FIGURES

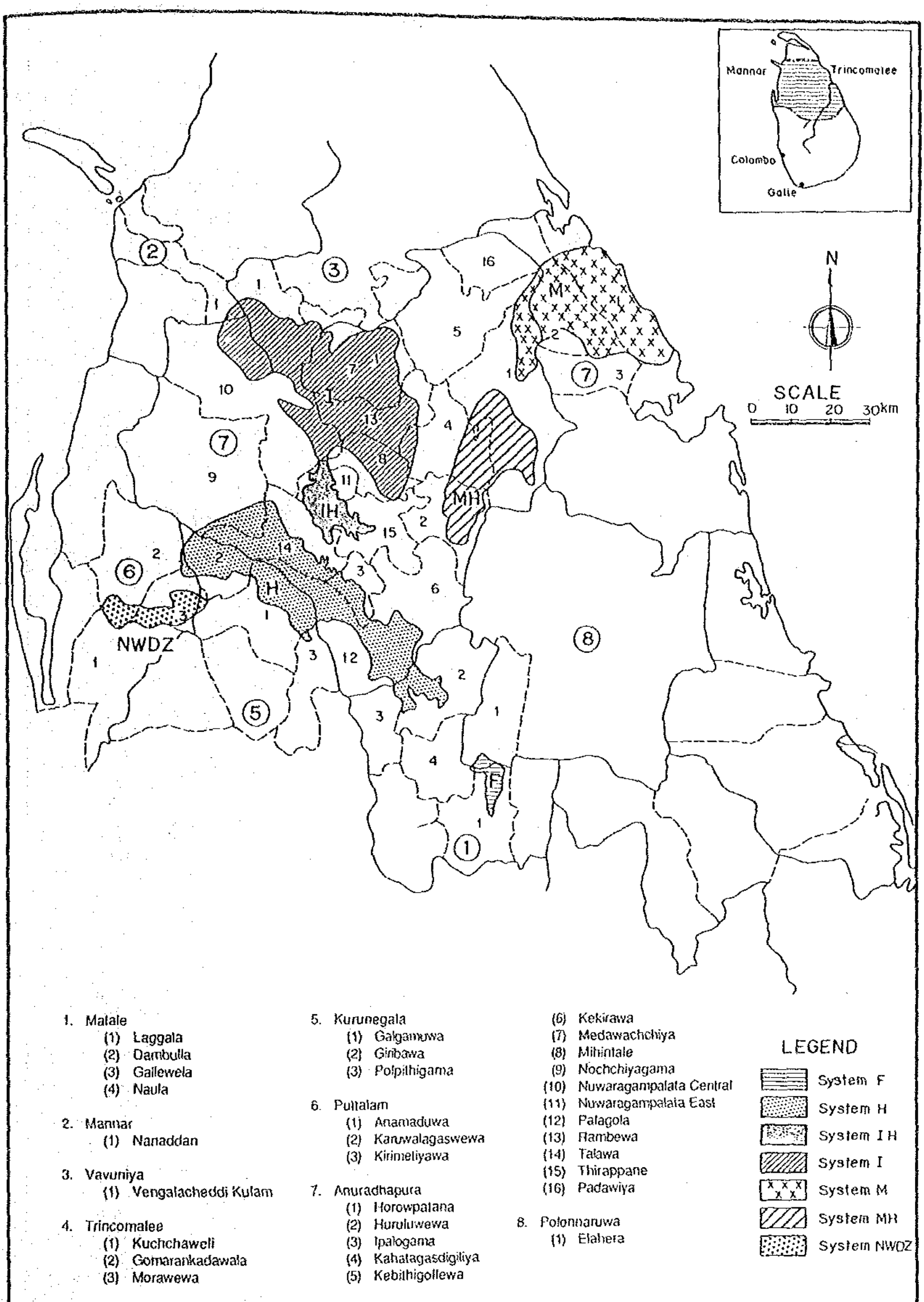

Fig. E.1-1 Administrative Division in Study Area: 1981

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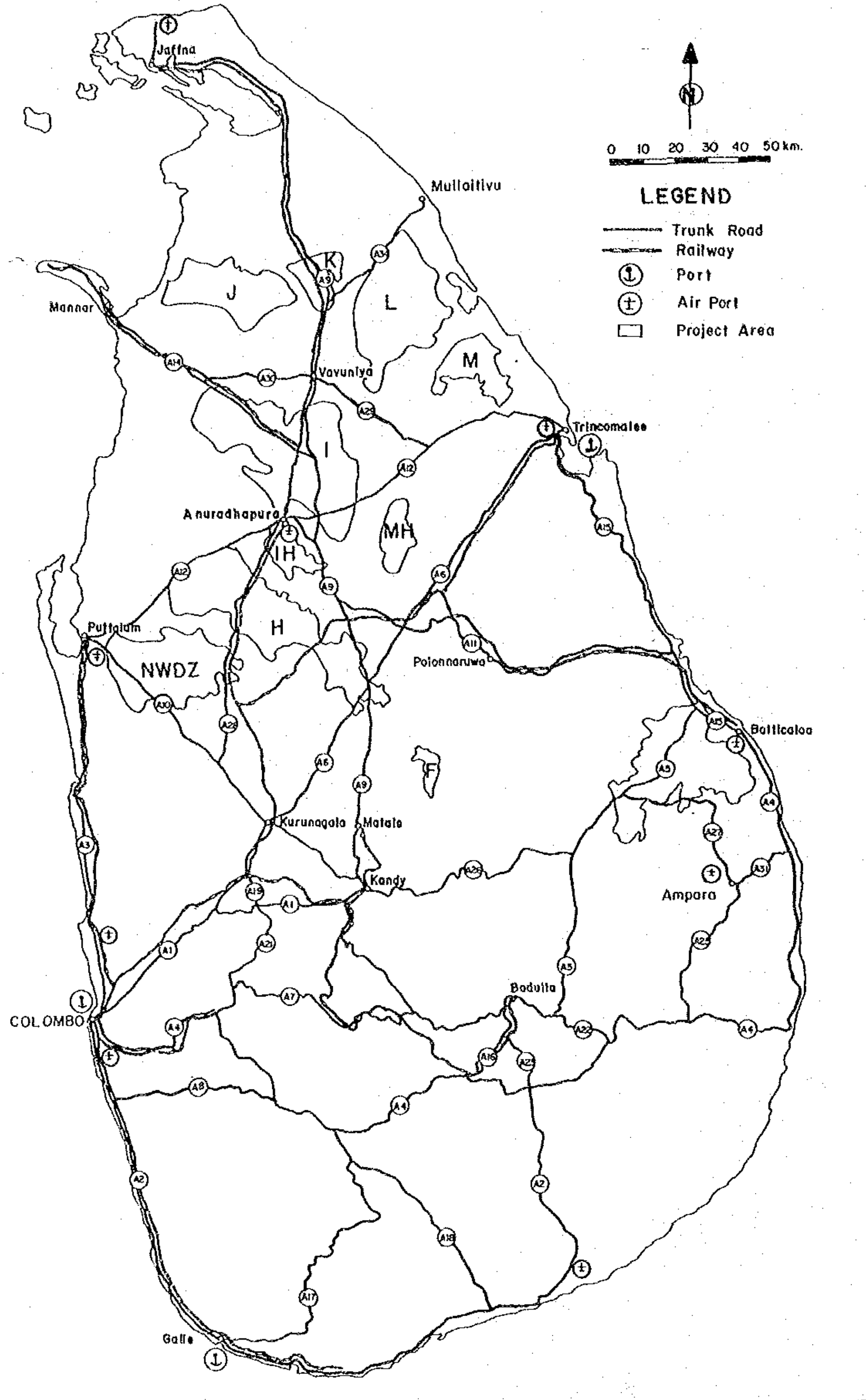

