Appendix D Land Subsidence

The National Environmental Board (NEB) made a comprehensive investigation programme to assess the land subsidence problem quantitatively in 1975. According to the programme, the investigation entitled "Investigation of Land Subsidence Caused by Deep Well Pumping in the Bangkok Area" was carried out from February 1978 to April 1981 by the Asian Institute of Technology (AIT) in the Division of Geotechnical and Transportation Engineering.

The investigation is a joint effort with the Royal Thai Survey Department (RTSD) and the Department of Mineral Resources. The land subsidence described in this report is based mainly on the result of this AIT study.

1 Historical Land Subsidence

During the year from 1978 to 1981, at six-month intervals, the RTSD carried out precise levelling from a stable bench mark at Khao Lao Mountain, Ratchaburi, for the 24 observation stations as well as the existing old bench marks in Bangkok.

Based on these levelling results as shown on Tables D.1 and D.2 and Figures D.1 and D.2, it was found that the existing bench marks are 30 to 80 cm lower than the original elevations which were established in the 1930s.

The subsidence rate varies from location to location, with the maximum being more than 10 cm per year, as shown in Figure D.3 and Table D.2. The zone of particularly high subsidence rate can be distinguished, and this corresponds to the area of heavy groundwater pumping which is shown in Figure D.4.

The much troubled areas are Lat Phrao, Hua Mark, Phra Khanong and Bang Na. The survey also revealed that the ground elevations in these areas are less than 1.0 m above MSL with the lowest area being less than 0.5 m above MSL as shown in Figure D.5.

Table D.1 Change of Elevation of Benchmarks, Total Subsidence from 1930 to 1981

and Average Subsidence Rates During 1978 - 1980

station No.	Bench Mark	Location	Elevation m + MSL							Total Subsidence upto 1981 (cm)	Average Subsidence Rate 1978-1981 (cm/year)
			old Elev. (1930's)	1st mid 1978	2nd end 1978	3rd early 1979	4th end 1979	5th early 1980	1981		
B1	P.RTSD	Royal Thai Survey Department	2.79	2.45	2.45	2.43	2.42	2.41	2.40	39	2.0
B2	P.RTSD School	RTSD School Rajdamnern Ave.	2.35	1.99	1.98	1.97	1.95	1.94	1.92	43	2.8
B3	P.BM.	Royal Palace Railway Station	3.35	2.81	2.79	2.77	2.75	2.73	2.70	65	4.4
B4	P.IA	Klong Sam Sen Railway Bridge	4.67	4.35	4.33	4.32	4.30	4.28	4.25	42	4.0
B5	P.IIIA.	Bang Son Railway Bridge	2.38	1.94	1.91	1.90	1.87	1.85	1.80	58	5.6
B6	P.236	King Tak Sin Monument Wong Wian Yai	2.52	2.23	2.22	2.21	2.20	2.19	2.19	33	1.6
B7	P.386	Meteorological Dept. Bank Kapi	2.31	1.83	1.81	1.79	1.77	1.74	1.68	63	3.6
B8	S.2269	Front of Bhumiphol Hospital, Don Muang	2.47	2.17	2.19	2.15	2.14	2.11	-	36*1	3.0*3
B9	S.2271	Nakseni Bridge (Sapanmai) Don Muang	4.41	4.22	4.24	4.20	4.19	4.18	-	23*1	2.0*3
B10	S.135	Khlong Lao	2.43	1.59	-	-	-	-	-	84*2	-
B11	S.136	Khlong Hua Mark	2.37	1.70	-	-	-	-	-	67*2	-

Note: All data from new survey runs were adjusted by the RTSD to the fixed reference BMRI located in Nong Khaen District. ilev. + 1.3689 m, and rounded off to 1 cm. The location is shown in Fig. D.1.

*1. Total Subsidence in 1980
*2. Total Subsidence in 1978
*3. Average Subsidence Rate between 1978 and 1980

Table D-2 Ground Surface Elevations at the Observation Stations Based on the Levelling Runs on Surface Reference Points by RTSD

Station Number	Ground Surface Elevation + m MSL					Average Subsidence Rate (78-79) cm/year
	1st mid 1978	2nd late 1978	3rd early 1979	4th late 1979	5th early 1980	
1	2.23	2.22	2.19	2.16	2.27	4.6
2	-	1.67	1.63	1.57	1.52	10.0
3	1.14	1.12	1.10	1.08	1.07	3.5
4		1.44	1.40	1.35	1.29	10.0
5	1.71	1.67	1.62	1.57	1.52	9.5
6	1.47	1.53	1.52	1.52	1.51	1.3
7	1.43	1.42	1.40	1.39	1.37	3.0
8	1.54	1.51	1.51	1.48	1.46	4.0
9	1.27	1.24	1.22	1.18	1.15	6.0
10	0.70	0.63	0.59	0.53	0.46	12.0
11	1.50	1.49	1.48	1.48	1.47	1.5
12	1.40	-	1.38	1.37	1.35	2.5
13	1.56	1.52	1.50	1.47	1.43	6.5
14	0.71	0.66	0.63	0.59	0.54	8.5
15	2.26	2.28	2.25	2.24	2.24	1.0
16	2.07	2.07	2.00	1.97	1.92	7.5
17	1.42	1.44	1.42	1.40	1.39	1.5
18	1.15	1.10	1.06	1.01	0.95	10.0
19	-	0.81	0.78	0.77	0.75	4.0
20	1.41	1.37	1.35	1.36	1.33	4.0
21	1.01	0.97	0.94	0.90	0.86	7.5
22	1.20	1.19	1.16	1.14	1.13	3.5
23	1.35	1.32	1.30	1.27	1.25	5.0
24	0.91	0.89	0.86	0.84	0.83	4.0

Note: All data were adjusted by RTSD to the reference BMR1, elev. + 1.3689 m, and rounded off to 1 cm.
The location is shown in Fig. D.2

2 Flooding and Land Subsidence

It is evident from the study of patterns of floods in Bangkok that land subsidence greatly aggravates the problem in the area. It is recognized that the east and southeast parts of the city are flood-prone and usually suffer more severely than any other area in Bangkok.

A spectacular example is the Hua Mark area. The measured ground elevation at the subsidence observation station at No. 10, in Figure D.2, Ramkhamhaeng University was 0.70 m above MSL in mid 1978 and rapid subsidence brought down the elevation to only 0.46 m above MSL in early 1980.

In 1980 and 1983, the University was submerged under 1 m of flood water for more than two months.

It is worth mentioning that there are numerous private housing estates in the area and there is no proper public water supply in the area. These estates rely on a large quantity of groundwater pumped from a large number of deep wells.

3 Groundwater Extraction and Land Subsidence

During the past few decades, rapid development has taken place in the industrial and agricultural sectors with a consequent increase in population. The need for water for municipal and industrial purposes has, therefore, steadily grown. To cope with this need, more than one million cubic meters of groundwater is extracted from aquifers underneath the city every day.

The exploitation of groundwater has lowered the groundwater level from the free flow conditions to a level lower than 45 m below ground at some places. The groundwater level has been dropping at the persistent rate of 2-3 m per year during the past decade.

When water is removed from a confined water bearing stratum the pressure of the water in the pore space of the soil is lowered. This lowering of the pore water pressure in an aquifer creates a hydraulic gradient between the aquifer and the adjacent clay layer. As the pore water flows out of the clay layer, consolidation takes place and the layer is compressed. The compression of these layers manifests itself as ground subsidence.

In the deep layers, the drop in groundwater level is large, and the level continues to decline at a rapid rate. The measured compression of the strata in this deep zone was found to form the major part of the subsidence of the ground, accounting for 6 cm out of 10 cm surface subsidence in one year.

In the upper 10 m of the subsurface, however, there is no persistent decline in the groundwater level and it fluctuates in the region of 1-2 m below ground. The measured compression of this top zone was found to be very small, amounting to less than 1 cm in a year.

This is due to the fact that most of the wells pump groundwater from deep aquifers at depths of 100~200 m.

4 Past Groundwater Development

The first large scale utilization of groundwater began in the early 1950s by the drilling of several large wells into deep aquifers by the Department of Public and Municipal Works. Subsequently, more than 150 large wells were installed in the period from 1955 to 1960 for public water supply.

The growth in groundwater development in the private sector was also being increased in the same period. The MWWA was formally established in 1967 and the use of groundwater for public water supply has been increasing ever since. In 1980, MWWA extracted about 450,000 CMD of groundwater from deep aquifers to cope with the public water demand. (Ref. to Table D.3)

At the same time, the growing number of groundwater wells in the private sector reached 8,000 with the estimated pumping rate of about 800,000 CMD. (Ref. to Table D.4 and Figure D.4)

The total rate of groundwater pumping in the Bangkok area at present, including both the private and public sectors, is about 1.2 MCMD, while surface water is consumed at 1.52 MCMD, it was realised that the land subsidence problem would become more serious if the use of groundwater is continued. Figure D.6 shows the groundwater pumping rate in the Bangkok area from 1955 to 1978.

Table D-3 Pumpage for Public Water Supply (MWWA,1980)

AREA	Pumpage in m^3/day 1980
Bangkok (112 Wells)	365,000
Nonthaburi (15 Wells)	61,000
Samut Prakan (7 Wells)	24,000
Total	450,000

Table D.4 Areal Distribution of Private Wells as of January 1982

(Source: Department of Mineral Resources)

Usage / Area	Domestic	Industry/Factory	Agriculture	Total	Total
	Number of Wells (Pumpage in m3/day)	Number of Wells (Pumpage in m3/day)	Number of Wells (Pumpage in m3/day)	Number of Wells	Pumpage in m3/day
Bangkok	3,353 (245,492)	1,838 (212,744)	100 (9,194)	5,291	467,430
Samut Prakan	1,478 (49,582)	1,392 (266,472)	103 (2,905)	2,973	318,959
Samut Sakhon	325 (4.779)	207 (30,594)	98 (2,741)	630	38,114
Nonthaburi	139 (27,738)	59 (14,000)	1 (10)	199	41,748
TOTAL	5,295 (327.591)	3,496 (523.810)	302 (14,850)	9,093	866,251

5 Future Groundwater Use

The Department of Mineral Resources is the authority that controls groundwater utilization. The department is regulating the installation of new groundwater wells and only allowing those who have real need and have no public water supply in the area.

The department also has a policy not to allow any more pumping after the year 1985. The MWWA, however, is not under this regulation. The MWWA is the largest single consumer of groundwater, using about one third of all groundwater extraction in Bangkok.

The MWWA needs groundwater to be replaced by the surface water supply which is severely below the level of demand of the ever-rising population of Bangkok. The MWWA, in foreseeing this problem, has devised a "Master Plan" which calls for rapid expansion of the surface water supply from 1.5 MCMD as of 1980 to 5.0 MCMD in the year 2000.

According to the MWWA Master Plan, the MWWA will phase out groundwater use entirely by 2000. It seems that, with a full production of 5.0 million cubic meter per day of surface water, there would be no need for private sector pumping in the year 2000.

6 Future Land Subsidence

6.1 Future Land Subsidence Estimated by AIT

There might be various causes which would delay the planned schedules of MWWA "Master Plan". Therefore, the land subsidence rate was estimated according to a different forecast of groundwater use by AIT. (See Table D.5)

Land subsidence rate will decline and ground elevation will stabilize as shown in Figure D.7 if surface water is substituted for the whole or part of the groundwater extraction. This would be the case with schemes C,D,E and F of Table D.5.

However, land subsidence will continue if groundwater of 1.65 MCMD or more after 1985 is extracted. This would be the case with schemes A and B.

The correlation between the future groundwater utilization and land subsidence are displayed in Figures D.7 and D.8.

6.2 Future Land Subsidence Estimation

The MWWA Master Plan is now being revised to cope with the future estimated population in 2000.

According to the draft revised Development Plan, the water demand in the Bangkok area in the year 2000 will decrease about 0.5 MCMD from that of Master Plan due to the decrease of the future stimated population. Even in case of the draft revised L velopment plan, MWWA will not be able to supply surface w ter all over the Bangkok Mertopolis. Some groundwater utilization in the private sectors (about 0.4 MCMD) will still remain after 1986 untill 2000.

The draft revised Development Plan is shown in Fig. D.9 and proposed future service area of public water supply by MWWA is shown in Fig. D.10.

At the meeting between MWWA and the Study Team in August 1983, it was reported that the latest MWWA surface water supply plan had been delayed by about 2 years. Under such situation to establish a basic condition for the estimation of land subsidence in this project, the Study Team assumed that the execution of the latest MWWA plan will be delayed for 5 years as a conservative figure.

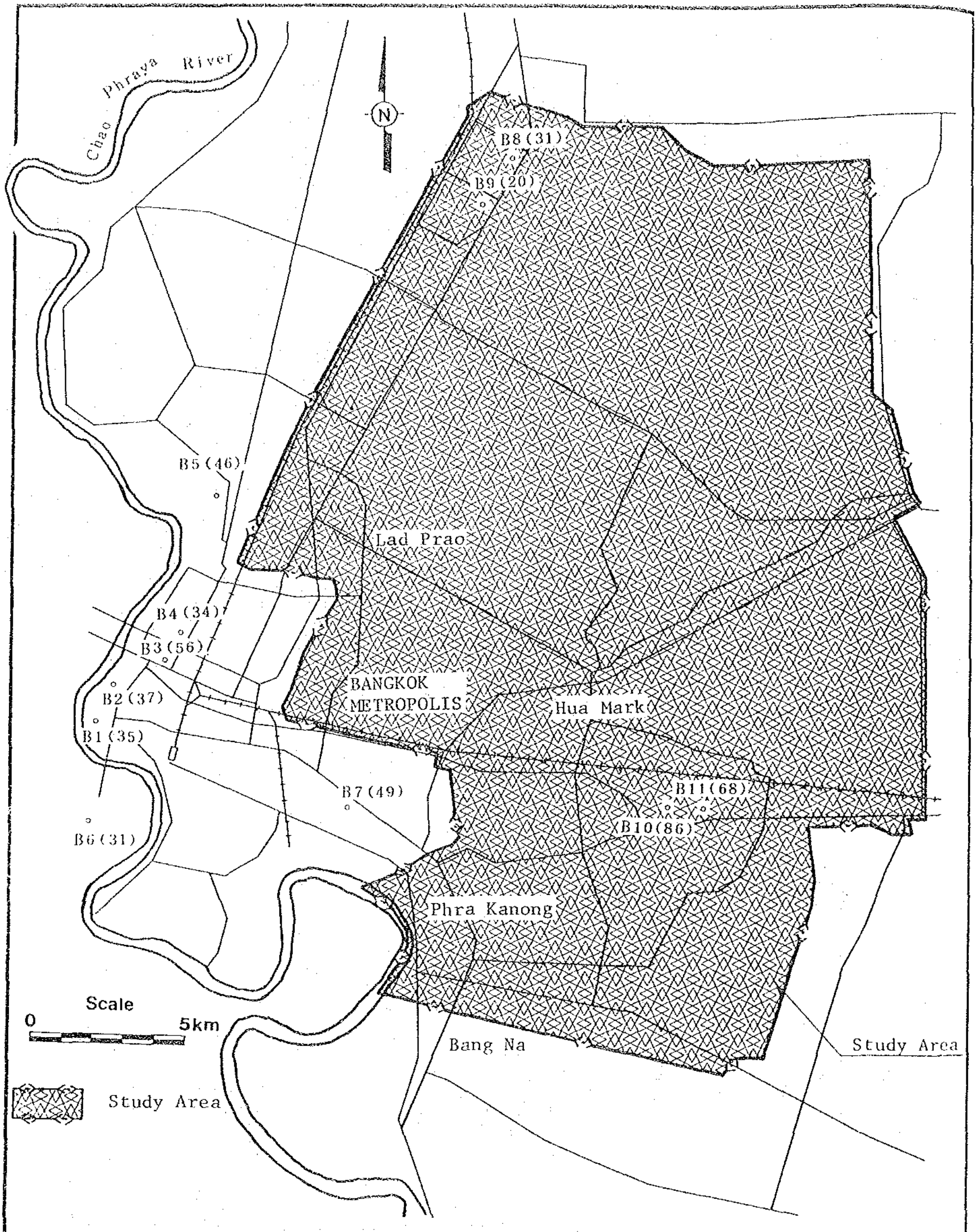
Base on this condition, the estimated land subsidence between 1983 and 2000 will be 1.0 meter in the critical area and 0.7 meter in other areas, and the expected ground elevation in the year 1990 and 2000 are shown in Figs. D.11 and D.12 respectively.

Table D.5 Supply of Water in million m^3/day (after AIT)

Year	Scheme A		B		C		D		E		F	
	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW
1980	1.2	1.6	1.2	1.6	1.2	1.6	1.2	1.6	1.2	1.6	1.2	1.6
1985	1.65	1.62	1.65	1.62	1.65	1.62	1.5	1.77	0.6	2.67	1.07	2.20
1990	2.15	1.56	1.65	2.06	1.30	2.41	0.6	3.11	0.6	3.11	0.81	2.80
1995	2.55	1.68	1.65	2.58	0.6	3.63	0.6	3.63	0.6	3.63	0.43	3.80
2000	3.00	1.74	1.65	3.09	0.6	4.14	0.6	4.14	0.6	4.14	0.0	4.74

These figures exclude about 0.4 MCMD groundwater usage for private sector.

GW - Supply from groundwater.
SW - Supply from surface water.



Note: B1 - B11 mean the Benchmark observation station.
Figures in parentheses show the total subsidence in the Bangkok Area between 1930s and Mid. 1978 in centimeter.

FIG. D.1	**Total Subsidence in the Bangkok Area between 1930s and Mid. 1978**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

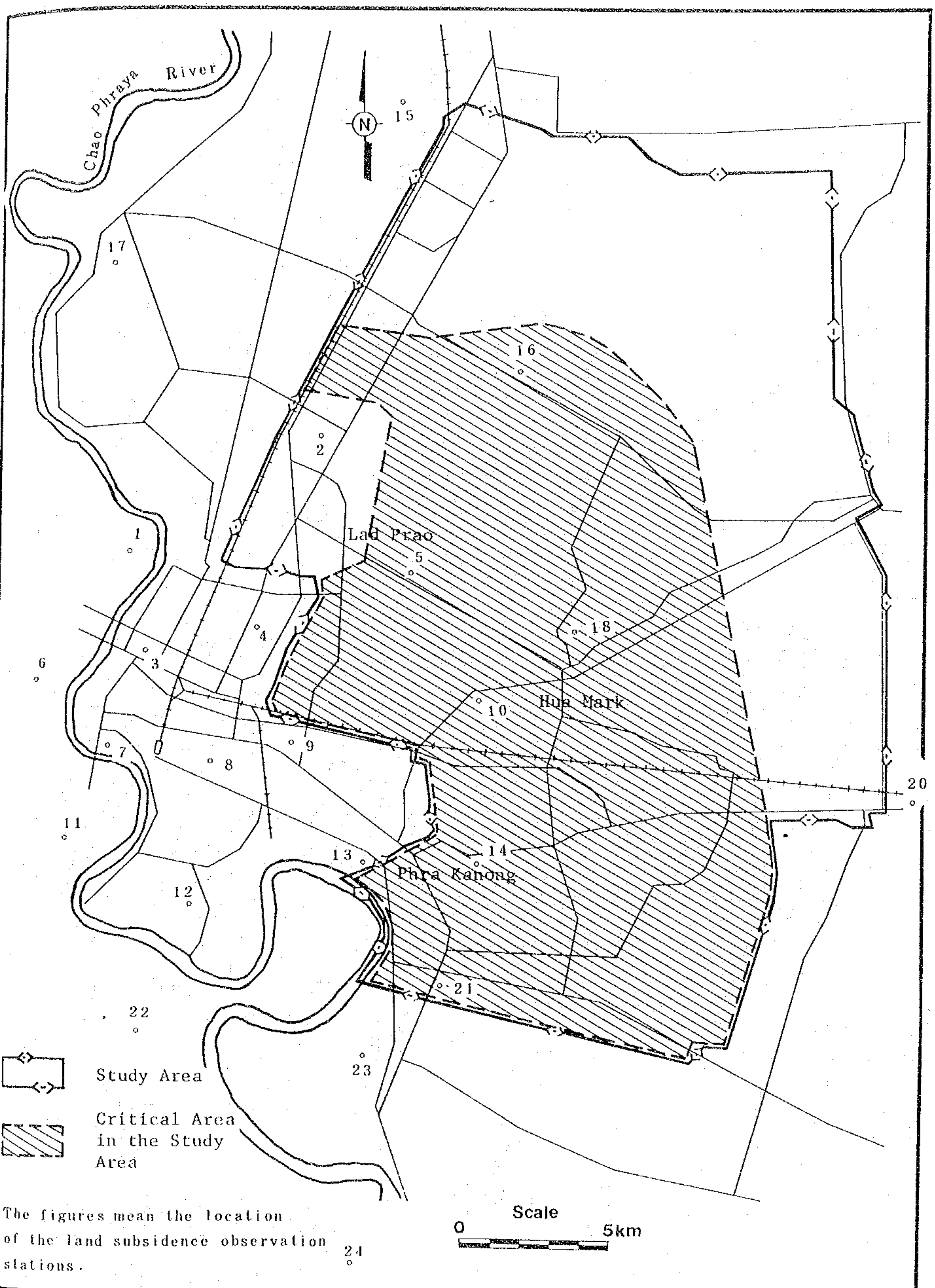


FIG. D. 2 **Locations of Subsidence Observation Station**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

