FIGURES

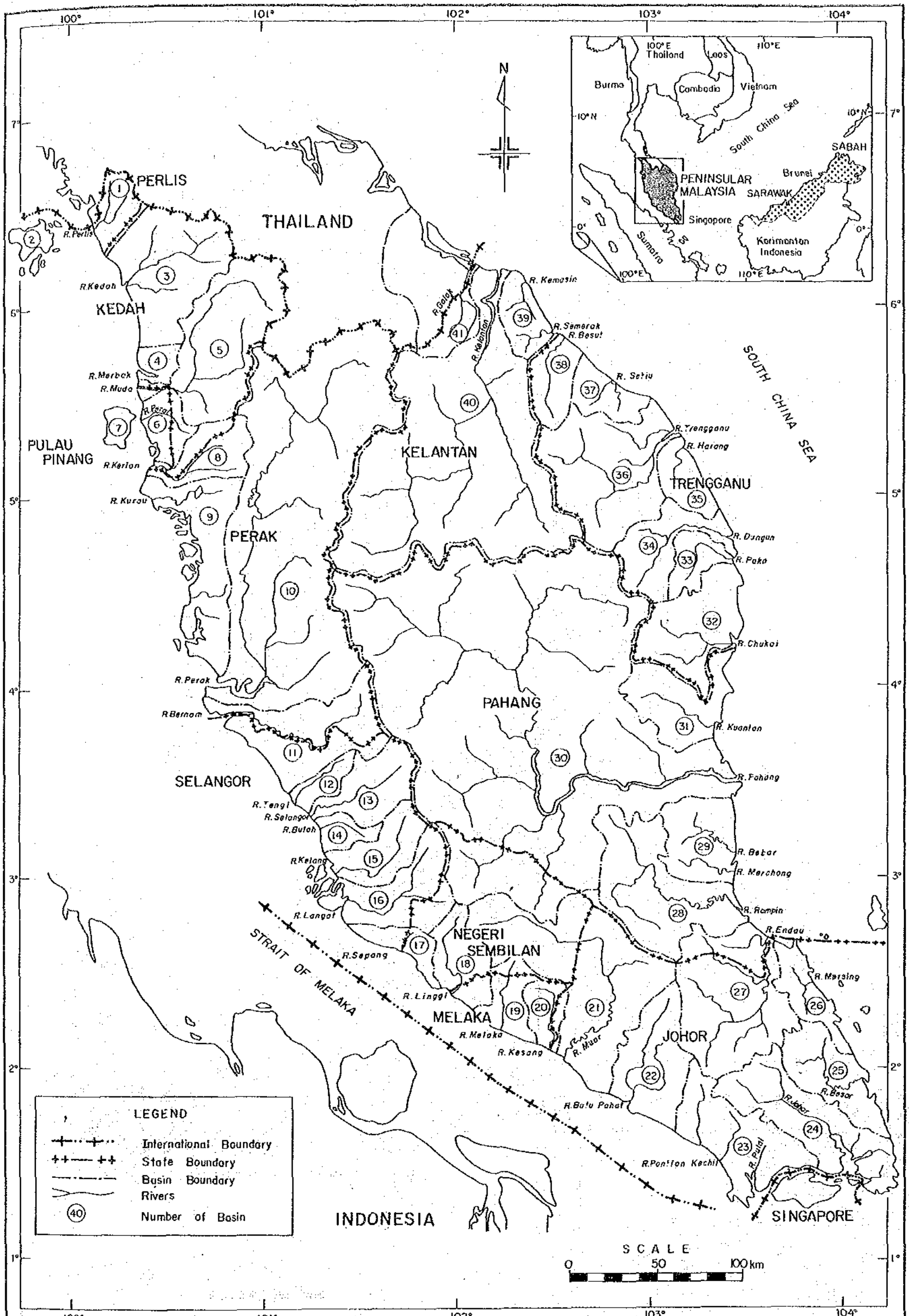

Fig. 1 Basin Division

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
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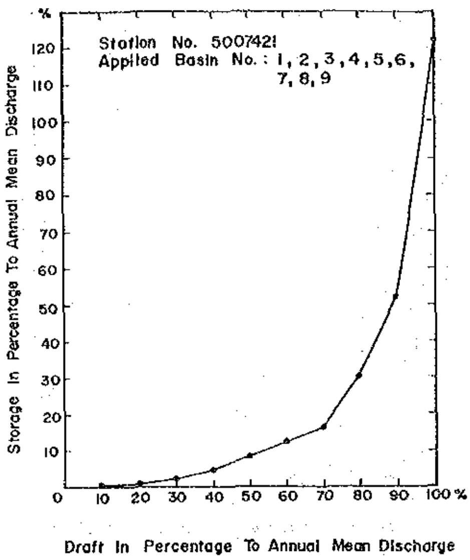
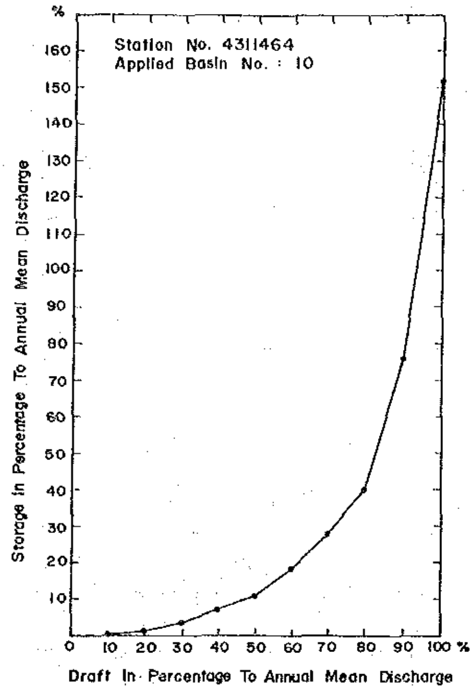
Fig. 2 Administrative Division

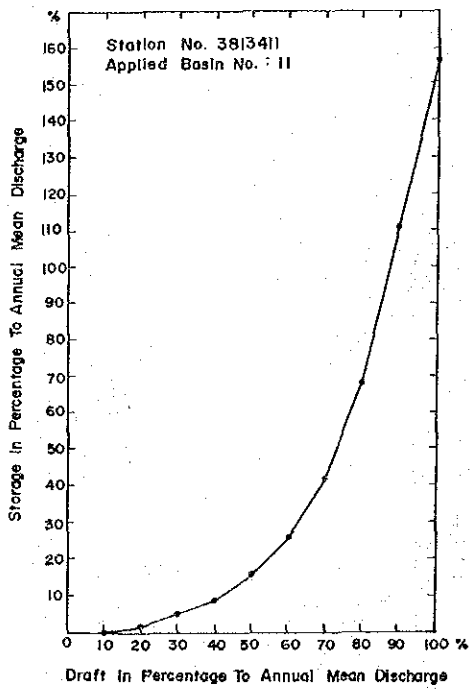
GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY







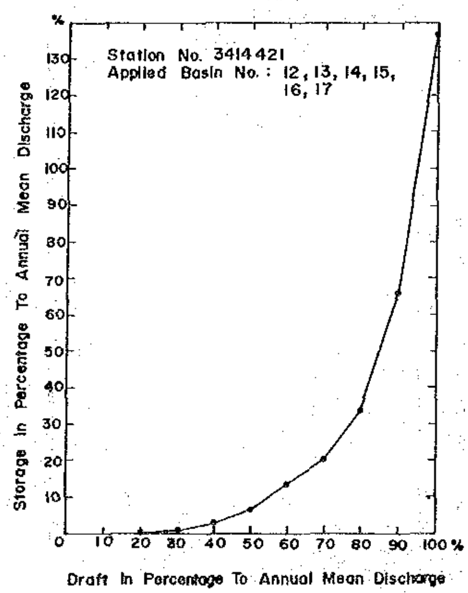


Fig. 3 Non - Dimensional Storage - Draft Curves (1/3)

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

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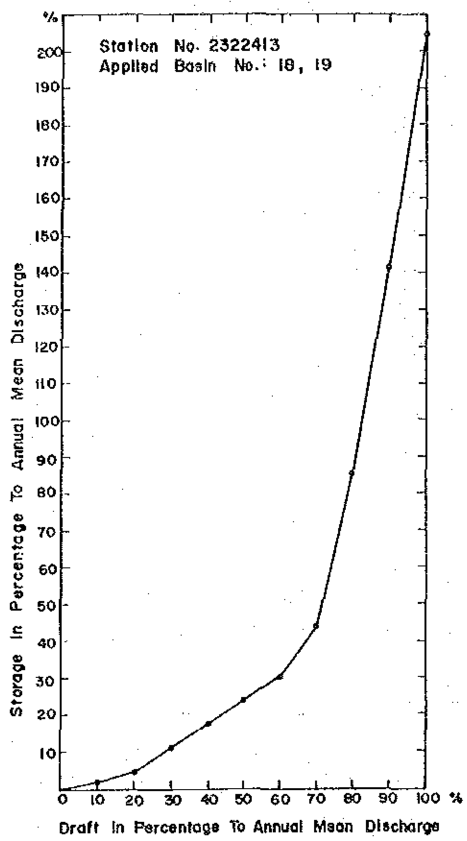

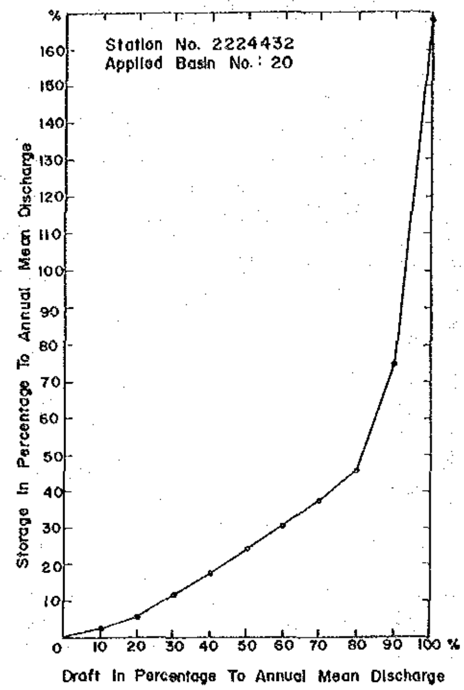

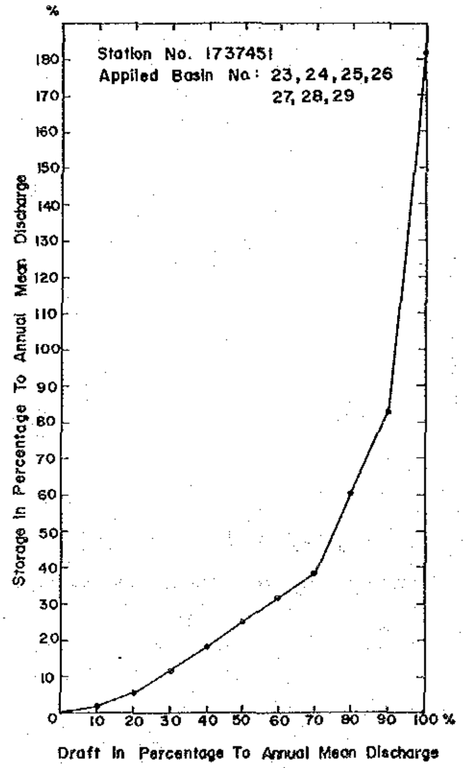

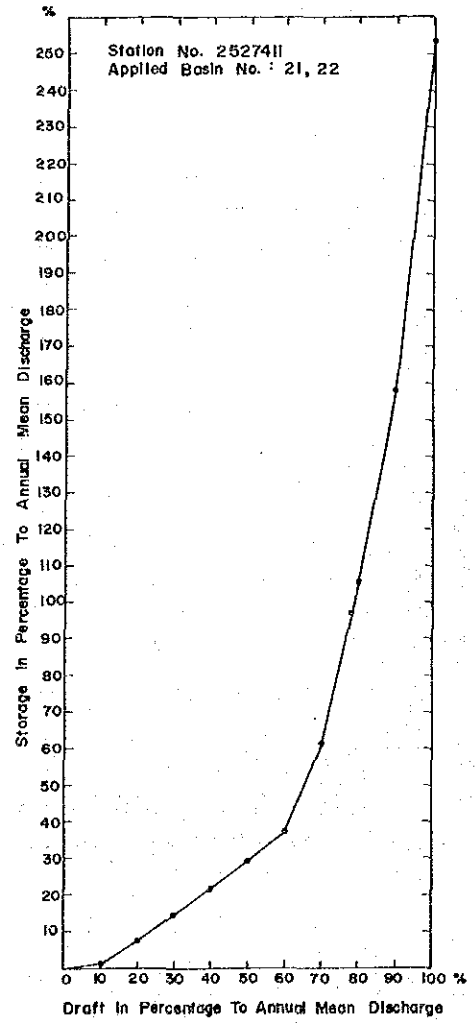

Fig.4 Non-Dimensional Storage-Draft Curves (2/3)

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NATIONAL WATER RESOURCES STUDY MALAYSIA
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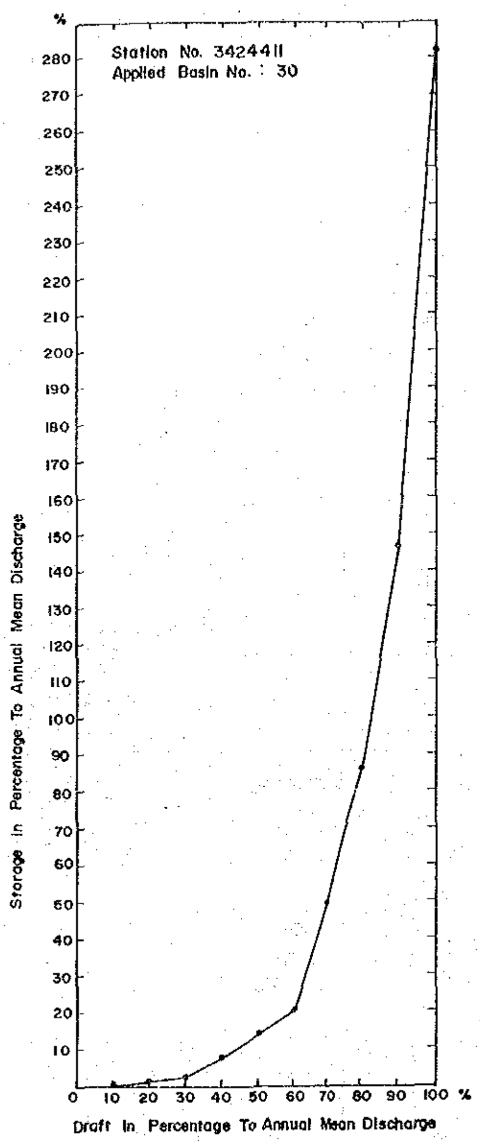

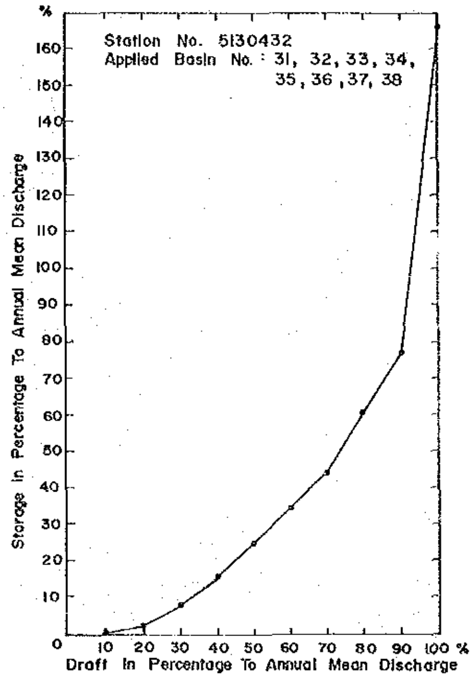

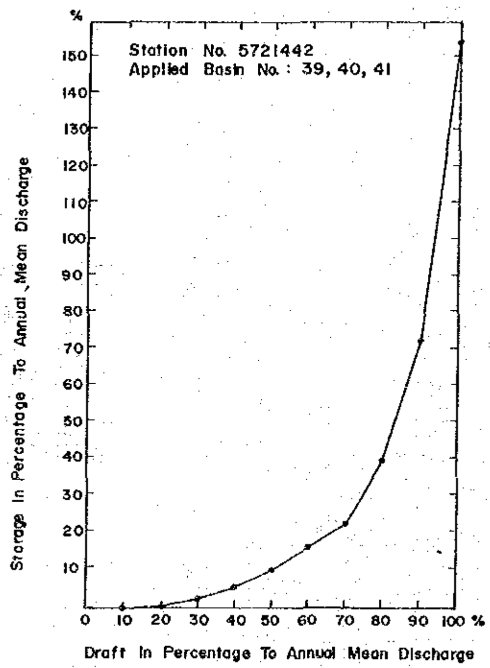

Fig. 5 Non-Dimensional Storage-Draft Curves (3/3)

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

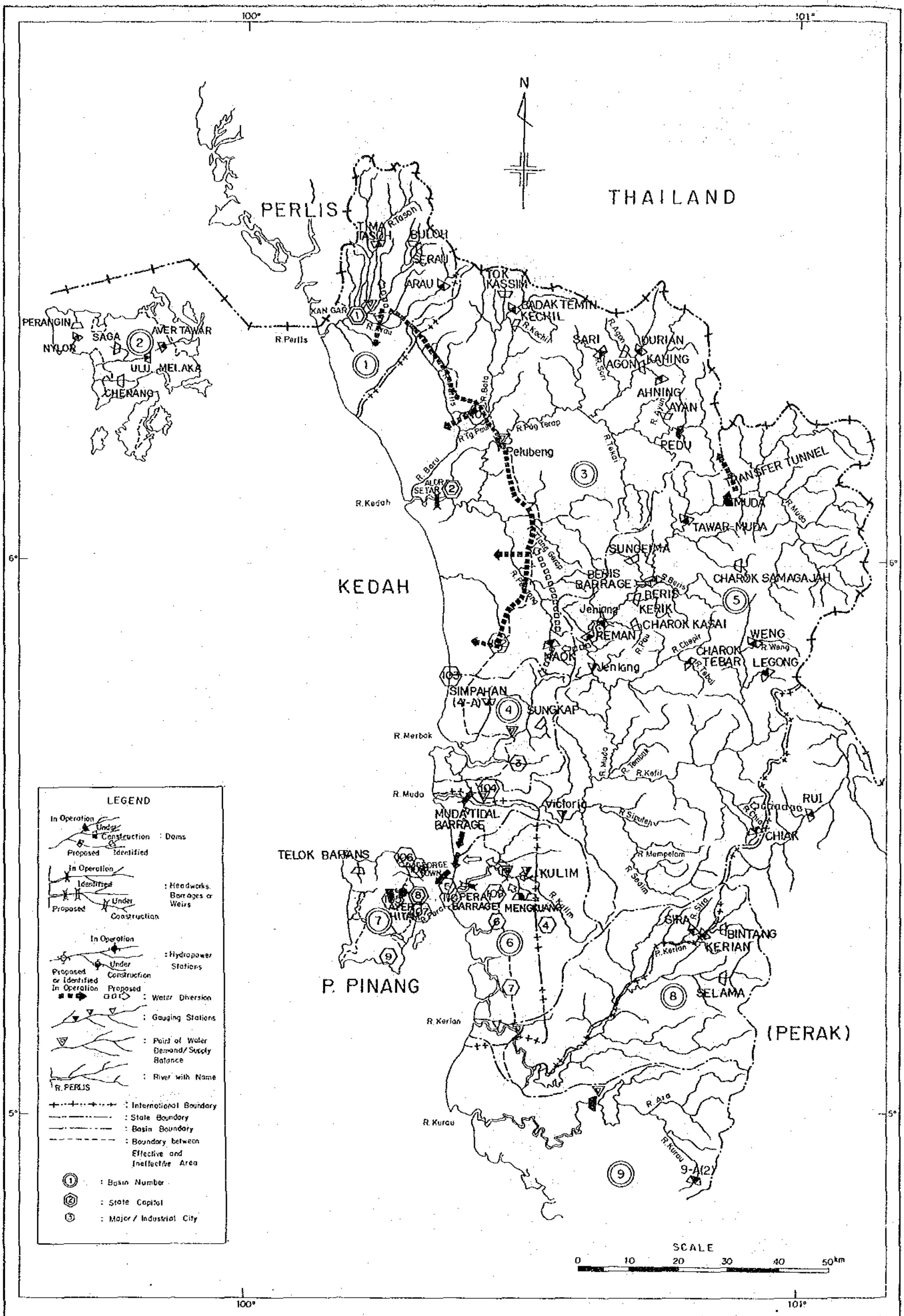

Fig. 6 Location of Potential and Proposed Water Source Facilities, Alternative B1 Basins 1 ~ 8

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

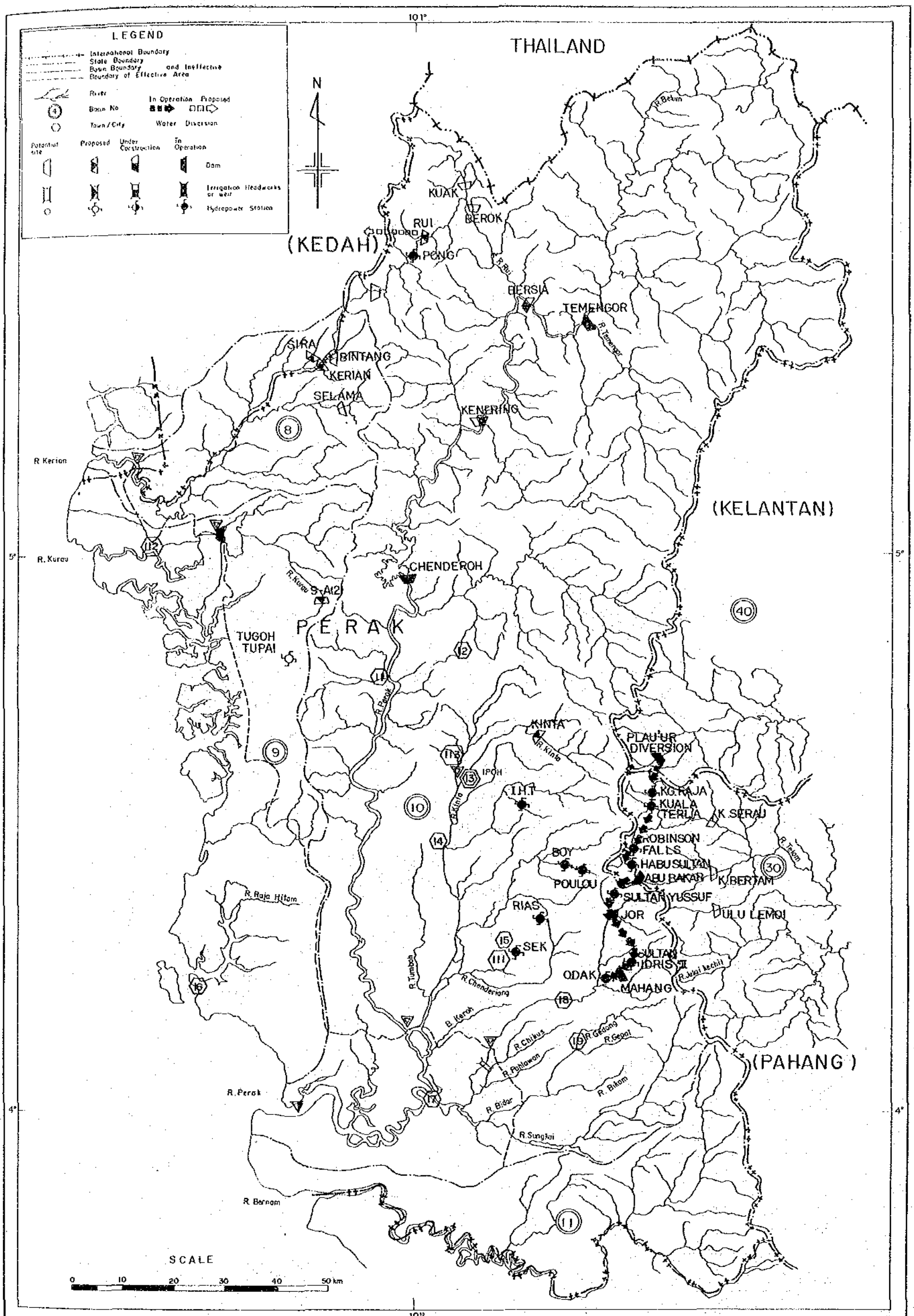

Fig. 7 Location of Potential and Proposed Water Source Facilities, Alternative B1 Basins 8 ~ 11