Fig. E.1-2 Transportation Network

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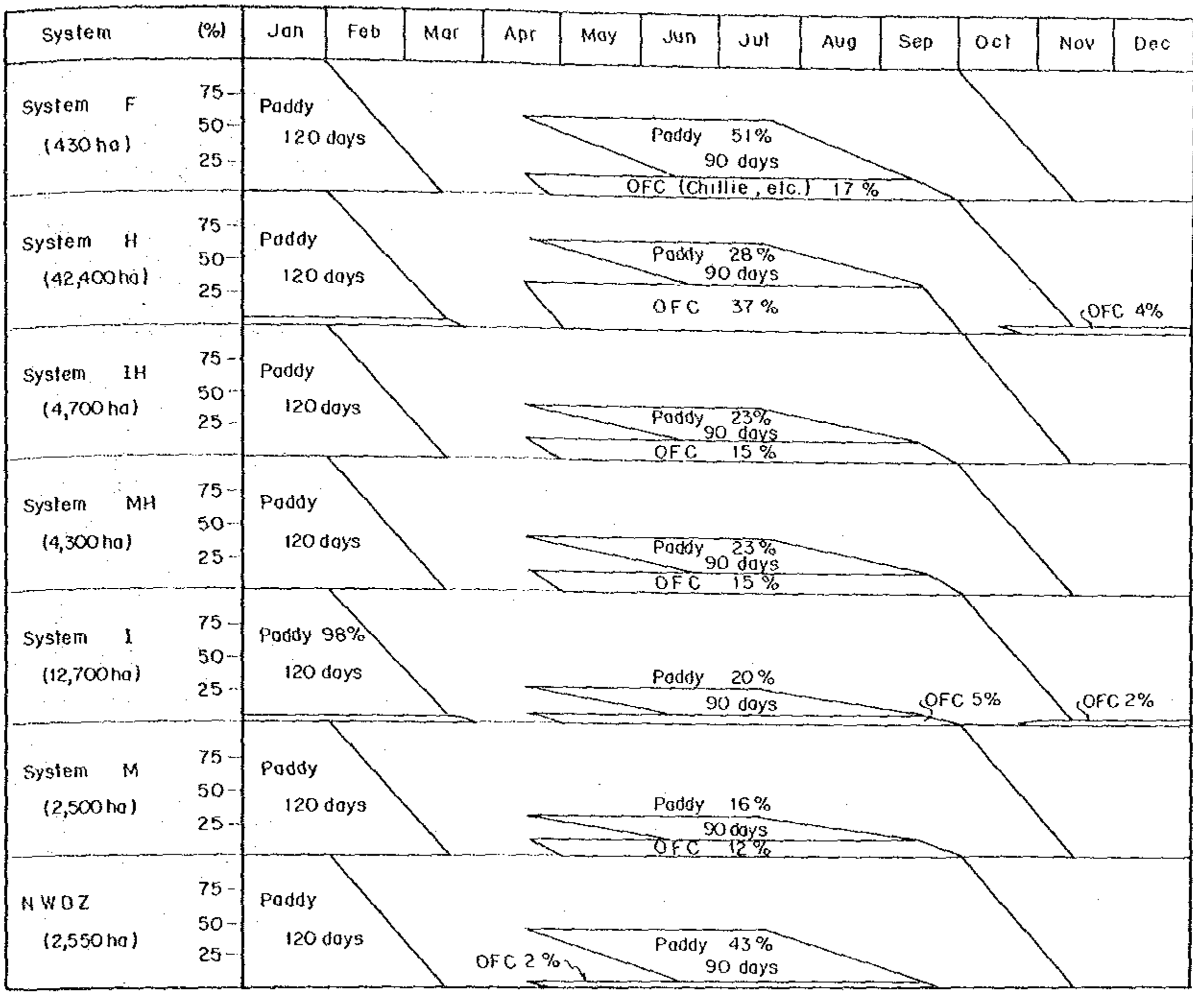
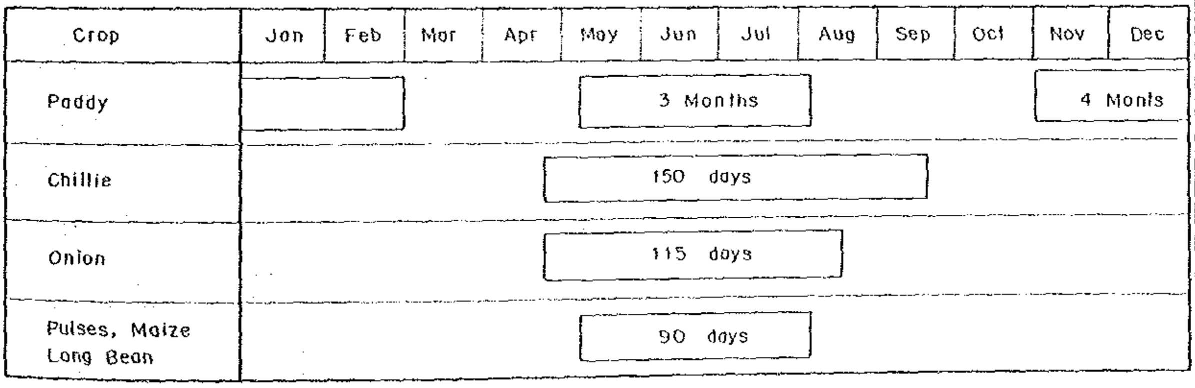


Fig. E.3-1 Present Cropping Pattern in Irrigated Field



Remark OFC = Other Field Crop

Fig. E.4-1 Future Cropping Calendar for Irrigated Crops

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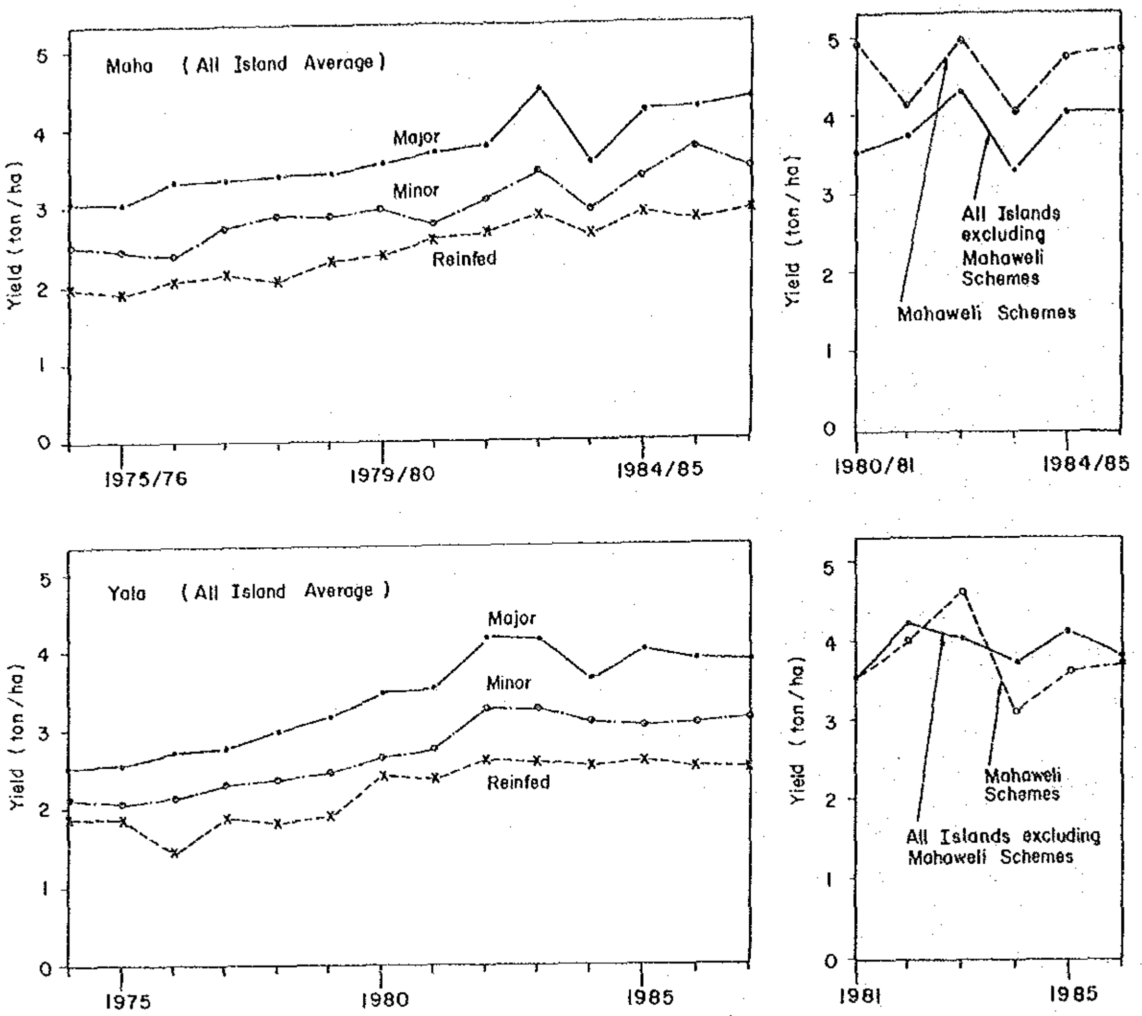

