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DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

MINISTRY OF LANDS, IRRIGATION AND MAHAWELI DEVELOPMENT

THE STUDY ON EXTENSION OF THE MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

MASTER PLAN

(PHASE-II)

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VOLUME-I MAIN REPORT

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JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the Democratic Socialist Republic of Sri Lanka, the Japanese Government decided to conduct a study on Extension of the Feasibility Study on the Moragahakanda Agricultural Development Project and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Sri Lanka a study team headed by Mr. Shin-ichi Yano, Nippon Koei Co., Ltd., for Phase-I study of updating Feasibility Study conducted in 1978, and the report presenting the results of study was submitted in May, 1988.

In succession to Phase-I study, JICA sent the team to Sri Lanka from July to December, 1988.

The team held discussions with the officials concerned of the Government of Sri Lanka and conducted field surveys in the Amban Ganga basin and its adjacent areas. After the team returned to Japan, further studies were made and the present report was prepared.

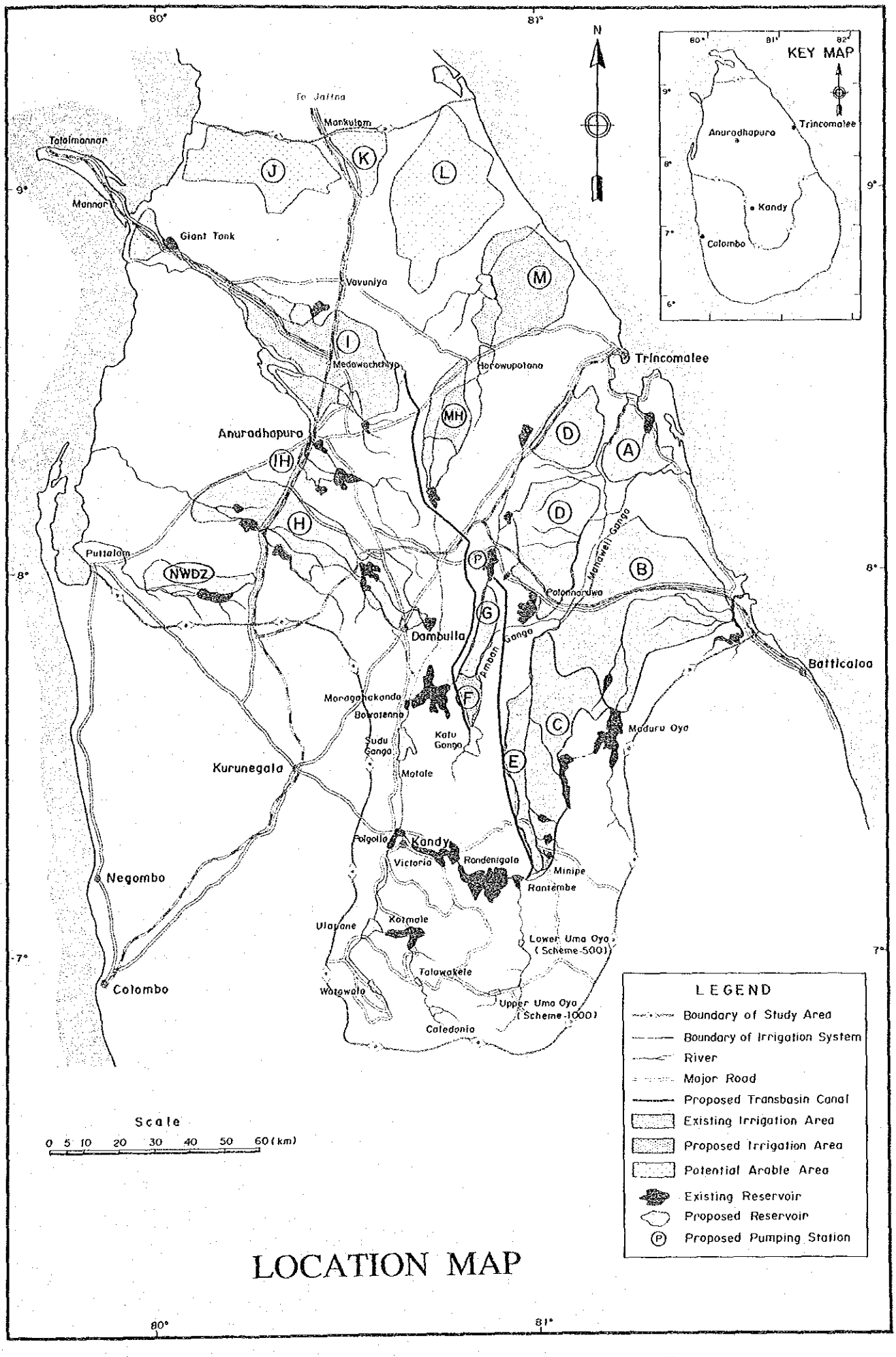
I hope that this report will contribute to the development of the Project and to the promotion of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Democratic Socialist Republic of Sri Lanka for their close cooperation extended to the team.

July, 1989



Kensuke YANAGIYA
President
Japan International Cooperation Agency



LOCATION MAP

SUMMARY AND RECOMMENDATIONS

I INTRODUCTION

01. This report is prepared in accordance with the Scope of Work agreed upon between MMD and JICA in October 1987, and presents the results of the Phase-II study on the Extension of the Moragahakanda Agricultural Development Project. The objectives of the Phase-II study are to formulate an overall agricultural development plan (Master Plan) in the Amban Ganga Basin for (1) the most effective use of available water in the Mahaweli river system for irrigation development in the Amban Ganga basin and its adjacent areas, and (2) priority irrigation projects and implementation of these projects.

02. In 1968, a master plan for the Mahaweli Ganga Development prepared with the assistance of UNDP/FAO comprised irrigation development of about 365,000 ha and hydropower development of 500 MW in installed capacity. The Government of Sri Lanka (GOSL) commenced the development at the Mahaweli Ganga Basin on the basis of this master plan in 1968. In 1977 GOSL revised the master plan to accelerate the Mahaweli Development Programme for yielding the quickest return to the nation. The revised plan, called the Accelerated Mahaweli Development Programme (AMDP), involves (1) irrigation development of about 204,000 ha with 8 irrigation systems, from A to D, G, H, IH and MH, and (2) hydropower development schemes of about 470 MW in installed capacity through the construction of 5 dams: Kotmale, Victoria, Randenigala, Moragahakanda and Maduru Oya dams.

03. In 1986, GOSL requested the Government of Japan (GOJ) to undertake (1) the updating of the feasibility study on the Moragahakanda Agricultural Development Project which was originally prepared in 1979 (Phase-I study), and (2) to formulate an overall agricultural development plan in the Amban Ganga basin, the North Central River Basin (NCRB), and the North West Dry Zone (NWDZ) (Master Plan, Phase-II study). In response to the above request, GOJ decided to conduct the Study on Extension of the Moragahakanda Agricultural Development Project.

2. BACKGROUND

04. The population of Sri Lanka was approximately 16.4 million in 1987, corresponding to 249 persons/km^2 . The annual growth rate of the population during the period from 1981 to 1987 was 1.63%. The population is expected to be over 20 million in 2001 and 24 million in 2020. The number of unemployed persons in 1987 was estimated to be about 1.19 million, corresponding to an 18% unemployment rate.

05. The Gross Domestic Product (GDP) in 1987 was estimated at about Rs. 177.7 billion with an annual growth rate of 4.8%. Per capita GDP is estimated to be Rs. 10,863 (about US$350). Agriculture in Sri Lanka has played an important role in its economy, contributing to about 27% to GDP and employing about 45% of the active labour force. Earnings from agricultural exports accounted for about 42% of the total exports in 1987.

06. The climate of Sri Lanka is suitable for year-round cultivation and the soils are generally suitable for agriculture if irrigation water is properly made available. The main export crops are tea, rubber and coconuts of which production was approximately $213x10^3$ tons, $122x10^3$ tons and $2,291x10^6$ nuts respectively in 1987. The main food crop is rice, of which production was about $2.59x10^6$ tons of paddy in 1986 and $2.13x10^6$ tons in 1987 respectively. The following table shows the average cultivated area and production during the period of 1983 to 1987:

Item		Maha	Yala	Total
Net cultivated Area	(10^3 ha)	500	274	774
Production (Paddy)	(10^3 tons)	1,595	860	2,455
Yield per ha	(ton/ha)	3.19	3.14	3.17

Source: Paddy Statistics 1983-87

07. The entire public power supply in Sri Lanka is managed and operated by the Ceylon Electricity Board (CEB). The total installed capacity of CEB was 1,116 MW in 1987 comprising 916 MW of hydropower and 200 MW of thermal powerplants. Annual energy generated in 1987 by CEB was 2,707 GWh of which the hydropower accounted for approximately 80%.

3. THE STUDY AREA

08. The study area for agricultural development covers approximately 27,000 km^2 or about 41% of Sri Lanka. The study area is situated in the northwest, the north central and the north east regions of Sri Lanka, which include existing irrigation areas in Systems H, IH and MH, potential irrigation areas in Systems F, I and M located in NCRB, and NWDZ. 51,400 ha of Systems H, IH and MH are irrigated by the existing Dambulu Oya and Kalawewa tanks receiving water mainly from the Mahaweli Ganga. Present land use is summarized below:

(Unit: ha in Gross)

Land Use Category	NCRB (F,H,IH,MH,I,M)	NWDZ (NW-1)	Total
1. Agricultural Land	191,600 (49.3%)	12,100 (34.0%)	203,700 (48.0%)
2. Urban Area and Homestead	26,800 (6.9%)	500 (1.4%)	27,300 (6.4%)
3. Forest	101,500 (26.1%)	22,600 (63.5%)	124,100 (29.2%)
4. Barren Land and Shrub	59,500 (15.3%)	400 (1.1%)	59,900 (14.1%)
5. Others	9,400 (2.4%)	0 (0.0%)	9,400 (2.3%)
Total	388,800 (100%)	35,600 (100%)	424,400 (100%)

09. The soils in the study area are mainly composed of the following great soil groups:

(Unit: ha in Gross)

Great Soil Groups	NCRB (Systems F,H,IH,MH,I,M)	NWDZ (NW-1)	Total
1. Alluvial Soils	45,800 (11.8%)	5,500 (15.4%)	51,300 (12.1%)
2. Old Alluvial	0 (0.0%)	500 (1.4%)	500 (0.1%)
3. Solonetz	3,900 (1.0%)	0 (0.0%)	3,900 (0.9%)
4. Low Humic Gley Soils	83,900 (21.6%)	6,000 (16.9%)	89,900 (21.2%)
5. Reddish Brown Earth	234,900 (60.3%)	21,500 (60.4%)	256,400 (60.4%)
6. Red Yellow Podzolic Soils	100 (0.03%)	0 (0.0%)	100 (0.02%)
7. Grumusols	200 (0.1%)	0 (0.0%)	200 (0.1%)
8. Lithosols (Rock outcrop)	16,200 (4.2%)	1,200 (3.4%)	17,400 (4.1%)
9. Marsh/Tank	3,800 (1.0%)	900 (2.5%)	4,700 (1.1%)
Total	388,800 (100%)	35,600 (100%)	424,400 (100%)

RBE soils generally extend over the undulating plains with gentle slopes of less than 4% and are well drained. Alluvial soils are well to moderately well drained soils, occurring on river levees and flood plains. Except for Solonetz and Lithosols, the soils in the study area are generally suitable for agriculture.

10. The climate in the study area is characterized by tropical monsoons with a dry (Yala) season from April to September and a rainy (Maha) season from October to March. The average annual rainfall ranges from about 1,300 mm to 2,100 mm of which about 70 to 77% falls during the rainy season. The monthly mean temperatures show rather little variation throughout the year, ranging from 25°C to 30°C. Annual mean pan evaporation ranges between 1,587 mm at Alutharama and 2,184 mm at Kantalai. The monthly mean relative humidity ranges between 60% and 90%. The daily mean sunshine hours vary from 6.3 to 7.8 hours. The annual natural runoff of the Mahaweli Ganga at Manampitiya located at about 65 km upstream from its estuary is estimated to be 8,330 MCM for the 37 years from 1949 to 1986.

11. The population in the study area was estimated at approximately 4.1 million in 1981. The population in NCRB and NWDZ was estimated at 349×10^3 in 1981. The labour force in these areas was estimated at 120×10^3 in the same year, of which about 73×10^3 were engaged in the agricultural sector. The average population growth rate during ten years between the census years of 1971 and 1981 was 2.7% according to the District's base data, while the growth rate in Sri Lanka was 1.6% during the same period. This high growth was caused by immigration from outside, since the natural rate of increase was about 2.0%.

12. Paddy is a main crop in NCRB and NWDZ. There are two cropping seasons for paddy production, Maha and Yala. In Maha, 97% of irrigated fields and 3% of rainfed fields were cultivated for paddy production, while in Yala only 26% of irrigated fields and less than 1% of rainfed fields were planted to paddy due to insufficient irrigation water. System H recorded the highest intensity of 1.65 among all Systems in the study area, while System M is the lowest with 0.70. Chilli is the second most important irrigated crop in the study area. The following table shows cropping areas as well as intensity:

Item	Net Area (ha)	Cultivated Area (ha)				Total	Cropping Intensity
		Maha		Yala			
		Paddy	Upland	Paddy	Upland		
Irrigated	69,600	67,500	2,100	18,300	18,000	105,900	1.52
Rainfed	63,500*	1,300	45,900	400	6,600	54,200	0.85
Total	133,100	68,800	48,000	18,700	24,600	160,100	1.20

* includes fallow area.

13. Paddy yields in Maha range between 2.8 ton/ha and 4.3 ton/ha under irrigation and from 1.5 ton/ha to 3.1 ton/ha under rainfed conditions, while in Yala they are between 2.0 ton/ha and 2.8 ton/ha under irrigation and from 1.8 ton/ha to 2.4 ton/ha under rainfed conditions. Dry chilli yields under irrigation are between 0.5 ton/ha and 1.1 ton/ha in Maha and increase from 1.2 ton/ha to 1.5 ton/ha in Yala. Pulses like cowpea, green gram, black gram, soybean and groundnut are in most cases grown under rainfed conditions with yields from 0.5 ton/ha to 1.5 ton/ha. The average annual crops production in the study area is about 306×10^3 tons of paddy, 12.7×10^3 tons of chillies, 34.4×10^3 tons of pulses and 13.7×10^3 tons of maize respectively.

14. The CEB power supply system is predominantly dependent on hydropower, especially hydropower in the Mahaweli power complex as seen in the following table:

Item	Total Installed Capacity (MW)		Mean Annual Energy (GWh)			
			Firm	Secondary	Total	
1. Hydropower						
- Mahaweli System	611	(55%)	1,234	876	2,110	(43%)
- Other System	305	(27%)	1,304	268	1,572	(32%)
2. Thermal Power	200	(18%)	1,265	-	1,265	(26%)
Total	1,116	(100%)	3,803	1,144	4,947	(100%)

The Mahaweli power complex totals 611 MW in installed capacity comprising Ukuwela (38 MW), Bowatenna (40 MW), Victoria (210 MW), Randenigala (122 MW) and Kotmale (201 MW). Moreover, the Rantembe hydropower scheme (50 MW) is under construction and will be completed in 1990.

4. PROSPECTIVE AGRICULTURAL AND WATER RESOURCES DEVELOPMENT

15. The available water resources in the study area consist mainly of the Mahaweli Ganga including its tributaries, and runoffs from the catchment areas of potential irrigable areas. Runoffs of the Mahaweli river basin and the potential arable areas was estimated at 8,330 MCM at Manampitiya and 1,580 MCM, respectively.

