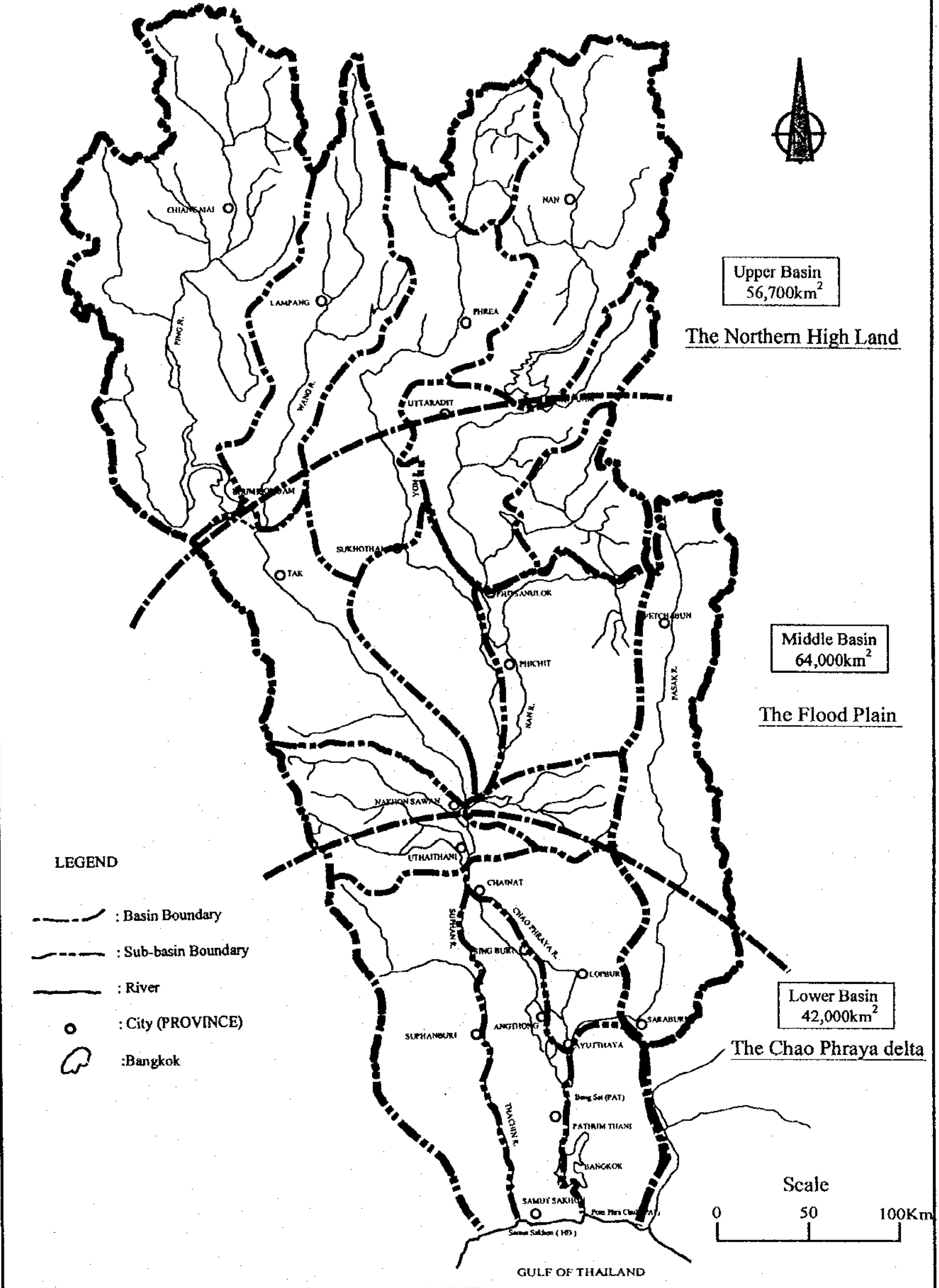


After G&D/DMR (1995,1996)

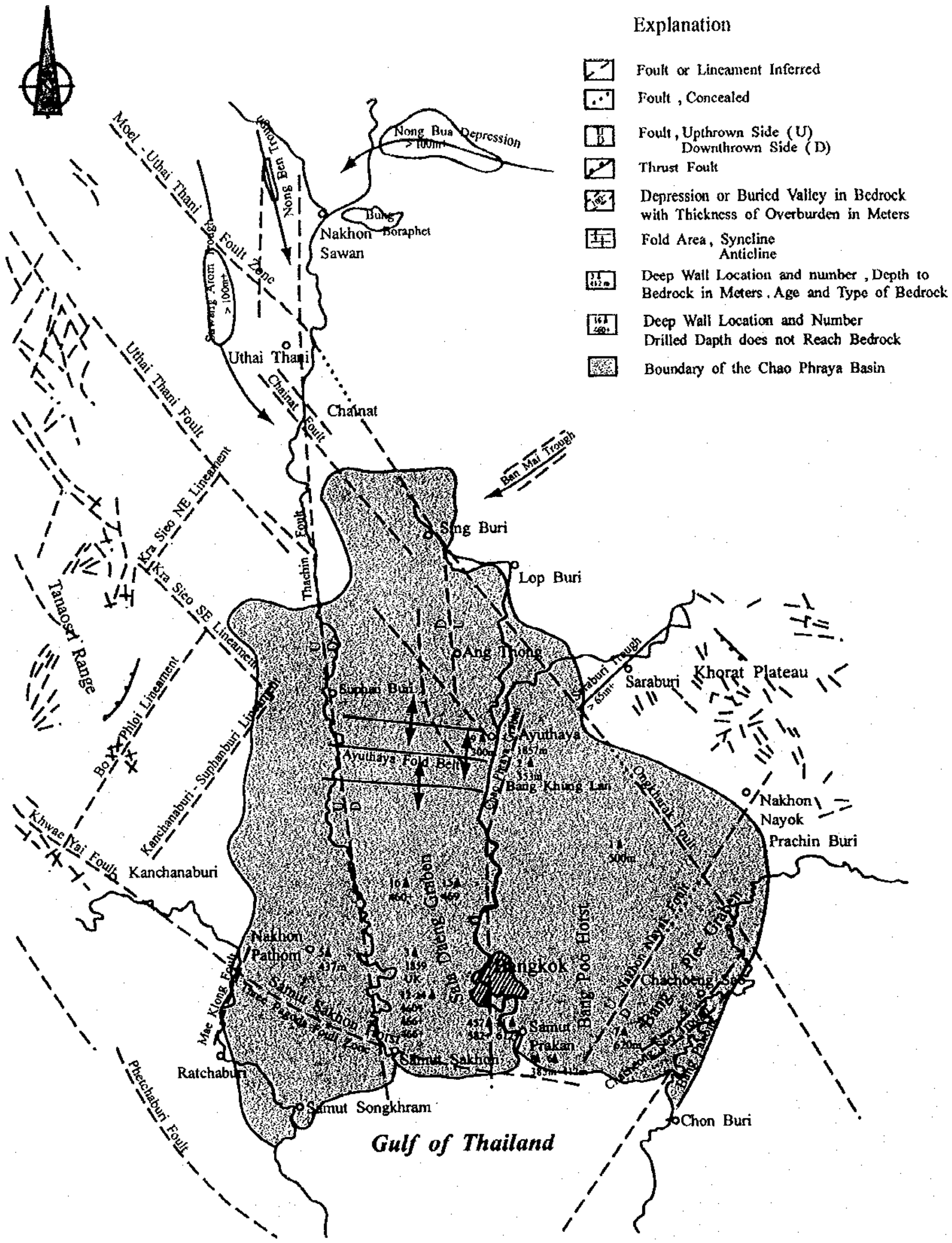
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig.2.3.11 LAND SUBSIDENCE OF GROUND IN AQUIFER LEVEL OF NB IN 1995 AND 1996
CTI ENGINEERING CO., LTD AND INA CORPORATION	



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig. 3.1.1 THE CHAO PHRAYA BASIN OF THAILAND FROM J.L. RAW & ATT (1981)
CTI ENGINEERING CO., LTD AND INA CORPORATION	



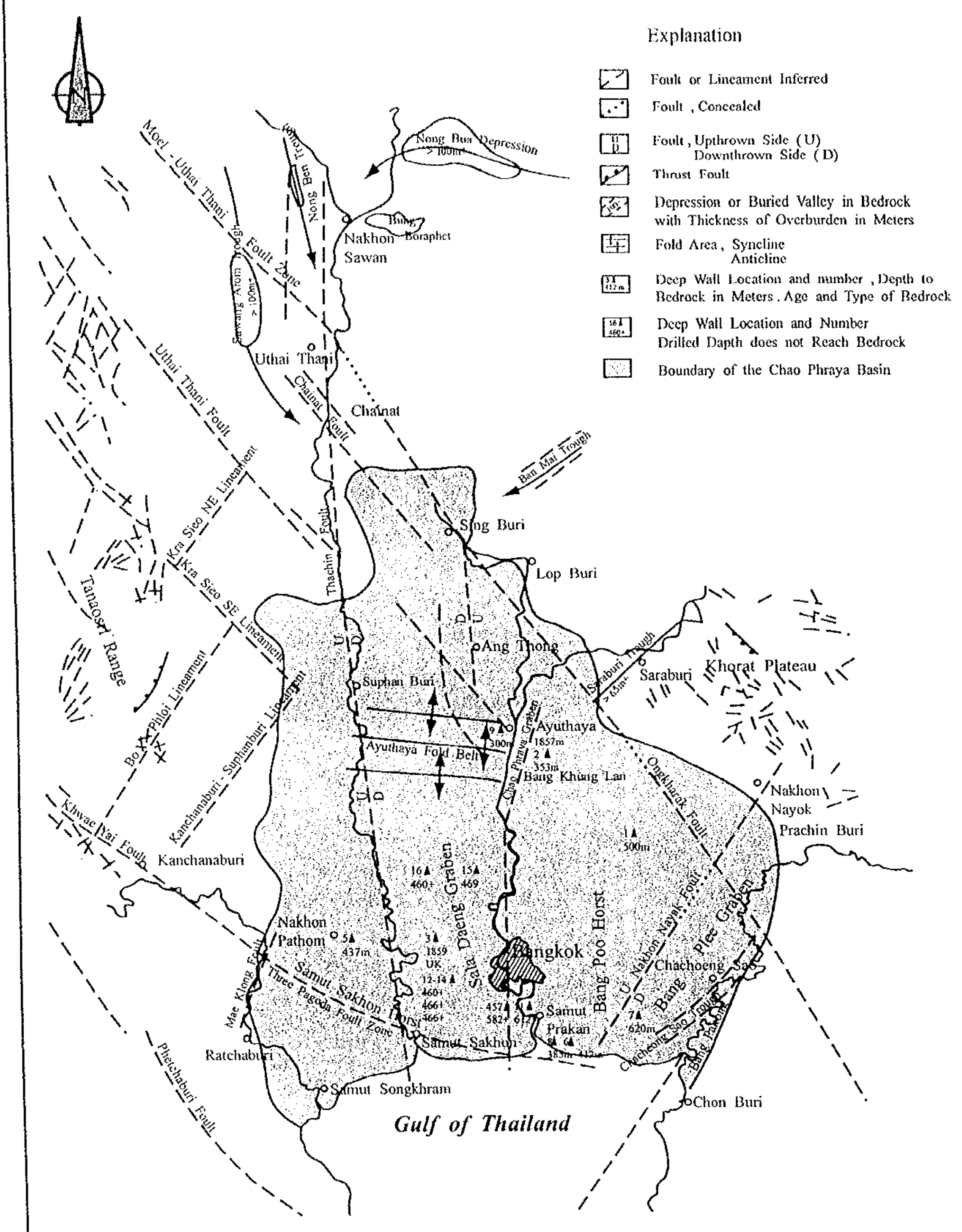
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig.3.1.2 THE DIVISION BY HYDROLOGICAL FEATURES IN CHAO PHRAYA RIVER BASIN
CTI ENGINEERING CO., LTD AND INA CORPORATION	



Map of the Chao Phraya basin showing its major stuctural elements

(From Rau, 1981 ; After Nutalaya and Rau, 1981)

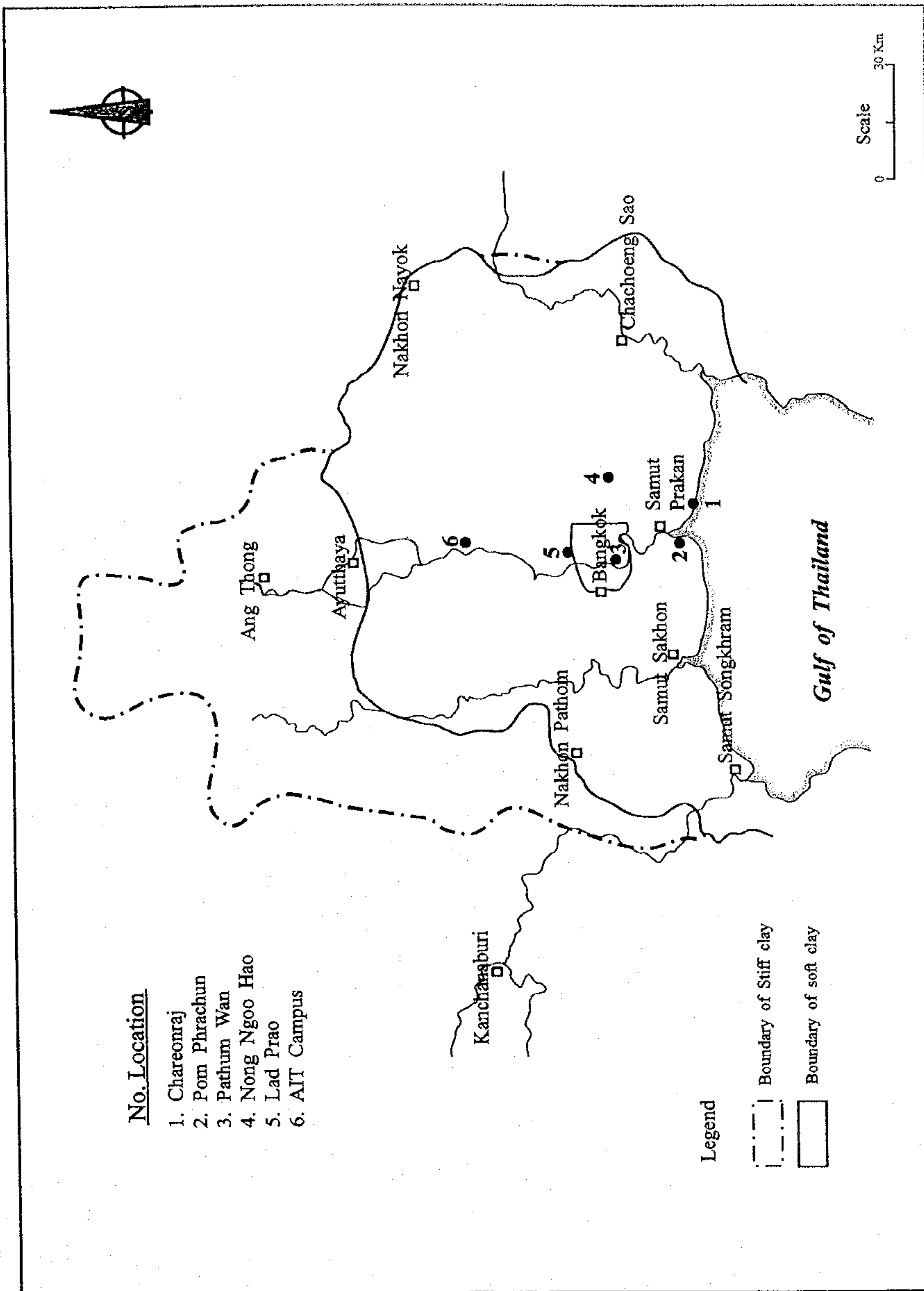
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 3.1.3 MAP OF THE CHAO PHRAYA BASIN SHOWING ITS MAJOR STRUCTURAL ELEMENTS
CTI ENGINEERING CO., LTD AND INA CORPORATION	