Fig. E.4-2 Trend of Average Paddy Yield by Scheme in Sri Lanka : 1974-1987

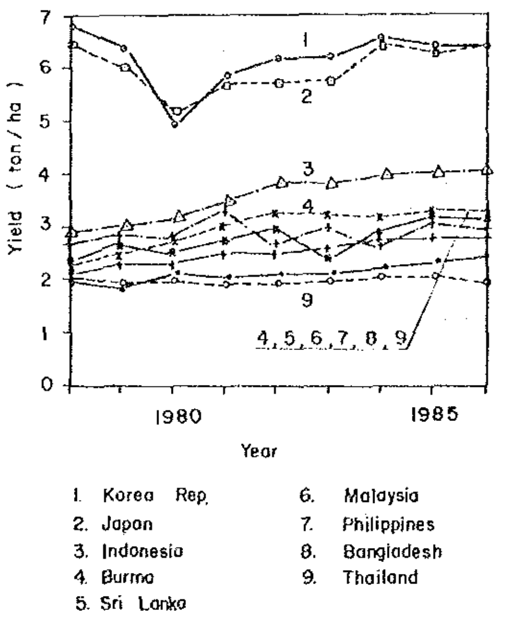

Fig. E-4-3 Trend of Paddy Yield in Selected Asian Countries : 1978-1986

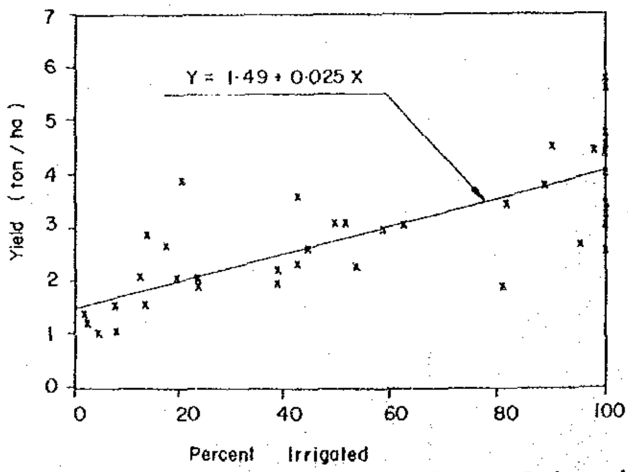

Fig. E.4-4 Paddy Yield and Percent Irrigated by Selected Countries : 1981

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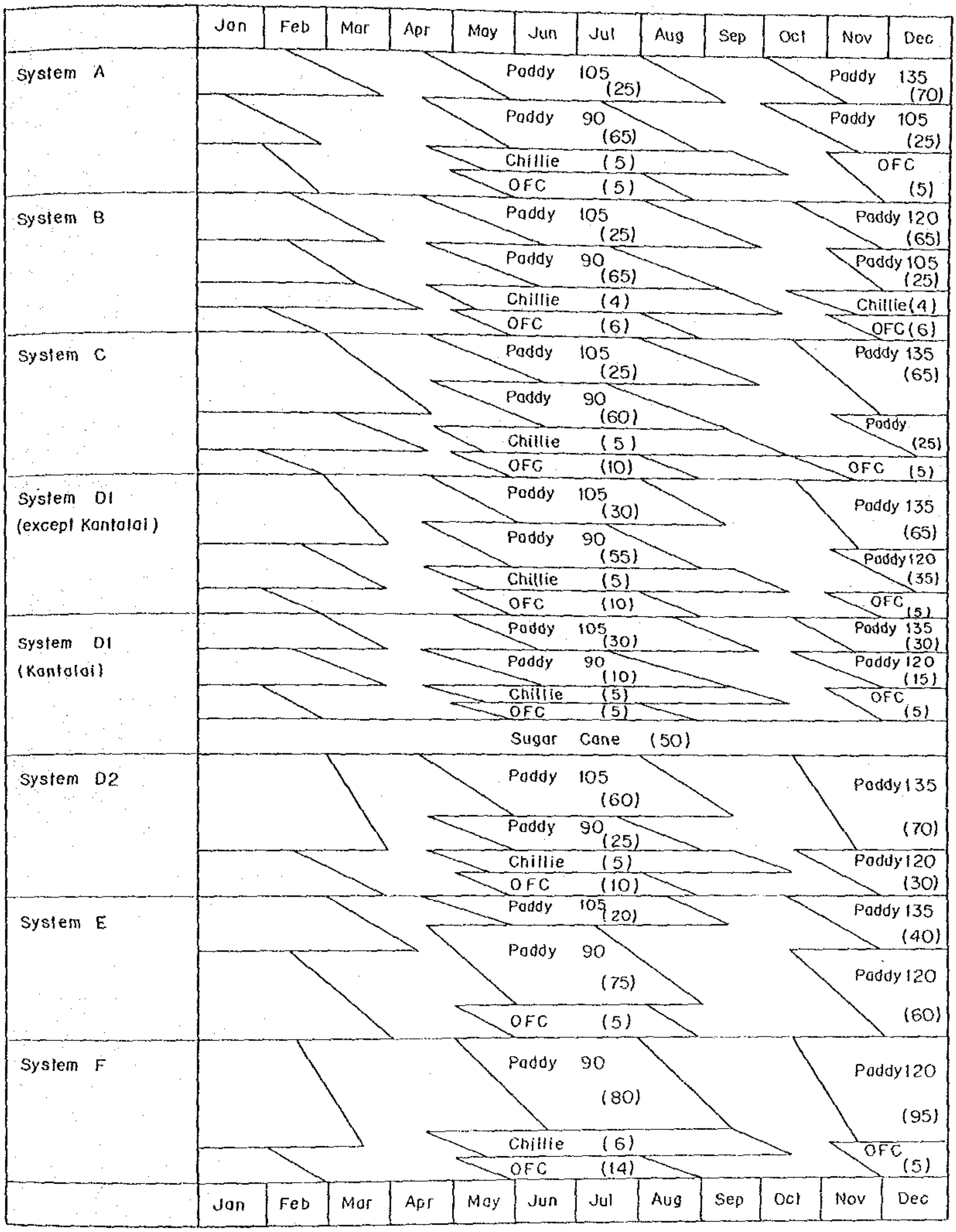

Remarks : OFC = Other Field Crops
Crop intensity (%) shown in brackets

Fig. E.4-5 Proposed Cropping Pattern (1/3)

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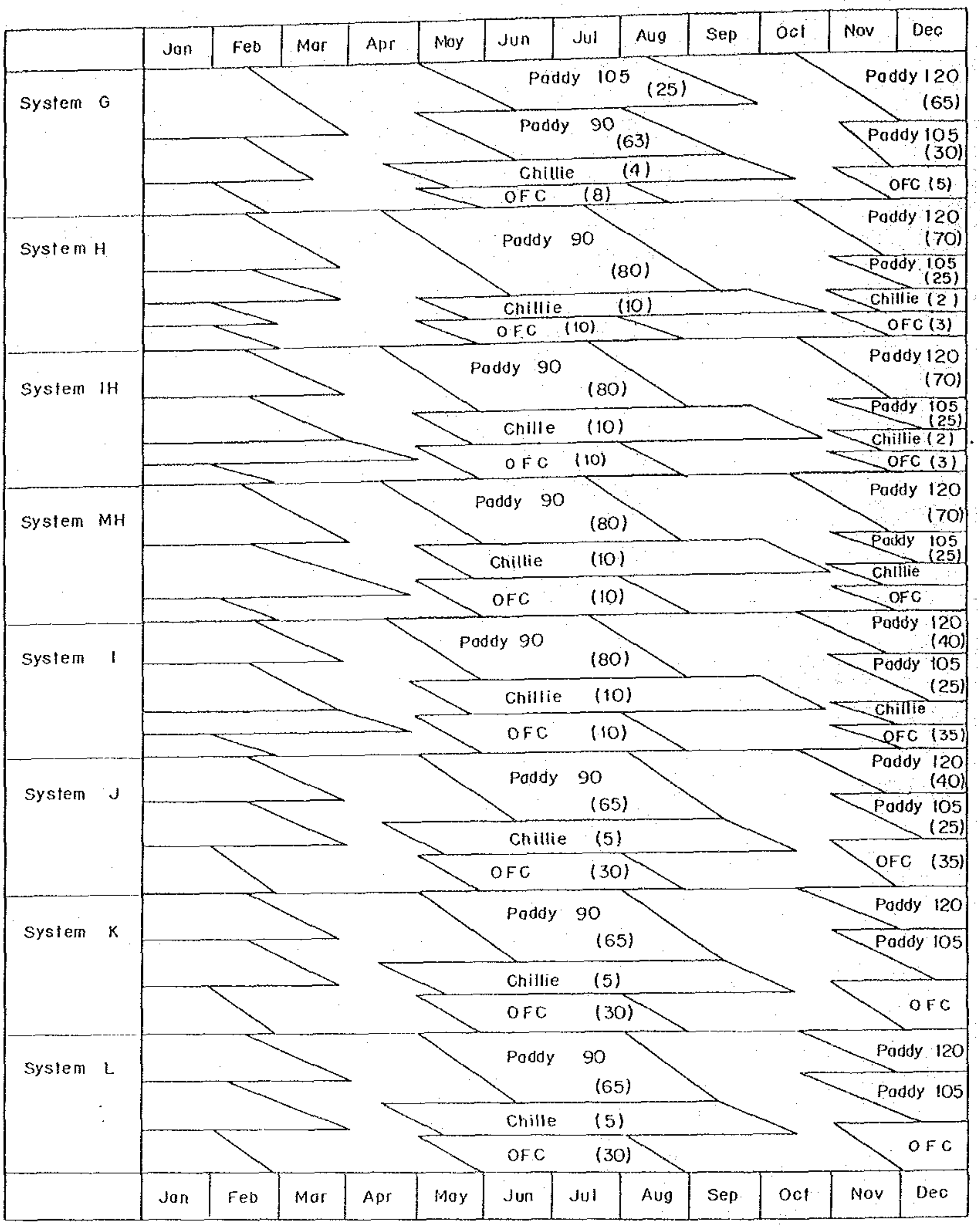

