GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY, MALAYSIA

SECTORAL REPORT

VOL. [illegible]

IRRIGATION WATER DEMAND

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY, MALAYSIA

SECTORAL REPORT

VOL. 11

IRRIGATION WATER DEMAND

OCTOBER 1982

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COMPOSITION OF THIS VOLUME

This Volume consists of two parts: Part 1 deals with the subject matters of Peninsular Malaysia and Part 2 is devoted to the States of Sabah and Sarawak.

ABBREVIATIONS

(1) Plan

FMP : First Malaysia Plan
SMP : Second Malaysia Plan
TMP : Third Malaysia Plan
4MP : Fourth Malaysia Plan
5MP : Fifth Malaysia Plan
6MP : Sixth Malaysia Plan
7MP : Seventh Malaysia Plan
NEP : New Economic Policy
OPP : Outline Perspective Plan
RESP : Rural Environmental Sanitation Program

(2) Domestic Organization

DID (JPT) : Drainage and Irrigation Department
DOA : Department of Agriculture
DOE : Division of Environment
DOF : Department of Forestry
DOFS : Department of Fishery
DOM : Department of Mines
DOS : Department of Statistics
EPU : Economic Planning Unit
FAMA : Federal Agricultural Marketing Authority
FELCRA : Federal Land Consolidation and Rehabilitation Authority
FELDA : Federal Land Development Authority
ICU : Implementation and Coordination Unit
MARDI : Malaysian Agricultural Research and Development Institute
MIDA : Malaysian Industrial Development Authority
MLRD : Ministry of Land and Regional Development
MMS : Malaysian Meteorological Service
MOA : Ministry of Agriculture
MOF : Ministry of Finance

MOH	:	Ministry of Health
MOPI	:	Ministry of Primary Industries
MRRDB	:	Malaysia Rubber Research and Development Board
NDPC	:	National Development Planning Committee
NEB (LLN)	:	National Electricity Board
PORIM	:	Palm Oil Research Institute of Malaysia
PWD (JKR)	:	Public Works Department
RDA	:	Regional Development Authority
RISDA	:	Rubber Industry Small-holders Development Authority
RRIM	:	Rubber Research Institute of Malaysia
SEB	:	Sabah Electricity Board
SEBC	:	State Economic Development Corporation
S(E)PU	:	State (Economic) Planning Unit
SESCO	:	Sarawak Electricity Supply Corporation
UDA	:	Urban Development Authority

(3) International or Foreign Organization

ADAA	:	Australian Development Assistance Agency
ADB	:	Asian Development Bank
ASCE	:	American Society of Civil Engineers
FAO	:	Food and Agriculture Organization of the United Nations
IBRD	:	International Bank for Reconstruction and Development
ILO	:	International Labour Organization
IMF	:	International Monetary Fund
IRRI	:	International Rice Research Institute
JICA	:	Japan International Cooperation Agency
JSCE	:	Japan Society of Civil Engineers
MOC	:	Ministry of Construction, Japan
OECD	:	Organization for Economic Cooperation and Development
OECF	:	Overseas Economic Cooperation Fund, Japan
UK	:	United Kingdom
UNDP	:	United Nations Development Program

UNSF	:	United Nations Special Fund
US or USA	:	United States of America
US/AID	:	United States Agency for International Development
USBR	:	United States Bureau of Reclamation
WHO	:	World Health Organization
WMO	:	World Meteorological Organization

(4) Others

B	:	Benefit
BOD	:	Biochemical Oxygen Demand
C	:	Cost
CIF	:	Cost, Insurance and Freight
COD	:	Chemical Oxygen Demand
D&I	:	Domestic and Industrial
dia	:	Diameter
EIRR	:	Economic Internal Rate of Return
El.	:	Elevation above mean sea level
Eq.	:	Equation
Fig.	:	Figure
FOB	:	Free on Board
FSL	:	Full Supply Level
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
H	:	Height, or Water Head
HWL	:	Reservoir High Water Level
LWL	:	Reservoir Low Water Level
O&M	:	Operation and Maintenance
Q	:	Discharge
Ref.	:	Reference
SITC	:	Standard International Trade Classification
SS	:	Suspended Solid
V	:	Volume
W	:	Width

ABBREVIATIONS OF MEASUREMENT

Length

mm = millimeter
cm = centimeter
m = meter
km = kilometer
ft = foot
yd = yard

Area

cm^2 = square centimeter
m^2 = square meter
ha = hectare
km^2 = square kilometer

Volume

cm^3 = cubic centimeter
l = lit = liter
kl = kiloliter
m^3 = cubic meter
gal. = gallon

Weight

mg = milligram
g = gram
kg = kilogram
ton = metric ton
lb = pound

Time

s = second
min = minute
h = hour
d = day
y = year

Electrical Measures

V = Volt
A = Ampere
Hz = Hertz (cycle)
W = Watt
kW = Kilowatt
MW = Megawatt
GW = Gigawatt

Other Measures

% = percent
PS = horsepower
° = degree
' = minute
" = second
°C = degree in centigrade
10^3 = thousand
10^6 = million
10^9 = billion (milliard)

Derived Measures

m^3/s = cubic meter per second
cusec = cubic feet per second
mgd = million gallon per day
kWh = kilowatt hour
MWh = Megawatt hour
GWh = Gigawatt hour
kWh/y = kilowatt hour per year
kVA = kilovolt ampere
BTU = British thermal unit
psi = pound per square inch

Money

M$ = Malaysian ringgit
US$ = US dollar
¥ = Japanese Yen

CONVERSION FACTORS

	From Metric System	To Metric System
Length	1 cm = 0.394 inch 1 m = 3.28 ft = 1.094 yd 1 km = 0.621 mile	1 inch = 2.54 cm 1 ft = 30.48 cm 1 yd = 91.44 cm 1 mile = 1.609 km
Area	1 cm^2 = 0.155 sq.in 1 m^2 = 10.76 sq.ft 1 ha = 2.471 acres 1 km^2 = 0.386 sq.mile	1 sq.ft = 0.0929 m^2 1sq.yd = 0.835 m^2 1 acre = 0.4047 ha 1 sq.mile = 2.59 km^2
Volume	1 cm^3 = 0.0610 cu.in 1 lit = 0.220 gal.(imp.) 1 kl = 6.29 barrels 1 m^3 = 35.3 cu.ft 10^6 m^3 = 811 acre-ft	1 cu.ft = 28.32 lit 1 cu.yd = 0.765 m^3 1 gal.(imp.) = 4.55 lit 1 gal.(US) = 3.79 lit 1 acre-ft = 1,233.5 m^2
Weight	1 g = 0.0353 ounce 1 kg = 2.20 lb 1 ton = 0.984 long ton = 1.102 short ton	1 ounce = 28.35 g 1 lb = 0.4536 kg 1 long ton = 1.016 ton 1 short ton = 0.907 ton
Energy	1 kWh = 3,413 BTU	1 BTU = 0.293 Wh
Temperature	°C = (°F - 32)·5/9	°F = 1.8°C + 32
Derived Measures	1 m^3/s = 35.3 cusec 1 kg/cm^2 = 14.2 psi 1 ton/ha = 891 lb/acre 10^6 m^3 = 810.7 acre-ft 1 m^3/s = 19.0 mgd	1 cusec = 0.0283 m^3/s 1 psi = 0.703 kg/cm^2 1 lb/acre = 1.12 kg/ha 1 acre-ft = 1,233.5 m^3 1 mgd = 0.0526 m^3/s
Local Measures	1 lit = 0.220 gantang 1 kg = 1.65 kati 1 ton = 16.5 pikul	1 gantang = 4.55 lit 1 kati = 0.606 kg 1 pikul = 60.6 kg

Exchange Rate
(as average between July and December 1980)

$1 = M$2.22
¥100 = M$1.03

PART 1

PENINSULAR MALAYSIA

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SPECIAL ABBREVIATIONS

GRP : Glass-reinforced Polyester

KADA: Kemubu Agricultural Development Authority

MADA: Muda Agricultural Development Authority

O&M : Operation and Maintenance

1. INTRODUCTION

This Sectoral Report presents the projection of irrigation water demand for the years 1990 and 2000 based on the information and data collected in Malaysia from October 1980 to January 1981. Results of the projection of irrigation water demand are used for succeeding water balance study for each river basin.