16. Food demand for national consumption in the year 2020 is estimated on the basis of both the projected population and the per capita consumption of food. Besides, exports of food crops are expected to grow at the same level as other major Asian countries. Thus, the total requirement of major food crops in the country is estimated as the sum of both domestic consumption and exports, and aggregated as follows: $4,220 \times 10^3$ tons of paddy, 89×10^3 tons of chilli, 131×10^3 tons of onion, 235×10^3 tons of pulses and nuts, 101×10^3 tons of maize, 25×10^3 tons of cashew (Kernels), and $2,294 \times 10^3$ tons of vegetables and fruits. In order to meet such requirement, the project area would play an important role of main food supplier in consideration of potentiality of both land and water resources.

17. Future cropping patterns under with-project condition are made for most-likely grown crops in the project area. The crops in irrigated fields are grouped into 6 categories, i.e., paddy, chilli, pulses, maize, onion and others. Cropping calenders for these crops follow existing typical cropping calenders.

18. Crop yields will increase year by year through improved farming practices. The following table shows the anticipated yields of proposed crops:

(Unit: ton/ha)

	Crop		Present Condition	Without Project	With Project
1.	Paddy				
	Irrigated	Maha	2.8 - 3.6	3.5	5.5
		Maha (System H)	4.3	4.5	5.5
		Yala	2.0 - 2.8	3.0	5.0
	Rainfed	Maha	1.5 - 3.1	2.5	-
2.	Chilli		0.5 - 1.5	1.5	1.9
3.	Onion		0.9 - 8.4	10.0	15.0
4.	Pulses (Green gram)		0.5 - 1.5	1.0	1.5
5.	Maize		0.9 - 1.5	2.0	3.5

19. After implementation of the proposed agricultural development in the study area, a considerable increase of agricultural production can be expected. The following table shows the anticipated production of the crop for the two development cases:

(Unit: 10^3 tons)

Crop	NCRB		NCRB+NWDZ		Production Target
	Present Condition	W/Project (161,600 ha)	Present Condition	W/Project (174,850 ha)	
Paddy	293	1,253	306	1,339	1,350
Chilli	13	37	13	38	36
Maize	14	24	14	31	32
Onion	-	50	-	54	52
Cashew (Kernels)	-	4.5	-	4.5	10

20. The irrigation water demand for existing, on-going, committed projects and potential irrigable area was calculated on monthly basis for 37 years from 1949 to 1986. Present overall irrigation efficiency was evaluated at 50% for Systems E and C, and 56% for other systems. The irrigation demand at the matured stage in the year 2020 was calculated by adopting an improved overall irrigation efficiency of 60%, since GOSL forces rehabilitation of existing projects to improve farming practices and to save water through proper water management. About 300,000 ha in total including about 200,000 ha of existing projects and schemes under AMDP and about 100,000 ha of new land, will be irrigated under the improved irrigation efficiency and the cropping intensity of 2.0 within an allowable deficit.

21. There are several transbasin diversion plans from the Mahaweli Ganga to NCRB, NWDZ and SEDZ which were studied by UNDP/FAO, subsequently in ISS and TDS. The increase of Polgolla diversion to the Amban Ganga will decrease hydropower generation at the existing hydropower stations on the Mahaweli main stream. However, this increased diversion will minimize losses of energy consumption at the pump station which will be necessary to irrigate the NCRB area. In order to establish an overall development plan, the following development plans of water conveyance are conceived for agricultural development in NCRB and NWDZ .

1) NCRB Area

The following three alternatives are considered:

Conveyance System	Merit or Demerit
A: New Alternative Plan Minipe - Minipe New LB canal - Minneriya tank - Pump station - NCP canal - NCRB area	Lowest pumping cost (40 m head) is required, but the canal has to pass through the National Park.
B: Electrowatt (TDS) Solution Modified Minipe - Hettipola Oya (Pump Station) - Kalu Ganga dam - Elahera - NCP canal - NCRB area	Existing Minipe LB canal can be utilized but huge pumping cost (80 m head) is required. No disturbance to the National Park be expected.
C: UNDP/FAO (ISS) Solution revised by NEDECO Minipe LB canal - Angamedilla - Kaudula - Kantalai Angamedilla - Pump station - NCP canal - NCRB area	Medium pumping cost (65 m head) is required, but the canal proposed still has to pass through the National Park.

2) NWDZ Area

In TDS, six alternative conveyance routes from the Mahaweli Ganga to NWDZ were studied. Among these six routes, it was concluded that irrigation water in NWDZ would be diverted through the existing Ukuwela power station and discharged into the Sudu Ganga, and then into the Bowatenna reservoir. From Bowatenna, water will be supplied through a second irrigation tunnel, being parallel to the existing irrigation tunnel. Diverted water is then impounded in the Kalawewa tank and supplied to NWDZ through the expanded Kalawewa LB canal.

22. CEB established the "Long Range Generation Expansion Plan - 1987" covering upto the year 2002. According to the Expansion Plan - 1987, the power demand will increase at an annual rates of 8.2% in 1988-90, 10% in 1991-1995, 9.5% in 1996-2002 and the peak demand and annual generation will exceed 2,000 MW and 10,000 GWh in 2002, respectively.

23. The forest area in the lower Mahaweli basin represents one of the richest and most diversified wildlife habitats in the dry zone of the country. Within the study area

several National Parks and wildlife reserves have been demarcated. The Parks and reserves being created are the Maduru Oya National Park, Somawathiya National Park, Flood Plain National Park, Trikonamadu Nature Reserve, Minneriya-Giritale Nature Reserve, Hurulu Forests Reserve, Ritigala Strict Natural Reserve, etc. In formulating the development programme, careful consideration had to be given to environment assessments of impacts in order to minimize adverse effects. In this connection, GOSL commissioned a comprehensive environment impact assessment which was conducted for the entire river basin. An action plan for management of the Mahaweli environment is being pursued by the relevant Government Agencies. Progress has been notable in relation to wildlife and forest conservation.

24. The Mahaweli river basin is divided into 21 sub-basins, in respect of existing and potential dam and intake sites, and the existing and potential irrigable areas are divided into 51 sub-basins. In the simulation model, a certain simplification for irrigation systems was introduced in representing irrigation systems by exclusion of reservoirs and tanks with active storage of less than 5 MCM. For the water balance study, operation methods of the existing and proposed multipurpose dams employed variable draft operation to allow for downstream water demand with retention of present water rights. The simulation runs were performed to evaluate rule curves to minimize diversion demands from the main system reservoirs and to make maximum use of local inflows, i.e. to minimize spillout from the various tanks, while at the same time, maintaining "allowable" irrigation reliability (as defined in next paragraph).

25. The water balance for two alternative cases, 875 MCM and 1,280 MCM diversion at Polgolla, was carried out by using the water balance simulation model and was based on allowable water deficit criteria for irrigation project, i.e. 80% probability in occurrence and 90% probability in quantity as adopted by ID. In this calculation, river maintenance flow was estimated at 15 m^3/sec at the estuary. In case of 875 MCM diversion, the maximum possible irrigable area of about 304,000 ha including the existing schemes under AMDP could be irrigated with reliable water supply. In case of 1,280 MCM diversion, the irrigation deficit ratio shows a little higher figure than that in the case of 875 MCM, and annual energy output especially on the existing hydropower stations would decrease substantially on the Mahaweli river system.

5. DEVELOPMENT FACILITIES AND COST ESTIMATES

26. For the water resources development of the entire Mahaweli Ganga basin, eight (8) multipurpose dams and power schemes are conceived. The following table shows principal features and construction costs estimated:

Item	Unit	Wata-wala	Ula-pane	Cale-donia	Talawa-kele	Kotmale Extension	Upper Uma (S-1000)	Lower Uma (S-500)	Wewa tenna	Sudu
River		Maha-weli	Maha-weli	Kotmale	Kotmale	Kotmale	Uma Oya	Uma Oya	Badulu Oya	Sudu Ganga
Catchment area	(km^2)	69	220	235	363	562	421	622	267	305
Annual runoff	(MCM)	119	381	412	636	984	354	523	207	1,144
Dam type		Concrete	Rockfill	Concrete	Concrete	Rockfill	Rockfill	Concrete	Rockfill	Rockfill
Dam height	(m)	60	70	70	20	115	90	25	80	55
Net storage volume	(MCM)	17.7	150	30	2	383	60	1.5	90	100
Power station										
Rated head	(m)	179	109	144	468	233	434	251	114	47
Installed capacity	(MW)	18	44	44	204	39*	150	96	22	45
Energy output	(GWh)	49	91	135	674	59*	342	310	69	122
Construction cost	(US10^6$)	44	117	156	216	237	249	228	86	83

* shows only incremental value.

27. Construction costs of transbasin canals, irrigation tanks, main and branch canals, and on-farm development for the various cases described in this Report are estimated and summarized below:

Item	Unit	Polgolla Diversion					
		875 MCM				1,280 MCM	
		A118	A145	B151	C145	A209	A242
1. Combination of Irrigation Areas		AMDP NCRB -	AMDP NCRB NWDZ	AMDP NCRB NWDZ	AMDP NCRB NWDZ	AMDP NCRB -	AMDP NCRB NWDZ
2. Irrigation Area*	10^3 ha	310.5	323.8	323.8	323.8	310.5	323.8
3. Development Facilities							
- NCP Canal							
. Kalu Ganga-Elahera (17 km)	m^3/s	15	15	80	15	15	15
. Elahera-Kiri Oya (42 km)	m^3/s	60	55	90	45/90	75	70
. Kiri Oya - Tammannewa (58 km)	m^3/s	----------		90/60/40		----------	
- Minipe LB Canal							
. Minipe Pump Station	m^3/s	60	65	65	65	55	55
	km	113	113	75	75	113	113
. Angamedilla - Kantalai (40/20 m^3/s)	km	-	-	-	70	-	-
- Pump Station							
. Design capacity	m^3/s	30	35	65	45	15	20
. Rated head	m	52	52	88	66	52	52
. Required capacity	MW	23	27	84	44	12	15
- Agricultural Development							
. New irrigation area	10^3 ha	77.5	88.2	88.2	88.2	77.5	88.2
. Non-irrigated cashew land	10^3 ha	20.0	20.0	20.0	20.0	20.0	20.0
. Rehabilitation	10^3 ha	64.1	66.7	66.7	66.7	64.1	66.7
Total	10^3 ha	161.6	174.9	174.9	174.9	161.6	174.9
4. Construction Cost							
- NCRB	US10^6$	1,352	1,375	1,587	1,502	1,295	1,315
- NWDZ	US10^6$	-	121	121	121	-	121
Total	US10^6$	1,352	1,496	1,708	1,623	1,295	1,436

* Including 20,000 ha of non-irrigated cashew land.

6. BENEFITS

28. Agricultural benefits will accrue from incremental production by the balance of the "with" and "without" project conditions. The value of total production is estimated as a product of crop budget and production of each crop in the project area. Typical crop budgets are estimated on the basis of the recommended farming practices. Economic prices of farm inputs and products of international tradable goods were estimated by referring to the IBRD price forecast. Incremental agricultural benefits accruing annually from the project were estimated as follows:

(Unit: Rs. 10^6)

Crop	NCRB* (F,H,IH,MH,I &M)	NWDZ (NW-1)	Total
Paddy	3,672	284	3,956
Chilli	425	22	447
Pulses	31	32	63
Maize	39	13	52
Onion	236	23	259
Cashew	397	0	397
Others	62	20	82
Total	4,862	394	5,256
Total Equivalent to US$10^6	150	12	162

* Including the incremental benefits in Systems H, IH and MH.

29. Annual power and incremental benefits obtainable by the downstream power stations for the respective schemes were estimated as shown in the following table:

(Unit: US$10^6)

Scheme	Total Annual Benefit	Scheme	Total Annual Benefit
1. Watawala	5.52	6. Upper Uma Oya (Scheme - 1000)	31.95
2. Ulapane	13.83	7. Lower Uma Oya (Scheme - 500)	26.14
3. Caledonia	15.54	8. Wewatenna	5.24
4. Talawakele	52.75	9. Sudu Ganga	9.36
5. Kotmale Extension	20.91		

7. COMPARISON OF OVERALL AGRICULTURAL DEVELOPMENT PLANS

30. A comparison of three alternative transbasin conveyance systems and irrigable areas in NCRB and NWDZ under the present Polgolla diversion policy of 875 MCM was carried out based on the results of the water balance simulation and costs and benefits. The annual equivalent costs of construction for the various cases were calculated at a discount rate of 8% per annum. The following table shows in summary a comparison of the three cases A, B and C:

Item	Unit	Alternative Plan		
		Case A145	Case B151	Case C145
1. Combination of Irrigation Areas		AMDP NCRB NWDZ	AMDP NCRB NWDZ	AMDP NCRB NWDZ
2. Irrigation Area*1	ha	323,750	323,750	323,750
3. Annual Benefits	US$10^6	155.6	149.8	149.7
4. Annual Costs*2	US$10^6	135.6	176.2	151.1
5. Economic Comparison				
- B/C	-	1.15	0.85	0.99
- B-C	US$10^6	20.0	-26.4	-1.4

*1 Including 20,000 ha of non-irrigated cashew land.
*2 A discount rate of 8% was applied. No consideration was given to the implementation schedule and the built-up period of the scheme.

It is very clear from the above table that the economic viability in each case is greatly affected by the heavy energy consumption for pumping. Therefore, the optimum solution for transbasin diversion must minimize energy consumption for pumping, and at the same time keep irrigated agriculture at a maximum. Accordingly Case A proposed in this study was recommended as the optimum plan in terms of B-C and B/C.

31. Two alternative development plans with Case A conveyance system were then studied under the present Polgolla diversion of 875 MCM and the possible alternative diversion of 1,280 MCM adopted for the Moragahakanda Project in 1979. This comparison may be summarized as follows:

Item	Unit	Present Diversion Policy 875 MCM		Alternative Diversion Policy 1,280 MCM	
		A118	A145	A209	A242
1. Combination of Irrigation Areas		AMDP NCRB -	AMDP NCRB NWDZ	AMDP NCRB -	AMDP NCRB NWDZ
2. Irrigation Area*1	ha	310,500	323,750	310,500	323,750
3. Annual Benefit	US$10^6	147.5	154.7	133.7	147.4
4. Annual Costs*2	US$10^6	122.1	135.6	113.3	126.3
5. Economic Comparison					
- B/C	-	1.21	1.14	1.18	1.17
- B-C	US$10^6	25.4	19.1	20.4	21.1

*1 Including 20,000 ha of non-irrigated cashew land.
*2 A discount rate of 8% was adopted. No consideration was given to the implementation schedule and the built-up period of the schemes.

It will be seen from the above that developing only NCRB, as in Case A118, is the most economical plan in terms of B-C and B/C among the four alternatives.

32. Economic analysis was made based on the estimated costs and benefits of each hydropower scheme, and the benefit-cost ratios, and ranking of each scheme were estimated as follows:

Scheme	B/C*	EIRR	Ranking
1. Watawala	1.25	9.8%	4
2. Ulapane	1.21	9.6%	5
3. Caledonia	1.55	11.9%	2
4. Talawakele	1.99	15.1%	1
5. Kotmale Extension	0.90	7.0%	8
6. Upper Uma Oya (Scheme-1000)	1.31	10.3%	3
7. Lower Uma Oya (Scheme-500)	1.17	9.2%	6
8. Wewatenna	0.62	4.4%	9
9. Sudu Ganga	1.14	8.6%	7

* Discount rate = 10%. No consideration was given to the implementation schedule and the built-up period of the schemes.

It will be seen from above, that the Caledonia, Talawakele, Upper Uma Oya (Scheme-1000) are more economically promising than the other six schemes. The Wewatenna scheme has the lowest ranking of the above schemes, and will not be economical at the present value of hydropower benefit. The Wewatenna scheme is deleted from this study, but should be re-examined in future studies in connection with the agricultural development of the SEDZ area.