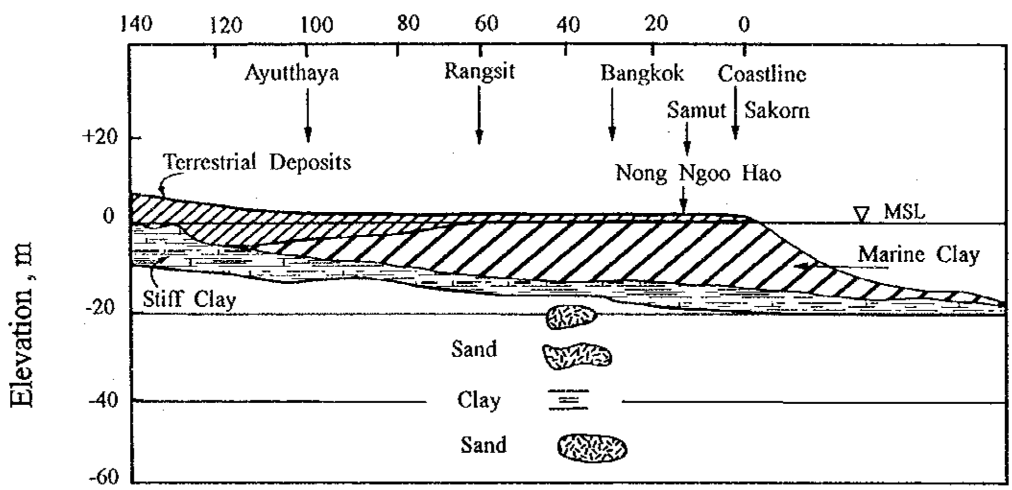
Map of the Chao Phraya basin showing its major stuctural elements

(From Rau , 1981 ; After Nutalaya and Rau , 1981)

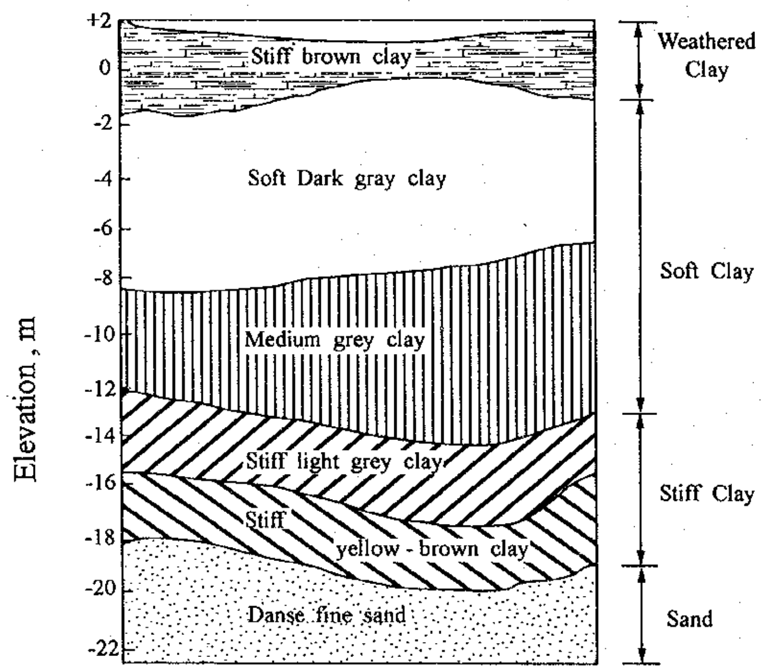
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 3.1.3 MAP OF THE CHAO PHRAYA BASIN SHOWING ITS MAJOR STRUCTURAL ELEMENTS
CTI ENGINEERING CO., LTD AND INA CORPORATION	



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig. 3.2.1 GEOTECHNICAL DESTRIBUTION MAP OF BANGKOK CLAY BY COX (1968,1970)
CTI ENGINEERING CO., LTD AND INA CORPORATION	

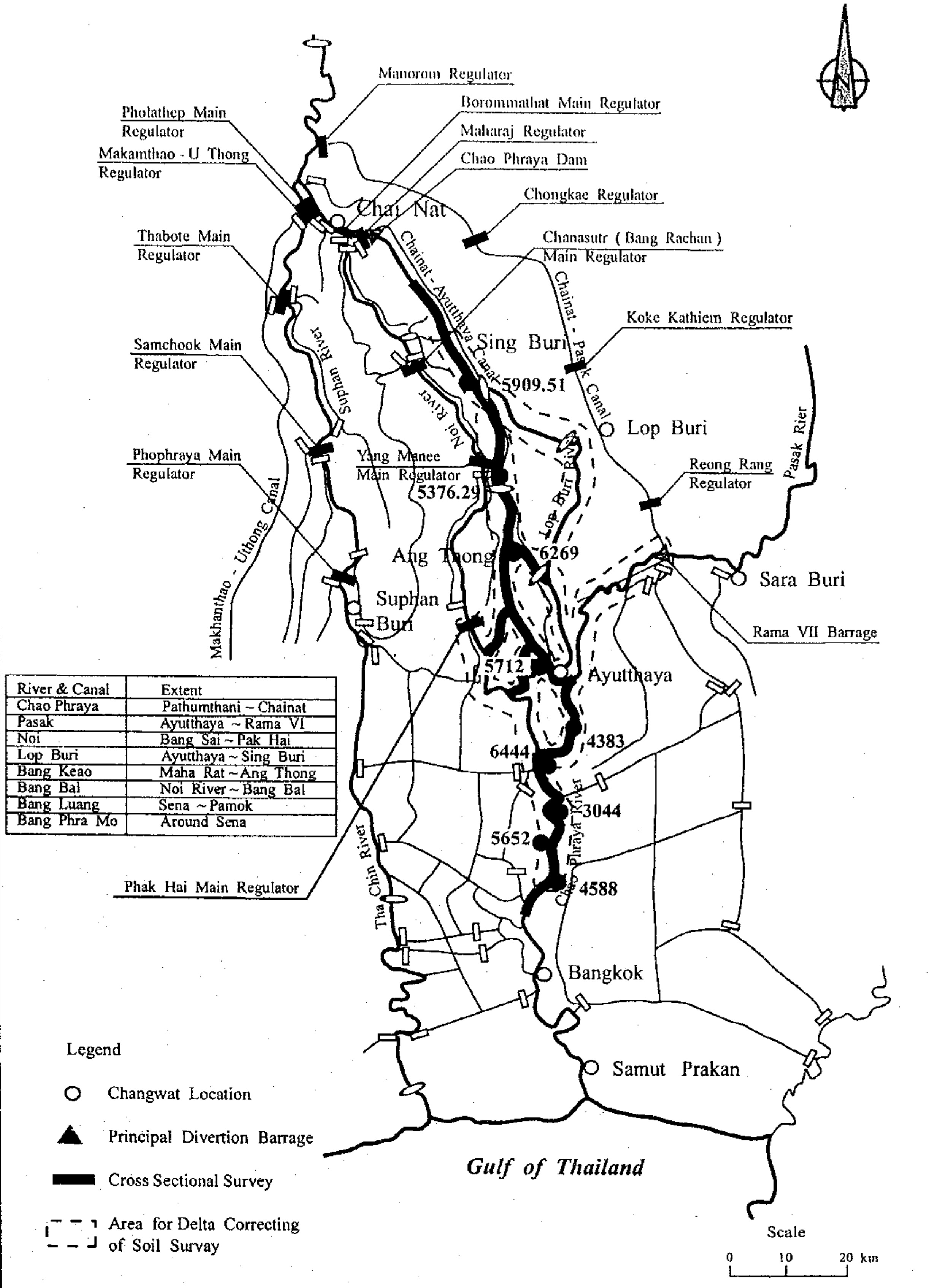


(a) Cross Section through Chao Phraya Delta
(after COX, 1970)



(b) Profile of Bangkok Subsoil
(after MUKTABHANT et al,. 1967)

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig .3.2.2 VERTICAL DISTRIBUTION OF BANGKOK CLAY (AFTER IEC 1990), PHYSICAL PROPERTIES OF BANGKOK SOFT CLAY
CTI ENGINEERING CO., LTD AND INA CORPORATION	

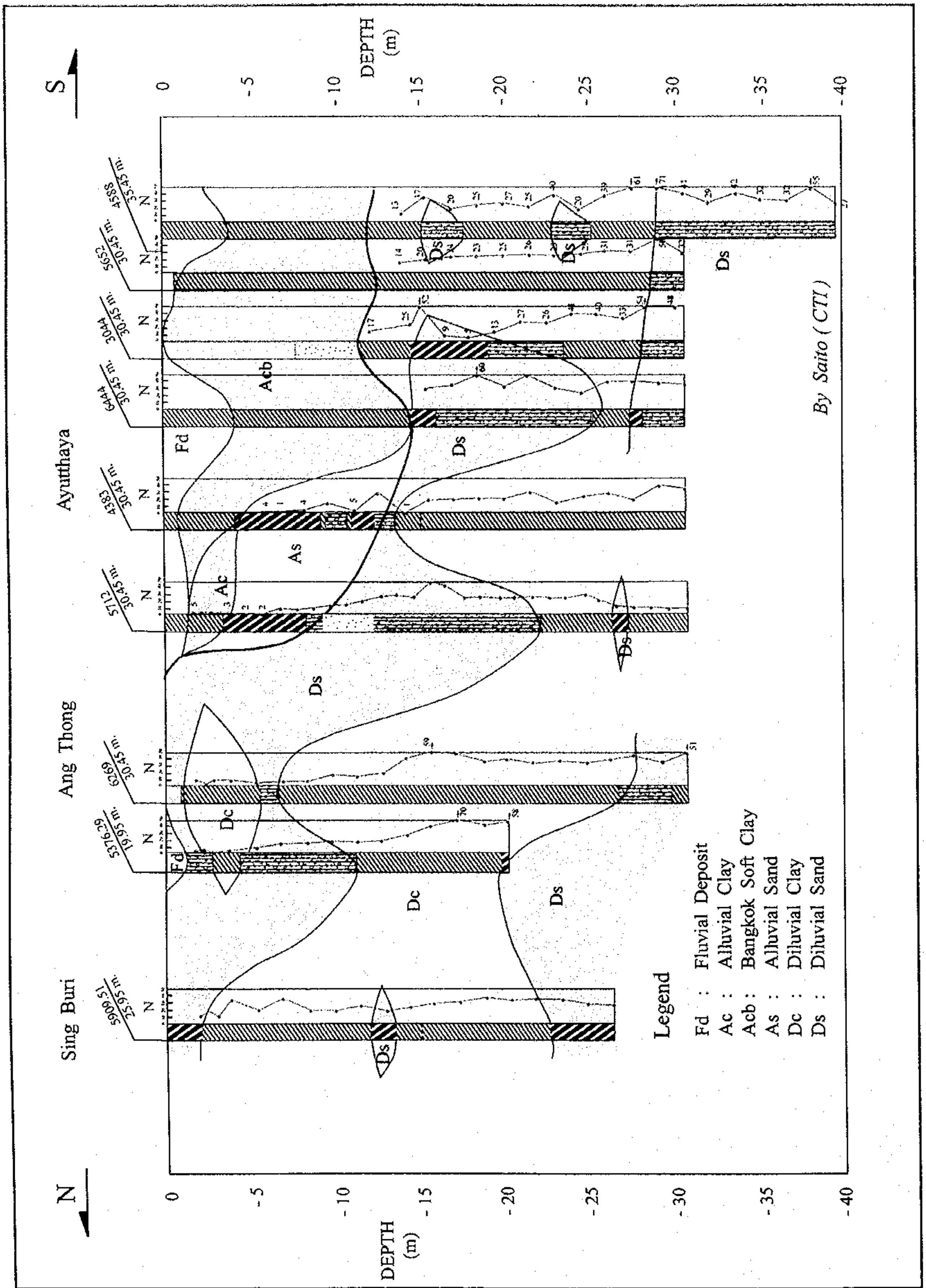


River & Canal	Extent
Chao Phraya	Pathumthani ~ Chainat
Pasak	Ayutthaya ~ Rama VI
Noi	Bang Sai ~ Pak Hai
Lop Buri	Ayutthaya ~ Sing Buri
Bang Keao	Maha Rat ~ Ang Thong
Bang Bal	Noi River ~ Bang Bal
Bang Luang	Sena ~ Pamok
Bang Phra Mo	Around Sena

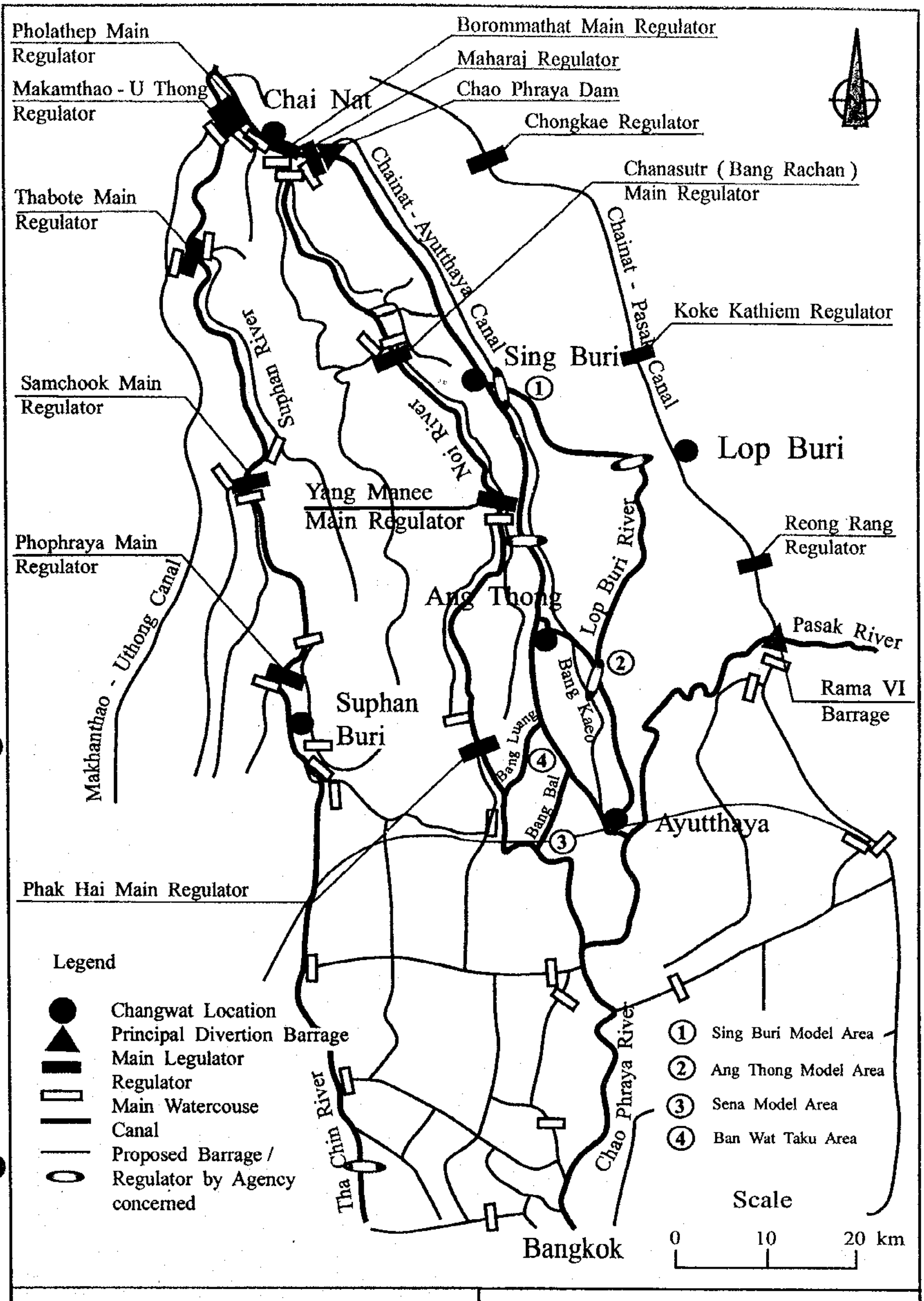
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN