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

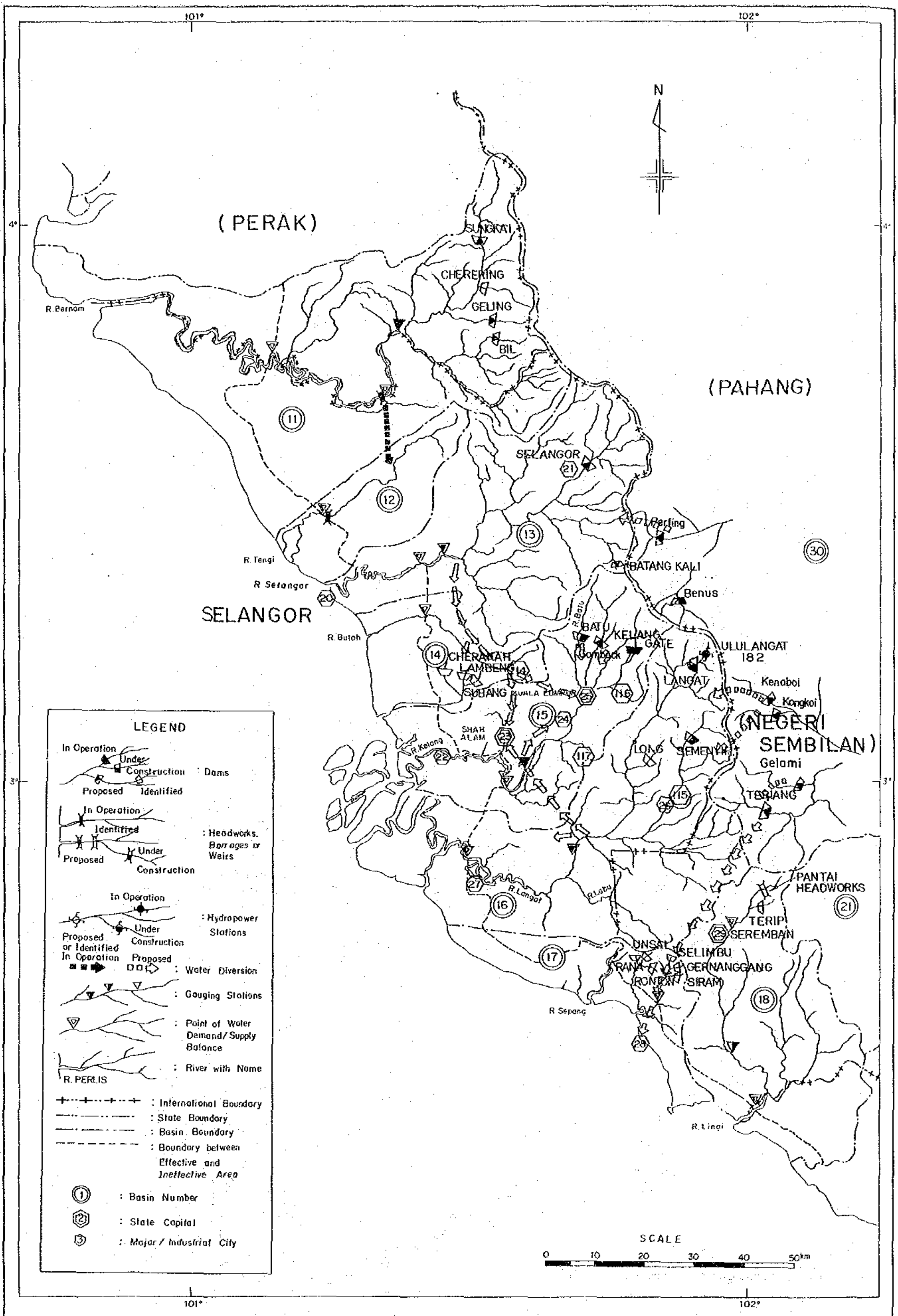

Fig. 8 Location of Potential and Proposed Water Source Facilities, Alternative B1 Basins 11~18

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NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

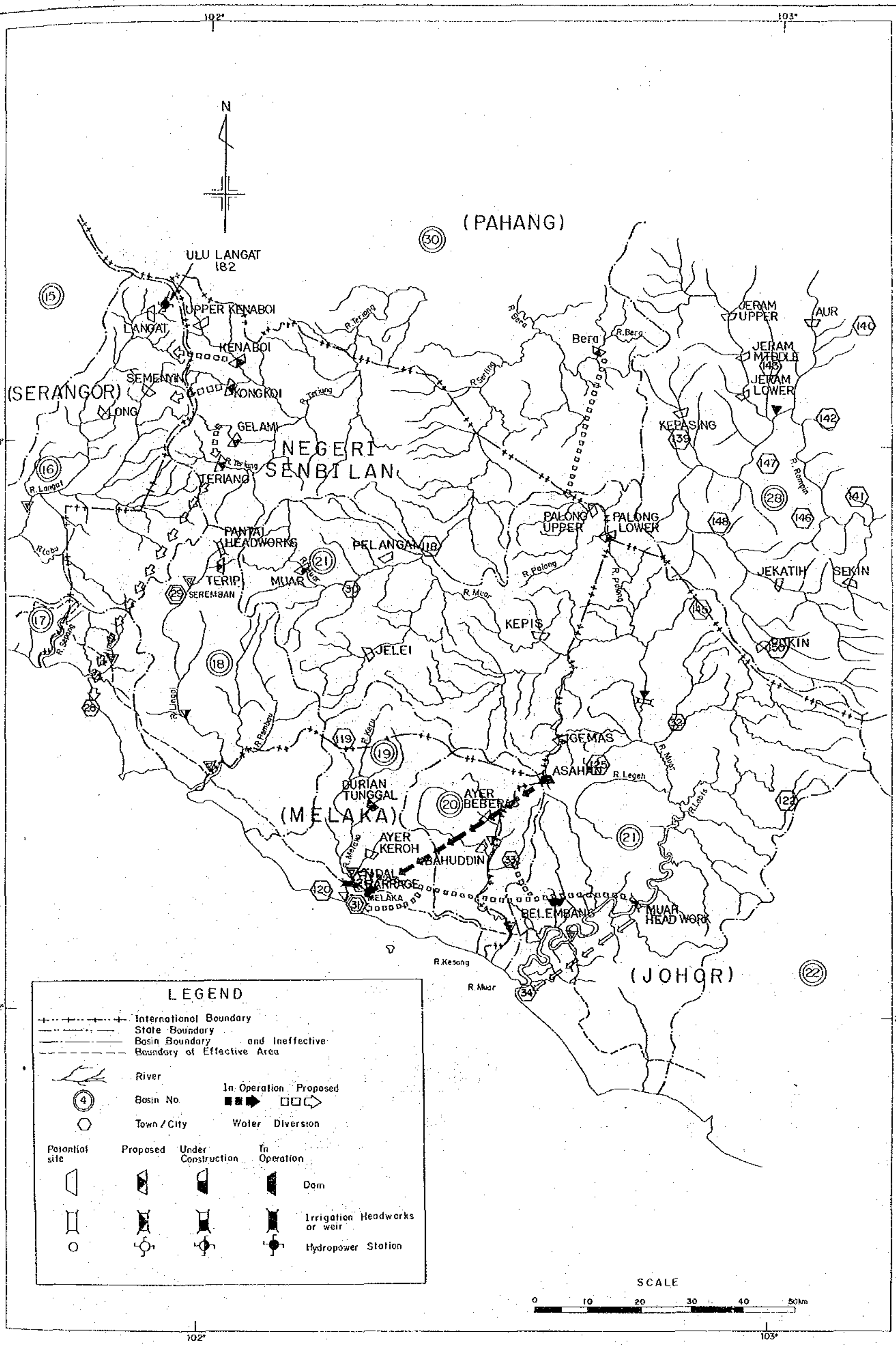

Fig. 9 Location of Potential and Proposed Water Source Facilities, Alternative B1 Basins 18~21

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NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

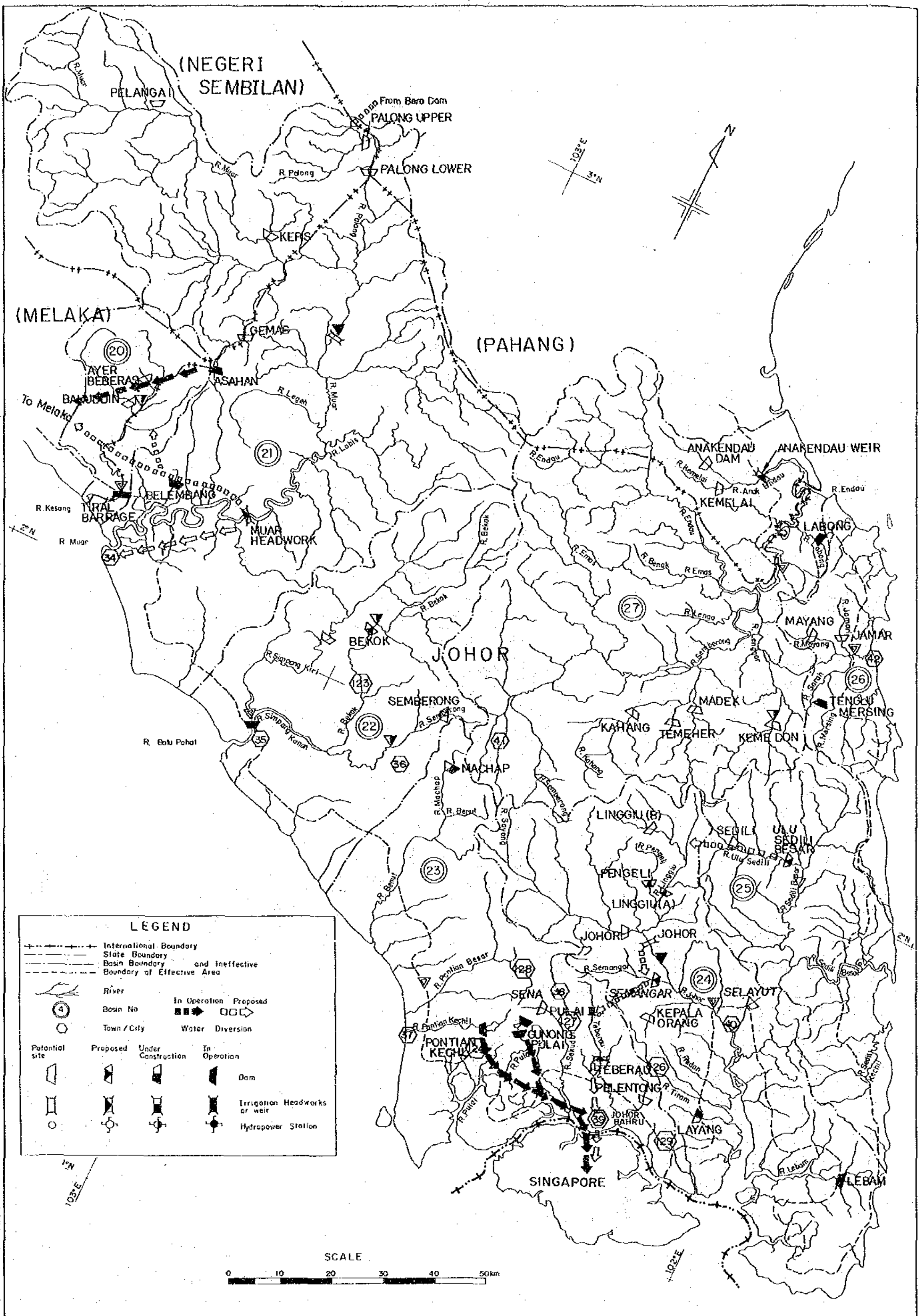

Fig. 10 Location of Potential and Proposed Water Source Facilities, Alternative B1 Basins 21 ~ 27

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NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

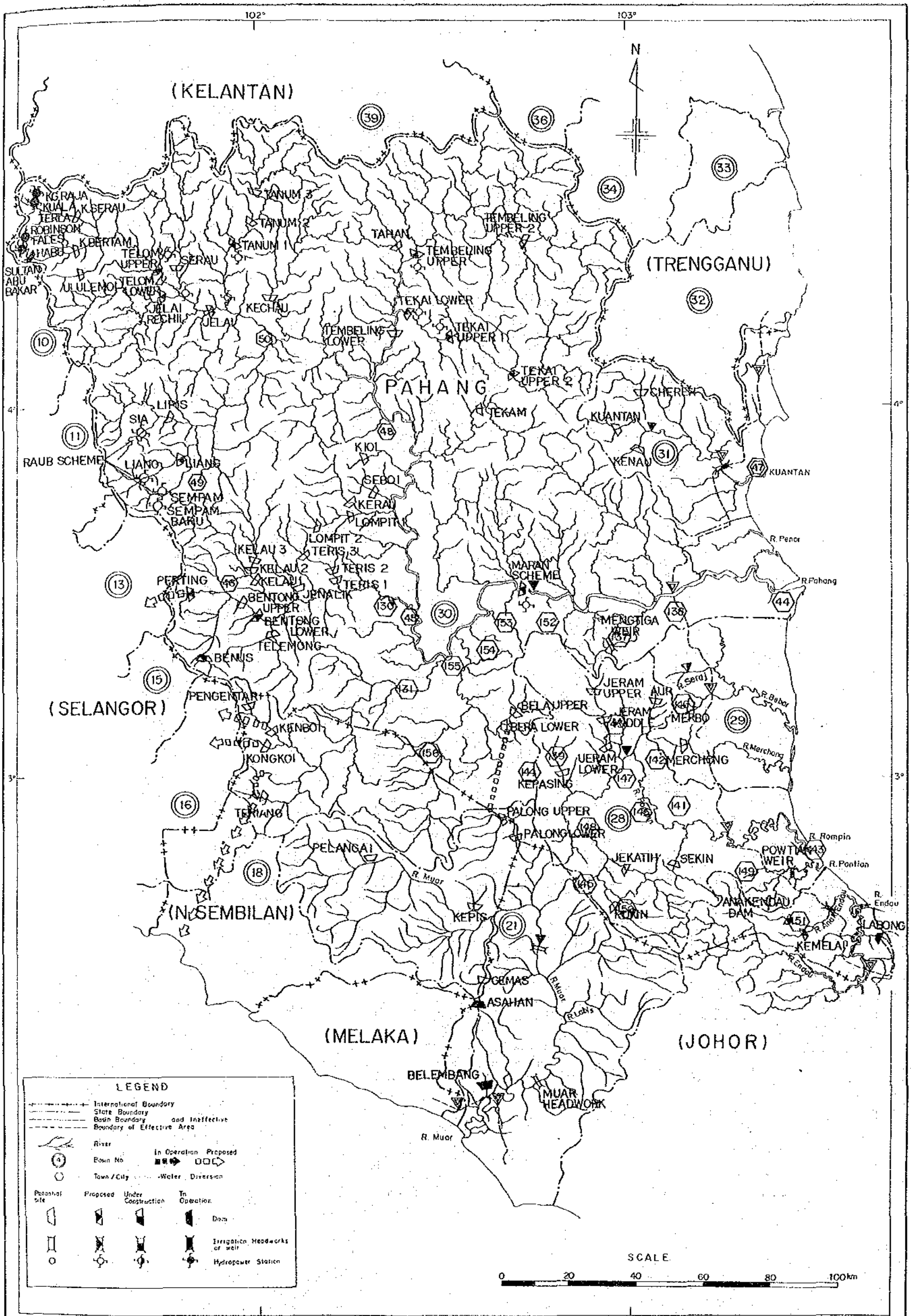

Fig. 11 Location of Potential and Proposed Water Source Facilities, Alternative B1 Basins 27 ~ 31

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

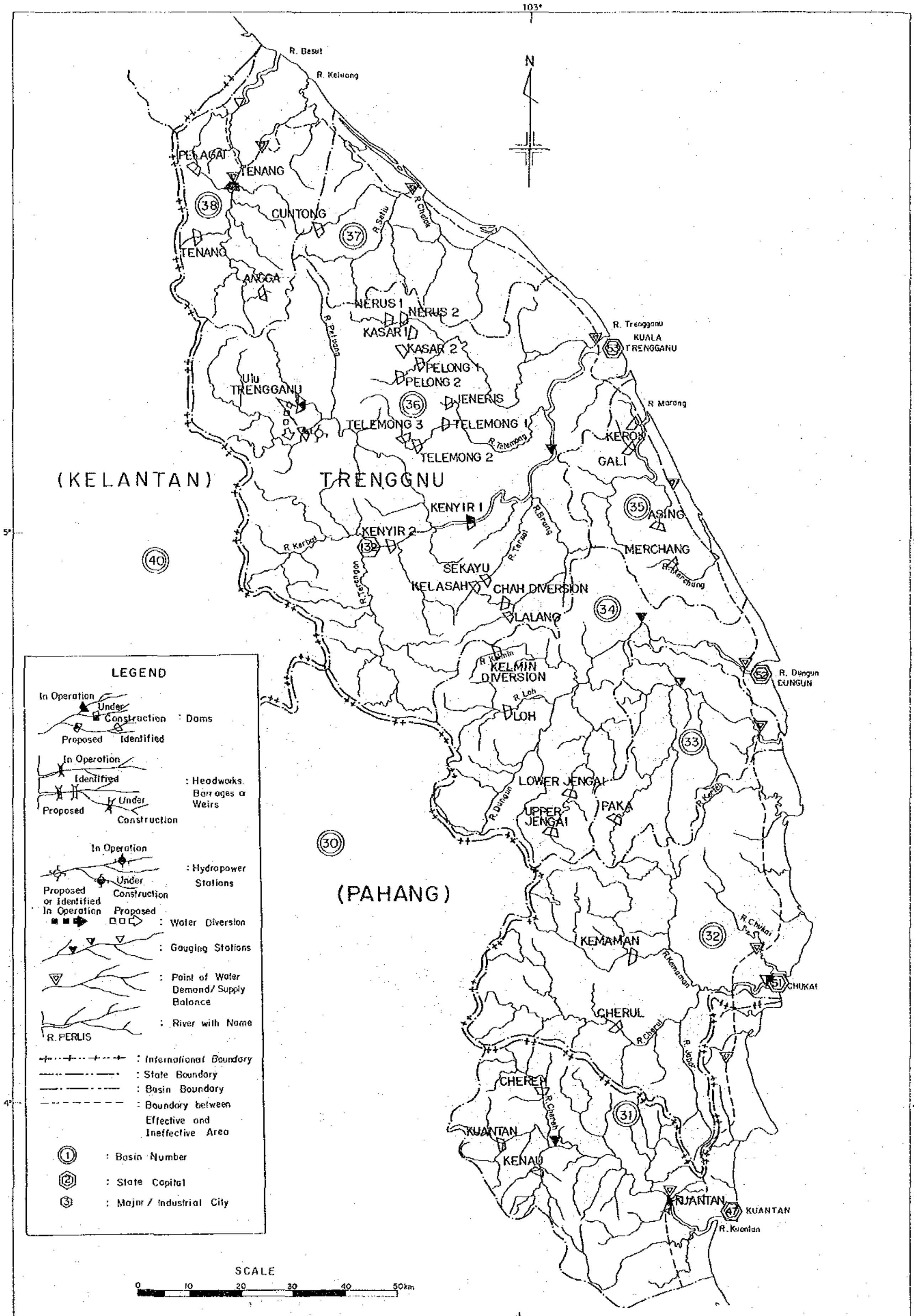

Fig. 12 Location of Potential and Proposed Water Source Facilities, Alternative B1 Basins 31 ~ 38

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NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

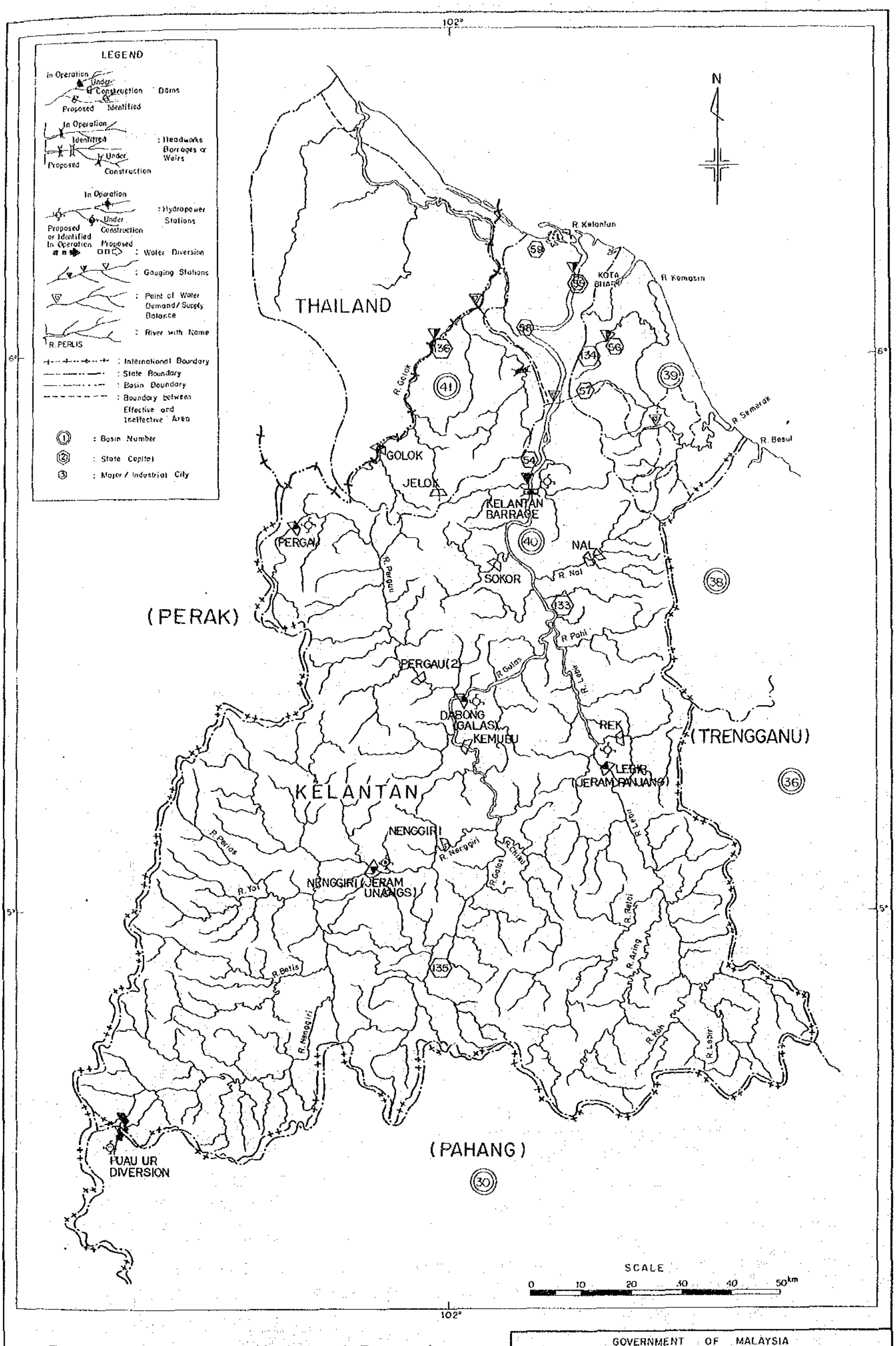

Fig. 13 Location of Potential and Proposed Water Source Facilities, Alternative B1 Basins 39 ~ 41

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

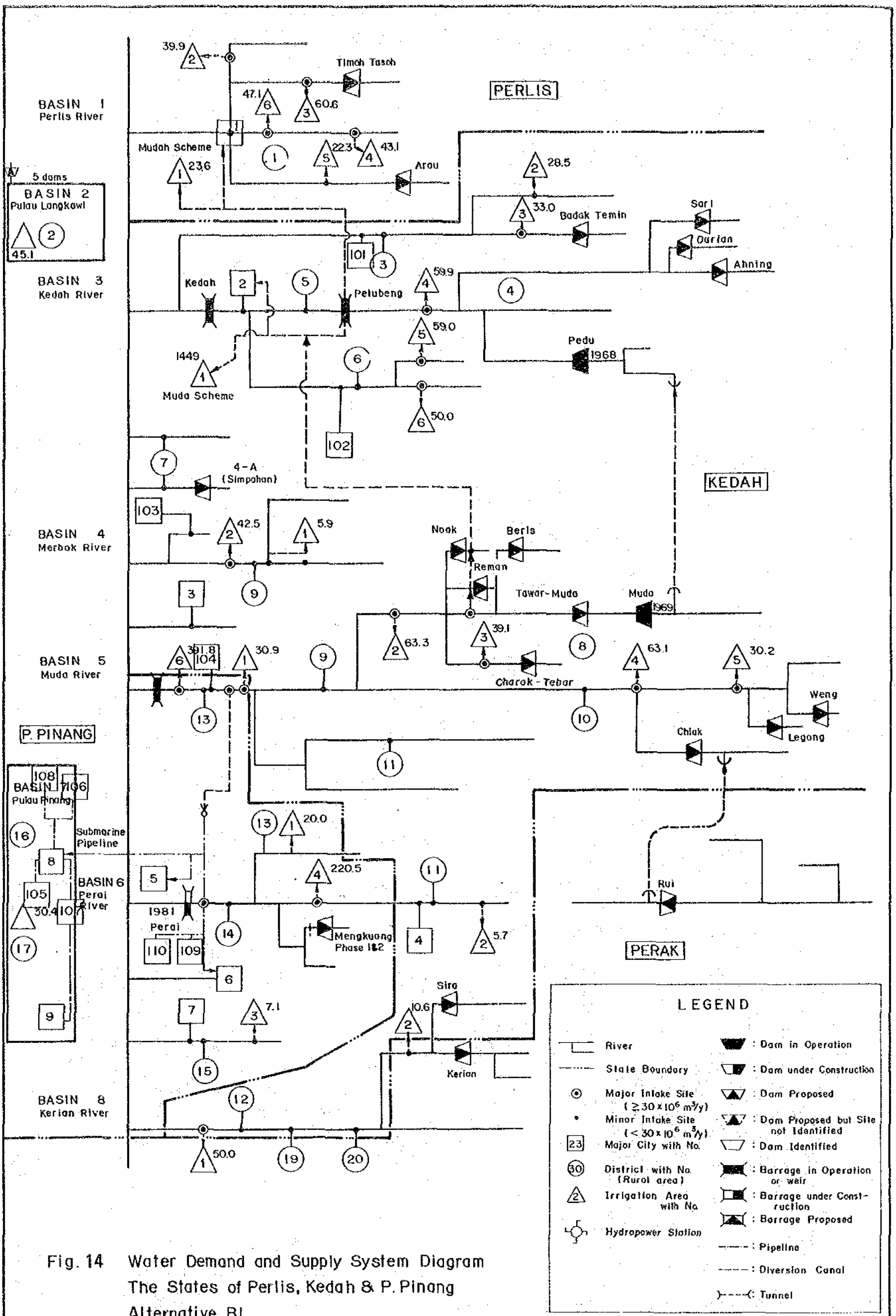

Fig. 14 Water Demand and Supply System Diagram
The States of Perlis, Kedah & P. Pinang
Alternative BI

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NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