The role of irrigation in Peninsular Malaysia has been devoted mostly to wet paddy, particularly for the double-cropping of paddy. Irrigation in Malaysia is totally dependent on surface water sources because of the relatively high costs of ground water development, and the high consumption of water in paddy production relative to the value of the crop. In this Sectoral Report irrigation water demand is projected only for irrigated paddy area.

Due to insufficiency of field measurement data such as evapotranspiration rate, percolation rate and irrigation efficiency, many assumptions are placed on the procedure of projection. Following the collection of such information in future, modification shall be conducted.

2. IRRIGATION SCHEMES IN PENINSULAR MALAYSIA

2.1 History of Irrigation Development

Irrigation development in Malaysia has been exclusively devoted to the cultivation of wet paddy. Development of the first major irrigation scheme, Krian (25 x 10^3 ha), was commenced in 1880 and completed in 1906 for a single paddy crop (Ref. 1). In 1932, DID was established. Following the establishment of DID, a number of irrigation projects were implemented and paddy growing areas with irrigation facilities increased steadily as shown in Table 1 and Fig. 1.

Up to about 1960, irrigation schemes were mainly constructed to stabilize the production of a single crop of paddy in a year against occasional water shortage in the rainy season. The Tanjong Karang Irrigation Project (19 x 10^3 ha) was developed in coastal mangrove swamps during late 1930s and early 1950s as shown in Fig. 2 (Ref. 2). The Sungai Manik Irrigation Project was commenced in 1933 by reclaiming swamp jungle and completed in 1939 (Ref. 1). In addition to these major projects, many small-scale irrigation areas were provided with irrigation facilities. A total of 214 x 10^3 ha of paddy area was irrigated in 1960, which was 61% of total wet paddy area of 351 x 10^3 ha.

The next stage of irrigation development in Peninsular Malaysia commenced in the early 1960s. This marked the beginning of a period of accelerated irrigation development as an integral part of the rural and socio-economic development program in the country following Merdeka. Irrigation development was concentrated on the intensification of paddy production in existing paddy areas. To permit double-cropping of paddy in existing paddy areas, construction of major irrigation facilities such as headworks, large pumping stations, main and secondary irrigation canals were undertaken. Survey and design for the Muda Irrigation Project, which is the largest irrigation scheme in Malaysia, was commenced in early 1960s (Ref. 3). With the completion of two storage reservoirs and major canals in the Muda area, double-cropping over an area of 96 x 10^3 ha was initiated in 1973. The largest pumping irrigation scheme, Kemubu (19 x 10^3 ha), was completed in 1973 (Ref. 4). By 1975, all major paddy growing areas (183 x 10^3 ha) were equipped with the necessary irrigation facilities to enable the double-cropping of paddy.

In recent years the major thrust of irrigation development in Peninsular Malaysia has shifted from the construction of new schemes for double-cropping to the rehabilitation and improvement of most of established schemes. Such rehabilitation work has begun with the initiation of the Lemal irrigation component of the North Kelantan Rural Development Project (Ref. 5). In addition, the Muda, the Krian, the Sungai Manik and the Tanjong Karang Projects are under rehabilitation as a tertiary development through the provision of tertiary canals and drains to provide a higher standard of water control. The National Small-Scale Irrigation Project was begun in 1978 aiming to rehabilitate and upgrade irrigation facilities for 126 sub-projects with financial assistance by IBRD. Small rainfed paddy areas still require basic systems to permit reliable main season cropping and the initiation of dry-season cropping. Trend of irrigation area in the last 10 years by state is shown in Table 2.

2.2 Present Condition of Irrigation Schemes

2.2.1 Classification of existing schemes

In 1979, the total wet paddy area was 428 x 10^3 ha comprising 299 x 10^3 ha of irrigated paddy area and 129 x 10^3 ha of rainfed area. Of the total irrigated area, about 230 x 10^3 ha, or 77% of irrigated paddy area, was double-cropped as mentioned in the Sectoral Report PF.

In Peninsular Malaysia, 779 irrigation schemes were maintained in 1979. List of minor irrigation schemes is tabulated in Appendix. They are classified by area and state as shown in Table 3 and are summarized below.

Classification	Irrigation Area		Number of Scheme	
	(10^3 ha)	(%)	(nos.)	(%)
Smaller than 50 ha	10.1	3.4	359	46.1
51 - 100 ha	12.3	4.1	167	21.4
101 - 500 ha	40.3	13.5	203	26.1
501 - 1,000 ha	17.1	5.7	24	3.1
1,001 - 5,000 ha	39.0	13.0	19	2.4
5,001 - 10,000 ha	25.3	8.5	3	0.4
Larger than 10,001 ha	155.3	51.8	4	0.5
Total	299.4	100.0	779	100.0

As shown in the above table, irrigation schemes smaller than 500 ha share only 21% (63 x 10^3 ha) of the total area of 299 x 10^3 ha, in spite of their large share (94%) in number. More than 57% of such small-scale irrigation schemes are scattered in the States of Negeri Sembilan and Pahang.

Among many existing irrigation schemes, 7 of them, i.e. the Muda (96 x 10^3 ha), Krian (23 x 10^3 ha), Sungai Manik (7 x 10^3 ha), Tanjong Karang (19 x 10^3 ha), Besut (5 x 10^3 ha), Kemubu (18 x 10^3 ha) and North Kelantan (12 x 10^3 ha), are categorized into "Major Project" by DID (Ref. 7). Such existing major project area totals 180 x 10^3 ha which is 60% of total irrigation area of 299 x 10^3 ha. Location of existing major project is shown in Fig. 2. Main irrigation facilities for the existing major projects were completed by 1976 and can provide irrigation water throughout the year as far as water sources permit. The principal features of the existing major projects are summarized in Table 4. Present condition of each major project is described in the succeeding section.

Irrigation schemes in Peninsular Malaysia can also be classified by type as summarized below. Details are shown in Table 5.

Type of Scheme	Total Area (10^3 ha)	Number of Scheme	Average Size of Scheme (ha/no.)
Gravity	156	445	351
Gravity + Pumping	62	52	1,185
Pumping	63	98	648
Control Drainage	16	135	116
Inundation	2	49	45
Total	299	779	384

Gravity scheme is the predominant type in Peninsular Malaysia. The area irrigated mainly by reservoir such as the Muda Irrigation Project is classified under gravity scheme in the table above. Gravity schemes are distributed to all the states in Peninsular Malaysia.