CTI ENGINEERING CO., LTD AND INA CORPORATION

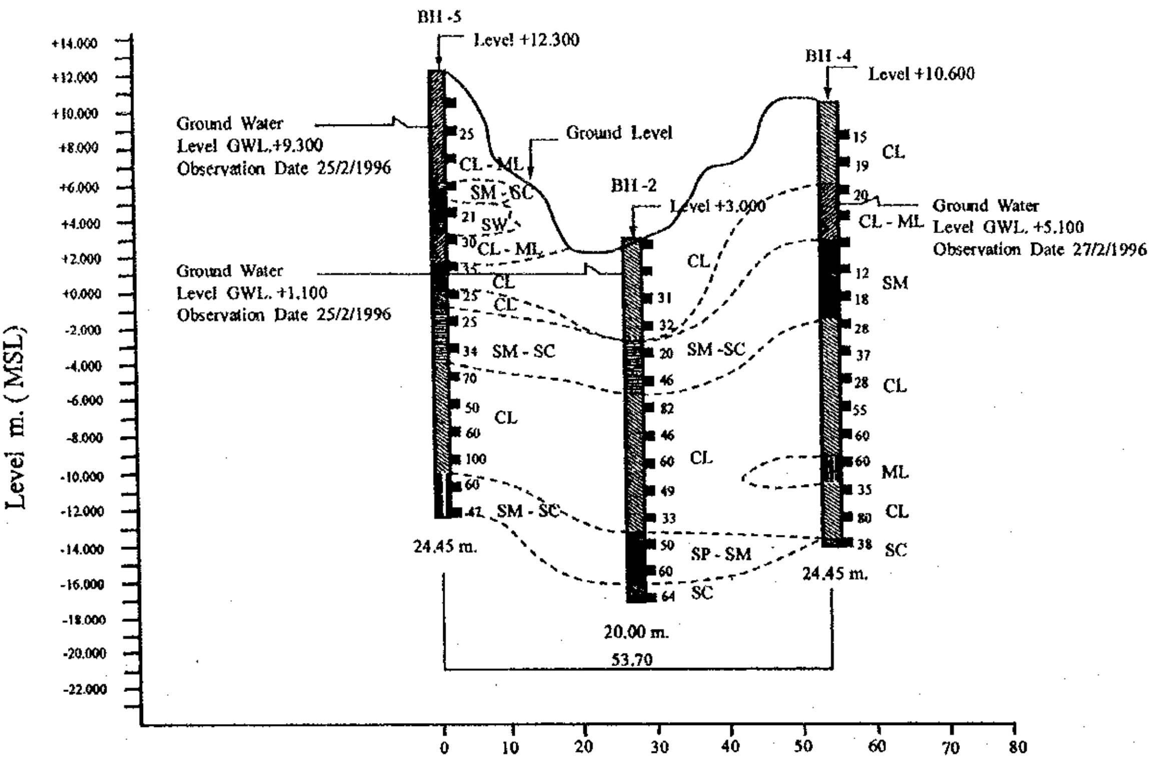
Fig . 3.3.1
AREA FOR DATA CORRECTING OF SOIL SURVAY



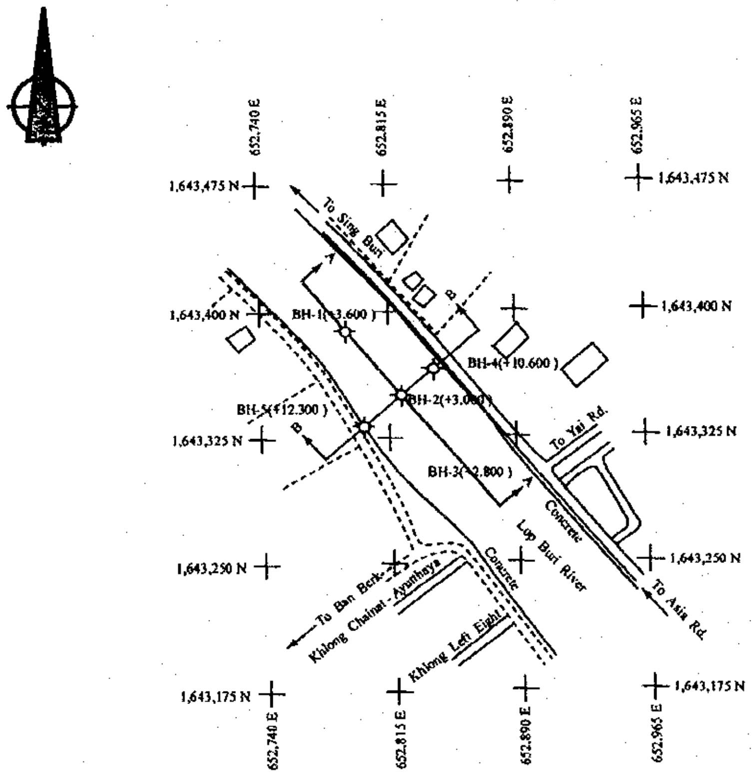
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 3.3.2 LONGTITUDE SECTION ALONG CHAO PHRAYA RIVER
CTI ENGINEERING CO., LTD AND INA CORPORATION	



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 3.3.3 LOCATION OF CROSS SECTION MODEL
CTI ENGINEERING CO., LTD AND INA CORPORATION	

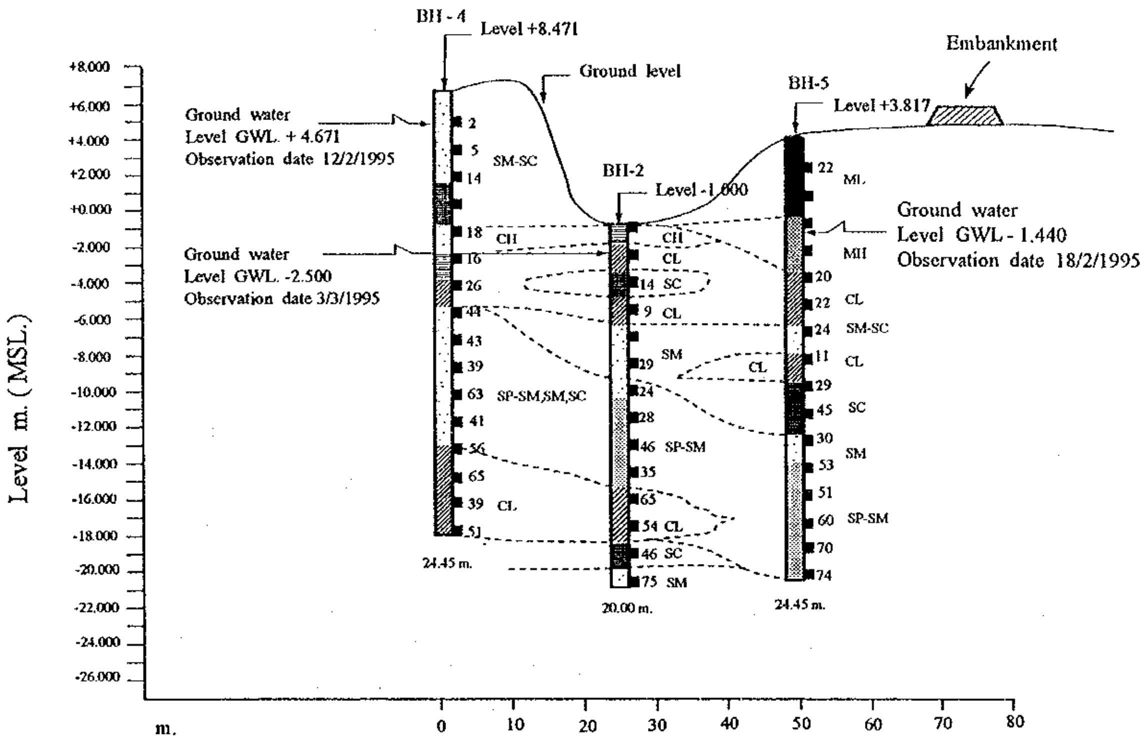


Cross Section B-B

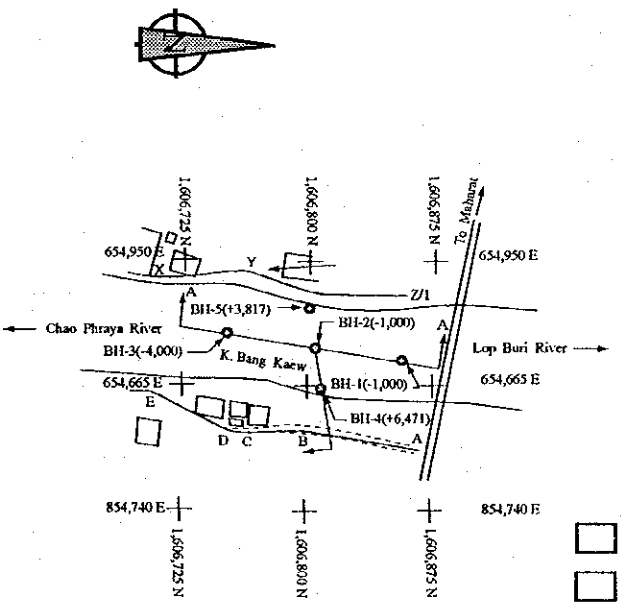


(From GMT, Co.,Ltd (1995), Survey Report Technical Geology Lop Buri River Development)

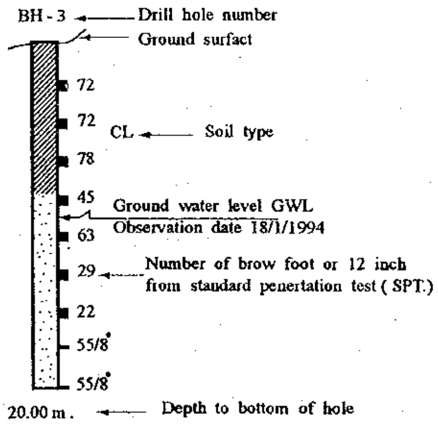
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig. 3.3.4 SOIL PROTILE OF SING BURI ALONG LOP BURI RIVER
CTI ENGINEERING CO., LTD AND INA CORPORATION	