Remarks : OFC = Other Field Crops
Crop intensity (%) shown in brackets

Fig. E.4-5 Proposed Cropping Pattern (2/3)

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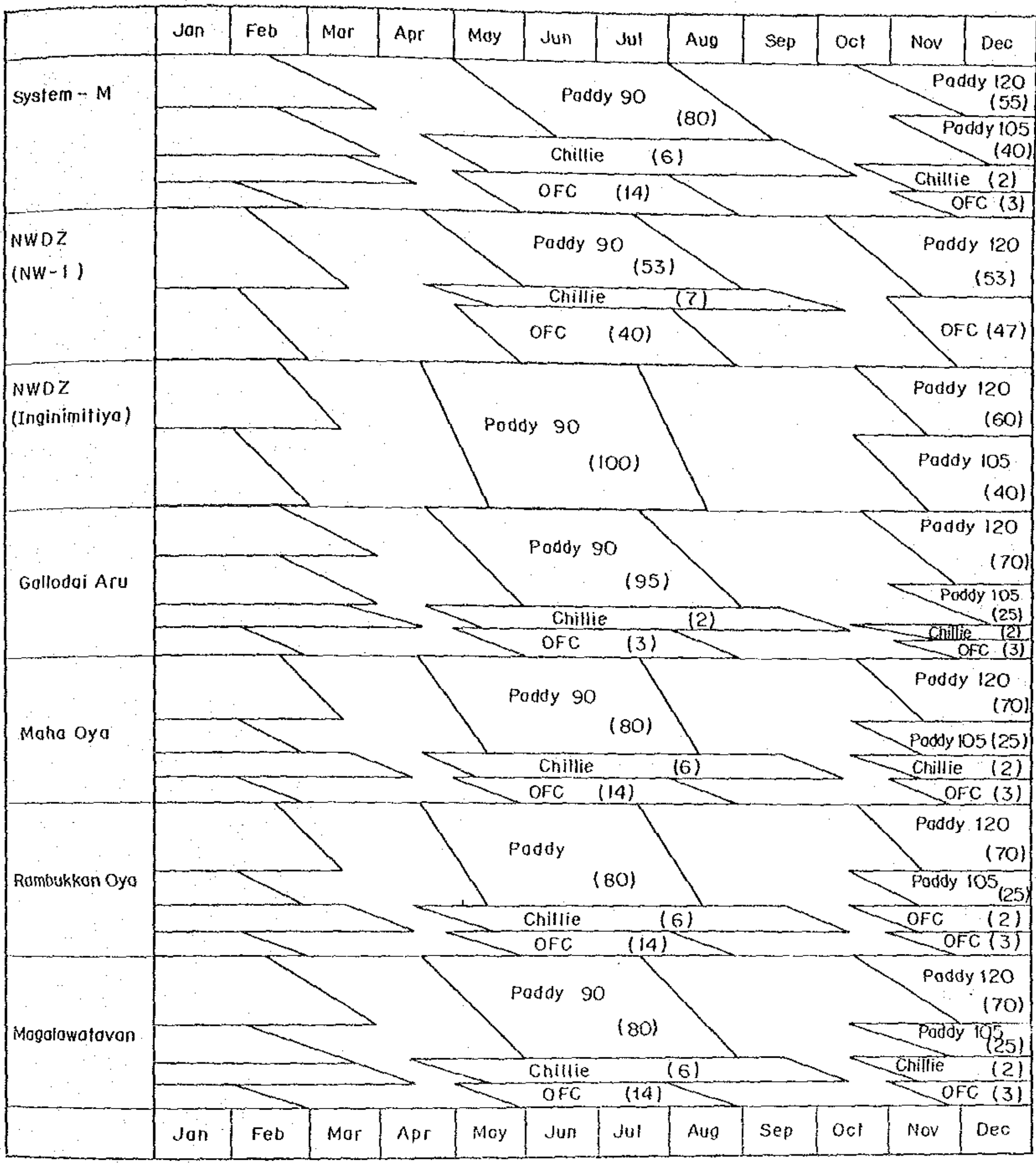

Remarks : OFC = Other Field Crops
Crop intensity (%) shown in brackets

Fig. E.4-5 Proposed Cropping Pattern (3/3)

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ANNEX-F

IRRIGATION

ANNEX - F

IRRIGATION

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ANNEX-F IRRIGATION

F.1 INTRODUCTION

This ANNEX presents the results of the studies on the irrigation development, irrigation water demand and preliminary cost estimate of the irrigation facilities.

The specific irrigation development plan and the development priorities will be determined based on the water balance study simulated for the most effective use of available water in the Mahaweli Ganga, Amban Ganga and the other river basins, as well as the economic evaluation. The irrigation water demand for the existing, on-going, and candidate schemes of future development originally considered in the previous studies was estimated to derive the material for the water balance studies.

New irrigation development areas particularly in the North Central River Basin (NCRB) and North West Dry Zone (NWDZ) were planned as the gravity irrigation system with the proposed tanks as much as possible, of which the details are presented in ANNEX-H. The preliminary delineation of the new project area was mainly based on topo-maps with a scale of 1/31,680 referring to the layout planned in the previous studies.

The cost of the irrigation facilities was estimated on the basis of the preliminary design of the main and branch canals, and the downstream development costs referring to the actual construction quantities of on-going projects executed under the Accelerated Mahaweli Development Programme (AMDP). The results of this ANNEX, the cost estimate of conveyance systems in ANNEX-J and the estimate of the agricultural benefit in ANNEX-E were incorporated in the project evaluation in ANNEX-L.

F.2 CLASSIFICATION OF IRRIGATION PROJECT

F.2.1 General

In the whole country, the total wet paddy area was 499,000 ha comprising 350,000 ha of irrigated paddy area and 149,000 ha of rainfed area as of 1987 according to Paddy Statistics 1987/88 MAHA. The Mahaweli project has been making a steadily increasing contribution to the irrigation development in the country culminating about 130,000 ha of irrigated area in the year 1987 as shown in Table F.2.1.

In the Mahaweli river basin including the Amban Ganga and the other river basins within the study area, there are many existing, on-going and committed schemes, and potential development areas. These irrigation areas can be classified into following three categories; i.e.(1) existing and on-going irrigation systems or schemes under the Accelerated Mahaweli Development Programme (AMDP), (2) future development irrigation system in the NCRB originally planned by UNDP/FAO and (3) expansion area in NWDZ. The location of each irrigation system is illustrated in Figs. F.2-1 to F.2-5 and principal features of major existing tanks are shown in Tables F.2.2 and F.2.3.

In the study area, all existing project except the area newly constructed under the AMDP are operated and maintained by the Irrigation Department (ID).

F.2.2 Existing and On-going Irrigation Project

As shown in Table F.2.1, about 130,000 ha of the agricultural land in total are currently irrigated with the water of the Mahaweli Ganga, the Amban Ganga and local catchment. A part of these irrigation systems located in the Amban Ganga basin is the first irrigation area which was realized by construction of the Polgolla and Bowatenna diversion tunnels as a water resource development in the Mahaweli Ganga. The Polgolla diversion provides the Mahaweli water to Systems H, IH and MH via the Bowatenna irrigation tunnel, and to Systems D1, D2 and G which are served by diversions at Elahera and Angamedilla anicuts with ancient origins.

In the Mahaweli Ganga basin itself, irrigation water is supplied to System E through the Minipe left bank canal and the existing Allai scheme in System A located in the lowest Mahaweli river basin. In addition, some areas of Systems B and C are irrigated by the diverted water through the Minipe Right Bank Transbasin canal. In these areas, construction activities for the development are concentrated at present. After completion of on-going and committed schemes under AMDP, about 200,300 ha will be irrigated by the Mahaweli water as shown in Table F.2.1. The principal features of these irrigation systems are also shown in Table F.2.1 and the present condition of these systems are described hereinafter.

F.2.2.1 Systems H, IH and MH

Systems H, IH and MH receive the Mahaweli water through the Polgolla and Bowatenna diversion tunnels as shown in Fig. 2-3.

System H is located in the Kalawewa basin. Major part of the project area lies in the Anuradhapura district and remaining part within the Matale and Kurunegala districts. This system consists of four major existing tank schemes i.e. Dambulu Oya, Kalawewa, Kandalama and Rajangana tanks. The net irrigation area is 42,400 ha in total including about 24,600 ha of new land developed under AMDP.

System IH is located in an upper part of the Malwatu Oya basin and lies in the Anuradhapura district. This system covering 4,700 ha is irrigated by the Nachchaduwa, Nuwarawewa, Tissawewa, Basawakkulam and other minor tanks which receive Mahaweli water through the existing Kalawewa right bank main canal. System MH of 4,300 ha is located in an upper part of the Huruluwewa basin, lies in the Anuradhapura district and is irrigated by the Huruluwewa tank.

Substantial parts of these systems are irrigated with the Mahaweli water mainly in Maha season. However due to the shortage of diverted water in Yala season, the cropping intensity was estimated at 1.35, ranging widely from 1.10 to 1.65 (1984-1987).