After gravity schemes, the next most common type is pumping. Among pumping irrigation areas, about 67% (43 x 10^3 ha) of the total pumping area exists in the east coast states of Peninsular Malaysia, i.e. Pahang, Trengganu and Kelantan, due to topographic conditions. List of existing pumping stations is tabulated in Appendix.

Control drainage scheme is a relatively inexpensive system built on flat gradient flood plains along the coast. Rainwater is stored as needed on the fields and in the drains by a system of bunds, drains, controls and gates. Excess water is drained out during low tide. Sea water intrusion is prevented by the bunds and closed gates during high tide. Total water management is not as good as in a pumping or gravity scheme and only one wet-season crop is normally grown in most areas. Control drainage scheme is the predominant in the State of Pahang sharing 55% of the total control drainage area.

About 49 small inundation schemes have been constructed in the rugged interior portions of the State of Pahang. They are used in the steeper upland valleys and are similar to controlled drainage schemes in that they store rainwater on the fields and are a one-crop wet-season system. They are composed of a series of low dams straddling the valley stream, 2 to 3 m high, and gated outlets to the stream. Water backs up behind each dam and when the water level reaches the upper end, that area is cultivated and planted.

2.2.2 Muda Irrigation Project

The Muda Irrigation Project is located in the States of Kedah and Perlis in northwestern Peninsular Malaysia (Fig. 2). The irrigation area occupies flat alluvial coastal plain of about 20 km wide and 65 km long between the foothills of the Central Range and the Straits of Malacca. Although the plain is flat on a macro-level, the micro-topography is variable. Most of the Muda soils are heavy, poorly drained and slightly acidic silty clays, which is ideal for rice production.

The Muda Irrigation Project was implemented during the period 1965-1970 and was aimed at introducing double-cropping of paddy over an area of 96 x 10^3 ha, previously devoted to a single paddy cultivation. The principal project components were:

(1) the construction of the Pedu Dam with a reservoir storage capacity of 1,070 x 10^6 m^3, the Muda Dam with a reservoir capacity of 160 x 10^6 m^3, and the 7 km long Saiong connecting tunnel between the two dams with a maximum capacity of 70 m^3/s;

(2) a conveyance system comprising an existing river channel, headworks and 115 km of main canals;

(3) an internal reticulation system with some 970 km of secondary canals from 1,200 - 2,000 m apart (canal density 10 m/ha), 870 km of drains (drain density 9 m/ha), some 2,000 structures, 24 pumping stations and about 780 km of laterite surfaced farm roads; and

(4) some 100 km of coastal bund with 25 tidal gates.

The source of water supply for the Muda Project are the controlled flow from the Pedu and the Muda reservoirs and the uncontrolled flow from the tributaries of the Kedah River. The former supplies 67% of the average annual irrigation water demand and the latter supplies the remainder (Ref. 3). For efficient utilization of the limited irrigation water source, drained water has been reused as irrigation supply in the lower part of the Muda area by using small pumps.

The present Muda system relies on field-to-field flooding over distances ranging from 1,200 to over 2,000 m, averaging about 1,600 m. Water must be moved across numerous parcels of land, each of which is surrounded by small field bunds required for water level control within the parcel. The drainage system is equally rudimentary, and difficulties in supplying and removing water on a field-to-field basis are compounded by the variations in micro-topography. Only about 10% of the parcels have direct access to either a canal or a drain, and associated roads. This situation results in lags of more than 40 days in farming activities within each block, which causes serious agricultural problems because of varying water requirements over the growing stages of the paddy crop.

The tertiary irrigation and drainage development in the existing Muda irrigation area has been on-going as the Muda II Irrigation Project was financially assisted by IBRD from 1979. It will provide tertiary canals, drains and access roads to nearly 25,000 ha of paddy area. After the completion of the tertiary irrigation and drainage development, the canal density will be augumented from the present 10 m/ha to 30 m/ha and better water management can be expected. The Muda II Irrigation Project is the first phase of the overall 15-year program for tertiary development covering the Muda irrigation area (Ref. 7). Field research program with technical assistance by the Japanese Government (1978-1983) has been carried out in order to establish recommendable measures for the implementation of tertiary development. The result of the program will be taken in the Muda II Project successively.

2.2.3 Krian Irrigation Project

The Krian Irrigation Project (23×10^3 ha) is located in the north-west region of the State of Perak, with some 1,500 ha extending into the State of Pulau Pinang (Fig. 2). The Krian Irrigation Project is situated on the west coast alluvial plain which slopes gently from about El 4 m at the Bukit Merah Reservoir to about El 0.8 m near the coast, a distance of about 29 km. The flat terrain is drained by the Krian and Kurau Rivers. Coastal areas were subject to direct salt water intrusion before being protected by a bund along the entire length of the coast. The coastal portion of the Krian Project area consists mainly of alluvial clay soils of marine origin while the inland area consists mainly of alluvial soils of riverine origin.

The original main structures of the Krian Irrigation Project, including the Bukit Merah Reservoir and the main canals, were completed in 1906. As the reservoir capacity was insufficient to supply adequate water in low rainfall seasons, the reservoir was enlarged during the early 1960s to about 76×10^6 m^3, which provided adequate storage for the entire main-season paddy and for about 12×10^3 ha of the off-season paddy. To increase the supply of off-season irrigation water to the lower portion of the sub-project area, a tidal barrage was constructed on the Krian River in 1973-76, together with an inlet channel to a new pumping station, which provides additional water to the lower reaches of the main canal. The pumping station, completed in 1976, is equipped with 4 pumps, each with a capacity of 5.1 m^3/s. With these recent major improvements the Krian Project can now provide sufficient water for full double-cropping of paddy.

The Krian area is provided with a sparse network of distributary irrigation canals and collector drains. The overall irrigation canal density is 15-20 m/ha, and in the lower half of the sub-project area canal banks have been eroded after decades of use. Water levels are the same in the canals, drains, and fields, and little movement or control of water is possible. Drainage is restricted by an almost total absence of tertiary and quarternary drains. In the higher areas, drainage conditions are better, but field distribution of irrigation water is slow because of insufficient command heights in the secondary canals and a complete lack of tertiary canals. Thus over the entire Krian area cropping schedules are almost continually out of phase, and proper water management is almost impossible (Refs. 1 and 8).

The tertiary irrigation and drainage development for the Krian Irrigation Project is on-going as a sub-project of the Krian-Sungai Manik Integrated Agricultural Development Project with financial assistance by IBRD (Ref. 1). The proposed project components are as follows:

(1) new construction of a rock-faced coastal bund (2.4 km) and improvement of the existing coastal and river earth bunds (104 km);

(2) improvement and upgrading of existing main and secondary canals (390 km in total); and

(3) new construction of 50 km of earth, 13 km of concrete lined, and 277 km of structural tertiaries and 58 km of earth quarternary ditchs.

Tertiary canals would be constructed to serve individual irrigation units varying in size from 20 to 100 ha. The construction of the supplementary tertiary and quarternary system would increase the irrigation canal density from the present 15-20 m/ha to 30-35 m/ha.

2.2.4 Sungai Manik Irrigation Project

The Sungai Manik Irrigation Project is located in southern Perak. The net irrigation area is about 6,600 ha. The Sungai Manik Project area slopes more sharply than the Krian area, with an elevation of about El 12 m near the headworks and about El 2 m at the flood protection bunds along the Perak River. The topography is more undulating and steeper near the headworks than in the lower portion. The lower flat slopes of the Sungai Manik Project area have alluvial clays and the higher areas consist of sandy clays. Low lying soils are currently almost permanently flooded, while better drainage has been possible on the higher areas.