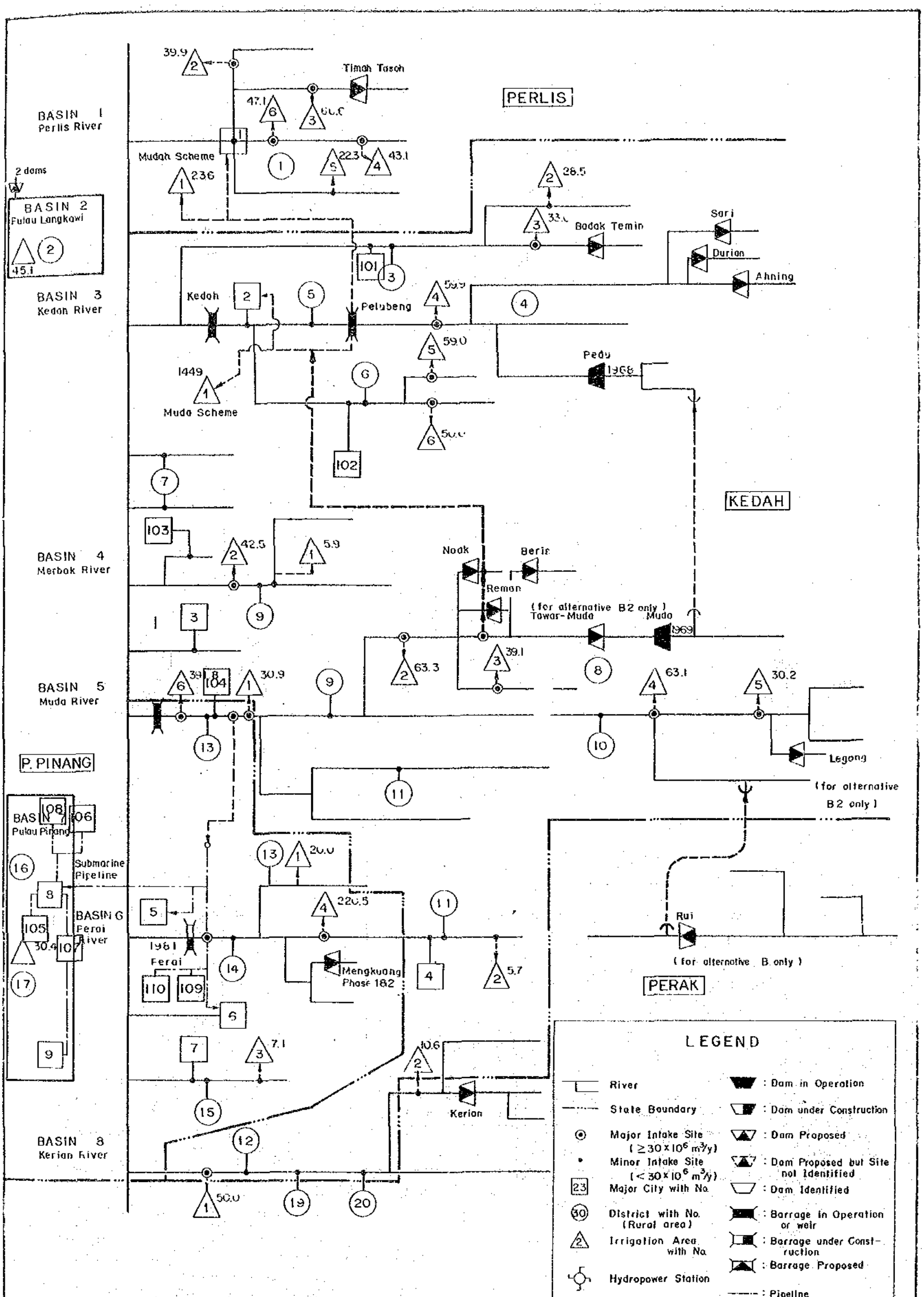

Fig. 15 Water Demand and Supply System Diagram
The States of Perlis, Kedah & P. Pinang
Alternatives B2 & B3

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

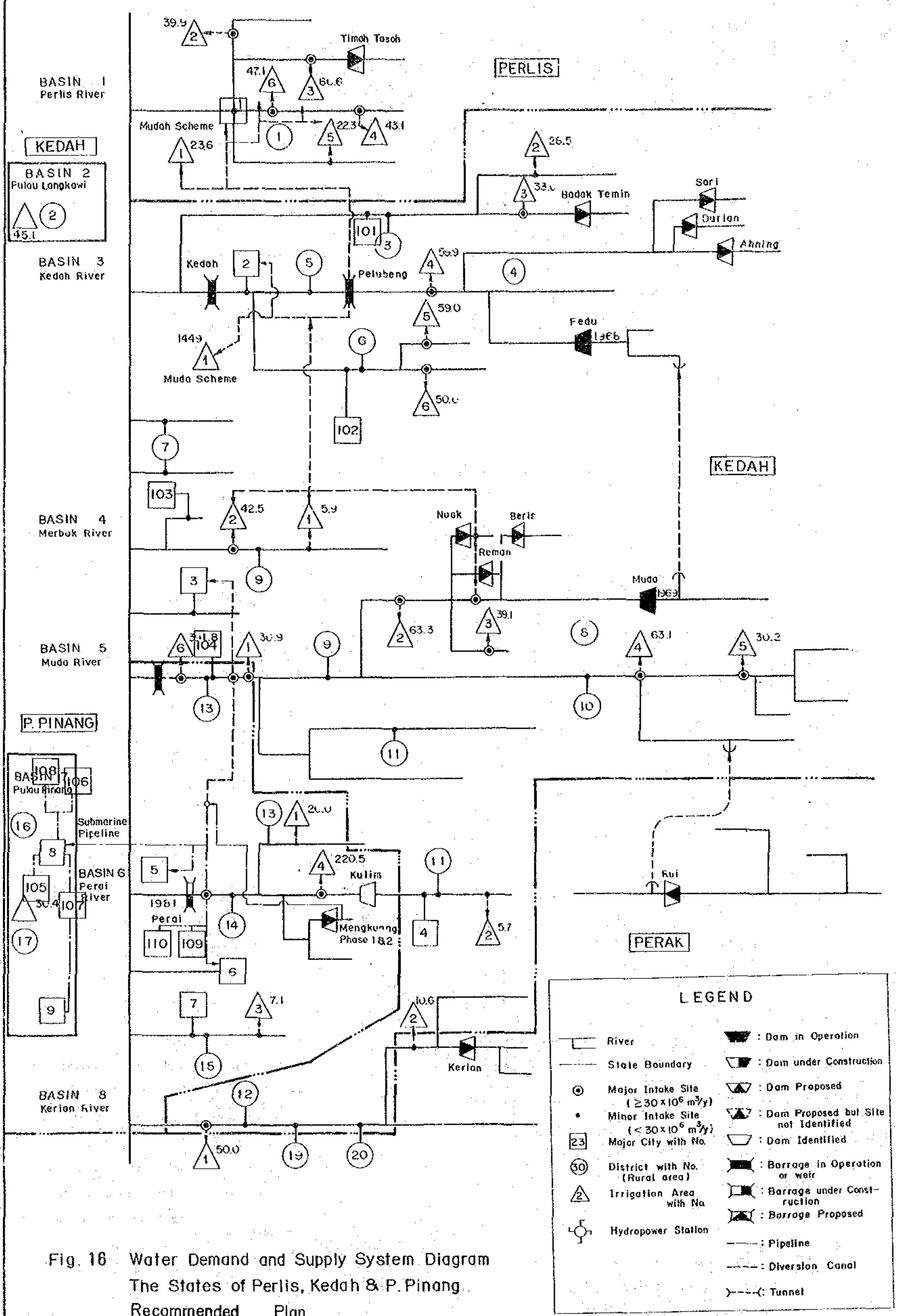

Fig. 16 Water Demand and Supply System Diagram
The States of Perlis, Kedah & P. Pinang
Recommended Plan

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

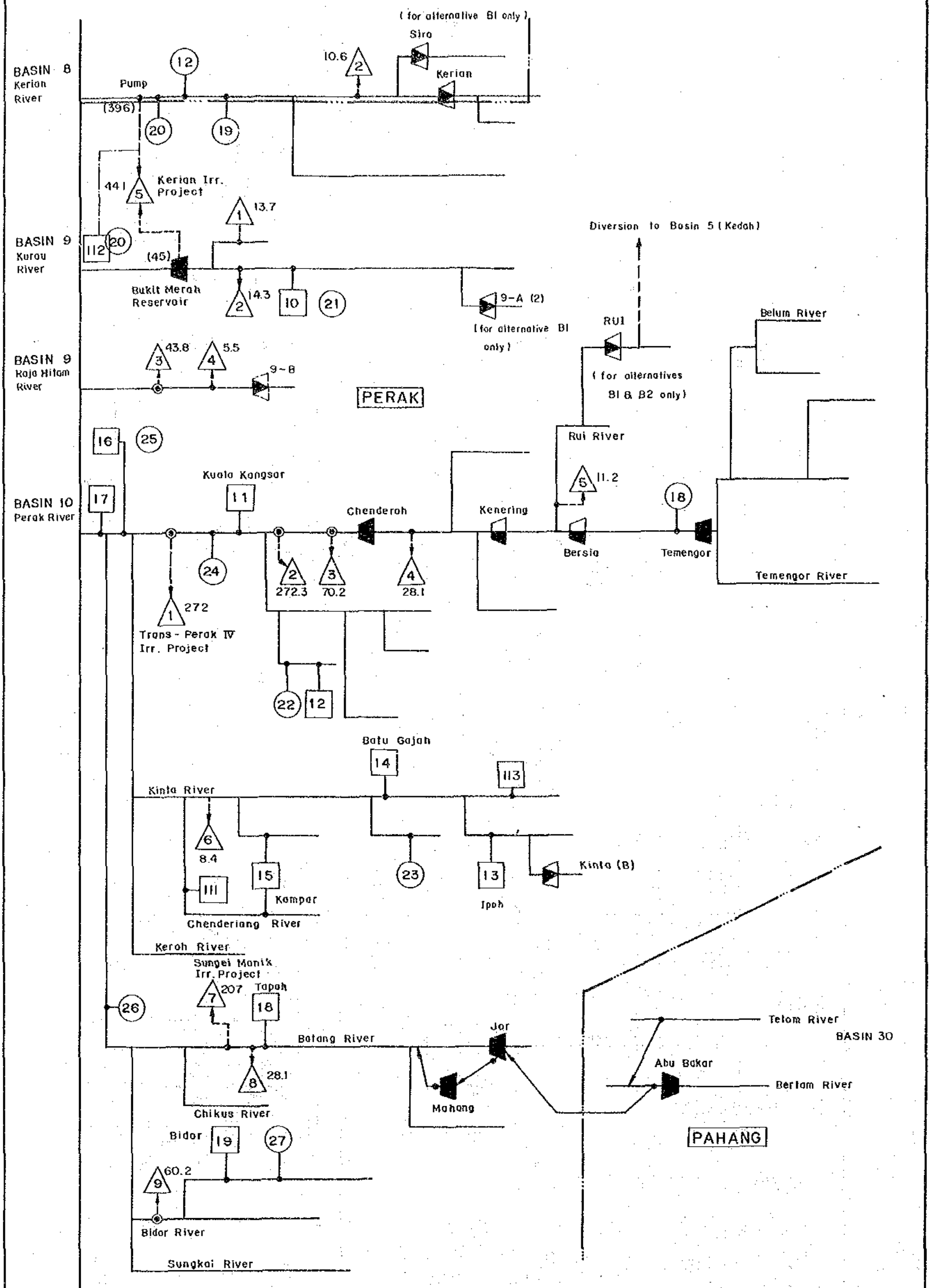

Fig. 17 Water Demand and Supply System Diagram
The State of Perak
Alternatives B1, B2 & B3

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

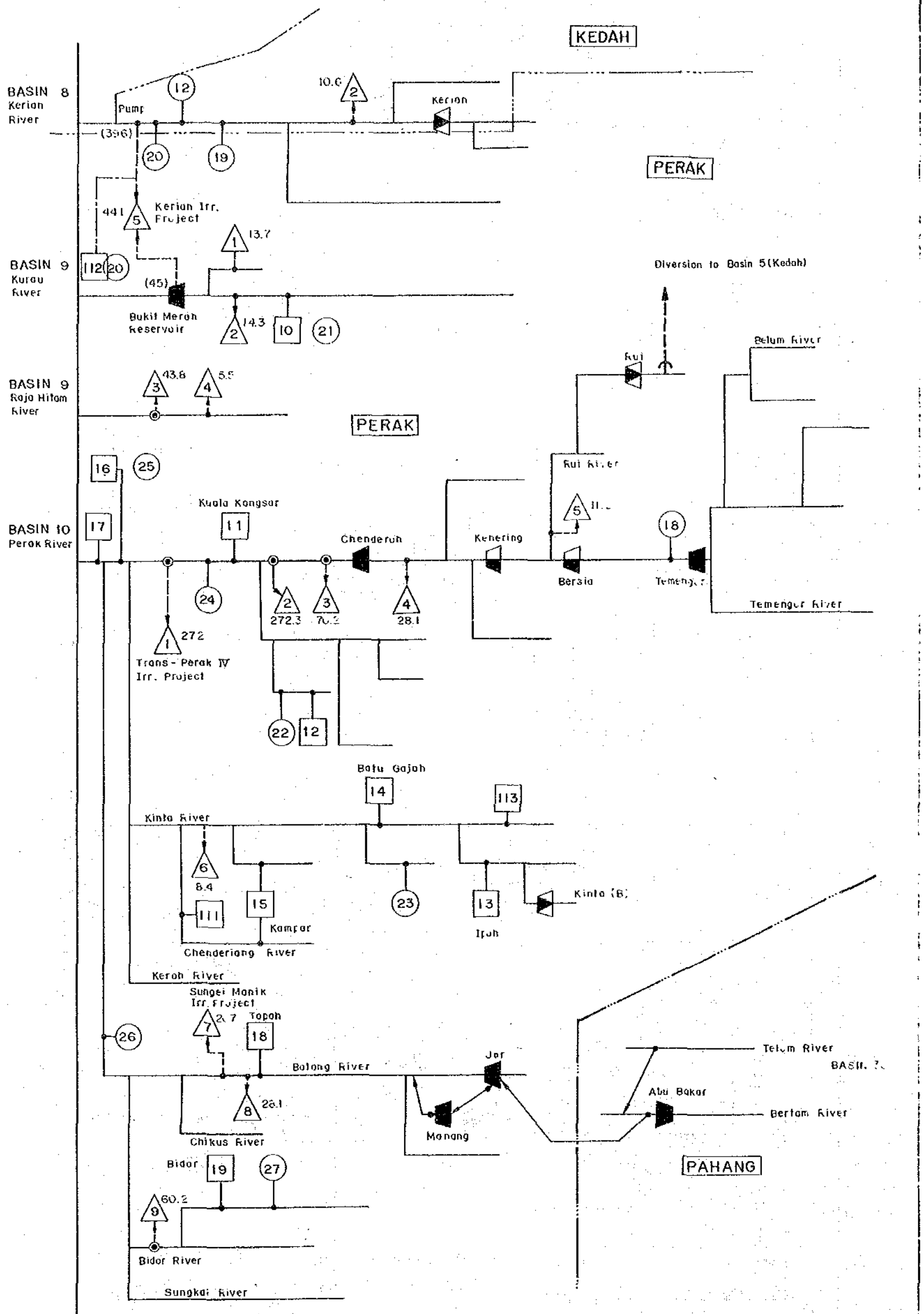

Fig. 18 Water Demand and Supply System Diagram
The State of Perak
Recommended Plan

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

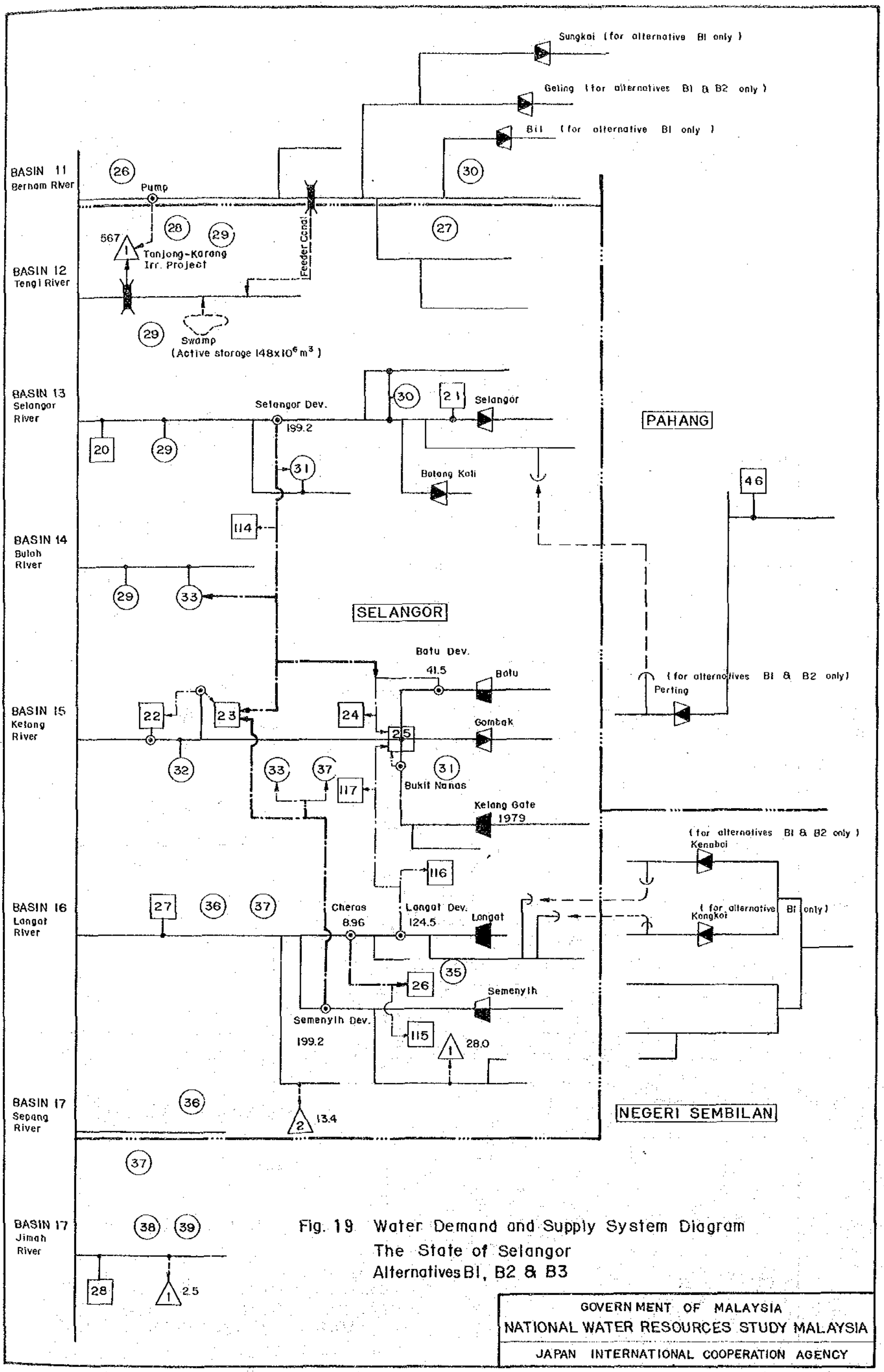

Fig. 19 Water Demand and Supply System Diagram
The State of Selangor
Alternatives B1, B2 & B3

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

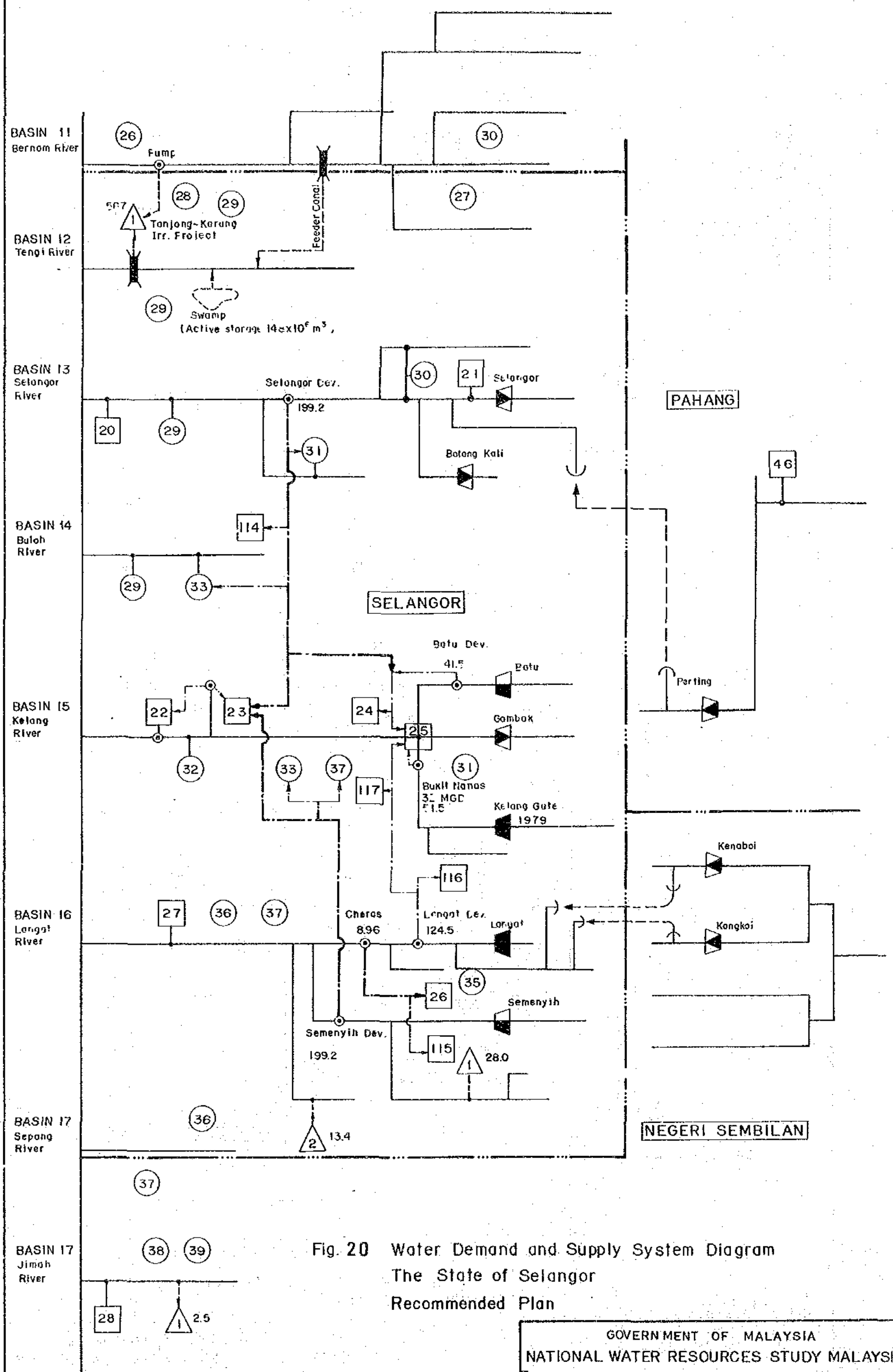

Fig. 20 Water Demand and Supply System Diagram
The State of Selangor
Recommended Plan

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

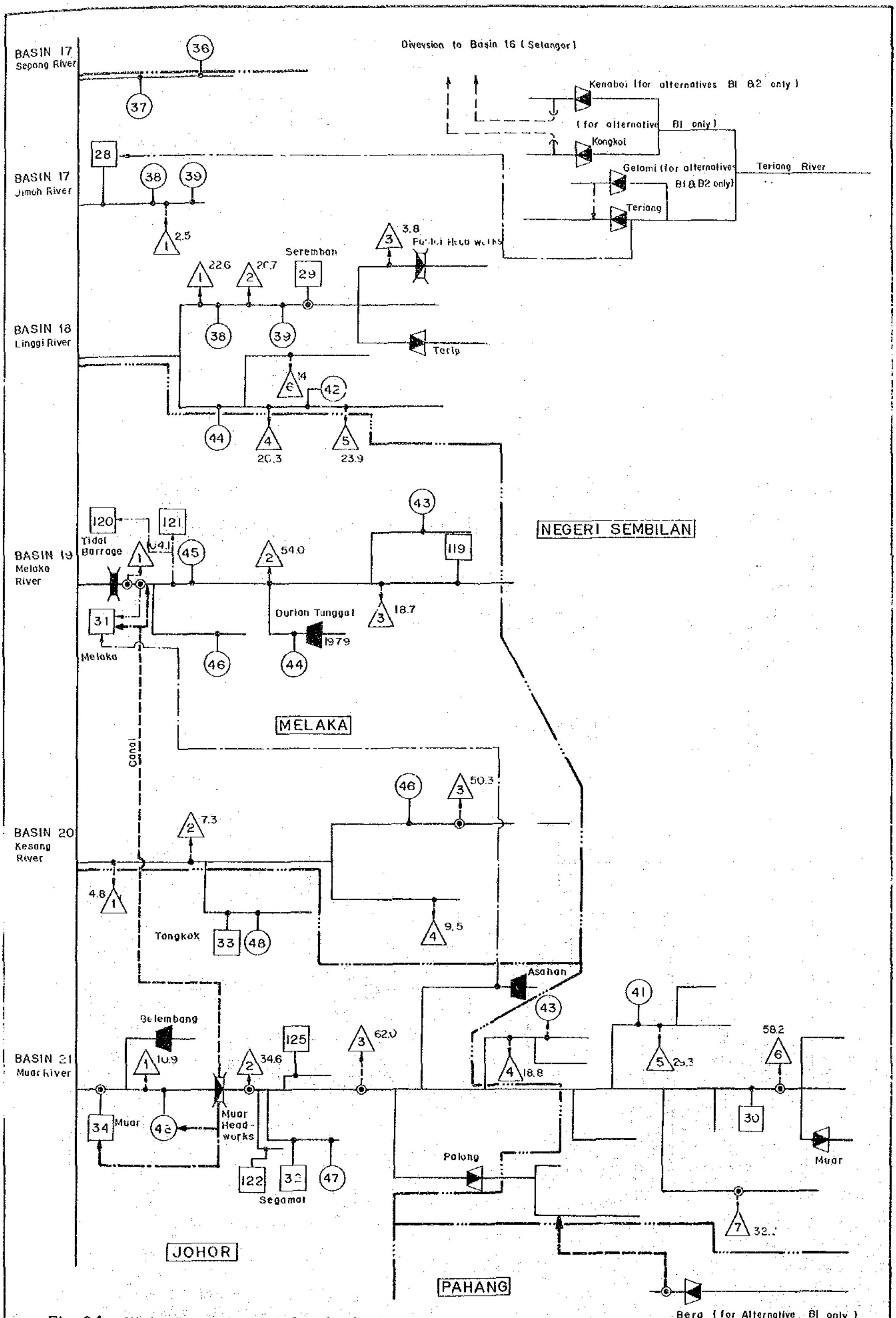

Fig. 21. Water Demand and Supply System Diagram
The States of Negeri Sembilan & Melaka
Alternatives B1, B2 & B3