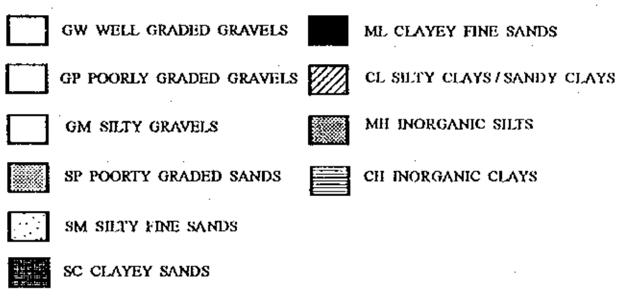


Cross Section B-B



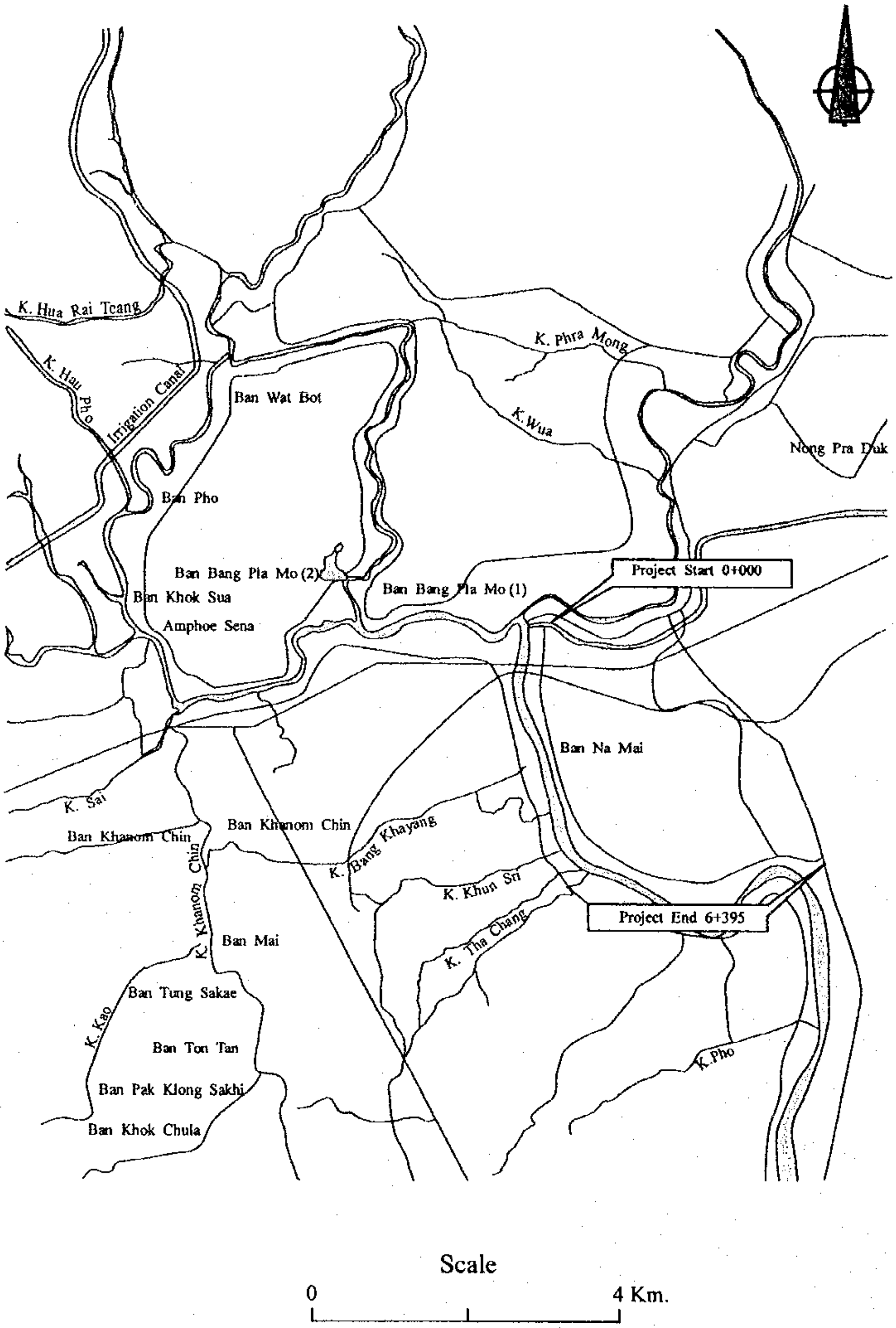
Explanation





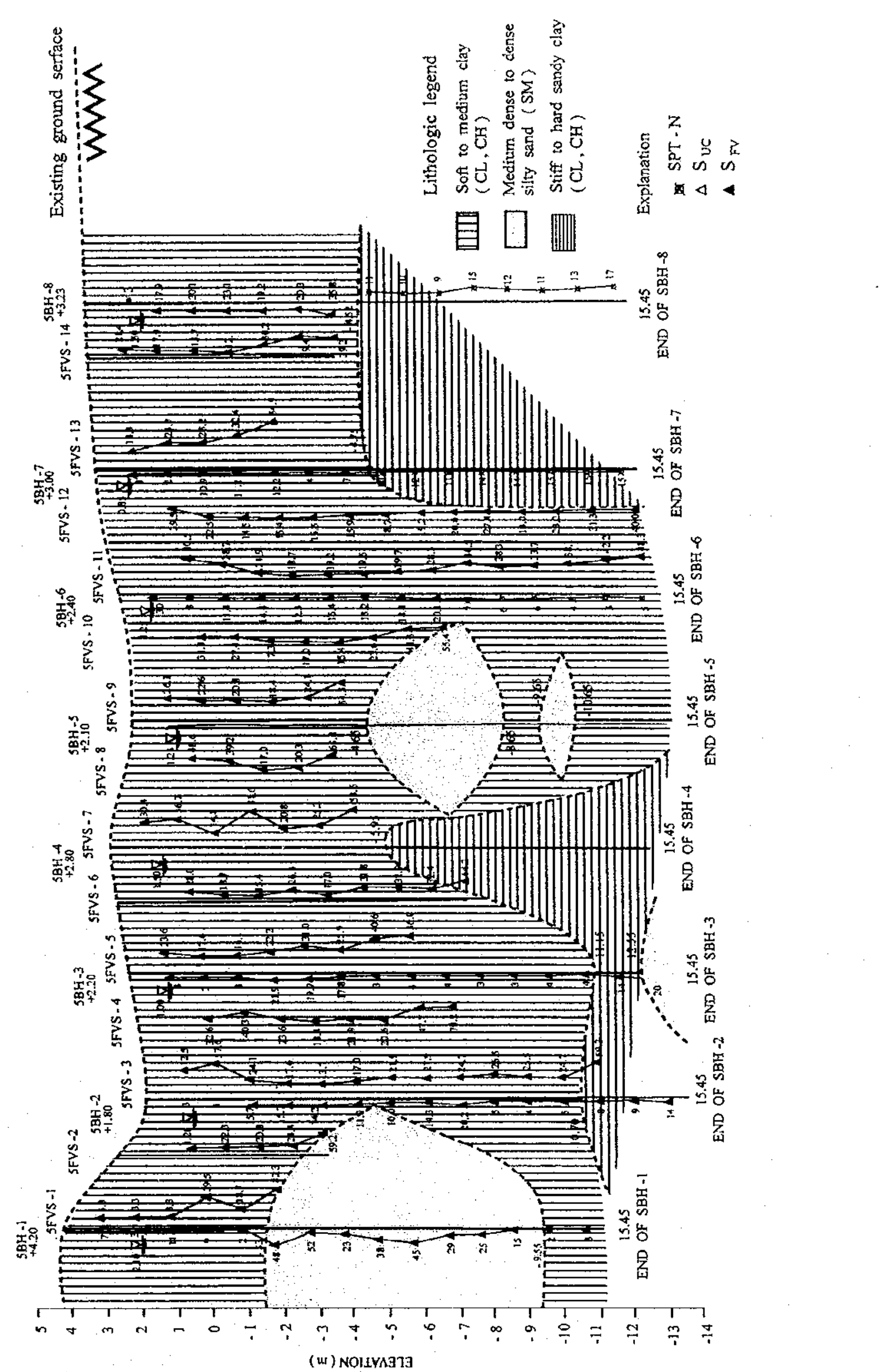
(From GMT, Co.,Ltd (1995), Survey Report Technical Geology Lop Buri River Development)

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig .3.3.5 SOIL PROTILE OF ANG THONG A LONG BANG KEAO RIVER
CTI ENGINEERING CO., LTD AND INA CORPORATION	



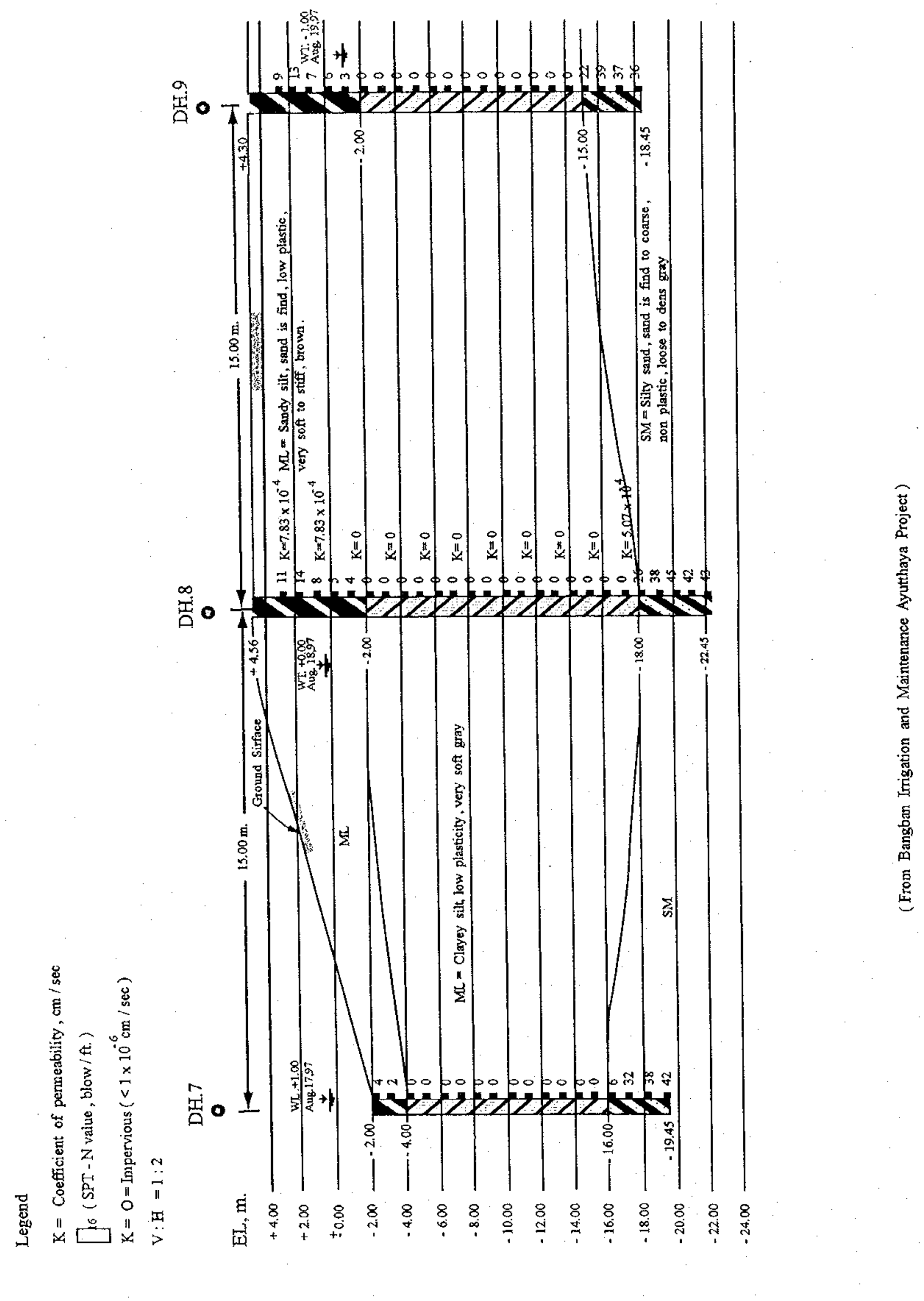
(From RID 1998) Construction Project and Improvement Responsible of RID 2

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig .3.3.6(a) LOCATION MAP OF SENA AREA (A LONG NOI RIVER)
CTI ENGINEERING CO., LTD AND INA CORPORATION	

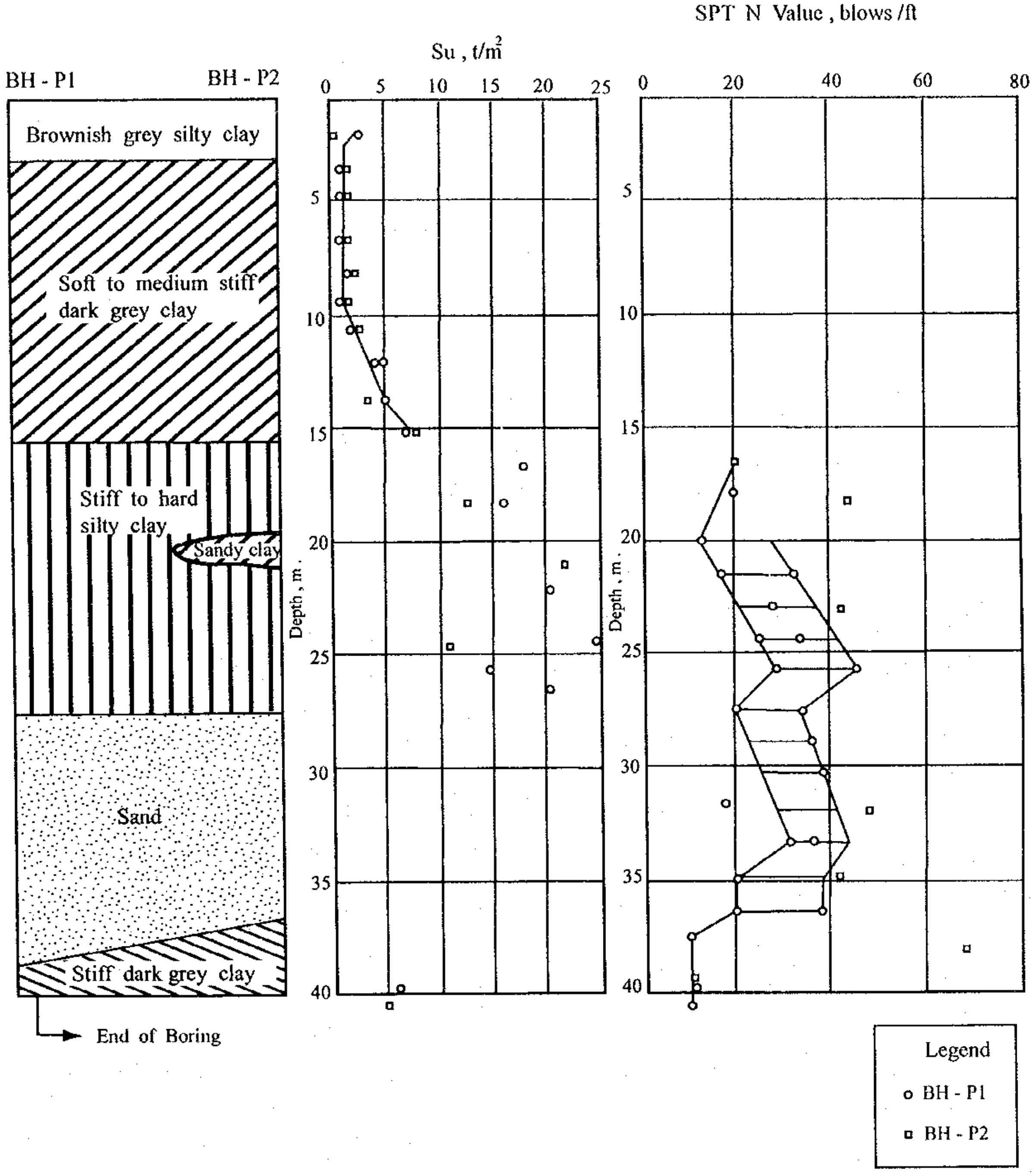


(From RID (1998) Construction project and improvement responsible of RID 2)

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig. 3.3.6 (b) CROSS SECTION OF AMPHOE SENA AREA (A LONG NOI RIVER)
CTI ENGINEERING CO., LTD AND INA CORPORATION	

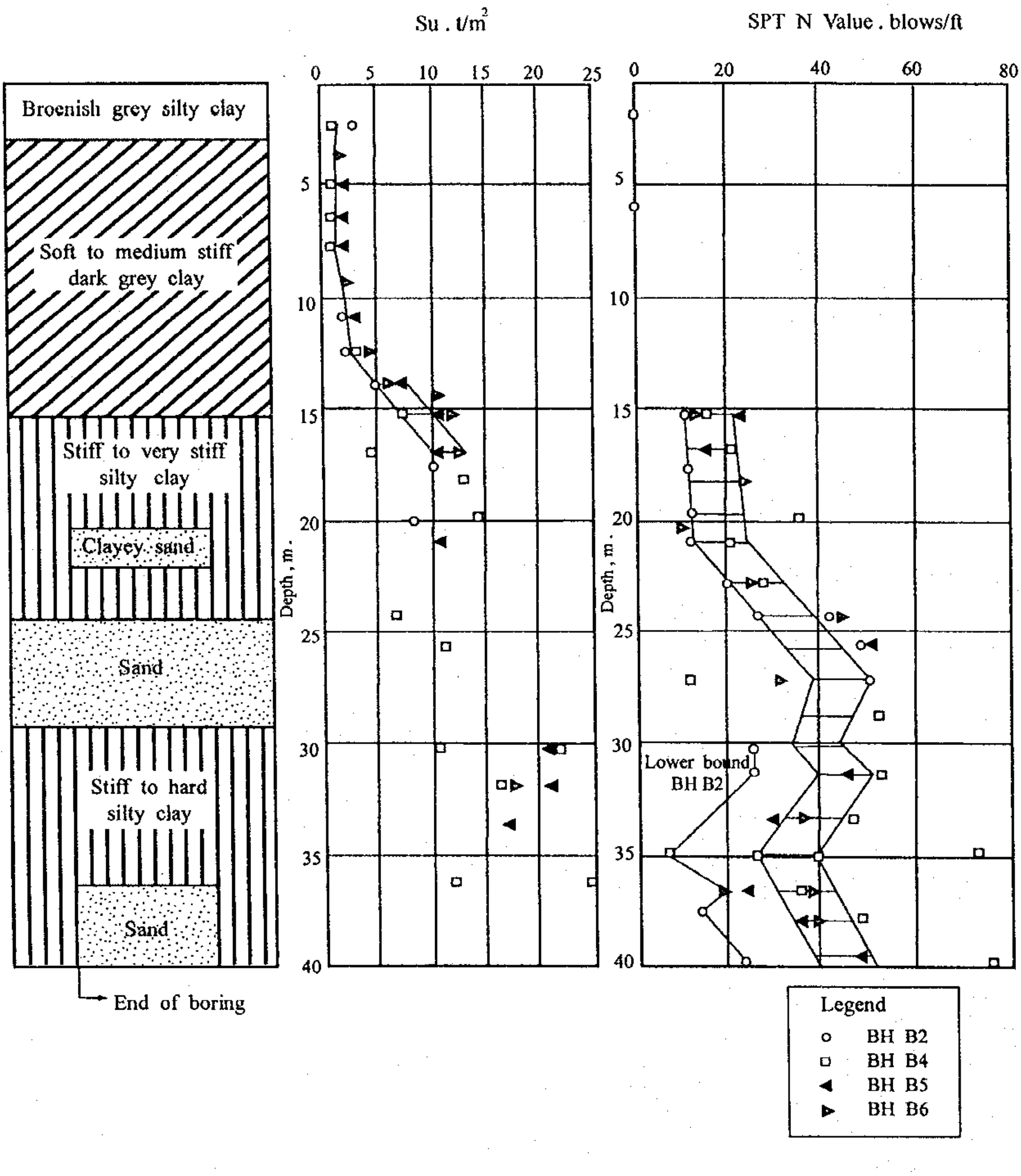


STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 3.3.7 CROSS SECTION OF BAN WAT TAKU (A LONG BANG LUANG RIVER)
CTI ENGINEERING CO., LTD AND INA CORPORATION	