8. STAGEWISE DEVELOPMENT

33. Agricultural land development is recommended in NCRB as a result of economic comparison, water balance simulation, and social considerations. Development of NCRB is too large to be developed as one package. A stagewise implementation programme is necessary to minimize technical and socio-economic constraints. The proposed irrigation project in NCRB would therefore be divided into three packages as a basis for a sequential implementation programme for overall water resources development. A summary of the respective packages is given as follows:

Package No.	Development Category	Beneficiary Area	Systems or Schemes
Package-1	Joint Facilities	-	Kalu Ganga dam NCP Canal (Kalu Ganga-Huruluwewa)
	New Irrigation Area	23,900 ha	System F, Yan Oya (M) Huruluwewa Extension (MH)
	Cashew Land	10,000 ha	Huruluwewa Extension (MH)
	Rehabilitation	25,500 ha	Huruluwewa (MH) A part of System H
Package-2	Joint Facilities	-	NCP canal (Huruluwewa-Mahakandarama) Minipe LB Canal (Minipe -Minneriya Tank)
	New Irrigation Area	26,600 ha	Horowupotanna (M) Malwatu (I), Mahakandarama Extension (I)
	Rehabilitation	38,600 ha	System IH, A part of System H Mahakandarama (I), Malwatu Oya (I)
Package-3	Joint Facilities	-	NCP Canal (Mahakandarama-Tammannewa) Minneriya Pump Station
	New Irrigation Area	27,000 ha	Tammannewa (I)
	Cashew Land	10,000 ha	System I

34. The following is a summary of investment costs, economic costs, benefit and EIRR for the three packages:

Package	Area (ha)	Investment Cost (US$10^6)	Allocated Economic Cost (US$10^6)	Agricultural Benefit (US$10^6)	EIRR (%)
Package-1	59,400	543.2	411.1	50.9	9.3
Package-2	65,200	435.8	507.8	60.4	9.2
Package-3	37,000	373.0	364.5	39.2	8.0
Whole Project	161,600	1,352.0	1,283.4	150.5	8.9

35. In addition to the primary direct benefits, substantial secondary direct benefits will stem from the project outputs and be induced by project inputs, and favourable intangible socio-economic impacts are expected from implementation of the proposed project, such as foreign exchange savings, increased employment opportunities, improvement in living standards, etc. Further implementation of the projects would increase inland fishery production and promote agro-based industries through introduction of diversified crops and various kind of fruits.

9. ACTION PLAN

36. Continued Agricultural Development for Rice Self-sufficiency

Although the self-sufficiency in rice in Sri Lanka is attainable in the near future with proper water management and introduction of improved farming practices, constant development of agriculture, particularly for increased food production will continue to be essential, since the population of Sri Lanka is expected to increase as much as 1.5 times from 16.4 million in 1987 to about 24 million by the year 2020.

37. Implementation of the Moragahakanda Agricultural Development Project

GOSL is going to complete the principal components of AMDP except System A and the Moragahakanda Development Project. In 1986, GOSL decided to take up the Moragahakanda project by maintaining continuously strong policy to complete AMDP and requested GOJ to update the Feasibility Study prepared in 1979. Updated Feasibility Study is ready for its implementation. The Moragahakanda dam plays an important role in supplying stable irrigation water to the existing and extension areas in System D. Moreover, since the Moragahakanda dam is of paramount importance for agricultural development in NCRB as recommended in this Master Plan, it is strongly recommended that the Moragahakanda project should be commenced at the earliest possible opportunity.

38. For Early Implementation of NCRB Development Package-I Mapping of Irrigation Areas and Preparations for Feasibility Study

Early implementation of Package-1 as proposed in the preceding Section is necessary to ensure satisfactory achievement of the contemplated overall development target by the year 2020, and attainment of the socio-economic target. For Package-1, the necessary actions are to prepare Terms of Reference for a feasibility study. Moreover, budgetary arrangements are essential for topographic map and core drillings. Topographic maps in the irrigation areas and along the transbasin conveyance canal (NCP canal) should be prepared in advance of the feasibility study.

39. Implementation of the Upper Kotmale Project (Talawakele and Caledonia Schemes)

In view of rapid expansion of power demand in Sri Lanka, power development by hydro and thermal power plants is urgently required. It is also strongly recommended that necessary and prompt action be taken for implementation of the Upper Kotmale project consisting of the Talawakele and Caledonia schemes.

THE STUDY ON EXTENSION OF THE MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

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ABBREVIATIONS

CB	Central Bank of Sri Lanka
CEB	Ceylon Electricity Board
CECB	Central Engineering Consultancy Bureau
DA	Department of Agriculture
DCS	Department of Census and Statistics
FAO	Food and Agriculture Organization, United Nations
FD	Forest Department
GDP	Gross Domestic Product
GNP	Gross National Product
GOJ	Government of Japan
GOSL	Government of Sri Lanka
IBRD	International Bank for Reconstruction and Development (World Bank)
ID	Irrigation Department
IDB	Industrial Development Board
JICA	Japan International Cooperation Agency
MADR	Ministry of Agricultural Development and Research
MASL	Mahaweli Authority of Sri Lanka
MEA	Mahaweli Economic Agency
MECA	Mahaweli Engineering and Construction Agency
MFP	Ministry of Finance and Planning
MLLD	Ministry of Lands and Land Development
MMD	Ministry of Mahaweli Development
MTI	Ministry of Trade and Industries
NCP	North Central Province
NCRB	North Central River Basin
NWDZ	North-Western Dry Zone
SEDZ	South-Eastern Dry Zone
SD	Survey Department
UNDP	United Nations Development Programme
WMP	Water Management Secretariat
GA	Government Agent Division
AGA	Assistant Government Agent Division
GS	Grama Sevaka Division

REPORTS

MGDP	Master Plan Mahaweli Ganga Development Project (UNDP/FAO, 1968)
AMDP	Accelerated Mahaweli Development Programme (NEDECO, 1977)
ISS	Implementation Strategy Study (NEDECO,1978)
HCP	Hydrological Crash Programme (NEDECO, 1981)
TDS	Transbasin Diversion Study (Electrowatt, 1981 & 1984)
MWRMP	Mahaweli Water Resources Management Project (ACRES,1986)

ABBREVIATIONS OF MEASUREMENT

Length

cm = Centimeter
m = Meter
km = Kilometer
ft = Foot
yd = Yard

Area

cm^2 = sq.cm = Square centimeter
m^2 = sq.m = Square meter
ha = Hectare
km^2 = sq.km = Square kilometer

Volume

cm^3 = cu.cm = Cubic centimeter
l = lit = liter
kl = Kiloliter
m^3 = cu.m = Cubic meter
gal. = Gallon
MCM = Million Cubic Meters

Weight

mg = Milligram
g = Gram
kg = Kilogram
ton = Metric ton
lb = Pound

Time

sec = 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 centigrade
10^3 = Thousand
10^6 = Million
10^9 = Billion (milliard)

Derived Measures

m^3/s = m^3/sec = 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

Money

Rs. = Sri Lanka Rupees
US$ = US dollar
Yen = Japanese Yen

CONVERSION FACTORS

	From Metric System			To Metric System		
Length	1 cm	=	0.394 inch	1 inch	=	2.54 cm
	1 m	=	3.28 ft = 1.094 yd	1 ft	=	30.48 cm
	1 km	=	0.621 mile	1 yd	=	91.44 cm
				1 mile	=	1.609 km
Area	1 cm^2	=	0.155 sq.in	1 sq.ft	=	0.0929 m^2
	1 m^2	=	10.76 sq.ft.	1 sq.yd	=	0.835 m^2
	1 ha	=	2.471 acres	1 acre	=	0.4047 ha
	1 km^2	=	0.386 sq.mile	1 sq.mile	=	2.59 km^2
Volume	1 cm^3	=	0.0610 cu.in	1 cu.ft	=	28.32 lit
	1 lit	=	0.220 gal. (imp.)	1 cu.yd	=	0.765 m^3
	1 kl	=	6.29 barrels	1 gal. (imp.)	=	4.55 lit
	1 m^3	=	35.3 cu.ft	1 gal. (US)	=	3.79 lit
	10^6 m^3	=	811 acre-ft	1 acre-ft	=	1,233.5 m^2
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 cusec	=	0.0283 m^3/s
	1 kg/cm^2	=	14.2 psi	1 psi	=	0.703 kg/cm^2
	1 ton/ha	=	891 lb/acre	1 lb/acre	=	1.12 kg/ha
	10^6 m^3	=	810.7 acre-ft	1 acre-ft	=	1,233.5 m^3
	1 m^3/s	=	19.0 mgd	1 mgd	=	0.0526 m^3/s

EXCHANGE RATE

US$1.0 = J. Yen 140.0 = Rs. 32.5

1. INTRODUCTION

1.1 Authorities

This report is prepared in accordance with the Scope of Work agreed upon between MMD and JICA in October 1987, and presents the results of the Phase-II study of the Extension of the Moragahakanda Agricultural Development Project (hereinafter referred to as the Phase-II study).

The objectives of the Phase-II study are to formulate an overall agricultural development plan (Master Plan) in the Amban Ganga basin for (1) the most effective use of available water in the Mahaweli river systems for irrigation development in the Amban Ganga basin and its adjacent areas, and (2) priority irrigation projects and the proper implementation of these projects.

The studies were performed mainly for the establishment of possible diversion plans from the Mahaweli Ganga to potential agricultural development areas, and study on potential water resources development in the Mahaweli Ganga, its tributaries and the catchment areas of the study area.

The possibility of a transbasin diversion plan to the North Central River Basin (NCRB) and the North West Dry Zone (NWDZ) was assessed in consideration of topographic conditions, the results of soil surveys and previous studies. This report was mainly prepared to establish the future overall agricultural development plan in NCRB and NWDZ based on the results of the surveys and studies.

1.2 Background of the Study

In the 1960s, GOSL promoted the Mahaweli Ganga Development Project to attain self-sufficiency in foodstuffs, increase job opportunities and to eliminate the shortage of electric power. This project aims to develop potential arable land in the central and north-central parts of Sri Lanka by supplying water diverted from the Mahaweli Ganga and its tributaries blessed with abundant water resources. In 1968, a master plan for the Mahaweli Ganga Development, prepared with the assistance of UNDP/FAO, proposed irrigation development of about 365,000 ha and hydropower development of 500 MW in capacity. The Government has proceeded with development in the Mahaweli Ganga basin since 1968 based on this master plan.

Since the implementation period of the master plan was over 30 years, in 1977 the Government revised the master plan to accelerate the Mahaweli Development Programme to yield the quickest return to the nation. The revised plan, called the Accelerated Mahaweli Development Programme (AMDP), involves (1) irrigation development of about 204,000 ha with 8 irrigation systems, from A to D, G, H, IH and MH, and (2) hydropower development schemes of about 470 MW in installed capacity through the construction of 5 dams: Kotmale, Victoria, Randenigala, Moragahakanda and Maduru Oya dams.

In 1978/1979, GOSL carried out the Implementation Strategy Study on the Mahaweli Development Programme (ISS) to formulate an optimum development strategy and policy. As regards the Moragahakanda reservoir only, it resulted in the irrigation functions of the Moragahakanda reservoir in AMDP being taken over by the Kotmale reservoir, and recommended that more detailed studies should be done at a later stage in conjunction with the study of the NCRB area, and that special attention should be given to downstream development.

In 1979-1981, GOSL also conducted a study on the Hydrological Crash Programme (HCP) which had the main objectives of (1) collecting high and low river flow data and (2) checking and where possible upgrading the existing hydrological data base in the potential development areas by using water resources of the Mahaweli Ganga. Based on HCP, the hydrological data-base system was established and had been available for use in further water resources development planning.

In 1980-1984, GOSL carried out the Transbasin Diversion Study (TDS) covering potential irrigation area in SEDZ, NWDZ and NCRB. All possible conveyance systems between the Mahaweli Ganga and SEDZ, NWDZ, and NCRB were studied and compared. It was recommended that development of SEDZ be given high priority among these zones, followed by NWDZ, then NCRB. Moreover, it was recommended that the Polgolla diversion policy should be examined in consideration of (1) variation of the policy as a means of irrigating more land in NWDZ, assuming the existence of high Moragahakanda reservoir, and (2) a more precise determination of the optimum active capacity of the Moragahakanda reservoir needed in conjunction with the development of sub-system NW1 in a part of NWDZ.

In 1983-1985, GOSL carried out a study on the Mahaweli Water Resources Management Project (MWRMP) to maximize economic and social benefits. It is noted that through the water balance study in committed Mahaweli Ganga development areas, Mahaweli complex stations (Kotmale, Victoria Randenigala, Rantembe, Ukuwela, and Bowatenna) and K-M complex stations (Canyon, New and Old Laxapana, Samanala and Wimalasurendra hydropower stations) excluding the Moragahakanda reservoir, an expansion area of 18,500 ha in Systems A, B and D1 could be irrigated within reasonable reliability. In addition to this expansion, a preliminary examination of the availability of water in the lower Mahaweli Ganga at Minipe indicated that approximately 470 MCM per annum could be diverted by new conveyance works for potential arable areas. System H should receive priority over energy generation as the firm energy capability of the electrical system is not jeopardized. In the MWRMP report, it is also suggested that given the social and regional development benefits of fostering irrigated agriculture in the existing Amban Ganga irrigation area, it is unlikely that significant reduction in the Polgolla diversion could be justified, unless saving water use in Systems D, G and H could be achieved.

In 1985-1986, GOSL also carried out the second TDS based on the recommendation as the result of the first TDS in 1981-1984, mainly to analyze options for the diversion of water from the Mahaweli Ganga to the Amban Ganga basin, and to make recommendations concerning the policy to be adapted for such diversions. In order to evaluate the consequences of carrying the Polgolla diversion, the Acres Reservoir Simulation Programme (ARSP) which was developed in 1983-1985 was used for water balance

simulation in the study. It was showed that maximum new land, about 14,700 ha to 17,800 ha at the most, could be served by diverting additional water from the Mahaweli Ganga at Polgolla within the range of 813 MCM to 955 MCM per annum, and providing a second additional irrigation tunnel at the Bowatenna reservoir and a reservoir capacity of 250 MCM on the Kalu Ganga.

Since 1978, the Government has commenced the implementation of hydropower generation and irrigation development projects in the Mahaweli Ganga basin as recommended in AMDP in 1977. As of 1987, the Government had almost completed four multi-purpose dams on the Mahaweli Ganga and one multi-purpose dam on the Maduru Oya with a hydropower generating capacity of 611 MW and irrigation development areas of about 135,000 ha in total irrigated with water of the Mahaweli Ganga, the Amban Ganga and local catchment according to AMDP. In the hydropower development sector, GOSL obtained good results exceeding the sector target of 470 MW in AMDP. On the other hand, irrigation development has been slower; irrigation systems covering only about 135,000 ha have been or are being implemented, corresponding to about 67% of the sector target.

Accordingly, GOSL intends to promote irrigation development based on the following basic concepts:

- to make the most effective use of the water resources in the Mahaweli river system for irrigation development considering the required water distribution to irrigation systems and hydropower generation,

- to maximize the irrigation area with available water and to increase crop intensity in the existing irrigation areas, and

- to work out a proper implementation programme for irrigation development considering the present difficulties in implementation, socio-economic conditions, development priorities, etc.

As discussed in the preceding paragraph, GOSL is going to complete the principal components of AMDP except System A and the Moragahakanda Agricultural Development Project. GOSL maintains a strong policy to complete AMDP, even though about 10 years has passed since completion of the feasibility study on the Moragahakanda Project. However, socio-economic conditions in the country have greatly changed since completion of the said feasibility study, and such changes have adversely affected the implementation schedule of irrigation development proposed in AMDP and the Moragahakanda project.

GOSL therefore requested GOJ in March 1986 to review and update the Feasibility Study on the Moragahakanda Agricultural Development Project prepared by JICA in 1979 (Phase-I), and to formulate an overall development plan (Master Plan) in the Amban Ganga basin (Phase-II). In response to the GOSL's request, GOJ sent a JICA Preliminary Survey Team in October 1987. The Scope of Work for the Study of Extension of the Moragahakanda Agricultural Development Project and the Minutes of Meeting were agreed upon and signed on 28th October 1987 between MMD and JICA. The updating of the Moragahakanda Agricultural Development (Phase-I) was completed in May 1988. GOSL decided to implement this project and to take appropriate action for its implementation.