Construction of the Sungai Manik Irrigation Project was commenced in 1933. Swamp jungle was reclaimed in four stages, with the first three (3,420 ha) completed by 1941 and the fourth (3,140 ha) in 1953. Construction of the headworks, a run-of-the-river gravity diversion weir on the Batang Padang River, was completed in 1939. The headworks, which also serves as a road bridge, is a concrete structure with a single radial gate. Since 1963 the flow of the Batang Padang River has been augmented and seasonally regulated by the Cameron Highlands Hydroelectric Project, which taps the catchments of two rivers in the State of Pahang and diverts them to the Batang Padang River.

The area presently used for paddy cultivation in Sungai Manik is 6,230 ha. Another 330 ha cannot be adequately irrigated with the present canal command levels. Distribution of water is slow due to inadequate command heights in some secondary canals and undulating topography. The northern half of the project area, or Stage IV, relies on field-to-field flooding over reaches of 800 m. In Stage IV, where two adjoining farms commanded from one off-take, the presaturation period may be as long as 45 days on the lot farthest away from the canal. Many of the old Sungai Manik canal structures need replacement, and the operation of the headworks is hindered by siltation and erosion problems.

Inadequate off-take structures, low drain capacities and flat terrain cause prolonged ponding of the lower area, where drainage water is evacuated into the tidal Perak River (Ref. 1).

The tertiary irrigation and drainage development for the Sungai Manik Irrigation Project is on-going as a sub-project of the Krian-Sungai Manik Integrated Agricultural Development Project with financial assistance by IBRD. The proposed project components are as follows:

(1) improvements of the existing river bund (8 km);

(2) improvement of existing main and secondary canals (50 km in total); and

(3) improvement of 178 km of existing distribution canals and new installation of 50 km of structural tertiary canals.

With these improvements an overall canal density of 35 m/ha would be obtained.

2.2.5 Tanjong Karang Irrigation Project

The Tanjong Karang Irrigation Project is located in the northwest corner of the State of Selangor (Fig. 2). The irrigation area occupies nearly 19×10^3 ha of paddy extending about 46 km along the coast and 11 km inland at its widest section. The bulk of the project area comprises of a flat coastal plain, with rising land and undulations in the southern section. Soils on the plain are fairly heavy alluvial soils developed under marine or brackish water conditions or peat soils developed under impeded surface drainage conditions in the low lying areas.

The Tanjong Karang Irrigation Project was developed from virgin jungle by DID through a series of programs beginning in 1936. Water was first provided for a single wet-season paddy crop by a weir on the Tinggi River via 40 km main canal along the inland border of the project area. To augment the water supply for double-cropping of paddy, headworks were constructed in 1957 and 1964 on the Bernam River, and a 15 km feeder canal was excavated through the peat swamp to divert the Bernam River to the Tinggi River. A pump-house was constructed in 1962 on the lower reaches of the Bernam River at Bagan Terap, to provide a more assured water supply for the northern portion of the project area. In the past, water shortage has never occurred in the project area.

The existing irrigation system has fulfilled its original purpose of permitting wet-season paddy production and dry-season cropping of an average of 70% of the project area, but still suffers from several deficiencies. The capacity of some reaches of the main canal is inadequate, and at present the gates of the old Tinggi headworks has leakage problem. Command head of the existing distributary canals is inadequate, causing slow inundation of fields and late transplanting.

Water must travel 800 m across farm lots with the present density of distributaries. Since the micro-topography is undulating, the water must often fill depressions to undesirable depths (30 m and above) before its flow can continue. These inadequacies have led to a situation where large areas of paddy are continually out of phase.

Upgrading and intensification of the existing Tanjong Karang Irrigation Project is now on-going as a component of the Northwest Selangor Integrated Agricultural Development Project financed by IBRD in 1978. The main components of the project are as follows (Ref. 2):

(1) rehabilitation of the existing headworks, feeder and main canals and structures; and

(2) construction of tertiary irrigation and drainage networks which would serve each individual paddy plot of 1.2 ha.

Under the project spacing between tertiary canals and drains would be reduced from the present 800 m to 200 m. The structural tertiary canal system, Grass-Reinforced Polyester (GRP) flume, has been completed by DID in the southern block (Sawah Sempadan) of Tanjong Karang as a pilot scheme. Recently, due to price increase of GRP flume, concrete flumes have been proposed for tertiary canal instead of the originally proposed structural canal. The total tertiary canal system would be 492 km in length, and hence the canal density will become 32 m/ha.

2.2.6 Besut Irrigation Project

The Besut Irrigation Project is located on the right bank of the Besut River in the northern part of the State of Trengganu close to the state boundary of Kelantan (Fig. 2). The irrigation area is a slightly undulating alluvial plain, interspersed by high ground area and drainage channels (Ref. 9).

The Besut Irrigation Project was developed in 2 stages. The Stage I development was completed in 1957 for 2,270 ha of irrigated paddy area of which 1,420 ha were to be used for double-cropping. The Stage I consisted of the construction of headworks on the Angga River, a tributary of the Besut River, and the irrigation canal system. Since discharge of the Angga River was low and drainage and water distribution facilities in the Stage I area were inadequate, rehabilitation of the Stage I area became indispensable and was incorporated in the succeeding Stage II project.

The Besut Irrigation Project, Stage II, was executed during the period of 1972-1976 with financial assistance by ADB. The main objective of the Project is to provide irrigation water to 5,058 ha of paddy field, including the whole of Stage I area, for double-cropping of paddy. The principal project components were:

(1) the construction of headworks on the Besut River;

(2) the rehabilitation of canals and structures within Stage I;

(3) the extension of the irrigation distribution on system to serve the total project area of Stage II;

(4) the improvement of major drainage system and the construction of additional field drains; and

(5) the construction of farm ditches within the irrigation unit blocks.

Under the project 29 km of main irrigation canals, 185 km of irrigation distribution networks and 73 km of drainage canals were completed. Hence the canal density became 37 m/ha, which is the highest in Malaysia. Using 2 headworks sufficient water can be provided to the whole area of the project.

Extension of some 850 ha is under consideration outside the Stage II area. With assistance by FAO/UNDP, some 600 ha of pilot scheme in the Besut Project area is on-going in order to establish recommendable measures for future on-farm development.

2.2.7 Kemubu Irrigation Project

The Kemubu Irrigation Project (19×10^3 ha) is located on the right bank of the Kelantan River in the northern part of the State of Kelantan (Fig. 2). The irrigation area is a gently sloping alluvial plain interspersed by numerous drainage channels meandering northeastward.

The primary objective of the project was to achieve double-cropping of paddy in the area. The main structures of the project were completed in 1972 with financial assistance by IBRD. Following the completion of the project, KADA was established to manage the Kemubu Irrigation Project together with 4 other existing irrigation schemes, i.e. the Alor Pasir, Sungai Lemal, Pasir Mas and Salor. The principal project components were as follows (Ref. 4):

(1) the Kemubu Pumping Station on the right bank of the Kelantan River being equipped with 5 diesel-driven pumps, each having a capacity of 7 m^3/s (250 cusec);

(2) a conveyance system comprising 68 km of main canals and the Ketereh Diversion Dam in the project area, which serve to divert locally available water;

(3) an internal recticulation system with some 410 km of irrigation canal (canal density 22 m/ha) and 350 km of drainage canal (drain density 18 m/ha); and

(4) 12 km of flood protection dikes.

