FIGURES

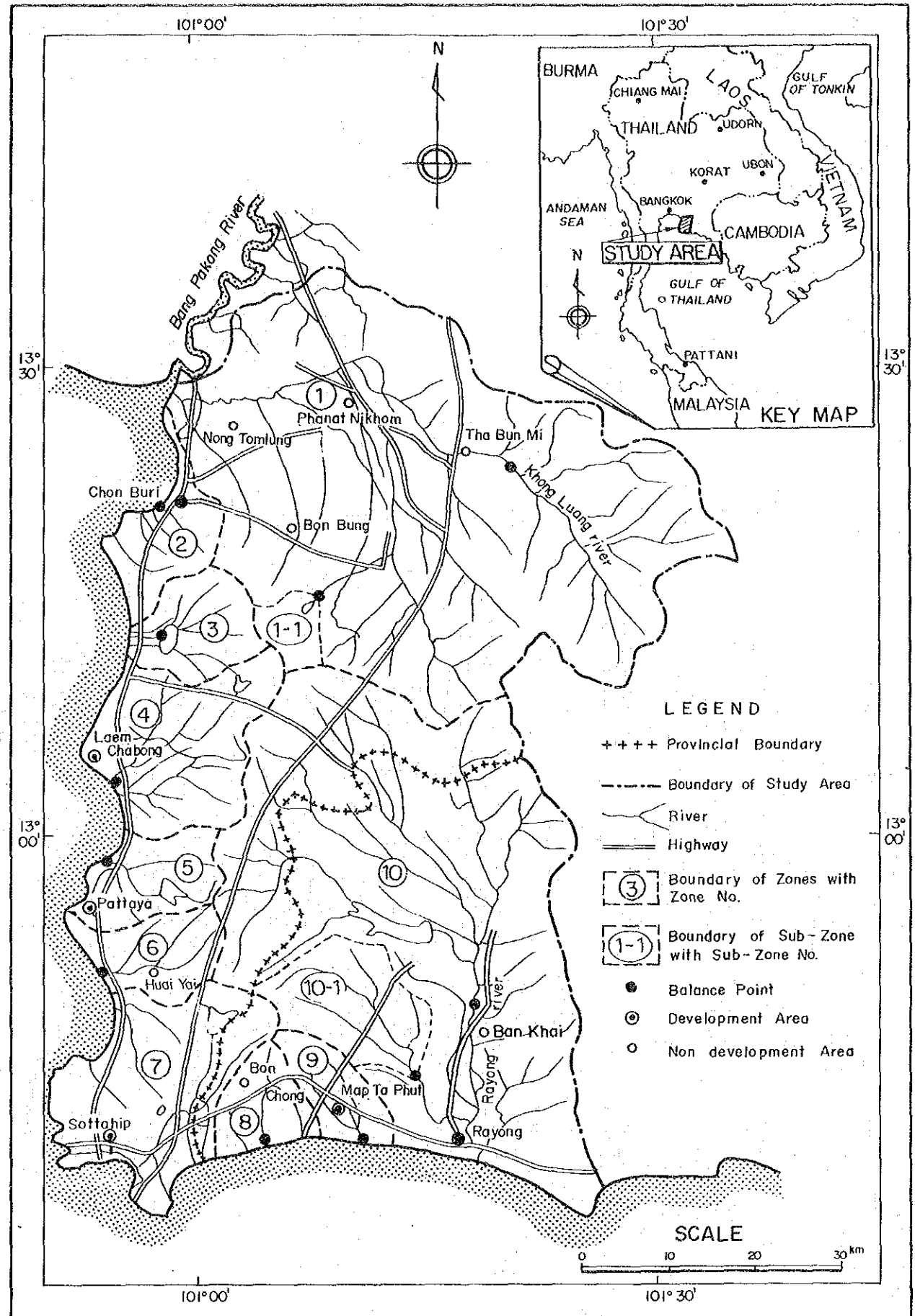

Fig. 1 Zones and Demand Centers

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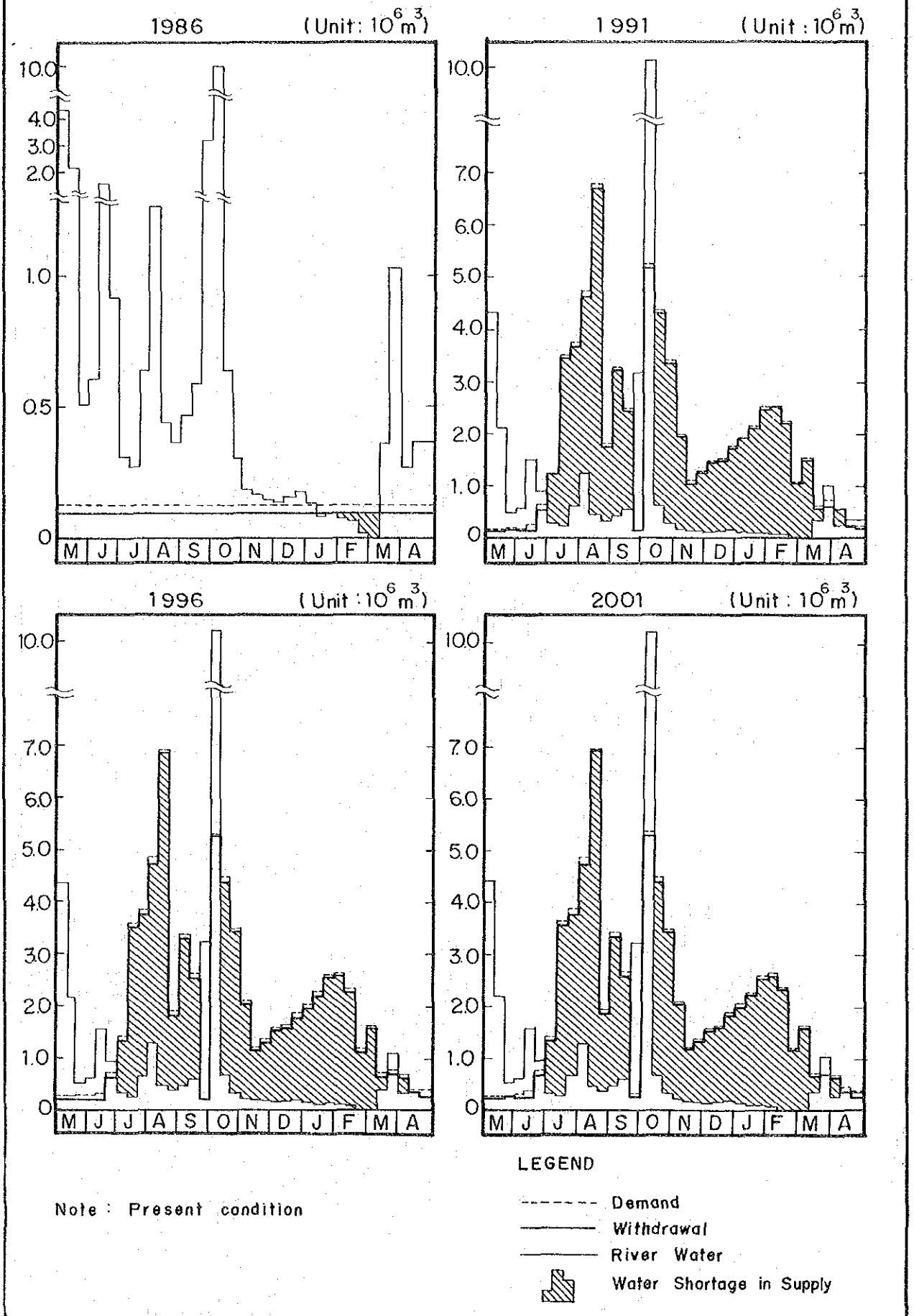

Note : Present condition

Fig. 2 (1) Water Demand and Supply Balance in Zone 1, (1)

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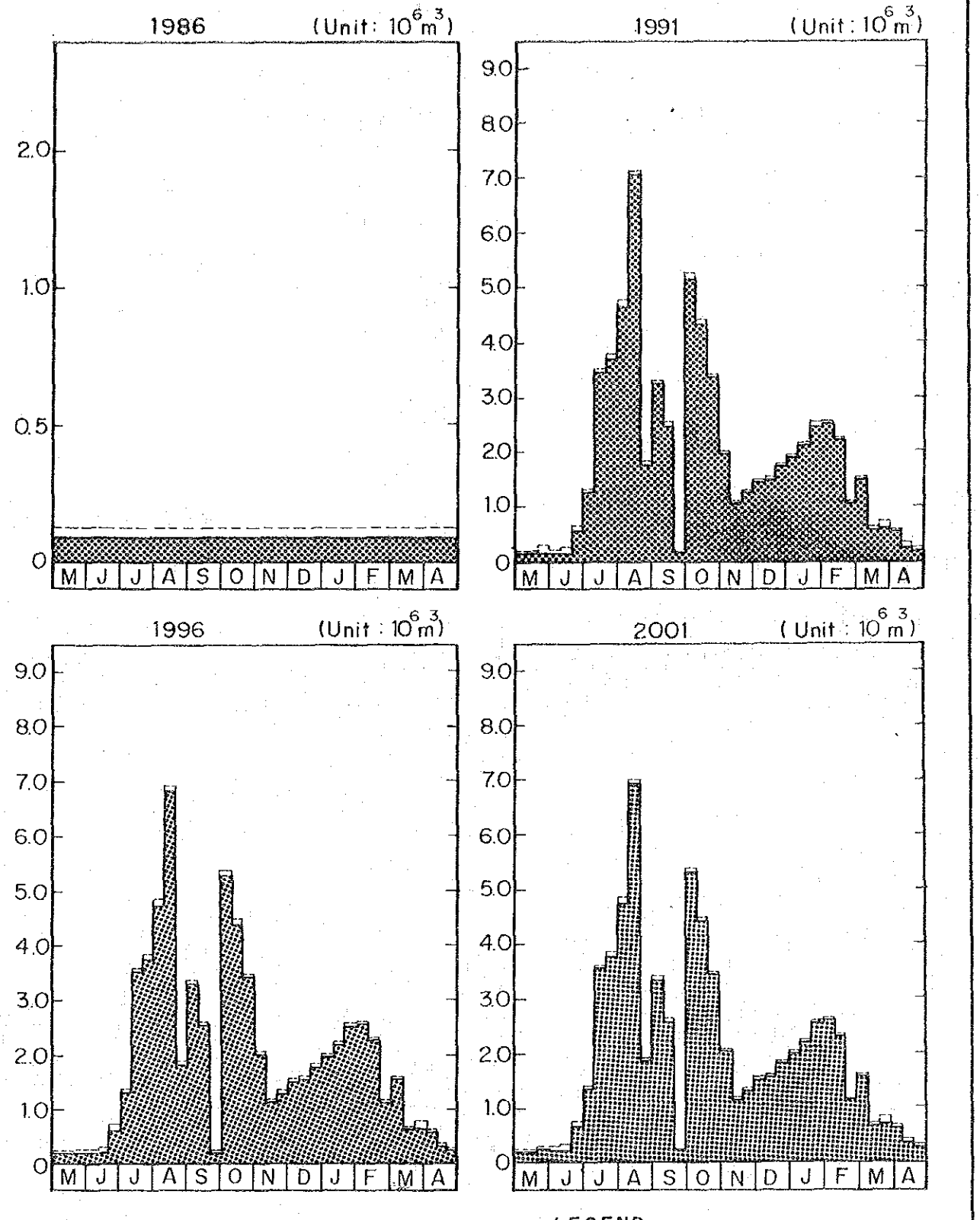

Note: With Khlong Luang Dam

Fig. 2(2)-7 Water Demand and Supply Balance in Zone 1,(2)

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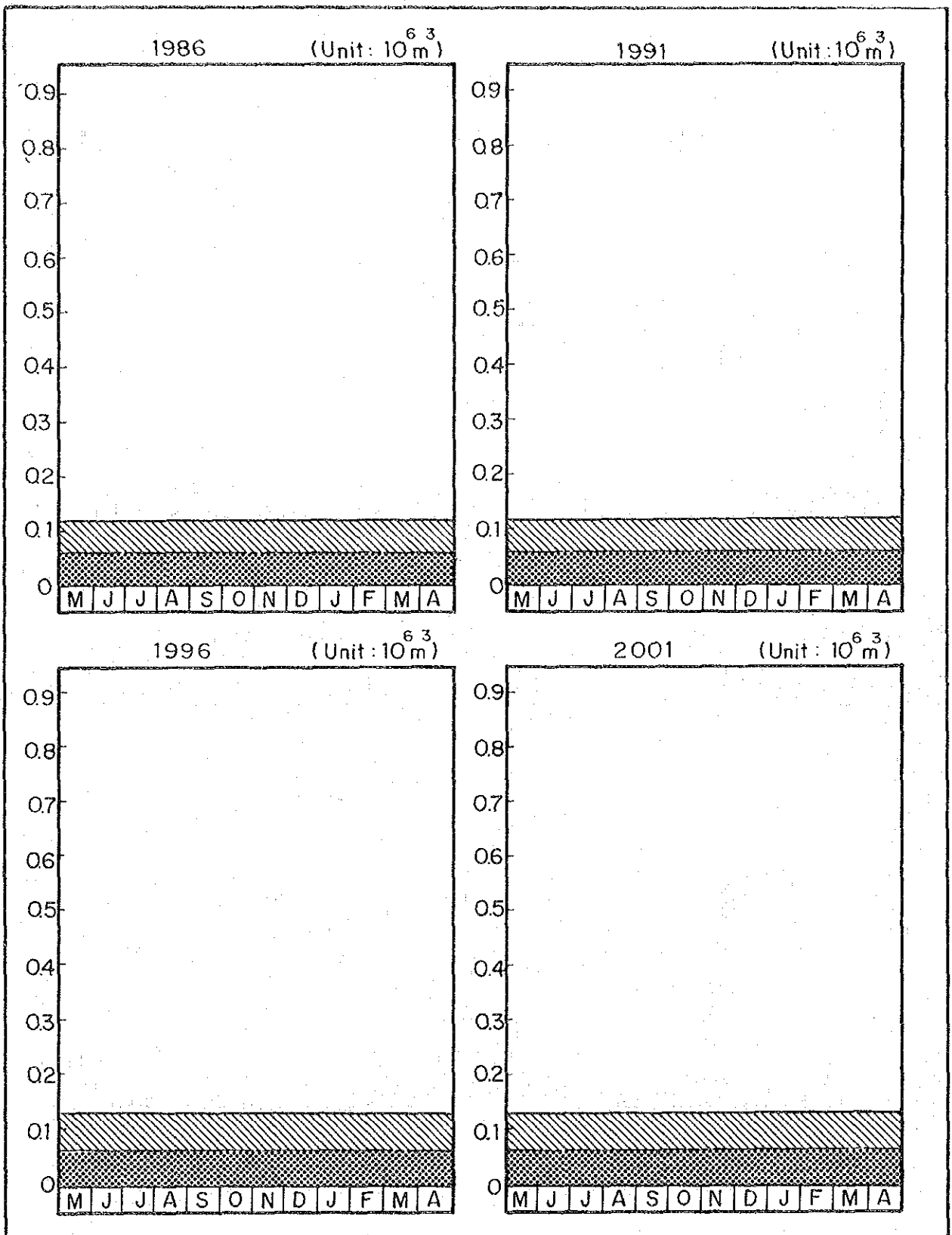

Fig. 3 (1) Water Demand and Supply Balance in Zone 1-1. (1)