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

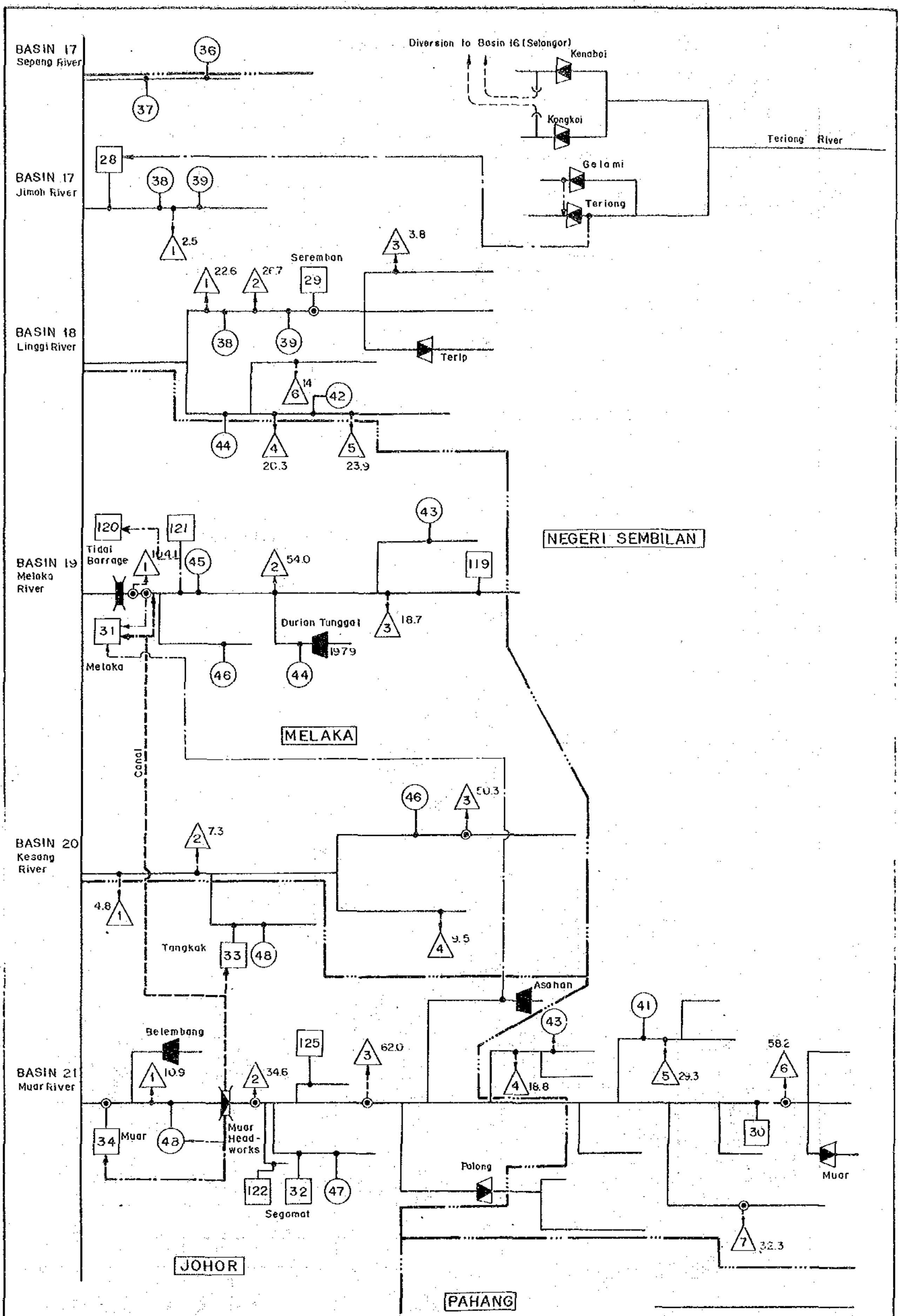

Fig. 22 Water Demand and Supply System Diagram
The States of Negeri Sembilan & Melaka
Recommended Plan

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

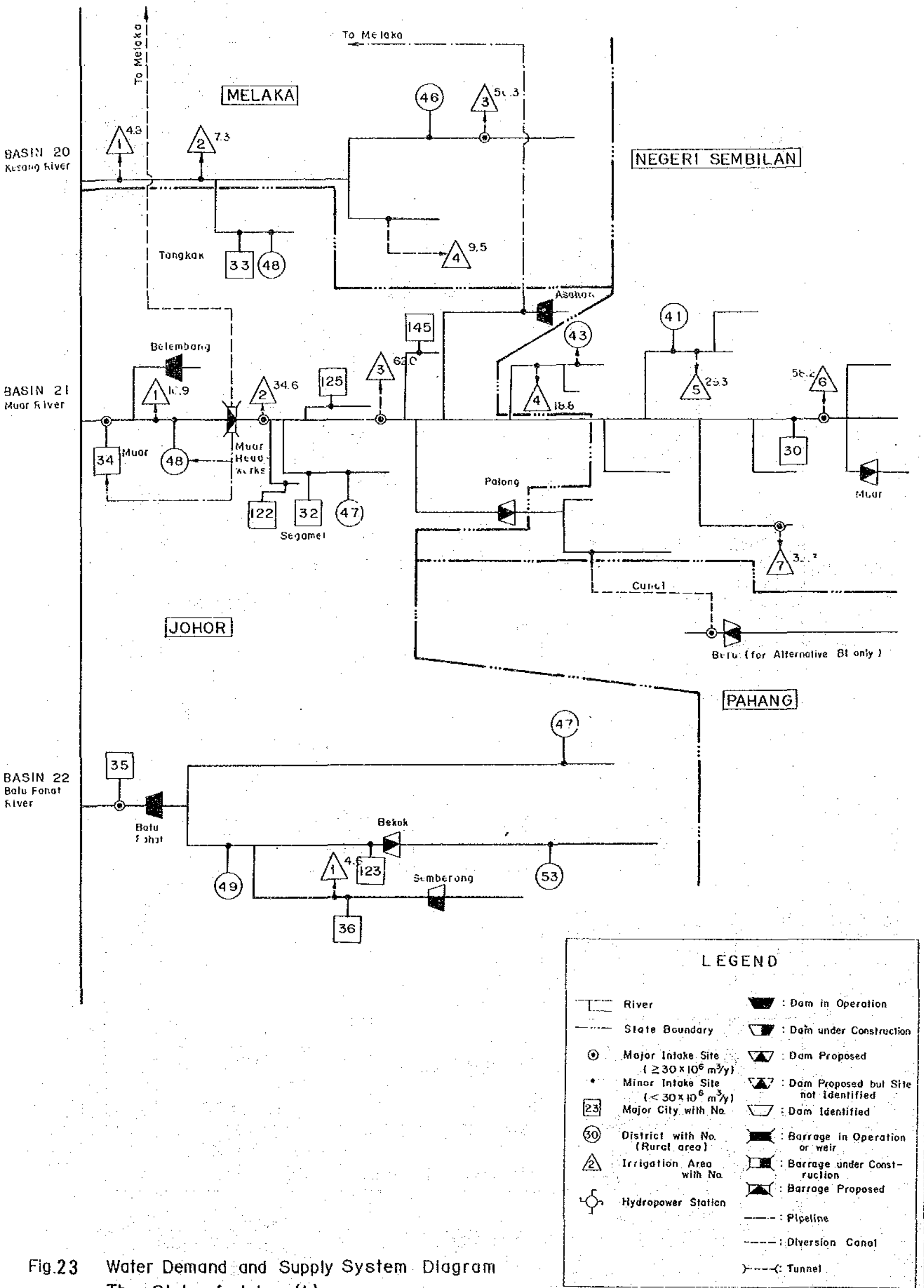

Fig.23 Water Demand and Supply System Diagram
The State of Johor (1)
Recommended Plan and Alternatives B1 - B3

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

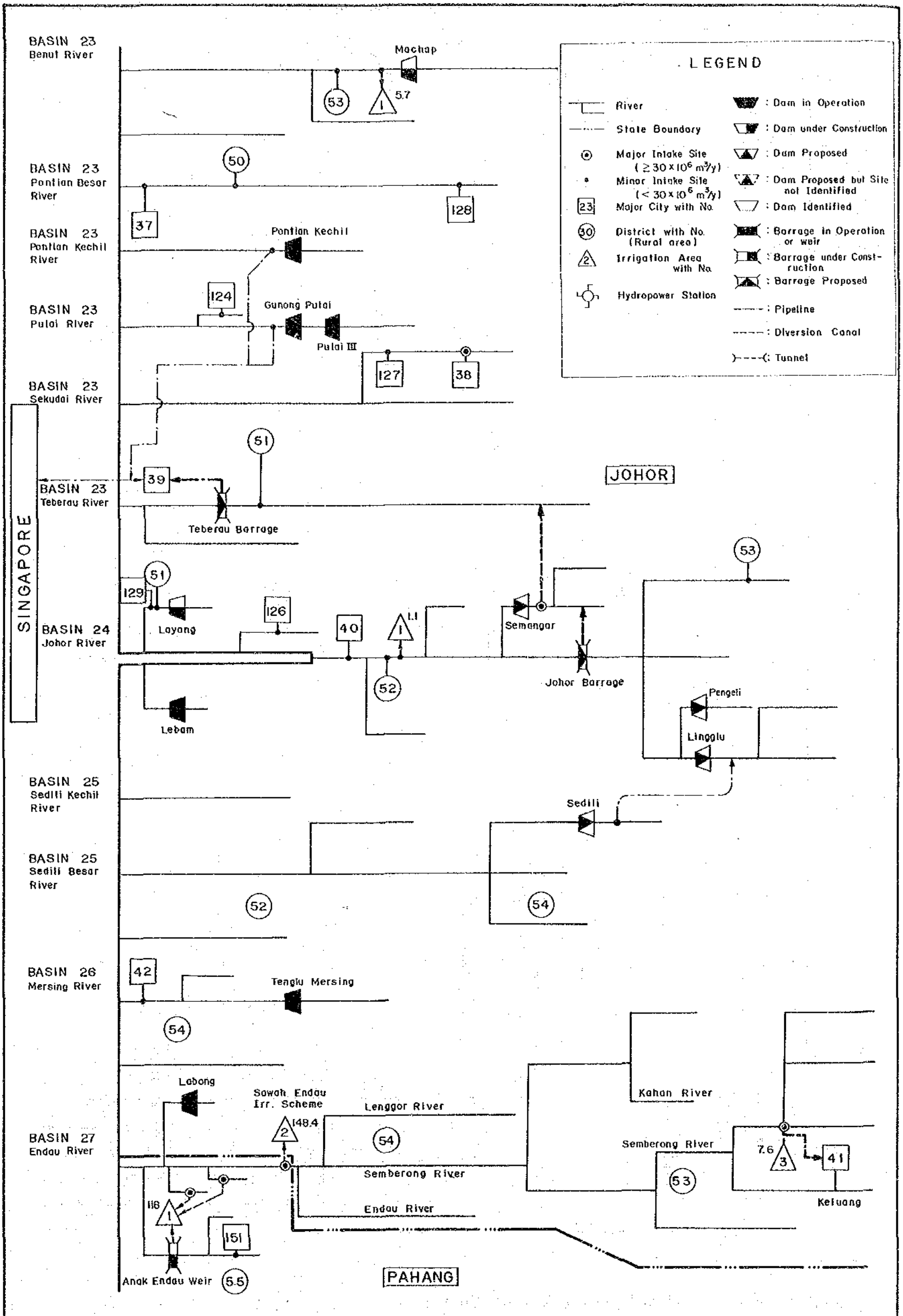

Fig.24 Water Demand and Supply System Diagram
The State of Johor (2)
Recommended Plan and Alternative B1

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

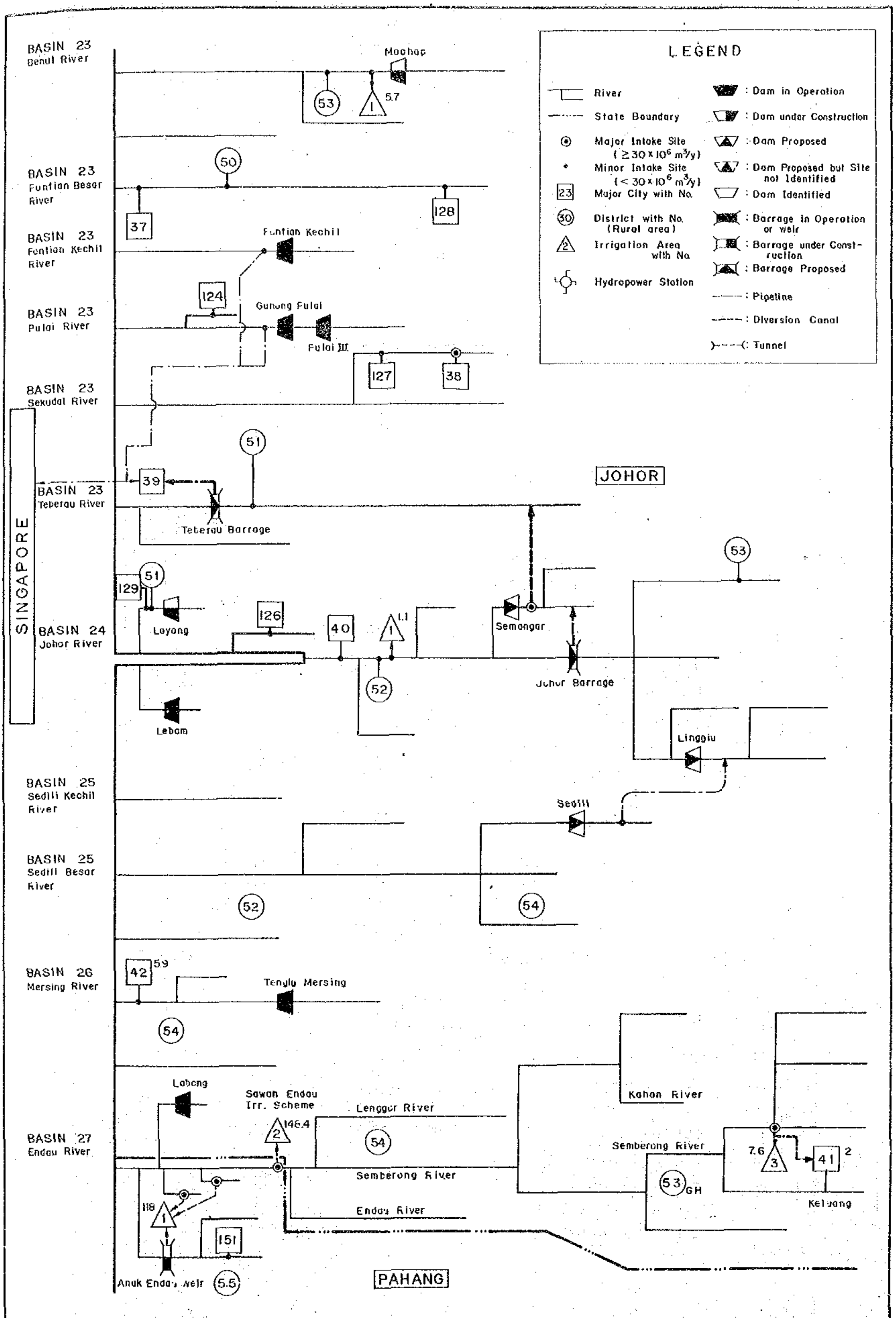

Fig.25 Water Demand and Supply System Diagram
The State of Johor (2)
Alternatives B2 & B3

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

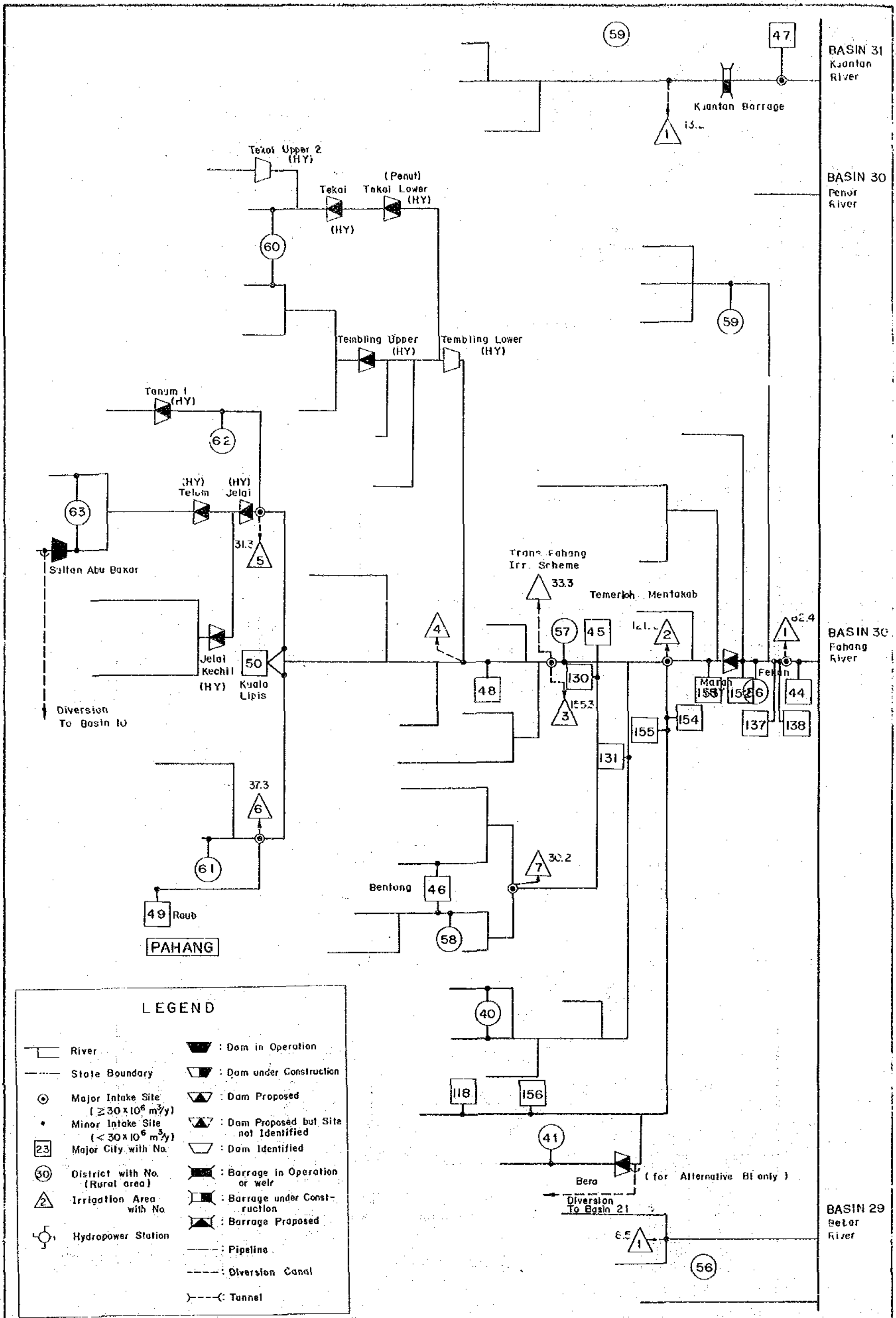

Fig.26 Water Demand and Supply System Diagram
The State of Pahang (1)
Alternative B1 , B2 & B3

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

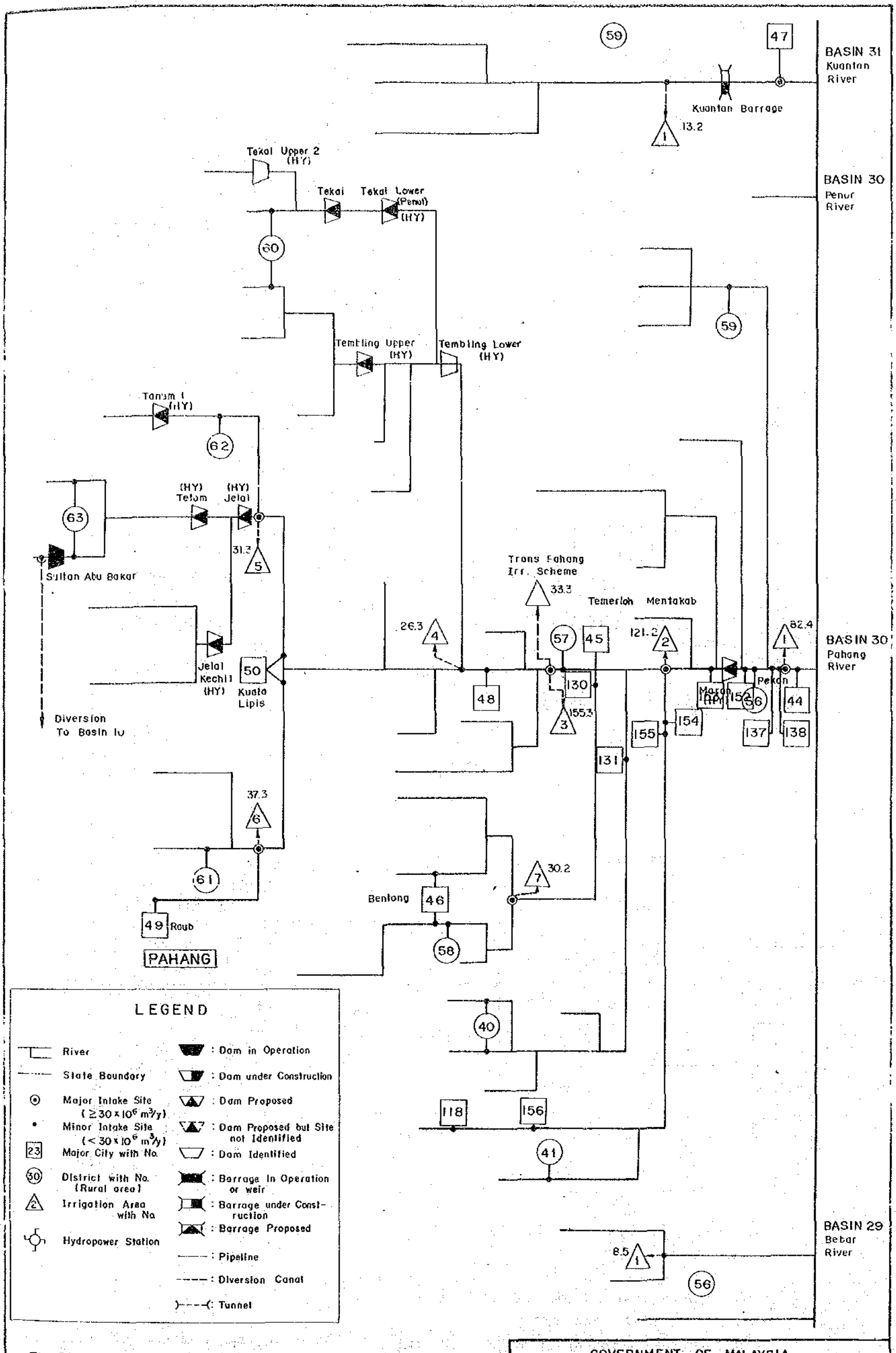

Fig.27 Water Demand and Supply System Diagram
The State of Pahang (1)
Recommended Plan

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

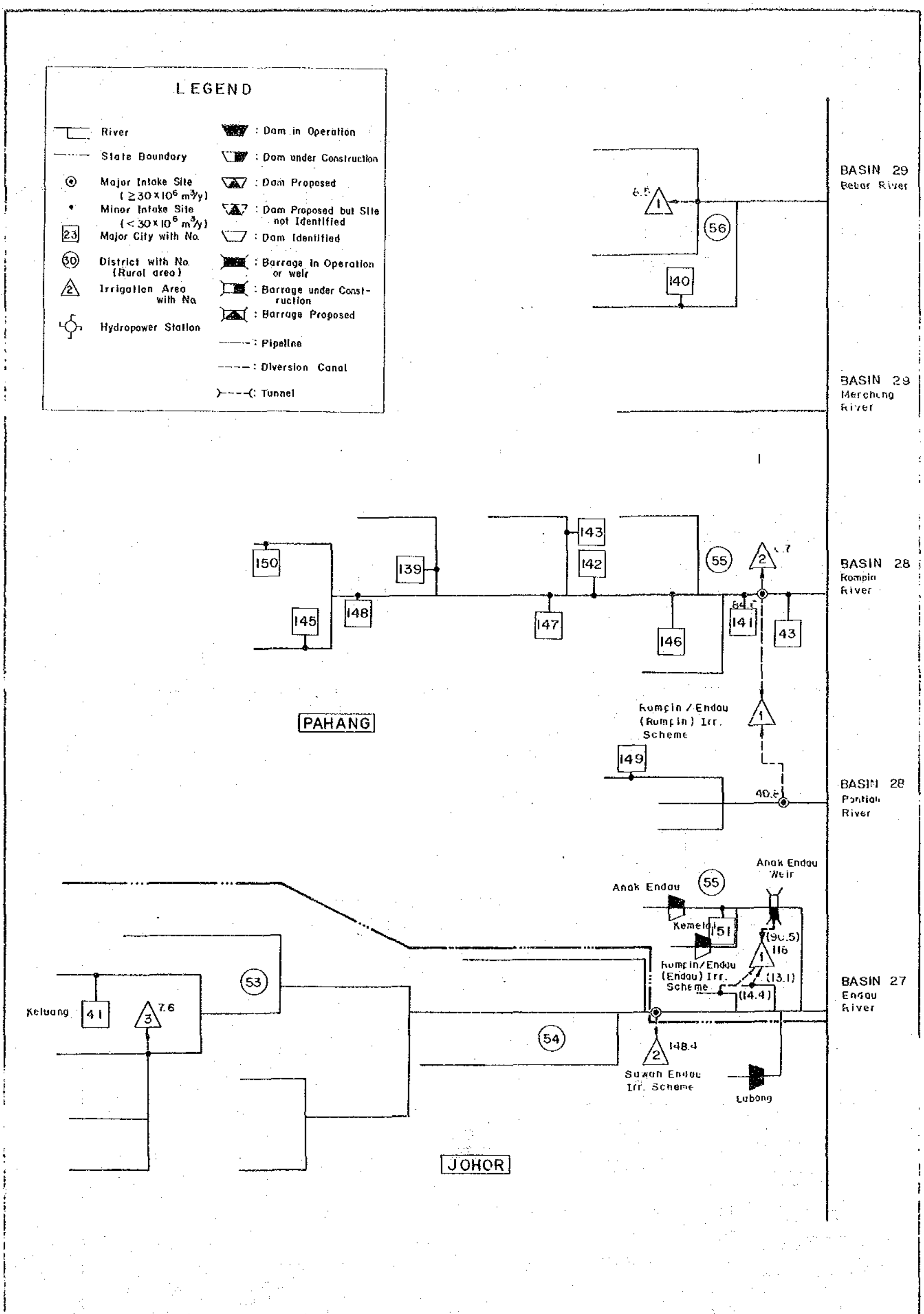

Fig.28 Water Demand and Supply System Diagram
The State of Pahang (2)
Recommended Plan and Alternatives BI - B3