F.2.2.2 Systems B, C and E

The Mahaweli water at Minipe is diverted to irrigate about 6,100 ha of existing paddy area of System E through the 31 km long Minipe LB canal, and to the Ulhitiya/Ratkinda reservoir and the Maduru Oya reservoir completed in 1984 and in 1983 respectively through the Minipe RB transbasin canal to irrigate about 59,000 ha of new paddy land in Systems B and C.

System B, which is consist of Maduru Oya/Pimburattewewa under AMDP and existing Vakaneri scheme located in the Maduru Oya basin, lies partly in the Polonnaruwa district and partly in the Batticaloa district. In System B, 28,000 ha of 42,000 ha are on the left bank of the Maduru Oya and the remaining area is on the right bank. Water issues to System B are from the Maduru Oya reservoir augmented by the Mahaweli water diverted at Minipe, and delivered through the Minipe RB transbasin canal and the Ratkinda - Maduru Oya link tunnel, taking off from the Ratkinda reservoir. The left bank area of about 28,000 ha made up of six zones, is fed through a concrete-lined main canal of about 53 km long, together with concrete-lined branch canals of a total length of about 85 km. The Maduru Oya right bank project would enable the development of about 14,000 ha for irrigated agriculture. The right bank main canal has already been constructed partially.

System C extends north of the Minipe anicut along the right bank of the Mahaweli Ganga, which forms the western boundary, while the Minipe RB transbasin canal, Ulhitiya-Ratkinda reservoirs and Pimburattewa tank forms the eastern boundary. The Maduru Oya branch canal and drainage line to Hungamala Ela together with Kalingayoda Ela form the undulating northern boundary. System C falls within the administrative districts of Badulla in the south, Ampara in the east and Polonnaruwa in the north. System C covers a gross extent of 66,100 ha, of which 24,500 ha in net is to be brought under gravity irrigation. The area is divided into six zones for the purpose of management and administration. Zone 1, the most southern area of the system constitutes the old Mahiyangana colonization scheme. It consists of about 1,800 ha of developed land irrigated mainly by the existing Sorabora, Mapakada, Dambarawa and other smaller tanks scattered in the region. Zone 1 is excluded from System C project management area and it is administered by the government agent, Badulla. However, these area with existing tank are incorporated into System C and receive supplemental water supply from the Minipe RB transbasin canal

At present, construction activities for downstream development is in progress in Zones 5 to 6 and scheduled to be completed in 1990. The total irrigation area of System C excluding Zone 1 is committed as 22,700 ha.

F.2.2.3 Systems D1, D2 and G

Systems D1, D2 and G are located in the Amban Ganga basin and lie in the administrative districts of Polonnaruwa and Trincomalee. Systems D1 and D2 are operated and maintained by the ID, and System G by the MEA.

There are two existing intake weirs at Elahera and Angamedilla on the Amban Ganga. Intake water at the Elahera anicut is supplied to the existing fields of 31,400 ha in Systems G and D1 through the Elahera-Minneriya canal. The canal links four major existing tanks; Minneriya, Giritale, Kaudulla and Kantalai. Water diverted at the Angamedilla anicut is once impounded at the Parakrama Samudra tank and regulated water is distributed to the existing field of 10,100 ha in System D2. These anicuts, canals and tanks have ancient origins.

In 1978 to 1979, GOSL carried out a feasibility study on the Moragahakanda Agricultural Development Project covering the irrigation development in these systems under a technical assistance of JICA within the frame work of the AMDP. According to this feasibility report, total irrigation area for Systems D1, D2 and G is summarized as in total, 44,100 ha of 117,900 ha of land in the project area have been used as existing field, 4,200 ha for expansion area of the Sugar Corporation and 13,900 ha are proposed as new irrigation areas. New irrigation areas in Systems D1, D2 and A/D the service area in system D1 commanded by the proposed tank and anicut are estimated to be 9,100 ha, 2,200 ha and 2,600 ha, respectively.

Only cost/benefit of the project formulated in this feasibility study was updated by JICA in February to April 1988, because socio-economic situation in Sri Lanka was substantially changed after completion of the said feasibility study. The final report of the updated feasibility study on the extension of the Moragahakanda Agricultural Development Project (Phase-I) was prepared in May 1988.

However, since the Somawathie and Floodplain National Parks declared in 1984/85 is located within the project area in the Systems D1 and D2, the new development area is revised in the Supplementary Note for the Feasibility Study on the Moragahakanda Agricultural Development Project. According to the results of this study, total committed areas of Systems D1 (including A/D) and D2 including existing paddy land are 40,500 ha and 10,100 ha respectively. The capacity of the Moragahakanda reservoir is modified based on the present Polgolla diversion policy of 875 MCM and irrigation area of 56,000 ha in Systems G, D1 and D2. Modified irrigation area is Systems D1 and D2 was applied in this Master Plan study.

System G includes the Old Elahera Colony having 1,900 ha of existing fields. The existing paddy fields are irrigated by water directly fed from the Elahera-Minneriya canal. New land development in the area of 3,600 ha located between the Old Colony scheme and the Amban Ganga will be completed in 1988.

Provision of a new head sluice gates for the Elahera intake was completed in 1985 under the supervision of the MECA and the Irrigation Department is providing improved irrigation facilities to the existing area, making necessary modifications to the old irrigation canal network in Systems D1 and D2.

F.2.2.4 System A

System A is situated in the deltaic region on the lowest reach of the Mahaweli river, extending some 70 km from Kandakadu to the river mouth in Koddiyar Bay. It lies within the administrative districts of Trincomalee, Batticaloa and Polonnaruwa. The southern boundary of this area adjoins System B and the western boundary adjoins Mahaweli River. Most of the area is subject to annual flooding during the North-east monsoon.

A final feasibility report on this system was prepared in March 1982 by International Consultants : Joint Venture Randenigala (Saltzgitter Consult GMBH, Agrar Hydrotechnik, & Electrowatt Engineering Services) with financial assistance from the World Bank.

According to this report, System A irrigation development will require the construction of a diversion weir across the Mahaweli Ganga downstream from Manampitiya, and the construction of main and branch canals and tertiary irrigation works to serve a net irrigable area of some 20,300 ha. The new development will incorporate the existing Allai scheme, which serve a net irrigable area of 7,000 ha.

The project layout in this system is subject to the modification at the detailed design stage because of overlapping of the Somawathie National Park and Trikonamadu Nature Reserve.

F.2.2.5 Activities by Irrigation Department within the Mahaweli Project

In the Mahaweli project area, a number of systems are administrated by ID at present. All existing project except the areas newly constructed under AMDP are operated and maintained by ID. The major existing tank project in the study area are involved in Table F.2.2.

F.2.3 Present Water Management in the Mahaweli Project

Principal objectives of water management in the Mahaweli Project is to achieve optimum benefits from both irrigated agriculture and hydropower generation. In order to attain the maximum benefits, the Water Management Panel (WMP) was established as a policy making body, headed by the Director General of the MASL and comprising government agencies concerned to the management and operation of the Mahaweli Project. The water management is performed at following three levels, i.e. (1) Macro System Level, (2) Irrigation System Level and (3) On-farm Level. The concepts and activities at each of these levels have common objectives of ensuring a reliable, timely, efficient and predetermined supply of water to the farmer.

F.2.3.1 Macro Level Water Management

In order to attain optimum benefits through proper water management within the Mahaweli Project, the Water Management Panel (WMP) was established as a policy making body. The WMP has responsibility for achieving optimum benefits from both irrigation and hydropower generation in the Mahaweli programme. The WMP is also responsible for approving the overall cultivation programmes in the areas served by the Mahaweli Programme. The WMP is advised and serviced by a technically specialized Water Management Secretariat (WMS) constituted within the MASL. The WMS provides necessary information and recommendations to the WMP in making operational policy decisions.

The WMS draws up a seasonal operation plan at the end of each cultivation, incorporating potential available water in the whole system, hydropower generation, irrigation water releases from the multipurpose reservoirs, diversions at key points, tank issues and cropping patterns, etc. which are furnished by the Mahaweli water users concerned, i.e. MEA, ID and CEB. At a meeting of the WMP, the seasonal operation plan is approved after discussion and necessary adjustment.

Within the frameworks of the seasonal operation plan, weekly operation plan is decided at the weekly meeting attended by the WMS and Head Work O&M staff, and the Mahaweli water users, i.e. CEB, MEA and ID. Based on the above decision, the operation of the multipurpose reservoirs (except for power generation), the diversions at Polgolla, Bowatenna and at Minipe to Systems B and C are carried out by the Headworks Operation and Maintenance Division of the MASL. Diversions at Elahera, Angamedilla and to System E at Minipe are carried out by the ID.

F.2.3.2 Irrigation System Water Management

At the irrigation system level, the responsibility of water management is primarily taken by the organization operating the schemes, i.e. ID in the case of old schemes and the MEA in the case of new systems and such existing schemes developed under AMDP. The activities of MEA and ID are water issues from irrigation tanks, distribution through a network of canals up to the on-farm irrigation unit controlled by farmer themselves according to the seasonal irrigation schedule prepared by MEA and ID. Irrigation intakes and drainage outlets are being calibrated, and monitoring of inflows and outflows is proceeding in co-ordination with MEA.