AMDP will be completed upon implementation of the Moragahakanda project. Accordingly GOSL requested GOJ to formulate an overall development plan (Master Plan), to make the most efficient use of water resources in the Mahaweli Ganga and its tributaries, as well as local inflows to proposed agricultural development areas.

1.3 Works Performed

In accordance with the Scope of Work agreed upon between MMD and JICA, formulation of an overall agricultural development plan (for Phase-II Study) has been carried out by the JICA team in collaboration with experts assigned from MASL, MECA, MEA, ID, MADR, the University of Colombo and CECB. The Scope of Work is attached in APPENDIX, and members of the counterpart and JICA team are listed in Table 1.

The field work was carried out in two stages. The first stage, during the three (3) months from February to April 1988, was mainly concerned with collection of general information and hydrological data in the study area. The second stage, covering the five (5) months from July to December 1988, included topographic survey, geological and soil mechanical surveys at Kalu Ganga damsite, meteo-hydrological study, soil and land use survey, irrigation and drainage survey, survey of the existing agricultural conditions, socio-economic survey, conceptional study of environmental conservation, electric power study, survey on price of construction materials and construction costs, formulation of alternative plans of water resources development, establishment of a basic overall agricultural development plan, etc, and the findings and results were compiled in a Progress Report. In December 1988, the JICA team submitted the Progress Report which contained the progress of the study and major findings of the field works.

The results of field surveys and studies were further elaborated in Tokyo and all the study results are compiled in this report. The supporting studies and basic data of the report are compiled in two volumes of ANNEXES and a volume of DRAWINGS.

1.4 Acknowledgement

During the execution of studies, the study team, both the JICA team and counterparts, received generous assistance and cooperation from the authorities concerned both in Colombo, at the site and in Tokyo. The team takes this opportunity to express its sincere gratitude to all the individuals, authorities, agencies, etc. concerned. The study team furthermore hopes that the joint efforts and cooperation extended to the study will contribute to the establishment of a long-term agricultural development plan in the study area and eventually to socio-economic development in Sri Lanka.

2. BACKGROUND

2.1 Land and Population

The total land area of the country is 65,610 km^2. Administratively, Sri Lanka is divided into nine (9) Provinces, the Provinces into Government Agency divisions which are called GA divisions or Districts, the Districts into Assistant Government Agency (AGA) divisions, and the AGA divisions into Grama Sevaka (GS) divisions as shown in Fig. 2.

Sri Lanka had a population of 16.4×10^6 in 1987, corresponding to 249 persons/km^2. The growth in population was about 1.63% per annum during the period from 1981 to 1987. The population in the year 2020 is expected to be 24.0×10^6 as shown in Table 2 and illustrated in Fig. 3. The labour force was estimated at 6.6×10^6 in 1987 and therefore the labour participation rate was 40.4%. The unemployed population in 1987 was estimated at 1.19×10^6, corresponding to an 18.0% unemployment rate. "Report of the High Level Committee of Officials on Poverty Alleviation through People-based Development" forecasts that the unemployment rate would increase to 21% by 1990.

2.2 National Economy

The Gross Domestic Product (GDP) of Sri Lanka was estimated at Rs. 177.7×10^9 in 1987. Although the national economy achieved stable improvement up to 1986, the growth of GDP in 1987 fell to 1.5% per annum in real terms. Per capita GDP was estimated at Rs. 10,863 (about US$350) in 1987 as shown in Table 3. The share of the agricultural sector in total GDP stayed at the same level of around 27% in 1987. Paddy production, however, decreased to 2.13×10^6 tons or 17.8% down compared with the production of 2.59×10^6 tons in 1986. The main reason for this decline was the prolonged drought conditions. The agricultural sector absorbed 45.5% of employed labour, aggregating 2.5×10^6 in 1987. In the national economy, the leading growth sector for the recent five years was the manufacturing subsector, which attained an average growth rate of 6.6% per annum. In addition, the mining and quarrying subsector and the finance subsector have recorded higher growth rates during the same period.

Government fiscal performance reflects the economic development policy which aims at attaining an increase of both employment opportunities and family incomes in order to improve living standards in the country. It has shown the following conspicuous characteristics in recent years: (1) expenditure has increased since 1977 and kept the level of expenditure to GDP at more than 18% except in 1984 which was about 9% in 1977, and (2) to meet the budget deficit Government finance has depended on domestic and foreign loans. Owing to retrenchment in expenditure in recent years, the ratio of net cash deficit to GDP has gradually declined year by year. Despite these budgetary constraints, the Government aims to maintain its comprehensive development policy.

Since 1987 the Colombo consumers price index has increased at a rate of more than 10% per annum. In 1985, it was 1.5%, but in 1986 and 1987 it increased to 8.0%. The price increases are thought to be caused mainly by the following economic factors: (1) a high degree of dependence upon imports; and (2) the upward trend in the prices of

subsidized consumer commodities and in public utility prices because of retrenchment in Government expenditure. The wholesale price index has also recorded a high rate of increase since 1978. Afterwards, the index declined sharply by 14.7% in 1985 and 2.9% in 1986. These declines were caused to a great extent by the drop in export prices of tea and coconut products. In 1987, the index again increased by 13.4% per annum.

Foreign trade is one of the most important economic activities for Sri Lanka. Since 1977 foreign trade has rapidly increased because of import liberalization. The Sri Lankan economy being sensitive to foreign trade trends, fluctuations of international prices of agricultural products, particularly tea, rubber and coconut directly influence the national economy.

Plantation products have played an important role in exports, but their proportion of total exports has gradually decreased. In particular, the trade amount of tea exports has increased slowly in recent years because of competitive markets, accounting for about a half of the total export in 1978 down to a quarter in 1987. On the other hand, industrial products such as textiles and garments in particular have grown as major export articles. Their share of 48.6% of total exports in 1987 exceeded the agricultural share of 42.4% (see Table 4). As regards imports, the share of consumer commodities seems to go down because of self-sufficiency endeavours. On the other hand, intermediate goods, petroleum in particular, represent a large portion of the total imports. Investment goods have grown at a high rate because of the development policy of the Government.

2.3 Agriculture in Sri Lanka

Agriculture dominates the national economy of Sri Lanka, contributing about 27% of GDP and employing about 45% of the total work force in 1987. The active population involved in agriculture related activities will be more than 50% of the national active population. Agriculture will continue to concentrate on the outstanding staples and provide the main support for the national revenue of Sri Lanka.

The climate of Sri Lanka is suitable for year-round cultivation, and variations in precipitation, topography, temperature and soils enable production of a wide range of crops. The production of agricultural crops accounted for 42.4% of total export earnings in 1987. The main export crops are tea, rubber and coconut of which the production was approximately 213×10^3 tons, 122×10^3 tons and $2,291 \times 10^6$ nuts respectively in 1987. The main crop is rice, of which the production was about 2.59×10^6 tons of paddy in 1986 and decreased to about 2.13×10^6 tons of paddy in 1987 due to prolonged drought condition as shown in Table 5. The average net cultivated areas and production during the period of 1983-87 are summarized below:

Item		Maha	Yala	Total
Net cultivated Area	(10^3 ha)	500	274	774
Production (Paddy)	(10^3 tons)	1,595	860	2,455
Yield per ha	(tons/ha)	3.19	3.14	3.17

Source : Paddy Statistics 1983-87

Self-sufficiency in foodstuffs, especially in rice, has been one of the main targets of the Government. Rice production has increased significantly in recent years to near self-sufficiency level. However, rice production is still vulnerable to weather conditions due to the lack of irrigation water in the Yala season. In fact, rice production in 1987 was seriously affected by drought as illustrated in Fig. 4.

Irrigation is essential for cultivation in the Yala season and some supplemental irrigation is necessary for Maha season cultivation. Irrigated rice production in Sri Lanka is a long-practiced and well-understood art using the traditional tank system. Traditional irrigation schemes are based on storage tanks designed to supplement irrigation water to Maha crops, and to store residual water used for the limited Yala season cropping. There are 180 such schemes in total having a storage capacity in excess of 2.5 MCM and countless of smaller schemes. The responsibilities of operation and maintenance of these schemes are borne by the farmers, and only the major headworks and canals come under the Government's purview.

The current policies of the Government emphasize (1) attainment of the self-sufficiency of the important basic food crops such as rice, maize, sugar, beans, etc., (2) expansion of exports of agricultural products and diversification of export crops, and (3) improvement of income levels and employment in rural areas. In addition, for the long-term, the Government is emphasizing expansion of irrigated agriculture with proper operation, improved water management practices, and introduction of appropriate cropping systems, and a substantial increase in cropped area into the dry zone through the development of Sri Lanka's major river basins, such as the Mahaweli Ganga basin.

2.4 Infrastructure

(1) Electricity

The entire public power supply system is managed and operated by the Ceylon Electricity Board (CEB), which is the statutory body of the Government. CEB supplies electrical power and energy to consumers both directly and indirectly through the Lanka Electricity Company (LECO).

CEB owned powerplants of 1,116 MW in total installed capacity in 1987, consisting of 916 MW of hydropower plants and 200 MW of thermal power plants. Hydropower plants can generate 3,682 GWh under normal hydrological conditions, and under very dry conditions, hydro energy falls to a firm level of 2,538 GWh giving a firm energy output of 3,803 GWh with thermal energy.

In 1987, the annual power demand in the CEB system was 2,253 GWh in sold energy and the peak demand was 570 MW. The length of power transmission lines was 1,688 km in 1987, consisting of 122 km of 220 kV line, 1,199 km of 132 kV line, and 367 km of 66 kV line. The Government has continuously promoted electrification and expansion of distribution lines. The rural electrification programme is being conducted with the assistance of foreign aids. The future demand is expected to grow at about 9% per annum, so additional installations of powerplants will be required annually.

(2) Transportation

Trunk lines such as the national roads A-1 to A-4 start from Colombo towards Kandy, Trincomalee, Galle, Anuradhapura, etc. the capital cities of each District, as shown in Fig. 5. They are completely asphalt-paved. Re-alignment and widening of the pavement as well as improvement of bridges are undertaken to some extent with the assistance of foreign aid. The railway network also connects major District capital cities, Colombo, Galle, Kandy, Batticaloa, Trincomalee, Anuradhapura, Jaffna, etc.

Marine transportation is provided in the ports of Colombo, Galle and Trincomalee. Colombo port has been developed to international port standards in order to cater for the increased traffic of the country. The first stage of the Colombo port expansion project was completed in 1987. It is expected that marine transportation will increase with the enhancement of port facilities. Katunayake International Airport is located at about 18 km north of Colombo handles air traffic.

(3) Agricultural Support Services

Agricultural support services provide essential assistance to small-holders. They foster significant changes in production and livelihood through research, extension, credit, proper marketing and other forms of support.

Research : Agricultural research is conducted by 15 research institutions under 7 Ministries and the Office of the President. In 1986, Councils of Agricultural Research Policy (CARP) was established to formulate an overall strategy for research by each institution and to set national research policy.

Extension services : The Department of Agriculture (DA) is dominantly in charge of extension services for paddy and upland production. Although the Department of Agrarian-Service (DAS) is mainly in charge of distribution of agricultural inputs, it instructs farmers in extension besides input services. Private firms distributing agricultural inputs give extensive information to farmers as well.

Credit : Agricultural credit for cultivation loans is provided through the following four channels: the People's Bank, the Bank of Ceylon, the Hatton National Bank, and the Regional Rural Development Bank (RRDB). The New Comprehensive Rural Credit Schemes (NCRCS), established in 1986 to promote flexibility of loans, is provided through RRDB.

Marketing : There are two principal marketing channels, public and private. In public marketing of paddy, the Ministry of Agricultural Development and Research is the leading ministry through the Paddy Marketing Board (PMB), other are agencies and Co-operatives. In addition, the Food Commissioner (FC) of the Ministry of Food plays an important role in distribution. The private free marketing channel is commonly from farmers (1) to farm-unit assembles, (2) to truck buyers and (3) to rice millers, etc. After enforcement of the liberalization policy, the share of the public marketing channel has gone down to about 10% of the production. In

subsidiary food crops, the following agencies work in the public marketing channel: the Marketing Department, Co-operative Marketing Federation (CMF) and Co-operative Wholesale Establishment (CWE). The relationship between public and private marketing channels for food crops is in the same situation as in paddy marketing.

2.5 Water Resources Development

Irrigation development in Sri Lanka has a long history and there are many ancient tanks scattered all over the northern part of the island. The total wet paddy area is about 500,000 ha (in net area) comprising 210,000 ha of major irrigation schemes, 115,000 ha of minor irrigation schemes and 175,000 ha of rainfed paddy areas. Due to lack of irrigation water in the dry season, rice production is still vulnerable to weather conditions. GOSL wishes to maximize the irrigation area with reliable water supply and to increase cropping intensity in the existing irrigation areas.

About 135,000 ha of agricultural lands are currently irrigated with the water of the Mahaweli Ganga, the Amban Ganga and local catchment areas under AMDP, as shown in Table 6. A part of these irrigation systems located in the Amban Ganga basin was realized by the development of water resources of the Mahaweli Ganga upon completion of the Polgolla and Bowatenna diversion works. The Polgolla diversion provides Mahaweli water to Systems H, IH and MH through the Bowatenna irrigation tunnel, and to Systems D1, D2 and G. In the Mahaweli Ganga basin, irrigation water is supplied to System E through the Minipe LB canal, to a part of Systems B and C which are under construction through the Minipe RB canal, and to the existing Allai scheme in System A located in the lowest Mahaweli Ganga basin.

Hydropower development was expedited to eliminate the shortage of electric power in the 1960s. Based on the UNDP/FAO master plan (Ref. 3), Ukuwela and Bowatenna hydropower stations were constructed in 1976 and 1981 respectively. In 1977, the Government revised the master plan to accelerate the Mahaweli Development Programme (AMDP). According to AMDP, hydropower in recent years has been developed as a component of multipurpose dam development: the Kotmale, Victoria, Randenigala, Maduru Oya multipurpose dams which were constructed in the early 1980s. The Samanalawewa and Rantembe hydropower stations are under construction. A list of existing hydropower plants and dams is presented in Tables 7 and 8.

GOSL has been paying attention of the systematic development of land and water resources to prepare the future economic development. Water resources development is one of the most important components.

2.6 Rationale of the Study

Production of adequate quantities of food, especially rice to satisfy the requirements of the increasing population in Sri Lanka, is one of the main aims of the long-term development strategy and food security strategy. With the present rate of population growth, the population in the years 2000 and 2020 would be about 19.9×10^6 and 24.0×10^6, respectively (see Table 2). As described in Section 4.2 "food balance studies", demands

for rice will increase year by year. To meet the demand for rice, stable rice production will be essential under reliable water supply.

Various measures will be continuously taken to meet water demand adequately in accordance with the proper long-term agricultural development plan. Average annual natural runoff at Manampitiya was estimated at 8,330 MCM, of which about 4,000 MCM, or 48%, would be used for 200,300 ha of irrigation area after completion of 65,300 ha of the committed development area under AMDP. However, there is still potential for use of the remaining surplus water of about 4,300 MCM which is wasted to sea, by providing proper conveyance systems and proper regulation dams and tanks.

The energy demand in Sri Lanka will have to be met predominantly by fossil fuel in the future. In this connection, hydropower to be made possible by construction of dams will be desirable to save fossil fuel as much as possible.

The present study will make clear the time and scale of agricultural development and dam construction for the future by selecting the most suitable conveyance system from the Mahaweli Ganga to other basins.