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

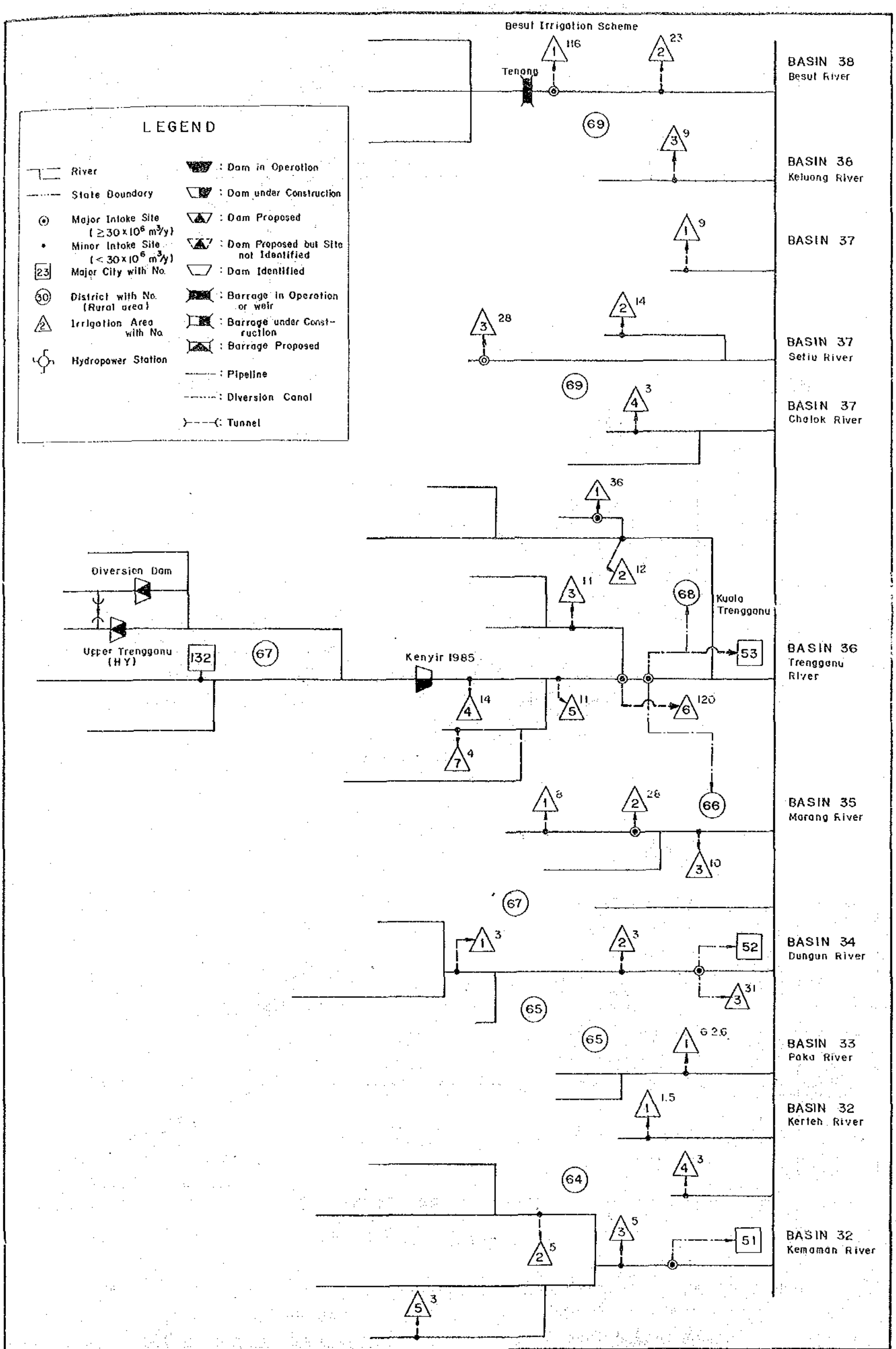

Fig.29 Water Demand and Supply System Diagram
The State of Trengganu
Recommended Plan and Alternatives B1~B3

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

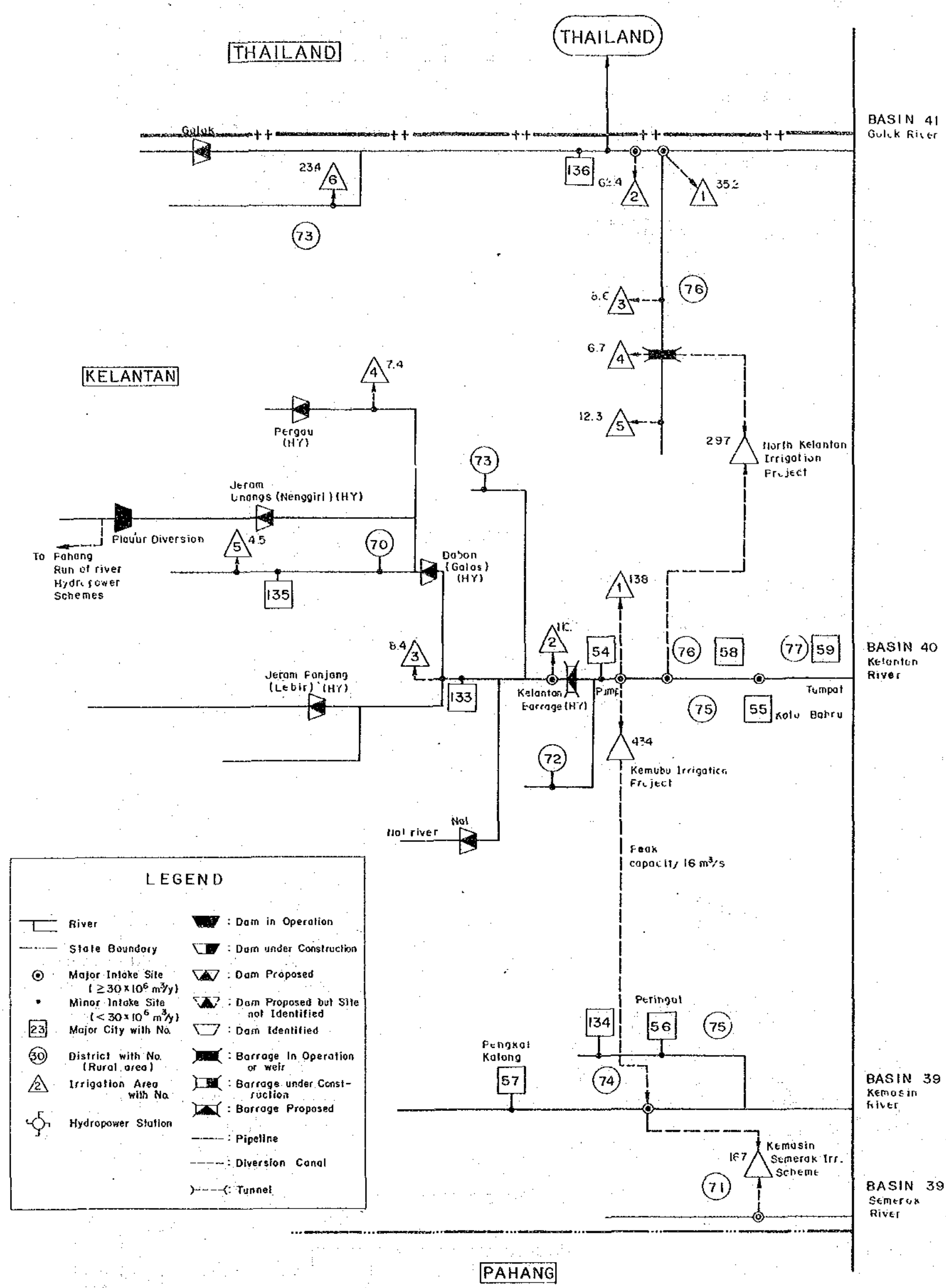

Fig.30 Water Demand and Supply System Diagram
The State of Kelantan
Recommended Plan

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

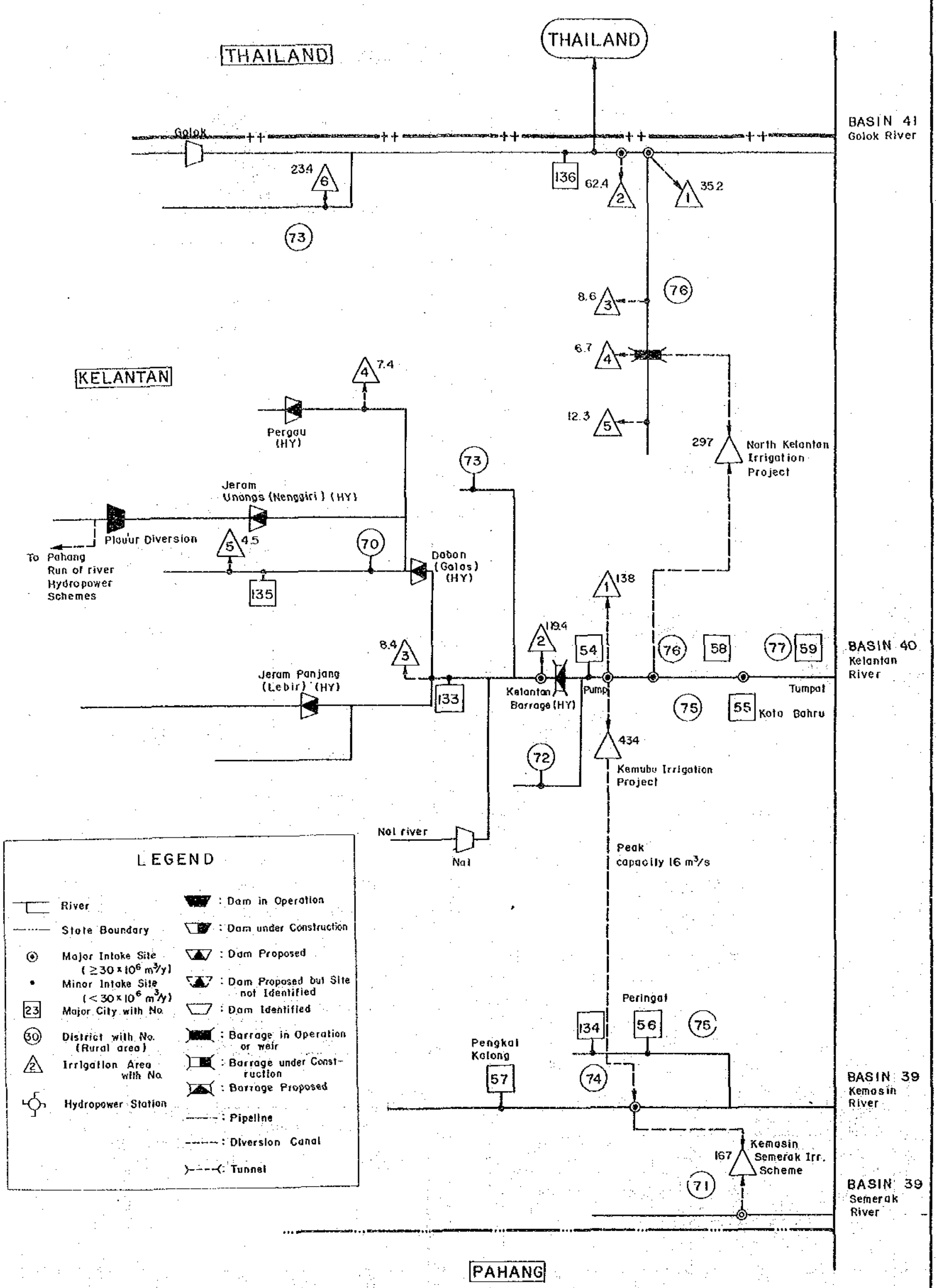

Fig.31 Water Demand and Supply System Diagram
The State of Kelantan
Alternatives B1 B2 & B3

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

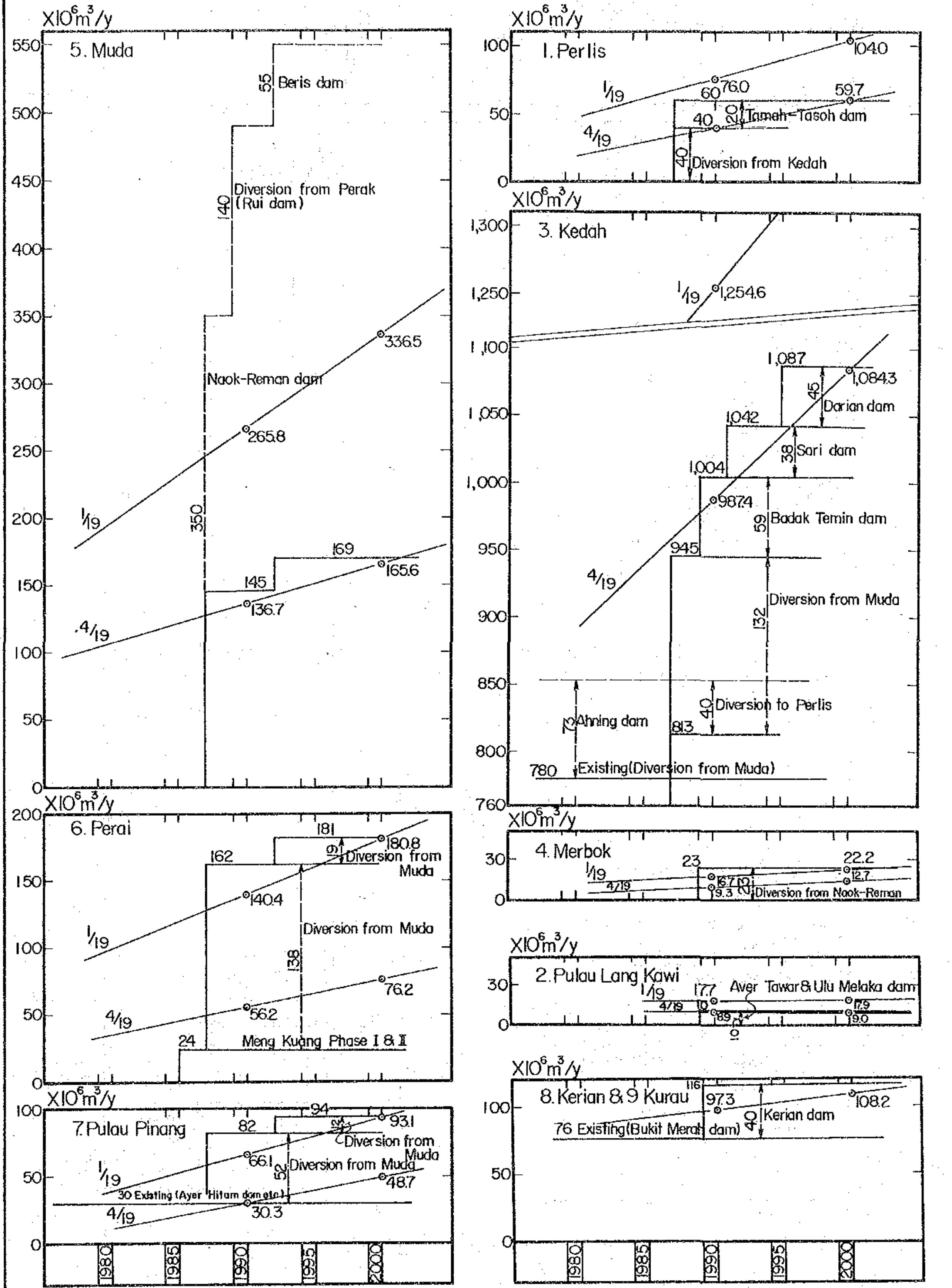

Fig.32 Recommended Water Demand and Suppy Balance Program For Perlis, Kedah and Pulau Pinang Region, Pulau Langkawi, and Kerian and Kurau River Basins

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

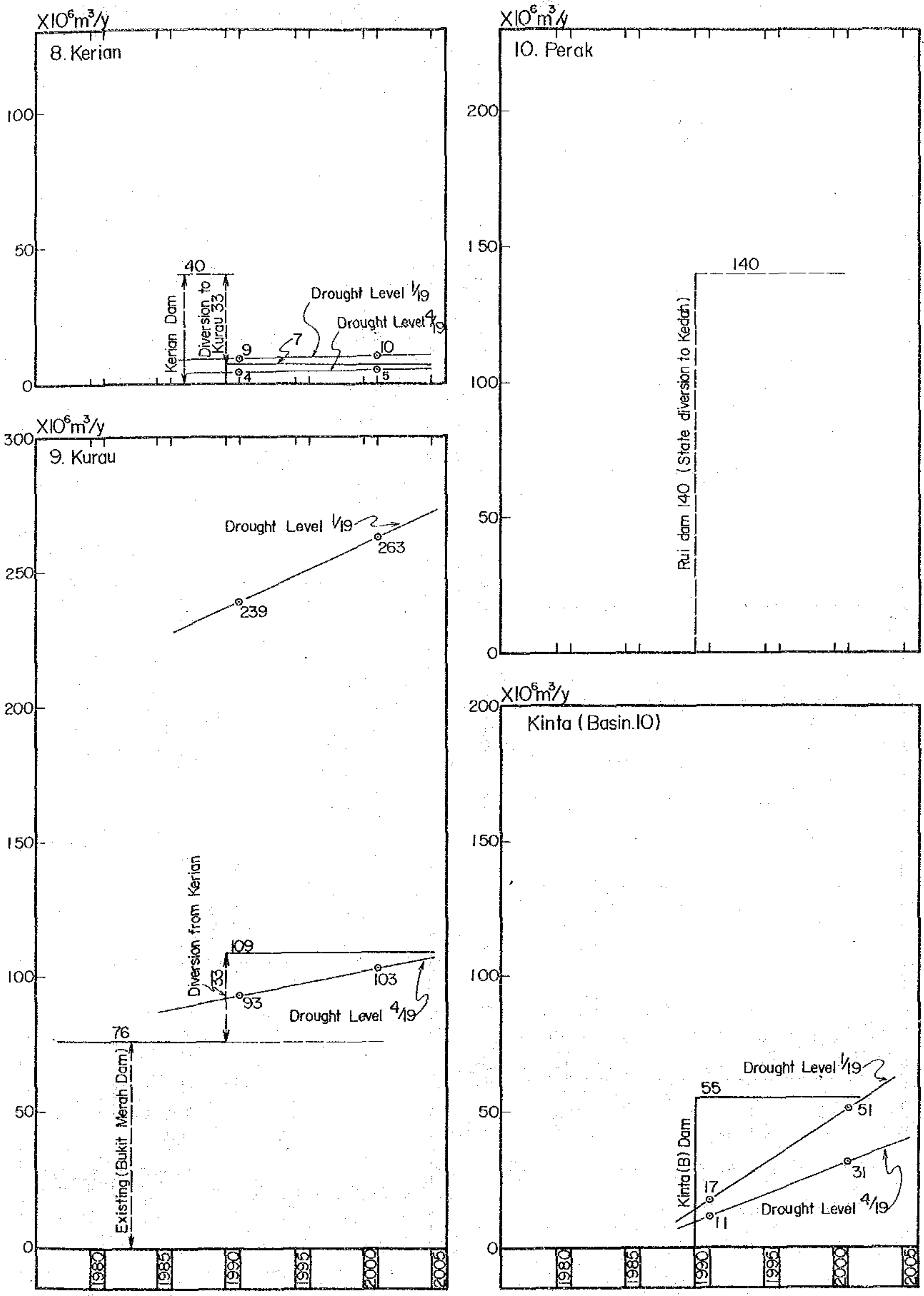

Fig.33 Recommended Water Demand and Supply Balance Program For Kinta Valley, and Kerian and Kurau River Basins

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

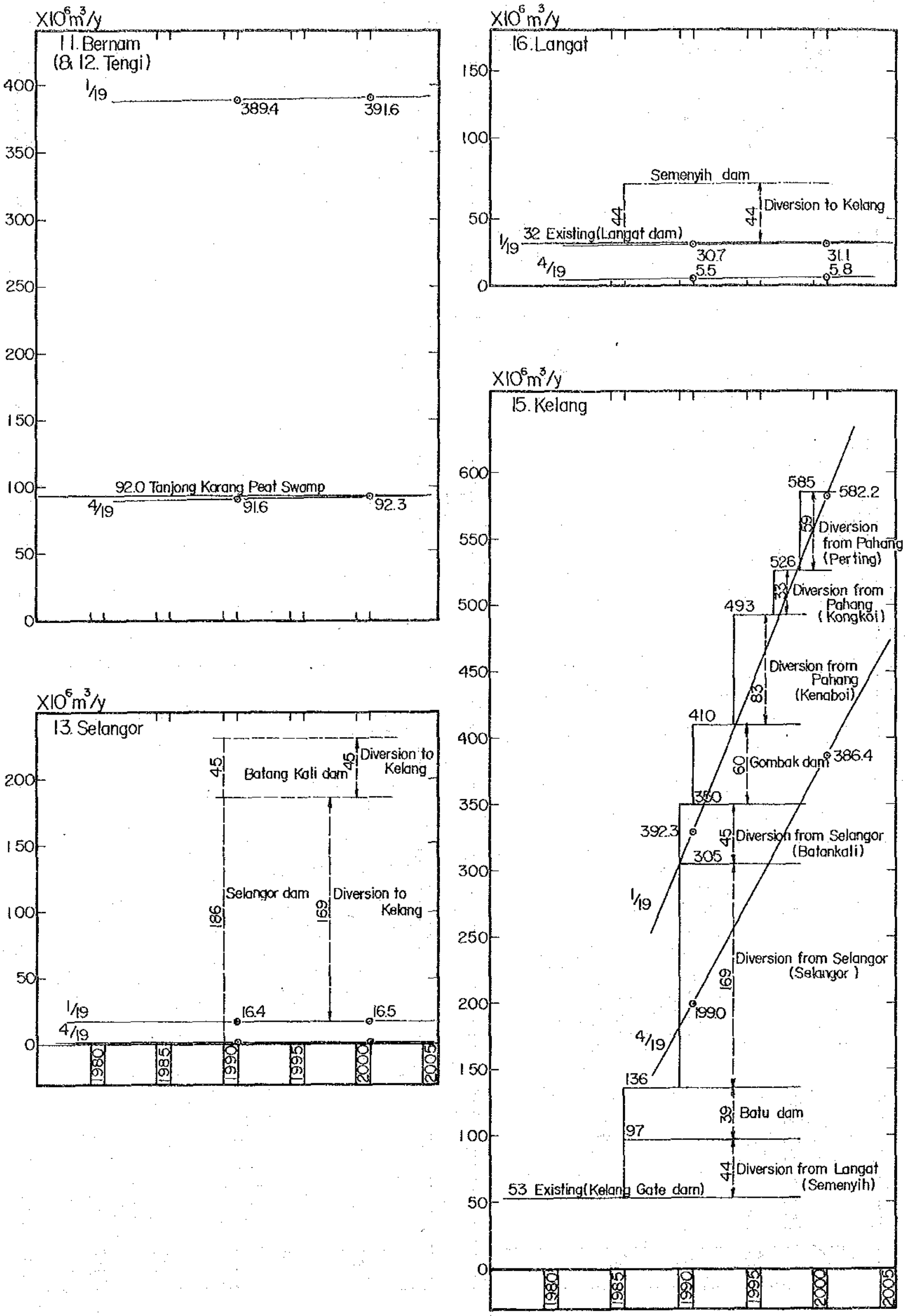

Fig.34 Recommended Water Demand and Supply Balance Program For Kelang Valley, and Bernam and Tengi River Basins

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

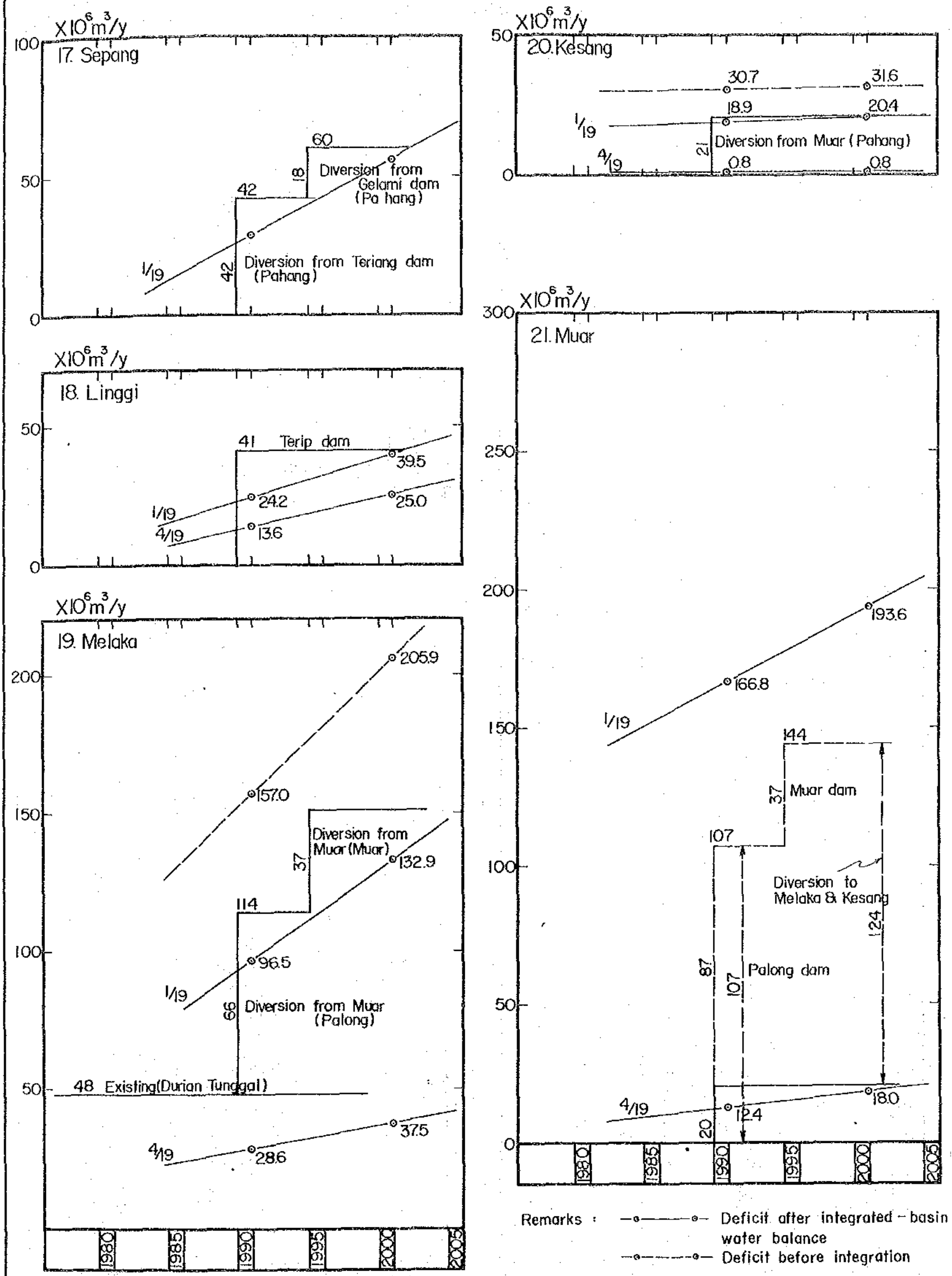

Fig.35 Recommended Water Demand and Suplly Balance Program For Melaka — Muar Region,and Sepang and Linggi River Basins