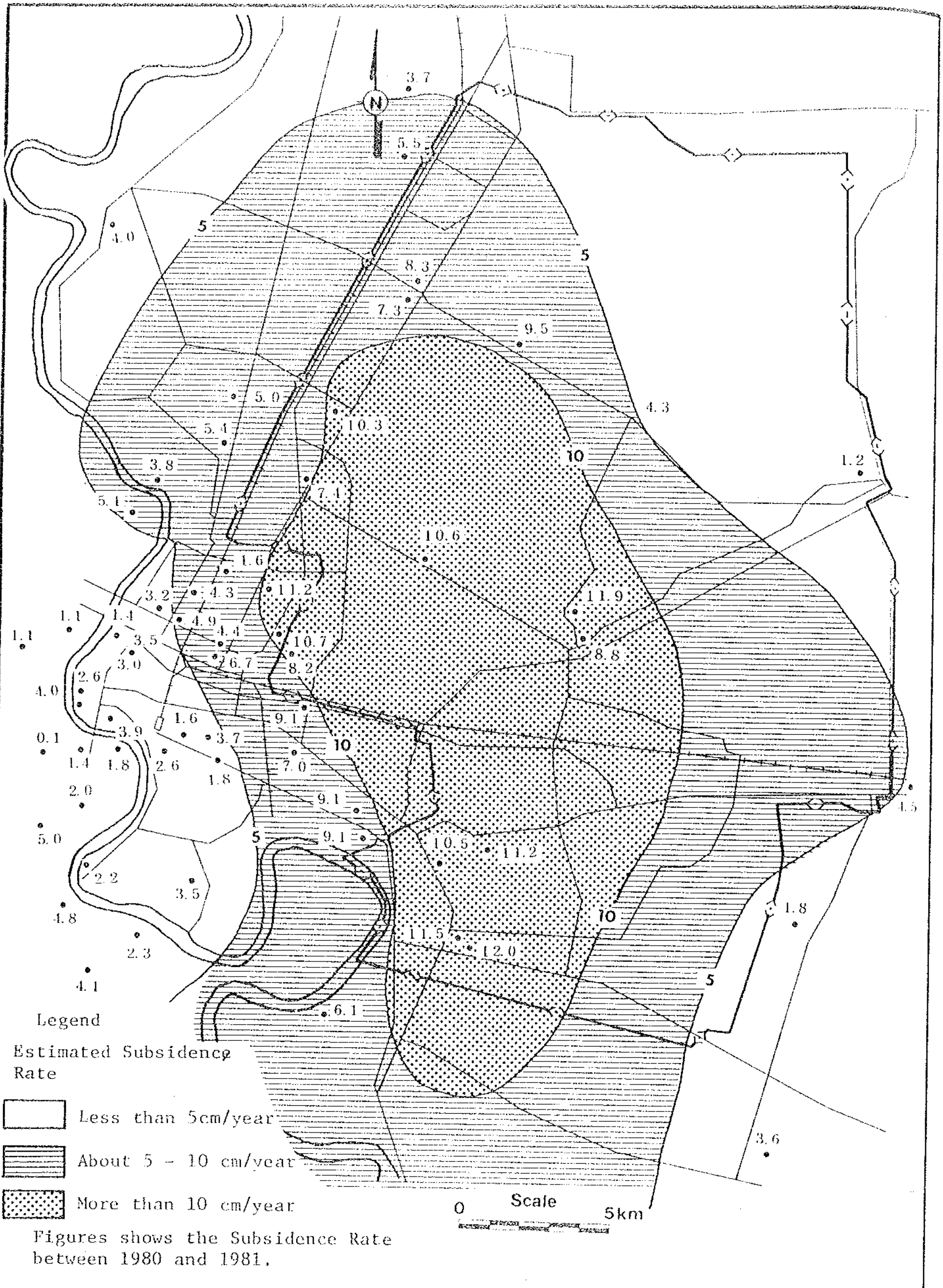
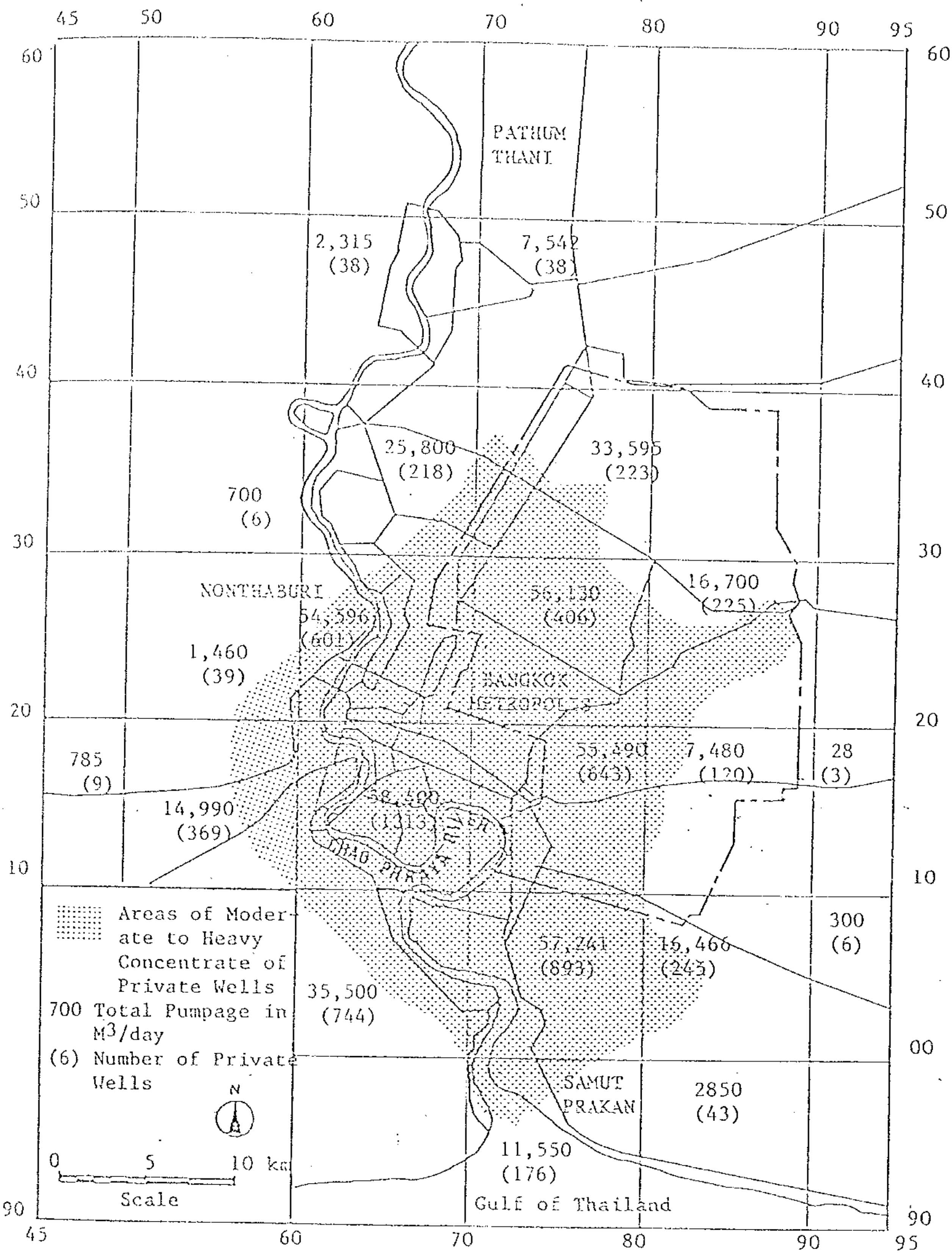


FIG. D. 3 Subsidence Rate in the Bangkok Area in 1981 (cm／year)

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



Private Pumpage Distribution.

: 431 private wells are not included in above figures. The pumpage of those wells is 18,024 M^3/day.

Source : Groundwater Resources in Bangkok Area : Development and Managment Study.

FIG. D.4	**Private Pumpage Distribution**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

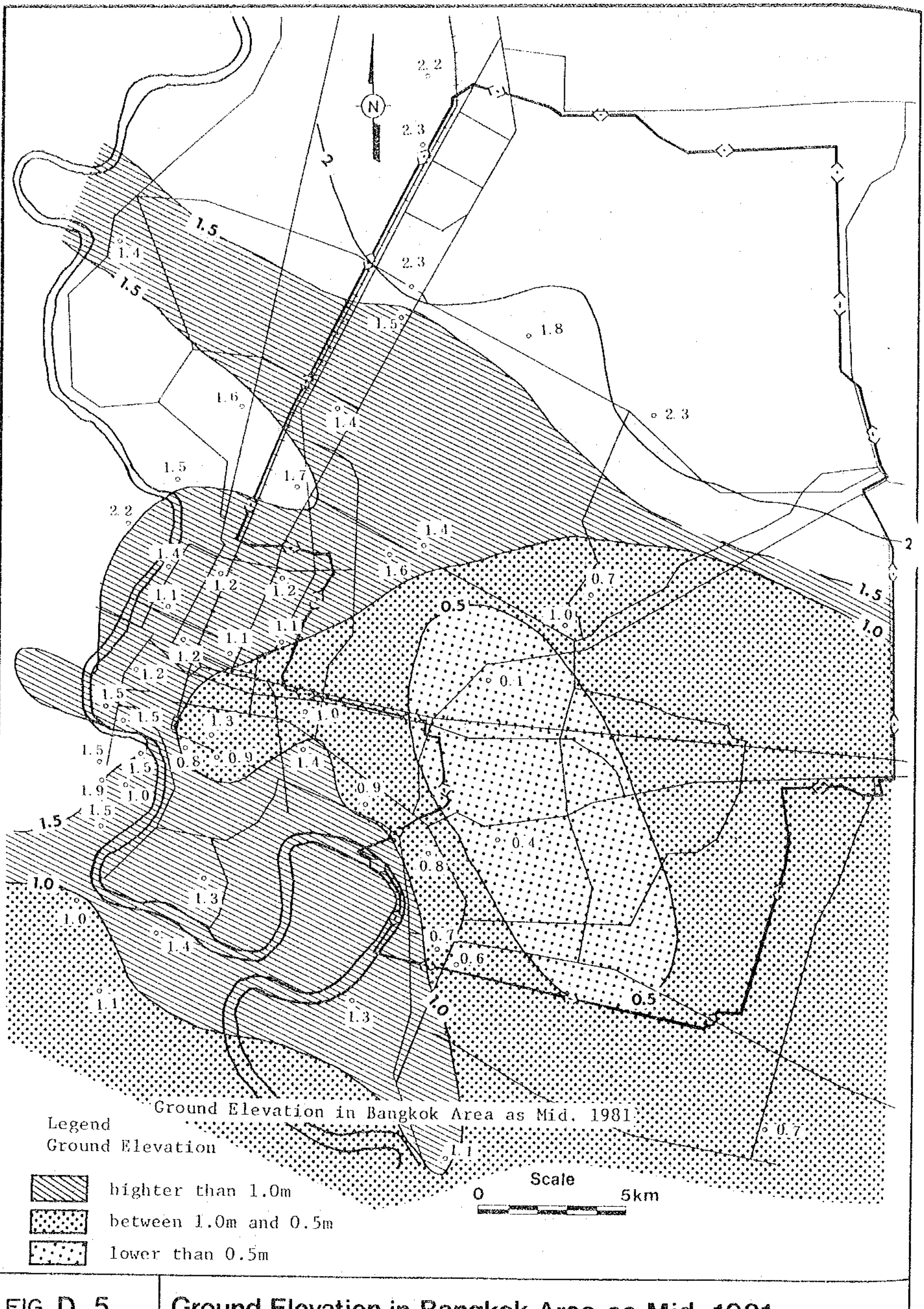
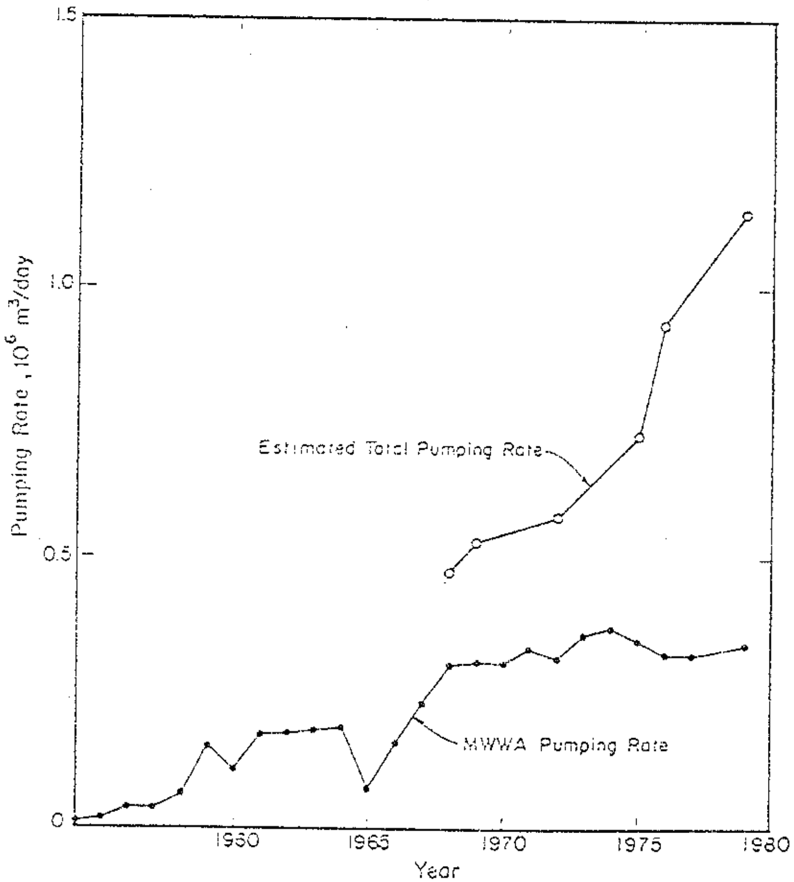
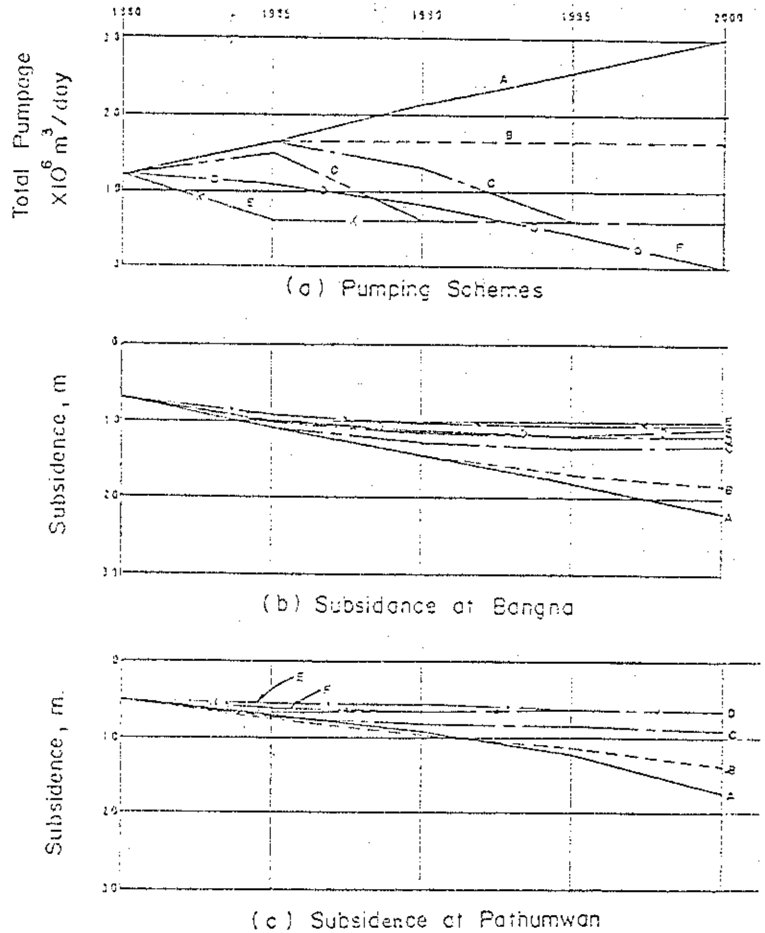


FIG. D.5	Ground Elevation in Bangkok Area as Mid. 1981

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



Rate of Groundwater Withdrawal in the Bangkok Area from 1955 to 1979



Summary of Model Predictions of Subsidence for Six Pumping Shemes (after AIT)

FIG. D.6	Rate of Groundwater withdrawal in the Bangkok Area from 1955 to 1979
FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK	

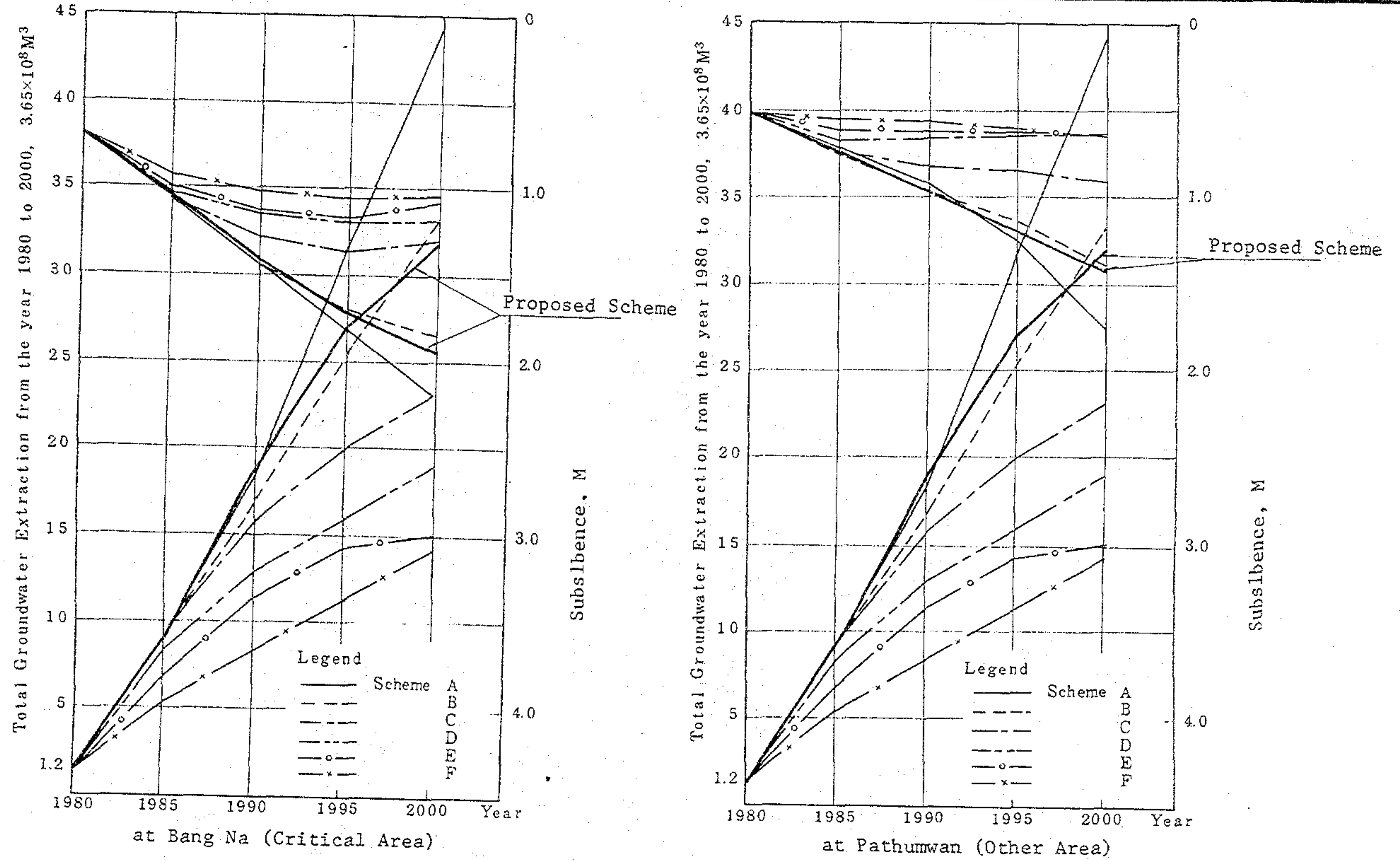
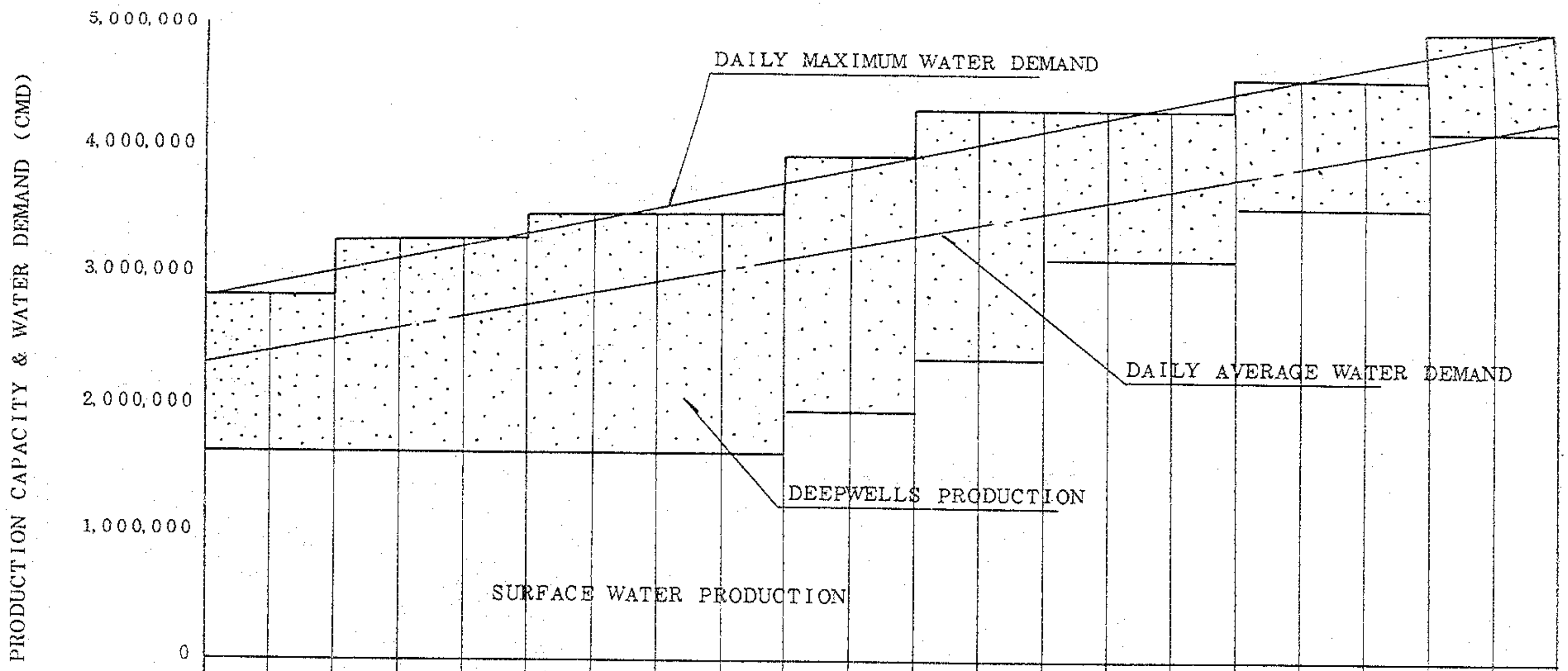