Operation and maintenance of the project facilities is good on the whole. Moderately serious problems have been occurred at the Kemubu Pumping Station. It was pointed out in Ref. 8 that the pumps were not capable of delivering their full design discharge when all pumps were in operation due to interference effects. Furthermore, recent measurements showed that the pumping capacity of each pump had deteriorated from the original 7 m^3/s (250 cusec) to 5.1 m^3/s (180 cusec). According to the previous report (Ref. 4), conveyance efficiency of the Kemubu canal system was measured at 85% and the overall irrigation efficiency was estimated at 30-40% due to heavy operational losses under present conditions of field-to-field flooding. Under these conditions, the amount of irrigation water is absolutely insufficient for full double-cropping of paddy in the Kemubu Project area. Local flooding from the Kemasin and Semerak Rivers remains a major problem for about 2,000 ha of the project area.

Improvement of 97 irrigation problem areas (810 ha) and 70 drainage problem areas (405 ha) is being executed by KADA and will finish by 1985. Five additional pumping station has been established in the Kemubu Project area in order to recycle drainage water as irrigation supply. In the near future, overall improvement plan for the Kemubu Irrigation Project will be worked under the KADA II study.

The Water Management Training Center Project is being conducted in the Kemubu area with technical assistance by the Japanese Government. The main function of the Center is to train DID staff and extension workers in techniques of water management. The water distribution problems in the Kemubu Irrigation Project is expected to be effectively solved by the execution of the "KADA II Project" and with the efforts of the Water Management Training Center.

2.2.8 North Kelantan Irrigation Project

The North Kelantan Irrigation Project (12×10^3 ha) is located on the left bank of the Kelantan River in the northern part of the State of Kelantan (Fig. 2). The project consists of three contiguous areas, i.e. the Pasir Mas (2,100 ha), Sungai Lemal (9,300 ha) and Alor Pasir Schemes (600 ha). The project area extends over the riverine plains of the Kelantan and Golok Rivers, the latter stream serving as the international border with Thailand. The most part of the project area was inundated by the 1979 flood.

Double-cropping of paddy in Kelantan commenced in 1962 with the completion of the Pasir Mas Scheme, which includes a pumping station on the Kelantan River downstream from the town of Pasir Mas and about 43 km of main and distributary canals. The Sungai Lemal Scheme which was completed in 1968, is supplied from a headworks on the Lemal River, supplemented by a pumping station on the Kelantan River upstream of Pasir Mas, and includes 113 km of main canals and distributaries. In 1970, the Alor Pasir Scheme was completed as an extension to the Sungei Lemal Scheme, with a 10 km distributary system drawing water from the

Sungai Lemal main canal. All three schemes provided only rudimentary water control because of lack of flood control, adequate drainage, and an articulated distribution system (Ref. 5).

In 1976, the North Kelantan Irrigation Project, which was a component of the North Kelantan Rural Development Project, was initiated as the nation's first tertiary irrigation and drainage development program. Its main aim was to solve constraints on water control. The project components are as follows:

(1) construction of 35 km of river bund by sheet pile;

(2) construction of drainage network including 12 km of primary drain, 65 km of secondary drain, 176 km of tertiary drain and 424 km of on-farm drain; and

(3) construction of 155 km of tertiary irrigation canal and 500 km of quarternary irrigation canal.

Under the project, distribution system can serve irrigation water to each 10 ha paddy block, and a canal density will be augmented from the present 10 m/ha to 55 m/ha. All construction works are scheduled to complete by 1983.

2.2.9 National Small-Scale Irrigation Project

The National Small-Scale Irrigation Project is being carried out with financial assistance by IBRD (Ref. 10). This project covers not only Peninsular Malaysia but Sabah and Sarawak as well. The major objective of the project is to raise the productivity and income of over 47×10^3 paddy small-holders throughout Malaysia through construction or rehabilitation of 126 small irrigation schemes (110 schemes in Peninsular Malaysia), ranging in size between 50 and 2,000 ha of net irrigable paddy land.

The proposed schemes would irrigate a total of about 42×10^3 net ha of paddy, 77% of which is now depending on rainfall, natural inundation, or primitive facilities which require rehabilitation or upgrading. Various types of schemes would be constructed under the project, comprising gravity diversion headworks (50%), pumping (35%), control drainage (9%) and inundation (6%).

Each irrigation scheme is being evaluated by DID from 1978. In the course of the evaluation, some schemes originally proposed will be eliminated. All project works are expected to be completed during 5 years, i.e. by 1983.

2.3 Future Irrigation Development

According to information obtained from MOA, the Government policy on future irrigation development will be as follows:

(1) To increase rice production in the country, a two-pronged irrigation strategy should be implemented comprising, (a) upgrading and improving of irrigation facilities to achieve better yields in existing paddy area and (b) reclamation and development of new areas with irrigation facilities for double-cropping of paddy;

(2) For existing irrigated areas current programs for provision of better water management and control facilities will be sustained. Irrigation service area will be reduced to about 10 ha and with a canal density of 30-35 m/ha;

(3) In the opening-up of new lands for the double-cropping of paddy, the recommendable minimum canal density of 50 m/ha would be provided from the start;

(4) Upgrading of the irrigation facilities in single cropped paddy to double-cropping will be undertaken wherever permitted by the availability of water for irrigation. In marginal paddy lands with technical and economic difficulties, conversion of the land should be considered. By 2000, no rainfed paddy area will exist;

(5) In those existing irrigation areas affected by low irrigation efficiency due to the lack of proper water management and control, the recycling or reuse of water should be considered as an interim measure for more effective water utilization; and

(6) In those areas where favorable deposits of groundwater are available, the feasibility of extracting and using groundwater to supplement surface water for the irrigation of non-paddy crops should be further investigated.

In Peninsular Malaysia, most existing paddy area suffers from poor water management. Current tertiary irrigation and drainage development program by DID is expected to stabilize double-cropping of paddy. To realize the full potential of high yielding varieties for double-cropping, water management technology should also be improved.

The potential major irrigation projects in Peninsular Malaysia identified by DID in 1980 are the Trans Perak Stage IV (10 x 10^3 ha), Rompin-Endau (11 x 10^3 ha), Sawah Endau (8 x 10^3 ha), Trans Pahang (13 x 10^3 ha) and Kemasin-Semerak (9 x 10^3 ha) as shown in Fig. 2 (Ref. 11). These potential projects are expected to have irrigation and drainage facilities for better water management. The projected paddy areas in Peninsular Malaysia for the years 1980, 1990 and 2000 are:

Unit: 10^3 ha

Year	Total Wet Paddy Area	Rainfed Paddy Area	Irrigation Area Main	Irrigation Area Off	Percentage of Irri. Area
1980	428	126	302	226	71
1990	436	44	392	282	91
2000	436	0	436	310	100

3. IRRIGATION WATER DEMAND

3.1 General

The role of irrigation in Malaysia has been devoted mostly to wet paddy, particularly for the double-cropping of paddy. Irrigation in Malaysia is totally dependent on surface water sources because of the relatively high costs of ground water development, and the high consumption of water in paddy production relative to the value of the crop. In this Sectoral Report irrigation water demand is projected only for irrigated paddy area.

Projection of irrigation water demand for the years 1980, 1990 and 2000 is conducted on monthly basis based on the cropping schedule prepared in the Sectoral Report of Agriculture. It is assumed that the tertiary development for existing schemes will be completed by 2000, and land consolidation work will not be initiated during this century. Due to insufficiency of field measurement data for evapotranspiration, percolation rate, effective rainfall and irrigation loss, many simplified assumptions are set in the present study. Details of calculation and background of the assumptions are described in the succeeding section.