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

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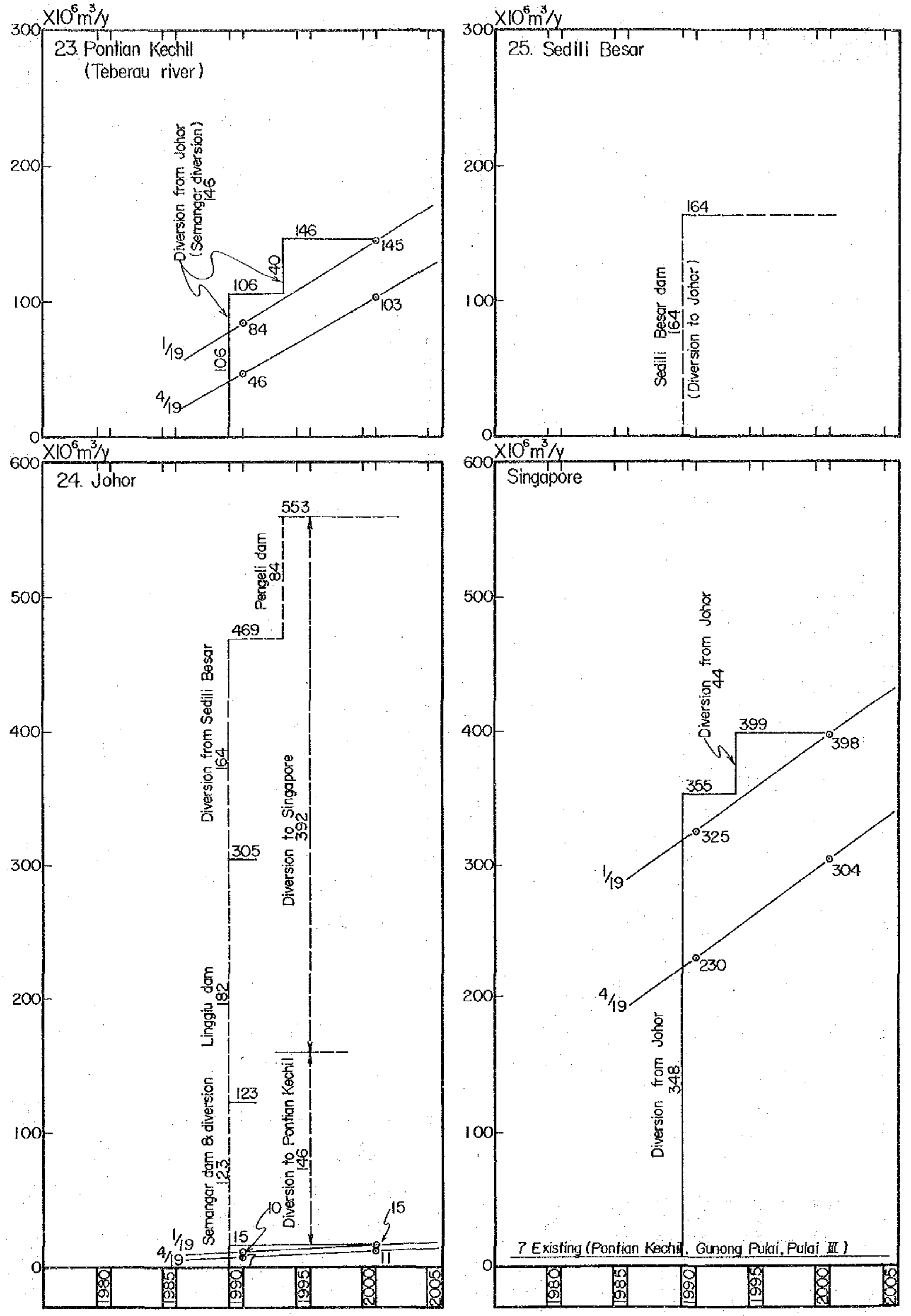

Fig.36 Recommended Water Demand and Supply Balance Program For South Johor Region

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

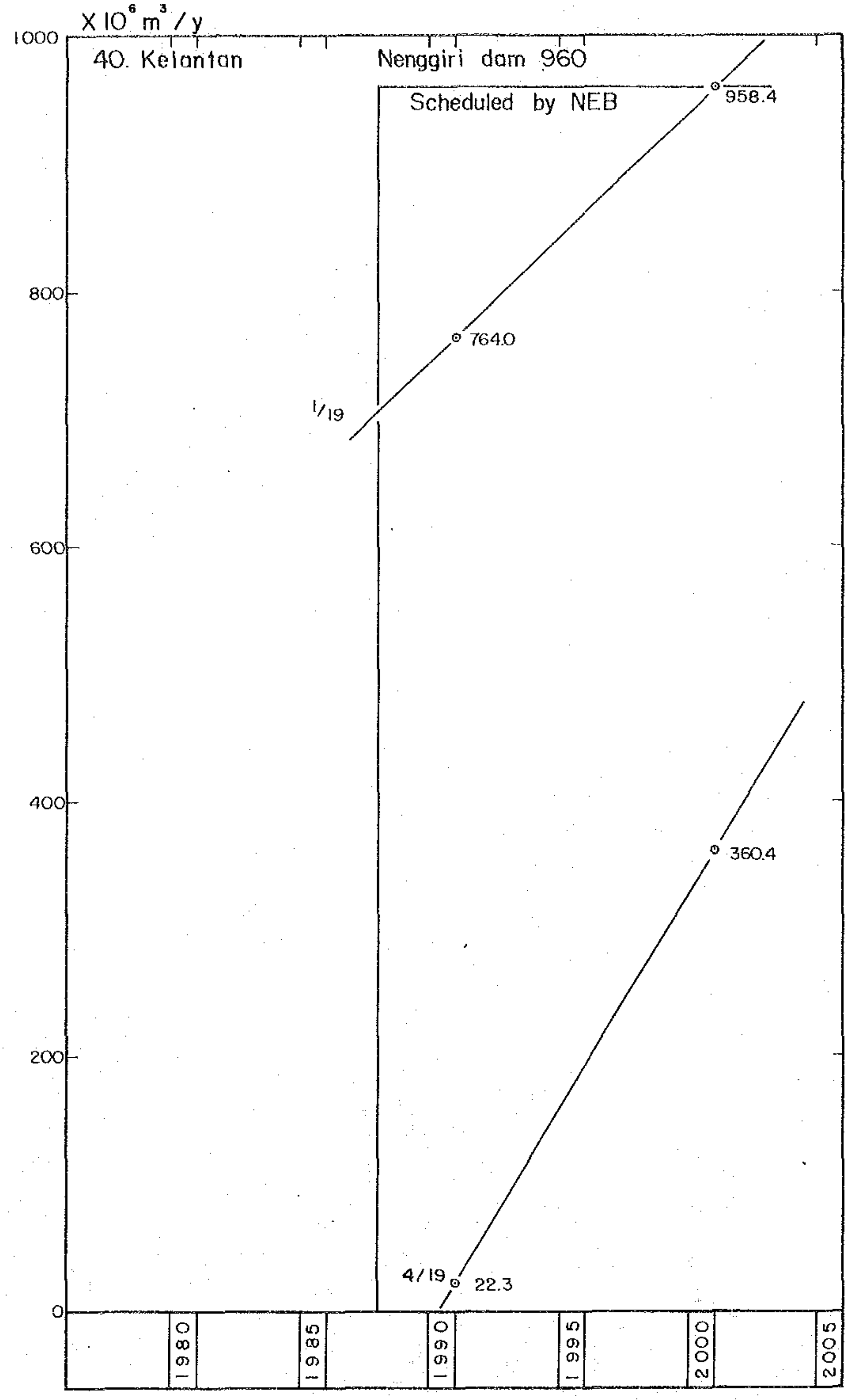

Fig.37 Recommended Water Demand and Supply Balance Program for Kelantan River Basin

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

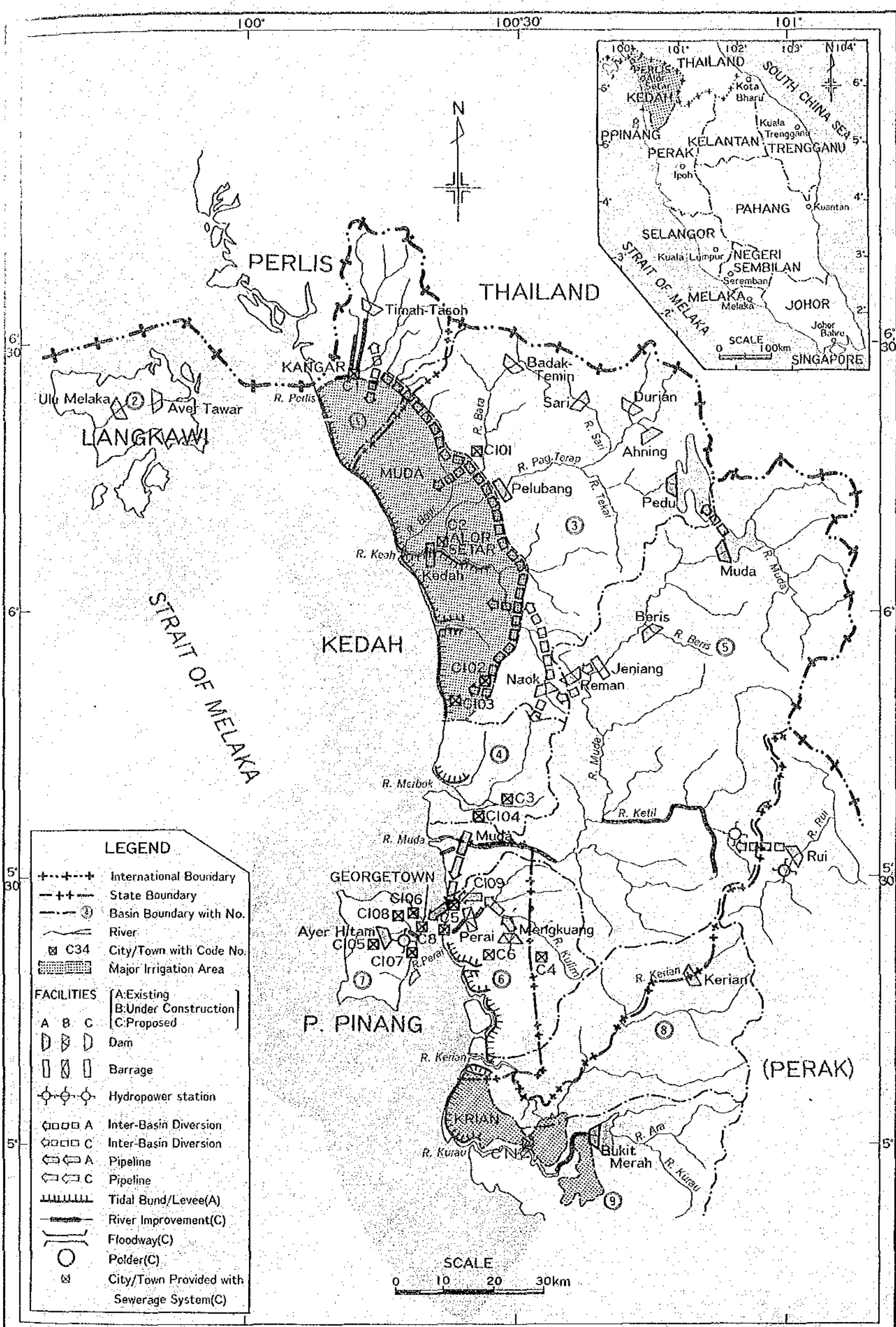

Fig. 38 Recommended Plan for the States of Perlis, Kedah & P. Pinang

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NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

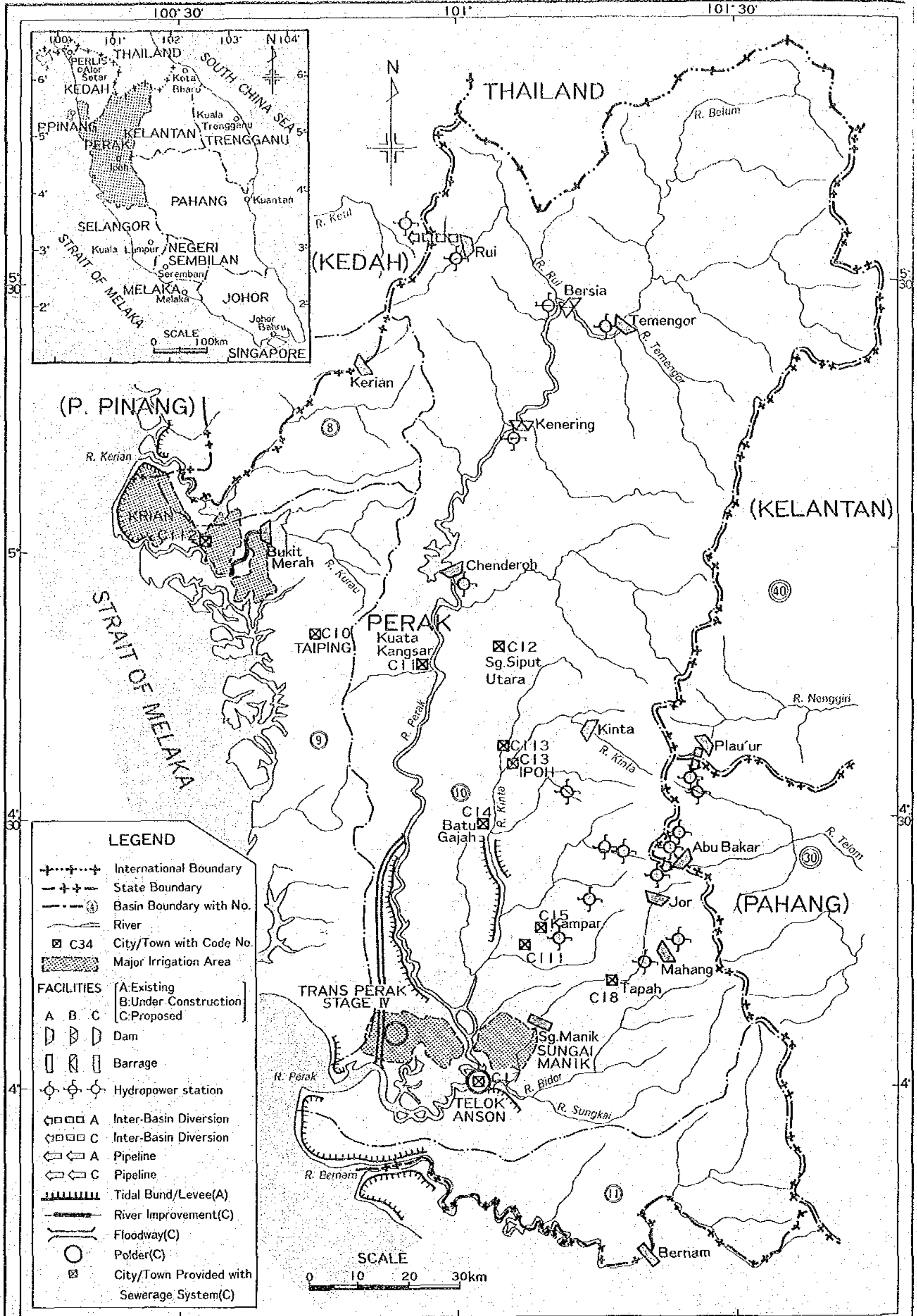

Fig. 39 Recommended Plan for the State of Perak

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 40 Recommended Plan for the State of Selangor

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

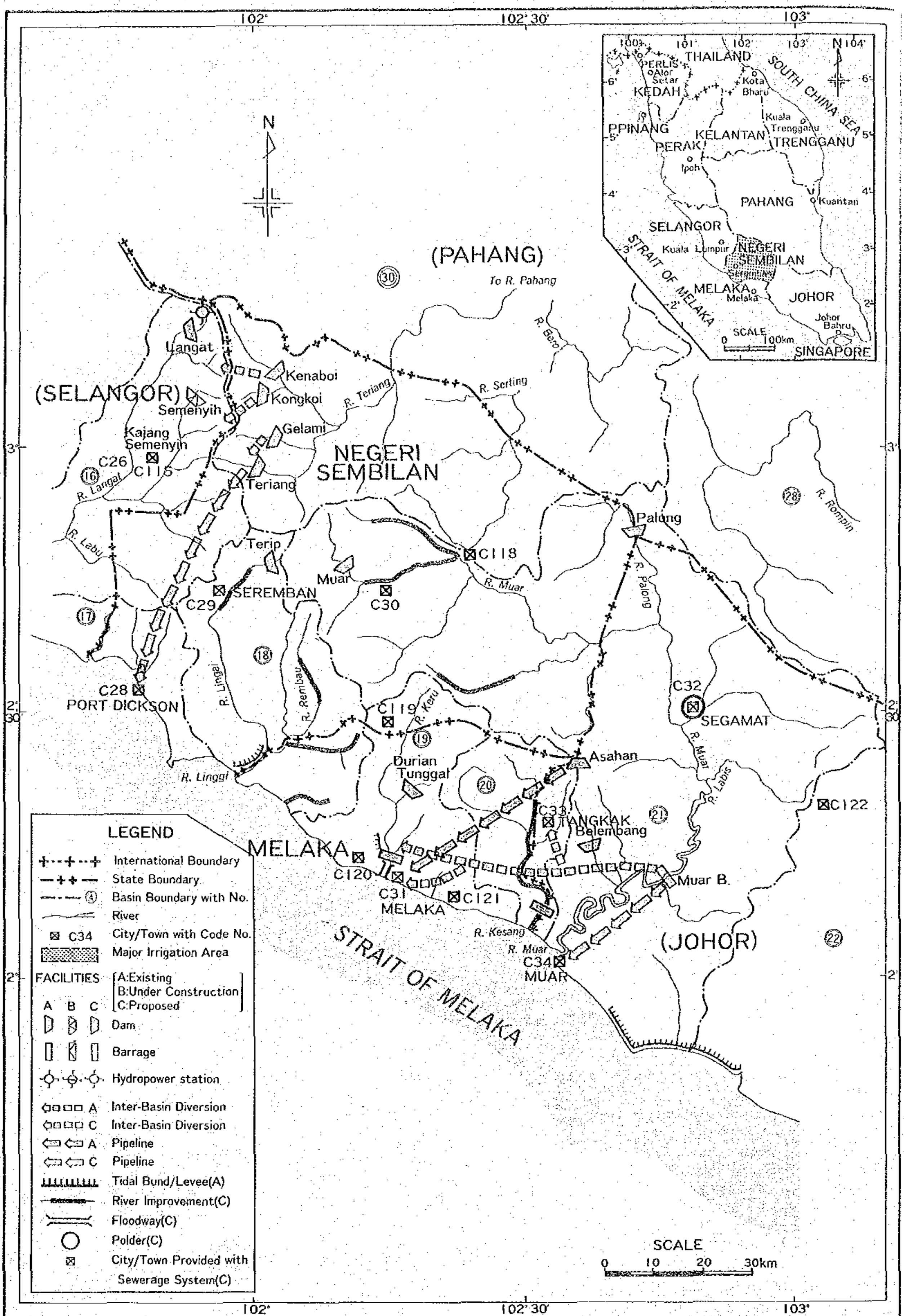

Fig. 41 Recommended Plan for the States of N. Sembilan and Melaka

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

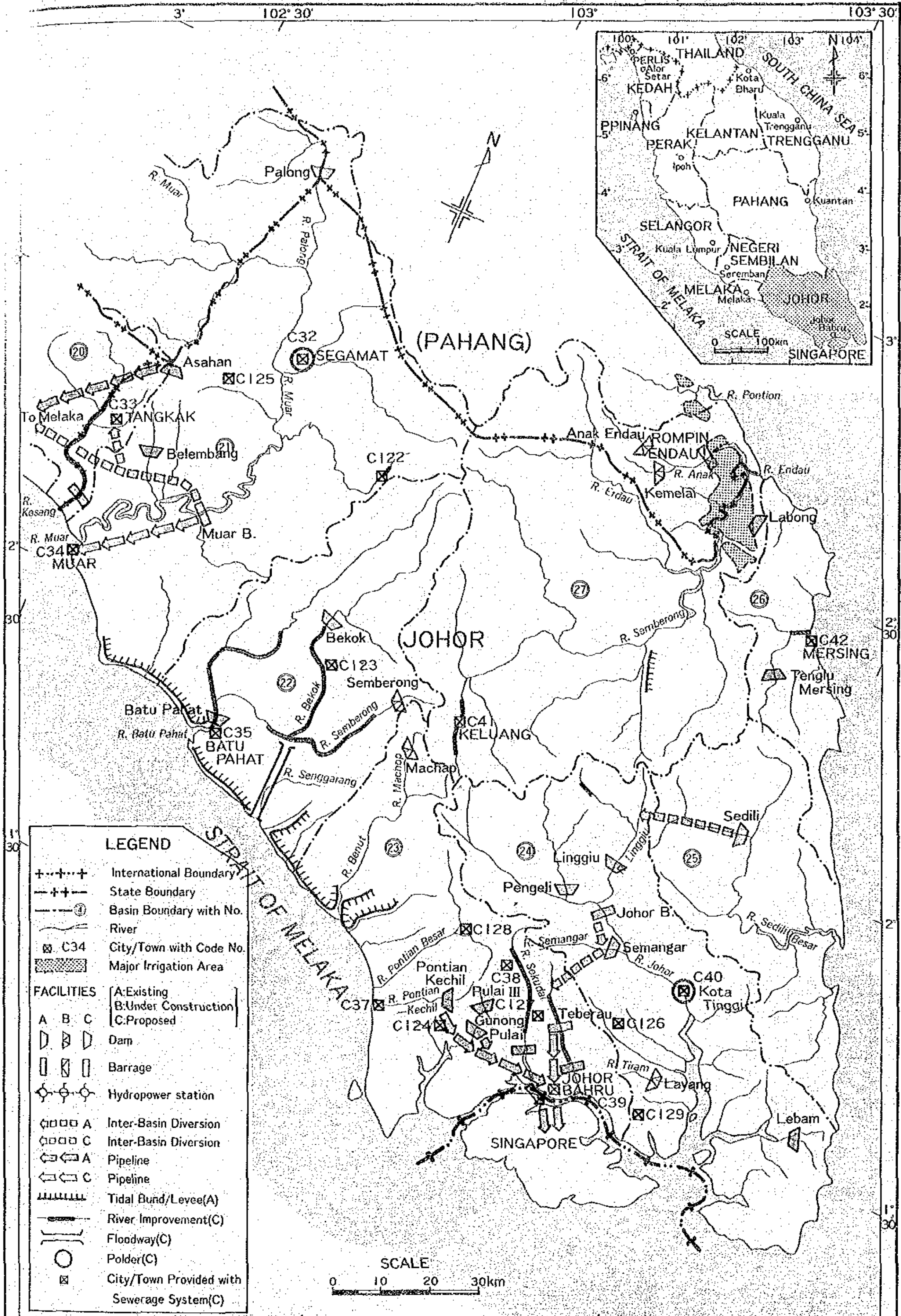

Fig. 42 Recommended Plan for the State of Johor

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

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Fig. 43 Recommended Plan for the State of Pahang