FIG. D. 7 Total Groundwater Pumpage from 1980 to 2000 and Land Subsidence for Six Schemes after ATT and Proposed Scheme by the Study Area

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
SURFACE WATER SUPPLY	1,600		1,600			1,600				1,920		2,320		3,100			3,500			4,100	
DEEPWELL	1,200		1,650			1,850				1,980		1,930		1,150			1,000			800	
TOTAL	2,800		3,250			3,450				3,900		4,250					4,500			4,900	

(×1,000 CMD)

NOTE: GROWNDWATER WITHDRAWING IN PRIVATE SECTORS 0.8 MCMD IN 1980 AND 0.4 MCMD IN 2,000 INCLUDE IN THESE FIGURES.

FIG. D.8 Water Demand and Assumed Water Supply Plan by the Study Team

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

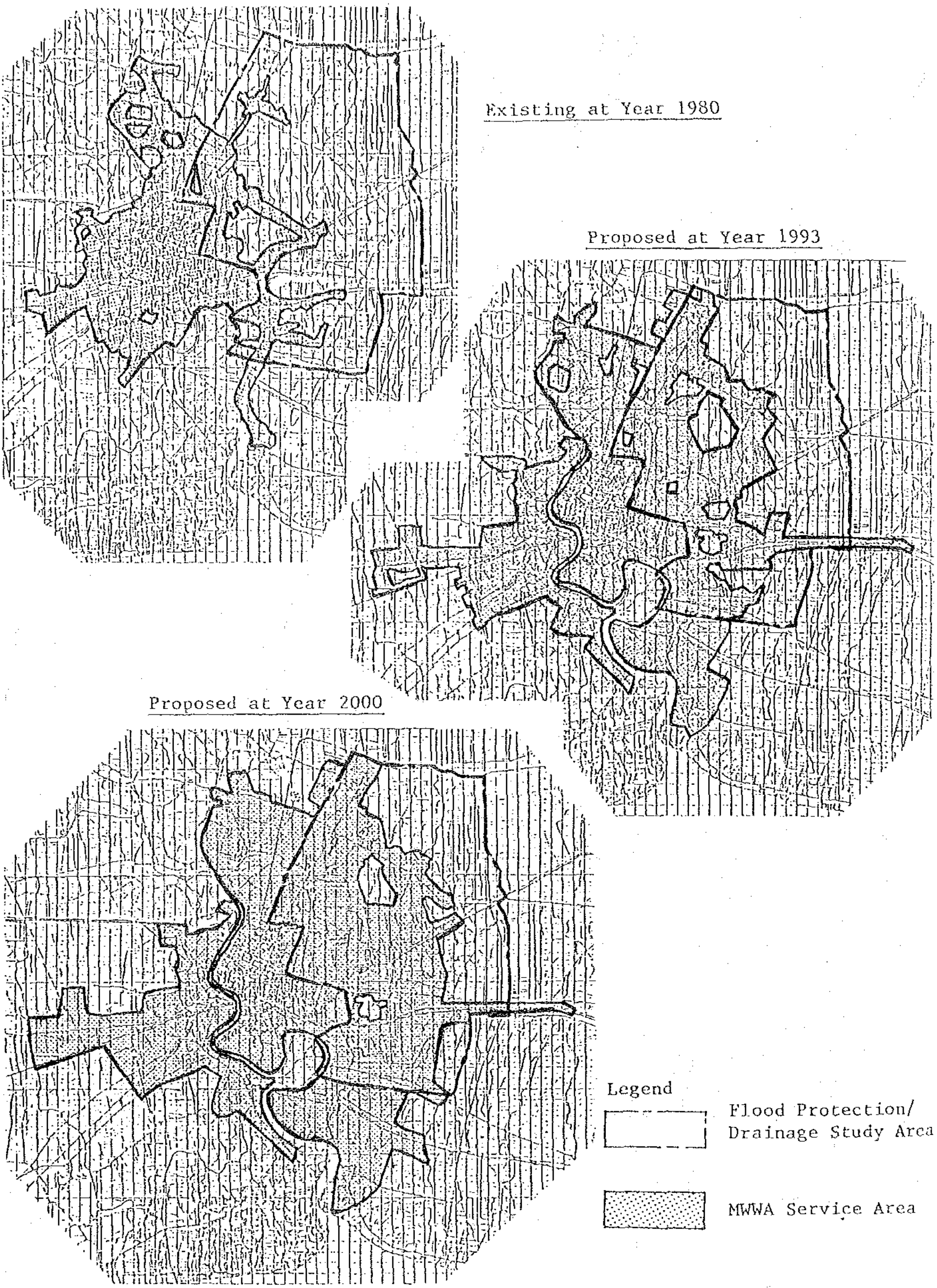


FIG. D.9 **MWWA Service Area Map, Existing and Future**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

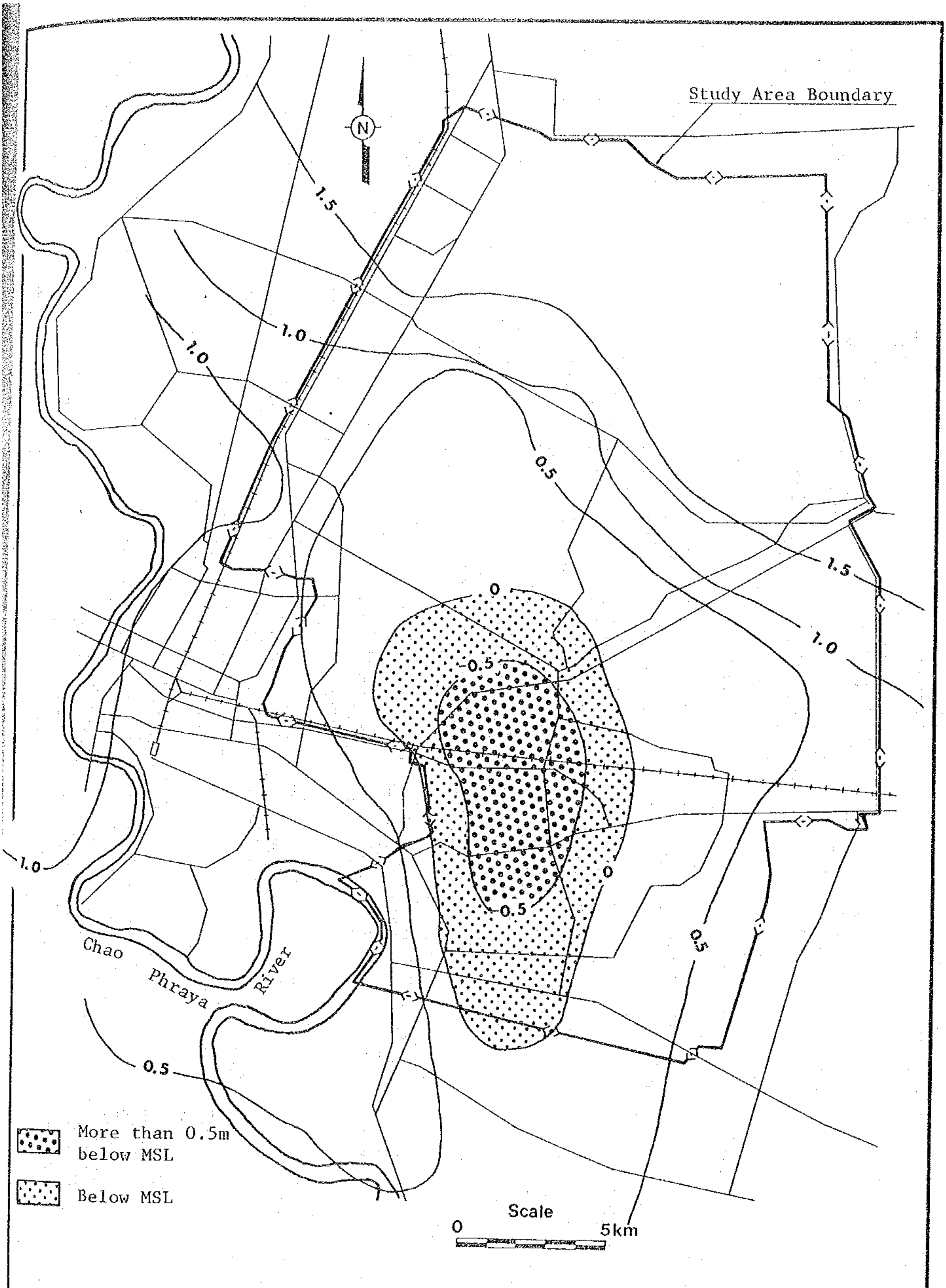


FIG. **D.10** **Expected Ground Elevation in 1990 based on the Proposed Scheme**

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

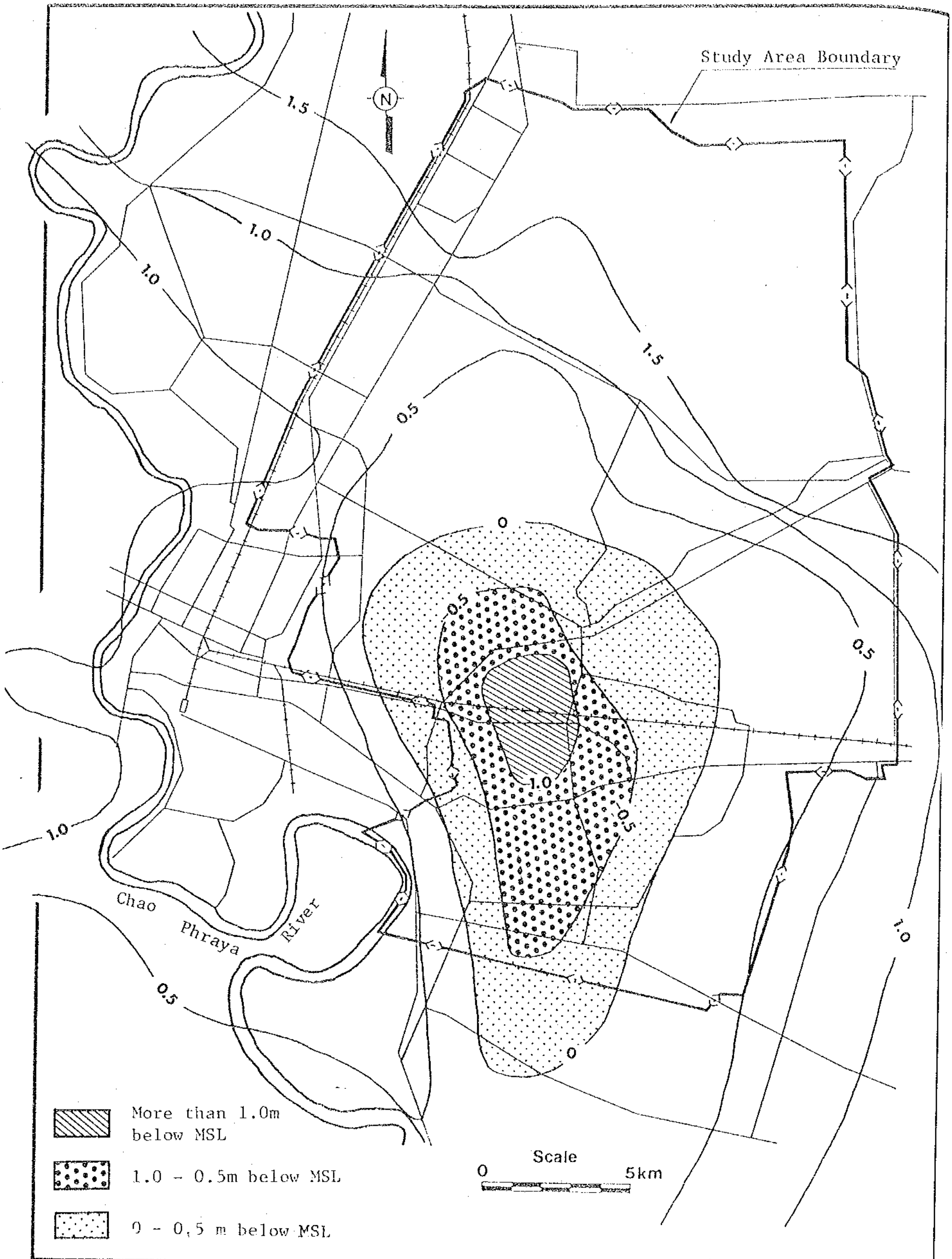


FIG. D.11 Expected Ground Elevation in 2000 based on the Proposed Scheme

FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

Appendix E

Hydrological and Hydraulic Simulation

Appendix E Hydrological and Hydraulic Simulation

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1. General

1.1 Applied Models for Hydrological and Hydraulic Simulation.

The hydrological and hydraulic models which were applied for the simulation of flood and evaluation of flood damage in the main report are as followings.

1) Two Basin Model
2) Bi-Dimensional Model
3) Polder Drainage Model (Excess Rainfall Model, Run-off Model)
   - Rainfall Excess Model
   - Sub water shed Model (Run-off Model: Quasi Storage Function Model)
   - One Basin Model (Liner Storage Basin Model: water Balance Model)

1.2 Subject Matters

In Appendix E,

1) Detailed explanation for theoretical equations of hydrological and hydraulic models which are applied to the study mentioned in Chapter 11 and Chapter 14.

2) Sample result of Two Basin Modeling including input and output data for 1983 flood.

3) Sample result of Bi-Dimensional Modeling including input and output data for 1983 flood.

4) Reference figures of schematic description for models.

5) Reference figures of the result of calculation cases.

2. Basic Explanation of Two Basin Model

2.1 Basic Equation

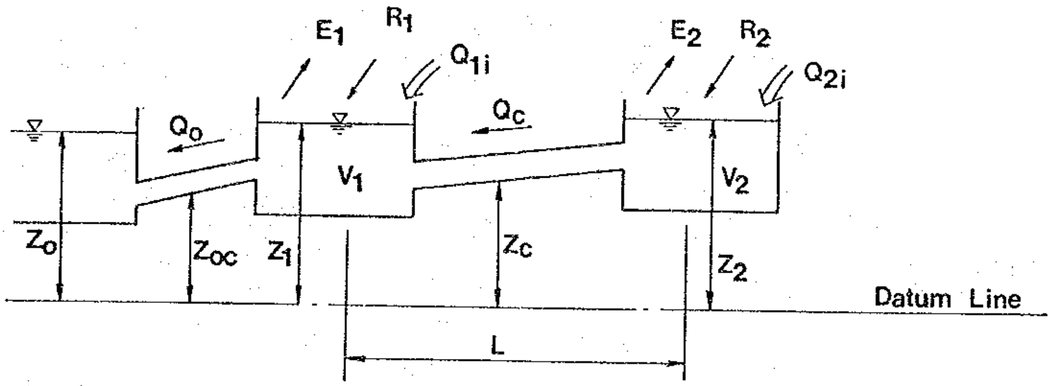
The basic equation of two-basin model is indicated by the continuity equation as follows.

$$(\Delta V_1)_t = \frac{1}{2} \cdot \int_{t-\Delta t}^{t} \left\{ (R_1 - E_1) \cdot A_1 \times 10^{-3} + (Q_c - Q_o + Q_{1i}) \right\} \cdot dt \quad \text{------} \quad (1)$$

$$(\Delta V_2)_t = \frac{1}{2} \cdot \int_{t-\Delta t}^{t} \left\{ (R_2 - E_2) \cdot A_2 \times 10^{-3} + (Q_{2i} - Q_c) \right\} \cdot dt \quad \text{-------} \quad (2)$$

$$V_{1,t} = V_{1,t-\Delta t} + \Delta V_{1,t} \quad \text{--------------------------} \quad (3)$$

$$V_{2,t} = V_{2,t-\Delta t} + \Delta V_{2,t} \quad \text{--------------------------} \quad (4)$$



where;

Zo	:	Water level in Chao Phraya River
Zoc	:	Bottom elevation of drainage facility ...(in meter above MSL)
Zc	:	Bottom elevation of connection facility..(")
Z1	:	Water level in basin one ....(")
Z2	:	Water levle in basin two ....(")
Qo	:	Outflow from basin one ....($10^6 m^3/\Delta T$)
Qc	:	Connection flow between basin one and basin two....(")
Q1c	:	Inflow into basin one ....(")
Q2i	:	Inflow into basin two ....(")

E	:	Evapotranspiration	(mm/ΔT)
R	:	Rainfall	(")
A1	:	Area of basin one	(km^2)
A2	:	Area of basin two	(")
V1	:	Storage volume of basin one	($10^6 m^3$)
V2	:	Storage volume of basin two	(")
ΔT	:	Calculation time interval	(sec)
L	:	Distance between basin one and basin two	(in meter)

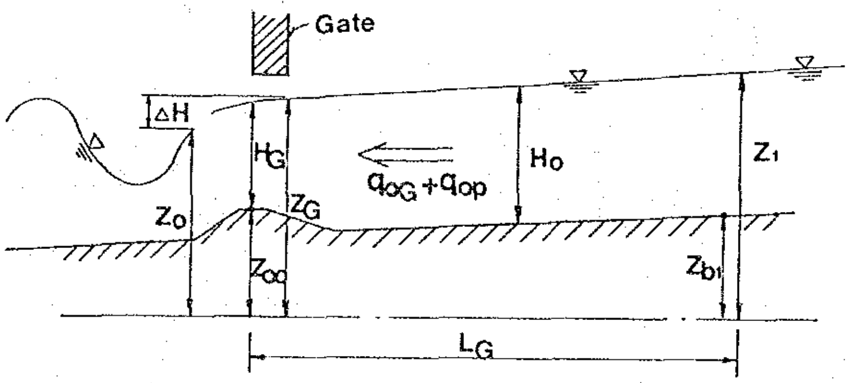
2.2 Calculation of Qo

$$Q_o = (q_{op} + q_{oG}) \cdot \Delta T \times 10^{-6}$$

q_{op}	:	Outflow from pump	(m^3/sec)
q_{oG}	:	Outflow from gate	(m^3/sec)

q_{op} is constant amount and pump is operated according to on-off level (Zep).

q_{oG} is introduced according to follow equations.