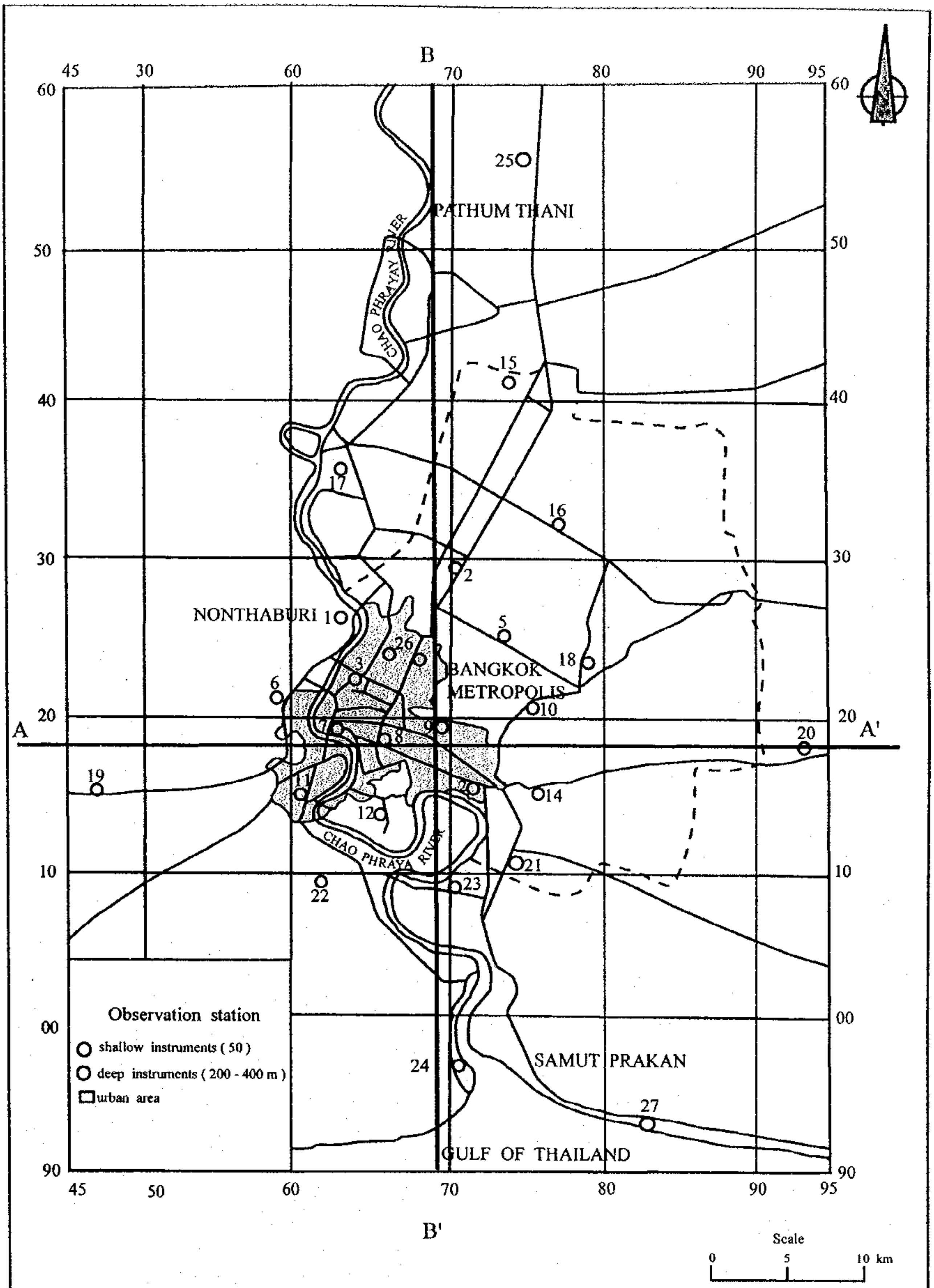
after ESUB Project (BMA / NEDECO , 1996)

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 4.2.1 GENERALIZED SOIL PROFILE AND SOME IMPORTANT SOIL PROPERTIES AT BUNG PIBUL WATANA
CTI ENGINEERING CO., LTD AND INA CORPORATION	

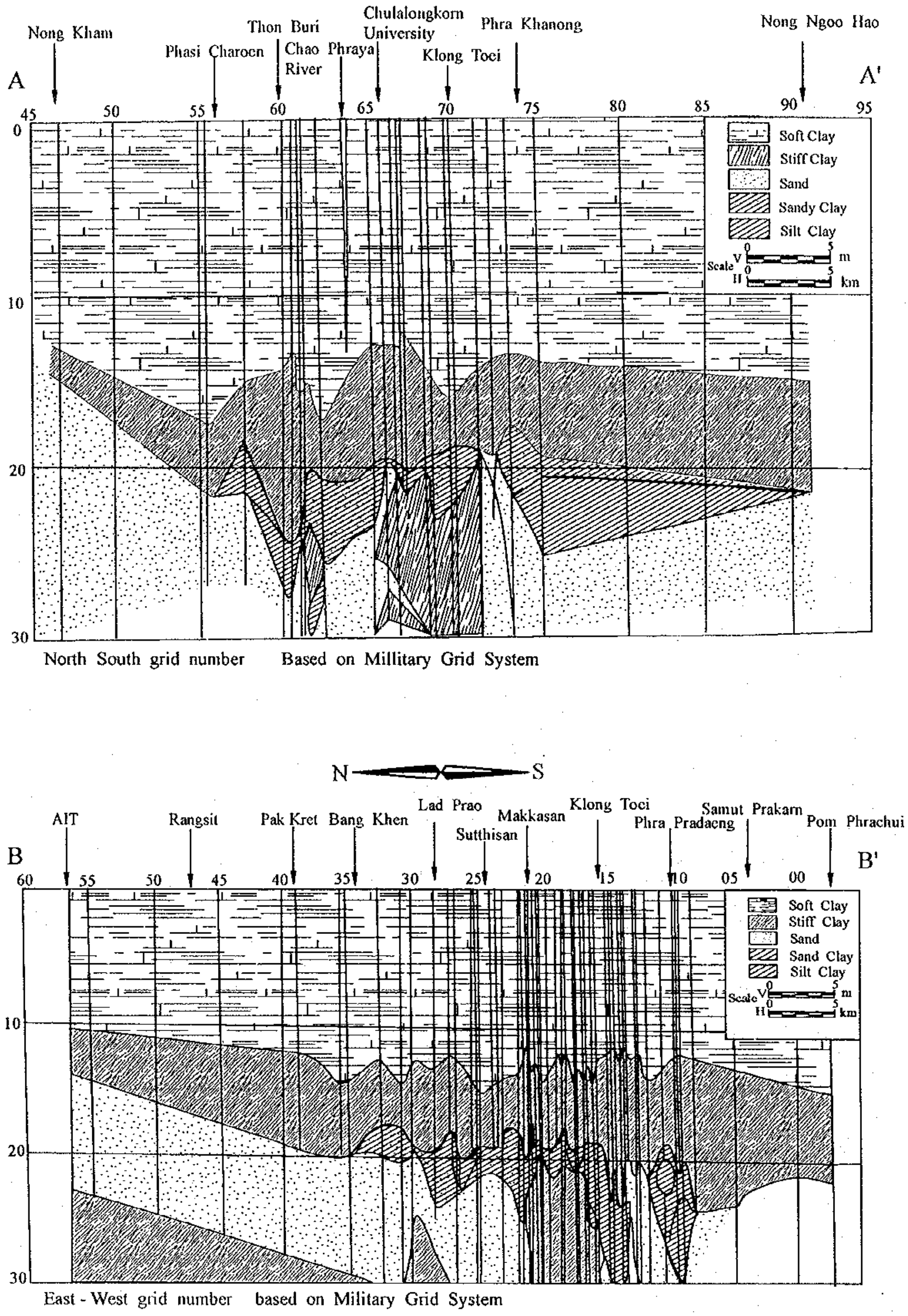


after ESUB Project (BMA / NEDECO , 1996)

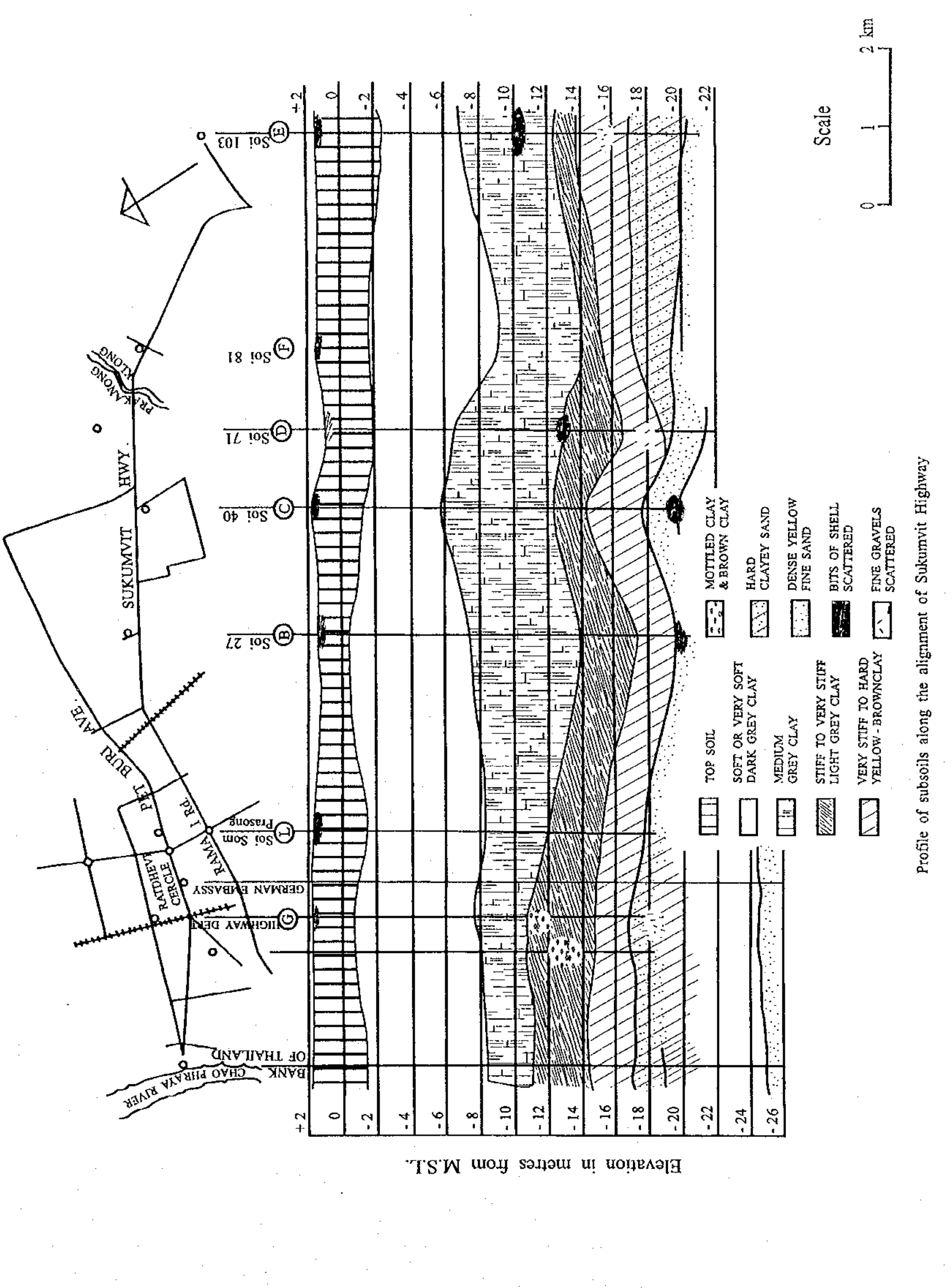
STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 4.2.2 GENERALIZED SOIL PROFILE AND SOME IMPORTANT SOIL PROPERTIES AT BUNG NONG BON
CTI ENGINEERING CO., LTD AND INA CORPORATION	



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 4.2.3 BANGKOK AREA AND VICINITY AND LOCATIONS OF CROSS SECTION
CTI ENGINEERING CO., LTD AND INA CORPORATION	

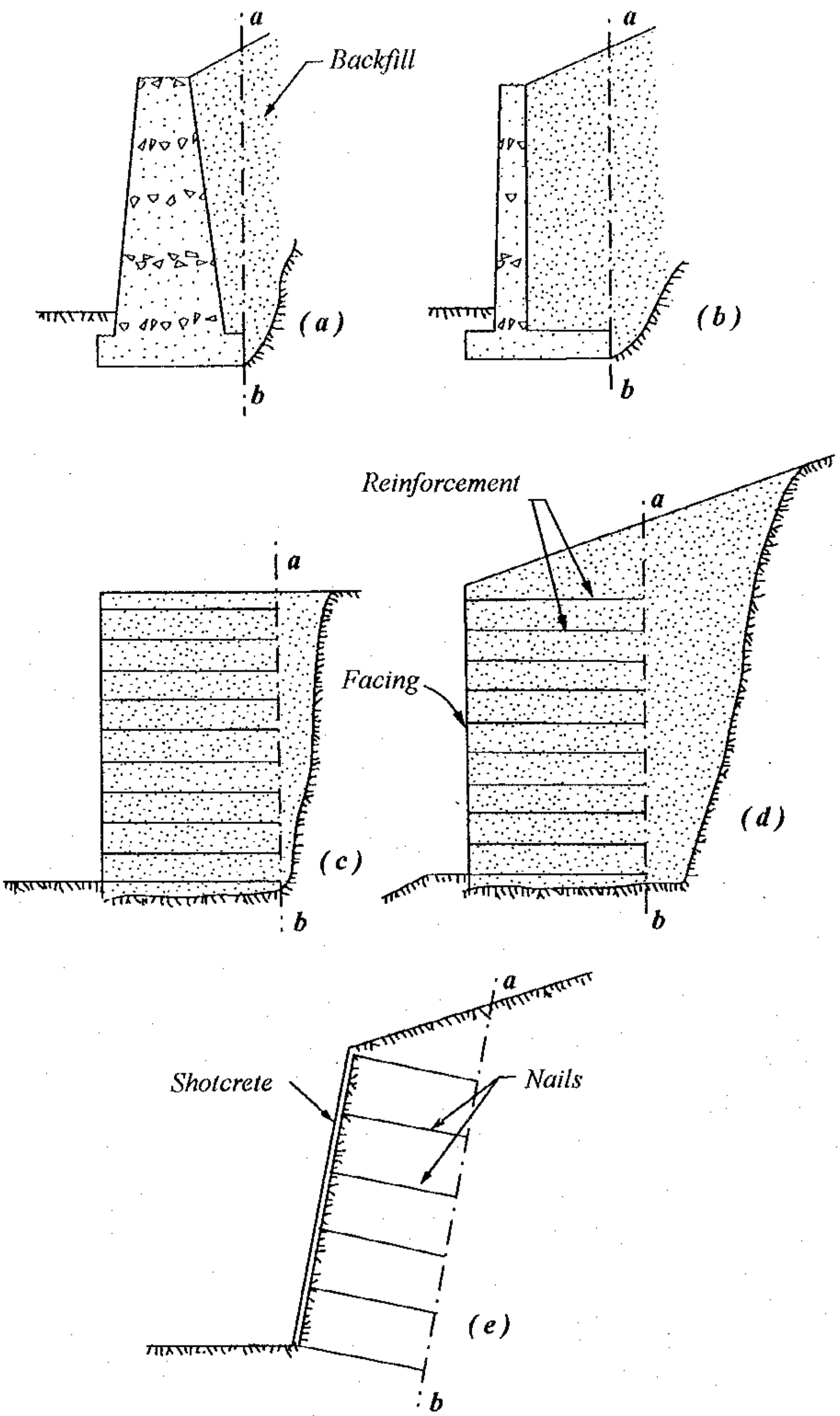


STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 4.2.4 PROFILE OF SUBSOILS OF THE BANKOK AREA
CTI ENGINEERING CO., LTD AND INA CORPORATION	