3.2 Previous Studies on Irrigation Water Demand of Paddy

Since 1960, some expatriate experts carried out field research on irrigation water required for double-cropping paddy cultivation and proposed the recommended amount for irrigation supply. Table 6 shows the recommended irrigation water requirement without subtraction by effective rainfall.

In 1962, Matsushima (Ref. 12) presented the required depth of irrigation water for double-cropping paddy cultivation in the Kedah Plain based on his experiments and investigations. He presented the desirable irrigation depth for paddy cultivation on the assumption that the paddy was cultivated under the sophisticated water management.

Van de Goor and Zijlstra (Ref. 13) carried out field investigations on irrigation water demand for paddy at 2 experimental stations and in 3 pumping irrigation schemes where double-cropping of paddy had already been introduced. They measured irrigation supply and surface runoff in the paddy plot and tank evapotranspiration placed in the paddy field for water balance calculation. Based on the results, they calculated the recommendable depth of irrigation as 1,194 mm/crop for main season paddy and 1,270 mm/crop for off season paddy including 50% distribution losses during normal irrigation as shown in Table 6. The percolation loss for low-land paddy was disregarded because of high groundwater level. The DID Manual published in 1973 followed the figure recommended by Van de Goor and Zijlstra.

Sugimoto (Ref. 14) carried out the field measurements of evapotranspiration and evaporation by using tanks placed in the paddy field in the Muda area from 1967 to 1969. Based on the results, he recommended the required consumptive use as 5.5 mm/d for main season paddy and 7.1 mm/d for off season paddy on an average basis. Furthermore he assumed the percolation loss of 1 mm/d for low-land in the Muda area. The crop water requirement (excluding effective rainfall and losses) recommended is 974 mm/crop for main season paddy and 1,344 mm/crop for off season paddy.

In the course of previous studies for major irrigation project, the irrigation water demand for each project has been calculated as shown in Tables 7 to 9. A review of calculation in these previous study reports shows that there has been no uniformity in the methodology and assumptions for estimation of irrigation water demand. The crop water requirement calculated in the previous reports varies between 839 and 1,489 mm/crop for main season paddy and between 915 and 1,524 mm/crop for off season paddy.

In the present study, irrigation water demand for each major project and minor irrigation scheme is estimated by using unified methodology and assumptions mainly based on the previous studies as mentioned in the succeeding section.

3.3 Calculation Basis of Irrigation Water Demand

3.3.1 Gist of calculation method and assumptions

The gist of calculation methodology and assumptions employed in the present study is summarized below.

(1) Calculation procedure is shown in the following equation.

$$FC = ET + PL \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$
$$CWR = PS + FC \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$
$$IWD = (CWR - RE)/IE \quad \ldots\ldots\ldots \quad (3)$$

where, FC : Field crop requirement
CWR: Crop water requirement
IWD: Irrigation water demand
ET : Evapotranspiration
PL : Percolation rate
PS : Presaturation
RE : Effective rainfall
IE : Overall irrigation efficiency

(2) Evapotranspiration is calculated using the following equation.

$$ET = EW \times (ET/EW\ Ratio) \quad \ldots\ldots\ldots\ldots \quad (4)$$

where, ET : Evapotranspiration rate in the paddy field
EW : Evaporation rate in the paddy field (90% of pan evaporation)
ET/EW ratio: Determined based on previous research

(3) Presaturation requirement is calculated based on "Presentation of Padi Fields" by S.H. Thavaraj, 1975 (Ref. 15). Total depth of water in the field is assumed to be 15 cm.

(4) Percolation rate is to be the same figure as used in the previous reports (see Tables 5 and 6). If it is not available, the following standard figures are adopted.

Major irrigation scheme	2 mm/d
Minor irrigation scheme	3 mm/d

(5) Effective rainfall is calculated on monthly basis for 20 years from 1960 to 1979 using the following equation.

Actual monthly rainfall(R)	Effective rainfall(RE)	
$R \leq 200$ mm/month	$RE = 0.6 \times R$	... (5)
$R > 200$ mm/month	$RE = (R - 200) \times 0.3 + 120$	

(6) Overall irrigation efficiency is generally considered to be 5% lower than the figures employed in the previous reports. Overall efficiency applied in the study is as follows.

	1980	1990 & 2000
Muda and Krian Irrigation Projects	60%	65%
Other major and minor irrigation schemes	50%	55%

3.3.2 Climatic zone in Peninsular Malaysia

Calculation of irrigation water demand and succeeding water balance study is carried out by basin established for study purpose. Among many meteorological factors, rainfall distribution influences foremost on the required amount of irrigation for each basin.

In 1959, Dale, W. L. divided Peninsular Malaysia into 5 rainfall regions, i.e. North-west, West, Port Dickson - Muar Coast, South-west and East regions (Ref. 16). Following that, Wycherly, P. R. (1967) modified the Dale's regional boundary and recommended 4 rainfall regions by omitting the South-west region as shown in Fig. 3 (Ref. 17).

In this study, 8 zones are recommended for the calculation of irrigation water demand for paddy taking into account not only the above rainfall regions but also the distribution of irrigation schemes (Ref. 18), location of major irrigation schemes, annual isohyet (Ref. 19), monthly distribution of rainfall, and basin boundary. Figure 3 shows the zone boundary together with location of paddy area. In case of Melaka area, the Port Dickson-Muar Coast region is incorporated into Zone P5 for simplification because paddy growing area in this rainfall region is scarcely distributed.

A rainfall station and an evaporation station (or meteorological station) being representative of major irrigation projects and/or scattered minor irrigation schemes are selected for each zone as shown in Table 10 and Fig. 3. An average monthly rainfall and monthly pan evaporation for each selected station are summarized in Table 11. The monthly rainfall for 20 years from 1960 to 1979 for each rainfall station are shown in Tables 12 to 19.

3.4 Evapotranspiration

Evapotranspiration, or consumptive use, from the paddy field varies seasonally correlating with the growing stages of paddy and meteorological factors. In general, evapotranspiration can be calculated by Eq. 4 with reasonable accuracy if data on ET/EW ratio measured in the field are available.

Several seasonal measurement records on evapotranspiration by paddy are available in Malaysia. Among them, Sugimoto's work in Muda area (Ref. 15) is the most useful for the estimation of evapotranspiration in this study because of its elaborated method. In addition, Yashima has carried out research on evapotranspiration by paddy in the Muda Irrigation Scheme (Refs. 20 and 21). They have been measured evapotranspiration (ET) and evaporation (EW) by using tanks placed inside the paddy field, and calculated the ET/EW ratio.

Figure 4 shows such ET/EW ratio correlating with time after transplanting. A smooth convex curve can be drawn on the graph as shown in the above figure. It has been recognized that ET/EW ratio is applicable to quite a wide area (Ref. 22). Hence this curve obtained in the Muda area is applied over Peninsular Malaysia. Based on the curve presented, monthly average figure is proposed for simplification of calculation of evapotranspiration. The recommended monthly figure is presented below.