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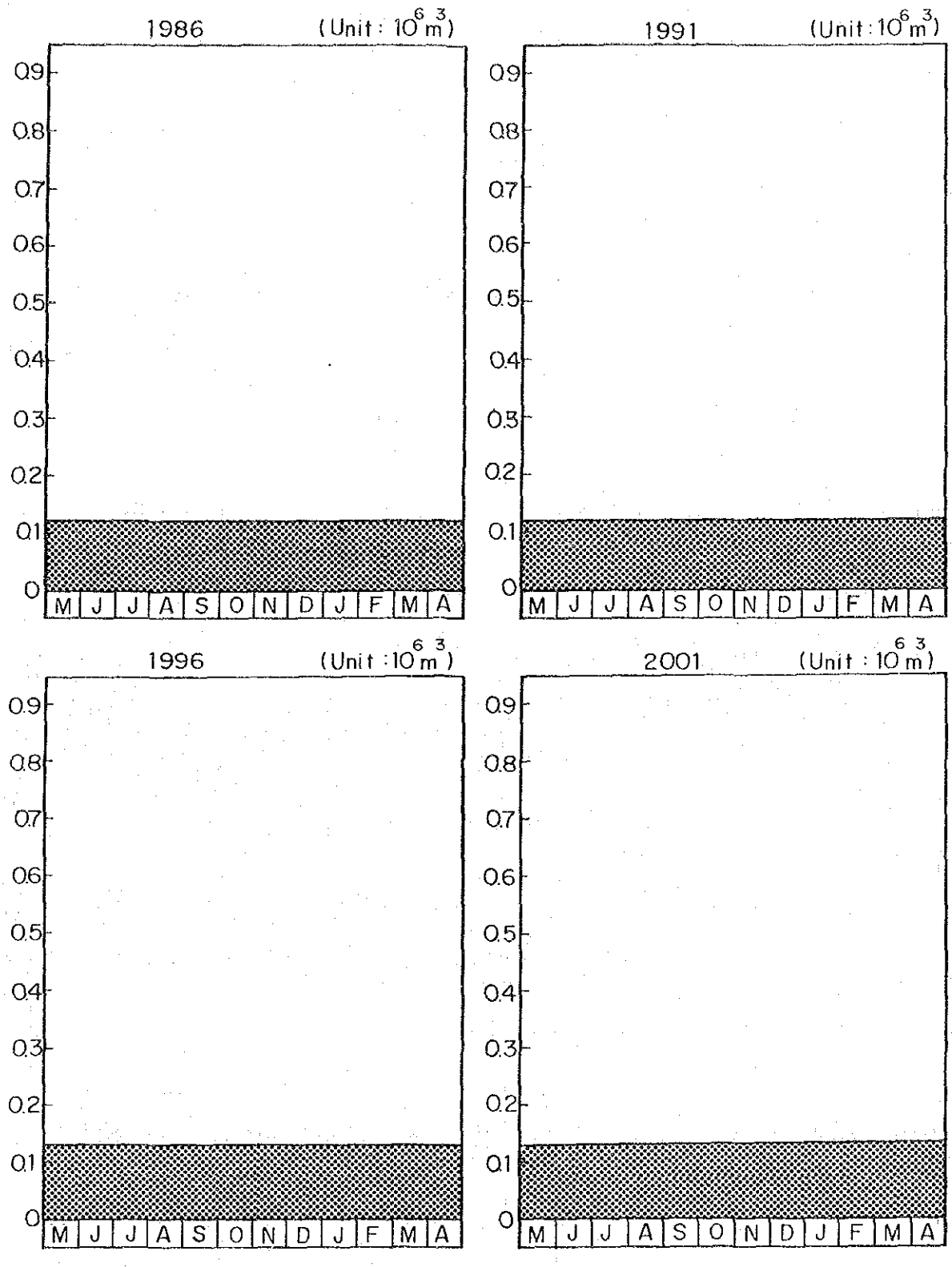

Fig. 3 (2) Water Demand and Supply Balance in Zone 1-1, (2)

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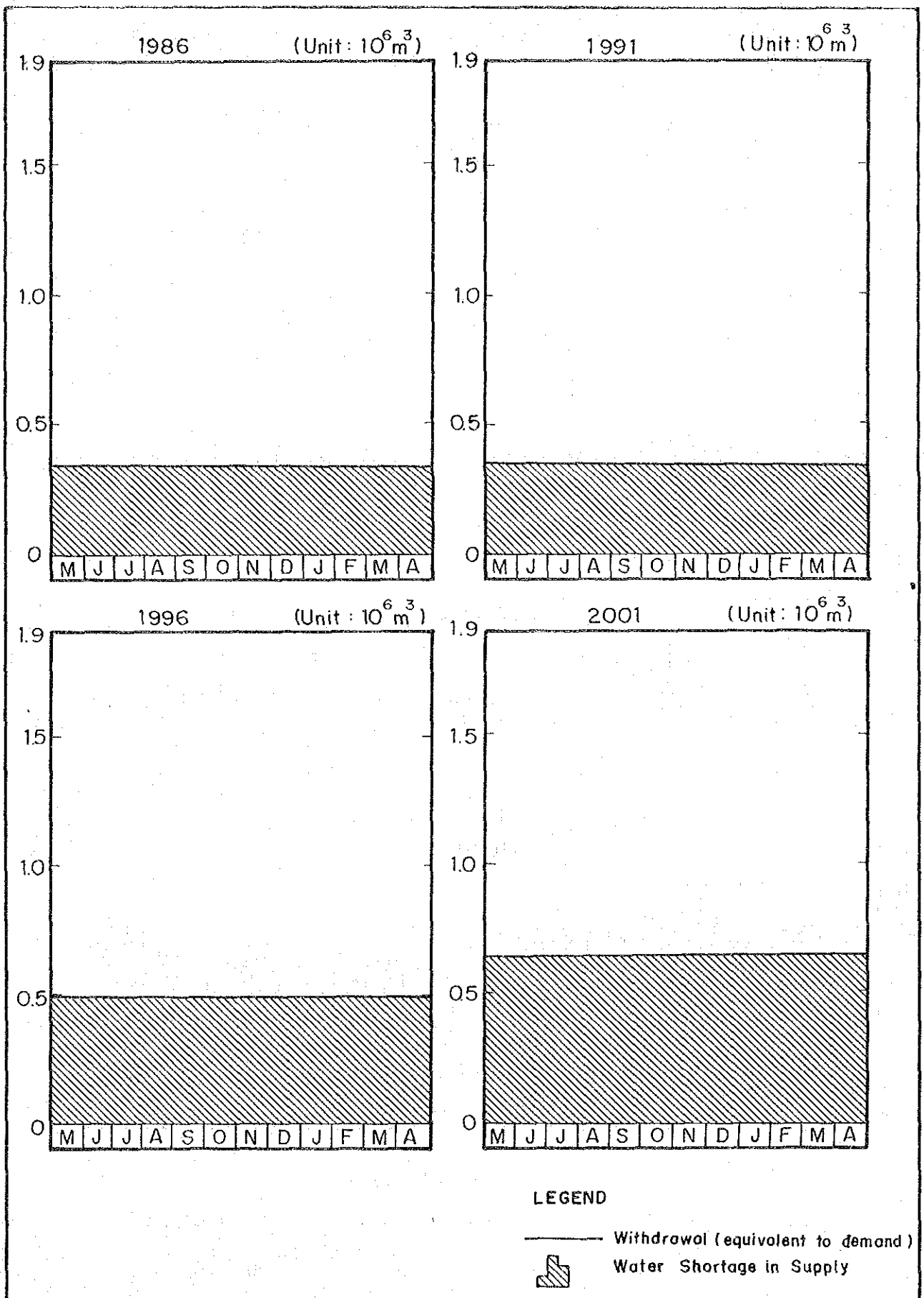

Fig. 4 Water Demand and Supply Balance in Zone 2

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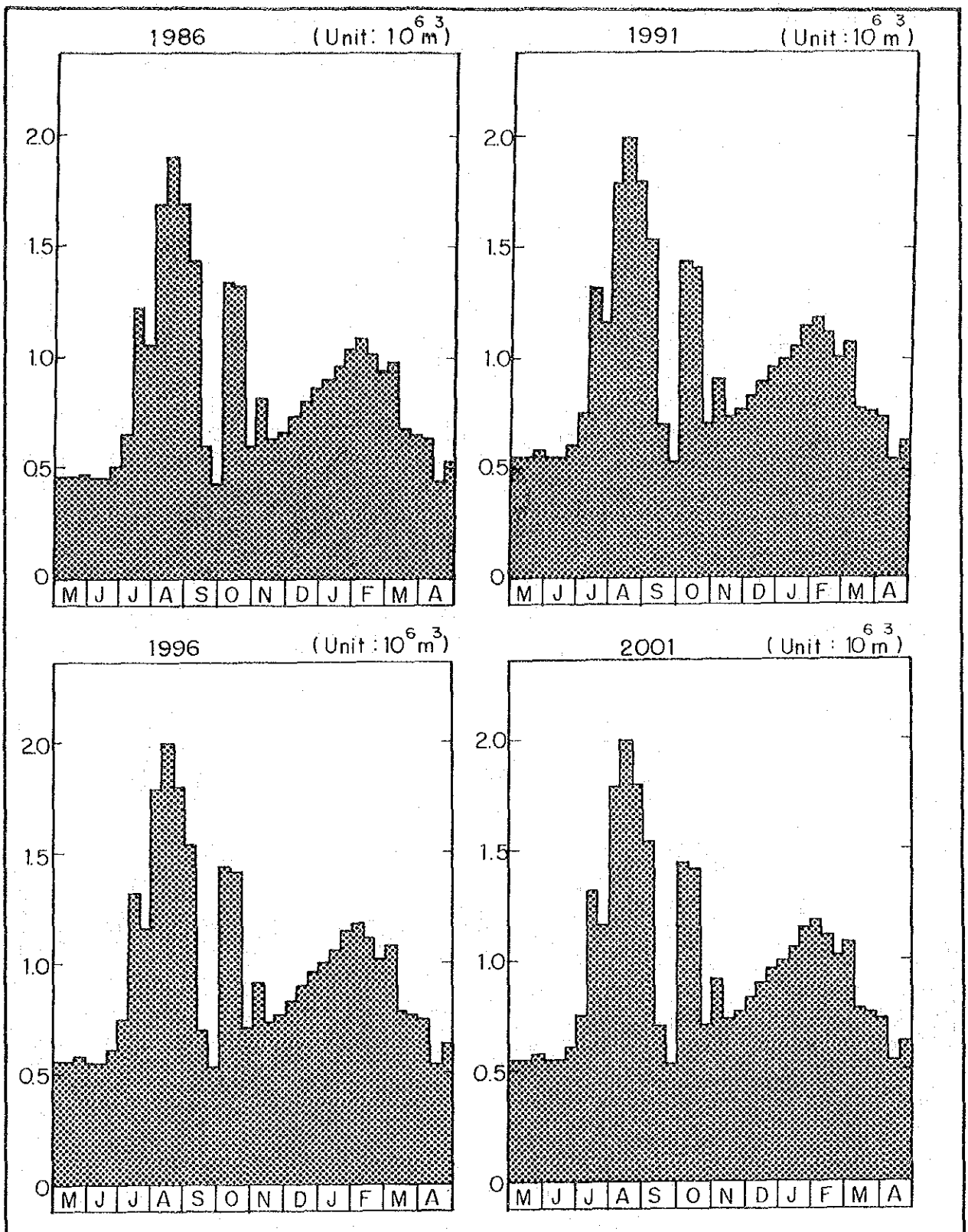

Fig. 5 Water Demand and Supply Balance in Zone 3

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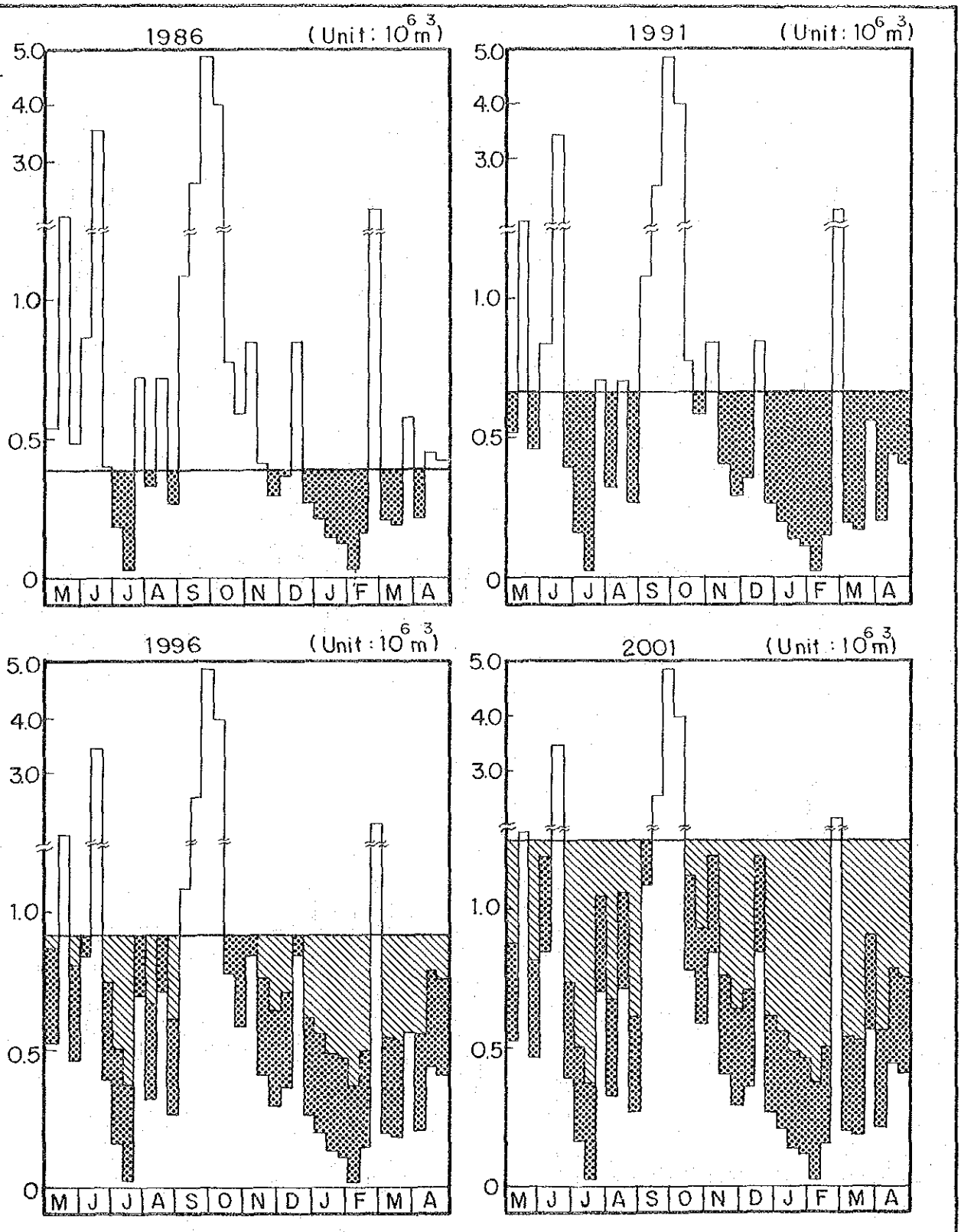

Fig. 6 Water Demand and Supply Balance in Zone 4.

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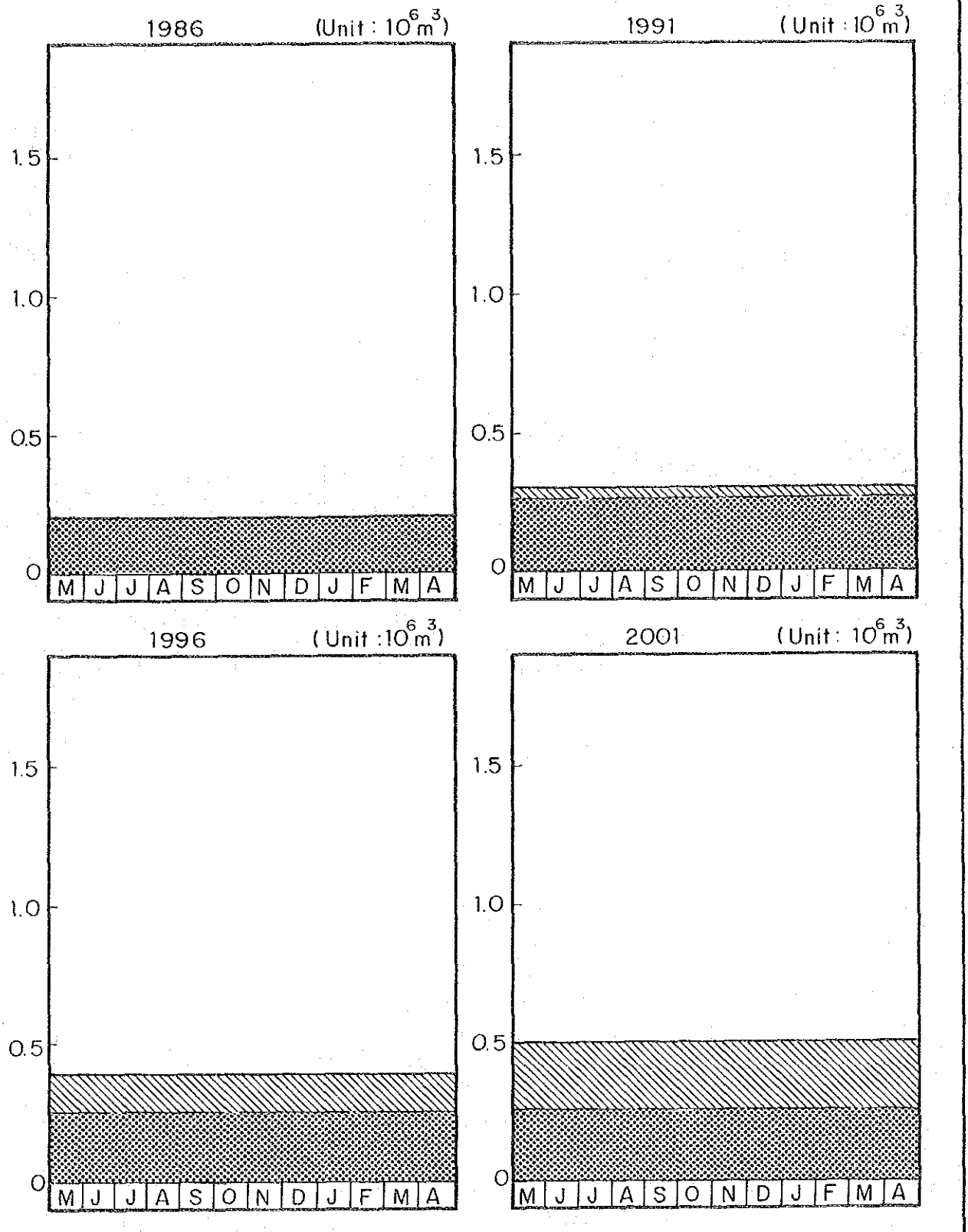