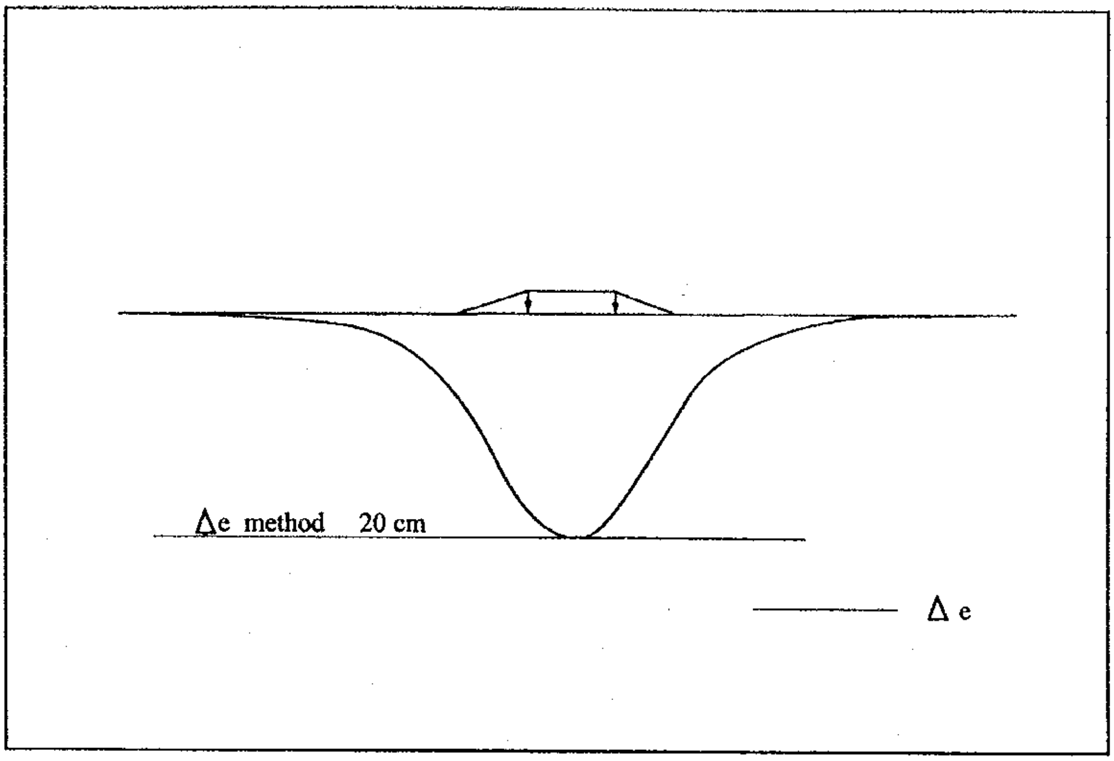
(after CHAI MUKTAB et al, 1966)

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig. 4.2.5 PROFILE OF SUBSOILS ALONG THE SUKUMVIT HIGHWAY
CTI ENGINEERING CO., LTD AND INA CORPORATION	

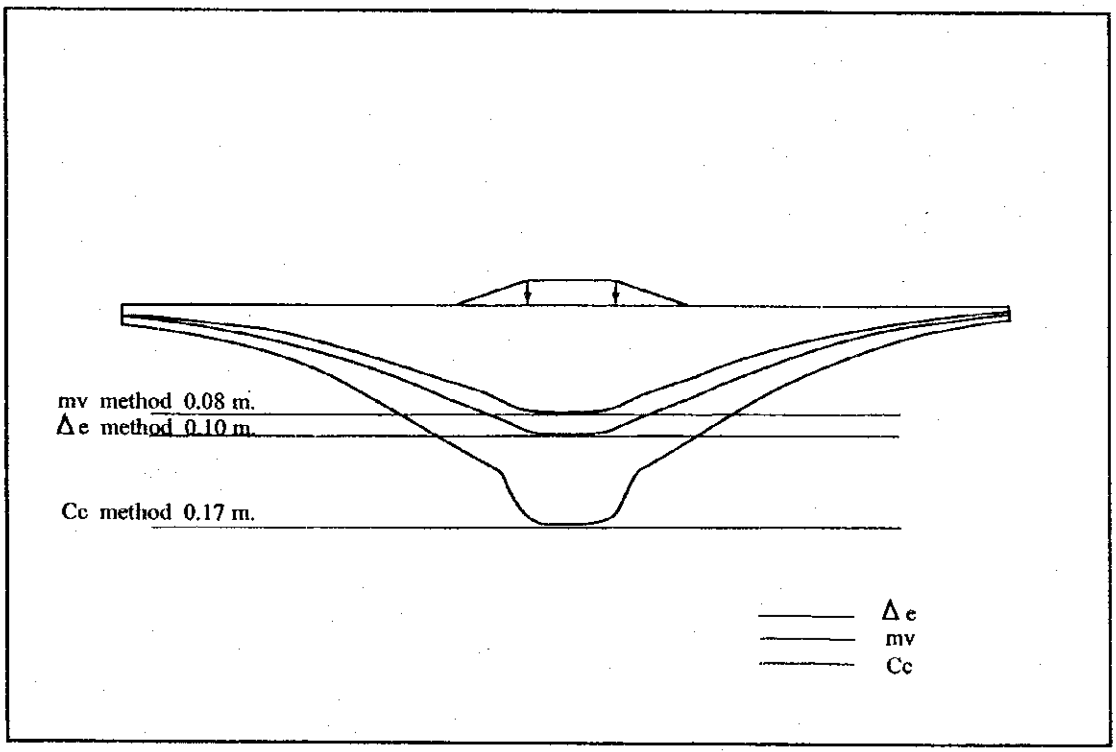


Types of retaining walls : (a) Concrete graving ; (b) reinforced - concrete cantilever ; (C) reinforced - soil support - ing fill with horizontal surface ; (d) reinforced- soil supporting fill with inclined surface ; (e) slope supported by soil nailing .

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 5.2.1 TYPES OF RETAINING WALLS (AFTER SOIL MECHANICS IN ENGINEERING PRACTICE, THIRD EDITION, 1996)
CTI ENGINEERING CO., LTD AND INA CORPORATION	



a . Sena Area



b. Ban Wat Taku Area

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 5.2.2 ILLUSTRATION OF SETTLEMENT OF MODEL RESULT
CTI ENGINEERING CO., LTD AND INA CORPORATION	

(1.5m)

Scale ; 1 / 300

Sing Buri

Minimum safety facter	F a MIN	= 4.485
Center of circle	X	= 16.00 (m)
	Y	= 3.00 (m)
Radius	R	= 3.00 (m)
Resistance moment	MR	= 21.38 (tf . m)
Motive moment	Mo	= 4.77 (tf . m)

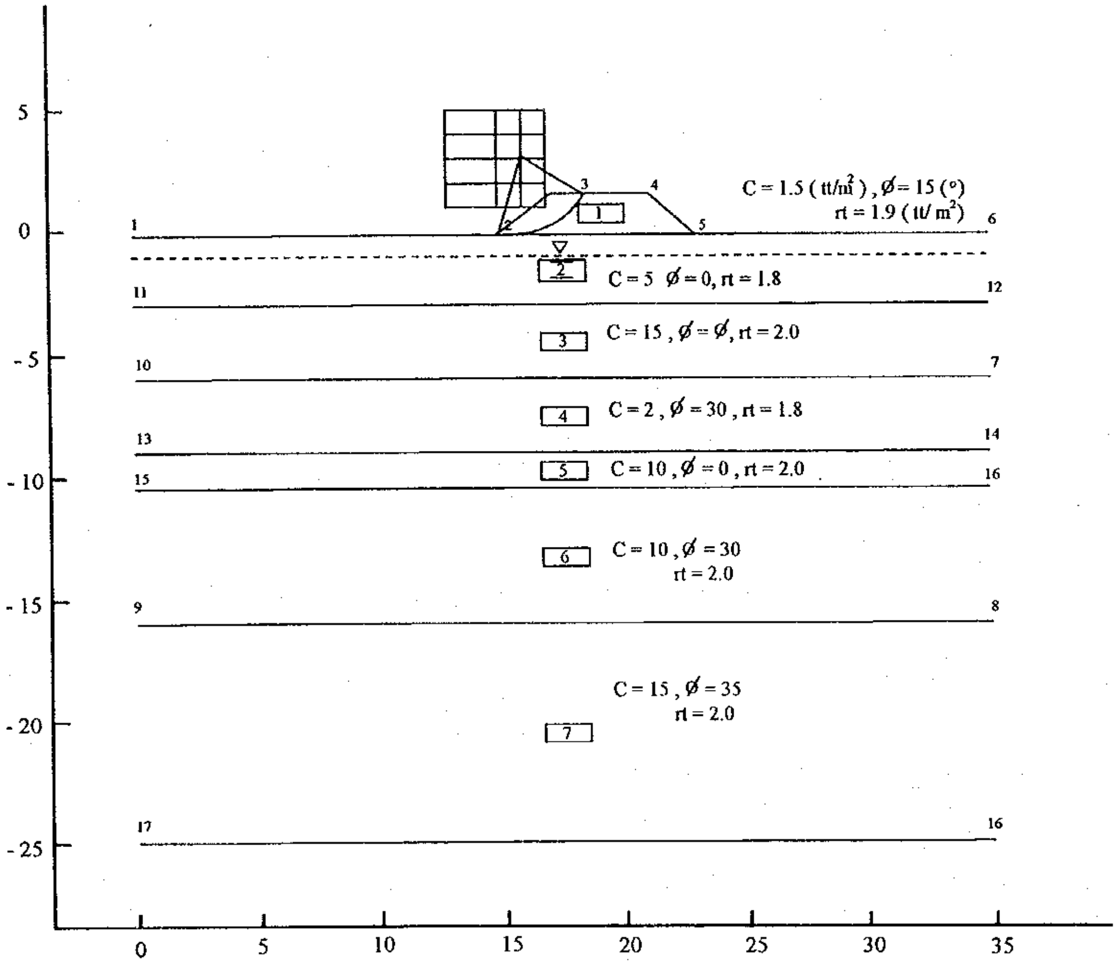


Illustration of safety factor

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig. 5.2.3 RESULT OF STABILITY CALCULATION IN ANG THONG A LONG BANG KEAO RIVER
CTI ENGINEERING CO., LTD AND INA CORPORATION	

Amphoe Sena (1.5m)

Scale ; 1 / 300

Minimum safety facter	Fa MIN	= 2.548
Center of circle	X	= 16.00 (m)
	Y	= 3.00 (m)
Radius	R	= 6.50 (m)
Resistance moment	MR	= 129.99 (tf . m)
Motive moment	Mo	= 51.01 (tf . m)

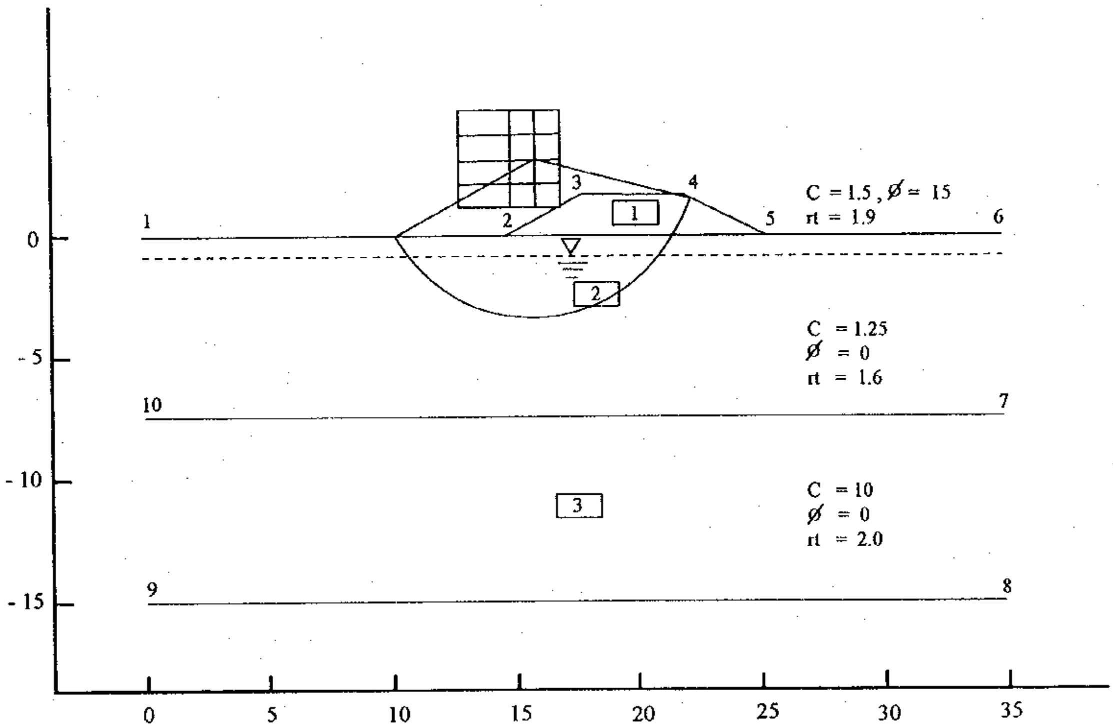


Illustration of safety factor

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 5.2.4 RESULT OF STABILITY CALCULATION IN SENA A LONG NOI RIVER
CTI ENGINEERING CO., LTD AND INA CORPORATION	

Scale ; 1 / 300

Bang Keao (1.5m)

Minimum safety facter	$F_{a\ MIN}$	= 4.485
Center of circle	X	= 16.00 (m)
	Y	= 3.00 (m)
Radius	R	= 3.00 (m)
Resistance moment	M_R	= 21.38 (tf . m)
Motive moment	M_o	= 4.77 (tf . m)