F.2.3.3 On-farm Water Management

At on-farm level in the rotational irrigation unit, the irrigation water management is carried by farmers' unit under the guidance of the project office of MEA or ID. A farm plot managed by farmer themselves is about 1 ha per family commanded by one turn-out structure on the field canal.

The irrigation efficiency at on-farm level is still low, and the excess water of actual required water at a given stage is wasted due to inexperienced water management technique. In order to improve on-farm water management, the following irrigation and cultivation practices are carried out under the guidance of MEA and ID.

(1) Use of rational water issue programmes, to have better control over farm deliveries and reduce over-use and wastage,

(2) Ensuring that delivery schedules are met without foreseeable shortages thereby instilling confidence in the farmers of a timely and reliable supply of water, and

(3) Effecting distribution and application taking into account cropping patterns, nature of soils and effective rainfall.

F.2.4 Potential Irrigation Project

For the phase-II study (Master Plan Study) of the Extension of the Moragahakanda Agricultural Development Project, only Systems I, F and NWDZ are included in the scope of work as future development area. However, in order to formulate the most effective use of available water resource on the Mahaweli Project, all potential project area originally planned by UNDP/FAO i.e System F and Systems I, J, K, L and M located in the North Central River Basin (NCRB) were considered. Principal features of existing tank systems are shown in Table.F.2.2.

F.2.4.1 System F

System F is located within the river basin of the Kalu Ganga, a tributary of the Amban Ganga, and lies in the administrative district of Polonnaruwa and Matale. In the present condition, a part of this area is irrigated by existing anicut at the Kalu Ganga as a minor scheme.

This system is planned to be irrigated directly by the Kalu Ganga left bank canal, which has the important function of transferring water from proposed Kalu Ganga reservoir to the Elahera Anicut. This transbasin canal is studied in succeeding ANNEXES-H and K. In this study, the proposed irrigation area of 1,900 ha was delineated within the left bank of Amban Ganga due to the extent of the Wasgomuwa National Park declared in 1984 along the right bank.

The general layout of System F is shown in Fig. F.2-2 and the demarcation of the project area and the layout of the proposed Kalu Ganga - Elahera transbasin canal is presented in DRAWINGS.

F.2.4.2 North Central River Basin (NCRB)

The potential irrigable area in NCRB i.e. Systems I, J, K, L and M are originally planned by UNDP/FAO in 1968, and subsequently studied in ISS and TDS in 1979 and 1981/84 respectively. In this study, potential irrigable areas were delineated referring to the

TDS layout with certain modifications due to the overlapping of the National Parks and the modifications of locations of proposed damsite and transbasin canal route. etc.

System I is located in the Aruvi Aru river basin, the second largest river basin in Sri Lanka, and lies in the Anuradhapura and Vavuniya districts. At present, about 4,800 ha of land have been irrigated by the existing Mahakandalama, Irat periya, Pavat kulam and many minor tanks mainly in Maha season.

In this system, the new development area under the Malwatu Oya and Tammannewa reservoirs and the extension area under the existing Mahakandalama reservoir were proposed in the previous studies. Within the Malwatu Oya project, more than 10,000 ha of new land were proposed along the left and right banks of the Malwatu Oya. However, due to the extent of the Wilpattu National Park along the left bank of the Malwatu Oya, only 3,600 ha of new area on the right bank is delineated in the present study. In stead of the development of area in the left bank, the responsible water release for the existing Giant tank scheme located in the downstream of the Malwatu Oya is included in order to make sure of the cropping in Maha and Yala reasons. The irrigation water requirement for 9,900 ha of Giant tank scheme is included in the irrigation water demand at the Malwatu Oya reservoir.

In addition, the new area of 27,000 ha under the Tammannewa reservoir and the extension area of 8,000 ha of existing Mahakandalama Tank to be realized by the construction of proposed NCP transbasin canal are proposed in this study.

System M is located in the Yan Oya basin and lies in the Anuradhapura and Trincomalee districts. In this system, about 10,000 ha of new land and Yan Oya reservoir has been proposed by UNDP/FAO. In addition, about 15,000 ha of new land with the Horowupotana reservoir and the extension area of System MH which will be commanded by the existing Huruluwewa tank was studied in the TDS. Also in the present study, 15,000 ha of Horowupotana project and 12,000 ha of this extension area are involved as the potential development area. At present, the effective storage capacity of existing Huruluwewa tank and the amount of water from Bowatenna diversion are too small to cover whole extension area. However, after completion of proposed NCP canal, it is considered this area will be prior to be developed as compared with the other Systems in NCP area on account of the shortest route of the proposed transbasin canal.

System J, K and L are located in the northern portion of the Mahaweli development area defined in the UNDP/FAO study. System J is located in the basin of the Parangi Aru and Pali Aru and lies in the Mullaitive, Vavuniya and Mannar districts. System K is located in the Kanagarayan Aru basin and lies in the Vavuniya and Mullaitive districts. System J is located in the Ma Oya basin and lies in the Mullaitive, Vavuniya and Anuradhapura districts.

In these systems, the new development area of 10,000 ha with Parangi Aru Tank, 9,000 ha with Pali Aru Tank in System J, 13,000 ha with Mukunuwewa Tank and 16,000 ha with Kitulgala Tank are included in the present study as the potential irrigable area for the water balance simulation presented in ANNEX-I. Due to the limited water diverted through the proposed NCP canal as concluded in ANNEX-I, a part of the NCRB area is proposed as irrigation area in this study.

The potential arable area and new development area in the NCRB area proposed in this study are summarized below.

System	Potential Arable Area	Proposed Irrigation Area
I *1	63,300 ha *2	51,300 ha
M	25,000 ha	25,000 ha
MH Extension	22,000 ha *2	12,000 ha
J	21,800 ha	-
K	9,000 ha	-
L	34,600 ha	-

Remarks: *1 Including existing Giant tank scheme.
*2 Including rainfed cashew land.

The general layout of the NCRB area are shown in Figs. 2-1 and 2-4 and DRAWINGS.

F.2.4.3 North West Dry Zone (NWDZ)

NWDZ was studied as expansion project area of the Mahaweli Project originally studied in 1981 in TDS (Ref. 14). This zone was considered to consist of two sub-zones i.e. NW1 and NW2 and lies within the Puttalam district and partly in the Kurunegala district. The NW1 area is located along the right bank of the Mi Oya basin, and NW2 area along the left bank of the Mi Oya. Due to limitation of available diversion water at Polgolla, only NW1 was included in the second TDS (Ref. 16). The irrigation layout for the NW1 adopted in TDS (Ref. 16) was used for this study. 10,700 ha of NW1 area is considered to be irrigated from the existing Galgamuwa tank which is proposed to be heightened in the present study as described in ANNEX-J.

In addition, the existing Inginimitiya project area located in the Mi Oya basin is included in the present study to formulate the most effective use of Mahaweli water. The construction activities to provide the irrigation facilities to full extent of 2,550 ha was completed in 1986 and administrated by ID.

The general layout of the NWDZ area shown in Fig. F.2-5 and DRAWINGS.

F.3 IRRIGATION WATER DEMAND

F.3.1 General

The irrigation water demand to be diverted at each irrigation system was estimated on monthly basis during the period from January, 1949 to December, 1986 in order to simulate overall water balance study. The study area is located widely in the NCRB and NWDZ areas and the characteristics of each system vary depending on the topographic, climatic, soil conditions, etc. Since there is scarce detailed data and actual field measurement for evapo-transpiration, percolation rate, effective rainfall etc., various kind assumption was adopted in the study referring the previous studies.

F.3.2 Previous Studies on Irrigation Water Demand

Since 1968, master plan studies and feasibility studies have been carried out within the Mahaweli project area. Similar formulae and parameters have been utilized to estimate the irrigation water requirement in the previous studies by UNDP/FAO, as well as in ISS, TDS, HCP, MWRMP, etc. However, there are some differences in the selection of calculating method and quantification of parameters. The procedures and parameters applied in the previous studies are summarized in Table F.3.1 and F.3.7.

F.3.3 Calculation Basis of Irrigation Water Demand

F.3.3.1 Basic Data

The incorporated meteorological data were monthly rainfall during the period from January, 1949 to December, 1986 and the long averaged mean monthly meteorological data of max. and min. air temperature, max. and min. relative humidity, 24 hours wind speed, day/night wind speed ratio, and sunshine hours as shown in Table F.3.2.

According to the MWRMP (Ref. 18) and TDS (Ref. 16), it was found that climatic factors affecting potential evapotranspiration do not vary significantly from year to year and among the irrigation systems. Since insufficient climatic data exist for any station close to the respective irrigation systems, the following meteorological stations are considered to represent for each irrigation system:

Meteorological Station	Represented System
Anuradhapura	All system except for System A
Trincomalee	System A
Batticaloa	SEDZ (Only reference)

Trincomalee meteorological station was considered to represent for System A taking the influence of the location close to the sea into account.