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

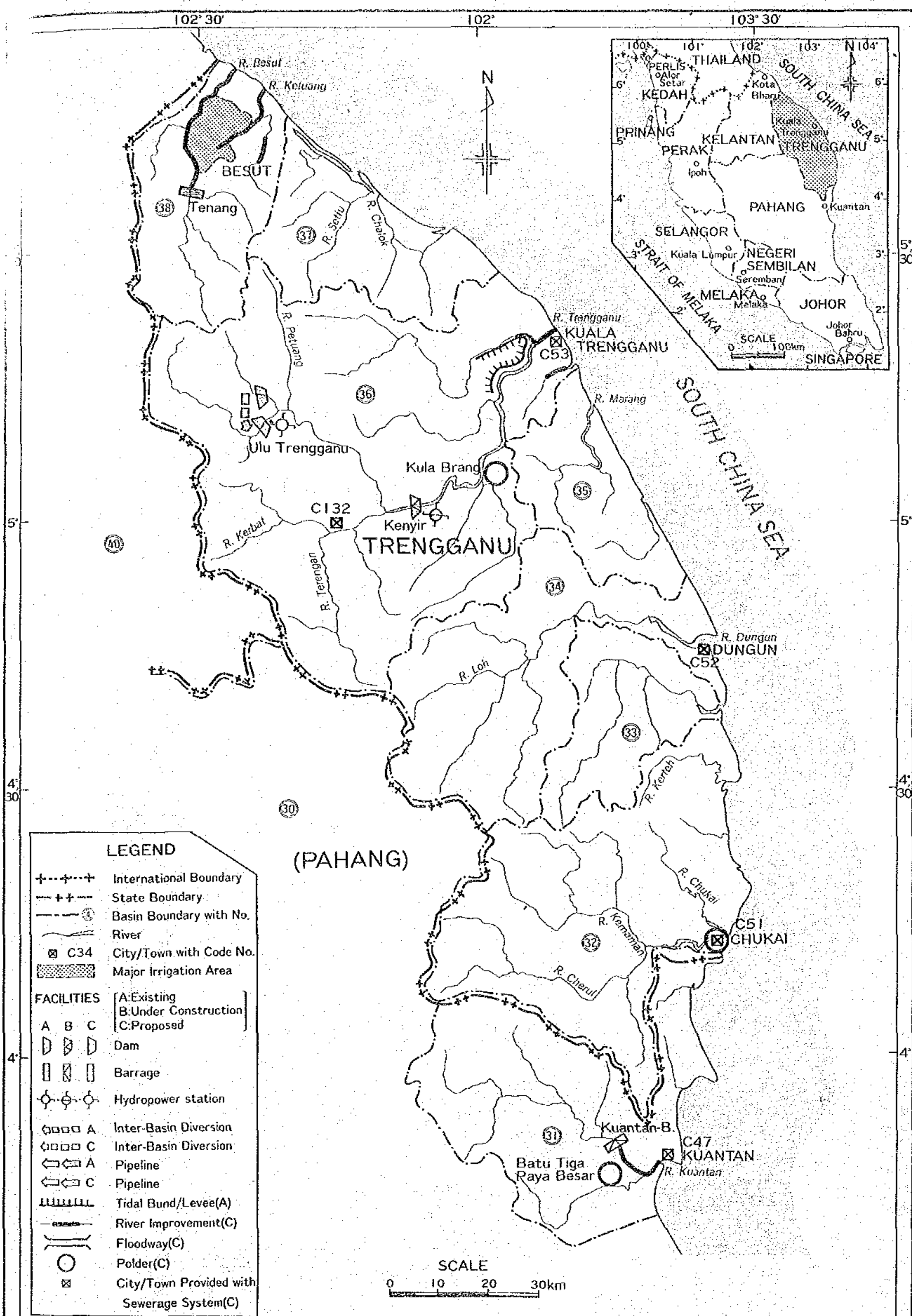

Fig. 44 Recommended Plan for the State of Trengganu

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

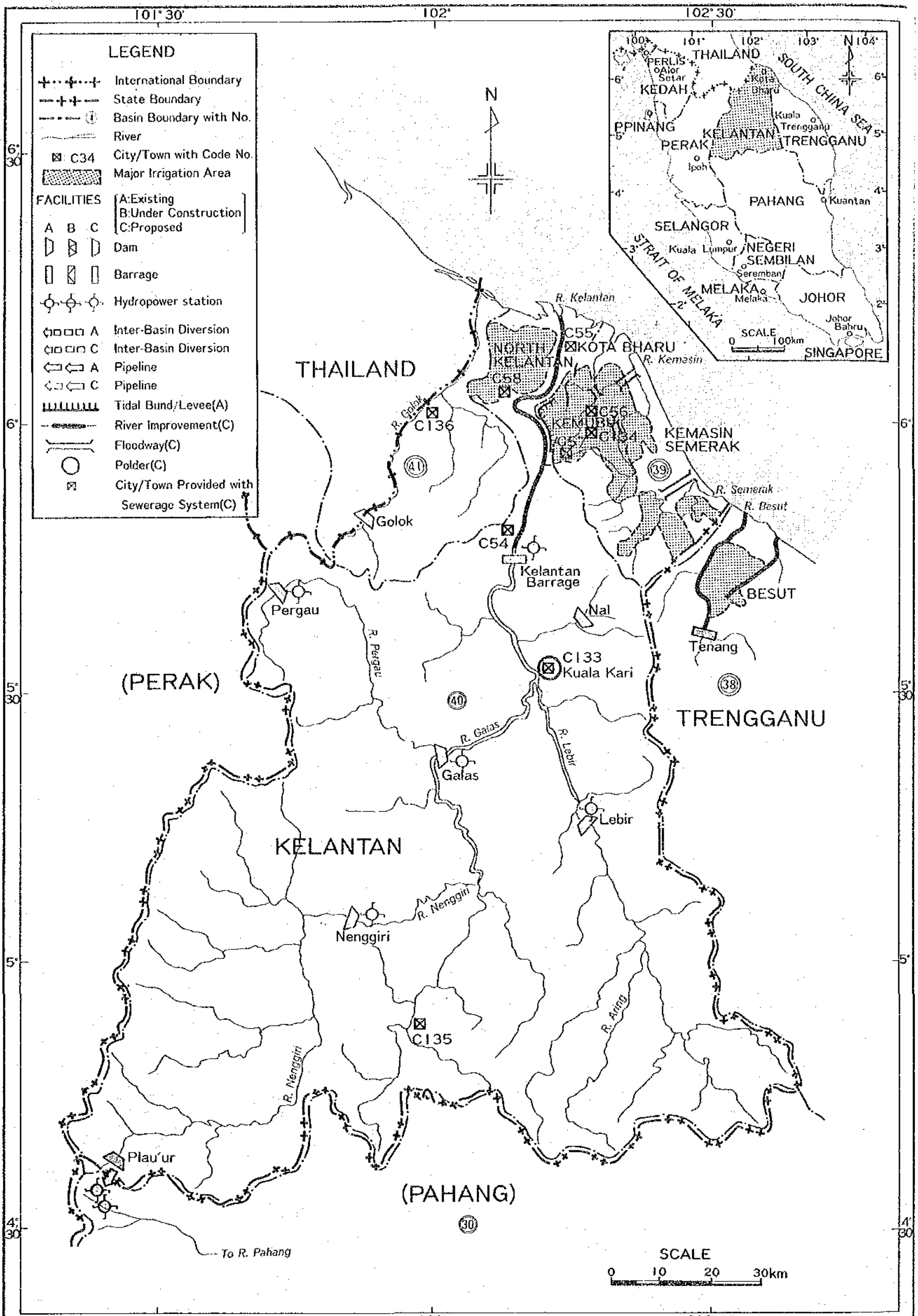

Fig. 45 Recommended Plan for the State of Kelantan

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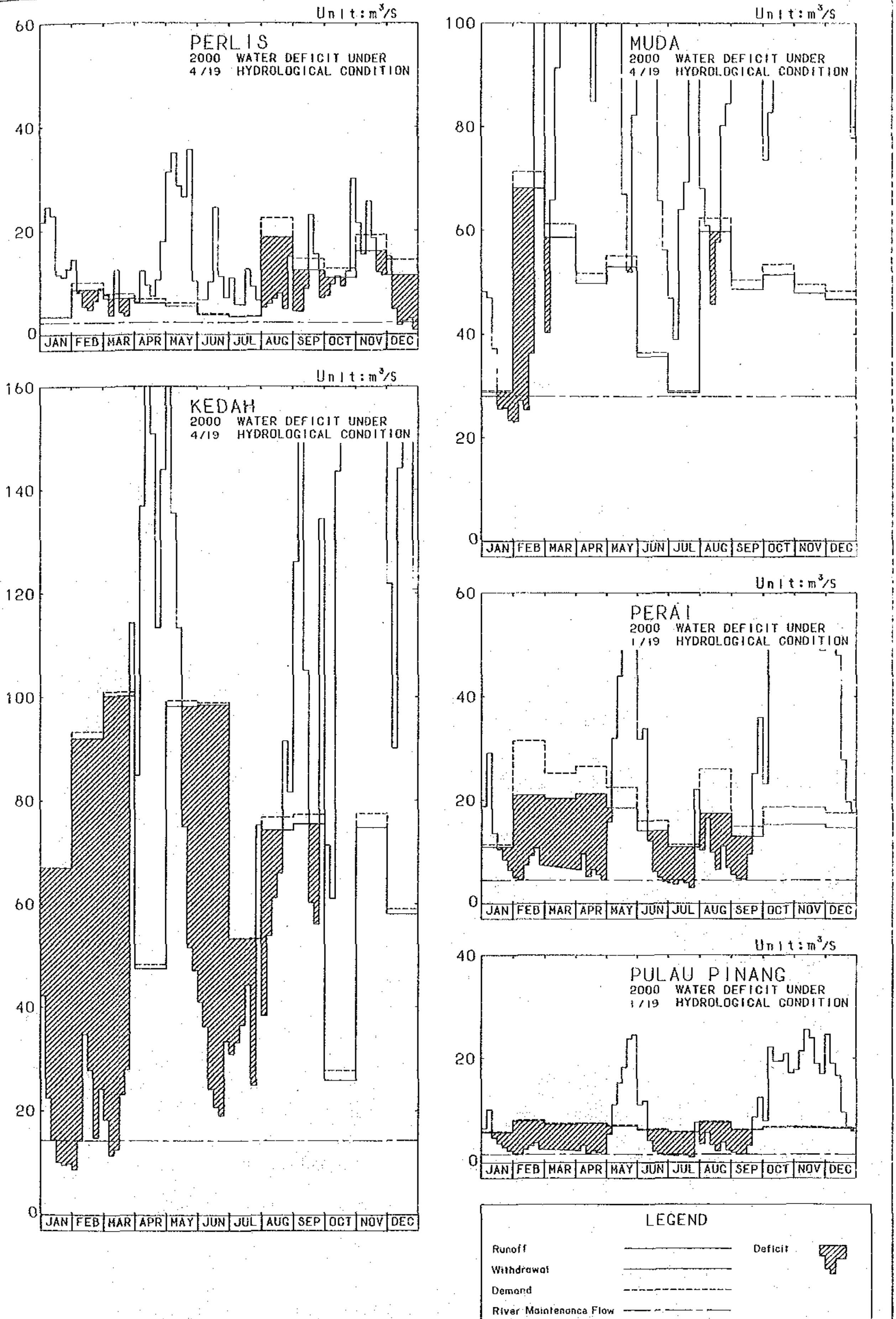

Fig. 46 Deficit in Water Demand and Supply Balance for Perlis, Kedah and Pulau Pinang Region.

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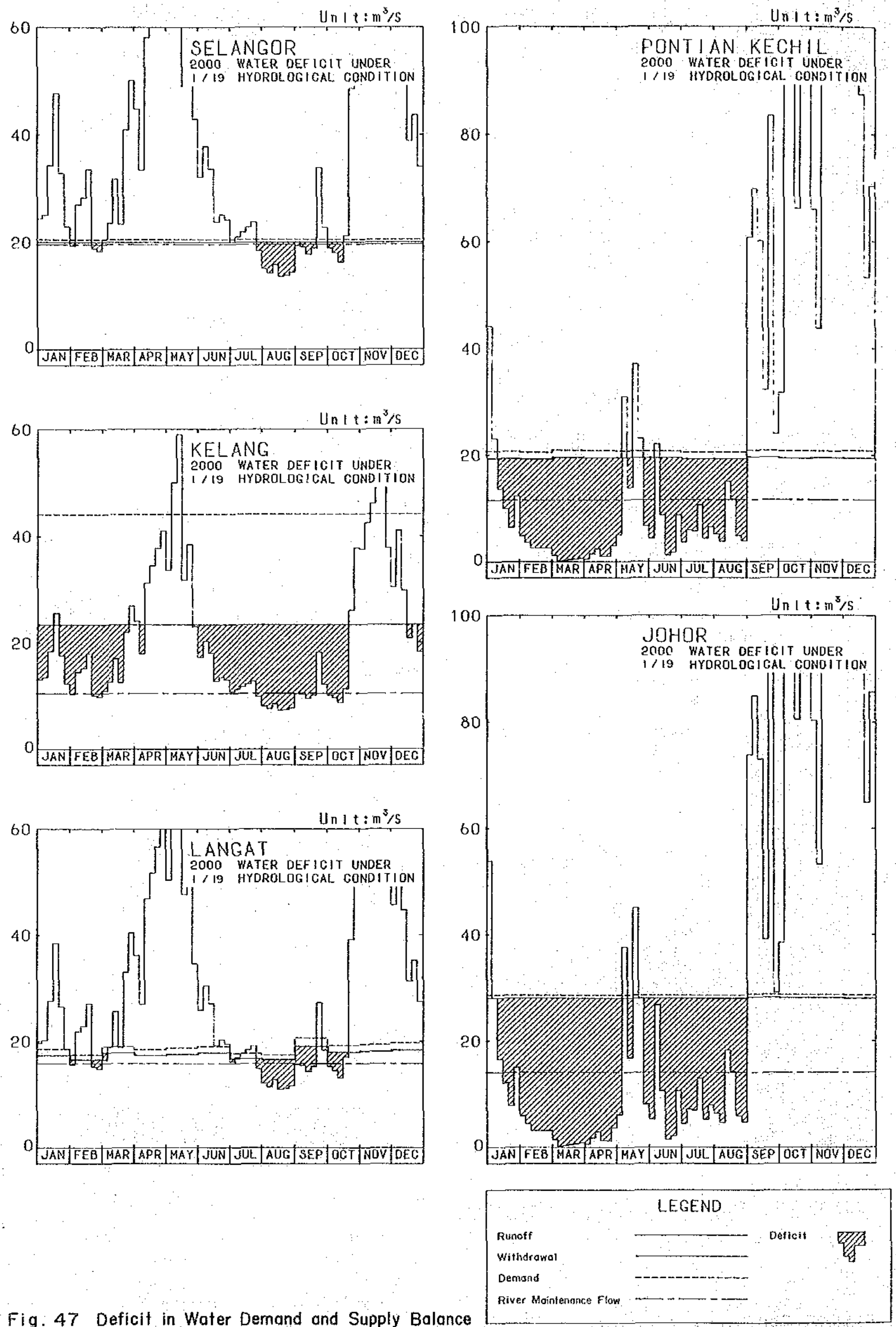

Fig. 47 Deficit in Water Demand and Supply Balance for Kelang Valley and South Johor Region.

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

PART 2

SABAH AND SARAWAK

SECTORAL REPORT

Vol. 16 WATER SOURCE AND HYDROPOWER DEVELOPMENT PLANNING
PART 2 The States of Sabah and Sarawak

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1. INTRODUCTION

The objective of the National Water Resources Study is to recommend a comprehensive and integrated approach of water resources development and use plans and improvement of legal and administration system to ensure efficient use of water and other natural resources for the target year of 1990 and 2000 based on the national short and long term development policy.

In the study process, identification survey of the present and future problems and needs in water resources development and use was done at first, and the present conditions of the use of water resources and water-related facilities and the results of interview survey with the officials were compiled in the Sectoral Report, Water Resources Engineering.

The objective of this report is to project and to evaluate the future problems and needs through the whole Malaysia with unified methodology and criteria, and to recommend the comprehensive and optimum development countermeasures for the year 1990 and 2000.

This report presents at first projection of water demand and supply balance between surface water resources and withdrawal of water demand, which was simulated by a computer data processing system by Basin or specified area in the year 1990 and 2000. Secondary alternative multipurpose water source development plans, which comprised domestic and industrial water supply, agriculture and irrigation, flood control and river maintenance, groundwater, and hydropower generation, were made taking into account watershed management, inland fishery, inland navigation, water-related recreation, water pollution abatement, aqua-ecology and people's amenity. The optimum development and use plans for 1990 and 2000 were made in trial and error process taking the comments of the officials into account, but only the final results are presented in this report. Environmental quality and adverse effects due to construction of dams and reservoirs were also identified not only qualitatively but also partially quantitatively.

2. WATER DEMAND AND SUPPLY BALANCE PLANNING

2.1 Methodology for Planning

2.1.1 Alternatives

The objective of water demand and supply balance planning is to provide water source facilities, such as dams, headworks, barrages and water diversion facilities in order to turn out the basin water deficit in the target year to be zero or surplus under uniform design criteria.

Water source facilities have been planned under the principles as follow:

(1) Demand of surface water be supplied by natural river run-off as practically as possible;

(2) The river minimum maintenance flow be kept all the year at least to maintain water depth, flow velocity, water quality, channel stability, aquatic eco-system, fishery, navigation, operation and maintenance of intakes and river facilities, sea water repulsion, prevention of estuary clogging by silting, conservation of groundwater, prevention of riparian land and people's amenity;

(3) Water deficit be replenished with regulated surface water by dams or water diversion facilities under a given risk of drought level; and

(4) Alternative water source facilities be formulated only in the river basins where the river utilization ratio becomes larger than or equal to 10%. The river utilization ratio is the ratio of annual source water demand to annual mean natural runoff in a Basin.

If the water deficit, which is projected in Section 2.4, cannot be replenished with regulated water, the minimum maintenance flow would be reduced or a river water would be dried up and eventually water demand would not be satisfied with different risk of drought level. However, quantity and frequency of water deficit will be minor if utilization ratio of river water is very low. Dam facilities will not be necessarily required if reduction of the minimum maintenance flow is minor. The result of water demand and supply balance analysis showed that the peak water withdrawal for domestic and industrial water supply and irrigation scheme was generally less than a half of the desirable minimum maintenance flow when the utilization ratio of river water was less than 10%.

Three alternatives were accordingly prepared for water demand and supply balance planning taking into account the river utilization ratio, the minimum maintenance flow and three different risk of drought level.

Alternatives	Guaranteed Risk of Drought Level	Minimum Maintenance Flow
B1	1/N	Q97%
B2	2/N	Q97%
B3	3/N	Q97%

1/N, 2/N and 3/N mean the driest, the second and the third severe drought respectively in N year simulation record period. The simulation period differs from 10 years to 16 years by Basin depending on the record period of discharge as shown in Table 1. Q97% means the desirable minimum maintenance flow which has been assumed to be the daily mean discharge with the probability of exceedence of 97%. The given condition is that no water deficit is permitted under given risk of drought level if the river utilization ratio is larger than or equal to 10%, but no water source facilities are provided if the ratio is less than 10%. In other words, the minimum maintenance flow is not fully guaranteed and no replenished water is provided for any drought in river basins where utilization of river water is minor.

2.1.2 Planning criteria

The risk of water demand and supply balance has been evaluated by Basin in terms of the total annual deficit, and the required regulated water source has been planned by Basin by alternative with the following planning criteria.

(1) Data used

(A) Map

Location of dam sites, catchment area, reservoir storage volume, reservoir surface area, elevation of structures and water surface and dimension and works quantities of structures (dams, barrages, canals, tunnels, roads) were all measured in the maps of 1/50,000 scale. The minimum contour interval is different in respective map. It is 50 feet (15.25 m), 100 feet (30.5 m) or 250 feet in plane and 50 feet, 100 feet, 250 feet, 500 feet or 1,000 feet in mountainous area. The error limit of the measured values, therefore, is not necessarily constant.

(B) Discharge

The daily discharge of less than 0.1 m^3/s could not be measured. The annual discharge were compiled from daily discharge and therefore the annual discharge of less than 3×10^6 m^3/y may be within the range of error.

(2) Priority of development

Priority of developing potential sites has been determined based on the following preference:

(a) nearest river system,

(b) nearest sites to the location of demand,

(c) higher investment efficiency, and

(d) storage capacity be large enough to meet the demand (required net supply capacity).

(3) Requirement of developed regulation water

The requirement of developed regulation water is composed of required net supply capacity and compensation discharge for shutdown at a site.

The required net supply capacity is expressed in annual basis (unit: 10^6 m^3/y). It is assumed to be 1.2 times of the estimated water deficit for the basin where seasonal variation of water demand is large, like major irrigation area or 1.1 times for the basin where constant rate of water demand is anticipated through a year, like domestic and industrial water demand area. The surplus capacity of 10% or 20% of the estimated deficit is assumed in order to adjust the discrepancy between constant draft operation and variable draft reservoir operation because the storage capacity required for the net supply capacity is estimated using the constant draft curves.

The compensation discharge, which is required for avoiding shutdown of discharge and maintaining the minimum water requirement in downstream of a dam site, is assumed to be 20% of the annual inflow at the catchment of a site (theoretically this varies depending on the river conditions).

(4) Return flow

Net water withdrawal is used for the basin water balance if the intake of irrigation or water supply is in the effective area; accordingly, return flow is taken into account. The total source water demand is used if the location is in the ineffective area.

(5) Extension of target year

Ultimate target of the net supply capacity was set for the year 2000 but the capacity has been extended up to the demand of the year 2005 when the required capacity of 2000 is extremely smaller than the possible maximum net supply capacity of a site.

(6) Development efficiency

The active storage (Vs) which is required for yielding the required regulation developed water (Wdt) is estimated by using development efficiency (Ed) as follows:

Active storage (Vs) = Wdt/Ed

Development efficiency is given by

Ed = developed water (draft)/active storage capacity

The development efficiency is obtained from the non-dimensional storage-draft curves.

(7) Active storage and dead storage

The storage capacity is defined as:

Gross storage capacity (Vg) = Active storage capacity (Vs) + Dead storage volume (Vd)

The maximum active storage capacity is assumed to be around 70% of the annual inflow at a dam site. Dead storage volume is assumed to be 2.0 x sedimentation volume of 100 years. If the maximum gross storage is limited by the physical possible maximum capacity (topographic constraint). The active storage is given as; Vs = Vg - Vd.

The sedimentation volume is assumed to be 20,000 $m^3/km^2/100$ years for Sabah and Sarawak.

(8) Freeboard

The freeboard from the full supply level (F.S.L or H.W.L) to the dam crest elevation is assumed to be at least 3.0 m.

(9) Investment efficiency

Investment efficiency of water resources development (EI) is used for evaluation and screening the best dam sites from the potential dam sites.

The investment efficiency is given as:

$$EI = Ed \times Es \times \frac{1}{Cd}$$

$$= \frac{Wd}{Vs} \times \frac{Vs}{Vd} \times \frac{Vd}{CD}$$

$$= \frac{Wd}{CD}$$

where, Ed: Water development efficiency
Es: Storage efficiency
Cd: Development cost per unit dam volume
Wd: Developed water (or net supply capacity)
Vs: Active storage capacity
Vd: Volume of dam body
CD: Development cost = dam construction cost + cost of water diversion facilities including O&M cost

(10) Non-dimensional storage curves

Non-dimensional storage-draft curves were made by constant draft operations for the selected 12 key stations. The 5-day mean natural discharges of different period from 10 to 20 years were used depending on stations under cycle period concept. The record was repeated two times connecting the top of the record to the end in order to find the largest storage requirement which could fall in the period between the end and the top of record.

The non-dimensional storage-draft curves are shown by key station in Figures 3 & 4.

2.1.3 Criteria of cost estimates

(1) Construction cost

Construction cost is composed of

(a) direct cost,

(b) engineering and administration : assumed to be minimum 10% of the direct cost, depending on the project scale

(c) land acquisition and resettlement, and

(d) Physical contingency: assumed to be 30% of the total of a, b and c.

(2) Construction period and disbursement schedule

All the construction period is assumed to be 5 years. The disbursement schedule of 5 years is assumed to be 10% of the total cost for the first year, 20% for the second year, 30% for the third year, 30% for the fourth year and 10% for the fifth year.

(3) Estimate of direct cost

The standardized values shown in Tables 2 - 6 are used for estimation of direct cost of dams, tunnels, canals, pipe lines, pumping stations, and access and relocation roads. These values are made from the data obtained in the cost survey (see Sectoral Report, Water Resources Engineering).

2.2 Water Demand and Supply Balance Analysis

2.2.1 Calculation model of water balance analysis

The purpose of the water demand and supply balance analysis is to project and evaluate the water balance of the whole East Malaysia by Basin with uniform criteria.

Water demand and supply balance is projected for the 47 Basins at the target years, 1990 and 2000 in the following procedure. The daily mean discharge records of the selected 41 gauging stations were examined and 12 reliable consecutive daily discharge records were selected at first (see Sectoral Report, Meteorology and Hydrology). The measured daily mean discharges of 12 gauging stations are converted into the natural daily mean discharge taking into account the water withdrawal of irrigation, domestic and industrial water supply and reservoir regulation effect during the measured period. The water demand and supply balance is estimated by each 5-day period in order to visuarize the seasonal fluctuation clearly, especially for irrigation demand. The daily mean discharge records therefore were compiled in 5-day mean discharge records. The 12 natural 5-day mean discharge records at the gauged river basins were projected to the ungauged river basins of similar hydrogic condition in proportion to the basin runoff (rainfall minus loss). The net water withdrawal in the target year, which corresponds to the projected water demand excluding the return flow, is estimated for each Basin. The minimum river maintenance flow is also taken into account. The water demand and supply balance is evaluated in terms of water deficit. The water deficit is given by the sum of the natural 5-day mean discharge and the sum of all the water withdrawal and the minimum river maintenance flow. That is, the water deficit (DTj) is given by the following formula:

$$DTj = NFj + RT - (MT + AT) - QM$$

where, DTj: Water deficit in the given j Basin, 5-day mean (m^3/s)

NFj: Natural 5-day mean discharge in the given j Basin (m^3/s)

RT : Regulated flow in the projected year (1990 and 2000), reservoir operated discharge and diversion water (m^3/s) in j Basin

MT : Net domestic and industrial water withdrawal in the projected year (m^3/s) in j Basin

AT : Net irrigation water withdrawal in the projected year (m^3/s) in j Basin

QM : Minimum river maintenance flow (m^3/s) in j Basin

DTj is the average water deficit in the given period of 5 days (Δt). The total water deficit of the j Basin (TDTj) during a certain period (t) is therefore given by

$$TDTj = \int^{t} DTj \cdot \Delta t$$

MT and MW were projected in the Sectoral Report, D&I Water Supply. AT and AW were projected in the Sectoral Report, Irrigation Water Demand.

The regulated flow in the projected year (RT) is assumed to be zero in order to figure out the condition when no regulation reservoir is provided for the target year.

The total water deficit of the j Basin (TDTj) during a certain period (t) is consequently given by

$$TDTj = \int^{t} DTj \cdot dt$$
$$= \int^{t} (NFj - MT - AT - QM) \cdot dt$$

The calculation output (deficit) is shown by plus (+) when the value (DTj) is minus (-). The surplus is expressed in minus.