$$I^t = \left\{ \frac{(q_{op}^{t-\Delta t} + q_{oG}^{t-\Delta t}) \cdot n}{B_{goc} \cdot (H_o^{t-\Delta t})^{5/3}} \right\}^2 \quad \text{------------------- (5)}$$

$$H_o^{t-\Delta t} = \left(\frac{Z_{oc} + H_G^{t-\Delta t} + Z_1^{t-\Delta t}}{2} - \frac{Z_{oc} + Z_{b1}}{2} \right) \quad \text{------------ (6)}$$

$$H_G^t = Z_1^{t-\Delta t} - L_G \cdot I^t - Z_{oc} \quad \text{-------------------- (7)}$$

$$\Delta H^t = Z_{oc} + H_G^t - Z_o^t = Z_G^t - Z_o^t \quad \text{---------------- (8)}$$

$$q_{oG}^t = C_o B_{go} \cdot (H_G^t - \Delta H^t/3) \sqrt{2g(\Delta H^t)} \quad \text{------------- (9)}$$

I^t	:	Hydraulic gradient between Z_G and Z_1 on time of (t)
$Ho^{t-\Delta t}$	:	Water depth at middle point of L_G on time of $(t-\Delta t)$ ....(in meter)
$H_G^{t-\Delta t}$	:	Water depth at Gate on time of $(t-\Delta t)$ ....(")
Z_G^t	:	Water level of upper side of gate on time of $(t-\Delta t)$ ....(in meter above MSL)
Zb_1	:	Bottom elevation of basin one ..(")
L_G	:	Distance between gate and basin one .... (in meter)
Bgoc	:	Equalized canal width between gate and basin one .... (")
Bgo	:	Gate width .... (")
Co	:	Coefficient of gate flow

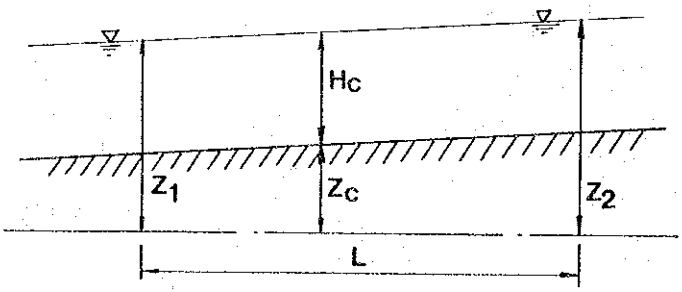
2.3 Calculation of Qc

Qc is expressed as a open channel flow shown as follows.

$$Qc = q_{cc} \cdot \Delta T \times 10^{-6}$$

$$q_{cc} = Bc \cdot H_c \cdot \frac{1}{n} \cdot H_c^{2/3} \left\{ \frac{(Z_2 - Z_1)}{L} \right\}^{1/2} \; (m^3/sec)$$

$$Hc = 1/2 (Z_1 + Z_2 - 2 \cdot Z_c)$$



where;

Bc	:	Channel width
n	:	Coefficient of roughness

2.4 Calculation of Qi

$$Q_{1i} = (C_1 + f_1 \cdot R_1) \cdot A_1 \times 10^{-3} \quad \text{-------------- (10)}$$

$$Q_{2i} = (C_2 + f_2 \cdot R_2) \cdot A_2 \times 10^{-3} \quad \text{-------------- (11)}$$

When, $Q_1i + Q_2i \doteqdot Q_2i$ and $\frac{R_1 + R_2}{2} = \bar{R}$ ($\bar{R}$ is areal average rainfall), following equation is usefull.

$$Q_i = Q_{2i} = (C + f\bar{R})(A_1 + A_2) \times 10^{-3} \quad \text{---------- (12)}$$

where;

C : constant inflow height .... mm/ΔT

f : coefficient of R

$\bar{R}$: areal average rainfall .... mm/ΔT

3. Basic Explanation of Bi-Dimensional Model

3.1 General

On the modelling for a spread of flood flow in the low flat land, Bi-Dimensional Type Model is useful one, for flood protection and drainage planning. This model can express the flood water level, storage volume submerged area and submerged depth with a time parameter. Therefore, the effect of capacity of drainage facilities and land surface storage capacity can be evaluated by the result of simulations of flood protection/drainage plans.

3.2 Basic Equations

The basic equations are introduced from unsteady flow formula, and consisted of Momentum and Continuity equations as follows.

$$\frac{dQ_x}{dt} + \frac{d}{dx}\left(\frac{Q_x^2}{A_x}\right) + gA_x\frac{dZ}{dx} + g\frac{n^2|Q_x|Q_x}{A_x(R_x)^{4/3}} = 0 \quad \text{-----} (1)$$

$$\frac{dQ_y}{dt} + \frac{d}{dy}\left(\frac{Q_y^2}{A_y}\right) + gA_y\frac{dZ}{dy} + g\frac{n^2|Q_y|Q_y}{A_y(R_y)^{4/3}} = 0 \quad \text{-----} (2)$$

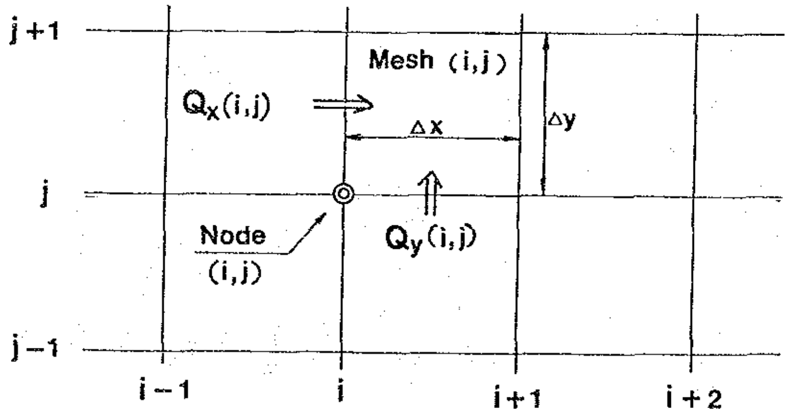
$$\frac{dZ}{dt} + \frac{dQ_x}{dx} + \frac{dQ_y}{dy} = R - E \quad \text{-----------------} (3)$$

where;

t	:	Time
X,Y	:	Direction of coordination
Qx,Qy	:	Flow of X and Y Direction
Ax,Ay	:	Sectional flow area of X and Y Direction
Z	:	Water level
g	:	Gravity acceleration
Rx,Ry	:	Hydraulic radius of X and Y Direction
R	:	Rainfall
E	:	Evapotranspiration

3.3 Mesh Components for Bi-Dimensional Model

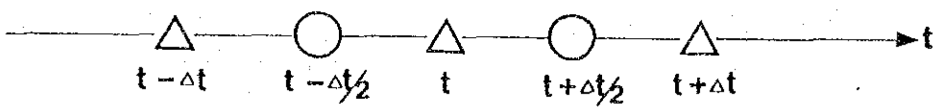
For the analysis, the study area shall be divided by meshes and each mesh size is divided under the conditions of topography, land use pattern, road and railway network, Klong network, and past flooded area. Each mesh can be identified with mesh node number (i,j) and this node has the definition value of water level(Z), water depth (D), storage volume (Vol), and water surface area (S). The section of ΔX, and ΔY have the definition value of discharge (Qx, Qy), velocity (Ux, Uy), section flow area (Ax, Ay) and coefficient of roughness.



3.4 Solution of Basic Equation

For the solution of the basic equation, the explicit difference scheme method was applied.

The concept of this scheme is shown in following figure.



where;

Δ : Calculation point of flow

O : Calculation point of water level

Δt : Calculation time interval

Based on the difference scheme mentioned above, the momentume equation (1) can be changed to following equation (4).

$$Q_{x\,ij}^{t+\Delta t/2} = Q_{x\,ij}^{t-\Delta t/2} - \Delta t \frac{d}{dx}\left(\frac{Q_x^2}{A_{x\,ij}}\right) - \Delta t g A_{x\,ij} \frac{2(Z_{ij} - Z_{i-1\,j})}{\Delta X_{ij} + \Delta X_{i-1\,j}}$$

$$- \Delta t g n^2 \frac{\left|U_{x\,ij}^{t-\Delta t/2}\right| Q_{x\,ij}^{t-\Delta t/2}}{(H_{x\,ij}^{t-\Delta t/2})^{4/3}} \quad \text{-----------------} \quad (4)$$

where;

$$U_{x\,ij} = \frac{Q_{x\,ij}}{A_{x\,ij}}$$

$$H_{x\,ij} \doteqdot R_{x\,ij}$$

Similarly, the continuity equation (3) can be changed to following equation (5).

$$Z_{ij}^{t+\Delta t} = Z_{ij}^{t} + \frac{\Delta t}{B_{ij}^{t}}\left(Q_{x\,i+1,j} - Q_{x\,i,j} + Q_{y\,i,j+1} - Q_{y\,i,j} + R - E\right) \quad \text{----} \quad (5)$$

In the equation (5), B_{ij}^{t} is the water surface area which is calculate from input data of the relationship of water level (Z) and surface area (B).

3.5 Numerical Stability

On the solution of basic equation by explicit difference scheme, the numerical stability shall be kept under the following condition.

$$\Delta t < \frac{\Delta S}{\sqrt{2gh} + U_{max}}$$

where;

Δt	:	Calculation time interval
Δs	:	Length of ΔX or ΔY
g	:	gravity acceleration
h	:	Water depth
Umax	:	Maximum Velocity

4. Data for Calibration Study of Two Basin and Bi-Dimensional Model

4.1 Basic Data

Table E.1 shows the basic data for calibration study of models.

Data \ Model	Two Basin Model	Bi-Dimensional Model
Rainfall	observed average areal daily rainfall in 1983	
Evapotrans-piration	Mean monthly evapotranspiration (1956 - 1974) source : AIT	
Topography	Existing condition shown in Fig. 2.3 was used for estimation of the relationship between flood water level and storage volume.	
Water Levels in the Chao Phraya River	Observed data at Bangkok Harbour in 1983	observed data at Bangkok Harbour and Bang Khen in 1980
Calculation Period	Aug. to Oct. in 1983	
Capacities of Gate and Pumps	Data from R.I.D and D.D.S were utilized	
Operation Conditions of Gate and Pumps	Data of operation records by R.I.D and D.D.S were utilized	

Table E.1 Basic Data for Calibration Study

4.2 Inflow amount from the outer area

Observed inflow amount shown in Fig. 4.11, and Fig. 4.12 were basic amount for estimation of inflow amount. In the calibration study, inflow amount (Qi) was estimated as function of rainfall (R) and constant coefficient (C).

$$Qi = (C + fR)\ A$$

Where ; C : Constant coefficient (mm/ day)
R : Rainfall height in study area (mm/day)
f : Coefficient of rainfall
A : Size of Study Area (km^2)

4.3 Data of Klongs and Coefficient of roughness (n)

Data of klongs such as flow sectional area, bottom elevations and length were based on the data surveyed by the Study Team.

Data of small klongs which have not been surveyed were presumed according to the topographic map.

Every sectional shapes for calibration were changed to rectangular shape keeping equalized flow area.

Coefficient of roughness (n) of parameter of klong and ground surface of flood plain, were used Manning's coefficient.

4.4 Adopted Coefficient of (Qi) and (n)

Calibrated water levels and discharge were calibrated comparing observed and recorded water levels and discharge.

Table E2 shows the adopted coefficient of (Qi) and (n) for final calibration.

Qi					n	
	Aug.	Sept.	Oct.	Nov.	Klong	Flood Plain
C(mm/day)	6.0	7.8	9.9	8.9	0.035	0.15 - 0.50
f	0.1	0.1	0.1	0.1		

Table E.2. Coefficient of (Qi) and (n)

5. Sample Result of Two Basin Modeling

This section presents the result of calibration study for the flood in the year of 1983 using two basin model.

The figures of this result are shown in Chapter 12 of main Report.

5.1 Input Data

(1) Basic Data

[[INPUT DATA]]

CASE Two B (001)

Aug. - Sep.

Time Step	(sec)	dT	=	7200
Area 1	(Km^2)	A1	=	278.8
Area 2	(Km^2)	A2	=	326.5
Distance	1 TO 2	L	=	10000

Aug.	C = 6.0	F = 0.1	Oct.	C = 9.9	F = 0.1
Sep.	C = 7.8	F = 0.1	Nov.	C = 8.9	F = 0.1

====== CHANNEL ======

Channel Width (1 to 2)	Bc (m)	=	70
Botton Elev of Channel (1)	Zc (m)	=	-2.5
Channel Width (0 to 1)	Bco (m)	=	70
Manning Roughness C	n	=	.035
Botton Elev of Basin (1)	Zb1	=	-2.5

====== OUT SIDE =======

Gate Width	Bgo (m)	=	30
Botton Elev of Gate	Zoc (m)	=	-2.5
	Co	=	.5
	Lg (m)	=	7000
	ng	=	.035
	Hg(T=1)	=	3.25

Pump Capacity Qp (m^3/sec)

Aug.	Qp	=	11.5
Sep.	Qp	=	16
	Zo1 (m)	=	.5

(2) Water Level - Storage Volume Data

Basin One : Protection Area

N	Z1(m)	V1(m^3 E6)
1	-2.5000E+00	0.0000E+00
2	-2.0000E+00	6.4500E-01
3	-1.5000E+00	1.4060E+00
4	3.0000E-01	6.1080E+00
5	3.5000E-01	6.2200E+00
6	4.0000E-01	6.3320E+00
7	4.5000E-01	7.2820E+00
8	5.0000E-01	8.2340E+00
9	5.5000E-01	9.9540E+00
10	6.0000E-01	1.1670E+01
11	6.5000E-01	1.4627E+01
12	7.0000E-01	1.8008E+01
13	7.5000E-01	2.2733E+01
14	8.0000E-01	2.7446E+01
15	8.5000E-01	3.3251E+01
16	9.0000E-01	3.9525E+01
17	1.0000E+00	5.0682E+01
18	1.0500E+00	5.7030E+01
19	1.2000E+00	7.8255E+01
20	1.2500E+00	8.6520E+01
21	1.5000E+00	1.2972E+02
22	1.5500E+00	1.3517E+02
23	2.0000E+00	2.3951E+02

Basin Two : Retention Area

N	Z2(m)	V2(m^3 E6)
1	-2.5000E+00	0.0000E+00
2	-2.0000E+00	0.0000E+00
3	-1.5000E+00	4.9300E-01
4	3.0000E-01	2.3300E+00
5	3.5000E-01	2.8690E+00
6	4.0000E-01	3.4090E+00
7	4.5000E-01	5.6460E+00
8	5.0000E-01	8.0570E+00
9	5.5000E-01	1.0587E+01
10	6.0000E-01	1.1117E+01
11	6.5000E-01	1.5828E+01
12	7.0000E-01	1.8170E+01
13	7.5000E-01	3.3561E+01
14	8.0000E-01	4.8957E+01
15	8.5000E-01	6.4462E+01
16	9.0000E-01	7.9154E+01
17	1.0000E+00	1.1071E+02
18	1.0500E+00	1.3015E+02
19	1.2000E+00	1.7906E+02
20	1.2500E+00	2.1386E+02
21	1.5000E+00	2.8200E+02
22	1.5500E+00	2.7666E+02
23	2.0000E+00	4.6443E+02

(3) Rainfall and Evapotranspiration Data

Day	R1(mm/dT)	R2(mm/dT)	E1(mm/dT)	E2(mm/dT)
Aug. 1 1	1.0500E+01	1.0500E+01	3.4200E+00	3.4200E+00
2	6.0000E-01	6.0000E-01	3.4200E+00	3.4200E+00
3	2.9000E+00	2.9000E+00	3.4200E+00	3.4200E+00
4	5.0800E+01	5.0800E+01	3.4200E+00	3.4200E+00
5	2.6000E+00	2.6000E+00	3.4200E+00	3.4200E+00
6	1.6700E+01	1.6700E+01	3.4200E+00	3.4200E+00
7	3.7500E+01	3.7500E+01	3.4200E+00	3.4200E+00
8	3.8500E+01	3.8500E+01	3.4200E+00	3.4200E+00
9	4.0000E-01	4.0000E-01	3.4200E+00	3.4200E+00
10	2.6000E+00	2.6000E+00	3.4200E+00	3.4200E+00
11	1.9000E+00	1.9000E+00	3.4200E+00	3.4200E+00
12	4.3200E+01	4.3200E+01	3.4200E+00	3.4200E+00
13	1.5500E+01	1.5500E+01	3.4200E+00	3.4200E+00
14	1.0000E+00	1.0000E+00	3.4200E+00	3.4200E+00
15	8.9000E+00	8.9000E+00	3.4200E+00	3.4200E+00
16	6.9000E+00	6.9000E+00	3.4200E+00	3.4200E+00
17	0.0000E+00	0.0000E+00	3.4200E+00	3.4200E+00
18	6.3000E+00	6.3000E+00	3.4200E+00	3.4200E+00
19	3.2400E+01	3.2400E+01	3.4200E+00	3.4200E+00
20	1.2300E+01	1.2300E+01	3.4200E+00	3.4200E+00
21	1.6000E+00	1.6000E+00	3.4200E+00	3.4200E+00
22	1.3600E+01	1.3600E+01	3.4200E+00	3.4200E+00
23	6.3000E+00	6.3000E+00	3.4200E+00	3.4200E+00
24	3.9000E+00	3.9000E+00	3.4200E+00	3.4200E+00
25	1.4800E+01	1.4800E+01	3.4200E+00	3.4200E+00
26	1.0000E+01	1.0000E+01	3.4200E+00	3.4200E+00
27	1.4500E+01	1.4500E+01	3.4200E+00	3.4200E+00
28	3.9000E+00	3.9000E+00	3.4200E+00	3.4200E+00
29	0.0000E+00	0.0000E+00	3.4200E+00	3.4200E+00
30	3.8700E+01	3.8700E+01	3.4200E+00	3.4200E+00
31	6.3400E+01	6.3400E+01	3.4200E+00	3.4200E+00
Sept.1 32	1.1500E+01	1.1500E+01	3.2700E+00	3.2700E+00
33	9.0000E+00	9.0000E+00	3.2700E+00	3.2700E+00
34	9.8000E+00	9.8000E+00	3.2700E+00	3.2700E+00
35	2.5000E+00	2.5000E+00	3.2700E+00	3.2700E+00
36	3.6000E+00	3.6000E+00	3.2700E+00	3.2700E+00
37	4.0000E-01	4.0000E-01	3.2700E+00	3.2700E+00
38	5.3300E+01	5.3300E+01	3.2700E+00	3.2700E+00
39	2.7400E+01	2.7400E+01	3.2700E+00	3.2700E+00
40	6.0000E-01	6.0000E-01	3.2700E+00	3.2700E+00
41	8.0000E-01	8.0000E-01	3.2700E+00	3.2700E+00
42	2.9000E+00	2.9000E+00	3.2700E+00	3.2700E+00
43	6.4000E+00	6.4000E+00	3.2700E+00	3.2700E+00
44	7.8000E+00	7.8000E+00	3.2700E+00	3.2700E+00
45	1.5100E+01	1.5100E+01	3.2700E+00	3.2700E+00
46	1.5100E+01	1.5100E+01	3.2700E+00	3.2700E+00
47	9.4000E+00	9.4000E+00	3.2700E+00	3.2700E+00
48	6.1000E+00	6.1000E+00	3.2700E+00	3.2700E+00
49	6.3000E+00	6.3000E+00	3.2700E+00	3.2700E+00
50	6.9000E+00	6.9000E+00	3.2700E+00	3.2700E+00
51	1.7000E+00	1.7000E+00	3.2700E+00	3.2700E+00
52	1.8000E+01	1.8000E+01	3.2700E+00	3.2700E+00
53	1.8000E+01	1.8000E+01	3.2700E+00	3.2700E+00
54	1.5700E+01	1.5700E+01	3.2700E+00	3.2700E+00
55	4.8000E+00	4.8000E+00	3.2700E+00	3.2700E+00
56	2.0100E+01	2.0100E+01	3.2700E+00	3.2700E+00
57	2.0600E+01	2.0600E+01	3.2700E+00	3.2700E+00
58	3.3500E+01	3.3500E+01	3.2700E+00	3.2700E+00
59	5.1000E+00	5.1000E+00	3.2700E+00	3.2700E+00
60	2.4200E+01	2.4200E+01	3.2700E+00	3.2700E+00
61	3.6000E+00	3.6000E+00	3.2700E+00	3.2700E+00

(4) Water level of Chao Phraya River (Zo data)