Month after transplanting	ET/EW ratio
1	1.1
2	1.4
3	1.4
4	1.1

The monthly open water evaporation at 105 stations is available in the Water Resources Publication No. 5 (Ref. 23) aiming to prepare the annual isoline map covering the whole of Peninsular Malaysia. In preparing the monthly figures in Ref. 32, three different calculation procedures, i.e. (1) 120 cm pan evaporation, (2) Penmans Method and (3) Hargreaves Method were employed. The 120 cm pan evaporation was converted into open water evaporation by multiplying the assumed ratio of 0.9. Difference in open water evaporation obtained by the above three procedures was small.

On the other hand, Yashima (Ref. 20) has observed the tank evaporation in the paddy (EW) and the 120 cm pan evaporation (EP), and obtained the EW/EP ratio varying from 0.89 to 1.0, which is close to the abovementioned ratio of 0.9. In this study, the open water evaporation in Ref. 32 is assumed to be applicable as EW to the calculation of evapotranspiration.

Based on the proposed procedure of calculation and assumption, evapotranspiration for each major project and for minor schemes in each zone is calculated as shown in Tables 20 to 28. Results of calculation are summarized in Table 29 making a comparison with the figures presented in previous reports.

3.5 Presaturation Requirement

In general, presaturation of paddy fields can be defined as the supply of water, either by irrigation or rainfall, to a group of farms so as to wet the ground to saturation and to provide a water layer to facilitate ploughing and the preparation of nursery beds (Ref. 15).

In Malaysia, nursery beds are generally located on the corner of each paddy plot and therefore irrigation water must be supplied covering the whole of the paddy plot in order to supply water to nursery beds. After presaturation, replenishment against evaporation and percolation losses is needed. The amount of water needed for replenishment up to transplanting is considered as presaturation requirement in the present study.

Presaturation requirement during the staggering period in the cropping schedule is calculated by the following formula (Ref. 15) which was developed specially for field-to-field irrigation in Malaysia taking into account the evaporation and percolation losses during the presaturation period.

$$q = (L - Eu)/(1 - e^{-m}) + Eu \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

where,
- q : Presaturation requirement (cm/d)
- L : Total loss from the saturated surface (cm/d)
- Eu: Evaporation loss from the unsaturated soil surface (cm/d)
- e : 2.718
- m : T (L - Eu) / F
- T : Presaturation period (staggering period in days)
- F : Total depth of water in the field (m)

Assuming that Eu and F in the above equation are to be 0.4 cm/d and 15 cm respectively, presentation requirement during staggering period for each cropping schedule are calculated. In addition, requirement for replenishment against losses up to transplanting are also calculated. Total presaturation requirement comprising the above two for each cropping schedule are shown in Tables 20 to 28. Result of calculation ranges from 311 to 353 mm for main season paddy and from 319 to 388 mm for off season paddy.

3.6 Percolation Rate

Information on percolation rate measured on paddy field are scarce in Peninsular Malaysia. The percolation rate measured in the Muda Irrigation Scheme was below 1 mm/d and the Feasibility Study prepared by MADA employed a figure of 1 mm/d as the expected percolation loss. In general, after puddling works, percolation rate becomes below 1 - 2 mm/d in clay soils or on condition that groundwater table is very high.

For the present study, percolation rate is generally assumed to be the same rate as used in the previous reports (see Tables 7 and 8). The average percolation rate used in the previous reports is 2 mm/d for major projects. On the other hand, minor schemes are mostly scattered in relatively elevated areas and their soils are generally more permeable than major project areas. In this study, the following percolation rates are assumed in case that percolation rate is not available in the previous reports.

Major irrigation project = 2 mm/d
Minor irrigation project = 3 mm/d

In case of the North Kelantan Project, percolation rate is assumed to be 2.0 mm/d instead of previous rate of 0.8 mm/d in order to set similar basis with other major projects taking its soil condition, topography and drainability into account.

Percolation rate for each project used in the present study is listed as follows:

Muda Irrigation Project	1.0 mm/d
Krian and Tanjong Karang Projects	1.8 mm/d
North Kelantan, Kemubu, Rompin-Endau and Sawah Endau Projects	2.0 mm/d
Kemasin-Semerak and Besut Projects	2.5 mm/d
Minor Schemes	3.0 mm/d
Sungai Manik Projects	3.3 mm/d

3.7 Effective Rainfall

Since there is no standardized method for the calculation of effective rainfall in Malaysia, comparative studies are first carried out. Effective rainfall for two representative irrigation project, i.e. the Muda Irrigation Project (Kepala Batas Rainfall Station) and the Kemubu Project (Kota Bharu Rainfall Station), was calculated for 20 years from 1960 to 1979 by using the daily balance method with the following assumptions.

(1) Maximum storage depth in the paddy field is 15 cm.

(2) During irrigation period, water layer on the ground is maintained to be 10 cm, hence a net storage space of 5 cm is available.

(3) Rainfall less than 5 mm/d is ineffective.

(4) Rainfall over the maximum storage depth is ineffective.

(5) Daily decreasing depth by evapotranspiration and percolation is assumed as follows:

	Main Season	Off Season
Muda Irrigation Project	6 mm/d	8 mm/d
Kemubu Irrigation Project	8 mm/d	9 mm/d

Results of calculation are summed up into monthly figures and plotted on the graphs against actual monthly rainfall as shown in Figs. 5 and 6. Both figures show that effectiveness of monthly rainfall is higher than 60% in most cases when actual monthly rainfall is less than 200 mm. However, effectiveness tends to decrease gradually with the increase in monthly rainfall over 200 mm.

In calculating effective rainfall by the daily balance method, it is assumed that ideal water control is to be conducted throughout the paddy cultivation. Any rainfall cannot be considered as effective if the amount of irrigation supply is not reduced after rainfall. Actual effective rainfall should, therefore, be less than the amount calculated by the above daily balance method. Taking practical conditions into account, recommendable effectiveness line of monthly rainfall is indicated in Figs. 5 and 6 by the inclined solid line.

In other words, the following calculation basis is recommended in the present study.

Actual monthly rainfall (R)	Effective rainfall (RE)
$R \leqq 200$ mm/month	$RE = 0.6 \times R$
$R > 200$ mm/month	$RE = (R - 200) \times 0.3 + 120$

Effective rainfall for each study area is estimated based on the above equation and is shown in Tables 30 to 37.

3.8 Irrigation Efficiency

Overall irrigation efficiency, or project efficiency, employed in the previous reports is 70% for the Krian Project, 60% for the Sungai Manik, the Tanjong Karang and the Rompin-Endau Projects, 64% for the Kemasin-Semerak Project and 52% for the North Kelantan Project as shown in Tables 7 and 8. Conveyance efficiency of 80% is employed in the previous study for the Muda Irrigation Project. In the case of the North Kelantan Project, irrigation water requirement for presaturation and normal irrigation periods were calculated separately applying different efficiency, i.e. 65% for presaturation period and 45% for normal irrigation. In the previous reports, there is scarce technical discussion on irrigation efficiency.

Field measurement data on irrigation efficiency are scarce in Malaysia. Since most irrigation schemes, except for pumping scheme have insufficient discharge measuring devices, the estimation of irrigation efficiency is not an easy task. In the Kemubu Irrigation Project, the largest pumping scheme in Malaysia, conveyance efficiency of its canal system was measured at 85% and the overall irrigation efficiency was estimated at 30 - 40% (Ref. 4). This low efficiency is mainly due to heavy operational losses under field-to-field flooding conditions.

The irrigation efficiency employed in the previous reports is difficult to achieve under the present water management technology by farmers. In view of the small size of holdings in Malaysia, even with increase in canal density (30 - 35 m/ha) by the tertiary development program, certain amount of irrigation water should be allowed as distribution loss.