Fig. 7 Water Demand and Supply Balance in Zone 5

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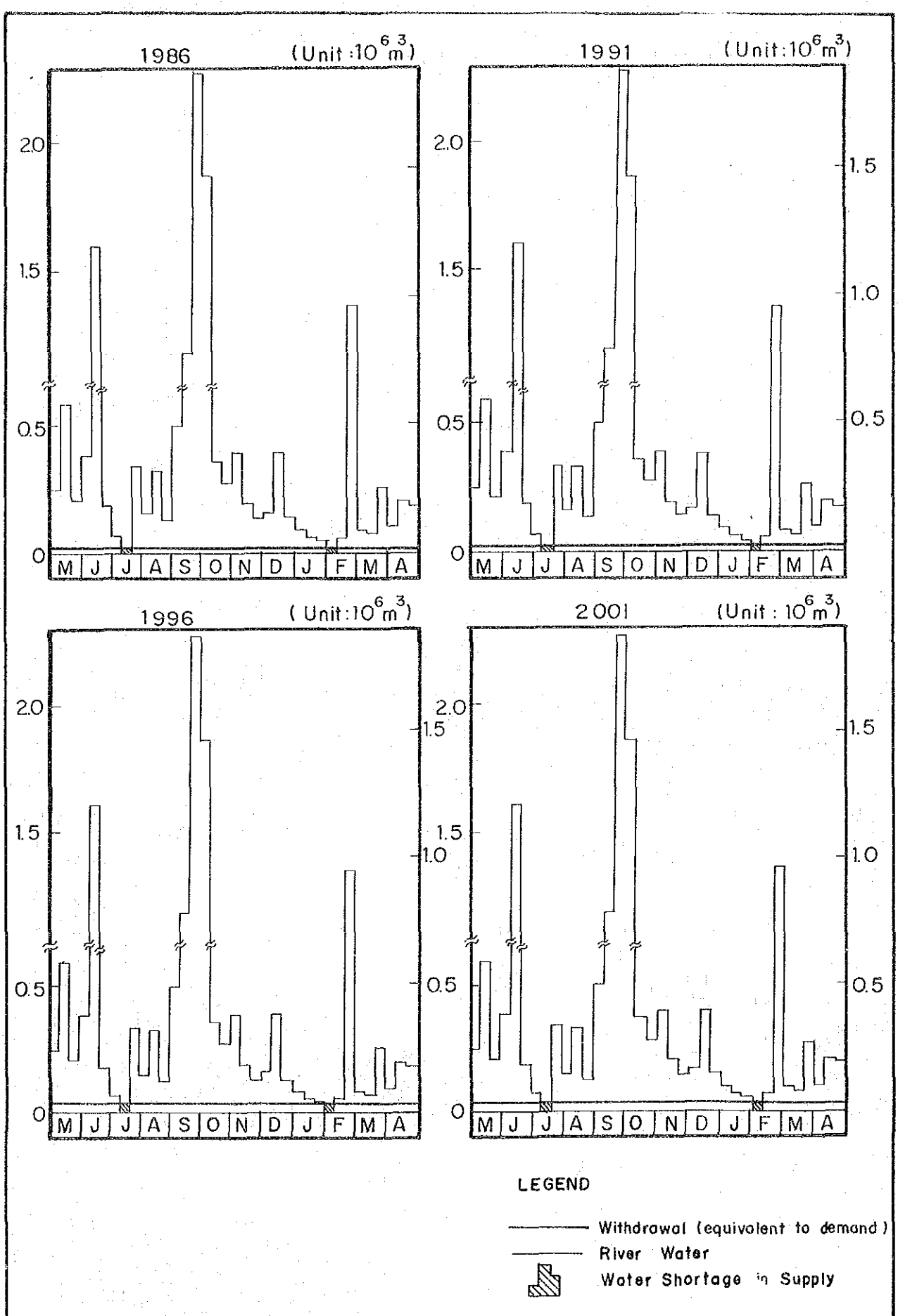

Fig. 8 Water Demand and Supply Balance in Zone 6

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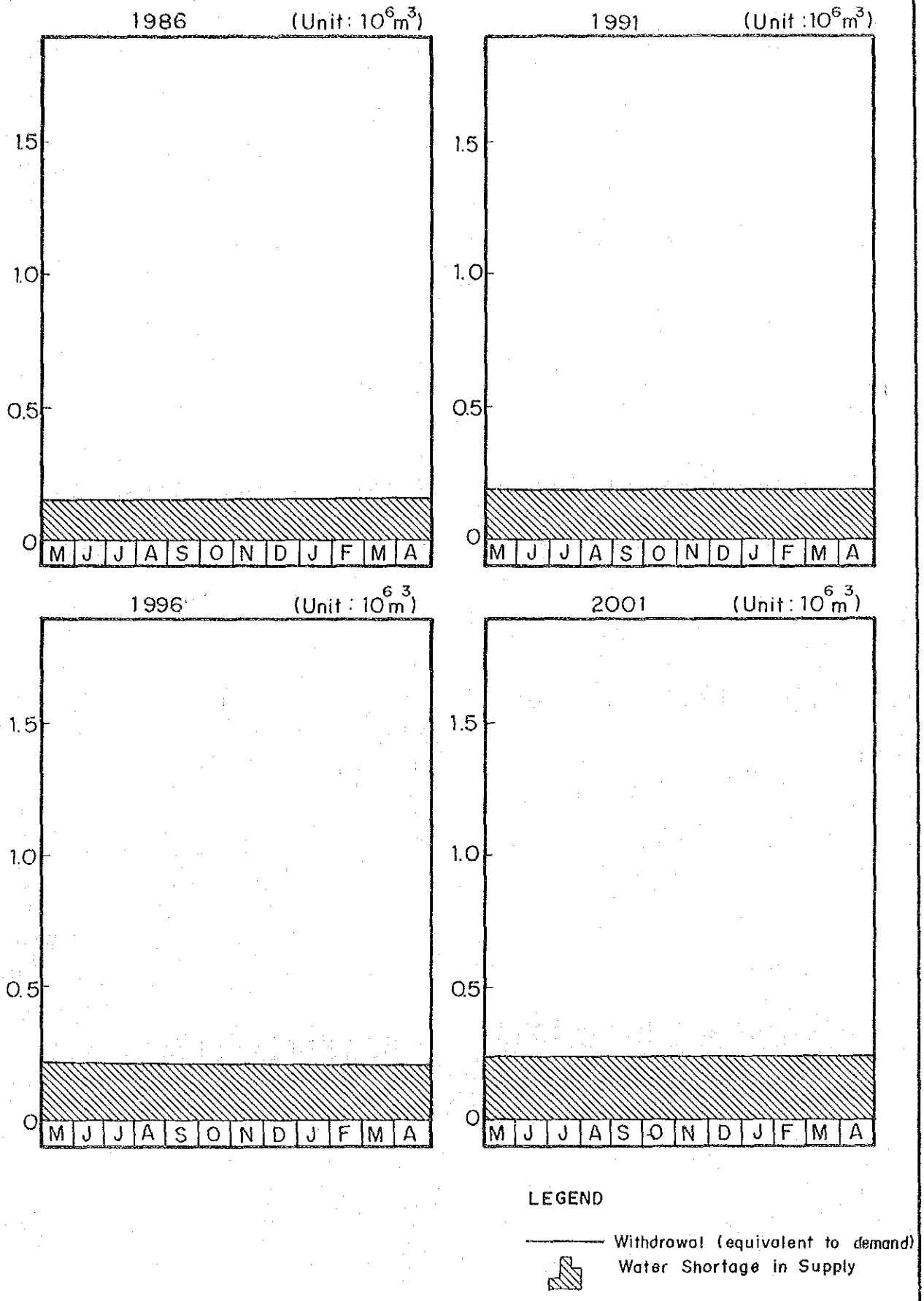

Fig. 9 Water Demand and Supply Balance in Zone 7

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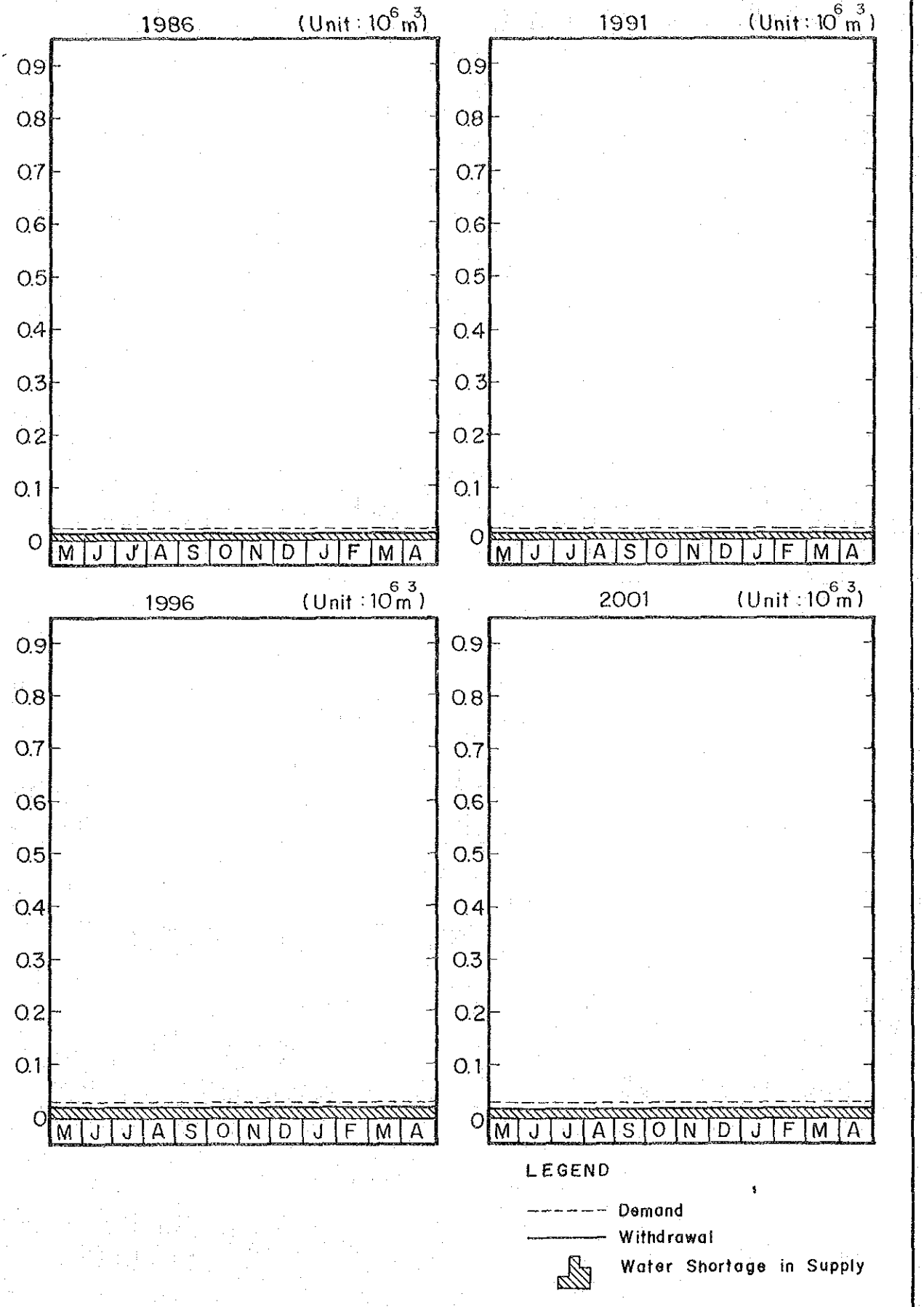

Fig. 10 Water Demand and Supply Balance in Zone 8

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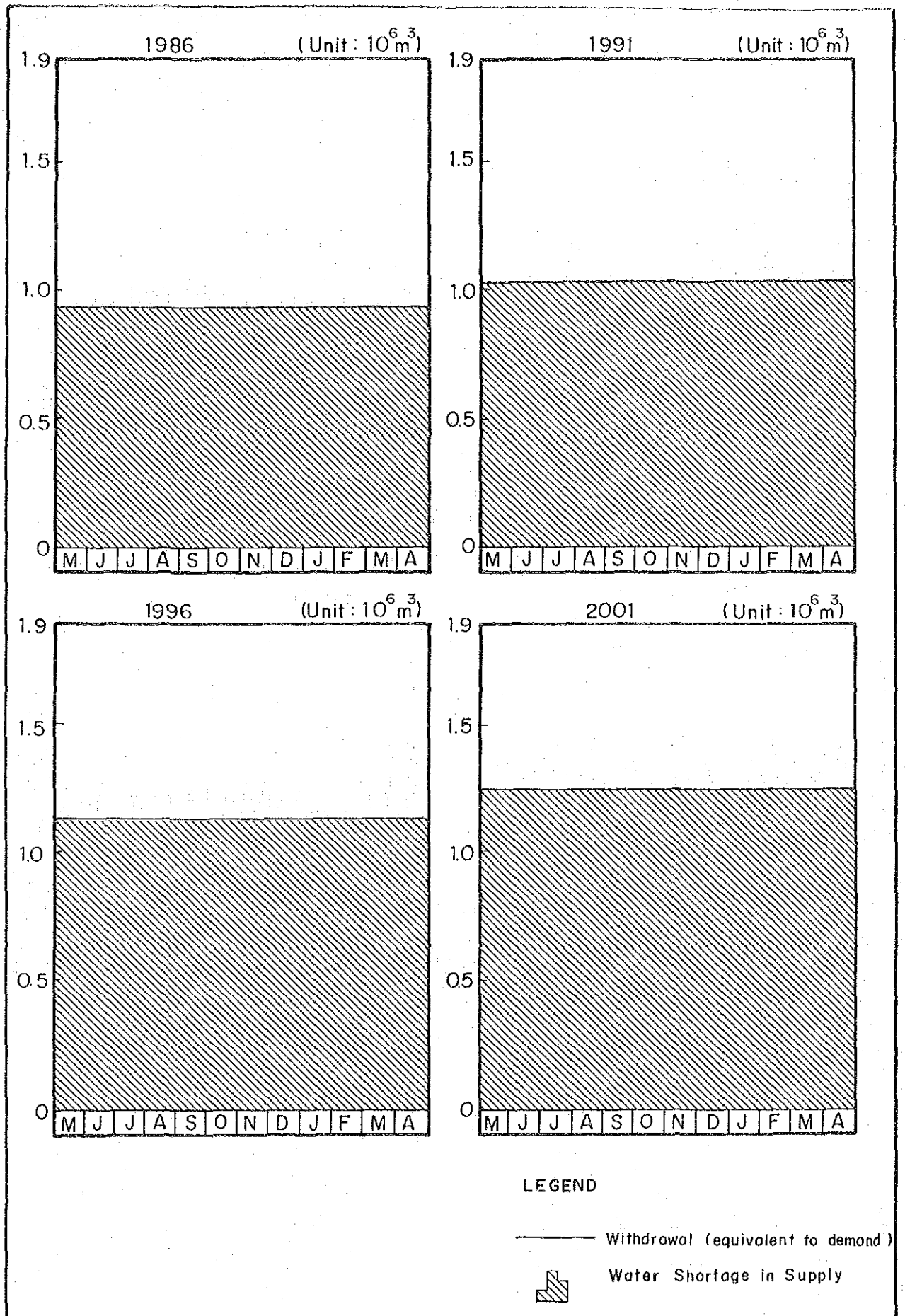