Station : Bangkok Harbour
Observed year : 1983

Unit : in meter above MSL

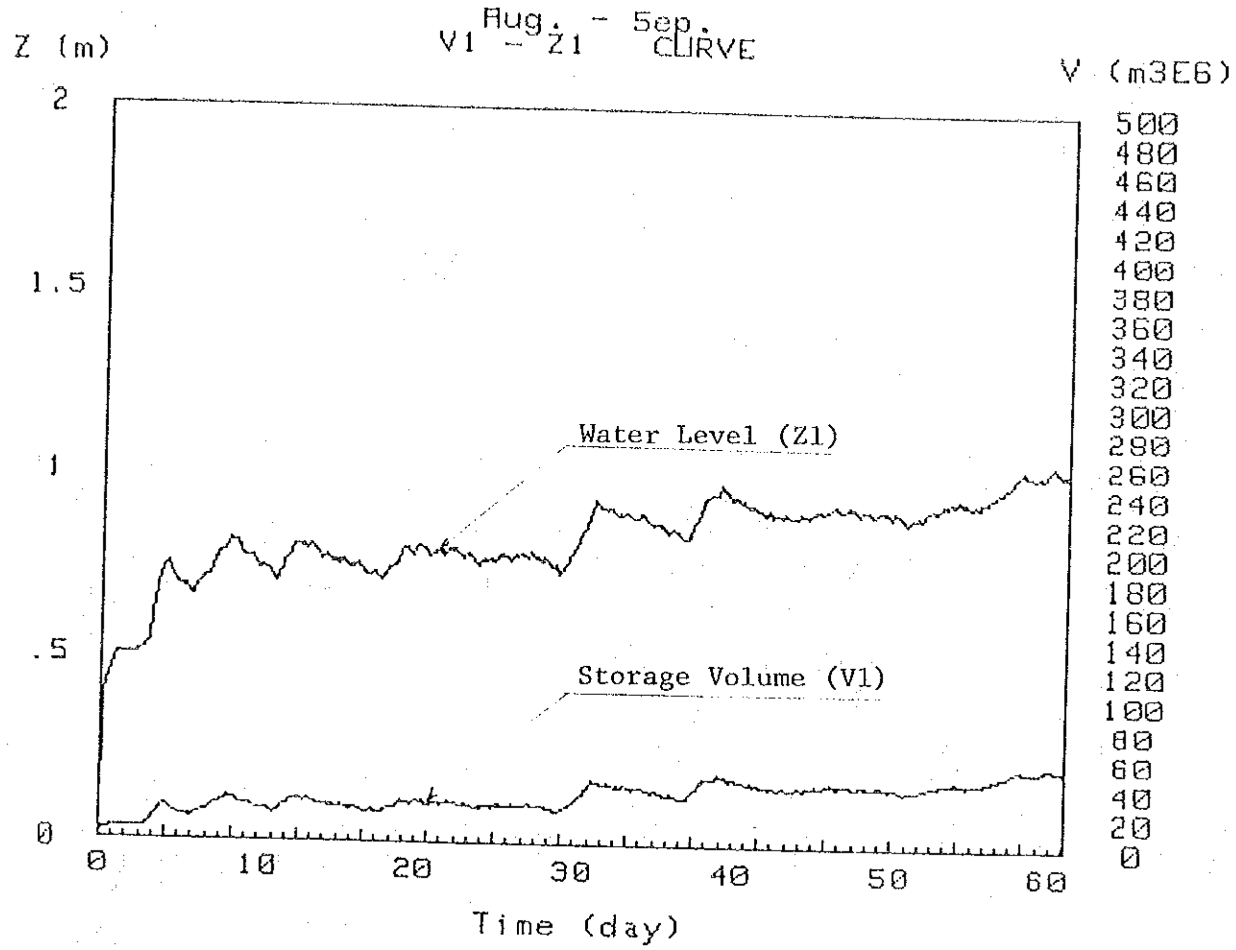
	days \ hour	0	2	4	6	8	10	12	14	16	18	20	22
Aug. 1	1	0.75	-.08	-.49	-.39	0.17	0.45	0.16	-.37	-.73	-.39	0.56	1.07
	2	1.07	0.27	-.25	-.64	-.48	0.03	0.08	-.19	-.48	-.30	0.36	0.89
	3	0.91	0.34	-.24	-.72	-.77	-.11	0.25	0.31	0.04	0.08	0.40	0.71
	4	0.86	0.45	-.19	-.77	-1.04	-.69	0.07	0.36	0.43	0.28	0.46	0.71
	5	0.75	0.38	-.24	-.77	-1.09	-1.19	-.49	0.23	0.49	0.56	0.42	0.47
	6	0.55	0.43	-.07	-.69	-1.12	-1.36	-.99	0.06	0.86	1.09	1.02	0.76
	7	0.61	0.35	0.25	-.29	-.82	-1.13	-1.27	-.47	0.68	1.26	1.38	1.09
	8	0.59	0.59	0.60	0.16	-.46	-.89	-1.17	-1.16	0.37	1.17	1.43	1.17
	9	0.69	0.58	0.69	0.55	-.11	-.64	-1.01	-1.20	-.25	1.01	1.39	1.28
	10	0.71	0.49	0.66	0.75	0.29	-.43	-.86	-1.12	-1.05	0.74	1.23	1.25
	11	0.61	0.27	0.24	0.63	0.55	-.14	-.74	-1.07	-1.25	0.09	1.14	1.26
	12	0.61	0.03	-.22	0.45	0.79	0.34	-.43	-.93	-1.16	-.13	1.16	1.27
	13	0.67	-.08	-.36	0.01	0.77	0.66	-.04	-.66	-.94	-.21	1.06	1.28
	14	0.75	-.02	-.45	-.43	0.48	0.73	0.19	-.43	-.73	-.22	0.79	1.01
	15	0.65	-.01	-.57	-.74	-.14	0.46	0.32	-.06	-.43	-.13	0.58	1.01
	16	0.75	0.15	-.42	-.68	-.44	0.30	0.51	0.35	0.11	0.13	0.48	0.85
	17	0.77	0.31	-.34	-.72	-.85	-.34	0.38	0.53	0.53	0.46	0.48	0.72
	18	0.78	0.41	-.13	-.63	-.79	-.57	0.11	0.57	0.82	0.84	0.77	0.72
	19	0.61	0.35	-.12	-.52	-.81	-.84	-.42	0.36	0.72	0.95	0.86	0.73
	20	0.49	0.33	0.05	-.30	-.67	-.82	-.73	0.16	0.84	1.23	1.11	0.84
	21	0.56	0.45	0.44	0.16	-.32	-.65	-.83	-.34	0.69	1.16	1.21	0.80
	22	0.45	0.34	0.41	0.34	-.15	-.59	-.86	-.69	0.46	1.06	1.26	0.86
	23	0.35	0.21	0.31	0.47	0.04	-.51	-.86	-.94	0.14	0.95	1.24	0.96
	24	0.24	0.15	0.35	0.55	0.17	-.43	-.85	-1.07	-.22	0.87	1.26	1.11
	25	0.36	0.18	0.27	0.65	0.47	-.18	-.68	-.95	-.36	0.81	1.14	0.95
	26	0.17	-.17	0.01	0.53	0.58	0.05	-.55	-.95	-.79	0.47	1.08	0.96
	27	0.23	-.23	-.22	0.36	0.61	0.21	-.43	-.88	-.89	0.14	0.95	0.95
	28	0.21	-.34	-.49	0.20	0.66	0.41	-.23	0.74	0.89	-.06	0.83	0.95
	29	0.20	-.36	-.64	-.28	0.47	0.52	0.04	-.55	-.77	-.09	0.72	0.86
	30	0.25	-.39	-.82	-.79	0.06	0.41	0.18	-.33	-.58	-.15	0.63	0.87
	31	0.31	-.29	-.82	-.96	-.13	0.43	0.52	0.41	0.34	0.37	0.63	0.79
Sept.1	32	0.49	-.02	-.49	-.73	-.41	0.32	0.60	0.29	0.07	0.28	0.78	0.96
	33	0.59	0.04	-.58	-.86	-.85	-.25	0.34	0.63	0.63	0.66	0.72	0.77
	34	0.75	0.15	-.33	-.72	-.94	-.77	0.01	0.64	0.98	1.05	0.96	0.61
	35	0.53	0.25	-.15	-.59	-.91	-1.09	-.73	0.19	0.80	1.04	0.83	0.61
	36	0.45	0.38	0.12	-.33	-.79	-1.09	-1.17	-.22	0.75	1.17	1.15	0.75
	37	0.46	0.49	0.56	0.18	-.52	-.96	-1.22	-.86	0.48	1.08	1.20	0.76
	38	0.28	0.27	0.57	0.55	-.04	-.72	-1.06	-1.21	0.16	1.11	1.37	0.93
	39	0.08	0.08	0.57	0.90	0.47	-.25	-.74	-.97	-.22	1.06	1.35	0.96
	40	0.11	-.21	0.11	0.81	0.86	0.16	-.54	-.86	-.52	0.95	1.32	1.09
	41	0.15	-.19	-.09	0.86	1.11	0.64	-.13	-.56	-.59	0.74	1.25	1.09
	42	0.16	-.39	-.62	0.06	0.87	0.76	0.11	-.44	-.55	0.38	1.21	1.05
	43	0.21	-.39	-.72	-.43	0.71	0.94	0.49	-.13	-.33	0.34	1.06	1.01
	44	0.24	-.39	-.74	-.77	0.26	0.79	0.74	0.35	0.13	0.39	0.88	0.97
	45	0.33	-.35	-.74	-.88	-.19	0.61	0.74	0.57	0.36	0.33	0.62	0.68
	46	0.45	-.15	-.65	-.86	-.66	0.11	0.67	0.85	0.71	0.68	0.74	0.78
	47	0.46	0.00	-.44	-.69	-.71	-.25	0.35	0.67	0.79	0.71	0.63	0.52
	48	0.31	0.05	-.32	-.59	-.71	-.55	0.02	0.61	0.94	0.95	0.75	0.54
	49	0.35	0.33	0.09	-.26	-.53	-.64	-.34	0.41	0.91	1.05	0.91	0.55
	50	0.28	0.27	0.09	-.14	-.44	-.71	-.77	-.09	0.81	1.14	1.01	0.52
	51	0.21	0.16	0.40	0.34	-.13	-.50	-.71	-.25	0.81	1.15	1.08	0.51
	52	0.11	0.05	0.37	0.49	0.06	-.38	-.71	-.67	0.45	1.05	1.09	0.64
	53	0.15	-.04	0.28	0.56	0.26	-.23	-.61	-.66	0.35	1.08	1.14	0.56
	54	-.04	-.22	0.28	0.79	0.62	-.02	-.51	-.74	0.01	0.88	0.98	0.47
	55	-.08	-.37	-.09	0.63	0.61	0.09	-.38	-.63	-.23	0.81	1.06	0.64
	56	-.09	-.45	-.39	0.57	0.87	0.61	-.01	-.42	-.19	0.77	1.10	0.64
	57	-.11	-.52	-.64	0.31	0.96	0.80	0.23	-.28	-.29	0.51	0.92	0.65
	58	-.06	-.52	-.75	-.25	0.74	0.89	0.51	0.02	-.14	0.41	0.88	0.71
	59	0.06	-.43	-.66	-.35	0.67	1.00	0.83	0.40	0.21	0.41	0.85	0.74
	60	0.06	-.43	-.69	-.63	0.37	0.98	0.98	0.65	0.45	0.51	0.71	0.69
	61	0.21	-.33	-.66	-.85	-.24	0.47	0.75	0.68	0.61	0.54	0.64	0.54
	62	-.01	-.43	-.74	-.89	-.69	-.08	0.48	0.77	0.87	0.74	0.64	0.53
	63	0.26	-.04	-.42	-.64	-.70	-.27	0.32	0.75	1.03	0.98	0.85	0.57
	64	0.31	0.09	-.14	-.44	-.62	-.64	-.28	0.61	1.10	1.25	1.03	0.61
	65	0.32	0.28	0.24	0.00	-.34	-.57	-.40	0.46	1.18	1.45	1.23	0.71
	66	0.33	0.40	0.62	0.51	0.07	-.34	-.49	0.20	1.06	1.38	1.13	0.44
	67	0.08	0.11	0.69	0.83	0.35	-.19	-.54	-.32	0.95	1.36	1.16	0.38
	68	-.06	-.19	0.65	1.03	0.75	0.11	-.33	-.47	0.49	1.29	1.18	0.46
	69	-.09	-.40	0.20	1.14	1.17	0.54	-.07	-.33	0.30	1.11	1.01	0.34
	70	-.27	-.57	-.47	0.92	1.15	0.71	0.05	-.24	0.03	1.01	1.14	0.55
	71	-.17	-.50	-.67	-.65	1.27	1.27	0.66	0.15	0.10	0.81	1.19	0.76

5.2 Calculation of [Qi]

	Day	Qi(m^3E6)	Zo(m)
Aug. 1	1	4.2674E+00	7.5000E-01
	2	3.6681E+00	0.0000E+00
	3	3.8073E+00	0.0000E+00
	4	6.7067E+00	0.0000E+00
	5	3.7892E+00	7.5000E-01
	6	4.6427E+00	5.5000E-01
	7	5.9017E+00	6.1000E-01
	8	5.9622E+00	5.9000E-01
	9	3.6560E+00	6.9000E-01
	10	3.7892E+00	7.1000E-01
	11	3.7468E+00	6.1000E-01
	12	6.2467E+00	6.1000E-01
	13	4.5700E+00	6.7000E-01
	14	3.6923E+00	7.5000E-01
	15	4.1705E+00	6.5000E-01
	16	4.0495E+00	7.5000E-01
	17	3.6318E+00	7.7000E-01
	18	4.0131E+00	7.8000E-01
	19	5.5930E+00	6.1000E-01
	20	4.3763E+00	4.9000E-01
	21	3.7286E+00	5.6000E-01
	22	4.4550E+00	4.5000E-01
	23	4.0131E+00	3.5000E-01
	24	3.8679E+00	2.4000E-01
	25	4.5276E+00	3.6000E-01
	26	4.2371E+00	1.7000E-01
	27	4.5095E+00	2.3000E-01
	28	3.8679E+00	2.1000E-01
	29	3.6318E+00	2.0000E-01
	30	5.9743E+00	2.5000E-01
	31	7.4694E+00	3.1000E-01
Sept. 1	32	5.4174E+00	4.9000E-01
	33	5.2661E+00	5.9000E-01
	34	5.3145E+00	7.5000E-01
	35	4.8727E+00	5.3000E-01
	36	4.9392E+00	4.5000E-01
	37	4.7456E+00	4.6000E-01
	38	7.9476E+00	2.8000E-01
	39	6.3799E+00	8.0000E-02
	40	4.7577E+00	1.1000E-01
	41	4.7698E+00	1.5000E-01
	42	4.8969E+00	1.6000E-01
	43	5.1087E+00	2.1000E-01
	44	5.1935E+00	2.4000E-01
	45	5.6353E+00	3.3000E-01
	46	5.6353E+00	4.5000E-01
	47	5.2903E+00	4.6000E-01
	48	5.0906E+00	3.1000E-01
	49	5.1027E+00	3.5000E-01
	50	5.1390E+00	2.8000E-01
	51	4.8242E+00	2.1000E-01
	52	5.8109E+00	1.1000E-01
	53	5.8109E+00	1.5000E-01
	54	5.6717E+00	-4.0000E-02
	55	5.0119E+00	-8.0000E-02
	56	5.9380E+00	-9.0000E-02
	57	5.9683E+00	-1.1000E-01
	58	6.7491E+00	-6.0000E-02
	59	5.0300E+00	6.0000E-02
	60	6.1862E+00	6.0000E-02
	61	4.9392E+00	2.1000E-01

5.3 Result of Solution

	Day	V1(m^3 E6)	Z1(m)	V2(m^3 E6)	Z2(m)
Aug. 1	1	5.8468E+00	2.0000E-01	3.4090E+00	4.0000E-01
	2	8.4043E+00	5.0495E-01	8.9891E+00	5.1842E-01
	3	8.3943E+00	5.0466E-01	1.0025E+01	5.3889E-01
	4	1.0226E+01	5.5794E-01	1.1900E+01	6.0831E-01
	5	2.3120E+01	7.5411E-01	3.2182E+01	7.4552E-01
	6	1.7145E+01	6.8723E-01	3.4105E+01	7.5177E-01
	7	1.8247E+01	7.0253E-01	3.9973E+01	7.7083E-01
	8	2.4198E+01	7.6554E-01	5.3790E+01	8.1558E-01
	9	2.9849E+01	8.2070E-01	6.7860E+01	8.6156E-01
	10	2.5318E+01	7.7743E-01	6.7351E+01	8.5983E-01
	11	2.2464E+01	7.4715E-01	6.6874E+01	8.5821E-01
	12	2.0259E+01	7.2382E-01	6.6198E+01	8.5591E-01
	13	2.8774E+01	8.1144E-01	8.0713E+01	9.0494E-01
	14	2.8746E+01	8.1120E-01	8.4808E+01	9.1791E-01
	15	2.5437E+01	7.7869E-01	8.3210E+01	9.1285E-01
	16	2.4201E+01	7.6558E-01	8.4189E+01	9.1595E-01
	17	2.3210E+01	7.5507E-01	8.4131E+01	9.1577E-01
	18	2.1074E+01	7.3244E-01	8.1396E+01	9.0710E-01
	19	2.1779E+01	7.3990E-01	8.1300E+01	9.0680E-01
	20	2.7846E+01	8.0345E-01	9.0948E+01	9.3737E-01
	21	2.8533E+01	8.0936E-01	9.3119E+01	9.4425E-01
	22	2.6808E+01	7.9323E-01	9.1402E+01	9.3881E-01
	23	2.7848E+01	8.0346E-01	9.4008E+01	9.4707E-01
	24	2.6460E+01	7.8954E-01	9.3757E+01	9.4627E-01
	25	2.4702E+01	7.7089E-01	9.2546E+01	9.4243E-01
	26	2.6324E+01	7.8810E-01	9.5290E+01	9.5113E-01
	27	2.6148E+01	7.8623E-01	9.6301E+01	9.5433E-01
	28	2.6854E+01	7.9371E-01	9.8791E+01	9.6222E-01
	29	2.5231E+01	7.7650E-01	9.7187E+01	9.5714E-01
	30	2.2791E+01	7.5062E-01	9.4451E+01	9.4847E-01
	31	3.0077E+01	8.2266E-01	1.0661E+02	9.8699E-01
Sept. 1	32	4.3174E+01	9.3270E-01	1.2780E+02	1.0439E+00
	33	4.1459E+01	9.1733E-01	1.3089E+02	1.0523E+00
	34	3.9926E+01	9.0360E-01	1.3266E+02	1.0577E+00
	35	3.9122E+01	8.9679E-01	1.3439E+02	1.0630E+00
	36	3.6307E+01	8.7435E-01	1.3322E+02	1.0594E+00
	37	3.4380E+01	8.5900E-01	1.3217E+02	1.0562E+00
	38	3.2549E+01	8.4396E-01	1.3050E+02	1.0511E+00
	39	4.4715E+01	9.4652E-01	1.4840E+02	1.1060E+00
	40	4.8546E+01	9.8085E-01	1.5659E+02	1.1311E+00
	41	4.5377E+01	9.5245E-01	1.5463E+02	1.1251E+00
	42	4.2983E+01	9.3099E-01	1.5252E+02	1.1186E+00
	43	4.1010E+01	9.1331E-01	1.5103E+02	1.1141E+00
	44	4.0414E+01	9.0797E-01	1.5075E+02	1.1132E+00
	45	4.0377E+01	9.0764E-01	1.5104E+02	1.1141E+00
	46	4.1512E+01	9.1781E-01	1.5407E+02	1.1234E+00
	47	4.3000E+01	9.3115E-01	1.5701E+02	1.1324E+00
	48	4.2512E+01	9.2678E-01	1.5775E+02	1.1347E+00
	49	4.1612E+01	9.1870E-01	1.5718E+02	1.1329E+00
	50	4.1193E+01	9.1495E-01	1.5667E+02	1.1314E+00
	51	4.0451E+01	9.0830E-01	1.5631E+02	1.1302E+00
	52	3.8572E+01	8.9240E-01	1.5412E+02	1.1235E+00
	53	4.1120E+01	9.1429E-01	1.5801E+02	1.1355E+00
	54	4.3405E+01	9.3478E-01	1.6197E+02	1.1476E+00
	55	4.4673E+01	9.4614E-01	1.6498E+02	1.1568E+00
	56	4.3248E+01	9.3337E-01	1.6404E+02	1.1540E+00
	57	4.6039E+01	9.5838E-01	1.6880E+02	1.1685E+00
	58	4.9019E+01	9.8510E-01	1.7402E+02	1.1846E+00
	59	5.4470E+01	1.0298E+00	1.8383E+02	1.2069E+00
	60	5.2450E+01	1.0139E+00	1.8333E+02	1.2061E+00
	61	5.5847E+01	1.0407E+00	1.8971E+02	1.2153E+00