3. THE STUDY AREA

3.1 Previous Studies

In 1980-84, GOSL carried out a study on TDS covering potential irrigable areas in SEDZ, NWDZ and NCRB. Possible conveyance systems between the Mahaweli Ganga, and SEDZ, NWDZ and NCRB were studied and compared (Ref. 27). It was concluded that development of about 40,000 ha in SEDZ was given higher priority, followed by NWDZ, then NCRB. Development of NCRB was given the lowest priority due to the high capital costs and high O&M costs for a pump station.

Based on the results of TDS in 1981-84, the second TDS (Ref. 16) was performed in 1985/86, mainly to analyze options for the diversion of water from the Mahaweli Ganga to the Amban Ganga basin which would serve potential irrigable areas in System D1 and NWDZ. It was noted that maximum irrigation areas of about 14,000 ha to 17,000 ha in System D1 and NWDZ could be served by diverting additional water from the Mahaweli Ganga at Polgolla within the range of 813 to 955 MCM, and providing a second additional tunnel at the Bowatenna reservoir and a new reservoir with a storage capacity of 250 MCM on the Kalu Ganga.

3.2 The Study Area

The study area consists of the existing irrigation areas in Systems H, IH and MH, and potential area in Systems F, I and M in NCRB, and NWDZ. The study area is briefly described below:

(1) Systems H, IH and MH

System H is located in the Kala Oya basin, System IH in the Malwatu Oya basin and System MH in the Yan Oya basin as shown in Fig. 1. Major part of these systems lies in Anuradhapura district, and remaining part in Matale and Kurunegala districts as shown in Fig. 2. These systems receive Mahaweli water through the Polgolla and Bowatenna diversion tunnels. Diverted water and local runoffs from their own catchment areas are once stored in major irrigation tanks, i.e. Dambulu Oya, Kalawewa, Rajangana,Huruluwewa tanks, etc. and regulated flows are supplied to respective irrigation areas having ancient origins.

However, as discussed in ANNEXES-E, F and I, and MWRMR (Ref. 18), these systems are facing shortage of irrigation water specially during the Yala season. Cropping intensity is low, ranging from 0.9 to 1.7 as seen in Table 17, and irrigated agriculture in these systems is still vulnerable to weather condition due to the lack of irrigation water in the Yala season.

(2) NCRB Area

Potential irrigable areas in NCRB consist of five Systems I, J, K, L and M, which were originally identified by UNDP/FAO in 1968 (Ref. 3), were subsequently

studied in ISS in 1979 (Ref. 7) and in TDS in 1981/84 (Refs. 14 and 15). The locations of these systems are shown on Figs. 1 and 16, and layout is shown in DRAWINGS. In TDS, some modification of the boundaries which were delineated by UNDP/FAO was made and recommended on the basis of the results of the detailed soil surveys. In this study, potential irrigable areas newly proposed in TDS was adopted with some minor modification, and the details are described in ANNEX-E. The potential irrigable area and local inflows to the proposed tanks in five Systems are shown in Tables 10 and 26, and summarized as follows:

	Gross Extent (ha)	Potential Net Irrigation Area (ha)	Local Inflow to Proposed Tank (MCM)
A. Study Area			
I	144,500	53,300	319
M*1	142,700	41,300	253
B. Potential Arable Area			
J	54,000	21,800	241
K	31,000	9,000	40
L	96,000	34,600	196

Remarks: *1 Including System MH.

(3) NWDZ Area

The NWDZ area is located in the Mi Oya and Deduru Oya basin as shown in Figs. 1 and 16, however due to limitation of available water which was permitted to divert at Polgolla, only NW1 area in the Mi Oya basin, a northern part of NWDZ delineated in TDS (Ref. 16), would be irrigated with reliable water supply. The irrigation layout for NW1 adopted in the second TDS (Ref. 27) was used for this study as shown in DRAWINGS.

As indicated in the results of the second TDS, it may be difficult to supply water without increasing diversion water at Bowatenna to System H. Under the fixed diversion policy at Polgolla, i.e. 875 MCM for long term average, the only way to increase diversion water at Bowatenna will be by decreasing downstream release through the Bowatenna hydropower station and the on-going Moragahakanda project.

Even under the present conditions in Systems H, IH and MH, almost all of the Systems are facing shortage of irrigation water, and the cropping intensity in 1981-87 was within a range of 0.9 to 1.7 (refer to ANNEX-E). Therefore, increasing cropping intensity in these Systems will be given high priority in the water balance study, since existing irrigation systems are available and ready for increasing cropping intensity with only minor investment.

3.3 Regional Economy

The study area consists of Systems F, H, IH, MH, I and M, and NWDZ. The study area is scattered in the following eight Districts: Matale, Mannar, Vavuniya, Trincomalee, Kurunegala, Puttalam, Anuradhapura and Polonnaruwa. In this sub-section, these eight Districts are named as the administrative study area.

The study area is a typical rural area in Sri Lanka and its dominant industry is agriculture, especially paddy production. The administrative study area occupied 27,000 km^2 or 41% of the country in 1981 census year. Regarding paddy production, the administrative study area produced $699x10^3$ tons in 1986/87 crop season, accounting for 33% of the national production. Incidentally, the gross extent harvested area occupies approximately 200,000 ha or 29% of the national gross extent harvested area and about 150,000 ha of net irrigable area in system schemes. The population in the study area was estimated at $349x10^3$ in 1981 or 10% of the administrative study area.

Minor food crops are generally grown in scattered homestead gardens. Therefore it is difficult to estimate their production in a statistical manner. Among several minor food crops, however, the study area produces more than three-quarters of the national production with regard to the following crops: mustard, soybean, gingelly, black gram and Bombay onion.

Livestock and poultry production relies on crop production oriented farmers, although there are a few small-scale ranches in rural area. Cattle and buffalo populations in the study area were $683x10^3$ and $464x10^3$ in 1987 accounting for 45% and 52% of national population, respectively. Meanwhile, the shares of sheep and pig populations were smaller than those of cattle and buffalo, accounting for 26% and 46% of the country.

In 1986, Sri Lanka produced $35x10^3$ tons from inland fishery, or around 20% of the national fishery production of $183x10^3$ tons. The administrative study area produced $15.9x10^3$ tons of inland fish or 45% of the national inland fishery production.

Concerning industrialization, the study area is quite backward at present. Of all industrial fields, however, the following four industrial groups exceeded a quarter of the country in terms of number of establishments: (1) food, beverages and tobacco; (2) wood and wood products; (3) non-metallic mineral products; and (4) machinery and equipment. Even in these groups, most of establishments were small-scale following two industrial groups exceeded a quarter of the national industrial production: (1) Mining and quarring; and (2) non-metalic products.

The main transport facilities linking or running through the study area to prospective major market places of Colombo, Kandy and Trincomalee are road and railway networks. The major national trunk roads concerned in the study area are as follows: A-3 connects Colombo and Puttalam; A-5, Kandy and Batticaloa; A-6 Colombo and Trincomalee; A-9, Kandy and Jaffna via Matale, Anuradhapura and Vavuniya; A-10, Kandy and Puttalam; A-11, Anuradhapura and Batticaloa, and A-12, Puttalam-Trincomalee as shown in Fig. 5. Other paved or graveled roads connect these trunk roads to villages, and villages to villages. They provide important transportation facilities for marketing of agricultural inputs and

outputs. At present, substantial quantities of farm products, particularly rice, are transported by trucks.

3.4 Topography and Geology

The topography of Sri Lanka is characterized by three steps of peneplains composed of high, middle and low plains, being more than 750 m, 90-750 m and less than 90 m in altitude respectively. The high peneplain corresponds to the so-called central highland surrounding Nuwara Eliya. The middle and low peneplains are surrounding the central highlands and decrease in height gradually toward the coast.

The Mahaweli Ganga rises in the high peneplain and flows down to the Indian Ocean through the middle and low peneplains. The study area is divided into the dam and reservoir areas, and agricultural areas. The former is located on the high to middle peneplains and the latter extends on middle to the low peneplains in the lower Mahaweli Ganga, and other rivers.

The geology of the study area is composed of very old, highly crystalline metamorphic rocks, so-called Highland series (Pre-Cambrian) and Vijayan series (Cambrian). The proposed damsite areas are located mainly on the region of the Highland series, and agricultural areas are on both series. Geological map of Sri Lanka is presented in Fig. 6.

The Highland series is classified into three groups by its rock types; these are Khondalite group, Charnockites and Kadugannawa gneisses. The Vijayan series are Cambrian polymetamorphic rocks, formed by metamorphism of the Highland series rocks (Pre-cambrian). The above two series are classified by metamorphic grade, and there is a transition zone of complicatedly mixed with the two series. The transition zone develops along the both banks of the Mahaweli Ganga from south to north 16 to 19 km in the width. East side of the transition zone lies on the Highland series region and west side on the Vijayan series region.

The geological structure of the Highland series region is characterized by a series of parallel folds, NNE-SSW in direction. The Vijayan series region and transition zone have also many folds, but in those regions, the folding direction is less uniform and less continuous than in the Highland series region. Dipping of the rock beds of these two series is generally gentle.

Quaternary deposits cover over the above base rocks. One of these deposits is river bed deposits along the Mahaweli Ganga, its tributaries and other rivers. The others are reddish brown or light brown coloured sand, silt and loam, which prevail over most of the project area. The river bed deposits are generally loose unconsolidated sediments, composed of sandy silt and clay, sometimes containing gravels.

3.5 Meteorology and Hydrology

The climate of Sri Lanka is characterized by tropical monsoons with dry and rainy seasons, i.e. the south-west monsoon from April to September (Yala season), and the

north-east monsoon from October to March (Maha season). The central highlands have a strong orographic influence in connection with the direction of monsoons, and lead to the subdivision of Sri Lanka into three hydrological zones, i.e. the wet zone, intermediate zone and dry zone as shown in Fig. 7. The dry zone is defined as the area where the annual evaporation exceeds the annual rainfall, and the wet zone as the area where the annual rainfall exceeds 2,000 mm. The intermediate zone is a transition zone between the wet zone and the dry zone. The potential irrigable areas mainly lie on the dry zone where rainfall occurs predominantly during the Maha, while the Yala season is very dry. The area of water source belongs to the wet and intermediate zones.

The study area is located in the north-west and north central to east dry zones. Taking into account the regional difference in meteorological conditions, the area was divided into two sub-areas, which are represented by Anuradhapura and Trincomalee. Data at these two meteorological stations are presented in Table 11. 11 representative rainfall gauging stations were selected for the estimate of irrigation water demand and the data are summarized in Table 12.

The monthly mean temperatures at two stations show a little variation throughout the year, ranging from 25°C to 30°C. Both monthly mean daily maximum and minimum temperatures range from 27°C to 35°C and from 20°C to 26°C, respectively. The lowest temperature usually occurs in January and the highest in May and June. The monthly mean relative humidity ranges between 60% and 90%. Annual pan evaporation ranges between 1,587 mm at Aluthrama and 2,184 mm at Kantalai. The annual rainfall ranges from 1,335 mm at Anuradhapura to 2,087 mm at Horaborawewa. About 70-77 % of total annual rainfall concentrates in October to February reflecting the north-east monsoon. The daily mean sunshine hours are 6.3 to 7.8 hours. They are longest in March and shortest in December. The wind velocity is 2.2 to 3.4 m/sec on average. The mean meteorological data in the study area is illustrated in Fig. 8.

The hydrological network in Sri Lanka is administrated by ID. There are 11 water level gauges in the Mahaweli Ganga including its tributaries and 9 gauges in other river basins of the study area. Some gauges have daily water level records since 1940. In 1979-81, hydrological observation was intensively carried out under HCP. Based on HCP, the hydrological data-base system has been established and is available for use in future water resources development planning. In 1983-85, under MWRMP, the hydrological monthly data-base was prepared for the period of 1949-81 on the basis of the results of HCP and ISS.

A hydrological study was carried out to estimate the inflow into the proposed dams and the runoffs at the water level gauges which were incorporated in the water balance study. Since transbasin diversion schemes and several multipurpose dams on the Mahaweli Ganga were commenced in the 1970s and the early 1980s respectively, the natural runoff from its own catchment area was duly calculated in consideration of the actual release from reservoirs and transbasin diversion water during the period of 1981-86, to keep the continuity of data.

The study period was set as the 37 years period of 1949-1986. The annual mean natural runoffs at major gauging stations and major existing and proposed dams are

summarized in Table 13. The annual natural runoff at Manampitiya located in the lower Mahaweli Ganga was estimated to be 8,330 MCM. Details of hydrological analysis and 37-year monthly natural runoffs are complied in ANNEX-B. The summary of flow patterns at the main points are illustrated in Fig. 9. The mass-curve at main points and dams are illustrated in Fig. 10. Runoff patterns at the main points show that the years 1949-72 were wet years, however 1972-83 was observed as a continuous dry spell especially in the dry zone. As far as the runoff pattern is concerned, there are very clear wet and dry spells in the dry zone.

3.6 Soils and Land Suitability

The semi-detailed soil survey and land classification in NCRB, NWDZ and SEDZ were carried out during the period of 1980/81 under TDS with an observation density of one per 270 ha for the entire survey area of 12,200 km^2 (Ref. 15). Soil maps and land classification maps were produced at a scale of 1/50,000, and reduced to 1/100,000 for the final presentation of TDS. The soils were classified according to the USDA Soil Taxonomy and the recently developed Sri Lanka classification system. In addition to the above, the review of previous studies, additional soil survey in System F, as well as the supplemental field checking and confirmation in NWDZ and NCRB were performed, then soil maps were prepared. Semi-detailed soil maps and, land classification maps in the study area are attached in DRAWINGS. The results are summarized as follows and the details are shown in Table 14, and a national soil map indicating the study area is shown in Fig. 11:

(Unit: ha in Gross)

Great Soil Group	NCRB (Systems F,H,IH,MH,I,M)	NWDZ (NW-1)	Total
1. Alluvial Soils	45,800 (11.8%)	5,500 (15.4%)	51,300 (12.1%)
2. Old Alluvial	0 (0.0%)	500 (1.4%)	500 (0.1%)
3. Solonetz	3,900 (1.0%)	0 (0.0%)	3,900 (0.9%)
4. Low Humic Gley Soils (LHG)	83,900 (21.6%)	6,000 (16.9%)	89,900 (21.2%)
5. Reddish Brown Earth (RBE)	234,900 (60.3%)	21,500 (60.4%)	256,400 (60.4%)
- well drained	195,900 (50.3%)	18,100 (50.8%)	214,000 (50.4%)
- imperfectly drained	39,000 (10.0%)	3,400 (9.6%)	42,400 (10.0%)
6. Red Yellow Podzolic Soils	100 (0.03%)	0 (0.0%)	100 (0.02%)
7. Grumusols	200 (0.1%)	0 (0.0%)	200 (0.1%)
8. Lithosols (Rock outcrop)	16,200 (4.2%)	1,200 (3.4%)	17,400 (4.1%)
9. Marsh/Tank	3,800 (1.0%)	900 (2.5%)	4,700 (1.1%)
Total	388,800 (100%)	35,600 (100%)	424,400 (100%)

Brief explanation of soils in respective areas is given as follows:

(1) Soils of NCRB (Systems F, H, IH, MH, I, M)

Alluvial soils in NCRB extend over the alluvial plain of the Kala Oya in System H, the Malwatu Oya in System IH, the Yan Oya in Systems MH and M, and the Aruvi Aru in System I. About 95% of these soils are imperfectly/poorly drained soils

which have higher suitability for low land rice cultivation. The soils of this group are characterized as dark brown to dark yellowish brown colored profiles with grey sub-soil and iron mottlings, this soil group is mainly developed on the floodplain. The rest of Alluvial soils (5%) are well to moderately well drained soils, occurring on river levees and floodplain.

RBE soils extend over the undulating plains with gentle slope less than about 4%. 83% of land covered by RBE soils is well drained and the rest 17% is imperfectly/poorly drained. RBE soils having well drainability extend over the upper portion of the slope land. A wide range of upland crops of the dry zone can be grown on these soils. RBE soils having imperfect/poor drainability occur on the typical ridge valley land. These soils could be used for cultivation of rice, sugarcane and pasture.