Fig. II Water Demand and Supply Balance in Zone 9

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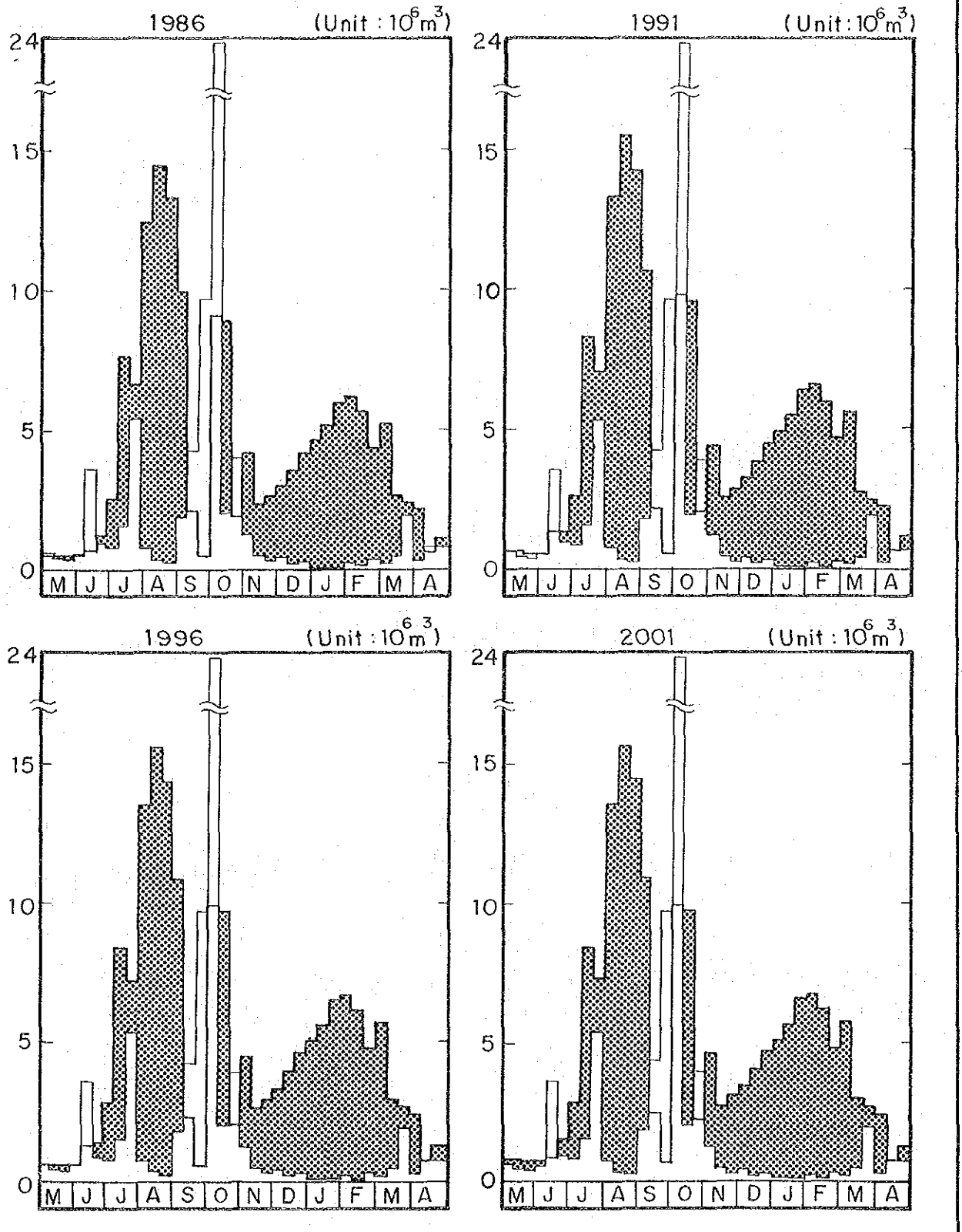

Fig. 12 (1) Water Demand and Supply Balance in Zone 10. (1)

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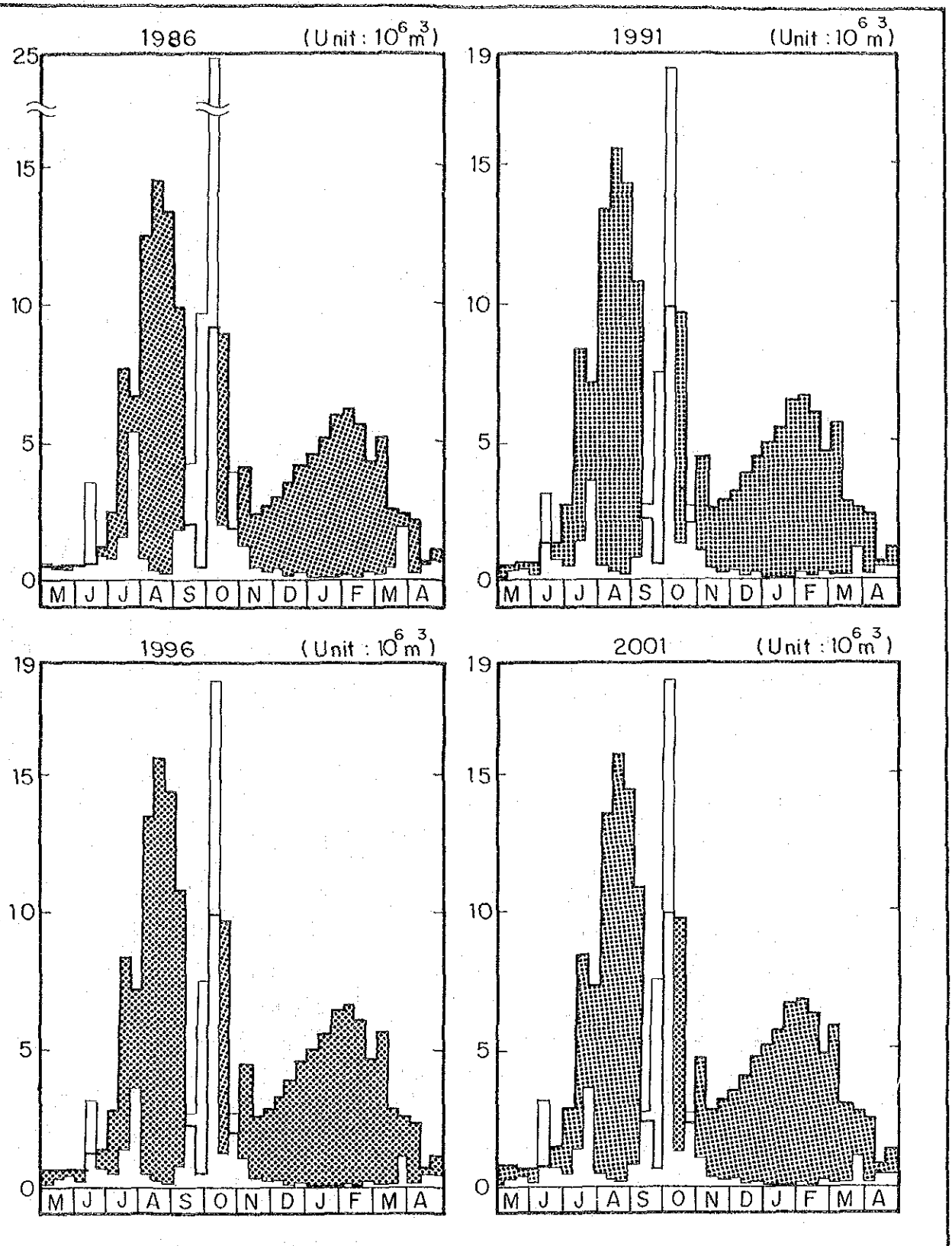

Fig. 12 (2) Water Demand and Supply Balance in Zone 10, (2)

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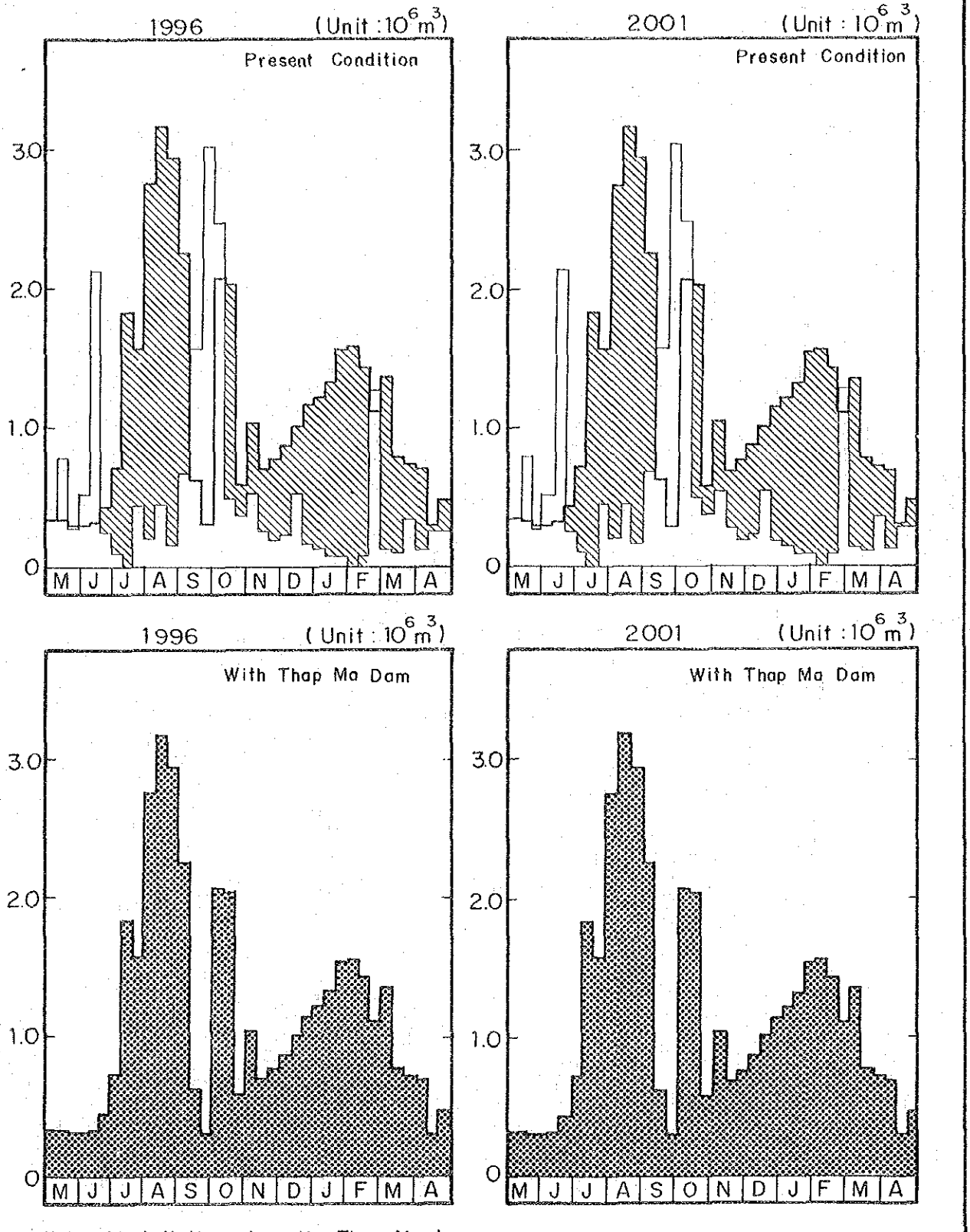

Fig. 13 Water Demand and Supply Balance in Zone 10 - 1

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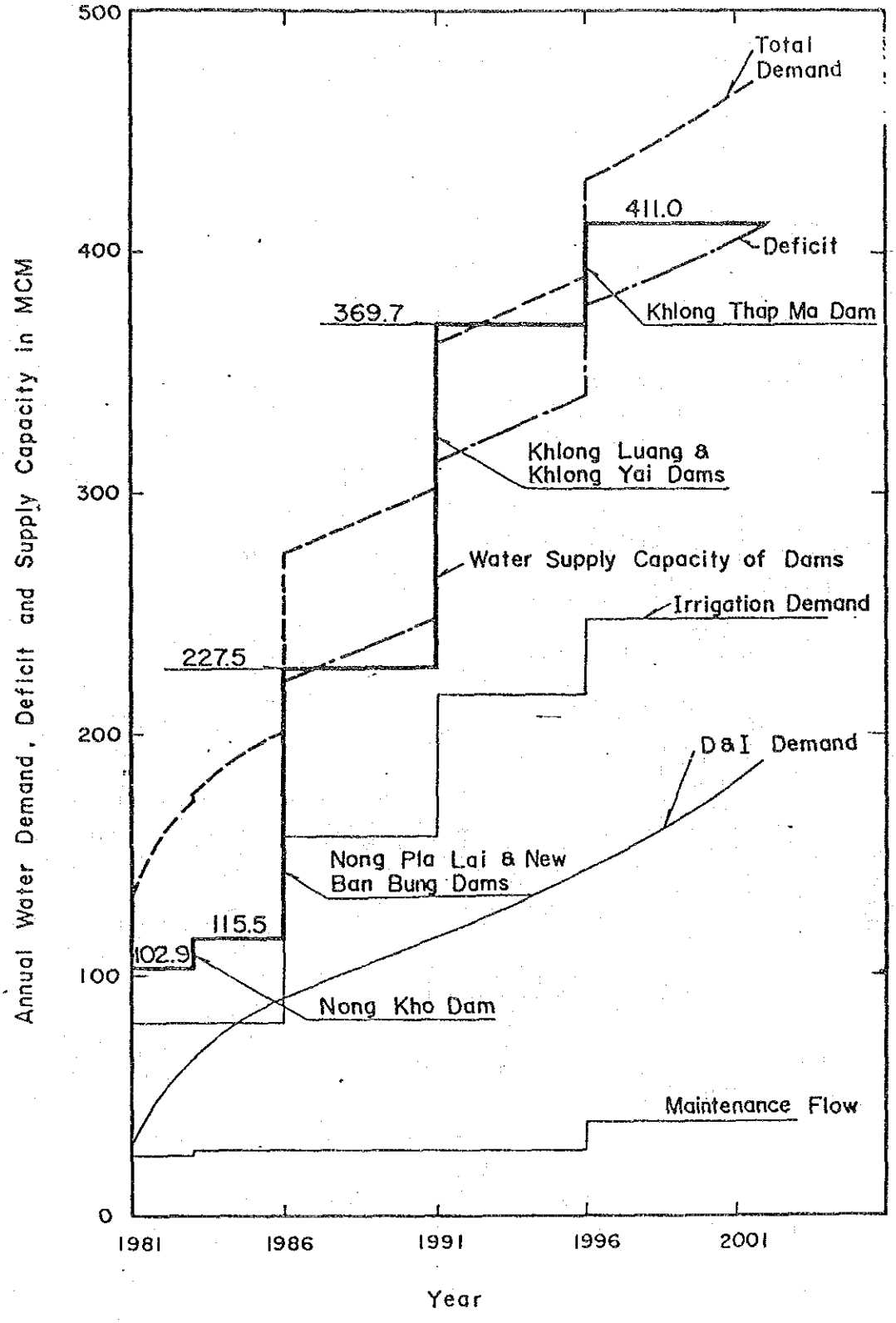

Fig. 14 Relationship among Water Demand, Deficit and Water Supply Capacity of Dams