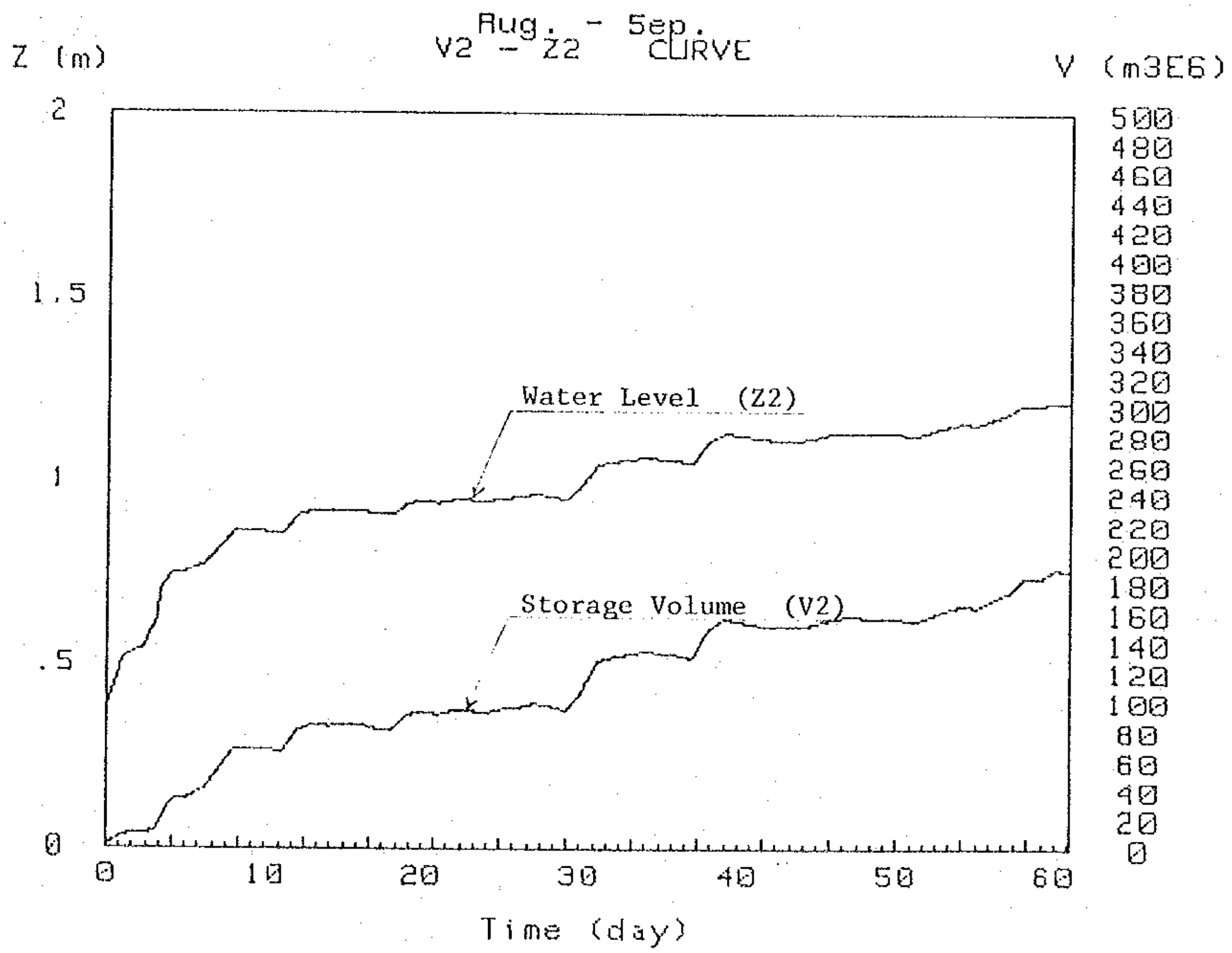


Fig. E.1 Result of Calibrated Water Level and Storage Volume

6. Sample Result of Bi-Dimensional Modeling

This section presents the result of calibration study for the flood in the year of 1983 using bi-dimensional model. The figures of this result are shown in Chapter 12 of main report.

6.1 Input Data for Bi-Dimensional Model

(1) Control data

```
0010 TITLE      EASTERN SUBURBAN-BANGKOK FLOOD SIMULATION MODEL(CASE-PM-520)
0020 NO1            7    15     7     4    31    50     1      8 2424    10     6  220
0030 NO2            5     3     6     5
0040 TIME          52500      184920        52500      184920       180.0   0   0   1   1
0050 OUTPUT         1440          30        52500      184920
0060 QV.CONT     1   899 0 0
0070 QV.CONT     2   7 1 0 0   8 1 1 0  11  1 0 0 1399 0 0 1299 0 0
0080 QV.CONT     3   599 0 0   7-1 0 0   8 125 0   9-1 0 0 10 199 1 11 1 1 1
0090 QV.CONT     3 12 125 2 13 1 ? 1  14  1 0 3
0100 QV.CONT     4   5 125 0   6 1 0 1   7 1 1 5   8 1 1 1   9 1 0 1 10 1 124
0110 QV.CONT     4 11-1 0 0 12 1 1 1  13 1 1 1  14 1 1 1  15 0 099
0120 QV.CONT     5   5-1 0 0   6-1 0 0   7 1 1 0   8 1 1 1   9 1 1 1 10 1 1 1
0130 QV.CONT     5 11-1 0 0 12-1 0 0  13 1 1 1  14 1 1 1  15 0 099
0140 QV.CONT     6   5 1 1 0   6 1 1 1   7 1 1 1   8 1 3 1   9 1 1 1 10 1 3 1
0150 QV.CONT     6 11-1 0 0 12-1 0 0  13-1 0 0  14 1 1 1  15 0 099
0160 QV.CONT     7   5 099 0   8 099 0  10 099 0
0170 BLOCK       2  7  24      2060.       3200.        -1.5       0.200   24     1 1.0
0180 BLOCK       2  8  19      3500.       1000.        -4.5       0.700   19     1 1.0
0190 BLOCK       2 11  10      1440.       5500.        -2.0       0.200   10     1 1.2
0200 BLOCK       3  8  20      2600.       3500.        -4.0       0.100   20     1 0.7
0210 BLOCK       3 10  12      3000.        860.        -4.0       0.200   12     1 0.7
0220 BLOCK       3 11  11      4000.       5230.        -2.0       0.200   11     1 0.5
0230 BLOCK       3 12   8      5120.       5000.        -2.0       0.300    8     1 1.5
0240 BLOCK       3 13   5      3820.       4500.        -2.0       0.400    5     1 1.5
0250 BLOCK       3 14   1      2370.       9000.        -2.0       0.500    1     1 2.0
0260 BLOCK       4  5  30      4670.        600.        -3.0       0.100   30     1 0.75
0270 BLOCK       4  6  28      4500.       3700.        -1.5       0.100   28     1 0.7
0280 BLOCK       4  7  25      4500.       4500.        -1.5       0.200   25     1 0.4
0290 BLOCK       4  8  21      3500.       3290.        -2.4       0.200   21     1 0.3
0300 BLOCK       4  9  16      4000.       2000.        -1.5       0.200   16     1 0.4
0310 BLOCK       4 10  13      3100.       1130.        -3.2       0.200   13     1 0.7
0320 BLOCK       4 12   9      7140.       3500.        -1.5       0.200    9     1 1.0
0330 BLOCK       4 13   6      6330.       4300.        -1.9       0.300    6     1 0.6
0340 BLOCK       4 14   2      5340.       8500.        -2.0       0.500    2     1 0.7
0350 BLOCK       5  7  26      3980.       6000.        -1.5       0.200   26     1 0.4
0360 BLOCK       5  8  22      4000.       2030.        -2.8       0.200   22     1 0.5
0370 BLOCK       5  9  17      3500.       4200.        -1.5       0.200   17     1 0.4
0380 BLOCK       5 10  14      6800.        690.        -2.9       0.200   14     1 0.4
0390 BLOCK       5 13   7      4920.       4920.        -2.0       0.400    7     1 0.7
0400 BLOCK       5 14   3      2750.      11000.        -2.0       0.600    3     1 0.7
0410 BLOCK       6  5  31      7700.        780.        -2.5       0.200   31     1 0.5
0420 BLOCK       6  6  29      7500.       3830.        -2.0       0.200   29     1 0.5
0430 BLOCK       6  7  27      4960.       8500.        -2.0       0.300   27     1 0.7
0440 BLOCK       6  8  23      7200.        900.        -2.6       0.300   23     1 0.4
0450 BLOCK       6  9  18      7500.       7470.        -2.0       0.350   18     1 0.7
0460 BLOCK       6 10  15      5500.       1470.        -2.8       0.400   15     1 1.5
0470 BLOCK       6 14   4      6110.      13000.        -2.0       0.600    4     1 0.7
0480 SECTION     2  7  24      0.0        50      -1.0        0.0        50      -1.0
0490 SECTION     2  8  19      0.0        32      -4.5        0.0        50      -4.5
0500 SECTION     2 11  10      0.0        50      -1.9        0.0        50      -1.9
0510 SECTION     3  8  20      0.0        34      -3.2        0.0        50      -4.5
0520 SECTION     3 10  12      0.0        50      -4.0        0.0        20      -4.0
0530 SECTION     3 11  11      0.0        18      -2.0        0.0        19      -4.0
0540 SECTION     3 12   8      0.0        17      -1.9        0.0        14      -1.5
0550 SECTION     3 13   5      0.0         8      -1.5        0.0         9      -2.0
0560 SECTION     3 14   1      0.0        50      -2.0        0.0         1      -0.8
0570 SECTION     4  5  30      0.0        48      -2.8        0.0        50      -3.8
0580 SECTION     4  6  28      0.0        50      -3.0        0.0        45      -3.0
0590 SECTION     4  7  25      0.0        41      -1.5        0.0        50      -1.5
0600 SECTION     4  8  21      0.0        35      -4.0        0.0        36      -2.4
```

NOTE : Card that has "TITLE" as a Key word means title head for every page of Output List.

Card that has "NO 1" as a Key word means number of I, J suffix, Q and H-boundary, pattern for H-V and H-A data, pattern of Rainfall, Maximum data of Q and H-boundary, H-V and H-A data, and Maximum data of Rainfall.

0610	SECTION	4	9	16	0.0	50	-2.4	0.0	27	-1.5
0620	SECTION	4	10	13	0.0	21	-4.0	0.0	22	-1.0
0630	SECTION	4	12	9	0.0	15	-1.0	0.0	16	-3.2
0640	SECTION	4	13	6	0.0	10	-1.0	0.0	11	-1.5
0650	SECTION	4	14	2	0.0	2	-2.0	0.0	3	-2.0
0660	SECTION	5	7	26	0.0	42	-1.5	0.0	50	-1.5
0670	SECTION	5	8	22	0.0	37	-2.8	0.0	38	-2.8
0680	SECTION	5	9	17	0.0	28	-1.5	0.0	29	-2.8
0690	SECTION	5	10	14	0.0	23	-3.2	0.0	24	-2.9
0700	SECTION	5	13	7	0.0	12	-1.0	0.0	13	-2.0
0710	SECTION	5	14	3	0.0	4	-2.0	0.0	5	-2.0
0720	SECTION	6	5	31	0.0	49	-3.0	0.0	50	-3.0
0730	SECTION	6	6	29	0.0	46	-2.0	0.0	47	-2.0
0740	SECTION	6	7	27	0.0	43	-2.0	0.0	44	-1.3
0750	SECTION	6	8	23	0.0	39	-2.8	0.0	40	-1.5
0760	SECTION	6	9	18	0.0	30	-1.5	0.0	31	-1.5
0770	SECTION	6	10	15	0.0	25	-2.9	0.0	26	-2.0
0780	SECTION	6	14	4	0.0	6	-2.0	0.0	7	-2.0

NOTE : Card that has "No2" as a Key word means number of Pump, Weir, Gate and Number of Gate-DH data.

Card that has "TIME" as a Key word means Start and End time of Simulation and Accumulation, ΔT and a Calculation type Key.

Card that has "OUTPUT" as a Key word means Control Data of Output.

Card that has "QV.CONT" as a Key word means Information of Each Mesh as flowing Calculation Condition for Mesh and X-Y section.

Card that has "BLOCK" as a Key word means Geometory data of Each Mesh as flowing I,J suffix, Mesh No., ΔX and ΔY, Lowest Height of Mesh, Initial Water level, V-H pattern No., Rainfall Pattern No., and Mean ground Height.

Card that has "SECTION" as a Key word means Geometory data of Each Section as flowing I,J suffix, Mesh No., H-A pattern No., and Lowest Height of Section.

(2) Qin-Boundary data

```
0010 QIN          4     15     2      8
0020 QIN-TQ   52500 -13.11  97135 -13.11   97140  -15.60 140335  -15.60
0030 QIN-TQ  140340 -18.94 184975 -18.94  184980  -16.25 228180  -16.25
0040 QIN          5     15     2      8
0050 QIN-TQ   52500  -9.44  97135  -9.44   97140  -11.23 140335  -11.23
0060 QIN-TQ  140340 -13.64 184975 -13.64  184980  -11.70 228180  -11.70
0070 QIN          6     15     2      8
0080 QIN-TQ   52500  -9.44  97135  -9.44   97140  -11.23 140335  -11.23
0090 QIN-TQ  140340 -13.64 184975 -13.64  184980  -11.70 228180  -11.70
0100 QIN          7     10     1      8
0110 QIN-TQ   52500 -10.49  97135 -10.49   97140  -12.48 140335  -12.48
0120 QIN-TQ  140340 -15.15 184975 -15.15  184980  -13.00 228180  -13.00
0130 QIN          7      8     1      8
0140 QIN-TQ   52500  -2.62  97135  -2.62   97140   -3.12 140335   -3.12
0150 QIN-TQ  140340  -3.79 184975  -3.79  184980   -3.25 228180   -3.25
0160 QIN          7      5     1      8
0170 QIN-TQ   52500  -7.34  97135  -7.34   97140   -8.74 140335   -8.74
0180 QIN-TQ  140340 -10.61 184975 -10.61  184980   -9.10 228180   -9.10
0190 QIN          3     10     1      8
0200 QIN-TQ   52500    2.5  97135    2.5   97140     2.5 140335     2.5
0210 QIN-TQ  140340    2.5 184975    2.5  184980     2.5 228180     2.5
```

NOTE : Card that has "QIN" as a Key Word means Mesh address for Q-boundary data and No. of QIN-TQ data.

Card that has "QIN-TQ" as a Key word means Time (min) - Q flow (m^3/sec.) Data.

(3) H - Boundary data

0005	B.H	1	8 2208						
0010	B.H-TH	52500	0.75	52560	0.36	52620	-0.08	52680	-0.37
0020	B.H-TH	52740	-0.49	52800	-0.51	52860	-0.39	52920	-0.1
0030	B.H-TH	52980	0.17	53040	0.38	53100	0.45	53160	0.38
0040	B.H-TH	53220	0.16	53280	-0.05	53340	-0.37	53400	-0.61
0050	B.H-TH	53460	-0.73	53520	-0.67	53580	-0.39	53640	0.08
0060	B.H-TH	53700	0.56	53760	0.89	53820	1.07	53880	1.11
0070	B.H-TH	53940	1.07	54000	0.67	54060	0.27	54120	-0.06
0080	B.H-TH	54180	-0.25	54240	-0.52	54300	-0.64	54360	-0.65
0090	B.H-TH	54420	-0.48	54480	-0.18	54540	0.03	54600	0.11
0100	B.H-TH	54660	0.08	54720	-0.04	54780	-0.19	54840	-0.35
0110	B.H-TH	54900	-0.48	54960	-0.45	55020	-0.30	55080	0.01
0120	B.H-TH	55140	0.36	55200	0.7	55260	0.89	55320	1.0
0130	B.H-TH	55380	0.91	55440	0.71	55500	0.34	55560	0.04
0140	B.H-TH	55620	-0.24	55680	-0.53	55740	-0.72	55800	-0.81
0150	B.H-TH	55860	-0.77	55920	-0.44	55980	-0.11	56040	0.13
0160	B.H-TH	56100	0.25	56160	0.28	56220	0.31	56280	0.22
0170	B.H-TH	56340	0.04	56400	0.01	56460	0.08	56520	0.17
0180	B.H-TH	56580	0.40	56640	0.61	56700	0.71	56760	0.89
0190	B.H-TH	56820	0.86	56880	0.70	56940	0.45	57000	0.11
0200	B.H-TH	57060	-0.19	57120	-0.51	57180	-0.77	57240	-0.94
0210	B.H-TH	57300	-1.04	57360	-0.97	57420	-0.69	57480	-0.32
0220	B.H-TH	57540	0.07	57600	0.19	57660	0.36	57720	0.4
0230	B.H-TH	57780	0.43	57840	0.33	57900	0.28	57960	0.31
0240	B.H-TH	58020	0.46	58080	0.59	58140	0.71	58200	0.56
0250	B.H-TH	58260	0.75	58320	0.5	58380	0.38	58440	0.14
0260	B.H-TH	58500	-0.24	58560	-0.57	58620	-0.77	58680	-0.94
0270	B.H-TH	58740	-1.09	58800	-1.17	58860	-1.19	58920	-0.88
0280	B.H-TH	58980	-0.49	59040	-0.09	59100	0.23	59160	0.35
0290	B.H-TH	59220	0.49	59280	0.57	59340	0.56	59400	0.53
0300	B.H-TH	59460	0.42	59520	0.44	59580	0.47	59640	0.54
0310	B.H-TH	59700	0.55	59760	0.5	59820	0.43	59880	0.23
0320	B.H-TH	59940	-0.07	60000	-0.41	60060	-0.69	60120	-0.93
0330	B.H-TH	60180	-1.12	60240	-1.25	60300	-1.36	60360	-1.36
0340	B.H-TH	60420	-0.99	60480	-0.44	60540	0.06	60600	0.56
0350	B.H-TH	60660	0.86	60720	1.05	60780	1.09	60840	1.09
0360	B.H-TH	60900	1.02	60960	0.91	61020	0.76	61080	0.66
0370	B.H-TH	61140	0.61	61200	0.56	61260	0.55	61320	0.43
0380	B.H-TH	61380	0.25	61440	-0.03	61500	-0.29	61560	-0.57
0390	B.H-TH	61620	-0.82	61680	-0.99	61740	-1.13	61800	-1.22
0400	B.H-TH	61860	-1.27	61920	-1.05	61980	-0.47	62040	0.22
0410	B.H-TH	62100	0.68	62160	1.04	62220	1.26	62280	1.39
0420	B.H-TH	62340	1.38	62400	1.31	62460	1.09	62520	0.87
0430	B.H-TH	62580	0.59	62640	0.54	62700	0.59	62760	0.59
0440	B.H-TH	62820	0.6	62880	0.41	62940	0.16	63000	-0.16
0450	B.H-TH	63060	-0.46	63120	-0.69	63180	-0.89	63240	-1.06
0460	B.H-TH	63300	-1.17	63360	-1.25	63420	-1.16	63480	-0.44
0470	B.H-TH	63540	0.37	63600	0.87	63660	1.17	63720	1.31
0480	B.H-TH	63780	1.43	63840	1.33	63900	1.17	63960	0.89
0490	B.H-TH	64020	0.69	64080	0.59	64140	0.58	64200	0.63
0500	B.H-TH	64260	0.69	64320	0.69	64380	0.55	64440	0.23
0510	B.H-TH	64500	-0.11	64560	-0.41	64620	-0.64	64680	-0.85
0520	B.H-TH	64740	-1.01	64800	-1.12	64860	-1.2	64920	-1.08
0530	B.H-TH	64980	-0.25	65040	0.56	65100	1.01	65160	1.23
0540	B.H-TH	65220	1.39	65280	1.39	65340	1.28	65400	1.07
0550	B.H-TH	65460	0.71	65520	0.55	65580	0.49	65640	0.51
0560	B.H-TH	65700	0.66	65760	0.73	65820	0.75	65880	0.61
0570	B.H-TH	65940	0.29	66000	-0.08	66060	-0.43	66120	-0.67
0580	B.H-TH	66180	-0.86	66240	-1.02	66300	-1.12	66360	-1.22
0590	B.H-TH	66420	-1.05	66480	-0.15	66540	0.74	66600	0.97

NOTE : Card that has "B.H" as a Key word means Mesh address for H-boundary data and No. of B.H-TH data.

Card that has "B.H-TH" as a Key word means Time (min) - H-boundary (m) data.