LHG soils develop over the low-lying old alluvium. Generally they are found in association with RBE soils in a catenary sequence, and the soils are best suited for paddy cultivation due to their soil characteristics. Other soils are Solonetz and Lithosols. The land covered with Solonetz extends over a part of Systems MH, M and I. Lithosols are developed on mountain and rock knob. These soils are not suited to irrigated farming due to shallow soil depth.

(2) Soils of NWDZ (NW-1)

The greater part of NWDZ consists of a gently undulating peneplain with most slopes of 0-4%. Alluvial soils are distributed in the floodplains of the Mi Oya. Old alluvium is distributing on the low-lying areas and sandy bottomland. LHG occurs on lower part of the gently undulating plains in NWDZ. Well drained RBE covers the greater part of NWDZ and is developed on eroded peneplains. Imperfectly to poorly drained RBE is generally found in the depressions of the undulating plains.

The land classification for the entire survey area was made in accordance with the modified United States Bureau of Reclamation (USBR) specifications. According to the results obtained from land classification, land in the survey area was divided into seven (7) classification categories. They are; 1-irrigable, 2-moderately suitable for irrigation, 3-arable, 4R-only suitable for wet land rice, 4P-only suitable for coconut plants, 4S-sprinkler or lift irrigation and 6-non-arable.

In order to evaluate the land resources, classes 1, 2 and 3 are considered as suitable both for upland crops and lowland paddy, class 4R as suitable for lowland paddy, and class 4S, 4P and 6 as unsuitable for gravity irrigated farming. The details are presented in ANNEX-D. The results are shown in Table 15, and are summarized as follows:

Class System	1, 2, 3*1 (ha)	(%)	4R*2 (ha)	(%)	4S, 4P, 6*3 (ha)	(%)	Total (ha)
F	4,400	(83.0)	100	(1.9)	800	(15.1)	5,300
H	42,300	(47.4)	33,500	(37.6)	13,400	(15.0)	89,200
IH	1,800	(25.4)	4,100	(57.7)	1,200	(16.9)	7,100
MH	24,200	(42.2)	20,900	(36.4)	12,300	(21.4)	57,400
I	74,200	(51.4)	64,200	(44.4)	6,100	(4.2)	144,500
M	27,900	(32.7)	39,000	(45.7)	18,400	(21.6)	85,300
NWDZ (NW-1)	21,500	(60.4)	12,000	(33.7)	2,100	(5.9)	35,600
Total	196,300	(46.2)	173,800	(41.0)	54,300	(12.8)	424,400

Remarks : *1: suitable for upland crop and lowland paddy
*2: only suitable for lowland paddy
*3: unsuitable for gravity irrigated farming

The results of land classification study show that more than 90% of System I and NWDZ (NW-1), 85% of Systems F and H, 83% of System IH and about 80% of Systems MH and M are suitable for irrigated farming. Considering the present land use condition, the potential newly irrigable lands are widely extending in Systems F, I and M, and NWDZ.

3.7 Land Use

Agricultural land of the study area in Systems F, H, IH, MH, I, and M, and NWDZ is 191,600 ha (49%) and 12,100 ha (34%), respectively. The present land use is shown in Table 16 and summarized as follows:

(Unit: ha in Gross)

Land Use Category	NCRB Systems (F,H,IH,MH,I,M)	NWDZ (NW-1)	Total
1. Agricultural Land	191,600 (49.3%)	12,100 (34.0%)	203,700 (48.0%)
- Paddy	97,700 (25.2%)	3,700 (10.4%)	101,400 (23.9%)
- Upland	90,600 (23.3%)	8,300 (23.3%)	98,900 (23.3%)
- Perennial	3,300 (0.8%)	100 (0.3%)	3,400 (0.8%)
2. Urban Area and Homestead	26,800 (6.9%)	500 (1.4%)	27,300 (6.4%)
3. Forest	101,500 (26.1%)	22,600 (63.5%)	124,100 (29.2%)
4. Barren Land and Shrub	59,500 (15.3%)	400 (1.1%)	59,900 (14.1%)
5. Others	9,400 (2.4%)	0 (0.0%)	9,400 (2.3%)
Total	388,800 (100%)	35,600 (100%)	424,400 (100%)

3.8 Agriculture

The population in the NCRB and NWDZ areas was estimated at $349x10^3$ in the 1981 census, accounting for 2.4% of the national population. The labour force in the project area was recorded at $120x10^3$ or 35% of the total population. Of the labour force, $73x10^3$ or 61% was engaged in agricultural production.

The average population growth rate during the ten years between the census years of 1971 and 1981 was 2.7% according to the District's base data, while the growth rate in Sri Lanka was 1.6% during the same period. This high growth was caused by immigration from outside areas, since the natural increase rate was estimated at 2.0%.

The NCRB and NWDZ areas have mainly produced paddy particularly in irrigated fields. There are two cropping seasons for paddy production, i.e., Maha cultivation (October-March) and Yala cultivation (April-September). Due to insufficient irrigation water, paddy production is quite limited even in Maha. In Maha, 97% of irrigated fields and 3% of rainfed fields were cultivated for paddy production, while in Yala only 26% of irrigated fields and less than 1% of rainfed fields were planted with paddy. In irrigated field, 3% in Maha and 26% in Yala were cultivated for upland crop production. Though 72% (45,900 ha) of rainfed field was planted by upland crop in Maha, only 10% (6,600 ha)was utilized for crop production in Yala. Therefore, cropping intensity of the study area was estimated as follows:

Item	Net Area (ha)	Cultivated Area (ha)				Total	Cropping Intensity
		Maha		Yala			
		Paddy	Upland	Paddy	Upland		
Irrigated	69,600	67,500	2,100	18,300	18,000	105,900	1.52
Rainfed	63,500	1,300	45,900	400	6,600	54,200	0.85
Total	133,100	68,800	48,000	18,700	24,600	160,100	1.20

Remark: * includes fallow area.

The details of cropping pattern and intensity are summarized in Table 17 and Fig. 12. System H recorded the highest intensity of 1.65 among all Systems in the study area. System M was the lowest with 0.71.

More than 50% of land is prepared by tractors in less populated areas like Systems H, IH, MH and I. In wetter areas like System F and NWDZ where fodder grasses are more available, more than 50% of the land is prepared by buffaloes. Manual ploughing is practiced in very limited areas. Except in System F, more than 65% of the paddy fields are directly sown. Direct sowing is practiced by broadcasting in most cases. In the transplanting method, random transplanting is predominant. In association with direct sowing, chemical weed control is widely practiced in the study area.

Predominant rice varieties are Bg 34-8 and Bg 94-1 for Yala, and Bg 90-2, Bg 400-1 and Bg 379-2 are recommended for Maha. Fertilizer amounts applied to paddy

are from 73 kg/ha to 104 kg/ha for N, from 27 kg/ha to 65 kg/ha for P_2O_5 and from 30 kg/ha to 48 kg/ha for K_2O.

Chilli is the second most important irrigated crop in the study area. Chilli is cultivated as a rainfed crop in Maha and also as an irrigated crop during Yala. Land preparation such as ploughing and harrowing to obtain good soil drainage is practiced. MI-1 and MI-2 are popular varieties of about 150 growing days. As a Yala crop MI-2 is used in the irrigated areas. In Maha under rainfed conditions seedlings are transplanted when they are 25 to 30 days old. White fly, aphids, mites, thrips, and pod borers are common pests of chilli. Regular routine spraying is done by farmers to keep the pests under control. Damping off, powdery mildew, bacterial wilt and fungal wilt are observed in plantations. Crop rotations and the use of fungicides like sulphur and captain are practiced to control the spread of these disease. Only the red ripened pods are picked. Harvesting commences 75-80 days after transplanting and continues for 3-4 months. Once they are picked, the pods are heaped indoors to get a uniform red colour. The pods are sundried for about a week, and they are flattened using a wooden plank on the 3rd day of drying which facilities the removal of moisture from the pod.

Paddy yields in Maha range between 2.8 ton/ha and 4.3ton/ha under irrigated condition and from 1.5 ton/ha to 3.1 ton/ha under rainfed condition, while in Yala between 2.0 ton/ha and 2.8 ton/ha under irrigated condition and from 1.8 ton/ha to 2.4 ton/ha under rainfed condition. Dry chilli yields under irrigated condition are between 0.5 ton/ha and 1.1 ton/ha in Maha and increase from 1.2 ton/ha to 1.5 ton/ha in Yala. Pulses like cowpea, green gram, black gram, soybean and groundnut are in most cases grown in rainfed condition with yields from 0.5 ton/ha to 1.5 ton/ha. Sesame is mainly cultivated in the rainfed fields with yields from 0.4 ton/ha to 0.7 ton/ha. Onion is grown under irrigation and its average yields range between about 0.9 ton/ha and 8.4 ton/ha. However, since onion is a "high-risk" product, it is cultivated in quite limited irrigated fields in the study area.

As shown in Table 18, the average annual crop production in the study area is 306×10^3 ton for paddy, 12.7×10^3 ton for chilli, 34.4×10^3 ton for pulses and 13.7×10^3 ton for maize.

3.9 Hydropower Plants

Hydropower is an essentially valuable resource in Sri Lanka, since coal and petroleum resources have not yet been found in Sri Lanka. The Government has consequently and continually pursued a policy of developing hydropower.

Hydropower development was implemented in the Kehelgamu-Maskeli basin in the 1950s, while the Mahaweli development was commenced in the late 1960s. Since then, hydropower development had been continued. In 1978, the Government formulated AMDP to spur development of the Mahaweli Ganga. Under AMDP, a series of large scale hydropower development schemes have been planned and almost completed. The Mahaweli complex has a water head of 640 m and a net reservoir storage of 1,980 MCM including under-construction and on-going dams. The Mahaweli complex is composed of the Ukuwela (38 MW), Bowatenna (40 MW), Victoria (210 MW), Randenigala (122 MW)

and Kotmale (201 MW) power stations, totaling 611 MW in installed capacity. The Rantembe power station (50 MW) is under construction, and will be completed in 1990. In addition to these, GOSL decided to implement the Moragahakanda agricultural development project with a power station (25 MW) and took necessary action for its implementation. All the above schemes were categorized in the existing project in this Master Plan.

The principal features of the existing and on-going hydropower stations are presented in Tables 7 and 8.

4. PROSPECTIVE AGRICULTURAL AND WATER RESOURCES DEVELOPMENT

4.1 Water Resources Development

The available water resources in the study area consist mainly of the Mahaweli Ganga including its tributaries, and runoffs from own catchment areas in the potential irrigable areas. Runoffs of both the Mahaweli river basin and the potential arable areas were estimated at 8,330 MCM at Manampitiya and 1,580 MCM, respectively.

GOSL has undertaken studies on various possible dam development schemes, originally identified by UNDP/FAO in 1968. The feasibility study on the Upper Kotmale Hydropower Development Project (Ref. 19) was completed in 1987. A Master Plan for the Electricity Supply of Sri Lanka has been undertaken by CEB since 1986 and will be completed in 1989. Based on the interim results of the above Master Plan, the feasibility study on the Uma Oya Basin Development for Hydropower and Irrigation is also undertaken by MMD. In order to formulate a Master Plan, the prospective sites for dam development were selected with reference to these previously proposed.

The candidate dams were selected mainly based on their multipurpose use for hydropower and irrigation by using the available topographic maps in scales of 1/31,680 and 1/10,000 (only limited site). The identified multipurpose and hydropower dam sites are shown in Fig. 13. Since there is so limited large scale reservoir sites in the Mahaweli basin after completion of AMDP, irrigation schemes should be planned to minimize spillout water at each intake site and irrigation tank usually located near the irrigable areas. The principal features of the candidate multipurpose, hydropower and irrigation dams are summarized in Tables 19 and 20, and details of dams in the Mahaweli river basin are described in ANNEX-G, and irrigation tanks in ANNEX-H.

4.2 Agricultural Development

Food demand in the future is one of the key factors for agricultural development. Food demand for national consumption in the year 2020 is estimated on the basis of both the projected population and the per capita consumption of food. Besides, exports of food crops will be expected to grow at the same level as other major Asian countries. Thus, the total requirement of major food crops in the country is estimated as the sum of both domestic consumption and exports, and aggregated as follows: $4{,}220 \times 10^3$ tons of paddy; 89×10^3 tons of chilli; 131×10^3 ton of onion; 235×10^3 tons of pulses and nuts; 25×10^3 tons of cashew (kernels); 899×10^3 tons of sugar; and $2{,}294 \times 10^3$ tons of vegetables and fruits. Details are described in ANNEX-E.

In order to meet such requirements, the project area should play an important role as the main food supplier in consideration of potentiality of both land and water resources. Thus, the project area will have to fulfill at least 30% of the total national food demand as shown in Table 21. Regarding special crops like onion and chilli suitable for the dry climate, the project area will provide around 40% of the national demand. As a result, target production in the project area is projected as follows: $1{,}350 \times 10^3$ tons for paddy;

$36x10^3$ tons of chilli; $52x10^3$ tons of onion; $32x10^3$ tons of maize; 75 tons of pulses; $10x10^3$ tons of cashew (kernels); and $734x10^3$ tons of vegetables and fruits.

Future cropping patterns under with-project condition were made for most-likely grown crops in the project area. The crops in irrigated fields were grouped into 6 categories, i.e., paddy, chilli, pulses, maize, onion and others. Cropping calenders for these crops follow existing typical cropping calendars. In formulating future cropping patterns under the with-project condition, basic consideration was paid to realize the target production to the maximum extent in the project area and further to realize irrigation benefit as much as possible. The future cropping pattern proposed for with-project condition is given in Table 22 and Fig. 14.

As for paddy, shorter growing varieties are proposed for the efficient utilization of irrigation water, i.e., 120 day varieties for Maha and 90 days varieties for Yala in principle. The major design criteria of proposed farming practices are given in Table 23.

Crop yields have been increasing year by year through improved farming practices. Therefore, anticipated crop yields are estimated as shown below, which are more than the present crop yields under not only with-project condition but without-project condition:

(Unit: ton/ha)

Crop			Present Condition	Without Project	With Project
1.	Paddy				
	Irrigated	Maha	2.8 - 3.6	3.5	5.5
		Maha (System H)	4.3	4.5	5.5
		Yala	2.0 - 2.8	3.0	5.0
	Rainfed	Maha	1.5 - 3.1	2.5	-
2.	Chilli		0.5 - 1.5	1.5	1.9
3.	Onion		0.9 - 8.4	10.0	15.0
4.	Pulses (Green gram)		0.5 - 1.5	1.0	1.5
5.	Maize		0.9 - 1.5	2.0	3.5

On the basis of the above projection of unit yields, a considerable increase of agricultural production can be expected after completion of the project. In terms of paddy, the project area will produce about $1.34x10^6$ tons, which is about 4.4 times of the present production in case of development of both NCRB and NWDZ. Moreover, other food crops will attain the target of production, as well. Expected production of other major crops is estimated as follows and the details of production are shown in Tables 24:

(Unit: 1,000 ton)

Crop	NCRB		NCRB+NWDZ		Production Target
	Present Condition	W/Project (161,600 ha)	Present Condition	W/Project (174,850 ha)	
Paddy	293	1,253	306	1,339	1,350
Chilli	13	37	13	38	36
Maize	14	24	14	31	32
Onion	-	50	-	54	52
Cashew (Kernels)	-	4.5	-	4.5	10

In the project area, small agricultural land holders seem to be in poor condition economically. In most Systems, they cannot cover their living expenses by farm income alone at present. However, their farm income will increase as a result of the project. Typical small holders will get their farm incomes as follows and the details of annual farm income are given in Table 25.