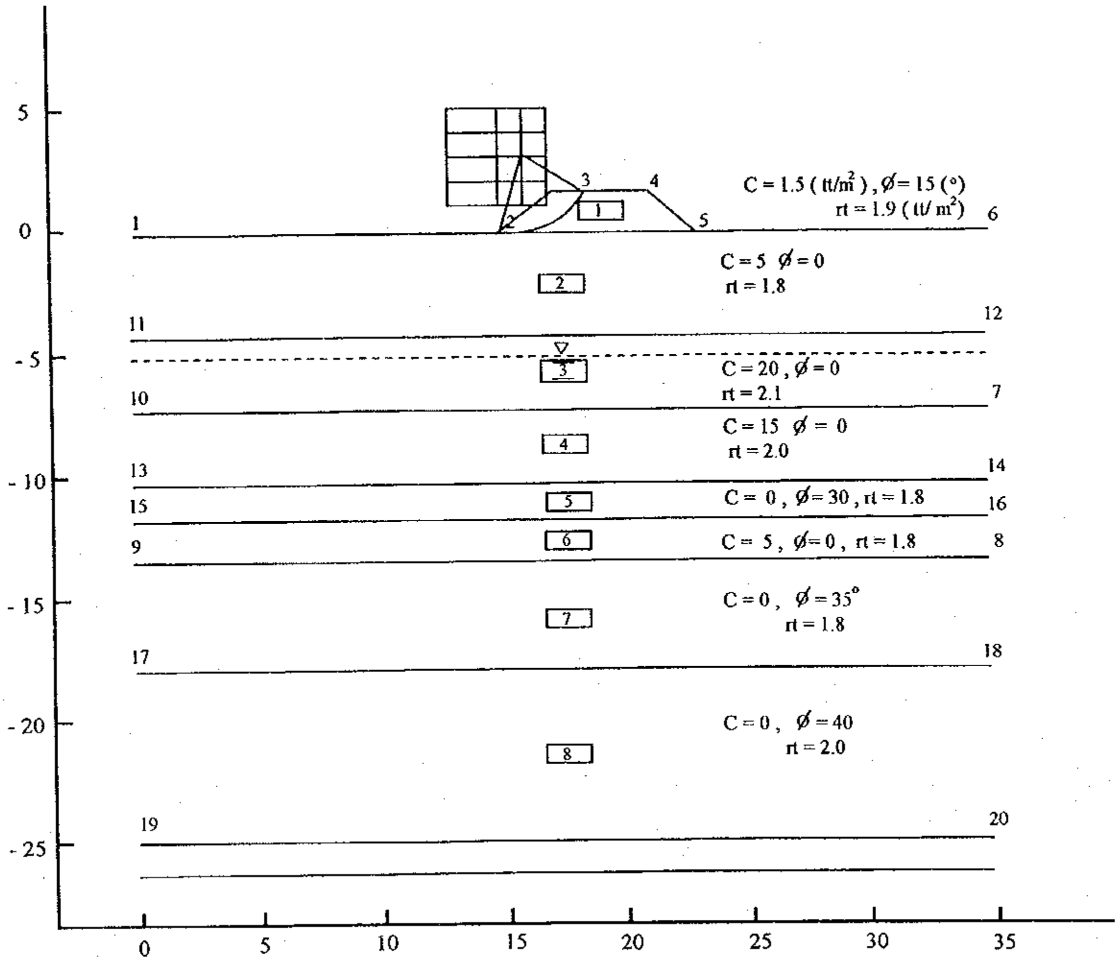


Illustration of safety factor

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 5.2.5 RESULT OF STABILITY CALCULATION IN ANG THONG A LONG BANG KEAO RIVER
CTI ENGINEERING CO., LTD AND INA CORPORATION	

(1.5m)

Scale ; 1 / 300

Bang Luang

Minimum safety facter	Fa MIN	= 1.467X
Center of circle	X	= 14.00 (m)
	Y	= 1.00 (m)
Radius	R	= 8.50 (m)
Resistance moment	MR	= 125.23 (tf . m)
Motive moment	Mo	= 85.37 (tf . m)

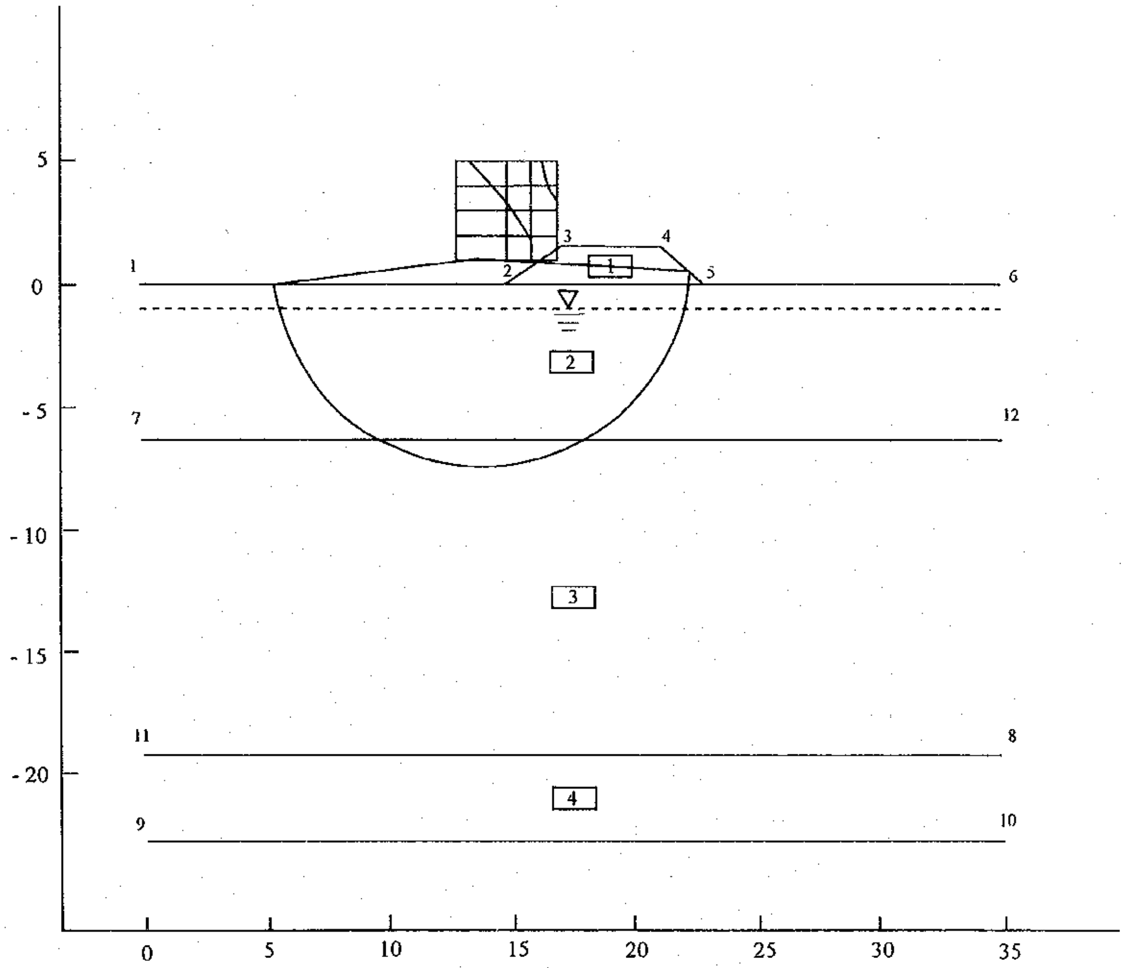
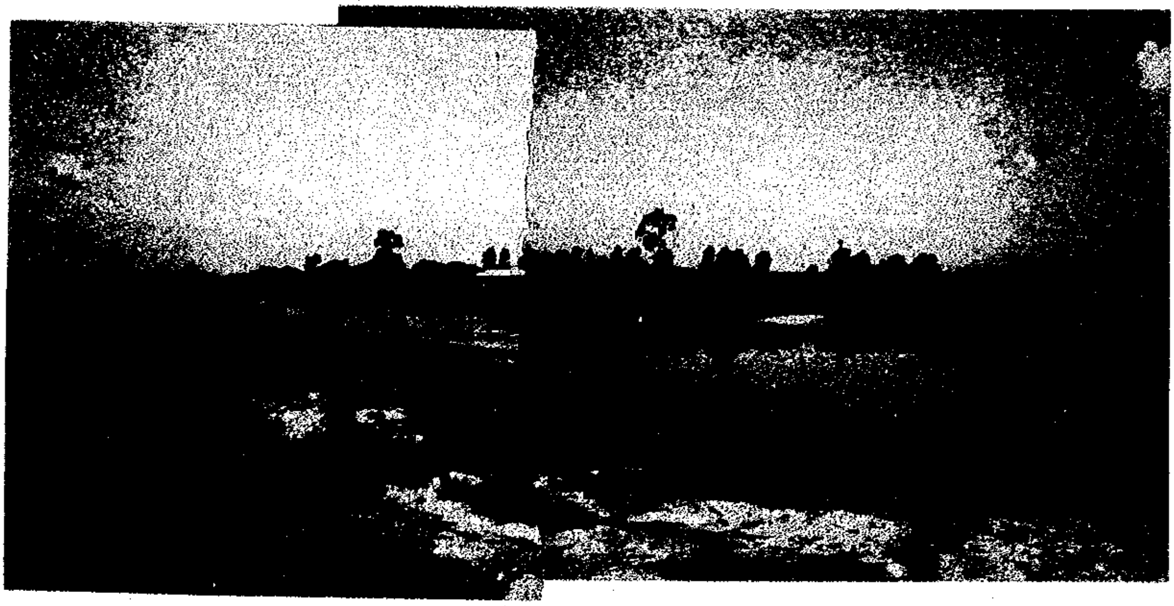
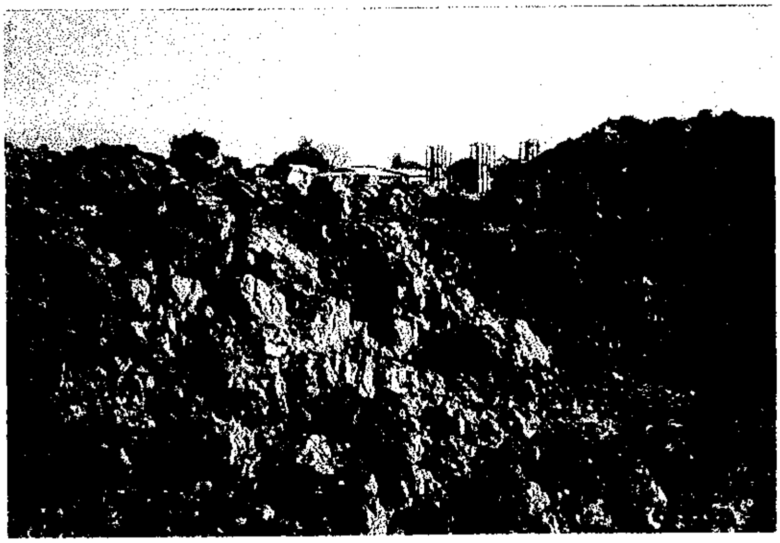


Illustration of safety factor

STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Fig . 5.2.6 RESULT OF STABILITY CALCULATION IN BAN WAT TAKU A LONG BANG LUANG RIVER
CTI ENGINEERING CO., LTD AND INA CORPORATION	



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Pic.3.3.1
CTI ENGINEERING CO., LTD AND INA CORPORATION	BROKEN BRIDGE IN PHAK HAI CANAL ALONG NOI RIVER



STUDY ON INTEGRATED PLAN FOR FLOOD MITIGATION IN CHAO PHRAYA RIVER BASIN	Pic.3.2.1
CTI ENGINEERING CO., LTD AND INA CORPORATION	BANG KEAO CANAL AREA

SECTOR V

FLOOD DAMAGE

SECTOR V:FLOOD DAMAGE

TABLE OF CONTENTS

4. FLOOD DAMAGE ESTIMATION FOR THE MASTER PLAN

5. FLOOD DAMAGE ESTIAMTON FOR THE FEASIBILITY STUDY

TABLES

FIGURES

List of Tables

List of Figures

1. GENERAL

1.1 Objectives

A flood damage analysis is indispensable for considering flood mitigation works because the ex/post situation of a project is an extremely important criterion for project formulation.

The first objective of the flood damage analysis is to analyze the characteristics of flood damage and to clarify the problems. The second is to conduct an economic evaluation to determine the feasibility by calculating the reduction of annual damage amount with or without the project proposed in the Study. For this purpose, statistical data such as quantity of damaged houses and damaged agricultural area are collected, and additional interview surveys are conducted to supplement the above data.

To estimate the annual flood damage amount, a computer simulation model is used because damage amount with project in the future condition is not known. In addition, even the historical flood damage data are sometimes not well recorded.

1.2 Study Area

The JICA Study Team had set the boundary of the inundation area due to floods of the Chao Phraya River and main tributaries, integrating the detailed contour maps with the past inundation maps. Since this boundary can be regarded as the external boundary of the possible maximum inundation, this was set as the boundary of the study area covering 35,000 km^2.

1.3 Study Procedure

The flood damage analysis was done in the following procedure (see Fig.1.1.1).

(1) Data collection

Statistical data including actual flood damage data, flood damage records and past study reports were collected.

(2) Interview survey

Interview surveys were conducted to collect the damage information especially of the 1995 and 1996 floods, because existing data were, unfortunately, not enough for the flood damage estimation. The interviewees included government agencies, households in the study area, and others including universities and private consulting companies. The conditions for the flood damage estimation were set up, and the interview survey helped to clarify the flood damage mechanism.

(3) Data analysis

The collected data were classified and analyzed. The situation and amount of damage by historical floods were classified. Based on these data the characteristics of flood were analyzed, and the flood damage mechanism was clarified.

(4) Conditions set up for flood damage estimation

Based on the data analysis the required conditions for flood damage estimation were derived and set up. The methodology and the simulation model of flood damage estimation were set, and the reliability was confirmed.

(5) Flood damage estimation for the Master Plan

Flood damage estimation for the Master Plan was made for both with and without-project situations. Project benefit is considered as the balance between with and without-project situations.

(6) Flood damage estimation for the Feasibility Study

The feasibility study area was set, based on the projects proposed in the Master Plan, which include Chainat, Singburi, Lopburi, Ang Thong, Ayuthaya, Pathum Thani, Nonthaburi, and Bangkok. The same simulation model was used to estimate the flood damage in the areas selected from the Master Plan by inputting more detailed data in case of river improvement and modification of dam operation rule.

2. DATA ANALYSIS

2.1 Data Collection

The agencies concerned were visited to collect data that included statistical data, actual flood damage data and related reports. Interview surveys were also conducted.

Based on the collected data, flood damage was analyzed to clarify the situation of flood damage, and the condition for flood damage estimation was derived.

2.1.1 Handling Agencies

The official flood damage records in Thailand was started in 1978 (Public Welfare Dept., Ministry of Labor and Social Welfare). Since 1988 the Civil Defence Department (DoLA) has been responsible for this task.

After a natural calamity including floods, post-evaluation is carried out and the province will issue a report. Later, the Division of Civil Defence collects such report from concerned provinces to integrate the relevant information.

Repair costs of roads and river structures are officially regarded as a part of damage amount. In recent years, once flooding occurs, damage becomes a considerable amount. Information on agricultural damage in an area covered by an agricultural extension office is reported to the Department of Agricultural Extension.