(4) Rainfall and Evaporation data

0005	RAIN	1	220							
0010	T-RAIN	52500	0.44	0.14	53935	0.44	0.14	53940	0.03	0.14
0020	T-RAIN	55375	0.03	0.14	55380	0.08	0.14	56815	0.08	0.14
0030	T-RAIN	56820	2.11	0.14	58255	2.11	0.14	58260	0.11	0.14
0040	T-RAIN	59695	0.11	0.14	59700	0.70	0.14	61135	0.70	0.14
0050	T-RAIN	61140	1.56	0.14	62575	1.56	0.14	62580	1.60	0.14
0060	T-RAIN	64015	1.60	0.14	64020	0.02	0.14	65455	0.02	0.14
0070	T-RAIN	65460	0.11	0.14	66895	0.11	0.14	66900	0.08	0.14
0080	T-RAIN	68335	0.08	0.14	68340	1.80	0.14	69775	1.80	0.14
0090	T-RAIN	69780	0.65	0.14	71215	0.65	0.14	71220	0.04	0.14
0100	T-RAIN	72655	0.04	0.14	72660	0.37	0.14	74095	0.37	0.14
0110	T-RAIN	74100	0.29	0.14	75535	0.29	0.14	75540	0.	0.14
0120	T-RAIN	76975	0.	0.14	76980	0.26	0.14	78415	0.26	0.14
0130	T-RAIN	78420	1.35	0.14	79855	1.35	0.14	79860	0.51	0.14
0140	T-RAIN	81295	0.51	0.14	81300	0.06	0.14	82735	0.06	0.14
0150	T-RAIN	82740	0.57	0.14	84175	0.57	0.14	84180	0.26	0.14
0160	T-RAIN	85615	0.26	0.14	85620	0.16	0.14	87055	0.16	0.14
0170	T-RAIN	87060	0.62	0.14	88495	0.62	0.14	88500	0.42	0.14
0180	T-RAIN	89935	0.42	0.14	89940	0.60	0.14	91375	0.60	0.14
0190	T-RAIN	91380	0.16	0.14	92815	0.16	0.14	92820	0.	0.14
0200	T-RAIN	94255	0.	0.14	94260	1.61	0.14	95695	1.61	0.14
0210	T-RAIN	95700	2.66	0.14	97135	2.66	0.14	97140	0.47	0.14
0220	T-RAIN	98575	0.47	0.14	98580	0.38	0.14	100015	0.38	0.14
0230	T-RAIN	100020	0.41	0.14	101455	0.41	0.14	101460	0.10	0.14
0240	T-RAIN	102895	0.10	0.14	102900	0.15	0.14	104335	0.15	0.14
0250	T-RAIN	104340	0.02	0.14	105775	0.02	0.14	105780	2.22	0.14
0260	T-RAIN	107215	2.22	0.14	107220	1.14	0.14	108655	1.14	0.14
0270	T-RAIN	108660	0.03	0.14	110095	0.03	0.14	110100	0.03	0.14
0280	T-RAIN	111535	0.03	0.14	111540	0.12	0.14	112975	0.12	0.14
0290	T-RAIN	112980	0.26	0.14	114415	0.26	0.14	114420	0.33	0.14
0300	T-RAIN	115855	0.33	0.14	115860	0.33	0.14	117295	0.12	0.14
0310	T-RAIN	117300	0.63	0.14	118735	0.63	0.14	118740	0.39	0.14
0320	T-RAIN	120175	0.39	0.14	120180	0.25	0.14	121615	0.25	0.14
0330	T-RAIN	121620	0.26	0.14	123055	0.26	0.14	123060	0.29	0.14
0340	T-RAIN	124495	0.29	0.14	124500	0.07	0.14	125935	0.07	0.14
0350	T-RAIN	125940	0.08	0.14	127375	0.08	0.14	127380	0.75	0.14
0360	T-RAIN	128815	0.75	0.14	128820	0.65	0.14	130255	0.65	0.14
0370	T-RAIN	130260	0.20	0.14	131695	0.20	0.14	131700	0.84	0.14
0380	T-RAIN	133135	0.84	0.14	133140	0.86	0.14	134575	0.86	0.14
0390	T-RAIN	134580	1.40	0.14	136015	1.40	0.14	136020	0.21	0.14
0400	T-RAIN	137455	0.21	0.14	137460	1.01	0.14	138895	1.01	0.14
0410	T-RAIN	138900	0.15	0.14	140335	0.15	0.14	140340	0.40	0.14
0420	T-RAIN	141775	0.40	0.14	141780	0.03	0.14	143215	0.03	0.14
0430	T-RAIN	143220	0.16	0.14	144655	0.16	0.14	144660	0.15	0.14
0440	T-RAIN	146095	0.15	0.14	146100	0.28	0.14	147535	0.28	0.14
0450	T-RAIN	147540	0.10	0.14	148975	0.10	0.14	148980	0.01	0.14
0460	T-RAIN	150415	0.01	0.14	150420	0.02	0.14	151855	0.02	0.14
0470	T-RAIN	151860	0.93	0.14	153295	0.93	0.14	153300	0.65	0.14
0480	T-RAIN	154735	0.65	0.14	154740	0.55	0.14	156175	0.55	0.14
0490	T-RAIN	156180	0.36	0.14	157615	0.36	0.14	157620	0.81	0.14
0500	T-RAIN	159055	0.81	0.14	159060	0.94	0.14	160495	0.94	0.14
0510	T-RAIN	160500	1.47	0.14	161935	1.47	0.14	161940	0.02	0.14
0520	T-RAIN	163375	0.02	0.14	163380	0.03	0.14	164815	0.03	0.14
0530	T-RAIN	164820	3.63	0.14	166255	3.63	0.14	166260	0.52	0.14
0540	T-RAIN	167695	0.52	0.14	167700	0.02	0.14	169135	0.02	0.14
0550	T-RAIN	169140	0.35	0.14	170575	0.35	0.14	170580	0.01	0.14
0560	T-RAIN	172015	0.01	0.14	172020	0.10	0.14	173455	0.10	0.14
0570	T-RAIN	173460	0.	0.14	174895	0.	0.14	174900	0.	0.14
0580	T-RAIN	176335	0.	0.14	176340	0.	0.14	177775	0.	0.14
0590	T-RAIN	177780	0.	0.14	179215	0.	0.14	179220	0.	0.14

NOTE : Card that has "RAIN" as a key word means number of pattern and number of Time-Rain data.

Card that has "T-RAIN" as a Key word means time (min) and rain, evaporation data (mm/hour).