The following eleven rainfall stations were adopted to represent each irrigation system taking the continuation of the record and distance from the study area into account:

	Station	Station No.	Irrigation Area
1.	Kal Aar	223	System A
2.	Polonnaruwa	487	System B and D2
3.	Horaborawewa	192	System C and E
4.	Hingurakgoda	186	System D1
5.	Bakamuna	40	System F
6.	Angamedilla	21	System G
7.	Maha Illuppallama	331	System H
8.	Anuradhapura	26	System I,IH and MH
9.	Kanakarayankulam	233	System J, K, L and M
10.	Mahauswewa	335	NWDZ
11.	Maha Oya	333	SEDZ (Only reference)

The details of rainfall data and meteorological data, i,e location of the stations, continuation of the record and filling-in of missing data etc. are described in ANNEX-B.

F.3.3.2 Calculation Method

Calculation formulae for estimating irrigation water requirement are outlined below.

$$FR = CU + LP + PL - ER$$
$$CU = Kc \times ETo$$
$$WD = FR/Ef$$

Where,
- FR : Farm irrigation water requirement (mm)
- CU : Consumptive use (mm)
- LP : Land preparation requirement (mm)
- PL : Percolation rate (mm)
- ER : Effective rainfall (mm)
- Kc : Crop coefficient at given stage
- ETo : Potential evapotranspiration (mm)
- WD : Water duty (mm)
- Ef : Irrigation efficiency

Irrigation water demand to be diverted at each tank or anicut was calculated using a computer model. The parameters employed in the computer model are mentioned in foregoing sections and input data are summarized in Table F.3.8.

F.3.3.3 Consumptive Use

Consumptive use is estimated as a product of the crop growth stage coefficient and the potential evapotranspiration which is calculated by means of the Modified Penman

Method recommended by FAO which is prevailing in the previous studies. Average figures of meteorological data for calculation of potential evapotranspiration are summarized in Table F.3.2.

Monthly value of the potential evapotranspiration (ETo) calculated by applying the average climatic data obtained at Anuradhapura, Trincomalee and Batticaloa are shown in Table F.3.3 with comparison of ETo estimated by the previous studies. As shown in this table, the annual values of ETo at Anuradhapura, Trincomalee and Batticaloa are estimated 2,048 mm, 2,226 mm and 2,083 mm respectively.

Crop coefficients (Kc) for each crop were determined according to the standard literature recommended by FAO and crop coefficient that had been determined experimentally for Sri Lanka conditions as presented in Table F.3.4.

Based on the proposed cropping patterns for respective irrigation systems as shown in Fig. F.3-2, consumptive use was calculated, and sample calculation of consumptive use is presented in Table F.3.15.

F.3.3.4 Percolation Rate

The percolation rate varies depending on the soil characteristics, hydropedological condition, groundwater table condition, topographic condition, etc. Since the actual measurement of percolation does not cover whole study area, average percolation rate were assumed for respective irrigation systems and soils, referring to the previous studies.

In the assumption of the percolation rate, following two types of soil characteristics are considered i.e. Low Humic Gley soils (LHG soil) which represent the soils of the low percolation rate and Reddish Brown Earth soils (RBE soil) which represent the soils of the high percolation rate. The detail of the characteristics of these two soils are described in ANNEX-D and the extents of these soils within the respective proposed irrigation systems are mentioned in ANNEX-E. The area of these soils adopted in the estimation for the irrigation water demand are summarized below:

(Unit: ha)

System	Total Area	LHG	RBE
A	20,300	12,000	8,300
B	42,000	8,800	33,200
C	24,500	18,300	6,200
D1	27,000	20,300	6,700
D1*1	13,500	5,400	8,100
D2	10,100	8,600	1,500
E	6,100	4,300	1,800
F	1,900	-	1,900
G	5,400	2,700	2,700
H	42,400	21,200	21,200

System	Total Area	LHG	RBE
IH	4,700	3,900	800
MH	16,300	7,600	8,700
I	53,300	27,800	25,500
J	21,800	8,000	13,800
K	9,000	5,800	3,200
L	34,600	8,600	26,000
M	25,000	13,100	11,900
NW1	10,700	3,100	7,600
NW1*2	2,550	2,550	-

Remarks: *1 Kantalai *2 Inginimitiya

Assumption of percolation rate of LHG soil and RBE soil adopted in the present study are complied in Table F.3.8.

F.3.3.5 Land Preparation Requirement

Land preparation requirements depend on soil type, moisture content, groundwater table, etc., and vary from season to season. In this study, land preparation requirements were considered to be 200 mm for poorly drained LHG soils and 300 mm for well drained RBE soils, respectively. As shown in Table F.3.15 "the sample calculation", rainfall was considered to be effective in reducing irrigation requirements.

F.3.3.6 Effective Rainfall

Effective rainfall is defined as the portion of total rainfall which meets with part of land preparation and crop water requirements. It is compositely influenced by several factors such as rainfall intensity and distribution, permeability and water holding capacity of soils, amount of irrigation water supplied, irrigation management practices, form of field plot and topography of lands. Generally little rainfall is not effective.

In the calculation of the water requirements in the study area, effective rainfall was separately computed for paddy and upland crops. Effective rainfall for paddy was calculated applying the standardized formula of the Land Use Division (LUD) of ID in Sri Lanka as follows:

$$ER = 0.67 \times (MR-25)$$
$$ER = 225 \qquad \text{when } ER > 225$$
$$ER = 0 \qquad \text{when } ER < 25$$

Where, ER : Effective Rainfall (mm)
MR : Monthly Rainfall (mm)

The effective rainfall for upland crops varies with rainfall intensity and distribution, soils, crops, etc. In this study, it was assumed that effective rainfall for upland crops was computed by using the S.C.S. Method adopted by U.S.D.A. (United States, Department of Agriculture's Soil Conservation Service Method) as follows (Ref: 2):

$$ER = MR \times Ratio$$

where, ER : Monthly effective rainfall
MR : Monthly rainfall

Before calculation of effective rainfall for paddy, the applicability of the LUD formula was confirmed by sample calculations using the daily balance method under following assumptions:

(1) Rainfall data : daily rainfall at Anuradhapura from 1951 to 1986 (36 years)

(2) Assumption :

- Rainfall less than 5 mm/day is ineffective
- Rainfall beyond the storage depth is ineffective
- Daily decreasing depth by evapotranspiration is based on the paddy 135
- Percolation rate is 2 mm/day
- (Case - 1)

  Irrigation water is supplied when water depth is lower than minimum water depth (50 mm) to recover up to maximum water depth (100 mm).
- (Case - 2)

  Irrigation water is supplied every day to maintain minimum water depth (50 mm) and maximum storage depth is 80 mm (effective storage depth : 30 mm)

The result of sample calculations are shown in Fig. F.3-1, which shows that the LUD formula is sufficiently applicable in the estimation of irrigation water demand in the present study.

Potential monthly effective rainfall for the selected eleven rainfall stations was calculated for 38 years from 1949 to 1986, and the average value of actual monthly rainfall and potential monthly effective rainfall at respective stations are summarized in Tables F.3.5 and F.3.6.

F.3.3.7 Irrigation Efficiency

Overall irrigation efficiency is attribute to farm application, conveyance and operation losses and varies depending on soil conditions, type of canal regulating structures, water management practices, etc.

Generally, the irrigation efficiency in the Maha season can be considered lower than in Yala season, because it is hardly possible to operate the regulating facilities quickly responding to unforeseeable rainfall. However, due to the difficulties to evaluate the difference in Maha and Yala season, irrigation efficiency is uniformly applied throughout the year in this study.

In the present study, the irrigation efficiency was applied taking following two case into consideration.

Case - 1 : Present water management practice
Case - 2 : Improved water management practice

Irrigation efficiencies of both two cases applied for respective systems are shown in Table F.3.8. As shown in this table, the irrigation efficiency with present water management practice was evaluated to be 50% for Systems E and C, and 56% for other systems. In Systems E and C, low efficiencies compared with the other systems are adopted according to the observation of the present conditions. The irrigation water demand for future case for all systems was calculated by adopting the irrigation efficiency of 60% under improved water management practice as mentioned in Section F.2.3 and the rehabilitation programme undertaken by MASL and ID.

F.3.4 Water Duty

Observed water duties in systems under the AMDP in Maha and Yala season are shown in Table F.3.9. As shown in the said table, average water duties for each systems varies from 1,000 to 1,600 mm approximately in Maha season and from 1,500 to 1,800 mm in Yala season with exception of Systems B, C and E in which the water duties varies from 2,200 to 2,500 mm in Maha season and from 2,700 to 3,700 mm in Yala season.

Table F.3.10 shows the comparison between the observed water duties and theoretical estimation of water duties calculated by adopting the actual cropping pattern, actual cropping date, period, and assumptions aforementioned. As result of the comparison shown in this table, the ratio of observed and theoretical water duties are from 0.9 to 1.3 with some exceptions. The methodology and assumptions can be considered to be applicable in this study.