A provincial flood report generally provides statistics on (1) affected citizens, (2) damaged road and public offices, and (3) emergency services. Other items of statistics vary among provinces. In terms of agricultural damage, for instance, crop farming, livestock and fishery do not always appear together as chapter titles in the flood report. A provincial flood report does not always provide damage cost and unit cost for damage assessment although it basically counts the number of victims in different sectors. As for cost of emergency services such as flood fighting activity and sanitation, some provinces report them in detail and others do not. There is no established format for this subject.

2.1.2 Data Availability

Table 2.1.1 shows the data availability. Provincial statistics data concerning provincial areas, population, number of households, commerce, industry, and agricultural area, are available, but actual damage data is not completely available. Official data on actual damage only include households, other establishments, fishery, livestock, and public utilities, but households, fishery and livestock sometimes do not include damage cost but only damaged quantity. Besides, no data are in the sectors of commerce and industry.

2.1.3 Historical Record and Scale of Damage

As shown in Fig. 2.1.1, the infrastructure damage amount in 1995 was the worst on record and it was 12 billion baht for the whole country. Even though the damage due to drought is serious in a year, the damage due to flood has been recognized in the recent 10 years (see Fig. 2.1.2).

2.1.4 Actual Data on 1995 Flood

The flood damage data in 1995 by the Department of Local Administration is as shown in Table 2.1.2. The flood damage for the whole country in the year 1995 estimated by the Ministry of Interior was about 11,860 million baht. The damages include those of the agricultural sector and infrastructure of the government sector. The Ministry of Interior also estimated the whole damage amount including the private sector in the report on flood damage in 1995. If the damage in the private sector was taken into account, the total loss would come to 50,000 million baht.

Fig. 2.1.3 compares the damage amount of agriculture, fishery, livestock, and public utilities in provinces in the study area in 1995. The total damage was 6,356 million baht. The share of agricultural damage was 48% of the total damage excluding those of households, commerce, industry and other establishments. Briefly, the significance of agricultural damage can be observed. Further, integrating fishery and livestock damage, the total agricultural related damage cost was 3,976 million baht, which was 1.7 times as high as the infrastructure damage of 2,381 million baht.

According to provincial flood reports, emergency medical assistance is naturally organized, and services and items provided are listed. Due to insufficient format of reporting the emergency service, it was impossible during the study to inquire on complete services cost from the provinces concerned.

2.2 Interview Survey

2.2.1 Objectives

The interview surveys were carried out in February to March 1998 to collect several aspects of damage by floods in 1995 and 1996. These included (1) Inundation depth, (2) Inundation duration, (3) Initial time of inundation, (4) Location of flood, (5) Cause of flood (by insufficient drainage and/or river flooding), (6) Economic damage (on properties and income), (7) Action taken against flood (flood fighting, evacuation and others), and (8) Requests and expectations on flood control programs of communities (or individuals).

In addition, the flood damage mechanism was investigated by the interview surveys to define how the flood or its damage occurred and how the people took measures for the flood in more detail.

2.2.2 Method

On the inner part of the study area, a grid was drawn. The vertical line was 100 degrees longitude and the horizontal line was 13 degrees and 45 minutes latitude, for convenience in reproducing lines in every 5-km interval. Each cell of the grid was 25 km^2 and was considered as a unit for the interview surveys (see Fig. 2.2.1).

1,600 grids were set for around 35,000 km^2 of the inundated area in 1995 according to information from RID. The cell was used as a reference on flood damage information to be collected, and 1,600 interview points were planned to be located in the grid to cover the study area.

Due to the organizational difference, interview forms were separately prepared for provincial offices and communities. A set of sample interview forms is shown in Table 2.2.1, which was translated into Thai language before the interview surveys.

In the interview survey with either an office or a community, flood events in 1995 and 1996 were queried without exception. Other years, of course, were worthy of collection but a smaller scale of inundation and uncertainties larger than those years have to be recognized.

2.3 Flood Damage Records

2.3.1 Major Floods

As far as people in Thailand could remember, the biggest flood was the 1942 flood. During this flood, the highest water level recorded at the Memorial Bridge in Bangkok was 2.27 m MSL, and the capital of the Kingdom, Bangkok City, received catastrophic damage.

In the last two decades, the years 1978, 1980, 1983, 1995 and 1996 are regarded as flood years, and flood damage in 1983 and 1995 were the most terrible. Maximum discharges and water levels were recorded as below.

Past Major Flood Records

Year	Maximum Discharge at Nakhon Sawan (C.2) (m^3/s)	Maximum Discharge at Chainat (C.13) (m^3/s)	Maximum Water Level at Ayutthaya (S.5) (MSL m)	Maximum Water Level at Memorial Bridge (C.4)* (MSL m)
1942			5.15	2.27
1978	3,539	3,769	4.60	1.99
1980	4,350	3,804	4.70	1.92
1983	2,290	3,290	4.54	2.04
1995	4,820	4,548	5.00	2.20
1996	3,100	3,250	4.38	2.12

* Affected by land subsidence

(1) 1942 Flood

Although the quality of official records is not good and the inundation map is not available, the river flood in 1942 may have caused one of the largest floods in the Chao Phraya River Basin. The peak water level at Nakhon Sawan was estimated to be 1.5 m higher than that recorded in 1995. Flood control measures in the basin were almost non-existing, and natural habitation on its flood plain was much smaller than at present.

Monsoon rains caused an exceptionally heavy precipitation of 1,600 mm over the upper reaches from May to October, especially in the rainy season (August and October), when rainfall was recorded at 710 mm (430 mm on the average). In contrast, in the lower basin, rainfall was not significantly larger than normal.

According to the discharge records, the peak in the main channel alone was 1,500 m^3/s at Ang Thong on September 28, 1942, which was considerably less than the 2,700 m^3/s in 1995. Floodwaters overflowed the dikeless riverbanks and ran down in the distributaries and flood plains. The total water volume through Nakhon Sawan was estimated at 33,000 million m^3, and it spread over the lower flood plain. In Bangkok, the peak water level reached 2.27 m MSL at the Memorial Bridge in October 12.

(2) 1983 Flood

The flood in 1983 is well known by the considerable damage, primarily in Bangkok, that lead to the present flood protection facilities. Exceptionally large rainfalls were recorded in the upper reaches of the Chao Phraya River from September to November. The discharge at Chainat reached 3,290 m^3/s in October and November due to the flow from the Sakae Krang tributary.

In the lower basin, heavy rains in August (434 mm compared to 170 mm on the average) caused local flooding, because of low water level after the dry season. After that, the total rainfall from September to November was recorded at 405 mm, compared to 215 mm on the average, which resulted in the peak water level of 2.04 m at the Memorial Bridge on November 9 and 26, 1983 and the extensive inundation in Bangkok.

(3) 1995 Flood

The flood in 1995 caused inundation to an area of approximately 15,000 km^2 from the upper to lower reaches. The difference with the other cases of flooding was that Bangkok was practically protected from floodwaters and hence, did not receive much damage in contrast with the heavy damage outside of the city's structural protection area and in provinces.

The cause of heavy rainfall was a sequence of tropical storms from the end of July to early September. August's rainfall in the Nan and Pasak catchment areas was recorded at 450 mm and 345 mm, respectively. The Sirikit Dam's huge reservoir, of which water level was between the lower and upper rule curves at the end of July, was filled with inflow from the upstream in August and September and the spillway came into operation for the first time after the completion of the dam. In spite of the spillage, the Sirikit Dam stored 3 billion m^3. The Bhumibol Dam Reservoir of which water level was below the lower rule curve at the end of July escaped from spillage and stored 4.5 billion m^3 from August to October. Had it not been for these reservoirs' capacities, the peak discharge at Nakhon Sawan could have reached 6,000 m^3/s, according to the study sponsored by the World Bank (1996).

Along the stretch of 310 km from Nakhon Sawan to Bangkok, the peak flow of 1,480 m^3/s of the Pasak River joined the Chao Phraya River. Although a substantial volume of water was released into the floating rice area and some sections of the left bank between Chainat and Ayuthaya were breached, the flood dike prevented flooding in the major high yielding rice areas.

The flood damage compiled by the Department of Local Administration is presented in Table 2.1.2. The inundation maps of the 1995 and 1996 floods shown in Fig. 2.3.1 and 2.3.2 were made according to the interview surveys.

2.3.2 Flood Damage in Urban Area

(1) Bangkok Area

Bangkok is located on the flat delta area of the Chao Phraya River at a distance extending to some 27 to 56 km from its mouth. The city has a ground level of 1.0 to 1.5 m above the mean sea level on the average.

There have been several studies on flood damage in the Study area. Most of them had focused on the Bangkok metropolitan area. JICA has been occasionally conducting study programs since the early 1980's.

Concerning flood damage assessment, JICA's report (JICA, 1987) provided the relation between flood damage and probability. Of recent studies, NEDECO carried out an interview survey on direct damage to different sectors except agriculture and other subsequent expenses due to inland water inundation in Bangkok in 1995.

Klongs developed in and around Bangkok used to have an effective drainage system before the rapid urbanization, and no serious damage by floods had occurred. In accordance with the rapid urbanization and land subsidence of Bangkok, floods became significant social problems and caused large amounts of damage estimated as follows (Source: Flood Forecasting System in the Chao Phraya River Basin, JICA, 1987):

(i) 1975 / Bangkok, 1,100 million baht
(ii) 1980 / Central Bangkok, 450 million baht
(iii) 1982 / Central Bangkok, no data available
(iv) 1983 / Greater Bangkok, 6,597 million baht

The inundation area in 1983 is shown in Fig. 2.3.3. Since the flood protection and drainage system in Bangkok has been improved to a certain extent since the 1983 flood, the flood damage in recent years has decreased. The 1995 flood was the biggest flood in a period of 13 years after the 1983 flood, and because of the flood protection facilities provided after 1983 such as dikes, gates and pumps, the flood damage was far less than that of 1983. Flood damage concentrated mainly in the lower areas along the banks of the Chao Phraya River and the suburbs outside the protection dike, as shown in Fig. 2.3.4.

(2) Major Cities in the Chao Phraya River Basin

As for flood damage in the provinces, one of RID's projects (RID, 1997) derived the average damage cost in Nakhon Sawan whose capital and surrounding area was inundated in 1995.

A series of interview surveys in eight municipal offices was carried out from January 7 to 10, 1997 to identify the flooding problems in major cities in the

Chao Phraya River Basin. All of the eight cities were severely damaged in 1995. Except Nakhon Sawan all of them were damaged by flood again in 1996.

The survey results are given in Table 2.3.1. Flood inundation maps of these cities are presented in Figs. 2.3.5 to 2.3.9.

Recent Major Floods

City	Population in 1994	Recent Major Floods
Sukhothai	39,044	1995, 1996
Phitsanulok	91,143	1995, 1996
Phichit	57,276	1994, 1995, 1996
Nakhon Sawan	145,636	1970, 1980, 1995
Chai Nat	19,706	1994, 1995, 1996
Sing Buri	21,329	1984, 1995, 1996
Ang Thong	21,183	1995, 1996
Ayuthaya	70,367	1995,1996

2.3.3 Flood Damage in Farmland

Agricultural areas damaged by natural calamities such as drought, flood and others (pest, disease, etc.) between 1983 and 1992 are shown in Tables 2.3.2 and 2.3.3. According to these tables, flood damage arose less frequently than the drought damage but its damaged areas were very extensive in 1983 and 1990.

Table 2.3.4 shows the rice cultivation damage by flood summarized by province in the Chao Phraya River Basin. Agricultural areas damaged by the 1995 and 1996 floods are summarized by province in Table 2.3.5. Based on the relief system, the Government gave free seeds and fertilizers to farmers whose farm products were damaged by flood.

The flood damage extended to the fishery sector, too, as shown in Table 2.3.6. The Department of Fishery provided seven million fries to the fishermen free of charge based on the relief system similar to the case of the Department of Agriculture, which was twice the usual quantity a year for inland fish culture.

2.4 Flood Damage Mechanism

2.4.1 Damaged Area

A province (Changwat) is divided into several districts (Amphoe), while some districts have municipalities (Tesaban) and sanitary cities (Sukabiban). A municipality and a sanitary city are considered as an urban area and a hub city, respectively.

Flood damages concentrate on the municipality in case of a district having a municipality. Otherwise, flood damages concentrate on the agricultural sector in case of a district without a municipality.

Most of the private sectors such as houses, commercial shops, and small factories are located in the municipalities. Most houses, commercial shops and small factories are of low floor type, and in such floor types, a large amount of assets exist.

On the other hand a small number of buildings in the private sector are in districts without a municipality. Thus, a small amount of assets is in the district except assets in the agricultural sector. In addition, most of the houses are of high floor type in rural areas, so that these houses are, functionally, relatively durable against floods.

2.4.2 Wisdom of Flood Countermeasures

When floods strike people try to protect their assets or mitigate flood damage by taking countermeasures. Since inundation comes up slowly, people can determine when the flood comes and have enough time to take countermeasures. Inundation level comes up several centimeters per day, and it took 20 to 30 days from the beginning of the inundation to reach the highest level in the case of Ayuthaya in 1995. The flood information is sometimes broadcast on radio or TV.

People make efforts to move their assets such as furniture and television to the second floor or an upper place like a shelf or desk in most cases. Some people try to construct a new floor on a higher level to move their household effects, and they live and sleep on this floor. Shopowners construct protection walls made of cement.

Large factories are located around municipalities or sanitary cities in general. Most of these factories have their own dikes for protection against floods. They usually have large amounts of assets such as facilities, machinery, materials and products, and with these flood protection works, the assets are relatively protected against floods. However, once these are submerged, the damage amount becomes very large.

People have developed the wisdom of providing flood countermeasures through their experiences. However, they cannot prevent or mitigate big floods and, actually, much damage has been inflicted.

2.4.3 Situation in Flood

During floods people go shopping by small boats, or peddlers come to their houses. Due to the flooding situation, however, people suffer because it is very difficult to go somewhere or to buy daily necessities in the inundated areas. As for drinking water, people in urban areas buy bottled water, while people in rural areas drink rainwater because they normally stock rainwater from their roofs in big pots. As for food, people tend to eat dry noodles.

2.4.4 Composition of Damage

It is easy to recognize direct damage on houses or its assets. Direct damage is not so much because people remove their assets to higher locations as mentioned before.

On the other hand, it is difficult to recognize indirect damage. Business suspension is considered as an indirect damage. People cannot work during floods, and floods sometimes take a long duration of more than three months.

In addition, the cost of countermeasures can be considered as an indirect flood damage. To estimate the total amount of damage, indirect damage cannot be ignored because the amount is unexpectedly large.

There is an interesting report by PWD. It shows diseases due to flood, consisting of 19% of conjunctivitis, 11% of diarrhea, 45% of athlete's foot, and 7% of food poisoning in 1995. It also shows curative costs for waterborne diseases amounting to 1,449 baht/household. In addition, it mentions problems such as traffic, commerce, sanitation, settlement, food, drinking water, diseases and others. These kinds of damage are also indirect damages. Indirect damage becomes more serious if these damages are taken into account.

Another interesting report on Ayuthaya by PWD mentions tourism damage. Ayuthaya is one of the most famous places for tourist in Thailand, therefore, income from tourism is a large amount. Since during floods no tourists come to Ayuthaya, the damage on tourism is estimated to be large.

It is difficult to recognize and estimate all indirect damage amounts as well as intangible damage.