(5) Topography data

```
0010 H-BLOCK        1     6
0020 H-V.A    0.0   0.0      0.064 3.5   0.224   0.064 3.55  0.374    3.00
0030 H-V.A    4.0   1.724    3.00  4.05  2.789   21.300 5.00 23.024   21.30
0040 H-BLOCK        2     6
0050 H-V.A    0.0   0.0      0.172 2.7   0.464   0.172 2.75  2.229    35.3
0060 H-V.A    3.5   28.704   35.3  3.55  30.974  45.400 4.0  51.404   45.4
0070 H-BLOCK        3     6
0080 H-V.A    0.0   0.0      0.120 2.7   0.324   0.120 2.75  1.708    27.68
0090 H-V.A    3.5   22.468   27.68 3.55  23.983  30.3   4.0  37.618   30.3
0100 H-BLOCK        4     6
0110 H-V.A    0.0   0.0      0.292 2.7   0.206   0.294 2.75  4.060    77.15
0120 H-V.A    3.5   61.922   77.15 3.55  65.892  79.400 4.0 101.622   79.40
0130 H-BLOCK        5     8
0140 H-V.A    0.0   0.0      0.106 2.6   0.265   0.106 2.65  0.421    2.76
0150 H-V.A    3.2   1.939    2.76  3.25  2.092   3.06  3.50  2.857    3.06
0160 H-V.A    3.55  3.717    17.20 4.0   11.457  17.20
0170 H-BLOCK        6     10
0180 H-V.A    0.0   0.0      0.106 2.5   0.265   0.106 2.55  1.315    20.99
0190 H-V.A    2.9   8.662    20.99 2.95  9.711   20.99 3.1   12.86    20.99
0200 H-V.A    3.15  14.015   23.09 3.4   19.788  23.09 3.45  21.148   27.20
0210 H-V.A    3.9   33.388   27.20
0220 H-BLOCK        7     10
0230 H-V.A    0.0   0.0      0.060 2.4   0.144   0.060 2.45  0.344    4.00
0240 H-V.A    2.7   1.344    4.00  2.75  2.214   17.40 3.0   6.554    17.40
0250 H-V.A    3.05  7.554    19.80 3.5   16.464  19.80 3.55  17.674   24.20
0260 H-V.A    4.0   28.564   24.20
0270 H-BLOCK        8     4
0280 H-V.A    0.0   0.0      0.044 3.5   0.154   0.044 3.55  1.434    25.60
0290 H-V.A    4.0   12.954   25.60
0300 H-BLOCK        9     8
0310 H-V.A    0.0   0.0      0.068 2.1   0.143   0.068 2.15  0.358    4.30
0320 H-V.A    2.5   1.863    4.30  2.55  2.753   17.80 2.7   5.423    17.80
0330 H-V.A    2.75  6.673    25.00 3.5   25.423  25.00
0340 H-BLOCK        10    4
0350 H-V.A    0.0   0.0      0.025 3.2   0.080   0.025 3.25  0.475    7.90
0360 H-V.A    4.0   6.4      7.90
0370 H-BLOCK        11    10
0380 H-V.A    0.0   0.0      0.10  2.5   0.250   0.100 2.55  0.850    12.00
0390 H-V.A    2.7   2.65     12.00 2.75  3.300   13.000 3.0  6.55     13.00
0400 H-V.A    3.05  7.275    14.50 3.20  9.45    14.50 3.25  10.495   20.90
0410 H-V.A    4.0   26.17    20.90
0420 H-BLOCK        12    4
0430 H-V.A    0.0   0.0      0.060 4.7   0.282   0.060 4.75  0.412    2.60
0440 H-V.A    6.0   3.662    2.60
0450 H-BLOCK        13    5
0460 H-V.A    0.0   0.0      0.062 0.7   0.242   0.062 3.95  0.364    2.45
0470 H-V.A    4.1   0.732    2.45  5.2   4.582   3.50
0480 H-BLOCK        14    8
0490 H-V.A    0.0   0.0      0.122 3.3   0.403   0.122 3.35  0.513    2.22
0500 H-V.A    3.6   1.068    2.22  3.65  1.179   2.22  3.9   1.734    2.22
0510 H-V.A    3.95  1.969    4.70  4.9   6.434   4.70
0520 H-BLOCK        15    6
0530 H-V.A    0.0   0.0      0.112 3.8   0.426   0.112 3.85  0.467    0.812
0540 H-V.A    4.3   0.832    0.812 4.35  1.237   8.100 4.80  4.882    8.10
0550 H-BLOCK        16    10
0560 H-V.A    0.0   0.0      0.028 1.9   1.953   1.028 1.95  2.054    2.028
0570 H-V.A    2.1   2.358    2.028 2.15  2.535   3.535 2.20  2.711    3.53
0580 H-V.A    2.25  3.011    6.00  2.3   3.311   6.00  2.35  3.711    8.00
0590 H-V.A    3.50  12.911   8.00
0600 H-BLOCK        17    8
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0610 H-V.A    0.0   0.0     0.024 1.9   0.046   0.024 1.95  0.371   6.50
0620 H-V.A    2.0   0.696   6.50  2.05  1.246   11.00 2.40  5.096   11.00
0630 H-V.A    2.45  5.831   14.70 3.50  21.266  14.70
0640 H-BLOCK    18    10
0650 H-V.A    0.0   0.0     0.228 2.4   0.547   0.228 2.45  1.312   15.30
0660 H-V.A    2.7   5.137   15.30 2.75  7.662   50.50 2.9   15.237  50.50
0670 H-V.A    2.95  17.912  53.50 3.0   20.587  53.50 3.05  23.387  56.00
0680 H-V.A    4.0   76.587  56.00
0690 H-BLOCK    19    4
0700 H-V.A    0.0   0.0     0.078 5.5   0.431   0.078 5.55  0.606   3.50
0710 H-V.A    6.5   3.93    3.50
0720 H-BLOCK    20    8
0730 H-V.A    0.0   0.0     0.080 4.3   0.301   0.080 4.35  0.304   0.08
0740 H-V.A    4.7   0.329   0.09  4.75  0.332   0.11  4.8   0.649   6.35
0750 H-V.A    4.85  1.104   9.10  6.0   10.465  9.10
0760 H-BLOCK    21    8
0770 H-V.A    0.0   0.0     0.094 2.7   0.254   0.094 2.75  0.479   4.50
0780 H-V.A    3.1   2.054   4.50  3.15  2.554   10.00 3.2   3.054   10.00
0790 H-V.A    3.25  3.629   11.50 4.4   16.854  11.50
0800 H-BLOCK    22    8
0810 H-V.A    0.0   0.0     0.100 3.3   0.330   0.100 3.35  0.505   3.50
0820 H-V.A    3.6   1.380   3.50  3.65  1.635   5.10  3.8   2.40    5.10
0830 H-V.A    3.85  2.805   8.10  4.8   10.50   8.10
0840 H-BLOCK    23    8
0850 H-V.A    0.0   0.0     0.180 3.0   0.540   0.180 3.05  0.670   2.60
0860 H-V.A    3.1   0.8     2.60  3.15  1.03    4.60  3.30  1.72    4.60
0870 H-V.A    3.35  2.05    6.50  4.60  10.18   6.50
0880 H-BLOCK    24    4
0890 H-V.A    0.0   0.0     0.128 2.5   0.32    0.128 2.55  0.650   6.60
0900 H-V.A    3.5   6.920   6.60
0910 H-BLOCK    25    8
0920 H-V.A    0.0   0.0     0.045 1.9   0.086   0.045 1.95  0.511   8.50
0930 H-V.A    2.3   3.486   8.50  2.35  4.236   16.80 2.50  6.846   16.80
0940 H-V.A    2.55  7.861   20.30 3.5   27.146  20.30
0950 H-BLOCK    26    8
0960 H-V.A    0.0   0.0     0.060 1.9   0.114   0.060 1.95  0.704   11.80
0970 H-V.A    2.2   3.654   11.80 2.25  4.397   14.86 2.5   8.112   14.86
0980 H-V.A    2.55  9.307   23.90 3.50  32.012  23.90
0990 H-BLOCK    27    6
1000 H-V.A    0.0   0.0     0.085 2.7   0.230   0.085 2.75  1.918   33.76
1010 H-V.A    3.0   10.358  33.76 3.05  12.468  42.200 4.0  52.56   42.20
1020 H-BLOCK    28    6
1030 H-V.A    0.0   0.0     0.043 2.2   0.095   0.043 2.25  0.666   11.41
1040 H-V.A    2.3   1.237   11.41 2.35  2.052   16.30 3.5   20.797  16.30
1050 H-BLOCK    29    4
1060 H-V.A    0.0   0.0     0.060 2.7   0.162   0.060 2.75  1.597   28.70
1070 H-V.A    4.0   37.47   28.70
1080 H-BLOCK    30    5
1090 H-V.A    0.0   0.0     0.093 3.75  0.456   0.10  3.8   0.568   2.24
1100 H-V.A    3.85  0.708   2.80  5.0   3.928   2.80
1110 H-BLOCK    31    6
1120 H-V.A    0.0   0.0     0.154 3.2   0.493   0.154 3.25  0.693   4.00
1130 H-V.A    3.3   0.893   4.00  3.35  1.193   6.00  4.50  8.093   6.00
1140 H-SECT     1     4
1150 H-A.N    0.0       0.0  0.035 2.8      19.6  0.035 2.9    266.6  0.150
1160 H-A.N    3.0     493.6  0.050
1170 H-SECT     2     4
1180 H-A.N    0.0       0.0  0.035 4.0      24.0  0.035 4.1    874.0  0.150
1190 H-A.N    4.5    4274.0  0.050
1200 H-SECT     3     4
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1210 H-A.N    0.0        0.0  0.035 4.0     12.0  0.035 4.1    546.0  0.150
1220 H-A.N    4.5     2682.0  0.050
1230 H-SECT     4        4
1240 H-A.N    0.0        0.0  0.035 3.5     42.0  0.035 3.6   1142.0  0.150
1250 H-A.N    4.0     5542.0  0.050
1260 H-SECT     5        4
1270 H-A.N    0.0        0.0  0.035 4.0     28.0  0.035 4.1    303.0  0.150
1280 H-A.N    4.5     1403.0  0.050
1290 H-SECT     6        4
1300 H-A.N    0.0        0.0  0.035 2.7     32.4  0.035 2.8   1332.4  0.150
1310 H-A.N    3.2     6532.4  0.050
1320 H-SECT     7        4
1330 H-A.N    0.0        0.0  0.035 3.8     53.2  0.035 3.9    664.2  0.150
1340 H-A.N    4.5     4330.2  0.050
1350 H-SECT     8        2
1360 H-A.N.   0.0        0.0  0.035 4.0     24.0  0.035
1370 H-SECT     9        4
1380 H-A.N    0.0        0.0  0.035 3.8     38.0  0.035 3.9    420.0  0.150
1390 H-A.N    4.3     1948.0  0.050
1400 H-SECT    10        4
1410 H-A.N    0.0        0.0  0.035 2.5      7.5  0.035 2.6    437.5  0.150
1420 H-A.N    3.0     2157.5  0.050
1430 H-SECT    11        5
1440 H-A.N    0.0        0.0  0.035 2.8     14.0  0.035 2.9    647.0  0.150
1450 H-A.N    3.5     4445.0  0.050 4.0   7610.0  0.050
1460 H-SECT    12        4
1470 H-A.N    0.0        0.0  0.035 2.5     10.0  0.035 2.6    502.0  0.150
1480 H-A.N    3.0     2470.0  0.050
1490 H-SECT    13        4
1500 H-A.N    0.0        0.0  0.035 3.6     36.0  0.035 3.7    528.0  0.150
1510 H-A.N    4.0     2004.0  0.050
1520 H-SECT    14        4
1530 H-A.N    0.0        0.0  0.035 3.0     18.0  0.035 3.1     18.6  0.150
1540 H-A.N    4.0       24.0  0.050
1550 H-SECT    15        4
1560 H-A.N    0.0        0.0  0.035 2.5      7.5  0.035 2.6    357.5  0.150
1570 H-A.N    3.0     1757.5  0.050
1580 H-SECT    16        4
1590 H-A.N    0.0        0.0  0.035 3.2     35.2  0.035 3.3    749.2  0.150
1600 H-A.N    4.9     3605.2  0.050
1610 H-SECT    17        3
1620 H-A.N    0.0        0.0  0.035 3.9     23.4  0.035 5.0     30.0  0.150
1630 H-SECT    18        4
1640 H-A.N    0.0        0.0  0.035 3.8     15.2  0.035 3.9    538.2  0.150
1650 H-A.N    4.3     2630.2  0.050
1660 H-SECT    19        6
1670 H-A.N    0.0        0.0  0.035 4.7     56.4  0.035 4.8     57.6  0.150
1680 H-A.N    4.9      157.6  0.150 5.3    576.7  0.050 6.0   1576.7  0.050
1690 H-SECT    20        4
1700 H-A.N    0.0        0.0  0.035 5.8    121.8  0.035 5.9    421.8  0.150
1710 H-A.N    6.3     1621.8  0.050
1720 H-SECT    21        5
1730 H-A.N    0.0        0.0  0.035 4.7     94.0  0.035 4.8    207.0  0.150
1740 H-A.N    4.9      433.0  0.150 6.0   1676.0  0.050
1750 H-SECT    22        4
1760 H-A.N    0.0        0.0  0.035 1.95    11.7  0.035 2.05    12.3  0.150
1770 H-A.N    3.0       18.0  0.050
1780 H-SECT    23        4
1790 H-A.N    0.0        0.0  0.035 4.3     86.0  0.035 4.4    155.0  0.150
1800 H-A.N    4.8      431.0  0.050
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1810 H-SECT        24       4
1820 H-A.N     0.0          0.0   0.035 4.1      16.4   0.035 4.2      16.8   0.150
1830 H-A.N     4.6       2736.8   0.050
1840 H-SECT        25       3
1850 H-A.N     0.0          0.0   0.035 1.5       4.5   0.035 3.0       9.0   0.035
1860 H-SECT        26       4
1870 H-A.N     0.0          0.0   0.035 3.6      36.0   0.035 3.7     586.0   0.150
1880 H-A.N     4.0       2236.0   0.050
1890 H-SECT        27       4
1900 H-A.N     0.0          0.0   0.035 3.3       3.3   0.035 3.4     403.3   0.150
1910 H-A.N     4.8       2803.3   0.050
1920 H-SECT        28       4
1930 H-A.N     0.0          0.0   0.035 2.7       2.7   0.035 2.8     427.7   0.150
1940 H-A.N     3.5       3362.7   0.050
1950 H-SECT        29       4
1960 H-A.N     0.0          0.0   0.035 4.6      18.4   0.035 4.7     368.4   0.150
1970 H-A.N     5.1       1768.4   0.050
1980 H-SECT        30       5
1990 H-A.N     0.0          0.0   0.035 2.4      12.0   0.035 2.5     759.0   0.050
2000 H-A.N     3.0       4494.0   0.150 4.0   11964.0   0.050
2010 H-SECT        31       4
2020 H-A.N     0.0          0.0   0.035 3.3      23.1   0.035 3.4     773.1   0.150
2030 H-A.N     4.0       5273.1   0.050
2040 H-SECT        32       4
2050 H-A.N     0.0          0.0   0.035 6.5     143.0   0.035 6.6     243.0   0.150
2060 H-A.N     7.0        643.0   0.050
2070 H-SECT        33       5
2080 H-A.N     0.0          0.0   0.035 5.7      22.8   0.035 5.8     152.8   0.150
2090 H-A.N     6.2        672.8   0.050 6.5    1062.8   0.050
2100 H-SECT        34       4
2110 H-A.N     0.0          0.0   0.035 4.7     122.2   0.035 4.8     124.8   0.150
2120 H-A.N     5.5        143.0   0.050
2130 H-SECT        35       4
2140 H-A.N     0.0          0.0   0.035 5.4     108.0   0.035 5.5     437.0   0.150
2150 H-A.N     5.9       1316.0   0.050
2160 H-SECT        36       5
2170 H-A.N     0.0          0.0   0.035 3.3      16.5   0.035 3.4     366.5   0.150
2180 H-A.N     3.8        506.5   0.050 4.4    2606.5   0.050
2190 H-SECT        37       4
2200 H-A.N     0.0          0.0   0.035 4.4      96.8   0.035 4.5     299.8   0.150
2210 H-A.N     4.9       1111.8   0.050
2220 H-SECT        38       5
2230 H-A.N     0.0          0.0   0.035 3.7      18.5   0.035 3.8     418.5   0.150
2240 H-A.N     4.2       2018.5   0.050 4.8    4418.5   0.050
2250 H-SECT        39       3
2260 H-A.N     0.0          0.0   0.035 1.5       4.5   0.035 3.0       9.0   0.035
2270 H-SECT        40       4
2280 H-A.N     0.0          0.0   0.035 2.8      16.8   0.035 2.9     736.8   0.150
2290 H-A.N     4.0       3656.8   0.050
2300 H-SECT        41       4
2310 H-A.N     0.0          0.0   0.035 3.5      10.5   0.035 3.6     460.5   0.150
2320 H-A.N     4.0       2260.5   0.050
2330 H-SECT        42       4
2340 H-A.N     0.0          0.0   0.035 3.1      15.5   0.035 3.2     615.5   0.150
2350 H-A.N     3.6       3015.5   0.050
2360 H-SECT        43       5
2370 H-A.N     0.0          0.0   0.035 2.7      13.5   0.035 2.8     566.2   0.150
2380 H-A.N     3.0       1666.2   0.050 3.1    2516.2   0.050
2390 H-SECT        44       4
2400 H-A.N     0.0          0.0   0.035 3.0      15.0   0.035 3.1     511.0   0.150
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2410	H-A.N	4.2	4975.0	0.050							
2420	H-SECT	45	4								
2430	H-A.N	0.0	0.0	0.035	4.4	22.0	0.035	4.5	472.0	0.150	
2440	H-A.N	4.9	2272.0	0.050							
2450	H-SECT	46	4								
2460	H-A.N	0.0	0.0	0.035	3.6	14.4	0.035	3.7	397.4	0.150	
2470	H-A.N	4.1	1933.0	0.050							
2480	H-SECT	47	4								
2490	H-A.N	0.0	0.0	0.035	2.7	13.5	0.035	2.8	885.0	0.150	
2500	H-A.N	4.0	9885.0	0.050							
2510	H-SECT	48	3								
2520	H-A.N	0.0	0.0	0.035	5.4	32.4	0.035	6.0	36.0	0.050	
2530	H-SECT	49	4								
2540	H-A.N	0.0	0.0	0.035	4.6	92.0	0.035	4.7	170.0	0.150	
2550	H-A.N	5.1	482.0	0.050							
2560	H-SECT	50	3								
2570	H-A.N	0.0	0.0	0.035	5.0	0.0	0.035	10.	0.0	0.035	

NOTE : Card that has "H-BLOCK" as a Key word means Number of Pattern data and H-V data.

Card that has "H-V.A" as a Key word means Depth (m) - Volume ($10^6 m^3$), Surface Area ($10^6 m^2$) data.

Card that has "H-SECT" as a Key word means Number of Pattern data and H-A data.

Card that has "H-A.N" as a Key word means Depth (m) - Section Area (m^2), Coefficient of roughness (Manning's N).

(6) Control Data for Facility

0010	PUMP	3	12	1	2	0	0.75	0.80		3.00
0020	PUMP	4	10	2	1	0	0.35	0.40		3.00
0030	PUMP	3	8	1	2	0	0.45	0.50		16.0
0040	PUMP	4	7	2	2	0	0.55	0.60		1.00
0050	PUMP	4	5	1	2	0	0.45	0.50		1.50
0070	SEKI	6	10	1	1.000		0.600	0.600		
0080	SEKI	6	8	1	0.900		0.600	0.600		
0082	SEKI	3	14	2	-0.800		0.600	0.600		
0085	GATE	3	13	1	5	2	0.700	1.20		5.00
0090	GATE-DH	-4.0	0.0		0.0	0.0	0.30	3.0	0.50	3.0
0100	GATE-DH	2.0	5.0							
0110	GATE	3	12	1	5	2	0.700	1.20		5.00
0120	GATE-DH	-4.0	0.0		0.0	0.0	0.3	3.0	0.50	3.0
0130	GATE-DH	2.0	5.0							
0140	GATE	3	12	2	5	1	0.700	1.20		5.00
0150	GATE-DH	-4.0	5.0		0.0	5.0	0.5	5.0	0.3	5.00
0160	GATE-DH	2.0	5.0							
0170	GATE	4	10	2	5	1	0.700	10.00		5.00
0180	GATE-DH	-2.0	0.0		-0.5	0.0	-0.30	0.0	0.0	0.00
0190	GATE-DH	2.0	0.0							
0200	GATE	3	8	1	5	2	0.700	1.00		4.00
0210	GATE-DH	-4.0	0.0		0.0	0.0	0.30	4.0	0.5	4.00
0220	GATE-DH	2.0	5.0							
0230	GATE	4	5	1	5	2	0.700	1.00		5.00
0240	GATE-DH	-4.0	0.0		0.0	0.0	0.3	4.0	0.5	4.0
0250	GATE-DH	2.0	5.0							

NOTE : Card that has "PUMP" as a Key word means Mesh Address, Direction of flow, Initial Condition, Pump off and on level (m) and Pump Capacity (m^3/sec.).

Card that has "SEKI" as a Key word means Information of Weir as flowing, Mesh Address, Elevation of top of Weir and Coefficients of Weir.

Card that has "GATE" as a Key word means Information of Gate as flowing Mesh Address, Number of GATE-DH data, Direction of flow, Coefficient of Gate, Control Water level (m) and Degree of Width for Gate in Control condition.

Card that has "GATE-DH" as a Key word means Def. of Water level (m) - Degree of width for Gate data.

6.2 Sample results of Simulation in 1983 using Bi-Dimensional Mode.

NOTE : These results refer to Chapter 12 in main report.
Program prints out the result of analysis in every selected time.
Items of print put are as follows :

B.NO	: Number of mesh (shown in Fig.12.9 of main report)
VOL(M3)	: Strage volume of mesh (unit : m^3)
D-MAX(M)	: Water level minus Lowest ground elevation (unit : m)
D-MEAN(M)	: In case "*" are printed, inundation depth. In other case, areal average depth. (unit : m)
S-AREA(M2)	: Surface area of flood (unit : m^2)
TYPE	: Type of connection between meshes. "oc" means open channal flow, "P" means pump facility, "W" means Weir, "G" means gate facility.
Q(M3/S)	: Quantity of flow in section, upper step are printed X-section's Q, lower step are printed Y-section's Q.
S.Q+(M3), S.Q-(M3)	: Summation of quantity of flow in section in plus and minus directions.
PUMP-Q(M/3)	: Quantity of pumped up in section.
PUMP-S.Q(M3)	: Summation of quantity of pumped up.

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*******************************************************
*                                                     *
*   FLOOD SIMULATION BY TWO DIMENSIONAL PLANE MODEL   *
*                                                     *
*                               V01-L01 (83,06)       *
*******************************************************

EASTERN SUBURBAN-BANGKOK FLOOD SIMULATION MODEL(CASE-PM-520)

RESTART  KEY      =     0

INERTIAL KEY      =     0

FIRST ITEM KEY    =     1

PUMP CONTROL KEY  =     1

CALCULATION RANGE = 52500 M (  17500 STEP )  T0184920 M (  61640 STEP )

MONITOR  RANGE    = 52500 M (  17500 STEP )  T0184920 M (  61640 STEP )

DELTA T           =  180.0SEC

PRINT INTERVAL    =   1440 M (    480 STEP )

FILE PUT INTERVAL =     30 M (     10 STEP )

NO. OF BLOCK(I,J) =  7, 15

NO. OF Q-BND      =     7

NO. OF H-BND      =     4

NO. OF PUMP       =     5

NO. OF WIER       =     3

NO. OF GATE       =     6
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FLOOD SIMULATION HY TWO DIMENSIONAL PLANE MODEL

EASTERN SUBURBAN-BANGKOK FLOOD SIMULATION MODEL(CASE-PM-520)

STEP= 56640 TIME=(2832H 0M 0S)

B.NO	VOL(M3)	Z(M)	D-MAX(M)	D-MEAN(M)	S-AREA(M2)	TYPE	Q(M3/S)	S.Q+(M3)	S.Q-(M3)	PUMP-Q(M3/S)	PUMP-SQ(M3)
3, 5	0.	0.090	0.	0.	0.						
							0.	0.	0.		
							0.	0.	0.		
4, 5	920125.	0.926	3.926	* 0.176	2.800E+06	G P	-1.889E+01	1.097E+02	-1.013E+08	-1.500E+00	-9.376E+06
							0.	0.	0.		
6, 5	1836333.	0.957	3.457	* 0.457	6.000E+06	OC	-1.214E+01	3.797E+04	-8.543E+07		
							0.	0.	0.		
7, 5	0.	0.	0.	0.	0.		-1.061E+01	0.	-6.115E+07		
							0.	0.	0.		
4, 6	3541022.	0.941	2.441	* 0.241	1.630E+07		0.	0.	0.		
						OC	-3.484E+00	4.505E+06	-2.808E+07		
6, 6	7545214.	0.957	2.957	* 0.457	2.870E+07	OC	-1.124E+00	2.326E+04	-7.419E+06		
						OC	-1.590E+00	9.823E+06	-3.073E+07		
2, 7	490857.	1.026	2.526	* 0.026	3.479E+06		0.	0.	0.		
							0.	0.	0.		
4, 7	7205453.	1.018	2.518	* 0.618	1.804E+07	OC	6.322E-01	5.277E+06	-3.281E+05		
						P	0.	0.	0.	-1.000E+00	-6.459E+06
5, 7	9083220.	1.041	2.541	* 0.641	2.221E+07	OC	-1.554E+00	1.184E+04	-1.514E+07		
							0.	0.	0.		
6, 7	12084783.	1.041	3.041	* 0.341	4.067E+07	OC	-5.300E+00	0.	-4.373E+07		
						OC	-2.083E+00	9.631E+04	-1.306E+07		
1, 8	0.	0.090	0.	0.	0.		0.	0.	0.		
							0.	0.	0.		
2, 8	410583.	0.739	5.239	5.264	7.800E+04	OC	-1.215E+02	2.824E+07	-3.893E+08		
							0.	0.	0.		
3, 8	1932029.	0.952	4.952	* 0.252	9.100E+06	G P	-1.050E+02	0.	-2.549E+08	-1.600E+01	-1.034E+08
							0.	0.	0.		
4, 8	5479845.	1.011	3.411	* 0.711	1.150E+07	OC	-3.571E+01	9.318E+06	-1.284E+08		
						OC	6.928E+00	2.382E+07	-1.286E+06		
5, 8	2720785.	1.040	3.840	* 0.540	7.476E+06	OC	-1.571E+01	2.379E+05	-9.860E+07		
						OC	3.603E+00	3.863E+07	-9.520E+04		
6, 8	5322955.	1.253	3.853	* 0.853	6.500E+06	W	-1.673E+00	0.	-3.885E+06		
						OC	-6.155E+00	3.343E+05	-3.552E+07		
7, 8	0.	0.	0.	0.	0.		-3.790E+00	0.	-2.183E+07		
							0.	0.	0.		
4, 9	3279254.	0.795	2.295	* 0.395	6.000E+06		0.	0.	0.		
						OC	1.094E+00	5.792E+06	-6.207E+04		
5, 9	11126672.	1.310	2.810	* 0.910	1.470E+07	OC	-1.615E+00	4.249E+04	-8.211E+06		
						OC	-1.042E+01	3.005E+04	-5.195E+07		
6, 9	37982221.	1.311	3.311	* 0.611	5.600E+07	OC	-1.436E+01	0.	-9.886E+07		
						OC	-4.020E+00	2.333E+05	-1.714E+07		
3, 10	1377578.	1.121	5.121	* 0.421	2.600E+06		2.500E+00	1.761E+07	0.		
						OC	-5.311E+01	2.517E+03	-2.337E+08		

FLOOD SIMULATION BY TWO DIMENSIONAL PLANE MODEL

EASTERN SUBURBAN-BANGKOK FLOOD SIMULATION MODEL(CASE-PM-S20)

STEP= 56640 TIME=(2832H 0M 0S)

B.NO	VOL(M3)	Z(M)	D-MAX(M)		D-MEAN(M)	S-AREA(M2)	TYPE	Q(M3/S)	S.Q+(M3)	S.Q-(M3)	PUMP-Q(M3/S)	PUMP-SQ(M3)
4, 10	1569869.	1.139	4.339	*	0.439	2.679E+06	OC	-3.876E+01	2.871E+02	-1.849E+08		
							G P	0.	0.	0.	3.000E+00	1.870E+07
5, 10	2944069.	1.257	4.157		0.626	4.700E+06	OC	-1.475E+01	2.158E+05	-1.123E+08		
							OC	1.828E+00	4.079E+07	-1.461E+06		
6, 10	1897928.	1.632	4.432	*	0.132	8.100E+06	W	-4.000E+00	0.	-1.189E+07		
							OC	-2.027E+01	0.	-1.088E+08		
7, 10	0.	0.	0.		0.	0.		-1.515E+01	0.	-8.734E+07		
								0.	0.	0.		
2, 11	78130.	1.125	3.125		3.125	2.500E+04		0.	0.	0.		
								0.	0.	0.		
3, 11	8348397.	1.124	3.124	*	0.624	1.450E+07	OC	4.617E-01	6.731E+06	-4.796E+05		
							OC	-1.076E+01	4.215E+06	-3.443E+07		
2, 12	0.	1.320	0.		0.	0.		0.	0.	0.		
								0.	0.	0.		
3, 12	147453.	1.351	3.351		3.351	4.400E+04	G P	-3.007E+00	0.	-4.483E+07	-3.000E+00	-1.364E+07
4, 12	8782556.	1.334	2.834	*	0.334	2.500E+07	G	-6.131E+00	2.910E+06	-1.843E+07		
							OC	5.945E-01	3.565E+06	-2.258E+06		
							OC	-2.004E+01	2.500E+04	-5.265E+07		
2, 13	0.	1.320	0.		0.	0.		0.	0.	0.		
								0.	0.	0.		
3, 13	2775040.	1.473	3.473		0.907	3.060E+06	G	-6.396E+00	0.	-5.183E+07		
4, 13	16437127.	1.355	3.255	*	0.755	2.309E+07	OC	-1.123E+01	2.238E+05	-5.529E+07		
							OC	1.818E+00	2.601E+06	-7.562E+06		
							OC	-1.568E+01	0.	-4.018E+07		
5, 13	17713886.	1.552	3.552	*	0.852	2.420E+07	OC	-3.041E+00	2.388E+05	-7.421E+06		
							OC	-9.290E+00	1.324E+03	-5.969E+07		
3, 14	616150.	1.631	3.631		0.205	3.000E+06		0.	0.	0.		
							W	-1.677E+01	2.250E+04	-9.087E+07		
4, 14	51035529.	1.992	3.992	*	1.292	4.540E+07	OC	-1.496E+01	5.539E+05	-7.496E+07		
							OC	-7.127E+00	0.	-3.260E+07		
5, 14	37372124.	1.992	3.992	*	1.292	3.030E+07	OC	-3.551E+00	3.662E+06	-1.615E+07		
							OC	-1.309E+01	0.	-6.526E+07		
6, 14	100977705.	1.992	3.992	*	1.292	7.940E+07	OC	-3.395E+00	2.648E+06	-1.489E+07		
							OC	-8.961E+00	2.293E+06	-3.080E+07		
4, 15	0.	0.	0.		0.	0.		0.	0.	0.		
5, 15	0.	0.	0.		0.	0.		-1.894E+01	0.	-1.092E+08		
								0.	0.	0.		
6, 15	0.	0.	0.		0.	0.		-1.364E+01	0.	-7.860E+07		
								0.	0.	0.		
								-1.364E+01	0.	-7.860E+07		

S.VOL(M3) 3.630E+08

FLOOD SIMULATION BY TWO DIMENSIONAL PLANE MODEL (V(M3),D-MAX(M), Z(M)) PAGE= 331

EASTERN SUBURBAN-BANGKOK FLOOD SIMULATION MODEL(CASE-PM-520) STEP= 56640 TIME=(2832H 0M 0S)

	1	2	3	4	5	6	7
15	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.
14	0.	0.	616149.750	51035528.500	37372124.000	************	0.
	0.	0.	3.631	3.992	3.992	3.992	0.
	0.	0.	1.631	1.992	1.992	1.992	0.
13	0.	0.	2775039.813	16437126.875	17713885.500	0.	0.
	0.	0.	3.473	3.255	3.552	0.	0.
	0.	1.320	1.473	1.355	1.552	0.	0.
12	0.	0.	147453.262	8782555.500	0.	0.	0.
	0.	0.	3.351	2.834	0.	0.	0.
	0.	1.320	1.351	1.334	0.	0.	0.
11	0.	78130.398	8348396.813	0.	0.	0.	0.
	0.	3.125	3.124	0.	0.	0.	0.
	0.	1.125	1.124	0.	0.	0.	0.
10	0.	0.	1377578.031	1569868.641	2944068.500	1897928.281	0.
	0.	0.	5.121	4.339	4.157	4.432	0.
	0.	0.	1.121	1.139	1.257	1.632	0.
9	0.	0.	0.	3279253.656	11126672.250	37982221.000	0.
	0.	0.	0.	2.295	2.810	3.311	0.
	0.	0.	0.	0.795	1.310	1.311	0.
8	0.	410583.266	1932029.438	5479845.375	2720785.094	5322955.125	0.
	0.	5.239	4.952	3.411	3.840	3.853	0.
	0.090	0.739	0.952	1.011	1.040	1.253	0.
7	0.	490857.438	0.	7205453.063	9083219.625	12084782.750	0.
	0.	2.526	0.	2.518	2.541	3.041	0.
	0.	1.026	0.	1.018	1.041	1.041	0.
6	0.	0.	0.	3541021.781	0.	7545213.750	0.
	0.	0.	0.	2.441	0.	2.957	0.
	0.	0.	0.	0.941	0.	0.957	0.
5	0.	0.	0.	920124.883	0.	1836333.359	0.
	0.	0.	0.	3.926	0.	3.457	0.
	0.	0.	0.090	0.926	0.	0.957	0.
4	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	0.	0.

7. Explanation of Polder Drainage System Model

The typical methods on the hydrological study to establish an effictive polder drainage system as is shown below, were applied as the sample analysis.

1) Rainfall model (Excess model)
2) Runoff model (Quasi storage function model)
3) Water balance model

For this sample analysis, the Ramkamhaeng district was selected as the model area. The flow chart of the analysis is shown in Fig. E.7.

7.1 Basic Study Condition

1) Rainfall model
   a) 5 Year Frequency
   b) Intensity-Duration Curve : $I = \frac{7,600}{t+40}$
   c) Rainfall Pattern : Front Concentration Type
   d) Parameter for Rainfall model

Table E-3 Parameter for Rainfall Model

Land use \ Pattern	Urbanized Area		Paddy Field	Open Space	Total
	Low Density	High Density			
Area (km^2) (%)	7.12 (80.8)	0.18 (2.0)	1.05 (11.9)	0.46 (5.3)	8.81 (100.0)
f1	0.7	0.9	0	0.2	
Rsa	55	55	50	200	
fsa	1.0	1.0	1.0	1.0	
C	240	240	1000	690	

f1 : Initial runoft coefficient
Rsa : Rainfall to be satulated
fsa · Satulated runoff coefficient
C : Value to be determined depending on land use (Refer to runoff model)

3) Runoff Model (Quasi storage function model)

$s = K.Q$

$K = tc/2$

$tc = C.A^{0.22} \cdot re^{-0.35}$

Where;

S : Storage volume

Q : Runoff

K : Constant

tc : Time of concentration (emperical equation)

C : Value to be determined depending on land use

A : Drainage area

re : Excess rainfall

4) Water Balance Model

$V = Qi - Qo$

Where;

V : Change of ponding volume

Qi : Total inflow

Qo : Total outflow

7·2 Cases of Calculation

Table E.4 Calculation Condition

Case	Pump Capacity	Storage Capacity	Hyetograph	Remarks
1.	Varied	Exixting *1)	R_{60} = 76mm/m.	Initial Water Level + 0.2m
2.	Varied	Urbanized *2)	R_{60} = 76mm/m	Pump Operation Water Level + 0.2m

Note: 1) Storage capacity under the existing topographical condition.

2) Storage capacity under the future topographical condition to be urbanized, which is only considered the canal storage. The canal dimensions assumed in this study are as follows:

Width : 9 meter

Length : 9 km

Height of Revetment : +0.5m

7.3 Result of Calculation

Table E.5 Result of Calculation

Case	Pump Capacity		Operation Time	Calculated Flood Level	Lowest Ground Elev. of Residential Land	Remarks
	Specific ($m^3/s/km^2$)	Total (m^3/s)	(Hour)	(m)	(m)	
1.	1.35	11.9	21	+0.50	+0.50	
2.	7.10	62.5	3	+0.50	+0.50	