Water duty for each irrigation system was calculated based on the calculation methodology aforementioned and the proposed cropping pattern presented in Figs. F.3-2. As shown in the said figures, the cropping intensities in the estimate of the irrigation water demand is supposed to be 2.0 for each system. However, in the case of System H, the cropping intensity at the present condition was estimated as 1.65 in order to meet the existing circumstance.

The average values of water duties in Maha and Yala season estimated for each system are shown in Table F.3.11 and annual water duties are summarized below:

(Unit : mm)

System	Case-1*1	Case-2*2	System	Case-1	Case-2
A	2,862	2,671	IH	2,588	2,415
B	3,162	2,951	MH	2,915	2,721
C	2,590	2,176	I	2,827	2,638
D1*3	2,276	2,124	J	2,487	2,322
D1*4	2,399	2,239	K	2,498	2,331
D2	2,207	2,060	L	2,557	2,386
E	2,699	2,267	M	2,767	2,583
F	3,045	2,842	NW1	2,357	2,200
G	2,719	2,537	NW*5	2,427	2,265
H	2,176*6	2,565*7			

Remarks :
*1 : Present condition
*2 : Improved condition
*3 : Minneriya, Giritale, Kaudulla and Vendarasan
*4 : Kantalai
*5 : Inginimitiya
*6 : Crop intensity CI = 1.65
*7 : Crop intensity CI = 2.00

F.3.5 Diversion Irrigation Water Demand

Irrigation water demands for each irrigation sub-system commanded by respective tanks were estimated during the period from January, 1949 to December, 1986 on the basis of water duty and net irrigation area shown in Table F.3.12. The calculation results of the irrigation water demand in present and future cases, which are incorporated in the water balance studies described in ANNEX-I, are summarized in Tables F.3.13 and F.3.14 and sample intermediate output of calculation of irrigation water requirement is shown in Table F.3.15. Water requirements for respective systems under the present and future conditions are presented in Tables F.3.16 and 3.17, respectively.

F.3.6 Return Flow

Irrigation water demand includes various kinds of unavoidable irrigation losses such as conveyance, distribution, application, percolation and operation losses. A certain amount of the above irrigation losses is expected to return to the river or downstream reservoir through drainage networks or underground permeable layer. For the water balance study, the amount of return flow should be considered as an usable water source. Since there is no actual measurement and evaluation for the return flow, it is assumed that 25% of diverted water for irrigation system locating upstream of the water balance study point may return to the river or downstream reservoir .

The schematic diagram of return flow included in the water balance study is mentioned in the ANNEX-I.

F.4 PRELIMINARY DESIGN AND COST ESTIMATE

F.4.1 General

The principal objectives of irrigation development within the study area are to increase agricultural products and to secure stable agricultural production by means of providing adequate irrigation and drainage systems and operation and maintenance (O&M) facilities. Basic requirements in the irrigation system are to supply stable irrigation water both in Maha and Yala seasons and to assure equitable and timely distribution of water to fields.

All new development areas in the present study are considered to be a gravity irrigation system with irrigation tank connected to diversion points on the Mahaweli Ganga and Amban Ganga as major water sources by the proposed transbasin canal. The tank irrigation system has merits. A main function of these tanks is to regulate local runoff and return flow from their own catchment areas and the upstream irrigation area. This results in reducing the system diversion water from the Mahaweli and Amban Gangas, and minimizing the diversion capacity of the proposed transbasin canal. And provision of irrigation tanks give flexible water management.

Each irrigation system is composed of intake structure on the proposed tank, main, branch, minor branch, distribution and field canals. Planning, preliminary design and cost estimate of the transbasin canal and proposed tanks with irrigation intake are studied in ANNEX-J. This chapter covers the preliminary design and cost estimate of downstream development from main canal to on-farm level.

Regarding the existing systems newly incorporated in this project, rehabilitation for irrigation facilities is proposed in order to make sure of distribution of diverted irrigation water and to provide proper water management.

F.4.2 Potential Irrigation Area

Distribution of the potential irrigable land in the NCRB and NWDZ area is clarified through the soil and land classification study. Of these candidate systems, Systems F, I, M, MH (extension) and NWDZ are screened out as new development area mainly based on the results of water balance study formulating the most effective water use in the Mahaweli Ganga, Amban Ganga and local catchment as described in ANNEX-I.

As concluded in the water balance study described in ANNEX-I, the tankwise potential irrigation area for new development is summarized below:

(Unit: ha)

System	Tank	Proposed Area
F		1,900
I	Mahakandalama Ext.	8,000
	Malwatu Oya	3,600
	Tammannewa	27,000
	(Sub-total)	38,600
M	Holowupotana	15,000
	Yan Oya	10,000
	(Sub-total)	25,000

System	Tank	Proposed Area
MH	Huruluwewa Ext.	12,000
NWDZ	Galgamuwa	10,700
Total		88,200

F.4.3 Preliminary Design of Main and Branch Canal

The unit design discharge for the preliminary design of main and branch canals and related structures was determined to be peak unit diversion water requirement with 80% probability of rainfall under improved irrigation efficiency. The design discharge of each irrigation facilities was obtained by multiplying the unit design discharge by its commanding area. Since the unit design discharges of respective proposed irrigation systems vary from 1.8 l/sec/ha to 2.2 l/sec/ha, the unit design discharge for the main and branch canals was assumed to be 2.2 l/sec/ha in this study.

Taking hydraulic reasons to minimize seepage losses, maintenance activities, etc. into consideration, all irrigation canals except field canal were planned to be thin concrete lined canals. Preliminary canal design was made by applying the Manning's formula under conditions as same as that of transbasin canal described in ANNEX-J.

Typical commanding area by each canal are assumed as follows, taking the operation of water management and administration into consideration.

	Commanding Area (ha)	Discharge (m^3/sec)
Main canal	>2,500	>5.5
Branch canal	500 - 2,500	1.1 - 5.5
Minor branch canal	250 - 500	0.5 - 1.1
Distribution canal (D-canal)	10 - 250	0.03 - 0.5
Field canal (F-canal)	< 15	0.03

Relating to the irrigation canals, many kinds and a number of related structures are required to effectively and efficiently convey, regulate and measure the discharge in the canal and also to protect the canal from external storm runoff and internal excess water caused mainly by missoperation. Those structures are broadly divided into i) conveyance structures, ii) regulating structures, iii) protective structures and v) other structures. Canal related structures considered in this study are bifurcation, regulator, turn out, offtake, drop, chute, drain under canal, siphon, culvert, bridge, etc.

F.4.4 On-farm Development

The construction works required for the on-farm development in the proposed irrigation systems are outlined as follows:

i) Providing minor branch, distribution and field canals with related structures
ii) Providing farm road with related structures
iii) Providing field drainage canal with related structures
iv) Land preparation works consisting of jungle clearing and rough leveling

In the present study, quantities of on-farm works were estimated on the basis of the actual construction quantities executed in the on-going Systems B and C projects under the AMDP. By adopting the actual work quantities and the unit construction costs for respective works, unit on-farm development cost was estimated as follows:

Category	Work Involving	Unit Cost (US$/ha)
Existing irrigation area	Rehabilitation, part of concrete lining and improving structure	200
Rainfed area	Overall development except clearing, rough leveling, etc.	2,200
New irrigation area	Overall development including clearing, rough leveling, etc.	2,500
Development for Cashew nut	Land preparation	300

F.4.5 Cost Estimate

F.4.5.1 Basic Condition of Cost Estimate

The direct construction cost is estimated on the basis of the preliminary facility plan and the standard unit cost at the price level as of September 1988. The construction cost of main and branch canals were estimated based on work quantities calculated on the preliminary design by using two inch-one mile topographic map. The construction cost of on-farm development including minor branch, distribution and field canal, field drain, farm road and land preparation is estimated based on the actual construction quantity of on-farm development executed in the on-going project of AMDP as described in Sub-section F.4.4. The major unit rates employed in the present study are mentioned in ANNEX-J.

The conversion rate among Sri Lanka Rupee, U.S. Dollar and Japanese Yen is assumed to be US$1.0 = Rs.32.50 = Yen 140 referring to the current exchange rate in September 1988.

The construction cost is divided into foreign and local currency components. The foreign currency component covers i) procurement cost for construction and O&M equipment and machinery, ii) materials to be imported, iii) expense and fees of consultants, etc.

F.4.5.2 Direct Construction Cost

The direct construction costs for each candidate irrigation systems are shown in Tables F.4.1 and F.4.2, and summarized below:

(Unit: 10^6 US$)

System	Work Item	Direct Construction Cost	System	Work Item	Direct Construction Cost
H	Rehabilitation	8.9	M	New development	93.4
IH	Rehabilitation	1.0	MH	New development and rehabilitation	49.6
F	New development	5.8	NWDZ	New development and rehabilitation	51.3
I	New development and rehabilitation	181.4			

The project cost for irrigation development including O/M cost, replacement cost, and cost for administrative, engineering service, and contingency are studied in ANNEX-J.