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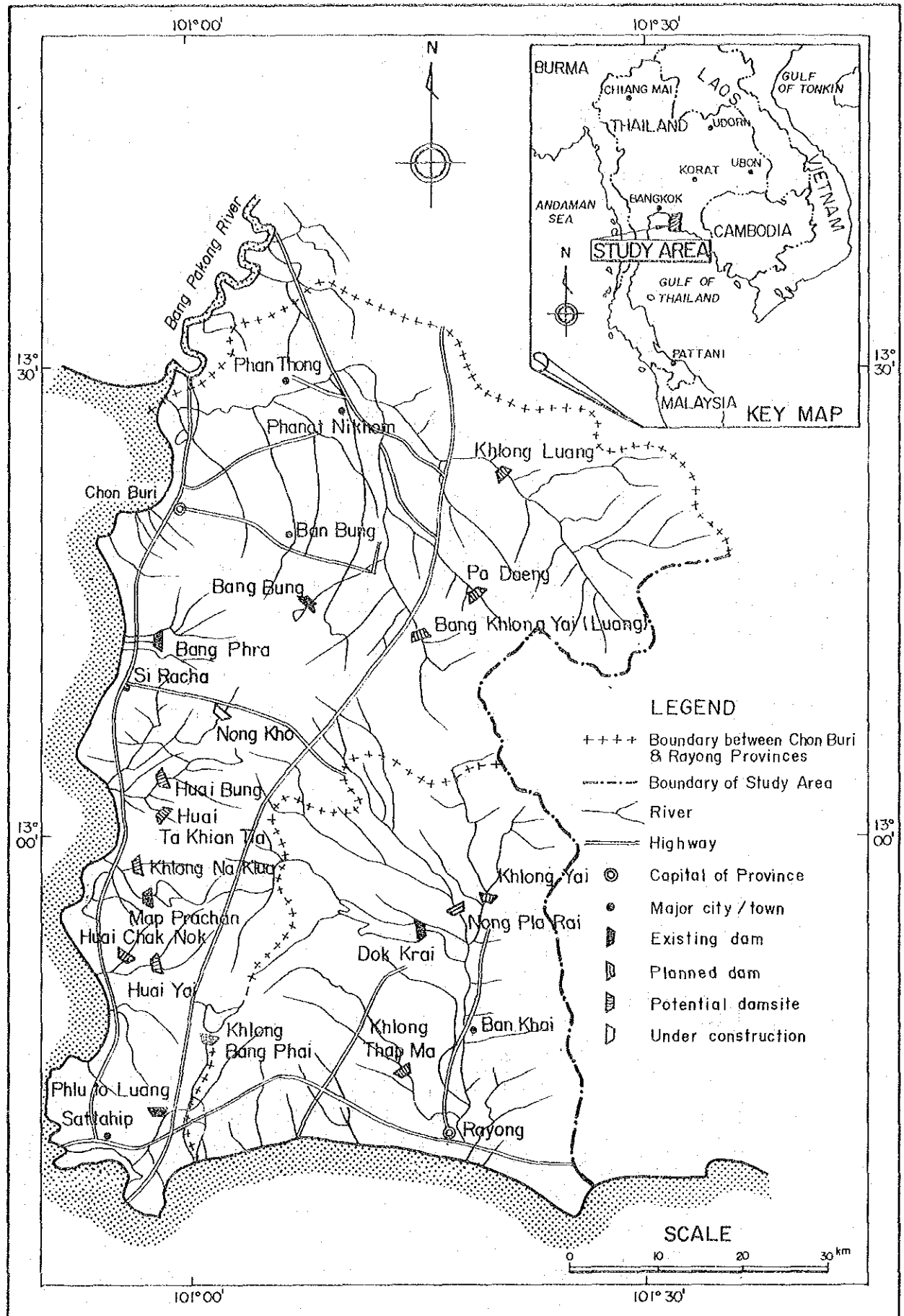

Fig. 15 Location Map of Existing Dams, Planned Dams and Potential Damsites

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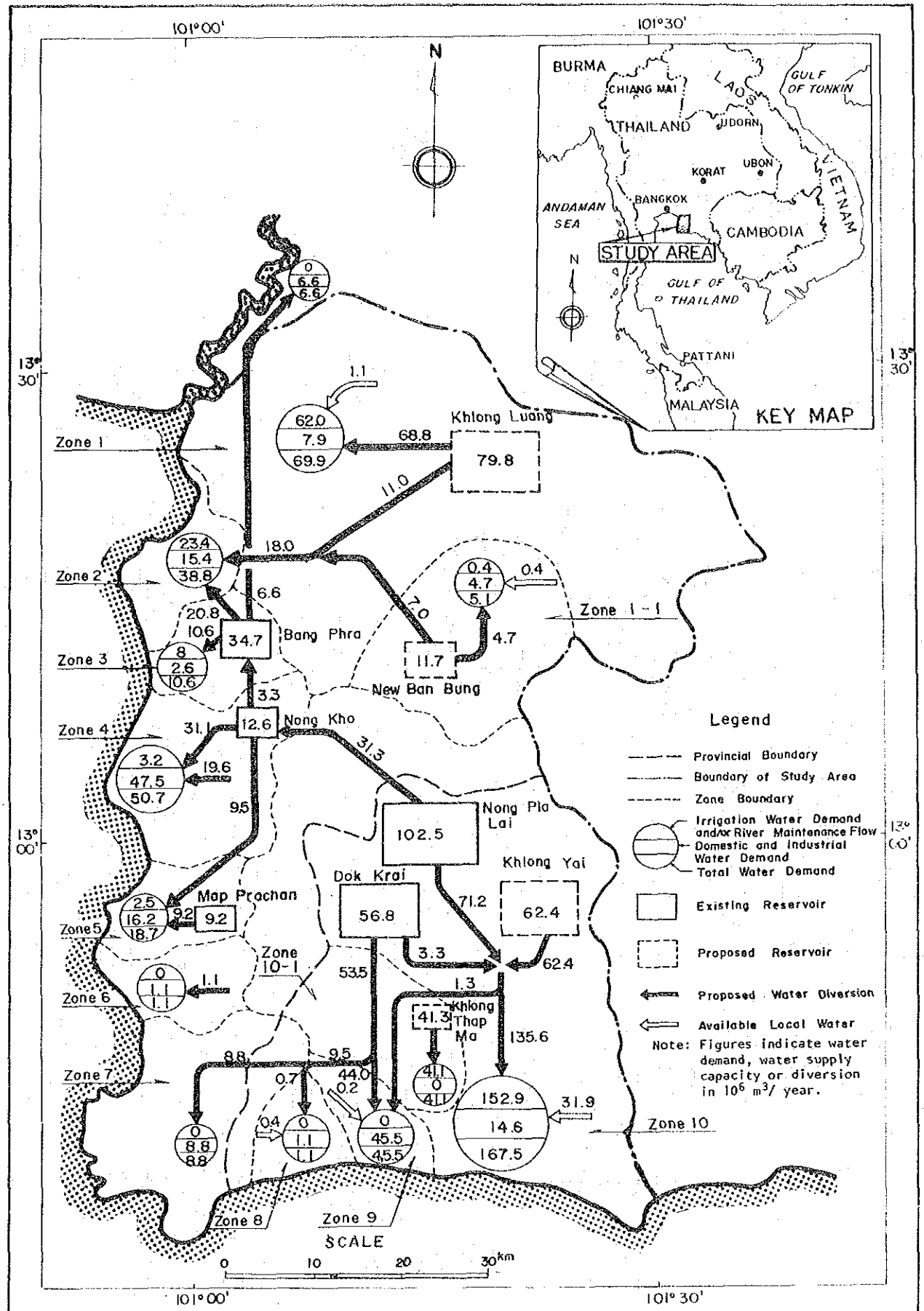

Fig. 16 Water Supply Plan in 2001, Alternative I

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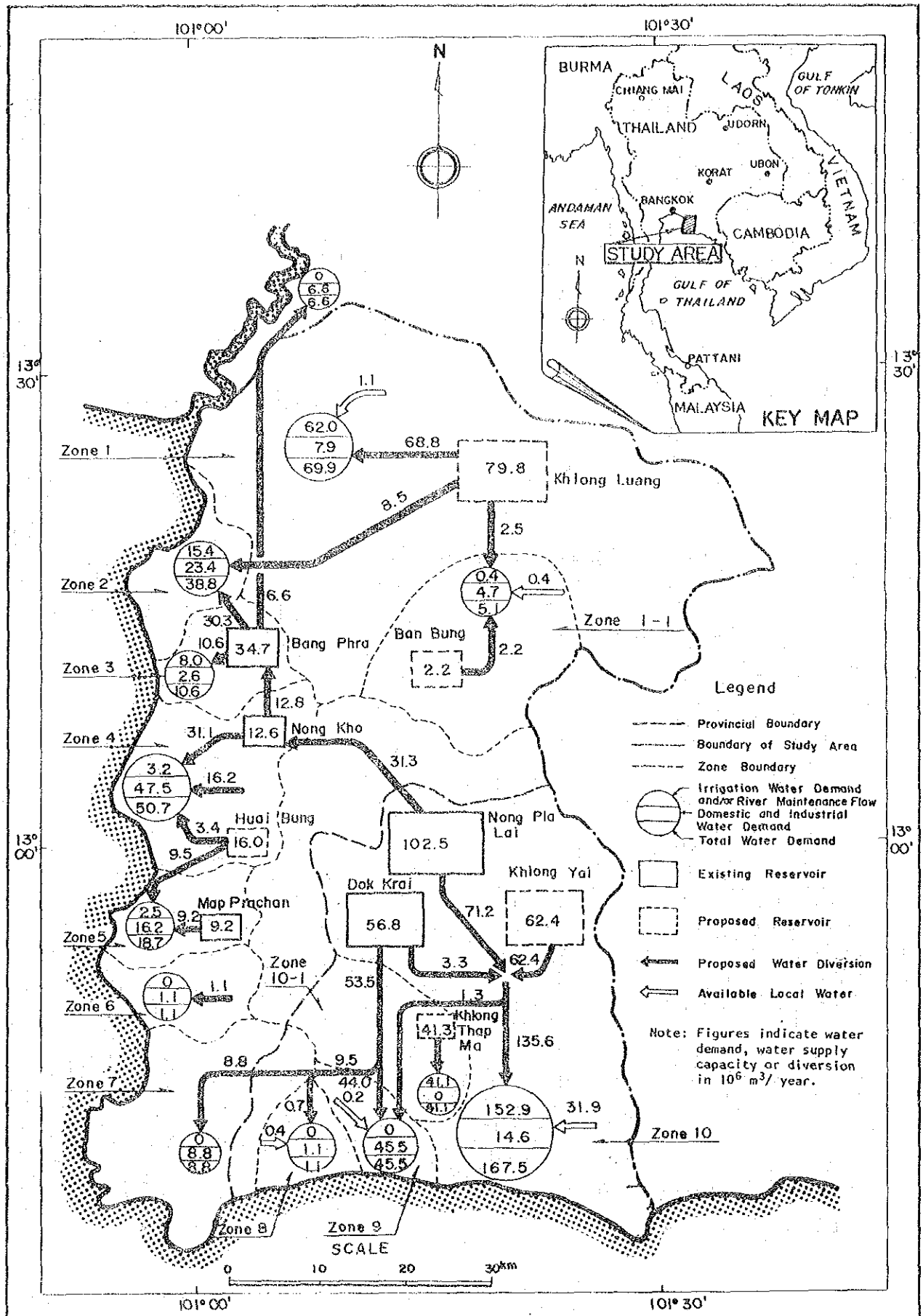

Fig. 17 Water Supply Plan in 2001, Alternative II

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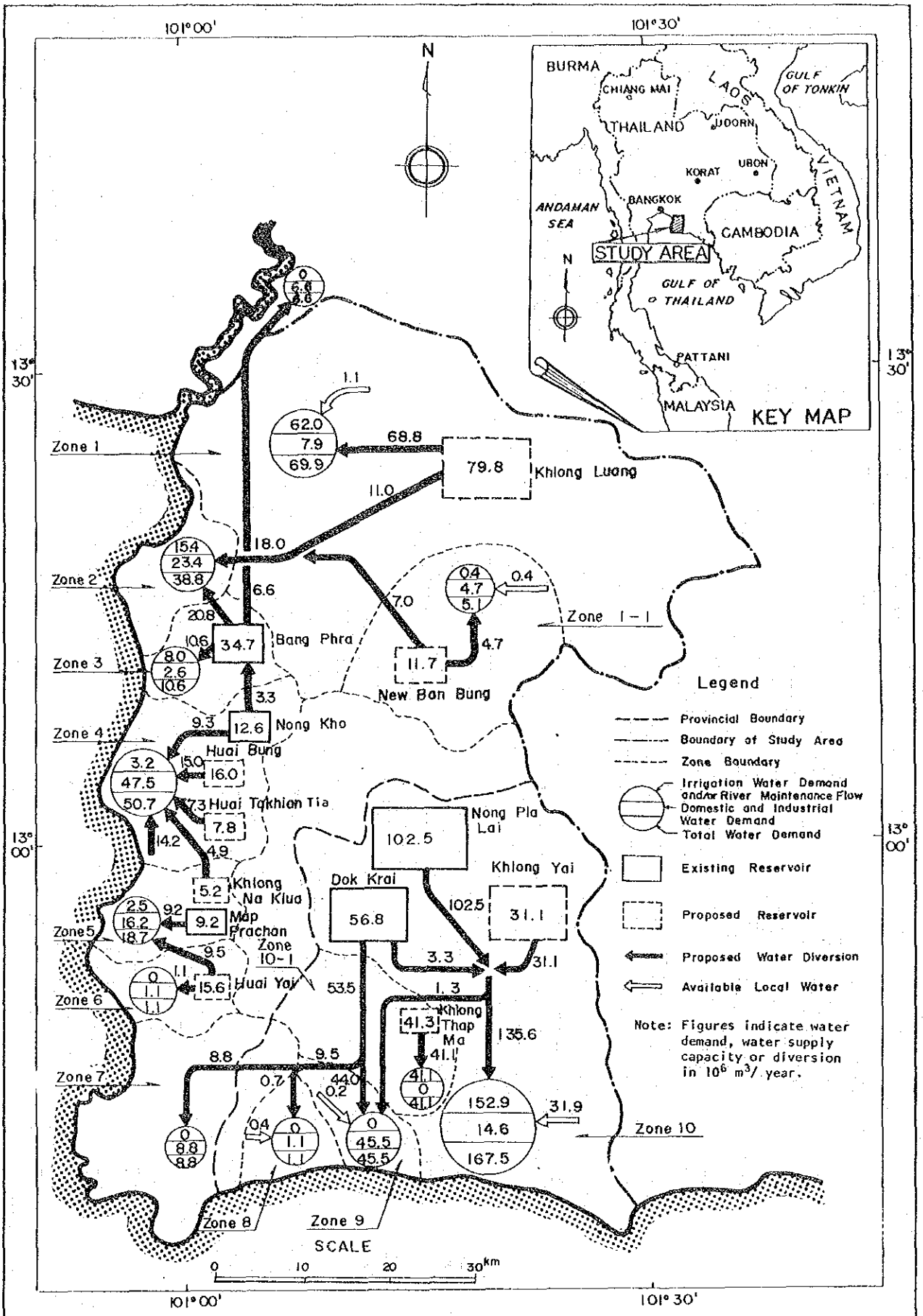

Fig. 18 Water Supply Plan in 2001, Alternative III

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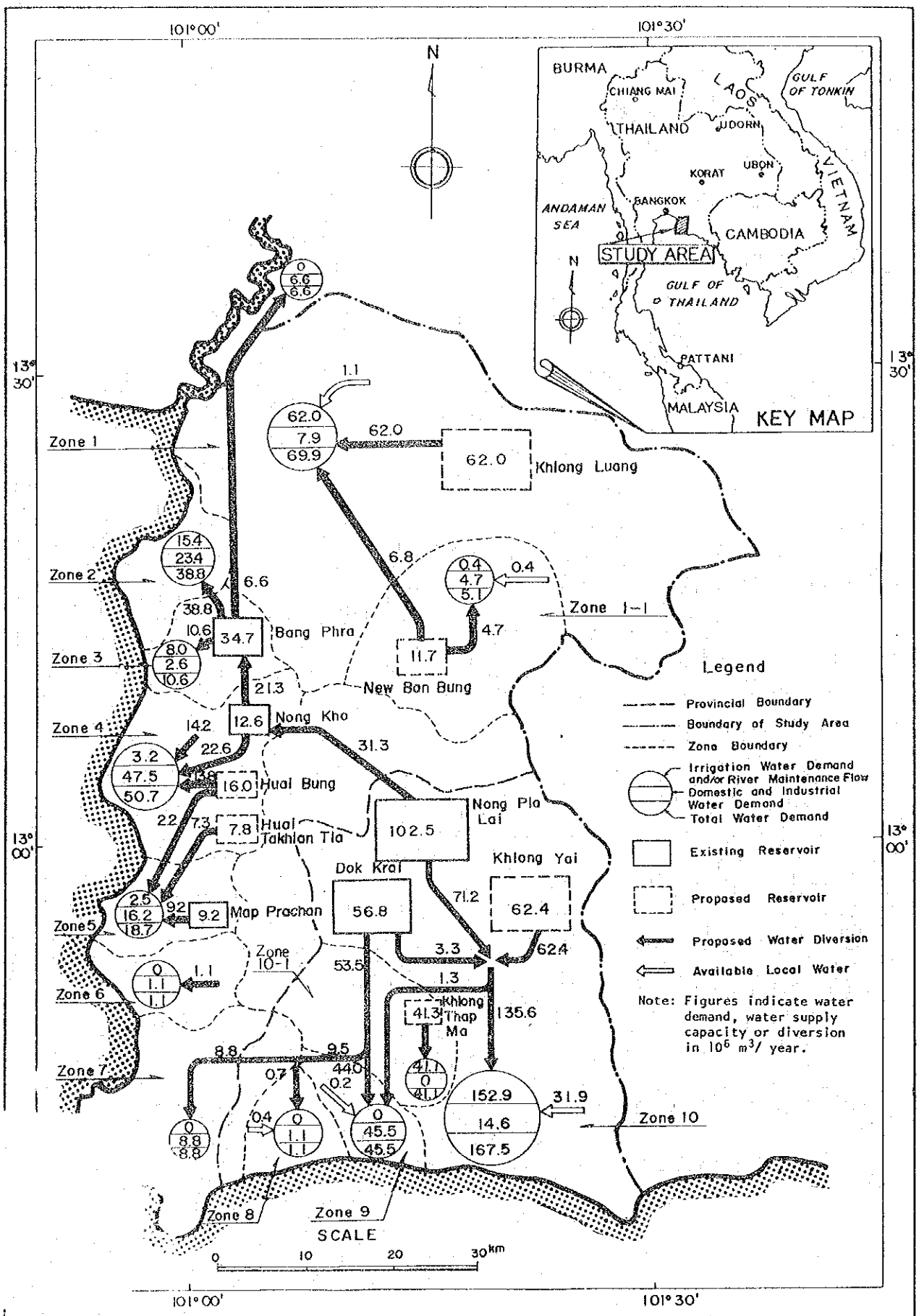