	Average Size of Farm Holding (ha)	Net Farm Income (Rs. 1,000)		Farmer's Capacity to Pay
		Present Condition	After Completion of the Project	
Existing farmer				
System F	0.7	10.6	24.7	7.8
System H	1.1	20.6	45.9	25.3
System IH	1.1	13.1	38.6	25.5
System MH	1.1	13.2	38.8	25.6
System I	1.1	11.5	38.3	26.7
System M	1.4	15.0	48.9	33.8
NWDZ	0.8	8.7	27.5	18.8
New Settler	1.0	-	34.8 - 41.7	17.4 - 24.8

4.3 Irrigation Water Demand

The irrigation water demand for respective existing, on-going, committed projects and potential irrigable area was calculated on a monthly basis for 38 years from 1949 to 1986, as summarized in Tables 26 and 27. General layouts of these irrigation areas are presented in Fig. 16. As shown in Table 28, the present overall irrigation efficiency was evaluated at 50% for Systems E and C, and 56% for other systems. The irrigation demand at the matured stage in the year 2020 was calculated by adopting an improved overall irrigation efficiency of 60%, since GOSL enforces the rehabilitation of existing projects to improve farming practices and to save water through proper water management.

The estimated irrigation water demand is about 9,300 MCM for all the potential arable land. However, the available annual river runoffs were estimated to be about 8,500 MCM as shown in Table 26. Accordingly, part of the potential arable areas will not be irrigated within the allowable deficit criteria. The comparison of irrigation demand calculated in the previous study is shown in Table 29. Irrigation demand of Systems B, C, H, IH and MH estimated in TDS is optimistic compared to the present study and MWRMP. Major constraints will be water resources development in the Mahaweli river basin and other minor river basins. As GOSL proceeds with proper water management and rehabilitation of existing deteriorated schemes, such continuous efforts are required to improve the present irrigation efficiency through introduction of proper water management and rehabilitation. This will result in increasing irrigable area, in other words, creating other water sources.

As described in Chapter 5 (details in ANNEX-I), about 304,000 ha including existing projects and schemes will be irrigated under the improved irrigation efficiency and the cropping intensity of 2.0 within an allowable deficit, as a result of the water balance simulation runs.

4.4 Transbasin Diversion Plan

There are several transbasin diversion plans from the Mahaweli Ganga to NCRB and NWDZ which were studied by UNDP/FAO, subsequently in ISS and TDS. The increase of Polgolla diversion water to the Amban Ganga will decrease hydropower generation at the existing hydropower stations on the Mahaweli main stream. However, this increased diversion policy will save energy consumption at a pump station which will be to irrigate the NCRB area. In order to establish an overall development plan, all the possible conveyance systems should be studied for their comprehensive overall benefits for the long term development.

In 1981/84, TDS was carried out under a certain condition. However, as shown in Table 29, there was optimistic estimation of irrigation water demand in the existing Systems B, C, H, IH and MH. Therefore, a basic and conceptional approach to the future development plan should be reviewed in consideration of available surplus water under the present committed and given conditions such as irrigation area, tank capacity, canal capacity, etc.

In 1981/84, TDS made alternative studies based on the UNDP/FAO and ISS (NEDECO) solutions. In this study, the recommended plan in TDS was adopted basically and added one alternative transbasin conveyance system to the NCRB area. According to the ISS and the TDS solutions, energy consumption at proposed pump stations would be about 1,400 GWh for the ISS solution being equivalent to about 60% of total energy consumption in 1987 in Sri Lanka, and about 440 GWh to about 20% for the TDS solution respectively. Since the pumping energy consumption would be so large compared to the annual energy consumption and generation capacity in Sri Lanka, a combined gravity and pump system was added in this study in order to minimize energy consumption at a proposed pump station which would serve the NCRB area.

The following three alternative cases for transbasin conveyance systems to NCRB and NWDZ were selected. Detailed explanation of the conveyance systems is presented in ANNEX-H, and a brief explanation is given as follows:

(1) Conveyance System to NCRB Area

In order to irrigate the NCRB area, there is only a way to select either the increase of Polgolla diversion resulting in decrease of power generation or pumping up of surplus water after hydropower generation on the Mahaweli main stream, or a combination of these as shown in Fig. 15 and schematically shown in Fig. 20. The followings are three alternatives:

Case A : New Alternative Plan

Minipe - Minipe New LB canal - Minneriya tank - Minneriya Pump Station - NCP canal - NCRB area

Case B : Elcctrowatt (TDS) Solution modified

Minipe - Hettipola Oya (Pump Station) - Kalu Ganga dam - Elahera - NCP canal - NCRB area

Case C : UNDP/FAO (ISS) Solution revised by NEDECO

Minipe LB canal - Angamedilla - Kaudulla - Kantalai
Angamedilla - Pump Station - NCP canal - NCRB area

(i) Case A (New Alternative Plan)

A gravity transbasin conveyance system from the Minipe anicut (crest El. 114.0 m) to the Minneriya tank (FWSL. El. 93.7m) was selected in order to minimize pumping energy consumption and to keep hydropower generation on the main stream of the Mahaweli Ganga. The conveyance system is shown in Fig. 15 (1/3), and schematic flow diagram in Fig. 20 (1/3). Diverted water from the Minipe anicut will be supplied through a newly proposed Minipe LB canal being parallel to the existing Minipe LB canal at the initial section, then crossing the Wasgomuwa National Park, and stored in the Minneriya tank. Water could be used to irrigate the existing System D1 including the expansion areas under the on-going Moragahakanda project. Irrigation water originally supplied from the on-going Moragahakanda project will be replaced and utilized for irrigation of the NCRB areas.

As described in Chapter 5, there is still possible diversion water at the Minneriya tank, even after replacing the irrigation water in System D1 and its expansion area. This water can be pumped up to the NCP canal at the Minneriya tank. Depending on the selected future plan, it may be possible to pump up some 650-760 MCM of water with a static head of about 45-53 m which could irrigate additionally about 30,000 ha in the NCRB area.

From the Moragahakanda dam, a newly proposed concrete lined canal was planned to be located generally parallel to the existing Elahera - Minneriya canal. The canal alignment between Elahera to the Kiri Oya was chosen along the foot of the hills forming the western slope of the Amban Ganga valley. A number of sections of deep-cut and tunnel are required. The NCP canal proposed by NEDECO (high level NCP canal) was basically adopted in this study with a minor modification to route alignment. The canal route is presented in DRAWINGS. Diverted water at Elahera to the NCRB area will be augmented after crossing the Kiri Oya, by pumping water diverted from the Mahaweli Ganga at the proposed Minneriya pump station.

TDS recommended provision of the Kiri Oya reservoir as a level crossing for the Kiri Oya valley. However, runoff in this catchment has been used as water sources for the Minneriya tank for a long time, moreover, since the Kiri Oya dam will be an approximately 40 m high dam, the canal traversing case with a small upper regulation pond for the Minneriya pump station is the

most economical solution based on a preliminary cost comparison. Other than the Kiri Oya level crossing, the detoured canal route was adopted as the NCP canal route. The proposed NCP canal route is presented in DRAWINGS.

(ii) Case B (TDS's Solution)

In TDS, water diverted at Minipe will be pumped at Hettipola into the parallel Kalu Ganga valley, and be fed to Elahera and the NCP canal originally proposed by UNDP/FAO. The Minipe-Hettipola canal from the Minipe anicut to the proposed Hettipola pump station was planned to have the same alignment of the initial section as originally proposed by UNDP/FAO. The static pumping head will be about 80 m instead of 61m which was proposed in TDS, since pumped water will be regulated in the proposed Kalu Ganga reservoir. In order to utilize available water resources adjacent to the development area, the Kalu Ganga dam was proposed to feed irrigation water to the NCRB areas. The conveyance system is shown in Fig. 15 (2/3), and schematic flow diagram in Fig. 20 (2/3).

The pump station will be located near the proposed lower regulating pond at Hettipola. Pumping water through the proposed penstocks with approximately 500 m in length will be delivered to a high-level canal leading to the transbasin diversion tunnel through the Sudu Ganga ridge between the valleys of the Mahaweli Ganga and Kalu Ganga. Diverted water will be once impounded in the proposed Kalu Ganga dam. Regulated water will be delivered to the Elahera anicut and to the NCRB area through the NCP canal as same as Case A.

If this plan were adopted, the pumping energy consumption would be huge compared to the total energy consumption in Sri Lanka, but no disturbance to the Wasgomuwa National Park is expected.

(iii) Case C (UNDP/FAO Solution, as revised by NEDECO)

The Minipe LB 2 canal was originally proposed by UNDP/FAO and revised by NEDECO. The canal would extend from Minipe to the existing Kantalai tank. An underground pump station would be required to feed water to the NCP canal. The route of Case C conveyance system is shown in Fig. 15 (3/3), and its schematic flow diagram in Fig. 20 (3/3).

The existing Minipe LB canal being under-rehabilitation by ID will be utilized as the initial section of the UNDP/FAO conveyance canal, and be enlarged in order to supply the additional flow to the NCRB area. The later section of the Minipe LB 2 canal should pass through the Wasgomuwa National Park as same as Case A conveyance route.

An underground pump station with a static head of about 65 m was planned at Wewela located near the outlet of the proposed Angamedilla syphon, and

would lift water from the Minipe-Angamedilla conveyance canal to the NCP canal. Due to the topographic conditions of the site, it was planned to construct an underground pump station, an 8 km long supply tunnel, surge chamber and vertical delivery shaft.

The NCP canal route for Case C is the same as described in Case A and B. The Minipe LB 2 canal originally recommend by UNDP/FAO was planned to serve a part of System D1. Irrigation water diverted from Minipe to a part of System D1 could replace water originally diverted from Elahera. Therefore, water originally supplied to a part of System D1 will be conveyed to the NCRB area through the NCP canal. In this case, pumping energy could be saved in comparison with Case B.

(2) Conveyance System to NWDZ Area

In TDS, six alternative conveyance routes from the Mahaweli Ganga to NWDZ were studied. Among these six routes, it was concluded that irrigation water to NWDZ would be diverted through the existing Ukuwela power station and discharged into the Sudu Ganga, and then into the Bowatenna reservoir. From the Bowatenna, water will be supplied through a second irrigation tunnel, being parallel to the existing irrigation tunnel.

Once water has been diverted into the upper Dambulu Oya near the Lenadora village, the following three possible routes to the Mi Oya valley where NWDZ exists were studied: (1) from an anicut on the Dambulu Oya at Lenadora, westward across into the upper Mi Oya valley, (2) from the Dambulu tank to the Siyambalangamuwa Oya valley, with a second canal from this valley to the proposed Galgamuwa tank, at the head of the Mi Oya right bank irrigation area (NW1), and (3) from Kalawewa, utilizing the System H left bank canal to the existing Mahakatnoruwa tank in the Siyambalangamuwa Oya valley and finally to the Galgamuwa tank.

Among the above three routes, Kalawewa - Mahakatnoruwa - Galgamuwa tanks route was selected as a transbasin conveyance canal route to NWDZ. In this study, due to the limitation of available water as studied in TDS (Ref.16) and described in Chapter 5, the TDS's recommended route to NWDZ was adopted as the NWDZ conveyance system.

In order to serve NWDZ under the fixed Polgolla diversion policy, no additional water will be taken from the Mahaweli Ganga at Polgolla. Rather, water originally used in Systems D and G will be replaced by the inflows of the Kalu Ganga, a tributary of the Amban Ganga, and released from Bowatenna to NWDZ. This will affect the on-going Moragahakanda project and the existing Bowatenna hydropower station due to the decrease of available water. This fact should be carefully studied in the water balance and comprehensive economic comparison.

Brief explanation of adopted conveyance route in the study is given below and details are described in ANNEX-H.

(i) Polgolla diversion water to Kalawewa tank

Diverted water through the Ukuwela power station (38 MW) will be impounded in the Bowatenna reservoir. From the Bowatenna, water will be released to the Moragahakanda dam through the 40 MW hydropower station, then to Systems D and G as well as to the NCRB area. In order to increase diversion water, a second diversion tunnel parallel to the existing irrigation tunnel to Dambulu Oya valley is required to supply additional water to Systems H and IH, and to NWDZ. And released water will be again impounded in the Dambulu Oya tank, then in the Kalawewa tank.

(ii) Kalawewa tank to Galgamuwa tank

The Kalawewa tank is one of key tanks to serve irrigation water to Systems H and IH, and NWDZ. Water diverted at Polgolla through the Bowatenna irrigation tunnel to the Dambulu Oya would be stored and regulated at the Kalawewa tank. The Kalawewa LB canal connected to the Mahakatnoruwa tank will be enlarged in order to supply additional irrigation water to NWDZ. However during the construction, special attention should be given to the construction method, because this canal is an existing canal which supplies water to the Kalawewa left bank area throughout the year.

4.5 Power Market

The gross power generation was 2,707 GWh and the maximum output was 570 MW in the CEB power supply system in 1987. The annual peak demand shows a little variation throughout the year, however peak demand usually appears in November, while the demand in January to March is growing high. The annual growth rate of power generation in 1987 was sharply dropped to the level being only 2% higher than 1986, due to persistent drought. The composition of energy sold in 1987 was 17% for domestic and religious, 38% for small, medium and heavy industries, 19% for commercial and hotels, and 26% for local authorities.

CEB established the "Long Range Generation Expansion Plan - 1987" covering upto the year 2002. According to the Expansion Plan - 1987, the power demand will increase at annual rates of 8.2% in 1988-1990, 10% in 1991-1995, 9.5% in 1996-2002 and finally the peak and annual generation demand will exceed 2,000 MW and 10,000 GWh in 2002, respectively. The plan envisaged to rise up installed capacity in the CEB system to over 2,500 MW by 2002. The coal thermal plants will be, in nature, base-load plants and would constitute about 36% of the total installed capacity. Hydropower will be most economical in a sense of energy saving, and it would be desirable that hydropower be developed, if a dam is constructed for any purpose. The details are given in ANNEX-G. The projection of power generation and power demand upto 2020 is tabulated in Table 30 and illustrated in Fig. 17 and summarized below:

Year	Peak Demand (MW)	Generation (GWh)	Growth Rate (%)	Load Factor (%)
1988	593	2,990	-	57.5
1990	682	3,500	8.2	58.5
1995	1,090	5,630	10.0	59.0
2000	1,710	8,860	9.5	50.0
2005	2,580	13,320	8.5	59.0
2010	3,780	19,580	8.5	59.0
2015	5,440	28,110	7.5	59.0
2020	7,630	39,420	7.0	59.0

4.6 Environmental Aspects

This Master Plan aims at utilizing the maximum benefits of Mahaweli Ganga water in the NWDZ and NCRB areas. A careful study of environmental issues with respect to the project area has to be performed in order to minimize their adverse effects. GOSL has already established several Forestry and Wildlife reserves within the project area to protect endemic and endangered fauna and flora. The Wildlife Reserves are summarized in Table 31 and illustrated in Fig. 18. In addition to this, provision of buffer zones around nature reserves is recommended in this study to minimize crop damages to farms by wild animals. There should be enough reservation along major streams where high concentration of wildlife habitants can be observed.

The importance of Mahaweli floodplains provides excellent breeding and feeding places for many aquatic species. The productivity of floodplains depends on flood peaks of Mahaweli Ganga. Release of minimum discharge is considered to provide floodplains with enough water during the Yala season. Deterioration of water quality of return flow can be minimized by having several preventive measures on an application of fertilizers and pesticides on farms and by providing river maintenance flows.

Careful study of canal routes is necessary to reduce the disturbances on wild life habitats. Special technique has to be deployed in construction activities within nature reserves. The canals passing through nature reserves can be used to fill abandoned water tanks for wild animals. This may reduce migration of animals from nature reserves during dry periods.

5. WATER BALANCE STUDY

5.1 Conditions of Water Balance

The Mahaweli river basin was divided into 21 sub-basins, considering the existing and potential dam and intake sites, and the existing and potential irrigable area into 51 sub-basins. A simulation model was developed to represent a water resource system by adopting nodes, with or without storage, which are connected by channels having flow limits, based on the schematic flow diagramme shown in Fig. 19.