After discussing this matter with DID officers and based on our judgement, the overall irrigation efficiency expected to be achieved is determined as follows, taking 5% deduction into account from the previous figure.

	1980	1990 & 2000
Irrigation schemes with storage reservoir (Muda and Krian Irrigation Project)	60%	65%
Other schemes	50%	55%

3.9 Result of Calculation

3.9.1 Crop water requirement

Based on the cropping pattern presented in Fig. 7, and calculation methodology aforementioned, crop water requirements are first calculated as shown in Tables 20 to 28. Calculated results for major schemes are tabulated in Table 29 making a comparison with figures in the previous reports.

3.9.2 Irrigation water demand

Irrigation water demand for the years 1980, 1990 and 2000 is calculated by basin on monthly basis applying monthly effective rainfall estimated for 20 years from 1960 to 1979 and projected irrigation areas as shown in Table 38. Results of calculation in a form of volume (10^6 m^3) are shown in Tables 39 to 85 for the year 1990 and in Tables 86 to 107 for the year 2000. The annual average of the estimated irrigation water demand by basin is summarized in Table 108.

The annual average irrigation water demand for the whole of Peninsular Malaysia is 7.0 x 10^9 m^3/y in 1980, 8.3 x 10^9 m^3/y in 1990, and 9.3 x 10^9 m^3/y in 2000.

4. NET IRRIGATION WATER WITHDRAWAL

4.1 Return Flow

Irrigation water demand comprises many kinds of irrigation losses which are unavoidable in process of conveyance and distribution of irrigation water to paddy fields. A certain percentage of irrigation losses such as conveyance, application, percolation and operational losses is considered to return to the river through drainage networks or underground permeable layer. Such return flow has never been measured in Malaysia and there is no evaluation basis for it.

For the basin-wide water demand and supply balance study, the amount of return flow should be considered as an usable water source. Since there is no evaluation basis for the return flow in Malaysia, it is assumed that 20% of diverted water for irrigation schemes locating upstream of the water balance study point (see Sectoral Report of Water Resource Engineering) may return to the river with little time lag, which is the same basis generally used in Japan based on long-term experience in water balance study.

4.2 Net Irrigation Water Withdrawal

In the present study, the net irrigation water withdrawal by irrigation schemes locating upstream of the water balance study point can be expressed as:

$$NIWW = IWD - RF = 0.8 \times IWD$$

where, NIWW: Net irrigation water withdrawal
IWD : Irrigation water demand
RF : Return flow (= 20% of IWD)

Irrigation areas of all major irrigation schemes except for the Trans Pahang Project are located downstream of the water balance study point and no return flow to the river is considered for these schemes. In case of minor irrigation schemes, ratio of irrigation areas locating upstream of the water balance study point to the total minor irrigation areas is first calculated for each basin. Then the ratio of net irrigation water withdrawal to the irrigation water demand is calculated as shown in Table 109.

The net irrigation water withdrawal is calculated by the irrigation water demand (Table 108) and the above ratio (Table 109). Results are shown in Table 110. The annual average net irrigation water withdrawal for the whole of Peninsular Malaysia is 6.6×10^9 m^3/y in 1980, 7.7×10^9 m^3/y in 1990, and 8.5×10^9 m^3/y in 2000.

5. PLANNING MATERIALS

Planning materials such as investment cost, O&M cost and manpower requirement necessary for irrigation development are prepared in this Chapter. Results of estimation of each item are used for succeeding project evaluation to be presented in the Main and State Reports of the Study.

5.1 Investment Cost

5.1.1 Unit construction cost

Construction cost for irrigation development varies widely depending on the location and topography of the project area, component of development, type of irrigation system and so on. In this study, standardized unit construction costs are assumed for projection of future development cost based on the previous studies.

Construction cost is estimated in the four categories, i.e. (1) direct construction cost, (2) engineering service & administration, (3) land acquisition, and (4) physical contingency. Engineering service and administration costs are assumed to be 10% of the direct cost. Physical contingency is assumed to be 30% of the total of the above (1) to (3).

In order to update (as of end 1980) the project cost estimate presented in the previous study reports, the following rates of the past price escalation are assumed as mentioned in the Sectoral Report Vol. 17.

Foreign currency portion:		8% per annum
Local currency portion :	1976 to 1978	0%
	1979 and 1980	27% per annum

Unit direct construction cost by type of development as of end 1980 is first estimated based on the previous study reports. Updated direct construction costs for major and minor irrigation projects are summarized in Tables 111 and 112. Average cost of the Muda II, Tanjong Karang and Krian/Sg. Manik Projects is assumed to be the standard cost for tertiary development. Average cost of the Lower Trengganu and Kemasin Semerak Projects is assumed to be the standard cost for development from rainfed paddy to double cropping paddy. For the assumption of the standard cost for irrigation development from virgin land, the updated cost of the Rompin-Endau Project is used. In addition, the average cost of minor irrigation project shown in Table 112 is assumed to be the average cost for development from single cropping paddy to double cropping paddy.

Land acquisition cost per unit project area is estimated by multiplying the unit land acquisition cost by the ratio of acquired area to the total project area. The ratio is estimated to be 2.4% based on the previous study reports as shown in Table 113.

The unit construction cost by type of irrigation development are estimated as shown in Table 114 and summarized below.

Type of Development	Unit Const. Cost (M$/ha)
Rainfed to double cropping paddy	14,800
Single cropping to double cropping paddy	8,000
Virgin land to double cropping paddy	16,000
Tertiary development	7,100

5.1.2 Investment cost

Estimation of investment cost for irrigation development is carried out based on the assumed type and area of irrigation development and the unit construction cost mentioned above.

Type of irrigation development is assumed as shown in Table 115. Based on information obtained from DID and our estimation, the development area of irrigation schemes by type by Malaysia Plan is projected as shown in Table 116 for major schemes and in Tables 117 to 120 for minor schemes.

Results of calculation of investment cost are summarized in Table 121 for major schemes and Tables 122 to 125 for minor schemes. Total investment costs up to the year 2000 amount to about M$3.4 x 10^9.

5.2 O&M Cost

O&M cost necessary for irrigation projects varies widely depending on the type of scheme. Actual O&M cost of minor irrigation schemes by type of scheme is shown in Table 126. Average O&M cost in 1979 varies from M$121/ha for pumping irrigation scheme to M$24/ha for inundation scheme. The expected development in future will be gravity or pumping irrigation types. In case that the type of irrigation scheme which is developed in future is known, the updated O&M cost shown in Table 126 is assumed and used for economic evaluation of irrigation development.

In case that the type of future irrigation scheme is not known, the standard ratio of O&M cost to the total construction cost is used. Table 127 shows the representative samples of the ratio calculated based on the previous reports. In this study, the annual O&M cost is assumed to be 1.5% of the total construction cost.

5.3 Manpower Requirement

For estimating the manpower requirement up to the year 2000, available information was first collected from DID. Based on the classification of manpower shown in Table 128, existing manpower in Federal DID and number of posts in State DIDs and Authorities are counted as shown in Tables 129 and 130. Existing manpower seems to be not enough to operate and manage irrigation projects well. For better O&M for irrigation project, increase in number of manpower is necessary.

After discussing this matter with DID officials and based on our estimation, calculation standard for manpower requirement for irrigation development was assumed as shown in Table 131. Result of estimation of manpower requirement by Malaysia Plan in Peninsular Malaysia is summarized in Table 132.

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