Fig. 19 Water Supply Plan in 2001, Alternative IV

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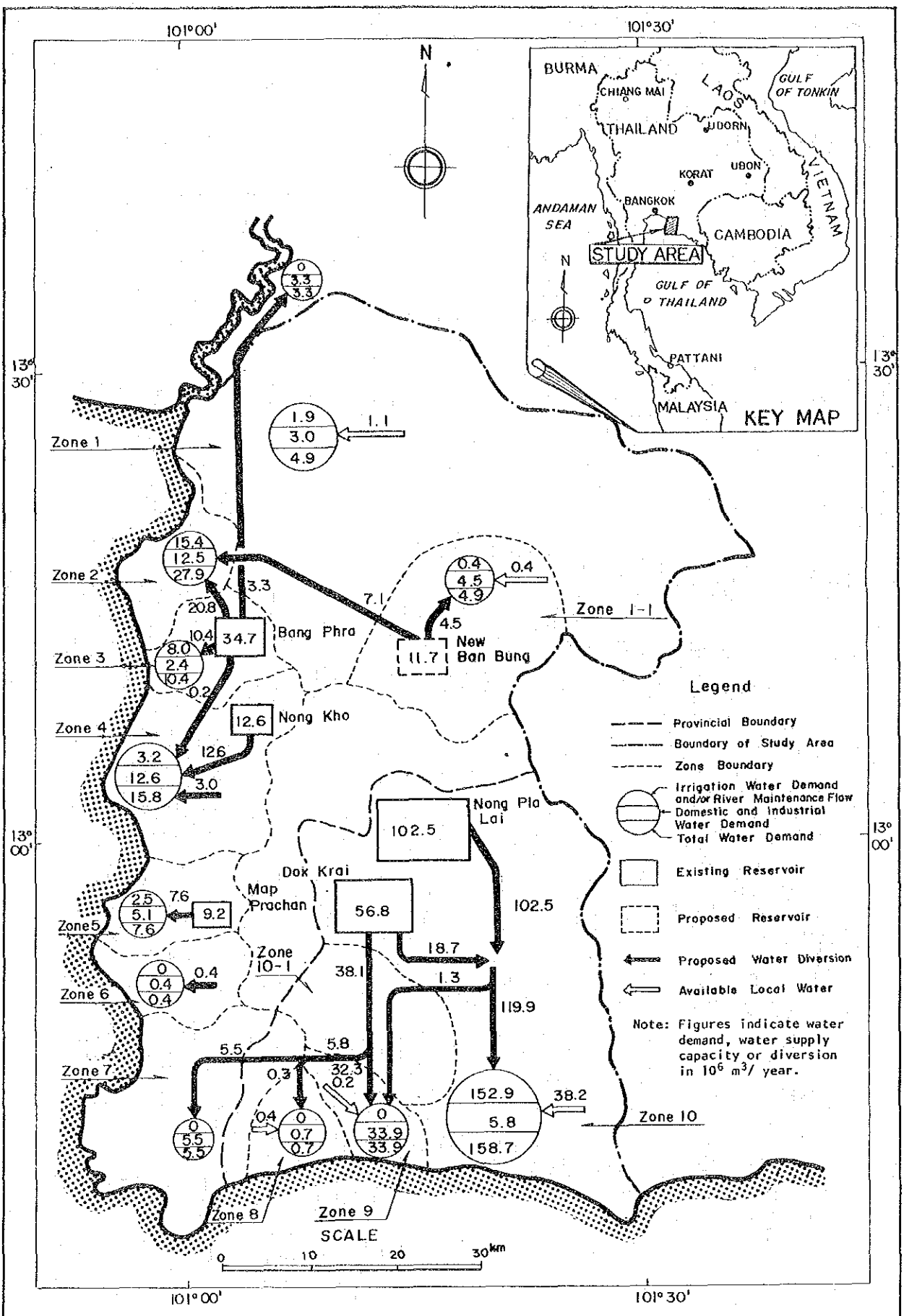

Fig. 20 Water Supply Plan in 1986.

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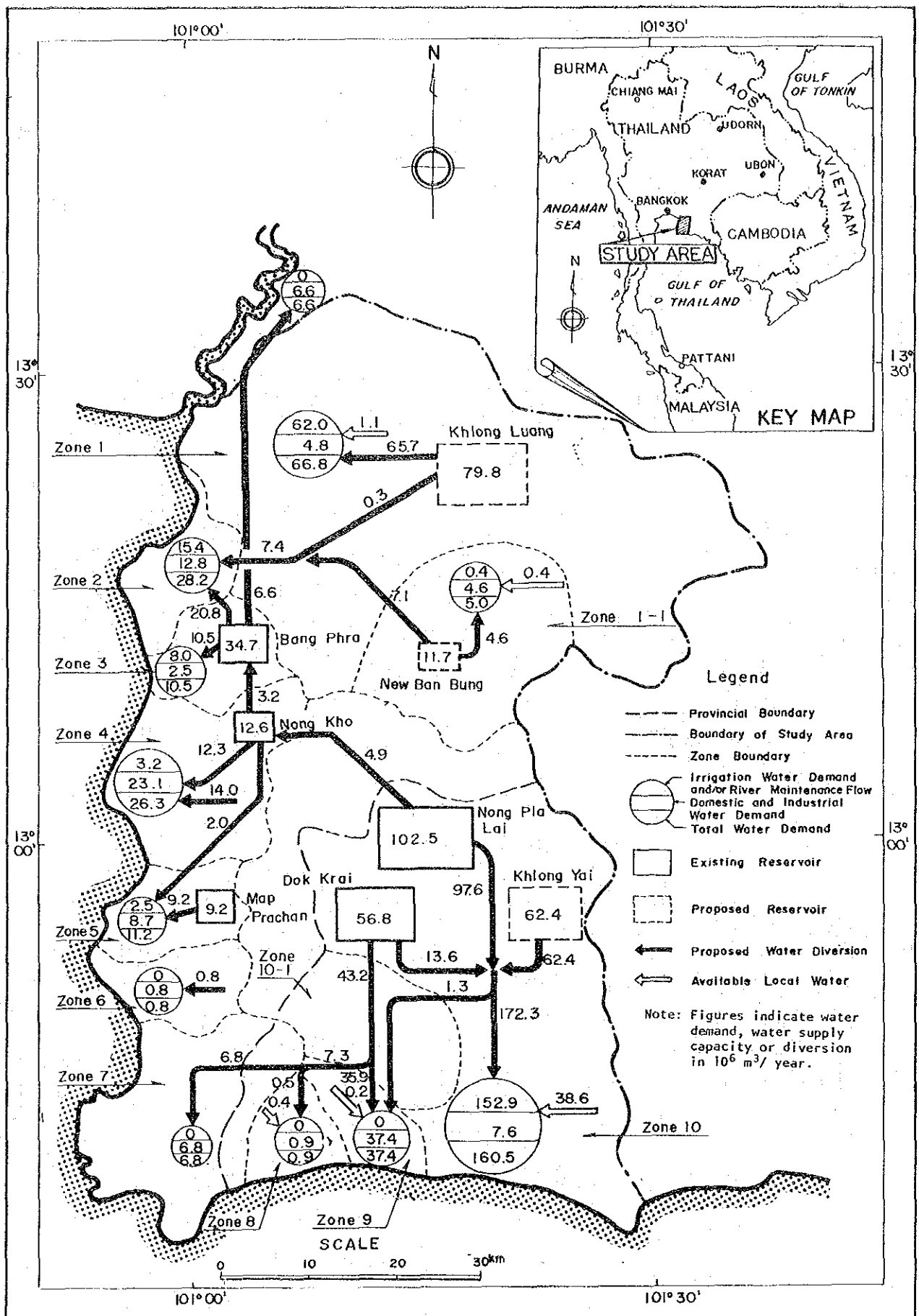

Fig. 21 Water Supply Plan in 1991

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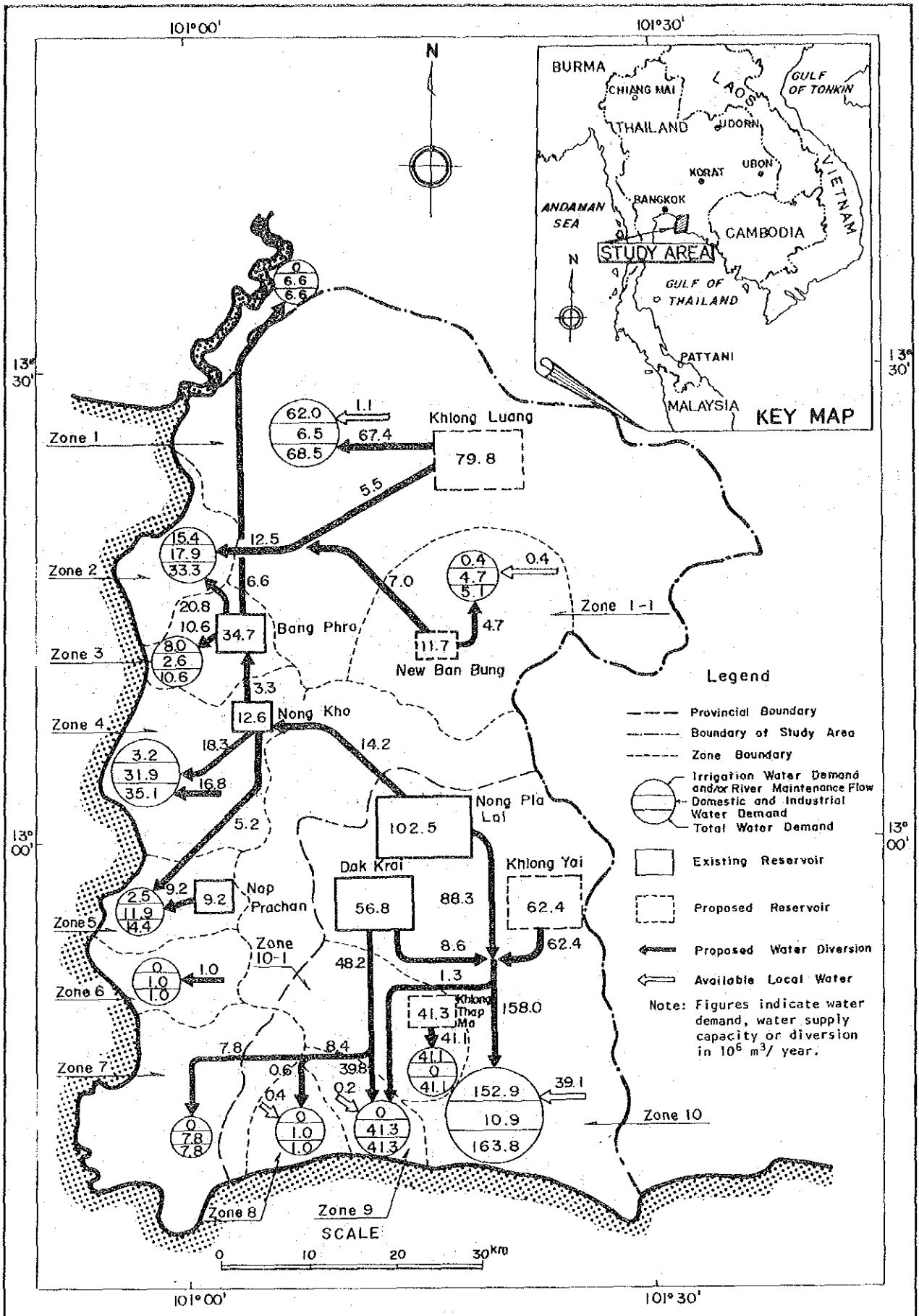

Fig. 22 Water Supply Plan in 1996

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JAPAN INTERNATIONAL COOPERATION AGENCY

SECTORAL REPORT XI
WATER RESOURCES ENGINEERING

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1. INTRODUCTION

The water resources engineering mainly leads up;

(i) to clarify the present water resources development conditions,

(ii) to reveal the characteristics of potential damsites for formulation of the long-term water demand and supply balance,

(iii) to identify the optimum development scale of the proposed development schemes, and

(iv) to carry out the preliminary design and cost estimate of the proposed plans to sound their economic feasibility and financial viability.

Out of the above objectives, objectives (i) and (ii) are directly concerned with the study of the long-term water demand supply balance and are reported at the time of submittal of "Progress Report". They were elaborated based on the field reconnaissance survey carried out during a 5-month period from July to December, 1982.

The objectives (iii) and (iv) take part in feasibility study of the Khlong Luang, Khlong Yai and Khlong Tap Ma dam schemes. The study is programmed to be carried out in Tokyo during a 7-month period from December 1982 to July 1983 and its results will be incorporated into "Interim Report" and/or "Final Report". A complete issue of this sectoral report is, therefore, scheduled in July 1982.

2. DIVISION OF THE STUDY AREA

For the purpose of the long-term water demand and supply balance study, the Study Area is broadly divided into 10 zones by river basins taking into consideration the locations of water demand centers and existing water source facilities, etc. Fig. 1 shows the divisions of the Study Area and Table 1 presents the characteristics of the respective zone. The followings are brief outlines of the respective zone.

Zone No.	Name of Zones	Area (km^2)	Representative River
1	Khlong Luang	2,118	Khlong Luang
2	Chon Buri	168	Khlong Yai Cheng
3	Bang Phra	128	Huai Sukhrip
4	Laem Chabang	361	Khlong Bang Lamung
5	Pattaya	142	Huai Nong Plu
6	Huai Yai	135	Huai Yai
7	Sattahip	422	Khlong Bang Phai
8	Ban Chang	109	Khlong Phayun
9	Map Ta Phut	120	Khlong Huai Yai
10	Rayong	1,776	Rayong
	Total	5,479	

The Zone No. 1, Khlong Luang includes approximately 193 km^2 of the Bang Pakong river basin.

3. PRESENT STATUS OF WATER RESOURCES DEVELOPMENT

3.1 Water Resources Development Agencies

The various government departments and agencies are involved in the water resources development in the Study Area. They are listed hereunder together with their main task.

Departments/Agencies	Main Task
RID	Irrigation, flood control, drainage
PWWA	Water supply
OARD	Rural water supply
DOF	Fishery
DMR	Rural water supply
NEB	Water quality control
PAT	Navigation
NESDB	Comprehensive water use planning

Out of the above departments and agencies, the DMR soley takes part in the groundwater resources development, mainly for the rural water supply.

The NESDB contemplates to launch the comprehensive water resources development and supply network plan over the Study Area in connection with the Eastern Seaboard Development, which is one of the most significant objectives of the Fifth National Social and Economic Development Plan (1982 to 1986). The present study is deeply concerned with the Eastern Seaboard Development Plan.

The RID has been playing an important role in the water resources development in the Study Area. Out of six existing dams, four dams were implemented by RID. The activity of RID includes the investigation, planning, design, construction,operation and maintenance of the water resources facilities and its field covers not only the surface water resources but also groundwater resources. The RID will hold the present situation even in future.

The PWWA also engages in the surface and groundwater resources development for the water supply. The water resource facilities developed by PWWA are minor structures. The source of the water is mainly relied on reservoirs, which are administrated by RID.

In addition to the above government agencies and departments, private enterprises sometimes exploit the groundwater for their own use. It is not uncommon that private enterprises have their own intakes in reservoirs, which are administrated by RID.

3.2 Present Water Resources Development Situation

3.2.1 The Khlong Luang River Basin

The Khlong Luang river basin, Zone No. 1 extends over approximately 2,120 km^2, out of which approximately 190 km^2 fall in the Bang Pakong river basin. It is roughly estimated that the Khlong Luang river produces approximately 460 x $10^6 m^3$ of run-off annually. However the water resources in the basin remains almost untapped. There have been constructed one small dam, Ban Bung for irrigation and industrial water supply and 5 intakes for rural and urban water supply in the basin. The present water use in the basin appears to be negligible compared to the annual run-off.

The basin encompasses approximately 81,500 ha of irrigable lands, which lie to the downstream from the proposed Khlong Luang damsite. At present only approximately 17,000 ha is irrigated, out of which approximately 6,500 ha is irrigated by the water resources of the basin.