The 5-day mean discharge (NFj) is more precisely given as:

NFj = Natural flow in the given j Basin (m^3/s)

$$= N_5 \times \left(\frac{A_{ij}}{A_{oj}} \times \frac{R_{ij}}{R_{oj}} \times \frac{f_{ij}}{f_{oj}}\right)$$

where, N_5 : MF_5 + MW + AW + RF
= Natural 5-day mean discharge at the standard gauging station (m^3/s)

MF_5: Measured flow at the standard gauging station, 5-day mean discharge which is compiled from daily discharge (m^3/s)

MW : Net domestic and industrial water withdrawal in the measured period (m^3/s)

AW : Net irrigation water withdrawal in the measured period (m^3/s)

RF : Regulated flow in the measured period (m^3/s)

A_{oj}: Effective catchment area at the gauging station of the j Basin (km^2)

A_{ij}: Effective catchment area of the j Basin at the i point of the water balance calculation (km^2), the catchment area at the river mouth is defined as A_{1j}

R_{oj}: Annual mean basin rainfall for the gauging station (mm/y) of the j Basin

R_{ij}: Annual mean basin rainfall for the catchment at the i point of the water balance calculation of the j Basin (mm/y)

f_{oj}: Mean runoff coefficient for the gauging station of the j Basin

f_{ij}: Mean runoff coefficient for the catchment at the i point of the water balance calculation of the j Basin

2.2.2 Basin diversion and effective area

(1) Basin division

The States of Sabah and Sarawak were divided into 47 divisions of "Basins" for the purpose of engineering study. Sabah was divided into 26 Basins and Sarawak was divided into 21 Basins. The Basin number, the name of Basin, the catchment area of each Basin are shown in Table 7. These Basins are shown in Fig. 1. The administrative divisions of the two States are shown in Fig. 2.

The Basin boundaries were delineated and the catchment area was measured on the map of 1/500,000 scale based on the following criteria:

(a) The Basin boundary is watershed;

(b) Each Basin is a river system or a group of river systems; and

(c) If an international boundary crosses a river basin, it is adopted as a Basin boundary.

In most cases, the Basin boundary coincides with the administrative boundary of Residency, Division and or District in case of Sabah and Sarawak.

(2) Effective area of Basin

An area of a Basin of which surface water can be practically used for the purpose of domestic and industrial water supply and irrigation schemes is defined as 'Effective Area' in this study. That is, the Basin catchment was divided into effective and ineffective areas. The border between effective and ineffective area is denoted as a broken line (--------) in Figs. 5-15. It is assumed that no intrusion of sea water was observed in the upstream of the border. This line was drawn based on the information from DID and PWD and study reports. The effective area is shown in Table 7.

The definition of the border line is assumed more precisely as follows:

(a) The upstream catchment from the lowest end sites of dams headworks, barrages or intakes for irrigation, water supply and/or hydropower be effective;

(b) The area of the large scale irrigation schemes of which the return flow cannot be used, for example the flow which is planned to be directly discharged to the sea, be ineffective;

(c) The area of the drainage schemes of which the return flow can not be used depending on the direction of drainage channels, the location of rivers and the topography be ineffective;

(d) The swamp area of which discharge cannot be used because of inadequacy of water quality and/or topographic conditions be ineffective; and

(e) If the area is fallen outside the above-mentioned four categories and is located within 5 km along the coastal line, it be ineffective.

2.2.3 Minimum river maintenance flow

Two cases of the minimum river maintenance flow have been established as alternatives. One is the desirable minimum maintenance flow which has been assumed to be the daily mean discharge with the probability of exceedence of 97% (Q97%). The other is the essential minimum maintenance flow which has been assumed to be the daily mean discharge with the probability of exceedence of 99% (Q99%). Table 8 shows the assumed minimum maintenance flow in the effective area by Basin.

Q97% and Q99% are the discharges with probability of exceedence of 97% and 99% of the daily mean discharge series of the record period respectively. No missing data was interpolated for the probability calculation.

2.2.4 Water demand and supply system diagrams

All the Basins, rivers, demand centers of cities, districts and irrigation schemes and supply facilities are expressed in models under uniform criteria as shown in the Water Demand and Supply System Diagrams of Figs. 16 - 24 in order to clarify the spatial condition of demand and supply balance.

The location of the major intakes is assumed to be the demand center of cities and major irrigation schemes if the intake sites are known. The location of demand center of district is assumed to be the gravity center of a district area. The gravity center of an area of minor irrigation schemes is assumed to be the demand center of a minor irrigation scheme when intake sites are unknown.

Numbering of notation system is applied for States (Table 9), Basins (Table 7), Prospective cities (Table 10), Districts (Table 11) and Irrigation major and minor schemes in order to show in the system diagrams and to process the data by a computer system.

2.3 Preliminary Evaluation of Water Demand and Supply Balance

2.3.1 Water balance of natural water resources

Table 12 shows the basin mean annual rainfall and runoff by Basin which were estimated in the Sectoral Report, Meteorology and Hydrology.

The annual hydrologic water balance among rainfall, evapo-transpiration, deep percolation and surface runoff are estimated by Basin as shown in Table 13. The balance of Sabah and Sarawak is compiled as follows:

	Total Catchment Area(km^2)	Unit	Mean Rainfall	Mean Evapo-tran-spiration	Mean Deep* Percola-tion	Mean Surface Runoff
Sabah	72,850	mm	2,663	926	189	1,548
		10^9 m^3/y	194.0	67.5	13.8	112.8
		%	100.0	34.8	7.1	58.1
Sarawak	124,449	mm	3,828	1,125	243	2,460
		10^9 m^3/y	476.4	139.9	30.3	306.2
		%	100.0	29.4	6.4	64.2
Whole East Malaysia	197,299	mm	3,398	1,051	224	2,123
		10^9 m^3/y	670.4	207.4	44.1	418.9
		%	100.0	30.9	6.6	62.5
Whole Peninsular Malaysia	131,680	mm	2,426	1,155	155	1,116
		10^9 m^3/y	319.4	152.1	20.4	146.9
		%	100.0	47.6	6.4	46.0

Remarks; * denotes groundwater recharge

The values of Peninsular Malaysia are shown for comparison. The deep percolation was estimated in the Sectoral Report, Groundwater Resources.

2.3.2 River utilization ratio in 1990 and 2000

The river utilization ratio, which is the ratio of the annual source water demand to annual surface runoff in effective area, are estimated by Basin for the year 1990 and 2000 in order to imagine the future conditions of supply capacity of surface water (i.e. river water). The results are shown in Table 14 for the case of target economic growth and Table 15 for the case of lower economic growth.

The source demand of domestic and industrial water supply was projected in the Sectoral Report, Domestic and Industrial Water Supply. Therein the D&I water demand was projected with the following conditions:

(a) all the urban water demand be supplied by surface water both for 1990 and 2000, and

(b) for rural water supply, the ratio of surface water to groundwater be assumed both for 1990 and 2000 as;

	Surface water	Groundwater
· piped supply	70%	30%
· non-piped supply	60%	40%

The demand in the ineffective area is assumed to be diverted by pipelines or canals from the effective area.

The irrigation water demand was estimated assuming the same crop yield for both cases of target and lower economic growth in the Sectoral Report, Irrigation Water Demand.

The Basins of which river utilization ratio is projected to be higher than 1% in the case of the target economic growth is as follows:

River Utilization Ratio (%)	State	Basin No.
1 ~ 4.9	Sabah	207, 212, 216, 217, 219, 221, 222, 223, 224
	Sarawak	232, 246
5 ~ 9.9	Sabah	218
	Sarawak	-
≧ 10	Sabah	220, 225
	Sarawak	231

The area is specified to the major 19 towns of which population is projected larger than or equal to 10,000 in 2000 and irrigation area, and the river utilization ratio of the specified sub-basins are estimated in Table 16 for the case of target economic growth and Table 17 for the case of lower economic growth.

The results show that the water resources will be still abandant in the future as a whole in Sabah and Sarawak. However, the river utilization will become locally very high in the prospective major towns and major irrigation area along the coastal line in Sabah and Sarawak.

2.4 Water Demand and Supply Balance in 1990 and 2000

The result of basin water demand and supply balance does not represent the actual deficit because the amount of water demand is relatively too small comparing to the size of each Basin in case of Sabah and Sarawak. Therefore, water demand and supply balance is focused on the 7 specified sub-basins where the river utilization ratio become higher than or equal to 10% in 2000.

Basin No.		Name of Sub-basin	River Utilization Ratio in 2000 (%)
207	C201	Tawau	25
212	C204	Sandakan	61
217	C206	Kudat	10
218	C207	Kota Belud and Irrigation (Kadamaian)	10
220	C208	Kota Kinabalu (Moyog)	28
225	C211	Labuan	25
231	C214	Miri	21

As the water demand and supply balance program is made based on the source demand for the sub-basins of Sandakan, Kudat and Labuan, the deficits of these sub-basins are not estimated. The deficit is estimated only for 4 sub-basins, Tawau, Kadamaian, Labuan and Miri. The sub-basins, Tuaran and Papar are subject to inter-basin water usage and, thus the deficit is estimated.

The water demand and supply balance of each 5 days has been computed using 5 day discharge data for at least 10 years (see Table 1) for the target year of 1990 and 2000. The 5 day water deficit has been summed to monthly and annual deficit, and the largest annual deficit (i.e. the most severe drought, drought level 1/N) in N year period, the second (2/N), the third (3/N), the fourth (4/N) and the fifth (5/N) are tabulated with the year occurred in Tables 18 (Target case) and 19 (Lower case) for 1990 and 2000. The desirable minimum maintenance flow (Q97%) is applied for these cases.

3. WATER SOURCE DEVELOPMENT PLAN

3.1 Water Demand and Supply Balance Alternatives

3.1.1 Problem area with regard to surface water development

(1) The 7 sub-basins set out below are identified as problem area where the river utilization ratio will become higher than or equal to 10% in 2000 and water shortage is projected (see Table 16).

(a) Tawau (C201) in the Tawau river basin (Basin 207),

(b) Sandakan (C204) in the Silibukan river basin (Basin 212),

(c) Kudat (C206) in the Bongan river basin (Basin 217),

(d) Kota Belud (C207) and irrigation minor schemes in the Kadamaian river basin (Basin 218),

(e) Kota Kinabalu (C208), Tuaran and Papar (C209) area in the Tuaran (Basin 219), Putatan (Basin 220) and Papar (Basin 221) river basins,

(f) Labuan (C211) in the Labuan island (Basin 225), and

(g) Miri (C214) in the Miri river basin (Basin 231).

(2) The dams in operation and under construction are listed in Table 20 for Sabah and Table 21 for Sarawak.

(3) The river utilization ratios of the sub-basins listed below are all smaller than 10% in 2000 and no regulation dam is required for these area:

(a) Ranau (C205) in Basin 213,

(b) Benkoka irrigation scheme in Basin 216,

(c) Minor irrigation schemes in Basin 217,

(d) Keningau (C208), Tambuan and minor irrigation schemes in Basin 224,

(e) Limbang (C212) in Basin 229,

(f) Marudi (C213) in Basin 230,

(g) Bintulu (C215) in Basin 236,

(h) Sibu (C216) and Sarikei (C217) in Basin 241,

(i) Serian (C218) in Basin 245, and

(j) Kuching (C219) and Irrigation scheme in Basin 246.

The water shortage experienced in the foregoing area was caused by the insufficient supply capacity of treatment or distribution facilities. The quantity of the surface water is considered enough in 2000 in these area except minor local area.

(4) The Timbangan dam (9.1×10^3 m^3/d = 2 MGD) is under construction for water supply to Semporna (C202) in the Kalumpang river in Basin 208. PWD projected that the supply capacity would be enough by the year 2000. The river utilization ratio of the sub-basin is estimated to be 3.3% in 2000, and therefore no additional water source facilities are required.

(5) The Sepagaya dam (9.1×10^3 m^3/d) is under construction for water supply to Lahad Datu (C203) in the Silibukan river in Basin 209. The supply capacity was planned to meet the demand of up to 2000 by PWD. The river utilization ratio of the sub-basin is estimated to be 8.7% in 2000, and therefore no additional regulation dam is required.

(6) Though the river utilization ratio in Keningau and Tambuan area is estimated less than 10% in 2000, water shortage could locally be met in dry season if irrigation water usage is done exactly following the DID plan. No water source facilities are proposed from cost-benefit viewpoint.

(7) The Sika reservoir is under construction for water supply to Bintulu in the Sika river, the tributary of the Sibiu river. The supply capacity (38.6×10^3 m^3/d = 8.5 MGD) was planned to meet the demand of up to 1995 by PWD. The river utilization of the Sibiu river, the tributary of the Kemena river is estimated to be 8.5% in 2000. Therefore no additional water source facilities are required by 2000. The water demand of Bintulu, however, will be variable in the future because the industrialization program is uncertain. One of the following alternative measures will be required if the growth of water demand is larger than the projected value by the Study:

(a) construction of a regulation dam in the main stream of the Sibiu river, and

(b) construction of a new intake at the upstream of Sebauh in the main stream of the Kemena river and a diversion pipeline system of about 30 km from the intake to Bintulu.

(8) The river utilization ratio at the Batu Kitang intake is estimated to be 3.5% in 2000 if all the domestic and industrial water demand of Kuching is assumed to be withdrawn from the site. The intake is in operation at about 15 km upstream from Kuching in the Sarawak Kiri river and its catchment area is

about 735 km^2. That is, it is concluded that no regulation dam is required for the Kuching water supply scheme still in 2000.

Severe water pollution due to sewage from the residents, however, is projected in the upstream of the intake, and PWD recognizes the need of countermeasures. If the intake is moved to the far upstream site where pollution is not severe as one of the alternative measures, construction of the Bengoh dam would be required. The maximum possible development scale of the damsite is estimated as follows:

(a) catchment area : 126 km^2,

(b) annual inflow : 344 x 10^6 m^3/y,

(c) net supply capacity : 275 x 10^6 m^3/y, and

(d) hydropower : 7 MW, 30 GWh.

(9) In the water balance analysis and water source planning it is theoretically assumed that the water demand of Sarawak drought prone area, located in the ineffective area, is diverted from the effective area by a pipeline. It is, however, obvious that it is practically impossible because of cost constraint. The countermeasures for the drought prone area is presented in the Sectoral Report, Domestic and Industrial Water Supply.

(10) Groundwater development is studied in the Sectoral Report, Groundwater Resources as a alternative source which is comparable with surface water.

3.1.2 Alternative water source development plans

Alternative water source facilities are planned for the 7 problem area identified in Section 3.1.1 so that the required regulation capacity (i.e. required supply capacity) can be replenished by the net supply capacity of the existing facilities and the additional net supply capacity of the newly proposed source facilities by the target year.

The net supply capacities of the reservoirs which were in operation, under construction, or commissioned at the beginning of 1982 are assumed to be the existing net supply capacity in the alternative planning. The major features of dams and reservoirs which are assumed to be existing facilities are listed in Tables 20 and 21. The capacity of very small facilities are assumed to be negligible.

Alternatives B1, B2 and B3 are planned by Basin or Sub-basin as a minimum unit with the planning criteria which are presented in Section 2.1. The basin plans are extended to multi-basin plans by integration of basin plans depending on the conditions. Possible combination of reservoirs and diversion facilities of canals, pipelines and tunnels is studied for each alternative and the optimum development plans are proposed by alternative as shown in Tables 22 to 24. Inter-basin water utilization is proposed for the following problem area:

(1) Sandakan in Basin 212; water diversion by a pipeline system from Basin 213 to Sandakan,

(2) Kudat in Basin 217; water diversion by a pipeline system from the Milian river to Kudat,

(3) Kota Kinabalu in Basin 220; water diversion by pipelines and a tunnel from Basins 219 and 220 to Kota Kinabalu, and

(4) Labuan in Basin 225; water diversion by a submarine pipeline from Basin 224 to the Labuan island.

The location of proposed water source facilities including dams and diversion facilities are shown in Figs. 5 to 15 for the alternatives B1 and B2 which cover also the location of the alternative B3.

Location of cities, irrigation schemes and dams and route of diversion canals, pipelines and tunnels are shown by a simplified model as shown in Figs. 16 to 24 (see Section 2.2.4).

3.2 Recommended Water Source Development Plans

3.2.1 Selection of drought level for recommended plans

As is in Section 3.1.2 alternative water source facilities are planned with the same risk of drought level for each alternative plan. No distinction is made among irrigation schemes, domestic and industrial water supply, rural water supply or hydropower generation. The risk of failure (or water shortage) of the alternative B1 (drought level 1/N) is least, but the development cost is highest; that is, water rate becomes high.

In Malaysia, the facilities for domestic and industrial water supply have been designed for the drought having the recurrence interval of 30 - 50 years depending on the policy of each state. Irrigation schemes have been planned for the drought with the recurrence interval of 5 years.

The recurrence interval (or probability) of each drought level is estimated for different simulation period in Table 25. The probability of exceedence of the alternative B1 is estimated to be 1/11 - 1/20 for 10-year simulation period, 1/14 - 1/26 for 13-year simulation period and 1/17 - 1/32 for 16-year simulation period. For the alternative B2 it is estimated to be 1/5.5 - 1/6.7 for 10-year simulation period. For the alternative B3 it is estimated to be 1/4.7 - 1/5.2 for 13-year simulation period and so on.

The following risk level, accordingly, are applied to the recommended water source development plans taking into account regional peculiarity, purpose of major water demand, river utilization ratio, cost-benefit and development priority:

(1) The net supply capacity of water source facilities be determined against the most severe drought ever recorded (i.e. 1/N drought level) for a river system where demand for domestic and industrial water supply is predominant;

(2) It be determined against the second or third severe drought ever recorded (i.e. 2/N or 3/N drought level) depending on the simulation period of hydrological record for a river system where irrigation water demand is predominant in case of Sabah and Sarawak; and

(3) Provided that structural measures of water source be required only if the river utilization ratio is larger than or equal to 10%.

3.2.2 Recommended water source development plans

The water demand and supply balance programs set out in Tables 26 to 32 and Fig. 25 are recommended for the seven problem area.

The 7 water source development plans set out below are recommended. The construction period and the major features are presented in Table 33. The location of dams and diversion facilities is shown in Fig. 26 for Sabah and Fig. 27 for Sarawak.

(1) The Tawau dam with active storage capacity of 7×10^6 m^3 in the upper reaches of the Tawau river (Basin 207) for the water supply to Tawau. The year of commission is 1992. The design drought level is 1/10.

(2) The Meliau dam with active storage capacity of 17×10^6 m^3 in the Meliau river (Basin 213) and the diversion pipeline system of 120 km from the site to Sandakan for water supply. The year of commission is 1988 for the initial stage of pipeline system and 1991 for the dam. The design drought level is 1/14. The supply capacity of the dam is determined for the source demand of Sandakan and its suburban, not for the deficit of the sub-basin because the effective catchment area of the existing intake is extremely small comparing to demand, and potential supply capacity is negligible.

(3) The Milau dam with active storage capacity of 5×10^6 m^3 in the Milau river (Basin 217) and the diversion pipeline system of 30 km from the site to Kudat for water supply. The year of commission is 1988 for the pipeline and 1992 for the dam.

The design drought level is 1/13. The supply capacity of the dam is determined for the source demand of Kudat and rural because the potential supply capacity in the effective catchment of the Kudat area is negligible.

(4) The Wariu dam with active storage capacity of 8 x 10^6 m^3 in the upper reaches of the Wariu river of Kadamaian river system (Basin 218) for the irrigation scheme including the Tempasuk North irrigation scheme (6,400 ha in 2000). The year of commission is 1990. The design drought level is 3/13. Groundwater potential is capable to supply the water demand of Kota Belud still in 2000 with cheaper development cost than surface water.

(5) The Papar dam with active storage capacity of 15 x 10^6 m^3 in the upper reaches of the Papar river (Basin 221) and the diversion tunnel and pipeline system from the site to Kota Kinabalu for water supply. The compensation and augmentation water for the irrigation and domestic and industrial water supply in the downstream of the site is also taken into account. The year of commission is 1990. Integrated water usage of the Tuaran (Basin 219), Moyog (Basin 220) and Papar (Basin 221) rivers is taken into account. The design drought level is 1/13 for Kota Kinabalu and 3/13 for the demand in Tuaran and Papar Basins. The Kota Kinabalu water supply extension project (Stage 1), a pipeline system from the Tuaran river to Kota Kinabalu (54,000 m^3/d, 19.7 x 10^6 m^3/y) is under construction and is scheduled to be completed by 1983.

(6) The submarine pipeline system from the Padas river (Basin 224) to Labuan (Basin 225) for water supply with net supply capacity of 10 x 10^6 m^3/y. The year of commission is 1988 for Stage 1 and 1993 for Stage 2. The supply capacity (12.3 x 10^3 m^3/d) of the three dams under design stage is only taken into account as potential surface water source. The average daily yield of groundwater in 1980 (5 x 10^3 m^3/d) is taken into account as the groundwater supply capacity.

(7) The Liku dam with active storage capacity of 5 x 10^6 m^3 in the upper reaches of the Riku river (Basin 231) where the PWD intake is in operation for water supply to Miri. The year of commission is 1989. The design drought level is 1/13.

Table 34 shows the water source development plans under the condition of lower economic growth.

Tables 71 to 76 show the major features of proposed dams, such as net supply capacity, active storage, gross storage, reservoir surface area and breakdown of project cost. The values which are not available are kept as blank.

4. HYDROPOWER DEVELOPMENT

4.1 Potential Hydropower

4.1.1 Previous studies

Though the potential hydropower has not been evaluated comprehensively yet in Sabah, SEB evaluated that of 12 major sites listed in Table 35. SESCO evaluated hydropower potential in Sarawak by the master plan of power system development in 1982 (Ref. 2).

In the master plan study a total of 155 dam sites in Basins 29, 30, 41 with an installed capacity of more than 50 MW each and a combined capacity of roughly 80,000 MW (for a plant factor of 50%) were identified in Sarawak. Of the 155 sites 51 mutually independent sites were assessed to be able to be constructed. Their combined installed capacity at a plant factor of 0.5 and annual generation were estimated to be 20,000 MW and 87,000 GWh, respectively. More than 90% of the generation was estimated to be firm. The best 11 sites were selected for detailed study and finally the Raja 284 (770 MW), Balu 037 (2,580 MW), Muro 040 (940 MW) and Bela 010 (260 MW) sites were proposed in the final report. The major features of the 4 sites are shown in Table 36. The Raja 284 (Midi Pelagus) site and the Balu 037 site were selected for the feasibility study as the most attractive sites.

4.1.2 Potential hydropower in Sabah

In this study potential hydropower of some 80 sites in Sabah was preliminarily examined using the maps of 1:50,000 scale and the results are shown in Tables 37 to 40. The total installed capacity including mutually inclusive sites is estimated to be 2,590 MW. Of 80 sites, 56 mutually independent sites are selected and their total installed capacity at a plant factor of 0.5 and annual energy are estimated to be 1,920 MW and 8,600 GWh/y respectively.

4.2 Planning Criteria for Hydropower Development

4.2.1 Demand forecast

The values of future electricity demand projected by SEB or SESCO are used for the hydropower development plan in 1990 and 2000. Tables 41 and 42 show the projected demand of annual energy, the maximum power and power factor for Sabah and Sarawak respectively up to 2000. Tables 43 and 44 show the future maximum demand of the major power stations in Sabah and Sarawak respectively. Further information with respect to demand forecast is presented in the Sectoral Report, Power Market.

In this study, future requirement of the maximum power demand is estimated based on the following assumption:

(1) Requirement of hydropower development is the balance of the maximum power demand and the supply capacity of the expansion program of generating facilities including facilities in operation. The expansion programs of up to 1985, which were prepared by SEB and SESCO, are presented in the Sectoral Report, Power Market; and

(2) The hydropower requirement of a city or town be larger than or equal to 50 MW. It is generally considered that thermal generation is more practical if the supply capacity is less than 50MW.

4.2.2 Screening criteria of potential sites

The sites having potential maximum capacity of larger than 30 MW are selected from the potential sites. Tables 45 and 46 show the selected hydropower sites in Sabah and Sarawak respectively.

The value of investment efficiency, the rate of total investment cost (M$) to the maximum power supply capacity (MW), is applied as the minimum requirement for practical development in the screening process. If the investment efficiency including cost of dams, power generation facilities, transmission lines and substations is larger than about M$8,000/kW, the site is rejected from economic viewpoint.

4.2.3 Criteria for estimating power output

The installed capacity of generator and the annual energy output are estimated by the following simplified criteria.

(1) Installed capacity

The installed capacity (power output) of generator (P) is given as:

$$P = 9.8 \cdot C \cdot Q \cdot He \quad \text{(kW)}$$

where,

C : Composit efficiency of generating equipment (assumed to be 0.8)

Q : Turbine discharge (m^3/sec)

He: Effective hydraulic head (m)

$$= \text{F.S.L.} - \frac{2.5}{4}\,(\text{F.S.L.} - \text{L.W.L.}) - \text{Riverbed elevation}$$

F.S.L.: Full supply level (m) corresponds to the water level for the active storage capacity

L.W.L.: Low water level (m)

$$= \text{F.S.L.} - \frac{1}{3}\,(\text{F.S.L.} - \text{Riverbed elevation})$$

If the low water level is calculated to be lower than the dead water level, the water level was assumed to be the same as the dead water level which corresponds to the sedimentation volume of 100 years with the safety factor of 2.0.

The daily generation time was assumed to be 12 hours/day. The maximum active storage capacity was assumed to be the storage which can yield the annual draft of 100% of the annual inflow at a dam site. If the maximum gross storage is limited by topographic constraint, the active storage capacity is governed by the possible maximum gross storage capacity.

(2) Annual energy

The annual energy (Ea) is given as

$$Ea = P.T \quad (kWh)$$

where, P: Installed capacity (kW)
T: Annual generation time (hours)

4.3 Hydropower Development Plans

4.3.1 Alternative setting criteria

In the master plan study of power system development by SESCO (Ref. 2), power transmission from the State of Sarawak to the State of Sabah or Peninsular Malaysia was proposed. In this study, however, alternative hydropower development plans are formed so that the power demand of each State is supplied by developing its own hydropower reserves at first.

A development plan which makes it possible to supply independently for each single demand center of which demand forecast is larger than 200 MW in the year 2000 is also made in order to bridge the large scale development required for a grid system of transmission line through a State. That is, development of a power transmission grid system is desirable but the commencement of such a large project is always involved in uncertainties with respect to the huge amount of initial investment.

4.3.2 Hydropower development plans in Sabah

Two alternative hydropower development plans are finally formed based on the foregoing criteria in Section 4.2. One is for the largest demand center, Kota Kinabalu, in which projected power demand is 148 MW in 1990 and 460 MW in 2000. The other one is for Kota Kinabalu, Labuan, Tawau, Sandakan and Keningau, in which projected power demand is 312 MW in 1990 and 969 MW in 2000. In the latter case, the demand centers are isolated each other, and therefore a grid system of transmission line is required to connect the five demand centers.