Since there are numerous irrigation tanks in the existing and potential irrigation areas, in the model a certain simplification for irrigation system was introduced in representing irrigation systems. Reservoirs or tanks with an active storage of more than 5 MCM were basically incorporated into the model.

In representation of the reservoir system, active reservoir storage was divided into 9 zones for the reservoir operation as illustrated in Fig. 21. Each storage zone has a purpose in storing and releasing water according to system water demand such as flood control, flow conservation and augmentation, etc. Each zone has a upper and lower boundary, and is specified within a space between the high water level (HWL) and the low water level (LWL) of a reservoir.

The upper zone (zone-1) is used for the flood surcharge storage space, the lowest zone (zone-8) for dead water storage, and the zone-7 only for a firm energy generation. The upper and lower rule curves were fixed on the basis of a try and error method, referring to the study results of MWRMP for the existing dams, to maximize power generation as well as to minimize water deficit in irrigation areas and spillout from respective reservoirs and tanks.

With regard to multipurpose dams and irrigation tanks, the following operation rule is given:

- In case that reservoir water level at a certain time is higher than the lower rule curve (above the 6th zone), water is released to meet downstream irrigation water demand or to maintain firm power generation, which is greater.

- In case that reservoir water level is lower than the lowest rule curve (within the 7th zone), water is released to maintain only firm power generation.

- As a first trial, water balance from the upper to lower reservoir is carried out to maintain firm power generation at each hydropower station. In case of irrigation water demand being higher than demand for firm generation, water release is first made from a reservoir or tank with the highest zone among all multipurpose dams and irrigation tanks, and if not to meet the irrigation demand, a downstream reservoir or tank with the 2nd highest zone releases water to meet irrigation demand.

Conceptional flow chart of the simulation model are illustrated in Fig. 22, and the details are described in ANNEX-I.

5.2 Natural River Flow

The most important factor for the water balance study is to correct the reliable flow data, which will affect the quality of the study. Flow data for the Mahaweli Ganga and Amban Ganga were scrutinized in HCP (Ref. 13) and prepared the data-base system on the weekly basis at each of the major structures and gauging stations.

In MWRMP (Ref. 18), the weekly flow data were recompiled into monthly basis for 31 years (1949-81), considering the existence of series of large storage reservoirs. The monthly natural river flow data complied in MWRMP for the period of 1949-81 were adopted in the present study. Moreover, additional flow data for the period of 1981-86 could be utilized for the study. Series of multipurpose dams on the Mahaweli Ganga and Amban Ganga, as well as the irrigation development projects have been performed since the late 1970s. In order to keep the continuity of the data base, all the measured river flows were converted to the natural river flow for the local catchment area.

As adopted in MWRMP, local inflows to the respective irrigation tanks were calculated by using available measured flows, or in case of missing data, by sorting rainfall-runoff correlation method to estimate the runoff coefficient in the catchment area. The details are presented in ANNEX-B.

The average natural river runoffs (1949-86) at the major control points such as reservoirs, tanks and diversion points are summarized in Table 13. The monthly inflow data at the existing and proposed dam sites and major structures are given in ANNEX-B. Figure 9 shows the average monthly flow patterns for the major control points. Annual runoffs varied widely, and there were very clear trends of continuous wet (1949-72) and very dry spells (1973-1983) in the dry zone as seen in Fig.10 (1/3-3/3).

5.3 River Maintenance Flow

Water has been utilized as need arises, not causing any hazard to other water uses in most rivers. The reduction of river flow due to intensified water use will, however, hurt various water users. The river maintenance flow is the minimum discharge which is required to maintain water depth, flow velocity, water quality, channel stability, aquatic eco-system and scenery, to the extent necessary for navigation, fish catch, operation and maintenance of intakes, maintenance of river facilities, sea water repulsion, prevention of estuary clogging, conservation of groundwater, preservation of riparian land and people's amenity, etc.

The river maintenance flow is the indicator of the allowable limit of water withdrawal from the river, to be considered in allocating and developing water resources. Increased water withdrawal should not be allowed, if it is expected to impair the river maintenance flow frequently.

As seen in Table 32 and illustrated in Fig.23, the minimum river flow at Manampitiya has substantially decreased with the progress of land and water resources development since 1976. The requirement for the river maintenance flow should be determined for each river, based on the conditions particular to the river. The river maintenance flow at Manampitiya decreased during the last 12 years, however it seems that there was no serious problem. The results of the flow duration analysis show that the average river flows during the low flow period (flow kept more than 275 days of the year) and the extremely low flow period (355 days) were estimated at 31 m^3/sec and 14 m^3/sec for the period of 1976-87, respectively. Usually the river maintenance flow ranges between the above two figures. Therefore, since there are no such available data and studies, the maintenance flow at the estuary was preliminarily estimated at 15 m^3/sec for the water balance study, referring to the results of the flow duration analysis at Manampitiya, and irrigation demand for the existing Allai scheme of 7,000 ha of which the intake is located at Manampitiya downstream.

5.4 Reservoir and Tank Operation

(1) Operation Rule for Main System Reservoirs

For the water balance study, the operation methods of the existing and proposed dams were set at the variable draft operation considering the characteristics of the multipurpose dams, except the proposed Talawakele, Watawala, Uma Oya Scheme-500 hydropower stations which are the river run-off type. Even though existing dam series in the Mahaweli river basin including several steps of transbasin diversion are so complicatedly connected, all the multipurpose reservoirs were set at the variable draft operation to release water to downstream, according to the downstream water demand keeping the present water rights for water users.

The Polgolla diversion policy is the most important key factor for the formulation of a future development policy and plan. Comprehensive economic and social benefit as a whole should be taken into consideration. At Polgolla, water demand for the Amban Ganga will be released through the power channel with maximum discharge of 148 MCM per month.

The principal concept of the rule curve for the main system reservoirs would be to maximize the overall hydroelectric energy, keeping the firm hydroelectric energy production for each system and/or as whole systems, and irrigation demand for the downstream areas.

Simulation was made in order to evaluate the rule curve for each reservoir, referring to the results of MWRMP for the present condition. For the future development cases, simulation runs were carried out to maximize the overall hydroelectric energy generation, at the same time to meet the irrigation water demand within an allowable deficit. The rule curves for the major reservoirs are illustrated in Fig. 24.

(2) Operation Rule for Irrigation Tanks

The simulation runs were performed to evaluate the rule curve to minimize diversion demands from the main system reservoirs and to make maximum use of local inflows, i.e. to minimize spillout from these tanks, while at the same time, maintaining allowable irrigation reliability.

Each irrigation tank has its own particular characteristics such as command area, its own catchment area, storage capacity, etc. As seen in Table 20, almost all of the tanks have very limited tank capacity to irrigate their commanding areas for about one-two months. High irrigation demand will usually occur in May to August and November to February. Therefore, reservoir water level at end April and end October has to be kept at a certain level for the next irrigation water issues. Considering these fact and referring to the results of MWRMP (Ref. 18), simulation runs were performed to fix the rule curve so as to minimize spillouts at respective tanks. The rule curves for major tanks are presented in Fig. 24.

5.5 Water Balance Studies

By using the water balance simulation model, simulation for possible alternative cases under the present case and future plans was performed and the results are summarized in Tables 33 and 34, and illustrated in Figs. 25 and 26. Details are explained in ANNEX-I. Results of simulations are briefly described below.

(1) Water Balance Simulation under the Present Condition
(Polgolla Diversion: 875 MCM)

The water balance study under the present condition including the committed irrigation areas in AMDP was carried out by using the water balance simulation model. All the irrigation areas including on-going and committed projects were categorized into the present conditions in this study, as shown in Table 6.

Prior to the establishment of a future development plan, the present conditions of water balance in the Mahaweli Ganga are essential, in order to know the available water sources for a future plan and the present reliability of irrigation water supply.

Results of the study are illustrated in Fig. 25. About 1,440 MCM at Minipe and about 4,300 MCM at the proposed Kandakadu intake site on the main stream of the Mahaweli Ganga, and about 720 MCM at Angamedilla on the Amban Ganga are wasted to downstream or discharged into the sea. After allowing for the river maintenance flow, such surplus water could be utilized for irrigation purposes. This surplus water is wasted mainly during the Maha season, because hydropower stations are generating electricity throughout the year by discharging water for firm energy generation even in the Maha season. However, irrigation demand in the Maha season is less; especially in March and April. It is possible to utilize this surplus water for irrigation purposes by providing regulating dams and tanks, and modifying the rule curves of certain multipurpose dams.

In order to utilize surplus water in the Maha season, it is possible that water could be released according to the irrigation demand, i.e. to relax the reservoir operation policy of the Randenigala power station under the firm energy output in the Mahaweli Ganga hydropower generation system as a whole.

Under the fixed Polgolla diversion policy, i.e. long term average of 875 MCM fixed by NEDECO, almost all of the diverted water should be released to Systems H, IH and MH areas through the Bowatenna irrigation tunnel. Unless there is modification of the diversion policy at Polgolla and the option to reduce the firm generation at the Bowatenna and Moragahakanda hydropower stations, there will be no possibility of increasing the diversion of water to Systems H, IH and MH, and NWDZ.

According to the results of MWRMP, two analytical approaches were made to examine the tradeoff between diversion of water to the Amban Ganga for predominantly irrigation purposes, versus use of water to generate hydropower energy on the main stream of the Mahaweli Ganga under the condition without the Moragahakanda dam. Based on the results, given the social and regional development benefits of fostering irrigated agriculture in the existing Amban Ganga irrigation area, it is unlikely that significant reductions in Polgolla diversions could be justified, unless improved water management could be achieved in Systems D, G, H, IH and MH.

(2) Water Balance Study for Future Case (Polgolla Diversion: 875 MCM)

According to the results of TDS (Ref. 27), all irrigation systems including 10,700 - 15,300 ha in NWDZ and about 40,000 ha in SEDZ could be irrigated depending on the conveyance system chosen. However, as seen in Table 29, the irrigation water demand for each system would differ mainly due to modification of the cropping pattern, assumptions and conditions applied for the studies. Depending on the conveyance system chosen, a water balance study for future potential irrigable areas is essential to determine the maximum development size, with due consideration given to the river maintenance flow at the estuary of the Mahaweli Ganga.

The potential irrigable area in each system was delineated on the basis of the results of soil surveys and topographical conditions, referring to the results of the previous studies mainly TDS, and the water balance study. The potential irrigation areas are shown in Fig. 16.

By using the water balance simulation model and allowable deficit criteria for irrigation projects, i.e. 80% probability in occurrence and 90% probability in quantity as adopted by ID, the maximum possible irrigable areas were delineated as shown in Table 33. System flow diagram is shown in Fig. 26, and masscurves and storage and inflow patterns for major reservoirs are presented in Fig. 27. The detailed results of the water balance simulation are described in ANNEX-I. Depending on the water conveyance system to be selected, about 103,000 ha including the existing tank schemes can be irrigated with reliable water supply under certain conditions.

According to the recommendation of MWRMP, monthly firm energy outputs of the existing power stations would be as follows:

Hydropower Station	Monthly Firm Energy (GWh/month)	Annual Firm (GWh/year)
Kotmale	22.5	270
Victoria	37.2	446
Randenigala	25.3	303
Rantembe	14.5	174
Ukuwela	13.7	164
Bowatenna	4.1	49

The above monthly firm energy outputs based on the present level of irrigation demand, should be modified to a certain extent (90% of firm during the Maha season) at the Randenigalla and Rantembe power stations as a variable draft depending on the transbasin canal system chosen in order to minimize irrigation deficits, keeping the whole Mahaweli system energy output as much as possible. Since all the simulation runs were based on the mature system, a certain gradual modification would be required according to the progress of agricultural land and water resources development.

The results of each case are summarized hereunder:

Case A (New Alternative Plan):

Under a certain limitation of the Polgolla diversion to the Amban Ganga, a new conveyance canal parallel to the existing Minipe LB canal was planned to divert water from the existing the Minipe anicut (crest El. 114) to the Minneriya tank (FSWL: 93.7 m) crossing the Wasgomuwa National Park with minimum disturbance to the park. This diverted water to the Minneriya tank will be utilized for the existing System D1 and its expansion areas of the on-going Moragahakanda Project (about 740 MCM per annum) which would be originally irrigated by using water supplied from the Moragahakanda reservoir. About 650-760 MCM per annum at the Minneriya tank depending on the conveyance system and development area selected will be pumped up to the NCP canal with a static head of 45-53 m.

The results of the simulation show that about 650-760 MCM out of about 1,400-1,490 MCM to be diverted to the Minneriya tank will be boosted up to the NCRB areas, and about 700-800 MCM of irrigation water originally supplied to System D1 from the on-going Moragahakanda dam and about 250 MCM from the proposed Kalu Ganga dam will be supplied through a new NCP canal to the NCRB area.

The results indicate that increased diversion water to NWDZ under the present Polgolla diversion policy (875 MCM) would make it difficult to maintain firm generation at the Bowatenna hydropower station (2 hrs peak operation) and the on-going Moragahakanda multipurpose project.

According to results of the water balance study, possible diversion water through the Minipe RB canal was estimated at about 1,400-1,500 MCM per annum on average (1949-1986) depending on the transbasin conveyance system chosen. The results indicate that it would be possible to divert about 240 MCM to the Gallodai Aru basin through the existing Minipe RB canal without increasing the flow capacity of the canal, subject to the provision of a 2nd tunnel between the Ulhitiya/Ratkinda and Maduru Oya reservoirs. This will be subject to further study.

Results of water balance simulation indicate that agricultural development in Systems F, MH, M and I in the NCRB area will be realized with acceptable reliability of water supply. The details are described in ANNEX-I.

Case - B (TDS Solution):

As discussed in Case A, about 1,500 MCM of surplus water at Minipe will be diverted to the NCRB areas. Possible irrigation area in NCRB is the same as Case A. However since the Kalu Ganga dam is proposed and pumped water should be regulated, in this case all diversion water should be pumped and the static pumping head will be about 85 m instead of 61 m recommended in TDS, and the annual O&M costs for the pump station will be very high compared with Case A. These comparisons will be subject to the economic comparisons described in Chapter 8.

As far as the water balance concerned, the possible irrigable area in the study area is similar to Case A with acceptable reliability of irrigation water supply.

Case-C (UNDP/FAO solution):

Diversion water at Minipe will be led to Angamedilla then to the Kaudulla tank by gravity through the enlarged and expanded existing Minipe LB canal. The results of simulation show that about 900 MCM out of 1,420 MCM diverted at Minipe will be boosted up to the NCP canal, and about 530 MCM of irrigation water originally supplied to a part of System D1 from the on-going Moragahakanda dam and about 250 MCM from the proposed Kalu Ganga dam will be supplied to the NCRB area through the NCP canal within the allowable deficit.

Three alternative cases to supply irrigation water to the NCRB area are considered, however these should be subject to comprehensive social and economic studies in consideration of power, agricultural, and social benefits, O&M costs for pumping station, environmental aspect, and conveyance systems as a whole for a long-term development plan.

(3) Water Balance Study for Future Case (Polgolla Diversion: 1,280 MCM)

Based on the economic comparison, Case-A was selected for further detailed study to formulate an overall development plan studied in Chapter 8. It would be possible to irrigate the NWDZ and NCRB areas, by increasing the Polgolla diversion to the Amban Ganga, NWDZ and NCRB, and by decreasing pumping water at the

proposed pump station. Water balance simulation runs under increased Polgolla diversion of 1,280 MCM per annum as adopted in the Moragahakanda Agricultural Development Project (Ref. 8) were carried out on the simulation model.

As seen in Table 34, an increase of diversion water at Polgolla would result in a decrease in average annual energy output especially at the existing hydropower stations on the Mahaweli main stream. Moreover, the irrigation deficit ratio is a little higher than in other cases. A detailed water balance simulation will be essential if the Polgolla diversion is to be increased as described in Section 8.2.