It has been reported that Phanat Nikhom has been affected by acute shortage of water supply. Approximately 39,900 ha of the paddy fields is subject to inundation every year, owing to flat topography, less discharge capacity of river channel, backwater from the Bang Pakong river, etc. The future socio-economic development would be largely dependent on the water resources development of the Khlong Luang river basin.

3.2.2 The Rayong River Basin

The Rayong river basin, Zone No.10 is blessed with fairly abundant water resources compared with the other river basins in the Study Area. The basin, approximately 1,730 km^2, receives approximately 1,400 mm of annual rainfall

and has a flow of approximately 740 x 10^6 m^3 per year.

A large scale water resources development in the basin was commenced in 1970s by construction of Dok Krai dam. The Dok Krai dam was completed in 1975 for the purpose of the irrigation and domestic water supplies and flood control. Its reservoir is capable of producing approximately 57 x $10^6 m^3$ of the regulated flow with an active storage capacity of 46.8 x $10^6 m^3$. The regulated flows are mainly used for irrigation in the Ban Khai area and for domestic water supply in Rayong. There have been no large scale development activity after the Dok Krai dam.

As same as the Khlong Luang river basin, the Rayong river basin embraces approximately 14,700 ha of fertile irrigable lands, which extends over the middle reach to the estuary. At present the irrigation systems are provided only for approximately 4,800 ha, which are located in the Ban Khai irrigation area. Most of the irrigable area are prone to inundation every year due to poor drainage and flooding of the Rayong river.

At present, the gross water use in the basin is only approximately 48 x $10^6 m^3$/year, corresponding to about 6 % of the annual run-off. It will gradually increase year after year with expansion of irrigation area and with introduction of industrial development in Rayong. The basin is closely located to Map Ta Phut and Sattahip, which are the major industrial development district in the Eastern Seaboard Development Plan. Both areas are scarce in water resources. Thus the basin will bear a role of water supply to the both areas.

3.2.3 Coastal Area

The coastal area defined herein covers the Zone Nos. 2 through 9 and is approximately 1,590 km^2. The area is characterized by a large number of small rivers, most of which have a catchment area less than 200 km^2.

The majority of the commercial and economic activity are concentrated in the coastal area, resulting in a large water use. In 1981, approximately 18 x $10^6 m^3$/1 of water were consumed, according to the water supply records

/1 Not including the water consumed in Sattahip Naval Base

of the Bang Phra and Map Prachan reservoirs.

There have been constructed 4 dams in the coastal area. They are Bang Phra, Map Prachan, Khlong Bang Phai and Phluta Luang dams. The latter two dams were constructed and are exclusively used by the Sattahip Naval Base. In order to cope with the increased water supply demand, Nong Kho dam is being implemented by RID. The water supply capacity by the Bang Phra, Map Prachan and Nong Kho dams is estimated to be approximately 57 x 10^6 m^3/year.

The water demand in the coastal area will rapidly increase, since the industrial development centers of the Eastern Seaboard Development Plan are mainly located in the coastal area. Contrarily the availability of the water resources in the area seems to be far from the demand. Although the water resources development would be continued in the area, inter-basin water supply would be inevitable to meet the demand.

3.3 Existing Water Resources Facilities

3.3.1 Dams and Reservoirs

There are 6 dams in operation and one dam under construction in the Study Area. Out of the existing dams, 2 dams, Phluta Luang and Khlong Bang Phai were constructed and are exclusively used by the Sattahip Naval Base and therefore they are excluded from the present study. The RID plans to implement the Nong Pla Lai dam situated in the Zone No. 10 and the new Ban Bung dam located in the Zone No. 1. The location and salient features of these dams are shown in Fig. 2 and Table 2, respectively. The followings are the brief summary.

Dam	Purpose	Gross Storage	Completed/Completion Year
		($10^6 m^3$)	
1. Dams in Operation			
Ban Bung	D & I, A, F	2.9	1958
Bang Phra	D & I, A	120.0	1975
Map Prachan	D & I, A	17.0	1979
Dok Krai	A, F	170.8	1975
2. Dam under Construction			
Nong Kho	D & I, A	26.0	1983
3. Dams under Planning			
New Ban Bung	D & I, A	21.9	-
Nong Pla Lai	A, F	200.7	1986

Note D & I : Domestic and industrial water supply
A : Irrigation water supply
F : Flood control

Data Source : RID

The Ban Bung dam is located in the Ban Bung river, a tributary of the Khlong Luang river and has only 0.4 x 10^6 m^3 of active storage capacity. According to the water supply record of RID, it supplies the industrial water for 2 factories in the Zone No. 1 and the irrigation water for 320 ha. Fig. 3 shows the area-storage curve of reservoir.

The Bang Phra dam is situated in the Zone No. 3 and has the largest storage capacity among the existing dams, 120 x $10^6 m^3$ in terms of gross storage capacity. It bears the domestic and industrial water in the Zone Nos. 2, 3 and 4 and the irrigation water for 1,120 ha lying in the Zone No. 2. Fig. 4 shows the area-storage curve of reservoir.

The Map Prachan dam is located at approximately 8 km east of Pattaya. The gross storage capacity is 17 x 10^6 m^3 and the dam is earth-fill type with the maximum dam height of 17.0 m. The Map Prachan dam feeds the domestic water to the Zone No. 5, where Pattaya is located, and irrigates approximately 480 ha. Fig. 5 shows the area-storage curve of reservoir.

The Dok Krai dam is one of a series of dams to be implemented in the Rayong river basin and was constructed aiming at securing the irrigation water supply to the Ban Khai irrigation area and at mitigating the flood damages. The gross storage capacity of reservoir is 70.8 x 10^6 m^3, of which 20 x 10^6 m^3 are planned to be utilized as flood control space. Fig. 6 shows the area storage curve of reservoir. Its nature would be altered into the domestic and industrial water supply to Sattahip and Map Ta Phut in near future. The irrigation water supply will be attained by the proposed Nong Pla Lai dam.

The Nong Kho dam, which is under construction, is located in the Huai Nong Kho river, approximately 15 km east of Laem Chabang, and it will complete in 1983. Fig. 7 shows the area-storage curve of reservoir. The dam creates a reservoir with gross storage capacity of 26 x 10^6 m^3 and aims at supplying the domestic and industrial water and the irrigation water to 1,200 ha of lands.

The new Bang Bung dam is proposed to be located at approximately 100 m downstream from the existing Ban Bung dam and envisages to satisfy the increased domestic and industrial water demand in and around Ban Bung. Its reservoir will have 12.2 x 10^6 m^3 of gross storage capacity.

The Nong Pla Lai dam is located in the Nong Pla Lai river, a tributary of the Rayong river, at about 12 km north of Ban Khai, and will be the largest dam within the Study Area. Fig. 8 shows the area-storage curve of reservoir. The dam creates a reservoir with 200.7 x 10^6 m^3 of gross storage capacity and is expected to be commissioned in service in 1986. The main purpose is to assure the irrigation water supply in the Ban Khai proper and extension areas in lieu of the Dok Krai dam and to mitigate the flood damages.

3.3.2 Barrages

In the Khlong Luang river basin, there are a large number of lift-gate-type weirs, particularly in a reach between Phanat Nikhom and river mouth. Their purpose is to maintain the river water level to lead the water easily into irrigation ditches. Most of them were constructed by the local government and/or public donations.

There exist 17 tidal gates along Route 3 in the Khlong Luang river basin. They were constructed by RID to protect the irrigated lands from the backwater effects of the Bang Pakong river. Their locations are shown in Fig. 2.

There are 3 diversion weirs in the Rayong river basin and one diversion weir in the Khlong Samnak Ma-mung river basin (Zone No.8). They were all constructed by RID for irrigation. Their location is shown in Fig. 2.

3.3.3 Intakes

The PWWA administrates the domestic water supply to the urban area and operates 5 water works at present in the Study Area. In addition, there are 8 rural water works, which are operated and maintained by the local administratives concerned. The urban and rural water works are listed hereunder and their locations are shown in Fig. 9.

Water Works		Plant	Water Resources	
Name	Zone No.	Capacity	Location of intake	Zone No.
		(m^3/day)		
1. Urban Water Supply				
Ban Bung	1	480	Ma Fai stream	1
			Chan Nam Pond	1
Phanat Nikhom	1	2,160	Sarika stream	1
Chon Buri	2	48,000	Bang Phra reservoir	3
Naklua-Pattaya	5	25,920	Map Prachan reservoir	5
Rayong	10	7,680	Tha Si Phet Lake	10
			Ban Khai weir	10

Water Works		Plant	Water Resources	
Name	Zone No.	Capacity	Location of intake	Zone No.
		(m^3/day)		
2. Rural Water Supply				
Phan Thong	1	720	Phan Thong channel	1
Tha Bun Mi	1	720	Irrigation canal	1
Nong Kakha	2	240	Pondage	2
Ao Udom	4	1,200	Pondage	2
Ban Soet	1	480	Small stream	1
Ban Chang	8	1,200	Pondage	8
Pluak Daeng	10	240	Small stream	10
Ban Khai	10	480	Ban Khai canal	10

Data Source : PWWA

3.3.4 Drainage Channels

The Khlong Luang and Rayong river basins are encountered with a serious drainage problem in the mid-stream to the estuary. During the wet season, a large area is inundated frequently by flooding of rivers and/or poor drainage. The RID has been endeavouring to improve the drainage conditions in both the Khlong Luang and Rayong river basins and the under-listed drainage channels have been constructed.

River Basin	Drainage Channel	Length	Discharge capacity
		(km)	(m^3/s)
Khlong Luang	Phan Thong	10.8	-
Rayong	No. 1	2.0	46
	No. 2	1.5	25
	No. 3	1.7	60
	Connecting channel	0.5	-

Data Source : RID

The locations of the above drainage channels are shown in Fig. 10.

The Phan Thong drainage channel in the Khlong Luang basin is composed of two channels. The upstream channel having a total length of about 2.8 km connects the Khlong Saet river with the Khlong Nam Khem. The downstream channel links the Khlong Nam Khem river with the Bang Pakong river with a distance of approximately 8.0 km. The channel also effectuates the function of irrigation water supply for the Phan Thong extension area. There are approximately 20 off-takes equipped with gate in the channel. At the downstream end of the channel, radial gates are installed to prevent the backwater from the Bang Pakong river.

In the estuary of the Rayong river, there have been constructed 4 drainage channels by RID. The drainage channel No. 1 connects the main stream of the Rayong river with the lagoon and the drainage channels, Nos. 2 and 3 link the Khlong Kha river, a tributary of the Rayong river, with the lagoon. All the drainage channels are equipped with a regulating gate at their inlet.

3.4 Present Water Use and Supply

Table 3 presents the historic water supply by the existing 4 reservoirs and intakes of PWWA during the period from 1977 to 1981.

In 1981, approximately 71.4 MCM of water were supplied, consisting of 68.8 MCM supplied by four reservoirs, the Ban Phra, Ban Bung, Map Prachan and Dok Krai, and 2.6 MCM supplied by intakes of PWWA. It is classified by water uses as shown below.

Water Supply	Quantity (MCM)
1. Supply by the reservoirs	68.8
Irrigation use	(53.4)
Domestic use	(10.0)
Industrial use	(5.3)
Others	(0.1)
2. Supply by the intakes of PWWA	
Domestic use/1	2.6

/1 Not including the amount supplied by the rural water works, since no data are available

The water use and supply situation in the Study Area largely varies from region to region and from year to year. The water use in the coastal area exceeds that in the inland area at present and is mostly accrued from the domestic and industrial use. In the Zone No. 10, the irrigation water use is predominant over the domestic and industrial water use, since the basin embraces a large irrigation area. In the Zone No. 1, the present water use is wholly attributable to the domestic and industrial use in a number of small urban areas.

3.5 Water Supply Capacity of Reservoir

The water supply capacity of reservoir means in other word the quantity of regulated outflow from reservoir.

The water supply capacity of the existing reservoirs is not exactly known, although it is one of important factors in formulating the long-term water demand and supply plan. It could be calculated easily, if the stream flow records at the damsite are available. The Ban Bung, Bang Phra, Map Prachan and Nong Kho reservoirs are not provided with necessary data. Therefore, their water supply capacity was estimated from draft curve of the Dok Krai reservoir. The draft curve analysis is reported in Section 4.4.

The water supply capacity of the Dok Krai and Nong Pla Lai reservoirs was obtained by means of mass-curve analysis.

Reservoir	Active Storage Capacity	Average Annual Inflow	Water Supply Capacity
	(MCM)	(MCM/Year)	(MCM/Year)
Bang Phra	104.0	42.9	34.7
Ban Bung	0.4	17.9	2.2
Map Prachan	14.0	13.2	9.2
Dok Krai	46.8	101.6	56.8
Nong Pla Lai	144.4	126.1	102.5
Nong Kho	18.0	16.9	12.6
New Ban Bung	12.5	17.9	11.7

The estimated water supply capacity of the respective reservoir is a little different from the figure presented in Phase I Report. The figures estimated herein indicates the minimum supply capacity during a 14-year period, while the figures of Phase I Report is based on the second drought year during a 13-year period.

4. POTENTIAL DAMSITES

4.1 General Description

The RID has been actively taking part in the water resources development in the Study Area and has already identified 10 potential damsites in the Study Area as under-listed. The locations of the potential damsites are shown in Fig. 2.

Potential Damsites	Zone No.	River	Catchment area
			(km^2)
Khlong Luang	1	Khlong Luang	526
Pa Daeng	1	Huai Pa Daeng	53.8
Ban Khlong Yai	1	Ban Khlong Yai	125
Huai Bung	4	Huai Bung	68.5
Huai Takhian Tia	4	Huai Takhian Tia	33.0
Khlong Na Klua	5	Khlong Na Klua	22.3
Huai Chak Nok	6	Huai Chak Nok	18.1
Huai Yai	6	Huai Yai	65.9
Khlong Yai	10	Khlong Yai	218
Khlong Tap Ma	10	Khlong Tap Ma	158

For the study of the long-term water demand and supply plan, all the above-listed potential damsites except the Ban Khlong Yai will be taken into account.

The RID is intending to implement the Khlong Luang, Khlong Yai and Khlong Tap Ma dams as earlier as possible in order to secure the stable irrigation, domestic and industrial water supply. The feasibility study of the said three dams will be carried out within the present study.

4.2 Location and Topography

The location and topography of each potential damsite are explained hereunder based on the field reconnaissance and documents made available from RID.

Khlong Luang damsite

The implementation of the Khlong Luang dam has for long been envisaged by RID. It is the largest dam among other potential dams in the Khlong Luang river basin and is contemplated to be developed with multiple nature of water supply, irrigation and flood control.

The damsite is located at approximately 18 km east of Phanat Nikhom and lies across two streams, the main stream of the Khlong Luang river and its tributary. A saddle dam is needed on the left bank. The river bed of the main stem of the Khlong Luang is approximately El. 25.4 m at the damsite. The catchment area of the Khlong Luang river is 526 km^2 at the proposed damsite.

A prominent hill of the Precambrian metamorphased shale forms the left abutment of the main damsite. The right abutment is the undulating which are wholly underlain by the terrace deposits of sand and gravelly clay. The river valley between the left and the right abutments spans approximately 3,900 m and its geological conditions are nearly the same as the right abutment. The area-storage curve of reservoir is presented in Fig. 11.

Pa Daeng damsite

It is located in the Huai Pa Daeng river, a tributary of the Khlong Luang river, at approximately 24 km south of Phanat Nikhom and is situated close to Ban Pa Daeng village.

The riverbed elevation is approximately El. 56 m at the damsite. The height of dam may be inhibited by the elevation of the left abutment. The left abutment is the low undulating uplands, composed of colluvial deposits. The right abutment is the prominent hill of schists. The river valley is the thin alluvium underlain by old colluvial deposits and is approximately 1,600 m in width. An earth-fill type of dam may be founded on the colluvial deposits and weathered schist.

The area-storage curve of reservoir is shown in Fig. 12. In the reservoir area, paddy field extends to a certain extent. This may involve a huge compensation cost.

Ban Khlong Yai damsite

It is situated at approximately 25 km south of Phanat Nikhom in the vicinity of hamlet Ban Nong Ta Sor and is located in the Khlong Yai river, a tributary of the Khlong Luang river.

The right abutment is the ridge originated from the Mt. Khao Min Do, while the left abutment is a undulating upland. The crest elevation of dam would be limited to below El. 70 m, constrained by topographic conditions of the left abutment. The geological conditions of the left and right abutments appear to be same, colluvial deposits thinly covering weathered granite. The river valley is relatively narrow, approximately 2,500 m at El. 70 m, and is mainly formed by thin alluvium and old colluvium underlain by granite.

An earth-fill type of dam is deemed to be built on the weathered granite. All weathered road is passing through the reservoir area and a sugar mill with about 77,000 ton of monthly production capacity is located in impounding area. It is foreseable that relocation of the sugar mill involves a huge amount of cost and would cause the socio-economic problems. Therefore, this potential damsite was decided to be eliminated from the present study.

Huai Bung damsite

The damsite crosses two streams, the Huai To Phayom and Huai Phak Kut rivers and is located at approximately 10 km east of Laem Chabang.

The left and right abutments are the undulating uplands, which are mainly composed of terrace deposits. The river valley is generally flat and is formed by thin alluvium underlain by terrace deposits. The river bed elevation is the lowest in the Huai To Phayom river approximately El. 19 m and dam crest elevation may be restrained to below El. 35 m, owing to the topographic conditions of the both abutments.

An earth-fill type dam is deemed to be suitable at this damsite. The area-storage curve of reservoir is shown in Fig. 13. The majority of the reservoir area are occupied by plantation areas and paddy fields.

Huai Takhian Tia damsite

It is located adjacent to the Huai Bung damsite and is situated in the Huai Takhian Tia river, a tributary of the Khlong Bang Lamung river.

The topographical and geological conditions of the damsite is the same as those of the Huai Bung damsite. The riverbed elevation is approximately El. 21. The dam height would be limited to around 15 m at the maximum, because of the topographic conditions.

The area-storage curve of reservoir is shown in Fig. 14. The circumstance of the reservoir area is almost similar to the Huai Bung damsite.

Khlong Na Klua damsite

It is located in the Khlong Na Klua river, a tributary of the Huai Nong Plu river, at approximately 4 km east of Bang Lamung.

The damsite is situated in the undulating hilly area. There are terrace deposits in the left and right abutments. In the river valley thick alluvium covers terrace deposits. The riverbed elevation is approximately El. 21 m. The dam height may be limited to approximately 20 m at the maximum, owing to the topographic conditions. An earth-fill type dam is deemed suitable.

The area-storage curve of reservoir is shown in Fig. 15. Situation of the reservoir area is also very similar to the Huai Bung damsite. The catchment area of the Khlong Na Klua is only 18.3 km^2 at the proposed damsite so that water supply capacity of reservoir is presumed to be very small. Therefore development cost of water (construction cost divided by net regulated outflow) would be very costly.

Huai Chak Nok damsite

It is located across two streams, the Huai Chak Nok river and its tributary, at approximately 8 km southeast of Pattaya.

The geological conditions at the damsite are the same as the Khlong Na Klua. The riverbed elevation is approximately El. 8 m. The topographic conditions limit the dam crest elevation at El. 25 m at the maximum.

Fig. 16 presents the area-storage curve of reservoir. The reservoir area embraces fertile paddy fields along the both banks of the Huai Chak Nok river. As same as the Khlong Na Klua damsite the development cost of water appears expensive, owing to the small catchment area and huge amount of compensation cost.

Huai Yai damsite

It is situated in the same river system as the Huai Chak Nok damsite and sits astride of four streams, the Huai Yai, Huai Yai Chin, Map Ton Yong and Map Wang Sang rivers.

The damsite is sandwitched inbetween two prominent hills. The hill on the left is formed by terrace deposits and weathered granite and that on the right by talus deposits and weathered granite. The river valley is so wide as approximately 5 km at El. 40 m and is composed of thick alluvium underlain by granite or terrace deposits. The riverbed elevation is approximately El. 16 m. The high water surface of reservoir may be raised up to El. 40 m.

The area-storage curve is shown in Fig. 17. The reservoir surface area extends over approximately 9 km^2 at El. 30.0 m. and is densely populated. The development of this scheme should carefully be studied paying an attention to the socio-economic situation prevailing over the reservoir area.

Khlong Thap Ma damsite

It is located in the Khlong Thap Ma river at approximately 10 km upstream from the confluence with the Rayong river. This dam scheme has been envisaged by RID for flood control and irrigation purposes.

The damsite is featured by relatively prominent hills trending north-south direction in both abutments and by wide U-shaped valley buried with the terrace deposits and the recent flood plain deposits. Hills in the both abutments are composed of the Precambrian mica schist and 3 - 5 m thick talus deposits. The river valley is underlain by granitic rock in the deeper subsurface than 15 m and by overlying terrace deposits of sandy and gravelly clay.

The riverbed is approximately El. 10.0 m. According to RID's preliminary design, the high water surface of reservoir is set out at El. 27.0 m and the dam crest elevation at El. 30.5 m. The dam, earth-fill with an impervious center core, is 20.5 m in height.

Fig. 18 shows the area-storage curve of reservoir. Most of the reservoir area is used for cultivation of cassava. There are about 160 houses in the reservoir area. The reservoir surface area is approximately 11.5 km² at HWS El. 27.0 m.

Khlong Yai damsite

The damsite is located astride of two streams, the Khlong Yai and Khlong Nong Ai Run rivers. The latter is a tributary of the Khlong Yai river and joins with the Khlong Yai river at one kilometer downstream from the damsite.

The damsite is situated in a low rolling hilly upland. In the left abutment, gneissose bedrock crops out, but the damsite is almost underlain by clayed gravelly sands of terrace deposits with thin alluvial covers. A buried old stream bed with depth of at least 8 m was found beneath the present riverbed.

The riverbed elevation is lower in the Khlong Yai river, approximately El. 34.5 m. According to RID's preliminary design, an earth-fill dam with a crest elevation El. 49.0 m is proposed. The high water surface of reservoir is set out at El. 47.0 m.

Fig. 19 shows the area-storage curve of reservoir. The gross storage capacity and reservoir surface area are approximately 48.5 x 10^6 m^3 and 11.1 km^2, respectively, for the proposed high water surface. Most of the reservoir area are used for cultivation of cassava and sugar cane.

4.3 Monthly Mean Discharge at Damsites

Tables 4 through 18 present the monthly mean discharges at the existing, proposed and potential damsites for the period from April 1968 to March 1982. They refer to Sectoral Report VI, Meteorology and Hydrology.

4.4 Storage-Draft Relation

The rate of withdrawal of water from the reservoir is called the draft rate, in other words the water supply capacity. There are uncontrollable withdrawals, such as those caused by evaporation and seepage. They should be added to the draft rate to produce the gross draft rate.

The draft rate varies with reservoir storage capacity. A relation between the draft rate and the reservoir storage could be derived from mass-curve analysis and is indicated by means of draft-storage curve.

The mass-curve analysis was made for the representative 4 reservoirs, the Khlong Luang, Dok Krai, Nong Pla Lai and Khlong Yai. They are selected taking into consideration the nature of hydrological data. Figs. 20 through 23 shows the mass-cruves of the selected reservoirs. The mass-curve analysis resulted in storage-draft relation as shown in Fig. 24.

4.5 Preliminary Cost Estimate

4.5.1 Basis for Cost Estimate

The preliminary construction cost estimate was attempted in order to grasp the economic behavior of each potential damsite and to formulate the long-term water demand and supply balance plan. The estimated construction cost is a very conservative, since no adequate studying materials were available other than topographic map in a scale of 1 to 50,000. The layout of dam was studied on the 1/50,000 topogrpahic maps. The area-storage curve is also based on the 1/50,000 topographic maps.

The construction quantity was roughly calculated by applying the empirical formulae. The unit construction cost was referred to "Interim Report, Feasibility Study on the Upper Pasak Medium Scale Irrigation Project, October 1982".

The construction cost was estimated only for dam and reservoir. Such structures as intake and pumping station necessary for D & I water supply were avoided, since they would be included in the cost of water transmission system.

4.5.2 Rough Construction Quantity

The construction quantity of dam and spillway was calculated by applying the following empirical formulae.

Dam (Earth-fill dam)

Excavation (m^3)	Vde	$= 10 \cdot H \cdot L$
Embankment (m^3)	Vdm	$= \frac{1}{2} \cdot a \cdot h \cdot (L + l) + 1/6(m + n) \cdot H^2 \cdot (L + 2l)$

Spillway

Excavation (m^3)	Vse	$= 84 \sqrt{Qf \cdot H}$
Concrete works (m^3)	Vsc	$= 13 \sqrt{Qf \cdot H}$
Reinforcement bars (ton)	Wr	$= 0.02$ Vsc

where,

- H : dam height (m)
- L : dam crest length (m)
- l : river channel width (m)
- a : crest width (m)
- m : slope of upstream surface of dam, assumed at 3.0
- n : slope of downstream surface of dam, assumed at 2.5
- Qf : spillway design discharge (m^3/s).

The spillway design discharge was arbitrarily determined to be a 100-year probable flood. Since no flood records are available, the 100-year probable flood at the damsite was estimated from Fig. 25.

4.5.3 Unit Construction Costs

The unit construction costs analyzed by the Upper Pasak Medium Scale Irrigation Project were applied for the preliminary cost estimate. The costs reflect the price level as of the end of 1981 and are summarized hereunder.

Work Items	Unit	Unit Cost /1	Unit Cost /2
Excavation, all classes	m^3	90.2	103.7
Embankment, all classes	m^3	161.9	186.2
Concrete in spillway	m^3	1,374.3	1,580.4
Reinforcement bars	ton	11,882.0	13,664.0

/1 : Without the contractor's profit

/2 : With the contractor's profit, 15 %

4.5.4 Compensation and Relocation Cost

The compensation and relocation cost was assessed for each potential damsite based on the actual evidences of the Nong Kho and Map Prachan dams and the results of the preliminary survey for the Khlong Luang, Khlong Yai and Khlong Thap Ma dam schemes. The preliminary survey was carried out by RID in collaboration with the Survey Team during the period from October to November, 1982.

The compensation and relocation cost could broadly be divided into two categories. The one is the compensation and relocation cost acrued from lands, crops, housings, trees and other assets. The other is properly led to the relocation of road, telephone line, electric-power line, etc.

Table 19 presents the actual evidences of the Nong Kho and Map Prachan dams and the results of the preliminary survey regarding the compensation and relocation cost for the Khlong Luang, Khlong Yai and Khlong Thap Ma dam schemes. There is a clear distinction in the compensation and relocation cost between the dams located in the coastal area and the dams located in the inland area. The cost in the coastal area is approximately 5 to 6 times of that for the inland area. Therefore it is not adequate to apply the same unit price for both the coastal area and inland area. For the dams located in the coastal

area, the unit price was quoted from the Nong Kho dam. The compensation and relocation cost for lands, crops, trees and other assets was calculated by multiplying the unit price by the reservoir surface area at HWS. The compensation costs of the Khlong Luang, Khlong Thap Ma and Khlong Yai dam schemes are referred to the preliminary survey results.

The relocation of the roads was roughly planned on the 1/50,000 topographic map. The unit construction cost was referred to that of the Nong Kho dam. That is ฿ 1,548 x 10^3/km for asphalt paved road and ฿ 786 x 10^3/km for the laterite road.

4.5.5 Preliminary Construction Cost

The preliminary construction cost was estimated in line with the work items set forth in Table 20. The estimated construction costs are shown in Tables 21 to 29, together with the main features of the various development scales.

4.6 Selection of Development Scale

As is clear from the storage-draft relation in Fig. 24, a rate of draft increases almost proportionally with the increase of active storage ratio until the storage ratio reaches 70 - 80 %. Beyond that point, the increasing rate of draft rate is reduced even the active storage capacity is increased substantially. This implies that there must be a certain point at which the water resources of a given site are most economically developable.

Fig. 26 shows a relation between the storage ratio (active storage divided by average annual run-off) and the cost of water (construction cost divided by net draft). The figure concludes two facts as described hereunder.

(1) The economic development scale of the potential damsites appears to be in a range of 80 to 100 % in terms of the storage ratio. The development cost is the cheapest in that range.

(2) The large dam schemes such as the Khlong Luang, Khlong Tap Ma and Khlong Yai have the great advantage of the other small dam, in viewpoint of the development cost.

The development scale of the potential damsites is, therefore, determined as follows:

Potential Damsites	Storage ratio (%)
Khlong Luang, Khlong Thap Ma, Khlong Yai	100
Pa Daeng, Huai Bung, Huai Takhian Tai, Khlong Na Klua, Huai Chak Nok, Huai Yai	80

The development scale of the Khlong Luang, Khlong Thap Ma and Khlong Yai damsite will be refined through their optimum development study in Chapter 5.

Table 30 shows the main features and construction cost of each potential damsite at the selected scale.

5. OPTIMIZATION STUDY

5.1 General Description

The Khlong Luang, Khlong Yai and Khlong Thap Ma dam schemes are formulated as multiple-purpose and areal-development projects. They are the keystone in the long-term water supply plan over the Study Area.

The Khlong Luang dam serves irrigation water supply, domestic and industrial water supply for both the inside and outside of its basin and flood control. The Khlong Yai dam serves irrigation water supply, domestic and industrial water supply for both the inside and outside of its basin and flood control in association with the Nong Pla Lai dam. The Khlong Thap Ma dam serves irrigation water supply and flood control.

The long-term water supply plan has been formulated laying a primary emphasis on the water demand and supply balance over the Study Area. The development scale of dam was tentatively adopted to be equal to average annual inflow in terms of active storage capacity of reservoir, from the viewpoint of development cost of water. The irrigation development plan was also tentatively set up with uniform cropping intensity (150 %) throughout the Study Area. Such tentative plan does not necessarily represent the optimum land and water resources development. It is a principle of water resources development that the proposed facilities should be formulated so as to generate the maximum economic return as far as circumstances permit.

Three dams were primarily optimized for use of the domestic and industrial water supply and irrigation development. Any specific flood control space or facilities other than surcharge space was not taken into consideration in this chapter. Need of provision of specific flood control space or facilities will be studied in due consideration of flood damage mitigation plan in a basin and will be determined in the Sectoral Report XII, Flood Mitigation Engineering.

Since the amount of the domestic and industrial water supply is premediated, the optimum land and water resources development plan will be determined dealing with three variables; extent of irrigation water, cropping intensity of the proposed cropping pattern and development scale of a dam. A relationship among the three variables was developed by means of simulation of reservoir operation.

The simulation of reservoir operation was carried out at 10-day time intervals based on the meteo-hydrological data for 14 years from April, 1968 to March, 1982 for which meteo-hydrological data were available.

5.2 Optimization of Khlong Luang Dam Scheme

5.2.1 Reservoir Operation Study

A number of reservoir operation studies were carried out in detail in order to obtain the relationship between the irrigation area, cropping intensity and reservoir active storage capacity. The Khlong Luang reservoir was operated based on the operating rule as follows:

(1) The reservoir provides irrigation water. 10-day diversion water, QIR were estimated in accordance with a cropping intensity of proposed cropping pattern and irrigation area.

(2) The reservoir provides domestic and industrial water for Zone No. 1 and the coastal area, Zone Nos. 2 through 5. Water shortage in the coastal area is planned to be supplied from the Khlong Luang and Rayong river basins. Diversion water from the both basins are shared in proportion to their net drafts in case that storage ratio is 100 % and runoff coefficients, i.e.

$$Qd = WD \times (k1 \times AD1)/(k1 \times AD1 + k2 \times AD2)$$

$$AD1 = ND1 - DI1 - MF1$$

$$AD2 = ND2 - DI2 - MF2$$

where Qd : diversion water from the Khlong Luang dam to the coastal area: 11.0 MCM/yr

WD : water shortage in the coastal area less available water supply of the Ban Bung new reservoir which is deducted by the demand in sub Zone No. 1-1: 42.3 MCM/yr

k1, k2 : runoff coefficients of the Khlong Luang river basin, 0.186 and Rayong river basin, 0.263 respectively

AD1, AD2 : available draft of 70.0 MCM/yr in the Khlong Luang basin and 140.3 MCM/yr in the Rayong river basin respectively

ND1, ND2 : net drafts from the Khlong Luang dam in Zone No. 1, 79.8 MCM/yr and Khlong Yai, Nong Pla Lai and Dok Krai dams in Zone No. 10, 221.7 MCM/yr respectively.

DI1, DI2 : D&I demand in Zone No. 1, 7.9 MCM/yr and Zone Nos. 7 through 10, 69.4 MCM/yr

MF1, MF2 : maintenance flow at Khlong Luang damsite, 1.9 MCM/yr and Ban Khai weir, 12.0 MCM/yr respectively

10-day water requirements, QDI are supplied at the constant rate of 0.56 m^3/s throughout the years.

(3) The reservoir releases river maintenance flow, QMF at the constant rate of 0.06 m^3/s throughout the years.

(4) Effective precipitation, QRAIN and evapolation loss, QEVAP are taken into account as a function of reservoir area. The data of precipitation and evapolation at Ban Mai gauge station were adopted to those at the damsite. Effective coefficients of precipitation and evapolation are assumed to be 0.75 and 0.7 respectively.

(5) The historical streamflow sequence, QIN at Ban Mai gauge station were used directly as a water supply source at damsite.